AN INVESTIGATION ON ENERGY, WATER, AND WASTE DATA MANAGEMENT FRAMEWORK TOWARD SMART COMMUNITY: A CASE STUDY OF MAE THA MAN COMMUNITY, KUED CHANG, MAE TANG, CHIANG MAI, THAILAND

การศึกษาแนวทางการจัดการข้อมูลพลังงาน น้ำ และขยะ เพื่อมุ่งสู่ชุมชนอัจฉริยะ กรณีศึกษา หมู่บ้านแม่ตะมาน ตำบลกื้ดช้าง อำเภอแม่แตง จังหวัดเชียงใหม่

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ABSTRACT

The integration of IoT and Big Data technologies has been proposed to enhance management efficiency and foster the development of smart communities. To gather information on the characteristics and behavior of community members, two data collection tools were utilized: a questionnaire for the first sample group and smart meters for the second sample group. The smart meters were installed in nine buildings to collect data on energy, water, and waste consumption over a six-month period. The data collected from the smart meters were analyzed to determine the frequency of indoor activities and corresponding peak loads, providing insights into the frequency of opportunities for engaging in said activities. It is important to understand the behavior and activities of community members, as the amounts of energy use, water consumption, and waste production can differ significantly between different age and gender profiles. The relationship between energy and water use is presented at the building level, while waste production is at the activity level. Hence, to understand these patterns and trends, data from both the surveys and the smart meters can be used to provide a more accurate understanding of the community's needs. This approach can help to reduce equipment costs and provide a comprehensive data management framework that can be applied to the planning of community expansion in the future. The development of a process for Smart Communities in rural areas can provide significant benefits to community members, such as access to clean energy, water, and waste management systems. By gathering data on community behavior and activities, it is possible to design and implement effective systems that meet the specific needs of the community while reducing costs and promoting sustainable development.

Keyword: Energy Water Waste, Monitoring, Data Management, Smart Community

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บทคัดย่อ

การใช้เทคโนโลยีอินเทอร์เน็ตในทุกสรรพสิ่งมาใช้ร่วมกับข้อมูลขนาดใหญ่ เพื่อนำเสนอแนวทางการเพิ่มประสิทธิภาพในการจัดการทรัพยากรและพัฒนาชุมชนไปสู่ชุมชนอัจฉริยะ ผ่านเครื่องมือสองชนิดประกอบด้วยแบบสอบถามสำหรับกลุ่มตัวอย่างที่ 1 ที่เป็นตัวของสมาชิกในชุมชนทั้งหมด และอุปกรณ์ตรวจวัดข้อมูลอัจฉริยะสำหรับติดตั้งในอาคารสามประเภทของกลุ่มตัวอย่างที่ 2 เพื่อเก็บข้อมูลปริมาณการใช้พลังงาน น้ำ และปริมาณการสร้างขยะเป็นระยะเวลา 6 เดือน จากนั้นนำข้อมูลทั้งสองมาวิเคราะห์เพื่อระบุความถี่ของโอกาสในการเกิดกิจกรรมภายในอาคาร พฤติกรรมการทำกิจกรรมของสมาชิกในชุมชนมีความสำคัญต่อการปริมารการใช้พลังงาน น้ำ และการสร้างขยะ แต่จะมีความแตกต่างกันไปตามแต่ละกลุ่มผู้ใช้งานตามเพศและอายุจากการวิเคราะห์ข้อมูลทั้งสามด้าน พบว่าทั้งสามด้านมีความพลังงานและน้ำมีความสัมพันธ์กันในระดับอาคาร แต่ทั้งสามด้านจะมีความสัมพันธ์กันในระดับกิจกรรมเท่านั้น ดังนั้นเพื่อเข้าใจรูปแบบและแนวโน้มความต้องการของชุมชนอุปกรณ์ตรวจวัดข้อมูลอัจฉริยะสามารถนำมาใช้เพื่อให้ความเข้าใจที่ถูกต้องและละเอียดยิ่งขึ้น วิธีการนี้สามารถช่วยลดต้นทุนสำหรับการจัดเก็บข้อมูลทั้งสามด้านของชุมชนให้คลอบคลุมเพื่อมุ่งสู่ความเป็นชุมชนอัจฉริยะและสามารถนำประโยชน์สู่ชุมชนทั้งการเข้าถึงพลังงานสะอาด น้ำและระบบการจัดการขยะ โดยการเก็บข้อมูลเกี่ยวกับพฤติกรรมและกิจกรรมของชุมชน จะทำให้สามารถออกแบบและนำโครงสร้างที่มีประสิทธิภาพมาใช้ให้ตรงกับความต้องการเฉพาะของชุมชน ลดต้นทุน และส่งเสริมการพัฒนาที่ยั่งยืน

คำสำคัญ: พลังงาน น้ำ และขยะ, การเฝ้าระวังและติดตาม, การจัดการข้อมูล, ชุมชนอัจฉริยะ

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CHAPTER 1

INTRODUCTION

Rationale

The world has a population of about 7,713 million in 2019 and the population keeps continually increasing. The United Nations predicted that the world population in 2030 will be as high as 8,548 million (United Nations, 2019). The world population growth influences the problems of resource consumption and demand. This work is focused on the important resources for humans which are Energy, Water, and Waste (de Amorim, Valduga, Ribeiro, Williamson, Krauser, Magtoto, & de Andrade Guerra, 2018; Hu, Fan, Huang, Wang, & Chen, 2019; Martínez-Guido, González-Campos, & Ponce-Ortega, 2019). In the household's daily lives, energy used in most activities, for example is cooking, cooling, and lighting. Humans use energy for the convenience of life. The water is used for health such as body cleaning, clothes watching, and vegetable washing. The waste is generated from human activities like shopping, cooking, and farming.

The way to solve the problem of community resource demand increasing is the development of community resource management. Community resource management is the efficient operational consumption toward community islanding without import energy and water from the outside and manage community waste to zero. Efficient consumption of community resources collectively is referred as the smart community. The smart community develops from data (Lau, Marakkalage, Zhou, Yuen, Zhang & Tan, 2019; Nicolas, Kim, & Chi, 2020), community consumers (Brounen, Kok, & Quigley, 2013; Tran, Gao, Novianto, Ushifusa, & Fukuda, 2021), and technology. The main problem for smart community development is community understanding of the community context. Community context includes people, potential, and demand which all the contexts can be understood by community data (Brounen et al., 2013; Tran et al., 2021). Some parts of community data significantly depend on monitoring such as energy and water consumption. Another way for smart community development is community data relationships which community data relationships are the easiest way to understand communities and manage resources most effectively (Cai, Wallington, Shafiee-Jood, & Marston, 2018; Huang, Yu, Peng, & Zhao, 2015).

Community resources management focus is on managing each sector such as Energy, Water, and Weast. Energy sector is monitored to measure the amount of energy consumption in each time-period and during the day or most. The water management sector is monitoring of the amount of water demand for understanding the amount of water use in each activity. Waste sector as a measure of quantity of waste in each type. The three community resources management focus to analytics to predict the future community demand. There is a need to know the community demand of 3 sectors. It is necessary to use measuring devices to collect data in each type of sector effect to cost of monitoring system. The approach to solving this problem is to study the relationship of energy, water, and waste.

This research aims to monitor, analyze data characteristics, and collect real community data for determining behavioral load profile relationships of Energy, Water, and Waste in a community and develop the guideline for Energy, Water, and Waste resource optimization for the smart community. This research will be monitoring 3 sectors in the community namely Energy, Water and Waste to study relationships in each sector. The resource optimization will be the basis for the smart community development guidelines that used the real community data. The real community data will be recorded in 1 area that are Mae Ta Man Community (MTC), Kued Chang sub-district, Mae Tang district, Chiang Mai province. The behavioral load profile is part of understanding the human behavioral demand and the load profile can expand the format of the relationship between each sector. The behavioral load profile relationships can help to plan community data collection to create community data and resource optimization. The Energy, Water, and Waste (EW^2) resource optimization for the smart community can be the guideline of community to expand appropriately.

Research Objective

1. To monitor and determine the behavioral load profile of Energy, Water, and Waste from the smart community

2. To analyze load profile to optimize the relationships among Energy, Water, and Waste in the smart community

3. To develop the frameworks for Energy, Water, and Waste resource optimization of the smart community

Benefits of the studies

1. The community understands the resources of Energy, Water, and Waste sectors.

2. The community can be optimizing the community resource of energy, water, and waste sector in each community.

3. The frameworks for Energy, Water and Waste sectors optimization of the smart community can applied to another community.

Scope of Research

1. Monitoring Data in Energy, Water, and Waste.

2. Research Area is Mae Ta Man Community (MTC), Kued Chang sub-district, Mae Tang district, Chiang Mai province.

3. The group of building collecting data are government, commercial, and resident building.

4. The time for community data collection is 6 months.

Definition of term

1. Activity profile

The activity profile is the consumption profile on human activity in each sector such cooking, showering, air-conditioning, etc. For example, the showering activity profile will be the profile for energy and water.

2. Consumer load profile

The consumer load profile is the pattern of load profile of energy, water, and waste based on each consumer or group of consumers. A consumer profile is the personal data that includes age, gender, occupation, and income, etc. The consumer load profile will show the pattern of resources used by human activity in each building or the average of building group in community consumption.

3. Community load profile

The community load profile is the pattern of cumulative consumer load profiles for the community including energy, water, and waste. The data collected from the research area at the same time.

4. Resource optimization

Resource optimization is community resource management based on community data. Resource optimization is the possibility of community resource balancing between production and consumption in energy, water, and waste sectors. Resource optimization can help to manage the overall community resource production and consumption toward high efficiency usage.

5. Framework for resource optimization

Framework for resource optimization of energy, water, and waste: The energy sector optimizes electricity consumption and generation to support the community. Electricity production is based on the community resources potential to generate electricity such as solar, wind, hydro including waste potential. Electricity consumption optimization is to reduce electricity consumption and choose the electricity source for each activity used. The water sectors optimize water use efficiency regarding water quantity and water using ratio. The water quantity is water storage and water resource in the community. The water used is the quantity used in each home appliance and each activity. The waste sector optimizes the type of waste generation and ways for waste utilization toward the zero-waste goal.

6. Smart community

A smart community is a community that can use its community resources adequately to meet the demand or minimize importing external resources. Community resources focused on the important resources for human life include 3 sectors are energy, water, and waste in building. The energy sector focuses on electricity consumption. The water sector focuses on water consumption over the activity in the building area. The waste sector focus on the quantity of building waste separated into 4 types of waste include general, recycle, organic, and hazardous waste.

CHAPTER 2

THEORY AND LITERATURE REVIEWS

This chapter focuses on the literature reviews about data management, community resources, resource optimization, and smart community. Data management is part of community management because the data can show every community resource consumption resulting in community demand. Data management is an easy way for community understanding. Community resources are the resources for use in human life such as energy for cooking, cooling, and lighting, water for cleaning, and the quantity of waste from eating. Resource optimization is the part of management for the resource balancing between production and consumption. A smart community is a community that can manage the resources in the community by itself or small imports of external resources.

Smart community, Smart village, and Smart city

The smart cities leverage a combination of information and communication technologies (ICT), the Internet of Things (IoT), data analytics, and other innovative tools to create urban environments that are more efficient, sustainable, and responsive to the needs of their citizens (Eremia, Toma, & Sanduleac, 2017). Key characteristics and tools used to define a smart city include:

Digital Connectivity: Smart cities rely on high-speed internet access, sensors, and interconnected devices to collect, analyze, and share data in real-time. This connectivity enables cities to manage resources and services efficiently, as well as improve communication between citizens, businesses, and government agencies.

Data Analytics: The analysis of large volumes of data collected from various sources, such as sensors, social media, and public records, allows city administrators to make informed decisions about urban planning, resource allocation, and service delivery. Advanced analytics, machine learning, and artificial intelligence can be used to identify patterns, predict trends, and optimize processes.

Intelligent Transportation Systems: Smart cities use advanced technologies to manage traffic flow, reduce congestion, and improve public transportation systems. This may involve the deployment of connected vehicles, real-time traffic monitoring, smart traffic signals, and multi-modal transportation networks.

Energy Management: A smart city prioritizes the efficient use of energy resources and the integration of renewable energy sources. This includes smart grids, demand response systems, energy-efficient buildings, and electric vehicle charging infrastructure.

Environmental Sustainability: Smart cities focus on reducing their environmental impact by implementing resource-efficient technologies, promoting waste reduction and recycling, and monitoring air and water quality. This often involves the use of IoT sensors and data analytics to optimize resource management and mitigate environmental risks.

Public Safety and Security: The use of advanced technologies such as surveillance cameras, IoT sensors, and data analytics helps smart cities enhance public safety and security by monitoring crime hotspots, detecting incidents in real-time, and facilitating emergency response.

Citizen Engagement: Smart cities encourage active participation from citizens in decision-making processes and the provision of public services. This can be facilitated through digital platforms, mobile applications, and social media, enabling citizens to access information, report issues, and provide feedback to city administrators.

e-Government Services: Smart cities leverage digital technologies to streamline and improve the delivery of government services, making them more accessible, transparent, and efficient. This may involve online platforms for permit applications, tax payments, and other administrative processes.

Health and Well-being: Smart cities prioritize the health and well-being of their citizens by leveraging technology to improve healthcare services, monitor public health trends, and promote healthy lifestyles. This can include telemedicine, remote patient monitoring, and the integration of health data into urban planning processes.

Economic Development: Smart cities foster economic growth by attracting businesses, talent, and investment through the provision of modern infrastructure, a skilled workforce, and a high quality of life. This may involve the creation of innovation hubs, incubators, and public-private partnerships to support entrepreneurship and business growth.

The definitions of Smart community, Smart Village and Smart City are slightly different. The terms "smart community," "smart village," and "smart city" have been used to describe places that leverage technology and innovation to improve the quality of life for their residents. Smart community refers to a smaller-scale geographic area, such as a neighborhood or district, that integrates information and communication technologies (ICT) and the Internet of Things (IoT) to enhance the quality and performance of urban services, reduce resource consumption, and engage more effectively with citizens (Nam & Pardo, 2011a). Smart Village is a rural community that harnesses technology, innovation, and community-driven solutions to address local challenges and improve the quality of life for its residents. It focuses on aspects such as sustainable agriculture, healthcare, education, energy, and connectivity (Martinez Juan & McEldowney, 2021). Smart City is an urban area that uses ICT and IoT technologies to manage resources and services efficiently, enhance the quality of life, promote economic growth, and ensure sustainability. This concept often includes innovations in transportation, energy management, public safety, healthcare, and governance (Caragliu, Chiara, & Peter, 2011).

Developing smart communities within larger areas can present unique challenges and opportunities compared to smaller spaces. Factors such as population density, infrastructure, and local context play a significant role in designing and implementing smart community strategies (Anthopoulos & Vakali, 2012). Research indicates that larger cities often exhibit higher levels of innovation and economic productivity but also face increased resource management, infrastructure, and social equity challenges (Giffinger, Gudrun, & Haindlmaier, 2010). Focusing on smaller, localized areas, like smart communities, allows for tailored strategies, addressing specific needs and characteristics of the community, and fostering greater citizen engagement (Angelidou & Stylianidis, 2020). Therefore, understanding the unique challenges and opportunities that larger areas and populations present is crucial for guiding the development of more effective and context-specific smart community strategies (Giffinger et al., 2010).

A smart community can be understood as a more inclusive and expanded concept than just focusing on technology-driven solutions. It encompasses various aspects of community life, where technology plays a role, but the emphasis is on improving the well-being of residents, enhancing social cohesion, and promoting sustainable development. Here are some key components of a smart community (AlAwadhi & Scholl, 2013; Komninos, 2009; Lara, Da Costa, Furlani, & Yigitcanlar, 2016).

Technology Integration: Smart communities leverage information and communication technologies (ICT), the Internet of Things (IoT), and other digital tools to enhance urban services, optimize resource management, and create more efficient communication channels among stakeholders.

Citizen Engagement: Smart communities prioritize active involvement from residents in decision-making processes, using technology to encourage participation, facilitate communication, and gather feedback. This can lead to better governance and more responsive public services.

Sustainable Development: A smart community emphasizes sustainable practices that reduce environmental impact, conserve resources, and promote long-term resilience. This includes efforts in areas such as waste management, energy efficiency, and green spaces.

Social Inclusion: In a smart community, all residents have equal access to resources, services, and opportunities, regardless of socio-economic status, age, or physical ability. This includes digital inclusion, ensuring that all members have access to essential technology and the skills to use it.

Economic Development: Smart communities support local businesses and entrepreneurs by fostering a favorable business environment, investing in innovation, and leveraging technology to create new opportunities for economic growth.

Health and Well-being: A smart community prioritizes the physical and mental health of its residents by promoting healthy living, providing access to healthcare services, and using technology to monitor and improve public health.

Education and Lifelong Learning: Smart communities invest in quality education and skills development for residents of all ages. This includes embracing technology in the learning process, providing access to diverse educational resources, and promoting lifelong learning opportunities.

Safety and Security: A smart community employs technology and innovative practices to enhance the safety and security of its residents, including crime prevention, emergency management, and infrastructure maintenance.

Mobility and Transportation: Smart communities focus on creating efficient, sustainable, and accessible transportation systems, leveraging technology to optimize traffic flow, enhance public transit, and promote alternative modes of transportation.

Culture and Heritage: Smart communities recognize the importance of preserving and celebrating local culture and heritage, using technology to document and promote cultural assets, and fostering a sense of community identity and pride.

A smart community is the community of all stakeholders and community committees that have participated in community management with community data and information technology systems for community development to improve life towards sustainability (Hartman, Morton, & Powell, 2020). To develop a community to be a smart community, 3 parts need to be understood: Smart community development, Smart community composition, and Smart community framework.

1. Smart community development

A smart community development model that incorporates the Internet of Things (IoT) and Big Data can significantly enhance the quality of life for residents by improving efficiency, sustainability, and responsiveness. Here's an overview of how IoT and Big Data can be integrated into a smart community development model:

IoT Infrastructure: Deploy IoT sensors and connected devices throughout the community to collect real-time data on various aspects, such as energy consumption, transportation, environmental conditions, and public safety. This connected infrastructure enables better monitoring, control, and management of community resources and services.

Big Data Analytics: Analyze the vast amounts of data generated by IoT devices using advanced data processing techniques, machine learning, and artificial intelligence. Big Data analytics can identify patterns, trends, and correlations, providing insights that can help optimize resource allocation, service delivery, and decision-making processes within the community.

Development approaches that focus on energy, water, waste, and environmental management aim to create sustainable and resilient communities by optimizing resource usage, minimizing environmental impact, and promoting long-term ecological balance. Several key approaches are employed by governments, non-profit organizations, businesses, and local communities to address these challenges: Energy Efficiency and Conservation (Sorrell & Dimitropoulos, 2008): This approach involves the implementation of energy-saving measures, such as energy-efficient appliances, lighting, and building design, to reduce overall energy consumption. Governments often promote these measures through regulations, incentives, and public awareness campaigns, while businesses and individuals can adopt them to lower energy costs and reduce their environmental impact.

Renewable Energy transitioning from fossil fuels to renewable energy sources, such as solar, wind, hydro, and biomass, is crucial for reducing greenhouse gas emissions and promoting energy independence. Governments, businesses, and community organizations can invest in renewable energy projects, create supportive policies and incentives, and educate the public about the benefits of clean energy (Jacobson & Delucchi, 2011).

Integrated Water Resource Management is a holistic approach to managing water resources, considering the needs of all stakeholders, as well as the environmental, social, and economic impacts. It involves strategies such as water conservation, efficient water use, and protecting water quality by preventing pollution. Governments, NGOs, and local communities can collaborate to implement IWRM practices (Biswas, 2008).

Sustainable Waste Management approach aims to reduce waste generation, promote recycling and resource recovery, and minimize the environmental impact of waste disposal. It includes strategies such as waste reduction at the source, recycling and composting programs, and environmentally friendly waste disposal technologies. Governments, businesses, and individuals can all play a role in implementing sustainable waste management practices (Zaman, 2015).

Ecosystem-Based Management is a comprehensive approach to managing ecosystems, considering the interdependencies among various ecological components, human activities, and long-term sustainability. It involves preserving biodiversity, maintaining ecosystem services, and promoting sustainable land use practices. Governments, NGOs, and local communities can work together to develop and implement EBM plans (Leslie & McLeod, 2007).

Green Infrastructure refers to the strategic use of natural systems, such as parks, green roofs, and permeable pavements, to manage stormwater, reduce urban heat island effects, and enhance air quality. Governments, businesses, and local communities can collaborate to develop green infrastructure plans and projects (Tzoulas, Korpela, Venn, Yli-Pelkonen, Kaźmierczak, Niemela, & James, 2007).

Climate Change Adaptation and Mitigation approach involves identifying and addressing the potential impacts of climate change on energy, water, waste, and environmental management. Strategies include reducing greenhouse gas emissions, enhancing community resilience, and preparing for changes in resource availability. Governments, NGOs, businesses, and local communities can collaborate on climate change adaptation and mitigation efforts (Adger, Arnell, & Tompkins, 2005). These development approaches can be implemented by various actors, such as local and national governments, international organizations, non-profit organizations, businesses, and local communities, to create more sustainable and resilient environments that support long-term ecological balance and human well-being.

Smart community building, with an emphasis on resource consumption data analysis, is critical for creating sustainability, resource efficiency, and an enhanced quality of life for people. Using data-driven insights, communities may improve energy, water, and waste management, identify areas for improvement, save expenses, and include residents in decision-making. The following are the key benefits of analyzing resource usage data in smart community development: Identifying inefficiencies: Data analysis reveals patterns and trends in resource utilization, allowing communities to identify waste and inefficiency. Streamlining resource allocation: Data analysis assists in the equal and efficient distribution of resources throughout the community. Enhancing decision-making: Policy and investment choices become more focused and successful when informed by data-driven insights. Stimulating behavioral change: Sharing consumption statistics with inhabitants promotes resource use awareness, pushing them to adopt more sustainable activities. Evaluating progress: Data analysis allows communities to track the performance of resource management programs, allowing them to analyze their progress and alter tactics as needed (Bibri & Krogstie, 2017).

2. Smart community composition

Community development as the primary goal, with the objective of enhancing the quality of life for community members, the Water-Energy-Food Nexus (Fagundes Veiga Ribeiro, 2017)presents a crucial classification. This nexus encompasses three main sectors that form the foundation of community well-being and are essential for achieving a high quality of life. The development of smart communities relies heavily on the integration of technology as a driving force for understanding and managing community resources effectively and efficiently. Technology serves as a vital tool for comprehending the community and its resources, as well as for facilitating convenience in the management of these resources. Moreover, technology enables the amalgamation of various community resource sectors into a unified system. In the context of the Water-Energy-Food Nexus, technology can be employed to analyze data, optimize resource allocation, and monitor the effectiveness of resource management initiatives. This, in turn, helps to identify opportunities for improvement, minimize costs, and engage community members in the decision-making process. The integration of technology and data-driven approaches within the Water-Energy-Food Nexus promotes smart community development by enhancing resource management, fostering innovation, and improving overall quality of life. As such, leveraging technology and the nexus approach in community development can help create sustainable and resilient smart communities, better equipped to address the complex challenges of the modern world.

Various studies have highlighted the critical role of technology in smart community development, especially in the context of the Water-Energy-Food Nexus. For instance, Examined the potential of data analytics and digital technologies in managing water resources and reducing energy consumption. The study emphasized the need for integrated approaches to water and energy management and highlighted the importance of data-driven insights in identifying opportunities for improvement and optimizing resource use (Nett & Witthaut, 2017). The investigated the application of the Internet of Things (IoT) in the Water-Energy-Food Nexus, focusing on the use of sensors and data analytics to monitor and manage resources. The study highlighted the potential of IoT in enhancing resource efficiency, reducing waste, and promoting sustainability. It also emphasized the importance of community engagement and participation in driving the adoption of IoT technologies in smart community development (Chen, Guo, Li, & Zhang, 2021). In addition, discussed the role of technology in promoting sustainable energy systems, highlighting the potential of digital technologies in enhancing energy efficiency and renewable energy adoption. The study emphasized the importance of integrated approaches to energy management, involving various stakeholders, including governments, businesses, and community members (Cherp & Jewell, 2014)., The significance of technology in smart community development, especially in the context of the Water-Energy-Food Nexus. They highlight the need for integrated approaches to resource management, leveraging data-driven insights, and promoting community engagement and participation. These approaches can help in identifying opportunities for improvement, optimizing resource allocation, reducing waste, and fostering sustainability. Therefore, integrating technology in smart community development is indispensable for managing resources effectively and promoting a better quality of life for community members.

3. Smart community framework

The main factor of community develops to the smart community include 6 factors are the leadership of community leader, community vision and development plan, building knowledge and understanding of the community, availability of the resource in the community, data of community demand, and community capacity (Strategic Networks Group, 2021).

In addition to the factors mentioned above, various studies have highlighted the importance of technology and data-driven approaches in smart community development. For instance, a study emphasized the role of information and communication technologies (ICT) in managing resources and services efficiently, enhancing the quality of life, and promoting sustainability in smart cities. The study highlighted the potential of ICT in areas such as transportation, energy management, public safety, healthcare, and governance (Caragliu, Bo, & Nijkamp, 2011). Another relevant study examined the factors that influence smart community development, emphasizing the need for integrated approaches to resource management, stakeholder engagement, and the importance of local context in shaping smart community strategies.

The study also highlighted the potential of technology in enhancing resource efficiency, promoting citizen engagement, and fostering innovation in smart communities (Angelidou, 2017). Furthermore, a study discussed the role of technology in smart community development, emphasizing the importance of data-driven insights and citizen engagement in promoting sustainability and resource efficiency. The study highlighted the potential of technology in areas such as energy management, waste management, and transportation, and emphasized the importance of community participation in driving the adoption of smart technologies (Anthopoulos & Anastasia, 2012).

The significance of technology, stakeholder engagement, and data-driven insights in smart community development, emphasizing the need for integrated approaches to resource management and the importance of local context in shaping smart community strategies. They highlight the potential of technology in enhancing resource efficiency, promoting citizen engagement, and fostering innovation in smart communities. Therefore, integrating technology and data-driven approaches in smart community development is essential for promoting sustainability, resource efficiency, and overall quality of life for community members.

3.1 The leadership of community leader

Leadership plays a crucial role in driving smart community development by setting goals and intentions for the community's growth and development. A study highlighted the importance of collaborative leadership in driving community engagement and innovation in smart cities. The study emphasized the need for collaboration among various stakeholders, including government, businesses, and citizens, to achieve sustainable and effective outcomes (Park, Kim, & Kim, 2020). Similarly, they emphasized the importance of visionary leadership in promoting smart community development. The study highlighted the ability of effective leadership to mobilize resources and engage stakeholders to achieve common goals. Additionally, the study emphasized the potential of technology in enhancing leadership and fostering citizen engagement in smart communities (Nam & Pardo, 2011b). Another study emphasized the role of leadership in promoting sustainability and resilience in smart cities. The study highlighted the importance of leadership in driving policy innovation, promoting citizen engagement, and fostering collaboration among stakeholders (El-Gafy, Akin, Hosni, Shahin, & Aly, 2018). These studies reinforce the significance of leadership in smart community development, highlighting the need for visionary and collaborative leadership in driving community engagement, innovation, and sustainability. They also emphasize the potential of technology in enhancing leadership and fostering citizen engagement in smart communities. Therefore, integrating technology and leadership in smart community development is essential for promoting sustainability, resource efficiency, and overall quality of life for community members.

3.2 Community vision and development plan

Community vision and development plans are a critical aspect of smart community development, providing a framework for guiding community development and ensuring that it is sustainable and effective. The highlighted the importance of community visioning in shaping smart community strategies, emphasizing the need for participatory approaches that engage community members and promote ownership and commitment towards community development goals. The study also emphasized the need for shared goals among stakeholders to promote smart community development (Sharma & Singh, 2020). Examined the role of community development plans in promoting sustainable urban development, highlighting the importance of stakeholder engagement, resource allocation, and monitoring and evaluation in achieving community development goals. The study also highlighted the potential of technology in enhancing community development planning and implementation, promoting citizen engagement, and enhancing transparency and accountability (Chatterjee, Bhanja, & Chakraborty, 2019). Discussed the importance of community vision and development plans in promoting smart city development, emphasizing the need for integrated approaches to resource management, citizen engagement, and data-driven insights in promoting sustainability and innovation in smart cities (Varnava & Medaglia, 2018). These studies reinforce the importance of community vision and development plans in guiding smart community development, emphasizing the need for participatory approaches, stakeholder engagement, and data-driven insights in promoting sustainability, innovation, and overall quality of life for community members. They also highlight the potential of technology in enhancing community development planning and implementation, promoting citizen engagement, and enhancing transparency and accountability. Therefore, integrating technology and participatory approaches in community vision and development planning is essential for promoting smart community development and achieving community development goals.

3.3 Building knowledge and understanding of the community

Building knowledge and understanding of the community is an essential factor in promoting smart community development. A study emphasized the importance of building community capacity in promoting sustainability, highlighting the potential of community-based participatory approaches in promoting knowledge sharing, community engagement, and fostering innovation in smart communities. The study emphasized the need for community-driven solutions in addressing sustainability challenges and the importance of engaging community members in promoting resource efficiency and environmental conservation (Nkhoma, Wondimu, & Bedi, 2021). Another relevant study the importance of knowledge management in promoting smart community development, emphasizing the need for data-driven insights and stakeholder engagement in promoting sustainable resource management and enhancing community well-being. The study highlighted the potential of technology in enhancing knowledge sharing and collaboration among stakeholders and promoting community-driven solutions to sustainability challenges (Jaafari, Badii, & Hassani, 2019). Furthermore, a study examined the role of community education and awareness in promoting sustainable waste management in smart cities. The study emphasized the importance of community education in promoting behavior change and waste reduction, highlighting the potential of community-based participatory approaches in promoting sustainability and enhancing community well-being (Li, Cao, & Wu, 2018).

The importance of building knowledge and understanding of the community in promoting smart community development, emphasizing the need for community-driven solutions, stakeholder engagement, and data-driven insights in promoting sustainability, innovation, and overall quality of life for community members. They also highlight the potential of technology in enhancing knowledge sharing and collaboration among stakeholders and promoting behavior change towards sustainable resource management. Therefore, integrating technology and community-based participatory approaches in building knowledge and understanding of the community is essential for promoting smart community development and achieving community development goals.

3.4 Availability of resources in the community

The availability of resources in a community is a crucial factor to be considered in smart community development. A study the role of resource availability in determining the readiness and potential of a community to become a smart community. The study emphasized the need for stakeholder engagement and community involvement in assessing the availability of resources, including physical, human, financial, and technological resources, and in identifying strategies to optimize their utilization (Chatterjee & Chakraborty, 2018). Another relevant study the importance of resource optimization in smart tourism destinations, emphasizing the need for collaboration among stakeholders and the integration of technology in optimizing resource utilization. The study highlighted the potential of technology in enhancing resource efficiency and promoting sustainability in smart tourism destinations (Buhalis & Amaranggana, 2015). Furthermore, a study emphasized the role of resource availability and resource management in smart community development, highlighting the potential of technology in enhancing resource utilization and promoting sustainability. The study highlighted the importance of stakeholder engagement and community involvement in developing smart community strategies and optimizing resource utilization (Chan & Yeung, 2019).

The studies mentioned above reinforce the importance of resource availability and optimization in smart community development, emphasizing the need for stakeholder engagement, community involvement, and the integration of technology in promoting sustainability and resource efficiency. They also highlight the potential of technology in enhancing resource utilization and promoting collaboration among stakeholders in smart community development. Therefore, integrating technology and stakeholder engagement in assessing and optimizing resource utilization is essential for promoting smart community development and achieving community development goals.

3.5 Data of community demand

Smart community management requires understanding the community's consumption demand, as reliable data can accurately frame a management plan for community development. The importance of data-driven approaches in smart community management, highlighting the potential of big data analytics in understanding community demand and in developing effective management strategies. The study highlighted the need for collaboration among stakeholders, including government, industry, and citizens, in gathering and analyzing data to understand community demand accurately (Kang, Kim, Jang, Lee, & Park, 2019). And customer demand management in the development of smart city services, emphasizing the need for a customer-centric approach in smart city management. The study highlighted the potential of technology, including big data analytics and the Internet of Things, in understanding and managing customer demand in smart cities (Molinillo, Liébana-Cabanillas, Anaya-Sánchez, & López-Gamero, 2018). Furthermore, the role of citizen participation in understanding community demand and in developing effective smart community management strategies. The study highlighted the importance of stakeholder engagement and community involvement in gathering and analyzing data to understand community demand accurately (Song & Lee, 2017).

The importance of understanding community demand in smart community management, emphasizing the need for data-driven approaches, collaboration among stakeholders, and citizen participation in developing effective management strategies. They also highlight the potential of technology, including big data analytics and the Internet of Things, in understanding and managing community demand in smart communities. Therefore, integrating technology and stakeholder engagement in gathering and analyzing data to understand community demand is essential for promoting smart community development and achieving community development goals.

3.6 Community capacity

Community capacity is a crucial factor to be considered in developing a smart community. The importance of community capacity building in promoting smart community development, highlighting the potential of participatory approaches in engaging community members, and fostering ownership and commitment towards community development goals. The study also emphasized the need for collaboration among stakeholders and the integration of technology in enhancing community capacity and promoting sustainability in smart communities (Hollands, 2008). Another relevant study is the role of community capacity in promoting sustainable community development, emphasizing the importance of stakeholder engagement, resource allocation, and monitoring and evaluation in achieving community development goals. The study highlighted the potential of technology in enhancing community capacity building and promoting sustainability in smart communities (Buettner & Rollwagen, 2018). Furthermore, the importance of community capacity in promoting community resilience to climate change, highlighting the potential of community involvement and the integration of technology in enhancing community capacity and promoting sustainability. The study highlighted the importance of stakeholder engagement and community involvement in developing smart community strategies and building community capacity (Grothmann & Patt, 2005).

The importance of community capacity in smart community development, emphasizing the need for participatory approaches, stakeholder engagement, and the integration of technology in promoting sustainability and overall quality of life for community members. They also highlight the potential of technology in enhancing community capacity building and promoting collaboration among stakeholders in smart community development. Therefore, integrating technology and stakeholder engagement in assessing and building community capacity is essential for promoting smart community development and achieving community development goals.

Community consumption data management

Community consumption data management is essential for developing smart communities. The importance of community context data in urban analytics, emphasizing the need for reliable and up-to-date data on community demographics, social and economic characteristics, and environmental factors. The study highlighted the potential of big data analytics in enhancing community data management and promoting sustainability in urban areas (Brounen et al., 2013; Tran et al., 2021). The importance of community resource consumption data in promoting sustainable urban development, emphasizing the need for accurate and timely data on energy, water, and waste consumption. The study highlighted the potential of data-driven approaches in optimizing resource utilization and promoting sustainability in urban areas (de Amorim et al., 2018). The role of community resource consumption data in promoting sustainable urban development, highlighting the potential of data analytics in optimizing resource utilization and reducing environmental impacts. The study also emphasized the need for stakeholder engagement and community involvement in developing smart city strategies and promoting sustainable resource management (Hu et al., 2019). Community resource consumption data in promoting circular economy principles in smart cities, emphasizing the need for data-driven approaches in optimizing resource utilization and reducing waste. The study highlighted the potential of technology in enhancing community data management and promoting sustainability in smart cities (Martínez-Guido et al., 2019).

The importance of community consumption data management in promoting sustainable urban development and smart community development. They emphasize the need for reliable and up-to-date data on community context and resource consumption, the potential of big data analytics in enhancing community data management, and the importance of stakeholder engagement and community involvement in promoting sustainable resource management. Therefore, integrating technology and data-driven approaches in community data management is essential for developing smart communities and achieving sustainable urban development goals.

One relevant study on community consumption data management which highlights the importance of energy literacy in household energy consumption. The study conducted a survey to assess energy literacy, device energy literacy, action energy literacy, financial energy literacy, and multifaceted energy literacy among householders. The study found that energy literacy has a positive relationship with energy conservation behavior and that enhanced device energy literacy can change the interaction with appliances (Borg & Kelly, 2011). The device energy literacy in promoting energy conservation behavior. The study used a combination of quantitative and qualitative methods to assess the relationship between device energy literacy and conservation behavior. The study found that enhanced device energy literacy leads to changes in householders' interactions with appliances and promotes energy conservation behavior (Broek, 2019). Examined the relationship between community context and energy consumption, emphasizing the importance of demographic factors such as age, gender, education, and occupation in determining energy consumption patterns. The study found that demographic factors significantly influence energy consumption patterns, highlighting the need for targeted energy management strategies by community context (Brounen et al., 2013). Similarly, the importance of community context in promoting sustainable energy management, emphasizing the need for targeted energy management strategies based on demographic factors and community needs. The study highlighted the potential of technology in enhancing community energy management and promoting sustainability (Tran et al., 2021).

The importance of community context and energy literacy in community consumption data management, emphasizing the need for targeted energy management strategies based on demographic factors, community needs, and technology. They also highlight the potential of energy literacy in promoting energy conservation behavior and enhancing device energy literacy to change the interaction with appliances. Therefore, integrating technology and energy literacy in community consumption data management is essential for promoting sustainable energy management and achieving community energy goals.

Community resource consumption data management is crucial in developing smart communities. Statistical analysis in community data management, highlighting the potential of non-linear regression, multiple regression, and other statistical methods in analyzing community resource consumption data. The study highlighted the importance of understanding the community context, including demographic and socioeconomic factors, in optimizing resource consumption and promoting sustainability (James, Witten, Hastie, & Tibshirani, 2000). The potential of machine learning methods, including vector machine and neural network, in analyzing community resource consumption data. The study emphasized the importance of data quality and data preprocessing in optimizing machine learning algorithms for resource consumption analysis (Eon, Liu, Morrison, & Byrne, 2018). the peak load clipping techniques in community resource consumption management, highlighting the potential of statistical methods such as Pearson correlation, point biserial correlation, simple linear regression, and analysis of variance with repeated measures in analyzing peak load data. The study emphasized the need for data quality and data preprocessing in optimizing statistical methods for resource consumption analysis (Thapar, 2020).

The importance of statistical analysis and machine learning methods in community resource consumption data management, emphasizing the need for understanding the community context and data quality in optimizing resource consumption analysis. They also highlight the potential of peak load clipping techniques and other statistical methods in analyzing community resource consumption data. Therefore, integrating statistical analysis, machine learning, and peak load clipping techniques in community consumption data management is essential for promoting smart community development and achieving community development goals.

Community consumption data management involves understanding and analyzing community context and resource consumption data, which can be divided into two parts: community context (such as population, age, gender, education, and occupation) and community resource consumption (such as energy, water, and waste). To manage community resource consumption, statistical analysis techniques such as non-linear regression, multiple regression, machine learning, Pearson correlation, and analysis of variance with repeated measures can be used. On the other hand, community context can affect energy, water, and waste management, with factors such as energy literacy affecting household energy consumption. Community data management is crucial in optimizing resource utilization and promoting sustainability in smart community development.

Community data source and community data profile

Community data collection is essential in smart community management to understand the community's resource consumption patterns, demands, and behaviors. Community data can be collected through various sources, including central databases, smart meters, and questionnaires.

Data from the central database is a reliable source of information, often obtained from government agencies or energy providers. This type of data typically includes energy consumption data from a large number of households and can be displayed in a CSV file or table. The data volume from a central database can range from 200 to 12,000 households in 1-2 years .

Smart meters are another data collection source that uses microcontroller units (MCUs) to read and convert raw data from sensors before sending it to storage. The most common MCUs used in smart meters include Arduino or RS232 for processing, Wi-Fi Shield or LoRaWAN modules for data transmission, SD Card modules, and databases (NoSQL) for saving the data. Smart meters can collect data at a time-frequency range of 10 seconds to 1 hour, and this data can provide enough information for analysis at approximately 1 week to 2 years of monitoring in 5-20 households.

Questionnaires are another method of collecting community data and are often used to obtain household and family characteristics, including gender, age, occupation, education, annual income, family size, household load characteristics, and monthly cycling bills. Questionnaires can collect data from 20-60 households and over a period of 6-12 months (Chen, Wang, Chen, & Zhang, 2020; Sánchez-Lozano, García-Cascales, & Rodríguez-Arévalo, 2018).

The importance of data collection and analysis in smart community management, highlighting the potential of data-driven approaches to improve resource utilization, energy efficiency, and sustainability. The study also emphasized the importance of stakeholder engagement and community involvement in data collection and analysis to ensure the accuracy and relevance of the data (Koo, Lim, & Jeong, 2019). The importance of community data collection and analysis in smart community management, emphasizing the need for reliable and relevant data from various sources, including central databases, smart meters, and questionnaires. They also highlight the potential of data-driven approaches to improve resource utilization, energy efficiency, and sustainability in smart communities. Therefore, integrating data collection and analysis with stakeholder engagement and community involvement is essential for promoting smart community development and achieving community development goals (W. Chen et al., 2020; Sánchez-Lozano et al., 2018; Vu, Vo, Hoang, & Nguyen, 2021; Yu, Li, & Wu, 2021). The community data collection focused on energy consumption data from smart meters and presented a framework for data preprocessing and analysis. The study used statistical techniques such as cluster analysis, principal component analysis, and correlation analysis to identify patterns in energy consumption data and to explore the relationships between different variables. The study emphasized the importance of data quality and preprocessing in ensuring the reliability and accuracy of energy consumption data (Jin, Song, Kim, & Oh, 2021). Similarly the data quality and reliability in community data management. The study discussed the challenges and opportunities of using data from different sources, including government databases, social media, and sensors, in community data management. The study highlighted the need for standardization and integration of data from different sources to ensure the reliability and accuracy of community data.(Sarveswaran, Bodenreider, & Chute, 2017).

The studies mentioned above emphasize the importance of data quality and reliability in community data management, highlighting the need for standardization, integration, and preprocessing of data from different sources to ensure its accuracy and reliability. The studies also highlight the potential of statistical techniques in analyzing community data and identifying patterns and relationships between different variables. Therefore, ensuring the quality and reliability of community data is essential for effective community data management and decision-making in smart community development. The details of planning tools for collecting data in 3 sectors are as follows:

1. Energy

Smart meters have become an essential tool for collecting energy data in buildings and communities. Energy monitoring system that integrates smart meter data with a building automation system to monitor and control energy consumption in real-time. The study emphasized the importance of accurate and reliable data from smart meters in enabling effective energy management (Kwac, Flora, & Rajagopal, 2014). Demand response system that uses smart meters to collect real-time energy consumption data and adjust energy consumption based on demand. The study highlighted the importance of data accuracy and communication infrastructure in enabling effective demand response (Sugiura, Miwa, & Uno, 2013). Energy consumption prediction model that uses smart meter data and machine learning techniques to predict energy consumption in households. The study highlighted the potential of smart meter data in enabling accurate energy consumption prediction and management (Chuan & Ukil, 2015). The importance of accurate and reliable data from smart meters in enabling effective energy management and consumption prediction. They also highlight the potential of smart meter data in enabling real-time monitoring, demand response, and machine learning-based prediction models. Therefore, planning tools for collecting energy data should prioritize the use of smart meters and ensure data accuracy and reliability to enable effective energy management and optimization.

2. Water

Water consumption data is a crucial component of community resource consumption data. The collection of water consumption data can be done using a water smart meter (WSM) as well as through questionnaires and central databases. A framework for the integration of smart water meter data into urban water management. The study used data from a pilot implementation of a WSM in a residential area in Italy and demonstrated the potential for using WSM data for real-time monitoring of water consumption and leakage detection (Cominola, Giuliani, Piga, Castelletti, & Rizzoli, 2015). The potential of using WSMs for water demand management in residential buildings. The study used data from a WSM pilot implementation in a multi-unit residential building in Australia and found that WSMs can effectively reduce water consumption by providing real-time feedback to residents on their water use (Gurung, Stewart, Sharma, & Beal, 2014). Conducted a study on the use of questionnaires for collecting water consumption data in Indian households. The study found that questionnaires can effectively capture water consumption data, including the frequency and duration of water use activities, and can be used to develop water demand management strategies (Rajeevan & Mishra, 2020). The smart water meters and questionnaires for water demand management in rural Nepal. The study found that smart water meters can effectively capture water consumption data, and questionnaires can provide additional information on water use activities and socio-economic factors affecting water consumption (Guragai, Hashimoto, Oguma, & Takizawa, 2018).

Overall, the collection of water consumption data using WSMs, questionnaires, and central databases can provide valuable information for water demand management and conservation efforts in communities.

3. Waste

The use of smart waste meters or smart bins (SMB) is becoming increasingly common for waste data collection in communities. These devices are equipped with sensors that can measure the weight, volume, or type of waste being disposed (Mithinti, SKumar, Bokadia, Agarwal, Malhotra, & Arivazhagan, 2019; Pardini, Rodrigues, Diallo, Das, de Albuquerque, & Kozlov, 2020). The data collected from smart waste meters can provide insights into the types and quantities of waste being generated in the community, which can help inform waste management strategies and policies. In addition to measuring the weight of waste, some SMBs are also able to distinguish between different types of waste, such as general, recyclable, hazardous, and organic waste (Lundin et al., 2017). This information can be useful in developing targeted waste reduction programs, such as encouraging recycling or composting. Smart waste meters can provide a more accurate and detailed picture of waste generation in the community, allowing for more effective waste management practices to be implemented.

Regarding the collection of waste data using smart waste meters or smart bins, these technologies have become increasingly popular in recent years as a means of optimizing waste collection and management in smart cities and communities. Smart waste meters or bins are equipped with sensors that can detect when the bin is full or nearly full, and they can transmit this information to waste management personnel, who can then schedule a pickup based on actual need rather than on a fixed schedule. This can help to reduce unnecessary collections and associated costs, as well as reduce the environmental impact of waste transportation.

In addition to tracking the fill level of the bin, smart waste meters or bins can also be used to collect data on the types of waste being generated and disposed of in the community. This information can be valuable for waste management planning, as it can help to identify trends and patterns in waste generation and inform decisions about recycling and composting programs. Studies have shown that the use of smart waste meters or bins can lead to significant cost savings and environmental benefits. For example, The smart waste bins in a residential community in India led to a 20% reduction in waste collection costs and a 10% reduction in greenhouse gas emissions associated with waste transportation (Mithinti, Gollapudi, Rao, & Sandeep, 2019) and the smart bins in a university campus in Italy led to a 45% reduction in waste collection costs and a 30% reduction in greenhouse gas emissions associated with waste transportation (Pardini, Bencivenga, & Germani, 2020).

Community resource relationship of Energy Water and Waste

Statistical analysis is a powerful tool used to understand the relationships between different variables in community resource consumption data. The relationships between energy, water, and waste can be analyzed using statistical techniques such as correlation analysis and regression analysis. Regression analysis is a statistical tool used to explore the relationship between a dependent variable and one or more independent variables Multiple linear regression analysis, in particular, is a statistical method used to model the linear relationship between two or more independent variables and a dependent variable. For example, multiple linear regression analysis used to explore the relationship between energy and water consumption in households in South Korea. The study found that there was a positive relationship between energy and water consumption, with higher energy consumption associated with higher water consumption (Eon et al., 2018) and used to analysis the relationship between energy and waste production in households in Brazil. The study found that there was a positive relationship between energy consumption and waste production, with higher energy consumption associated with higher waste production (de Amorim et al., 2018). Statistical analysis is a valuable tool for exploring the relationships between different variables in community resource consumption data, and multiple linear regression analysis is a common statistical technique used to model these relationships.

Statistical analysis plays a crucial role in understanding the relationship between different variables in the context of community resource consumption. For example, multiple linear regression analysis can be used to explore the relationships between energy consumption, water consumption, waste production, and other variables such as demographic factors, weather, and building characteristics. This can help to identify the most significant factors affecting community resource consumption and inform decisions about resource management strategies. Other statistical techniques that can be used to analyze community resource consumption include cluster analysis, principal component analysis, correlation analysis, and machine learning. For example, machine learning algorithms such as neural networks and support vector machines can be used to predict community resource consumption based on historical data and other factors. Several studies have used statistical analysis to explore the relationship between energy, water, and waste in the context of community resource consumption. Multiple regression analysis use to identify the factors affecting household energy consumption in Singapore, including household size, income, and appliance usage (Chua, Li, & Li, 2017). And identify the patterns of water consumption in a residential community in China and found that household income, family size, and education level were significant factors affecting water consumption patterns (Lu, Guo, Zhang, & Cao, 2020).

A general system for examining the relationship of a collection of independent variables to a single dependent variable is represented by multiple linear regression. The relationships of a set of predictors to a criterion at a single point in time can be summarized through the use of multiple regression (MR) analysis for description. Prediction can be achieved through its use as well. A characterization of the form of their relationships, such as linear, curvilinear, or interactive, is provided by MR. The estimation of a multiple regression equation that summarizes the relationship of a set of predictors to the observed criterion is involved in multiple regression analysis (Aiken, West, Pitts, Baraldi, & Wurpts, 2012; Olive & Olive, 2017).

Statistical analysis is essential for understanding relationships between variables in community resource consumption data. Multiple linear regression analysis is a common method used to model linear relationships between independent and dependent variables. This technique can help identify significant factors affecting community resource consumption and inform resource management strategies. Other statistical methods, such as cluster analysis, principal component analysis, correlation analysis, and machine learning, can also be employed to analyze community resource consumption. Multiple linear regression analysis, in particular, examines the relationship of a collection of independent variables to a single dependent variable, allowing for description, prediction, and characterization of the form of their relationships.

The community resource relationship between energy, water, and waste can be analyzed using statistical techniques such as multiple linear regression, cluster analysis, principal component analysis, correlation analysis, and machine learning. By analyzing community resource consumption data, statistical analysis can identify the most significant factors affecting community resource consumption and inform decisions about resource management strategies. Studies have used statistical analysis to explore the relationship between energy, water, and waste in the context of community resource consumption. Multiple regression analysis can be used to identify the factors affecting household energy consumption, including household size, income, and appliance usage. Cluster analysis can be used to identify the patterns of water consumption in a residential community, and correlation analysis can be used to analyze the relationship between energy consumption and waste generation. Overall, statistical analysis is a powerful tool for understanding the complex relationships between energy, water, and waste in the context of community resource consumption.

Economic analysis of smart community

Economic analysis is an essential tool to assess the feasibility of community development investment, including smart community frameworks. This analysis considers various factors such as technology cost, operational life, and resource potential to understand the potential economic benefits of a project. Net Present Value (NPV), Internal Rate of Return (IRR), and Payback period (PB) are commonly used economic indicators for smart community frameworks. NPV calculates the sum of discounted net flows of a project, IRR is defined as the discount rate that zeroes out the net present value of costs and benefits of an investment, and PB represents the period required for an investment to recover its initial cost (Arranz-Piera, Kemausuor, Addo, & Velo, 2017; Hafiz, Rodrigo de Queiroz, Fajri, & Husain, 2019). The importance of economic analysis in the planning and implementation of smart communities. The study highlighted the need to consider the cost and benefits of a project over its lifetime, including the potential economic benefits to the community, such as improved resource management and reduced costs (Ahmad & Tahar, 2014). Economic analysis to evaluate the economic feasibility of a smart city project in Spain and found that the project had a positive NPV and a reasonable payback period (Arranz-Piera et al., 2017). It can use to evaluate the feasibility of a smart city project in Pakistan, and found that the project had a positive NPV and IRR, indicating its economic viability.

CHAPTER 3

METHOD AND EXPERIMENTAL SETUP

Research Methodology

This study aims to improve the smart community by using data management techniques. The best use of community resources will result in a smart community. The Mae Ta Man Community (MTC), which has three different types of buildings residential, governmental, and commercial is the subject of the investigation. There are six steps in the research process.: 1. Community context study; 2. Analysis of building activity profile, 3. Analysis of Community profile, 4. Development of smart community framework, 5. Design of framework, and 6. Test the smart community framework.

1. Community Context Study

The study of the community context will be conducted through a questionnaire to analyze the overall profile of the entire community. Personal information of the sample group, such as age, gender, and occupation, will be collected for activity data collection. The consumer profile data will then be analyzed for each consumer load profile. Previous studies (Bello, 2018; Thapar, 2020; Tran et al., 2021) have shown that personal data in the consumer profile have an influence on household consumption.

To conduct the study, measuring equipment will be installed to collect energy consumption, water consumption, and waste production data in 9 sample buildings from 3 different groups of buildings including Residential, Office, and Commercial. The consumer load profile will use ESM to collect energy consumption data, WSM to collect water consumption data, and SMB to collect waste production data. The data collection process for the consumer load profile will be carried out for approximately 6 months (from September 2022 to February 2023) in the sample buildings.

1.1 Questionnaire designing

The questionnaire for collecting the community data is divided into 4 sections 1. personal data of consumers, 2. appliance in the building, 3. The period of each activity, and 4. The cost of community consumption.

1.1.1 Personal data of consumer

This section will be a multiple-choice question. The question will consist of personal data including gender, age, education level, occupation, and average monthly income. Personal data can be used to group the consumer because the personal data of consumer profile affect household consumption (Bello, 2018; Novianto, Koerniawan, Munawir, & Sekartaji, 2022; Thapar, 2020; Tran et al., 2021). The multiple-choice question for collect the personal data include 5 part as the gender, age, education, occupation, and monthly income. The gender are collect between male and female, Age in the community separation rage 10 year old to 9 groups include age low than 10, age between 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, and more than 71 year old. Education level of the population in community collect 6 levels include lower than elementary school, elementary level, secondary level, high vocational certificate, bachelor's degree, and postgraduate. In community, it has the any occupation in the questionnaire just specify in 7 occupation of the most occupation in the local community in the norther part of Thailand are the farmer, private employee, general employee, students, personal business, homemaker, government officer, and the sample group can specify by own self. The monthly separate in 10,000 THB start from 0 bath to more than 50,000 bath in 6 groups.

1.1.2 Appliance in the building

The gadget in the household collects data through a series of multiple-choice and open-ended questions. The first question in this section comprises a list of household appliances such as the number and size of light bulbs, fans, air conditioners, washing machines, irons, TVs, etc. According to the informants, the two parts collect the frequency and time of household activities, such as the duration and number of times the lights turn on, showers, washing dishes, and other activities that take place within the building. In this section, three parts include the building type in the community, list and details of the appliances in building, and the time and frequency of household activities. The building sector of community collected in three sectors of the building of community include the residential building, office building, and commercial building.

1.1.3 Time period of each activity

Time period of each activity collects the time of each activity with a table checklist question of activity by time to collect activity interval data from 0:00 – 23:30 hrs. with an activity interval frequency of 30 minutes. The activity in the table checklist question corresponds to the questionnaire section 2 (II.III The frequency of household activities) to identify the time and duration of the activity. However, specifying the time and duration of the activity, the data collection is divided into 2 periods, which are activities that occur on weekdays and weekends because some activities may have the frequency and duration of the weekly activity occurring only once and occurring on weekdays or weekends.

1.1.4 Cost for community resource consumption

Section 4 of the questionnaire will collect the monthly quantity and cost of energy and water consumption in the household. Data on the quantity and cost of water consumption were collected retrospectively for a period of 1 year to characterize seasonal changes of the year.

1.2 Determination of the sample population

The sample population for menage the energy, water, and waste of community will be collected from the sample population in the Mae ta Man Community (MTC). This community has a population of around 760 people divided to male 375 people and female 380 people and 328 households. This research studies the community context with the questionnaire in the sample group. The sample group of the total population in the community uses the Taro Yamane method with a degree of error expected of 0.05 shown in the equitation where there will be a sample group for data collection with a questionnaire totaling 262 people or the 1st sample group.

$$n = \frac{N}{1 + Ne^2} \qquad [3.1]$$

When n is the sample group

N is the sample population (total population of MTC)

e is the degree of error expected of 0.05

1.3 Questionnaire validity

Questionnaire designed are validity analysis by the Index of item objective congruence (IOC). IOC is the procedure used in test questionnaires. IOC uses 3 consultants in this research sector to evaluate each questionnaire question before implementation. The content validity of the questionnaire Acceptable is based on an expert average rating above 0.5, which can be calculated from the equation. The expert will assess the question in questionnaire corresponding to the research objective with the following scoring criteria: (Kajornatthapol et al., 2020)

+1 when it is deemed appropriate that the questions are consistent with the research objectives.

0 when it is uncertain whether the questions are consistent with the research objectives.

-1 when the questions are not consistent with the research objectives.

When receiving expert scores, then adjusting them to be more consistent and suitable for the research objectives. IOC Assessment of questionnaires suitable for actual use can be evaluated by the equation if the index level is higher than 0.5, it can be concluded that the questionnaire is suitable for further use.

$$IOC = \frac{\sum R}{N} \qquad [3.2]$$

When IOC is Index of item objective congruence

N is the number of consultants

R is the score from consultants

2. Analysis of building activity profile

Activity profiles show how each consumer in a building uses energy, water, and produces waste. The activity profile is created using actual consumption and generation data from households. The activity profile makes use of two types of data: questionnaire results and data from smart meters. The building activity profile analysis is done in three steps: determining the second sample group, collecting building consumption data with Smart meters, and determining and integrating the building activity.

2.1 Determination of the 2nd sample group

Collecting data on the consumption of energy, water, and trash within the facility to create the building activity profile. It is important to collect three types of data within each building of the community using Smart meters (SM). The sample community comprises over 328 buildings, making it impossible to install SM in each one. As a result, a sample building must be chosen before installing such SM. According to general community information, the community has a population of roughly 760 people, divided into male 375 persons and female 380 persons, with 328 households.

Based on a study by Harvard University on the impact of age on energy use, sample groups were divided into 5-year age groups. It was found that the energy demand levels for each age group at 10-year intervals, namely between 10-14 years, 15-19 years, 20-24 years, and 25-29 years, were similar with no significant differences. This corresponds to the findings of the energy use patterns in each age group every 10 years, from 1980 to 2030, across six 10-year intervals. The study found that energy use increased steadily in every 10-year period and increased sharply in every sample group in the years 2000, 2010, and 2020. The age and building type were identified as factors that influenced the resource demand within buildings. Furthermore, the study identified a trend of increasing energy demand with increasing age in the sample group. This means that as the sample group ages, the energy demand also increases. (Estiri & Zagheni, 2019; Inoue, Matsumoto, & Mayumi, 2022; Powell, 2019)

Therefore, the study of consumer profile for the purpose of creating a framework to understand and develop smart communities will classify age groups of the sample population every 10 years. This information will be used to gain insights into the needs and behaviors of consumers within the community, and to facilitate the development of the community. From the community population when considering age groups. Selection of the second sample group by the community sample MTC population classified by age group as shown in Figure 3.1 found most of the people in the community to be 21–31 years old, or 133 people, or 17.50%, divided into 65 females and 68 males. In the age range of 31–40 and 41–50 years, there are approximately 115 people, divided into 62 females. 53 males and 116 people, divided into 63 females and 53 males, accounted for 15.13% and 15.26%, respectively, with both age groups having the second and third largest proportion of the community. Under 10 years old, the population is up to 109 people, divided into 53 females and 56 males, and in the 11–20 year range, there is a population of 44 females and 55 males, and the population will decrease with increasing age. By the age of 51–60 years, there were 92 people in the population, which reduced to 67 people in the age range of 61–70 years and continued to decrease to 23 and 6 people in the age range of 71–80 and more than 81 years, respectively.

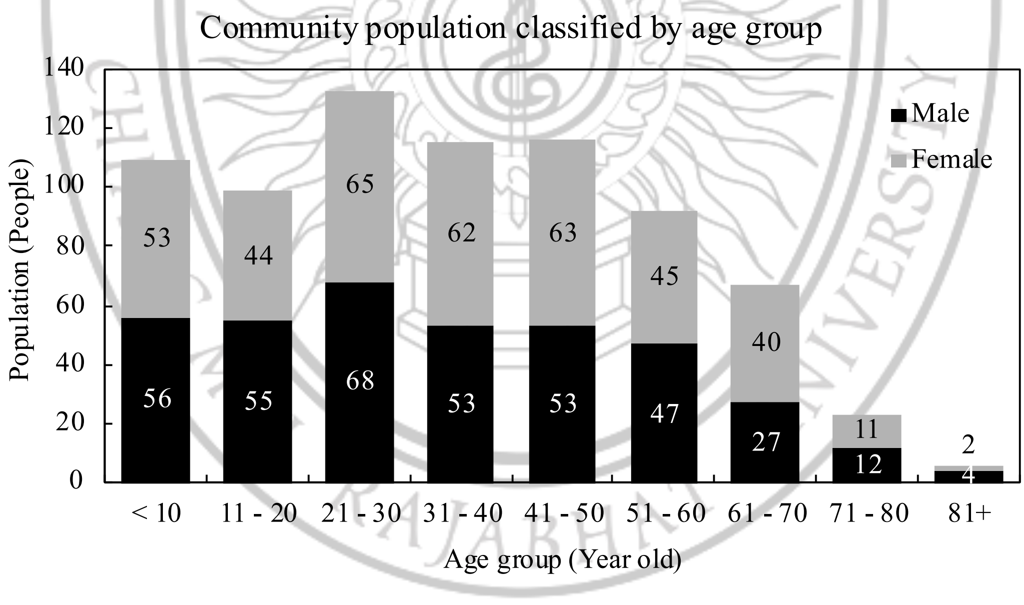


Figure 3.1 MTC population classified by age group

Specific community samples determine the second sample group for SM installation for real-time collecting data on energy, water, and waste. The sample for the SM installation was separated into two parts: selection based on building type and selection based on the personal data of population living in the building. The personal data of the population was chosen from an age range of 11 to 70 years old since this age had the largest impact on household energy and water waste consumption of any age group. However, when the age range of the community statistics is taken into consideration, the population accounts for 95.74% of the overall community population. Building types in community are classified into three categories: residential, office, and commercial buildings.

There are a total of 9 buildings considered as a sample building for real-time data collecting, which are separated into 6 residential buildings, 2 office buildings, and 4 commercial buildings, with details as follows. Residential buildings are organized into three sub-groups: two general public houses, two school houses, and two community hospital houses. There are 2 general public houses, and each house has information about the sample population that resides there. The first home (1st general public house: GH1) contains three residents, two females and one male, ranging in age from 21 to 60 years. The second home (2nd general public house: GH2) contains one male and one female resident aged 51 to 70. Two school houses separate the first home (1st school house: SH1) has three residents, one female and two males, ranging in age from 31 to 60 years, while the second home (2nd school house: SH2) has four female residents, ages 21 to 30 and 41 to 50 years old. The community hospital is separated into two buildings, with house 1 (1st community hospital house: HH1) housing two female residents aged between 21 to 30 year old and 2nd community hospital house (HH2) housing two male residents aged from 21 to 40 year old.

A collection of office buildings includes the primary office building of Baan Mae Tha Man School (BMS) is the school office (SCO), while the second office building is the community hospital office (CHO). The commercial building group has 1 building, the coffee shop. A coffee shop (COF) is also another building that is a commercial building and consumes energy, water, and waste generated in a different manner than other buildings. This may have an impact on the community's total resource consumption estimates.

2.2 Collecting of building consumption data with Smart meters

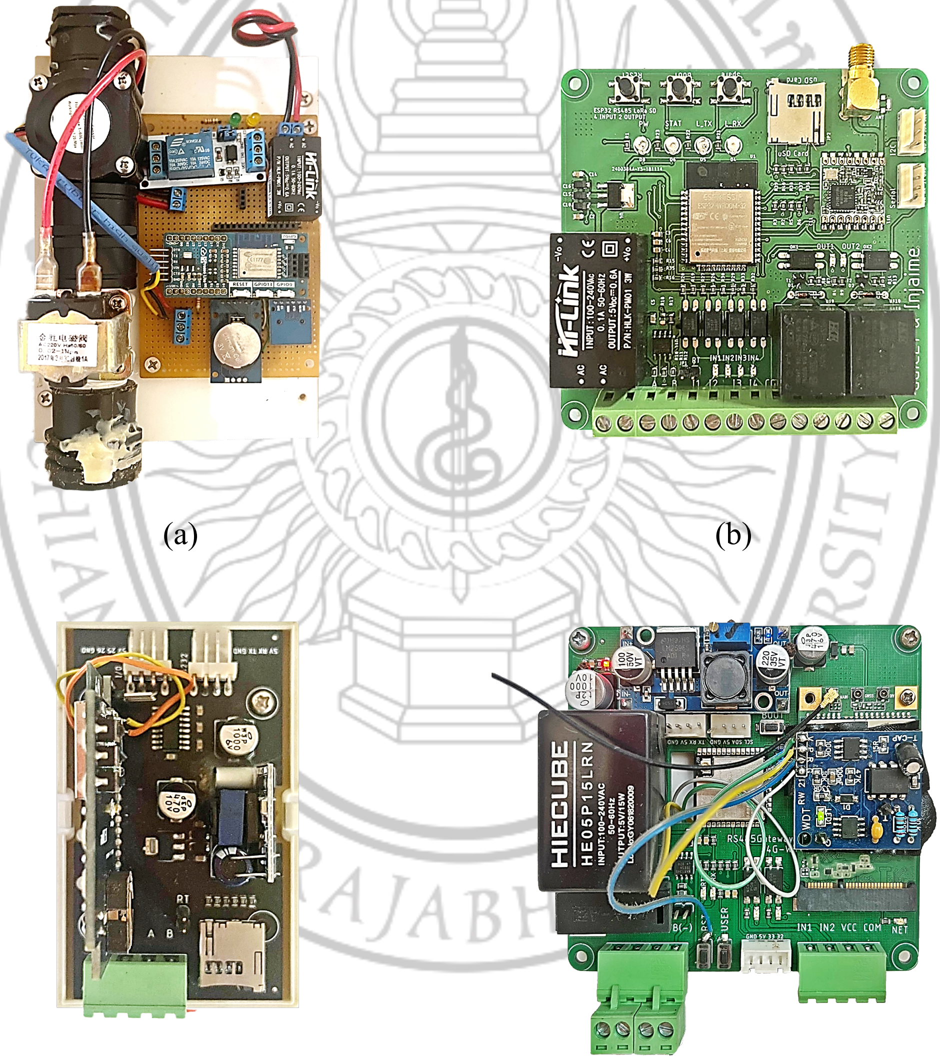
Analyzing population behavior is necessary in order to analyze data on a community's consumption of energy, water, and waste generation, which includes individual buildings. However, the monitoring of such data necessitates the employment of apparatus and implements that can constantly verify the data's time. By collecting the data for all three resources at once every 15 minutes, SM is used to measure and record the data as it is collected from the community. The development and installation details are as follows:

2.2.1 Smart meter design

The design of a Smart Meter involves the development of a device for monitoring and collecting data from a community. The focus of this study is on the measurement and collection of data related to energy, water, and waste produced at the building level. The data collected from the monitoring process will be sent to an online database, which can be used for analysis. To ensure that the system operates efficiently, a variety of technologies must be utilized, and the advantages of each technology should be combined. The development of Smart Meters can be divided into two parts: Smart Monitor, Smart Meters System, Online Communication, and Database Design.

2.2.1.1 Smart monitor (Hardware)

Several generations and prototypes of monitoring and measuring equipment for energy, water, and waste management have been developed within the community. This is due to the problems and obstacles encountered in the operation of both the data transmission and storage devices. All monitoring and measuring devices have been developed in five generations, and each generation's equipment prototype is shown in Figure 3.2. The first generation, as shown in Figure (a), was developed on a non-PCB base development board that could easily replace internal equipment and was cost-effective, but the system could not transmit data to the database. The second generation, shown in Figure (b), was an improvement over the original monitoring and measuring equipment, but installed all equipment on a PCB board and developed a data transmission system on LoRa technology. However, this technology was still relatively new during the development of monitoring and measuring equipment and was expensive, resulting in data transmission problems. Therefore, it was further developed to the third generation, shown in Figure (c), by developing a data transmission system through each building's wireless internet network. However, since it used the building's network, which included other equipment, it affected the data and network connectivity, resulting in the affected data. Therefore, it was further developed to the fourth generation, shown in Figure (d), which was developed on a 4G-LTE network that was more stable and comprehensive. However, it was much more expensive than other systems, as it required one data transmission device per measurement device and had data transmission limitations, as summarized in Table 3.1.



(a) (b)

(c) (d)

Figure 3.2 Smart monitor prototype board

Table 3.1 Strengths and problems in developing a smart monitoring system

Version	Strength	Problems
Non-PCB Base	• Affordable equipment • Internal equipment can be easily replaced	• Data storage discontinuity • Unstable • No network connectivity
LoRa- Base	• More durable • Data transmission via LoRa	• Data storage discontinuity and instability are observed. • Network connection is unavailable.
WiFi-Base	• continuously collected and transmitted • Fast data transmission • Higher data frequency	• The MCU freeze is caused by a high frequency of data recording, resulting in incomplete or missing recordings. • The MCU performs data acquisition from the sensor, processing, and network transmission, which affects high-level processing.
LTE-Base	• 4G-LTE • Continuous data transmission • Less frequent downtime • error detection circuit should be installed for the purpose of rebooting and restarting	• The cost per unit is high • The frequency and volume of data are low • Lower data transmission frequency Significantly higher production costs

Smart meters have been developed to perform a variety of functions and to enable the collection of diverse data that can be effectively managed. To design and develop hardware for smart meters, the ESP32 microcontroller family has been chosen as the main processing unit. The ESP32 is small and inexpensive and can efficiently connect to wireless networks on the 802.11 b/g/n standard, supporting both Station softAP and Wi-Fi direct modes. Additionally, it boasts high processing speed, thanks to its Tensilica LX6 architecture with 2 cores, a clock signal of 240 MHz, and 512 KB of built-in RAM, with support for external memory connections of up to 16 MB. Another advantage of the ESP32 is that it can use direct current electrical power with a voltage level of 2.6V to 3V, which is a voltage range that can be supported by small backup power devices. With all of these advantages, the ESP32 has been chosen as the primary processing unit for smart meters to support sensor and network connectivity. Therefore, the development of smart meters is the development of devices to support sensor connections in RS232, RS485, I2C, and SPI signal formats. The smart meter circuit connection is shown in Figure 3.3, which uses the ESP32 as the central processing unit, connected to the power supply module that converts alternating current electricity at 220V into direct current electricity at 5V to power the entire system. The design of the smart meter electrical circuit includes communication ports that control the connection ports in microcontroller formats, such as UART, I2C, and SPI.

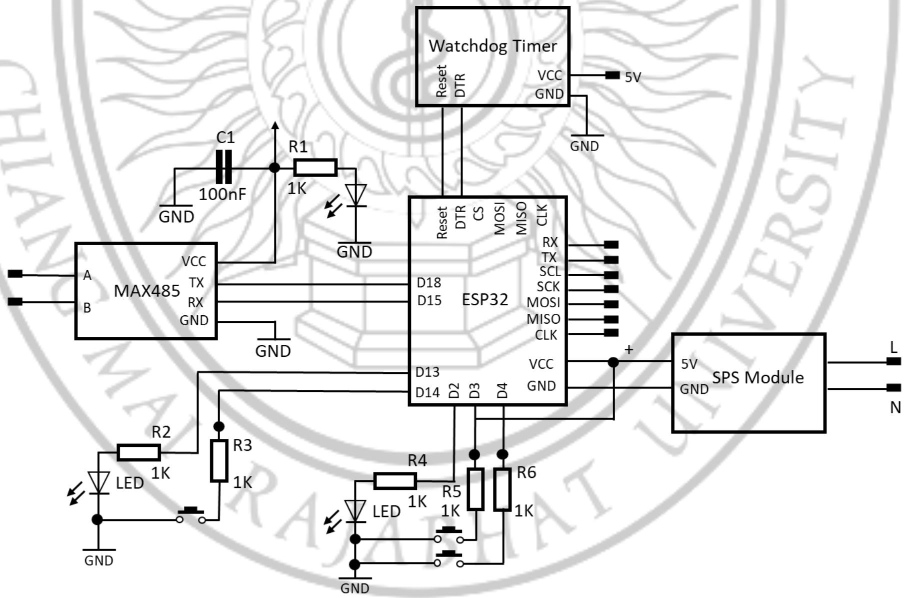


Figure 3.3 Diagram of smart meter circuit

In order to make the SM suitable for data measurement within a building, it will be developed into three types based on the characteristics of each type of data on all aspects. The appropriate type of data for measurement will be selected for further use. The details of each type of equipment are as follows:

Energy Smart meter: The energy sector is electricity. Energy consumption in each building will be collected by electricity smart meter (ESM) (Kwac et al., 2014; Sugiura et al., 2013; Tran et al., 2021) (Figure 3.4). Electricity data are power consumption in watt (kWh) units.

Figure 3.4 Electricity smart meter

Water Smart meter: The water data is water consumption volume in the community. The water consumption is measured by the water-smart meter (WSM) (Cominola et al., 2015; Gurung et al., 2014) (Figure 3.5). The data of water volume in liter (l) unit.

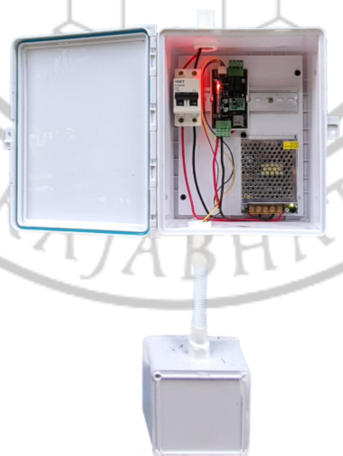


Figure 3.5 Water smart meter

Smart bin: This part collects waste of weight in the community by the smart waste meter or smart bin (SMB) (S. Mithinti et al., 2019; K. Pardini et al., 2020) (Figure 3.6). Data of waste includes the types of waste that are general, recycle, hazardous, and organic (Lundin, Ozkil, & Schuldt-Jensen, 2017). The data of waste collected in weight unit is kilogram (kg).

Figure 3.6 Smart bin

2.2.1.2 Smart meters system

The design of the working principles of a smart meter system involves the overall architecture design of the system. The system is designed to manage the conditions, events, or cases that occur within the system in order to make the hardware system work efficiently and reduce errors in the electronic system. The working principles of the system can be explained as shown in Figure 3.7. The system's working principles begin with sensing data from the sensor using a smart meter, processing the data, and managing it, then sending the data via Wi-Fi to the Server-Side Script system. In this research, Node-Red program was used to process the data online. Node-Red is a programming tool based on Node.JS that uses JavaScript for development. In this research, Node-Red was used to process data commands from the MQTT Protocol and record the data results in the Influx DB database, which is a type of time-series database. The database stores all historical statistical data. Currently, the Influx DB database works in conjunction with the MySQL database, which is used to store detailed information about the target community. This enables the web display to indicate which Time-Series Data belongs to each house. Based on these principles, the web display can show real-time data and historical statistics data simultaneously, while also processing data generated by the system for potential community assessment.

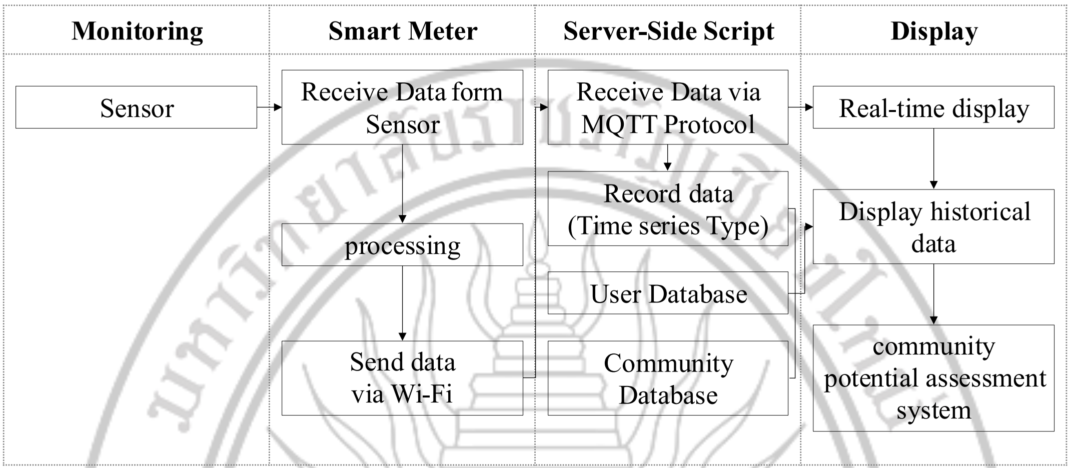


Figure 3.7 The workflow diagram of the smart meters system

2.2.1.3 online communication

The online communication system designed in this research employs the MQTT Protocol (Message Queuing Telemetry Transport) to facilitate data communication. The advantages of using MQTT include its client/server architecture with a hub-and-spoke topology, in which the destination client acts as the client and connects via TCP to a server known as the broker. The broker serves as a conduit for message exchange between clients acting as both publishers and subscribers, as illustrated in Figure 3.8. The system operates by the broker being informed of the subscriber's topic and waiting for the publisher to send data to the desired topic. The system then immediately forwards the data to the appropriate subscriber.

To leverage the aforementioned advantages of data transmission, the current research applies the MQTT Protocol to enable the system to communicate autonomously and manage data simultaneously, utilizing minimal resources for data transmission and reception. However, it is important to note that the MQTT Protocol only allows for string payloads, and the system cannot detect how to manage the received payloads. Therefore, the communication format has been defined with topics for the development of the communication system.

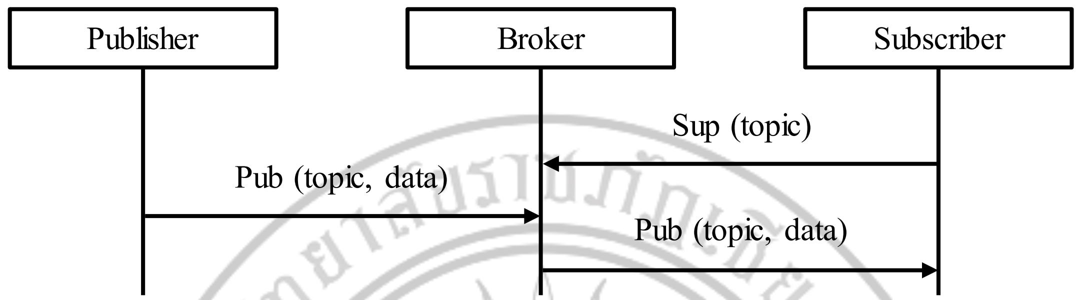


Figure 3.8 Smart meters MQTT protocol

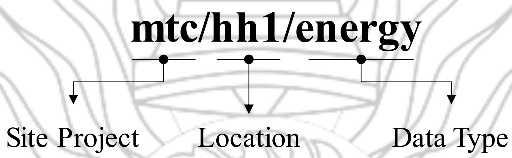


Figure 3.9 The data partitioning topic format

The topic format of data partitioning refers to the type of data identifier used in the MQTT protocol. The symbol "/" (slash) is used to specify the topic of interest to be subscribed to. The communication format design has subdivided the topic into three parts, as shown in Figure 3.9 The first part, "mtc" is an abbreviation for Mae Tha Man Community, indicating the Site Project location or the community where the data originated. The second part, "hh1" is an abbreviation for Hospital house 1, indicating the name of the installation point, such as a building, house, or other location, to distinguish where the installation point is located. The final part is "energy" which indicates the data type used to specify the type of data, such as electricity data, water usage data, and waste weight data. By defining the communication format based on the topic, the system can understand how to manage the data. The payload obtained from subscribing to the topic is formatted in JSON format, and the message must be under an object named "results" in an array format.

Table 3.2 The JSON data format

JSON Format
{ "results":[{"Data1":"xxx"}, {"Data2":"xxx"}, {"Data3":"xxx"},] }

Table 3.2 presents the Payload format specified in JSON format, which enables the system to directly convert String-formatted messages. This is beneficial for real-time data display and faster data logging, as well as immediate understanding upon viewing the Payload message.

2.2.1.4 database design

Designing a database involves designing the relationship between databases so that the Server-Side Script system and the display system can be linked, and display data as specified. In this research, a MySQL database will be used in conjunction with Influx-DB to store community data, consumer information, smart meter connections, and data display templates. The relationship between databases can be described as shown in Figure 3.10, which illustrates the relationship between databases. Consumers can create Site Projects to store data for community groups, which are related to the Device Table that stores information on what smart meters are included in the group. The Sub Project Table is created to store installation details, such as house names, building names, or other locations. The Time Series Topic Table is used to store Influx DB connection data, enabling the two databases to connect.

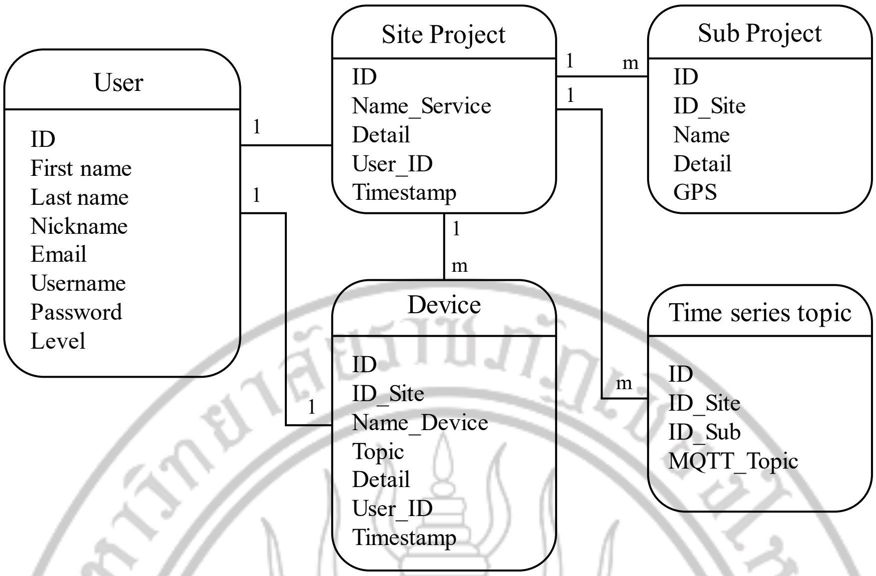


Figure 3.10 The relationship between databases

2.2.2 Smart meter installation

Community data will be collected with a smart meter and recorded to the SD card and database. The location for smart meter installation is 9 buildings in MTC as Table 3.3 and show as map in Figure 3.11. The activity data will be collected for Energy, Water, and Waste. The sample of buildings includes 3 groups as residential, Governmental, and commercial groups because the 3 building groups are part of the community which is necessary to contain a house to live, a government office to supervise and assist, and a commercial for building a community economy (Brounen et al., 2013; Tran et al., 2021). The sample of the residential building sector includes 6 buildings are General public house 1 (GH1), 2 (GH2), School house 1 (SH1), 2 (SH2), Community hospital house 1 (HH1), and 2 (HH2). The sample of the office building sector includes 2 buildings are school office (SCO), and the community hospital office (CHO). The sample of commercial building sector includes 1 building are coffee shop (COF).

Table 3.3 Location for monitoring and measurement in MTC

No.	Building group	Building	Building code
1	Residential	General public house 1	GH1
2		General public house 2	GH2
3		School house 1	SH1
4		School house 2	SH2
5		Community hospital house 1	HH1
6		Community hospital house 2	HH2
7	Office	School office	SCO
8		Community hospital office	CHO
9	Commercial	Coffee shop	COF

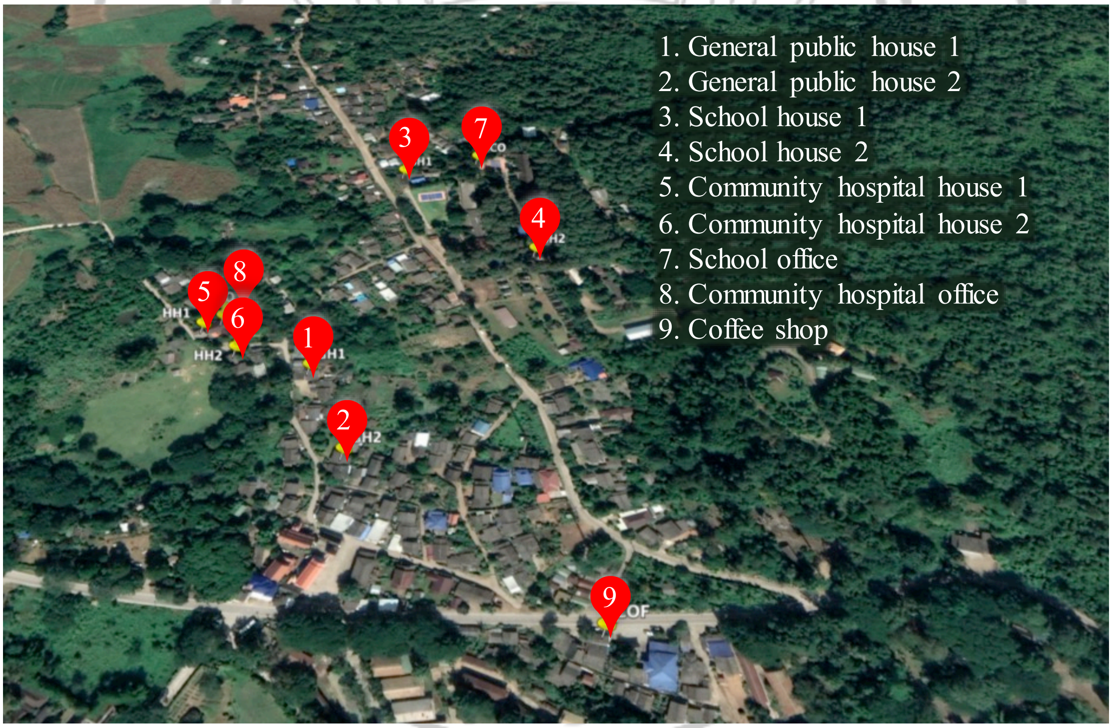


Figure 3.11 Map of smart meter installation in MTC

2.3 Determine and integrated of the building activity profile

The building activity profile provides insights between human life activity and EW2 consumption data because household energy savings relate to activity (Broek

& L., 2019; Brounen et al., 2013). Creating an activity profile using SM data and the questionnaire Determine the peak load from SM as the period activity and the questionnaire for generating the building activity on each side of EW2. SM provided the data set for the 15-minute frequency of EW2. Questionnaire data is data gathered during a 30-minute period on weekdays and weekends. Then, an analysis of the relationship between the EW2 side. The relationship of the building activity used to classify to personal activity profile based on the building activity profile. This part has 3 steps are Identification and verification of activity, relationship analysis of building activity profile, and determine the personal activity in building.

2.3.1 Identification and verification of activity

The information is utilized to investigate the pattern or trend of human activities in the neighborhood. Every 15 minutes, the community statistics for power use, water consumption, and garbage output will be recorded (Cominola et al., 2015; Haben, Singleton, & Grindrod, 2016; Li, Allinson, & He, 2018). This part focuses on finding and confirming the building activity profile of the second sample group. The sample activity profile will be defined using data from human life activities such as lighting, air conditioning, washing, and cooking in the water section and organic waste from cooking in the waste part collected with a questionnaire. The step to identify the building activity profile included two data sets: data from the smart meter collected over a 15 minute period and data from the questionnaire collected over a 30 minute period, divided by weekday and weekend.

The activity specifies the peak load of EW^2 as well as the activity time and is classified by sector. The activity profile is used to understand the community's resource use in each activity. Each activity profile can use the resource in one or more sectors of a community resource. The regression is generated by the consumption activity profile using the building activity data (Oh, Haberl, & Baltazar, 2020). The activity profile assists in predicting overall community demand. The verification of activities within the building and the analysis of each building's activity behavior will be carried out daily. by examining 15-minute data over the last 6 months.

The data collected from surveys, energy and water usage, and waste generation in each building are used to determine the timing of actual events in each activity. In this process, the frequency of each activity that occurs is determined to create consumer activity profiles based on the actual timing and frequency of events from the data. The timing of each activity is determined by comparing the actual maximum energy usage data for each day, followed by determining the frequency of repeated events in each time period of the day from all data.

2.3.2 Relationship analysis of building activity profile

The activity profile will be analyzed with a statistical process. The profile is the activity data comparisons in the relationship between energy, water, and waste. It can be divided into 4 formats of EW^2 including the relationship between energy and water, energy and waste, water and waste, and energy water and waste. The relationship between EW^2 analysis with significant relations shows the example in Table 3.4.

Table 3.4 The sample of activity profile relationship of EW^2 in community

Relationship between load profile	Example relationship load profile	Reference of relationship
Energy – Water	• Water pumping of resident • Hydro generator • Water Heater for bathing	(Bartos & Chester, 2014; S. Chen & Chen, 2016; Eon et al., 2018; Fang & Chen, 2016; S. Wang & Chen, 2016)
Energy – Waste	• Energy for Waste treatment • Electricity consumption in the refrigerator to Waste in the convenience store	(Çokay, 2018; Fetanat, Mofid, Mehrannia, & Shafipour, 2019; Panigrahi, Sharma, & Dubey, 2020; Silva, Santos, Mensah, Gonçalves, & Barros, 2020; Sözer & Sözen, 2019; Wang, Wang, Song, Ren, & Duan, 2019)

Table 3.4 (Cont.)

Relationship between load profile	Example relationship load profile	Reference of relationship
Water – Waste	• Water for Waste Treatment • Water to clean the production and waste generated from farm	(Dilekli & Cazcarro, 2019; Han, Chua, & Hyun, 2019; Kibler, Reinhart, Hawkins, Motlagh, & Wright, 2018)
Energy – Water – Waste	• Cooking • Energy and water consumption to waste products in a coffee shop	(Macintosh, Astals, Sembera, Ertl, Drewes, Jensen, & Koch, 2019; Morone, Falcone, Imbert, & Morone, 2018; Pace, Yazdani, Kendall, Simmons, & VanderGheynst, 2018)

Statistics were utilized to analyze the relationships between the activity profiles of each sector. The relationship of community load consists of the relationship between a resource and each activity. The relationship can help identify the significant factor of EW^2. The statistical relationship analysis to find the degree of relationship between the variables between EW^2 using Pearson Correlation may expand the degree of the relationship and cut the community resource out of certain activity when the relationship is not significant. The Point Biserial Correlation is used to analyze the relationship between the quantity of EW^2 and the consumer group. This may be used to determine the degree of correlation between the independent variable on an interval or ratio scale and the dependent variable on a numerical scale.

Activity load profile relationship analyzes by the analysis of variance with repeated measures equation to repeated more than once at different intervals. It is used to analyze one or more samples with more than one repeat measurement. If one sample group will not appear independent variable. It can analyze the relationship by the variable data set in interval or ration level which it can be analysis the relationship 1 dependent variable and another variable on a different scale. The Analysis of variance with Repeated measures is used to analyze the relationship between the quantity of EW^2 and between the quantity of EW^2 and the consumer group.

The relationships among all three aspects of data are the Pearson correlation coefficient as a method that indicates the relationship and direction between two variables. The Pearson correlation coefficient ranges from -1 to +1, with values approaching ±1 indicating a strong relationship between the two variables. If the correlation coefficient is close to 0, it means that the two variables have a weak or no relationship. The plus-minus sign (±) indicates the direction of the relationship. If the correlation coefficient is positive (+), it means that the two variables have a relationship in the same direction. If the correlation coefficient is negative (-), it means that the two variables have a relationship in the opposite direction (Bolboacă & Jäntschi, 2006; Pearson, 1920). This research is divided into two forms of analysis: the relationship between each aspect and the period of usage, and the relationship between resource usage quantities in all three aspects over time.

3. Analysis of Community profile

The Community profile analysis involves the process of expanding information from activity and building profiles into data on energy, water, and waste requirements for the entire community, including population data. This analysis is divided into three steps: collecting activity data through questionnaires, Determine the community activity profile, and extrapolating to the actual community.

3.1 Collecting of activity data with questionnaire

To determine the characteristics and resource requirements of the entire community, an analysis of activity behaviour within buildings is conducted based on data collected through questionnaires. The questionnaires are distributed to a sample group of 264 individuals, and the resulting data is analyzed according to activity profiles to identify similarities and differences in activity types and times within all buildings. Additionally, the questionnaires also collect data on the equipment and devices within the buildings, which can affect energy and water usage within the buildings. The sample group is categorized based on factors such as gender, age, average income, educational level, and occupation, which may impact the number of resources consumed within the buildings. Based on the collected data, the community's energy and water usage can be estimated and analyzed to identify potential areas for resource conservation and management.

3.2 Determine the community activity profile

The analysis will focus on the significant data of the relationship from the consumer load profile. The community load profile is most of the community population consumption in the MTC data. The community load profile analyzes data for the identification of the consumer load profile. The data of the community load profile is used to create mathematical models (Math model). The math model is the equation of community load profile to resource management. That is used for the specification of consumption volume, frequency of load, and consumption using time in the community resource sector on a daily, weekly, monthly, and yearly. The community load profile analyzes the consumption of EW^2 with time. The community load profile can be considered consumer and community demand on EW2. The community load profile can identify the time of each community resource sector. That properly analyzes the community resources. Suitable community resources are used for calculating the community consumption demand. For example, energy demand on the day can use the energy resource from solar energy because solar energy can generate energy in the daytime only. The community load profile is determined from the consumer load profile. That can explain the community load by the time.

3.3 Extrapolation to the actual community

After obtaining a community activity profile that identifies the characteristics and frequency of activities occurring in a building from a sample group (consisting of 264 individuals), extrapolation to the actual community was performed by referencing data from the entire population of the community (765 individuals) divided by profile to estimate the quantity of energy, water, and waste generated in the entire community.

3.4 Community profile verification

Once the total quantity of energy, water, and waste generated by the community has been estimated, the reliability of the dataset is confirmed through monthly expenditure bills for energy, water, and waste management expenses, using data from a one-year retrospective survey. Verification of the community profile is necessary by considering other factors that affect resource utilization, such as the climate conditions in each season that directly affect energy consumption, as well as the effect on water sources in the area. Then, the parameter values are adjusted to align with the data to ensure that the community profile is reliable.

4. Development of smart community framework

This part analyzes the possibility and preparedness of the community in the energy, water, and waste sector. The possibility and preparedness of the community are guidelines for the development of a smart community. The Smart community development plan can be divided into 3 parts which are study of community potential, smart community development planning, and economic analysis.

4.1 Study of community potential

The performance assessment focuses on energy, water, and waste sectors from topography, community characteristic, and resource demand identified based on resource availability. The topography includes area, natural water source, and energy potential. The community characteristic includes population, occupation, and facilities. the resource demand includes used frequency, demand quantity, and resource balance (Akour, Al-Heymari, Ahmed, & Khalil, 2018).

4.1.1 Energy

The energy potential focuses on renewable energy for energy optimization for the community. Renewable energy includes solar energy, wind, biomass, and waste (Ahmad & Tahar, 2014; Medina-Santana, Flores-Tlacuahuac, Cárdenas-Barrón, & Fuentes- Cortés, 2020). The possibility of energy exploration in table 3 showed the potential collection in each part of community energy.

Table 3.5 The potential collection of energy part

Energy part	Potential collection	References
Solar	◦ Solar irradiation ◦ Percentage of solar shading ◦ Installation space	(Janjai, 2014; Solar PathFinder, 2016; Zhong & Tong, 2020)

Table 3.5 (Cont.)

Energy part	Potential collection	References
Wind	◦ Wind speed ◦ Wind direction ◦ Installation space	(Akour et al., 2018; Gagliano, Nocera, Patania, & Capizzi, 2013; Idriss, A. I., Ahmed, Omar, Said, & Akinci, 2019; Kouloumpis, Sobolewski, & Yan, 2020)
Waste	◦ Quantity of Waste ◦ Type of Waste ◦ Heating valued of waste ◦ Installation space	(Ayodele, Ogunjuyigbe, & Alao, 2017; Joseph & Prasad, 2020)

4.1.2 Water

The water potential focuses on 2 resources of community water such as natural water and recycling water. Natural water is the water source in the community for consuming water and drinking water. Recycling water is the water treatment of the community for consuming and farming. The possibility of natural water finds the water source in the community and the recycling water explores the wastewater from the household.

4.1.3 Waste

The waste possibility in the community focuses on the quantity of waste. The quantity of waste can be collected from SWM. The community waste possibility is the ability to reapply the waste. That is a value creation from waste and the possibility for waste reduction such as converting waste into energy and making the fertilizer from waste.

4.2 Smart community development framework

The framework develops on the possible data of community resources. The planning is a systematic resource management procedure. The smart community guideline develops for community resource optimization by the community. Community resource optimization can be divided into 3 resources. Compare data from total community load profile with EW^2 potential to find resources within the community that are suitable for use. The case has sufficient potential and appropriate calculate the size and budget of the technology to adequately support all community demand. The case has insufficient potential calculate the size and budget of the technology and transportation system and storage to support all community demand.

4.2.1 Energy

The energy part analyzes the energy potential including solar, wind, biomass, and waste. The optimization of energy potential must be suitable for the community context (Y. Chen & Hu, 2016; Silva et al., 2020; Xu, Hu, Cao, Huang, & Chen, 2020; Zhu, Shen, Song, Zhou, Zhang, & Kusiak, 2019).

4.2.2 Water

The water sector analyzes demand, supply, storage, and water treatment for worthwhileness water consumption (Al-Ansari, Alibrahiem, Alsaman, & Knutsson, 2014; Dupont, 2013; Dupont & Renzetti, 2013; United Nations World Water Assessment Programme (UN-Water), 2015).

4.2.3 Waste

The waste part analyzes type, derivation, and quantity for planning to maximum benefit used in each community waste (H. Han et al., 2019; Sözer & Sözen, 2019; Yeo, Oh, Cheung, Lee, & An, 2019).

4.3 Economic analysis

The economic analysis of community investment possibility and preparedness to community development. The economic analysis on technology cost, tools, and necessary tools. The economic analyzes in net present value (NPV), the internal rate of return (IRR), and the payback period (PB) (Garcia & You, 2018; Han, Kimura, & Sandu, 2019).

5. Design of framework

A community development framework for a smart community can be designed by collecting and analyzing data from multiple sources, including questionnaires (Huang, Huang, Gao, & Guo, 2021), smart meters for gathering data on water and waste consumption (Dumitru, Mureșan, Szakály, & Cosma, 2020), and public databases can also provide useful information on environmental factors such as weather patterns (Yang, Ye, Cao, Zou, & Chen, 2020).

Once the data is collected, an activity profile can be built by analyzing it to identify the community's demand. Activity-based analysis to identify energy savings opportunities in buildings (Su & Zhang, 2019). This can help in understanding how the community uses energy, water, and waste, as well as identifying opportunities for improvement. The data analysis to identify the community's needs for energy, water, and waste management (Dumitru et al., 2020).

After identifying the community's needs, the potential of the community to meet those needs should be analyzed. This includes assessing the potential for implementing renewable energy sources such as solar and wind power, as well as considering water conservation measures such as rainwater harvesting. The framework for assessing the potential of renewable energy communities, and can provide guidance on considering the potential for implementing water conservation measures (Kim, Seo, & Baek, 2018; Siriwardena, Bhattacharya, & Sadiq, 2021).

Finally, an economic analysis should be conducted to determine the suitability and feasibility of implementing various energy, water, and waste management strategies. Economic analysis for sustainable infrastructure projects and provide guidance on conducting such an analysis to determine the costs and benefits of different options. It can assess the return on investment for implementing renewable energy sources such as solar and wind power (Dumitru et al., 2020; Miraftab & Sutaria, 2018).

Overall, designing a community development framework for a smart community requires a comprehensive approach that involves data collection and analysis from various sources, identifying the community's needs, assessing its potential to meet those needs, and conducting an economic analysis to determine the feasibility of implementing various strategies.

Research flow

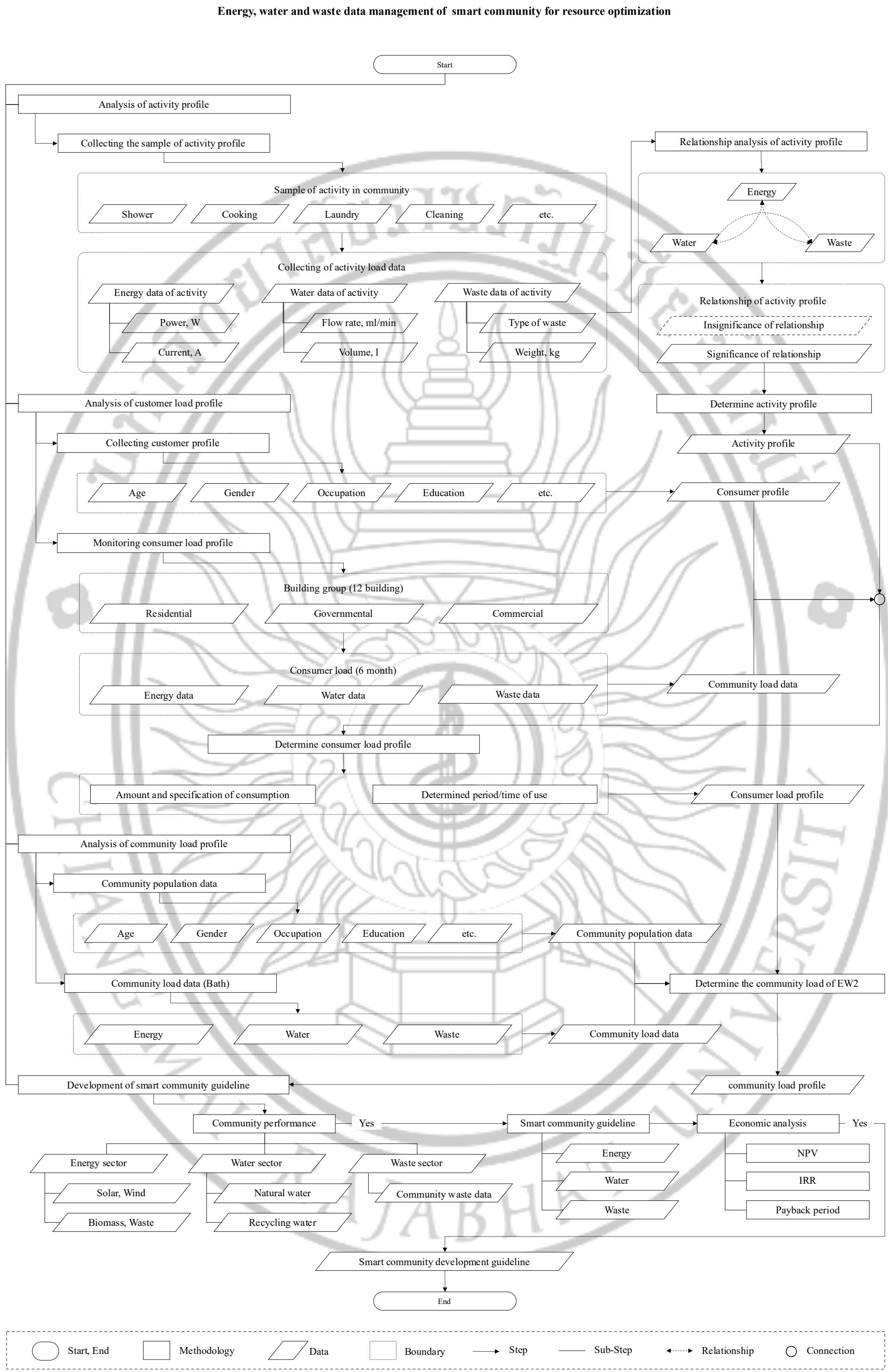


Figure 3.12 Conceptual framework energy, water, and waste data management framework toward smart community

CHAPTER 4

RESULT AND DISCUSSION

Community context

Mae Tha Man Community (MTC) is the local community in the northern part of Thailand. The topography of the area is a high mountain complex, and some parts are hilly plains. The location of most residential buildings is in the hilly plains. The entire area of the community is in the watershed forest of the two main rivers in the northern part of Thailand and is a national reserved forest area. This community has a population of around 760 people divided to male 375 people and female 380 people and 328 households. The population data show as Table 4.1, the samples group were aged between 11-20 years, 6.00%, 21-30 years, 12.80%, 31-40 years, 14.80%, 41-50 years, 18.00%, 51-60 years, 18.40%, 61-70 years, 21.20%, and more than 71 years, 8.40%. The population's level of education in the community found that most of them graduated from the elementary level 51.37%, a secondary level 22.35%, a bachelor's degree 9.80%, a High vocational certificate 4.71%, and 1.96% graduated with a postgraduate degree. The occupation of community population has 6 occupations including general employees 40.32%, government officer 7.51%, personal business 15.81%, farmers 1.98%, private employee 6.72%, and students 6.72%. The average monthly income of around 73.09% lower than 10,000 Baht, 21.29% have an average income between 10,001 – 20,000 Baht, 3.61% have an average income between 20,001 – 30,000 Baht, 0.80% have an average income between 30,001 – 40,000 Baht, 0.40% have an average income between 40,001 – 50,000 Baht, and 0.80% have an average income more than 50,001 Baht.

Table 4.1 Community context

Community data type		Number (People)	Percentage
Gender	Male	111	42.86
	Female	148	57.14
Age (Year)	< 10	1	0.40
	11-20	15	6.00
	21-30	32	12.80
	31-40	37	14.80
	41-50	45	18.00
	51-60	46	18.40
	61-70	53	21.20
	> 71	21	8.40
Education	Below elementary school	25	9.80
	Elementary level	131	51.37
	Secondary level	57	22.35
	Bachelor's degree	12	4.71
	Postgraduate degree	25	9.80
Occupation	Farmer	5	1.96
	Private employee	5	1.98
	General employee	17	6.72
	Students	102	40.32
	Personal business	17	6.72
	Housekeeper	40	15.81
	Government officer	53	20.95
Monthly income (Baht)	< 10,000	19	7.51
	10,001 – 20,000	182	73.09
	20,001 – 30,000	53	21.29
	30,001 – 40,000	9	3.61
	40,001 – 50,000	2	0.80
	> 50,000	1	0.40

There is a relationship between each data segment and the correlation of variables used to characterize the identity of community populations or monitor resource consumption. The age range was discovered to be a variable that was related to other factors. In Pearson correlational analysis, aging was significantly correlated with or had a negative influence on all levels of education, occupation, and income. The correlation was significant at the 0.01 level. Age was also related to occupation at a -0.265 level, and income was related at a -0.285 level. They both have at the 0.05 level; the connection is significant. In addition, the level of education has a positive relationship with occupation and monthly income at the 0.587 and 0.704 correlation levels, with the correlation being significant at the 0.01 level. The occupation of the population was positively connected with monthly income at the 0.437 level with the connection is significant at the 0.01 level. Table 4.2 shows the information on the correlation between the variables in the population categorization. In other words, as the population ages, so does the level of education and the average monthly income. The occupation information is gathered from the level of education and is then matched to the sample's average income. This is consistent with the results of a research of household water usage behavior, which discovered that socioeconomic characteristics including income and household composition were regarded indirect drivers that had no impact on building resource consumption behavior (Jorgensen, Graymore, & O'Toole, 2009).

Furthermore, from the study on the age range that affects resource utilization within the building, it was found that the age group under 10 years old has no significant effect on resource utilization within the building, while the community as a whole is of significant importance (Estiri & Zagheni, 2019). Therefore, the variable group for the age range used in the study was narrowed down to only 7 groups, ranging from the age group between 11 to the group of individuals above 70 years old. The correlation data of such variables could be used to identify relevant variables for the investigation of the data on energy, water, and waste creation in the scenario.

From the correlation data of personal data variables presented in Table 4.2, it was found that gender did not have a significant correlation with any other variables. However, Age, Education, Occupation, and Income showed significant positive correlations with each other, as determined by statistical analysis. Therefore, in the analysis and development of activity profiles, all profiles will be classified into 14 customer profiles, consisting of two gender factors and seven age ranges.

Table 4.2 Correlation of personal data variable

		Sex	Age	Education	Occupation	Income
Sex	Pearson Correlation	1.000	-0.007	0.008	0.168	-0.179
	Sig. (2-tailed)		0.951	0.949	0.165	0.139
	Covariance	0.230	-0.006	0.005	0.143	-0.086
	N	72	70	70	70	70
Age	Pearson Correlation	-0.007	1.000	-0.538**	-0.265*	-0.285*
	Sig. (2-tailed)	0.951		0.000	0.026	0.017
	Covariance	-0.006	2.713	-1.197	-0.788	-0.475
	N	70	70	70	70	70
Education	Pearson Correlation	0.008	-0.538**	1.000	0.587**	0.704**
	Sig. (2-tailed)	0.949	0.000		.000	0.000
	Covariance	0.005	-1.197	1.825	1.431	0.962
	N	70	70	70	70	70
Occupation	Pearson Correlation	0.168	-0.265*	0.587**	1.000	0.437**
	Sig. (2-tailed)	0.165	0.026	0.000		0.000
	Covariance	0.143	-0.788	1.431	3.255	0.799
	N	70	70	70	70	70
Income	Pearson Correlation	-0.179	-0.285*	0.704**	0.437**	1.000
	Sig. (2-tailed)	0.139	0.017	0.000	0.000	
	Covariance	-0.086	-0.475	0.962	0.799	1.025
	N	70	70	70	70	70

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

1. Community building characterizations

Building characteristics are details on the equipment and appliances that use or create energy, water, and trash. Building characteristics are separated into two types: those that are averaged over the whole community and those that are segregated by consumer characteristics. to study the relationship between each factor that may impact the information acquired from each building. The information on building equipment and appliances is shown in Table 4.3.

The building equipment and appliances table. Lighting equipment: It was determined that there are three types in the community, including LED, fluorescent, and incandescent bulbs. LED accounted for 69.83% of the utilization of 6.92 LED bulbs with an average power of 13.96 W, fluorescent accounted for 55.17% of 4.84 bulbs with an energy consumption of 21.74 W, and incandescent bulbs accounted for 5.17% of 6.83 bulbs with an energy consumption of 29.25 W.

Due to the community's location in the mountains of northern Thailand, where the average temperature is rather low, community members rarely use air conditioners (AC). As a result, the percentage of households that use air conditioning amounts to just 6.03% of the overall community. and the average income in the community is low, which impacts the decision to employ a fan as a device for regulating the room temperature in the building. The community employs three types of fans: ceiling, wall-mounted, and table. The average fan size is roughly 16.61 in., with ceiling fans accounting for 15.52%, wall-mounted fans accounting for 24.14%, and table fans accounting for 77.59%. A typical home contains 3.73 units of ceiling fans, 2.29 units of wall-mounted fans, and 2.23 units of table fans.

Regarding cabinet coolers in the community, including refrigerators and freezers, most of the equipment that is installed within a residential building That is, conventional single-door refrigerators account for 46.55% of interior usage, whereas conventional double-door refrigerators account for 3.46%. The utilization of inverter refrigerators in residential buildings was 10.34%, with both single-door unit and 9.48% with double-door unit. The most popular sizes in the community are 5.42 ft3 for single-door cabinets and 7.45 ft3 for double-door cabinets. And used in building 1.36 unit of the conventional single-door type, 1.03 unit of conventional double-door type, 1.17 unit of inverter single-door type, and 1.18 unit of inverter double-door type. A solid-door freezer is the only type of freezer used in residential buildings. A conventional solid-door freezer accounts for 1.72% of all residential buildings in a community, with an average size of roughly 8.00 ft3 among of 1.00 unit average for each building.

The water heaters in the resident building are of three types: an LPG water heater, an electrical water heater, and a hot water kettle, of which the LPG and electrical water heaters are used as a system to provide hot water in the bathroom for bathing and the kettle is used to boil water for consumption. percentage of hot water systems in bathrooms for all of the community are 7.76% LPG water heaters and 31.90% electrical water heaters. The largest electrical water heater in the resident building averages around 3,008.00 W among the 1.03 units/building. In the building, there are two types of hot water kettles: kettles and thermoses. The hot water kettle percentage is 19.83% for the kettle and 37.07% for the thermos. A kettle is typically 1.54 l. in size, with 1.04 units/building, and a thermos is typically 2.60 l. in size, with 1.00 Unit/building.

The community regularly uses four kinds of cooking equipment: a rice cooker, microwave, air fryer, hot air oven, and mixer. The most popular type of rice cooker in this community is the conventional rice cooker, which accounts for 70.69% of the 1.52 l. size and 1.02 unit/building The second most popular type is the digital rice cooker, which accounts for 6.900.63% of the 2.24 l. size and 1.00 unit/building. Microwaves are not a very popular appliance in the kitchen because the average amount of microwave-equipped households is around 21.55% of the total community, with a consumption of 1,064.80 W 1.00 unit/household. The air fryer, hot air oven, and mixer, on the other hand, are less popular in households, accounting for around 3.45% of the total for the air fryer, 0.86% for the oven, and 18.10% for the mixer. The energy consumption of the air fryer to be used in the household is 660.00 W, and each household has 1.00 unit. The size of the hot air oven to be used in the house is 2,400.00 W for energy consumption, and each household has 1.00 unit. The energy consumption of the household mixer is 613.97 W, and each house has 1.00 unit.

There are four types of washing machines and one type of drying machine in the community. The washing machine includes a twin tub, top load, front load, and washer/dryer. The twin tub washer is the most popular in the community, with a percentage to having in the building approximately 65.52% at 12.33 kg of size and each household having 1.08 unit, while the top load washer has a percentage of the building having around 9.48% at 11.73 kg and each household having 1.00 units. Front load washers and washer/dryers are only used by people in the community around 0.86% at 15.00 kg and 0.86% at 15.00 kg, respectively. Each family has 1.00 unit of front load washer, and each household has 1.00 unit of washer/dryer.

The community is in a remote location, and most residents are general employees and Personal business, according to occupational data in the community. There is no requirement for immaculate clothes or uniforms on a regular basis. thus, affecting the number of irons available in the building. Buildings with irons account up only 46.55% of all buildings, according to the statistics. Each building contains an average of 1.02 unit, each of which requires roughly 810.03 W of power.

Television (TV) is the most used device in the home, and it is classified into two types: LCD TV and LED TV. Because of their new technology and lower power consumption, LED TVs are more popular than LCD TVs. LED use in the household is around 49.14% with 35.23 in., but LCD use in the household is only 12.93% with 35.67 in. Each household has 1.20 unit of LED TV and 1.00 unit of LCD TV.

Table 4.3 Building equipment and appliance.

Equipment and appliance			Average	SD	Percentage	max	min
Lighting	LED	Size	13.96	9.68	67.24	60.00	4.00
		Amount	6.92	4.61	69.83	20.00	1.00
	Fluorescent	Size	21.74	12.27	54.31	41.00	6.00
		Amount	4.84	3.35	55.17	14.00	1.00
	Incandescent	Size	29.25	6.82	3.45	60.00	14.00
		Amount	6.83	1.83	5.17	11.00	1.00
Fan	Ceiling	Size	16.61	6.44	15.52	20.00	14.00
		Amount	3.73	2.59	12.93	18.00	1.00
	Wall mounted	Size	16.14	6.74	18.97	18.00	14.00
		Amount	2.29	1.45	24.14	11.00	1.00
	Table	Size	15.87	5.66	75.86	20.00	1.00
		Amount	2.23	1.13	77.59	5.00	1.00
Ac	Invertor	Size	10,228.57	2,663.36	6.03	12,200.00	8,000.00
		SEER	765.00	224.98	2.59	2,250.00	22.50
		Amount	1.14	0.31	6.03	2.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
AC	Conventional	Size	12,662.50	3,626.33	6.90	20,000.00	9,000.00
		SEER	13.63	2.99	4.31	15.00	13.00
		Amount	1.00	0.29	7.82	1.00	1.00
Refrigerator	Conventional single door	Size	5.42	2.85	46.55	10.00	1.60
		Amount	1.36	0.96	46.55	7.00	1.00
	Invertor single door	Size	6.46	2.27	10.34	10.00	3.40
		Amount	1.17	0.40	10.34	2.00	1.00
	Conventional double-door	Size	7.45	3.46	25.00	9.50	5.00
		Amount	1.03	0.49	26.72	2.00	1.00
	Invertor double-door	Size	8.30	2.62	9.48	9.40	6.40
		Amount	1.18	0.42	9.48	3.00	1.00
Freezer	Conventional solid door	Size	8.00	1.16	1.72	10.00	6.00
		Amount	1.00	0.14	1.72	1.00	1.00
Electric water heater		Size	2894.25	3,008.00	1,580.76	31.90	4,500.00
		Amount	1.03	1.03	0.51	31.90	2.00
Hair dry		Size	1,173.15	482.49	11.21	2,600.00	1.00
		Amount	1.00	0.37	13.79	1.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
Rice cook	Conventional rice cooker	Size	1.52	0.70	70.69	2.00	0.60
		Amount	1.02	0.42	70.69	2.00	1.00
	Digital rice cook	Size	2.24	0.63	6.90	3.00	1.50
		Amount	1.00	0.27	6.90	1.00	1.00
Microwave		Size	1046.67	1,064.80	513.87	21.55	2,000.00
		Amount	1.00	1.00	0.45	23.28	1.00
Water boiler	Hot water kettle	Size	1.54	0.72	19.83	3.00	0.80
		Amount	1.04	0.45	19.83	2.00	1.00
	Thermos	Size	2.60	2.71	37.07	25.00	1.00
		Amount	1.00	0.50	37.93	1.00	1.00
Air fryer		Size	660.00	162.90	3.45	1,400.00	220.00
		Amount	1.00	0.20	3.45	1.00	1.00
Oven		Size	2,400.00	240.00	0.86	2,400.00	2,400.00
		Amount	1.00	0.10	0.86	1.00	1.00
Mixer		Size	613.97	341.34	18.10	1,800.00	220.00
		Amount	1.00	0.43	20.69	1.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
Washing machines	Twin tub	Size	13.00	1.30	0.86	13.00	13.00
		Amount	1.00	0.10	0.86	1.00	1.00
	Top load	Size	12.33	5.89	65.52	17.00	6.00
		Amount	1.08	0.53	67.24	3.00	1.00
	Front load	Size	11.73	3.77	9.48	15.00	8.00
		Amount	1.00	0.31	9.48	1.00	1.00
Washing machines	Washer/dryer	Size	15.00	1.50	0.86	15.00	15.00
		Amount	1.00	0.10	0.86	1.00	1.00
Iron		Size	810.03	533.41	46.55	2,500.00	10.00
		Amount	1.02	0.51	52.59	2.00	1.00
TV	LCD	Size	35.67	13.04	12.93	50.00	24.00
		Amount	1.00	0.35	12.07	1.00	1.00
	LED	Size	35.23	18.49	49.14	55.00	20.00
		Amount	1.20	0.70	50.86	3.00	1.00

2. Building activity

The analysis of activities occurring within all buildings was conducted based on data collected from a questionnaire. The data collection process involved recording all activities that occurred within the buildings and presenting their characteristics and abbreviations in Table 4.4. The analysis of building activities was divided into two main parts, namely, the analysis of the frequency of each activity that occurred in the building and the analysis of the time period during which each activity took place. In addition, the activities were grouped according to the characteristics of each consumer in order to identify trends and directions of activity behavior within the building. This involved identifying consumer characteristics and analyzing their behavior within the building.

Table 4.4 Abbreviations and definition of activity in building

No.	Activity	Abbrev.	Definition
1	Cake freezer	CF	The activity of using a cake freezer involves storing cakes or other baked goods at low temperatures to preserve their freshness and prevent spoilage.
2	Cooking	CK	The activity of cooking involves preparing and heating food to make it safe and palatable to eat. This may involve selecting ingredients, following a recipe, and using various cooking methods such as baking, or grilling.
3	Eating	ET	The activity of eating involves preparing food and consuming it for nourishment and enjoyment.
4	Electric water heater	WH	The activity of using an electric water heater involves heating water for use in various applications such as bathing, washing dishes, and cleaning.
5	Fan	FA	The activity of using a fan involves turning on and adjusting the settings of the device to circulate air and provide ventilation.

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
6	Toilet	TL	The activity of flushing a toilet involves pressing a button or pulling a lever to release water from a tank and flush away waste. This may involve adjusting the amount of water used and checking for any potential clogs.
7	Gardening	GN	The activity of gardening involves planting and caring for plants in a garden or other outdoor space.
8	Hair dry	HD	The activity of drying one's hair involves using a hair dryer to blow hot air over wet hair, allowing it to dry quickly.
9	Iron clothes	IC	The activity of ironing clothes involves using a heated iron to smooth out wrinkles and creases in fabric.
10	Laptop	LP	The activity of using a laptop involves accessing and using software applications and other digital resources for various purposes such as work, communication, entertainment, and education.
11	Lighting	LT	The activity of lighting involves installing and using light sources to illuminate a space. This can include selecting the appropriate type of lighting for a given space, positioning light fixtures, and adjusting lighting levels for various purposes such as task lighting or ambiance.
12	Microwave	MI	The activity of using a microwave involves selecting the appropriate settings and placing food inside the microwave to heat it quickly.
13	Mixer	MX	The activity of using a mixer involves combining ingredients for baking or cooking and mixing them together to create a homogeneous mixture.

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
14	Oven	OV	The activity of using an oven involves preheating the appliance to the appropriate temperature, selecting the appropriate cooking mode, and placing food inside to bake, roast, or broil.
15	Pet	PT	The activity of caring for an animal or pet involves providing food, water, shelter, and exercise for the animal, as well as ensuring its health and well-being.
16	Refrigerator	RE	The activity of using a refrigerator involves storing food and beverages inside the appliance to keep them fresh and prevent spoilage.
17	Rice cook	RC	The activity of cooking rice involves measuring out the correct amount of rice and water, adding them to a rice cooker, and selecting the appropriate settings to cook the rice.
18	Bathing	BA	The activity of taking a shower involves preparing the bathroom with the necessary supplies, such as towels and soap, and then getting undressed and entering the shower.
19	TV	TV	The activity of watching TV involves selecting a program or channel to watch and adjusting the volume and picture settings as needed.
20	Wash car	WR	The activity of washing a car involves cleaning the exterior of the vehicle to remove dirt, dust, and other debris.
21	Wash clothes	WC	The activity of washing clothes involves sorting laundry by color and fabric type, adding detergent and other cleaning products to a washing machine, and selecting the appropriate settings for the load

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
22	Wash dish	WD	The activity of washing dishes involves cleaning and sanitizing plates, utensils, and other kitchen items used for eating and cooking.
23	Water boiler	WB	The activity of using a water boiler involves filling the device with water and selecting the appropriate temperature setting to heat the water quickly.

2.1 Building activity frequency

The frequency of activities is compared with the activity time and activity frequency for each activity. to analyze the factors related to personal data that affect the duration of the activity. including the frequency of all activities within the building. When considering the duration of each activity classified by gender, it was found that the average duration of most activities for males was longer than for females.

From Figure 4.1, the duration and frequency of each activity occurring within the building were shown. It was found that the duration of activities carried out by males in the building was slightly longer on average than those by females. When considering the duration of each activity, it was found that turning the light (LT) was the activity that took the longest time for both male and female consumers. The average duration for this activity was 235.55 minutes for males and 222.66 minutes for females. Additionally, there were three other activities that took longer than an hour to complete, which were turning the fan, with an average duration of 162.78 minutes for males and 180.39 minutes for females, watching TV, with an average duration of 174.34 minutes for males and 174.35 minutes for females, and using the air conditioner is a singular activity, with a discernible difference in the duration of activity between the two genders. On average, males engage in this activity for 120.00 minutes, while females do so for 256.67 minutes. The disparity in the duration of the activity between the two groups is evident, with a time difference of 136.67 minutes.

Upon examining activities with a duration of less than one hour, it was discovered that there was a total of 14 such activities. Each of these activities had a differing average duration, with an average of approximately 4.18 minutes. The average duration for each activity between the two genders is as follows: 48.75 minutes for cooking, 46.53 minutes for washing clothes, 29.23 minutes for rice cooking, 31.21 minutes for washing a car, 28.53 minutes for ironing clothes, 22.61 minutes for pet care, 16.25 minutes for boiling water, 19.61 minutes for eating, 20.41 minutes for gardening, 16.28 minutes for bathing, 12.92 minutes for reheating food in the microwave, 10.84 minutes for washing dishes, 8.37 minutes for hair drying, and 4.78 minutes for using the toilet.

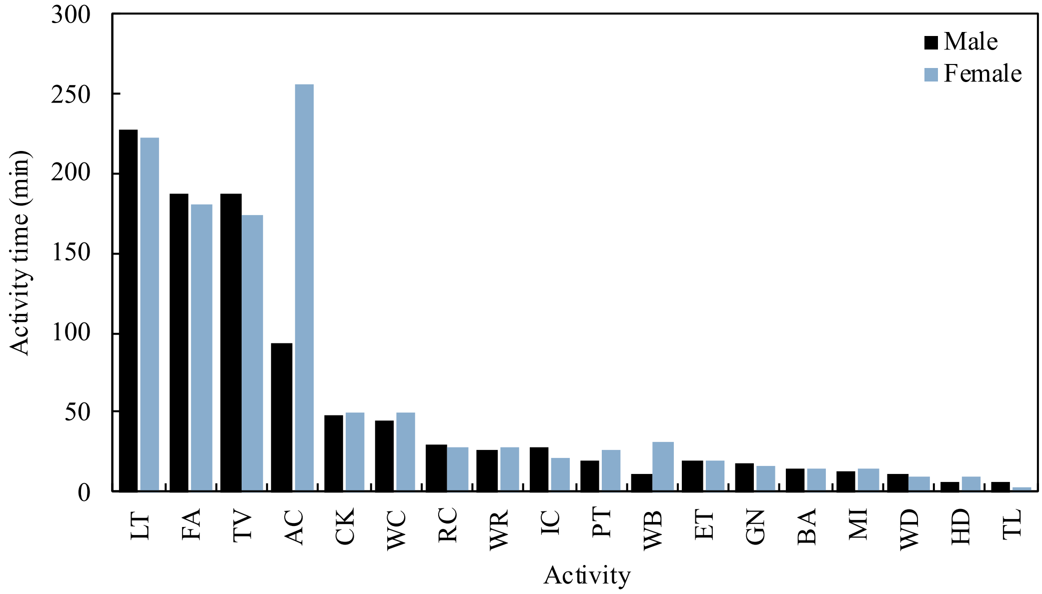


Figure 4.1 Time of activity comparison by gender

Each activity that occurs has an average frequency per day that is close to each other, except for HD, which has a lower frequency for males than females by about half. When considering activities that occur more than once a day for both groups, there are a total of 11 activities: TL, ET, WD, CK, LT, BA, AC, TV, FA, WB, and RC. The average frequency of performing these activities per day is similar, with a mean difference of only 0.12 times per day. HD is the only activity that has a frequency of more than once a day, and it is only females who have a frequency of doing that activity more than once a day. The activity with the highest frequency within the building each day is TL, with an average of 4.00 times per day for males and 3.69 times per day for females, followed by an average frequency of 2.66 times per day for eating, 2.12 times per day for dishwashing, 1.83 times per day for cooking, 1.74 times per day for turning on lights, 1.49 times per day for personal hygiene, 1.50 times per day for air conditioning, 1.39 times per day for watching TV, 1.26 times per day for turning on fans, 1.28 times per day for boiling water, and 1.07 times per day for rice cooking. There are a total of 6 activities that occur less than once a day, with a frequency of once a day, including GN, MI, WC, IC, PT, and WR, with average frequencies of 6.52 times per week, 4.26 times per week, 3.21 times per week, 2.72 times per week, 1.94 times per week, and 2.78 times per month sequentially, with all the details shown in Figure 4.2.

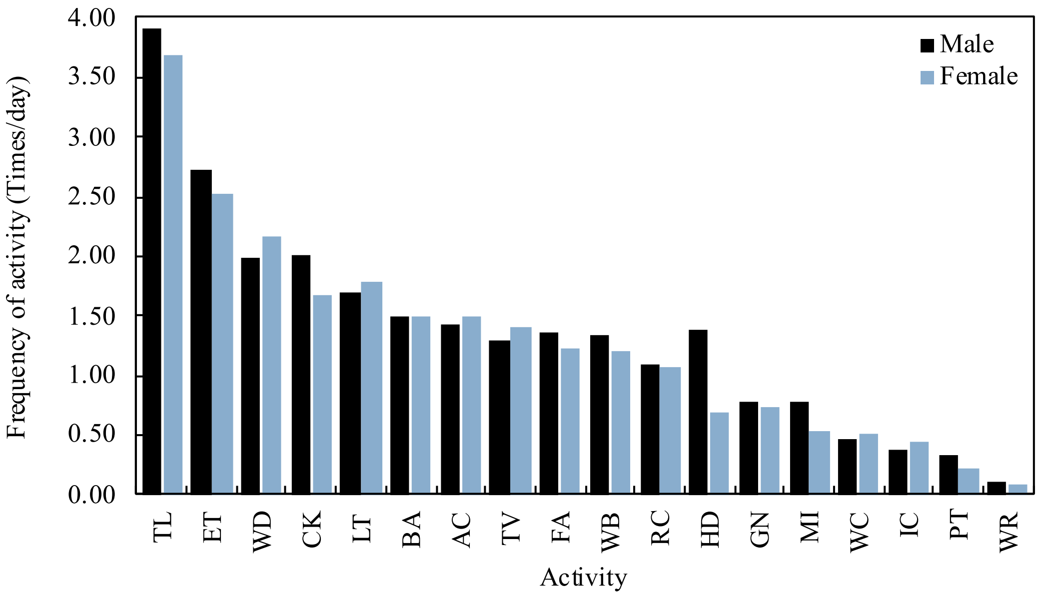


Figure 4.2 Frequency of activity comparison by gender

From the data on the duration and frequency of activities categorized by gender, it can be observed that the data on both the duration and frequency of activities follow a similar trend. This is because the basic data of the community shows that the majority of the residential buildings in the sample community are medium to large-sized housing units, with an average number of occupants residing in the same building being more than 2 people, with at least one male and one female resident. This has an impact on the average time spent on activities within the building for both gender groups. Some activities may also indicate gender differences that affect the duration and frequency of those activities, such as the use of air conditioning to increase comfort, the duration of laundry cycles, and the use of hair dryers. From the physical characteristics of gender, it is found that females tend to have longer hair than males, which affects the duration and frequency of using hair dryers.

From the comparison of data from both groups on the duration and frequency of activities within a building that occur more than once a day, it was found that the average duration of activities varies according to their frequency. Specifically, activities that have a longer average duration have a lower frequency of occurrence per day. For example, turning on the lights takes an average of 229.10 minutes per day for both groups combined, with an occurrence rate of only 1.74 times per day. In contrast, cooking has an average activity duration of approximately 48.75 minutes but occurs at a rate of 1.83 times per day. Furthermore, the activity with the highest daily occurrence rate is using the bathroom, with an average duration of only 3.84 times per day and a duration of only 4.78 minutes per occurrence.

When considering activities with a duration of one hour or more, it was found that these were mostly activities that support other activities within the home, including those that improve comfort and convenience within the home, such as turning on the lights to increase brightness inside the building during the evening or in the absence of natural light, and activities that promote socialization, such as cooking, eating, and cleaning dishes, as well as activities that are conducted in tandem with longer activities, such as turning on a fan or air conditioner to create a more comfortable environment during other activities. Upon examining activities that occur less frequently than once a day, it was found that the characteristics of these activities are similar to those of activities that occur more frequently than once a day. Specifically, when the duration of the activity is longer, it results in a decrease in the frequency of occurrence of that activity.

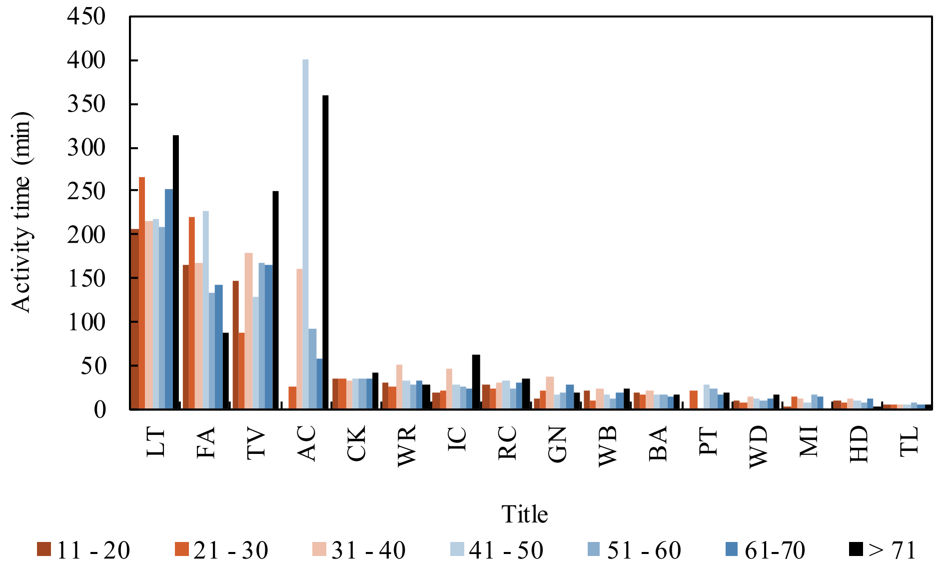


Figure 4.3 Time of activity comparison by age group

Afterwards, an analysis of the duration and frequency of activities by age group, as shown in Figure 4.3, reveals that the duration of each activity differs by age group. Specifically, only the group of activities with an average duration longer than 60 minutes exhibits significant differences in usage patterns across age groups. The trend for the light switch activity is that its usage time decreases as consumers age. Specifically, the age groups of 11-20, 31-40, and 51-60 years old exhibit usage times of 205.71, 214.40, and 207.60 minutes, respectively. Similarly, the age groups of 21-30, 41-50, and 61-70 year old also exhibit decreasing usage times of 265.65, 217.33, and 252.11 minutes, respectively. However, the highest usage time for the light switch activity is found in the age group over 71 years old, as consumers over 71 years old are considered as elderly, their daily life necessities require more light compared to other age groups. Additionally, this group tends to start their morning activities earlier and take longer to complete them compared to other age groups, resulting in a noticeably longer time required for turning on the lights. Moreover, the duration of time used for turning on lights affects the duration of other activities that rely on bright light for daily living, such as watching television and operating air conditioning. It was found that in the elderly age group, the duration of time spent on watching television and operating air conditioning was the longest, with an average of 248.82 minutes for watching television and 360.00 minutes for operating air conditioning.

The activity of operating fans inside a building found that the duration of fan usage decreases as consumers age. However, the age group with the longest average fan usage duration was found to be the 41-50 years old group, with an average usage duration of 226.52 minutes and decreasing to 165.71, 219.79, 166.32, 142.76, 133.70, and 86.67 minutes for the age groups of 11-20, 21-30, 31-40, 61-70, 41-50, and above 71 years old, respectively. This is in contrast to the activity of operating televisions, which had average usage durations of 156.74 minutes for the age groups of 11-20, 31-40, 41-50, 51-60, and 61-70 years old, except for the above 71 years old group, which had the longest average activity duration of 248.82 minutes, making it the age group with the highest television watching behavior. The age group with the lowest average television watching duration was the 21-30 years old group, with an average duration of only 87.00 minutes. When analyzing the television watching behavior of each group, it was observed that the elderly or above 71 years old group spent the most time watching television because their behavior is associated with being inside the building for a longer time, which is consistent with the age group residing inside the building the longest. Conversely, the age group of 21-30 years old, who spent the least amount of time watching television, had a behavior associated with being inside the building the least.

However, when considering the behavior of air conditioning usage within buildings that occurred throughout the community, it was found that only 6.25% of the 21-30 age group, 5.41% of the 31-40 age group, 6.67% of the 41-50 age group, 8.70% of the 51-60 age group, 5.66% of the 61-70 age group, and 9.09% of the group over 71 years old thought to use air conditioning. This indicates that the proportion of air conditioning usage within the community is relatively low due to the environmental conditions and the average temperature within the community is not very high. Furthermore, the community chooses to use fans to reduce the temperature inside the buildings, which has a higher proportion of usage across all age groups, accounting for approximately 50.31%. This results in a higher proportion of fan usage than air conditioning usage, which is consistent with the data on the number of electrical appliances found within the buildings, indicating that fans make up 77.59% of all appliances, while air conditioning units comprise only 7.82% of installed appliances, which is a relatively small proportion when compared.

The activity characteristics with a duration of less than one hour per session were examined, and the average durations for each group were found to be similar. When ordered by the average duration of each group, the activities were WC, RC, CK, WR, WB, IC, ET, GN, BA, PT, WD, MI, HD, and TL, with durations of 39.11, 25.18, 31.05, 28.48, 15.32, 28.15, 17.04, 18.90, 14.89, 13.04, 9.98, 7.62, 7.22, and 4.50 minutes, respectively. However, cooking activities were only carried out by four age groups, namely 31-40, 41-50, 51-60, and 61-70 years, which are age groups that are responsible for household care. This is consistent with the use of microwave ovens, which are only used by the aforementioned groups, but with the addition of the age group between 21-30 years, indicating a more hurried and streamlined lifestyle. Furthermore, based on the observed activity behaviors within the building, it was noted that the older age groups tended to spend less time on each activity compared to the younger age group.

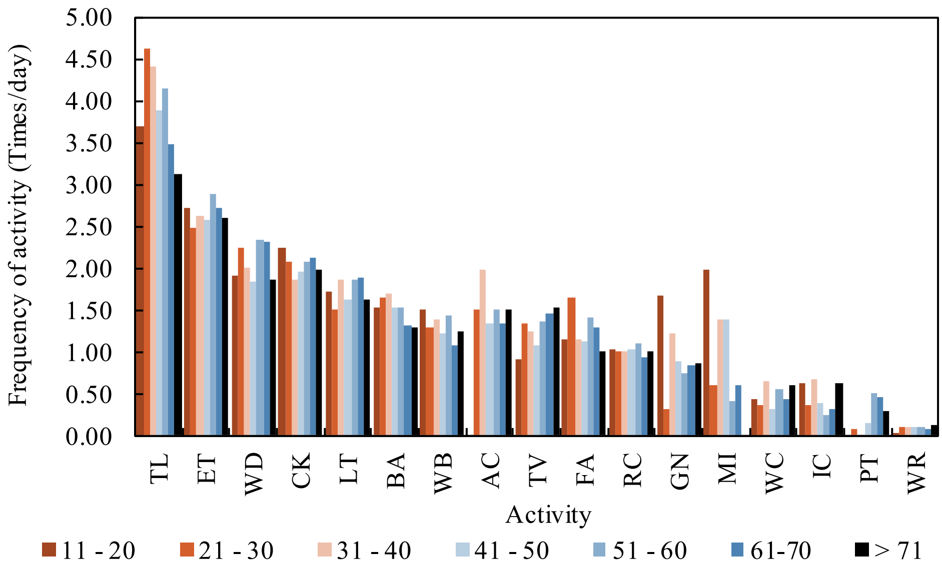


Figure 4.4 Frequency of activity comparison by age group

When analyzing the frequency of each activity that occurs daily, grouped by the age range of consumers within the building, as shown in Figure 4.4, it was found that activities with a frequency of more than once per day in all age groups consist of a total of eight activities: TL, WD, LT, BA, WB, TV, FA, and RC with average frequencies of 3.91, 2.67, 2.09, 2.06, 1.73, 1.51, 1.31, 1.31, and 1.25 times per day, respectively. Further analysis of the frequencies of WD, LT, BA, WB, TV, and FA activities, which occur more than once per day, also revealed that all age groups have similar frequencies. The analysis of the standard deviation of the average frequency of each age group shows that the data has a standard deviation of only 0.20. Excluding the activity with the highest frequency in the building, which is using the restroom, the average frequency of activities for each group is approximately 3.91 times per day. The group with the highest frequency is the 21-30 age group, with an average daily activity frequency of 4.63 times, followed by a decrease to 4.41 times for the 31-40 age group, 4.15 times for the 51-60 age group, 3.89 times for the 41-50 age group, 3.50 times for the 61-70 age group, 3.70 times for the 11-20 age group, and 3.13 times for the group over 71 years old.

The behavior of using the restroom differs significantly when considering the data by age group due to differences in behavior and lifestyle characteristics among age groups. For example, the age range of 21-70 years is a range with similar lifestyles within the building and high consumption, affecting the activities that occur within the building. This is in contrast to the 11-20 age group, which corresponds to the data on the timing of each activity for the age group of 11-20 years, which has a frequency of opportunity for activity in only two time periods. The group aged over 71 years old had a high frequency of occurrence of activities during approximately the same time period and had a generally evenly distributed frequency (with similar interquartile range values) from the beginning until the end of the observation period. This differs from the frequency of activity opportunities for the group aged between 21-70 years old, which had a noticeably high frequency of the aforementioned activities when compared to the two preceding age groups.

The frequency of activities occurring within a building for a group of consumers with a frequency of more than once per day and a group with a frequency of less than once per day were investigated. The study found that there were five activities in total, including AC, CK, GN, HD, and MI. From the data, it was found that there was no activity related to the use of air conditioning for the age group of

11-20 years, which differed from other age groups. The age group with the highest frequency of air conditioning usage was the 31-40 year age group with an average frequency of 2.00 times per day. The age groups of 21-30 years and 51-60 years had the same frequency of use per day with an average frequency of 1.50 times per day. The age groups of 41-50 years and 61-70 years had the same frequency of air conditioning usage with an average frequency of 1.33 times per day. Finally, the age group over 71 years old had a frequency of air conditioning usage at 1.50 times per day.

The act of cooking rice is an activity that occurs with a frequency average of approximately 1.02 times per day for every age group that is in close proximity to one another, with a standard deviation of 0.05. However, there is one age group, the 61-70 age group, which has an average frequency of cooking rice per day less than 1, specifically 0.93 times per day. This group is the only age group that has a frequency of cooking rice less than once per day. The age groups that cook rice more than once a day include the age groups 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, and those above 71 years. The average frequency of cooking rice per day for each of these age groups is 1.04, 1.02, 1.02, 1.04, 1.11, and 1.01 times per day, respectively. These findings are data collected from a sample population of individuals living in a semi-rural community in the northern part of the country. The majority of the population in this area consumes sticky rice as their main food, which contributes to the overall frequency of cooking rice for all age groups. Additionally, it was found that the frequency of cooking rice was lower than the frequency of engaging in other cooking activities, with an average of only 35.30%.

Activity related to watering plants and using a microwave have a similar frequency of occurrence among age groups. It was found that the age group with the highest frequency for both activities was between 11-20 years old, with an average frequency of 1.67 times per day for watering plants and 2.00 times per day for using the microwave to heat up food. The frequency decreases for the age groups between 31-40 years old, over 71 years old, 61-70 years old, 51-60 years old, and 11-20 years old for gardening and watering plants, and for the age groups between 31-40 years old, 41-50 years old, 61-70 years old, 21-30 years old, and 51-60 years old for using the microwave to cook. Both activities have an average frequency of 0.93 and 0.92 times per day for watering plants and using the microwave, respectively, across all age groups. The age group over 71 years old does not use the microwave due to both lack of cooking and unfamiliarity with the appliance. Therefore, the frequency of use for the microwave in this age group is 0 times per day, similar to the use of a hair dryer, which has a frequency of zero for the age group over 71 years old. The aforementioned age group is the only age group that does not use the aforementioned device, the reasoning mentioned above. When considering the use of hair dryers in the field, the age groups between 11-20 years and 21-30 years are the two age groups with the highest frequency of use, averaging 0.44 and 0.36 times per day, respectively. The age groups between 31-40 years, 41-50 years, and 61-70 years have similar average frequencies of hair dryer usage, with an average value of 0.47 times per day across all three age groups, or approximately 3.32 times per week. The age group between 51-60 years has an average frequency of hair dryer usage of approximately 0.55 times per day or engaging in the aforementioned activity once every 2 days.

The group of activities that occur less frequently than once a day consists of four activities: laundry, ironing, pet care, and car washing. It was found that the frequency of doing laundry and ironing activities had similar averages, at 3.21 and 3.04 times per week, respectively. When considering the highest frequency of these two activities, it was found that they were performed by the same age group, specifically those aged 31-40 years. The average frequency of doing laundry and ironing for this group was 4.61 and 4.82 times per week, respectively, while the lowest frequency was found in the age group of 41-50 years, at 2.28 times per week for doing laundry, and in the age group of 51-60 years, at 1.71 times per week for doing laundry.

The frequency data of doing laundry and ironing activities, it was found that in some buildings, the ironing activity was performed more frequently by the age group of 11-20 years, with a frequency rate that was close to the maximum. The average frequency of this activity for this age group was approximately 4.38 times per week. This finding can be attributed to the fact that this age group is mostly composed of students who have a school uniform, and thus ironing is necessary to maintain a neat appearance. Similarly, the age group of 31-40 years, who are mostly families with young children aged under 10 years old, had a high frequency of doing laundry and ironing activities. This is because they need to take care of their young children who cannot take care of themselves fully, resulting in the higher frequency of laundry and ironing activities for this age group, compared to other age groups. The activity of pet care is an infrequent activity, with an average frequency of 6.28 times per month. It was found that the age group with the highest frequency of pet ownership was the age group between 51-60 years old, with an average frequency of 15.00 times per month. The frequency then decreases to 13.57, 8.57, 4.64, and 2.14 times per month for the age groups between 61-70 years old, over 71 years old, 41-50 years old, and 21-30 years old, respectively.

2.2 Building activity period

The behavioral data and frequency of activities that occurred within the building of the entire sample group, there were 18 activities including turning on lights, using fans, watching TV, adjusting air conditioning, cooking, rice cooking, preparing or reheating food with a microwave, boiling water, eating, washing dishes, bathing, using the bathroom, hair during, doing laundry, ironing, watering plants, taking care of pets, and washing cars. The data presented only indicate the duration and frequency of activities on each day, without specifying the time periods and opportunities for activity occurrence in each time interval. Therefore, it is necessary to conduct an analysis to observe the activity behavior of each consumer group. This analysis will generate a consumer profile of the sample community. In this section, the analysis of activity behavior within the building is divided into two data groups of individuals, Gender and age group. The analysis will focus on the frequency of time intervals in which each activity occurred. The analysis is separated into two categories of days, workdays (Monday to Friday) and non-workdays (Saturday and Sunday). The data used for analyzing the frequency of time intervals for each activity is from survey data collected from a sample population in the community.

The results of the data analysis indicate that overall, there is no clear distinction between the patterns of activities during workdays and days off. This is particularly evident for activities that occur less frequently than once a day, such as laundry, watering plants, pet care, and car washing, which tend to occur more often on weekends than on weekdays. The time intervals for all activities are presented in Table 4.5 to Table 4.23 and the percentage of the number of activities towards a consumer group in Table 4.24

Table 4.5 Percentage of lighting frequency over time on weekday and weekend

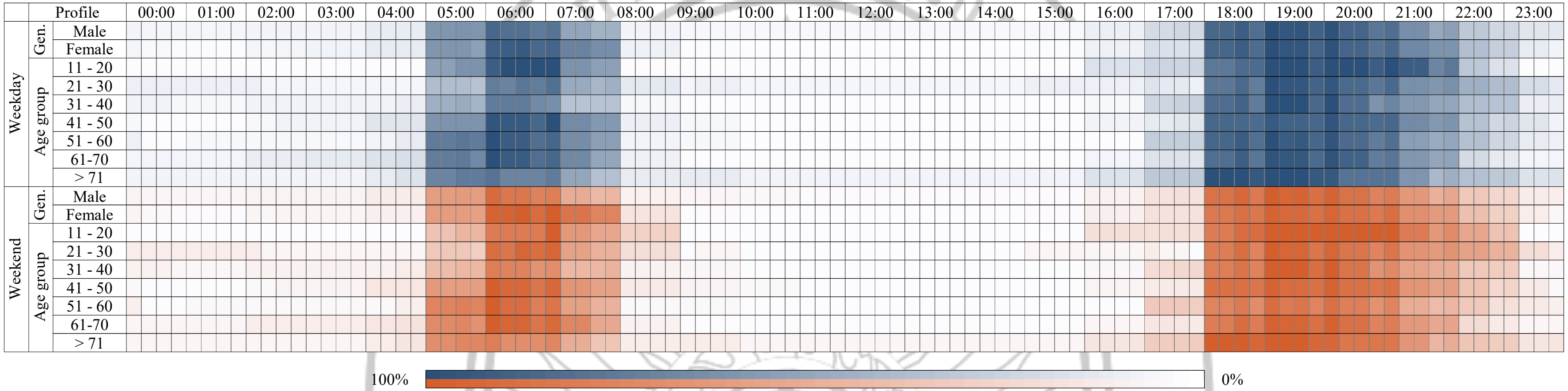


Table 4.6 Percentage of fan frequency over time on weekday and weekend

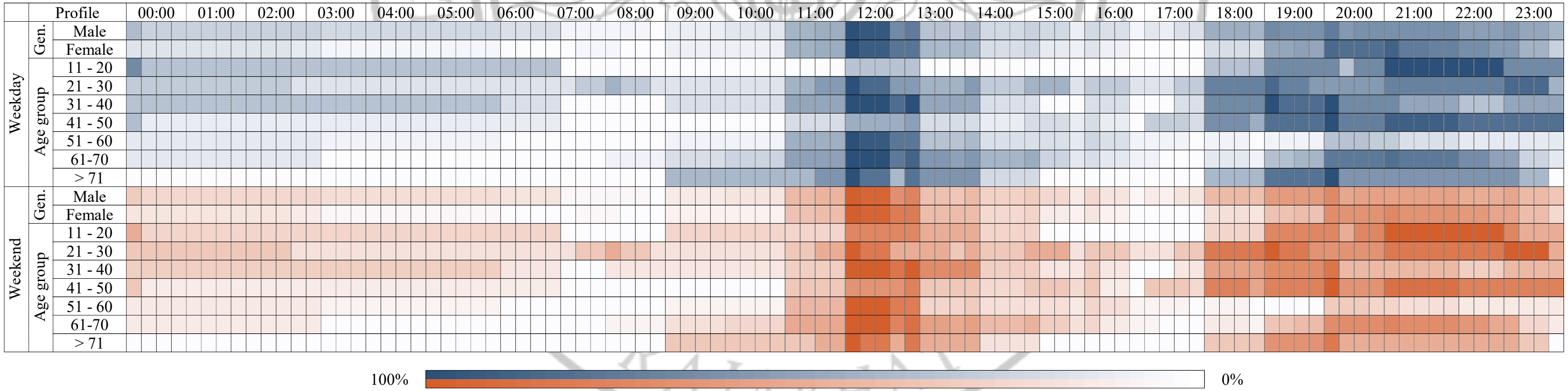


Table 4.7 Percentage of using air conditioner frequency over time on weekday and weekend

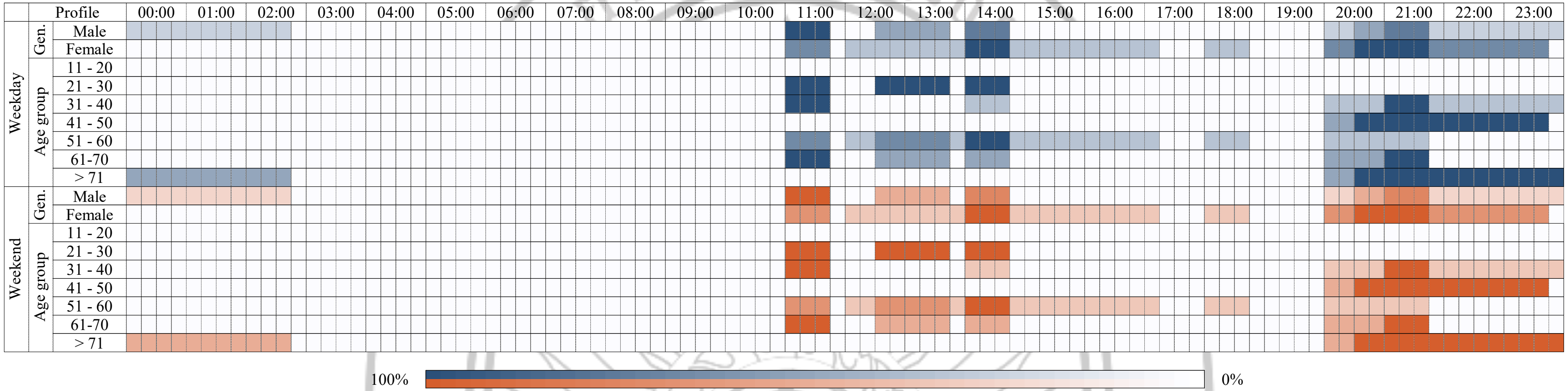


Table 4.8 Percentage of watching TV frequency over time on weekday and weekend

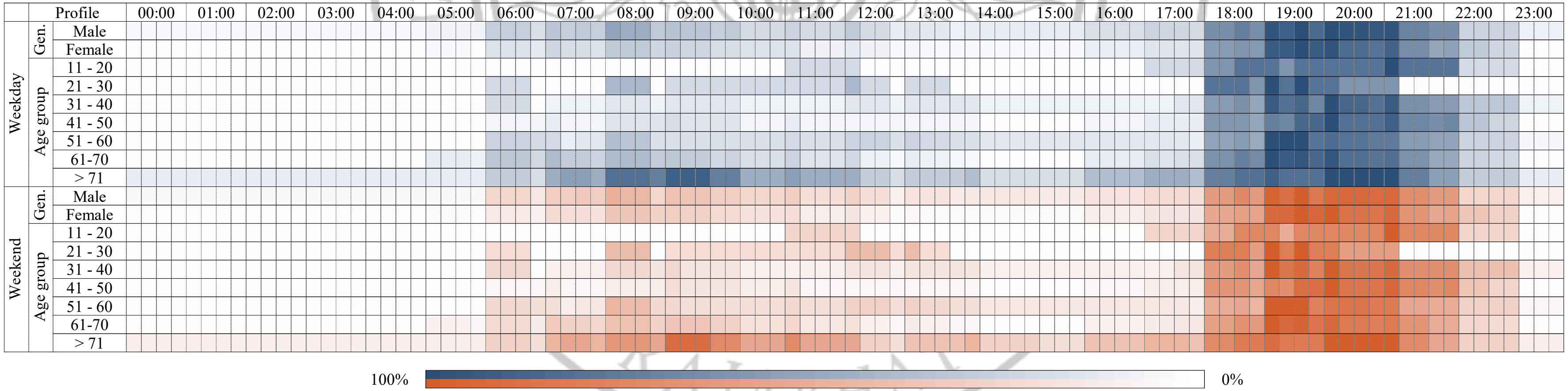


Table 4.9 Percentage of cooking frequency over time on weekday and weekend

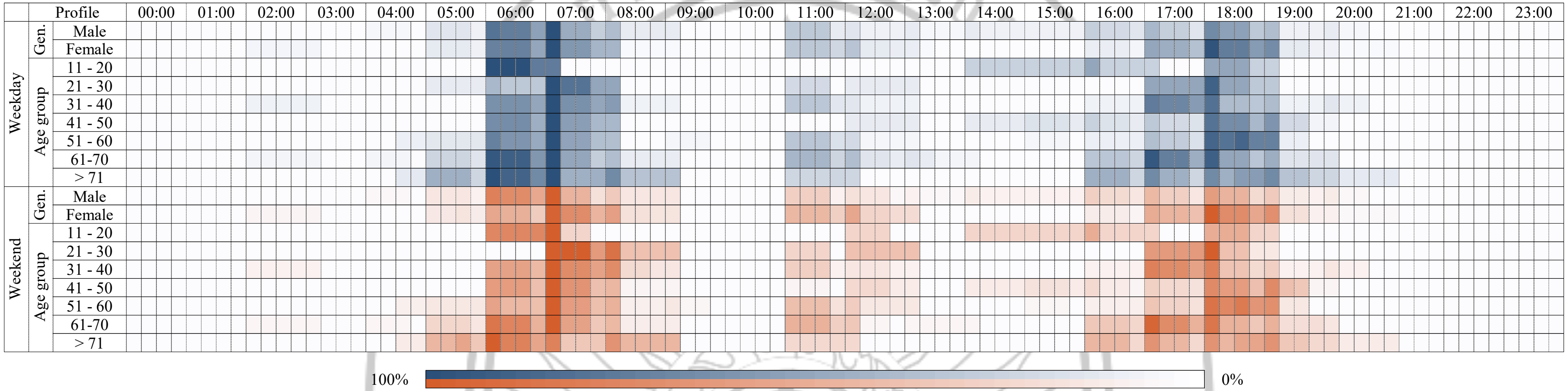


Table 4.10 Percentage of rice cooking frequency over time on weekday and weekend

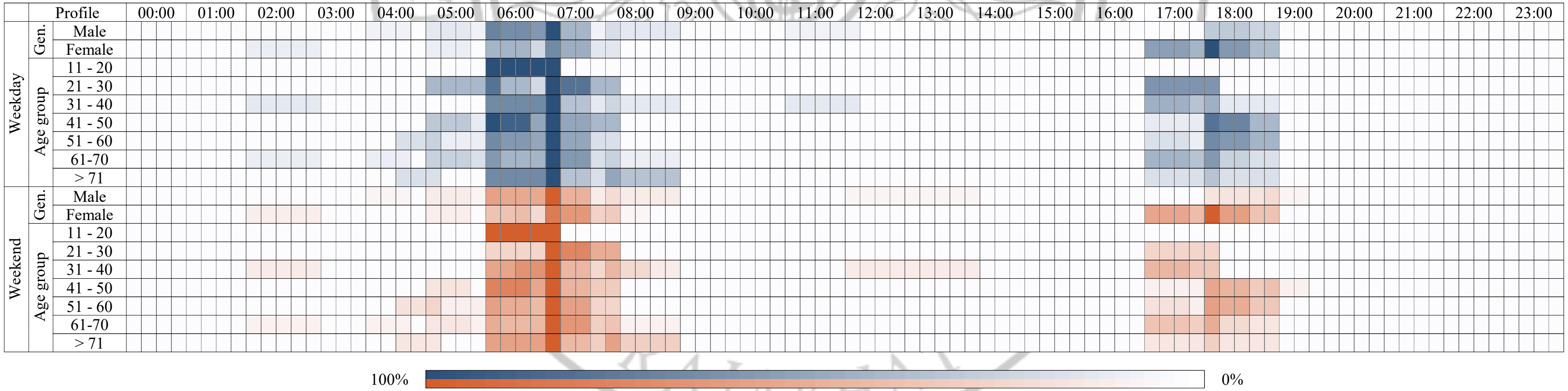


Table 4.11 Percentage of microwave frequency over time on weekday and weekend

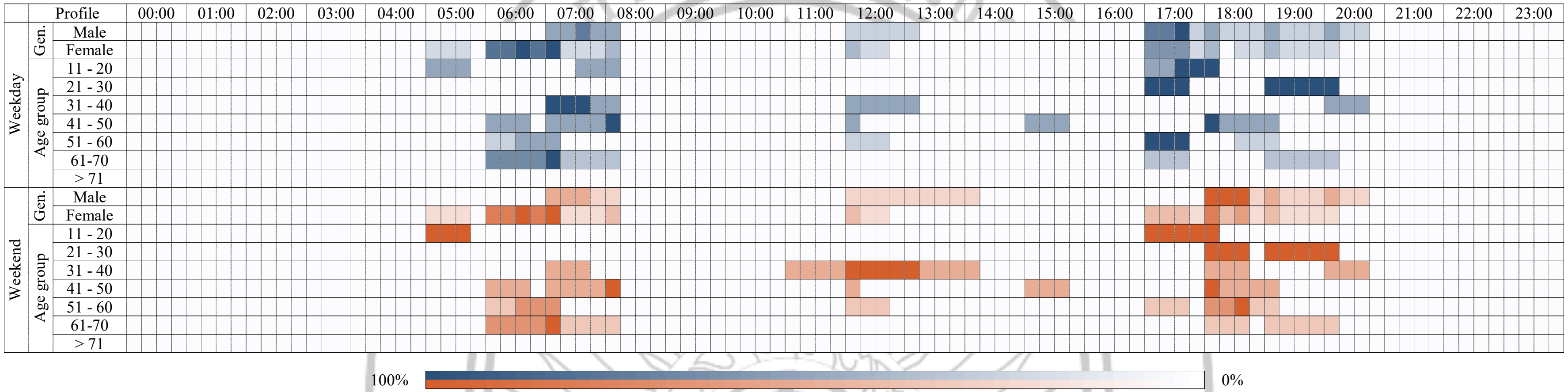


Table 4.12 Percentage of water boiling frequency over time on weekday and weekend

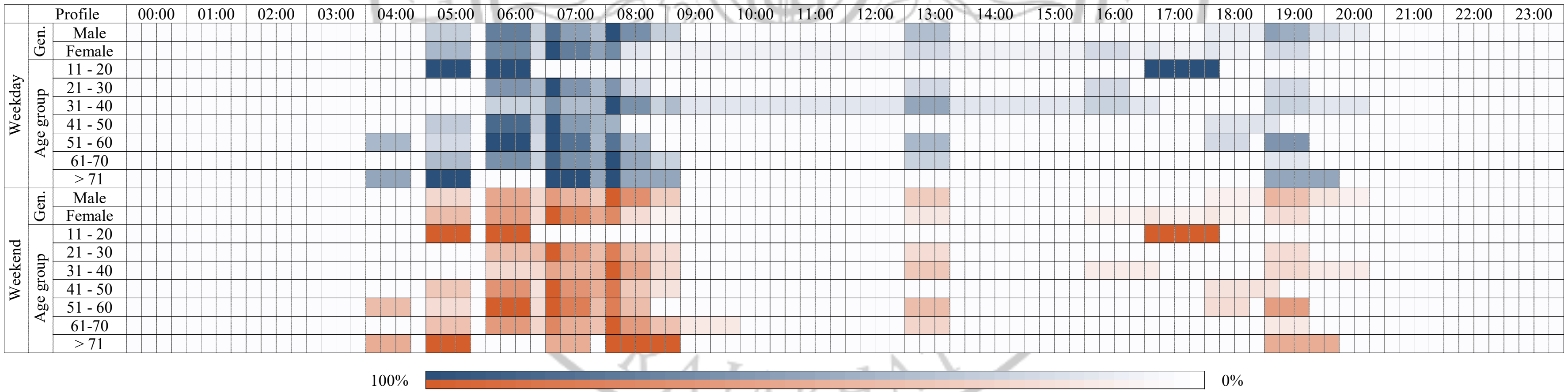


Table 4.13 Percentage of eating frequency over time on weekday and weekend

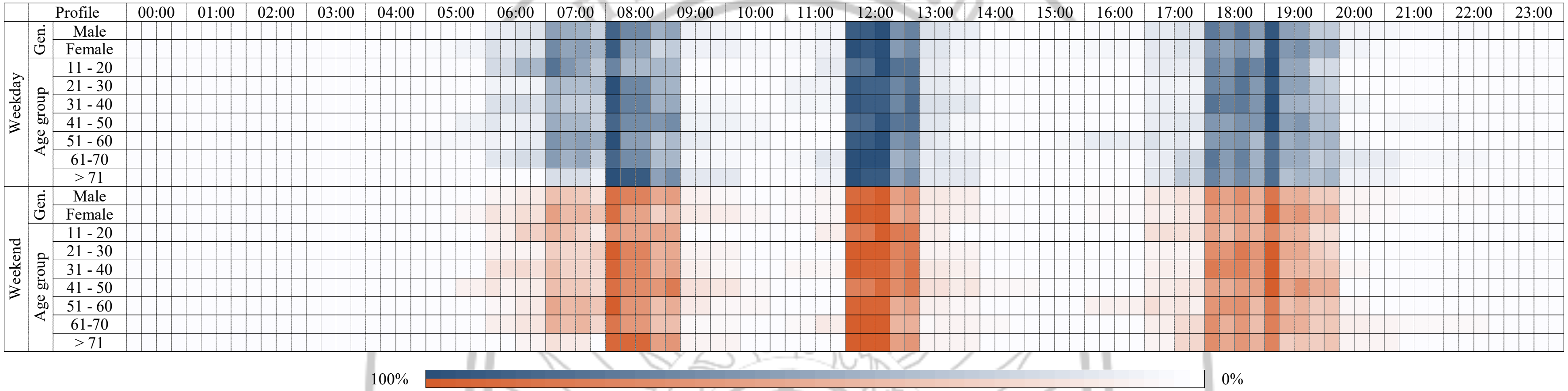


Table 4.14 Percentage of washing dish frequency over time on weekday and weekend

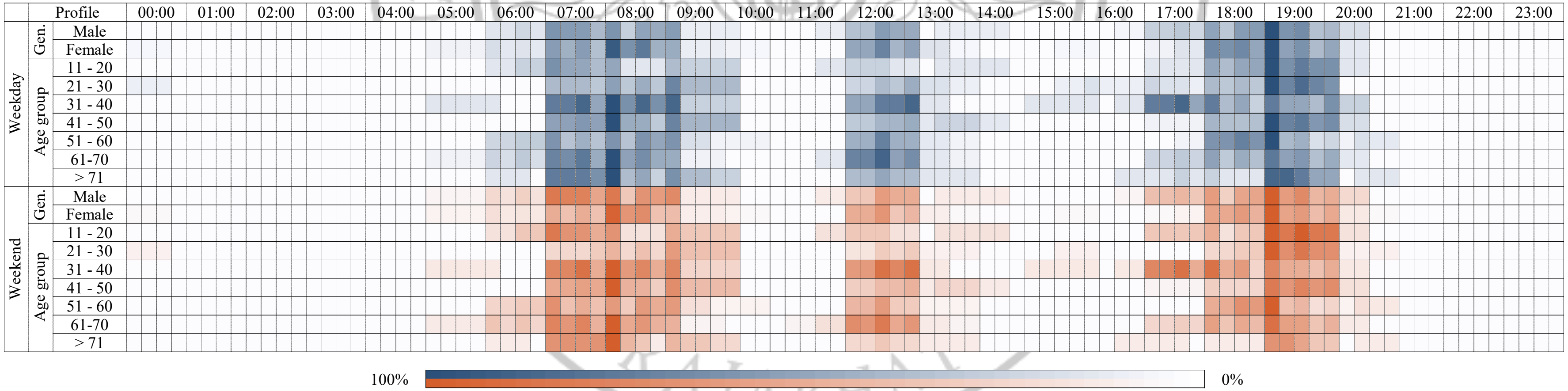


Table 4.15 Percentage of bathing frequency over time on weekday and weekend

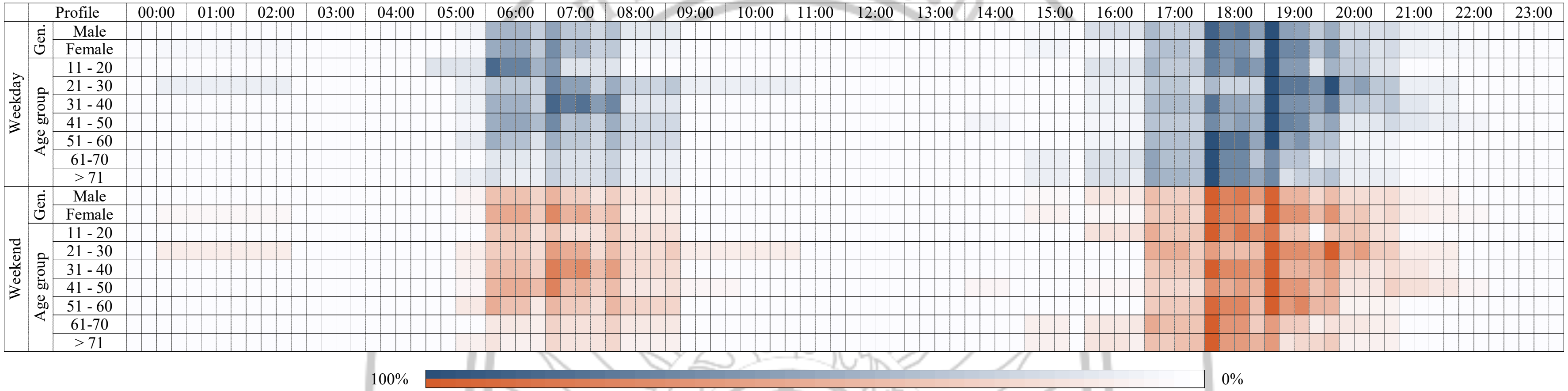


Table 4.16 Percentage of electricity water heater frequency over time on weekday and weekend

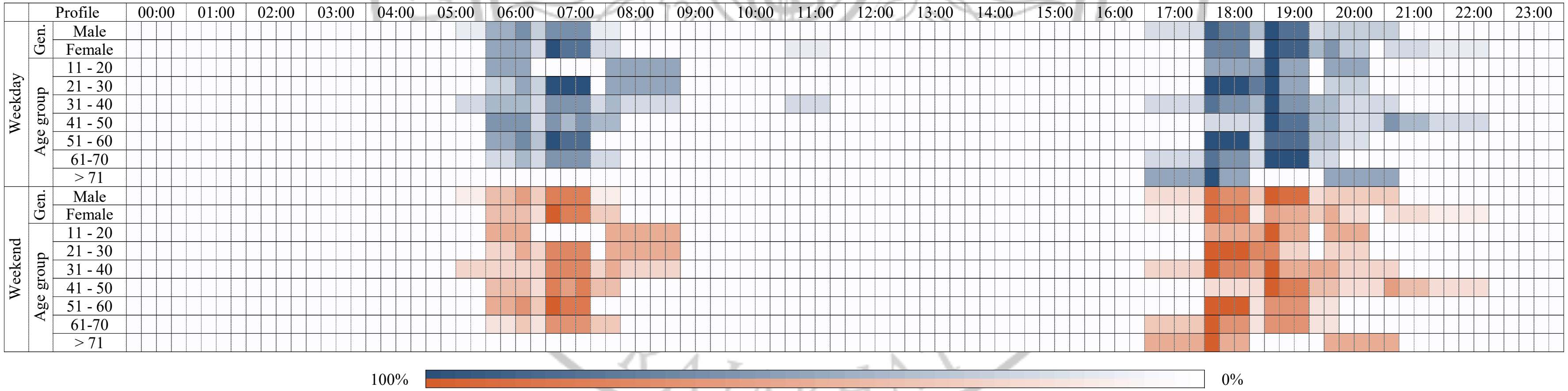


Table 4.17 Percentage of toilet frequency over time on weekday and weekend

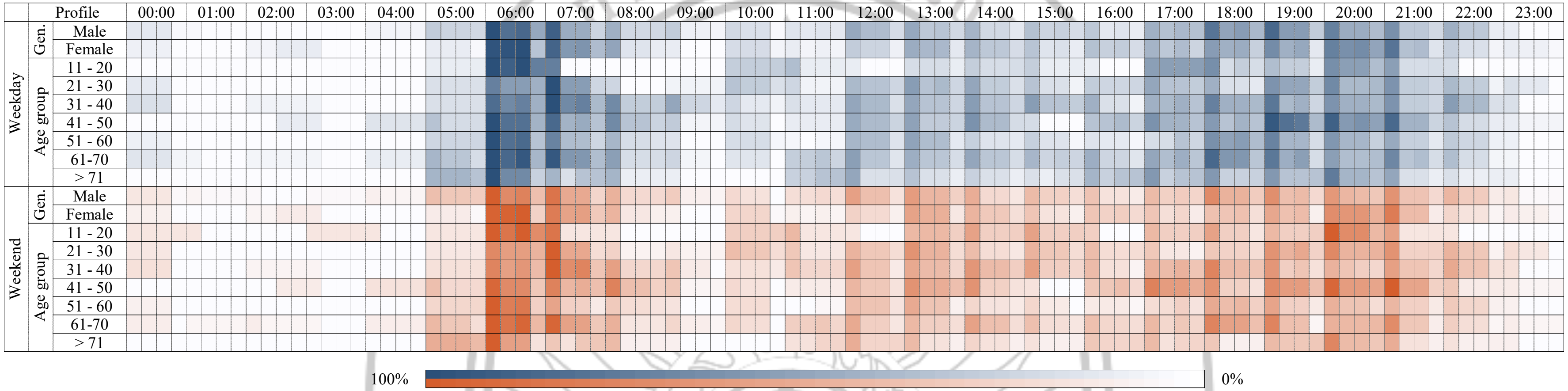


Table 4.18 Percentage of hair drying frequency over time on weekday and weekend

Table 4.19 Percentage of washing clothes frequency over time on weekday and weekend

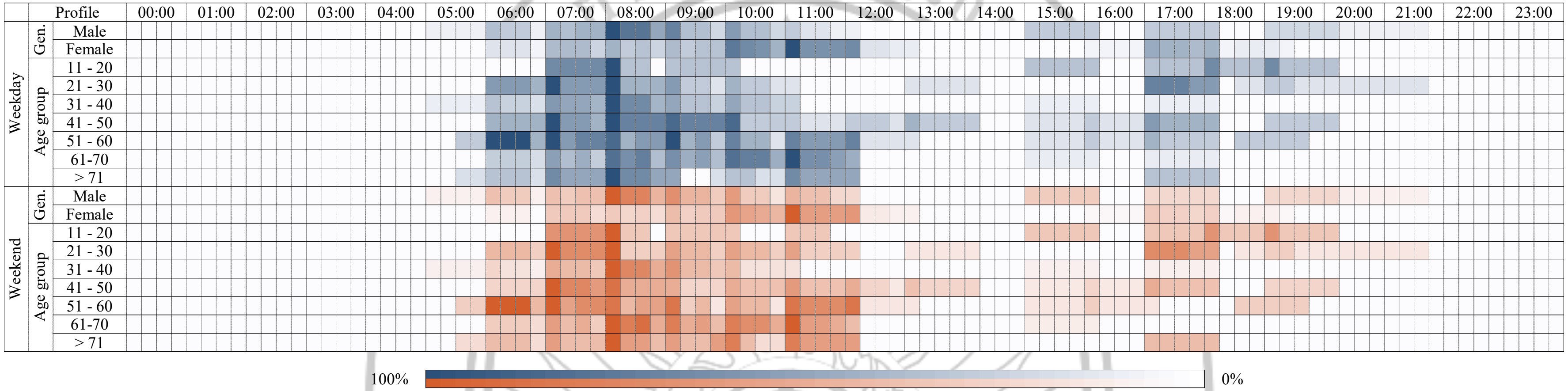


Table 4.20 Percentage of iron clothes frequency over time on weekday and weekend

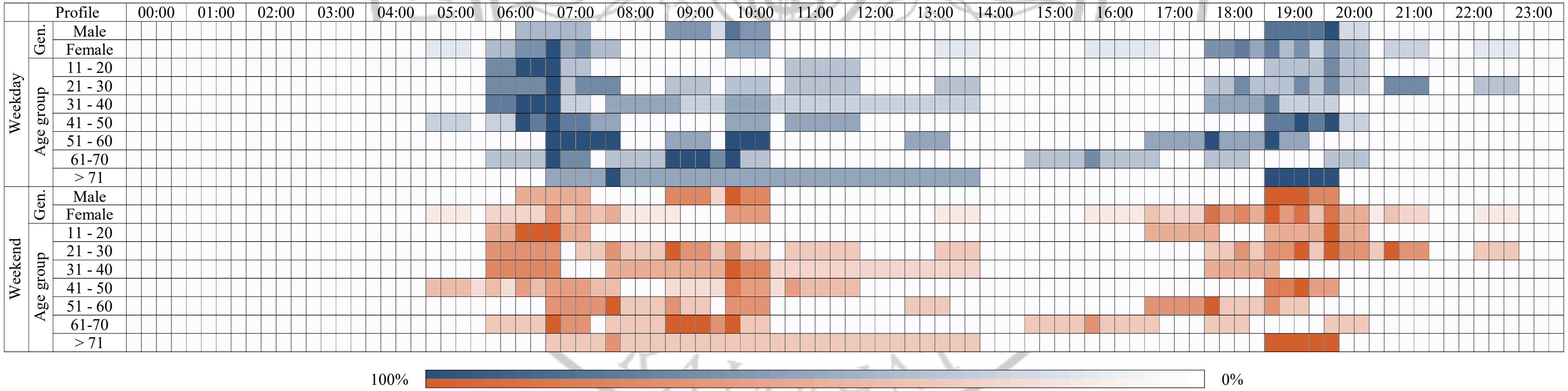


Table 4.21 Percentage of gardening frequency over time on weekday and weekend

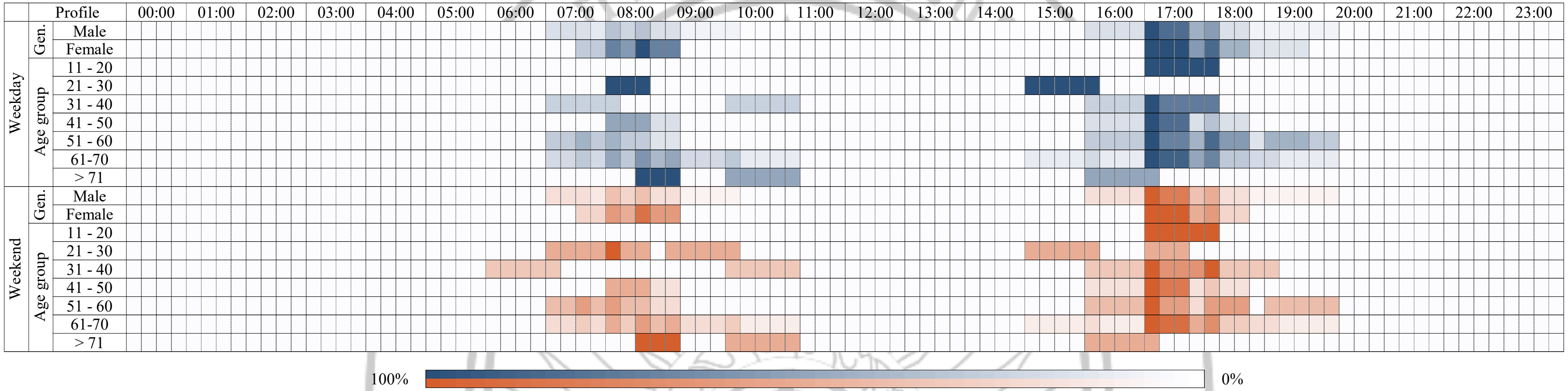


Table 4.22 Percentage of pet care frequency over time on weekday and weekend

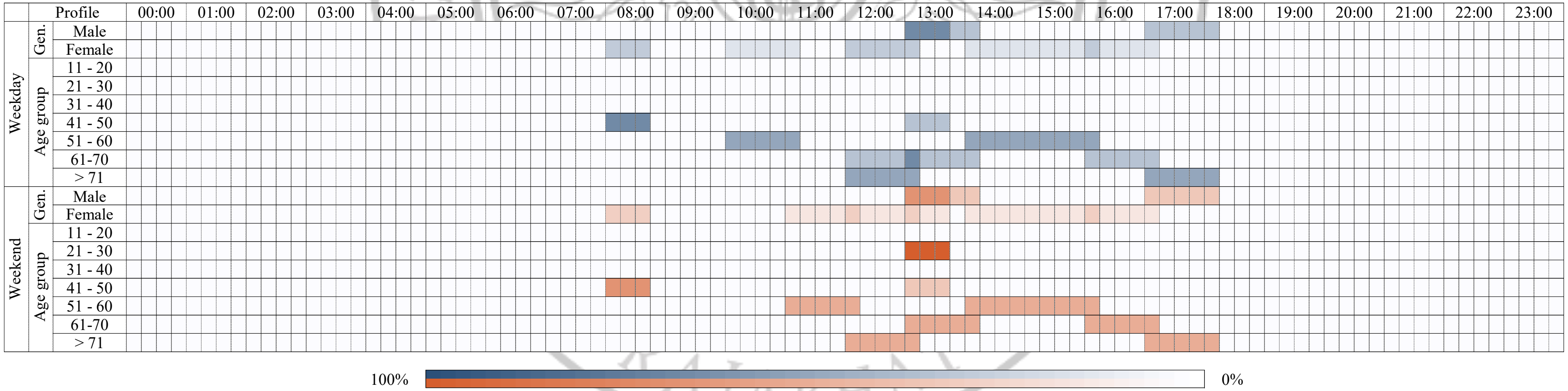


Table 4.23 Percentage of washing car frequency over time on weekday and weekend

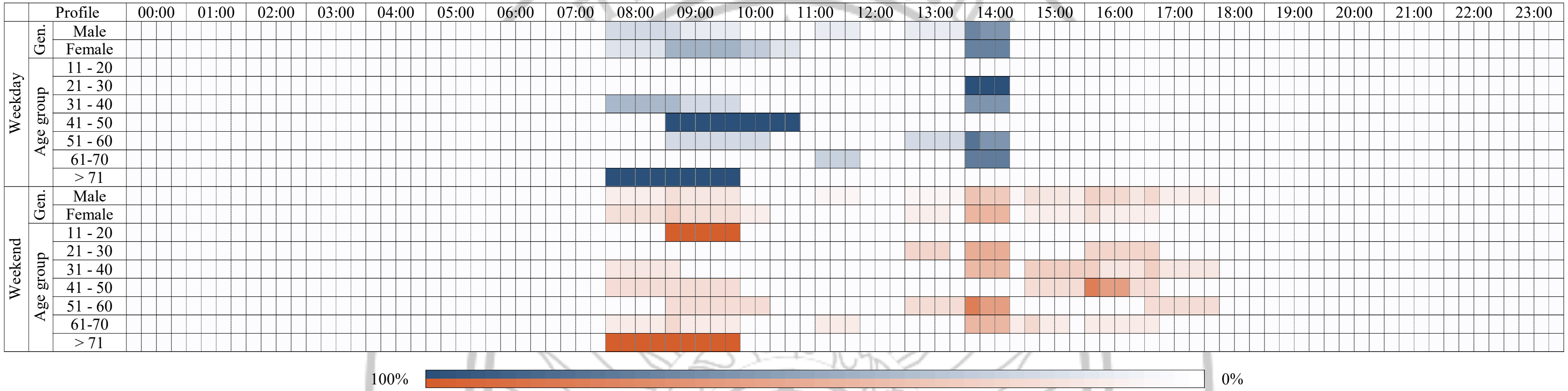


Table 4.24 Percentage of the number of activities towards a consumer group

Consumer group		**LT**	**BA**	**ET**	**TL**	**WD**	**WC**	**TV**	**CK**	**FA**	**RC**	**IC**	**GN**	**WB**	**WR**	**MI**	**HD**	**AC**	**PT**
Gender	Male	83.78	81.98	73.87	60.36	45.05	45.05	60.36	39.64	45.95	27.03	24.32	34.23	20.72	26.13	11.71	5.41	6.31	5.41
	Female	63.51	61.49	57.43	51.35	56.76	54.05	41.89	43.24	37.84	39.19	35.14	17.57	25.00	8.78	7.43	8.78	4.05	4.73
Age	11 – 20	93.33	86.67	86.67	66.67	80.00	60.00	53.33	26.67	46.67	26.67	53.33	20.00	13.33	6.67	6.67	6.67	0.00	0.00
(Year)	21 – 30	96.88	96.88	87.50	71.88	71.88	75.00	31.25	34.38	43.75	46.88	59.38	21.88	28.13	18.75	12.50	15.63	6.25	3.13
	31 – 40	94.59	91.89	81.08	72.97	64.86	75.68	56.76	62.16	51.35	43.24	45.95	21.62	27.03	24.32	13.51	13.51	5.41	0.00
	41 – 50	100.00	93.33	93.33	84.44	75.56	80.00	71.11	55.56	51.11	60.00	53.33	40.00	31.11	24.44	8.89	4.44	6.67	6.67
	51 – 60	97.83	100.00	91.30	86.96	82.61	78.26	71.74	73.91	50.00	45.65	36.96	39.13	30.43	17.39	19.57	8.70	8.70	8.70
	61 – 70	100.00	100.00	92.45	73.58	75.47	66.04	88.68	73.58	54.72	58.49	32.08	45.28	33.96	18.87	7.55	5.66	5.66	11.32
	> 71	100.00	90.91	81.82	72.73	72.73	77.27	77.27	63.64	54.55	45.45	31.82	31.82	18.18	13.64	0.00	4.55	9.09	9.09

2.2.1 Lighting

The frequency data of the lighting operation period within the building presented in Table 4.5, it was found that the behavior of lighting operation did not differ significantly between genders in terms of usage periods for both weekdays and weekends. The frequency of lighting operation within the building was divided into two periods. The first period had a high frequency of usage starting from 5:00 until peaking at 6:45, followed by a decline in usage and stopping at around 8:15. The second period began at around 6:00 with the highest frequency of usage between 19:00 - 20:00 and gradually declining until approximately 22:15, with very low or no usage at around 23:15. When considering the frequency of lighting operation periods according to age groups, it was found that the behavior of lighting operation was similar to that of gender analysis. That is, the usage behavior was divided into two periods. The first period had high usage from 6:00 - 7:15, while the second period had high usage from 18:00 – 21:00. However, when the behavior was categorized by age group, differences were observed, but the usage behavior in each group was similar between weekdays and weekends.

The behavior of turning on lights when analyzed by age groups revealed that among individuals aged 11-20, the frequency of light usage was highest at 6:15-7:15 and at 17:00, on average. The percentage of light usage in this age group was observed to decrease and then increase again from 18:00 onwards, with a continuously high frequency of usage until approximately 21:30 After this, the frequency decreased and stopped at 22:45, with the highest frequency of light usage observed at 21:00 on average. The average frequency of light usage from the sample group was found to be 92.90%.

The light opening behavior of individuals aged between 21-30 years and those aged between 31-40 years exhibits similar patterns. Specifically, there is a small number of light openings in the morning, beginning around 5:00 a.m., and an increased frequency of light usage from 6:00 a.m. to 7:15 a.m., followed by a decrease in usage until stopping at 8:15 a.m. Furthermore, it was found that the frequency of light openings during a particular period for both groups is still less than that observed in the evening and in other age groups at the same time. The maximum number of consumers during the morning period for the sample group was 81.48% for those aged between 21-30 years and 75.00% for those aged between 31-40 years. In the second period for both groups, which starts at 6:00 p.m., there is an increased frequency of light usage, peaking at approximately 19:00 for the sample group aged between 21-30 years and at 19:00-19:45 for the sample group aged between 31-40 years. The maximum average value of light openings during this period was 100.00% for both groups.

The age group between 41-50 years old exhibits similar behavior to the other age groups in terms of light usage. Specifically, there is a slight increase in light switch usage starting around 5:00 with an average percentage of 60.53%, which increases to 94.74% between 6:00 and 7:15, reaching a maximum frequency of 100.00%. The usage then gradually decreases and stops at 8:15. In the evening, the usage starts again at 18:00, and the average percentage of consumers reaches 97.37% until 19:15, before gradually decreasing and stopping at 22:15.

The age groups between 51-60 years old and 61-70 years old exhibit similar patterns of behavior in regard to turning on lights during two time periods. In the morning, both groups start turning on lights around 5:00 with an average usage of approximately 75.63% for the first group and 72.83% for the second group. Usage gradually increases and reaches its peak frequency of 95.00% for the 51-60 years old group and 95.65% for the 61-70 years old group between 6:00 and 6:45. Subsequently, the usage decreases, and there are no consumers at 8:15. The groups then start turning on lights again in the evening from 18:00 onwards, with an average usage of approximately 87.50% and 83.70% for the 51-60 years old and 61-70 years old groups, respectively. The peak frequency is 100.00% for the 51-60 years old group at 19:00 and 97.83% for the 61-70 years old group at 20:00.

Finally of lighting activity, the age group above 71 years old starts using electricity in the morning at 5:00 and stops around 7:30, with an average consumer rate of 68.64%. The peak electricity usage is at 6:00 with a maximum of 80.00%. The second period of electricity usage begins within the building at 17:00 with approximately 30.00% usage from the consumer group, increasing to 100.00% from 18:00 to 19:30. After that, it gradually decreases until 23:45 with only 15.00% of electricity usage remaining within the building. It should be noted that the age group above 71 years old has the lowest average electricity usage rate of approximately 5.00% throughout the day compared to the other age groups.

2.2.2 Fan

When analyzing the usage of fans in a building based on gender during different time periods, as shown in Table 4.6, it was found that the patterns of usage were similar, with fans being used throughout the day, and there were three time periods with particularly high usage: the late night/early morning period, the midday period, and the evening/bedtime period. In the first time period, from 0:00 to 7:15, females had a higher percentage of fan usage, at 22.56%, compared to males at 7.64%. Usage then decreased until around 7:15, after which it increased again, peaking at 12:00 for both genders. Afterwards, usage decreased at similar rates for both genders, with the final time period for female usage starting at 18:00 and peaking at 20:00 at 75.00% usage, before decreasing to 57.22% between 20:15 and 23:45. This was slightly different from males, who started their final peak usage period at 19:00, reaching 50.89%, and then increasing to a maximum of 89.29% between 20:00 and 21:15, before decreasing to 58.77% between 21:15 and 23:45 every day. The analysis of fan usage behavior by gender, it was found that there are similarities in the patterns of usage. However, on average, females have a higher likelihood of using fans compared to males. The average usage rate for females is 32.51%, which is higher than that of males at 26.45%.

The behavior of fan usage according to age group in the sample population, it was found that the characteristics of usage can be divided into three time intervals, similar to the pattern of usage according to gender. Among the age group of 11-20 years, the longest duration of usage occurred in interval 1, starting from 0:00-7:00, with an average fan usage of 33.33% throughout the duration of usage. The second interval, starting from 12:00-13:00, showed an average fan usage of 33.33%. Subsequently, fan usage was stopped and started again at 18:00, which then increased gradually until reaching its peak at 21:00-23:00 with a usage rate of 100% for the aforementioned age group and decreased to 66.67% at 23:45.

The age group between 31-30 years old is a group that exhibits continuous fan usage behavior throughout the day. It was found that during the time period from 0:00-2:45, the proportion of fan usage among the sample group was on average 28.57%. This proportion then decreased to approximately 14.29% until 10:00. However, during the time period between 7:30-8:45, the proportion of fan usage increased to a maximum of 42.86%. The second highest period of fan usage occurred between 11:00 and 14:00, with the highest proportion of fan usage occurring from 12:00-12:45 on average at 90.48%. Finally, fan usage increased again from 18:00 onwards, with an average usage rate of 69.64% during the third period of the day, and a maximum frequency of usage at 82.71% at 19:00.

When analyzing age groups between 41-50, 51-60, and 61-70 years old, it was found that the proportion of fan usage in the morning was relatively low. This was only 9.09% of the 41-50 year old who used fans from 0:00-7:15, 11.11% of the 51-60 year old who used fans for less time, from 0:00-6:00, and 11.76% of the 61-70 year old who used fans from 0:00-3:00. When considering fan usage during the second part of the day for all three age groups, it was found that the 41-50 year old had the lowest proportion of fan usage during midday compared to the other two groups. Only 47.27% of the 41-50 year old used fans during this time, which was lower than the 51-60 and 61-70 year old who had a proportion of fan usage between 12:00-13:00 at 88.89% and 92.94%, respectively. The 51-60 and 61-70 year old used fans during the midday between 11:00-14:00 and 11:00-15:00, respectively. During the third part of the day, the 41-50 year old had a higher proportion and duration of fan usage compared to the other two age groups. They started using fans at 18:00 and continued until 23:45, with an average proportion of fan usage of 79.55% for all age groups during this time. The highest frequency of fan usage was 100.00% at 20:00 for the 41-50 year old. The age group of 51-60 years old has the lowest proportion of fan usage during the evening hours compared to all other age groups. It was found that fan usage starts at 20:00 with only 33.33% and gradually decreases until 23:45 where the percentage of fan usage in the sample group is only 11.11%. The average fan usage during this time period is only 18.75%. On the other hand, the age group of 61-70 years old has the highest proportion of fan usage during the third period of the day, starting from 19:00 and increasing from 20:00 to 22:00, with an average fan usage proportion of 77.12%. Subsequently, the fan usage proportion decreases, with the highest fan usage proportion for the 61-70 age group occurring at 21:00, which is 82.35%.

The final group consists of individuals aged over 71 years old. It was found that they only have two periods of fan usage each day: midday and evening. During the midday period, fans are turned on starting at 9:00 and continuing until 15:00. The highest proportion of fan usage during this period is between 12:00 and 13:00, with an average of 76.00% of individuals using fans, and the maximum fan usage is 100.00% at 12:00. Fans are turned on again in the evening period, from 18:00 until 23:45, with an average fan usage proportion of 60.00% throughout this period. In this age group, the highest average fan usage proportion occurs from 19:00 to 20:00 and the maximum fan usage proportion is 100.00% at 20:00.

The analysis of fan usage behavior when classified by gender and age groups reveals that each group exhibits similar but not identical fan usage behaviors. When examining the fan usage behavior of each group during workdays and holidays, no significant differences in behavior were found. Thus, it can be concluded that fan usage behavior within the building depends on the gender and age of the building occupants. The information in Table 4.24, which displays the quantity of fan usage by all population groups, the proportion of time and frequency of all fan usage is found to be an average of 50.31% from all sample groups.

2.2.3 Air conditioning

The behavior of air conditioner usage among consumers categorized by gender, age group, and time of day is presented in Table 4.7. The results indicate that the behavior of air conditioner usage does not differ significantly between weekday and weekends across all consumer groups. However, there are differences in behavior between gender and age groups. Analysis of the behavior of air conditioner usage among each consumer group reveals that usage patterns vary depending on consumer characteristics. It is important to note that the proportion of air conditioner usage in the area is relatively low, averaging only 5.95% according to the data shown in Table 4.24.

For male consumers, the behavior of air conditioner usage occurs during the following time slots: 0:00-2:45, 11:00-11:45, 12:30-13:45, 14:00-14:45, and 20:00-23:45. The proportion of air conditioner usage during these time slots averages 25.00%, 100.00%, 50.00%, 75.00%, 37.50%, and 75.00%, respectively. In contrast, female consumers exhibit air conditioner usage behavior only during the following time slots: 11:00-11:45, 12:00-17:15, 18:00-18:45, and 20:00-23:45, with the proportion of air conditioner usage during these time slots averaging 66.67%, 42.86%, 33.33%, and 72.92%, respectively.

If we consider the behavior of using air conditioners among age groups, it is found that the age group between 11-20 years old does not use air conditioners. Moreover, the age group between 21-70 years old does not exhibit the behavior of using air conditioners in the morning, but only during midday and early evening. However, the age group between 21-30 years old exhibits behavior of using air conditioners during the time periods of 11:00-11:45, 12:30-13:45, and 14:00-14:45, with an average proportion of air conditioner usage at 100.00% for each time period. This is due to the fact that only 6.25% of the sample population use air conditioners from the aforementioned age group.

The study examined the air conditioning usage behavior of different age groups in a certain population. The first age group, 31-40 years old, exhibited air conditioning usage behavior during three periods, namely 11:00-11:45, 14:00-14:45, and 20:00-23:45, with average usage proportions of 100.00%, 33.33%, and 45.83%, respectively. However, this group had the highest proportion of air conditioning usage during the period of 21:00-21:45, which accounted for 100.00% of their usage behavior. The second age group, 41-50 years old, exhibited air conditioning usage behavior during only one period, namely 20:00-20:45, with an average usage proportion of 93.33%. The third age group, 51-60 years old, exhibited relatively continuous air conditioning usage behavior from 11:00 to 21:45, with breaks during 11:45-12:00, 17:15-18:00, and 18:45-20:00. The average usage proportions for each period were 66.67%, 50.79%, 33.33%, and 33.33%, respectively. The fourth age group, 61-70 years old, exhibited air conditioning usage behavior during four periods, namely 11:00-11:45, 12:30-13:45, 14:00-14:45, and 20:00-21:45, with average usage proportions of 100.00%, 50.00%, 50.00%, and 31.25%, respectively. Finally, the last age group, over 71 years old, exhibited air conditioning usage behavior during only one period, namely 20:00-2:45, with an average usage proportion of 75.93%. The period with the highest usage proportion, 100.00%, occurred during the period of 20:30-23:45 pm.

The proportionate behavior data regarding the use of air conditioning systems within buildings, when analyzed according to gender and age groups, could not clearly indicate whether all community behaviors were similar to the data obtained from the questionnaire. This is because the analysis of air conditioning usage behavior characteristics according to consumer profiles still requires the use of other datasets, such as usage duration, frequency, and internal air conditioning system data, to accurately summarize the air conditioning usage behavior according to the characteristics of the consumers, and to ensure the reliability of the results in the future.

2.2.4 TV

When analyzing television viewing behavior by gender and age groups of consumers within a building, it was found that usage was divided into two periods each day, namely period 1 from 6:00 to 2:00 and period 2 from 6:00 to 10:00, as shown in Table 4.8. The overall television viewing behavior data from all sample groups, it was found that the majority, 74.13%, watched television most frequently from 7:00 to 8:00. In examining gender differences in watching television habits, it was found that males had a higher proportion of television viewing during one period than females, with an average proportion of 25.15% compared to females' average proportion of 14.51%. Additionally, usage increased during period 2 at 4:00 for males and 6:00 for females, with both genders having the highest average frequency of use at the same time, 7:00 to 9:00, with averages of 95.66% and 90.62% for males and females, respectively. Throughout the 24-hour period, males were found to use the television continuously without pause, whereas females stopped using it for an average of 5.30 hours per day.

If we analyze the television viewing behavior of different age groups, we find that the behavior increases as the age of the sample group increases. The age group over 71 years old is the only group that watches television continuously for 24 hours, with a minimum average usage of 9.09% throughout the day. The proportion of viewership increases during the period starting at 6:00. In the first period, the highest proportion of viewership is from 9:00-10:00, with an average of 90.91% for the sample group. This is followed by a continuous decrease in viewership, with a proportion of only 18.18% between 14.15-15.45. Subsequently, the proportion of viewership increases again in the second period, with the highest proportion of viewership for the sample group being at 20.00-21.00, with 100.00% of the sample group watching television.

The group with the lowest proportion of television viewing is the age group between 11 and 20 years old, with an average proportion of television viewing in the first period of 3.03% from the sample group of all age groups. The television viewing behavior occurred during the time interval between 11:00 to 12:00, followed by a cessation of television usage, and resumed again from 16:45 until 23:00. The largest proportion of the sample group, 100.00%, viewed television at 21:00.

The age group between 21 and 30 years old is a group that exhibits television viewing behavior distributed throughout the day. In the morning, there is a proportion of 20.00% of television viewing occurring between 6:00 to 6:30, followed by a cessation of television usage and another period of viewing in the morning at 8:00 to 8:30 with a proportion of 40.00%, which then decreases to 20.00% until 12:00. This period has the highest proportion of the sample group viewing television during the first period of the day at 40.00%, which subsequently decreases and stops at 13:45. Then, television viewing behavior resumes again from 18:00 to 21:00 with an average proportion of television viewing in the second period of the day of 77.65%. Specifically, at 19:00 and 19:30, there is a proportion of 100.00% of the sample group viewing television, which is the highest proportion during the second period of the day.

The age groups of 31-40 years old and 51-60 years old exhibit similar television viewing behaviors. The television viewing period ranges from 6:00 to 11:45 with the lowest average proportion of television viewing at 6.25% for the 61-40 years old group and 4.00% for the 51-60 years old group. During the first part of the day, the highest average proportion of television viewing for the 31-40 years old group is 12.50% between 8:00-10:00 and 12:00-14:00. For the 51-60 years old group, the highest proportion is 36.00% at 8:00, followed by a decrease and an increase in the proportion of television viewing during the second period at 18:00. The maximum continuous and increasing rate of the number of sample groups is 100.00% at 20:00 for the 31-40 years old group and 19:00-19:45 for the 51-60 years old group. Then, both groups experience a decrease and stop at 23:00.

The study examines television viewing habits among two age groups, namely individuals aged 41-50 and 61-70 years old. Both groups had similar periods of time during which they watched television. However, there were differences in the proportion of individuals within each group who watched television. The first period of time was between 6:00-14:00 for the 41-50 age group and 5:00-14:00 for the 61-70 age group. Within the 41-50 age group, the highest proportion of individuals who watched television was 18.75% during the time slot of 6:00-6:45. For the 61-70 age group, the highest proportion of individuals who watched television was 37.93% during the time slots of 7:00 and 8:00-8:30. The second period of time during which both groups had similar television viewing habits was from 16:00-23:00. During this period, the proportion of individuals within each age group who watched television more than half of the time was highest at 59.09% for the 41-50 age group and 62.07% for the 61-70 age group. The proportion of individuals who watched television continued to increase steadily until it reached 100.00% at 20:00 and 19:00, respectively. The average proportion of individuals within each age group who watched television during the second period of time was 73.26% and 75.46% for the 41-50 and 61-70 age groups, respectively.

The data on TV viewing behavior, when considering gender, it was found that males have a continuous TV viewing pattern, which corresponds to the sample group aged over 71 years with similar TV viewing behavior. From the aforementioned data, it can be seen that selecting profiles for analyzing various activity behaviors within may affect the number of resources used. Therefore, it is advisable to consider the characteristics of each individual consumer.

2.2.5 Cooking

When examining the cooking behavior of consumers by gender and age groups shown in Table 4.9, it was found that cooking activities were mostly frequent in the morning between 6:00-7:30 and in the evening between 17:00-19:15. Some activities also occurred during midday between 11:00 AM-13:00. These patterns correspond to the meal consumption behavior of humans, who typically have three meals per day. The frequency of cooking during midday was lower than other times, likely due to the fact that the midday meal for most participants was similar to the breakfast meal, and some participants may have eaten outside of their homes, affecting their cooking behavior. When analyzing the gender differences, it was found that the differences in behavior were relatively small, and the peak times for cooking were at 7:00-7:15 and 18:00-18:15 for both genders. The average percentage of cooking activities for males was 100.00% in the morning and 66.67% in the evening, while for females it was 100.00% in the morning and 97.83% in the evening. It is evident that cooking activities during the evening meal were mostly performed by females.

Upon examination by age group, it was found that nearly every age group had the highest frequency of cooking activity occurring around 7:00-7:15 and 18:00-18:15. However, the age groups between 11-20 years old, 61-70 years old, and over 71 years old had higher frequencies of cooking activity in the morning, occurring from 6:00, and during dinner for those between 11-20 years old and over 71 years old. In the evening, the frequency of such activity was relatively lower compared to other age groups.

The age group of 21-30 years old exhibits a slower average breakfast cooking behavior compared to other age groups, starting from 7:00, which is the time of highest morning activity frequency for this age group. The evening cooking behavior for this age group starts at approximately 17:00, with the highest frequency occurring between 18:00-18:15. All age groups between 31-70 years old exhibit similar breakfast cooking behavior patterns, with cooking starting at 6:00 am and increasing until it reaches 100% frequency at 7:00-7:15 and then decreasing until it stops at 8:15. Additionally, some of these age groups exhibit lunch cooking behavior between 11:00 and 12:30, with the average frequency of 13.33% for the 21-30 age group, 20.83% for the 31-40 age group, 3.33% for the 41-50 age group, 22.67% for the 51-60 age group, and 32.58% for the 61-70 age group. The evening cooking behavior for all age groups is highest between 18:00-19:15, with the highest frequency occurring between 18:00-18:15.

The data on cooking behaviors of the sample group, which includes factors of gender and age, when comparing weekdays and weekends, it was found that there was no significant difference in behavior between the two. This may be due to the fact that the study area is a community where the majority of occupations are general wage labor, which does not have a clearly defined work schedule. This results in no difference in cooking behavior between Monday to Friday and Saturday to Sunday.

2.2.6 Rice cooking

On Table 4.10, the cooking behavior of the sample group was analyzed by gender and age groups. It was found that cooking behavior occurred during the same time periods as breakfast and dinner. Specifically, cooking was most frequent during the morning period from 6:00-7:30 and in the evening from approximately 5:00-7:15. In the morning period, the frequency of rice cooking compared to the population sample in each group was 100% at 7:00-7:15 for all sample groups. In the evening period, the frequencies were 15.03%, 55.09%, 33.33%, 28.40%, 37.78%, 36.11%, 33.33%, and 18.52% for the male, female, age groups 21-30, 31-40, 41-50, 51-60, 61-70, and over 71 years old, respectively.

2.2.7 Microwave

The frequency of microwave usage is highly variable due to it being an electrical appliance that is not commonly used within communities. Analyzing the proportional frequency of microwave usage within a building by gender, age group, and day type, as shown in Table 4.11, reveals that microwave usage can be categorized into three distinct periods each day: morning from approximately 5:00-8:15, midday from approximately 11:00-14:15, and evening from approximately 17:00-22:45.

The data on usage behavior during normal days and holidays, there are differences observed in some sample groups. Specifically, among male consumers, there is a tendency to use the service during the hours of 7:00-8:00, with usage rates of 55.00% and 40.00% on normal days and holidays, respectively. During midday on normal days, there is a usage trend between 12:00-13:15, with an average usage rate of 25.00%. However, during holidays, there is an increase in the length of usage time, with usage occurring between 12:00-14:15, with an average usage rate of 25.00% for the sample group using the microwave. In the evening on normal days, there is a trend of quick and prolonged usage, starting from 17:00-22:45, with an average usage rate of 41.67%, and a maximum frequency of 100.00% occurring between 17:30-17:45 among all consumers. On holidays, there is a trend of microwave usage occurring between 18:00-20:45, with an average usage rate of 50.00%, and a maximum frequency of 100.00% occurring between 18:00-18:45 among all consumers. This has a higher average usage frequency compared to normal days. As for female consumers, there is a pattern of microwave usage at the same three time periods: 5:00-8:15, 12:00-12:45, and 17:00-23:15, with average usage frequencies of 50.00%, 26.67%, and 33.33% on normal days, and 50.00%, 26.67%, and 35.38% on holidays. There is also a high frequency of usage during both normal and holiday mornings, particularly at 7:00-7:15.

Upon analyzing the behavior of microwave usage among age groups, it was found that the age group between 11-20 years old exhibited microwave usage behavior in 3 time periods on a normal day and 2 time periods on a work day. These time periods are between 5:00-5:45, 7:30-8:15, and 17:00-18:15, with an average usage rate of 50.00%, 50.00%, and 80.00%, respectively. The same time periods on weekends and holidays were also analyzed, with usage rates recorded as 50.00% and 80.00% for the time periods of 5:00-5:45 and 17:00-18:15, respectively.

The group of individuals aged 21-30 years old has a specific time period during which microwave usage is concentrated. This time period is during the evenings, specifically between 17:00-17:45 and 19:00-20:15, where the average number of consumers during each time slot is 100.00% of the normal day's usage. Similarly, during the time periods of 18:00-18:45 and 19:00-20:15 on weekends, the average number of consumers during each time slot is 100.00% of the normal day's usage. When analyzing the data, it was found that this group constitutes only a single sample group or 12.50% of the same sample group that uses microwaves.

In contrast, the group of individuals aged 31-40 years old exhibits a higher variance in microwave usage behavior between weekdays and weekends compared to other sample groups. The morning time period shows activity beginning at 6:00 and ending at 8:15 for weekdays and 7:45 for weekends. The second time period for weekdays exhibits only usage during the time slot of 12:00-13:15, while on weekends, the usage extends from 11:00 to 14:15. This results in a longer duration of activity during weekends, which is notably different from weekdays. Additionally, during weekends, the frequency of microwave usage during the time slot of 12:00-13:15 is as high as 100.00%, which is higher than the average frequency of 50.00% observed during weekdays. Furthermore, during weekday evenings, microwave usage is concentrated during the time period of 20:00-20:45, with an average frequency of 100.00%, while on weekends, the usage increases during the time slot of 18:00-18:45, with an average frequency of 100.00% for both weekday evenings and weekends.

The group of individuals aged between 41-50 years old exhibited similar characteristics and behaviors in using microwave ovens on both regular and weekend. It was found that in the morning, microwave ovens were used between 6:00-8:15 with an average rate of 56.25%. During midday, microwave usage was observed at 12:00-12:15 and 15:00-15:45 with an average rate of 50.00%. In the evening, microwave ovens were used between 18:00-19:15 with an average rate of 60.00%, on both regular and weekend.

On the other hand, the group of individuals aged between 51-60 years old showed slightly different behaviors in microwave usage during the evening on regular and weekend. For instance, on regular days, the observed usage rates were 40.00%, 25.00%, 100.00%, and 25.00% at 6:00-7:15 am, 12:00-12:45 pm, 17:00-17:45 pm, and 18:30-19:15 pm, respectively. On weekend, microwave usage was observed to be higher and occurred earlier in the evening at 18:00-19:15 with an average rate of 53.33%, 33.33%, 33.33%, and 55.56%, respectively, for the same time periods.

The final group that uses microwave ovens consists of individuals between the ages of 61 and 70. Their usage behavior can be divided into three similar time frames on regular days, which are from 6:00-8:15, 17:00-17:15, and 19:00-20:15. On holidays, the second time frame occurs between 18:00-18:45 instead. The average usage rate for each time frame is 55.56%, 33.33%, and 33.33%, respectively, for the entire sample group that uses microwave ovens.

Upon an examination of each sample group's microwave oven use behaviors, it was found that microwave usage often occurs in the morning or during meal preparation activities, as microwave ovens are part of the food preparation process in the residential building. However, microwave usage during the evening exhibits variation among each consumer group. Furthermore, the time frames for these activities align with dishwashing activities, as both activities are related to each other.

2.2.8 Boiling water

A study was conducted on the characteristics of hot water consumption activities for domestic use among a sample group on both regular workdays and holidays, as presented in Table 4.12. It was found that the frequency of these activities occurred mostly in the morning for all groups, but there were variations observed among the consumer groups. However, when comparing the behavior on regular workdays and holidays, no significant differences were observed. Among the male participants, hot water consumption was most frequent during the time slots of 5:00-5:45, 6:00-6:45, 7:00-7:45, and 8:00-8:45, with an average consumer percentage of 27.27%, 72.73%, 63.64%, and 75.76%, respectively. There was a lower usage during the time slots of 13:00-13:45 and 19:00-19:45, with an average consumer percentage of 36.36% and 48.48%, respectively. On the other hand, among the female participants, the hot water consumption activities were most frequent during the time slots of 5:00-5:45, 6:00-6:45, and 7:00-8:15, with the frequency percentage of 40.00%, 66.67%, and 73.33%, respectively. There were also some minor activities observed that continued until approximately 19:30, with an average consumer percentage of 9.57% throughout this time period.

When analyzing activity by age group, it was found that the age group of 11-20 years had the highest frequency of usage among consumers in the same age group, with an average of 100.00% during the time periods of 5.00-5.45, 6.00-6.45, and 17.00-18.00. The age group of 21-30 years had the highest frequency of usage in the time period of 6.00-8.45, with an average of 100.00% during the time period of 7.00-7.15, and an average number of activity participants throughout this time period of 52.73%. There was a relatively small amount of activity from consumers in this age group during the time periods of 16.00-16.45 and 19.00-19.45, with only 20.00% of consumers participating in these activities. The age group of 31-40 years exhibited the longest continuous boiling behavior, starting from 6.00 to 17.15 and 19.00-20.45, with an average of 18.01% for the sample group. The highest frequency of activity for this age group occurred during the time period of 7.00-8.45, with an average of 57.14%, and the highest frequency occurred during the time period of 8.00-8.15 at 100.00%. The age group of 41-50 years had a frequency of boiling water during the time period of 5.00-8.15, with an average of 51.65%. There was a relatively small amount of activity during the time period of 18.00-19.15, with approximately 14.29% of consumers participating in these activities. Additionally, the highest frequency of boiling water for this age group was found to occur at 7.00-7.15 every day. The age group of 51-60 years exhibited boiling behavior on a daily basis in the morning, with each occurrence spread out every 30 minutes from 4.00-8.45. During the day, the period with the highest frequency of activity is between 6:00-8:00, accounting for 77.78% of the total activity, with another peak occurring between 13:00-13:45 and 18:00-19:45, with average frequencies of 40.00% and 34.29%, respectively. The age group of 61-70 year old begin boiling water as early as 5:00, with the highest frequency of activity occurring between 6:00-8:45, averaging 61.36%, followed by a small amount of activity at 25.00% and

12.50% during the periods of 13:00-13:15 and 19:00-19:15, respectively. The age group over 71 engage in boiling water behavior in three time periods: early morning from 4:00-5:45, morning from 7:00-9:15, and evening from 19:00-20:15, with average frequencies of 64.29%, 72.22%, and 50.00%, respectively.

The behavior data of boiling water activities in each sample group, there are significant differences among them, despite the activities occurring during similar time periods. Therefore, to use this behavioral data to create a model, it is necessary to incorporate other data sets related to this activity to help identify the specific details of the activity and increase the reliability of the data for future use.

2.2.9 Eating

Table 4.13 displays the eating behavior of all sample groups in the same direction. Eating behavior occurred in three time periods, namely 7:00-9:00, 12:00-13:00, and 18:00-20:00. The maximum eating frequency for each group was 89.29% at 8:00 for the male group, 93.33% at 8:00 the female group, 80.00% at 7:00 for the group aged 11-20 years, and 100.00%, 96.00%, 87.50%, 100.00%, 87.50%, and 100.00% at 8:00 for the groups aged 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years, respectively.

During the second time period, the maximum frequency of meal consumption for almost all sample groups occurred between 12:00 and 12:45. The average meal consumption rates for each sample group were 95.24% for males, 98.33% for females, 86.67% for those aged 11-20 years, 91.23% for those aged 21-30 years, 93.33% for those aged 31-40 years, 88.54% for those aged 41-50 years, 95.70% for those aged 51-60 years, 100.00% for those aged 61-70 years, and 96.08% for those aged over 71 years, in that order.

During the second period of the day, the maximum frequency of food intake for almost all groups occurred between 12:00 and 12:45. The average values for each group were as follows: 95.24% for males, 98.33% for females, 86.67% for those aged 11-20 years, 91.23% for those aged 21-30 years, 93.33% for those aged 31-40 years, 88.54% for those aged 41-50 years, 95.70% for those aged 51-60 years, 100.00% for those aged 61-70 years, and 96.08% for those aged over 71 years.

The data on eating behavior, it was found that eating is an activity that occurs after cooking and preparing food. In human lifestyle, preparing food before eating is necessary for good health and well-being. Following the act of eating, the necessary and continuous activity that follows is dishwashing, to clean the utensils for future use.

2.2.10 Washing dishes

Upon analyzing the characteristics of dishwashing activities from Table 4.14, there are time periods during which dishwashing occurs concurrently with food preparation, cooking, and consumption. Dishwashing occurs three times a day, namely during Time Period 1 between 7:00 and 9:00, Time Period 2 between 12:00 and 13:00, and Time Period 3 between approximately 17:00 and 20:00. When considering the frequency of dishwashing activities in comparison to food preparation, cooking, and consumption activities, it was found that dishwashing activities with higher frequency occur during the same time periods as the aforementioned activities. Specifically, during Time Period 1 of each day, dishwashing activities occur from 8:00 to 8:15. During Time Period 2, dishwashing activities occur at 12:45, which is the end of the midday meal consumption activity. Finally, during Time Period 3, dishwashing activities occur at 19:00 to 19:15, which is the time period with a high frequency of meal consumption activities.

From the analysis of dishwashing behavior based on the characteristics of each consumer, it was found that the behavior of the sample group aligns with activities related to cooking and dining. However, the frequency and duration of dishwashing activities vary among individuals. Therefore, when using behavior data to generate consumer profiles for water usage, it is necessary to consider the aforementioned information in order to increase the credibility of the dataset.

2.2.11 Bathing

From the activity data on bathing behavior of each sample group, as shown in Table 4.15, it was found that bathing behavior occurred on average for two time periods per day in all population groups. One period occurred between 6:00-8:15 and the other between 17:00-21:00. The morning period of the activity usually occurred after the opening of the light activity and before the meal activity, while the evening period occurred near the time of the light activity and the dinner activity. Overall analysis revealed that the frequency of bathing behavior was highest in the evening period for most sample groups, with males, females, and age groups between 11-50 years having the highest frequency of bathing behavior between 19:00-19:15. The age group of 51-60 years had the highest frequency of bathing behavior during the time period of 18:00-18:15 or 19:00-19:15. For the age group of 61 years and above, the highest frequency of bathing behavior was found at around 18:00-18:15. In the morning period of the day, the sample group of age between 11-40 years had a frequency of bathing behavior that was similar to the evening period of the same sample group. The table and data on the duration and frequency of bathing activity for the aforementioned sample groups indicate that there were no significant differences in bathing behavior between weekday and weekends for all sample groups.

The maximum number of female participants engaged in morning bathing activity was 51.22%, while the maximum number of male participants was 69.23%. For the age group 21-30 years, the maximum participation rate was 69.23%, for the age group 31-40 years it was 87.50%, for the age group 41-50 years it was 66.67%, for the age group 51-60 years it was 45.00%, and for the age group 61-70 years it was 24.00%. The participation rate for the age group above 71 years was 25.00%. At 7.00-7.15, the participation rate for the age group 11-20 years was 85.71%, while at 18:00-18:15, the participation rate was 100.00% for male and female participants and for the age group between 11-60 years. However, for the age group 21-30 years, the participation rate was 100.00% during the time period of 20:00-20:15. Additionally, the age group above 51 years had the highest participation rate during the time period of 18:00-18:15.

2.2.12 Electricity water heater

The data on bathing behaviour of the sample group presented in Table 4.16 indicates that an analysis of hot water usage during bathing reveals a corresponding pattern of usage with bathing activity. Upon examination of the gender of the sample group, it was observed that the time period and peak frequency of usage occurred at 19:00-19:15 for both genders. Furthermore, an examination of the age groups of the sample group revealed that those aged between 11-70 years exhibited a pattern of hot water usage during the same time period as bathing activity, whereas the group aged over 71 years did not exhibit any significant frequency of hot water usage.

It is important to note that the aforementioned bathing activity aligns with the frequency data of hot water usage in each respective sample group. Thus, it can be concluded that the hot water usage of each sample group corresponds with the time period of bathing activity, except for the group aged over 71 years.

2.2.13 Toilet

The behavior of restroom usage among all sample groups tends to be excessive throughout the day, starting from the morning upon waking up or along with the start of other activities within the building, such as turning on bright lights, as well as taking a shower. These activities usually begin at 6:00 and occur sporadically throughout the day. Data indicating the frequency of restroom usage for each sample group, as shown in Table 4.17, the frequency of restroom usage during workdays and holidays does not differ significantly. The highest frequency of restroom usage for each day occurs between 6:00-6:30 in all age groups.

From the table showing the frequency of restroom usage, it was found that the frequency of restroom usage increases consistently every hour in each sample group. In the morning, the frequency is highest at 6:00 and 7:00 am with an average of 81.40%, 83.26%, 87.27%, 65.56%, 73.33%, 78.10%, 74.07%, 83.64%, and 60.00% for each sample group, respectively. The frequency then decreases at 9:00 am and increases again from 12:00-4:00 pm with an average frequency of 40.93%, 36.74%, 18.18%, 41.11%, 51.11%, 42.86%, 31.85%, 47.27%, and 33.33% for each hour, respectively. The frequency then increases again to 68.84%, 62.79%, 54.55%, 56.67%, 63.33%, 78.10%, 51.85%, 67.27%, and 60.00% for male, female, age group 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years old, respectively.

The data on restroom usage behavior of all sample groups, it can be observed that the aforementioned activity is one that can occur throughout the day and cannot be specified to a definite time interval. Therefore, analyzing restroom usage behavior for community management planning requires an assessment of the resources used in such activities to identify the necessity of time allocation for planning and management efficiency.

2.2.14 Hair drying

The activity of using a small hot air blower to dry hair is an activity that was performed by eight sample groups, except for the sample group over the age of 71. The behavior of engaging in this activity varied slightly between normal days and holidays among the 31-40 year old age group. This is shown in Table 4.18 which indicates that, when considering the behavior of the male sample group, the activity occurred during three time periods: 5:30-7:45, 18:00-18:45, and 20:00-22:15, with an average frequency of use of 66.67%, 50.00%, and 50.00%, respectively. Period 1 had the highest frequency of use at 100.00% at 6:30-7:00, which differed from the female sample group, who had the highest frequency of use in the evening at 20:00-20:45, with the activity occurring during three time periods similar to those of the male sample group, but with different time slots at 5:30-7:15, 17:00-18:45, and 19:00-21:15, with an average frequency of use of 12.50%, 14.29%, and 51.39%, respectively.

If the analysis of hair dryer usage to dry hair is performed according to age groups, it will be found that the frequency of activity occurrence mainly takes place during the evening. Among the age group of 11-20 years old, there is only one time period with the highest average frequency of 100.00% which is at 20:00-20:45. The age group between 21-30 years old has two time periods with a frequency of activity, which are at 5:30-7:30 and 20:00-22:15, with average frequencies of 20.00% and 46.67%, respectively. The time period of 20:30-20:45 has the highest frequency of activity in this sample group. The age groups of 31-40 years old and 41-50 years old are similar in behavior with one time period of activity each, which is 19:00-21:15 for the 31-40 age group, and 19:00-20:45 for the 41-50 age group, with average frequencies of 55.56% and 85.71%, respectively. Both age groups have the highest average frequency of activity at 100.00% at 20:00-20:15 for the 31-40 age group, and 19:00-19:45 and 20:00-20:45 for the 41-50 age group. As for the age groups between 51-60 years old and 61-70 years old, their behavior is divided into two time periods: a morning period from 6:30-7:10 with low activity, and an evening period from 18:00-22:45 for the 51-60 age group, and 17:00-20:15 for the 61-70 age group. Both age groups have the same average amount of people performing activities, which is 16.67%, but there is a difference in the second period. The 51-60 age group has an average quantity of people performing activities at 40.91%, while the 61-70 age group has an average quantity of people performing activities at 22.22%.

2.2.15 Washing clothes

The Table 4.19 displays laundry activities that predominantly occur in the morning between approximately 6:00-12:15 and are distributed in the afternoon between 15:00-16:15, 17:00-17:15, and 19:00-20:15. Upon analyzing activity patterns during workdays and weekends across all age groups, a slight difference was observed among the 11-20 year-old group, which had a higher proportion of individuals engaging in laundry activities on weekends. This is attributed to the fact that the majority of individuals in this age group are students who only have free time to do laundry on weekends, resulting in a higher number of activities during weekends compared to weekdays. When analyzing activity patterns by gender, it was found that males tend to spend less time on laundry activities than females. Laundry activities typically start at 6:00, with the highest number of individuals engaging in activities at 8:00. Females tend to start activities at 7:00, with the highest number of individuals engaging in activities at 11:00.

Upon analyzing the behavior of laundry washing activities by age groups, it was found that all age groups had the highest number of people washing laundry at 8:00, with activities beginning at 6:00 on both weekdays and weekends. Among the age group of 11-20 years, only one group had laundry activities starting at 7:00 and ending at 10:15 on weekdays and 11:45 on weekends. The average percentage of activity during the morning period was 46.15% on weekdays and 36.84% on weekends. Upon considering the average proportion of people washing laundry during the period with the highest frequency of activity for each group, it was found that the values were similar, ranging from 35.98% to 61.38%, in the following order of gender groups and age groups: male, female, 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years. The average percentage of laundry washing activity during the afternoon period from all sample groups was 22.99%. Therefore, it can be concluded that the activity is influenced by age groups since the age of consumers is related to professions that affect their lifestyle behavior, especially government officials and students who mostly wash laundry on weekends.

2.2.16 Ironing

The activity of laundry pressing is another task that differs slightly in behavior between workdays and weekends, as shown in Table 4.20. It was found that noticeable differences in behavior were observed among the age groups of 21-30 years old and 41-50 years old. The former group tends to have a different pattern of leisure time activity on weekends than on workdays, whereas the latter group has an increased number of participants engaging in laundry pressing on weekends. Upon analyzing the characteristics of laundry pressing activity, it was found that this activity is not significantly related to other activities. Moreover, when examining the gender of the consumers, the time periods of laundry pressing were divided into three time slots: 6:00-8:15, 9:00-10:45, and 18:00-21:45. The majority of male consumers engaged in laundry pressing between 19:00-20:15, which accounted for an average of 84.00% of the time slot. This behavior differed from female consumers, who engaged in laundry pressing during both the morning and evening time slots, specifically between 7:00-7:15 and 18:00-19:15, with an average of 100.00% and 65.00%, respectively.

If behavior is analyzed by age groups, it can be found that the behavior of ironing clothes of age group 11-70 years has the highest frequency during the time of 6:30-7:15 for the age group 11-20 years, 7:00-7:15 for the age group 21-30 years, 6:30-7:15 for the age group 31-40 years, 6:30-7:15 for the age group 41-50 years, 7:00-8:15 for the age group 51-60 years, and 7:00-7:15 for the age group 61-70 years, except for the age group over 71 years old that has a high frequency of ironing clothes in the evening during the time of 19:00-20:15. Additionally, for the age group between 31-40 years old, the behavior of ironing clothes is distributed throughout the day, from 8:00-14:15, with an average percentage of individuals engaging in the activity during this time being 33.00%.

When analyzing the average number of individuals engaging in the behavior of ironing clothes for each age group, it was found that during the morning of a workday, the age group of 11-20 years old had an average percentage of 48.33%, 21-30 years old had an average of 46.00%, 31-40 years old had an average of 52.50%, 41-50 years old had an average of 86.36%, 51-60 years old had an average of 57.41%, 61-70 years old had an average of 50.00%, and the age group over 71 years old had an average of 62.50%. During the afternoon, the average percentages were 38.10%, 47.62%, 41.67%, 67.86%, 59.09%, 35.56%, and 100.00%, respectively.

The frequency data of ironing activity, it is found that the morning and afternoon periods have similar frequencies due to ironing being a behavior performed by all age groups and cannot accurately determine a specific time period in which it occurs. This is because ironing is an activity that occurs with a proportion of occurrence from the entire population averaging only 44.69%. This information is presented in Table 4.24.

2.2.17 Gardening

The activity of watering trees and gardening is an activity in the Table 4.21, that is carried out with an average proportion of 31.39% from each sample group. The behavior of watering trees occurs twice a day for each group, which is from 7:00 to 11:00 and 15:00 to 20:00 on a regular day, and from 6:00 to 11:00 and 15:00 to 20:00 on a holiday. The behavior of watering trees on holidays is more prevalent than on weekday, especially in the age group of 21-30 years, which begins the activity at 8:00 on weekday and at 7:00 on holidays, and in the age group of 31-40 years, which started the activity at 7:00 and now starts at 6:00.

When considering each time period of the activity, it was found that the highest number of activities occurred during the time period from 17:00 to 18:15 on both weekday and regular days. Male participants tended to water trees from 7:00 to 9:15 and from 16:00 to 20:00, with the highest number of activities occurring on average at 17:00 to 17:45. Female participants tended to water trees from 7:30 to 9:15 and from 17:00 to 19:45, with the highest number of activities occurring on average at 17:00 to 17:45.

The age group of 11-20 years had a 100.00% activity rate during the 17:00-18:15 time period, both on weekday and holidays. The age group of 31-40 years had an average activity rate of 25.00%, 25.00%, and 55.56% during the 7:00-8:15, 10:00-11:15, and 16:00-18:15 time periods on regular days, and an average activity rate of 33.33%, 33.33%, and 51.28% during the 6:00-7:15, 10:00-11:15, and 16:00-19:15 time periods. The age group of 41 to over 71 years had an average activity rate on both weekday and holidays, and the activity rate varied between 25.00% and 66.67% during different time periods.

2.2.18 Pets

The activity of pet care, as displayed in Table 422, reveals discernible differences in the activity patterns of each group. This is evident due to the relatively low proportion of participants engaging in the activity in each group. Specifically, the average proportion of participation across each group is only 5.56%. Table 4422 shows that among the groups, males engage in pet care during 13:00-14:15 and 17:00-18:15, with average participation rates of 53.33% and 33.33%, respectively. Females, on the other hand, engage in pet care during 8:00-8:45, 10:00-11:15, 12:00-13:15, and 14:00-17:15, with average participation rates of 28.57%, 14.29%, 28.57%, and 15.38%, respectively.

If analyzed by age group, it was found that the age group between 11-40 years old did not engage in pet care activities on regular weekdays, whereas the age group of 21-30 years old had pet care activities during weekends between 13:00-13:45. The age group of 41-60 years old and the age group of over 71 years old had similar pet care behaviors on both weekdays and weekends. For the age group of 41-50 years old, pet care activities occurred at 8:00-8:45 and 13:00-13:45 with an average activity rate of 66.67% and 33.33%, respectively. For the age group of 51-60 years old, pet care activities occurred at 10:00-11:15 and 14:00-16:15 with an average activity rate of 50.00% for both time periods. For the age group of over 71 years old, pet care activities occurred at 12:00-13:15 and 17:00-18:15 with an average activity rate of 50.00% for both time periods. Finally, for the age group of 61-70 years old, pet care activities occurred at 12:00-13:15 and 16:00-17:15 with an average activity rate of 37.04% and 33.33% on regular weekdays, and 50.00% for both time periods of 13:00-14:15 and 16:00-17:15 on weekends.

The relatively low percentage of individuals who engage in pet care activities within each age group may have implications for the quantity of resources allocated to such activities.

2.2.19 Washing cars

The activity of car washing is the least frequent activity, occurring on average only 2.75 times per month. The majority of such activities take place on weekends, as shown in Table 4.23. When analyzing car washing on weekdays, both males and females exhibit similar behavior, with two distinct time periods, from approximately 8:00 to 10:30 and from 14:00 to 14:45. Additionally, there is an increase in car washing behavior between 15:00 and 18:00 on weekends for all groups in the sample.

On weekdays, car washing behavior exhibits high and consistent frequency across all age groups during the time period of 14:00-14:45, except for the age groups of 41-50 years and above 71 years, where all car washing activities occurred during the time periods of 9:00-11:00 and 8:00-10:00, respectively. These are the only time periods during weekdays where car washing activities were observed for both age groups.

As for car washing behavior on holidays, it is observed that there is a time period where activity frequency is similar to that of regular days, with the highest number of car washers occurring between 14:00-14:45 across all age groups, except for those between 11-20 years old and those above 71 years old. The latter two groups exhibit all of their car washing behavior during the time periods of 9:00-10:15 and 8:00-10:00, respectively. It can be noted that car washing behavior on holidays can be divided into three time periods based on the data collected, which are 8:00-10:00, 13:00-14:45, and 15:00-18:00. The average percentage of car washing during these time periods is 36.74%, 34.83%, and 19.92%, respectively.

From the community context data on building activity frequency, which analyzed the duration of each activity captured in the building and the frequency of activities occurring on each day, as well as data on the building activity frequency showing the time intervals and proportions of activity occurrence during each time interval of the day for each sample group, it can be observed that the behavior of activity within the building that may occur can be understood. All the data, it can be concluded that developing a dataset to understand patterns of energy, water, and waste resource usage within the building will require an understanding of the behavior that influences resource usage patterns, including the interrelationships among all three aspects of each activity. From the aforementioned data, it is evident that the population residing in the sample community consists of diverse groups that influence lifestyle choices, necessitating the grouping of all 14 groups as shown in Table 4.25

Table 4.25 Consumer profile

Profile symbol	Personal data		Population group	
	Gender	Age (Year old)	(Number)	(Percentage)
CP1	Male	11 - 20	10	4.00
CP2	Male	21 - 30	13	5.20
CP3	Male	31 - 40	18	7.20
CP4	Male	41 - 50	17	6.80
CP5	Male	51 - 60	13	5.20
CP6	Male	61 -70	24	9.60
CP7	Male	>71	12	4.80
CP8	Female	11 - 20	5	2.00
CP9	Female	21 - 30	19	7.60
CP10	Female	31 - 40	19	7.60
CP11	Female	41 - 50	28	11.20
CP12	Female	51 - 60	33	13.20
CP13	Female	61 -70	29	11.60
CP14	Female	>71	10	4.00
Total (Person)			250	100.00

Analysis of building activity profile

An analysis of the building activity profile is a study of the features of the building's data on energy, water, and waste from SM that has monitored the building's resource usage. The building activity profile is a data collection that is used to understand community resource consumption and forecast future community demand. This sector consists of two steps: analyzing building consumption data and creating a building activity profile.

3. Building consumption data

Data collection on the consumption of all three resources, including energy consumption, water consumption, and the amount of waste disposed of inside the building. the overall sample data for the three community resources listed below:

3.1 Energy

In terms of energy, it collects data on the quantity of power utilized in each building. The total quantity of power consumed in the building every 15 minutes is what will be utilized to calculate how much electricity was used throughout each period. to monitor the building's energy use patterns. The energy consumption assessment is separated into three characteristics: the building's general average energy consumption behavior, energy consumption characteristics by weekday and weekend, and energy consumption characteristics by days of the week.

3.1.1 Residential building

3.1.1.1 General public house 1

Average energy consumption data collected at a 15-minute frequency within the GH1 with a smart meter found that the indoor energy consumption increased from the normal consumption with an average indoor energy consumption of 0.10–0.12 kWh at 6:00, was constantly used at a high consumption, and decreased slightly until around 13:30. The energy consumption rate increases for the second period at 17:30 until the maximum daily energy consumption is reached. The daily average maximum use was 0.19 kWh at 19:00. The standard deviation (SD) average of period energy consumption is 0.11. The SD of the average household energy consumption data, on the other hand, is directly proportional to the amount of energy consumed in each period shown in Figure 4.5.

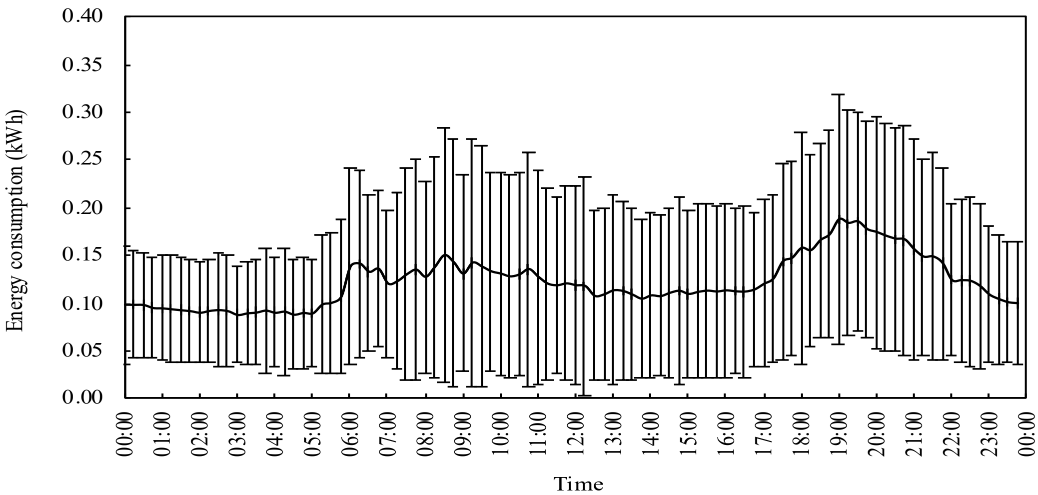


Figure 4.5 Average energy consumption in GH1

An analysis of the correlation between the time that passes, and the volume of energy consumed by the building. Table 4.26 shows the relational data. It was discovered that there was a relatively significant positive correlation between time and energy consumption. The correlation analysis results in a correlation value of 0.151, which is significant at the level of 0.01; in addition, there is 0.004 level of variance between the two variables, assuming that both data are variance in the positive direction. but didn't significantly adhere to it.

Table 4.26 Correlation between time and energy consumption in GH1

		Time	Power consumption
Time	Pearson Correlation	1.000	.151**
	Sig. (2-tailed)		.000
	Covariance	.083	.004
	N	31,067	27,587
Power	Pearson Correlation	.151**	1.000
	Sig. (2-tailed)	.000	
	Covariance	.004	.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

The energy consumption data in the GH1 study is categorized by days of the week. The average daily energy consumption before 6:00 is roughly 0.09-0.10 kWh, and it is greater and peaks in the morning, between 8:00 to 10:00. From Sunday to Saturday, the average maximum energy consumption is 0.17, 0.16, 0.17, 0.15, 0.15, 0.16, and 0.17 kWh. After then, energy consumption began to slowly decrease and afterwards gradually increase again, peaking around 19:00 to 20:00, when the building's daily energy use was maximum. In the following order from Sunday to Saturday, the average daily maximum indoor energy consumption was 0.22, 0.20, 0.21, 0.19, 0.20, 0.19, and 0.19 kWh. The average SD of all 7 days in energy consumption data separated by day of the week is 0.09. Figure 4.6 depicts the characteristics of GH1 internal energy consumption averaged each day of the week at a frequency of every 15 minutes.

The information in Table 4.27 comes from an investigation of the relationship between the time of each day of each week and the quantity of energy consumed by the building. It was found that daytime and energy consumption had a moderately significant negative correlation. The correlation analysis shows a correlation value of 0.033, which is significant at the level of 0.01; in addition, there is 0.006 level of variance between the two variables, assuming that both data are variance in the negative direction. but didn't significantly adhere to it.

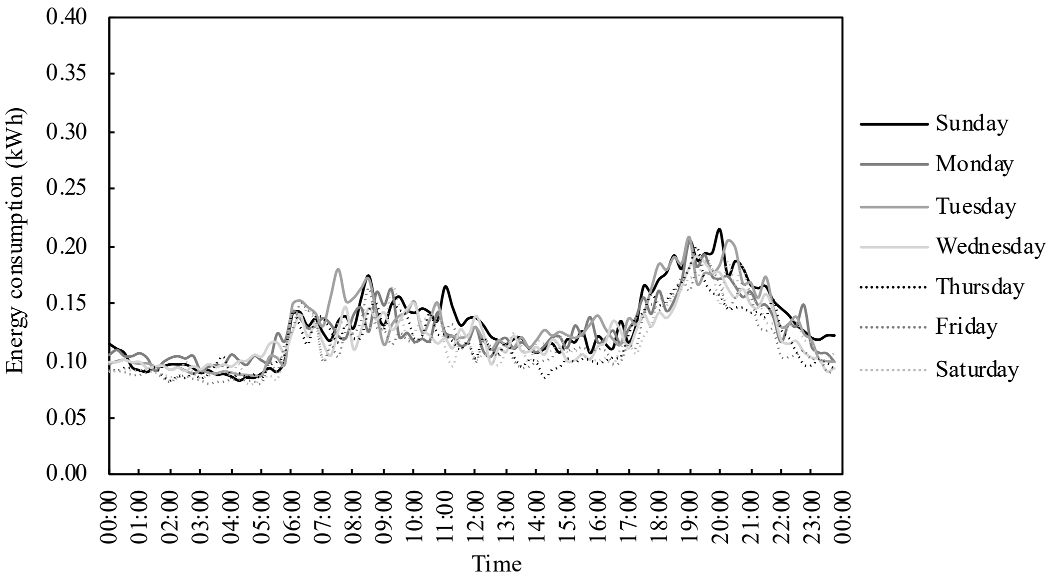


Figure 4.6 Average energy consumption in GH1 (day of the week)

Table 4.27 Correlation between Time-day and energy consumption in GH1

		Time-day	Energy consumption
Time-day	Pearson Correlation	1.000	-0.033**
	Sig. (2-tailed)		0.000
	Covariance	4.080	-0.006
	N	31,067	27,587

Table 4.27 (Cont.)

		Time-day	Energy consumption
Energy consumption	Pearson Correlation	-0.033**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	-0.006	0.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

When the quantity of energy consumed on weekdays and weekends was considered (as shown in Figure 4.7), it was discovered that the energy consumption inside GH1 was not different according to the days of the week. The amount of energy consumed correlates with the energy consumption characteristics of the day of the week. In terms of energy consumption, the largest consumption occurred in the morning on a weekday at 0.15 kWh at 8:30 and on weekends at around 0.16 kWh at 9:15, with a standard deviation of 0.09 across all datasets as the mean.

According to the GH1 building energy consumption statistics, the quantity of energy consumed within a building does not vary during the day. Every day of the week or weekday and weekends Because daily energy use is significantly correlated. However, as seen above, the quantity of energy consumed in the building is related to the time of day.

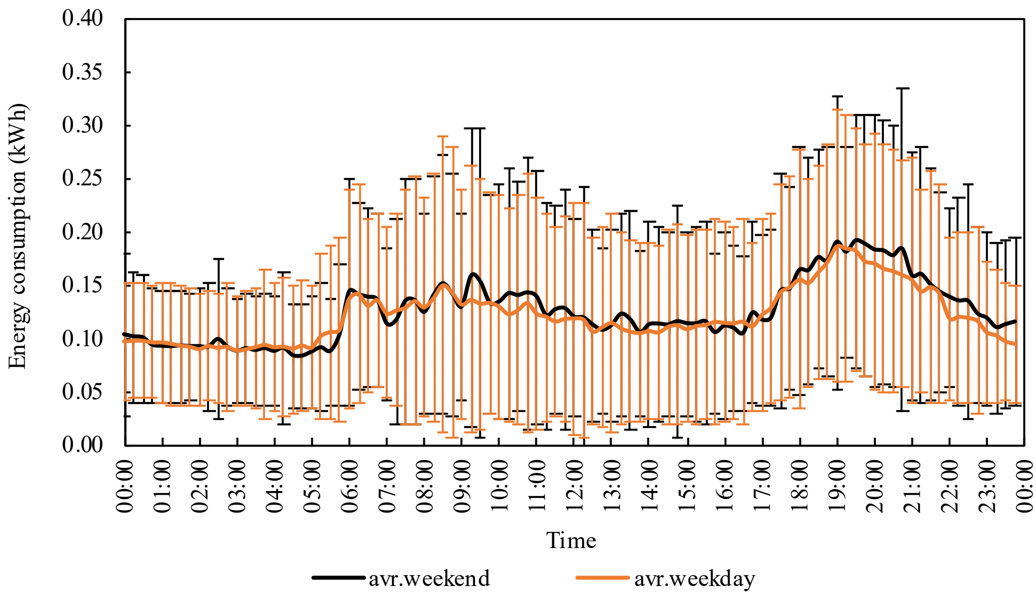


Figure 4.7 Average energy consumption in GH1 (Weekday/Weekend)

Table 4.28 Correlation between Weekday/weekend and energy consumption in GH1

		Time-week	**Energy consumption**
Time-week	Pearson Correlation	1.000	0.093**
	Sig. (2-tailed)		0.000
	Covariance	.288	0.005
	N	31,067	27,587
Energy consumption	Pearson Correlation	0.093**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.005	0.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

3.1.1.2 General public house 2

Average energy consumption data collected at a 15-minute frequency within the GH2 with a smart meter found that the household energy consumption increased from normal consumption with an average indoor energy consumption around 0.10 kWh at 4:45, was constantly used at a high consumption to 0.03 kWh at 5:15 and decreased slightly until around 6:45. The energy consumption rate increases for the second period at 16:45 until the maximum daily energy consumption is reached. The daily average maximum use was 0.04 kWh at 18:30-19:30. The standard deviation (SD) average of period energy consumption is 0.02. The SD of the average household energy consumption data, on the other hand, is directly proportional to the amount of energy consumed in each period shown in Figure 4.8.

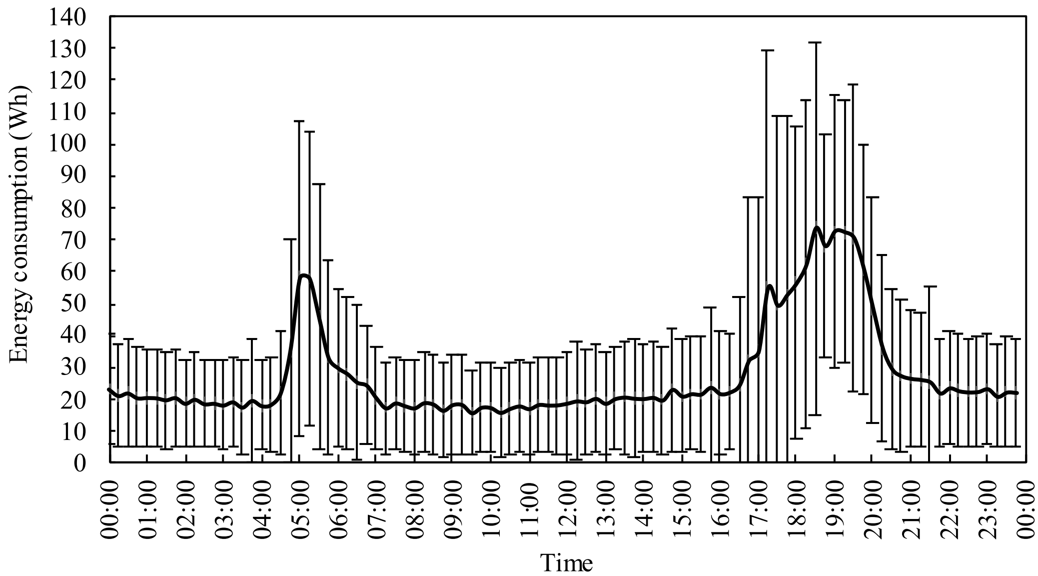


Figure 4.8 Average energy consumption in GH2

The information in comes from an investigation of the relationship between the time and the quantity of energy consumed by the building as Table C1. It was found that daytime and energy consumption had a moderately significant negative correlation. The correlation analysis shows a correlation value of 0.100, which is significant at the level of 0.01; in addition, there is 0.001 level of variance between the two variables, assuming that both data are variance in the negative direction. but didn't significantly adhere to it.

The energy consumption data in the GH2 analysis is categorized by weekday. According to the statistics, the two peak times for the day are about 4:45-6:00 and 17:15-20:00, as shown in Figure 4.9, which depicts the characteristics of GH2 building energy consumption averaged each day of the week at a frequency of every 15 minutes. For the first period, the average energy consumption in GH2 is approximately 21.96 Wh at SD 7.76, and for the second period, it is around 31.32 Wh at SD 7.87. The average maximum energy usage of the first period from Sunday to Saturday is 29.83, 31.05, 44.91, 39.61, 32.24, 30.09, and 26.76 Wh, with SD of 37.27, 35.96, 38.37, 35.18, 30.86, 32.57, and 27.58. The second period in average energy consumption has a max of 53.47 Wh with SD 49.04, 34.08 Wh with SD 41.59, 40.32 Wh with SD 45.74, 45.75 Wh with SD 46.20, 42.82 Wh with SD 46.03, 38.54 Wh with SD 56.79, and 31.02 Wh with SD 36.80 for Sunday to Saturday, respectively. When examining the average daily resource consumption pattern, it can be observed that individuals consume energy slightly differently on Sunday and Saturday than on other days, especially on Sunday evenings, when there is a higher consumption of energy than on any other day. Furthermore, the rate of energy consumption has increased since 11:00.

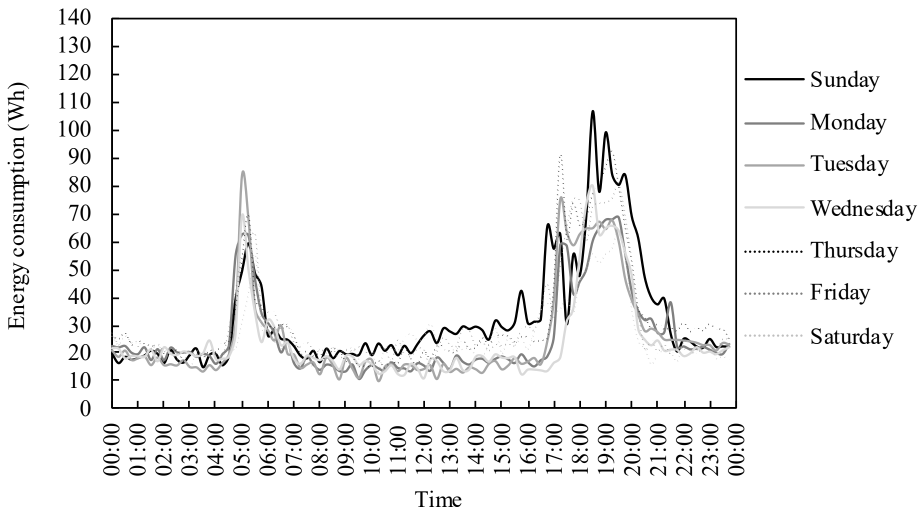


Figure 4.9 Average energy consumption in GH2 (day of the week)

When analyzing the connection between the amount of energy consumption in buildings per day as shown in Table C1, it was discovered that both data sets had a negative correlation of just 0.007, indicating that the amount of energy consumption in buildings was separated by day of the week. There was no statistically significant correlation.

However, when analyzing the average energy consumption in General Public House 2, classified by weekday and weekend, it was found that the characteristics of the data were the same as the total daily average energy consumption and the total average separated by day of the week. The peak power consumption was divided into two time periods per day: period 1 with a peak energy consumption of 25.65 Wh at 5:30 and period 2 with a peak energy consumption of 39.92 Wh at 18:30 of a weekend, and on a normal day, the maximum energy consumption indoors is the first session at 5:00, 33.28 Wh, and the second session at 18:30, 37.32 Wh of working day, shown in Figure 4.10.

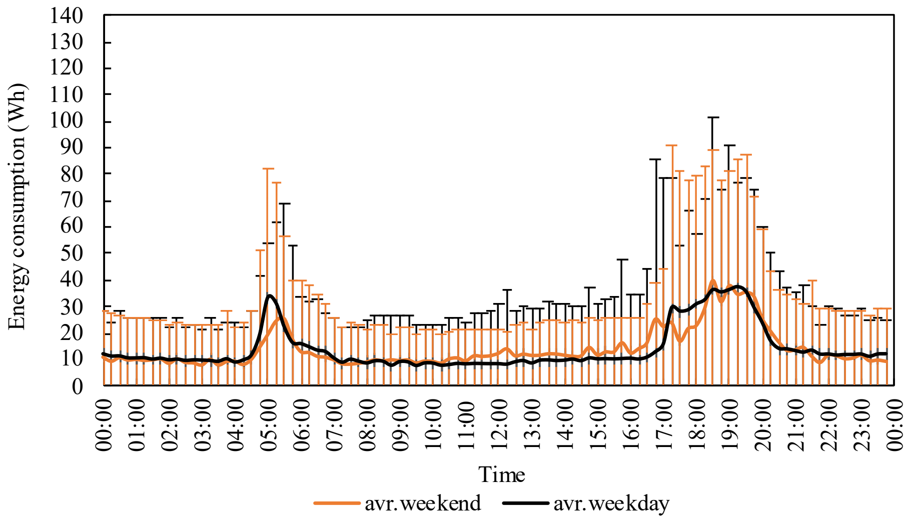


Figure 4.10 Average energy consumption in GH2 (Weekday/Weekend)

However, the correlation between the characteristics of residential energy consumption by weekday and weekends, as shown in Table C1, indicates that information classification into such data groups affects the data relationship. The statistics demonstrate that both variables are positively correlated at the 0.063 correlation level, where correlation is significant at the 0.01 level, but the covariance of the two is not statistically correlated.

The character of indoor usage does not depend on the day of the week, according to an analysis of the character and amount of energy consumption within GH2 , defined by different day groups. This suggests that the daily energy consumption inside GH2 is the same at all times of the day. with no variation between the days However, according to the SD mean of all data sets, there is a relatively large variance in the data from day to day. There are additional criteria, such as the information of consumers to live in this building and work as general employees, because of the quantity of energy consumed, and the occupation is independent of the day because of this. the nature of the amount of energy consumed in every situation. Therefore, there are characteristics of data that are statistically related.

3.1.1.3 School house 1

The average electricity consumption within the residential building of Teacher's Housing, House 1, as shown in Figure 4.11, exhibits a behavior of 22.98 Wh throughout the day. During the time period of 0:00-1:00, there is a slight increase in energy usage rate from the average, followed by a decrease until 5:00. Subsequently, the energy usage rate rapidly increases until 6:45, which is the time that corresponds to the highest average electricity consumption within the first section of the building, with an average consumption of 48.84 Wh and a standard deviation of 77.59. The energy usage rate then decreases to an average value, and slightly increases again during the time period of 12:00-14:00. By 17:00, it is observed that the energy usage rate has been consistently increasing, reaching its maximum at 19:00 with an average consumption of 53.54 Wh and a standard deviation of 78.92, followed by a decrease until the average value of energy consumption in the entire building at approximately 23:15.

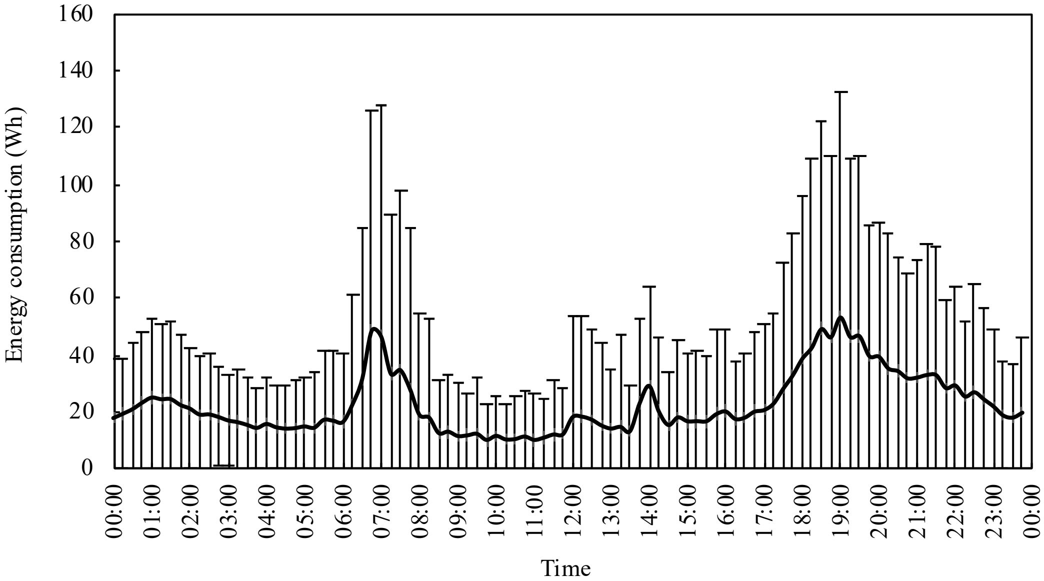


Figure 4.11 Average energy consumption in SH1

When analyzing the level of correlation between energy use within the building and the time of day as presented in Table C1, a positive correlation coefficient of 0.109 was found to be significant at the 0.01 level. Additionally, the variance of energy use data within the building was found to be 0.001 in the positive direction, but it was not statistically significant for the dataset.

Examining the energy usage behavior within the building on a daily basis throughout the week (Sunday to Saturday) as shown in Figure 4.12, it was found that the average energy consumption in every 15-minute interval was 22.88, 23.13, 24.23, 23.48, 23.13, 22.62, and 21.35 Wh respectively, while the average standard deviation values were 29.47, 31.30, 32.14, 30.73, 28.07, 26.75, and 27.57 for Sunday to Saturday respectively. The data presented for both the mean and standard deviation values for each day of the week shows that there is no significant difference in the energy usage behavior within the building throughout the week. Furthermore, the energy consumption pattern throughout the week is similar to the overall average values, with two periods of high energy usage occurring around 6:30-7:15 and 18:15-20:00.

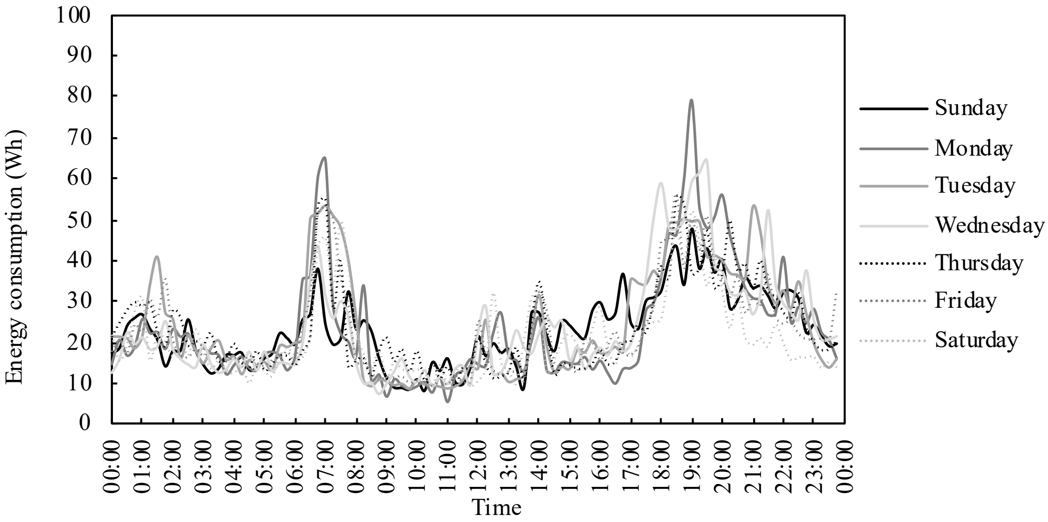


Figure 4.12 Average energy consumption in SH1 (day of the week)

Upon analyzing the correlation level of the energy consumption dataset within the building for each day at different times as presented in Table C1, it was found that the energy consumption behavior for each day has a negative correlation over time at a level of 0.007, but it is not statistically significant, and there is no significant variability between the two datasets. The correlation level data indicating that there is no statistically significant correlation between the datasets, it can be concluded that there is no statistically significant difference in energy consumption behavior for each day of the week.

Moreover, when analyzing the energy consumption data within the building every 15 minutes and separating them by weekday and weekends, it was found that the average energy consumption behavior of both days still remains the same. That is, there is a high energy consumption in the morning during weekday at 6:45, with an average amount of 52.01 Wh, and at the same time on weekends, the highest average energy consumption is 40.69. However, when analyzing the standard deviation value, it was found to be high due to the differences in energy consumption each day. Nevertheless, there is still a consistent energy consumption behavior in the same direction. The average standard deviation value throughout the day on weekends is 31.19, and on weekdays is 28.91. The comparison of energy consumption behavior within the building between weekday and weekends is shown in Figure 4.13.

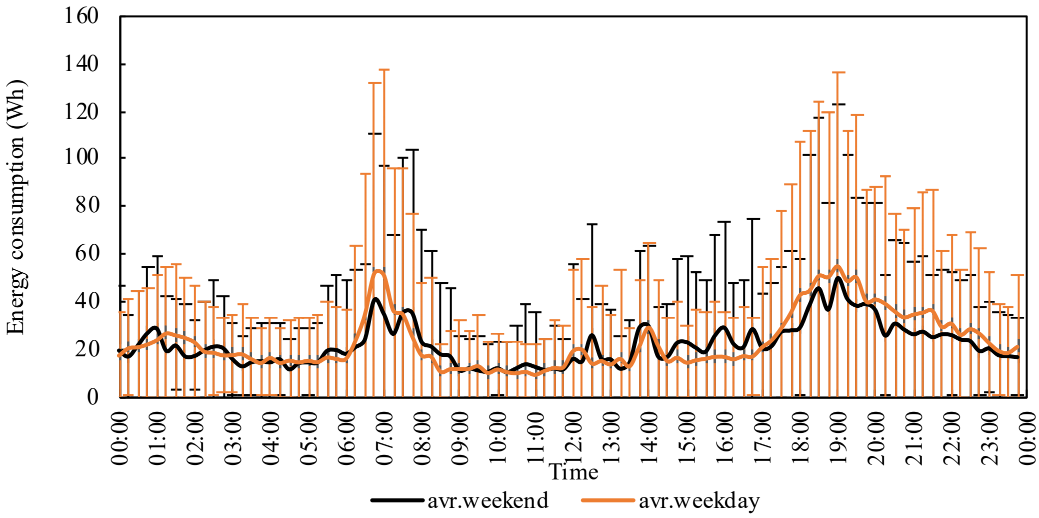


Figure 4.13 Average energy consumption in SH1 (Weekday/Weekend)

The level of correlation between energy usage data within the building during weekdays and weekends revealed a statistically significant positive correlation with a correlation coefficient of 0.047 at the Correlation is significant at the 0.01 level. Both datasets, however, still exhibit low variance between variables, indicating that the amount of energy usage within the building is related to both weekdays and weekends.

3.1.1.4 School house 2

The characteristics of energy consumption within the teacher housing building 2 were found to be similar to those of teacher housing building 1 (SH1) but differ in their levels of consumption as shown in Figure 4.14. The energy consumption pattern within the building showed a high usage rate during two distinct time periods. The first period begins at 5:00 and continues until 6:30, during which time the energy consumption rate increases from the average value, reaching a peak at 73.21 Wh. This is followed by a decrease in energy consumption, and then a second increase in consumption starting at 17:00 and continuing until 19:45, during which the energy consumption rate reaches its maximum of 76.41 Wh. The energy consumption then decreases again starting at 20:30 and continues until the average consumption rate at 23:15. The average energy consumption rate every 15 minutes within teacher housing building 2 (SH2) throughout the day is 43.64 Wh/15 min, with a standard deviation of 53.02.

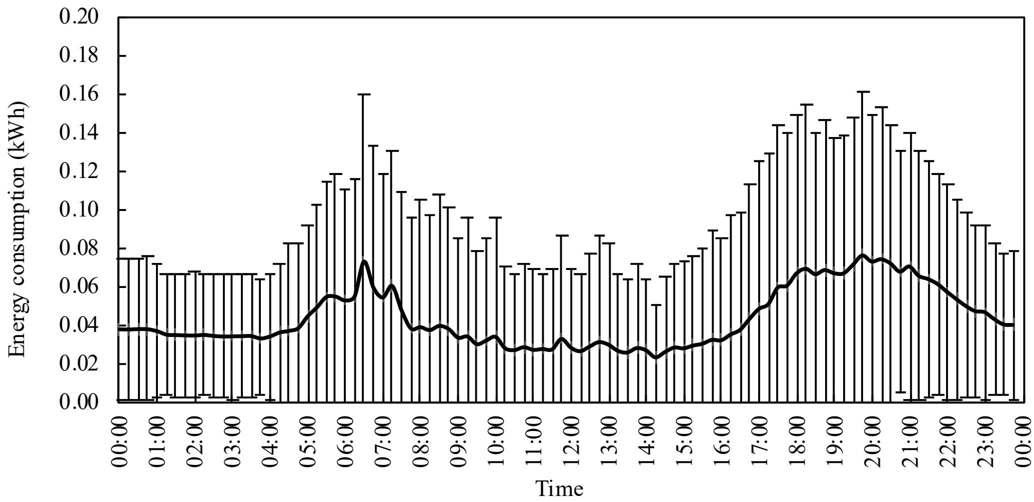


Figure 4.14 Average energy consumption in SH2

Furthermore, when analyzing the correlation between energy consumption and usage time from Table C1, it was found that there is a statistically significant positive correlation between the energy consumption within the teacher housing building 2 and the usage time during each day. The Correlation is significant at the 0.01 level with a correlation coefficient of 0.114 and a standard deviation of 0.002. This implies that an increase in usage time during each day has a significant positive impact on the energy consumption level.

The study of energy usage behaviour on a daily basis over the course of one week revealed a consistent pattern of energy consumption, with two periods of high energy usage occurring each day, in the morning and evening, as shown in Figure 4.15. When considering the average daily energy usage data, it was found that the average energy consumption for each day during the period of 5:00 to 7:30 was 38.39, 57.61, 65.01, 68.19, 61.24, 55.50, and 40.66 Wh respectively, from Sunday to Saturday. Similarly, during the period of 5:00pm to 11:00pm, the average energy usage for each day at 15-minute intervals was 61.91, 72.42, 74.02, 69.93, 61.52, 56.51, and 46.39 Wh respectively. From the graph and the average energy consumption data for both time periods, it can be observed that on Sundays, the average energy consumption within the building is lower than on other days during the same time period. Additionally, the average energy usage during the second period of Saturdays is the lowest among all days during the same time period.

Furthermore, an analysis of the correlation between the energy consumption within the building and the time of usage on each day of the week was conducted, and the results are shown in Table C1. It was found that there is no significant correlation between the energy consumption on each day of the week and the time of usage based on statistical principles. This is supported by a negative correlation coefficient of 0.004 and a p-value of 0.001, indicating a weak negative correlation between the two variables.

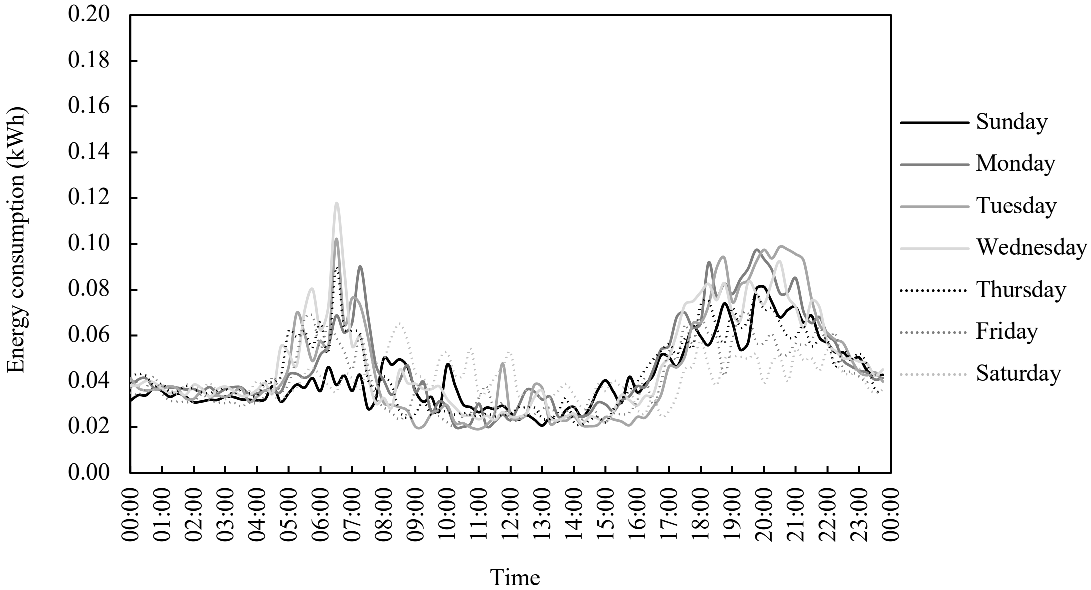


Figure 4.15 Average energy consumption in SH2 (day of the week)

From the daily energy usage behaviour data, a possible relationship between energy usage and time of day within the building can be observed. However, the results of the correlation analysis show that there is no relationship between energy usage and each day. Nonetheless, the energy usage quantities on Saturdays and Sundays differ from those of other days, as evidenced by the data. Hence, an analysis of the energy usage quantities within the building is performed by categorizing the data according to the type of working day and holiday, as shown in Figure 4.16. It is found that the average energy usage every 15 minutes on holidays is lower than that on weekday. The accumulated energy usage every 15 minutes throughout the day on weekday is 44.54 Wh, which is higher than the average energy usage quantity on holidays at 41.35 Wh. When considering high energy usage periods during weekday, it is found that energy usage on holidays has a smoother pattern, or a delayed peak by two hours compared to weekday, as measured from the highest average value in the morning of weekday and holidays. However, during midday, the average energy usage quantity on holidays is higher than on weekday. In the evening, the average energy usage quantity on holidays is lower than on weekday, with an average energy usage quantity of 55.43 Wh on holidays and 67.92 Wh on weekday, between 17:00 and 23:00.

Upon analyzing the correlation between energy consumption levels on workdays versus non-workdays during a specified time period, it was found that there exists a slightly positive correlation between energy usage and time spent utilizing energy. The correlation coefficient was determined to be 0.040 at a significance level of 0.01. Additionally, the variance between the two datasets was only 0.001, indicating that these datasets remain related.

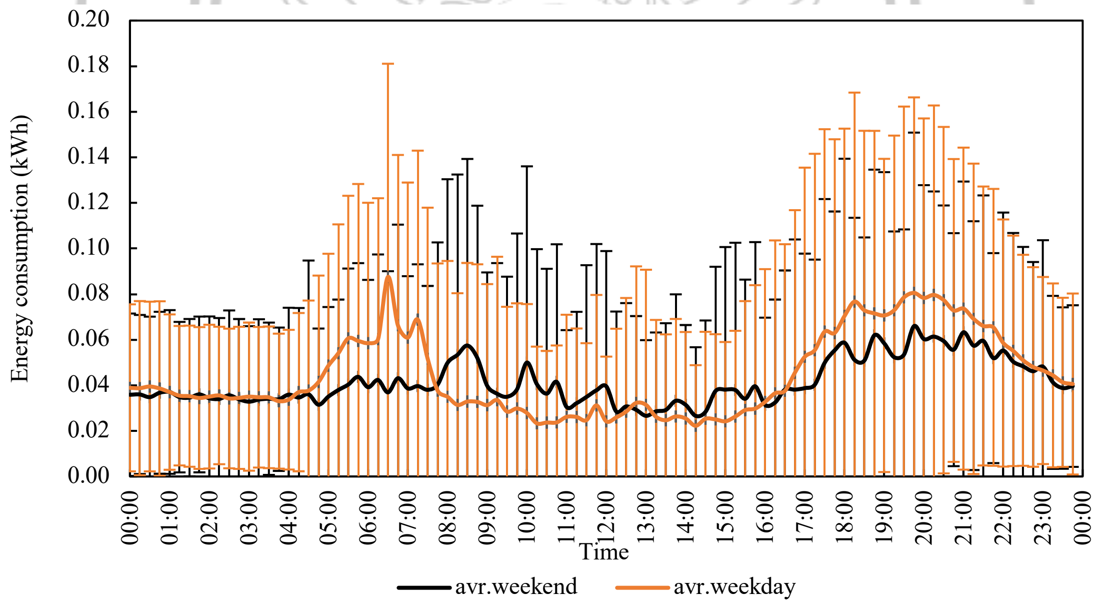


Figure 4.16 Average energy consumption in SH2 (Weekday/Weekend)

The analysis of energy consumption data collected every 15 minutes within the residential building for teachers (SH2) revealed a positive correlation between energy use. Daily and grouped analyses were performed, with energy usage behavior directly affected by the building's occupants, who are civil servants. Further analysis of the morning period revealed that energy use was stopped at 8:00. and resumed at 17:00. on weekday. During the second period on Saturdays, energy usage was lower than other days due to the fewer number of occupants staying in the building, as they had returned home. As a result, energy usage during Saturday evenings and Sunday mornings was lower than other days, with an increase in usage when occupants returned on Sunday afternoons. This led to a higher average energy consumption during the increased evening period.

3.1.1.5 Community hospital house 1

The energy usage behavior within physician residences, as depicted in Figure 4.17, exhibits distinct characteristics from those of GH1, GH2, SH1, and SH2 building energy usage patterns, as observed. The data demonstrates three time intervals where energy usage exceeds the average value of 32.63 Wh, which are from 0:00-3:00, 7:30-8:00, and 18:45-23:45, respectively. The mean values of energy usage for each of these time intervals are 44.64, 53.62, and 44.59 Wh/15 minutes, while the standard deviations are 69.72, 84.76, and 75.25, respectively. The high SD levels indicate significant variability within the dataset, consistent with the analysis of the relationship between cumulative building energy usage every 15 minutes, as presented in Table C1. Analysis of the usage duration shows a covariance value of 0 between the two variables, indicating no linear relationship between the variables. Additionally, the correlation coefficient value is 0.023 in the positive direction, but not statistically significant.

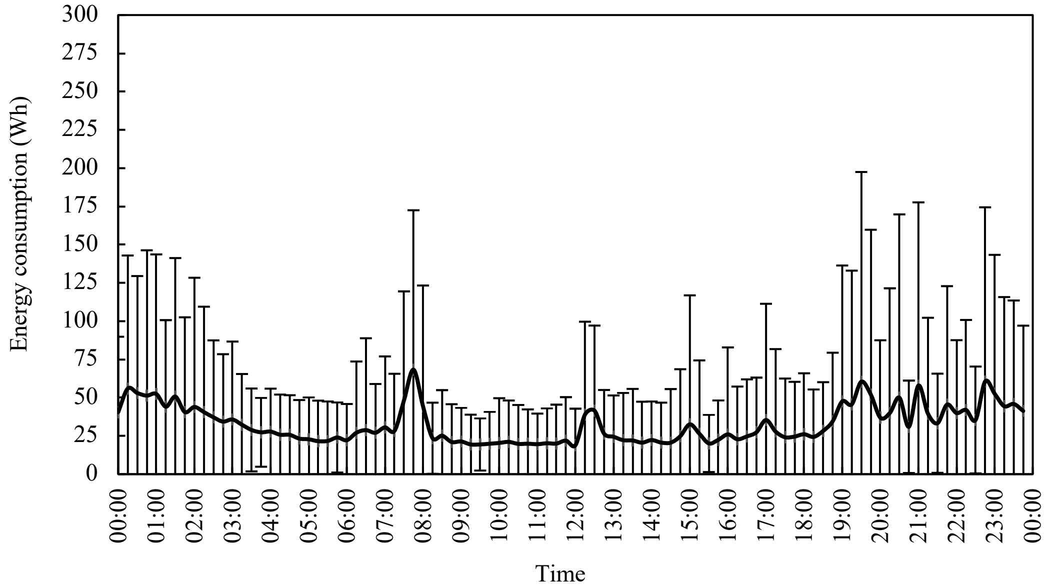


Figure 4.17 Average energy consumption in HH1

The behaviour of energy consumption within a building over the course of a week, as presented in Figure 4.18, indicates a high level of variability during times of high energy usage, specifically between the hours of 0:00-3:00, 7:30-8:00, and 18:45-23:45. Upon analyzing the average energy consumption during the time period of 0:00-3:00, the values were found to be 24.82, 37.99, 42.94, 49.66, 55.40, 53.04, and 34.68 Wh. During the time period of 7:30-8:00, the values were found to be 12.61, 29.89, 86.96, 67.44, 76.26, 74.27, and 29.73 Wh. Finally, during the time period of 18:45-23:45, the values were found to be 60.25, 46.84, 35.32, 50.19, 47.22, 38.81, and 31.89 Wh, from Sunday to Saturday in sequence.

The graph of energy consumption within the building on each day of the week and the data on the average values for each time period of each day show that the energy consumption on Sundays is lower than on other days between the hours of 0:00-8:00. Furthermore, on Saturdays, the energy consumption between the hours of 18:45-23:45 is notably lower than on other days. This is likely due to the fact that the building in question is a residential building used by community hospital staff and civil servants, with a specific pattern of behaviour during the afternoons on Sundays through Friday evenings. As a result, the energy consumption data shows that from

Friday evenings until Sunday afternoons, the energy consumption levels are relatively consistent.

Upon analyzing the relationship between the quantities of energy usage on a daily basis within one week for each period of usage, it was found that both sets of data have a significant positive correlation at a statistically significant level of 0.01, with a correlation coefficient of 0.019. Additionally, upon analyzing the covariance, it was found to be equal to 0.002, indicating a linear positive relationship between the two sets of data, as shown in Table C1.

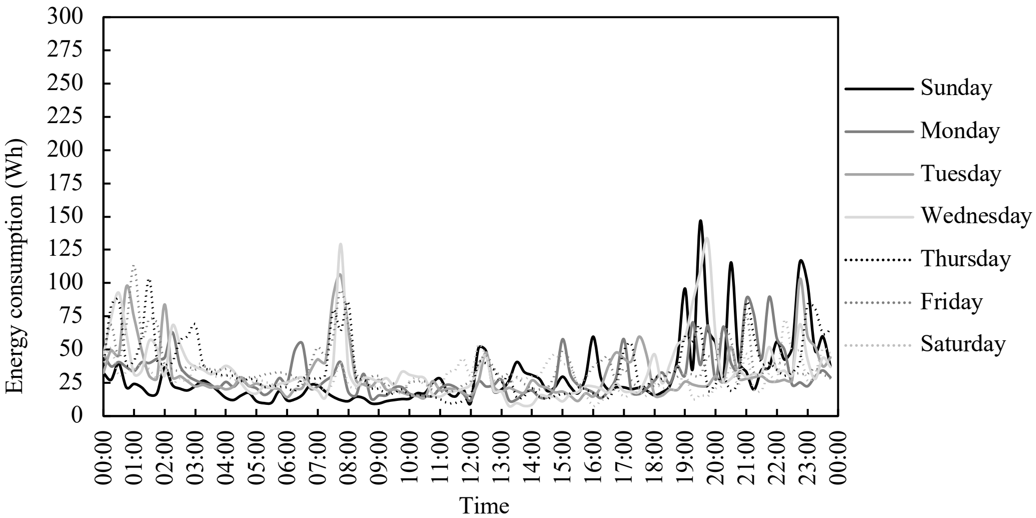


Figure 4.18 Average energy consumption in HH1 (day of the week)

When classifying the amount of energy usage within a building according to weekdays and weekend as shown in Figure 4.19, it was found that the data was consistent with the analysis of energy usage according to days of the week, with energy usage within the building during weekday being higher during the periods of 0:00-3:00 and 7:30-8:00 than on weekend, as clearly seen. The average amount of energy used within the building on weekend during both time periods was 30.11 Wh and 21.58 Wh, respectively, which is lower than the average energy usage on regular days, which was 50.54 Wh and 66.56 Wh. In the time period of 8:45-23:45, the average energy usage within the building on weekday was slightly lower than on weekend, with energy usage of 43.70 Wh and 46.87 Wh, respectively. However, when considering the energy usage during these time periods on weekend, it was found to have a high degree of variability. When analyzing the covariance between the data sets of energy usage within the building classified by weekday and weekend, a value of 0.000 was found, indicating that there is no linear relationship between the two data sets. This is consistent with the correlation coefficient of the two data sets, which has a negative value of 0.015.

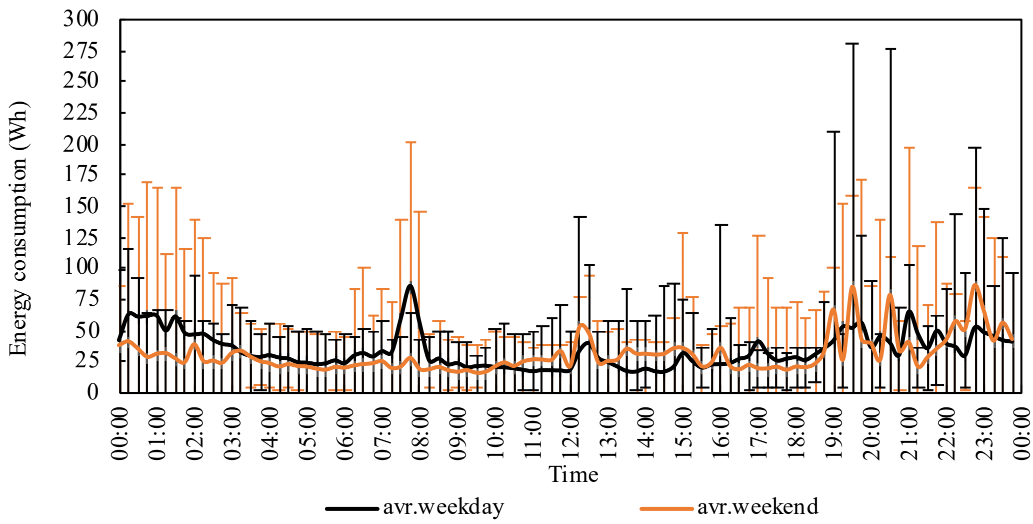


Figure 4.19 Average energy consumption in HH1 (Weekday/Weekend)

The energy consumption data within the community hospital house 1 (HH1), it can be concluded that the amount of energy usage within the building affects the duration of usage at the daily level during the week. This is due to the fact that energy usage behavior within the building is directly influenced by its occupants, who are civil servants. If we analyze the period of time with energy usage rates during the evening from Sunday to Friday, it can be observed that the amount of energy consumption within the building is lower than the same period of time on other days. This is because there are fewer occupants within the building or there are no residents present within the building.

3.1.1.6 Community hospital house 2

The energy usage characteristics within the second phase of a community hospital residential building 2 (HH2), as shown in Figure 4.20, exhibit similarities to those of typical residential buildings with high energy usage occurring during two time periods. The internal energy consumption during these periods is higher than the average daily energy consumption of 57.95 Wh/15 min. The two time periods are from 7:00-9:15 and 18:00-23:15, with average energy consumption values of 104.92 Wh and 89.92 Wh, respectively. The maximum average energy consumption values occur at 155.81 Wh at 8:00 and 121.06 Wh at 19:30. When considering the standard deviation values of each time period, it is found that there is a high variability during periods of high energy usage. The average value of the standard deviation throughout the day is 51.30.

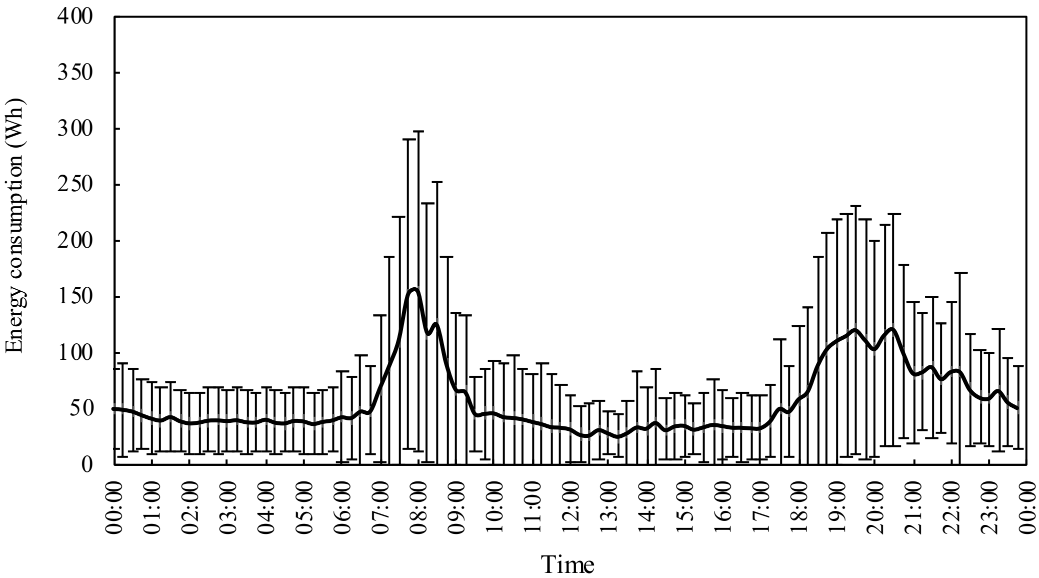


Figure 4.20 Average energy consumption in HH2

Furthermore, an analysis of the relationship between energy consumption data and the time of day reveals a significant positive correlation coefficient of 0.141, indicating statistical significance at the 0.01 level. The covariance level between the two variables, which shows the linear relationship between the variables, has a value of 0.003.

Figure 4.21, the energy usage within the building was observed over the course of 7 days. The usage patterns were found to be similar across each time period and were closely related in terms of energy consumption. The average energy consumption within the building from Sunday to Saturday was 64.67, 57.72, 58.23, 56.22, 52.86, 53.20, and 64.45 Wh, respectively, with a standard deviation of 49.34, as calculated from the SD data for each 15-minute time interval where high energy consumption was observed.

According to the data from time period 1, energy usage was higher than that of time period 2 on each day. The average energy consumption for each time period between 7:00-9:15 from Sunday to Saturday was 131.11, 105.21, 108.05, 99.15, 88.61, 76.74, and 129.48 Wh, respectively, while the second time period, between 18:00-23:15, was 85.46, 91.52, 92.56, 99.67, 81.24, 87.63, and 90.49 Wh. The data showed that energy consumption was similar across each day, and when analyzing the relationship between energy usage data separated by day of the week, it was found that both data sets were significantly correlated in a positive direction at the 0.01 level, with a correlation coefficient of 0.034. Furthermore, the level of variance of the linear variable indicated a positive relationship between energy consumption and time and day of the week at the 0.005 level.

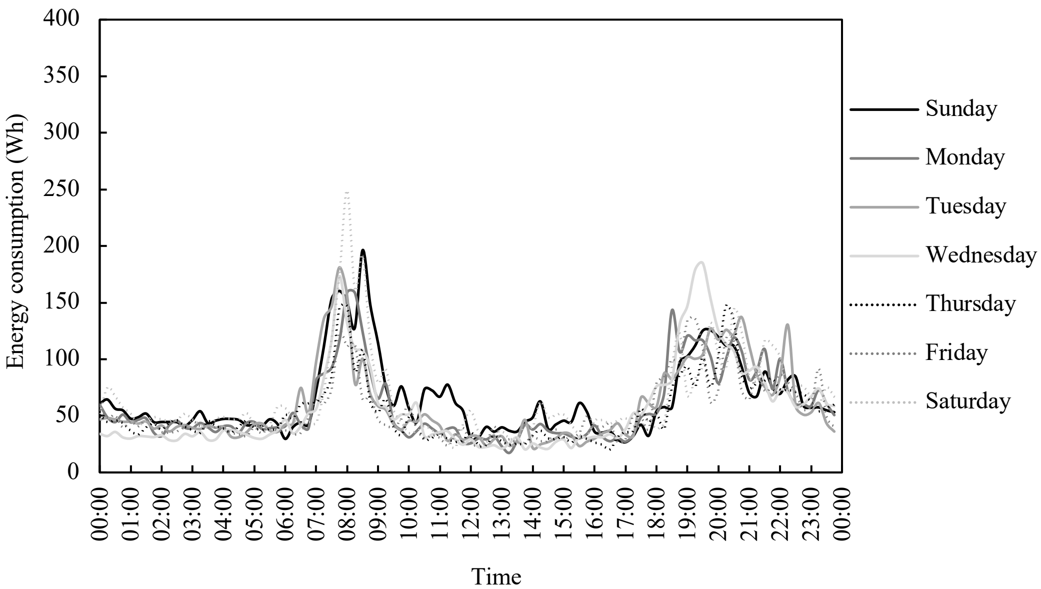


Figure 4.21 Average energy consumption in HH2 (day of the week)

When the energy usage data within the building is classified into two groups, namely weekday and holidays, as shown in Figure 4.22, it is found that the overall average cumulative energy consumption in the building at a 15-minute frequency on holidays is higher than on weekday. The average energy usage on holidays is 64.58 Wh, which is higher than the average energy usage on weekday, which is 59.46 Wh. If the amount of energy usage during the peak usage periods between 7:00-9:15 and 18:00-23:15 is considered, it is found that in the morning period, energy consumption on holidays is higher than on weekday, at 130.40 Wh and 102.46 Wh, respectively. However, in the second period, it is found that weekday have higher energy consumption inside the building than holidays, with energy usage of 91.37 Wh for weekday and 87.62 Wh for holidays.

Furthermore, when analyzing the level of correlation between the two data sets, it is found that the energy consumption inside the building, separated by weekday and holidays, has a positive correlation at a statistically significant level of 0.01. The covariance value also indicates a linear correlation level of 0.003 between the variables.

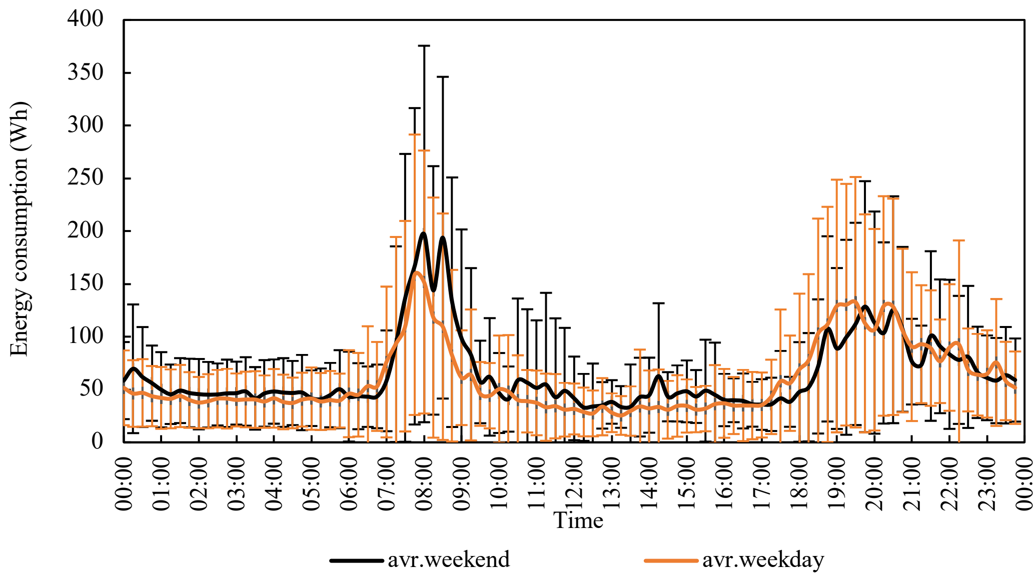


Figure 4.22 Average energy consumption in HH2 (Weekday/Weekend)

The information about the characteristics and energy usage behaviors within the second-phase community hospital residential buildings, it is evident that there is no significant difference in daily energy usage behaviors statistically. That is to say, there are similar usage behaviors during the same time period, but with varying usage quantities. This includes both weekday and holidays, which demonstrate energy usage behaviors and residential occupancy within the buildings. This is due to the fact that energy usage during the evening period is consistently high for a longer duration, unlike in the morning period where usage is higher but for a shorter period. Furthermore, analysis of the behaviors of residents with the same number of occupants during all time periods indicates that if the amount of energy usage for each activity is the same in two time periods, there is a higher frequency of usage in the morning compared to the evening, resulting in a higher cumulative energy usage in the shorter time period. This is because the average energy usage value is similar.

3.1.2 Office building

3.1.2.1 School office

From the data on energy consumption within the office-type building of the school (SCO), as shown in Figure 4.23, it was found that there was no clear difference in energy usage throughout the day. However, there was a characteristic of energy consumption quantities that had a high standard deviation from the mean value throughout the day. Specifically, during the time periods of 6:15-9:00 and 16:15-19:00, the average energy consumption within the building was found to be 10.93 Wh and 10.30 Wh, respectively, which was higher than the average energy consumption throughout the day, which was 9.49 Wh. When analyzing the correlation level of energy usage within the building over the time periods, it was found that the two data sets were not statistically correlated.

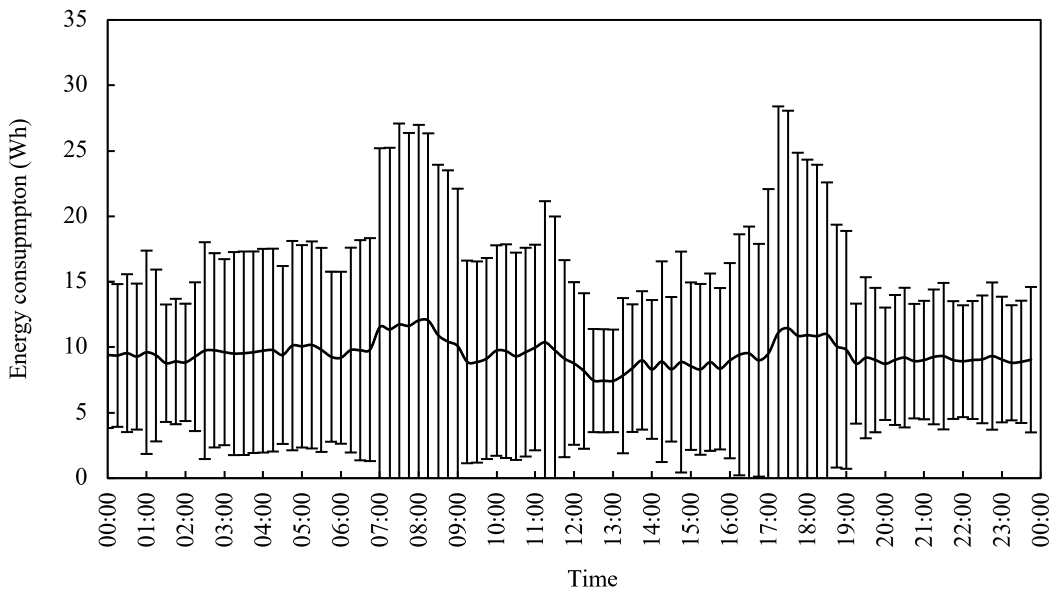


Figure 4.23 Average energy consumption in SCO

After analyzing the average energy usage per day of the week, as shown in Figure 4.24, it was found that during periods of high data variability for each day, there were distinctive patterns in energy consumption for different buildings. Specifically, when examining energy usage patterns on Sundays, it was observed that between 6:45-8:00 am, there was a noticeably lower amount of energy consumption than during the same time period on other days. However, when analyzing the cumulative energy usage every 15 minutes throughout the entire day, from Sunday to Saturday, it was found that the average values did not differ significantly and were equal to 8.55, 10.25, 10.04, 8.48, 8.93, 10.48, and 9.36 Wh, respectively, with corresponding standard deviations of 5.13, 8.09, 7.75, 4.36, 5.00, 9.90, and 7.46.

Further analysis of the relationship between energy consumption and time of day revealed that there was no statistically significant correlation between the two variables, but they did exhibit opposite directions of variability with a correlation coefficient of 0.435.

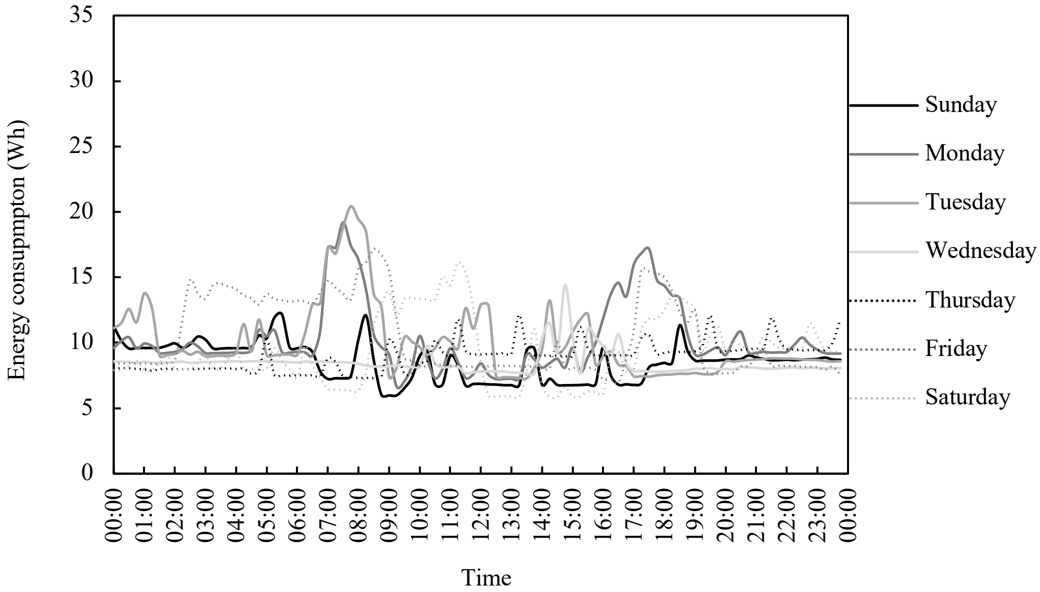


Figure 4.24 Average energy consumption in SCO (day of the week)

The analysis of energy consumption within SCO, when dividing the data set into weekday and weekend, reveals that the energy consumption pattern within the building throughout weekday has a higher average than weekend. Based on data collected every 15 minutes, the average energy consumption within the building on weekday is 9.66 Wh, which is higher than weekend with an average energy consumption of only 8.98 Wh. By referring to Figure 4.25, which shows the average data for each day, it is found that during the time interval of 6:30-8:00, the electricity consumption on weekday increases, while during the same time interval weekend, there is a decrease in energy consumption. However, there is an increase in energy consumption at around 9:00 on both weekday and weekend. Furthermore, when considering the energy consumption from 16:00 onwards, it is found that the behaviour of energy consumption on both days tends to increase at a similar rate and energy consumption reaches its peak at 19:00 on both weekday and weekend.

The analysis of the energy consumption data separated into weekday and weekend shows a negative correlation between the amount of energy consumption and time used. The correlation coefficient is 0.051, which is statistically significant at the 0.01 level. Additionally, the covariance in the opposite direction is 0.319.

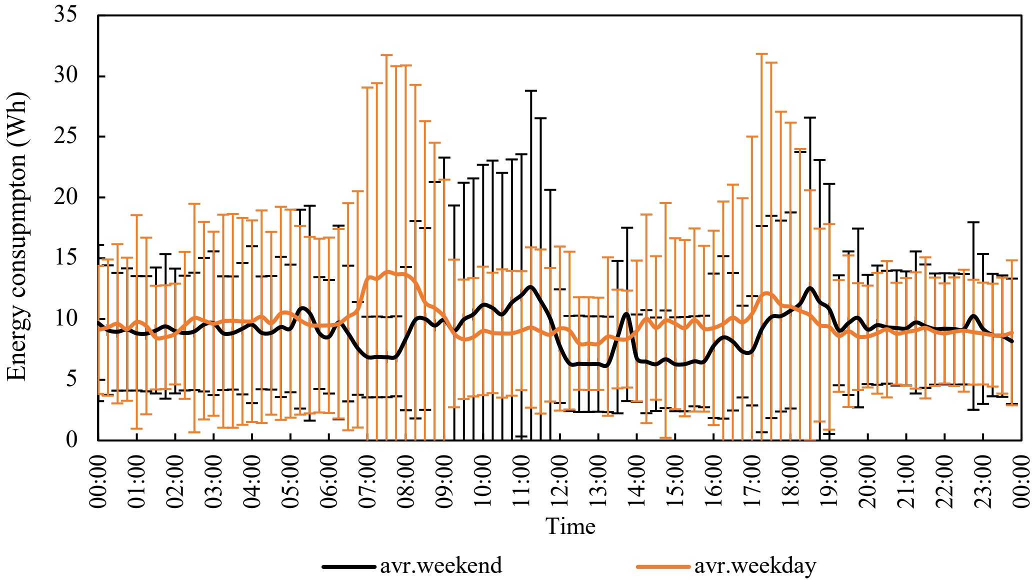


Figure 4.25 Average energy consumption in SCO (Weekday/Weekend)

The data on energy usage behavior within an office building in a school, it was found that there is high variability in energy usage during two time periods: 7:00-8:30 and 17:00-19:00. Upon analyzing the data by building function and location, it was observed that the building in question is designed to support the teaching activities of school teachers. Specifically, the building is primarily used before the start of classes at 8:30 AM and after the end of classes at 16:30, which is consistent with the observed energy usage patterns.

3.1.2.2 Community hospital office

The data on energy consumption within the community hospital office building, as shown in Figure 4.26, demonstrates the average energy usage every 15 minutes. The graph depicts an increase in energy usage starting from 7:00 until it stabilizes at approximately 8:30, followed by a slight decrease in electricity usage within the building between 11:30 and 12:30. Subsequently, energy usage rises again during the afternoon and decreases twice more, ultimately returning to a consistent energy consumption level around 17:00. Additionally, it was found that the majority of energy consumption within the building occurs between 8:00 and 16:45, during which the energy usage is higher than the daily average of 144.75 Wh. During this period, the average energy usage is 223.54 Wh, with a standard deviation of 141.89 for the same time range.

The relationship between the energy consumption data within the community hospital office building and time usage, it was found that the two datasets have a positive correlation with a Pearson's correlation coefficient of 0.040, which is statistically significant at the 0.01 level.

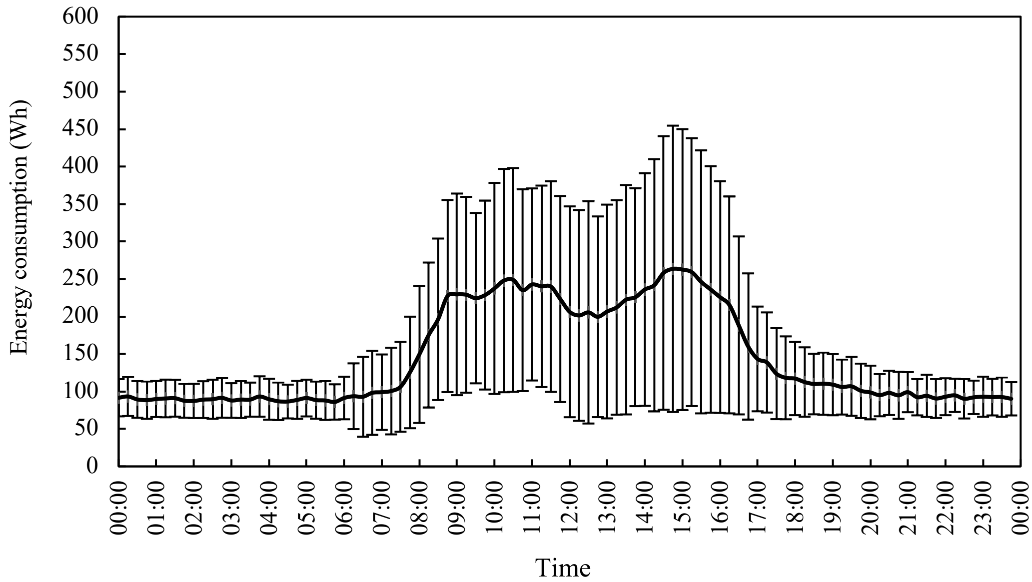


Figure 4.26 Average energy consumption in CHO

The energy consumption behavior within the building on a daily basis, it was found that the amount of energy used in the building varies slightly on Sundays and Saturdays. Figure 4.27 displays the energy consumption data within the building on Sundays, with increased energy usage occurring only during the time period from 8:00 to 12:00. This time period marks the day with the highest energy usage within the 7-day week cycle. The energy consumption data on Saturdays shows a clear division into two time periods, with energy usage starting higher than the normal level from 8:00 to 15:30, but then a brief stoppage in usage occurs from 11:30 to 12:00. These patterns are in contrast to the patterns observed from Monday to Friday. Moreover, when the average energy usage from 8:00 to 16:45 on each day was analyzed, it was found that the average energy consumption on Sundays and Saturdays was lower than that of Monday to Friday, with the average energy consumption being 105.97, 221.07, 267.68, 284.84, 288.67, 260.64, and 137.30 Wh for Sundays to Saturdays, respectively.

The relationship between each day of the week and energy consumption during each time period, it was found that the two variables had a significant negative correlation with a statistically significant level of Correlation at the 0.01 level.

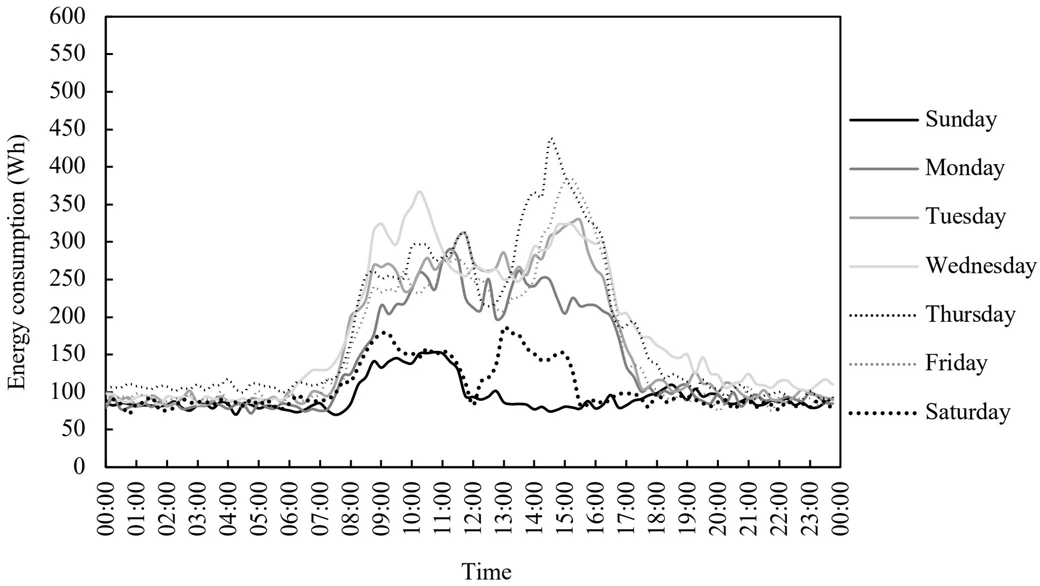


Figure 4.27 Average energy consumption in CHO (day of the week)

The energy consumption data is aggregated into weekday and weekend, as shown in Figure 4.28, it is evident that the amount of energy used within the building on weekday is higher than on weekend. When considering the standard deviation values of energy consumption on weekday, it can be observed that the minimum energy usage opportunity in the building is at the level of constant energy usage, and it varies according to the time of day. However, when considering the energy usage behavior on weekend during the time period of 0:00-12:00, the energy usage behavior and SD values are in the same direction and close in value. However, between 12:00-15:30, a higher standard deviation value is found due to the fact that the energy consumption data inside the building on Sundays and Saturdays shows that there is energy usage during that time on Saturdays, but not on Sundays, which affects the higher SD value.

The average energy consumption within the building separately for weekday and weekend, it was found that it was equal to 163.42 Wh with an SD value of 74.23 on weekday, and 98.61 Wh with an SD value of 40.91 on weekend. Specifically, when considering only the time periods with higher than normal energy usage, the average energy usage was 265.60 Wh with an SD value of 139.72 on weekday, and 119.97 Wh with an SD value of 66.34 on weekend. When analyzing both datasets for their correlation, it was found that they were significantly negatively correlated at the 0.01 level of statistical significance, with a correlation coefficient of 0.107.

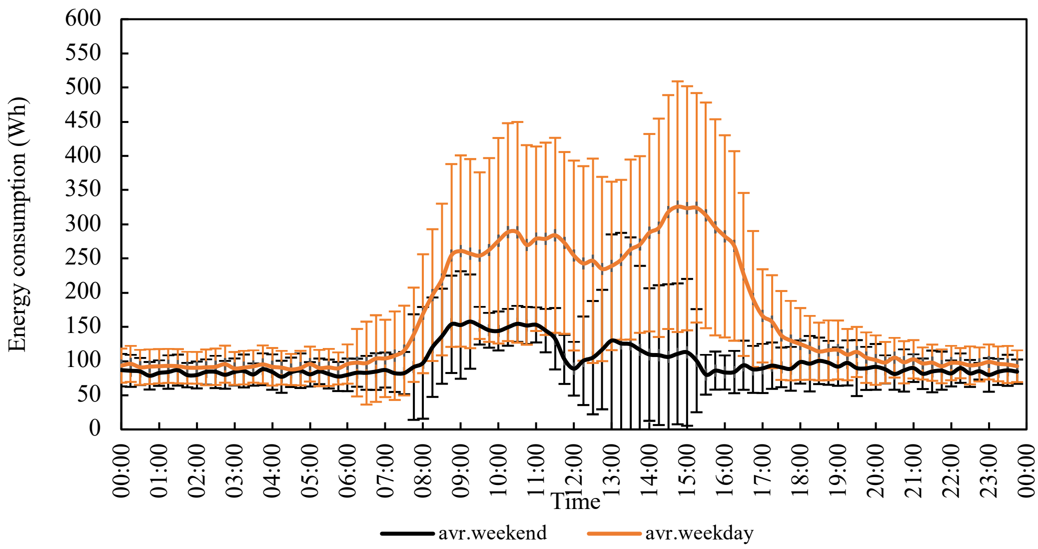


Figure 4.28 Average energy consumption in CHO (Weekday/Weekend)

The data regarding energy usage within the community hospital office building, it has been found that the time of day, day of the week, and type of work day all have significant impacts on the amount of energy consumed within the building. The quantity of energy usage within the building is dependent on the electrical appliances present within the building, as well as the manner in which the building is utilized.

3.1.3 Commercial

3.1.3.1 Coffee shop

The energy usage characteristics of a commercial building, specifically a beverage selling business (COF), as presented in Figure 4.29, reveal that energy consumption occurs only during specific time periods, between 5:30 and 19:15. This is evident from the graph showing the peak energy usage times during the early hours of each day, where the rate of energy consumption rapidly increases, averaging 32.73 Wh/15 min at 5:30 and reaching its highest daily usage rate of 134.33 Wh at 6:15, after which energy consumption reduces and stabilizes at a nearly constant rate throughout the day.

When considering three distinct time periods, namely the period with the lowest energy consumption rates or usage below the daily average of 20.69 Wh, which occurs from 0:00 to 5:30 and from 17:00 to 23:45, the period with the highest energy consumption rate, which is from 5:30 to 6:45, and the final period, which has energy usage rates that are similar to the constant average throughout the day and occurs between 6:45 and 17:00, it is found that energy consumption rates are 1.84 Wh/15min, 72.03 Wh/15min, and 37.42 Wh/15min, respectively.

From the energy consumption behavior during the peak usage periods at the start of the day, it is evident that this is when electrical appliances are being turned on and used simultaneously within the building. This includes the operation of coffee makers, lights, and boiling water for the tea shop.

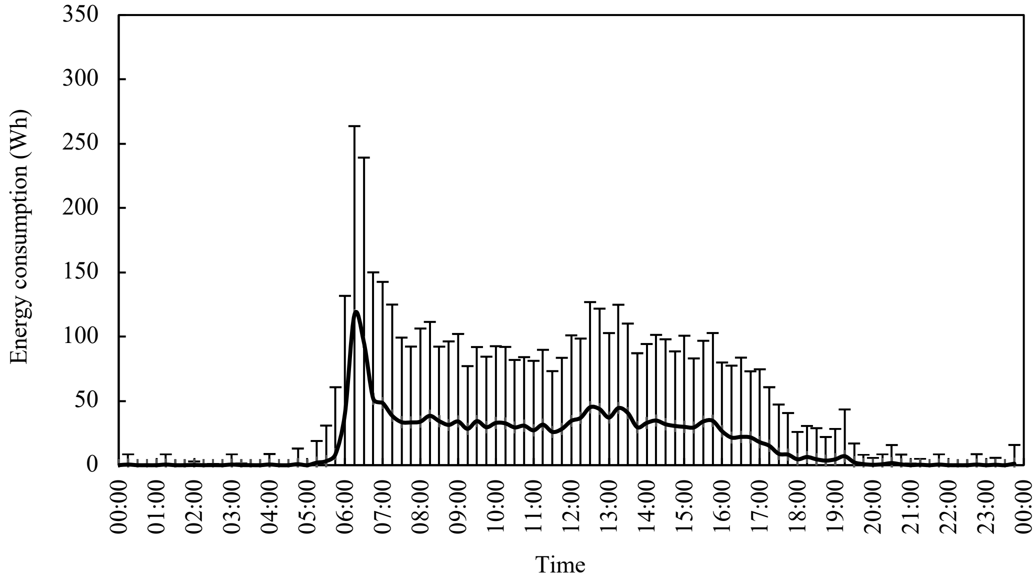


Figure 4.29 Average energy consumption in COF

The relationship between energy use inside buildings and time of day, when categorized by day type for energy use behavior analysis in a week as shown in Figure 4.30, it can be observed that on Sundays and Saturdays during high energy consumption periods, the average energy usage is lower than that of weekdays, which is clearly evident. The average energy consumption inside buildings on Sundays and Saturdays during the aforementioned period is only 45.24 Wh and 49.49 Wh respectively, which is lower than weekdays, where the average energy consumption during the same period is 81.93, 92.98, 80.88, 82.50, and 71.17 Wh respectively. However, when considering the period between 6.45am to 5.00pm, it was found that the average energy consumption was similar on all days from Sunday to Saturday, with values of 39.67, 36.74, 36.88, 37.05, 39.63, 35.79, and 36.23 Wh, respectively. Additionally, the standard deviation (SD) of energy use is found to change in the same direction as the energy consumption, which means that high energy use periods in buildings affect the high SD value, where the average SD value throughout the day is 53.02. Moreover, analyzing the relationship between energy consumption on each day, it was found that the amount of energy consumption has a statistically significant negative correlation with the day of the week at the 0.01 level, which is consistent with the direction of the joint variance level, with a value of 0.002 in the opposite direction.

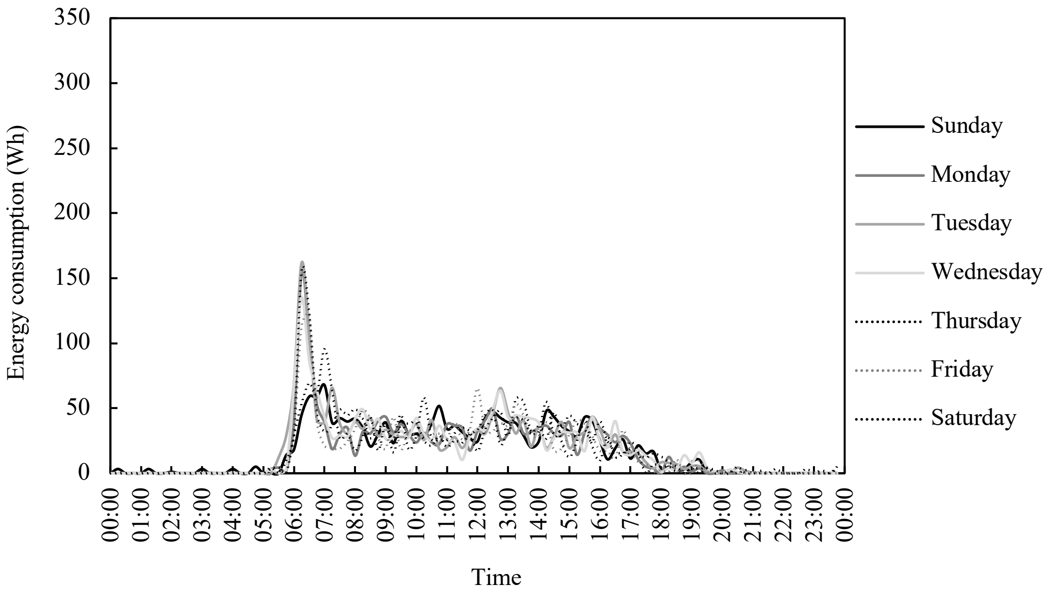


Figure 4.30 Average energy consumption in CHO (day of the week)

When categorizing the days into weekday and holidays, it is clear that the energy usage patterns exhibit distinct differences, as shown in Figure 4.31. Upon examining the energy consumption behavior separately for weekday and holidays during three time periods, similar to the previous analysis, it is observed that the time period with the lowest average energy usage is 1.39 Wh on weekday and 2.13 Wh on holidays. The time period with the highest energy usage is 71.46 Wh on weekday and 40.76 Wh on holidays. The continuous energy usage time period averages 32.48 Wh on weekday and 32.65 Wh on holidays. Furthermore, when considering the daily overall averages of weekday and holidays, they are found to be close to each other at 18.31 Wh on weekday and 17.18 Wh on holidays. Upon analyzing the correlation levels, it is found that there is a statistically significant negative correlation at the 0.01 level, with a correlation coefficient of 0.031.

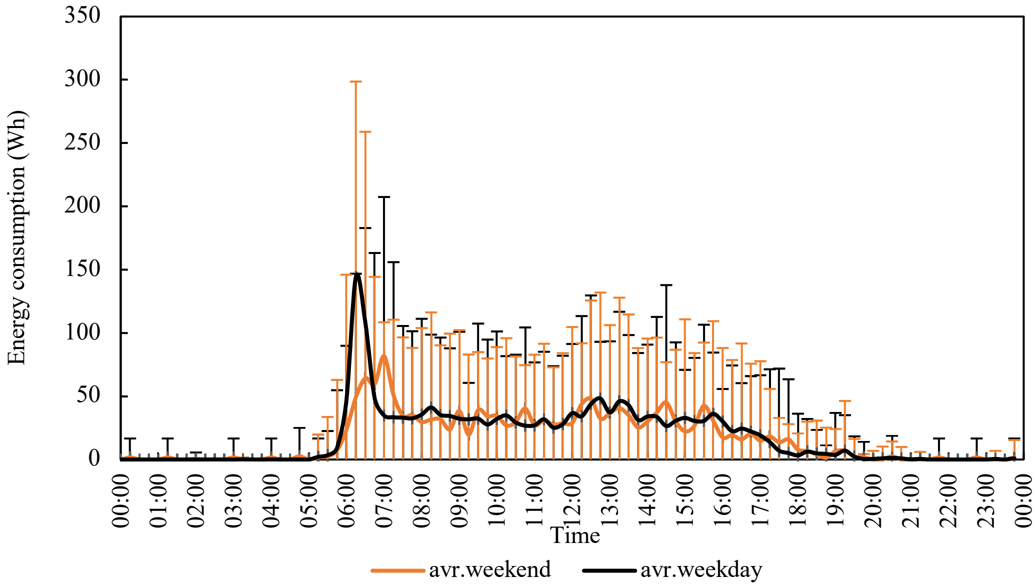


Figure 4.31 Average energy consumption in CHO (Weekday/Weekend)

The data on energy consumption in a beverage shop building, it was found that there is only one pattern of energy use. This pattern starts at around 5:30 a.m. and ends at approximately 6:00. The average duration of energy stoppages in the building varies depending on each day. It usually occurs during the period between 6:00 and 8:00. Moreover, data shows that there is high energy consumption during the initial phase of usage every day due to the simultaneous use of various heating equipment such as hot water boilers, coffee makers, etc. These devices require energy for preparation in readiness for daily use. In contrast, the energy consumption during high-usage periods on weekends is lower than that of weekdays due to the shorter operating hours or longer preparation time for the equipment and the reduced usage of devices.

Analyzing the energy use during the constant period of 8:00 to 17:00, it was found that the majority of the energy consumption comes from heating water, brewing coffee, and using fruit juicers. The average energy consumption of each device is consistent with its energy demand.

3.2 Water

Data on water consumption in every building is gathered by the system through measuring the total water usage every 15 minutes. The volume of water consumed during each period is then calculated based on this measurement, enabling monitoring of the building's water usage patterns. The assessment of water consumption is segmented into three components: the overall average water consumption behavior of the building, water usage patterns during weekdays and weekends, and water usage patterns by the days of the week. The water usage behavior within buildings can be categorized into three types based on the building type, namely residential buildings, office buildings, and commercial buildings.

3.2.1 Residential

The water usage characteristics of residential buildings are generally consistent in the same direction on each roof. There is high water usage behavior in the morning and evening of each day. When the water use characteristics of the aforementioned buildings were examined, it can be observed that the amount of water usage has a relatively uncertain behavior. This depends on the behavior that changes daily, but there is still a consistent amount of water usage in the same direction, as shown in Figure 4.32. In general, the average water usage in the first public housing building throughout the day is 10.75 liters, with a standard deviation of 23.42 The period of highest water usage is during the morning between 6:00 and 7:30 am, with an average water usage during that time of 45.46 liters, with a standard deviation of 57.10 When analyzing the relationship between water usage data inside the building and the time used, it was found that the water usage in GH1 has a statistically significant correlation with time, with a positive direction and a correlation coefficient of 0.050 at the 0.01 significance level, as shown in Table 4.29.

Normally, the behavior of water usage within residential buildings of the housing type follows a similar pattern. Data on water usage within all residential buildings of the housing type are displayed in Figure C1 to Figure C15, which show the quantity of water usage within the buildings GH2, SH1, SH2, HH1, and HH2, respectively. It is evident that the behavior of water usage within all residential buildings of the housing type can be clearly divided into two distinct ranges that are consistent with the data on water usage in GH1. The average quantity of water usage per house throughout the day is 6.75, 2, 2, 2, 2, 3, and 5 liters, with standard deviations of 5.33, 2, 3, 4, and 5, respectively. Additionally, the maximum cumulative water usage every 15 minutes in the morning is 39.28 liters at SD 56.60 of GH2, 2 liters at SD 2 of

SH1, 3 liters at SD 3 of SH2, 5 liters at SD 4 of HH1, and 15 liters at SD 5 of HH2. Furthermore, the maximum cumulative water usage every 15 minutes in the evening is 1 liter at SD 15 of GH2, 2 liters at SD 2 of SH1, 3 liters at SD 3 of SH2, 5 liters at SD 4 of HH1, and 15 liters at SD 5 of HH2.

Upon analyzing the relationship between water usage quantity and time of usage regardless of day, it was found that nearly all residential buildings exhibited a positive correlation at a significant level of 0.01. Specifically, the correlation coefficients were 0.020 for SH1, 0.064 for SH2, 0.065 for HH1, and 0.041 for HH2, as shown in Table C1. The analysis did not consider the specific day of usage.

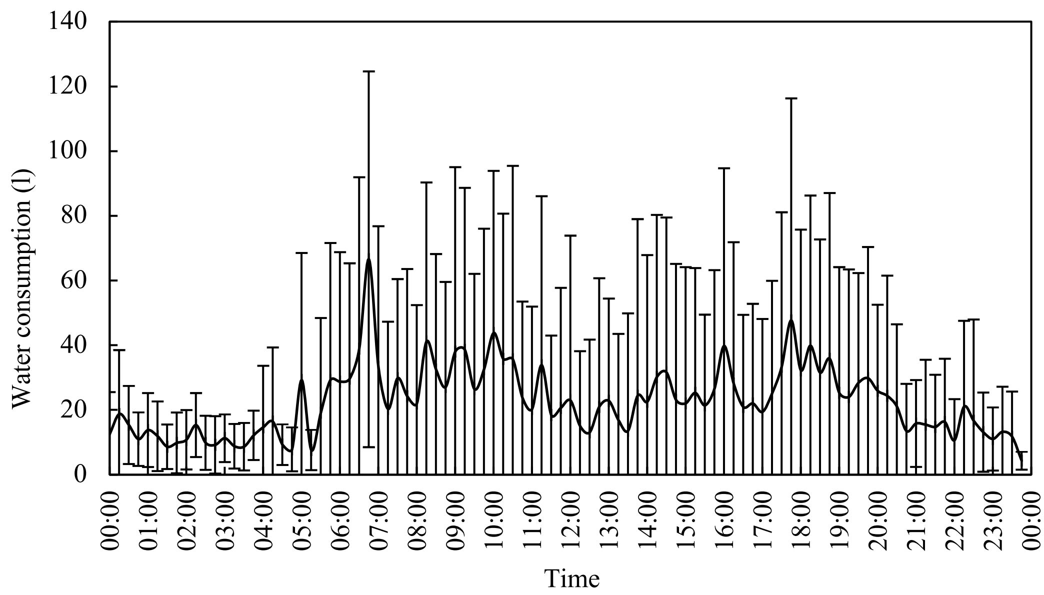


Figure 4.32 Average water consumption in GH1

Table 4.29 Correlation between time and water consumption in GH1

		Time	Water consumption
Time	Pearson Correlation	1.000	0.050**
	Sig. (2-tailed)		0.000
	Covariance	0.083	0.368
	N	10,225	10,225

Table 4.29 (Cont.)

		Time	Water consumption
Water consumption	Pearson Correlation	0.050^{**}	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.368	650.113
	N	10,225	10,225

**. Correlation is significant at the 0.01 level (2-tailed).

After analyzing the amount of water used inside buildings by considering the day of the week, it was found that the usage behavior did not vary significantly within GH1 building as shown in Figure 4.33. The accumulated water consumption every 15 minutes for each day of the week inside GH1 building had an average of 13.58, 7.05, 11.27, 8.48, 11.47, 12.08, and 11.63 litters, respectively, with standard deviation (SD) of 20.29, 13.38, 17.83, 13.71, 18.56, 19.84, and 16.66 for Sunday to Saturday. When comparing the accumulated water consumption every 15 minutes for two time periods with the highest usage behavior, it was found that the highest water consumption occurred during the daytime on Sundays to Saturdays, with a maximum of 60.55, 34.42, 74.58, 44.67, 109.67, 60.75, and 63.18 litters, respectively in the same order.

The data of water usage behavior within residential buildings of a sample building, it was found that when analyzed on a day-to-day basis within a week, the behavior of water usage inside the building was not clearly differentiated by days and had statistically significant correlations between the amount of water usage and the time of usage. Most of these correlations were negative to a small extent, and statistically insignificant in all buildings except for building HH2, where a statistically significant correlation of 0.027 at the 0.05 significance level was observed, as shown in Table C1.

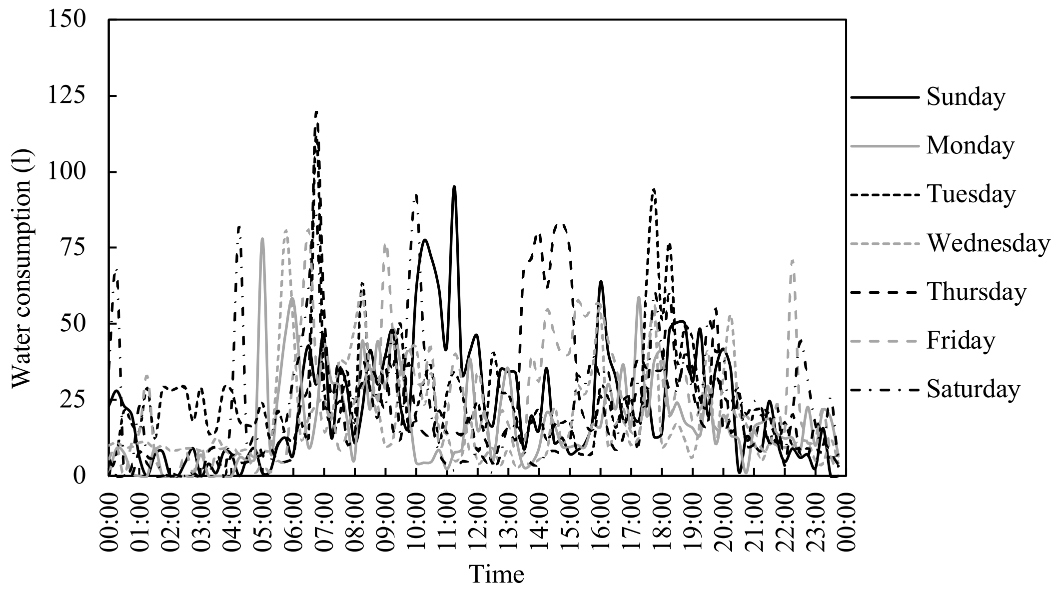


Figure 4.33 Average water consumption in General public house 1 (day of the week)

Table 4.30 Correlation between Time-day and water consumption in GH1

		Time-day	**Water consumption**
Time-day	Pearson Correlation	1.000	0.021*
	Sig. (2-tailed)		.034
	Covariance	4.050	1.074
	N	10,225	10,225
Water consumption	Pearson Correlation	0.021*	1.000
	Sig. (2-tailed)	0.034	
	Covariance	1.074	650.113
	N	10,225	10,225

*. Correlation is significant at the 0.05 level (2-tailed).

Upon analyzing the water usage behavior within the building, it was found that there was a slight difference in the usage patterns between weekday and weekends. It was observed that there was a lower volume of water usage during weekends. Furthermore, the highest water usage period was in the morning, approximately 1 hour after waking up, and the water usage behavior in the evening was highly variable, but the average volume of water usage was similar to that of weekday. The water usage data segregated according to weekday and weekends for building GH1 is presented in Figure 4.34. The analysis of the data revealed that the average water usage on weekday was 7.65 liters with a standard deviation (SD) of 19.76, while the average water usage on weekends was 8.94 liters with an SD of 20.24. Furthermore, the correlation analysis of the two data sets showed a significant negative correlation between the water usage and time of day, with a statistically significant correlation coefficient of 0.047 at the 0.05 level, as shown in Table 4.31.

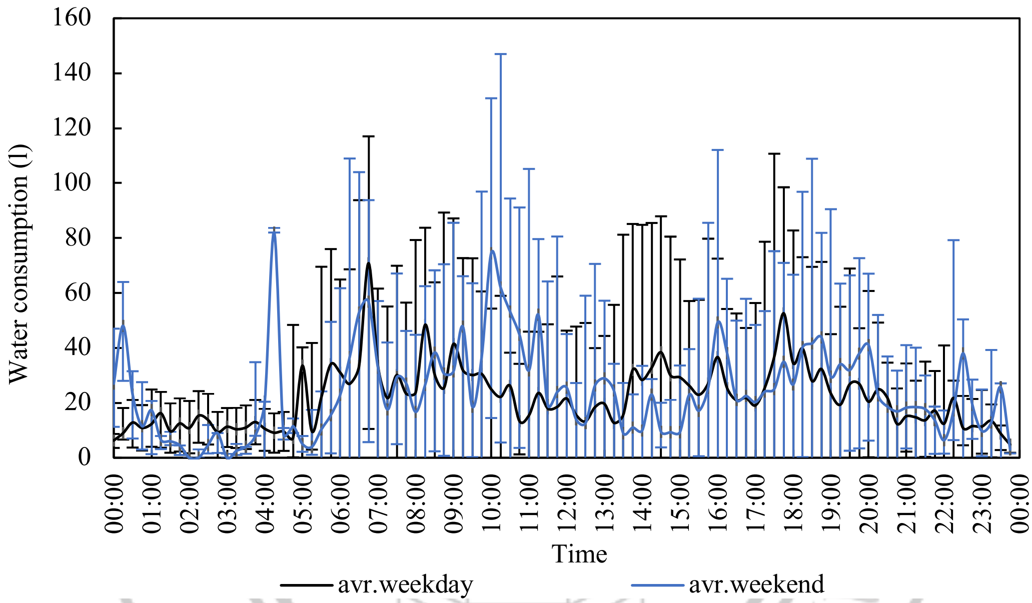


Figure 4.34 Average energy consumption in General public house 1 (Weekday/Weekend)

Table 4.31 Correlation between Weekday/weekend and water consumption in GH1

		Time-week	Water consumption
Time-week	Pearson Correlation	1.000	0.047**
	Sig. (2-tailed)		0.000
	Covariance	0.285	0.640
	N	10,225	10,225
Water consumption	Pearson Correlation	0.047**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.640	650.113
	N	10,225	10,225

**. Correlation is significant at the 0.01 level (2-tailed).

When considering the weekday and weekend of residential buildings, it was found that there was a consistent pattern in the water usage behavior across all buildings, as shown in Figure C3, Figure C6, Figure C9,Figure C12, and Figure C15. Both types of days had similar levels of water usage in each building

When the water usage data within each building was separated by weekday and weekend, it was found that some buildings had statistical relationships. These included the SH1 and HH2 buildings, which had a negative correlation between water usage per time considering weekday and weekend, with correlation coefficients of 0.059 and 0.036, respectively. The correlation was significant at the 0.01 level. Additionally, the GH2 and HH1 buildings had a negative correlation, while the GH1 and SH2 buildings had a positive correlation. All four buildings had low correlation coefficients, indicating that there was no statistical relationship between them.

From the water usage data of residential buildings, it was found that the water usage behavior within the buildings occurred mostly during two time periods, namely between 7:00-9:00 and 17:00-22:30 in every building, with accumulated water usage being highest during these times. When considering the water usage patterns and correlation levels of water usage according to weekdays and weekends for one week, it was found that most residential buildings did not have statistically significant correlations with each other. Therefore, it can be concluded that residential buildings have time-dependent water usage behavior, regardless of the type of day. In other words, residential buildings have similar water usage patterns every day.

3.2.2 Office building

It was found that water usage behavior within office buildings differs significantly from that of residential buildings, as evidenced by the data presented in Figure 4.35 which depicts water usage patterns within a school office building (SCO) during a single day from 6:30 to 19:30. The volume of water usage peaked initially and then decreased over time. The average daily water usage within the building was 5.79 liters, which is higher than the standard deviation of 4.37. When considering only periods of water usage within the building, the average cumulative water usage every 15 minutes was 8.31 liters, which is similar to the standard deviation of 9.13. Similar water usage patterns were also observed in the community hospital office building depicted in Figure C16, where water usage started at 8:00 and ceased at 16:30.

The data on the water consumption within office buildings, it can be observed that there is a high volume of water usage during a specific time period, which is during midday or working hours. It is essential for this group of buildings to support the work of teachers within schools, who work between the hours of 7:00 to 17:30 during working days. Additionally, community hospital office buildings must accommodate and provide convenience for patients who receive hospital services, with working hours from 8:00 to 17:00 on working days.

Upon analyzing the relationship between water usage data and time of usage within office buildings of both groups without considering the day, it was found that if considered throughout the day, time did not significantly affect the water consumption within the building, as indicated by the statistics. The data shows negative correlations between the amount of water usage and time of usage, with a level of 0.003 for school office buildings and 0.013 for community hospital office buildings. In other words, an increase in time during each day will lead to a decrease in the amount of water usage within the building, as shown in Table C1.

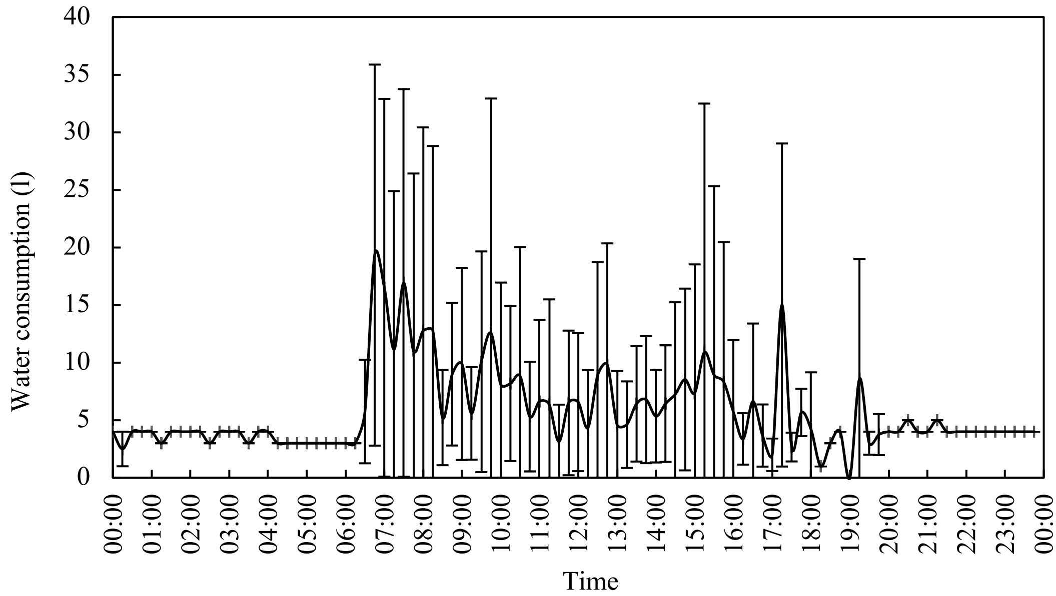


Figure 4.35 Average water consumption in SCO

If the water usage data within the office building is analyzed on a weekly basis, it can be found that the usage varies slightly every day. The wastewater data of the SCO building separated by day of the week, as shown in Figure 436, indicates that the average water usage during the time periods of typical water usage behavior from Monday to Friday are 3.10, 2.73, 4.42, 5.23, and 4.75 liters, respectively, with standard deviations of 2.30, 1.84, 3.12, 3.43, and 3.78 liters, respectively, in the order of the days of the week, and decreases to 0.71 liters on Saturday and 0.27 liters on Sunday, with SDs of 0.03.

Similarly, the water usage data within the CHO building separated by day of the week, as shown in Figure C17, which shows the water usage behavior within the building in the same direction from Monday to Friday, indicates that the accumulated average water usage is highest in the morning and decreases as time passes, with an average water usage during the time period of 7:30 am to 5:00 pm of 62.27, 60.09, 61.72, 53.71, 50.26, 37.31, and 31.08 liters, respectively, with standard deviations of 13.52, 17.32, 17.93, 17.97, 17.25, 16.81, and 14.27 liters, respectively, in the order of the days of the week. From the water usage data of both types of office buildings, it can be observed that the average water usage on Saturdays and Sundays is lower than that from Monday to Friday.

Moreover, when analyzing the relationship between the water usage data separated by the day of the week and time, it was found that there is no significant correlation between the water usage of both buildings and the time of usage, although it should be noted that there are some small variations in the data.

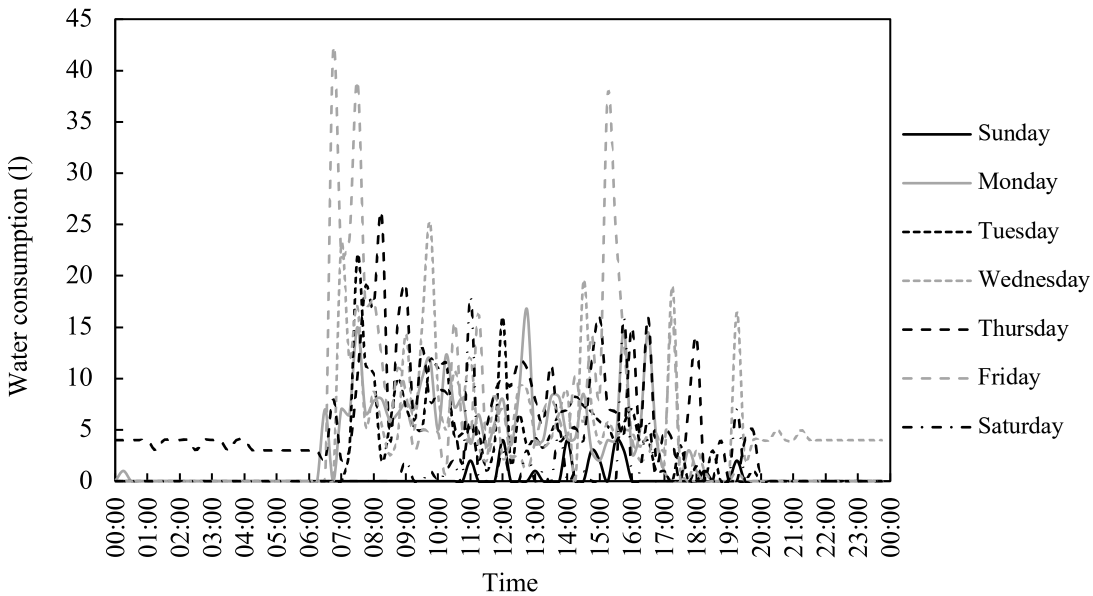


Figure 4.36 Average water consumption in SCO (day of the week)

The data on water usage separated by day of the week, it is evident that the amount of water used within the buildings on Saturdays and Sundays differs from other days. When the data is classified into two groups, working days and weekends, it is clear that the water usage behavior within both buildings differs significantly. Figure 4.37 shows the amount of water usage within the School Office (SCO) building separated by working days and weekends, where on working days, the amount of water usage within the building is significantly higher than on weekends. The average cumulative water usage within the building on working days is 42.94 liters, which is higher than the average cumulative water usage within the building on weekends, which is only 32.48 liters, with standard deviation values of 24.24 and 11.32, respectively. When considering the water usage behavior, it is found that there is an increase in water usage when the time increases on weekends, which is different from working days where water usage decreases. This behavior differs slightly from the water usage pattern on weekends in the hospital building, which has a water usage behavior within the building during the time frame of 8:30-12:00. When comparing the building characteristics, it is found that on Saturdays, there is still usage within the building in the morning, which affects the amount of water used within the building. Upon analysis of the quantity of water usage within the building in relation to time of usage, considering both working days and non-working days, it was discovered that time has a significant statistical negative effect on the quantity of water usage within the building. The correlation coefficients were found to be -0.064 for SCO and -0.041 for CHO, and the significance level of the correlation was 0.01. It can be observed from the data on water usage behavior within office buildings that the behavior tends to be similar within buildings of the same type. Moreover, the quantity of water usage within a building varies over time, depending significantly on the type of working day and day off, as indicated by statistically significant correlations.

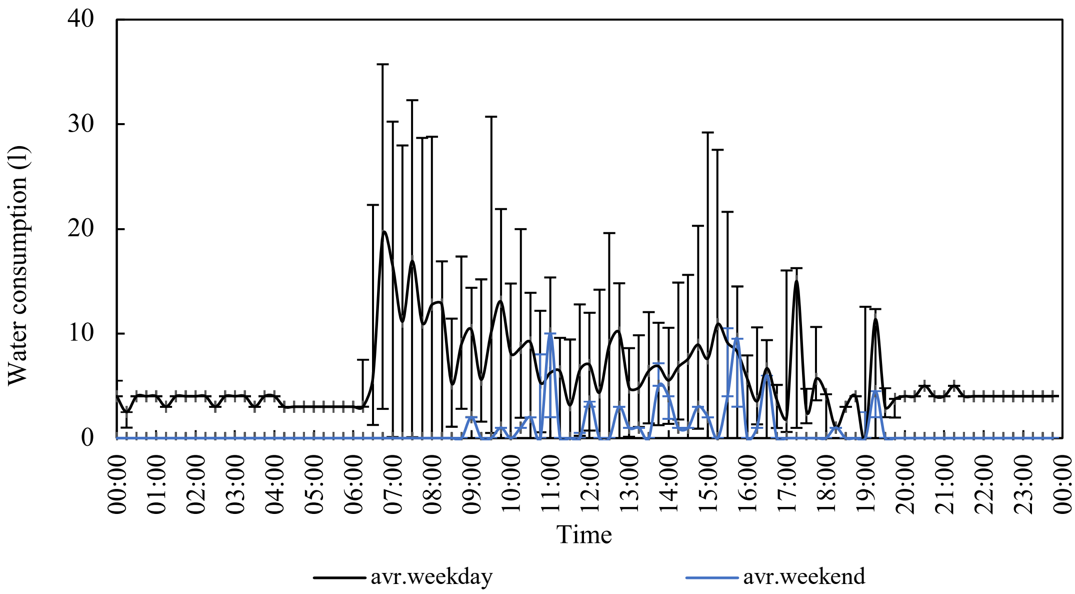


Figure 4.37 Average energy consumption in SCO (Weekday/Weekend)

3.2.3 Commercial

For commercial buildings, water usage behavior is similar to that of office buildings, but there are differences in the pattern of consumption. Specifically, in commercial buildings, such as shopping malls, water usage is lower at the beginning and end of the day, and higher during the middle of the day. This pattern is based on data from water usage behavior in a coffee shop (COF), as shown in Figure 4.38. The average daily water usage from 6:00 to 20:00 is 0.58 liters, with a standard deviation of 0.60. However, when considering only the period of high water usage, the average is 0.94 liters, with a standard deviation of 0.97. Furthermore, when examining water usage during the morning hours (6:00 to 8:30), the behavior is more variable and irregular due to the cleaning and sanitation of equipment and containers, which are necessary for maintaining product quality and safety.

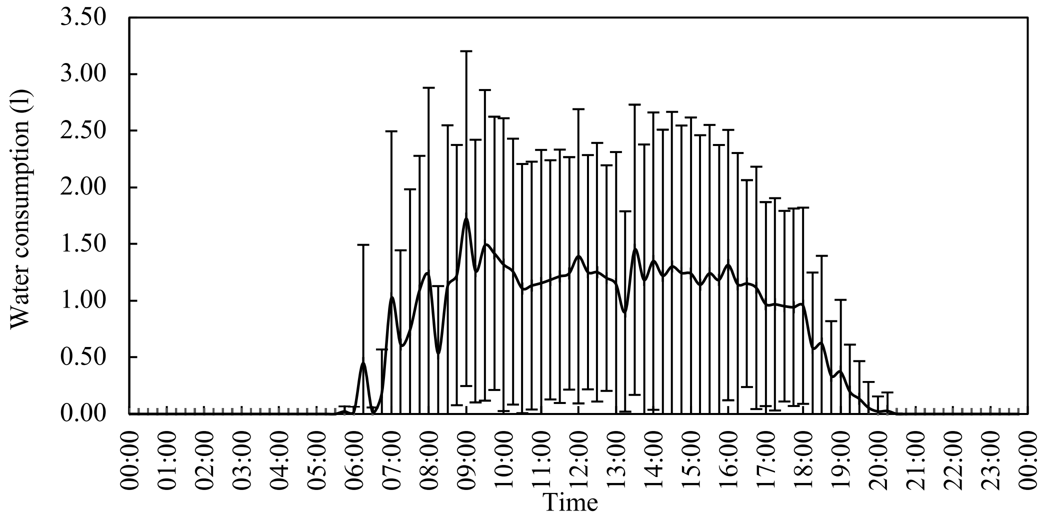


Figure 4.38 Average water consumption in COF

When the data on water usage within the building is analyzed to separate the usage amounts for each day of the week, it is found that there is no observable difference in water usage patterns within the building. The average cumulative water usage for Sunday through Saturday is 1.01, 0.83, 0.81, 0.94, 1.07, 0.80, and 0.90 liters, respectively, with standard deviations of 1.02, 0.72, 0.82, 0.79, 0.92, 0.76, and 0.94, respectively.

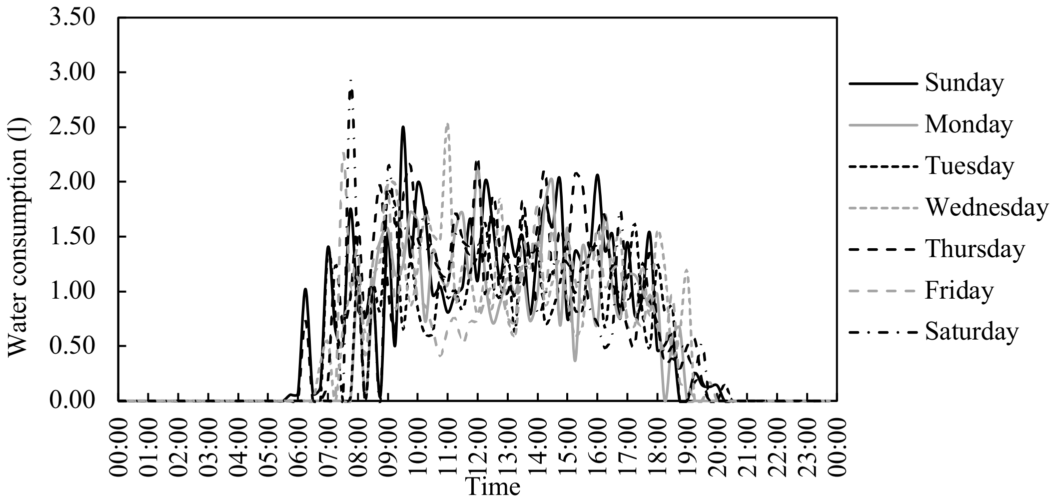


Figure 4.39 Average water consumption in COF (day of the week)

Upon considering the water consumption separated by workdays and holidays, it was found that the pattern of water usage was consistent in terms of both usage periods and consumption levels, as shown in Figure 4.40. Furthermore, when analyzing the relationship of water consumption according to workdays and holidays, no statistically significant difference was found. Thus, it can be concluded that the water consumption within commercial buildings does not show a difference in usage when considering the days of operation.

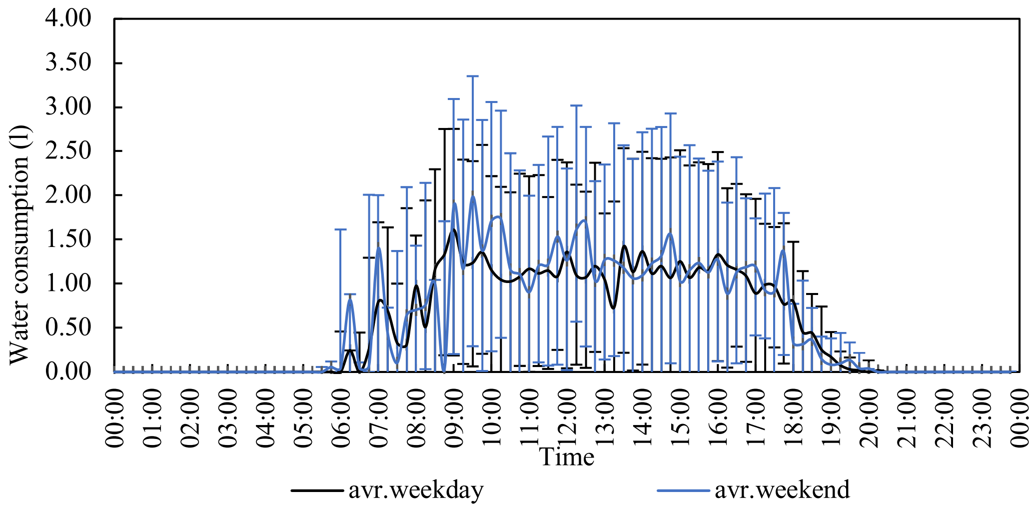


Figure 4.40 Average energy consumption in COF (Weekday/Weekend)

3.3 Waste

3.3.1 Residential

The average waste generation within a General Public House 1 building, as illustrated in Figure 4.41, exhibits an unclear waste disposal pattern in terms of both time and the quantity of waste disposed within the building. It was found that the average values of general waste, organic waste, and recyclable waste accumulated every 15 minutes were equal to 0.01 for all types of waste. The maximum average waste disposal quantities for each type were 0.04 kg at 16:45 for general waste, 0.02 kg at 4:45 for organic waste, and 0.05 kg at 22:00 for recyclable waste. Upon examining the relationship between the waste generation within the building and time, it was revealed that all three types of waste had a slightly significant statistical relationship with the time of day, particularly general waste with a correlation coefficient of 0.023 at a correlation significant at the 0.01 level, and recyclable waste with a coefficient of 0.081 at a correlation significant at the 0.01 level, both in a positive direction. However, the quantity of each type of waste had a significant statistical relationship with the corresponding waste disposal, as demonstrated in Table 4.32.

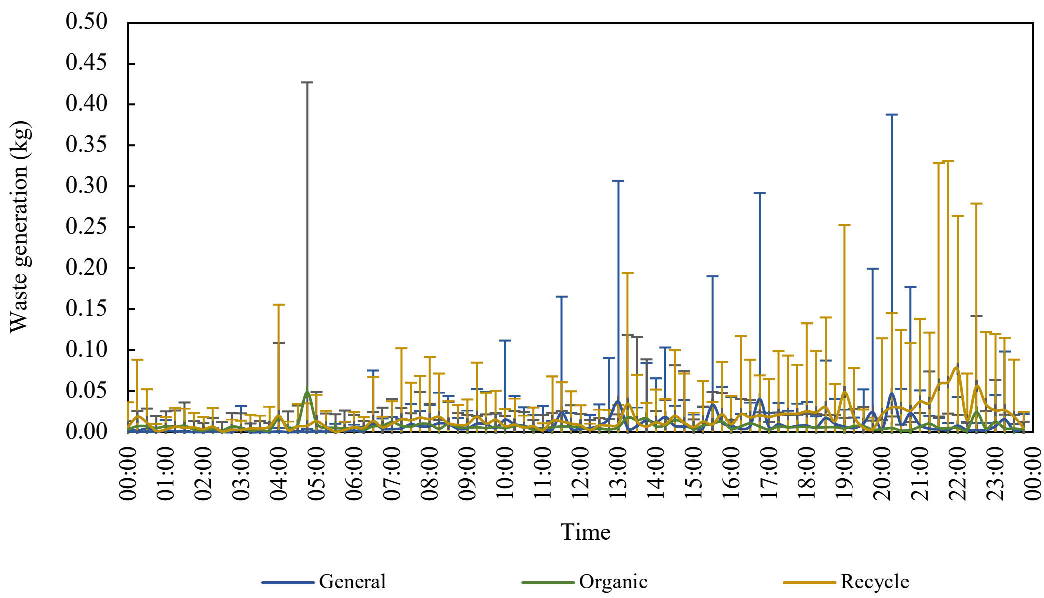


Figure 4.41 The average amount of waste accumulated at a frequency of 15 minutes in General public house 1

Table 4.32 Correlation between time and waste creation in GH1 (15m)

		Time	Gen	Org	Rec
Time	Pearson Correlation	1.000	0.023**	0.001	0.081**
	Covariance	0.084	0.000	0.000	0.002
	N	16,357	16,357	16,357	16,357
Gen	Pearson Correlation	0.023**	1.000	0.061**	0.277**
	Covariance	0.000	0.005	0.000	0.002
	N	16,357	16,357	16,357	16,357
Org	Pearson Correlation	0.001	0.061**	1.000	0.229**
	Covariance	0.000	0.000	0.001	0.001
	N	16,357	16,357	16,357	16,357
Rec	Pearson Correlation	0.081**	0.277**	0.229**	1.000
	Covariance	.002	0.002	0.001	0.006
	N	16,357	16,357	16,357	16,357

**. Correlation is significant at the 0.01 level (2-tailed).

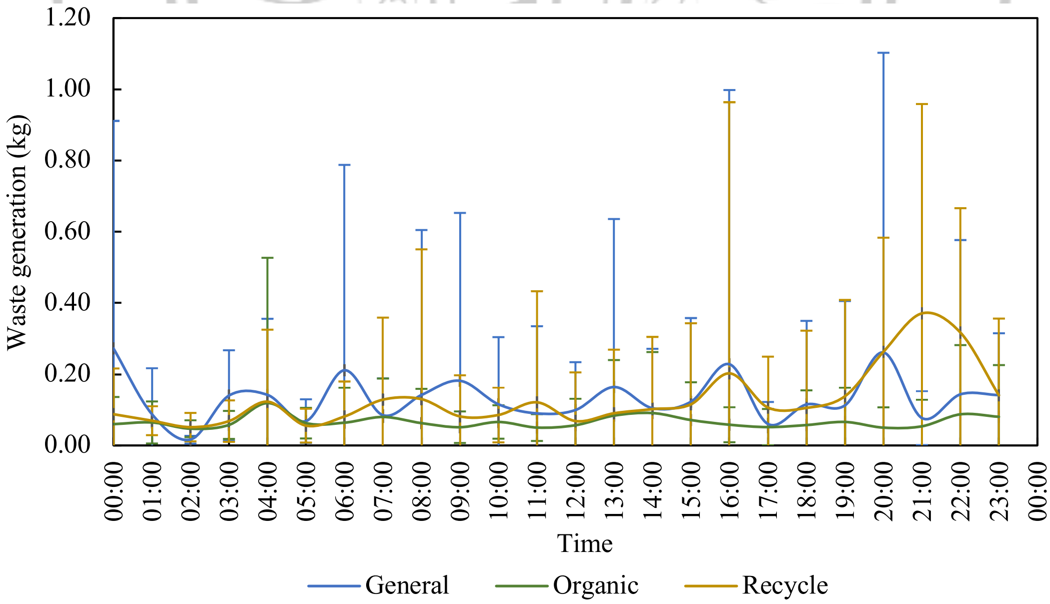


Figure 4.42 The average amount of waste accumulated at a frequency of 1 hour in General public house 1

The average accumulated waste generation within the building every hour, it was found that the data showed a clearer trend of waste generation within the building. This is because the waste generation at the 15 minute accumulated frequency level had relatively low quantities, which might affect the reliability of the measuring device that can detect a minimum waste mass of only 0.01 kg, consequently impacting the uncertainty of the measured data. When analyzing the data at a 1 hour accumulated frequency as shown in Figure 4.42, it was observed that general waste disposal occurs throughout the day but has higher quantities than the daily average during the morning and evening periods. This differs from organic waste and recyclable waste, which have higher waste disposal quantities only during the morning for organic waste and during the evening for recyclable waste. Upon examining the average waste disposal quantities throughout the day, it was found that general waste had an average quantity of 0.15 kg, organic waste had 0.07 kg, and recyclable waste had 0.13 kg, with standard deviations of 0.32, 0.10, and 0.22, respectively.

The correlation levels of waste quantities of each type in relation to the waste generation time within the building revealed that only the recyclable waste quantity demonstrated a significant positive correlation to the time of day at a level of 0.079 (Correlation is significant at the 0.01 level). Furthermore, waste quantities of each type exhibited positive correlations among themselves at levels of 0.076 between general waste and organic waste, 0.071 between general waste and recyclable waste, and 0.264 between organic waste and recyclable waste. From the correlation level data within each waste type, it was observed that recyclable waste had a relationship with the waste generation quantities of all types within the building. The correlation level data of accumulated waste quantities at a frequency of 1 hour is presented in Table 4.33.

Table 4.33 Correlation between time and waste creation in GH1 (1h)

		Time	Gen	Org	Rec
Time	Pearson Correlation	1.000	0.007	-0.018	0.079**
	Covariance	0.083	0.000	0.000	0.002
	N	4081	4081	4081	4081

Table 4.33 (Cont.)

		Time	Gen	Org	Rec
Gen	Pearson Correlation	0.007	1.000	0.076**	0.071**
	Covariance	0.000	0.007	0.000	0.001
	N	4,081	4,081	4,081	4,081
Org	Pearson Correlation	-0.018	0.076**	1.000	0.264**
	Covariance	0.000	0.000	0.001	0.001
	N	4,081	4,081	4,081	4,081
Rec	Pearson Correlation	0.079**	0.071**	0.264**	1.000
	Covariance	0.002	0.001	0.001	0.012
	N	4,081	4,081	4,081	4,081

**. Correlation is significant at the 0.01 level (2-tailed).

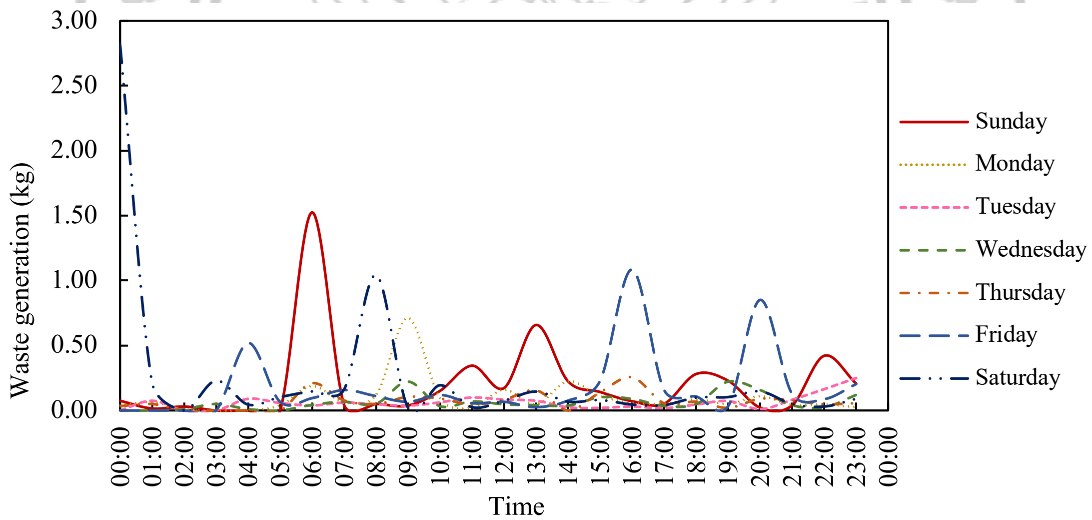


Figure 4.43 The average amount of waste accumulated at a frequency of 1 hour in General public house 1 (Day of week)

When considering the average waste quantity per day over a week, it was found that there were no noticeable differences in waste disposal behavior for each day on average across all waste types, as shown in Figure 4.43. However, the data indicated that the average waste generation within residential-type buildings tended to have higher waste disposal during Fridays, Saturdays, and Sundays. Upon analyzing the average waste disposal quantities from Sunday to Saturday, it was found that the daily average waste quantities were 0.20, 0.10, 0.06, 0.06, 0.07, 0.18, and 0.25 kg/hour for general waste; 0.08, 0.06, 0.05, 0.07, 0.06, 0.08, and 0.07 kg/hour for organic waste; and 0.13, 0.09, 0.13, 0.15, 0.11, 0.16, and 0.14 kg/hour for recyclable waste, respectively.

The waste disposal quantity into two groups, weekdays and weekends, as depicted in Figure 4.44, it was observed that the general waste and recyclable waste disposal behaviors differed between the two groups of days. During weekdays, there was an increase in the disposal of general waste in the middle of the day compared to the average waste disposal quantity. However, on weekends, it was found that the disposal of general waste was higher than the average in the evening at 20:00. In contrast, for recyclable and organic waste, the waste disposal behavior followed the same direction for both weekdays and weekends.

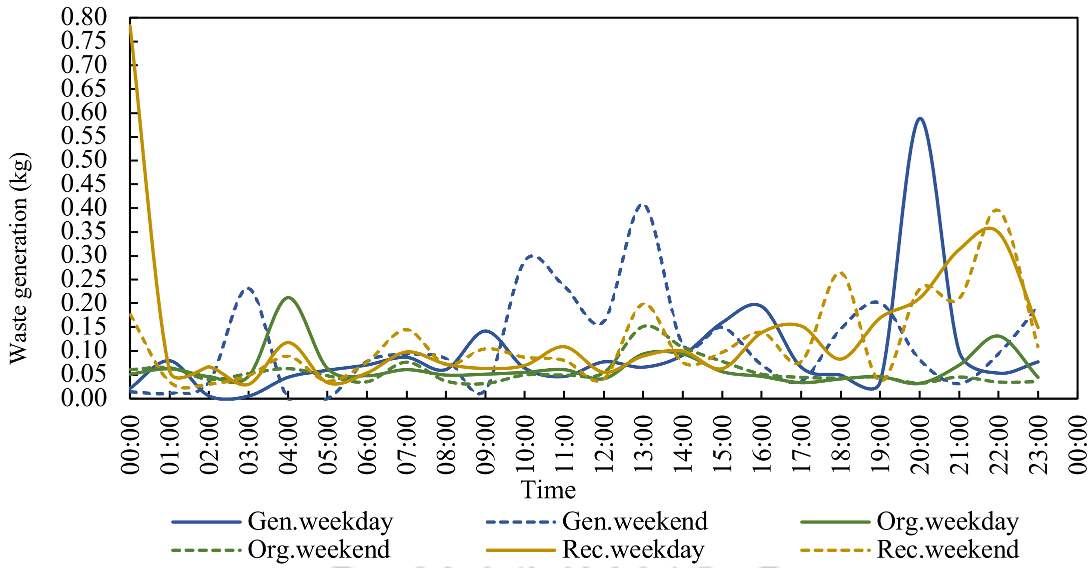


Figure 4.44 The average amount of waste accumulated at a frequency of 1 hour in General public house 1 (Weekday/Weekend)

From the data on waste generation behavior for different types of waste occurring within residential buildings, it was found that waste generation followed the same direction throughout the day. However, variations were observed depending on age groups, gender, and the number of building occupants. In general, it was discovered that buildings of the same type exhibited similar waste generation behaviors.

3.3.2 Office building

Waste disposal patterns within office buildings were found to involve varying quantities of each waste type during working hours, or between 7:00 – 17:00. An example of waste quantities for a community hospital office is presented in Figure 4.45, which shows average hourly accumulated waste quantities of 0.01 kg for general waste, 0.02 kg for organic waste, and 0.01 kg for recyclable waste. Upon analyzing the data according to time intervals, it was observed that waste disposal behaviors for each type of waste generated within the building had higher frequency and quantity during two periods: 8:00 – 10:00 and 13:00 – 16:00. These periods corresponded to the highest number of service users accessing the building. Consequently, the waste disposal behaviors occurring within the building were significantly correlated with the number of people accessing the services of the building.

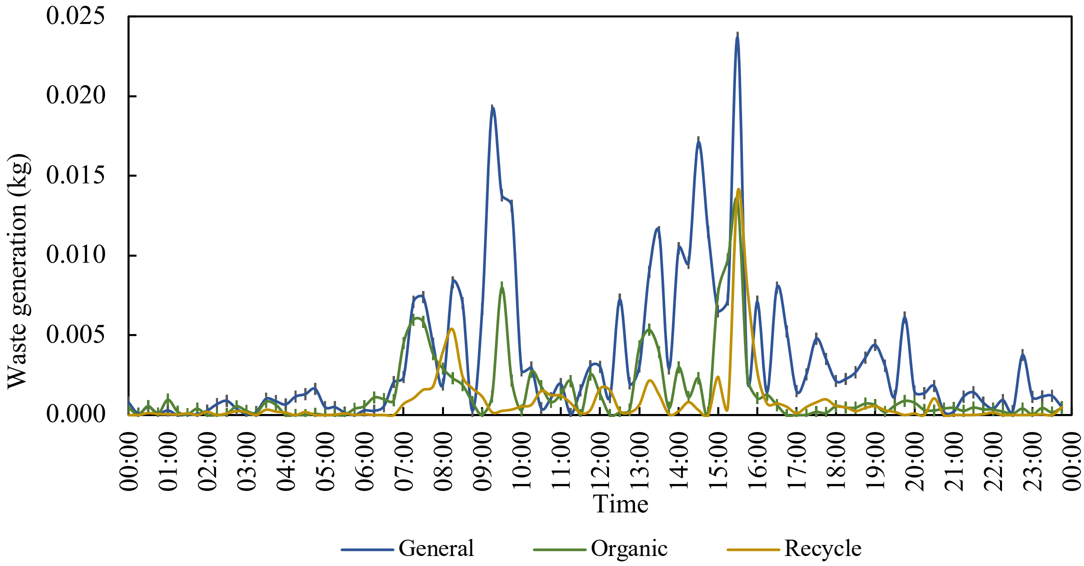


Figure 4.45 The average amount of waste accumulated at a frequency of 15 minutes in Community hospital office

Upon analyzing waste disposal patterns by day of the week, it was found that waste disposal behaviors on each day did not exhibit statistically significant differences with respect to the time of waste disposal. The characteristics of waste quantities generated within the building, separated by days from Sunday to Saturday, as shown in Figure 4.46, revealed that waste disposal behaviors could not be differentiated by individual days within a week for analysis, as the day of the week did not influence the changes in waste disposal behaviors within the building. The data indicated that average general waste quantities during working hours were 23.17, 42.58, 31.24, 31.30, 4.97, 17.47, and 20.96 g/hour; organic waste quantities were 23.93, 16.06, 15.60, 14.00, 22.30, 7.25, and 5.68 g/hour; and recyclable waste quantities were 7.13, 8.14, 16.39, 12.24, 10.65, 8.96, and 4.04 g/hour for Sunday through Saturday, respectively. Furthermore, the analysis of the correlation between different types of waste disposal behaviors within the building and the time of waste disposal revealed that each type of waste exhibited a positive relationship with one another and a significant positive relationship with time.

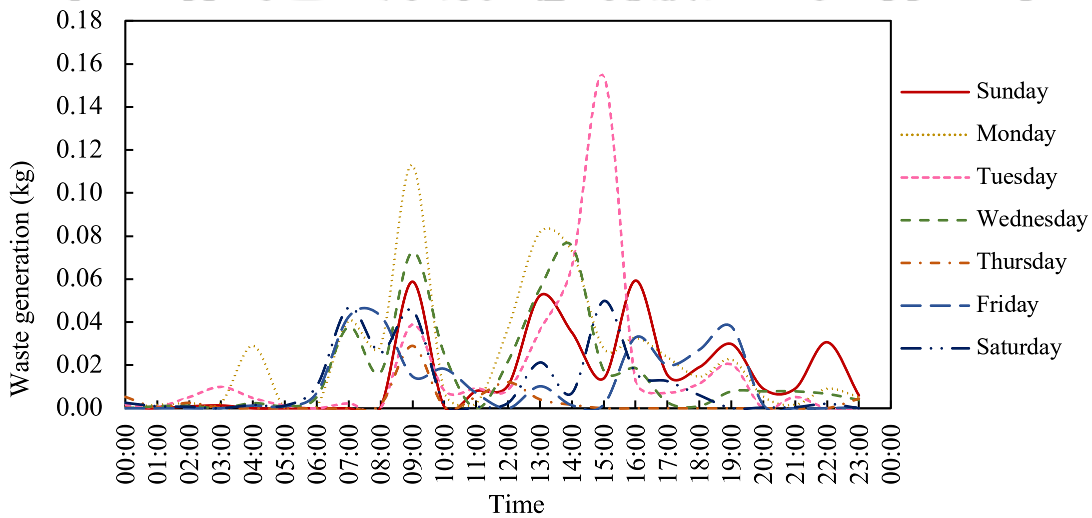


Figure 4.46 The average amount of waste accumulated at a frequency of 1 hour in Community hospital office (Day of week)

waste disposal behaviors for each type of waste when separated by working days and non-working days, as shown in Figure 4.47, it was found that all three types of waste exhibited similar disposal patterns on both working and non-working days, with frequency and quantity of waste disposal occurring in the two aforementioned time periods for general waste and recyclable waste. For organic waste, a high quantity of waste was generated only during the average evening working days. When considering the overall data correlation, it was determined that the waste quantities generated, separated by working and non-working days, did not exhibit any relationship with the time of occurrence. However, the increasing quantities of each type of waste were found to be correlated with one another.

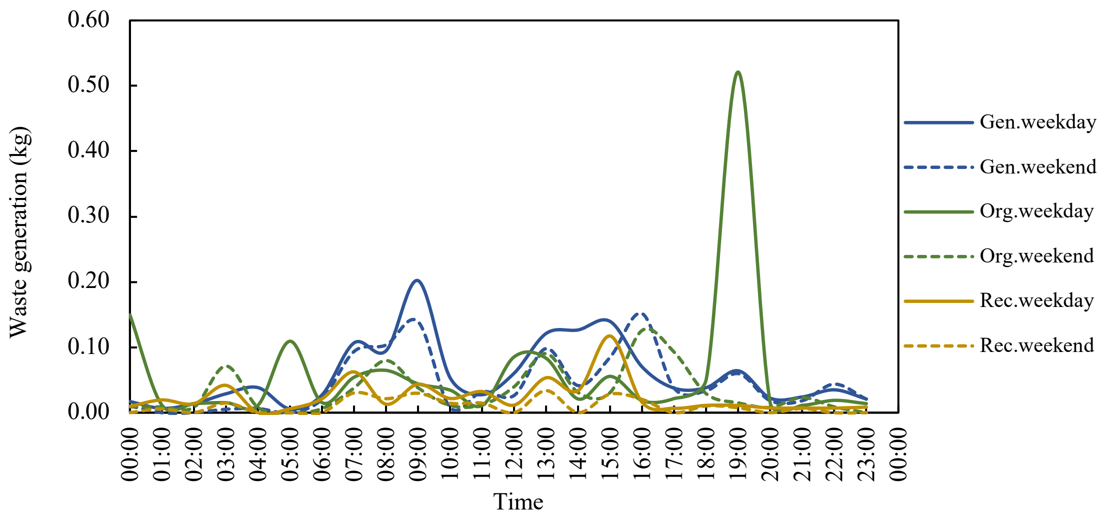


Figure 4.47 The average amount of waste accumulated at a frequency of 1 hour in Community hospital office (Weekday/Weekend)

4. Building activity profile

The Building Activity Profile study is an investigation of the behavior and characteristics of activities that occur within a sample building. It is used to compare and analyze energy usage, water consumption, and waste generation characteristics of each building activity. The building activity profile analysis is divided into three phases, which include determining and integrating the building activity profile, studying the relationship of building activity, and verifying the activity profile. The results of the study are as follows:

4.1 Determine and integrated of the building activity profile

The results of this process can be divided into two steps. The first step involves studying the patterns of activities occurring within the building, utilizing questionnaire tools. The second step, "Identification of activity," involves combining data from the questionnaire with data collected from Smart meters measuring energy, water, and waste consumption.

4.1.1 Building activity (Questionnaire)

The analysis of activities taking place within all buildings was conducted using data collected through a questionnaire from the sample of residents living in the buildings equipped with a smart meter. The process of data collection involved documenting all activities that occurred within the buildings and presenting their characteristics and abbreviations in Table 4.4. The analysis of building activities was divided into two main parts: the first being the frequency analysis of each activity that occurred in the building, and the second being the time analysis of each activity that took place. Additionally, the activities were classified based on the characteristics of each consumer to identify the trends and patterns of activity behavior within the building. This involved identifying the consumer characteristics and analyzing their behavior within the building.

4.1.1.1 Residential

General public house 1: The data regarding activities that occurred within GH1 for occupants 1 and 2 exhibit similar behavioral patterns, with activities occurring during two distinct time periods per day: morning and evening. For the occupants of the first unit, there were a total of 16 activities per day, as detailed in Figure 4.48, which included RE, FA, LT, TL, WD, ET, BA, TV, MI, CK, GN, WR, IC, WC, WB, RC, and HD. Notably, the RE activity was continuously executed throughout the day due to its necessity as an electrical appliance. Furthermore, all activities were characterized by specific details. For instance, the FA activity was divided into three time intervals per day: 00:00-5:45, 12:00-13:45, and 20:00-23:45, with an average usage time of approximately 11 hours per day. Additionally, the LT activity occurred twice per day during specific time intervals, from 6:00-7:45 and 18:00-23:45, with an average duration of approximately 420 minutes per day.

The TL frequency of activities is six times per day, in three time slots, namely 5:00-6:45, 16:00-18:15, and 20:00-21:45, with an average duration of approximately one minute per occurrence. The frequency of occurrence of activities for WD is twice per day, in two time slots, namely 7:30-10:15 and 18:00-18:45, with an average duration of approximately 15 minutes per occurrence. The frequency of occurrence of activities for ET is twice per day, in two time slots, namely 9:00-10:15 and 17:00-18:45, with an average duration of approximately 25 minutes per occurrence. The frequency of occurrence of activities for BA is twice per day, in two time slots, namely 6:00-6:45 and 19:00-20:45, with an average duration of approximately 10 minutes per occurrence. The frequency of occurrence of activities for TV is approximately three times per week, during the time slot of approximately 19:00-20:45, with an average duration of approximately 60 minutes per occurrence.

The MI group has an average frequency of approximately 5 activities per week, divided into 3 time slots: 6:00-6:45, 12:00-12:15, and 17:00-17:15, with an average activity duration of approximately 2 minutes per occurrence. The CK group has an average frequency of 1 activity per day during the time slot of 17:00-18:45, with an average activity duration of approximately 45 minutes per occurrence. The GN group has an average frequency of 4 activities per week during the time slot of 7:30-8:45, with an average activity duration of approximately 30 minutes per occurrence. The WR group has an average frequency of 1 activity per month during the time slot of 9:00-10:30, with an average activity duration of approximately 30 minutes per occurrence. The IC group has an average frequency of 2 activities per week during the time slot of 7:00-8:00, with an average activity duration of approximately 60 minutes per occurrence. The WC group has an average frequency of 2 activities per week during the time slot of 7:00-7:45, with an average activity duration of approximately 60 minutes per occurrence. The WB and RC groups have an average frequency of approximately 1 activity per day during the time slot of 6:00-6:45, with an average activity duration of approximately 15 minutes per occurrence for WB and 20 minutes per occurrence for RC. Finally, the HD has an average frequency of 4 activities per week during the time slot of 20:00-20:30, with an average activity duration of approximately 5 minutes per occurrence.

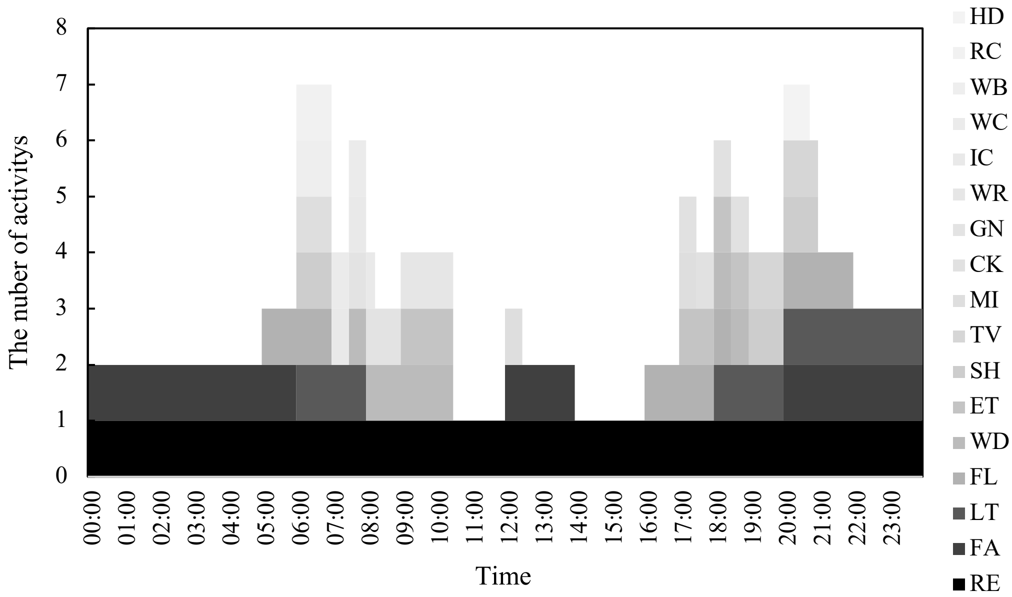


Figure 4.48 The number of events in GH1 of the 1st consumer

The details of the activity data within the second resident's building are presented according to the time intervals shown in Figure 4.49, consisting of 12 activities, namely RE, CF, LT, ET, MI, WC, BA, CK, RC, IC, WB, and HD. Two of these activities, RE and CF, are continuously carried out throughout the day due to their dependence on the use of electricity. Each activity has the following details: LT occurs twice daily for an average duration of approximately 14 hours, between 6:00-8:00 and 18:00-23:45; ET occurs twice daily for an average duration of approximately 30 minutes per occurrence, between 9:00-10:30 and 17:00-19:00; MI occurs approximately four times per week, divided into three time intervals, 8:00-8:30, 12:00-12:30, and 18:00, with an average duration of approximately 10 minutes per occurrence; and WC occurs three times per week for an average duration of approximately 45 minutes per occurrence, between 7:00-7:45. The BA activity occurs twice a day, at two different time periods, namely 7:30-7:45 and 19:00-19:30, with an average activity duration of approximately 15 minutes per occurrence. The CK activity has an average frequency of 2 occurrences per day, during the time periods of 6:00-6:30 and 18:00-18:30, with an average activity duration of approximately 45 minutes per occurrence. The RC activity has an average frequency of 5 occurrences per week, during the time periods of 6:00-6:30 and 18:00-18:30, with an average activity duration of approximately 30 minutes per occurrence. The IC activity has an average frequency of 2 occurrences per week, during the time period of 7:45-8:00, with an average activity duration of approximately 60 minutes per occurrence. The WB activity occurs once a day, at approximately 7:00-7:15, with an average activity duration of approximately 5 minutes per occurrence. Finally, the HD activity has an average frequency of 3 occurrences per week, during the time period of 19:00-19:30, with an average activity duration of approximately 10 minutes per occurrence.

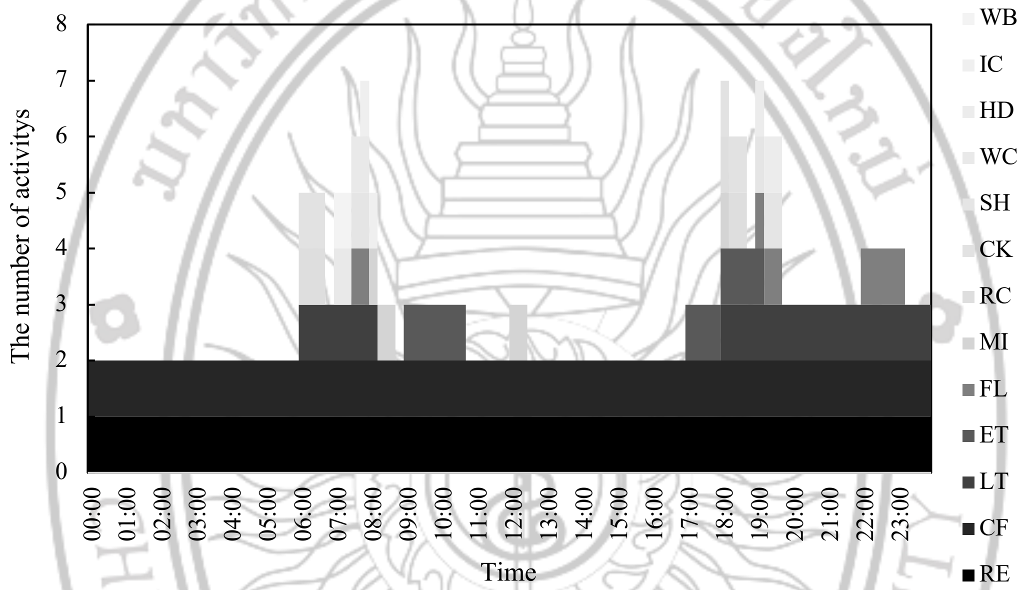


Figure 4.49 The number of events in GH1 of the 2nd consumer

The data on the activities of both consumers within GH1 reveals that there are activities that are continuously utilized and shared within the building, namely RE, and one activity that is utilized continuously within the building, namely CF. Therefore, in analyzing the collective activities within the building, data from both activities will be used. Upon examination of the activities that occurred within the building from both residents, it was found that in the morning (6:00-10:30), there were LT at 6:00-7:45, RC at 6:00-3:60, WC at 7:00-7:45, IC at 7:30-8:00, and ET at 9:00-10:15. During midday, there was only one activity, namely MI at 12:00-12:30, and in the evening, there were four activities, namely LT at 18:00-23:45, ET at 17:00-18:45, CK at 18:00-18:30, and BA at 19:00-19:30. Moreover, upon considering the activities that occurred within the building from only one resident, there were the following activities: FA at 00:00-5:45, 12:00-13:45, and 20:00-23:45, TL at 5:00-6:45, 16:00-18:15, and 20:00-21:45, BA at 6:00-6:45, 7:30-7:45, and 19:45-20:45, WD at 7:30-10:15 and 18:00-18:45, MI at 6:00-6:45, 8:00-8:30, 17:00-17:15, and 18:00, CK at 6:00-6:30 and 17:00-17:45, RC at 18:00-18:30, TV at 19:00-20:45, GN at 7:30-8:45, WR at 9:00-10:15, WB at 6:00-7:15, and HD at 19:00-19:30 and 20:00-20:30.

Upon examining the data on energy usage, water usage, and waste generation for GH1, it was found that there was no significant difference between weekdays and weekends. Therefore, activities that occur less frequently than once per day within the building may have a negligible impact on energy usage, water usage, and waste generation. If we consider activities that occur less frequently than once per day, we find that there are five such activities: HD, WC, IC, MI, and WR, with average activity durations of 6.67 minutes, 35 minutes twice per week, 60 minutes twice per week, 4.67 minutes 4.67 times per week, and 30 minutes once per month, respectively.

General public house 2: The data on activities occurring within GH1 for residents 1 and 2 displays similar behavior patterns based on survey responses. The activities are divided into two time periods per day, morning, and evening, and are detailed in Figure 4.50 and Figure 4.51. There are a total of 13 activities, including RE, FA, LT, TV, ET, WD, CK, AC, GN, HD, TL, BA, and WB. Only one activity, RE, is performed continuously throughout the day, while the other activities, FA is divided into three time periods per day, 00:00-03:00, 12:00-13:00, and 20:00-23:45, with an average duration of approximately 9 hours per day. LT occurs twice per day at 5:00-6:30 and 17:00-19:00, with an average activity duration of approximately 300 minutes per day. TV occurs once per day, around 18:00-21:00, with an average activity duration of approximately 180 minutes. ET, WD, and CK each occur twice per day at 6:00-7:00 and 18:00-19:00, with an average activity duration of approximately 25 minutes per occurrence for ET and WD and 60 minutes per occurrence for CK. AC activities occur once a day during the period of approximately 20:00-21:30. However, this behavior is dependent on external temperature factors, and as such, the frequency of use by building occupants is typically around five times per week during the hot season (March-June). GN activities occur once a day on average during the time period of 17:00-18:30, with an average duration of approximately 30 minutes per occurrence. HD activities occur once a day on average during the time period of 6:00-6:30 or 18:00-18:30, with an average duration of approximately 5 minutes per occurrence. TL and BA activities occur during the same time periods of approximately 6:00-6:30 and 18:00-18:30. TL has an average duration of approximately 3 minutes per occurrence and occurs four times per day, while BA has an average duration of approximately 30 minutes per occurrence and occurs twice per day. Finally, WB activities occur once a day on average during the time period of approximately 6:00-6:45, with an average duration of approximately 15 minutes per occurrence. The average duration of WB activities is approximately 5 minutes, and they occur once per day during the time period of 6:00-6:30.

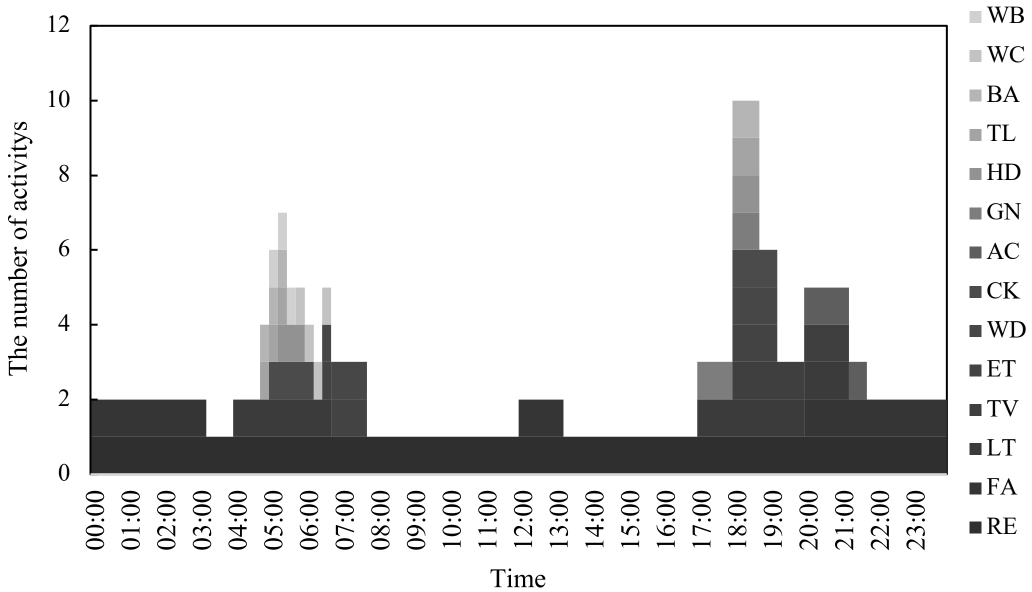


Figure 4.50 The number of events in GH2 of the 1st consumer

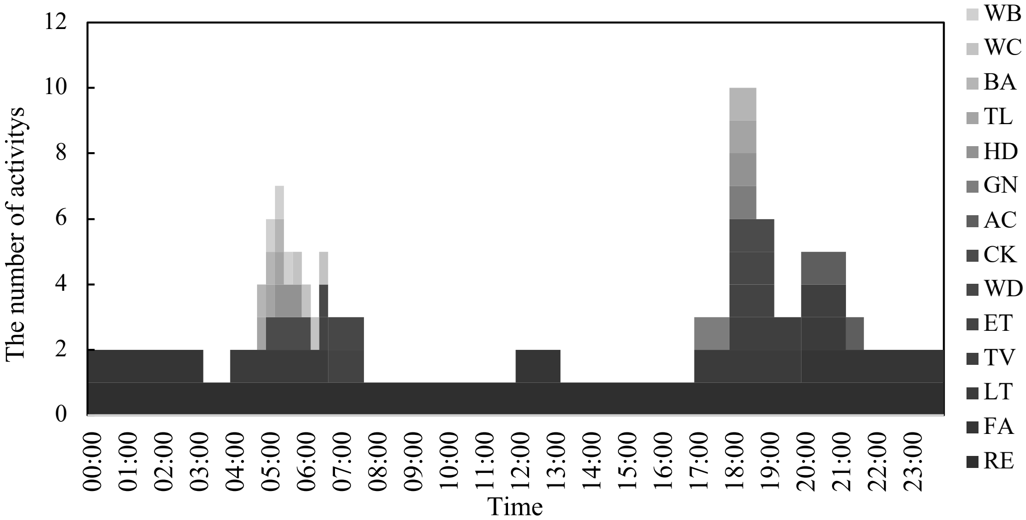


Figure 4.51 The number of events in GH2 of the 2nd consumer

School house 1: The activities within the female resident number 1 of SH1, aged between 51 and 60, are detailed in Figure 4.52, consisting of a total of 10 activities: LT, TL, MI, BA, WB, ET, WD, MI, HD, and IC. Each activity has behavior patterns for their occurrence within the building as follows: LT occurs twice daily at two different times, from 6:00 to 7:00 and 18:30 to 22:30, with an average activity duration of approximately 5 hours per occurrence. TL occurs four times daily at three different times, namely from 6:00 to 6:30, 18:30 to 19:00, and 22:00 to 22:30, with an average activity duration of approximately 2 minutes per occurrence. MI occurs approximately twice weekly at two different times, from 6:30 to 7:00 and 18:30 to 19:00, with an average activity duration of approximately 5 minutes per occurrence. BA and WB occur simultaneously at two different times, namely from 6:30 to 6:30 and 19:00 to 19:30, with an average activity duration of approximately 10 minutes per occurrence for BA and 3 minutes per occurrence for WB. ET occurs twice daily at approximately 6:30 to 7:00 and 19:00 to 19:30, with an average activity duration of approximately 20 minutes per occurrence. WD occurs twice daily with an average activity frequency of 2 times per day and an average activity duration of 5 minutes per occurrence, occurring after ET at approximately 7:00 to 7:30 and 19:30 to 20:00. MI activities occur on average twice per day, with two time intervals: 6:30-7:00 and 18:30-19:00. The duration of each activity is approximately 5 minutes. On the other hand, HD activities occur on average once per week, during the 19:30-20:00 time interval, with each activity lasting around 5 minutes. Lastly, the IC activities occur on average once per week, during the 19:00-19:30 time interval, with each activity lasting around 10 minutes.

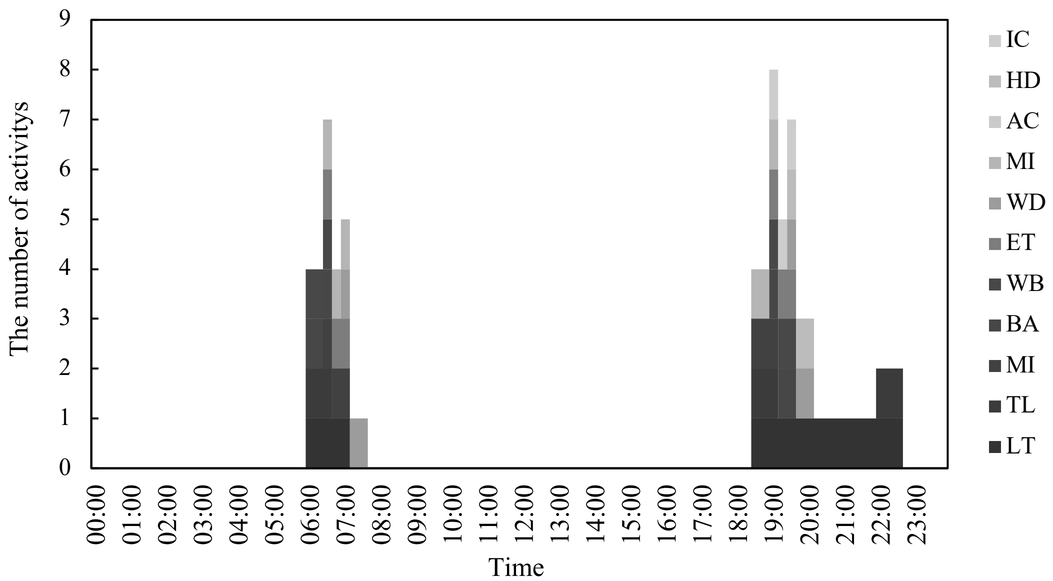


Figure 4.52 The number of events in SH1 of the 1st consumer

From Figure 4.53, the characteristics of activities that occur within SH 1 of male residents aged between 41 and 50 years old, who are resident number 2, are shown. The findings reveal that there are six activities that occur among all consumers, namely FA, LT, BA, MI, ET, and WD. The behaviors of the activities occurring within the building are divided into two periods: from 0.00 to 8.00 and from 17.00 to 23.45, which are outside of working hours. The details of each activity are as follows: FA occurs once a day in both periods, from 00.00 to 7.00 and from 17.00 to 23.45, with an average duration of 14 hours per day. This activity is the longest occurring activity because consumers primarily use fans as a device to adjust the indoor air condition, and the fans also help with the air circulation system, which directly affects the comfort level inside the building. Additionally, since the building is not a private residence, it cannot adjust the environmental conditions that affect the air circulation inside the building, which is the reason why the fans are used for an extended period. LT occurs twice a day in both periods, from 5.00 to 8.00 and from 18.00 to 23.00, with an average duration of 8 hours per day. BA has two periods of activity, which are from 6.00 to 7.00 and from 20.00 to 21.00, with an average duration of approximately 15 minutes per occurrence. MI, ET, and WD occur twice in the same time period, with two occurrences of each activity per day.

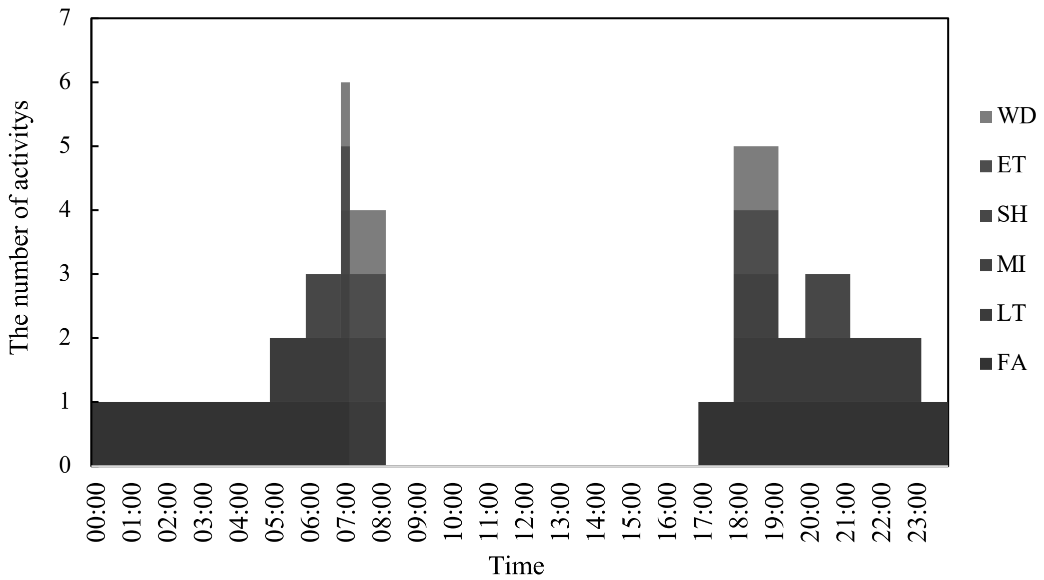


Figure 4.53 The number of events in SH1 of the 2nd consumer

For the third resident of SH1 who is male and aged between 31-40 years old, there are detailed activities within the building as shown in Figure 4.54. There are a total of nine activities comprising of RE, FA, LT, TL, BA, CK, MI, ET, and WD. It was found that there is one activity that occurs throughout the day, which is RE, due to the requirement of continuous use of electricity. The consumer has specified that this activity was carried out by the third consumer of SH1, as it occurred or utilized equipment in their private living quarters and not in the common area of the building. Other activities carried out by the consumer include FA, which occurs once a day during two time periods, from 0.00-6.00 and 23.00-23.45, with an average duration of 6 hours per day. LT occurs once a day during the time period of 18.00-23.00, with an average duration of approximately 4 hours per day. TL and BA occur twice a day during the same time periods, from 7.00-7.30 and 21.00-21.30, with each activity occurring twice per day and an average duration of 10 minutes for BA and 2 minutes for TL. BA also occurs four times per day during three time periods, which are 7.00-7.30, 12.00-13.00, and 21.00-21.30.

There are four activities, CK, MI, ET, and WD, which occur in close proximity to each other. All four activities are performed sequentially, beginning with food preparation and microwaving, followed by meal consumption, and concluding with dishwashing. These four activities are performed twice daily, during the time periods of 7:00-7:30 and 20:00-20:30. The average duration of each activity is as follows: CK, 35 minutes; MI, 2 minutes; ET, 25 minutes; and WD, 1 minute.

Characteristics and behavior of activities within the SH1 of all consumers within the building reveal a total of 12 activities occurring during two distinct time periods within a given day. Necessary activities that require constant energy usage throughout the day, regardless of occupancy, such as refrigeration, were not included. During the first time period, or morning hours, most activities occurred in close proximity to one another, beginning with the FA activity that occurred with two residents and commencing with additional activities around 5:00. The first time period ended at 8:00 with the final LT activity that occurred between 5:00 and 8:00, followed by BA and TL activities that occurred at roughly 6:00-6:30 and 7:00-7:30, respectively. This was followed by the WB activity at 6:00-6:30, and then the breakfast period, which began with CK and MI for meal preparation, followed by ET for meal consumption, and WD for dishwashing, with breakfast occurring between 6:30 and 8:00. The highest level of concurrent consumer activities within the building occurred during the breakfast period, particularly around 7:00-7:30. There was a second occurrence of activities within the building after 5:00, with the longest duration being for the lighting system (LT) and the air conditioning system (FA). This was followed by a period of dinner consumption activities (CK, MI, WB, ET, and WD), which did not occur in close proximity to one another like the morning activities, but still occurred during a relatively short time period.

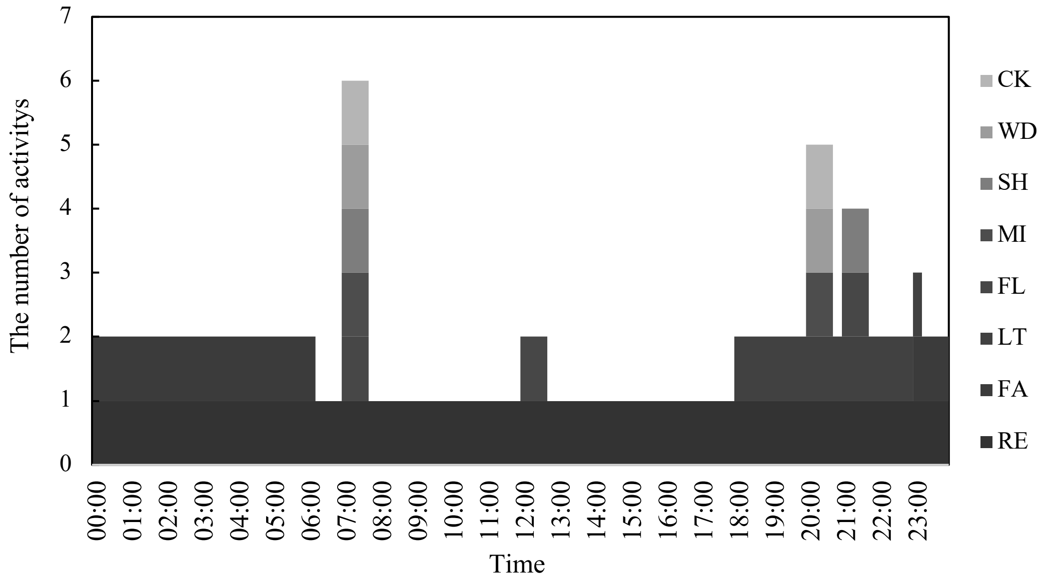


Figure 4.54 The number of events in SH1 of the 3rd consumer

The data, it was found that the quantity of behavioral characteristics that occur within the building changes in two periods of the day: weekday and weekends. According to the correlation data of energy, water, and waste within the building, it is seen that the estimated use of energy and water within the building has a significant correlation with the time and type of working day. Additionally, the data within the building shows that the amount of energy used is also correlated with the amount of water used, and the amount of water used has an impact on the amount of waste generated within the building, which is statistically significant. Therefore, it can be concluded that the behavior of activities that occur within the building has an impact on the quantity of resources used within the building.

School house 2: The activities that occurred within the building by 1st consumer, a female aged between 21-30 years old, consisted of a total of nine activities, namely RE, LT, FA, TL, BA, WC, ET, WD, and IC, as shown in Figure 4.55. The most frequent activity that occurred throughout the 24-hour period was the refrigerator. It was found that the majority of the activities occurred between 17:00-23:45, accounting for eight out of the nine activities. In the morning, only three activities occurred during the period of 6:30-7:45, including lighting, bathing, and toilet.

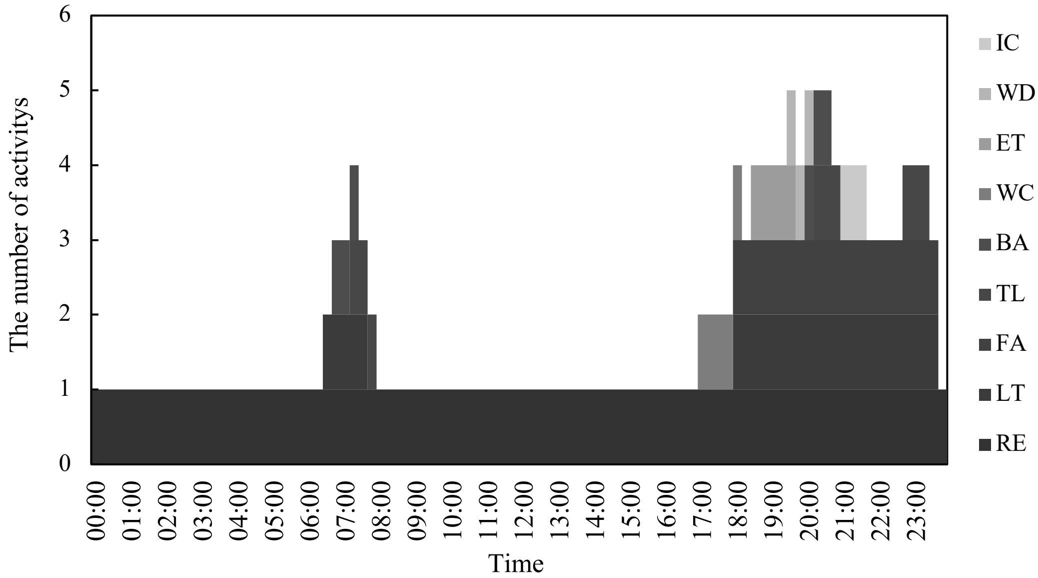


Figure 4.55 The number of events in SH2 of the 1st consumer

Upon analysis of the characteristics of each activity, it was determined that the activity denoted as lighting took place twice per day, between the hours of 6:30-7:30 and 18:00-23:30, with an average daily usage time of 720 minutes. The activity associated with turning on the fan took place once per day on average, during the period of 18:00-23:30, with an average usage time of approximately 690 minutes per day. The activity labeled as toilet occurred during three distinct time periods, namely 7:15-7:45, 20:15-20:45, and 22:45-23:15, with a frequency of three times per day and an average duration of 2 minutes. Bathing took place twice per day, during the periods of 6:45-7:15 and 20:00-20:30, with an average duration of 30 minutes per occurrence. The activity associated with eating occurred once per day on average, with an average duration of 20 minutes during the period of 18:30-19:30. Washing dishes took place after mealtime, during the period of 19:30-20:00, with an average duration of 5 minutes and occurring once per day. The activity denoted as laundry took place once per week, during the period of 17:00-18:00, with an average duration of 60 minutes.

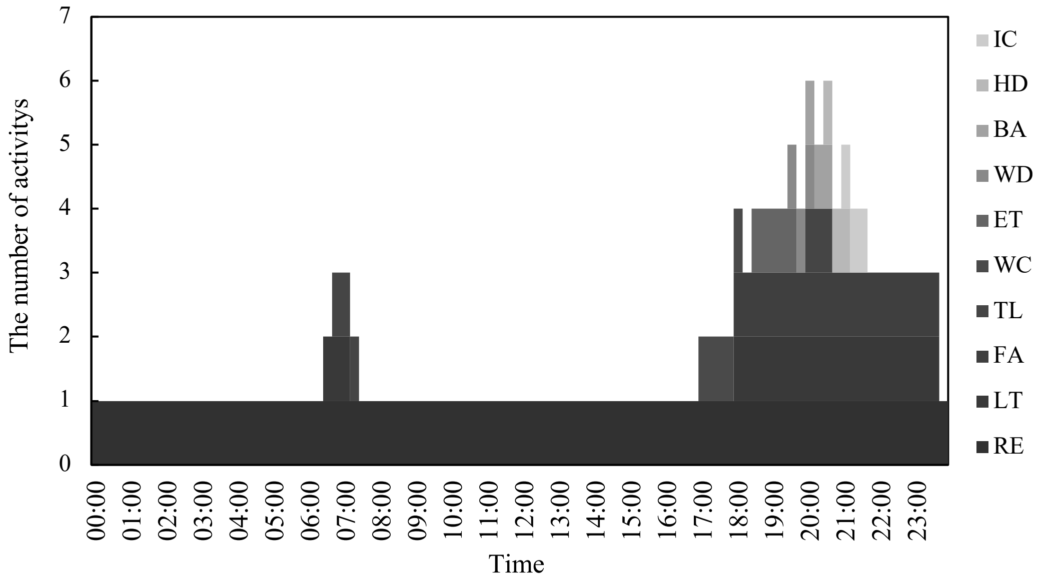


Figure 4.56 The number of events in SH2 of the 2nd consumer

After examining the activities that occurred within the building by female consumers between the ages of 21-30, a total of 10 activities were identified, including RE, LT, FA, TL, WC, ET, WD, BA, HD, and IC, which were similar to those of Consumer 1, with the addition of one activity, namely hair drying, as indicated in Figure 4.56. It was found that the refrigerator was the activity that occurred throughout the 24-hour period, and that most activities occurred between 17:00-23:45, with a total of 8 activities. Only 2 activities occurred in the morning, namely lighting and toilet, which occurred between 6:30-7:45.

The characteristics of daily activities indicate that there is a lighting period from 6:30 to 7:00 in the morning, followed by restroom use from 6:45 to 7:15. Evening activities consist of lighting periods from 18:00 to 23:30, coinciding with the use of fans, with an average lighting time of approximately 390 minutes per day and an average fan usage time of approximately 327 minutes per day. This is followed by a mealtime period from 18:30 to 19:30, which lasts approximately 25 minutes and occurs once per day, followed by dishwashing from 19:30 to 20:00, which takes approximately 5 minutes and occurs once per day.

Bathing and restroom use occur simultaneously from 20:00 to 20:30, with an average of one bath per day taking approximately 25 minutes and two restroom uses per day taking approximately 1 minute each. This is followed by hair drying from 20:30 to 21:00, which takes approximately 5 minutes and occurs once per day, and ends with laundry wringing from 21:00 to 21:30, which takes approximately 5 minutes and occurs once per day. Laundry washing occurs only once per week during the time period of 17:00 to 18:30, taking approximately 50 minutes.

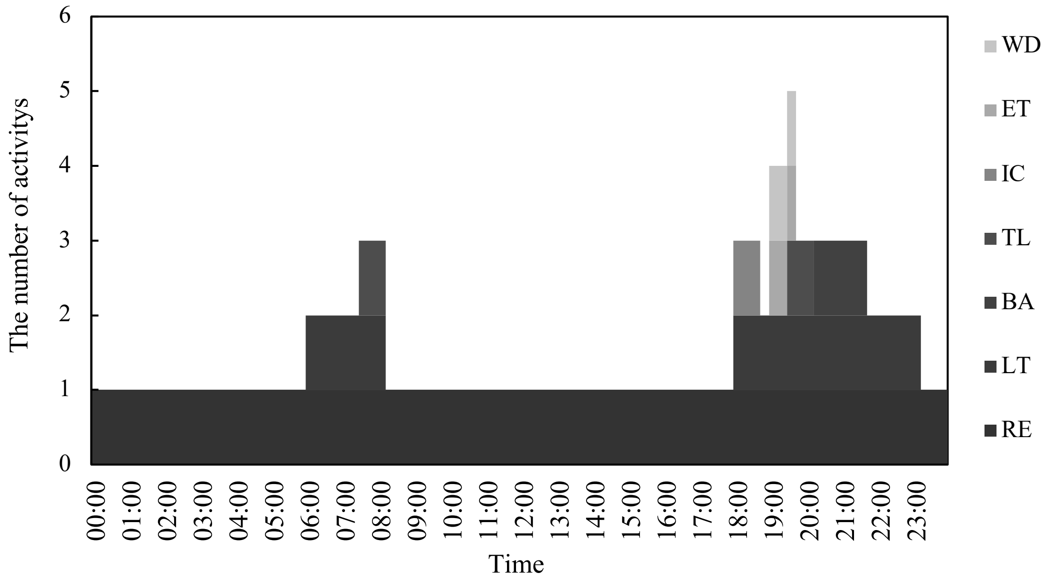


Figure 4.57 The number of events in SH2 of the 3rd consumer

Within the building, activities of female consumers aged between 21 and 30 years were recorded and categorized as RE, LT, BA, TL, IC, ET and WD, as shown in Figure 4.57. The activities occurring over 24 hours were examined and it was found that the most prevalent activity was the use of the refrigerator, with the majority of activities taking place between 18:00 and 23:00. Only two activities, lighting and toilet use, occurred in the morning, specifically between 6:00 and 8:00.

Further analysis revealed that lighting activities occurred during two distinct time periods: between 6:00 and 8:00 and between 18:00 and 23:00. The average duration of lighting use per day was found to be 420 minutes. Bathing activities occurred between 20:15 and 21:30, with an average duration of 30 minutes per session, once per day. Toilet use was found to occur with a high frequency of three times per day, on average taking one minute per use, during two time periods: 7:30-8:00 and 19:30-20:00. Laundry activities occurred between 18:00 and 18:30, with an average duration of five minutes per session, once per day. Eating and dishwashing activities occurred at the same time, specifically between 19:00 and 19:30, with an average duration of 25 minutes for eating and five minutes for dishwashing. Both activities occurred within the building once per day on average.

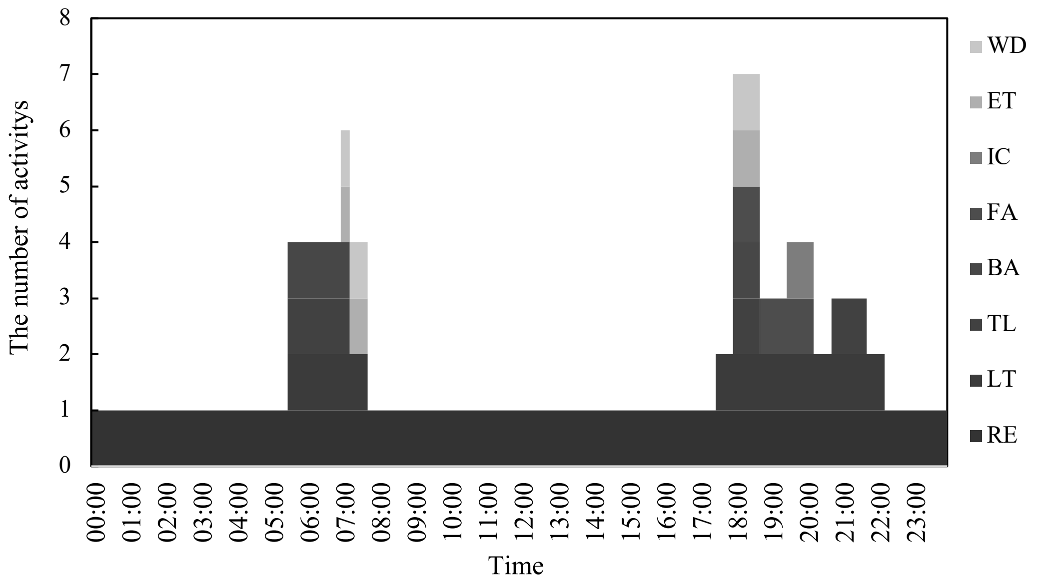


Figure 4.58 The number of events in SH2 of the 4th consumer

For the 4th consumer of the residential building for teachers, who is a female aged between 41-50 years old, as shown in Figure 4.58, there are a total of 8 activities within the building, namely RE, LT, TL, BA, FA, IC, ET, and WD. From the data, it was found that there is 1 activity that occurs continuously for 24 hours, which is the refrigerator activity. It was found that the activity of turning on the lights occurs twice a day, between 5:30-7:30 and 17:30-22:00, averaging about 420 minutes per day. The activity of taking a shower occurs twice a day, in the time periods of 5:30-7:00 and 18:00-18:30, averaging 15 minutes per occurrence, with a frequency of 2 occurrences per day. The activity of using the bathroom occurs in 3 time periods, with the first 2 periods occurring at the same time as the shower activity, and the third period occurring between 20:45-21:30, averaging 1 minute per occurrence, with a frequency of 3 occurrences per day.

The activity of using the fan occurs once a day within the building, with an average duration of 120 minutes, in the time period of 18:00-20:00. The activity of doing laundry occurs once a day within the building, averaging 5 minutes in duration, in the time period of 19:30-20:00. The last two activities occur simultaneously, which are the activity of eating and dishwashing, which occur twice a day in the time periods of 7:00-7:30 and 18:00-18:30, averaging 2 occurrences per day with a duration of 15 minutes for eating and 5 minutes for dishwashing.

The characteristics and behaviors of activities conducted within SH2 building, as observed by 4 consumers, are shown to comprise a total of 9 activities. These activities include the use of a refrigerator, the operation of a fan, the turning on of lights, bathing, the use of a restroom, hair drying, swimming, eating, dishwashing, and laundry washing and drying. These activities mostly occur between 18:00 and 23:30, with only the activities of turning on lights, bathing, using the restroom, having meals, and washing dishes happening between 5:30 and 8:00 in the morning. The most frequently encountered behaviors in the morning are turning on lights between 6:00 and 7:30, bathing from 6:45 to 7:00, and using the restroom from 6:45 to 7:45, occurring more than twice a day. The analysis of activity frequencies in the evening indicates that simultaneous activities mostly involve turning on lights between 18:00 and 23:30 and operating fans between 18:00 and 23:30. Among the evening activities, meal consumption occurs between 18:30 and 19:30, dishwashing from 19:30 to 20:00, bathing and restroom usage from 20:00 to 20:45, hair drying from 20:00:30 to 21:00, and laundry washing, ironing, and fabric drying from 21:00 to 21:30.

The average duration of each activity that occurs within the building was found to be as follows: the activity of turning on the lights had an average usage time of 465.00 minutes once per day; the activity of using the hair dryer had an average usage time of 379.00 minutes 0.75 times per day; the activity of taking a shower had an average duration of 25.00 minutes 1.50 times per day; the activity of using the restroom had an average duration of 1.25 minutes 2.75 times per day; the activity of blow drying hair had an average duration of 5 minutes 0.25 times per day; the activity of eating had an average duration of 21.25 minutes 1.25 times per day; the activity of washing had an average duration of 5 minutes 1.25 times per day; and the activity of doing laundry had an average duration of 55 minutes 0.5 times per week.

The activities observed within the building are typical of those that occur in a residential facility where people carry out their daily routines. For example, the need to turn on the lights and use household appliances is common to all homes. Similarly, personal care activities such as taking a shower and using the restroom are also typical daily routines for individuals living in a residential facility. Meals are also a regular activity that occurs in all households, and doing laundry is a necessary task that needs to be performed periodically. Therefore, the observed activities are not unexpected and reflect the daily routines of the occupants in the building.

Community hospital house 1: Activity within the first residence building of Community hospital house 1 from the first occupant shows the time range of activities as depicted in Figure 4.59. It is found that there are eight activities that occur within the building, which include using the refrigerator, lighting, fan, toilet, bathing, eating, washing dishes, and ironing clothes. The activity that occurs for the longest period within the building is the refrigerator, which is in use 24 hours a day. Additionally, activities related to turning on the lights occur during multiple time periods, including 0:00-2:00, 7:00-8:00, 12:00-12:45, and 18:30-23:45, and on average, last 300.00 minutes per day. Activities related to turning on the fan occur during the time periods of 0:00-3:00, 7:30-8:00, 19:00-19:30, and 22:00-23:45, and on average last approximately 300.00 minutes per day. Bathing activities occur during the time periods of 7:00-7:30 and 20:30-21:00, and on average take 10 minutes to complete, twice per day. Entering the toilet is a high-frequency activity that occurs four times per day and lasts approximately 1 minute per occurrence, during the time periods of 0:00-0:30, 7:00-7:30, 12:15-12:45, and 21:00-21:30. Eating occurs three times per day and on average takes 30 minutes per occurrence during the time periods of 0:00-0:30, 12:15-12:45, and 19:00-19:30. Lastly, washing dishes occurs twice per day during the time periods of 0:00-0:30 and 12:15-12:45, and on average takes 10 minutes per occurrence. The last activity that occurs within the building from this occupant is ironing clothes, which occurs once per day and on average takes approximately 10 minutes to complete.

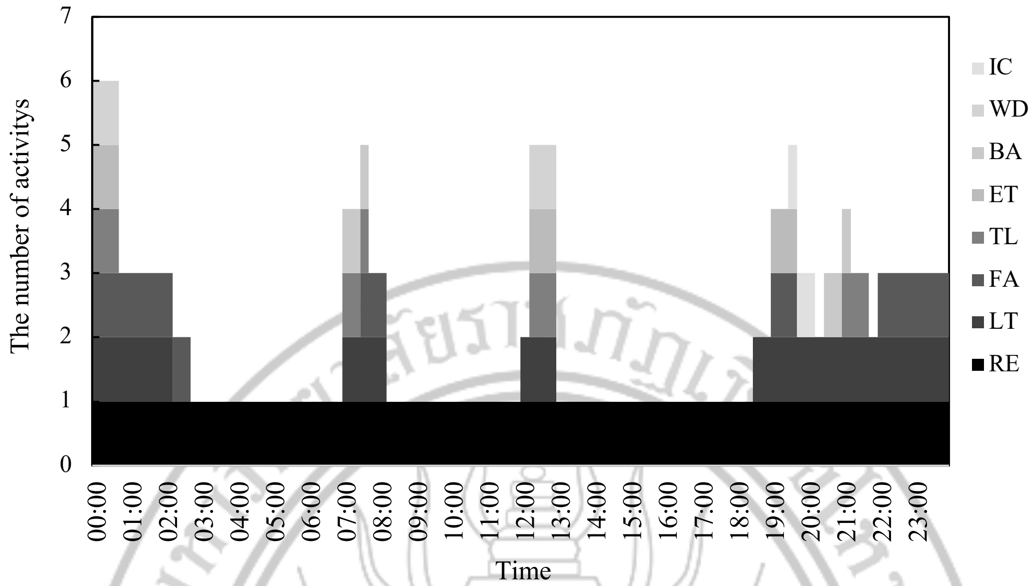


Figure 4.59 The number of events in HH1 of the 2nd consumer

Within the community hospital house 1, resident number 2, who is female and aged between 21-30 years old, demonstrated the activities as shown in Figure 4.60. A total of nine activities were identified, including the use of the refrigerator, fan, lighting, toilet, bathing, ironing clothes, washing clothes, using a hair dryer, and electric water heater. The refrigerator was found to be active 24 hours a day. If we consider each activity that occurs within the building, it was found that turning on the fan occurs twice a day for a total of 120 minutes on average, during the time periods of 0:00-2:15 and 18:00-23:45. The activity of turning on the lights occurred during the time periods of 6:00-8:00 and 18:00-23:00, averaging 300 minutes per day. The activity of bathing and using the restroom occurred during two time periods, which are 6:00-6:30 and 19:00-13:90. Additionally, a water heater was used in the morning for approximately 10 minutes twice a day. The water heater was used only once in the morning, averaging 10 minutes per day. Furthermore, the activity of using the restroom increased by one time period, which is 23:00-23:30, with an average time of 2 minutes and occurring three times per day. Hair drying occurred once a day during the time period of 20:00-20:30, averaging 3 minutes per day. Finally, the activity of washing and ironing clothes occurred only once a week, with an average time of 45-60 minutes per instance.

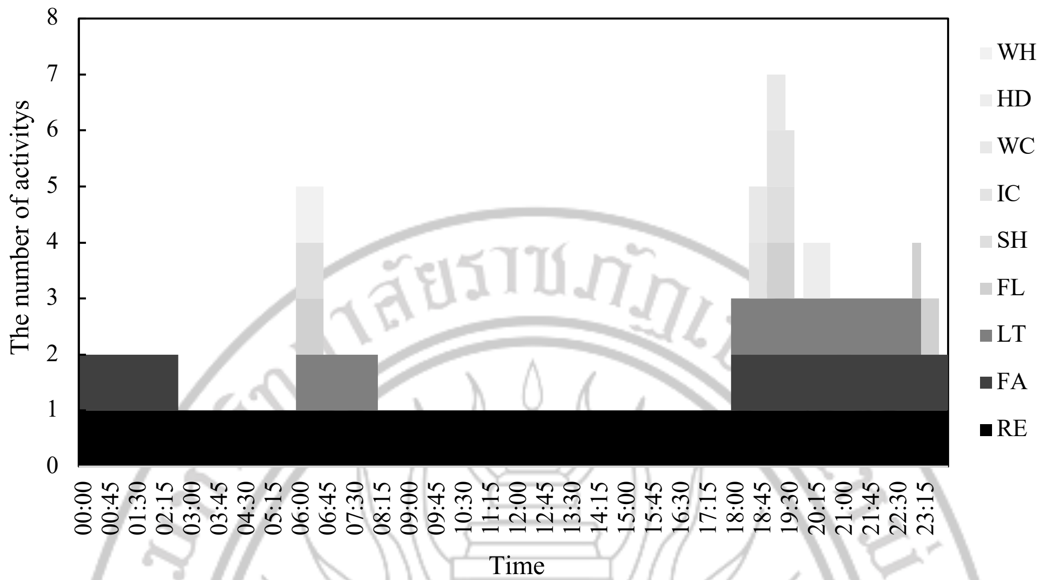


Figure 4.60 The number of events in HH1 of the 1st consumer

The activity data from 2 consumers within community hospital house 1, it was observed that the activities occurring within the building were divided into 4 time intervals, namely 0:00-2:30, 6:00-8:00, 12:00-12:45, and 18:00-23:45. The activities during interval 1 included turning on the lights, turning on the fan, using the bathroom, having meals, and washing dishes. The activities during interval 2 included turning on the lights, turning on the fan, using the bathroom, and having meals. The activities during interval 3 included turning on the lights, using the bathroom, having meals, and washing dishes. The activities during interval 4 included turning on the lights, turning on the fan, using the bathroom, taking a shower, having meals, and blow-drying hair.

On average, the lights were turned on for 300.00 minutes per day, the fan was turned on for 210 minutes per day, showering occurred twice a day for an average of 10 minutes each time, using the bathroom occurred 1.5 minutes per visit, meals were consumed three times a day for an average of 30 minutes each time, dishes were washed for an average of 10 minutes twice a day, hair was blow-dried for an average of 3 minutes 0.5 times per day, and clothes were laundered for an average of 35 minutes, four times per week.

The activity data, it is apparent that the building under observation serves as a residential facility where people conduct their daily activities. The activities are broadly classified into three categories, namely personal care, household chores, and meals. The personal care activities, which include showering and blow-drying hair, take place during the last time interval of the day, between 18:00-23:45. On average, showering occurs twice daily, and each session lasts 10 minutes, while hair is blow-dried for an average of 3 minutes 0.5 times per day. Household chores, such as turning on lights and fans, using the bathroom, and washing dishes, are carried out in various time intervals during the day. Turning on the lights and fans is a recurrent activity that takes place in all time intervals. On average, the lights are on for 300 minutes and fans for 210 minutes daily. Bathroom use takes approximately 1.5 minutes per visit and occurs throughout the day. Washing dishes lasts for an average of 10 minutes twice a day. The third category of activities is meals, which are consumed three times a day and each time lasts for 30 minutes. Laundry is done four times a week, with each occasion taking approximately 35 minutes. The observations suggest that the occupants conduct their activities in typical residential routines. The timing and duration of each activity provide insights into the occupants' daily lives.

Community hospital house 2: Activity within the second community hospital house from consumer 1, who is male, aged between 21-30, was examined based on the time period of each activity as shown in Figure 4.61. The findings revealed a total of 10 activities, including the refrigerator, lighting, fan, bathing, toilet, hair wash, clothes washing, eating, dishwashing, and TV. The time periods in which activities occurred were divided into 2 time periods. The activity that lasted the longest was the refrigerator, which was used for 24 hours. The fan activity occurred in two time periods, between 00:00-8:30 and 17:30-23:45, with an average duration of 900 minutes per day. The lighting activity was used for approximately 900 minutes per day, occurring between 1:00-8:00 and 17:00-23:45. Bathing activity occurred twice a day, averaging 30 minutes each time, between 5:30-7:30 and 20:00-22:00. Bathroom and hair drying activities occurred at the same time, twice a day, averaging 1 minute for bathroom use and 5 minutes for hair drying, between 5:30-7:30 and 20:00-22:00. Meal consumption and dishwashing activities occurred twice a day, between 7:45-8:30 and 19:00-19:45, with an average duration of 15 minutes for meal consumption and 5 minutes for dishwashing. TV viewing occurred once a day for an average of 60 minutes, between 19:30-21:00. Finally, clothes washing occurred once a day, on average 45 minutes, between 19:00-21:30.

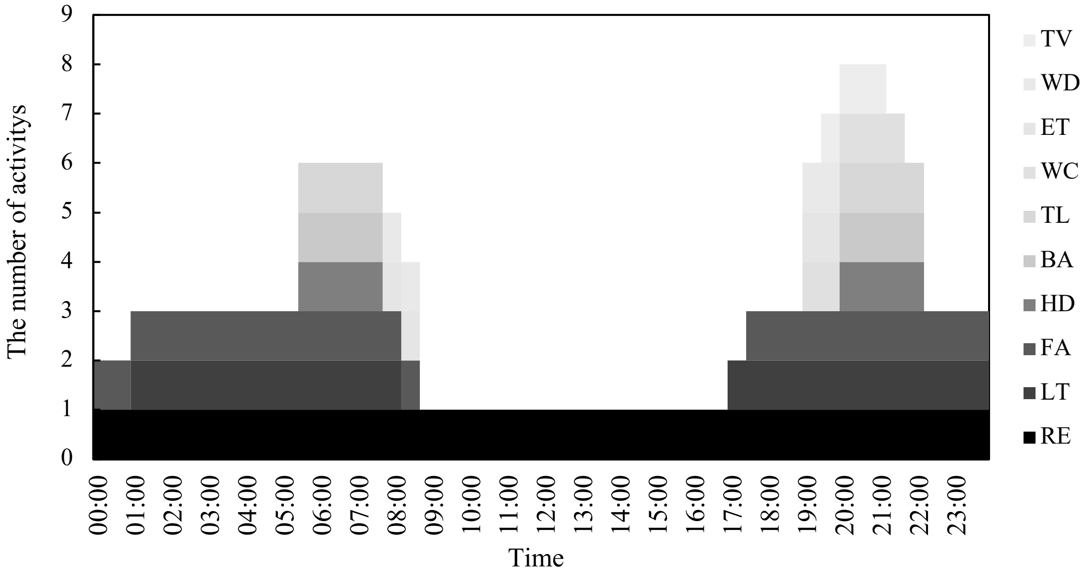


Figure 4.61 The number of events in HH2 of the 1st consumer

The second consumer of the building are males aged between 31 to 40 years old. Their activity patterns within the building at different times, as shown in Figure 4.62, reveal a total of 10 activities: refrigerator, fan, lighting, bathing, electric water heater, toilet, microwave, eating, dishwashing, and TV viewing. Activities involving the use of lighting and fans occur frequently throughout the day, except for the refrigerator which is an essential electrical appliance that operates 24 hours a day. The duration of lighting and fan usage during 0:00-7:00 and 17:30-23:45 averages 780 minutes per day. Additionally, during the morning period, high activity levels were observed for bathing and the use of a water heater from 5:30-7:30, using the common bathroom from 6:00-6:45. The same three activities occurred again in the evening from 19:00-21:00, with an average duration of 30 minutes for each occurrence, twice a day for bathing and water heater usage, and an average of 2 minutes per occurrence, twice a day for toilet usage. During the evening period, there was also a microwave usage activity for food heating and a communal meal from 19:00-20:30, with an average duration of 30 minutes per occurrence for microwave usage and 20 minutes per occurrence for meal consumption, with a frequency of 5 times per week. Dishwashing occurred twice a week during the time of 20:00-21:00, with an average duration of 20 minutes per occurrence. TV viewing activity occurred between 21:00-23:00, with an unspecified duration.

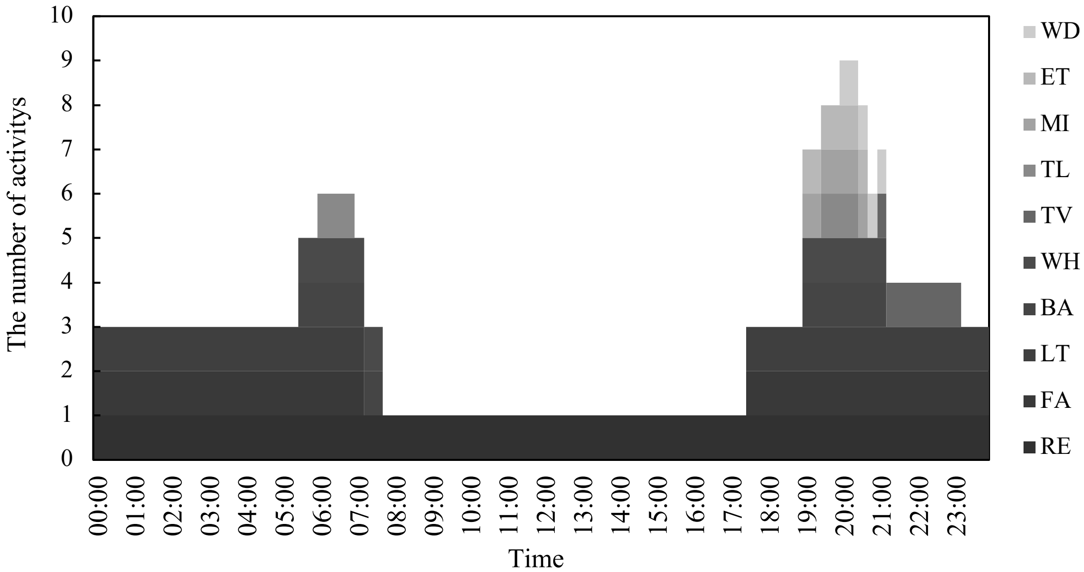


Figure 4.62 The number of events in HH2 of the 2nd consumer

From the activities that occurred within Community hospital house 2, it was found that the activities can be divided into two time periods. The use of electricity and fans would exceed the limit during the hours of 0:00-8:00 and 17:30-23:45, with an average duration of 840 minutes per day. Shower activities would occur during the morning at the same time between 5:30-7:30 and during the evening between 20:00-21:00, with an average duration of 30 minutes, twice a day. During these same time periods, the activity of using the restroom would also occur, with an average duration of 1.50 minutes per instance, 2.5 times per day. Hair drying activities would occur during the same time period as showering activities between 5:30-7:30 and 20:00-22:00, with an average duration of 5 minutes, once a day. The activity of warming food using a microwave, consuming food, and dishwashing would occur during the morning at 7:45-8:30 and during the evening at 19:00-20:30, with an average duration of 30 minutes, 2.50 times per week for warming food with a microwave, 17.50 minutes, 1.36 times per day for consuming food, and 12.50 minutes, 1.14 times per day for dishwashing. The activity of watching television would occur within the building for one time period per day, during the hours of 19:30-23:00, with an average duration of 90 minutes, once a day.

The functions taking place within Community hospital house 2 are indispensable for the daily functioning of its inhabitants. The use of electricity and fans during the hours of 0:00-8:00 and 17:30-23:45 is fundamental to ensuring a comfortable and healthy living environment. Sanitation and personal hygiene are critical, and thus, the use of showers and restrooms is indispensable. Furthermore, hair drying activities are necessary for personal grooming during the same time periods as showering activities. The activities of warming food using a microwave, consuming food, and dishwashing are imperative for daily sustenance and maintaining good health. Lastly, the activity of watching television serves as a source of entertainment and relaxation for the occupants during the hours of 19:30-23:00. In summary, the nature of these activities in Community hospital house 2 is rationalized as they are essential for the daily life and well-being of the occupants.

4.1.1.2 Office building

With regards to the characteristics of activities that take place inside office buildings, the group of consumers or residents living within the building are not identified because of the building's constant flow of consumers entering and exiting throughout the day. As a result, a comprehensive analysis is conducted on the potential collective activities that may transpire within the building, which can have significant implications for energy consumption, water utilization, and waste production.

School office: The nature of activities occurring within a school office building were found to take place between the hours of 7:00 and 19:00, as shown in Figure 4.63. An analysis of all potential activities within the building was conducted, which may impact energy consumption, water usage, and waste generation. Eight activities were identified, namely, refrigerator use, lighting, hot water boiling, fan use, microwave use, meal consumption, dishwashing, and watering of plants. The refrigerator was found to be in constant operation 24 hours a day. Lighting usage began at 7:00 and ended at 18:30, with an average usage time of 300.00 minutes per day. Fans were used twice a day between 11:00 and 14:00, with an average usage time of 60 minutes. Hot water boiling occurred between 7:30 and 18:00, with an average usage time of 600.00 minutes per day. The microwave was used three times a day at 7:30-9:00 and 18:00-19:00, with an average usage time of 3.00 minutes per usage. Meal consumption occurred twice a day for an average of 60 minutes per meal at 7:00-8:00 and 11:30-12:30. Dishwashing occurred twice a day for an average of 10 minutes per session at 7:30-8:00 and 12:00-12:30. Lastly, watering of plants occurred once a day for an average of 30 minutes between 8:00-8:30.

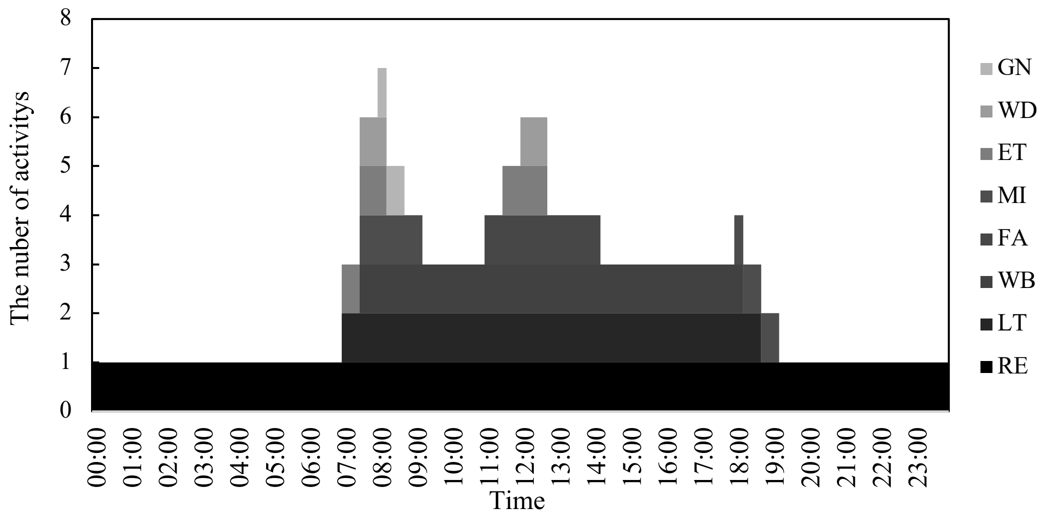


Figure 4.63 The number of events in SCO

The activities taking place within a school office building are deemed imperative for the smooth operation of the premises. Among these activities, the refrigeration of food and other perishable items is necessary to sustain their freshness. Adequate lighting ensures visibility within the building, while fans are employed to promote air circulation, enhancing occupants' comfort levels. The availability of hot water is essential for various functions, such as preparing tea or coffee, and dishwashing is indispensable for cleaning utensils used during meals.

In addition, microwaves serve the purpose of heating food, while meal consumption occurs during stipulated meal times. Moreover, watering plants is a requisite to maintain an attractive and healthy environment. The aforementioned activities play a pivotal role in the proper functioning of a school office and in meeting the demands of its occupants. However, these activities are associated with energy and water consumption, as well as waste generation, warranting the need for an analysis of their usage and the implementation of strategies to mitigate their environmental impact.

Community hospital office: The activities that occur within the community hospital office building comprise only five activities, which include the use of refrigerators, fans, lighting, restrooms, and other medical activities that require energy, as shown in Figure 4.64. The entire time frame during which these activities take place is divided into two periods, between 8:00-12:00 and 13:00-18:30, except for the use of the refrigerator, which is in constant operation 24 hours a day.

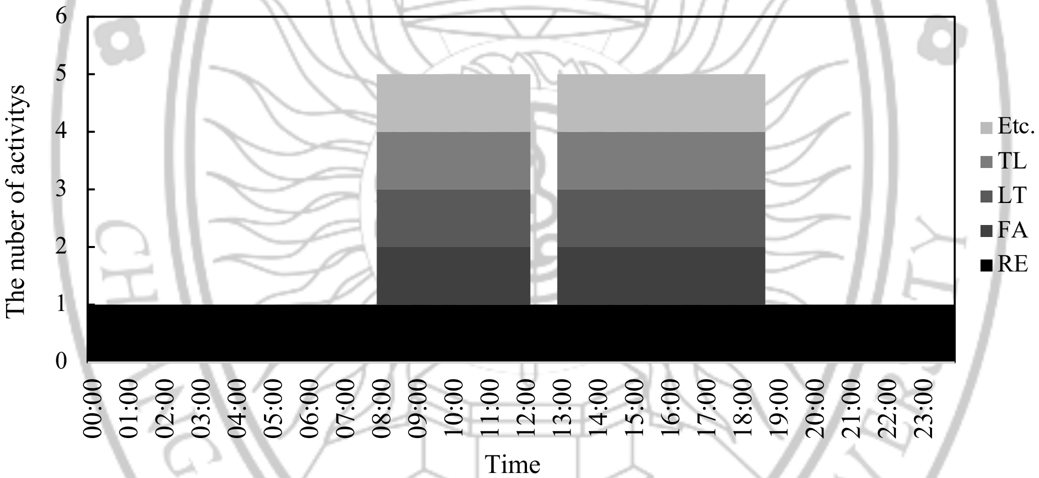


Figure 4.64 The number of events in CHO

The listed activities for the community hospital office building are crucial for the effective functioning of the building and the safety of its occupants. The use of refrigerators is necessary to store perishable medical items, while fans maintain a comfortable environment and reduce humidity, which is crucial in a medical facility. Lighting is critical for visibility and effective performance of staff, and proper restroom facilities are crucial for hygiene and the prevention of the spread of infections.

Additionally, other medical activities requiring energy, such as the use of medical equipment, are essential for the treatment and care of patients. All in all, these activities are necessary for the proper functioning of the community hospital office building and the health of its occupants.

4.1.1.3 Commercial

Coffee shop: The characteristics and number of activities that occur within a commercial building that sells drinks or coffee were investigated, and it was found that there were only five activities: turning on lights, boiling water, using a blender, washing dishes, and brewing coffee with a coffee maker. The time intervals for each activity are presented in Figure 4.65. The frequency and duration of each activity were examined, it was found that the activity with the longest duration was boiling water, which occurred between 6:30 and 18:30, averaging 12 hours per day. The second activity, washing dishes, occurred at similar intervals, starting from 7:00 to 18:00, with an average duration of 1 minute and occurring about 50 times per day. The third activity, brewing coffee, took approximately 1 minute per brew and occurred about 10 times per day between 7:30 and 15:15. The fourth activity, turning on lights, occurred twice a day at 6:30-9:45 and 17:15-19:00, averaging 240 minutes per day and happening twice a day. Finally, the last activity, using a blender to make drinks, occurred between 12:00 and 16:30, averaging 3 minutes per blend and occurring about 20 times per regular day and approximately 40 times on weekends.

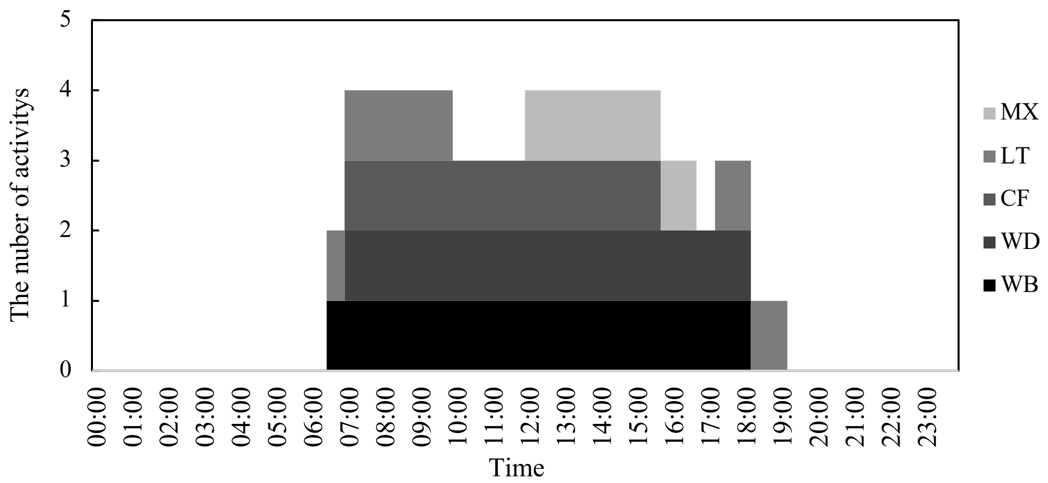


Figure 4.65 The number of events in COF

The behavior of the activities occurring within a commercial building that sells drinks or coffee has been investigated, and it has been found that boiling water has the longest duration among the activities due to its multiple uses, including making tea, and coffee. dishes and glasses occur at similar intervals to boiling water since maintaining hygiene is crucial in coffee shops, and customers tend to visit at various times throughout the day. Turning on the lights during operational hours is essential to provide proper visibility for customers and employees, and the timing of this activity is based on the opening and closing hours of the coffee shop. The use of a blender is most frequent during the afternoon and especially at weekends when the majority of the student population is off work.

4.1.2 Identification of activity

To present the frequency of activities in each building, a detailed breakdown of data presentation is provided for each sector, categorized by individual buildings. Energy-related data can be classified into two categories: activities or electrical appliances that continuously require energy usage, and activities that consume energy over a long period, such as refrigerators, freezers, lighting systems, televisions, fans, air conditioning systems, as well as other short-term activities like bathroom use, cooking, and bathing. To determine the activities that occur, peak loads for each sector are considered to identify patterns or behaviors of normal usage, or activities that may use resources in a coordinated manner. The frequency of activities that occur in each building varies accordingly.

The process of activity identification involves the utilization of data on energy consumption, water usage, and waste generation obtained from smart meters to confirm the peak load period for each activity. Questionnaires are utilized to determine the timing of each activity, and the analysis is divided based on consumer profiles, as illustrated in Table 4.25. By comparing the data from both groups, the behavior of each consumer profile can be ascertained. It is important to separate the data on the quantity of energy consumption, water usage, and waste generation of each activity that occurs in each building, which is a summary of data for all consumers within the building, as shown in Table 4.34, to identify each individual consumer. Therefore, data quantification needs to be separated to identify each individual consumer.

Table 4.34 Consumer profile of people living in each building

Community profile	Building								
	GH1	GH2	SH1	SH2	HH1	HH2	SCO	CHO	COF
CP1									
CP2						✓			
CP3			✓			✓			
CP4			✓						
CP5									
CP6		✓							
CP7									
CP8									
CP9				✓✓✓	✓✓				
CP10									
CP11	✓		✓	✓					
CP12	✓	✓							
CP13									
CP14									

An analysis of the behavioral characteristics that occur within the building with respect to the quantity of energy usage, water consumption, and waste generation, when compared to the frequency of each activity that occurs from each individual consumer as shown in Figure 4.66 which illustrates the percentage frequency of each activity within the building from the first consumer in building GH1, and Figure 4.67 which provides details of the second consumer, it can be concluded that.

Upon analyzing the energy consumption quantity from Figure 4.66 (a) and Figure 4.67 (a) depicting the average daily energy consumption within the building over different time intervals, it becomes evident that the amount of activity occurring during each time interval is directly proportional to the energy consumption quantity within the building. As observed from the graph, the energy consumption quantity is influenced by the activities taking place within the building, just like the water consumption quantity shown in Figure 4.66 (b) and Figure 4.67 (b). The time intervals with a higher frequency of activities contribute to a greater water consumption quantity, which is dependent on the individual usage patterns of the consumers.

The quantity of waste generated within a building, as illustrated in Figure 4.66, does not necessarily have a significant impact on the occurrence of waste generation for each activity during different time periods within the building. This is different from the amount of waste that is actually generated, which is of considerable importance. The average daily amount of waste disposed of for (c) General, (d) Organic, and (e) Recyclable waste, by Consumer 1 in house GH1. Similarly, Figure 4.67 (c)-(e) shows the same for Consumer 2. It was found that the time periods with the highest average amount of waste disposed of did not correspond to the time periods with the highest occurrence of activities within the building.

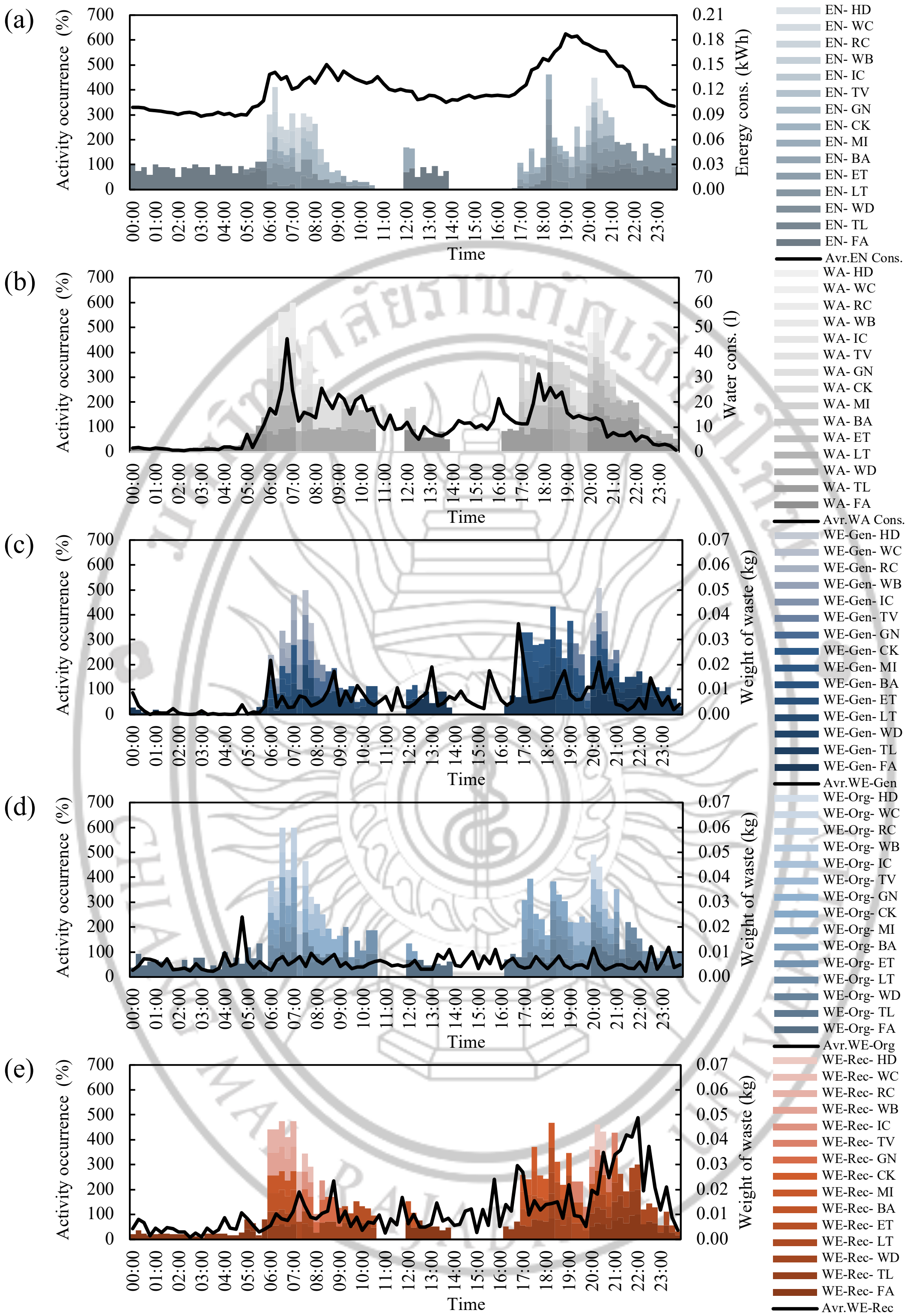


Figure 4.66 The activity occurrence in GH1 of 1st consumer with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

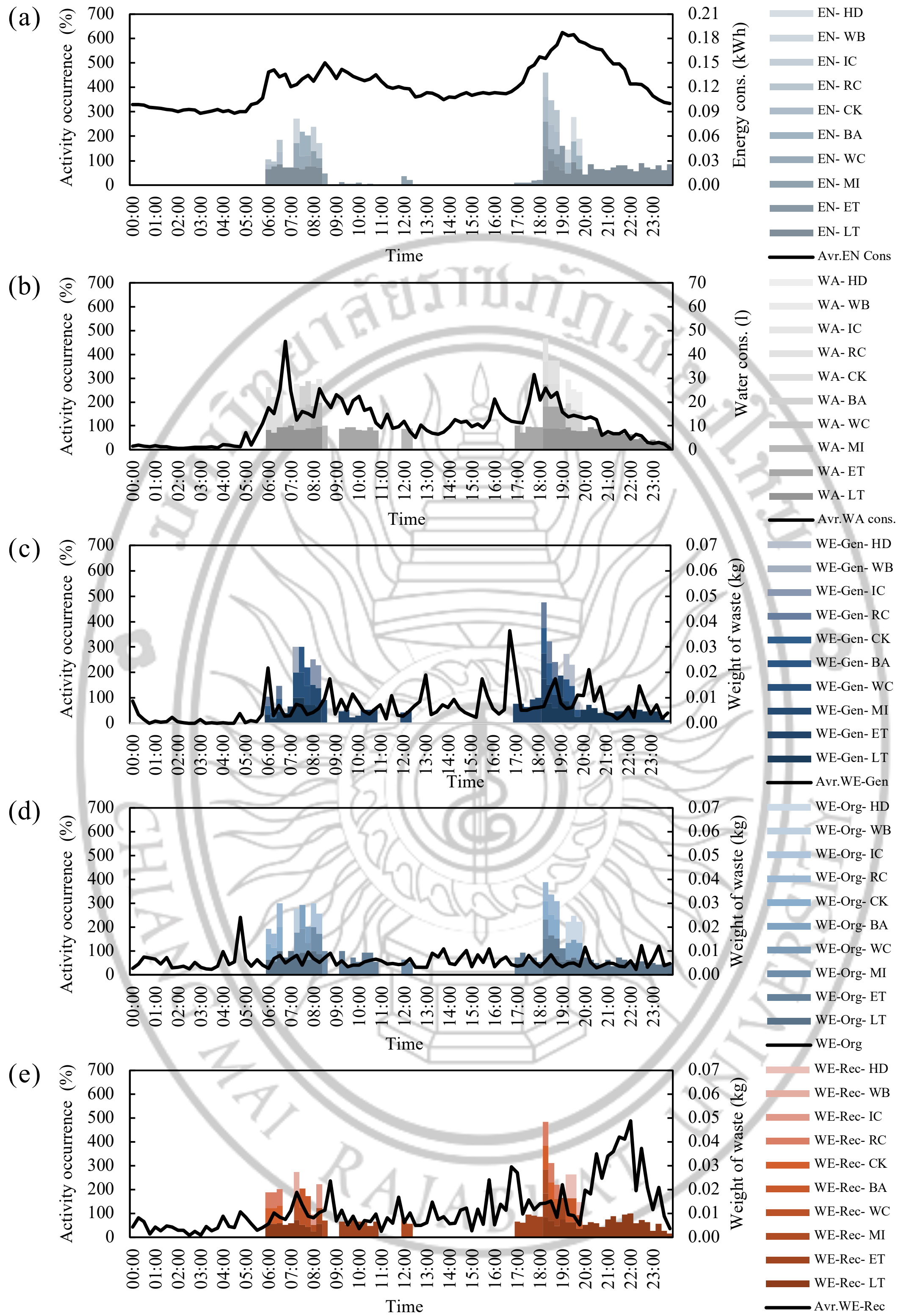


Figure 4.67 The activity occurrence in GH1 of 2nd consumer with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

Table 4.35 Size, number, proportion, and total consumption of appliances in each sample building

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9	CP9	CP9	CP11	CP9	CP9	CP2	CP3
Lighting	LED	Size (W)	18.00	18.00	10.00	10.00	22.00	15.00	15.00	15.00	15.00	15.00	15.00	10.00	10.00	12.00	12.00
		Unit	10.00	12.00	9.00	9.00	1.00	2.00	2.00	8.00	8.00	8.00	8.00	8.00	8.00	3.00	3.00
	Fluorescent	Size (W)	23.00	-	12.46	12.46	-	41.00	41.00	-	-	-	-	-	-	18.00	18.00
		Unit	1.00	-	13.00	14.00	-	1.00	1.00	-	-	-	-	-	-	3.00	3.00
	Total load (W)		203.00	216.00	252.00	264.46	22.00	71.00	71.00	120.00	120.00	120.00	120.00	80.00	80.00	90.00	90.00
Fan	Ceiling	Size (inch)	16.00	16.00	16.00	16.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	4.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Wall mounted	Size (inch)	-	-	16.00	16.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	-	3.00	3.00	-	-	-	-	-	-	-	-	-	-	-
	Table	Size (inch)	14.00	18.00	16.00	16.00	18.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
		Unit	1.00	2.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
	Total load (W)		70.00	245.00	353.25	353.25	64.00	50.25	50.25	50.25	50.25	50.25	50.25	50.25	50.25	100.50	100.50
AC	Conv.	Size (BTU)	-	-	18,000	18,000	-	-	-	-	-	-	-	-	-	-	-
		Seer	-	-	15.00	15.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (Wh)		-	-	1,200.00	1,200.00	-	-	-	-	-	-	-	-	-	-	-
Refrigerator	Conv. Single-d	Size (ft^3)	6.40	5.50	6.40	6.40	5.20	5.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00	-	-
		Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-
	Inv. Single-d	Size (ft^3)	-	-	-	-	-	-	-	-	-	-	-	-	-	3.40	3.40
		Unit	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00

Table 4.35 (Cont.)

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9	CP9	CP9	CP11	CP9	CP9	CP2	CP3
Refrigerator	Conv. Double-d	Size (ft^3)	-	7.70	6.40	6.40	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Inv. Double-d	Size (ft^3)	6.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		265.50	332.90	331.75	331.75	123.73	122.32	122.32	122.32	122.32	122.32	122.32	196.42	196.42	65.55	65.55
Heater	Electricity	Size (w)	4,500.00	4,500.00	4,311.00	4,311.00	-	-	-	-	-	-	-	4,500.00	4,500.00	3,500.00	3,500.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	1.00	1.00	1.00	1.00
	Total load (W)		4,500.00	4,500.00	4,311.00	4,311.00	-	-	-	-	-	-	-	4,500.00	4,500.00	3,500.00	3,500.00
Hair dry		Size (W)	1,000.00	1,000.00	1,350.00	1,350.00	-	-	-	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	-	1,200.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00
	Total load (W)		1,000.00	1,000.00	1,350.00	1,350.00	-	-	-	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	-	1,200.00
Rice cook	Conv.	Size (L)	1.80	1.80	-	-	-	-	-	-	-	-	-	1.80	1.80	-	-
		Unit	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00	-	-
	Total load (W)		630.00	630.00	-	-	-	-	-	-	-	-	-	630.00	630.00	-	-
Microwave		Size (W)	1,300.00	700.00	800.00	800.00	1,500.00	1,800.00	1,800.00	-	-	-	-	-	-	1,200.00	1,200.00
		Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	1.00	1.00
	Total load (W)		1,300.00	700.00	800.00	800.00	1,500.00	1,800.00	1,800.00	-	-	-	-	-	-	1,200.00	1,200.00
Water boiler	Kettle	Size (l)	-	-	-	-	0.50	-	1.70	1.00	1.00	1.00	1.00	-	-	-	-
		Unit	-	-	-	-	1.00	-	1.00	1.00	1.00	1.00	1.00	-	-	-	-

Table 4.35 (Cont.)

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9	CP9	CP9	CP11	CP9	CP9	CP2	CP3
Water boiler	Thermos	Size (l)	2.50	-	1.80	1.80	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		700.00	-	657.15	657.15	1,000.00	-	1,500.00	1,510.00	1,510.00	1,510.00	1,510.00	-	-	-	-
Blender		Size (W)	-	1,400.00	800.00	800.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		-	1,400.00	800.00	800.00	-	-	-	-	-	-	-	-	-	-	-
Washer	Twin tub	Size (kg)	11.00	11.00	11.00	11.00	-	-	-	8.00	8.00	8.00	8.00	-	-	-	-
		Unit	2.00	2.00	2.00	2.00	-	-	-	1.00	1.00	1.00	1.00	-	-	-	-
	Top load	Size (kg)	-	-	-	-	-	-	-	-	-	-	-	8.00	8.00	8.00	8.00
		Unit	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00	1.00	1.00
	Total load (W)		952.42	952.42	952.42	952.42	-	-	-	390.00	390.00	390.00	390.00	350.00	350.00	350.00	350.00
Iron		Size (W)	1,000.00	1,500.00	1,000.00	1,000.00	-	-	1,200.00	1,500.00	1,500.00	1,500.00	1,500.00	1,200.00	1,200.00	-	-
		Unit	1.00	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-
	Total load (W)		1,000.00	1,500.00	1,000.00	1,000.00	-	-	1,200.00	1,500.00	1,500.00	1,500.00	1,500.00	1,200.00	1,200.00	-	-
TV	LED	Size (inch)	32.00	32.00	55.00	55.00	-	-	-	-	-	-	-	-	-	32.00	32.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00
	Total load (W)		45.00	45.00	108.33	108.33	-	-	-	-	-	-	-	-	-	45.00	45.00

Table 4.36 Activity time, Frequency, and period of each consumer and building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Lighting	Time (min)	840.00	420.00	300.00	300.00	240.00	480.00	300.00	720.00	390.00	420.00	330.00	300.00	300.00	900.00	780.00
	Frequency (Times)	1.00	2.00	2.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
Fan	Time (min)	600.00	660.00	540.00	540.00	360.00	840.00	5.00	690.00	327.00	-	120.00	300.00	120.00	900.00	780.00
	Frequency (Times)	2.00	2.00	-	-	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	2.00	1.00	1.00
	Period	Day	Day	-	-	Day	Day	Day	Day	Day	-	Day	Day	Day	Day	Day
Bathing	Time (min)	15.00	10.00	30.00	30.00	10.00	15.00	10.00	30.00	25.00	30.00	15.00	10.00	10.00	30.00	30.00
	Frequency (Times)	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
Toilet	Time (min)	1.00	1.00	1.00	1.00	2.00	-	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00	2.00
	Frequency (Times)	10.00	6.00	4.00	4.00	4.00	-	3.00	3.00	2.00	3.00	3.00	4.00	3.00	3.00	2.00
	Period	Day	Day	Day	Day	-	-	Day	Day	Day	Day	Day	Day	Day	Day	Day
Hair drying	Time (min)	10.00	5.00	15.00	15.00	-	-	5.00	-	5.00	-	-	-	3.00	5.00	-
	Frequency (Times)	0.43	0.57	1.00	1.00	-	-	0.14	-	1.00	-	-	-	1.00	2.00	-
	Period	Day	Day	Day	Day	-	-	Day	-	Day	-	-	-	Day	Day	-
Washer	Time (min)	45.00	30.00	-	50.00	-	-	-	60.00	50.00	-	-	-	45.00	45.00	-
	Frequency (Times)	3.00	2.00	-	2.00	-	-	-	1.00	1.00	-	-	-	1.00	1.00	-
	Period	Week	Week	-	Week	-	-	-	Week	Week	-	-	-	Week	Week	-
Iron	Time (min)	60.00	60.00	-	-	-	-	10.00	5.00	5.00	5.00	10.00	10.00	60.00	-	-
	Frequency (Times)	2.00	2.00	-	-	-	-	1.00	7.00	7.00	7.00	7.00	7.00	1.00	-	-
	Period	Week	Week	-	-	-	-	Week	Week	Week	Week	Week	Week	Week	-	-

Table 4.36 (Cont.)

Building		**GH1**		**GH2**		**SH1**			**SH2**				**HH1**		**HH2**	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Rice cook	Time (min)	30.00	20.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	0.71	2.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Period	Day	Day	-	-	-	-	-	-	-	-	-	-	-	-	-
Microwave	Time (min)	10.00	2.00	2.00	2.00	2.00	6.00	5.00	-	-	-	-	-	-	-	30.00
	Frequency (Times)	4.00	5.00	1.00	1.00	14.00	14.00	2.00	-	-	-	-	-	-	-	5.00
	Period	Week	Week	Week	Week	Week	Week	Week	-	-	-	-	-	-	-	Week
Water boiling	Time (min)	5.00	15.00	5.00	5.00	-	-	3.00	5.00	-	-	-	-	-	-	-
	Frequency (Times)	1.00	1.00	1.00	1.00	-	-	2.00	1.00	-	-	-	-	-	-	-
	Period	Day	Day	Day	Day	-	-	Day	Day	-	-	-	-	-	-	-
Mixer	Time (min)	10.00	-	3.00	3.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	5.00	-	0.50	0.50	-	-	-	-	-	-	-	-	-	-	-
	Period	Week	-	Week	Week	-	-	-	-	-	-	-	-	-	-	-
TV	Time (min)	-	60.00	180.00	180.00	-	-	-	-	-	-	-	-	-	60.00	120.00
	Frequency (Times)	-	0.43	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00
	Period	-	Day	Day	Day	-	-	-	-	-	-	-	-	-	Day	Day
Eating	Time (min)	30.00	25.00	25.00	25.00	25.00	30.00	20.00	20.00	25.00	25.00	15.00	30.00	-	15.00	20.00
	Frequency (Times)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00	3.00	-	2.00	0.71
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	-	Day	Day
Washing dish	Time (min)	10.00	15.00	5.00	5.00	1.00	5.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00	5.00	20.00
	Frequency (Times)	2.00	2.00	2.00	2.00	2.00	2.00	-	1.00	1.00	1.00	2.00	2.00	2.00	2.00	0.29
	Period	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	Day	Day	Day	Day	Day

Table 4.36 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Gardening	Time (min)	-	30.00	30.00	30.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	-	0.57	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Period	-	Day	Day	Day	-	-	-	-	-	-	-	-	-	-	-
Wash car	Time (min)	-	30.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-
	Period	-	Week	-	-	-	-	-	-	-	-	-	-	-	-	-
Pet	Time (min)	30.00	-	30.00	30.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	1.00	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Period	Week	-	Week	Week	-	-	-	-	-	-	-	-	-	-	-
Cooking	Time (min)	45.00	45.00	60.00	60.00	35.00	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	2.00	1.00	2.00	2.00	2.00	-	-	-	-	-	-	-	-	-	-
	Period	Day	Day	Day	Day	Day	-	-	-	-	-	-	-	-	-	-

An analysis was conducted on the amount of energy usage, water consumption, and waste generation for each individual consumer within a building, in order to distinguish usage patterns and create customer profiles for all buildings with regards to their resource consumption. The quantity of energy usage and waste generation was compared across all customer profiles. To conduct this analysis, activity, and device usage data from each individual consumer at the time of measurement was collected, as presented in Table 4.35 and Table 4.36. The percentage of energy usage and waste generation was then determined and adjusted accordingly for each individual consumer. The analysis was performed using two methods: analyzing usage patterns for each individual consumer with respect to the type of community resource consumed, and analyzing activities in which energy, water, and waste were generated by each individual consumer through the use of community resources.

An analysis was conducted on the energy consumption of consumer 1 within GH1, as shown in Figure 4.68. It was found that the activity with the highest and most sustained energy usage was the use of the refrigerator (GH1CP12-RE), with an average consumption of 32.75 Wh (SD = 5.99) throughout the day. The next activity with the highest energy consumption was the use of electric lighting (GH1CP12-LT), which occurred during 6:00 – 8:00 and 18:00 – 23:45 with an average electricity consumption of 10.19 Wh (SD = 4.98). The third activity was the use of a fan (GH1CP12-FA), which was divided into three time periods according to the frequency of the activity occurring within the building, with an average energy consumption of 4.02 Wh (SD = 2.12) during each period. Other activities with lower energy consumption included bathing (2.15 Wh, SD = 0.82), cooking rice (1.27 Wh, SD = 0.30), laundry (1.18 Wh, SD = 0.28), washing clothes (0.40 Wh, SD = 0.07), hair drying (0.27 Wh, SD = 0.05), TV viewing (0.16 Wh, SD = 0.05), and using a microwave (0.16 Wh, SD = 0.05).

It should be noted that the quantity of energy used within a building by the first consumer is generally higher than that of the second consumer, with almost all activities except for the use of refrigerators. This is due to the fact that the second consumer has an additional cake refrigerator, which is an electrical appliance that operates continuously and has a relatively high power consumption rate. Consequently, this has an impact on the energy usage pattern of the second consumer, as depicted in Figure 4.69. The average energy consumption for the refrigerator throughout the day was found to be 26.12 Wh with a standard deviation (SD) of 4.77, while for the cake refrigerator, it was 52.15 Wh with an SD of 9.53. On the other hand, the average energy consumption for other activities throughout the day was found to be 9.53, 4.15, 1.00, 0.83, 0.71, 0.31, 0.30, and 0.24 Wh with SDs of 4.73, 0.95, 0.15, 0.15, 0.21, 0.06, 0.08, and 0.02, respectively, in the order of turning on lights, taking a shower, washing clothes, doing laundry, cooking rice, blow-drying hair, using a microwave, and boiling water.

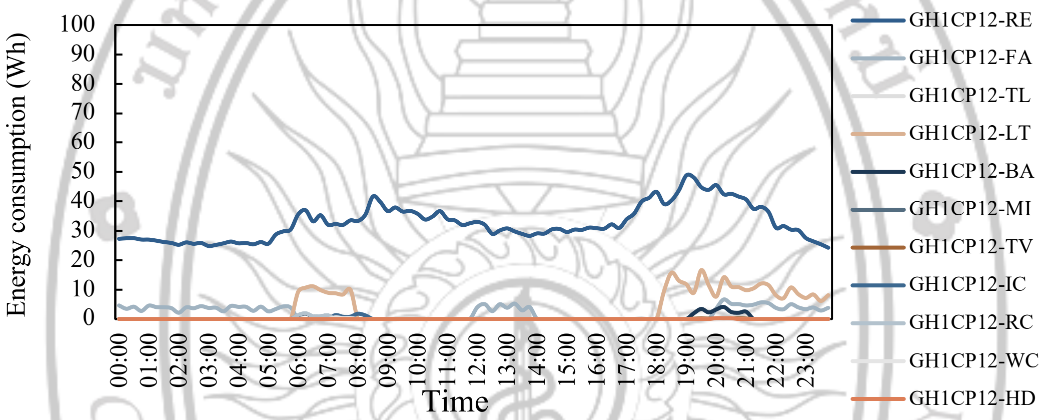


Figure 4.68 Energy consumption of each activity by 1st consumer in GH1

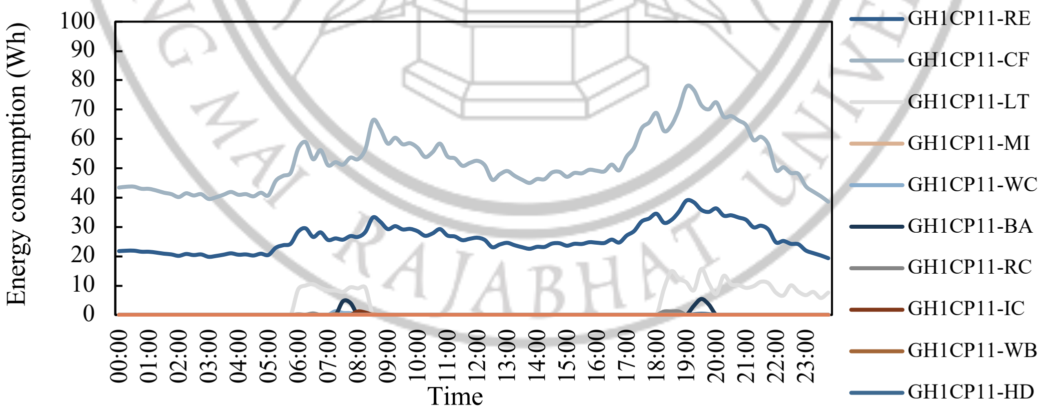


Figure 4.69 Energy consumption of each activity by 2nd consumer in GH1

Water consumption quantities of each activity by each user as shown in Figure 4.70 and Figure 4.71, it was found that water was used during activity periods within the buildings by all users. Upon considering the average water usage of the first user for each of the 10 activities, namely watering and caring for plants, boiling water, cooking rice, bathing, cooking, dishwashing, eating, using the bathroom, doing laundry, and washing the car, the values were 6.05, 5.91, 5.91, 5.07, 4.51, 4.21, 3.78, 3.08, 3.07, and 2.86 liters, respectively, with a standard deviation of 1.77, 1.57, 1.57, 2.01, 1.47, 1.92, 1.57, 2.39, 0.57, and 0.72. However, for the second user, water was used in all 6 activities within the buildings, namely using the bathroom, cooking rice, eating, doing laundry, bathing, and cooking, with an average water usage of 3.71, 3.66, 2.63, 2.61, 2.13, and 0.49 liters, respectively, and a standard deviation of 1.22, 0.90, 1.12, 0.52, 0.49, and 0.12, respectively. Upon analyzing the water usage quantities of the same activity by both users, it was found that the first user used slightly more water than the second user. It should be noted that the water usage quantity for each activity varied depending on the activity duration.

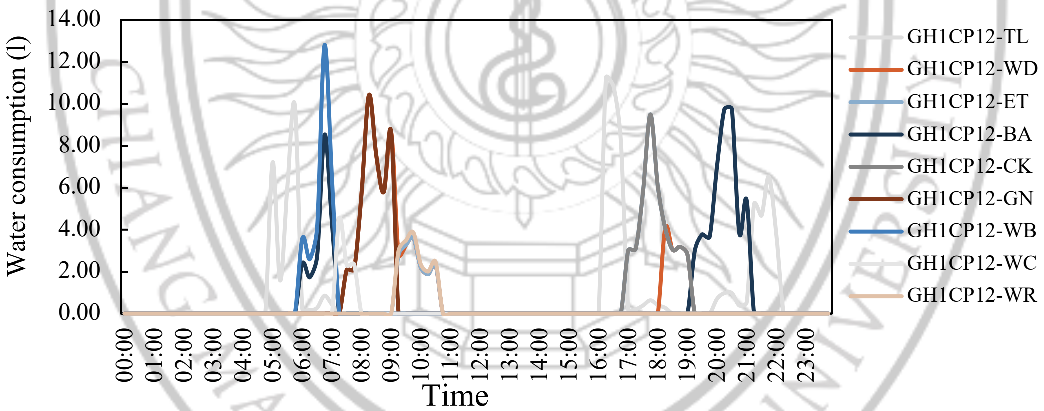


Figure 4.70 Water consumption of each activity by 1st consumer in GH1

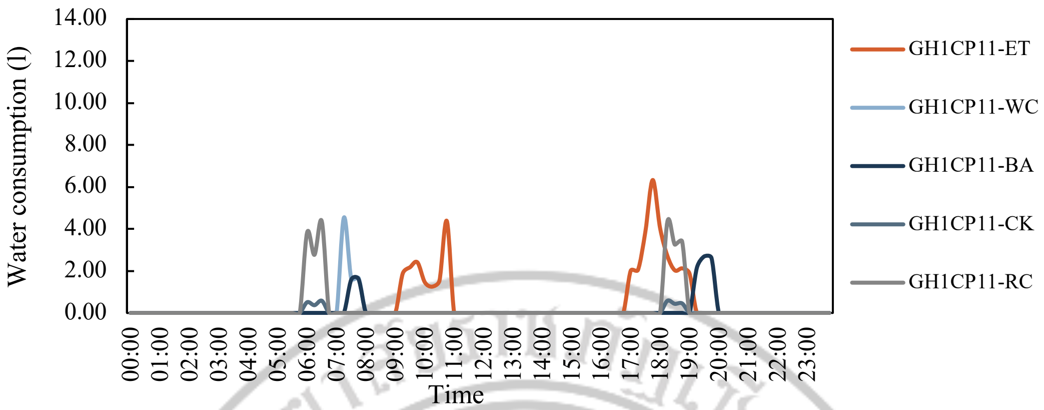


Figure 4.71 Water consumption of each activity by 2nd consumer in GH1

The quantity of waste generated within the building by each user, classified by waste type as depicted in Figure 4.72 and Figure 4.73, was analyzed. The average general waste generated for user 1 and user 2 was found to be 0.01 kg and 0.006 kg, respectively. Figure 4.74 and Figure 4.75 display the amount of organic waste generated, whereas Figure 4.76 and Figure 4.77 show the amount of recyclable waste. The quantity of waste generated fluctuates considerably and varies according to the timing of different activities carried out within the building. The average organic waste generation of 0.001 kg and recyclable waste generation of 0.002 kg for both users showed similar patterns of variability in waste generation.

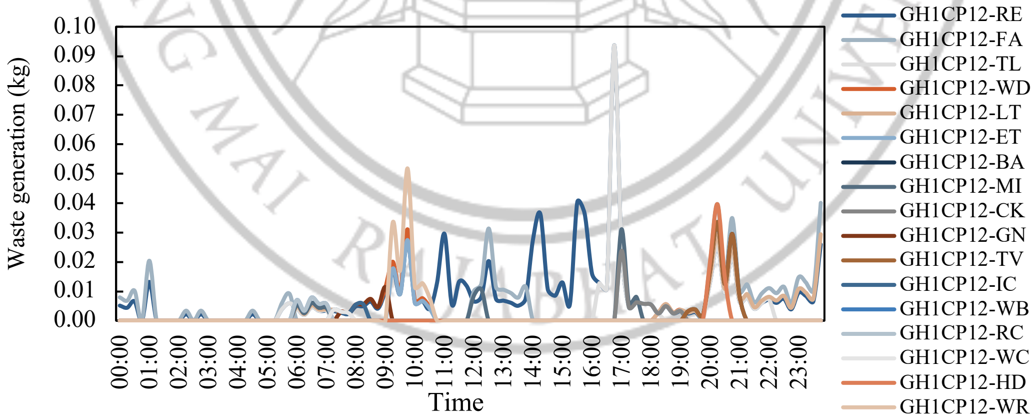


Figure 4.72 General waste generation of each activity by 1st consumer in GH1

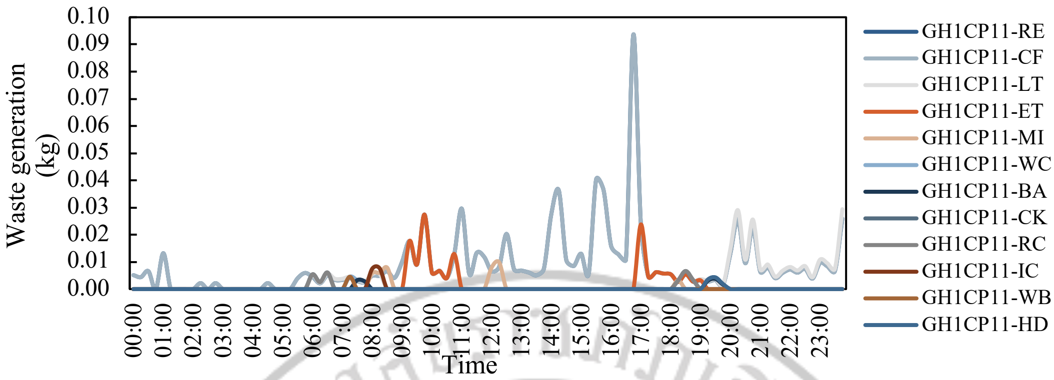


Figure 4.73 General waste generation of each activity by 2nd consumer in GH1

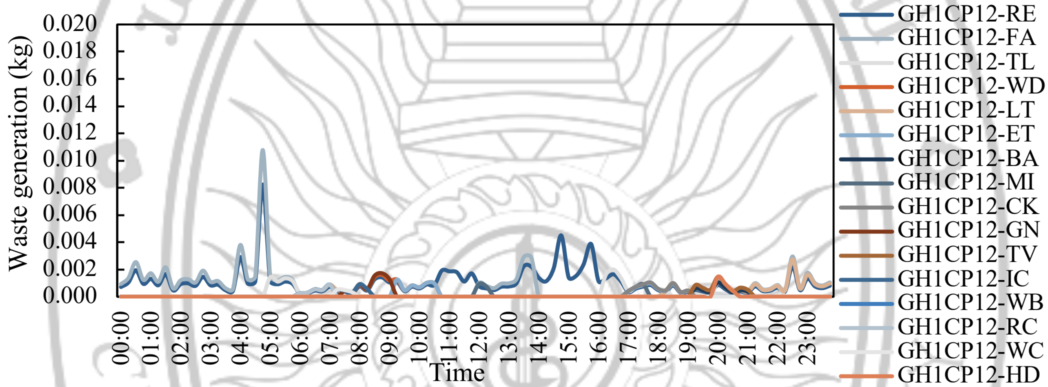


Figure 4.74 Organic waste generation of each activity by 1st consumer in GH1

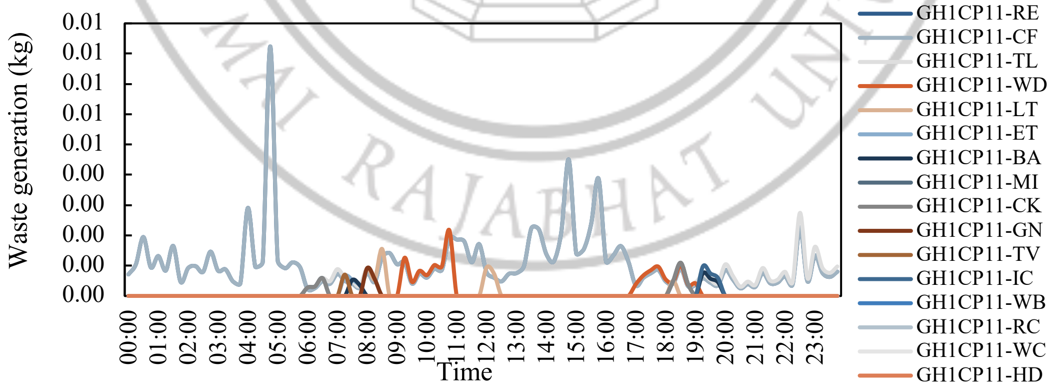


Figure 4.75 Organic waste generation of each activity by 2nd consumer in GH1

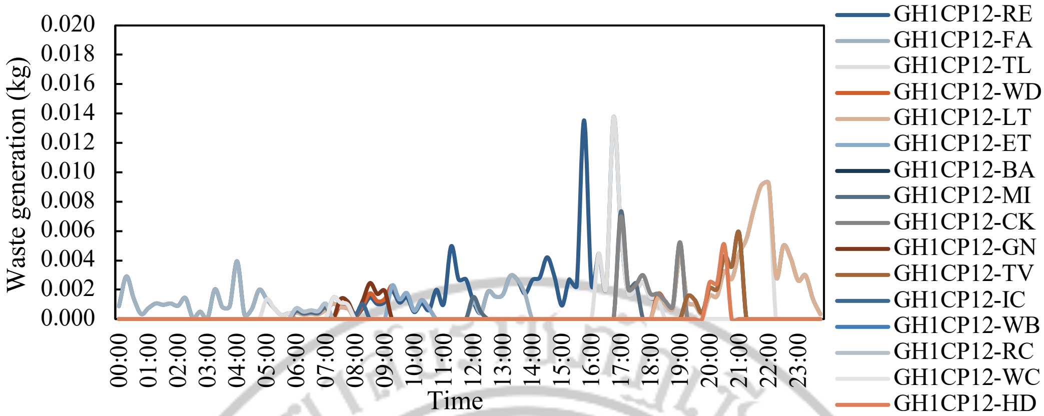


Figure 4.76 Recycle waste generation of each activity by 1st consumer in GH1

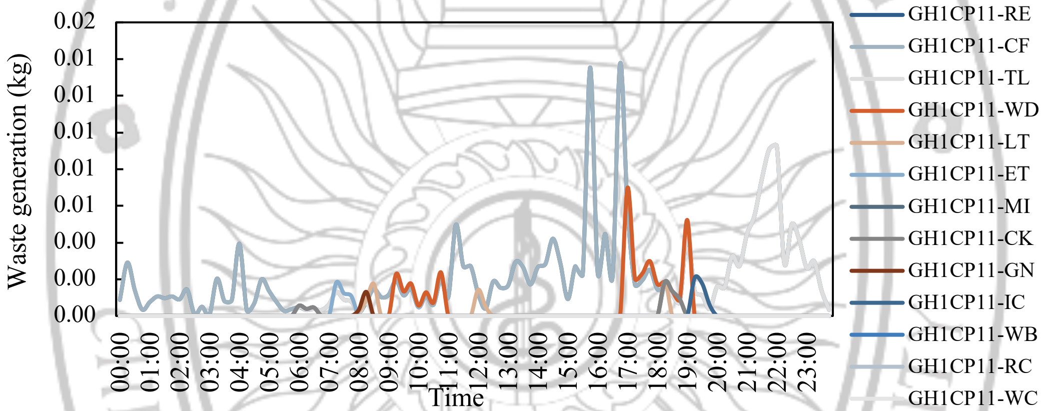


Figure 4.77 Recycle waste generation of each activity by 2nd consumer in GH1

The quantities of energy consumption, water usage, and waste generation that arise from the activities of each individual user residing in each building are displayed in the data. These quantities are calculated from the usage behaviors of both energy and water, as indicated by the trends of the data sets that point in the same direction within each group of buildings. These quantities are presented in Table 4.37. It should be noted that the amount of energy consumed by users residing in the same building and engaging in similar activities is likely to be similar due to the shared use of certain types of electrical appliances, although it may vary among users due to differences in the duration of their activities.

Table 4.37 Energy consumption of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	26.12	32.75	11.38	11.38	21.05	-	-	10.10	10.10	10.10	11.20	15.62	15.62	21.48	17.98
	SD	4.77	5.99	5.88	5.88	8.98	-	-	2.68	2.68	2.68	4.11	5.89	5.89	11.89	9.80
FA	Avr.	-	4.02	1.97	1.97	1.08	1.55	-	1.32	0.62	-	10.10	0.36	0.40	9.27	8.83
	SD	-	2.12	0.98	0.98	0.51	0.90	-	0.57	0.27	-	2.68	0.19	0.19	6.42	4.67
TL	Avr.	-	0.00	0.00	0.00	0.01	-	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
	SD	-	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
WD	Avr.	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-
LT	Avr.	9.55	10.19	5.63	5.90	0.92	0.83	3.85	6.55	3.51	3.46	-	1.19	1.09	16.55	15.68
	SD	4.74	4.98	2.87	3.02	0.40	0.44	1.70	3.02	1.59	1.63	-	0.64	0.63	11.29	8.37
ET	Avr.	-	-	-	-	-	-	-	-	-	-	2.53	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	1.41	-	-	-	-
BA	Avr.	4.17	2.15	5.83	5.83	-	-	-	-	-	-	-	2.56	2.33	26.24	13.60
	SD	0.95	0.82	1.45	1.45	-	-	-	-	-	-	-	0.71	0.64	11.39	3.50
MI	Avr.	0.30	0.04	-	-	1.04	1.09	0.59	-	-	-	-	-	-	-	-
	SD	0.08	0.01	-	-	0.25	0.33	0.15	-	-	-	-	-	-	-	-
CK	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GN	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.37 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	-	0.16	0.87	0.87	-	-	-	-	-	-	-	-	-	0.79	0.76
	SD	-	0.05	0.32	0.32	-	-	-	-	-	-	-	-	-	0.21	0.27
IC	Avr.	1.00	1.18	-	-	-	-	0.42	0.60	0.59	0.60	-	0.77	0.98	-	-
	SD	0.15	0.28	-	-	-	-	0.07	0.11	0.10	0.10	-	0.19	0.17	-	-
WB	Avr.	0.24	-	0.15	0.15	-	-	1.64	-	-	-	0.65	-	-	-	-
	SD	0.02	-	0.03	0.03	-	-	0.43	-	-	-	0.22	-	-	-	-
RC	Avr.	0.71	1.27	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.21	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	0.84	0.40	-	0.38	-	-	-	0.25	0.21	-	-	-	-	0.68	0.34
	SD	0.16	0.07	-	0.08	-	-	-	0.06	0.05	-	-	-	-	0.22	0.07
HD	Avr.	0.31	0.27	0.88	0.88	-	-	-	-	0.41	-	-	-	-	-	1.64
	SD	0.06	0.05	0.22	0.22	-	-	-	-	0.07	-	-	-	-	-	0.42
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	52.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	9.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.38 Water consumption of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FA	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TL	Avr.	3.71	3.08	0.12	0.12	2.35	3.57	2.01	7.75	1.98	2.73	2.73	18.69	11.92	0.87	0.34
	SD	1.22	2.39	0.04	0.04	0.79	0.88	0.67	3.06	0.91	0.90	0.90	8.66	8.34	0.46	0.09
WD	Avr.	-	4.14	2.72	1.81	1.33	1.23	2.01	1.88	2.14	1.20	1.20	-	17.09	11.11	3.78
	SD	-	1.92	1.27	0.85	0.35	0.41	0.63	0.36	0.40	0.21	0.21	-	4.16	3.33	1.22
LT	Avr.	-	-	-	-	2.84	2.80	2.24	-	-	-	-	-	-	-	-
	SD	-	-	-	-	1.35	1.87	1.14	-	-	-	-	-	-	-	-
ET	Avr.	2.63	3.78	2.72	2.72	1.33	1.23	2.73	9.62	7.20	6.02	3.61	-	26.08	11.11	5.67
	SD	1.12	1.57	1.27	1.27	0.35	0.41	0.83	2.57	1.65	1.06	0.64	-	7.70	3.33	1.84
BA	Avr.	2.13	4.63	1.23	1.84	1.95	2.57	1.63	20.71	10.02	19.08	9.54	33.16	64.02	8.68	5.03
	SD	0.49	1.95	0.40	0.61	0.56	0.96	0.43	5.53	1.76	5.16	2.58	8.89	15.64	4.57	1.34
MI	Avr.	-	-	-	-	1.33	1.23	2.58	-	-	-	-	-	-	-	-
	SD	-	-	-	-	0.35	0.41	0.83	-	-	-	-	-	-	-	-
CK	Avr.	0.49	4.51	2.88	2.88	1.33	-	-	-	-	-	-	-	-	-	4.25
	SD	0.12	1.47	1.22	1.22	0.35	-	-	-	-	-	-	-	-	-	1.30
GN	Avr.	-	5.87	3.75	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	1.76	1.39	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.38 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IC	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB	Avr.	-	5.91	3.93	1.31	-	-	1.63	-	-	-	-	-	-	-	1.51
	SD	-	1.57	0.69	0.23	-	-	0.43	-	-	-	-	-	-	-	0.27
RC	Avr.	3.66	5.91	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.90	1.57	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	2.61	2.61	6.72	6.72	-	-	-	8.60	7.22	-	-	43.06	-	10.20	4.47
	SD	0.52	0.52	1.37	1.37	-	-	-	2.02	1.70	-	-	9.47	-	3.47	0.83
HD	Avr.	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	0.32	-	-	-	-	-	-	-	-
WR	Avr.	-	2.86	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.72	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.39 General waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0107	0.0107	0.0217	0.0217	0.0026	-	-	0.0075	0.0075	0.0075	0.0075	0.0027	0.0027	0.0035	0.0020
	SD	0.0123	0.0123	0.0383	0.0383	0.0040	-	-	0.0101	0.0101	0.0101	0.0101	0.0037	0.0037	0.0053	0.0019
FA	Avr.	-	0.0133	0.0079	-	0.0002	0.0017	-	0.0026	-	-	-	0.0017	0.0007	0.0020	0.0032
	SD	-	0.0085	0.0063	-	0.0000	0.0023	-	0.0016	-	-	-	0.0014	0.0005	0.0019	0.0018
TL	Avr.	-	0.0119	0.0030	0.0030	0.0009	0.0009	0.0002	0.0032	-	0.0032	0.0032	0.0030	0.0009	0.0011	0.0010
	SD	-	0.0106	0.0008	0.0008	0.0004	0.0003	0.0001	0.0013	-	0.0010	0.0010	0.0011	0.0004	0.0005	0.0002
WD	Avr.	-	0.0081	0.0037	0.0037	0.0010	0.0008	0.0009	0.0026	-	0.0043	0.0043	-	0.0011	0.0025	0.0016
	SD	-	0.0043	0.0019	0.0019	0.0003	0.0004	0.0003	0.0005	-	0.0008	0.0008	-	0.0003	0.0008	0.0007
LT	Avr.	0.0079	0.0080	0.0075	0.0075	0.0002	0.0004	0.0004	0.0046	-	0.0048	0.0048	0.0005	0.0006	0.0017	0.0008
	SD	0.0056	0.0056	0.0069	0.0069	0.0001	0.0004	0.0003	0.0050	-	0.0051	0.0051	0.0005	0.0006	0.0017	0.0004
ET	Avr.	0.0090	0.0087	0.0037	0.0037	0.0010	0.0008	0.0012	0.0182	-	0.0043	0.0043	-	0.0011	0.0025	0.0016
	SD	0.0045	0.0044	0.0019	0.0019	0.0003	0.0004	0.0004	0.0047	-	0.0008	0.0008	-	0.0004	0.0008	0.0007
BA	Avr.	0.0029	0.0104	0.0030	0.0030	0.0011	0.0006	0.0001	0.0113	-	0.0027	0.0027	0.0034	0.0014	0.0011	0.0010
	SD	0.0007	0.0051	0.0008	0.0008	0.0003	0.0003	0.0000	0.0048	-	0.0007	0.0007	0.0010	0.0004	0.0005	0.0002
MI	Avr.	0.0068	0.0088	-	-	0.0010	0.0008	0.0010	-	-	-	-	-	-	-	-
	SD	0.0017	0.0037	-	-	0.0003	0.0004	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0045	0.0066	0.0207	0.0207	0.0010	-	-	-	-	-	-	-	-	-	0.0011
	SD	0.0012	0.0027	0.0110	0.0110	0.0003	-	-	-	-	-	-	-	-	-	0.0004
GN	Avr.	-	0.0058	0.0042	0.0042	-	-	-	-	-	-	-	-	-	-	0.0010
	SD	-	0.0017	0.0013	0.0013	-	-	-	-	-	-	-	-	-	-	0.0003

Table 4.39 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	-	0.0139	0.0080	0.0080	-	-	-	-	-	-	-	-	-	0.0009	0.0017
	SD	-	0.0051	0.0046	0.0046	-	-	-	-	-	-	-	-	-	0.0003	0.0007
IC	Avr.	0.0076	0.0044	-	-	-	-	0.0001	0.0040	-	0.0221	0.0221	0.0029	0.0015	-	-
	SD	0.0011	0.0010	-	-	-	-	0.0000	0.0007	-	0.0043	0.0043	0.0007	0.0003	-	-
WB	Avr.	0.0045	0.0062	0.0498	0.0498	-	-	0.0001	-	-	-	-	-	-	-	0.0018
	SD	0.0005	0.0014	0.0094	0.0094	-	-	0.0000	-	-	-	-	-	-	-	0.0003
RC	Avr.	0.0045	0.0062	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0012	0.0014	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	0.0036	0.0036	0.0246	0.0246	-	-	-	0.0432	-	-	-	0.0022	-	0.0011	0.0013
	SD	0.0006	0.0006	0.0087	0.0087	-	-	-	0.0084	-	-	-	0.0006	-	0.0005	0.0003
HD	Avr.	0.0033	0.0249	0.0213	0.0213	-	-	0.0002	0.0017	-	-	-	0.0024	-	0.0011	0.0011
	SD	0.0006	0.0047	0.0094	0.0094	-	-	0.0000	0.0003	-	-	-	0.0005	-	0.0005	0.0003
WR	Avr.	-	0.0224	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0067	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0107	-	-	0.0079	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0123	-	-	0.0063	-	-	-	-	-	-	-	-	-	-	-

Table 4.40 Organic waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0011	0.0011	0.0334	0.0334	0.0029	-	-	0.0026	0.0026	0.0026	0.0026	0.0019	0.0019	0.0014	0.0021
	SD	0.0010	0.0010	0.0376	0.0376	0.0048	-	-	0.0013	0.0013	0.0013	0.0013	0.0023	0.0023	0.0018	0.0026
FA	Avr.	-	0.0014	0.0381	0.0381	0.0006	0.0005	-	0.0009	0.0008	-	-	0.0013	0.0017	0.0008	0.0018
	SD	-	0.0013	0.0108	0.0108	0.0003	0.0004	-	0.0002	0.0001	-	-	0.0009	0.0015	0.0007	0.0012
TL	Avr.	0.0007	0.0008	0.0026	0.0026	0.0005	-	0.0007	0.0009	0.0120	0.0013	0.0013	0.0015	0.0028	0.0005	0.0007
	SD	0.0004	0.0004	0.0006	0.0006	0.0002	-	0.0003	0.0001	0.0012	0.0002	0.0002	0.0004	0.0017	0.0002	0.0002
WD	Avr.	0.0008	0.0008	0.0050	0.0050	0.0005	0.0008	0.0006	-	-	-	-	-	0.0012	0.0011	0.0006
	SD	0.0004	0.0004	0.0012	0.0012	0.0001	0.0003	0.0002	-	-	-	-	-	0.0002	0.0004	0.0002
LT	Avr.	0.0009	0.0007	0.0213	0.0213	0.0013	0.0006	0.0005	0.0031	0.0036	0.0028	0.0028	0.0015	0.0013	0.0006	0.0007
	SD	0.0002	0.0004	0.0108	0.0108	0.0007	0.0004	0.0003	0.0012	0.0012	0.0012	0.0012	0.0015	0.0015	0.0004	0.0004
ET	Avr.	0.0005	0.0007	0.0050	0.0050	0.0005	0.0008	0.0011	0.0008	0.0008	-	-	-	0.0007	0.0011	0.0006
	SD	0.0001	0.0003	0.0012	0.0012	0.0001	0.0003	0.0003	0.0001	0.0001	-	-	-	0.0002	0.0004	0.0002
BA	Avr.	0.0005	0.0005	0.0026	0.0026	0.0004	0.0009	0.0013	0.0120	-	0.0007	0.0007	0.0001	0.0059	0.0005	0.0007
	SD	0.0001	0.0002	0.0006	0.0006	0.0001	0.0003	0.0003	0.0012	-	0.0001	0.0001	0.0000	0.0026	0.0002	0.0002
MI	Avr.	0.0005	0.0006	-	-	0.0005	0.0008	0.0009	-	-	-	-	-	-	-	-
	SD	0.0001	0.0002	-	-	0.0001	0.0003	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0005	0.0007	0.0026	0.0026	0.0005	-	-	-	-	-	-	-	-	-	0.0007
	SD	0.0001	0.0002	0.0006	0.0006	0.0001	-	-	-	-	-	-	-	-	-	0.0003
GN	Avr.	0.0007	0.0010	0.0314	0.0314	-	-	-	-	-	-	-	-	-	-	0.0009
	SD	0.0001	0.0003	0.0113	0.0113	-	-	-	-	-	-	-	-	-	-	0.0003

Table 4.40 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	0.0007	0.0008	0.0005	0.0005	-	-	-	-	-	-	-	-	-	0.0005	0.0008
	SD	0.0001	0.0002	0.0001	0.0001	-	-	-	-	-	-	-	-	-	0.0001	0.0003
IC	Avr.	0.0008	0.0006	-	-	-	-	0.0018	0.0007	0.0007	-	-	0.0005	0.0002	-	-
	SD	0.0001	0.0001	-	-	-	-	0.0002	0.0001	0.0001	-	-	0.0002	0.0000	-	-
WB	Avr.	-	0.0005	0.0056	0.0056	-	-	0.0013	-	-	-	-	-	-	-	0.0012
	SD	-	0.0001	0.0009	0.0009	-	-	0.0003	-	-	-	-	-	-	-	0.0002
RC	Avr.	-	0.0005	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0001	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	-	0.0005	-	-	-	-	-	0.0013	0.0013	-	-	0.0007	-	0.0005	0.0009
	SD	-	0.0001	-	-	-	-	-	0.0001	0.0001	-	-	0.0002	-	0.0002	0.0002
HD	Avr.	-	0.0009	0.0031	0.0031	-	-	0.0054	-	-	-	-	0.0056	-	0.0005	0.0007
	SD	-	0.0002	0.0006	0.0006	-	-	0.0008	-	-	-	-	0.0006	-	0.0002	0.0002
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0010	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.41 Recycle waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0022	0.0022	0.0150	0.0150	0.0032	-	-	0.0074	0.0032	0.0032	0.0032	0.0009	0.0009	0.0012	0.0010
	SD	0.0024	0.0024	0.0163	0.0163	0.0036	-	-	0.0089	0.0039	0.0039	0.0039	-	-	0.0018	0.0011
FA	Avr.	-	0.0022	0.0021	0.0021	0.0025	0.0015	-	0.0034	0.0015	-	-	0.0098	0.0079	0.0001	0.0008
	SD	-	0.0019	0.0005	0.0005	0.0014	0.0015	-	0.0014	0.0006	-	-	-	-	0.0001	0.0005
TL	Avr.	0.0025	0.0032	0.0007	0.0007	0.0015	-	0.0010	0.0020	0.0009	0.0019	0.0019	-	0.0008	0.0001	0.0000
	SD	0.0019	0.0023	0.0001	0.0001	0.0006	-	0.0003	0.0005	0.0002	0.0005	0.0005	-	-	0.0000	0.0000
WD	Avr.	0.0022	0.0015	0.0203	0.0203	0.0005	0.0007	0.0010	0.0136	0.0018	0.0057	0.0057	-	0.0009	0.0002	0.0001
	SD	0.0011	0.0007	0.0081	0.0081	0.0001	0.0002	0.0003	0.0024	0.0003	0.0010	0.0010	-	-	0.0001	0.0000
LT	Avr.	0.0011	0.0026	0.0076	0.0076	0.0007	0.0008	0.0010	0.0033	0.0015	0.0016	0.0016	0.0004	0.0019	0.0001	0.0001
	SD	0.0003	0.0019	0.0062	0.0062	0.0003	0.0006	0.0005	0.0014	0.0006	0.0007	0.0007	-	-	0.0001	0.0001
ET	Avr.	0.0014	0.0022	0.0203	0.0203	0.0005	0.0007	0.0011	0.0045	0.0030	0.0057	0.0057	-	0.0009	0.0002	0.0001
	SD	0.0002	0.0010	0.0081	0.0081	0.0001	0.0002	0.0003	0.0010	0.0007	0.0010	0.0010	-	-	0.0001	0.0000
BA	Avr.	0.0014	0.0019	0.0007	0.0007	0.0008	0.0007	0.0007	0.0029	0.0009	0.0026	0.0026	-	0.0011	0.0001	0.0000
	SD	0.0003	0.0009	0.0001	0.0001	0.0002	0.0002	0.0002	0.0006	0.0002	0.0004	0.0004	-	-	0.0000	0.0000
MI	Avr.	0.0009	0.0017	-	-	0.0005	0.0007	0.0011	-	-	-	-	-	-	-	-
	SD	0.0003	0.0008	-	-	0.0001	0.0002	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0009	0.0028	0.0021	0.0021	0.0005	-	-	-	-	-	-	-	-	-	0.0001
	SD	0.0003	0.0010	0.0007	0.0007	0.0001	-	-	-	-	-	-	-	-	-	0.0000
GN	Avr.	0.0008	0.0015	0.0244	0.0244	-	-	-	-	-	-	-	-	-	-	0.0002
	SD	0.0001	0.0004	0.0062	0.0062	-	-	-	-	-	-	-	-	-	-	0.0001

Table 4.41 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	0.0018	0.0027	0.0011	0.0011	-	-	-	-	-	-	-	-	-	0.0001	0.0001
	SD	0.0002	0.0009	0.0002	0.0002	-	-	-	-	-	-	-	-	-	0.0000	0.0000
IC	Avr.	0.0015	0.0011	-	-	-	-	0.0007	0.0097	-	0.0019	0.0019	0.0002	-	-	-
	SD	0.0003	0.0003	-	-	-	-	0.0001	0.0010	-	0.0003	0.0003	-	-	-	-
WB	Avr.	-	0.0007	0.0079	0.0079	-	-	0.0007	-	-	-	-	-	-	-	0.0000
	SD	-	0.0002	0.0014	0.0014	-	-	0.0002	-	-	-	-	-	-	-	0.0000
RC	Avr.	-	0.0007	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	-	0.0014	0.0041	0.0041	-	-	-	0.0077	0.0030	-	-	0.0002	-	0.0000	0.0000
	SD	-	0.0002	0.0006	0.0006	-	-	-	0.0023	0.0010	-	-	-	-	0.0000	0.0000
HD	Avr.	-	0.0033	0.0040	0.0040	-	-	0.0009	0.0059	0.0043	-	-	0.0015	-	0.0001	0.0000
	SD	-	0.0006	0.0006	0.0006	-	-	0.0002	0.0010	0.0004	-	-	-	-	0.0000	0.0000
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0022	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0024	-	-	-	-	-	-	-	-	-	-	-	-	-	-

5. Relationship of building activity

The relationship between energy, water, and waste is analyzed in two parts in this study, which include the overall relationship and the relationship within activities. Specifically, the relationship between energy, water, and waste data with respect to each building is examined, as well as the relationship between energy, water, and waste data based on the activities that occur within each building.

5.1 The relationship in each building

When data related to energy consumption, water usage, and waste generation across various consumer groups are analyzed, the relationships between these factors are often studied. Such an analysis can be divided into four distinct groups: the relationship between Energy and Water, Energy and Waste, Water and Waste, and the overall relationship between Energy, Water, and Waste.

To study the patterns and trends in the relationships between energy, water, and waste data, statistical techniques are used by researchers to identify correlations between the variables. Correlations help to identify the strength and direction of the relationship between two variables. For example, a positive correlation between energy and water usage would suggest that as energy usage increases, so does water usage. In contrast, a negative correlation between energy and waste generation would suggest that as energy usage increases, waste generation decreases.

When data within different buildings or consumer groups are compared, different patterns of correlations are often found by researchers. For example, in a study of six different buildings, it was found that there was a correlation only between energy and water at a level of 0.109 in GH1. In contrast, GH2 had a negative correlation between energy and waste generation at a level of 0.028. Similarly, two positive correlations were found in SH1: one between energy and water usage at a level of 0.022 and another between water usage and waste generation at a level of 0.023. SH2 had three different correlations: energy to water usage at a level of 0.082, energy to waste generation at a level of 0.037, and water usage to waste generation at a level of 0.023. HH1 and HH2 also had two positive correlations each: one between energy and water usage at levels of 0.102 and 0.300, respectively, and another between water usage and waste generation at levels of 0.090 and 0.018, respectively.

Furthermore, it is important to note that the relationships between energy, water, and waste usage within each building or consumer group also have external relationships with other buildings or consumer groups. For instance, energy usage in one building may be correlated with energy usage in other buildings, whereas water usage in one building may not be as strongly correlated with water usage in other buildings. When correlation pairs across all six buildings are examined, it is found that all three variables have statistically significant relationships, which form a complex web of interrelated factors.

In conclusion, valuable insights into patterns of resource usage and sustainability are provided by studying the relationships between energy, water, and waste usage across different consumer groups and buildings. The use of statistical techniques to identify correlations between variables can help researchers to identify areas where improvements in resource usage can be made.

5.2 The relationship based on the activities

From the data on energy consumption, water usage, and waste generation of each activity by each user, when analyzed for the relationship between energy, water, and waste as shown in Table 4.42 to Table 4.45, the behavior of actual activities within the building can be divided into two groups. The first group consists of activities that have continuous and long durations, such as using a refrigerator, turning on a fan, turning on lights, and watching television. The second group consists of activities that occur at certain intervals, such as taking a shower, using the bathroom, blow-drying hair, cooking, and eating. When analyzed, it can be seen that activities with long durations are the only ones that use electricity exclusively, which affects the amount of energy consumed within the building. When data from all three areas are analyzed, it is found that all three activities have a statistically significant relationship with each other, since the behavior of using water and disposing of waste within the building occurs during the aforementioned activities, leading to an increase in the level of correlation. Based on the data, it is found that energy usage within the building has a statistically significant relationship with waste generation within the building from activities such as using a refrigerator, turning on a fan, and turning on lights, with a mostly positive correlation. Furthermore, all three activities have a statistically significant relationship with waste generation within the building for all three types of waste, based on the data.

Upon consideration of the activities of the second group that occurred during a short period, it can be observed that each activity from each user had a different relationship level between energy, water, and waste. This is due to the type of housing, occupation, and age range, which differ as stated in the above information. These characteristics indicate that all individuals have an impact on the quantity and behavior within the building that affects the relationship level. From the activity data of using the bathroom and showering, it was found that all of them had a positive relationship level in all directions, both energy-water, energy-waste, water-waste, as well as the relationship between each type of waste, which is statistically significant.

Cooking activities have a relationship only in terms of water and waste. The relationship between water and waste is positive, and there is a significant relationship between each type of waste. This is due to the behavior of the residents within the building who mostly choose to use LPG gas as a fuel for cooking, which does not affect the amount of electricity used during the activity significantly. Therefore, it affects the relationship level between water and waste and waste to a moderate level. However, the use of fuel for cooking and lifestyle behavior still affects the relationship between energy, water, and waste that occur in rice cooking activities, as rice cooking activity is an activity that requires energy, water, and creates waste in a small amount, but this activity occurs frequently.

It was found that both the activity of boiling water and the use of a microwave had a significant statistical relationship with energy, water, and waste. Furthermore, there was a correlation between the different types of waste generated during each activity. Upon considering the activity of eating and dishwashing, it was found that both activities had a significant positive statistical correlation with water and waste, but there was little correlation between the two activities with respect to energy. Analyzing the conducted activities revealed that, in the sample group, the majority engaged in the activity of eating followed by dishwashing, and both activities were carried out by disposing of the remaining waste generated during eating before washing the utensils used for eating with water. From this observed behavior, it is evident that the activities were conducted only with the presence of water and waste. The low correlation with respect to energy is due to the fact that the activities do not require much energy, except for the use of light in the building. It is noteworthy that both eating and dishwashing activities typically occur in conjunction with turning on the lights, according to the behavioral data collected within the building. Therefore, the two activities have little statistical correlation with energy consumption.

The activity of laundry washing is another activity that has a relationship between energy and water, exclusively in a positive direction without any relationship to waste generation. Upon analysis of the activity characteristics, it can be observed that only two resources are utilized: water for cleaning clothes and electricity-powered washing machines to assist in the activity. This directly affects both relationships. Additionally, the relationship data shows that each type of waste generated during the activity is not affected by other factors and has its own level of correlation. Furthermore, the analysis of the laundry washing activity reveals that a significant amount of energy is utilized, resulting in waste generation during the activity. This is evident from the relationship data between energy and waste generated during the laundry washing activity, which shows a positive correlation. However, each type of waste generated during the activity is not correlated with each other, as observed from all user data. Consequently, the laundry washing activity only has a relationship between energy and waste generation in general.

The activity of watering plants has a relationship between energy and waste, water and waste, and the relationship within each type of waste. This is data that shows that all three relationships have a positive correlation. This is due to the fact that plant care activities involve using a large and continuous amount of water, which affects the amount of water used during the activity period. In addition, such activities involve trimming, weed removal, as well as rice collection or house cleaning, which increases the amount of waste in all three categories. However, due to the fact that the water used inside the building does not use a water pump that requires energy, this has an impact on the amount of energy used in such activities that is not related to energy.

Furthermore, data on energy consumption, water usage, and waste generation during hair blow-drying and dishwashing activities indicate that there is no correlation between energy, water, and waste in these activities. Statistical analysis concludes that both activities consume resources but are not related to each other.

Table 4.42 Energy, Water, Waste relationship in activity of refrigerator, fan toilet, and washing dish

Building (Consumer)	Resource	RE					FA					TL					WD				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-			-0.295**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	0.398**	-	-	-	-	-	-
	Gen-WE	-	-	-	-	0.540**	-	-	-	-	0.540**	-	-	-	-	-	-	-	-	-	-
	Org-WE	-0.295**	-	-	-	-	-	-	-	-	-	-	0.398**	-	-	0.567**	-	-	-	-	0.618**
	Rec-WE	-	-	0.540**	-	-	-	-	0.540**	-	-	-	-	-	0.567**	-	-	-	-	0.618**	-
GH1 (CP12)	EN	-	-	-	-0.295**	-	-	-	0.389**	0.328**	0.399**			0.337**	-	-	-	-	0.675**	0.253*	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.407**	0.800**	0.587**	-	-	0.419**	0.783**	0.606**
	Gen-WE	-	-	-	-	0.540**	0.389**	-	-	-	0.381**	0.337**	0.407**	-	0.519**	0.685**	0.675**	0.419**	-	0.689**	0.456**
	Org-WE	-0.295**	-	-	-	-	0.328**	-	-	-	0.292**	-	0.800**	0.519**	-	0.540**	0.253*	0.783**	0.689**	-	0.648**
	Rec-WE	-	-	0.540**	-	-	0.399**		0.381**	0.292**	-	-	0.587**	0.685**	0.540**	-	-	0.606**	0.456**	0.648**	-
GH2 (CP6)	EN	-	-	-	-	-	-	0.522**	-	-	0.222**	-	-	-	0.998**	-	-	-	-	0.994**	-
	WA	-	-	-	-	-	0.522**	-	-	-	-	-	-	0.693**	-	0.661**	-	-	0.765**	-	0.487**
	Gen-WE	-	-	-	-	-	-	-	-	-	0.488**	-	0.693**	-	-	-		0.765**	-	-	0.863**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.998**	-	-	-	-	0.994**	-	-	-	-
	Rec-WE	-	-	-	-	-	0.222*	-	0.488**	-	-	-	0.661**	-	-	-	-	0.487**	0.863**	-	-
GH2 (CP1)2	EN	-	-	-	-	-	-	0.522**	-	-	0.222**	-	-	-	0.998**	-	-	-	-	0.994**	-
	WA	-	-	-	-	-	0.522**	-	-	-	-	-	-	0.693**	-	0.661**	-	-	0.765**	-	0.487**
	Gen-WE	-	-	-	-	-	-	-	-	-	0.488**	-	0.693**	-	-	-	-	0.765**	-	-	0.863**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.998**	-	-	-	-	0.994**	-	-	-	-
	Rec-WE	-	-	-	-	-	0.222*	-	0.488**	-	-	-	0.661**	-	-	-	-	0.487**	0.863**	-	-
SH1 (CP3)	EN	-	-	-	0.392**	-	-	-	-	0.335**	0.378**	-	-	-	0.248*	0.327**	-	-	-	0.330**	0.838**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.486**	0.5911**	0.779**	-	-	0.490**	0.803**	0.454**
	Gen-WE	-	-	-	-	0.510**		-	-	-	-	-	0.489**	-	0.664**	0.467**	-	0.490**	-	0.674**	0.377**
	Org-WE	0.392**	-	-	-	-	0.335**	-	-	-	0.689**	0.248**	0.591**	0.664**	-	0.674	0.334**	0.803**	0.674**	-	0.674**
	Rec-WE	-	-	0.510**	-	-	0.378**	-		0.689**	-	0.327**	0.779**	0.467**	0.674**	-	0.838**	0.4554**	0.377**	0.674**	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	0.219*	0.409**	0.408*	-	-	0.925**	-	-	-	-	-	-	0.396**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.482**	0.625**	0.841**
	Gen-WE	-	-	-	-	-	0.219*	-	-	-	0.709**	-	0.925**	-	-	-	-	0.482**	-	0.57**	0.446**
	Org-WE	-	-	-	-	-	0.409**	-	-	-	-	-	-	-	-	-	-	0.625**	0.574**	-	0.720**
	Rec-WE	-	-	-	-	-	0.408**	-	0.709**		-	-	-	-	-	-	0.396**	0.841**	0.446**	0.720**	-
SH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	0.729**	0.545**	0.455**	0.788**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.729**	-	0.504**	0.605**	0.925**	-	-	0.550**	0.936**	0.922**
	Gen-WE	-	-	-	-	-	-	-	-	-	-	0.545**	0.504**	-	-	0.745**	-	0.550**	-	0.761**	0.621**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0455**	0.605**	-	-	0.389**	-	0.936**	0.761**	-	0.925**
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.788**	0.25**	0.754**	0.389**	-	-	0.922**	0.621**	0.925**	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	0.455**	-	0.360**	-	0.663**	0.594**	0.255*	0.679**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.663**	-	0.262**	0.344**	0.525**	-	-	0.908**	-	0.909**
	Gen-WE	-	-	-	0.355**	-	0.455**	-	-	0.219*	0.528**	0.594**	0.262**	-	-	0.242**	-	0.908**	-	-	0.976**
	Org-WE	-	-	0.355**	-	-	-	-	0.219*	-	0.203*	0.255*	0.344**	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	0.360**	-	0.528**	0.203*	-	0.679**	0.525**	0.242**	-	-	-	0.909**	0.976**	-	-

Table 4.42 (Cont.)

Building (Consumer)	Resource	RE					FA					TL					WD				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.509**	-	0.356**	0.639**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.509**	-	-	-	0.502**	-	-	-	-	0.927**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	0.356**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.639**	0.520**	-	-	-	-	0.927**	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.578**	0.661**	0.397**	0.858**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.578**	-	0.770**	0.854**	0.767**	-	-	0.909**	-	0.994**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	0.661**	0.770**	-	0.864**	0.678**	-	0.909**	-	-	0.906**
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	0.397**	0.854**	0.864**		0.676**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.858**	0.767**	0.678**	0.676**	-	-	0.994**	0.906**	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0..770**	0.854**	0.764**	-	-	0.909**	-	0.994**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	-	0.770**	-	0.864**	0.678**	-	0.909**	-	-	0.906**
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	-	0.854**	0.864**	-	0.676**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	0.767**	0.678**	0.676**	-	-	0.994**	0.906**	-	-
HH1 (CP9)	EN	-	-	0.369**	-	-	-	-	-	0.369**	-	-	-	0.665**	0.246*	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.369**		-	-	-	-	-	0.369**	-	-	0.665**	-	-	0.429**	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.223*	-	-	-	-	-	0.246*	-	0.429**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	0.223*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.369**	-	-	-	-	-	-	-	-	-	0.481**	-	-	-	-	0.534**	0.247**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.369**	-	-	-	-	-	-	-	0.347**	-	0.481**	-	-	0.272**	0.582**	0.534**	-	-	0.224*	0.829**
	Org-WE	-	-	-	-	0.223*	-	-	-	-	-	-	-	0.272**	-	-	0.247*	-	0.224*	-	-
	Rec-WE	-	-	-	0.223*	-	-	-	0.347**	-	-	-	-	0.582**	-	-	-	-	0.829**	-	-
HH2 (CP2)	EN	-	-	-	-	0.215*	-	-	0.341**	0.412**	0.489**	-	-	-	0.271**	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.666**	0.714**	0.560**	-	-	0.863**	0.453**	0.718**
	Gen-WE	-	-	-	0.660**	0.718**	0.341**	-	-	0.245*	0.229*	-	0.666**	-	0.544**	0.298**	-	0.863**	-	0.721**	0.780**
	Org-WE	-	-	0.660**	-	0.650**	0.412**	-	0.245*	-	0.227*	0.271**	0.714**	0.544**	-	0.314**	-	0.453**	0.721**	-	0.498**
	Rec-WE	-0.215*		0.718**	0.650**	-	0.489**	-	0.229*	0.227*	-	-	0.560**	0.298**	0.314**	-	-	0.718**	0.780**	0.498**	-
HH2 (CP3)	EN	-	-	-	-	-0.240*	-	-	0.295**	0.579**	-	-	-	-	0.659**	-	-	-	-	0.611**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.343**	0.654**	0.829**	-	-	0.680**	0.685**	0.687**
	Gen-WE	-	-	-	0.273**	0.244*	0.295**	-	-	0.379**	0.349**	-	0.343**	-	0.509**	-	-	0.680**	-	0.476**	0.269**
	Org-WE	-	-	0.273**	-	0.234*	0.579**	-	0.379**	-	0.524**	0.659**	0.654**	0.509**	-	0.533**	0.611**	0.685**	0.476**	-	0.649**
	Rec-WE	-0.240*	-	0.244*	0.234*	-	-	-	0.349**	0.524**	-	-	0.829**	-	0.533**	-	-	0.687**	0.269**	0.649**	-

Table 4.43 Energy, Water, Waste relationship in activity of lighting, eating, bathing, and microwave

Building (Consumer)	Resource	LT					ET					BA					MI				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	0.645**	-	-	-	-	-	-	-	-	0.989**	0.981**	0.937**	0.927**	-	-	0.702**	0.218*	0.510**
	WA	-	-	-	-	-	-	-	0.633**	-	-	0.959**	-	0.936**	0.959**	0.910**	-	-	-	-	-
	Gen-WE	0.645**	-	-	-	-	-	0.633**	-	-	-	0.981**	0..936**	-	0.964**	0.979**	0.702**	-	-	-	-
	Org-WE	-	-	-	-	0.844**	-	-	-	-	0.995**	0.937**	0.959**	0.964**	-	0.976**	0.218*	-	-	-	0.865**
	Rec-WE	-	-	-	0.844**	-	-	-	-	0.995*	-	0.927**	0.910**	0.979**	0.976**	-	0.510**	-	-	0.865**	-
GH1 (CP12)	EN	-	-	0.539**	0.713**	0.620**	-	-	0.671**	0.315**	-	-	0.729**	0.825**	0.884**	0.709**	-	-	0.751**	0.466**	-
	WA	-	-	-	-	-	-	-	0.418**	0.767**	0.712**	0.729**	-	0.608**	0.685**	0.746**	-	-	-	-	-
	Gen-WE	0.539**	-	-	0.608**	0.348**	0.617**	0.418**	-	0.712**	0.542**	0.825**	0.608**	-	0.763**	0.565**	0.751**	-	-	0.716**	0.659**
	Org-WE	0.713**	-	0.608**	-	0.569**	0.315**	0.767**	0.712**	-	0.603**	0.884**	0.685**	0.763**	-	0.559**	0.466**	-	0.716**	-	0.504**
	Rec-WE	0.620**	-	0.348**	0.569**	-	-	0.712**	0.542**	0.603**	-	0.709**	0.746**	0.565**	0.559**	-	-	-	0.659**	0.504**	-
GH2 (CP6)	EN	-	-	0.357**	-	-	-	-	-	0.994**	-	-	0.742**	0.462**	-	0.396**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.765**	-	0.487**	0.742**	-	0.693**	-	0.661**	-	-	-	-	-
	Gen-WE	0.3587**	-	-	-	0.207*	-	0.765**	-	-	0.863**	0.462**	0.693**	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.670**	0.994**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	0.207*	0.670**	-	-	0.487**	0.863**	-	-	0.396**	0.661**	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	0.357**	-	-	-	-	-	0.994**	-	-	0.742**	0.462**	-	0.396**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.765**	-	0.487**	0.742**	-	0.693**	-	0.661**	-	-	-	-	-
	Gen-WE	0.357**	-	-	-	0.207*	-	0.765**	-	-	0.863**	0.462**	0.693**	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.670**	0.994**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	0.207*	0.670**	-	-	0.487**	0.863**	-	-	0.396**	0.661**	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	0.688**	0.435**	0.525**	0.751**	-	-	-	0.334**	0.838**	-	-	-	0.396**	0.727**	-	0.842**	0.599**	0.846**	0.832**
	WA	0.688**	-	0.670*	0.550**	0.719**	-	-	0.490**	0.803**	0.454**	-	-	0.410**	0.427**	0.497**	0.842**	-	0.490**	0.803**	0.454**
	Gen-WE	0.435**	0.670**	-	0.426**	0.470**	-	0.409**	-	0.674**	0.377**	-	0.410**	-	0.807**	0.519**	0.599**	0.409**	-	0.674**	0.377**
	Org-WE	0.525**	0.550**	0.426**	-	0.455**	0.334**	0.803**	0.674**	-	0.674**	0.396**	0.427**	0.807**	-	0.851**	0.846**	0.803**	0.674**	-	0.674**
	Rec-WE	0.751**	0.719**	0.470**	0.455**	-	0.838**	0.454**	0.377**	0.674**	-	0.727**	0.497**	0.519**	0.851**	-	0.832**	0.454**	0.377**	0.674**	-
SH1 (CP4)	EN	-	0.539**	0.416**	0.490**	0.518**	-	-	-	-	0.396**	-	-	-	-	0.403**	-	0.763**	0.522**	0.441**	0.737**
	WA	0.539**	-	-	0.526**	0.815**	-	-	0.482**	0.625**	0.841**	-	-	0.838**	0.850**	0.780**	0.763**	-	0.482**	0.625**	0.841**
	Gen-WE	0.416**	-	-	0.445**	0.212*	-	0.482**	-	0.574**	0.446**	-	0.838**	-	0.610**	0.516**	0.522**	0.482**	-	0.574**	0.446**
	Org-WE	0.490**	0.526**	0.445**	-	0.457**	-	0.625**	0.574**	-	0.720**	-	0.850**	0.610**	-	0.621**	0.441**	0.625**	0.574**	-	0.720**
	Rec-WE	0.518**	0.815**	0.212*	0.457**	-	0.396**	0.841**	0.446**	0.720**	-	0.403**	0.780**	0.516**	0.621**	-	0.737**	0.841**	0.446**	0.720**	-
SH1 (CP11)	EN	-	0.795**	0.522**	0.554**	0.829**	-	-	-	-	-	-	-	-	-	-	-	0.770**	0.663**	0.675**	0.870**
	WA	0.795**	0.778**	0.778**	0.709**	0.849**	-	-	0.926**	0.873**	0.925**	-	-	0.256*	0.885**	0.902**	0.770**	-	0.944**	0.889**	0.911**
	Gen-WE	0.522**	0.778**	-	0.567**	0.502**	-	0.925**	-	0.717**	0.795**	-	0.256*	-	-	0.427**	0.663**	0.944**	-	0.718**	0.828**
	Org-WE	0.554**	0.709**	0.567**	-	0.513**	-	0.873**	0.717**	-	-	-	0.885**	-	-	0.646**	0.675**	0.889**	0.817**	-	0.743**
	Rec-WE	0.829**	0.849**	0.502**	0.513**	-	-	0.925**	0.795**	0.719**	-	-	0.902**	0.427**	0.646**	-	0.870**	0.911**	0.828**	0.743**	-
SH2 (CP9)	EN	-	-	0.370**	-	0.629**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.408**	0.306**	0.812**	-	-	0.779**	0.652**	0.385**	-	-	-	-	-
	Gen-WE	0.370**	-	-	0.920**	-	-	0.408**	-	-	0.685**	-	0.779**	-	0.963**	-	-	-	-	-	-
	Org-WE	-	-	0.920**	-	-	-	0.306**	-	-	0.543**	-	0.652**	0.963**	-	-	-	-	-	-	-
	Rec-WE	0.692**	-	-	-	-	-	0.812**	0.685**	0.543**	-	-	0.385**	-	-	-	-	-	-	-	-

Table 4.43 (Cont.)

Building (Consumer)	Resource	LT					ET					BA					MI				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	0.691**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	0.564**	0.988**	-	-	-	-	0.675**	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	0.564**	-	-	0.535**	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.691**	-	-	-	-	-	0.988**	-	0.535**	-	-	0.675**	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	0.378**	-	0.627**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.909**	-	0.994**	-	-	0.822**	0.207*	0.570**	-	-	-	-	-
	Gen-WE	0.378**	-	-	0.924**	-	-	0.909**	-	-	-	-	0.822**	-	0.672**	0.316***	-	-	-	-	-
	Org-WE	-	-	0.924**	-	-	-	-	-	-	-	-	0.207*	0.672**	-	-	-	-	-	-	-
	Rec-WE	0.627**	-	-	-	-	-	0.994**	0.906**	-	-	-	0.570**	0.316**	-	-	-	-	-	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	0.232*	0.215*	-	0.235*	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	0.232*	-	0.909**	-	0.994**	-	-	0.822**	0.207*	0.570**	-	-	-	-	-
	Gen-WE	-	-	-	0.924**	-	0.215*	0.909**	-	-	0.906**	-	0.822**	-	0.672**	0.316**	-	-	-	-	-
	Org-WE	-	-	0.924**	-	-	-	-	-	-	-	-	0.207*	0.672**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	0.235*	0.994**	0.906**	-	-	-	0.570**	0.316**	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.226*	0.416**	-	-	-	-	-	-	-	-	0.523**	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.226*	-	-	0.210*	-	-	-	-	-	-	0.523**	-	-	0.722**	-	-	-	-	-	-
	Org-WE	0.416**	-	0.210*	-	-	-	-	-	-	-	-	-	0.722**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.348**	0.345**	-	-	-	0.454**	0.274*	-	-	-	0.635**	0.6748**	0.308**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.348**	-	-	0.307**	-	0.454**	-	-	-	0.710**	0.635**	-	-	0.458**	0.688**	-	-	-	-	-
	Org-WE	0.345**	-	0.307**	-	-	0.247*	-	-	-	-	0.648**	-	0.458**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	0.710**	-	-	0.308**	-	0.688**	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	0.258**	0.331**	0.534**	-	-	-	-	-	-	0.726**	0.627**	0.622**	0.566**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.863**	0.453**	0.718**	0.726**	-	0.666**	0.714**	0.560**	-	-	-	-	-
	Gen-WE	0.285**	-	-	-	-	-	0.863**	-	0.712**	0.780**	0.627**	0.666**	-	0.544**	0.298**	-	-	-	-	-
	Org-WE	0.331**	-	-	-	-	-	0.453**	0.721**	-	0.498**	0.622**	0.714**	0.544**	-	0.314**	-	-	-	-	-
	Rec-WE	0.534**	-	-	-	-	-	0.718**	0.780**	0.489**	-	0.566**	0.560**	0.298**	0.314**	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	0.583**	0.635**	0.324**	-	-	-	0.611**	-	-	0.776**	0.466**	0.735**	0.600**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.680**	0.685**	0.687**	0.776**	-	0.343**	0.654**	0.829**	-	-	-	-	-
	Gen-WE	0.583**	-	-	0.422**	0.417**	-	0.680**	-	0.476**	0.269**	0.466**	0.343**	-	0.509**	-	-	-	-	-	-
	Org-WE	0.635**	-	0.422**	-	0.330**	0.611**	0.685**	0.476**	-	0.649**	0.735**	0.654**	0.509**	-	0.533**	-	-	-	-	-
	Rec-WE	0.324**	-	0.417**	0.330**	-	-	0.687**	0.269**	0.649**	-	0.600**	0.829**	-	0.533**	-	-	-	-	-	-

Table 4.44 Energy, Water, Waste relationship in activity of cooking, gardening, TV, and ironing

Building (Consumer)	Resource	CK					GN					TV					IC				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.980**	-	-
	WA	-	-	0.945**	0.866**	0.874**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.945**	-	0.933**	0.799**	-	-	-	-	-	-	-	-	-	-	0.980**	-	-	-	-
	Org-WE	-	0.866**	0.933**	-	0.865**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.971**
	Rec-WE	-	0.874**	0.799**	0.865**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.971**	-
GH1 (CP12)	EN	-	-	0.828**	0.425**	-	-	-	0.923**	0.326**	-	-	-	0.689**	0.485**	-	-	-	0.923**	0.955**	0.552**
	WA	-	-	0.312**	0.816**	0.694**	-	-	0.336**	0.812**	0.836**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.828**	0.312**	-	0.664**	0.503**	-	0.336**	-	0.628**	0.395**	0.689**	-	-	0.788**	0.564**	0.923**	-	-	0.774**	0.300*
	Org-WE	0.425**	0.816**	0.664**	-	0.623**	0.326**	0.812**	0.628**	-	0.874**	0.485**	-	0.788**	-	0.643**	0.955**	-	0.774**	-	0.679**
	Rec-WE	-	0.694**	0.503**	0.623**	-	-	0.836**	0.395**	0.874**	-	-	-	0.564**	0.643**	-	0.552**	-	0.300**	0.679**	-
GH2 (CP6)	EN	-	-	-	0.998**	-	-	-	-	0.667**	-	-	-	0.491**	0.503**	0.319**	-	-	-	-	-
	WA	-	-	0.303**	-	0.621**	-	-	0.762**	0.317**	0.528**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.303**	-	-	0.892**	-	0.762**	-	0.552**	0.772**	0.491**	-	-	-	-	-	-	-	-	-
	Org-WE	0.998**	-	-	-	-	0.667**	0.317**	0.552**	-	0.731**	0.503**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.621**	0.892**	-	-	-	0.528**	0.772**	0.731**	-	0.319**	-	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	-	0.998**	-	-	-	-	0.667**	-	-	-	0.491**	0.503**	0.319**	-	-	-	-	-
	WA	-	-	0.303**	-	0.621**	-	-	0.762**	0.317**	0.528**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.303**	-	-	0.892**	-	0.762**	-	0.552**	0.772**	0.491**	-	-	-	-	-	-	-	-	-
	Org-WE	0.998*	-	-	-	-	0.667**	0.317**	0.552**	-	0.731**	0.503**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.621**	0.892**	-	-	-	0.528**	0.772**	0.731**	-	0.319**	-	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.829**	0.558**	0.947**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.829**	-	-	-	0.607**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.558**	-	-	-	0.764**
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.647**	-	0.607**	0.764**	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.938**	0.551**	0.572**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.938**	-	-	0.775**	0.304**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.551**	-	0.775**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.572**	-	0.304**	-	-

Table 4.44 (Cont.)

Building (Consumer)	Resource	CK					GN					TV					IC				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.563**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.563**	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.585**	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.585**	-	-	-	0.606**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.702**	0.362**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.702**	-	-	0.418**	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.361**	-	0.418**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.874**	0.592**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.874**	-	-	0.814**	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.592**	-	0.814**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	-	-	-	-	-	-	-	-	-	-	0.229*	0.655**	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	0.229*	-	-	-	0.275**	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.655**	-	-	-	0.429**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	0.275**	0.429**	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	-	0.522**	-	-	-	-	0.462**	-	-	-	0.221*	0.617**	-	-	-	-	-	-
	WA	-	-	0.640**	0.677**	0.531**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.640**	-	0.542**	0.395**	-	-	-	0.469**	0.507**	0.221*	-	-	0.436**	0.455**	-	-	-	-	-
	Org-WE	0.522**	0.677**	0.542**	-	0.560**	0.462**	-	0.49**	-	0.304**	0.617**	-	0.436**	-	0.455**	-	-	-	-	-
	Rec-WE	-	0.531**	0.395**	0.560**	-	-	-	0.507**	0.304**	-	-	-	0.430**	0.455**	-	-	-	-	-	-

Table 4.45 Energy, Water, Waste relationship in activity of water boiling, rice cooking, wash clothes, hair dying, and car wash

Building (Consumer)	Resource	WB					RC					WC					HD and WR				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	0.980**	0.973*	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.756*	-	-	0.980**	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	0.756*	-	-	-	0.973*	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GH1 (CP12)	EN	-	0.201*	0.986**	0.804**	0.447**	-	-	0.896**	-	-	-	-	0.999**	-	-	-	-	-	-	-
	WA	0201*	-	0.249*	0.623**	0.778**	-	-	-	-	-	-	-	-	-	0.939*	-	-	-	-	-
	Gen-WE	0.986*	0.249*	-	0.835**	0.480**	0.896**	-	-	-	-	0.999**	-	-	-	-	-	-	-	-	-
	Org-WE	-	0804**	0.623**	0.835**	0.835**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.447**	0.778**	0.480**	0.835**	-	-	-	-	-	-	-	0.939*	-	-	-	-	-	-	-	-
GH2 (CP6)	EN	-	-	-	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	0.586**	-	0.606**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.586**	-	-	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.606**	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	-	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	0.586**	-	0.606**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.586**	-	-	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.606**	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP11)	EN	-	0.770**	0.735**	0.441**	0.891**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	0.770**	-	0.256*	0.885**	0.902**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.735**	0.256*	-	-	0.427**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.441**	0.885**	-	-	0.646**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.891**	0.902**	0.427**	0.646**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.45 (Cont.)

Building (Consumer)	Resource	WB					RC					WC					HD and WR				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.834*	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.834*	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	-	-	-	-	-	-	-	-	-	-0.673*	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-0.673*	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.647*	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-0.647*	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

6. Verification of consumer profile

The results of the verification of consumer profiles were obtained by grouping the usage behavior data of a sample community according to the characteristics of each group, with a total of 14 groups. This grouping was performed for the purpose of adjusting the quantities of energy, water usage, and waste generation based on the usage behavior data from the second sample group, within a building that has been equipped with Smart meters. The results of the data analysis were divided into two stages as follows:

6.1 The activity occurrence consumer profile

The amount of energy, water, and waste consumption of each consumer, it will be analyzed from the consumer data and the measured usage from the smart meter. Then, the set of consumption data will be expanded to each consumer group, from CP1 to CP14, with activity data that occurred within each consumer group building, as shown in Figure 4.78 - Figure 4.91.

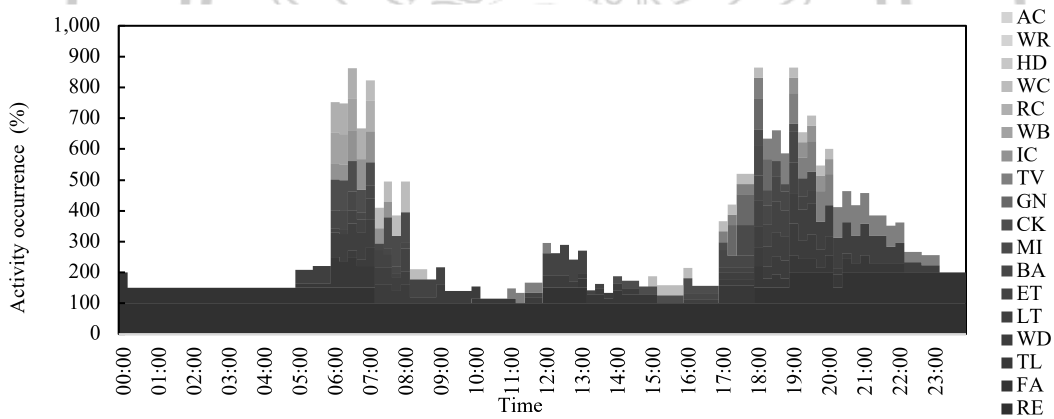


Figure 4.78 The activity occurrence consumer profile 1

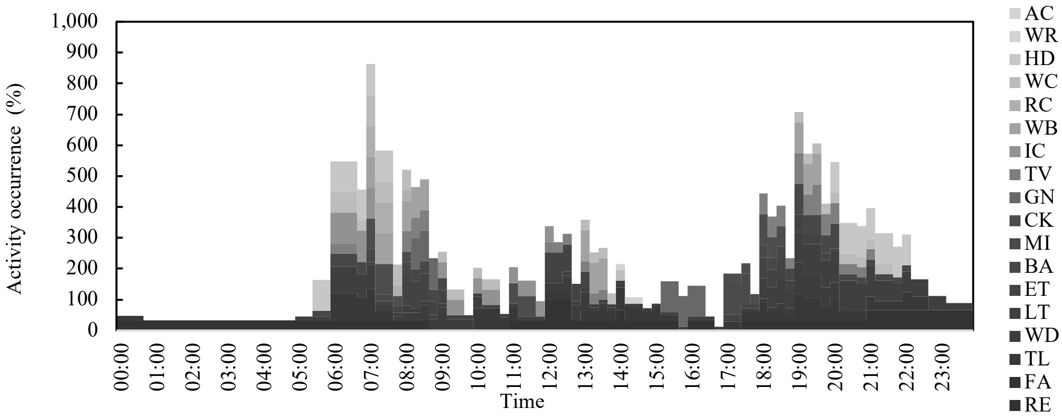


Figure 4.79 The activity occurrence consumer profile 2

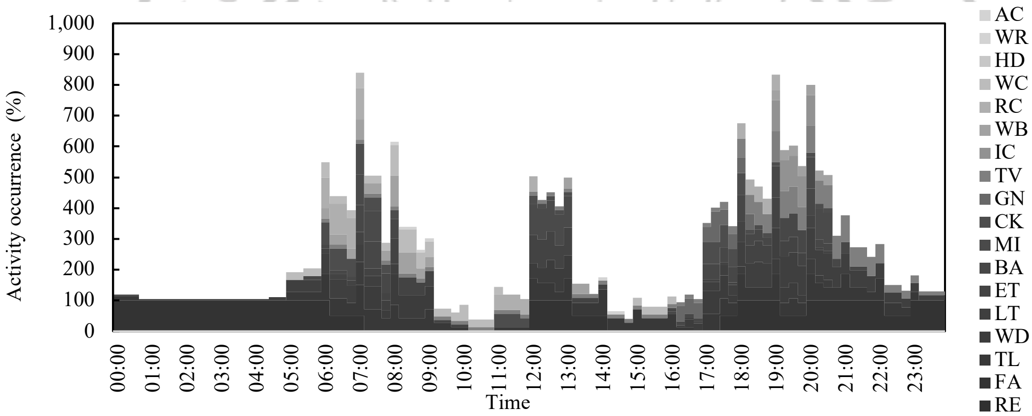


Figure 4.80 The activity occurrence consumer profile 3

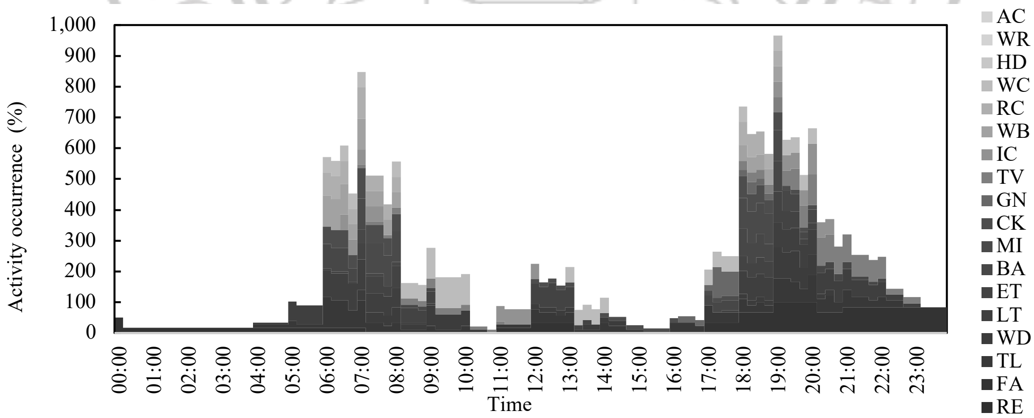


Figure 4.81 The activity occurrence consumer profile 4

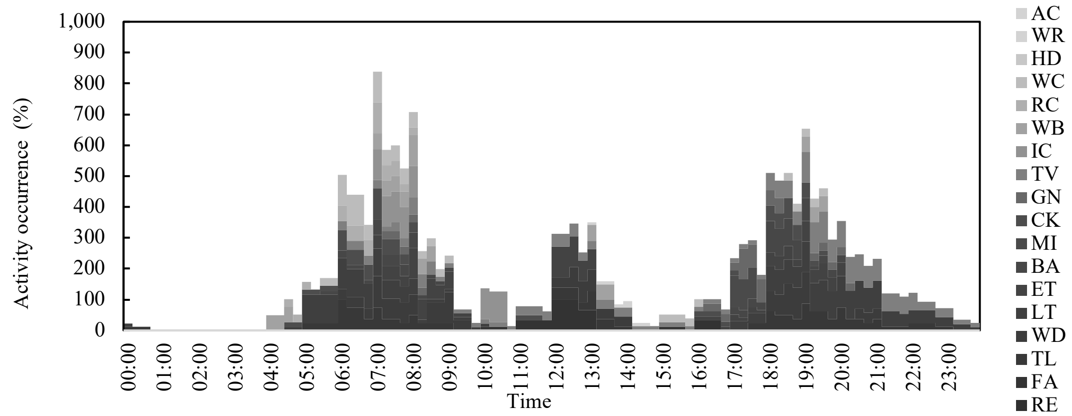


Figure 4.82 The activity occurrence consumer profile 5

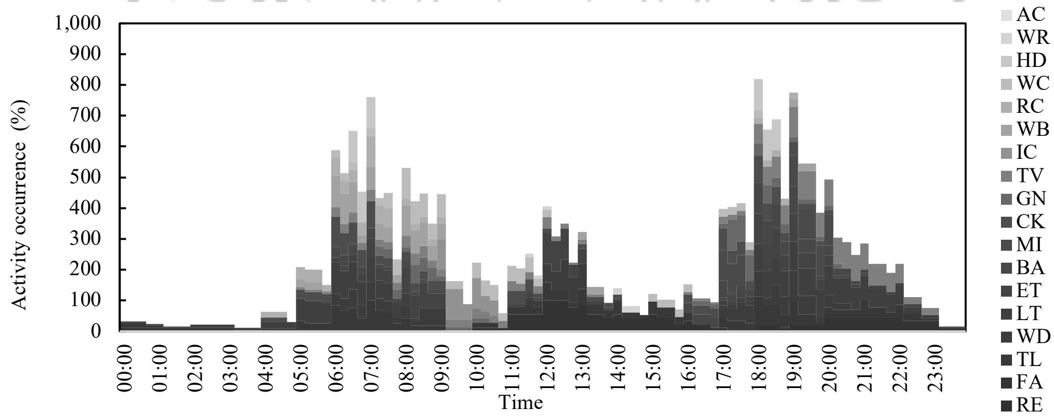


Figure 4.83 The activity occurrence consumer profile 6

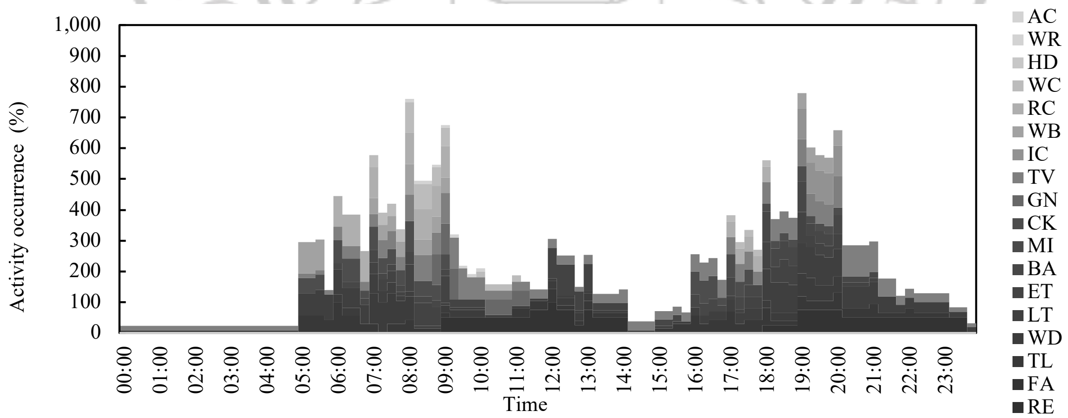


Figure 4.84 The activity occurrence consumer profile 7

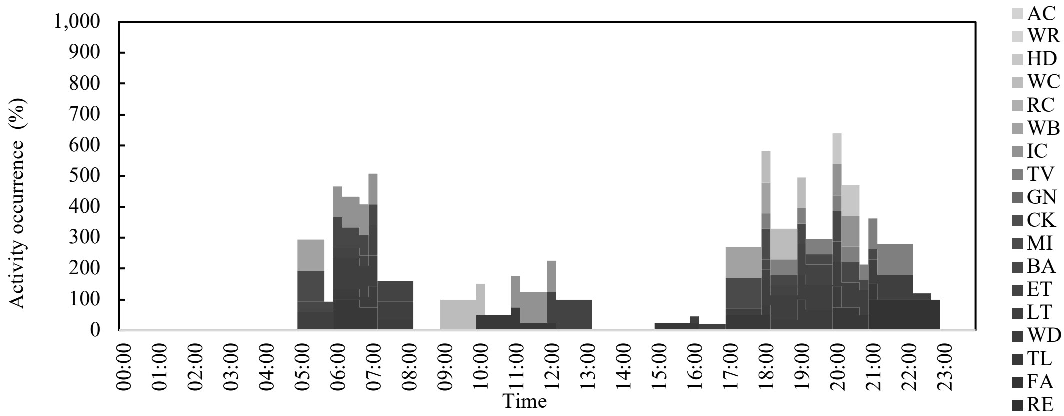


Figure 4.85 The activity occurrence consumer profile 8

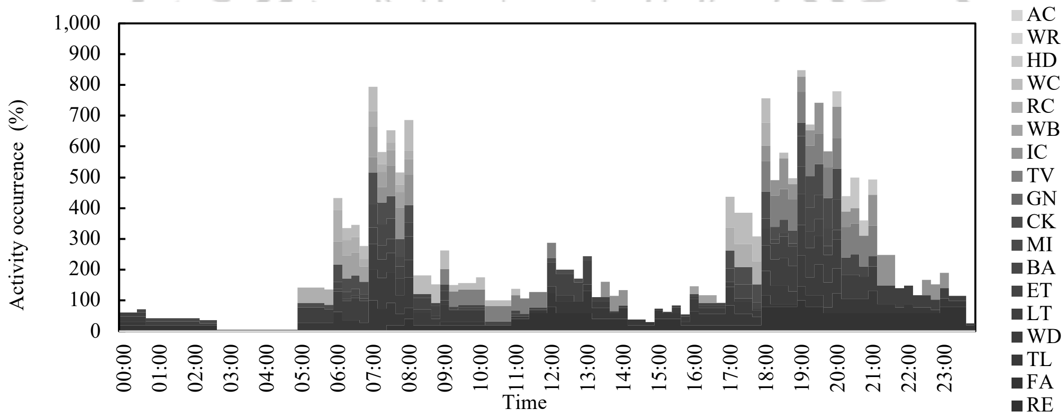


Figure 4.86 The activity occurrence consumer profile 9

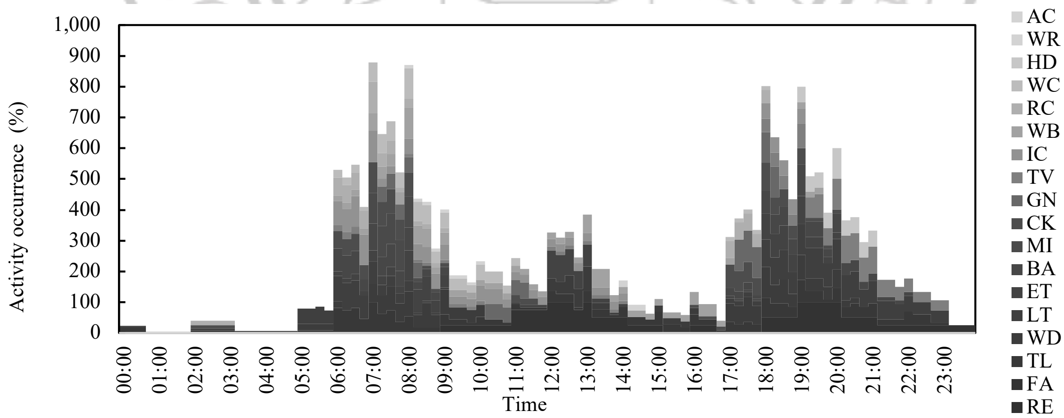


Figure 4.87 The activity occurrence consumer profile 10

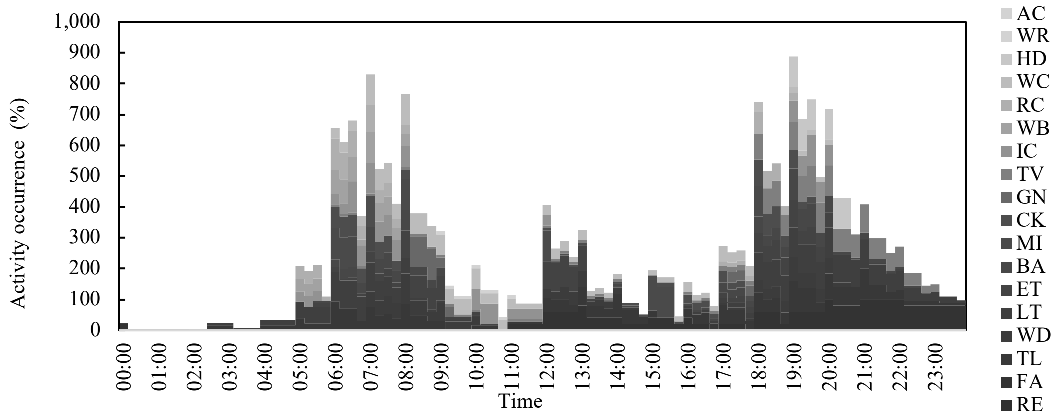


Figure 4.88 The activity occurrence consumer profile 11

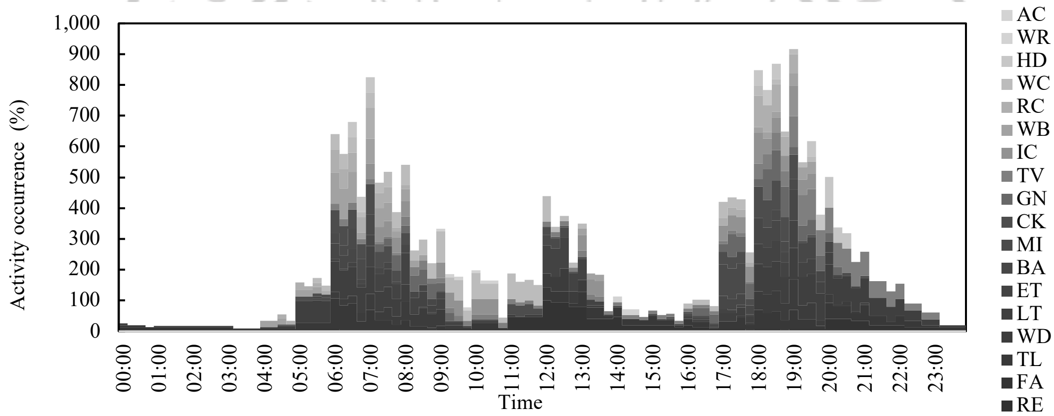


Figure 4.89 The activity occurrence consumer profile 12

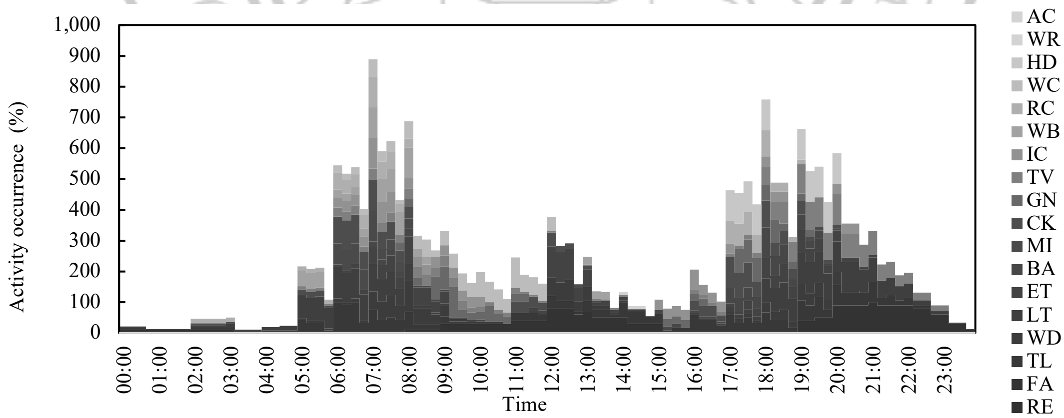


Figure 4.90 The activity occurrence consumer profile 13

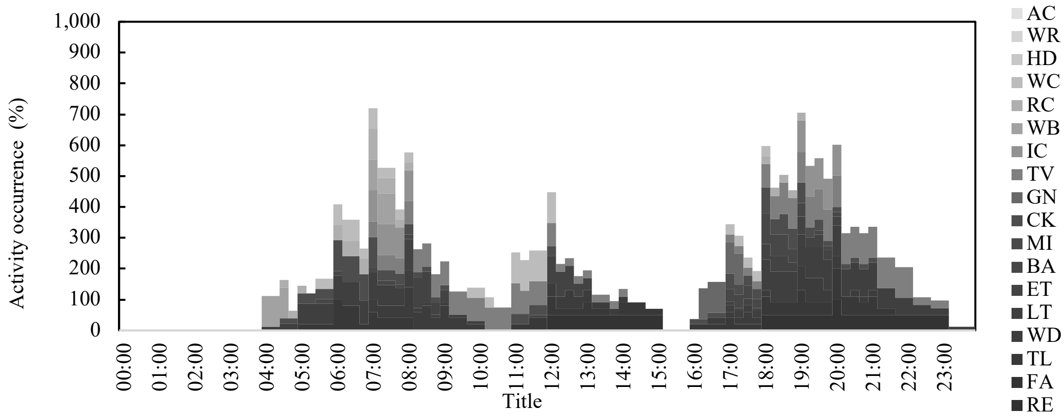


Figure 4.91 The activity occurrence consumer profile 14

Table 4.46 Appliances in each building and for each customer profile, including their size, quantity, and percentage of sample group

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Lighting	LED light	Size (W)	11.13	17.13	16.57	13.54	8.17	11.39	16.80	29.25	14.15	13.64	11.54	12.73	13.71	9.33
		Number (Unit)	5.78	7.33	5.57	7.54	8.17	7.11	5.91	9.75	6.59	8.38	6.13	7.36	6.16	5.86
		Percentage	90.00	69.23	77.78	76.47	46.15	79.17	91.67	80.00	89.47	68.42	85.71	75.76	86.21	70.00
	Fluorescent	Size (W)	23.71	24.50	18.92	25.00	18.67	22.47	25.67	16.67	18.40	22.25	22.50	20.70	23.95	24.00
		Number (Unit)	2.71	4.00	5.08	3.73	5.14	5.64	5.33	4.00	4.80	5.42	4.20	5.13	4.79	4.83
		Percentage	70.00	46.15	72.22	64.71	53.85	58.33	50.00	60.00	52.63	63.16	53.57	69.70	65.52	60.00
	Incandescent	Size (W)	25.00	-	25.00	18.00	-	31.05	18.00	-	25.20	25.00	18.00	14.00	42.60	-
		Number (Unit)	1.00	-	1.00	11.00	8.00	9.75	11.00	-	25.00	4.50	9.50	8.33	14.50	-
		Percentage	10.00	-	5.56	11.76	7.69	16.67	8.33	-	5.26	10.53	7.14	9.09	6.90	-
	Total Power Consumption (W)		105.45	132.17	142.58	161.63	82.48	188.48	175.94	268.15	163.01	166.21	123.42	155.60	190.57	107.87
Fan	Ceiling	Size (Inch)	15.00	17.00	17.00	16.67	18.00	16.43	-	17.00	16.00	17.50	16.67	16.60	16.67	-
		Number (Unit)	1.00	3.00	7.33	1.00	1.00	7.00	-	3.00	1.00	3.00	2.00	4.00	9.50	-
		Percentage	10.00	15.38	16.67	11.76	7.69	25.00	-	40.00	15.79	10.53	10.71	36.36	6.90	-
	Wall mounted	Size (Inch)	16.75	-	12.40	17.20	16.00	16.30	17.00	-	16.80	15.00	17.14	14.50	16.25	18.00
		Number (Unit)	2.00	1.00	2.25	1.17	3.00	3.25	1.00	-	1.20	1.60	1.57	2.11	3.22	1.00
		Percentage	50.00	7.69	22.22	35.29	7.69	50.00	25.00	-	26.32	26.32	25.00	27.27	31.03	30.00
	Table	Size (Inch)	14.89	15.40	16.47	16.65	16.73	15.06	16.44	16.40	16.00	16.47	15.68	16.00	15.96	16.75
		Number (Unit)	2.11	2.18	2.40	2.06	2.18	2.56	2.20	2.80	2.06	3.00	1.96	2.22	2.26	2.00
		Percentage	90.00	84.62	83.33	100.00	84.62	75.00	83.33	100.00	89.47	78.95	89.29	96.97	93.10	90.00
	Total power consumption (W)		192.46	144.89	117.26	271.99	112.71	212.55	120.28	161.73	122.06	211.32	195.67	121.76	192.46	144.89

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Air conditioner	Inv.	Size (BTU)	10,600.00	12,200.00	9,000.00	12,200.00	10,600.00	10,600.00	8,500.00	-	9,000.00	9,800.00	10,600.00	10,600.00	10,600.00	-
		SEER	2,250.00	22.50	-	2,250.00	22.50	22.50	-	-	-	22.50	2,250.00	22.50	2,250.00	-
		Number (unit)	1.50	1.00	1.00	2.00	1.00	1.25	1.00	-	2.00	1.00	1.50	1.00	2.00	-
		Percentage	20.00	15.38	5.56	5.88	15.38	16.67	16.67	-	5.26	21.05	7.14	12.12	6.90	-
	Conv.	Size (BTU)	9,000.00	-	9,000.00	-	-	12,000.00	-	20,000.00	-	14,500.00	12,000.00	12,100.00	-	-
		SEER	-	-	-	-	-	14.00	-	-	-	-	13.00	14.58	-	-
		Nmber (unit)	1.00	-	1.00	-	-	1.00	-	1.00	-	1.00	1.00	1.00	-	-
		Percentage	10.00	-	5.56	-	-	20.83	-	20.00	-	10.53	7.14	12.12	-	-
	Total power consumption (W)		292.55	83.39	83.40	87.48	86.95	317.77	90.25	400.00	63.12	272.45	138.22	175.41	93.17	-
Refrigerator	Conv. Single-door	Size (ft^3)	4.46	5.38	5.11	5.32	5.48	5.47	5.80	4.00	5.87	5.53	5.31	5.33	5.43	5.23
		Number (unit)	1.60	1.00	1.20	1.44	2.00	1.27	1.40	1.00	1.43	1.38	1.79	1.47	1.21	1.67
		Percentage	50.00	46.15	55.56	52.94	30.77	62.50	41.67	40.00	73.68	42.11	50.00	51.52	65.52	60.00
	Inv. Single-door	Size (ft^3)	-	4.20	3.40	-	5.00	12.00	5.00	-	12.00	5.00	8.03	5.00	9.25	5.00
		Number (unit)	-	1.00	1.00	-	1.50	1.00	1.00	-	1.00	1.50	1.33	1.67	1.00	1.00
		Percentage	-	15.38	5.56	-	15.38	4.17	8.33	-	5.26	10.53	10.71	9.09	13.79	10.00
	Conv. Double-door	Size (ft^3)	6.90	9.65	6.73	7.45	8.25	7.53	7.20	8.50	7.54	8.20	7.81	7.46	7.62	7.45
		Number (unit)	1.00	1.50	1.00	1.50	1.00	1.00	1.00	1.00	1.20	1.00	1.14	1.08	1.00	1.00
		Percentage	10.00	15.38	16.67	23.53	30.77	20.83	33.33	20.00	26.32	21.05	25.00	39.39	31.03	20.00
	Inv. Double-door	Size (ft^3)	9.20	7.70	9.20	9.00	8.20	8.70	-	8.55	-	8.72	8.60	7.96	8.50	-
		Number (unit)	1.00	1.00	1.00	2.00	1.00	1.00	-	1.00	-	1.40	1.00	1.00	1.00	-
		Percentage	20.00	15.38	11.11	11.76	7.69	8.33	-	40.00	-	26.32	7.14	15.15	6.90	-
	Total power consumption (W)		166.68	148.16	138.83	199.61	170.75	162.93	135.70	167.70	200.35	189.44	198.20	208.66	190.94	174.16

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Water-heater	LPG	Number (unit)	-	-	1.00	-	-	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	-
		Percentage	-	-	5.56	-	-	8.33	8.33	20.00	-	10.53	-	3.03	3.45	-
	Electricity	Size (W)	3,850.75	3,660.00	3,567.17	3,260.00	3,000.00	3,647.03	600.00	3,500.00	4,134.45	3,233.83	3,240.00	3,281.10	2,914.76	2,460.67
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.17	1.00	1.00	1.00	1.00
		Percentage	40.00	38.46	33.33	35.29	23.08	41.67	8.33	20.00	15.79	31.58	35.71	30.30	20.69	30.00
	Total power consumption (W)		1,540.30	1,407.64	1,188.94	1,150.45	692.40	1,519.72	49.98	1,400.00	652.83	1,191.45	1,157.00	994.17	603.06	738.20
Hair dry		Size (W)	900.00	1,100.00	1,050.00	-	-	1,687.50	1,000.00	2,600.00	1,000.00	937.75	1,000.00	1,137.50	1,316.67	1,000.00
		Number (unit)	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Percentage	10.00	23.08	11.11	-	-	16.67	8.33	20.00	21.05	21.05	14.29	12.12	13.79	10.00
	Total power consumption (W)		1,540.30	90.00	253.88	116.66	-	-	281.31	83.30	520.00	210.50	197.40	142.90	137.87	181.57
Rice cook	Conv.	Size (L)	1.41	1.49	1.53	1.64	1.59	1.52	1.33	1.70	1.69	1.63	1.60	1.66	1.51	1.39
		Number (unit)	1.00	1.00	1.00	1.07	1.00	1.05	1.00	1.00	1.00	1.13	1.00	1.00	1.04	1.00
		Percentage	90.00	69.23	66.67	82.35	53.85	79.17	83.33	80.00	84.21	78.95	78.57	72.73	89.66	80.00
	Digital	Size (L)	-	-	-	-	-	2.40	1.80	-	-	-	2.38	1.80	-	-
		Number (unit)	-	-	-	-	-	1.00	1.00	-	-	-	1.00	1.00	-	-
		Percentage	-	-	-	-	-	8.33	8.33	-	-	-	14.29	6.06	-	-
	Total power consumption (W)		501.77	396.54	387.34	529.03	317.81	551.36	516.49	486.70	511.53	535.12	585.44	486.02	536.59	442.13
Microwave		Size (W)	1,500.00	884.00	986.67	1,300.00	1,000.00	1,262.50	800.00	220.00	-	906.67	1,014.29	1,157.78	966.67	-
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	-
		Percentage	20.00	38.46	33.33	23.53	7.69	33.33	8.33	20.00	-	15.79	28.57	27.27	24.14	-
	Total power consumption (W)		300.00	339.99	328.86	305.89	76.90	420.79	66.64	44.00	-	143.16	289.78	315.73	233.35	-

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Water boiler	Kettle	Size (L)	1.20	-	1.50	1.70	2.10	1.40	-	2.00	1.27	1.40	1.23	1.60	1.58	2.40
		Number (unit)	1.00	-	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.20	1.00
		Percentage	30.00	-	16.67	23.53	23.08	8.33	-	20.00	31.58	21.05	28.57	18.18	17.24	20.00
Water boiler	Thermos	Size (L)	1.50	1.93	6.60	2.07	2.83	1.62	2.19	1.90	1.35	5.11	2.28	2.16	3.40	1.00
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Percentage	20.00	53.85	27.78	52.94	23.08	54.17	66.67	40.00	31.58	52.63	46.43	45.45	62.07	20.00
	Total power consumption (W)		568.64	382.63	546.49	760.49	568.05	520.49	466.44	634.41	691.49	744.52	728.89	610.46	760.77	521.50
Air fryer		Size (W)	-	-	-	-	-	-	-	-	800.00	220.00	1,100.00	-	220.00	-
		Number (unit)	-	-	-	-	-	-	-	-	1.00	1.00	1.00	-	1.00	-
		Percentage	-	-	-	-	-	-	-	-	15.79	5.26	7.14	-	3.45	-
	Total power consumption (W)		568.64	382.63	546.49	760.49	568.05	520.49	466.44	634.41	691.49	744.52	728.89	610.46	760.77	521.50
Washing machine	Twin tub	Size (kg)	12.86	11.75	12.42	12.83	13.05	12.08	11.63	12.50	12.14	13.04	12.94	12.52	12.82	10.78
		Number (unit)	1.00	1.13	1.00	1.00	1.20	1.18	1.00	1.00	1.00	1.00	1.05	1.17	1.00	1.00
		Percentage	70.00	61.54	72.22	82.35	76.92	70.83	75.00	80.00	73.68	68.42	67.86	87.88	79.31	90.00
	Top load	Size (kg)	15.00	9.00	8.00	-	13.00	7.50	12.00	15.00	7.00	13.33	12.50	12.00	5.00	-
		Number (unit)	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-
		Percentage	10.00	15.38	5.56	-	7.69	8.33	8.33	20.00	15.79	15.79	21.43	9.09	3.45	-
	Front load	Size (kg)	-	-	-	-	-	-	-	-	-	-	15.00	-	15.00	-
		Number (unit)	-	-	-	-	-	-	-	-	-	-	1.00	-	1.00	-
		Percentage	-	-	-	-	-	-	-	-	-	-	3.57	-	3.45	-
	Total power consumption (W)		457.66	423.68	419.61	468.73	572.21	478.75	430.50	562.23	452.64	477.23	586.61	617.16	530.16	436.66

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			**Male**							**Female**						
age			**11 – 20**	**21 – 30**	**31 – 40**	**41 – 50**	**51 – 60**	**61 – 70**	**> 71**	**11 – 20**	**21 – 30**	**31 – 40**	**41 – 50**	**51 – 60**	**61 – 70**	**> 71**
Iron		Size (W)	728.00	1,036.67	480.00	1,041.82	732.86	773.33	1,400.00	794.00	1,253.33	770.77	1,038.75	918.70	808.57	1,100.00
		Number (unit)	1.00	1.14	1.17	1.00	1.00	1.00	1.33	1.20	1.00	1.21	1.00	1.04	1.00	1.00
		Percentage	50.00	53.85	33.33	70.59	53.85	66.67	50.00	100.00	63.16	73.68	64.29	75.76	55.17	30.00
	Total power consumption (W)		364.00	637.99	186.65	735.42	394.64	515.58	933.33	952.80	791.61	689.60	667.81	723.84	446.09	330.00
TV	Conv.	Size (inch)	20.50	32.75	22.50	37.00	29.67	24.25	20.67	27.00	26.67	25.50	31.33	26.29	24.80	20.00
		Number (unit)	1.00	1.40	1.50	1.00	1.00	1.00	1.00	1.67	1.00	1.50	1.00	1.29	1.00	1.00
		Percentage	20.00	38.46	22.22	11.76	23.08	16.67	33.33	60.00	15.79	21.05	21.43	21.21	17.24	20.00
	LCD	Size (inch)	32.00	37.00	33.25	34.00	-	38.00	36.00	-	41.00	35.00	36.00	33.33	36.50	32.00
		Number (unit)	1.00	1.00	1.00	1.00	-	1.00	1.43	-	1.00	1.60	1.00	1.00	1.22	1.00
		Percentage	20.00	15.38	22.22	23.53	-	16.67	58.33	-	10.53	26.32	25.00	9.09	31.03	20.00
	LED	Size (inch)	33.80	30.80	40.25	32.70	31.80	37.93	32.00	31.50	34.00	34.67	34.58	34.21	35.00	34.50
		Number (unit)	1.40	1.00	1.00	1.20	1.33	1.20	1.50	1.00	1.13	1.10	1.31	1.14	1.25	1.00
		Percentage	50.00	38.46	44.44	58.82	46.15	62.50	16.67	40.00	42.11	52.63	46.43	63.64	55.17	40.00
	Total power consumption (W)		65.54	125.44	73.05	81.72	63.53	77.14	111.73	135.72	55.13	100.89	89.30	76.35	90.35	49.27

Table 4.47 Comparison of activity time, Frequency, and period of consumer profile between community population (1st sample group) and consumer in sample building (2nd sample group)

Profile	CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
LT T	246.00	-	252.50	900.00	241.18	510.00	171.18	480.00	194.33	-	236.54	300.00	353.33	-	105.00	-	273.95	426.00	189.11	-	245.36	490.00	212.42	360.00	265.00	-	251.00	-
F	1.70	-	1.62	1.00	1.93	1.00	1.65	2.00	1.85	-	1.65	2.00	1.67	-	1.75	-	1.42	1.00	1.82	-	1.61	1.00	1.88	2.00	2.07	-	1.60	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
AC T	-	-	25.00	-	-	-	-	-	20.00	-	56.67	-	260.00	-	-	-	-	-	160.00	-	400.00	-	116.67	-	-	-	-	-
F	-	-	1.50	-	-	-	-	-	2.00	-	1.33	-	1.50	-	-	-	-	-	2.00	-	1.33	-	1.33	-	-	-	-	-
P	-	-	Day	-	-	-	-	-	Day	-	Day	-	Day	-	-	-	-	-	Day	-	Day	-	Day	-	-	-	-	-
FA T	172.00	-	218.33	900.00	225.56	570.00	216.67	840.00	30.00	-	141.54	540.00	78.89	-	150.00	-	254.63	287.40	113.00	-	232.86	241.67	149.25	600.00	143.75	-	110.00	-
F	1.20	-	1.83	1.00	1.11	1.00	1.11	1.00	1.33	-	1.50	-	0.88	-	1.00	-	1.50	1.00	1.20	-	1.14	1.33	1.42	1.00	1.13	-	1.50	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-
BA T	18.33	-	17.08	30.00	20.63	20.00	13.75	15.00	16.15	-	15.75	30.00	18.33	-	20.00	-	17.37	21.00	19.72	-	16.15	13.33	16.21	20.00	13.28	-	15.00	-
F	1.44	-	1.62	2.00	1.56	2.00	1.44	2.00	1.54	-	1.43	2.00	1.42	-	1.75	-	1.68	1.60	1.83	-	1.62	2.00	1.52	1.50	1.21	-	1.13	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
TL T	6.61	-	7.25	1.00	3.60	2.00	3.50	2.00	9.92	-	4.88	1.00	6.28	-	1.00	-	3.44	1.40	4.95	-	6.18	1.00	4.31	1.00	4.48	-	4.00	-
F	3.86	-	5.78	3.00	4.15	3.00	3.14	2.00	4.08	-	4.00	4.00	2.89	-	3.33	-	3.82	3.00	4.47	-	4.24	5.33	4.17	5.00	3.05	-	3.43	-
P	Day	-	Day	Day	Day	-	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
HD T	-	-	5.00	5.00	15.00	2.50	-	-	-	-	15.00	15.00	1.00	-	10.00	-	7.67	1.60	11.67	-	10.00	5.00	7.50	10.00	10.00	-	-	-
F	-	-	1.29	2.00	0.29	1.00	-	-	-	-	1.00	1.00	-	-	1.00	-	0.86	0.40	0.48	-	0.71	0.19	0.46	0.79	0.57	-	-	-
P	-	-	Day	Day	Day	-	-	-	-	-	Day	Day	-	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	-	-
WC T	39.17	-	36.67	45.00	43.00	-	40.45	-	42.50	-	56.82	-	41.25	-	51.67	-	46.56	31.00	44.72	-	58.40	15.00	41.61	40.00	46.67	-	35.00	-
F	3.17	-	2.33	1.00	3.50	-	2.18	-	2.50	-	3.55	-	3.38	-	3.00	-	2.50	0.60	5.22	-	2.32	1.00	4.25	2.00	2.88	-	2.78	-
P	Week	-	Week	Week	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	Week	Week	-	Week	-
IC T	16.25	-	25.00	-	32.50	-	28.33	-	25.00	-	30.83	-	15.50	-	22.50	-	19.58	17.00	48.85	-	26.39	26.67	26.54	30.00	18.82	-	16.67	-
F	3.25	-	2.29	-	4.25	-	3.17	-	1.25	-	2.45	-	2.63	-	5.50	-	3.33	5.80	5.00	-	2.63	3.33	1.85	1.00	2.11	-	3.00	-
P	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	Week	Week	-	Week	Week	Week	Day	Week	-	Week	-

Table 4.47 (Cont.)

Profile		CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
RC	T	26.67	-	23.33	-	27.50	-	32.86	-	28.33	-	26.82	-	41.67	-	30.00	-	23.33	-	30.42	-	32.75	10.00	22.50	10.00	31.50	-	25.00	-
	F	0.71	-	1.17	-	0.79	-	1.14	-	0.71	-	1.05	-	0.84	-	2.00	-	0.92	-	1.10	-	1.01	0.24	1.17	1.00	0.87	-	1.25	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-
MI	T	1.00	-	10.67	-	11.00	16.00	6.00	6.00	25.00	-	10.67	2.00	-	-	-	-	20.00	-	10.50	-	8.33	5.00	12.71	2.00	20.00	-	-	-
	F	14.00	-	4.67	-	11.00	9.50	14.00	14.00	1.13	-	3.33	1.00	-	-	-	-	3.00	-	8.00	-	8.33	2.00	3.46	3.00	7.00	-	-	-
	P	Week	-	Week	-	Week	Week	Week	Week	Week	-	Week	Week	-	-	-	-	Week	-	Week	-	Week	-	Week	Week	Week	-	-	-
WB	T	10.00	-	10.00	-	15.00	-	17.00	-	13.75	-	13.89	5.00	45.00	-	30.00	-	9.29	1.00	27.86	-	17.22	2.67	11.30	10.00	21.11	-	15.00	-
	F	1.00	-	2.00	-	1.33	-	1.20	-	1.50	-	1.14	1.00	2.00	-	2.00	-	1.00	0.20	1.43	-	1.22	1.00	1.40	1.00	1.03	-	1.00	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
TV	T	168.00	-	55.71	60.00	179.09	60.00	132.50	-	175.00	-	161.82	180.00	297.00	-	110.00	-	160.00	-	173.64	-	124.50	-	164.00	120.00	166.40	-	180.00	-
	F	0.86	-	1.49	1.00	1.03	0.50	1.08	-	1.38	-	1.41	1.00	1.43	-	1.00	-	1.00	-	1.43	-	1.08	-	1.38	0.71	1.51	-	1.71	-
	P	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
ET	T	17.50	-	21.36	15.00	20.71	22.50	19.41	30.00	23.18	-	20.48	25.00	17.50	-	16.67	-	20.59	20.00	17.50	-	19.60	21.67	19.52	25.00	21.96	-	18.13	-
	F	2.64	-	2.49	2.00	2.77	1.36	2.71	2.00	3.00	-	2.85	2.00	2.50	-	3.00	-	2.58	1.20	2.53	-	2.56	2.00	2.87	2.00	2.63	-	2.75	-
	P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	Day	Day	-	Day	-
WD	T	9.00	-	9.17	5.00	12.44	10.50	10.00	5.00	12.78	-	11.54	5.00	18.75	-	9.00	-	7.12	7.00	15.00	-	11.36	6.67	9.14	10.00	12.78	-	11.88	-
	F	2.29	-	2.71	2.00	2.04	1.14	1.56	2.00	2.22	-	2.36	2.00	1.38	-	1.40	-	2.08	1.40	2.00	-	2.00	1.33	2.39	2.00	2.31	-	2.38	-
	P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	-
GN	T	11.67	-	30.00	-	40.00	-	14.44	-	20.00	-	26.25	30.00	15.00	-	-	-	15.25	-	32.50	-	17.22	-	18.64	30.00	30.00	-	27.50	-
	F	1.67	-	0.25	-	1.39	-	0.75	-	0.74	-	0.97	1.00	1.00	-	-	-	0.38	-	1.04	-	1.03	-	0.74	0.79	0.72	-	0.57	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	-	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
WR	T	30.00	-	30.00	-	55.00	-	25.71	-	27.50	-	38.57	-	28.33	-	-	-	20.00	-	46.00	-	45.00	-	30.00	15.00	20.00	-	-	-
	F	0.25	-	0.42	-	1.06	-	0.82	-	0.88	-	0.71	-	0.83	-	-	-	1.00	-	0.60	-	0.44	-	0.44	0.13	0.25	-	-	-
	P	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	-	-	Week	-	Week	-	Week	-	Week	Day	Week	-	-	-
Pet	T	-	-	-	-	-	-	25.00	-	-	-	17.33	30.00	15.00	-	-	-	20.00	-	-	-	30.00	10.00	23.00	15.00	17.00	-	20.00	-
	F	-	-	-	-	-	-	1.13	-	-	-	3.33	1.00	2.00	-	-	-	0.50	-	-	-	1.00	0.33	3.50	0.50	3.00	-	2.00	-
	P	-	-	-	-	-	-	Week	-	-	-	Week	Week	Week	-	-	-	Week	-	-	-	Week	-	Week	Day	Week	-	Week	-

Table 4.47 (Cont.)

Profile	CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
CK T	35.00	-	31.67	-	33.89	35.00	35.00	-	30.00	-	31.54	60.00	32.14	-	-	-	35.63	-	31.43	-	33.53	45.00	36.11	52.50	36.92	-	52.86	-
F	2.25	-	2.67	-	2.00	2.00	2.13	-	1.86	-	2.00	2.00	1.71	-	-	-	1.88	-	1.79	-	1.88	2.00	2.15	1.50	2.19	-	2.29	-
P	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	-	-	Day	-	Day	-	Day	Day	Day	Day	Day	-	Day	-

From the comparative activity behavior data of each customer profile between the data from sample population 1 from the community and sample population 2 residing in buildings equipped with Smart Meters as shown in Table 4.47, it was found that sample population 2 had a total of 7 customer profiles, consisting of CP2, CP3, CP4, CP5, CP6, CP7, CP8, CP9, CP10, CP11, and CP12. Considering group CP2, the activity of turning on lights occurred in the same manner in both sample groups, with 9 activities, as follows: the activity duration of sample population 1 was longer than sample population 2. It was found that the first sample group turned on lights for an average of 407.88 minutes per day, which was lower than the second sample group that turned on lights for an average of 900 minutes per day. The same was true for the activity of using fans, which had an average activity time of 400.28 minutes per day for sample population 1 and 900.00 minutes per day for sample population 2. As for the activity of bathing, the frequency of this activity was slightly lower in sample population 1 compared to sample population 2, with a frequency of 1.62 times per day and an average duration of 17.08 minutes per time for sample population 1, which was lower than sample population 2 that had an average frequency of 2 times per day and 30 minutes per time. However, the activity of using the bathroom (TL) had a longer activity time in sample population 1 with an average duration of 725 minutes per time, which occurred 5.78 times per day, which was higher than sample population 2 that had an activity duration of only 1 minute per time and occurred 3 times per day. The hair drying activity (HD) is characterized by a similar duration of activity of 5 minutes per session, with a slightly different frequency observed between the two sample groups, where Sample Group 1 exhibited an average frequency of 1.29 times per day, which is lower than Sample Group 2 that had an average frequency of 2 times per day. With regards to the clothes washing activity (WC), Sample Group 1 had a longer duration of activity than Sample Group 2, with an average time of 85.56 minutes per week and an average frequency of 2.33 times per week, compared to Sample Group 2 which only had an average time of 45.00 minutes per week and an average frequency of 1 time per week. As for the TV watching activity, both groups had a similar duration of activity per session, with Sample Group 1 and Sample Group 2 having an average time of 55.71 minutes and 60.00 minutes, respectively. However, Sample Group 1 exhibited a lower frequency of activity than Sample Group 2, with an average frequency of 1.49 times per day and 1 time per day, respectively. Finally, for the eating (ET) and dishwashing (WD) activities, Sample Group 1 had a longer duration of activity and a higher frequency of activity than Sample Group 2. The average duration of activity for Sample Group 1 was 21.36 minutes per session, with an average frequency of 2.49 times per day for the eating activity and 9.17 minutes per session, with an average frequency of 2.71 times per day for the dishwashing activity, which were both higher than those observed in Sample Group 2. The first sample group conducted activities within a building that differed from all of the activities conducted by the second sample group. The activities included the use of air conditioning, clothes ironing, rice cooking, microwave usage, hot water boiling, plant watering, car washing, and food preparation. It was found that the average activity duration for each activity was 25.00, 23.33, 10.00, 30.00, and 31.37 minutes per occurrence, respectively, while the average frequency of each activity was 1.50, 1.17, 2.00, 0.25, and 2.67 times per day for AC, RC, WB, GN, and CK, respectively. For IC, MI, and WC, the corresponding activity durations were 25.00, 10.67, and 30.00 minutes per occurrence with an average frequency of 2.29, 4.67, and 30.00 times per week, respectively.

A total of 10 activities were performed by two CP3 groups that conducted similar activities. These activities included turning on lights, turning on fans, taking a shower, using the restroom, blow drying hair, using a microwave, watching TV, having meals, washing dishes, and cooking. The first sample group exhibited higher frequencies and longer durations for each activity compared to the second sample group. Specifically, the first group spent an average of 241.18 minutes and performed the activity 1.93 times per day for turning on lights, 225.56 minutes and 1.11 times per day for turning on fans, 20.63 minutes and 1.56 times per day for taking a shower, 3.60 minutes and 4.15 times per day for using the restroom, 15.00 minutes and 0.29 times per day for blow drying hair, 11.00 minutes and 11.00 times per week for using a microwave, 179.09 minutes and 1.03 times per day for watching TV, 20.71 minutes and 2.77 times per day for having meals, 12.44 minutes and 2.04 times per day for washing dishes, and 33.89 minutes and 2 times per day for cooking. In contrast, the second sample group spent only 510.00 minutes once per day for turning on lights, 570.00 minutes once per day for turning on fans, 20.00 minutes and 2 times per day for taking a shower, 2.00 minutes and 3 times per day for using the restroom, 2.50 minutes and once per day for blow drying hair, 16.00 minutes and 9.50 times per week for using a microwave, 60.00 minutes and 0.50 times per day for watching TV, 22.50 minutes and 1.36 times per day for having meals, 10.50 minutes and 1.14 times per day for washing dishes, and 35.00 minutes and 2 times per day for cooking, respectively. The activities that occurred were specific to sample group 1, consisting of 6 activities, namely clothing washing, fabric ironing, rice cooking, watering plants, car washing, and pet care. The average time spent on these activities was 43.00 minutes per session, 3.50 sessions per week, 32.50 minutes per session, 4.25 sessions per week, 27.50 minutes per session, 0.76 sessions per day, 15.00 minutes per session, 1.33 sessions per day, 40.00 minutes per session, 1.39 sessions per day, and 55.00 minutes per session, 1.06 sessions per week, respectively.

A total of seven activities were observed to occur simultaneously in CP4. These activities consisted of turning on the lights, turning on the fan, taking a shower, using the bathroom, using the microwave, eating, and washing dishes. From the data, it was found that both sample groups had similar durations and frequencies of activities. Sample group 1 spent an average of 171.18 minutes, or 1.65 times per day, on all activities combined. Sample group 2 spent an average of 480.00 minutes, or 2.00 times per day, on all activities combined. For turning on the lights, sample group 1 spent an average of 216.67 minutes, or 1.11 times per day, while sample group 2 spent an average of 480.00 minutes, or 1.00 time per day. For turning on the fan, sample group 1 spent an average of 13.75 minutes, or 1.44 times per day, while sample group 2 spent an average of 15.00 minutes, or 2.00 times per day. For taking a shower, sample group 1 spent an average of 3.50 minutes, or 3.14 times per day, while sample group 2 spent an average of 2.00 minutes, or 2.00 times per day. For using the bathroom, sample group 1 spent an average of 2.00 minutes, or 2.00 times per day. Both sample groups used the microwave for an average of 6 minutes, 14 times per week. For eating, sample group 1 spent an average of 19.41 minutes, or 2.71 times per day, while sample group 2 spent an average of 30.00 minutes, or 2.00 times per day. For washing dishes, sample group 1 spent an average of 10.00 minutes, or 1.56 times per day, while sample group 2 spent an average of 5.00 minutes, or 2.00 times per day. It should be noted that sample group 1 had an additional nine activities that occurred, which sample group 2 did not perform, namely washing clothes, ironing, cooking rice, boiling water, watching television, watering plants, washing the car, looking after pets, and cooking, with an average time of 40.45 minutes and a frequency of 2.18 times per week, 28.33 minutes and a frequency of 3.17 times per week, and 32.86 minutes, respectively. From the behavioral data of each user group, a comparison is made with the activity dataset and the characteristics of each user group from section CHAPTER 42 Building activity. This is done in order to compare and adjust the quantities of energy consumption, water usage, and waste generation from the sample group 2 to align with the overall behavior of each customer profile.

When all the data on energy consumption, water usage, and waste generation are analyzed, it can be seen that only refrigerators have an impact on energy consumption throughout the day. The energy usage characteristics of refrigerators are the amount used by each building according to the size of the equipment and the activity data that occurs within the building. This is because the energy usage characteristics of refrigerators are consistent with the time and number of activities that occur throughout the day, as shown in the example in Figure 4.92, which shows the average energy consumption throughout the day of User 1 's refrigerator usage in a doctor's dormitory. The behavior of refrigerator usage is consistent across all buildings and all users. When the data on the amount of energy used per appliance in each building is considered according to each user, it can be determined.

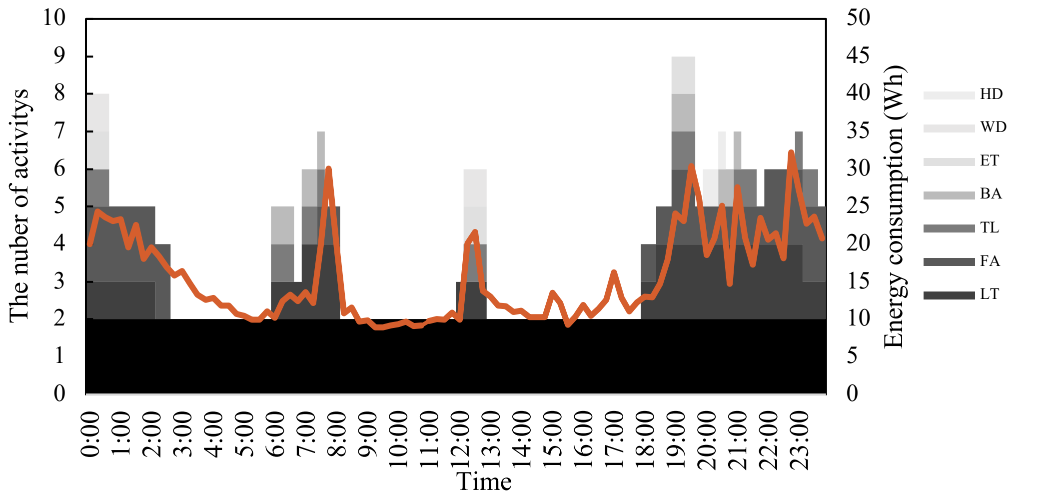


Figure 4.92 The energy consumption of the refrigerator by 1st customer in HH1

When the data on electrical appliance usage for each activity was calculated to find the average energy consumption within 15 minutes, it was found to be consistent with the previously analyzed data. The coefficient of variation calculated from the data measured by the smart meters of each user, each building, and each activity was lower than the calculated average by 15.27%. Therefore, when considering the amount of electricity consumed by each activity based on the electrical appliance data, it is necessary to calculate a reduction from the aforementioned calculated values for all activities.

As for the data on water usage, it will be considered based on the average rate of water usage per 15 minutes throughout the day and the duration of each activity. It was found that the average water consumption in residential buildings was 3.60 liters per 15 minutes. When calculated the duration of each activity, the average amount of water consumption is shown in Table 4.48, which also displays the energy and waste generated per person per 15 minutes. The waste is measured in Wh/15 min per person, the water consumption is measured in liters/15 min per person, and the waste generated is measured in grams/15 min per person. All of this data will be used to create the consumer profile for the next phase.

Table 4.48 Energy, Water, Waste in activity by customer profile

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
RE	EN	35.31	31.38	29.41	42.28	36.17	34.51	28.75	35.52	42.44	40.13	41.98	44.20	40.45	36.89
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.89	0.24	0.17	0.11	1.18	2.36	2.39	0.49	0.37	1.19	1.72	2.20	1.61	1.88
	Org-WE	0.01	0.00	0.00	0.00	0.02	0.03	0.06	0.01	0.00	0.01	0.00	0.02	0.06	0.09
	Rec-WE	0.01	0.01	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.03	0.05
FA	EN	1.91	2.18	3.19	2.31	0.26	2.83	0.65	2.34	2.25	1.34	2.09	2.32	2.07	0.99
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	28.38	2.29	0.60	0.41	30.40	17.50	43.91	4.47	1.25	4.44	3.05	27.82	16.41	29.77
	Org-WE	0.30	0.03	0.01	0.04	1.69	0.74	2.55	0.26	0.01	0.30	0.03	0.41	1.17	2.69
	Rec-WE	0.05	0.01	0.02	0.01	0.33	0.05	0.42	0.09	0.03	0.17	0.03	0.05	0.21	0.39
TL	EN	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01
	WA	1.90	2.08	1.03	1.00	2.85	1.40	1.80	0.29	0.99	1.42	1.77	1.24	1.28	1.15
	Gen-WE	93.15	28.28	28.83	6.30	18.39	96.25	67.06	462.37	72.21	130.94	76.94	337.45	192.27	358.12
	Org-WE	0.67	0.27	0.25	0.07	0.11	0.73	0.77	5.98	0.60	0.90	0.25	0.61	1.14	0.04
	Rec-WE	0.53	0.17	0.43	0.31	0.47	0.25	2.35	5.29	0.24	0.55	0.29	0.83	2.71	4.00
WD	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	6.65	6.78	9.20	7.39	9.45	8.53	13.86	6.65	5.26	11.09	8.40	6.76	9.45	8.78
	Gen-WE	94.79	27.56	7.80	2.05	28.55	50.88	42.87	40.52	35.81	11.16	62.56	126.66	58.65	86.66
	Org-WE	0.68	0.27	0.09	0.04	0.18	0.59	0.55	0.38	0.09	0.21	0.11	0.49	0.58	1.31
	Rec-WE	1.82	0.22	0.05	0.16	0.65	3.29	2.13	2.34	0.45	0.68	0.27	2.22	4.22	7.68

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
LT	EN	6.49	7.93	9.78	6.70	4.35	10.84	15.24	7.25	9.33	8.43	7.16	9.14	15.39	6.37
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	2.38	0.57	0.15	0.04	1.45	3.03	2.37	2.55	0.65	4.37	3.03	3.82	2.80	4.19
	Org-WE	0.03	0.01	0.00	0.01	0.04	0.07	0.09	0.10	0.00	0.01	0.01	0.04	0.11	0.25
	Rec-WE	0.03	0.01	0.00	0.00	0.02	0.04	0.05	0.08	0.00	0.00	0.00	0.02	0.07	0.15
ET	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	4.31	5.26	5.10	4.78	5.71	5.05	4.31	4.11	5.07	4.31	4.83	4.81	5.41	4.47
	Gen-WE	47.39	11.83	5.54	1.06	3.93	28.67	22.42	52.75	36.84	87.28	67.36	62.58	43.91	60.97
	Org-WE	0.39	0.12	0.05	0.02	0.09	0.33	0.55	0.29	0.02	0.21	0.07	0.23	0.84	1.44
	Rec-WE	0.00	0.09	0.03	0.08	0.42	1.86	2.74	1.68	0.10	0.25	0.14	1.08	3.45	6.83
BA	EN	4.15	3.54	3.61	2.33	1.65	3.52	0.13	4.12	1.67	3.46	2.75	2.37	1.18	1.63
	WA	3.97	3.70	4.46	2.98	3.50	3.41	3.97	4.33	3.76	4.27	3.50	3.51	2.87	3.25
	Gen-WE	37.48	12.00	4.96	1.06	16.94	29.85	33.92	48.84	26.01	59.41	32.34	80.76	128.54	145.00
	Org-WE	0.22	0.11	0.05	0.03	0.09	0.23	0.31	0.63	0.15	0.34	0.09	0.15	1.01	1.36
	Rec-WE	0.00	0.07	0.04	0.06	0.25	0.08	0.55	0.12	0.06	0.23	0.10	0.15	0.33	0.13
MI	EN	0.09	0.36	0.84	0.54	0.05	0.31	0.00	0.00	0.00	0.25	0.42	0.29	0.69	0.00
	WA	0.48	1.70	4.14	2.88	0.96	1.22	0.00	0.00	2.05	2.88	2.38	1.51	4.79	0.00
	Gen-WE	1,030.80	73.60	5.71	1.71	74.59	242.55	0.00	0.00	69.49	1.74	107.12	275.00	59.73	0.00
	Org-WE	0.86	0.25	0.06	0.05	0.12	0.17	0.00	0.00	0.00	0.00	0.13	0.15	0.12	0.00
	Rec-WE	0.92	-0.03	0.06	0.09	1.04	0.41	0.00	0.00	0.01	0.00	0.10	0.49	0.34	0.00

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
CK	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	2.04	1.85	1.98	2.04	1.75	1.84	1.87	0.00	2.08	1.83	1.95	2.10	2.15	3.08
	Gen-WE	12.19	0.47	2.91	3.49	47.77	102.75	96.45	0.00	19.61	28.63	37.05	74.08	65.91	58.33
	Org-WE	0.09	0.06	0.03	0.02	0.04	0.11	0.25	0.00	0.02	0.14	0.03	0.07	0.20	0.28
	Rec-WE	0.16	0.03	0.03	0.03	0.17	0.12	0.58	0.00	0.02	0.00	0.03	0.13	0.50	0.52
GN	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	3.80	1.46	10.89	2.11	2.89	5.00	2.93	0.00	1.14	6.58	3.47	2.70	4.20	3.07
	Gen-WE	236.42	188.00	5.60	0.00	1.76	25.75	66.34	0.00	76.17	33.57	87.66	71.10	40.35	47.65
	Org-WE	0.77	0.40	0.10	0.16	0.84	1.69	2.80	0.00	0.00	0.00	0.07	1.81	2.43	5.68
	Rec-WE	2.04	0.95	0.03	0.18	0.78	1.79	4.08	0.00	0.64	0.00	0.05	1.75	4.15	9.85
TV	EN	1.62	1.03	1.92	1.59	1.64	1.84	4.88	2.20	1.30	2.58	1.64	1.84	2.21	1.30
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.29	2.11	2.13	0.77	1.61	11.29	1.08	42.80	4.13	9.52	3.29	13.06	11.28	15.18
	Org-WE	0.01	0.03	0.00	0.00	0.00	0.00	0.02	0.08	0.02	0.03	0.01	0.01	0.00	0.02
	Rec-WE	0.01	0.02	0.01	0.01	0.03	0.01	0.04	0.04	0.01	0.05	0.01	0.02	0.10	0.06
IC	EN	0.40	0.77	0.54	1.39	0.26	0.82	0.80	2.48	1.09	3.54	0.97	0.75	0.37	0.35
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	392.60	128.22	15.54	1.90	37.94	31.04	107.00	31.11	78.54	24.77	274.02	121.88	42.18	83.77
	Org-WE	0.18	0.22	0.04	0.05	0.08	0.06	0.53	0.03	0.03	0.06	0.16	0.13	0.17	0.89
	Rec-WE	0.06	0.00	0.12	0.08	0.84	0.47	1.50	0.09	0.25	0.15	0.14	0.29	0.38	0.28

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
WB	EN	0.84	1.13	1.61	2.28	1.72	1.22	6.18	5.60	0.94	4.36	2.26	1.42	2.44	1.15
	WA	0.26	0.52	0.52	0.53	0.54	0.42	2.35	1.57	0.24	1.04	0.55	0.41	0.57	0.39
	Gen-WE	99.53	8.97	28.63	20.81	200.89	491.93	78.46	54.38	157.87	0.00	30.29	346.90	228.56	513.35
	Org-WE	0.97	0.13	0.14	0.06	0.31	0.49	0.29	0.57	0.65	0.00	0.10	0.30	1.53	3.84
	Rec-WE	0.95	0.10	0.14	0.06	0.31	0.93	0.29	0.21	0.09	0.00	0.04	0.51	1.45	3.41
RC	EN	1.41	1.59	1.23	2.92	0.95	2.29	2.67	4.30	1.62	2.62	2.84	1.89	2.16	2.03
	WA	4.57	6.52	5.18	9.00	4.85	6.76	8.43	14.38	5.15	7.98	7.91	6.33	6.55	7.49
	Gen-WE	199.05	45.59	14.97	0.10	10.30	5.35	7.61	12.13	22.28	27.63	37.66	46.19	33.95	34.50
	Org-WE	0.05	0.06	0.03	0.01	0.01	0.01	0.05	0.00	0.00	0.00	0.05	0.03	0.37	0.00
	Rec-WE	0.00	0.03	0.15	0.03	0.18	0.23	0.21	0.01	0.03	0.11	0.04	0.05	0.10	0.18
WC	EN	1.19	0.76	1.33	0.87	1.28	2.03	1.26	1.83	1.11	2.34	1.67	2.29	1.49	0.89
	WA	4.25	2.93	5.15	3.02	3.64	6.90	4.77	5.31	3.99	8.00	4.64	6.05	4.59	3.33
	Gen-WE	1.34	12.19	18.96	18.89	139.92	134.16	175.60	154.40	131.20	42.02	50.27	109.28	149.03	319.52
	Org-WE	0.06	0.15	0.03	0.04	0.02	0.02	0.12	0.00	0.04	0.00	0.08	0.03	0.41	0.00
	Rec-WE	0.37	0.07	0.09	0.10	0.37	0.27	1.05	0.41	0.13	0.16	0.14	0.20	1.33	2.48
HD	EN	0.00	0.24	0.07	0.00	0.00	0.62	0.00	0.76	0.20	0.16	0.15	0.07	0.15	0.00
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.00	31.89	110.01	0.00	0.00	222.39	0.00	168.67	29.95	64.02	66.66	1,297.88	842.65	0.00
	Org-WE	0.00	0.30	0.75	0.00	0.00	0.28	0.00	1.48	0.48	1.22	0.25	0.89	2.44	0.00
	Rec-WE	0.00	0.19	0.43	0.00	0.00	0.50	0.00	1.42	0.34	1.56	0.12	1.96	1.17	0.00

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
WR	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	0.20	0.34	1.59	0.58	0.66	0.74	0.64	0.00	0.54	0.75	0.54	0.36	0.14	0.00
	Gen-WE	0.00	75.36	53.30	69.35	545.81	941.50	919.10	0.00	301.01	334.31	942.50	2,337.49	4,954.64	0.00
	Org-WE	10.12	1.45	0.26	0.43	2.22	4.39	8.71	0.00	1.86	0.64	0.73	4.25	52.07	0.00
	Rec-WE	0.00	0.53	0.37	0.31	0.99	1.95	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.2 Consumer profile

In the process of creating a consumer profile, it is necessary to analyze the factors that influence personal consumption of energy, water, and waste in households. This analysis revealed that increased access to electricity does not necessarily result in increased usage among low-income households and may actually widen the gap in energy use between high- and low-income households. Moreover, household characteristics such as education level, head of household, household size, and housing quality and efficiency were identified as significant factors affecting electricity consumption (Son & Yoon, 2020). Additionally, it was found that there are direct and indirect drivers of resource use behavior in buildings, which can be categorized into direct and indirect drivers (Jorgensen et al., 2009).

The direct drivers of household water consumption can be classified into various categories, including incentives or disincentives provided through tariff structures, pricing mechanisms, or rebates on water-saving technologies. Furthermore, regulations and ordinances such as water restrictions and local government planning regulations play a significant role in influencing household water consumption. The characteristics of the property, such as lot size, pool, bore, tank, house size, and age, also impact the water usage patterns. In addition, household characteristics such as the composition of the household, household income, availability of water-saving technology, and water supply technology are crucial in determining the amount of water consumed. Finally, personal characteristics such as an individual's intention to conserve water and their knowledge of water conservation methods also play a role in influencing water consumption patterns in households. By understanding these direct drivers, policymakers and water management authorities can develop effective strategies to promote water conservation and sustainable water use practices in households.

The indirect drivers of water conservation behavior are factors that are less directly linked to water use but can still have a significant impact on the decision-making processes that drive water consumption. These drivers include various personal characteristics, such as subjective norms, behavioral control, and attitudes towards water conservation. Another important indirect driver is trust, both in the water provider and in other consumers. Additionally, perceptions of fairness in decision-making processes related to water management, including restrictions, tariffs, and infrastructure development, can impact water conservation behavior. Environmental values and conservation attitudes are also relevant, as is the principle of intergenerational equity. Socio-economic factors, such as household income, composition, age, gender, and education level, are also important drivers of water conservation behavior, as they can impact the availability of water-saving technologies, the affordability of water bills, and the knowledge and awareness of water conservation strategies.

The conditions and all factors that affect energy consumption, water usage, and waste generation resulting from each activity of each consumer group, it is possible to create a total of 14 profiles as illustrated in Figure 4.93 to Figure 4.106

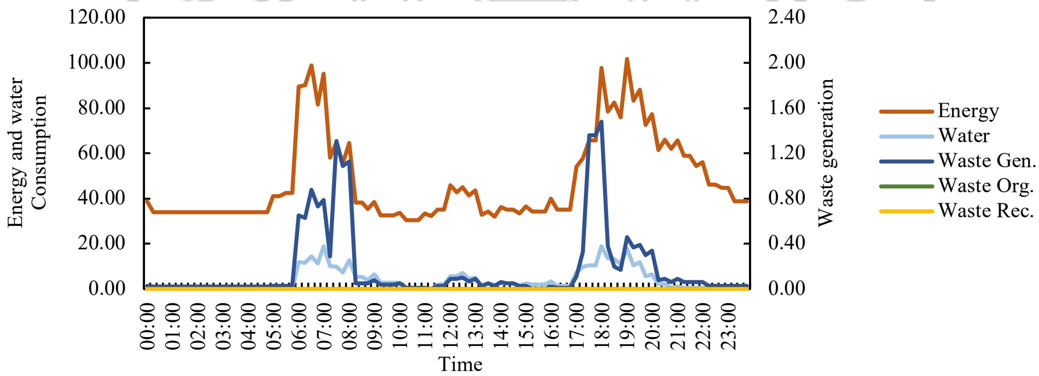


Figure 4.93 Consumer profile 1

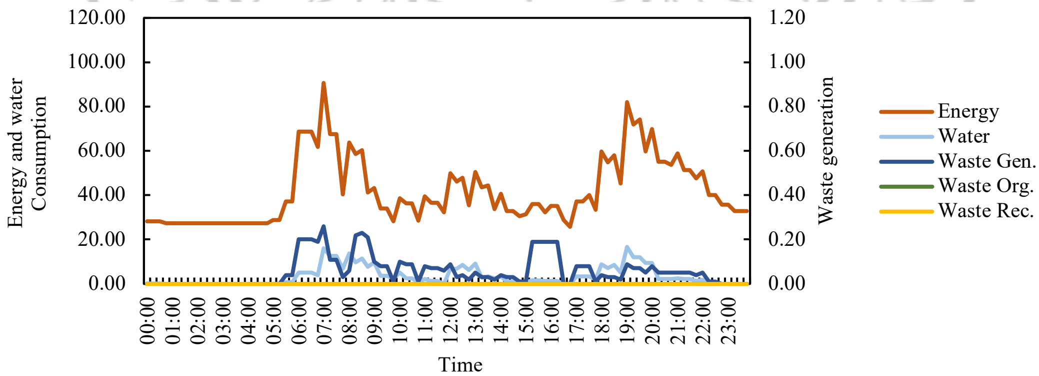


Figure 4.94 Consumer profile 2

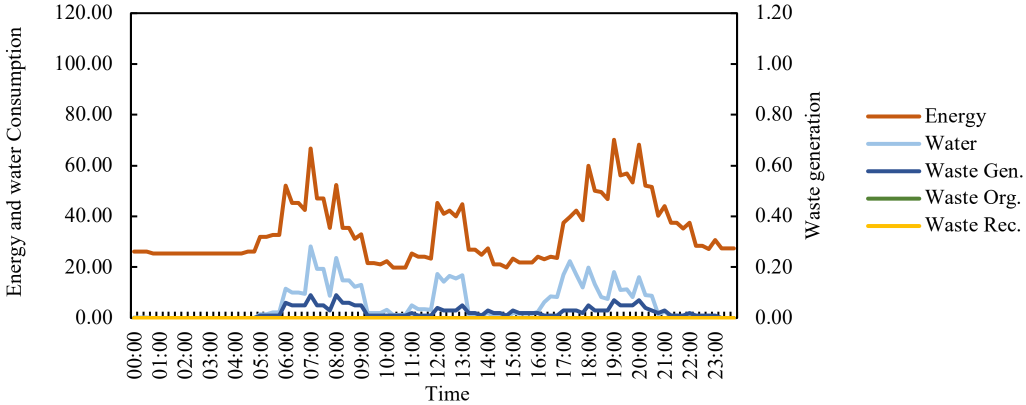


Figure 4.95 Consumer profile 3

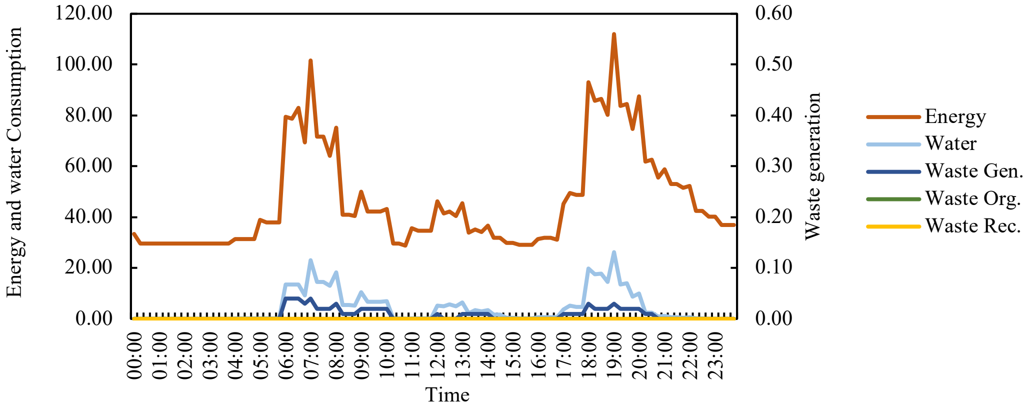


Figure 4.96 Consumer profile 4

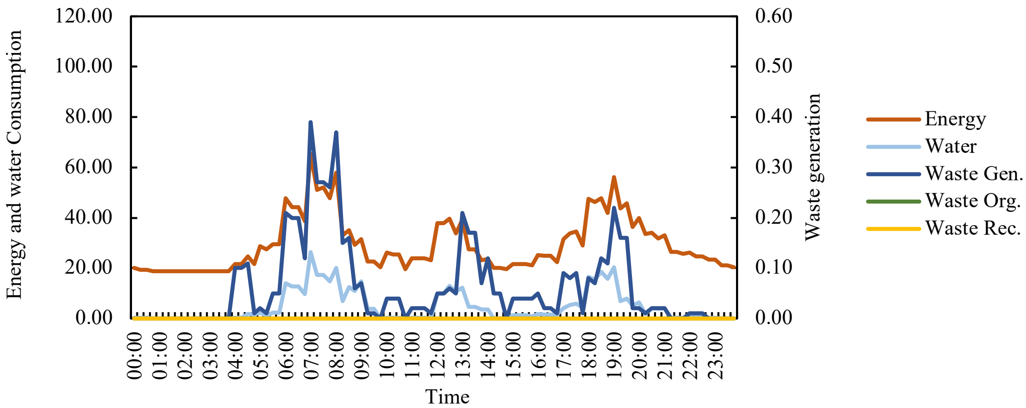


Figure 4.97 Consumer profile 5

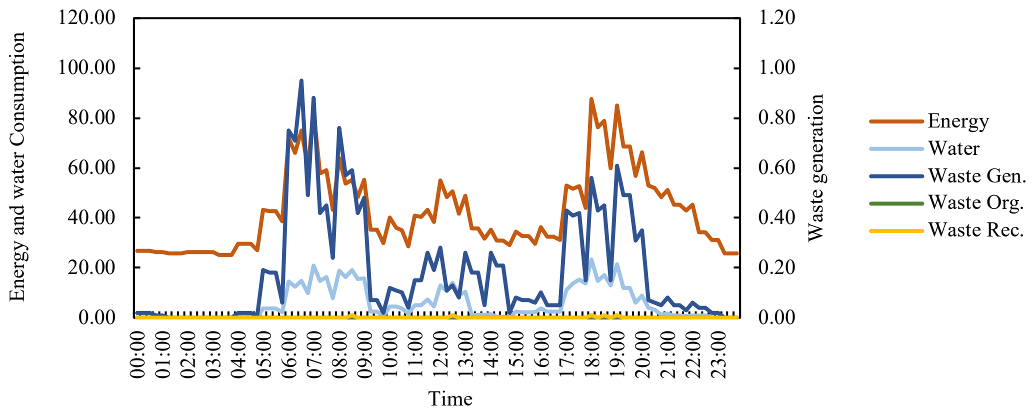


Figure 4.98 Consumer profile 6

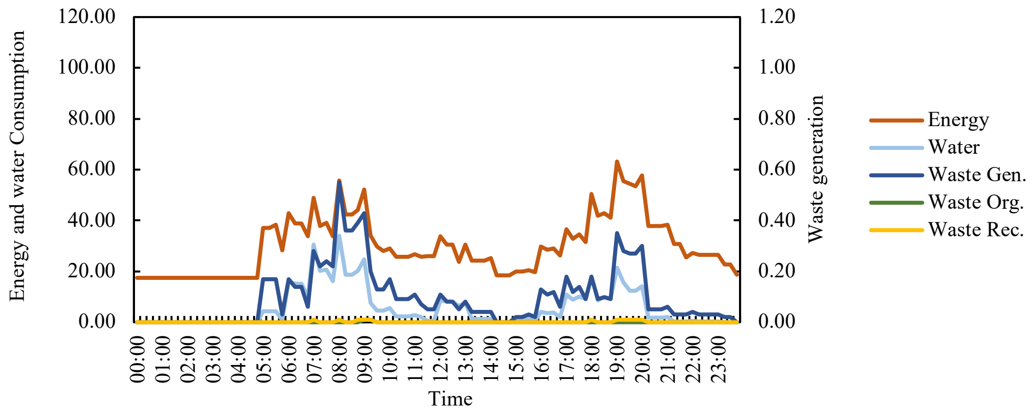


Figure 4.99 Consumer profile 7

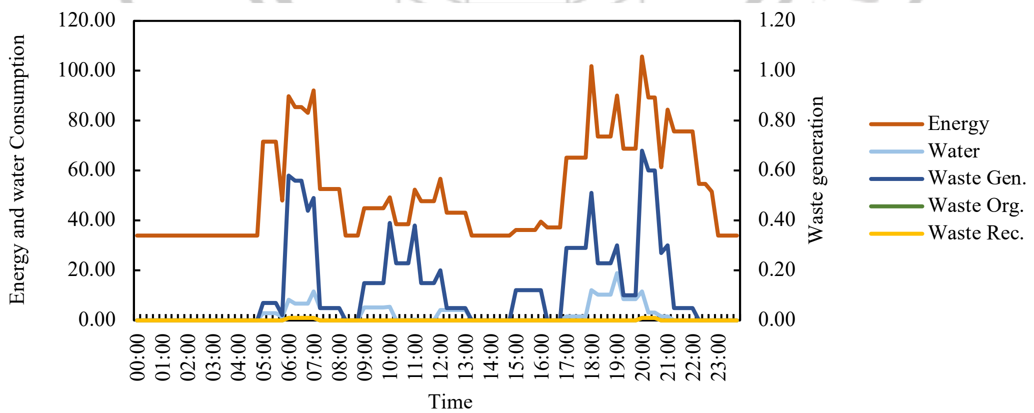


Figure 4.100 Consumer profile 8

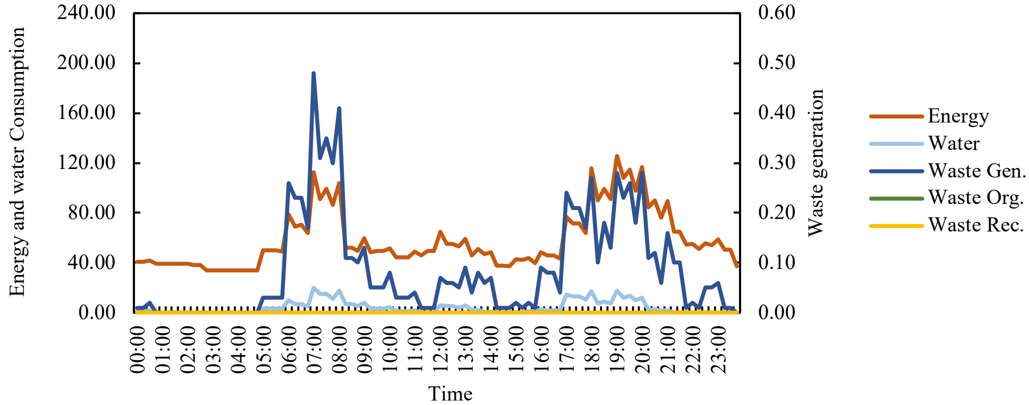


Figure 4.101 Consumer profile 9

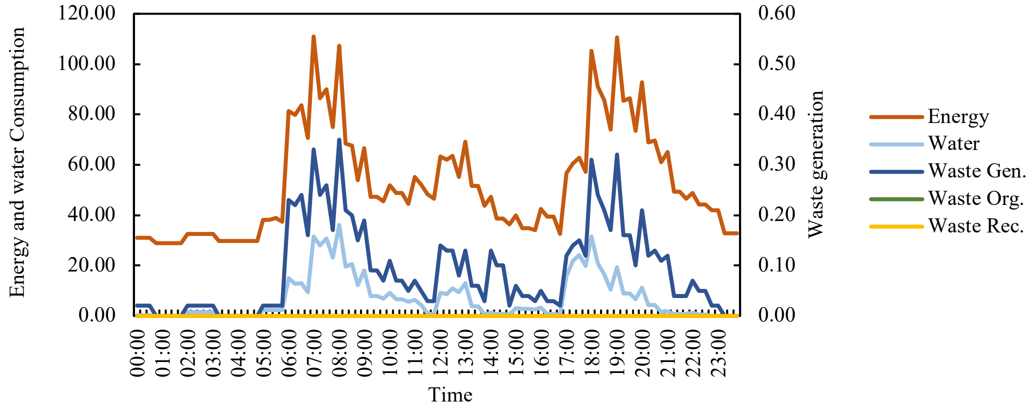


Figure 4.102 Consumer profile 10

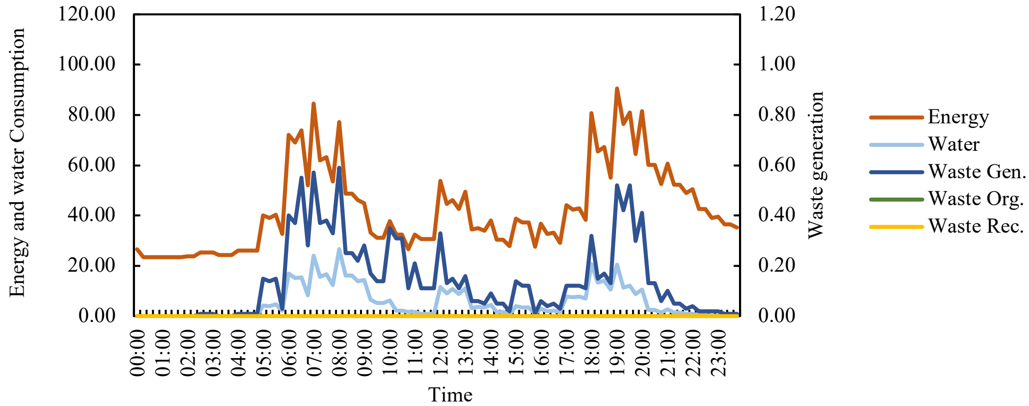


Figure 4.103 Consumer profile 11

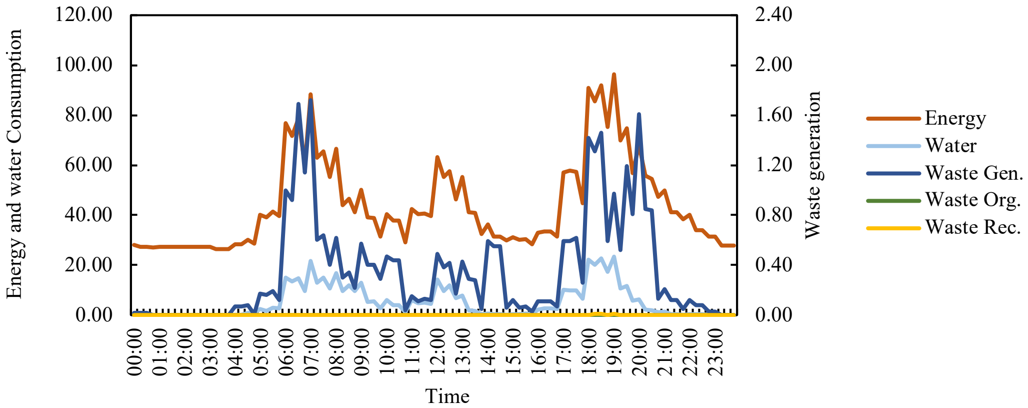


Figure 4.104 Consumer profile 12

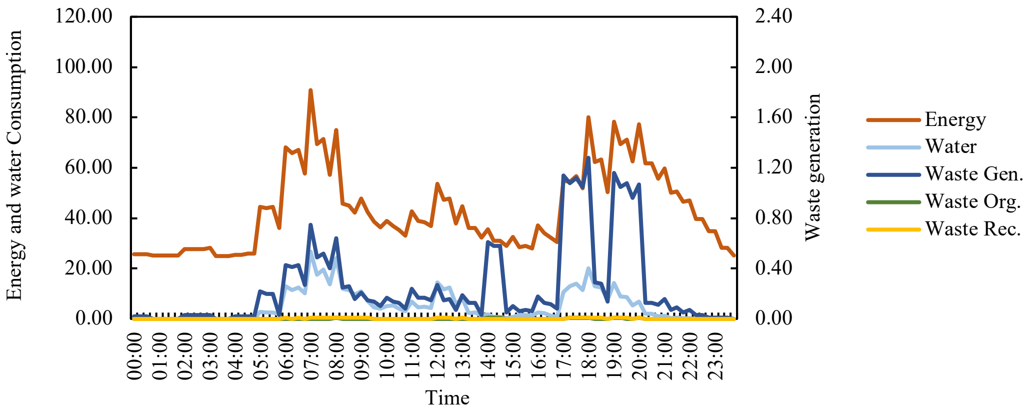


Figure 4.105 Consumer profile 13

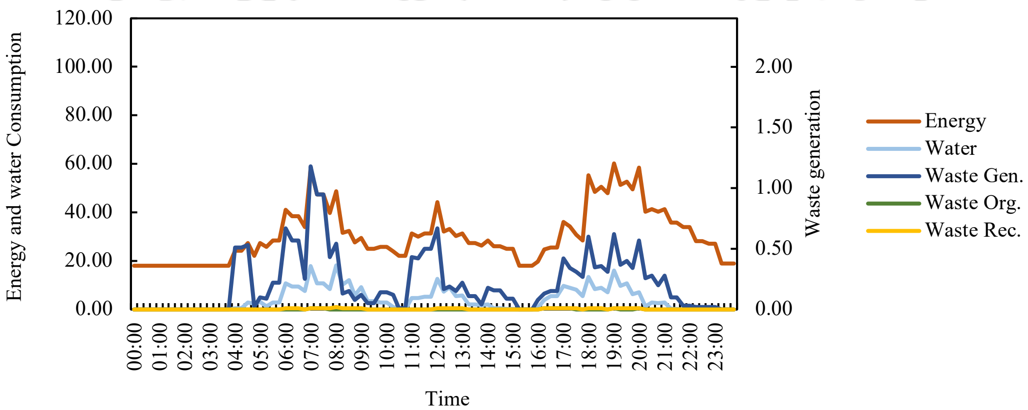


Figure 4.106 Consumer profile 14

Community load

From the population data of approximately 760 individuals in the community, consisting of 375 males and 380 females, the distribution among 16 consumer groups is as follows Table 4.49.

Table 4.49 Mae Tha Man community population

Profile symbol	Personal data		Community population	
	Gender	**Age (Year old)**	**(Number)**	**(Percentage)**
-	Male	< 10	45	5.92
CP1		11-20	55	7.24
CP2		21 - 30	68	8.95
CP3		31 - 40	53	6.97
CP4		41 - 50	53	6.97
CP5		51 - 60	47	6.18
CP6		61 -70	27	3.55
CP7		>71	16	2.11
-	Female	< 10	64	8.42
CP8		11-20	44	5.79
CP9		21 - 30	65	8.55
CP10		31 - 40	62	8.16
CP11		41 - 50	63	8.29
CP12		51 - 60	45	5.92
CP13		61 -70	40	5.26
CP14		>71	13	1.71
Total (Person)			**760**	**100.00**

The population data of the community, multiplying it by the amount of energy, water usage, and waste generation per profile yields the average usage and generation per day as shown in Figure 4.107 to Figure 4.109. These figures depict the quantity of energy, water, and different types of waste generated during different times of the day. Analysis of the data reveals that the average daily energy consumption is 1451.69 kWh/day, with the maximum electricity consumption of 29.29 kWh occurring at 19:30 and the minimum consumption of 9.78 kWh at 13:30. The average electricity consumption throughout the day is 15.12 kWh. Regarding water usage, the data show that the average daily consumption is 307,887.22 liters, or 405.11 liters per person per day, which is higher than the average water usage. The time of highest estimated water usage is at 6:45, with a total consumption of 10,189.22 liters for the entire community, while the lowest water usage occurs at 12:15 with a consumption of 1396.03 liters. The average daily water usage for the community is 3,207.16 liters. Examining the waste generation of the community, the data indicate high variability during the early morning hours, and the amount of waste does not correspond with energy and water usage patterns. The average waste generation of the community is 3057.34 kilograms per day, consisting of 1694.82 kilograms of general waste, 1004.86 kilograms of organic waste, and 357.66 kilograms of recyclable waste.

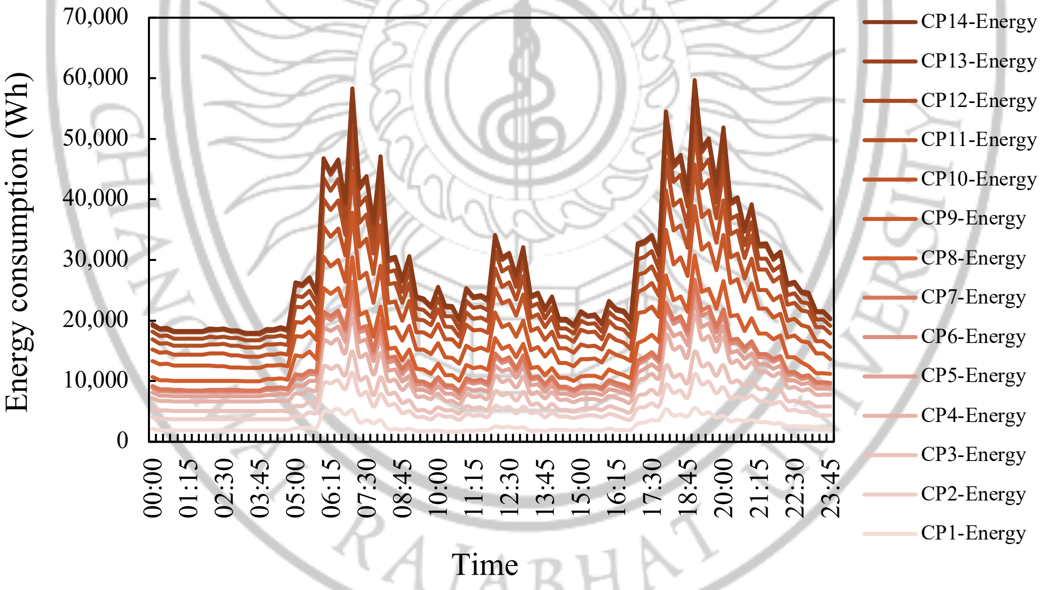


Figure 4.107 The average daily energy consumption of community

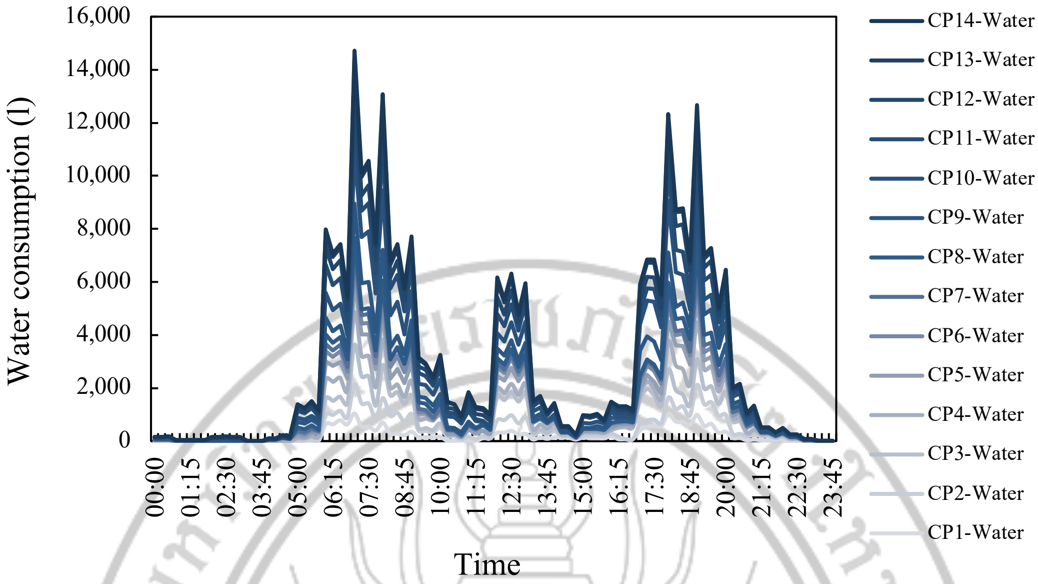


Figure 4.108 The average daily water consumption of community

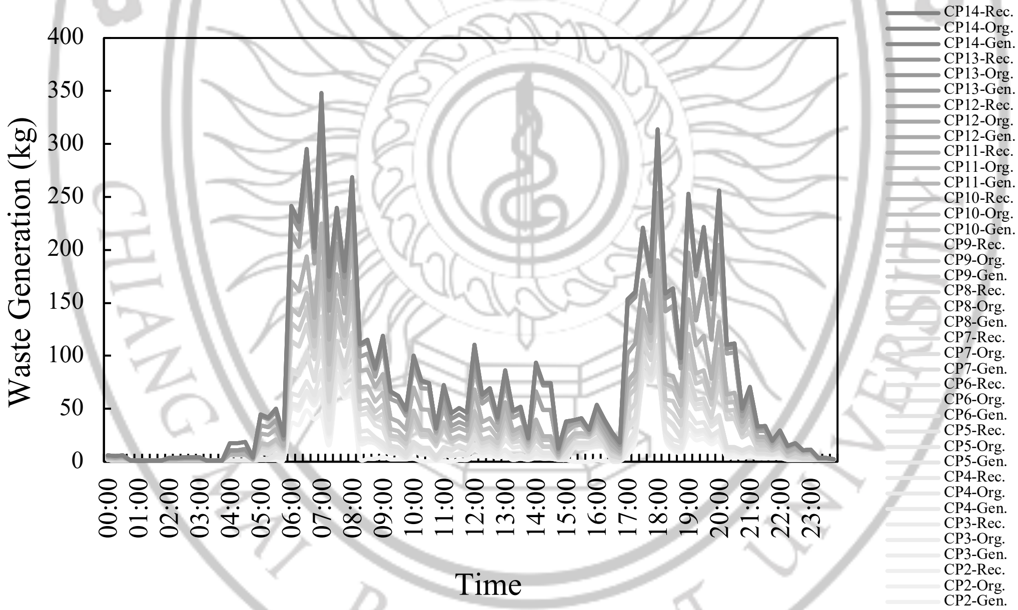


Figure 4.109 The average daily waste generation of community

When analyzing the quantity of energy, water usage, and waste generation within the community on a monthly basis, it is necessary to consider the environmental conditions of the community since the data on energy usage and water consumption within the buildings is retrospective. When comparing the average energy and water usage for each time period throughout the month, it varies in the same direction as the environmental conditions, as shown in Figure 4.110. Additionally, the positive correlation between water usage within the buildings and energy usage within the buildings causes the water usage within the buildings to also vary directly with the external temperature, similar to the energy usage. However, the generation of waste does not have a statistically significant correlation with energy and water usage, and thus, the analysis of accumulated waste did not consider environmental factors.

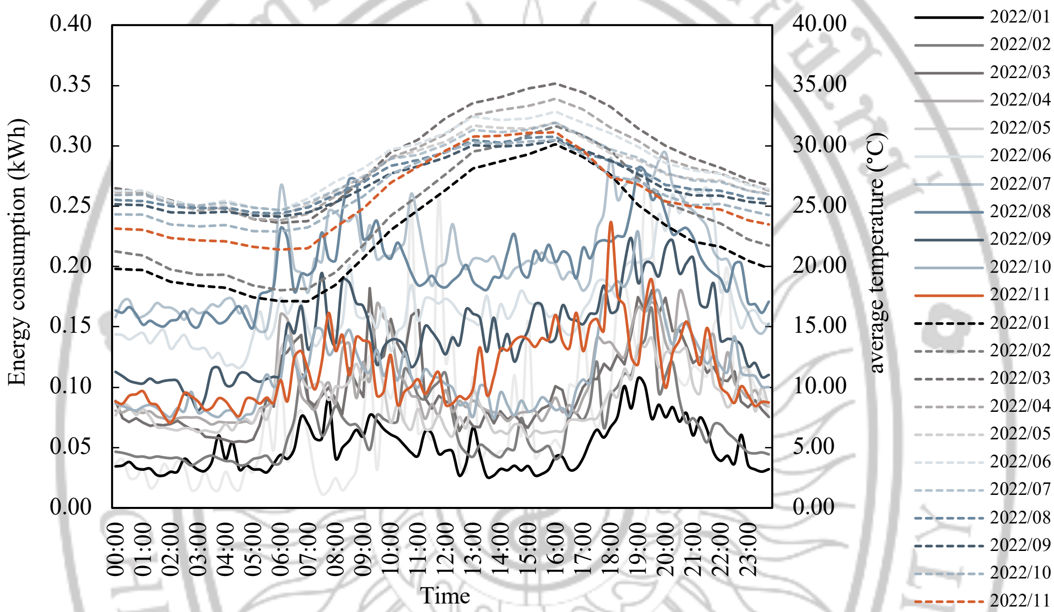


Figure 4.110 The average of energy consumption in CH1 and outdoor ambient temperature in community

The analysis revealed that, when analyzing the amount of energy, water usage, and waste, it was found that the total amount of energy used by the community in one year was as follows: 84,947.24, 88,839.21, 119,988.03, 116,469.74, 131,999.19, 118,090.05, 105,681.56, 110,074.08, 107,450.75, 105,931.00, 97,528.94, and 99,806.62 kWh per month, for the months of January to December 2022.

Development of smart community frameworks

1. Analysis of community potential

1.1 Energy sector

It was found from the data on solar irradiance intensity in the community that the level of irradiance was higher than 900 W/m2 during the period from February to October. When considering the potential for electricity production, it was found to be equal to 2,729.61, 2,716.84, 2,347.43, 1,923.32, 1,816.43, 1,741.49, 1,844.76, 1,749.13, 1,573.23, 1,686.07, 1,658.88, and 1,637.05 kWh/m^2/month, respectively, as a quantity of potential electricity production from solar radiation from January to December.

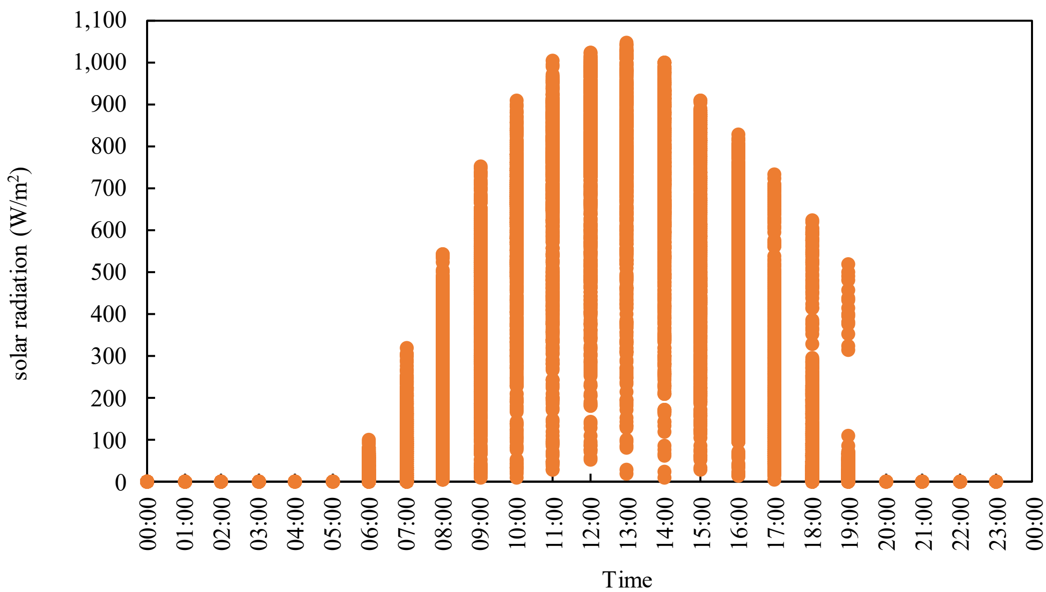


Figure 4.111 Solar radiation in community

Wind potential in the area, the average wind speed is found to be approximately 5.40 m/s. By considering the wind speed to assess the potential size of wind turbines that could be installed for electricity generation within the community, it is observed that the amount of electricity generated by a wind speed of 5.4 m/s is contingent upon both the size of the wind turbine and its efficacy in generating electricity. Typically, wind turbines utilized for community installations range in size from 10 kW to 100 kW. It is assumed that a 50 kW wind turbine with a 40% efficiency has the capacity to generate an approximate amount of 26.38 kWh of electricity. Thus, with the implementation of a 50 kW wind turbine possessing a 40% efficiency, a wind speed of 5.4 m/s has the ability to generate 26.38 kWh of electricity per hour.

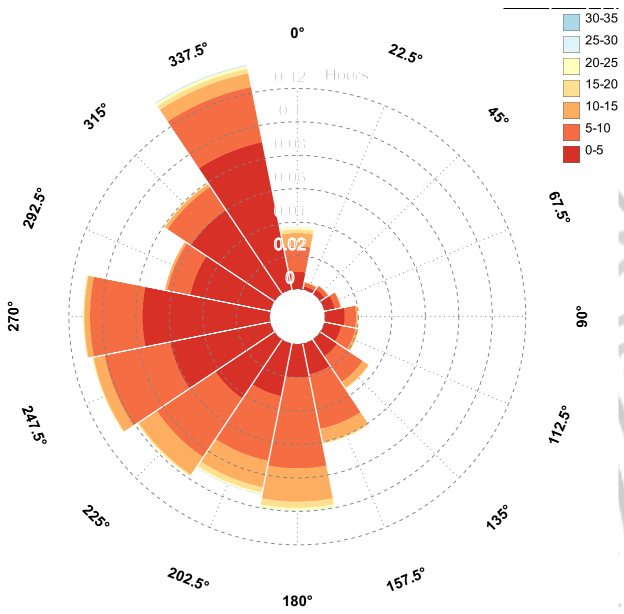


Figure 4.112 Wind speed and direction in community

1.2 Water sector

The community's necessary water source within the village is a natural water source that is mainly used by the community. The data obtained from the survey on water usage and demand from a sample group, it is evident that a large portion of residential buildings, specifically residential homes, already have two water systems in place, namely the community tap water system and the natural water source system. However, from the data, it was found that the water system derived from the natural water source cannot be used during the period between months, due to the natural water source being dry and experiencing turbidity.

1.3 Waste sector

Derived from the waste generation data in the Mae Tha Man community based on the consumer profile of the entire village, it was found that general waste was produced at 7.59 kg, wet waste at 0.01 kg, and recyclable waste at 0.02 kg. Upon aggregating the data, it was determined that the average waste disposal per capita per day in the Mae Tamarn community was 0.01 kg, which is considerably lower than the national average for Thailand, which stands at 1.15 kg per capita per day.

Upon examining the community context, it was discovered that the Mae Tamarn community has been actively engaged in waste management with societal participation. This social process involves raising community awareness about the current waste situation, fostering understanding, and discussing suitable waste management strategies for the community. Prior to implementing the participatory waste management plan, the Mae Tamarn community had an average waste generation of 1.05 kg per capita per day. Following the initiation of the community-based waste management process, the waste generation was reduced by 0.02 kg per capita per day. The obtained data, it can be observed that waste reduction has been consistently achieved over time. Thus, it can be concluded that the waste generation data analyzed from the consumer profile closely aligns with the reality.

2. Development of smart community framework

2.1 Energy sector

Upon assessing the total energy demand of the village, divided into one-hour intervals and juxtaposed with the solar and wind energy potential in the area, several observations have been made. It has been ascertained that electricity production from solar energy exhibits potential primarily during the morning hours and is sufficient to meet the energy demand between 10:00 to 16:00. The capacity of solar panels to address energy requirements during this period is limited, accounting for only 30.28% of the total energy demand. However, when analyzing the energy consumption potential throughout the day, a significant finding emerges. It has been determined wind energy possesses the capability to replace up to 83.99% of the total energy demand. This discovery underscores the importance of leveraging both solar and wind energy resources to optimize the village's energy management strategies and harness the full potential of renewable energy sources. That show in Figure 4.113.

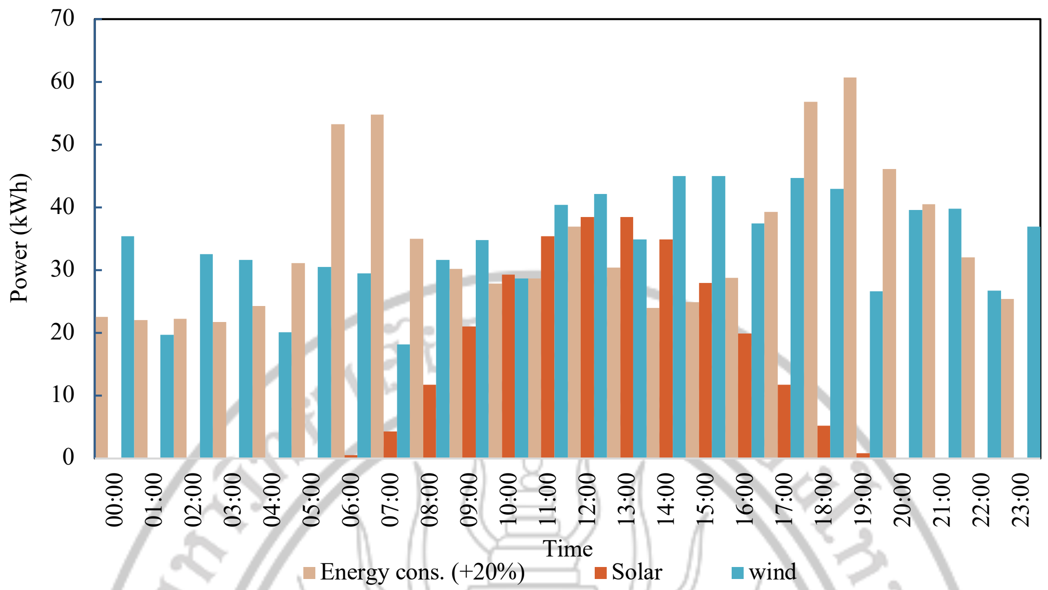


Figure 4.113 The energy production over time from the community's solar and wind potential

2.2 Water sector

To analyze the investment for a clean water production system for the community, it is crucial to consider both the initial investment and the ongoing operational costs. The clean water production system must operate for 12 months to provide clean water during the six months when the natural water source is turbid. The investment for the clean water production system will depend on the system's type, size, and installation and maintenance costs. Operational costs will include energy, chemical, and maintenance expenses. Conducting a feasibility study is necessary to determine the most appropriate and cost-effective system for the community's requirements.

If the cost of the clean water production system is affordable and feasible, it will provide the community with access to clean water year-round, decrease the risk of water-borne diseases, and enhance overall health and well-being. It will also reduce the community's dependence on the natural water source during the six months when the water is turbid, ensuring a consistent supply of clean water.

2.3 Waste sector

The daily waste generation data in the community revealed a mere 7.63 kg/day from all individuals in the village, which is considered to be an insufficient amount for practical utilization. Consequently, it can be concluded that this particular community does not yet necessitate waste management interventions.

3. Economic analysis of smart community guideline

3.1 Energy

The cost of solar energy systems is an important factor in evaluating the financial feasibility of a solar energy project. The cost of the solar system installation is generally measured in terms of the cost per watt. For instance, the cost of the 52.25 kW solar system installation mentioned in the example is calculated at THB 40 per watt, resulting in an initial cost of THB 2,090,000.

The net present value (NPV), internal rate of return (IRR), and payback period are all financial metrics used to assess the financial feasibility of solar energy projects. These metrics are calculated the initial cost of the solar system installation and the estimated future cash inflows and outflows associated with the project.

A positive NPV, higher IRR, and shorter payback period all indicate that a solar energy project is financially viable. In the example given, the NPV of the solar system installation is found to be positive, the IRR is higher than before, and the payback period is approximately 1.74 years, all of which suggests that the project is financially viable. Financial metrics can help investors or businesses make informed decisions regarding solar energy projects and their financial returns.

The cost of installing a wind power system is calculated by multiplying the total wattage by the cost per watt, which in this case is THB 90 per watt. With an assumed total wattage of 20 kW, the initial cost of the wind power system is THB 1,800,000. To determine the profitability of the wind power system, the NPV, IRR, and payback period are calculated the assumption that the system can save around THB 3,334,402.62 per year.

The NPV of the wind power system installation is calculated to be THB 39,338,262.03, which is positive and indicates that the project is profitable based on the assumptions made. The IRR of the wind power system installation is 58.45%, which is high and indicates that the project will generate a high return the assumptions made. The payback period for the wind power system installation is approximately 0.54 years, which means that the project will pay for itself in approximately 0.54 years based on the assumptions made.

These calculations show that a wind power system can be a profitable investment with a relatively short payback period. However, it is important to note that these calculations are certain assumptions and may not be applicable to all situations. Factors such as location, wind patterns, and maintenance costs may affect the actual costs and benefits of a wind power system.

The cost per watt is used to measure the cost of solar system installation. The net present value (NPV), internal rate of return (IRR), and payback period are financial metrics used to assess the financial feasibility of solar energy projects. A positive NPV, higher IRR, and shorter payback period suggest that a solar energy project is financially viable. The same method is used to calculate the cost of wind power system installation, and the profitability of the system is determined by the NPV, IRR, and payback period. The calculations show that wind power systems can be profitable with a relatively short payback period, but it is important to consider other factors such as location, wind patterns, and maintenance costs.

3.2 Water

Investing in a clean water production system for the community is a feasible approach to provide year-round access to clean water. However, a feasibility study is necessary to determine the most appropriate and cost-effective system. To estimate the cost of installation and operation of a clean water production system, several factors such as the type of system, capacity, location, and maintenance requirements must be considered. The cost of installation can vary widely depending on the system type and location. For instance, a simple filtration system with a capacity of 304,000 liters/day may cost between 100,000 to 500,000 baht, whereas a more advanced reverse osmosis system with the same capacity may cost between 500,000 to 1,500,000 baht.

Operational costs may include electricity, maintenance, and labor costs. The electricity costs depend on the system's capacity and energy efficiency, ranging from 20,000 to 50,000 baht per month. Maintenance costs vary with system complexity and maintenance frequency, estimated to be around 10,000 to 30,000 baht per month. Labor costs depend on the number of staff required to operate and maintain the system, ranging from 20,000 to 50,000 baht per month. Overall, the cost of installation and operation of a clean water production system can range from 150,000 to 2,000,000 baht, depending on several factors. Conducting a feasibility study is necessary to determine the most suitable system type, location, and operation model to optimize cost-effectiveness.

Smart community framework

A framework for the development of smart community based on the quantification of energy demand, water consumption, and waste generation within the community has been proposed. This is achieved by comparing the community's potential with the collected and analyzed data from the community, as illustrated in Figure 4.114. The development framework and analysis are divided into three data sources: data obtained from surveys, data measured by smart meter, and data from public databases, with details as follows:

Data from surveys, which are obtained through on-site collection from a sample group within the community for the purpose of analyzing behavioral patterns in building activities by age and gender, consist of four main components: user characteristics, electrical devices and appliances within the building, frequency and duration of each activity, and historical expenditure data. This information is gathered from two sample groups: a majority or at least 35% of the community population, and a sample group of residents living in representative buildings.

Data from smart meters are derived from measurements of energy consumption, water usage, and waste generation of various types (general waste, recyclable waste, and organic waste) within buildings in real-time, with data collection frequency every 15 minutes. These devices are installed in three groups of representative buildings, including residential buildings, office buildings, and commercial buildings. The increased number of buildings with installed smart measuring devices contributes to the reliability of the data used in the analysis of user profiles.

Public database information comprises general data accessible from both government agencies and private organizations. This data includes the total population of the area, categorized by age and gender groups, and current and historical information on the community's fundamental potential, such as solar radiation intensity, wind speed and direction, as well as the quantity and size of water sources in the area. This information is utilized for comparative analysis with the community's needs.

Upon obtaining data from all three sources, management, and analysis yield four sets of data, which include: 1. Behavioral data within the community from the sample population and residents living in representative buildings; 2. Real-time energy, water, and waste generation data; 3. Community context data categorized by age and gender groups; and 4. Community potential data, with details as follows:

Behavioral data within the community from the sample population is obtained by analyzing the frequency and probability of behaviors and activities occurring within buildings for each profile group. This data is used to adjust and compare with values obtained from representative buildings to ensure accuracy and precision. The behavioral data of residents living in representative buildings is used to create activity profiles for each activity occurring within the buildings, which can be utilized for prediction or user profile creation.

Real-time energy, water, and waste generation data within representative buildings are used to identify quantities derived from activities occurring during the time periods when residents are engaged in their respective activities within each building. This data is combined with information from questionnaires to create user profiles.

Community context data, categorized by age and gender groups, is used to analyze the quantity of energy and water consumption and waste generation within all buildings. This analysis determines the potential and costs associated with resource management.

Community potential data assesses the readiness of the area to support current community needs and accommodate future community expansion. This data indicates the feasibility of local resources to accommodate the development of the community towards a smart community.

The provided information, an analysis is conducted using the data obtained from the activities occurring within the sample population, in conjunction with the activity profile data. This analysis aims to identify the energy, water, and waste generation quantities of each activity, in order to create and adjust user profiles for accuracy and reliability. Additionally, the data from the entire community population is used to calculate community needs, taking into consideration the user profiles.

Subsequently, the potential of the community in three aspects is analyzed to determine its suitability. Generally, solar energy can generate an average of 30% of the estimated daily energy demand, while areas with wind energy potential can generate an average of 80% or more, depending on the community's location. The suitability of a community is calculated using the investment costs for installing solar energy systems at approximately 40 THB/watt, and wind energy systems at an average of 90 THB/watt, with the system size depending on the community's energy demand. The clean water production system is calculated by the average daily water consumption at a rate of approximately 3.50 THB/liter. The expenses for waste management, which the community cannot handle independently, are on average between 800 and 2,500 THB/ton, depending on the area and transportation distance.

The appropriateness of community development towards a smart community for energy, water, and waste management is determined by considering the investment value for the preparedness and management of energy, water, and waste in the entire area, divided by the costs that the community can reduce. If all three aspects have a low payback period, it indicates that the community has the potential to develop towards a smart community.

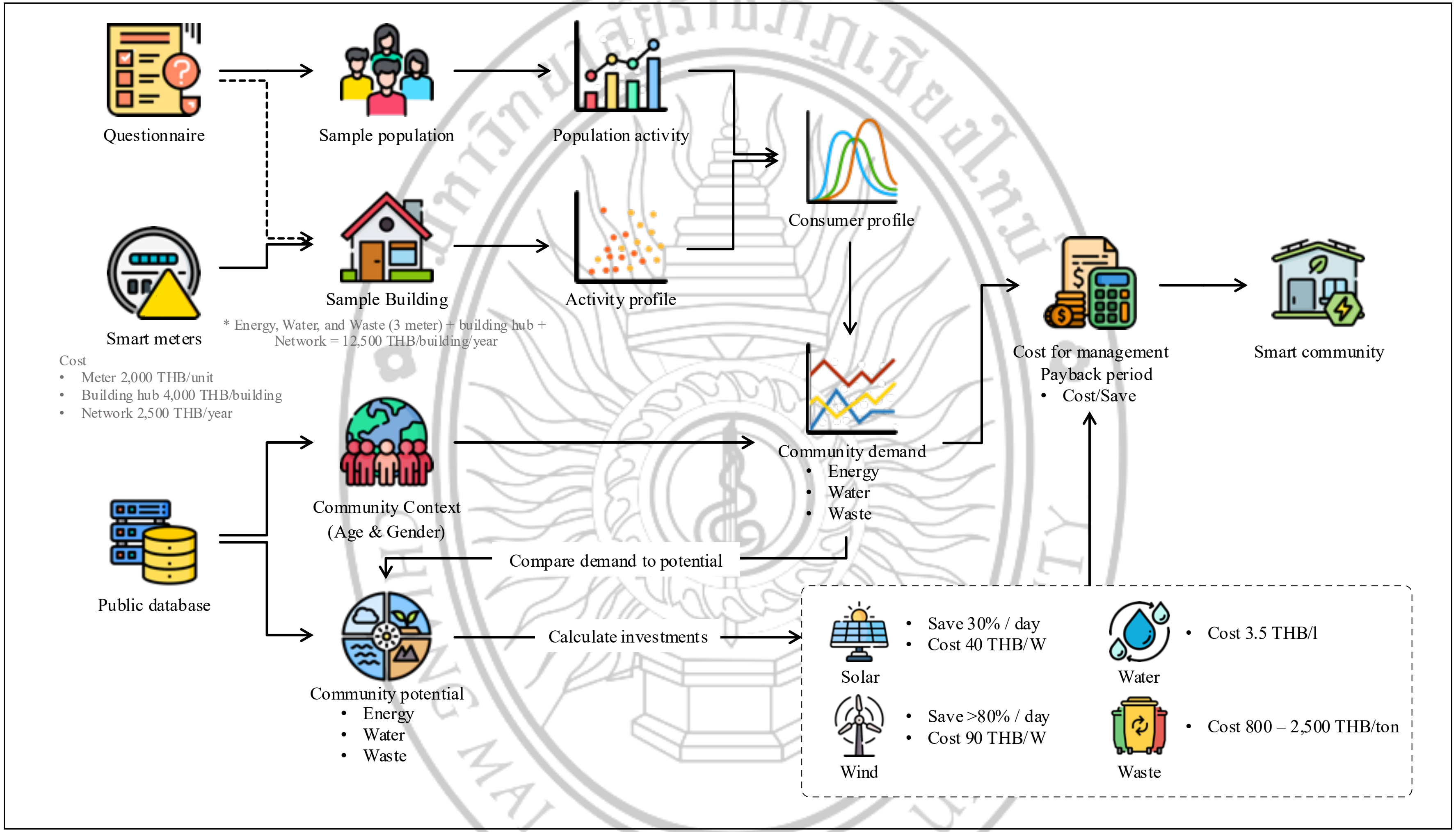


Figure 4.114 Smart community framework infographic

CHAPTER 4

RESULT AND DISCUSSION

Community context

Mae Tha Man Community (MTC) is the local community in the northern part of Thailand. The topography of the area is a high mountain complex, and some parts are hilly plains. The location of most residential buildings is in the hilly plains. The entire area of the community is in the watershed forest of the two main rivers in the northern part of Thailand and is a national reserved forest area. This community has a population of around 760 people divided to male 375 people and female 380 people and 328 households. The population data show as Table 4.1, the samples group were aged between 11-20 years, 6.00%, 21-30 years, 12.80%, 31-40 years, 14.80%, 41-50 years, 18.00%, 51-60 years, 18.40%, 61-70 years, 21.20%, and more than 71 years, 8.40%. The population's level of education in the community found that most of them graduated from the elementary level 51.37%, a secondary level 22.35%, a bachelor's degree 9.80%, a High vocational certificate 4.71%, and 1.96% graduated with a postgraduate degree. The occupation of community population has 6 occupations including general employees 40.32%, government officer 7.51%, personal business 15.81%, farmers 1.98%, private employee 6.72%, and students 6.72%. The average monthly income of around 73.09% lower than 10,000 Baht, 21.29% have an average income between 10,001 – 20,000 Baht, 3.61% have an average income between 20,001 – 30,000 Baht, 0.80% have an average income between 30,001 – 40,000 Baht, 0.40% have an average income between 40,001 – 50,000 Baht, and 0.80% have an average income more than 50,001 Baht.

Table 4.1 Community context

Community data type		Number (People)	Percentage
Gender	Male	111	42.86
	Female	148	57.14
Age (Year)	< 10	1	0.40
	11-20	15	6.00
	21-30	32	12.80
	31-40	37	14.80
	41-50	45	18.00
	51-60	46	18.40
	61-70	53	21.20
	> 71	21	8.40
Education	Below elementary school	25	9.80
	Elementary level	131	51.37
	Secondary level	57	22.35
	Bachelor's degree	12	4.71
	Postgraduate degree	25	9.80
Occupation	Farmer	5	1.96
	Private employee	5	1.98
	General employee	17	6.72
	Students	102	40.32
	Personal business	17	6.72
	Housekeeper	40	15.81
	Government officer	53	20.95
Monthly income (Baht)	< 10,000	19	7.51
	10,001 – 20,000	182	73.09
	20,001 – 30,000	53	21.29
	30,001 – 40,000	9	3.61
	40,001 – 50,000	2	0.80
	> 50,000	1	0.40

There is a relationship between each data segment and the correlation of variables used to characterize the identity of community populations or monitor resource consumption. The age range was discovered to be a variable that was related to other factors. In Pearson correlational analysis, aging was significantly correlated with or had a negative influence on all levels of education, occupation, and income. The correlation was significant at the 0.01 level. Age was also related to occupation at a -0.265 level, and income was related at a -0.285 level. They both have at the 0.05 level; the connection is significant. In addition, the level of education has a positive relationship with occupation and monthly income at the 0.587 and 0.704 correlation levels, with the correlation being significant at the 0.01 level. The occupation of the population was positively connected with monthly income at the 0.437 level with the connection is significant at the 0.01 level. Table 4.2 shows the information on the correlation between the variables in the population categorization. In other words, as the population ages, so does the level of education and the average monthly income. The occupation information is gathered from the level of education and is then matched to the sample's average income. This is consistent with the results of a research of household water usage behavior, which discovered that socioeconomic characteristics including income and household composition were regarded indirect drivers that had no impact on building resource consumption behavior (Jorgensen, Graymore, & O'Toole, 2009).

Furthermore, from the study on the age range that affects resource utilization within the building, it was found that the age group under 10 years old has no significant effect on resource utilization within the building, while the community as a whole is of significant importance (Estiri & Zagheni, 2019). Therefore, the variable group for the age range used in the study was narrowed down to only 7 groups, ranging from the age group between 11 to the group of individuals above 70 years old. The correlation data of such variables could be used to identify relevant variables for the investigation of the data on energy, water, and waste creation in the scenario.

From the correlation data of personal data variables presented in Table 4.2, it was found that gender did not have a significant correlation with any other variables. However, Age, Education, Occupation, and Income showed significant positive correlations with each other, as determined by statistical analysis. Therefore, in the analysis and development of activity profiles, all profiles will be classified into 14 customer profiles, consisting of two gender factors and seven age ranges.

Table 4.2 Correlation of personal data variable

		Sex	Age	Education	Occupation	Income
Sex	Pearson Correlation	1.000	-0.007	0.008	0.168	-0.179
	Sig. (2-tailed)		0.951	0.949	0.165	0.139
	Covariance	0.230	-0.006	0.005	0.143	-0.086
	N	72	70	70	70	70
Age	Pearson Correlation	-0.007	1.000	-0.538**	-0.265*	-0.285*
	Sig. (2-tailed)	0.951		0.000	0.026	0.017
	Covariance	-0.006	2.713	-1.197	-0.788	-0.475
	N	70	70	70	70	70
Education	Pearson Correlation	0.008	-0.538**	1.000	0.587**	0.704**
	Sig. (2-tailed)	0.949	0.000		.000	0.000
	Covariance	0.005	-1.197	1.825	1.431	0.962
	N	70	70	70	70	70
Occupation	Pearson Correlation	0.168	-0.265*	0.587**	1.000	0.437**
	Sig. (2-tailed)	0.165	0.026	0.000		0.000
	Covariance	0.143	-0.788	1.431	3.255	0.799
	N	70	70	70	70	70
Income	Pearson Correlation	-0.179	-0.285*	0.704**	0.437**	1.000
	Sig. (2-tailed)	0.139	0.017	0.000	0.000	
	Covariance	-0.086	-0.475	0.962	0.799	1.025
	N	70	70	70	70	70

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

1. Community building characterizations

Building characteristics are details on the equipment and appliances that use or create energy, water, and trash. Building characteristics are separated into two types: those that are averaged over the whole community and those that are segregated by consumer characteristics. to study the relationship between each factor that may impact the information acquired from each building. The information on building equipment and appliances is shown in Table 4.3.

The building equipment and appliances table. Lighting equipment: It was determined that there are three types in the community, including LED, fluorescent, and incandescent bulbs. LED accounted for 69.83% of the utilization of 6.92 LED bulbs with an average power of 13.96 W, fluorescent accounted for 55.17% of 4.84 bulbs with an energy consumption of 21.74 W, and incandescent bulbs accounted for 5.17% of 6.83 bulbs with an energy consumption of 29.25 W.

Due to the community's location in the mountains of northern Thailand, where the average temperature is rather low, community members rarely use air conditioners (AC). As a result, the percentage of households that use air conditioning amounts to just 6.03% of the overall community. and the average income in the community is low, which impacts the decision to employ a fan as a device for regulating the room temperature in the building. The community employs three types of fans: ceiling, wall-mounted, and table. The average fan size is roughly 16.61 in., with ceiling fans accounting for 15.52%, wall-mounted fans accounting for 24.14%, and table fans accounting for 77.59%. A typical home contains 3.73 units of ceiling fans, 2.29 units of wall-mounted fans, and 2.23 units of table fans.

Regarding cabinet coolers in the community, including refrigerators and freezers, most of the equipment that is installed within a residential building That is, conventional single-door refrigerators account for 46.55% of interior usage, whereas conventional double-door refrigerators account for 3.46%. The utilization of inverter refrigerators in residential buildings was 10.34%, with both single-door unit and 9.48% with double-door unit. The most popular sizes in the community are 5.42 ft3 for single-door cabinets and 7.45 ft3 for double-door cabinets. And used in building 1.36 unit of the conventional single-door type, 1.03 unit of conventional double-door type, 1.17 unit of inverter single-door type, and 1.18 unit of inverter double-door type. A solid-door freezer is the only type of freezer used in residential buildings. A conventional solid-door freezer accounts for 1.72% of all residential buildings in a community, with an average size of roughly 8.00 ft3 among of 1.00 unit average for each building.

The water heaters in the resident building are of three types: an LPG water heater, an electrical water heater, and a hot water kettle, of which the LPG and electrical water heaters are used as a system to provide hot water in the bathroom for bathing and the kettle is used to boil water for consumption. percentage of hot water systems in bathrooms for all of the community are 7.76% LPG water heaters and 31.90% electrical water heaters. The largest electrical water heater in the resident building averages around 3,008.00 W among the 1.03 units/building. In the building, there are two types of hot water kettles: kettles and thermoses. The hot water kettle percentage is 19.83% for the kettle and 37.07% for the thermos. A kettle is typically 1.54 l. in size, with 1.04 units/building, and a thermos is typically 2.60 l. in size, with 1.00 Unit/building.

The community regularly uses four kinds of cooking equipment: a rice cooker, microwave, air fryer, hot air oven, and mixer. The most popular type of rice cooker in this community is the conventional rice cooker, which accounts for 70.69% of the 1.52 l. size and 1.02 unit/building The second most popular type is the digital rice cooker, which accounts for 6.900.63% of the 2.24 l. size and 1.00 unit/building. Microwaves are not a very popular appliance in the kitchen because the average amount of microwave-equipped households is around 21.55% of the total community, with a consumption of 1,064.80 W 1.00 unit/household. The air fryer, hot air oven, and mixer, on the other hand, are less popular in households, accounting for around 3.45% of the total for the air fryer, 0.86% for the oven, and 18.10% for the mixer. The energy consumption of the air fryer to be used in the household is 660.00 W, and each household has 1.00 unit. The size of the hot air oven to be used in the house is 2,400.00 W for energy consumption, and each household has 1.00 unit. The energy consumption of the household mixer is 613.97 W, and each house has 1.00 unit.

There are four types of washing machines and one type of drying machine in the community. The washing machine includes a twin tub, top load, front load, and washer/dryer. The twin tub washer is the most popular in the community, with a percentage to having in the building approximately 65.52% at 12.33 kg of size and each household having 1.08 unit, while the top load washer has a percentage of the building having around 9.48% at 11.73 kg and each household having 1.00 units. Front load washers and washer/dryers are only used by people in the community around 0.86% at 15.00 kg and 0.86% at 15.00 kg, respectively. Each family has 1.00 unit of front load washer, and each household has 1.00 unit of washer/dryer.

The community is in a remote location, and most residents are general employees and Personal business, according to occupational data in the community. There is no requirement for immaculate clothes or uniforms on a regular basis. thus, affecting the number of irons available in the building. Buildings with irons account up only 46.55% of all buildings, according to the statistics. Each building contains an average of 1.02 unit, each of which requires roughly 810.03 W of power.

Television (TV) is the most used device in the home, and it is classified into two types: LCD TV and LED TV. Because of their new technology and lower power consumption, LED TVs are more popular than LCD TVs. LED use in the household is around 49.14% with 35.23 in., but LCD use in the household is only 12.93% with 35.67 in. Each household has 1.20 unit of LED TV and 1.00 unit of LCD TV.

Table 4.3 Building equipment and appliance.

Equipment and appliance			Average	SD	Percentage	max	min
Lighting	LED	Size	13.96	9.68	67.24	60.00	4.00
		Amount	6.92	4.61	69.83	20.00	1.00
	Fluorescent	Size	21.74	12.27	54.31	41.00	6.00
		Amount	4.84	3.35	55.17	14.00	1.00
	Incandescent	Size	29.25	6.82	3.45	60.00	14.00
		Amount	6.83	1.83	5.17	11.00	1.00
Fan	Ceiling	Size	16.61	6.44	15.52	20.00	14.00
		Amount	3.73	2.59	12.93	18.00	1.00
	Wall mounted	Size	16.14	6.74	18.97	18.00	14.00
		Amount	2.29	1.45	24.14	11.00	1.00
	Table	Size	15.87	5.66	75.86	20.00	1.00
		Amount	2.23	1.13	77.59	5.00	1.00
Ac	Invertor	Size	10,228.57	2,663.36	6.03	12,200.00	8,000.00
		SEER	765.00	224.98	2.59	2,250.00	22.50
		Amount	1.14	0.31	6.03	2.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
AC	Conventional	Size	12,662.50	3,626.33	6.90	20,000.00	9,000.00
		SEER	13.63	2.99	4.31	15.00	13.00
		Amount	1.00	0.29	7.82	1.00	1.00
Refrigerator	Conventional single door	Size	5.42	2.85	46.55	10.00	1.60
		Amount	1.36	0.96	46.55	7.00	1.00
	Invertor single door	Size	6.46	2.27	10.34	10.00	3.40
		Amount	1.17	0.40	10.34	2.00	1.00
	Conventional double-door	Size	7.45	3.46	25.00	9.50	5.00
		Amount	1.03	0.49	26.72	2.00	1.00
	Invertor double-door	Size	8.30	2.62	9.48	9.40	6.40
		Amount	1.18	0.42	9.48	3.00	1.00
Freezer	Conventional solid door	Size	8.00	1.16	1.72	10.00	6.00
		Amount	1.00	0.14	1.72	1.00	1.00
Electric water heater		Size	2894.25	3,008.00	1,580.76	31.90	4,500.00
		Amount	1.03	1.03	0.51	31.90	2.00
Hair dry		Size	1,173.15	482.49	11.21	2,600.00	1.00
		Amount	1.00	0.37	13.79	1.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
Rice cook	Conventional rice cooker	Size	1.52	0.70	70.69	2.00	0.60
		Amount	1.02	0.42	70.69	2.00	1.00
	Digital rice cook	Size	2.24	0.63	6.90	3.00	1.50
		Amount	1.00	0.27	6.90	1.00	1.00
Microwave		Size	1046.67	1,064.80	513.87	21.55	2,000.00
		Amount	1.00	1.00	0.45	23.28	1.00
Water boiler	Hot water kettle	Size	1.54	0.72	19.83	3.00	0.80
		Amount	1.04	0.45	19.83	2.00	1.00
	Thermos	Size	2.60	2.71	37.07	25.00	1.00
		Amount	1.00	0.50	37.93	1.00	1.00
Air fryer		Size	660.00	162.90	3.45	1,400.00	220.00
		Amount	1.00	0.20	3.45	1.00	1.00
Oven		Size	2,400.00	240.00	0.86	2,400.00	2,400.00
		Amount	1.00	0.10	0.86	1.00	1.00
Mixer		Size	613.97	341.34	18.10	1,800.00	220.00
		Amount	1.00	0.43	20.69	1.00	1.00

Table 4.3 (Cont.)

Equipment and appliance			Average	SD	Percentage	max	min
Washing machines	Twin tub	Size	13.00	1.30	0.86	13.00	13.00
		Amount	1.00	0.10	0.86	1.00	1.00
	Top load	Size	12.33	5.89	65.52	17.00	6.00
		Amount	1.08	0.53	67.24	3.00	1.00
	Front load	Size	11.73	3.77	9.48	15.00	8.00
		Amount	1.00	0.31	9.48	1.00	1.00
Washing machines	Washer/dryer	Size	15.00	1.50	0.86	15.00	15.00
		Amount	1.00	0.10	0.86	1.00	1.00
Iron		Size	810.03	533.41	46.55	2,500.00	10.00
		Amount	1.02	0.51	52.59	2.00	1.00
TV	LCD	Size	35.67	13.04	12.93	50.00	24.00
		Amount	1.00	0.35	12.07	1.00	1.00
	LED	Size	35.23	18.49	49.14	55.00	20.00
		Amount	1.20	0.70	50.86	3.00	1.00

2. Building activity

The analysis of activities occurring within all buildings was conducted based on data collected from a questionnaire. The data collection process involved recording all activities that occurred within the buildings and presenting their characteristics and abbreviations in Table 4.4. The analysis of building activities was divided into two main parts, namely, the analysis of the frequency of each activity that occurred in the building and the analysis of the time period during which each activity took place. In addition, the activities were grouped according to the characteristics of each consumer in order to identify trends and directions of activity behavior within the building. This involved identifying consumer characteristics and analyzing their behavior within the building.

Table 4.4 Abbreviations and definition of activity in building

No.	Activity	Abbrev.	Definition
1	Cake freezer	CF	The activity of using a cake freezer involves storing cakes or other baked goods at low temperatures to preserve their freshness and prevent spoilage.
2	Cooking	CK	The activity of cooking involves preparing and heating food to make it safe and palatable to eat. This may involve selecting ingredients, following a recipe, and using various cooking methods such as baking, or grilling.
3	Eating	ET	The activity of eating involves preparing food and consuming it for nourishment and enjoyment.
4	Electric water heater	WH	The activity of using an electric water heater involves heating water for use in various applications such as bathing, washing dishes, and cleaning.
5	Fan	FA	The activity of using a fan involves turning on and adjusting the settings of the device to circulate air and provide ventilation.

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
6	Toilet	TL	The activity of flushing a toilet involves pressing a button or pulling a lever to release water from a tank and flush away waste. This may involve adjusting the amount of water used and checking for any potential clogs.
7	Gardening	GN	The activity of gardening involves planting and caring for plants in a garden or other outdoor space.
8	Hair dry	HD	The activity of drying one's hair involves using a hair dryer to blow hot air over wet hair, allowing it to dry quickly.
9	Iron clothes	IC	The activity of ironing clothes involves using a heated iron to smooth out wrinkles and creases in fabric.
10	Laptop	LP	The activity of using a laptop involves accessing and using software applications and other digital resources for various purposes such as work, communication, entertainment, and education.
11	Lighting	LT	The activity of lighting involves installing and using light sources to illuminate a space. This can include selecting the appropriate type of lighting for a given space, positioning light fixtures, and adjusting lighting levels for various purposes such as task lighting or ambiance.
12	Microwave	MI	The activity of using a microwave involves selecting the appropriate settings and placing food inside the microwave to heat it quickly.
13	Mixer	MX	The activity of using a mixer involves combining ingredients for baking or cooking and mixing them together to create a homogeneous mixture.

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
14	Oven	OV	The activity of using an oven involves preheating the appliance to the appropriate temperature, selecting the appropriate cooking mode, and placing food inside to bake, roast, or broil.
15	Pet	PT	The activity of caring for an animal or pet involves providing food, water, shelter, and exercise for the animal, as well as ensuring its health and well-being.
16	Refrigerator	RE	The activity of using a refrigerator involves storing food and beverages inside the appliance to keep them fresh and prevent spoilage.
17	Rice cook	RC	The activity of cooking rice involves measuring out the correct amount of rice and water, adding them to a rice cooker, and selecting the appropriate settings to cook the rice.
18	Bathing	BA	The activity of taking a shower involves preparing the bathroom with the necessary supplies, such as towels and soap, and then getting undressed and entering the shower.
19	TV	TV	The activity of watching TV involves selecting a program or channel to watch and adjusting the volume and picture settings as needed.
20	Wash car	WR	The activity of washing a car involves cleaning the exterior of the vehicle to remove dirt, dust, and other debris.
21	Wash clothes	WC	The activity of washing clothes involves sorting laundry by color and fabric type, adding detergent and other cleaning products to a washing machine, and selecting the appropriate settings for the load

Table 4.4 (Cont.)

No.	Activity	Abbrev.	Definition
22	Wash dish	WD	The activity of washing dishes involves cleaning and sanitizing plates, utensils, and other kitchen items used for eating and cooking.
23	Water boiler	WB	The activity of using a water boiler involves filling the device with water and selecting the appropriate temperature setting to heat the water quickly.

2.1 Building activity frequency

The frequency of activities is compared with the activity time and activity frequency for each activity. to analyze the factors related to personal data that affect the duration of the activity. including the frequency of all activities within the building. When considering the duration of each activity classified by gender, it was found that the average duration of most activities for males was longer than for females.

From Figure 4.1, the duration and frequency of each activity occurring within the building were shown. It was found that the duration of activities carried out by males in the building was slightly longer on average than those by females. When considering the duration of each activity, it was found that turning the light (LT) was the activity that took the longest time for both male and female consumers. The average duration for this activity was 235.55 minutes for males and 222.66 minutes for females. Additionally, there were three other activities that took longer than an hour to complete, which were turning the fan, with an average duration of 162.78 minutes for males and 180.39 minutes for females, watching TV, with an average duration of 174.34 minutes for males and 174.35 minutes for females, and using the air conditioner is a singular activity, with a discernible difference in the duration of activity between the two genders. On average, males engage in this activity for 120.00 minutes, while females do so for 256.67 minutes. The disparity in the duration of the activity between the two groups is evident, with a time difference of 136.67 minutes.

Upon examining activities with a duration of less than one hour, it was discovered that there was a total of 14 such activities. Each of these activities had a differing average duration, with an average of approximately 4.18 minutes. The average duration for each activity between the two genders is as follows: 48.75 minutes for cooking, 46.53 minutes for washing clothes, 29.23 minutes for rice cooking, 31.21 minutes for washing a car, 28.53 minutes for ironing clothes, 22.61 minutes for pet care, 16.25 minutes for boiling water, 19.61 minutes for eating, 20.41 minutes for gardening, 16.28 minutes for bathing, 12.92 minutes for reheating food in the microwave, 10.84 minutes for washing dishes, 8.37 minutes for hair drying, and 4.78 minutes for using the toilet.

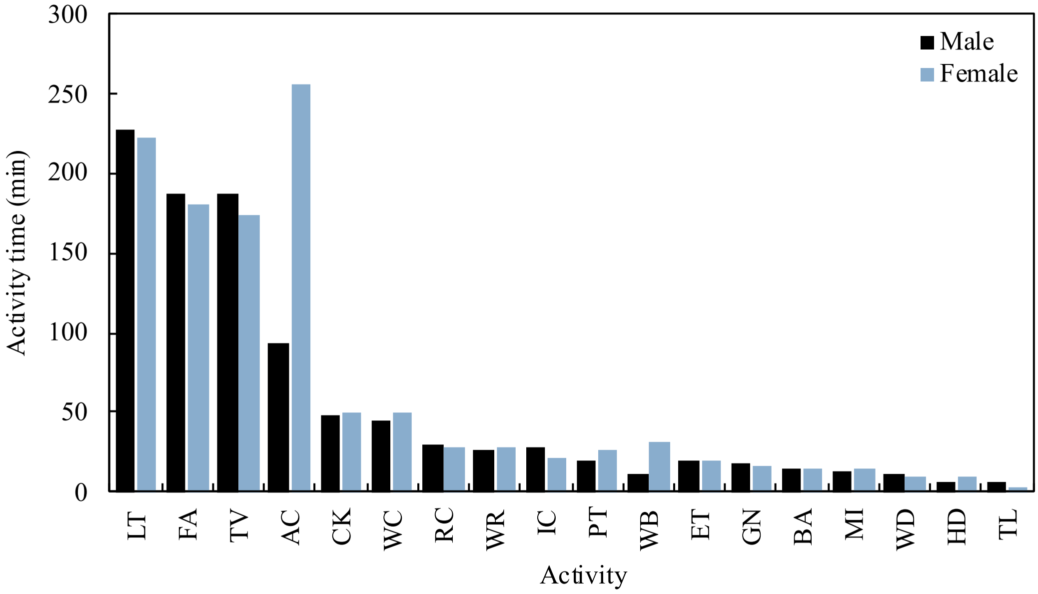


Figure 4.1 Time of activity comparison by gender

Each activity that occurs has an average frequency per day that is close to each other, except for HD, which has a lower frequency for males than females by about half. When considering activities that occur more than once a day for both groups, there are a total of 11 activities: TL, ET, WD, CK, LT, BA, AC, TV, FA, WB, and RC. The average frequency of performing these activities per day is similar, with a mean difference of only 0.12 times per day. HD is the only activity that has a frequency of more than once a day, and it is only females who have a frequency of doing that activity more than once a day. The activity with the highest frequency within the building each day is TL, with an average of 4.00 times per day for males and 3.69 times per day for females, followed by an average frequency of 2.66 times per day for eating, 2.12 times per day for dishwashing, 1.83 times per day for cooking, 1.74 times per day for turning on lights, 1.49 times per day for personal hygiene, 1.50 times per day for air conditioning, 1.39 times per day for watching TV, 1.26 times per day for turning on fans, 1.28 times per day for boiling water, and 1.07 times per day for rice cooking. There are a total of 6 activities that occur less than once a day, with a frequency of once a day, including GN, MI, WC, IC, PT, and WR, with average frequencies of 6.52 times per week, 4.26 times per week, 3.21 times per week, 2.72 times per week, 1.94 times per week, and 2.78 times per month sequentially, with all the details shown in Figure 4.2.

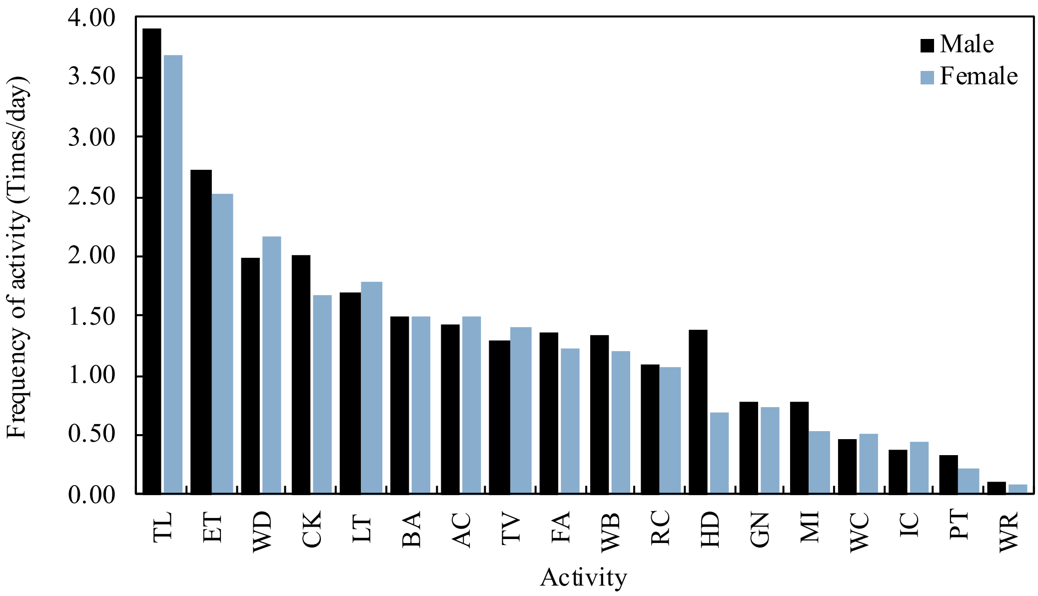


Figure 4.2 Frequency of activity comparison by gender

From the data on the duration and frequency of activities categorized by gender, it can be observed that the data on both the duration and frequency of activities follow a similar trend. This is because the basic data of the community shows that the majority of the residential buildings in the sample community are medium to large-sized housing units, with an average number of occupants residing in the same building being more than 2 people, with at least one male and one female resident. This has an impact on the average time spent on activities within the building for both gender groups. Some activities may also indicate gender differences that affect the duration and frequency of those activities, such as the use of air conditioning to increase comfort, the duration of laundry cycles, and the use of hair dryers. From the physical characteristics of gender, it is found that females tend to have longer hair than males, which affects the duration and frequency of using hair dryers.

From the comparison of data from both groups on the duration and frequency of activities within a building that occur more than once a day, it was found that the average duration of activities varies according to their frequency. Specifically, activities that have a longer average duration have a lower frequency of occurrence per day. For example, turning on the lights takes an average of 229.10 minutes per day for both groups combined, with an occurrence rate of only 1.74 times per day. In contrast, cooking has an average activity duration of approximately 48.75 minutes but occurs at a rate of 1.83 times per day. Furthermore, the activity with the highest daily occurrence rate is using the bathroom, with an average duration of only 3.84 times per day and a duration of only 4.78 minutes per occurrence.

When considering activities with a duration of one hour or more, it was found that these were mostly activities that support other activities within the home, including those that improve comfort and convenience within the home, such as turning on the lights to increase brightness inside the building during the evening or in the absence of natural light, and activities that promote socialization, such as cooking, eating, and cleaning dishes, as well as activities that are conducted in tandem with longer activities, such as turning on a fan or air conditioner to create a more comfortable environment during other activities. Upon examining activities that occur less frequently than once a day, it was found that the characteristics of these activities are similar to those of activities that occur more frequently than once a day. Specifically, when the duration of the activity is longer, it results in a decrease in the frequency of occurrence of that activity.

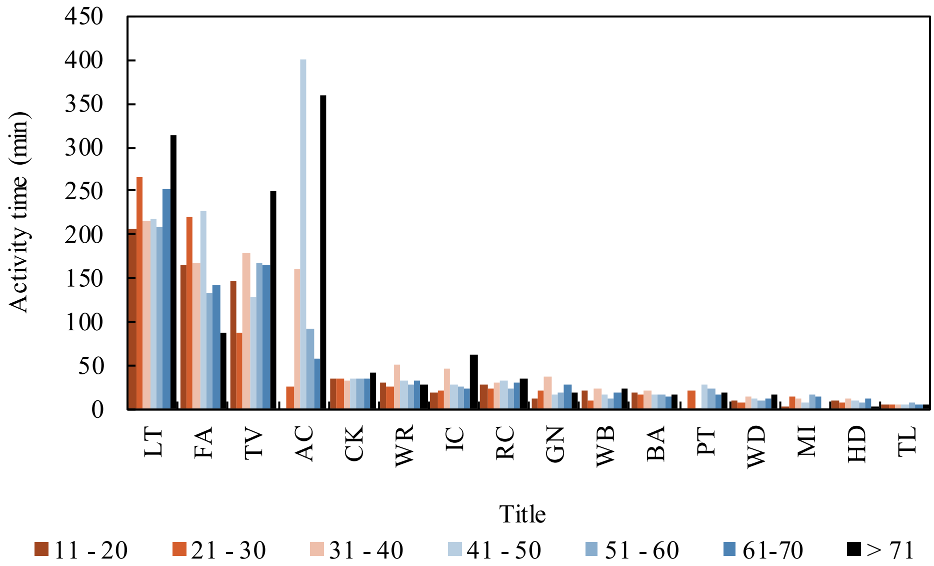


Figure 4.3 Time of activity comparison by age group

Afterwards, an analysis of the duration and frequency of activities by age group, as shown in Figure 4.3, reveals that the duration of each activity differs by age group. Specifically, only the group of activities with an average duration longer than 60 minutes exhibits significant differences in usage patterns across age groups. The trend for the light switch activity is that its usage time decreases as consumers age. Specifically, the age groups of 11-20, 31-40, and 51-60 years old exhibit usage times of 205.71, 214.40, and 207.60 minutes, respectively. Similarly, the age groups of 21-30, 41-50, and 61-70 year old also exhibit decreasing usage times of 265.65, 217.33, and 252.11 minutes, respectively. However, the highest usage time for the light switch activity is found in the age group over 71 years old, as consumers over 71 years old are considered as elderly, their daily life necessities require more light compared to other age groups. Additionally, this group tends to start their morning activities earlier and take longer to complete them compared to other age groups, resulting in a noticeably longer time required for turning on the lights. Moreover, the duration of time used for turning on lights affects the duration of other activities that rely on bright light for daily living, such as watching television and operating air conditioning. It was found that in the elderly age group, the duration of time spent on watching television and operating air conditioning was the longest, with an average of 248.82 minutes for watching television and 360.00 minutes for operating air conditioning.

The activity of operating fans inside a building found that the duration of fan usage decreases as consumers age. However, the age group with the longest average fan usage duration was found to be the 41-50 years old group, with an average usage duration of 226.52 minutes and decreasing to 165.71, 219.79, 166.32, 142.76, 133.70, and 86.67 minutes for the age groups of 11-20, 21-30, 31-40, 61-70, 41-50, and above 71 years old, respectively. This is in contrast to the activity of operating televisions, which had average usage durations of 156.74 minutes for the age groups of 11-20, 31-40, 41-50, 51-60, and 61-70 years old, except for the above 71 years old group, which had the longest average activity duration of 248.82 minutes, making it the age group with the highest television watching behavior. The age group with the lowest average television watching duration was the 21-30 years old group, with an average duration of only 87.00 minutes. When analyzing the television watching behavior of each group, it was observed that the elderly or above 71 years old group spent the most time watching television because their behavior is associated with being inside the building for a longer time, which is consistent with the age group residing inside the building the longest. Conversely, the age group of 21-30 years old, who spent the least amount of time watching television, had a behavior associated with being inside the building the least.

However, when considering the behavior of air conditioning usage within buildings that occurred throughout the community, it was found that only 6.25% of the 21-30 age group, 5.41% of the 31-40 age group, 6.67% of the 41-50 age group, 8.70% of the 51-60 age group, 5.66% of the 61-70 age group, and 9.09% of the group over 71 years old thought to use air conditioning. This indicates that the proportion of air conditioning usage within the community is relatively low due to the environmental conditions and the average temperature within the community is not very high. Furthermore, the community chooses to use fans to reduce the temperature inside the buildings, which has a higher proportion of usage across all age groups, accounting for approximately 50.31%. This results in a higher proportion of fan usage than air conditioning usage, which is consistent with the data on the number of electrical appliances found within the buildings, indicating that fans make up 77.59% of all appliances, while air conditioning units comprise only 7.82% of installed appliances, which is a relatively small proportion when compared.

The activity characteristics with a duration of less than one hour per session were examined, and the average durations for each group were found to be similar. When ordered by the average duration of each group, the activities were WC, RC, CK, WR, WB, IC, ET, GN, BA, PT, WD, MI, HD, and TL, with durations of 39.11, 25.18, 31.05, 28.48, 15.32, 28.15, 17.04, 18.90, 14.89, 13.04, 9.98, 7.62, 7.22, and 4.50 minutes, respectively. However, cooking activities were only carried out by four age groups, namely 31-40, 41-50, 51-60, and 61-70 years, which are age groups that are responsible for household care. This is consistent with the use of microwave ovens, which are only used by the aforementioned groups, but with the addition of the age group between 21-30 years, indicating a more hurried and streamlined lifestyle. Furthermore, based on the observed activity behaviors within the building, it was noted that the older age groups tended to spend less time on each activity compared to the younger age group.

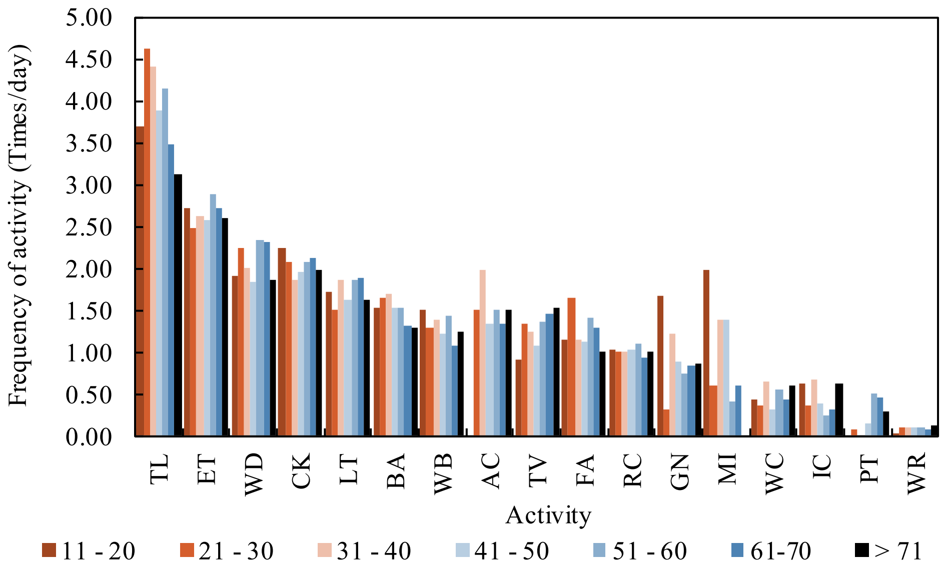


Figure 4.4 Frequency of activity comparison by age group

When analyzing the frequency of each activity that occurs daily, grouped by the age range of consumers within the building, as shown in Figure 4.4, it was found that activities with a frequency of more than once per day in all age groups consist of a total of eight activities: TL, WD, LT, BA, WB, TV, FA, and RC with average frequencies of 3.91, 2.67, 2.09, 2.06, 1.73, 1.51, 1.31, 1.31, and 1.25 times per day, respectively. Further analysis of the frequencies of WD, LT, BA, WB, TV, and FA activities, which occur more than once per day, also revealed that all age groups have similar frequencies. The analysis of the standard deviation of the average frequency of each age group shows that the data has a standard deviation of only 0.20. Excluding the activity with the highest frequency in the building, which is using the restroom, the average frequency of activities for each group is approximately 3.91 times per day. The group with the highest frequency is the 21-30 age group, with an average daily activity frequency of 4.63 times, followed by a decrease to 4.41 times for the 31-40 age group, 4.15 times for the 51-60 age group, 3.89 times for the 41-50 age group, 3.50 times for the 61-70 age group, 3.70 times for the 11-20 age group, and 3.13 times for the group over 71 years old.

The behavior of using the restroom differs significantly when considering the data by age group due to differences in behavior and lifestyle characteristics among age groups. For example, the age range of 21-70 years is a range with similar lifestyles within the building and high consumption, affecting the activities that occur within the building. This is in contrast to the 11-20 age group, which corresponds to the data on the timing of each activity for the age group of 11-20 years, which has a frequency of opportunity for activity in only two time periods. The group aged over 71 years old had a high frequency of occurrence of activities during approximately the same time period and had a generally evenly distributed frequency (with similar interquartile range values) from the beginning until the end of the observation period. This differs from the frequency of activity opportunities for the group aged between 21-70 years old, which had a noticeably high frequency of the aforementioned activities when compared to the two preceding age groups.

The frequency of activities occurring within a building for a group of consumers with a frequency of more than once per day and a group with a frequency of less than once per day were investigated. The study found that there were five activities in total, including AC, CK, GN, HD, and MI. From the data, it was found that there was no activity related to the use of air conditioning for the age group of

11-20 years, which differed from other age groups. The age group with the highest frequency of air conditioning usage was the 31-40 year age group with an average frequency of 2.00 times per day. The age groups of 21-30 years and 51-60 years had the same frequency of use per day with an average frequency of 1.50 times per day. The age groups of 41-50 years and 61-70 years had the same frequency of air conditioning usage with an average frequency of 1.33 times per day. Finally, the age group over 71 years old had a frequency of air conditioning usage at 1.50 times per day.

The act of cooking rice is an activity that occurs with a frequency average of approximately 1.02 times per day for every age group that is in close proximity to one another, with a standard deviation of 0.05. However, there is one age group, the 61-70 age group, which has an average frequency of cooking rice per day less than 1, specifically 0.93 times per day. This group is the only age group that has a frequency of cooking rice less than once per day. The age groups that cook rice more than once a day include the age groups 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, and those above 71 years. The average frequency of cooking rice per day for each of these age groups is 1.04, 1.02, 1.02, 1.04, 1.11, and 1.01 times per day, respectively. These findings are data collected from a sample population of individuals living in a semi-rural community in the northern part of the country. The majority of the population in this area consumes sticky rice as their main food, which contributes to the overall frequency of cooking rice for all age groups. Additionally, it was found that the frequency of cooking rice was lower than the frequency of engaging in other cooking activities, with an average of only 35.30%.

Activity related to watering plants and using a microwave have a similar frequency of occurrence among age groups. It was found that the age group with the highest frequency for both activities was between 11-20 years old, with an average frequency of 1.67 times per day for watering plants and 2.00 times per day for using the microwave to heat up food. The frequency decreases for the age groups between 31-40 years old, over 71 years old, 61-70 years old, 51-60 years old, and 11-20 years old for gardening and watering plants, and for the age groups between 31-40 years old, 41-50 years old, 61-70 years old, 21-30 years old, and 51-60 years old for using the microwave to cook. Both activities have an average frequency of 0.93 and 0.92 times per day for watering plants and using the microwave, respectively, across all age groups. The age group over 71 years old does not use the microwave due to both lack of cooking and unfamiliarity with the appliance. Therefore, the frequency of use for the microwave in this age group is 0 times per day, similar to the use of a hair dryer, which has a frequency of zero for the age group over 71 years old. The aforementioned age group is the only age group that does not use the aforementioned device, the reasoning mentioned above. When considering the use of hair dryers in the field, the age groups between 11-20 years and 21-30 years are the two age groups with the highest frequency of use, averaging 0.44 and 0.36 times per day, respectively. The age groups between 31-40 years, 41-50 years, and 61-70 years have similar average frequencies of hair dryer usage, with an average value of 0.47 times per day across all three age groups, or approximately 3.32 times per week. The age group between 51-60 years has an average frequency of hair dryer usage of approximately 0.55 times per day or engaging in the aforementioned activity once every 2 days.

The group of activities that occur less frequently than once a day consists of four activities: laundry, ironing, pet care, and car washing. It was found that the frequency of doing laundry and ironing activities had similar averages, at 3.21 and 3.04 times per week, respectively. When considering the highest frequency of these two activities, it was found that they were performed by the same age group, specifically those aged 31-40 years. The average frequency of doing laundry and ironing for this group was 4.61 and 4.82 times per week, respectively, while the lowest frequency was found in the age group of 41-50 years, at 2.28 times per week for doing laundry, and in the age group of 51-60 years, at 1.71 times per week for doing laundry.

The frequency data of doing laundry and ironing activities, it was found that in some buildings, the ironing activity was performed more frequently by the age group of 11-20 years, with a frequency rate that was close to the maximum. The average frequency of this activity for this age group was approximately 4.38 times per week. This finding can be attributed to the fact that this age group is mostly composed of students who have a school uniform, and thus ironing is necessary to maintain a neat appearance. Similarly, the age group of 31-40 years, who are mostly families with young children aged under 10 years old, had a high frequency of doing laundry and ironing activities. This is because they need to take care of their young children who cannot take care of themselves fully, resulting in the higher frequency of laundry and ironing activities for this age group, compared to other age groups. The activity of pet care is an infrequent activity, with an average frequency of 6.28 times per month. It was found that the age group with the highest frequency of pet ownership was the age group between 51-60 years old, with an average frequency of 15.00 times per month. The frequency then decreases to 13.57, 8.57, 4.64, and 2.14 times per month for the age groups between 61-70 years old, over 71 years old, 41-50 years old, and 21-30 years old, respectively.

2.2 Building activity period

The behavioral data and frequency of activities that occurred within the building of the entire sample group, there were 18 activities including turning on lights, using fans, watching TV, adjusting air conditioning, cooking, rice cooking, preparing or reheating food with a microwave, boiling water, eating, washing dishes, bathing, using the bathroom, hair during, doing laundry, ironing, watering plants, taking care of pets, and washing cars. The data presented only indicate the duration and frequency of activities on each day, without specifying the time periods and opportunities for activity occurrence in each time interval. Therefore, it is necessary to conduct an analysis to observe the activity behavior of each consumer group. This analysis will generate a consumer profile of the sample community. In this section, the analysis of activity behavior within the building is divided into two data groups of individuals, Gender and age group. The analysis will focus on the frequency of time intervals in which each activity occurred. The analysis is separated into two categories of days, workdays (Monday to Friday) and non-workdays (Saturday and Sunday). The data used for analyzing the frequency of time intervals for each activity is from survey data collected from a sample population in the community.

The results of the data analysis indicate that overall, there is no clear distinction between the patterns of activities during workdays and days off. This is particularly evident for activities that occur less frequently than once a day, such as laundry, watering plants, pet care, and car washing, which tend to occur more often on weekends than on weekdays. The time intervals for all activities are presented in Table 4.5 to Table 4.23 and the percentage of the number of activities towards a consumer group in Table 4.24

Table 4.5 Percentage of lighting frequency over time on weekday and weekend

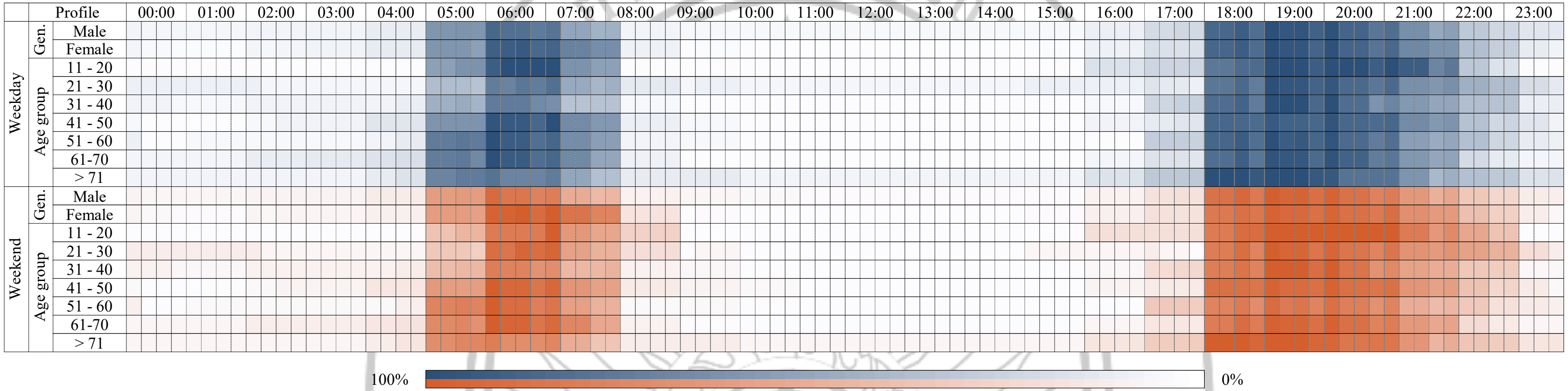


Table 4.6 Percentage of fan frequency over time on weekday and weekend

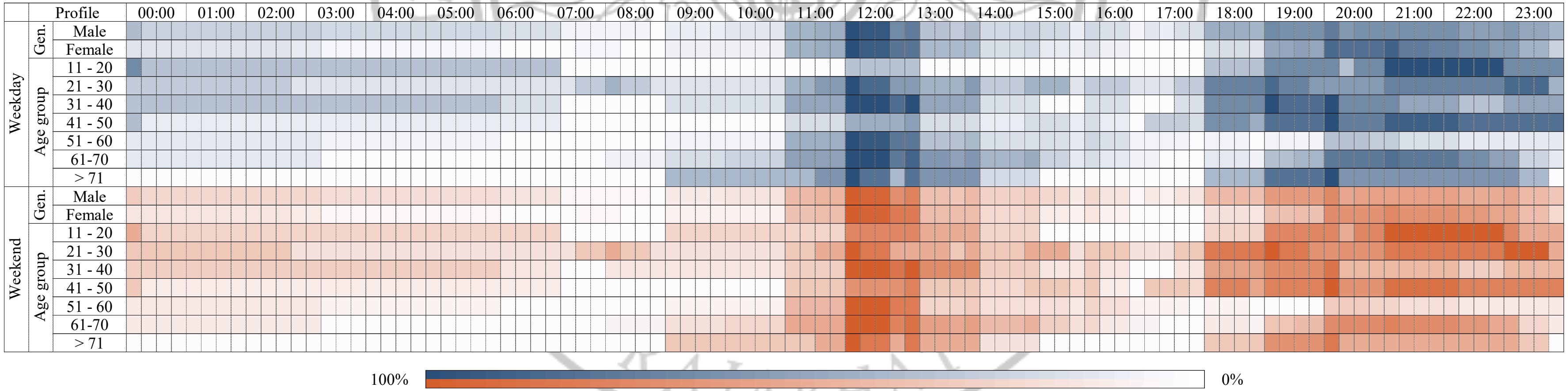


Table 4.7 Percentage of using air conditioner frequency over time on weekday and weekend

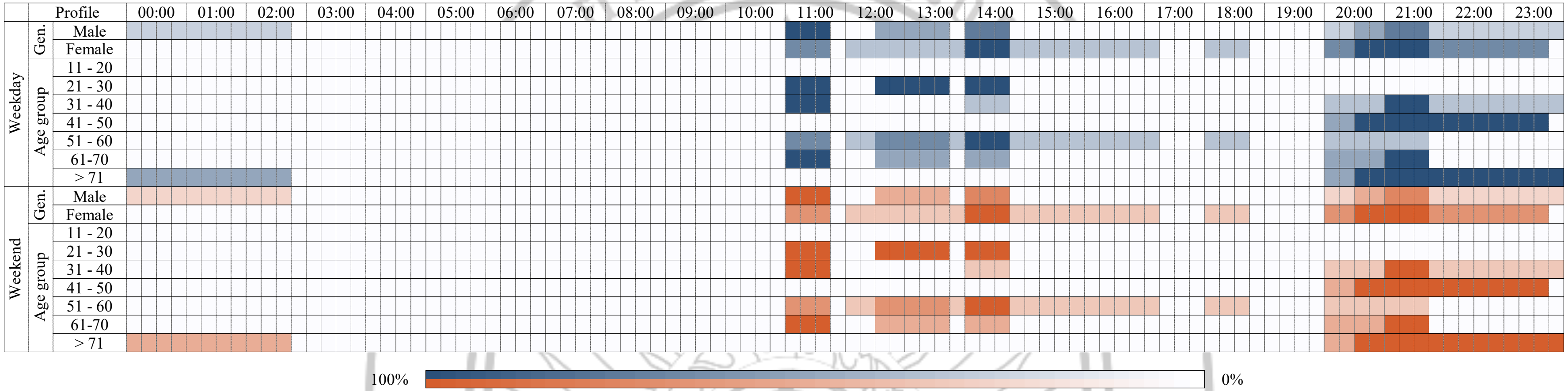


Table 4.8 Percentage of watching TV frequency over time on weekday and weekend

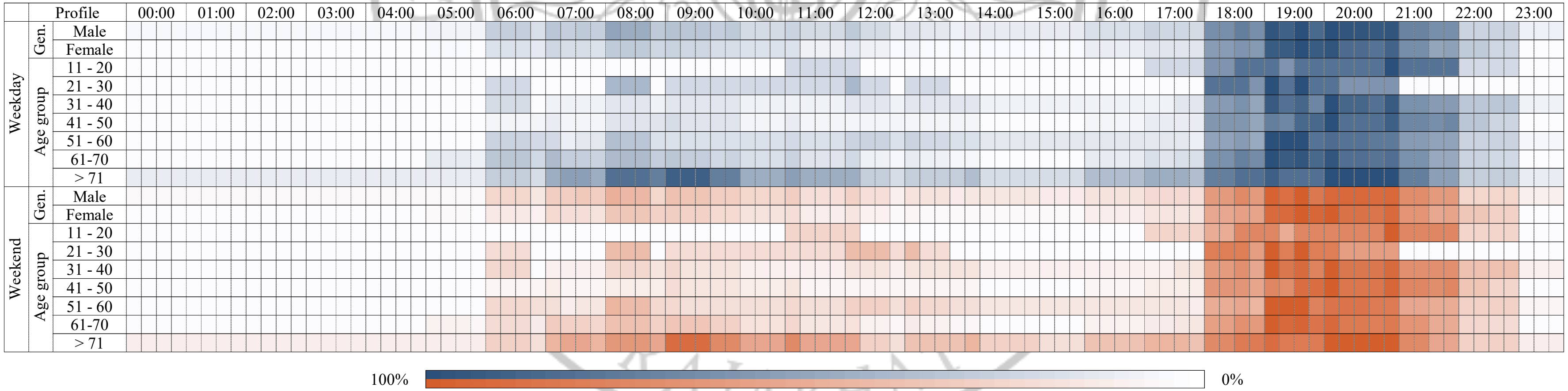


Table 4.9 Percentage of cooking frequency over time on weekday and weekend

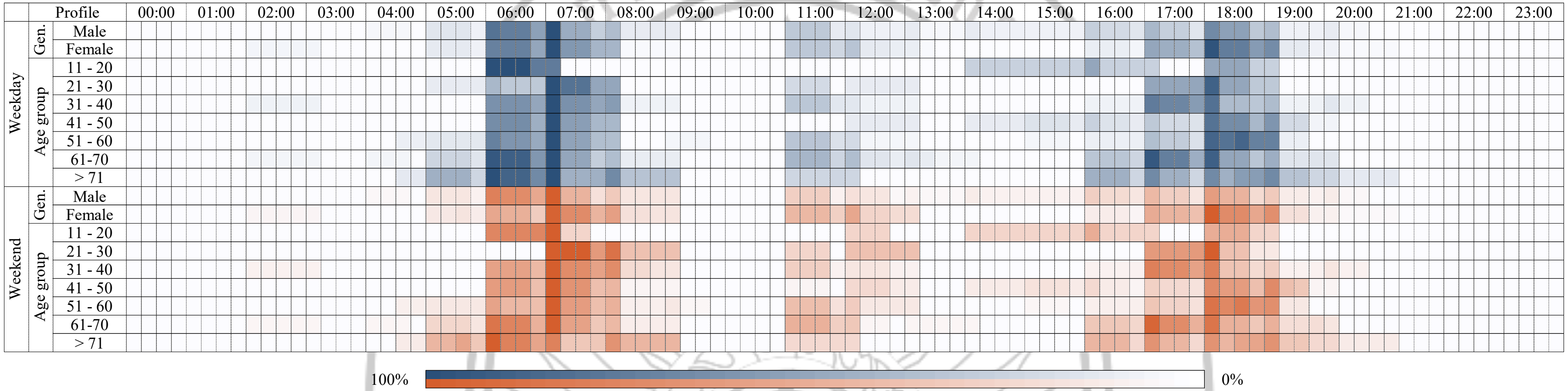


Table 4.10 Percentage of rice cooking frequency over time on weekday and weekend

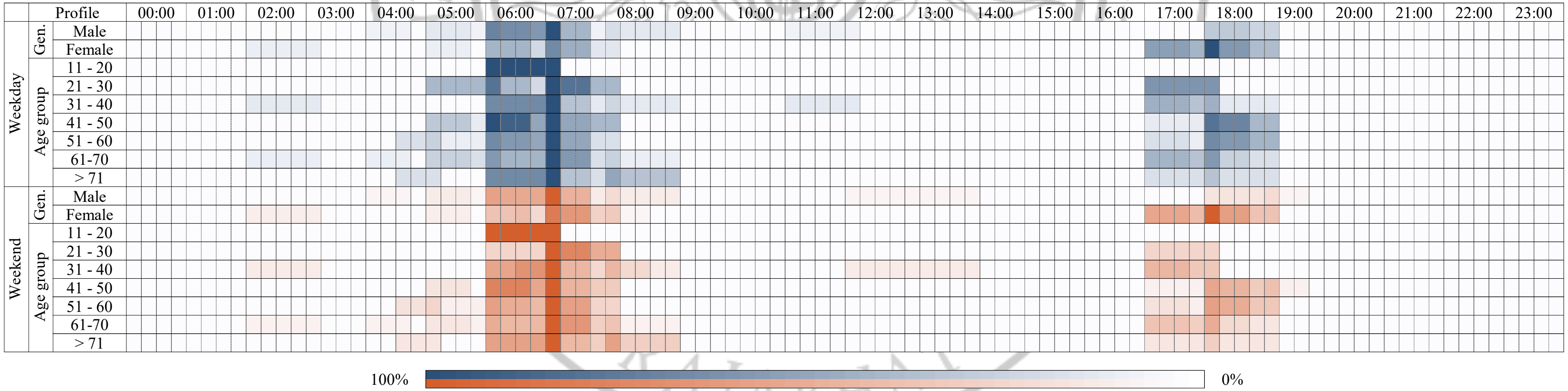


Table 4.11 Percentage of microwave frequency over time on weekday and weekend

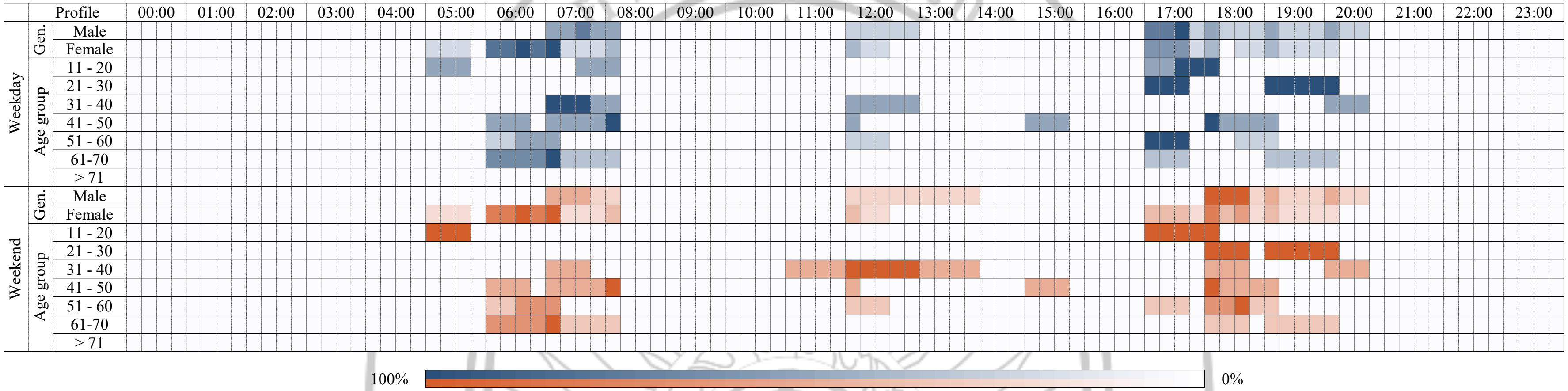


Table 4.12 Percentage of water boiling frequency over time on weekday and weekend

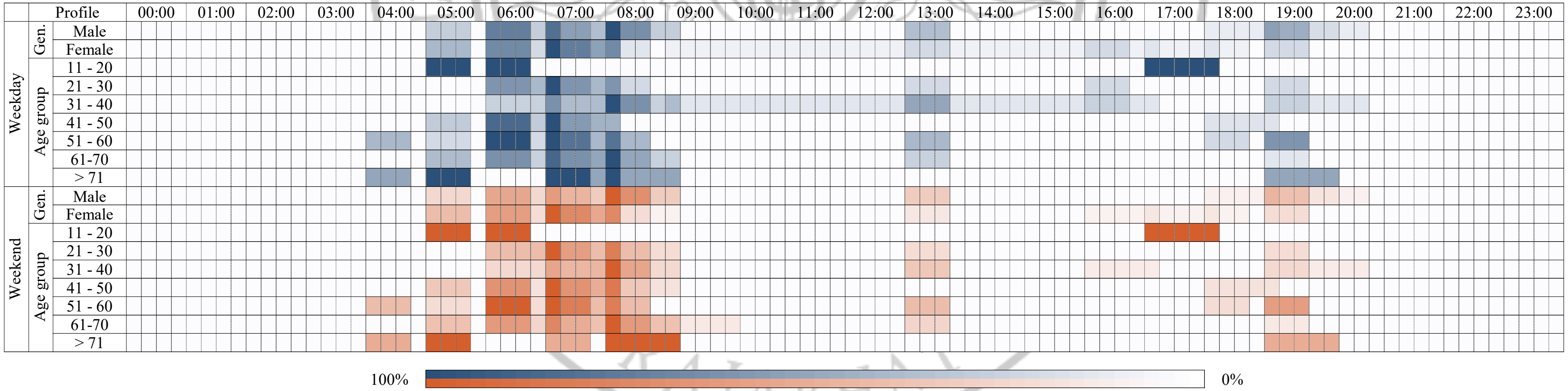


Table 4.13 Percentage of eating frequency over time on weekday and weekend

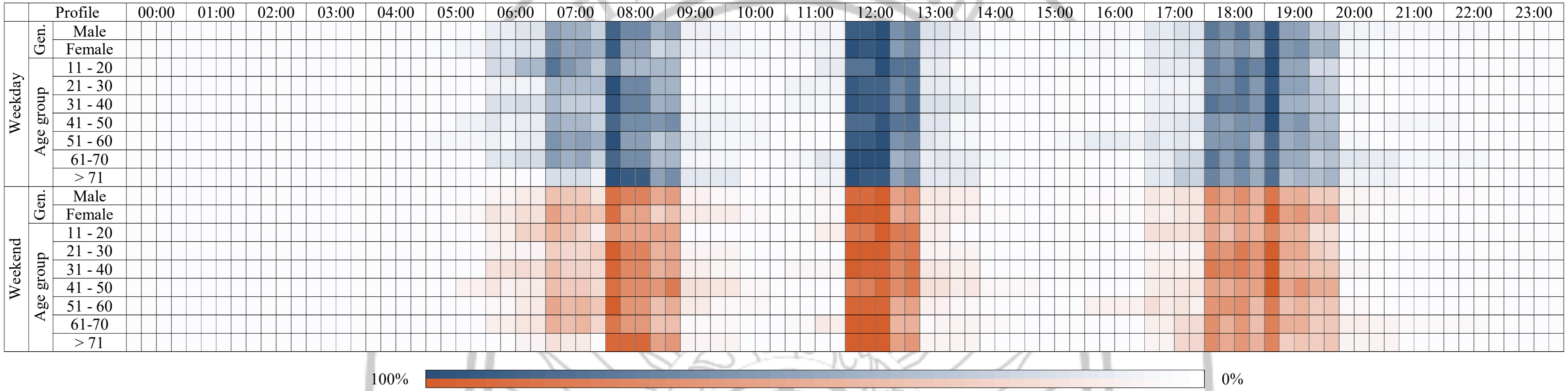


Table 4.14 Percentage of washing dish frequency over time on weekday and weekend

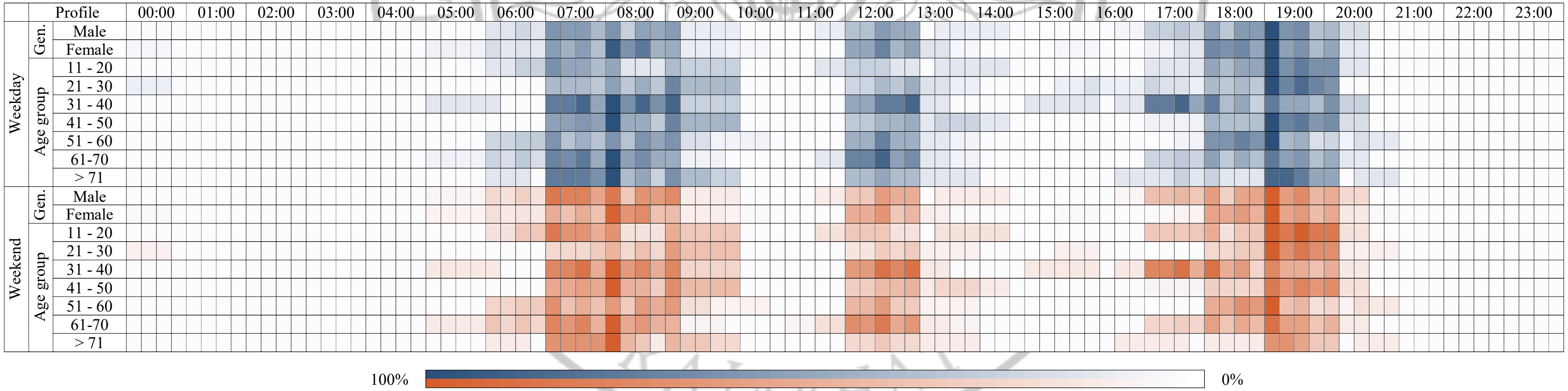


Table 4.15 Percentage of bathing frequency over time on weekday and weekend

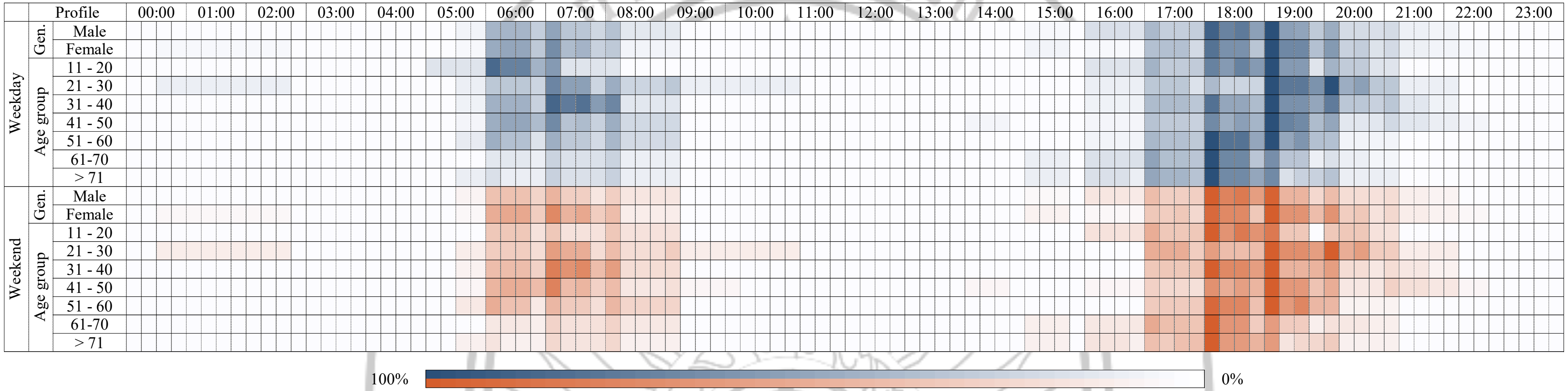


Table 4.16 Percentage of electricity water heater frequency over time on weekday and weekend

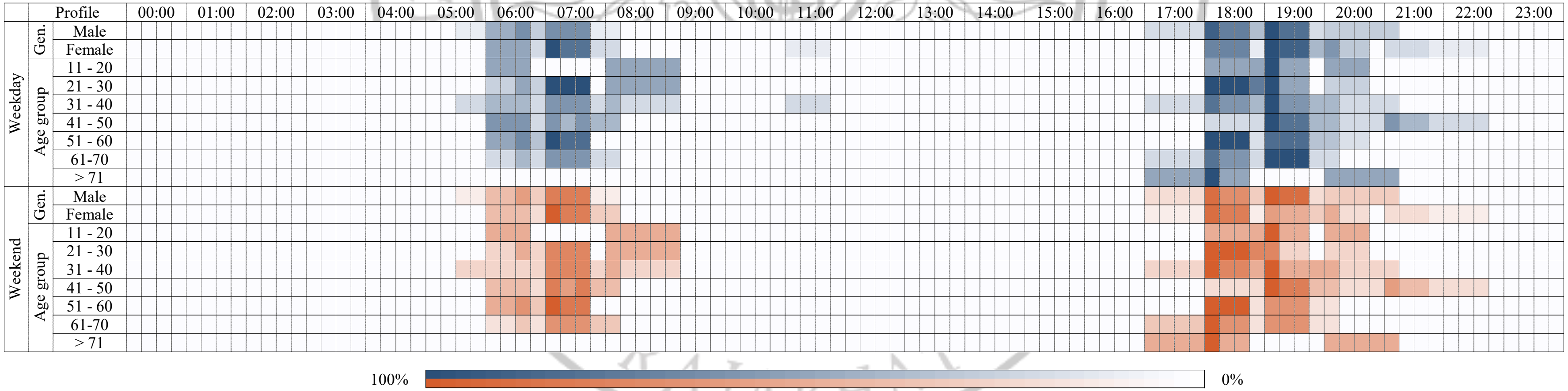


Table 4.17 Percentage of toilet frequency over time on weekday and weekend

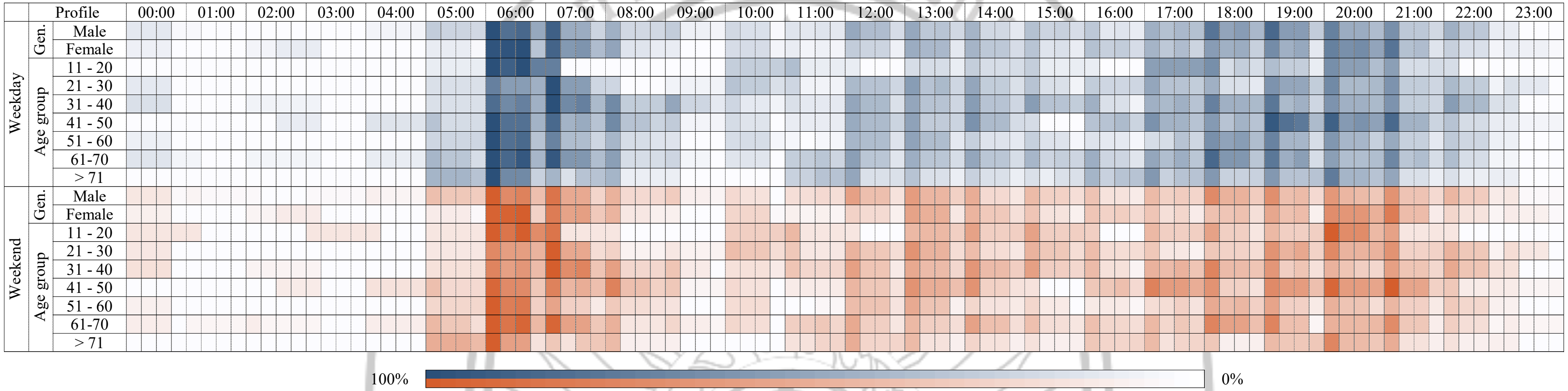


Table 4.18 Percentage of hair drying frequency over time on weekday and weekend

Table 4.19 Percentage of washing clothes frequency over time on weekday and weekend

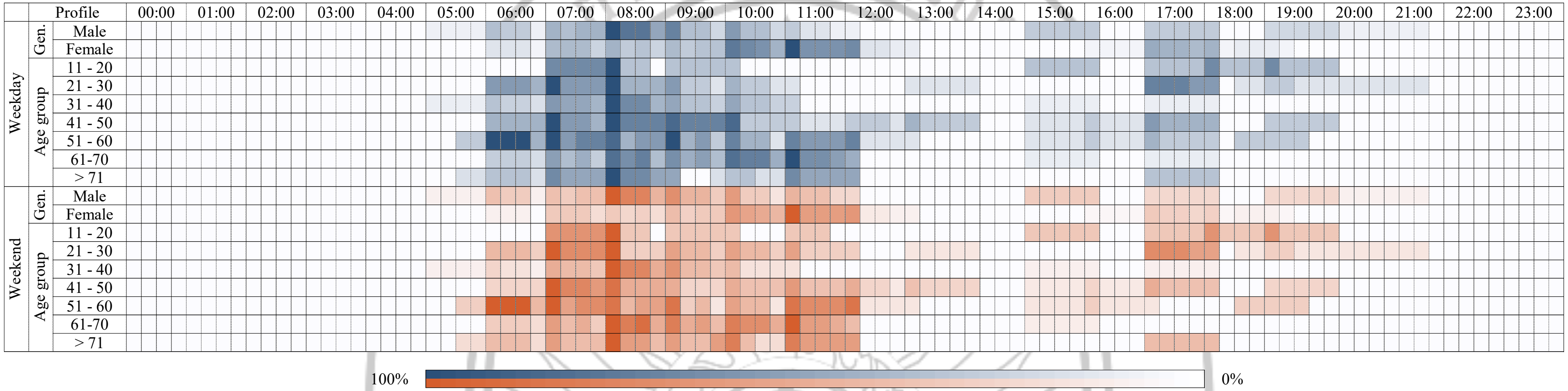


Table 4.20 Percentage of iron clothes frequency over time on weekday and weekend

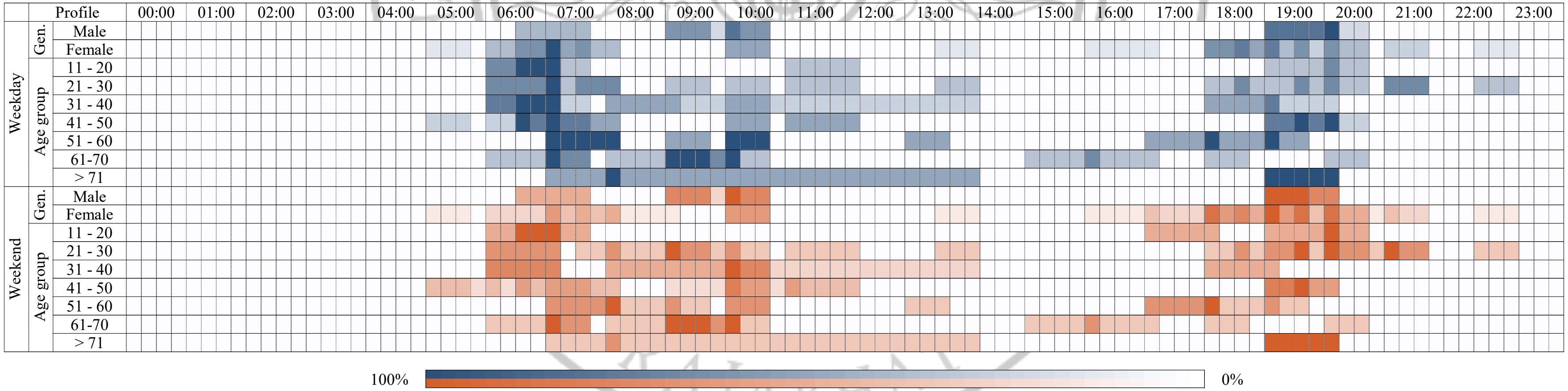


Table 4.21 Percentage of gardening frequency over time on weekday and weekend

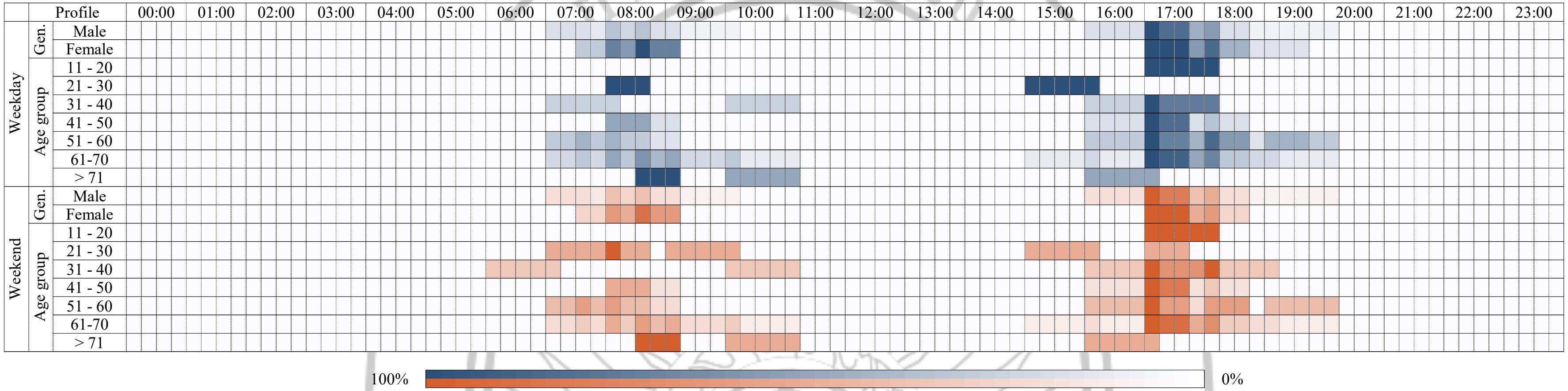


Table 4.22 Percentage of pet care frequency over time on weekday and weekend

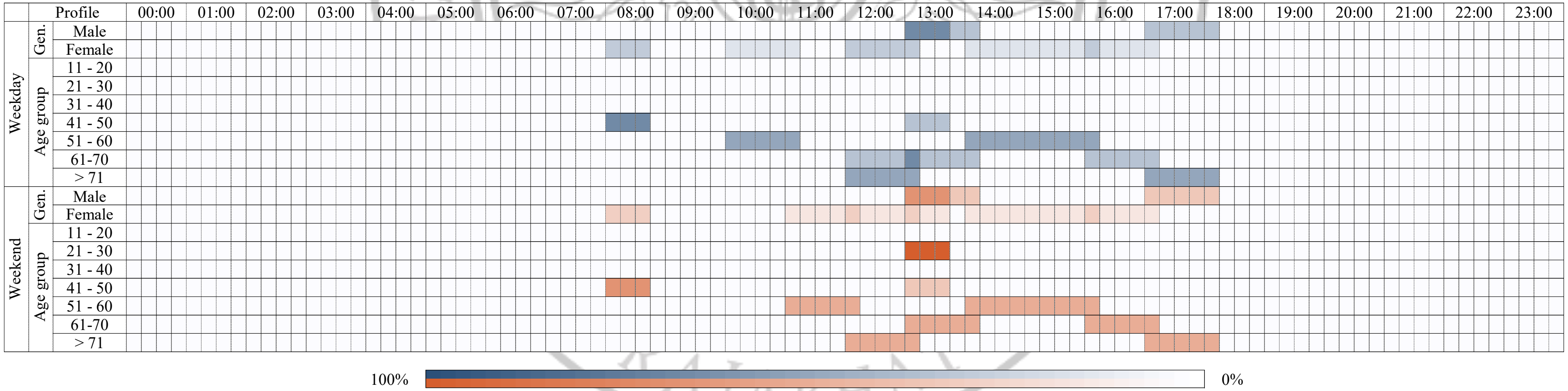


Table 4.23 Percentage of washing car frequency over time on weekday and weekend

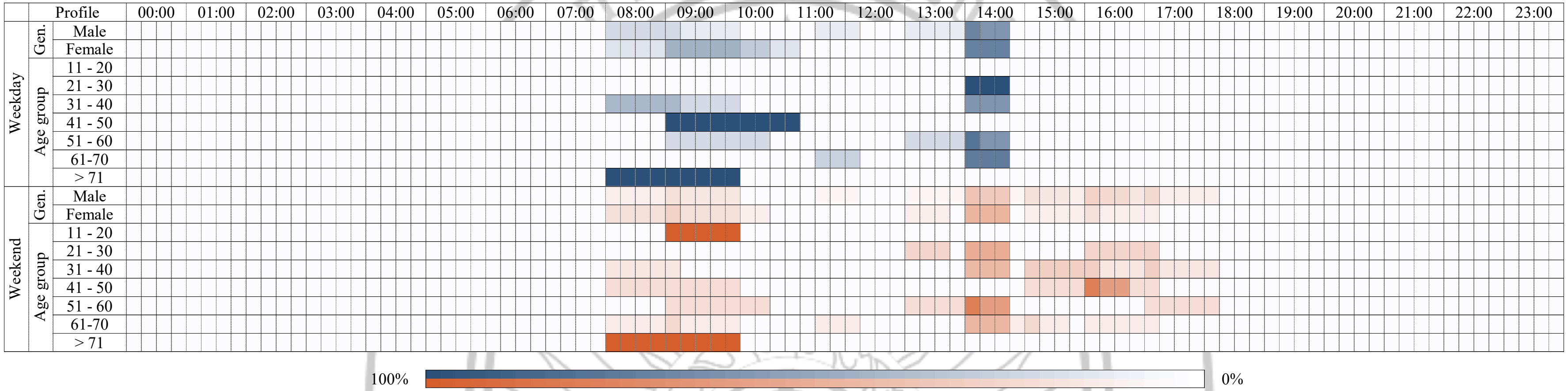


Table 4.24 Percentage of the number of activities towards a consumer group

Consumer group		**LT**	**BA**	**ET**	**TL**	**WD**	**WC**	**TV**	**CK**	**FA**	**RC**	**IC**	**GN**	**WB**	**WR**	**MI**	**HD**	**AC**	**PT**
Gender	Male	83.78	81.98	73.87	60.36	45.05	45.05	60.36	39.64	45.95	27.03	24.32	34.23	20.72	26.13	11.71	5.41	6.31	5.41
	Female	63.51	61.49	57.43	51.35	56.76	54.05	41.89	43.24	37.84	39.19	35.14	17.57	25.00	8.78	7.43	8.78	4.05	4.73
Age	11 – 20	93.33	86.67	86.67	66.67	80.00	60.00	53.33	26.67	46.67	26.67	53.33	20.00	13.33	6.67	6.67	6.67	0.00	0.00
(Year)	21 – 30	96.88	96.88	87.50	71.88	71.88	75.00	31.25	34.38	43.75	46.88	59.38	21.88	28.13	18.75	12.50	15.63	6.25	3.13
	31 – 40	94.59	91.89	81.08	72.97	64.86	75.68	56.76	62.16	51.35	43.24	45.95	21.62	27.03	24.32	13.51	13.51	5.41	0.00
	41 – 50	100.00	93.33	93.33	84.44	75.56	80.00	71.11	55.56	51.11	60.00	53.33	40.00	31.11	24.44	8.89	4.44	6.67	6.67
	51 – 60	97.83	100.00	91.30	86.96	82.61	78.26	71.74	73.91	50.00	45.65	36.96	39.13	30.43	17.39	19.57	8.70	8.70	8.70
	61 – 70	100.00	100.00	92.45	73.58	75.47	66.04	88.68	73.58	54.72	58.49	32.08	45.28	33.96	18.87	7.55	5.66	5.66	11.32
	> 71	100.00	90.91	81.82	72.73	72.73	77.27	77.27	63.64	54.55	45.45	31.82	31.82	18.18	13.64	0.00	4.55	9.09	9.09

2.2.1 Lighting

The frequency data of the lighting operation period within the building presented in Table 4.5, it was found that the behavior of lighting operation did not differ significantly between genders in terms of usage periods for both weekdays and weekends. The frequency of lighting operation within the building was divided into two periods. The first period had a high frequency of usage starting from 5:00 until peaking at 6:45, followed by a decline in usage and stopping at around 8:15. The second period began at around 6:00 with the highest frequency of usage between 19:00 - 20:00 and gradually declining until approximately 22:15, with very low or no usage at around 23:15. When considering the frequency of lighting operation periods according to age groups, it was found that the behavior of lighting operation was similar to that of gender analysis. That is, the usage behavior was divided into two periods. The first period had high usage from 6:00 - 7:15, while the second period had high usage from 18:00 – 21:00. However, when the behavior was categorized by age group, differences were observed, but the usage behavior in each group was similar between weekdays and weekends.

The behavior of turning on lights when analyzed by age groups revealed that among individuals aged 11-20, the frequency of light usage was highest at 6:15-7:15 and at 17:00, on average. The percentage of light usage in this age group was observed to decrease and then increase again from 18:00 onwards, with a continuously high frequency of usage until approximately 21:30 After this, the frequency decreased and stopped at 22:45, with the highest frequency of light usage observed at 21:00 on average. The average frequency of light usage from the sample group was found to be 92.90%.

The light opening behavior of individuals aged between 21-30 years and those aged between 31-40 years exhibits similar patterns. Specifically, there is a small number of light openings in the morning, beginning around 5:00 a.m., and an increased frequency of light usage from 6:00 a.m. to 7:15 a.m., followed by a decrease in usage until stopping at 8:15 a.m. Furthermore, it was found that the frequency of light openings during a particular period for both groups is still less than that observed in the evening and in other age groups at the same time. The maximum number of consumers during the morning period for the sample group was 81.48% for those aged between 21-30 years and 75.00% for those aged between 31-40 years. In the second period for both groups, which starts at 6:00 p.m., there is an increased frequency of light usage, peaking at approximately 19:00 for the sample group aged between 21-30 years and at 19:00-19:45 for the sample group aged between 31-40 years. The maximum average value of light openings during this period was 100.00% for both groups.

The age group between 41-50 years old exhibits similar behavior to the other age groups in terms of light usage. Specifically, there is a slight increase in light switch usage starting around 5:00 with an average percentage of 60.53%, which increases to 94.74% between 6:00 and 7:15, reaching a maximum frequency of 100.00%. The usage then gradually decreases and stops at 8:15. In the evening, the usage starts again at 18:00, and the average percentage of consumers reaches 97.37% until 19:15, before gradually decreasing and stopping at 22:15.

The age groups between 51-60 years old and 61-70 years old exhibit similar patterns of behavior in regard to turning on lights during two time periods. In the morning, both groups start turning on lights around 5:00 with an average usage of approximately 75.63% for the first group and 72.83% for the second group. Usage gradually increases and reaches its peak frequency of 95.00% for the 51-60 years old group and 95.65% for the 61-70 years old group between 6:00 and 6:45. Subsequently, the usage decreases, and there are no consumers at 8:15. The groups then start turning on lights again in the evening from 18:00 onwards, with an average usage of approximately 87.50% and 83.70% for the 51-60 years old and 61-70 years old groups, respectively. The peak frequency is 100.00% for the 51-60 years old group at 19:00 and 97.83% for the 61-70 years old group at 20:00.

Finally of lighting activity, the age group above 71 years old starts using electricity in the morning at 5:00 and stops around 7:30, with an average consumer rate of 68.64%. The peak electricity usage is at 6:00 with a maximum of 80.00%. The second period of electricity usage begins within the building at 17:00 with approximately 30.00% usage from the consumer group, increasing to 100.00% from 18:00 to 19:30. After that, it gradually decreases until 23:45 with only 15.00% of electricity usage remaining within the building. It should be noted that the age group above 71 years old has the lowest average electricity usage rate of approximately 5.00% throughout the day compared to the other age groups.

2.2.2 Fan

When analyzing the usage of fans in a building based on gender during different time periods, as shown in Table 4.6, it was found that the patterns of usage were similar, with fans being used throughout the day, and there were three time periods with particularly high usage: the late night/early morning period, the midday period, and the evening/bedtime period. In the first time period, from 0:00 to 7:15, females had a higher percentage of fan usage, at 22.56%, compared to males at 7.64%. Usage then decreased until around 7:15, after which it increased again, peaking at 12:00 for both genders. Afterwards, usage decreased at similar rates for both genders, with the final time period for female usage starting at 18:00 and peaking at 20:00 at 75.00% usage, before decreasing to 57.22% between 20:15 and 23:45. This was slightly different from males, who started their final peak usage period at 19:00, reaching 50.89%, and then increasing to a maximum of 89.29% between 20:00 and 21:15, before decreasing to 58.77% between 21:15 and 23:45 every day. The analysis of fan usage behavior by gender, it was found that there are similarities in the patterns of usage. However, on average, females have a higher likelihood of using fans compared to males. The average usage rate for females is 32.51%, which is higher than that of males at 26.45%.

The behavior of fan usage according to age group in the sample population, it was found that the characteristics of usage can be divided into three time intervals, similar to the pattern of usage according to gender. Among the age group of 11-20 years, the longest duration of usage occurred in interval 1, starting from 0:00-7:00, with an average fan usage of 33.33% throughout the duration of usage. The second interval, starting from 12:00-13:00, showed an average fan usage of 33.33%. Subsequently, fan usage was stopped and started again at 18:00, which then increased gradually until reaching its peak at 21:00-23:00 with a usage rate of 100% for the aforementioned age group and decreased to 66.67% at 23:45.

The age group between 31-30 years old is a group that exhibits continuous fan usage behavior throughout the day. It was found that during the time period from 0:00-2:45, the proportion of fan usage among the sample group was on average 28.57%. This proportion then decreased to approximately 14.29% until 10:00. However, during the time period between 7:30-8:45, the proportion of fan usage increased to a maximum of 42.86%. The second highest period of fan usage occurred between 11:00 and 14:00, with the highest proportion of fan usage occurring from 12:00-12:45 on average at 90.48%. Finally, fan usage increased again from 18:00 onwards, with an average usage rate of 69.64% during the third period of the day, and a maximum frequency of usage at 82.71% at 19:00.

When analyzing age groups between 41-50, 51-60, and 61-70 years old, it was found that the proportion of fan usage in the morning was relatively low. This was only 9.09% of the 41-50 year old who used fans from 0:00-7:15, 11.11% of the 51-60 year old who used fans for less time, from 0:00-6:00, and 11.76% of the 61-70 year old who used fans from 0:00-3:00. When considering fan usage during the second part of the day for all three age groups, it was found that the 41-50 year old had the lowest proportion of fan usage during midday compared to the other two groups. Only 47.27% of the 41-50 year old used fans during this time, which was lower than the 51-60 and 61-70 year old who had a proportion of fan usage between 12:00-13:00 at 88.89% and 92.94%, respectively. The 51-60 and 61-70 year old used fans during the midday between 11:00-14:00 and 11:00-15:00, respectively. During the third part of the day, the 41-50 year old had a higher proportion and duration of fan usage compared to the other two age groups. They started using fans at 18:00 and continued until 23:45, with an average proportion of fan usage of 79.55% for all age groups during this time. The highest frequency of fan usage was 100.00% at 20:00 for the 41-50 year old. The age group of 51-60 years old has the lowest proportion of fan usage during the evening hours compared to all other age groups. It was found that fan usage starts at 20:00 with only 33.33% and gradually decreases until 23:45 where the percentage of fan usage in the sample group is only 11.11%. The average fan usage during this time period is only 18.75%. On the other hand, the age group of 61-70 years old has the highest proportion of fan usage during the third period of the day, starting from 19:00 and increasing from 20:00 to 22:00, with an average fan usage proportion of 77.12%. Subsequently, the fan usage proportion decreases, with the highest fan usage proportion for the 61-70 age group occurring at 21:00, which is 82.35%.

The final group consists of individuals aged over 71 years old. It was found that they only have two periods of fan usage each day: midday and evening. During the midday period, fans are turned on starting at 9:00 and continuing until 15:00. The highest proportion of fan usage during this period is between 12:00 and 13:00, with an average of 76.00% of individuals using fans, and the maximum fan usage is 100.00% at 12:00. Fans are turned on again in the evening period, from 18:00 until 23:45, with an average fan usage proportion of 60.00% throughout this period. In this age group, the highest average fan usage proportion occurs from 19:00 to 20:00 and the maximum fan usage proportion is 100.00% at 20:00.

The analysis of fan usage behavior when classified by gender and age groups reveals that each group exhibits similar but not identical fan usage behaviors. When examining the fan usage behavior of each group during workdays and holidays, no significant differences in behavior were found. Thus, it can be concluded that fan usage behavior within the building depends on the gender and age of the building occupants. The information in Table 4.24, which displays the quantity of fan usage by all population groups, the proportion of time and frequency of all fan usage is found to be an average of 50.31% from all sample groups.

2.2.3 Air conditioning

The behavior of air conditioner usage among consumers categorized by gender, age group, and time of day is presented in Table 4.7. The results indicate that the behavior of air conditioner usage does not differ significantly between weekday and weekends across all consumer groups. However, there are differences in behavior between gender and age groups. Analysis of the behavior of air conditioner usage among each consumer group reveals that usage patterns vary depending on consumer characteristics. It is important to note that the proportion of air conditioner usage in the area is relatively low, averaging only 5.95% according to the data shown in Table 4.24.

For male consumers, the behavior of air conditioner usage occurs during the following time slots: 0:00-2:45, 11:00-11:45, 12:30-13:45, 14:00-14:45, and 20:00-23:45. The proportion of air conditioner usage during these time slots averages 25.00%, 100.00%, 50.00%, 75.00%, 37.50%, and 75.00%, respectively. In contrast, female consumers exhibit air conditioner usage behavior only during the following time slots: 11:00-11:45, 12:00-17:15, 18:00-18:45, and 20:00-23:45, with the proportion of air conditioner usage during these time slots averaging 66.67%, 42.86%, 33.33%, and 72.92%, respectively.

If we consider the behavior of using air conditioners among age groups, it is found that the age group between 11-20 years old does not use air conditioners. Moreover, the age group between 21-70 years old does not exhibit the behavior of using air conditioners in the morning, but only during midday and early evening. However, the age group between 21-30 years old exhibits behavior of using air conditioners during the time periods of 11:00-11:45, 12:30-13:45, and 14:00-14:45, with an average proportion of air conditioner usage at 100.00% for each time period. This is due to the fact that only 6.25% of the sample population use air conditioners from the aforementioned age group.

The study examined the air conditioning usage behavior of different age groups in a certain population. The first age group, 31-40 years old, exhibited air conditioning usage behavior during three periods, namely 11:00-11:45, 14:00-14:45, and 20:00-23:45, with average usage proportions of 100.00%, 33.33%, and 45.83%, respectively. However, this group had the highest proportion of air conditioning usage during the period of 21:00-21:45, which accounted for 100.00% of their usage behavior. The second age group, 41-50 years old, exhibited air conditioning usage behavior during only one period, namely 20:00-20:45, with an average usage proportion of 93.33%. The third age group, 51-60 years old, exhibited relatively continuous air conditioning usage behavior from 11:00 to 21:45, with breaks during 11:45-12:00, 17:15-18:00, and 18:45-20:00. The average usage proportions for each period were 66.67%, 50.79%, 33.33%, and 33.33%, respectively. The fourth age group, 61-70 years old, exhibited air conditioning usage behavior during four periods, namely 11:00-11:45, 12:30-13:45, 14:00-14:45, and 20:00-21:45, with average usage proportions of 100.00%, 50.00%, 50.00%, and 31.25%, respectively. Finally, the last age group, over 71 years old, exhibited air conditioning usage behavior during only one period, namely 20:00-2:45, with an average usage proportion of 75.93%. The period with the highest usage proportion, 100.00%, occurred during the period of 20:30-23:45 pm.

The proportionate behavior data regarding the use of air conditioning systems within buildings, when analyzed according to gender and age groups, could not clearly indicate whether all community behaviors were similar to the data obtained from the questionnaire. This is because the analysis of air conditioning usage behavior characteristics according to consumer profiles still requires the use of other datasets, such as usage duration, frequency, and internal air conditioning system data, to accurately summarize the air conditioning usage behavior according to the characteristics of the consumers, and to ensure the reliability of the results in the future.

2.2.4 TV

When analyzing television viewing behavior by gender and age groups of consumers within a building, it was found that usage was divided into two periods each day, namely period 1 from 6:00 to 2:00 and period 2 from 6:00 to 10:00, as shown in Table 4.8. The overall television viewing behavior data from all sample groups, it was found that the majority, 74.13%, watched television most frequently from 7:00 to 8:00. In examining gender differences in watching television habits, it was found that males had a higher proportion of television viewing during one period than females, with an average proportion of 25.15% compared to females' average proportion of 14.51%. Additionally, usage increased during period 2 at 4:00 for males and 6:00 for females, with both genders having the highest average frequency of use at the same time, 7:00 to 9:00, with averages of 95.66% and 90.62% for males and females, respectively. Throughout the 24-hour period, males were found to use the television continuously without pause, whereas females stopped using it for an average of 5.30 hours per day.

If we analyze the television viewing behavior of different age groups, we find that the behavior increases as the age of the sample group increases. The age group over 71 years old is the only group that watches television continuously for 24 hours, with a minimum average usage of 9.09% throughout the day. The proportion of viewership increases during the period starting at 6:00. In the first period, the highest proportion of viewership is from 9:00-10:00, with an average of 90.91% for the sample group. This is followed by a continuous decrease in viewership, with a proportion of only 18.18% between 14.15-15.45. Subsequently, the proportion of viewership increases again in the second period, with the highest proportion of viewership for the sample group being at 20.00-21.00, with 100.00% of the sample group watching television.

The group with the lowest proportion of television viewing is the age group between 11 and 20 years old, with an average proportion of television viewing in the first period of 3.03% from the sample group of all age groups. The television viewing behavior occurred during the time interval between 11:00 to 12:00, followed by a cessation of television usage, and resumed again from 16:45 until 23:00. The largest proportion of the sample group, 100.00%, viewed television at 21:00.

The age group between 21 and 30 years old is a group that exhibits television viewing behavior distributed throughout the day. In the morning, there is a proportion of 20.00% of television viewing occurring between 6:00 to 6:30, followed by a cessation of television usage and another period of viewing in the morning at 8:00 to 8:30 with a proportion of 40.00%, which then decreases to 20.00% until 12:00. This period has the highest proportion of the sample group viewing television during the first period of the day at 40.00%, which subsequently decreases and stops at 13:45. Then, television viewing behavior resumes again from 18:00 to 21:00 with an average proportion of television viewing in the second period of the day of 77.65%. Specifically, at 19:00 and 19:30, there is a proportion of 100.00% of the sample group viewing television, which is the highest proportion during the second period of the day.

The age groups of 31-40 years old and 51-60 years old exhibit similar television viewing behaviors. The television viewing period ranges from 6:00 to 11:45 with the lowest average proportion of television viewing at 6.25% for the 61-40 years old group and 4.00% for the 51-60 years old group. During the first part of the day, the highest average proportion of television viewing for the 31-40 years old group is 12.50% between 8:00-10:00 and 12:00-14:00. For the 51-60 years old group, the highest proportion is 36.00% at 8:00, followed by a decrease and an increase in the proportion of television viewing during the second period at 18:00. The maximum continuous and increasing rate of the number of sample groups is 100.00% at 20:00 for the 31-40 years old group and 19:00-19:45 for the 51-60 years old group. Then, both groups experience a decrease and stop at 23:00.

The study examines television viewing habits among two age groups, namely individuals aged 41-50 and 61-70 years old. Both groups had similar periods of time during which they watched television. However, there were differences in the proportion of individuals within each group who watched television. The first period of time was between 6:00-14:00 for the 41-50 age group and 5:00-14:00 for the 61-70 age group. Within the 41-50 age group, the highest proportion of individuals who watched television was 18.75% during the time slot of 6:00-6:45. For the 61-70 age group, the highest proportion of individuals who watched television was 37.93% during the time slots of 7:00 and 8:00-8:30. The second period of time during which both groups had similar television viewing habits was from 16:00-23:00. During this period, the proportion of individuals within each age group who watched television more than half of the time was highest at 59.09% for the 41-50 age group and 62.07% for the 61-70 age group. The proportion of individuals who watched television continued to increase steadily until it reached 100.00% at 20:00 and 19:00, respectively. The average proportion of individuals within each age group who watched television during the second period of time was 73.26% and 75.46% for the 41-50 and 61-70 age groups, respectively.

The data on TV viewing behavior, when considering gender, it was found that males have a continuous TV viewing pattern, which corresponds to the sample group aged over 71 years with similar TV viewing behavior. From the aforementioned data, it can be seen that selecting profiles for analyzing various activity behaviors within may affect the number of resources used. Therefore, it is advisable to consider the characteristics of each individual consumer.

2.2.5 Cooking

When examining the cooking behavior of consumers by gender and age groups shown in Table 4.9, it was found that cooking activities were mostly frequent in the morning between 6:00-7:30 and in the evening between 17:00-19:15. Some activities also occurred during midday between 11:00 AM-13:00. These patterns correspond to the meal consumption behavior of humans, who typically have three meals per day. The frequency of cooking during midday was lower than other times, likely due to the fact that the midday meal for most participants was similar to the breakfast meal, and some participants may have eaten outside of their homes, affecting their cooking behavior. When analyzing the gender differences, it was found that the differences in behavior were relatively small, and the peak times for cooking were at 7:00-7:15 and 18:00-18:15 for both genders. The average percentage of cooking activities for males was 100.00% in the morning and 66.67% in the evening, while for females it was 100.00% in the morning and 97.83% in the evening. It is evident that cooking activities during the evening meal were mostly performed by females.

Upon examination by age group, it was found that nearly every age group had the highest frequency of cooking activity occurring around 7:00-7:15 and 18:00-18:15. However, the age groups between 11-20 years old, 61-70 years old, and over 71 years old had higher frequencies of cooking activity in the morning, occurring from 6:00, and during dinner for those between 11-20 years old and over 71 years old. In the evening, the frequency of such activity was relatively lower compared to other age groups.

The age group of 21-30 years old exhibits a slower average breakfast cooking behavior compared to other age groups, starting from 7:00, which is the time of highest morning activity frequency for this age group. The evening cooking behavior for this age group starts at approximately 17:00, with the highest frequency occurring between 18:00-18:15. All age groups between 31-70 years old exhibit similar breakfast cooking behavior patterns, with cooking starting at 6:00 am and increasing until it reaches 100% frequency at 7:00-7:15 and then decreasing until it stops at 8:15. Additionally, some of these age groups exhibit lunch cooking behavior between 11:00 and 12:30, with the average frequency of 13.33% for the 21-30 age group, 20.83% for the 31-40 age group, 3.33% for the 41-50 age group, 22.67% for the 51-60 age group, and 32.58% for the 61-70 age group. The evening cooking behavior for all age groups is highest between 18:00-19:15, with the highest frequency occurring between 18:00-18:15.

The data on cooking behaviors of the sample group, which includes factors of gender and age, when comparing weekdays and weekends, it was found that there was no significant difference in behavior between the two. This may be due to the fact that the study area is a community where the majority of occupations are general wage labor, which does not have a clearly defined work schedule. This results in no difference in cooking behavior between Monday to Friday and Saturday to Sunday.

2.2.6 Rice cooking

On Table 4.10, the cooking behavior of the sample group was analyzed by gender and age groups. It was found that cooking behavior occurred during the same time periods as breakfast and dinner. Specifically, cooking was most frequent during the morning period from 6:00-7:30 and in the evening from approximately 5:00-7:15. In the morning period, the frequency of rice cooking compared to the population sample in each group was 100% at 7:00-7:15 for all sample groups. In the evening period, the frequencies were 15.03%, 55.09%, 33.33%, 28.40%, 37.78%, 36.11%, 33.33%, and 18.52% for the male, female, age groups 21-30, 31-40, 41-50, 51-60, 61-70, and over 71 years old, respectively.

2.2.7 Microwave

The frequency of microwave usage is highly variable due to it being an electrical appliance that is not commonly used within communities. Analyzing the proportional frequency of microwave usage within a building by gender, age group, and day type, as shown in Table 4.11, reveals that microwave usage can be categorized into three distinct periods each day: morning from approximately 5:00-8:15, midday from approximately 11:00-14:15, and evening from approximately 17:00-22:45.

The data on usage behavior during normal days and holidays, there are differences observed in some sample groups. Specifically, among male consumers, there is a tendency to use the service during the hours of 7:00-8:00, with usage rates of 55.00% and 40.00% on normal days and holidays, respectively. During midday on normal days, there is a usage trend between 12:00-13:15, with an average usage rate of 25.00%. However, during holidays, there is an increase in the length of usage time, with usage occurring between 12:00-14:15, with an average usage rate of 25.00% for the sample group using the microwave. In the evening on normal days, there is a trend of quick and prolonged usage, starting from 17:00-22:45, with an average usage rate of 41.67%, and a maximum frequency of 100.00% occurring between 17:30-17:45 among all consumers. On holidays, there is a trend of microwave usage occurring between 18:00-20:45, with an average usage rate of 50.00%, and a maximum frequency of 100.00% occurring between 18:00-18:45 among all consumers. This has a higher average usage frequency compared to normal days. As for female consumers, there is a pattern of microwave usage at the same three time periods: 5:00-8:15, 12:00-12:45, and 17:00-23:15, with average usage frequencies of 50.00%, 26.67%, and 33.33% on normal days, and 50.00%, 26.67%, and 35.38% on holidays. There is also a high frequency of usage during both normal and holiday mornings, particularly at 7:00-7:15.

Upon analyzing the behavior of microwave usage among age groups, it was found that the age group between 11-20 years old exhibited microwave usage behavior in 3 time periods on a normal day and 2 time periods on a work day. These time periods are between 5:00-5:45, 7:30-8:15, and 17:00-18:15, with an average usage rate of 50.00%, 50.00%, and 80.00%, respectively. The same time periods on weekends and holidays were also analyzed, with usage rates recorded as 50.00% and 80.00% for the time periods of 5:00-5:45 and 17:00-18:15, respectively.

The group of individuals aged 21-30 years old has a specific time period during which microwave usage is concentrated. This time period is during the evenings, specifically between 17:00-17:45 and 19:00-20:15, where the average number of consumers during each time slot is 100.00% of the normal day's usage. Similarly, during the time periods of 18:00-18:45 and 19:00-20:15 on weekends, the average number of consumers during each time slot is 100.00% of the normal day's usage. When analyzing the data, it was found that this group constitutes only a single sample group or 12.50% of the same sample group that uses microwaves.

In contrast, the group of individuals aged 31-40 years old exhibits a higher variance in microwave usage behavior between weekdays and weekends compared to other sample groups. The morning time period shows activity beginning at 6:00 and ending at 8:15 for weekdays and 7:45 for weekends. The second time period for weekdays exhibits only usage during the time slot of 12:00-13:15, while on weekends, the usage extends from 11:00 to 14:15. This results in a longer duration of activity during weekends, which is notably different from weekdays. Additionally, during weekends, the frequency of microwave usage during the time slot of 12:00-13:15 is as high as 100.00%, which is higher than the average frequency of 50.00% observed during weekdays. Furthermore, during weekday evenings, microwave usage is concentrated during the time period of 20:00-20:45, with an average frequency of 100.00%, while on weekends, the usage increases during the time slot of 18:00-18:45, with an average frequency of 100.00% for both weekday evenings and weekends.

The group of individuals aged between 41-50 years old exhibited similar characteristics and behaviors in using microwave ovens on both regular and weekend. It was found that in the morning, microwave ovens were used between 6:00-8:15 with an average rate of 56.25%. During midday, microwave usage was observed at 12:00-12:15 and 15:00-15:45 with an average rate of 50.00%. In the evening, microwave ovens were used between 18:00-19:15 with an average rate of 60.00%, on both regular and weekend.

On the other hand, the group of individuals aged between 51-60 years old showed slightly different behaviors in microwave usage during the evening on regular and weekend. For instance, on regular days, the observed usage rates were 40.00%, 25.00%, 100.00%, and 25.00% at 6:00-7:15 am, 12:00-12:45 pm, 17:00-17:45 pm, and 18:30-19:15 pm, respectively. On weekend, microwave usage was observed to be higher and occurred earlier in the evening at 18:00-19:15 with an average rate of 53.33%, 33.33%, 33.33%, and 55.56%, respectively, for the same time periods.

The final group that uses microwave ovens consists of individuals between the ages of 61 and 70. Their usage behavior can be divided into three similar time frames on regular days, which are from 6:00-8:15, 17:00-17:15, and 19:00-20:15. On holidays, the second time frame occurs between 18:00-18:45 instead. The average usage rate for each time frame is 55.56%, 33.33%, and 33.33%, respectively, for the entire sample group that uses microwave ovens.

Upon an examination of each sample group's microwave oven use behaviors, it was found that microwave usage often occurs in the morning or during meal preparation activities, as microwave ovens are part of the food preparation process in the residential building. However, microwave usage during the evening exhibits variation among each consumer group. Furthermore, the time frames for these activities align with dishwashing activities, as both activities are related to each other.

2.2.8 Boiling water

A study was conducted on the characteristics of hot water consumption activities for domestic use among a sample group on both regular workdays and holidays, as presented in Table 4.12. It was found that the frequency of these activities occurred mostly in the morning for all groups, but there were variations observed among the consumer groups. However, when comparing the behavior on regular workdays and holidays, no significant differences were observed. Among the male participants, hot water consumption was most frequent during the time slots of 5:00-5:45, 6:00-6:45, 7:00-7:45, and 8:00-8:45, with an average consumer percentage of 27.27%, 72.73%, 63.64%, and 75.76%, respectively. There was a lower usage during the time slots of 13:00-13:45 and 19:00-19:45, with an average consumer percentage of 36.36% and 48.48%, respectively. On the other hand, among the female participants, the hot water consumption activities were most frequent during the time slots of 5:00-5:45, 6:00-6:45, and 7:00-8:15, with the frequency percentage of 40.00%, 66.67%, and 73.33%, respectively. There were also some minor activities observed that continued until approximately 19:30, with an average consumer percentage of 9.57% throughout this time period.

When analyzing activity by age group, it was found that the age group of 11-20 years had the highest frequency of usage among consumers in the same age group, with an average of 100.00% during the time periods of 5.00-5.45, 6.00-6.45, and 17.00-18.00. The age group of 21-30 years had the highest frequency of usage in the time period of 6.00-8.45, with an average of 100.00% during the time period of 7.00-7.15, and an average number of activity participants throughout this time period of 52.73%. There was a relatively small amount of activity from consumers in this age group during the time periods of 16.00-16.45 and 19.00-19.45, with only 20.00% of consumers participating in these activities. The age group of 31-40 years exhibited the longest continuous boiling behavior, starting from 6.00 to 17.15 and 19.00-20.45, with an average of 18.01% for the sample group. The highest frequency of activity for this age group occurred during the time period of 7.00-8.45, with an average of 57.14%, and the highest frequency occurred during the time period of 8.00-8.15 at 100.00%. The age group of 41-50 years had a frequency of boiling water during the time period of 5.00-8.15, with an average of 51.65%. There was a relatively small amount of activity during the time period of 18.00-19.15, with approximately 14.29% of consumers participating in these activities. Additionally, the highest frequency of boiling water for this age group was found to occur at 7.00-7.15 every day. The age group of 51-60 years exhibited boiling behavior on a daily basis in the morning, with each occurrence spread out every 30 minutes from 4.00-8.45. During the day, the period with the highest frequency of activity is between 6:00-8:00, accounting for 77.78% of the total activity, with another peak occurring between 13:00-13:45 and 18:00-19:45, with average frequencies of 40.00% and 34.29%, respectively. The age group of 61-70 year old begin boiling water as early as 5:00, with the highest frequency of activity occurring between 6:00-8:45, averaging 61.36%, followed by a small amount of activity at 25.00% and

12.50% during the periods of 13:00-13:15 and 19:00-19:15, respectively. The age group over 71 engage in boiling water behavior in three time periods: early morning from 4:00-5:45, morning from 7:00-9:15, and evening from 19:00-20:15, with average frequencies of 64.29%, 72.22%, and 50.00%, respectively.

The behavior data of boiling water activities in each sample group, there are significant differences among them, despite the activities occurring during similar time periods. Therefore, to use this behavioral data to create a model, it is necessary to incorporate other data sets related to this activity to help identify the specific details of the activity and increase the reliability of the data for future use.

2.2.9 Eating

Table 4.13 displays the eating behavior of all sample groups in the same direction. Eating behavior occurred in three time periods, namely 7:00-9:00, 12:00-13:00, and 18:00-20:00. The maximum eating frequency for each group was 89.29% at 8:00 for the male group, 93.33% at 8:00 the female group, 80.00% at 7:00 for the group aged 11-20 years, and 100.00%, 96.00%, 87.50%, 100.00%, 87.50%, and 100.00% at 8:00 for the groups aged 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years, respectively.

During the second time period, the maximum frequency of meal consumption for almost all sample groups occurred between 12:00 and 12:45. The average meal consumption rates for each sample group were 95.24% for males, 98.33% for females, 86.67% for those aged 11-20 years, 91.23% for those aged 21-30 years, 93.33% for those aged 31-40 years, 88.54% for those aged 41-50 years, 95.70% for those aged 51-60 years, 100.00% for those aged 61-70 years, and 96.08% for those aged over 71 years, in that order.

During the second period of the day, the maximum frequency of food intake for almost all groups occurred between 12:00 and 12:45. The average values for each group were as follows: 95.24% for males, 98.33% for females, 86.67% for those aged 11-20 years, 91.23% for those aged 21-30 years, 93.33% for those aged 31-40 years, 88.54% for those aged 41-50 years, 95.70% for those aged 51-60 years, 100.00% for those aged 61-70 years, and 96.08% for those aged over 71 years.

The data on eating behavior, it was found that eating is an activity that occurs after cooking and preparing food. In human lifestyle, preparing food before eating is necessary for good health and well-being. Following the act of eating, the necessary and continuous activity that follows is dishwashing, to clean the utensils for future use.

2.2.10 Washing dishes

Upon analyzing the characteristics of dishwashing activities from Table 4.14, there are time periods during which dishwashing occurs concurrently with food preparation, cooking, and consumption. Dishwashing occurs three times a day, namely during Time Period 1 between 7:00 and 9:00, Time Period 2 between 12:00 and 13:00, and Time Period 3 between approximately 17:00 and 20:00. When considering the frequency of dishwashing activities in comparison to food preparation, cooking, and consumption activities, it was found that dishwashing activities with higher frequency occur during the same time periods as the aforementioned activities. Specifically, during Time Period 1 of each day, dishwashing activities occur from 8:00 to 8:15. During Time Period 2, dishwashing activities occur at 12:45, which is the end of the midday meal consumption activity. Finally, during Time Period 3, dishwashing activities occur at 19:00 to 19:15, which is the time period with a high frequency of meal consumption activities.

From the analysis of dishwashing behavior based on the characteristics of each consumer, it was found that the behavior of the sample group aligns with activities related to cooking and dining. However, the frequency and duration of dishwashing activities vary among individuals. Therefore, when using behavior data to generate consumer profiles for water usage, it is necessary to consider the aforementioned information in order to increase the credibility of the dataset.

2.2.11 Bathing

From the activity data on bathing behavior of each sample group, as shown in Table 4.15, it was found that bathing behavior occurred on average for two time periods per day in all population groups. One period occurred between 6:00-8:15 and the other between 17:00-21:00. The morning period of the activity usually occurred after the opening of the light activity and before the meal activity, while the evening period occurred near the time of the light activity and the dinner activity. Overall analysis revealed that the frequency of bathing behavior was highest in the evening period for most sample groups, with males, females, and age groups between 11-50 years having the highest frequency of bathing behavior between 19:00-19:15. The age group of 51-60 years had the highest frequency of bathing behavior during the time period of 18:00-18:15 or 19:00-19:15. For the age group of 61 years and above, the highest frequency of bathing behavior was found at around 18:00-18:15. In the morning period of the day, the sample group of age between 11-40 years had a frequency of bathing behavior that was similar to the evening period of the same sample group. The table and data on the duration and frequency of bathing activity for the aforementioned sample groups indicate that there were no significant differences in bathing behavior between weekday and weekends for all sample groups.

The maximum number of female participants engaged in morning bathing activity was 51.22%, while the maximum number of male participants was 69.23%. For the age group 21-30 years, the maximum participation rate was 69.23%, for the age group 31-40 years it was 87.50%, for the age group 41-50 years it was 66.67%, for the age group 51-60 years it was 45.00%, and for the age group 61-70 years it was 24.00%. The participation rate for the age group above 71 years was 25.00%. At 7.00-7.15, the participation rate for the age group 11-20 years was 85.71%, while at 18:00-18:15, the participation rate was 100.00% for male and female participants and for the age group between 11-60 years. However, for the age group 21-30 years, the participation rate was 100.00% during the time period of 20:00-20:15. Additionally, the age group above 51 years had the highest participation rate during the time period of 18:00-18:15.

2.2.12 Electricity water heater

The data on bathing behaviour of the sample group presented in Table 4.16 indicates that an analysis of hot water usage during bathing reveals a corresponding pattern of usage with bathing activity. Upon examination of the gender of the sample group, it was observed that the time period and peak frequency of usage occurred at 19:00-19:15 for both genders. Furthermore, an examination of the age groups of the sample group revealed that those aged between 11-70 years exhibited a pattern of hot water usage during the same time period as bathing activity, whereas the group aged over 71 years did not exhibit any significant frequency of hot water usage.

It is important to note that the aforementioned bathing activity aligns with the frequency data of hot water usage in each respective sample group. Thus, it can be concluded that the hot water usage of each sample group corresponds with the time period of bathing activity, except for the group aged over 71 years.

2.2.13 Toilet

The behavior of restroom usage among all sample groups tends to be excessive throughout the day, starting from the morning upon waking up or along with the start of other activities within the building, such as turning on bright lights, as well as taking a shower. These activities usually begin at 6:00 and occur sporadically throughout the day. Data indicating the frequency of restroom usage for each sample group, as shown in Table 4.17, the frequency of restroom usage during workdays and holidays does not differ significantly. The highest frequency of restroom usage for each day occurs between 6:00-6:30 in all age groups.

From the table showing the frequency of restroom usage, it was found that the frequency of restroom usage increases consistently every hour in each sample group. In the morning, the frequency is highest at 6:00 and 7:00 am with an average of 81.40%, 83.26%, 87.27%, 65.56%, 73.33%, 78.10%, 74.07%, 83.64%, and 60.00% for each sample group, respectively. The frequency then decreases at 9:00 am and increases again from 12:00-4:00 pm with an average frequency of 40.93%, 36.74%, 18.18%, 41.11%, 51.11%, 42.86%, 31.85%, 47.27%, and 33.33% for each hour, respectively. The frequency then increases again to 68.84%, 62.79%, 54.55%, 56.67%, 63.33%, 78.10%, 51.85%, 67.27%, and 60.00% for male, female, age group 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years old, respectively.

The data on restroom usage behavior of all sample groups, it can be observed that the aforementioned activity is one that can occur throughout the day and cannot be specified to a definite time interval. Therefore, analyzing restroom usage behavior for community management planning requires an assessment of the resources used in such activities to identify the necessity of time allocation for planning and management efficiency.

2.2.14 Hair drying

The activity of using a small hot air blower to dry hair is an activity that was performed by eight sample groups, except for the sample group over the age of 71. The behavior of engaging in this activity varied slightly between normal days and holidays among the 31-40 year old age group. This is shown in Table 4.18 which indicates that, when considering the behavior of the male sample group, the activity occurred during three time periods: 5:30-7:45, 18:00-18:45, and 20:00-22:15, with an average frequency of use of 66.67%, 50.00%, and 50.00%, respectively. Period 1 had the highest frequency of use at 100.00% at 6:30-7:00, which differed from the female sample group, who had the highest frequency of use in the evening at 20:00-20:45, with the activity occurring during three time periods similar to those of the male sample group, but with different time slots at 5:30-7:15, 17:00-18:45, and 19:00-21:15, with an average frequency of use of 12.50%, 14.29%, and 51.39%, respectively.

If the analysis of hair dryer usage to dry hair is performed according to age groups, it will be found that the frequency of activity occurrence mainly takes place during the evening. Among the age group of 11-20 years old, there is only one time period with the highest average frequency of 100.00% which is at 20:00-20:45. The age group between 21-30 years old has two time periods with a frequency of activity, which are at 5:30-7:30 and 20:00-22:15, with average frequencies of 20.00% and 46.67%, respectively. The time period of 20:30-20:45 has the highest frequency of activity in this sample group. The age groups of 31-40 years old and 41-50 years old are similar in behavior with one time period of activity each, which is 19:00-21:15 for the 31-40 age group, and 19:00-20:45 for the 41-50 age group, with average frequencies of 55.56% and 85.71%, respectively. Both age groups have the highest average frequency of activity at 100.00% at 20:00-20:15 for the 31-40 age group, and 19:00-19:45 and 20:00-20:45 for the 41-50 age group. As for the age groups between 51-60 years old and 61-70 years old, their behavior is divided into two time periods: a morning period from 6:30-7:10 with low activity, and an evening period from 18:00-22:45 for the 51-60 age group, and 17:00-20:15 for the 61-70 age group. Both age groups have the same average amount of people performing activities, which is 16.67%, but there is a difference in the second period. The 51-60 age group has an average quantity of people performing activities at 40.91%, while the 61-70 age group has an average quantity of people performing activities at 22.22%.

2.2.15 Washing clothes

The Table 4.19 displays laundry activities that predominantly occur in the morning between approximately 6:00-12:15 and are distributed in the afternoon between 15:00-16:15, 17:00-17:15, and 19:00-20:15. Upon analyzing activity patterns during workdays and weekends across all age groups, a slight difference was observed among the 11-20 year-old group, which had a higher proportion of individuals engaging in laundry activities on weekends. This is attributed to the fact that the majority of individuals in this age group are students who only have free time to do laundry on weekends, resulting in a higher number of activities during weekends compared to weekdays. When analyzing activity patterns by gender, it was found that males tend to spend less time on laundry activities than females. Laundry activities typically start at 6:00, with the highest number of individuals engaging in activities at 8:00. Females tend to start activities at 7:00, with the highest number of individuals engaging in activities at 11:00.

Upon analyzing the behavior of laundry washing activities by age groups, it was found that all age groups had the highest number of people washing laundry at 8:00, with activities beginning at 6:00 on both weekdays and weekends. Among the age group of 11-20 years, only one group had laundry activities starting at 7:00 and ending at 10:15 on weekdays and 11:45 on weekends. The average percentage of activity during the morning period was 46.15% on weekdays and 36.84% on weekends. Upon considering the average proportion of people washing laundry during the period with the highest frequency of activity for each group, it was found that the values were similar, ranging from 35.98% to 61.38%, in the following order of gender groups and age groups: male, female, 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, and over 71 years. The average percentage of laundry washing activity during the afternoon period from all sample groups was 22.99%. Therefore, it can be concluded that the activity is influenced by age groups since the age of consumers is related to professions that affect their lifestyle behavior, especially government officials and students who mostly wash laundry on weekends.

2.2.16 Ironing

The activity of laundry pressing is another task that differs slightly in behavior between workdays and weekends, as shown in Table 4.20. It was found that noticeable differences in behavior were observed among the age groups of 21-30 years old and 41-50 years old. The former group tends to have a different pattern of leisure time activity on weekends than on workdays, whereas the latter group has an increased number of participants engaging in laundry pressing on weekends. Upon analyzing the characteristics of laundry pressing activity, it was found that this activity is not significantly related to other activities. Moreover, when examining the gender of the consumers, the time periods of laundry pressing were divided into three time slots: 6:00-8:15, 9:00-10:45, and 18:00-21:45. The majority of male consumers engaged in laundry pressing between 19:00-20:15, which accounted for an average of 84.00% of the time slot. This behavior differed from female consumers, who engaged in laundry pressing during both the morning and evening time slots, specifically between 7:00-7:15 and 18:00-19:15, with an average of 100.00% and 65.00%, respectively.

If behavior is analyzed by age groups, it can be found that the behavior of ironing clothes of age group 11-70 years has the highest frequency during the time of 6:30-7:15 for the age group 11-20 years, 7:00-7:15 for the age group 21-30 years, 6:30-7:15 for the age group 31-40 years, 6:30-7:15 for the age group 41-50 years, 7:00-8:15 for the age group 51-60 years, and 7:00-7:15 for the age group 61-70 years, except for the age group over 71 years old that has a high frequency of ironing clothes in the evening during the time of 19:00-20:15. Additionally, for the age group between 31-40 years old, the behavior of ironing clothes is distributed throughout the day, from 8:00-14:15, with an average percentage of individuals engaging in the activity during this time being 33.00%.

When analyzing the average number of individuals engaging in the behavior of ironing clothes for each age group, it was found that during the morning of a workday, the age group of 11-20 years old had an average percentage of 48.33%, 21-30 years old had an average of 46.00%, 31-40 years old had an average of 52.50%, 41-50 years old had an average of 86.36%, 51-60 years old had an average of 57.41%, 61-70 years old had an average of 50.00%, and the age group over 71 years old had an average of 62.50%. During the afternoon, the average percentages were 38.10%, 47.62%, 41.67%, 67.86%, 59.09%, 35.56%, and 100.00%, respectively.

The frequency data of ironing activity, it is found that the morning and afternoon periods have similar frequencies due to ironing being a behavior performed by all age groups and cannot accurately determine a specific time period in which it occurs. This is because ironing is an activity that occurs with a proportion of occurrence from the entire population averaging only 44.69%. This information is presented in Table 4.24.

2.2.17 Gardening

The activity of watering trees and gardening is an activity in the Table 4.21, that is carried out with an average proportion of 31.39% from each sample group. The behavior of watering trees occurs twice a day for each group, which is from 7:00 to 11:00 and 15:00 to 20:00 on a regular day, and from 6:00 to 11:00 and 15:00 to 20:00 on a holiday. The behavior of watering trees on holidays is more prevalent than on weekday, especially in the age group of 21-30 years, which begins the activity at 8:00 on weekday and at 7:00 on holidays, and in the age group of 31-40 years, which started the activity at 7:00 and now starts at 6:00.

When considering each time period of the activity, it was found that the highest number of activities occurred during the time period from 17:00 to 18:15 on both weekday and regular days. Male participants tended to water trees from 7:00 to 9:15 and from 16:00 to 20:00, with the highest number of activities occurring on average at 17:00 to 17:45. Female participants tended to water trees from 7:30 to 9:15 and from 17:00 to 19:45, with the highest number of activities occurring on average at 17:00 to 17:45.

The age group of 11-20 years had a 100.00% activity rate during the 17:00-18:15 time period, both on weekday and holidays. The age group of 31-40 years had an average activity rate of 25.00%, 25.00%, and 55.56% during the 7:00-8:15, 10:00-11:15, and 16:00-18:15 time periods on regular days, and an average activity rate of 33.33%, 33.33%, and 51.28% during the 6:00-7:15, 10:00-11:15, and 16:00-19:15 time periods. The age group of 41 to over 71 years had an average activity rate on both weekday and holidays, and the activity rate varied between 25.00% and 66.67% during different time periods.

2.2.18 Pets

The activity of pet care, as displayed in Table 422, reveals discernible differences in the activity patterns of each group. This is evident due to the relatively low proportion of participants engaging in the activity in each group. Specifically, the average proportion of participation across each group is only 5.56%. Table 4422 shows that among the groups, males engage in pet care during 13:00-14:15 and 17:00-18:15, with average participation rates of 53.33% and 33.33%, respectively. Females, on the other hand, engage in pet care during 8:00-8:45, 10:00-11:15, 12:00-13:15, and 14:00-17:15, with average participation rates of 28.57%, 14.29%, 28.57%, and 15.38%, respectively.

If analyzed by age group, it was found that the age group between 11-40 years old did not engage in pet care activities on regular weekdays, whereas the age group of 21-30 years old had pet care activities during weekends between 13:00-13:45. The age group of 41-60 years old and the age group of over 71 years old had similar pet care behaviors on both weekdays and weekends. For the age group of 41-50 years old, pet care activities occurred at 8:00-8:45 and 13:00-13:45 with an average activity rate of 66.67% and 33.33%, respectively. For the age group of 51-60 years old, pet care activities occurred at 10:00-11:15 and 14:00-16:15 with an average activity rate of 50.00% for both time periods. For the age group of over 71 years old, pet care activities occurred at 12:00-13:15 and 17:00-18:15 with an average activity rate of 50.00% for both time periods. Finally, for the age group of 61-70 years old, pet care activities occurred at 12:00-13:15 and 16:00-17:15 with an average activity rate of 37.04% and 33.33% on regular weekdays, and 50.00% for both time periods of 13:00-14:15 and 16:00-17:15 on weekends.

The relatively low percentage of individuals who engage in pet care activities within each age group may have implications for the quantity of resources allocated to such activities.

2.2.19 Washing cars

The activity of car washing is the least frequent activity, occurring on average only 2.75 times per month. The majority of such activities take place on weekends, as shown in Table 4.23. When analyzing car washing on weekdays, both males and females exhibit similar behavior, with two distinct time periods, from approximately 8:00 to 10:30 and from 14:00 to 14:45. Additionally, there is an increase in car washing behavior between 15:00 and 18:00 on weekends for all groups in the sample.

On weekdays, car washing behavior exhibits high and consistent frequency across all age groups during the time period of 14:00-14:45, except for the age groups of 41-50 years and above 71 years, where all car washing activities occurred during the time periods of 9:00-11:00 and 8:00-10:00, respectively. These are the only time periods during weekdays where car washing activities were observed for both age groups.

As for car washing behavior on holidays, it is observed that there is a time period where activity frequency is similar to that of regular days, with the highest number of car washers occurring between 14:00-14:45 across all age groups, except for those between 11-20 years old and those above 71 years old. The latter two groups exhibit all of their car washing behavior during the time periods of 9:00-10:15 and 8:00-10:00, respectively. It can be noted that car washing behavior on holidays can be divided into three time periods based on the data collected, which are 8:00-10:00, 13:00-14:45, and 15:00-18:00. The average percentage of car washing during these time periods is 36.74%, 34.83%, and 19.92%, respectively.

From the community context data on building activity frequency, which analyzed the duration of each activity captured in the building and the frequency of activities occurring on each day, as well as data on the building activity frequency showing the time intervals and proportions of activity occurrence during each time interval of the day for each sample group, it can be observed that the behavior of activity within the building that may occur can be understood. All the data, it can be concluded that developing a dataset to understand patterns of energy, water, and waste resource usage within the building will require an understanding of the behavior that influences resource usage patterns, including the interrelationships among all three aspects of each activity. From the aforementioned data, it is evident that the population residing in the sample community consists of diverse groups that influence lifestyle choices, necessitating the grouping of all 14 groups as shown in Table 4.25

Table 4.25 Consumer profile

Profile symbol	Personal data		Population group	
	Gender	Age (Year old)	(Number)	(Percentage)
CP1	Male	11 - 20	10	4.00
CP2	Male	21 - 30	13	5.20
CP3	Male	31 - 40	18	7.20
CP4	Male	41 - 50	17	6.80
CP5	Male	51 - 60	13	5.20
CP6	Male	61 -70	24	9.60
CP7	Male	>71	12	4.80
CP8	Female	11 - 20	5	2.00
CP9	Female	21 - 30	19	7.60
CP10	Female	31 - 40	19	7.60
CP11	Female	41 - 50	28	11.20
CP12	Female	51 - 60	33	13.20
CP13	Female	61 -70	29	11.60
CP14	Female	>71	10	4.00
Total (Person)			250	100.00

Analysis of building activity profile

An analysis of the building activity profile is a study of the features of the building's data on energy, water, and waste from SM that has monitored the building's resource usage. The building activity profile is a data collection that is used to understand community resource consumption and forecast future community demand. This sector consists of two steps: analyzing building consumption data and creating a building activity profile.

3. Building consumption data

Data collection on the consumption of all three resources, including energy consumption, water consumption, and the amount of waste disposed of inside the building. the overall sample data for the three community resources listed below:

3.1 Energy

In terms of energy, it collects data on the quantity of power utilized in each building. The total quantity of power consumed in the building every 15 minutes is what will be utilized to calculate how much electricity was used throughout each period. to monitor the building's energy use patterns. The energy consumption assessment is separated into three characteristics: the building's general average energy consumption behavior, energy consumption characteristics by weekday and weekend, and energy consumption characteristics by days of the week.

3.1.1 Residential building

3.1.1.1 General public house 1

Average energy consumption data collected at a 15-minute frequency within the GH1 with a smart meter found that the indoor energy consumption increased from the normal consumption with an average indoor energy consumption of 0.10–0.12 kWh at 6:00, was constantly used at a high consumption, and decreased slightly until around 13:30. The energy consumption rate increases for the second period at 17:30 until the maximum daily energy consumption is reached. The daily average maximum use was 0.19 kWh at 19:00. The standard deviation (SD) average of period energy consumption is 0.11. The SD of the average household energy consumption data, on the other hand, is directly proportional to the amount of energy consumed in each period shown in Figure 4.5.

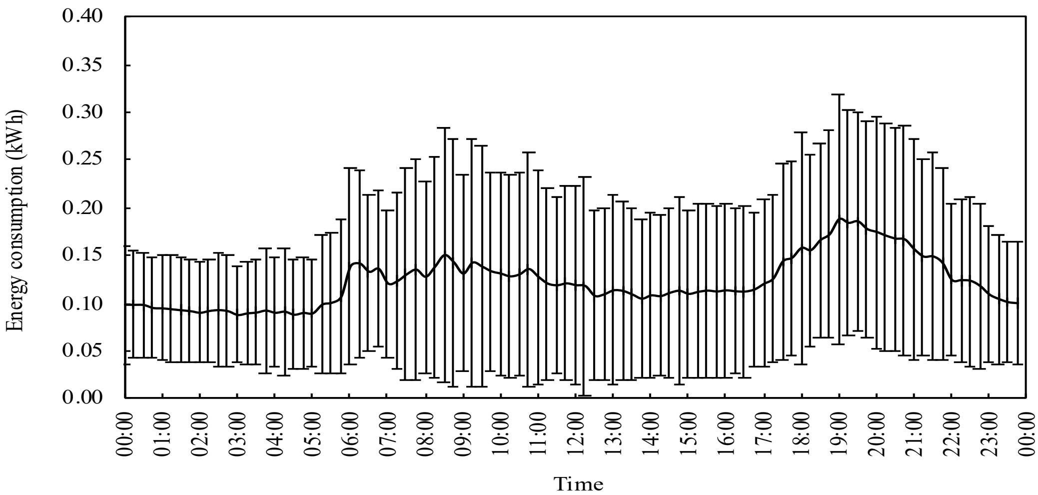


Figure 4.5 Average energy consumption in GH1

An analysis of the correlation between the time that passes, and the volume of energy consumed by the building. Table 4.26 shows the relational data. It was discovered that there was a relatively significant positive correlation between time and energy consumption. The correlation analysis results in a correlation value of 0.151, which is significant at the level of 0.01; in addition, there is 0.004 level of variance between the two variables, assuming that both data are variance in the positive direction. but didn't significantly adhere to it.

Table 4.26 Correlation between time and energy consumption in GH1

		Time	Power consumption
Time	Pearson Correlation	1.000	.151**
	Sig. (2-tailed)		.000
	Covariance	.083	.004
	N	31,067	27,587
Power	Pearson Correlation	.151**	1.000
	Sig. (2-tailed)	.000	
	Covariance	.004	.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

The energy consumption data in the GH1 study is categorized by days of the week. The average daily energy consumption before 6:00 is roughly 0.09-0.10 kWh, and it is greater and peaks in the morning, between 8:00 to 10:00. From Sunday to Saturday, the average maximum energy consumption is 0.17, 0.16, 0.17, 0.15, 0.15, 0.16, and 0.17 kWh. After then, energy consumption began to slowly decrease and afterwards gradually increase again, peaking around 19:00 to 20:00, when the building's daily energy use was maximum. In the following order from Sunday to Saturday, the average daily maximum indoor energy consumption was 0.22, 0.20, 0.21, 0.19, 0.20, 0.19, and 0.19 kWh. The average SD of all 7 days in energy consumption data separated by day of the week is 0.09. Figure 4.6 depicts the characteristics of GH1 internal energy consumption averaged each day of the week at a frequency of every 15 minutes.

The information in Table 4.27 comes from an investigation of the relationship between the time of each day of each week and the quantity of energy consumed by the building. It was found that daytime and energy consumption had a moderately significant negative correlation. The correlation analysis shows a correlation value of 0.033, which is significant at the level of 0.01; in addition, there is 0.006 level of variance between the two variables, assuming that both data are variance in the negative direction. but didn't significantly adhere to it.

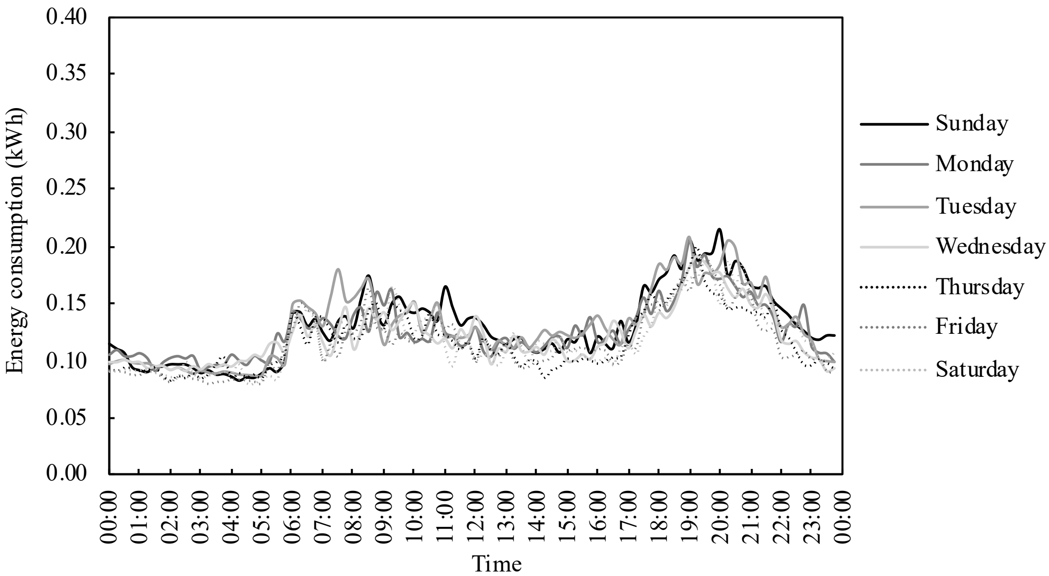


Figure 4.6 Average energy consumption in GH1 (day of the week)

Table 4.27 Correlation between Time-day and energy consumption in GH1

		Time-day	**Energy consumption**
Time-day	Pearson Correlation	1.000	-0.033**
	Sig. (2-tailed)		0.000
	Covariance	4.080	-0.006
	N	31,067	27,587

Table 4.27 (Cont.)

		Time-day	Energy consumption
Energy consumption	Pearson Correlation	-0.033**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	-0.006	0.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

When the quantity of energy consumed on weekdays and weekends was considered (as shown in Figure 4.7), it was discovered that the energy consumption inside GH1 was not different according to the days of the week. The amount of energy consumed correlates with the energy consumption characteristics of the day of the week. In terms of energy consumption, the largest consumption occurred in the morning on a weekday at 0.15 kWh at 8:30 and on weekends at around 0.16 kWh at 9:15, with a standard deviation of 0.09 across all datasets as the mean.

According to the GH1 building energy consumption statistics, the quantity of energy consumed within a building does not vary during the day. Every day of the week or weekday and weekends Because daily energy use is significantly correlated. However, as seen above, the quantity of energy consumed in the building is related to the time of day.

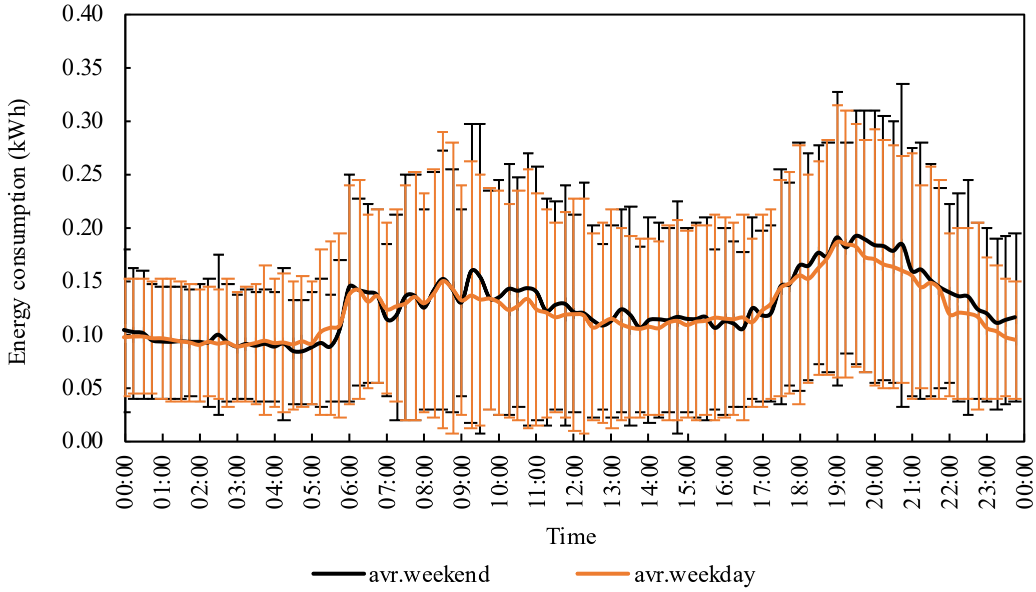


Figure 4.7 Average energy consumption in GH1 (Weekday/Weekend)

Table 4.28 Correlation between Weekday/weekend and energy consumption in GH1

		Time-week	**Energy consumption**
Time-week	Pearson Correlation	1.000	0.093**
	Sig. (2-tailed)		0.000
	Covariance	.288	0.005
	N	31,067	27,587
Energy consumption	Pearson Correlation	0.093**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.005	0.009
	N	27,587	27,587

**. Correlation is significant at the 0.01 level (2-tailed).

3.1.1.2 General public house 2

Average energy consumption data collected at a 15-minute frequency within the GH2 with a smart meter found that the household energy consumption increased from normal consumption with an average indoor energy consumption around 0.10 kWh at 4:45, was constantly used at a high consumption to 0.03 kWh at 5:15 and decreased slightly until around 6:45. The energy consumption rate increases for the second period at 16:45 until the maximum daily energy consumption is reached. The daily average maximum use was 0.04 kWh at 18:30-19:30. The standard deviation (SD) average of period energy consumption is 0.02. The SD of the average household energy consumption data, on the other hand, is directly proportional to the amount of energy consumed in each period shown in Figure 4.8.

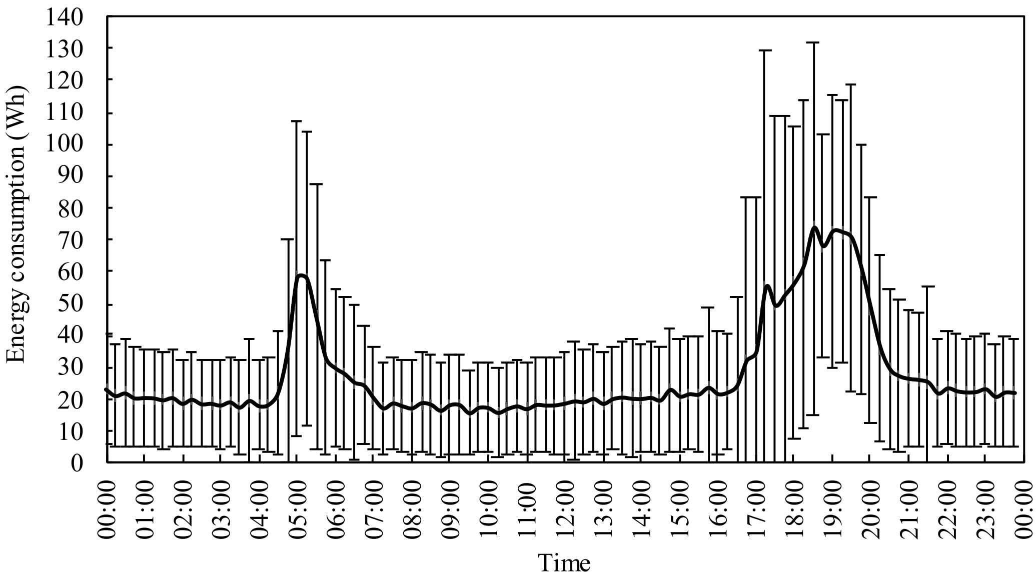


Figure 4.8 Average energy consumption in GH2

The information in comes from an investigation of the relationship between the time and the quantity of energy consumed by the building as Table C1. It was found that daytime and energy consumption had a moderately significant negative correlation. The correlation analysis shows a correlation value of 0.100, which is significant at the level of 0.01; in addition, there is 0.001 level of variance between the two variables, assuming that both data are variance in the negative direction. but didn't significantly adhere to it.

The energy consumption data in the GH2 analysis is categorized by weekday. According to the statistics, the two peak times for the day are about 4:45-6:00 and 17:15-20:00, as shown in Figure 4.9, which depicts the characteristics of GH2 building energy consumption averaged each day of the week at a frequency of every 15 minutes. For the first period, the average energy consumption in GH2 is approximately 21.96 Wh at SD 7.76, and for the second period, it is around 31.32 Wh at SD 7.87. The average maximum energy usage of the first period from Sunday to Saturday is 29.83, 31.05, 44.91, 39.61, 32.24, 30.09, and 26.76 Wh, with SD of 37.27, 35.96, 38.37, 35.18, 30.86, 32.57, and 27.58. The second period in average energy consumption has a max of 53.47 Wh with SD 49.04, 34.08 Wh with SD 41.59, 40.32 Wh with SD 45.74, 45.75 Wh with SD 46.20, 42.82 Wh with SD 46.03, 38.54 Wh with SD 56.79, and 31.02 Wh with SD 36.80 for Sunday to Saturday, respectively. When examining the average daily resource consumption pattern, it can be observed that individuals consume energy slightly differently on Sunday and Saturday than on other days, especially on Sunday evenings, when there is a higher consumption of energy than on any other day. Furthermore, the rate of energy consumption has increased since 11:00.

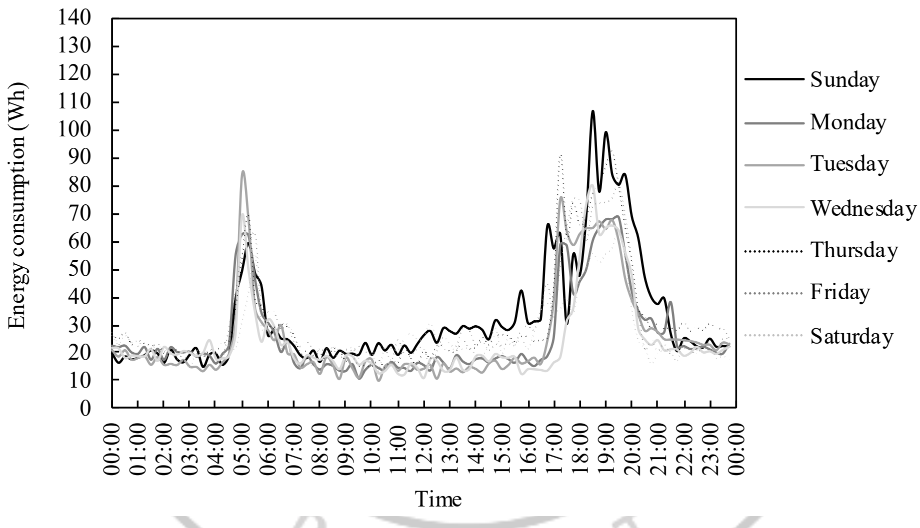


Figure 4.9 Average energy consumption in GH2 (day of the week)

When analyzing the connection between the amount of energy consumption in buildings per day as shown in Table C1, it was discovered that both data sets had a negative correlation of just 0.007, indicating that the amount of energy consumption in buildings was separated by day of the week. There was no statistically significant correlation.

However, when analyzing the average energy consumption in General Public House 2, classified by weekday and weekend, it was found that the characteristics of the data were the same as the total daily average energy consumption and the total average separated by day of the week. The peak power consumption was divided into two time periods per day: period 1 with a peak energy consumption of 25.65 Wh at 5:30 and period 2 with a peak energy consumption of 39.92 Wh at 18:30 of a weekend, and on a normal day, the maximum energy consumption indoors is the first session at 5:00, 33.28 Wh, and the second session at 18:30, 37.32 Wh of working day, shown in Figure 4.10.

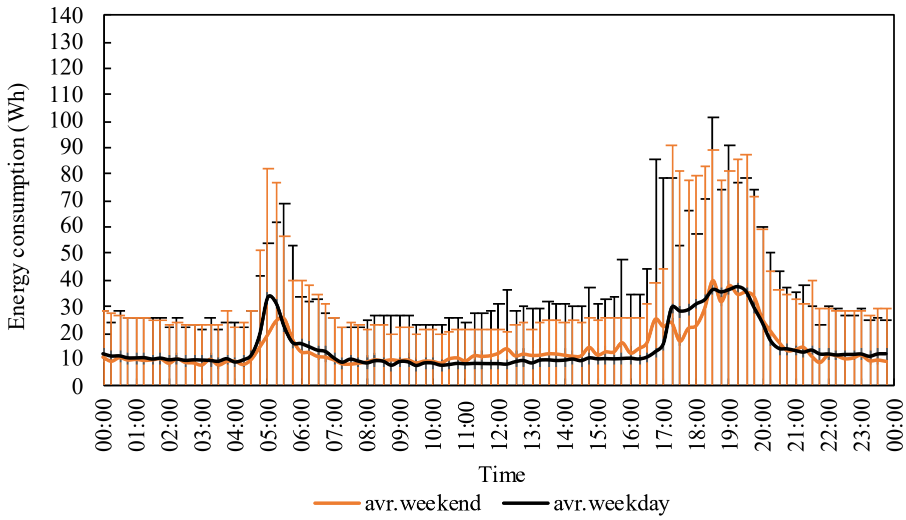


Figure 4.10 Average energy consumption in GH2 (Weekday/Weekend)

However, the correlation between the characteristics of residential energy consumption by weekday and weekends, as shown in Table C1, indicates that information classification into such data groups affects the data relationship. The statistics demonstrate that both variables are positively correlated at the 0.063 correlation level, where correlation is significant at the 0.01 level, but the covariance of the two is not statistically correlated.

The character of indoor usage does not depend on the day of the week, according to an analysis of the character and amount of energy consumption within GH2 , defined by different day groups. This suggests that the daily energy consumption inside GH2 is the same at all times of the day. with no variation between the days However, according to the SD mean of all data sets, there is a relatively large variance in the data from day to day. There are additional criteria, such as the information of consumers to live in this building and work as general employees, because of the quantity of energy consumed, and the occupation is independent of the day because of this. the nature of the amount of energy consumed in every situation. Therefore, there are characteristics of data that are statistically related.

3.1.1.3 School house 1

The average electricity consumption within the residential building of Teacher's Housing, House 1, as shown in Figure 4.11, exhibits a behavior of 22.98 Wh throughout the day. During the time period of 0:00-1:00, there is a slight increase in energy usage rate from the average, followed by a decrease until 5:00. Subsequently, the energy usage rate rapidly increases until 6:45, which is the time that corresponds to the highest average electricity consumption within the first section of the building, with an average consumption of 48.84 Wh and a standard deviation of 77.59. The energy usage rate then decreases to an average value, and slightly increases again during the time period of 12:00-14:00. By 17:00, it is observed that the energy usage rate has been consistently increasing, reaching its maximum at 19:00 with an average consumption of 53.54 Wh and a standard deviation of 78.92, followed by a decrease until the average value of energy consumption in the entire building at approximately 23:15.

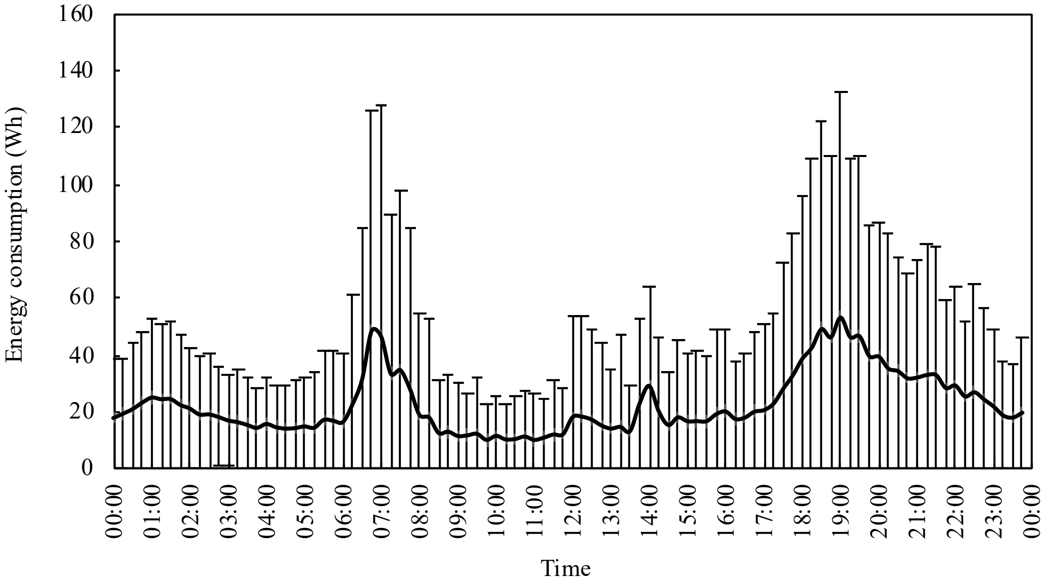


Figure 4.11 Average energy consumption in SH1

When analyzing the level of correlation between energy use within the building and the time of day as presented in Table C1, a positive correlation coefficient of 0.109 was found to be significant at the 0.01 level. Additionally, the variance of energy use data within the building was found to be 0.001 in the positive direction, but it was not statistically significant for the dataset.

Examining the energy usage behavior within the building on a daily basis throughout the week (Sunday to Saturday) as shown in Figure 4.12, it was found that the average energy consumption in every 15-minute interval was 22.88, 23.13, 24.23, 23.48, 23.13, 22.62, and 21.35 Wh respectively, while the average standard deviation values were 29.47, 31.30, 32.14, 30.73, 28.07, 26.75, and 27.57 for Sunday to Saturday respectively. The data presented for both the mean and standard deviation values for each day of the week shows that there is no significant difference in the energy usage behavior within the building throughout the week. Furthermore, the energy consumption pattern throughout the week is similar to the overall average values, with two periods of high energy usage occurring around 6:30-7:15 and 18:15-20:00.

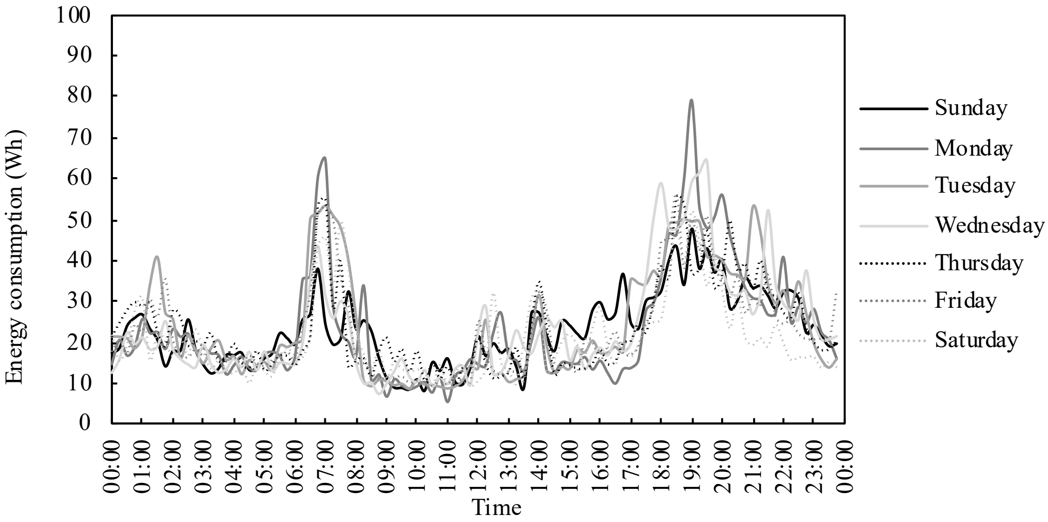


Figure 4.12 Average energy consumption in SH1 (day of the week)

Upon analyzing the correlation level of the energy consumption dataset within the building for each day at different times as presented in Table C1, it was found that the energy consumption behavior for each day has a negative correlation over time at a level of 0.007, but it is not statistically significant, and there is no significant variability between the two datasets. The correlation level data indicating that there is no statistically significant correlation between the datasets, it can be concluded that there is no statistically significant difference in energy consumption behavior for each day of the week.

Moreover, when analyzing the energy consumption data within the building every 15 minutes and separating them by weekday and weekends, it was found that the average energy consumption behavior of both days still remains the same. That is, there is a high energy consumption in the morning during weekday at 6:45, with an average amount of 52.01 Wh, and at the same time on weekends, the highest average energy consumption is 40.69. However, when analyzing the standard deviation value, it was found to be high due to the differences in energy consumption each day. Nevertheless, there is still a consistent energy consumption behavior in the same direction. The average standard deviation value throughout the day on weekends is 31.19, and on weekdays is 28.91. The comparison of energy consumption behavior within the building between weekday and weekends is shown in Figure 4.13.

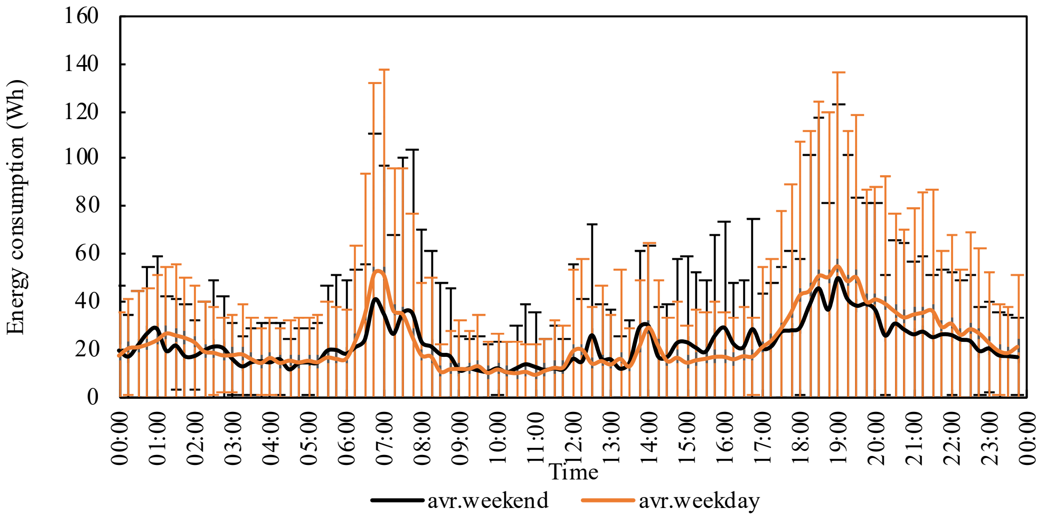


Figure 4.13 Average energy consumption in SH1 (Weekday/Weekend)

The level of correlation between energy usage data within the building during weekdays and weekends revealed a statistically significant positive correlation with a correlation coefficient of 0.047 at the Correlation is significant at the 0.01 level. Both datasets, however, still exhibit low variance between variables, indicating that the amount of energy usage within the building is related to both weekdays and weekends.

3.1.1.4 School house 2

The characteristics of energy consumption within the teacher housing building 2 were found to be similar to those of teacher housing building 1 (SH1) but differ in their levels of consumption as shown in Figure 4.14. The energy consumption pattern within the building showed a high usage rate during two distinct time periods. The first period begins at 5:00 and continues until 6:30, during which time the energy consumption rate increases from the average value, reaching a peak at 73.21 Wh. This is followed by a decrease in energy consumption, and then a second increase in consumption starting at 17:00 and continuing until 19:45, during which the energy consumption rate reaches its maximum of 76.41 Wh. The energy consumption then decreases again starting at 20:30 and continues until the average consumption rate at 23:15. The average energy consumption rate every 15 minutes within teacher housing building 2 (SH2) throughout the day is 43.64 Wh/15 min, with a standard deviation of 53.02.

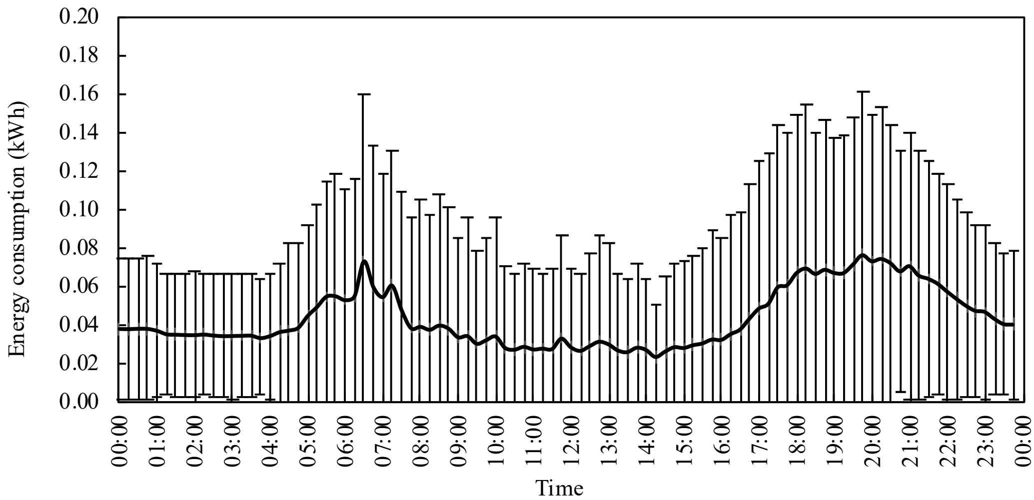


Figure 4.14 Average energy consumption in SH2

Furthermore, when analyzing the correlation between energy consumption and usage time from Table C1, it was found that there is a statistically significant positive correlation between the energy consumption within the teacher housing building 2 and the usage time during each day. The Correlation is significant at the 0.01 level with a correlation coefficient of 0.114 and a standard deviation of 0.002. This implies that an increase in usage time during each day has a significant positive impact on the energy consumption level.

The study of energy usage behaviour on a daily basis over the course of one week revealed a consistent pattern of energy consumption, with two periods of high energy usage occurring each day, in the morning and evening, as shown in Figure 4.15. When considering the average daily energy usage data, it was found that the average energy consumption for each day during the period of 5:00 to 7:30 was 38.39, 57.61, 65.01, 68.19, 61.24, 55.50, and 40.66 Wh respectively, from Sunday to Saturday. Similarly, during the period of 5:00pm to 11:00pm, the average energy usage for each day at 15-minute intervals was 61.91, 72.42, 74.02, 69.93, 61.52, 56.51, and 46.39 Wh respectively. From the graph and the average energy consumption data for both time periods, it can be observed that on Sundays, the average energy consumption within the building is lower than on other days during the same time period. Additionally, the average energy usage during the second period of Saturdays is the lowest among all days during the same time period.

Furthermore, an analysis of the correlation between the energy consumption within the building and the time of usage on each day of the week was conducted, and the results are shown in Table C1. It was found that there is no significant correlation between the energy consumption on each day of the week and the time of usage based on statistical principles. This is supported by a negative correlation coefficient of 0.004 and a p-value of 0.001, indicating a weak negative correlation between the two variables.

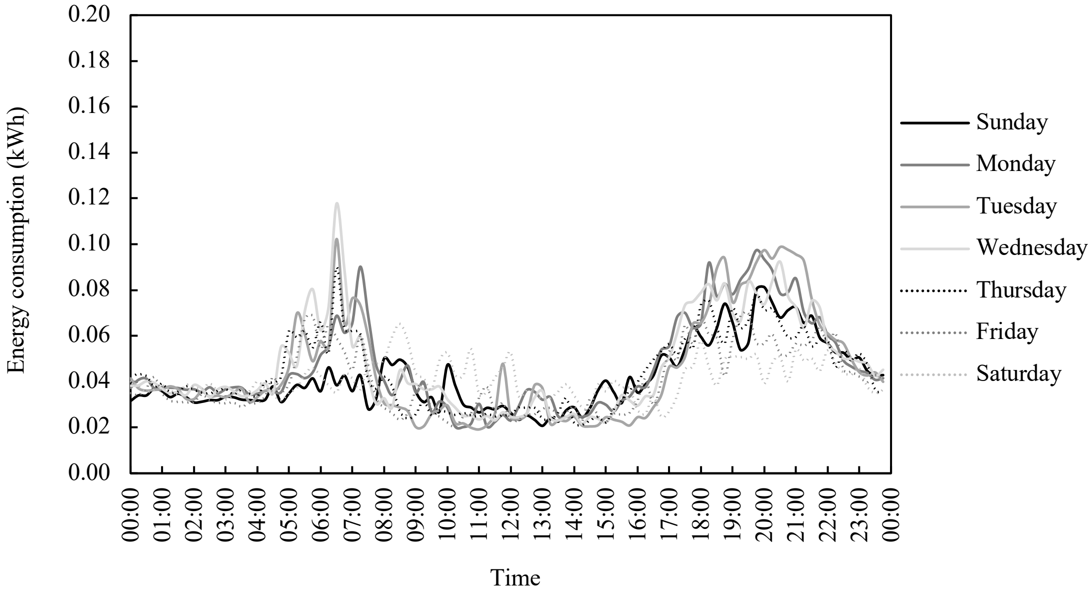


Figure 4.15 Average energy consumption in SH2 (day of the week)

From the daily energy usage behaviour data, a possible relationship between energy usage and time of day within the building can be observed. However, the results of the correlation analysis show that there is no relationship between energy usage and each day. Nonetheless, the energy usage quantities on Saturdays and Sundays differ from those of other days, as evidenced by the data. Hence, an analysis of the energy usage quantities within the building is performed by categorizing the data according to the type of working day and holiday, as shown in Figure 4.16. It is found that the average energy usage every 15 minutes on holidays is lower than that on weekday. The accumulated energy usage every 15 minutes throughout the day on weekday is 44.54 Wh, which is higher than the average energy usage quantity on holidays at 41.35 Wh. When considering high energy usage periods during weekday, it is found that energy usage on holidays has a smoother pattern, or a delayed peak by two hours compared to weekday, as measured from the highest average value in the morning of weekday and holidays. However, during midday, the average energy usage quantity on holidays is higher than on weekday. In the evening, the average energy usage quantity on holidays is lower than on weekday, with an average energy usage quantity of 55.43 Wh on holidays and 67.92 Wh on weekday, between 17:00 and 23:00.

Upon analyzing the correlation between energy consumption levels on workdays versus non-workdays during a specified time period, it was found that there exists a slightly positive correlation between energy usage and time spent utilizing energy. The correlation coefficient was determined to be 0.040 at a significance level of 0.01. Additionally, the variance between the two datasets was only 0.001, indicating that these datasets remain related.

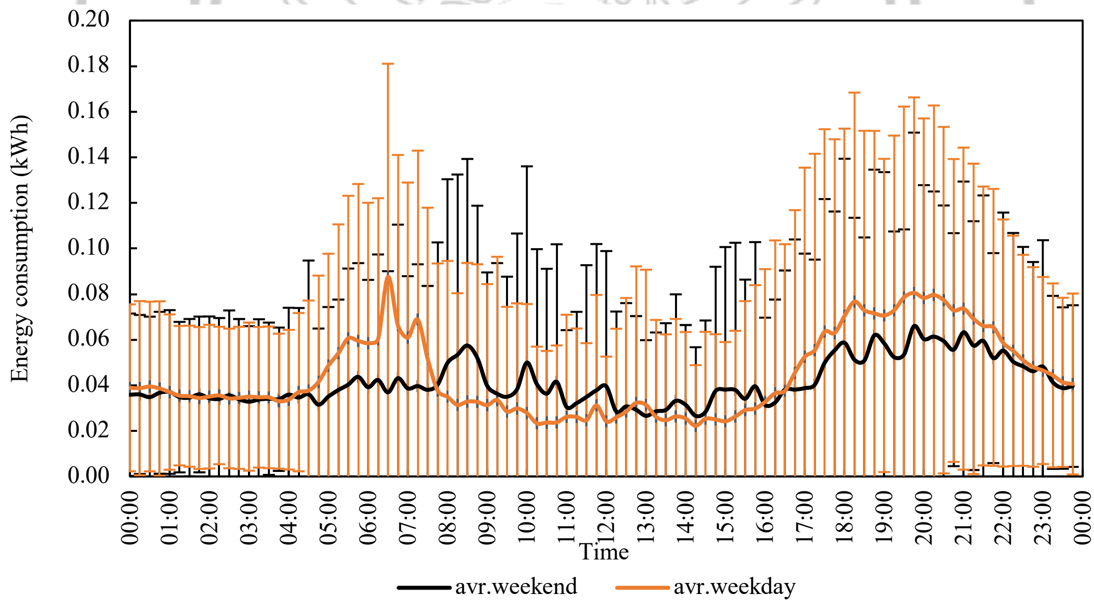


Figure 4.16 Average energy consumption in SH2 (Weekday/Weekend)

The analysis of energy consumption data collected every 15 minutes within the residential building for teachers (SH2) revealed a positive correlation between energy use. Daily and grouped analyses were performed, with energy usage behavior directly affected by the building's occupants, who are civil servants. Further analysis of the morning period revealed that energy use was stopped at 8:00. and resumed at 17:00. on weekday. During the second period on Saturdays, energy usage was lower than other days due to the fewer number of occupants staying in the building, as they had returned home. As a result, energy usage during Saturday evenings and Sunday mornings was lower than other days, with an increase in usage when occupants returned on Sunday afternoons. This led to a higher average energy consumption during the increased evening period.

3.1.1.5 Community hospital house 1

The energy usage behavior within physician residences, as depicted in Figure 4.17, exhibits distinct characteristics from those of GH1, GH2, SH1, and SH2 building energy usage patterns, as observed. The data demonstrates three time intervals where energy usage exceeds the average value of 32.63 Wh, which are from 0:00-3:00, 7:30-8:00, and 18:45-23:45, respectively. The mean values of energy usage for each of these time intervals are 44.64, 53.62, and 44.59 Wh/15 minutes, while the standard deviations are 69.72, 84.76, and 75.25, respectively. The high SD levels indicate significant variability within the dataset, consistent with the analysis of the relationship between cumulative building energy usage every 15 minutes, as presented in Table C1. Analysis of the usage duration shows a covariance value of 0 between the two variables, indicating no linear relationship between the variables. Additionally, the correlation coefficient value is 0.023 in the positive direction, but not statistically significant.

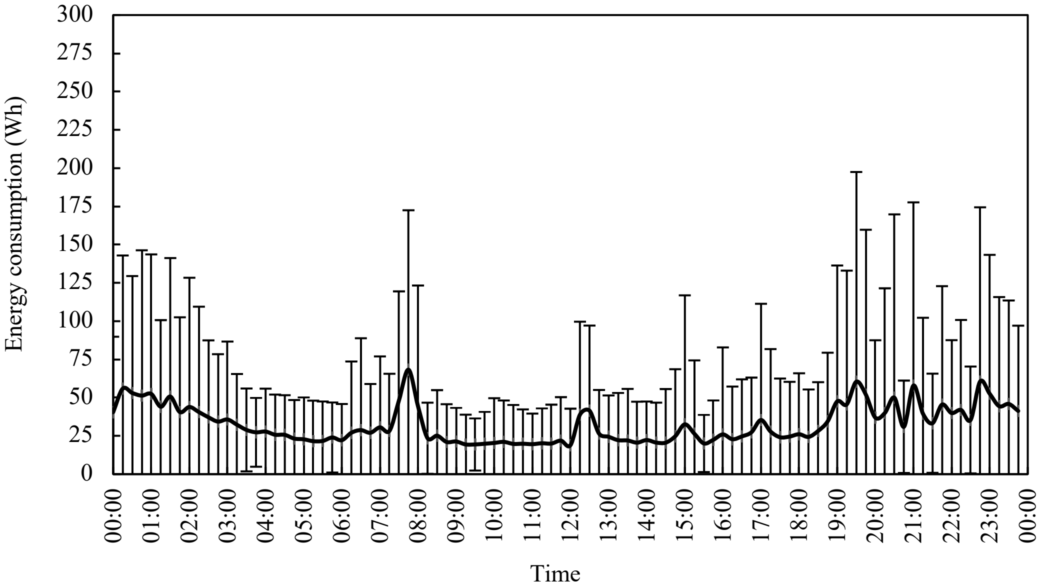


Figure 4.17 Average energy consumption in HH1

The behaviour of energy consumption within a building over the course of a week, as presented in Figure 4.18, indicates a high level of variability during times of high energy usage, specifically between the hours of 0:00-3:00, 7:30-8:00, and 18:45-23:45. Upon analyzing the average energy consumption during the time period of 0:00-3:00, the values were found to be 24.82, 37.99, 42.94, 49.66, 55.40, 53.04, and 34.68 Wh. During the time period of 7:30-8:00, the values were found to be 12.61, 29.89, 86.96, 67.44, 76.26, 74.27, and 29.73 Wh. Finally, during the time period of 18:45-23:45, the values were found to be 60.25, 46.84, 35.32, 50.19, 47.22, 38.81, and 31.89 Wh, from Sunday to Saturday in sequence.

The graph of energy consumption within the building on each day of the week and the data on the average values for each time period of each day show that the energy consumption on Sundays is lower than on other days between the hours of 0:00-8:00. Furthermore, on Saturdays, the energy consumption between the hours of 18:45-23:45 is notably lower than on other days. This is likely due to the fact that the building in question is a residential building used by community hospital staff and civil servants, with a specific pattern of behaviour during the afternoons on Sundays through Friday evenings. As a result, the energy consumption data shows that from

Friday evenings until Sunday afternoons, the energy consumption levels are relatively consistent.

Upon analyzing the relationship between the quantities of energy usage on a daily basis within one week for each period of usage, it was found that both sets of data have a significant positive correlation at a statistically significant level of 0.01, with a correlation coefficient of 0.019. Additionally, upon analyzing the covariance, it was found to be equal to 0.002, indicating a linear positive relationship between the two sets of data, as shown in Table C1.

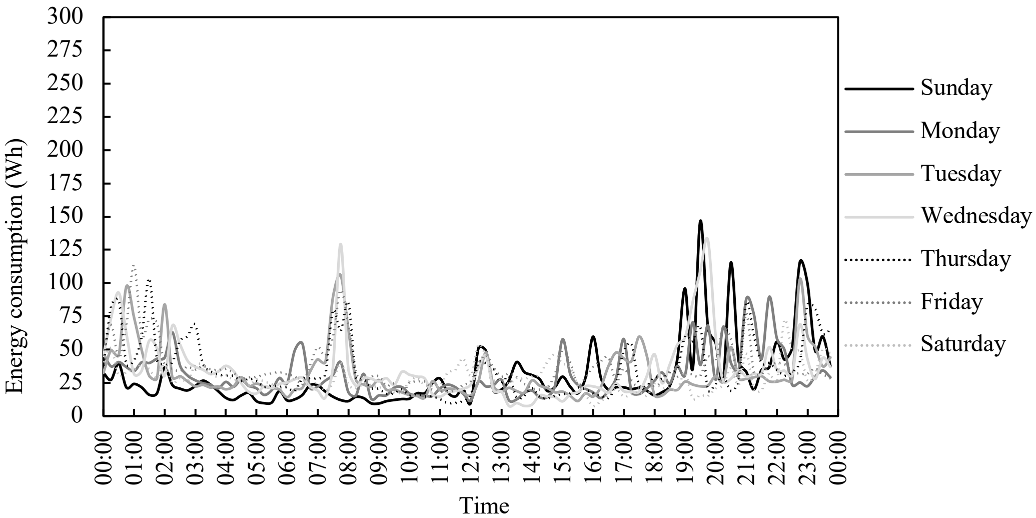


Figure 4.18 Average energy consumption in HH1 (day of the week)

When classifying the amount of energy usage within a building according to weekdays and weekend as shown in Figure 4.19, it was found that the data was consistent with the analysis of energy usage according to days of the week, with energy usage within the building during weekday being higher during the periods of 0:00-3:00 and 7:30-8:00 than on weekend, as clearly seen. The average amount of energy used within the building on weekend during both time periods was 30.11 Wh and 21.58 Wh, respectively, which is lower than the average energy usage on regular days, which was 50.54 Wh and 66.56 Wh. In the time period of 8:45-23:45, the average energy usage within the building on weekday was slightly lower than on weekend, with energy usage of 43.70 Wh and 46.87 Wh, respectively. However, when considering the energy usage during these time periods on weekend, it was found to have a high degree of variability. When analyzing the covariance between the data sets of energy usage within the building classified by weekday and weekend, a value of 0.000 was found, indicating that there is no linear relationship between the two data sets. This is consistent with the correlation coefficient of the two data sets, which has a negative value of 0.015.

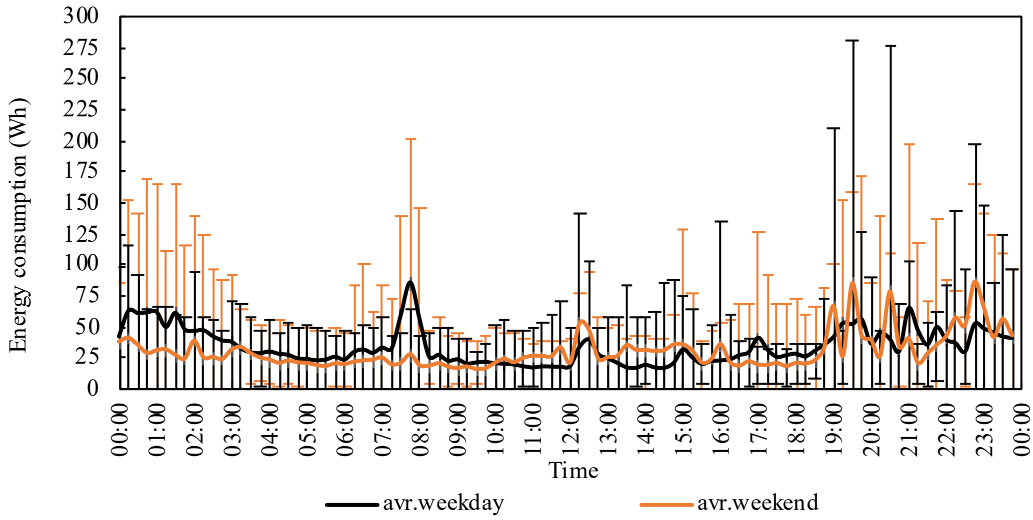


Figure 4.19 Average energy consumption in HH1 (Weekday/Weekend)

The energy consumption data within the community hospital house 1 (HH1), it can be concluded that the amount of energy usage within the building affects the duration of usage at the daily level during the week. This is due to the fact that energy usage behavior within the building is directly influenced by its occupants, who are civil servants. If we analyze the period of time with energy usage rates during the evening from Sunday to Friday, it can be observed that the amount of energy consumption within the building is lower than the same period of time on other days. This is because there are fewer occupants within the building or there are no residents present within the building.

3.1.1.6 Community hospital house 2

The energy usage characteristics within the second phase of a community hospital residential building 2 (HH2), as shown in Figure 4.20, exhibit similarities to those of typical residential buildings with high energy usage occurring during two time periods. The internal energy consumption during these periods is higher than the average daily energy consumption of 57.95 Wh/15 min. The two time periods are from 7:00-9:15 and 18:00-23:15, with average energy consumption values of 104.92 Wh and 89.92 Wh, respectively. The maximum average energy consumption values occur at 155.81 Wh at 8:00 and 121.06 Wh at 19:30. When considering the standard deviation values of each time period, it is found that there is a high variability during periods of high energy usage. The average value of the standard deviation throughout the day is 51.30.

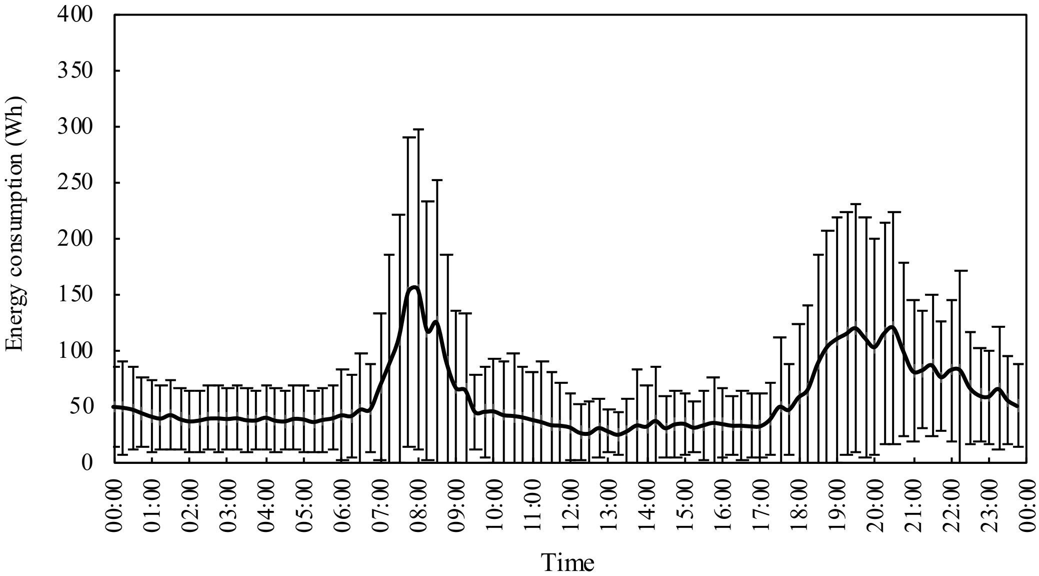


Figure 4.20 Average energy consumption in HH2

Furthermore, an analysis of the relationship between energy consumption data and the time of day reveals a significant positive correlation coefficient of 0.141, indicating statistical significance at the 0.01 level. The covariance level between the two variables, which shows the linear relationship between the variables, has a value of 0.003.

Figure 4.21, the energy usage within the building was observed over the course of 7 days. The usage patterns were found to be similar across each time period and were closely related in terms of energy consumption. The average energy consumption within the building from Sunday to Saturday was 64.67, 57.72, 58.23, 56.22, 52.86, 53.20, and 64.45 Wh, respectively, with a standard deviation of 49.34, as calculated from the SD data for each 15-minute time interval where high energy consumption was observed.

According to the data from time period 1, energy usage was higher than that of time period 2 on each day. The average energy consumption for each time period between 7:00-9:15 from Sunday to Saturday was 131.11, 105.21, 108.05, 99.15, 88.61, 76.74, and 129.48 Wh, respectively, while the second time period, between 18:00-23:15, was 85.46, 91.52, 92.56, 99.67, 81.24, 87.63, and 90.49 Wh. The data showed that energy consumption was similar across each day, and when analyzing the relationship between energy usage data separated by day of the week, it was found that both data sets were significantly correlated in a positive direction at the 0.01 level, with a correlation coefficient of 0.034. Furthermore, the level of variance of the linear variable indicated a positive relationship between energy consumption and time and day of the week at the 0.005 level.

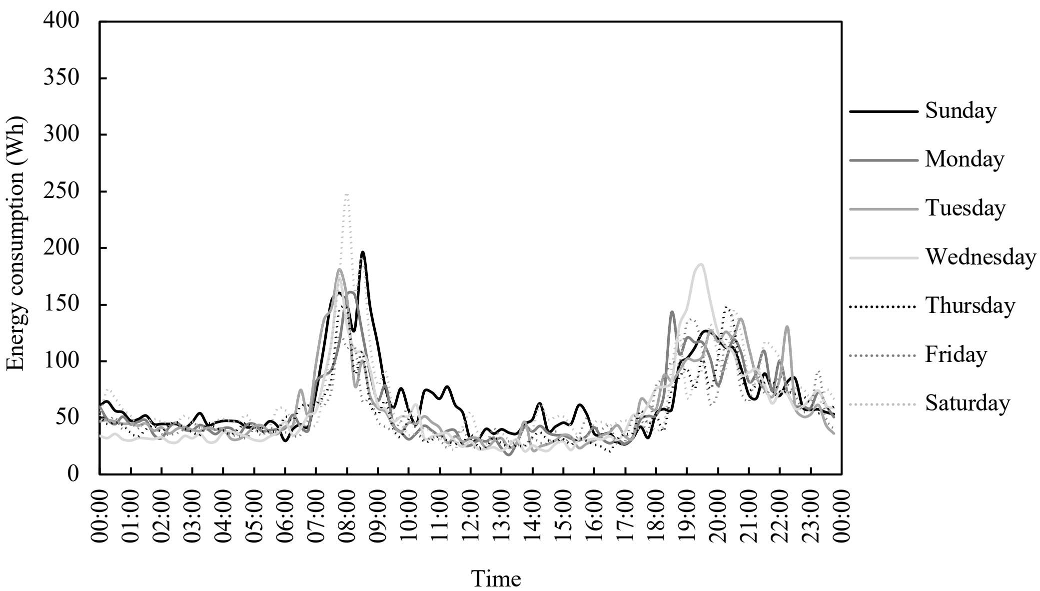


Figure 4.21 Average energy consumption in HH2 (day of the week)

When the energy usage data within the building is classified into two groups, namely weekday and holidays, as shown in Figure 4.22, it is found that the overall average cumulative energy consumption in the building at a 15-minute frequency on holidays is higher than on weekday. The average energy usage on holidays is 64.58 Wh, which is higher than the average energy usage on weekday, which is 59.46 Wh. If the amount of energy usage during the peak usage periods between 7:00-9:15 and 18:00-23:15 is considered, it is found that in the morning period, energy consumption on holidays is higher than on weekday, at 130.40 Wh and 102.46 Wh, respectively. However, in the second period, it is found that weekday have higher energy consumption inside the building than holidays, with energy usage of 91.37 Wh for weekday and 87.62 Wh for holidays.

Furthermore, when analyzing the level of correlation between the two data sets, it is found that the energy consumption inside the building, separated by weekday and holidays, has a positive correlation at a statistically significant level of 0.01. The covariance value also indicates a linear correlation level of 0.003 between the variables.

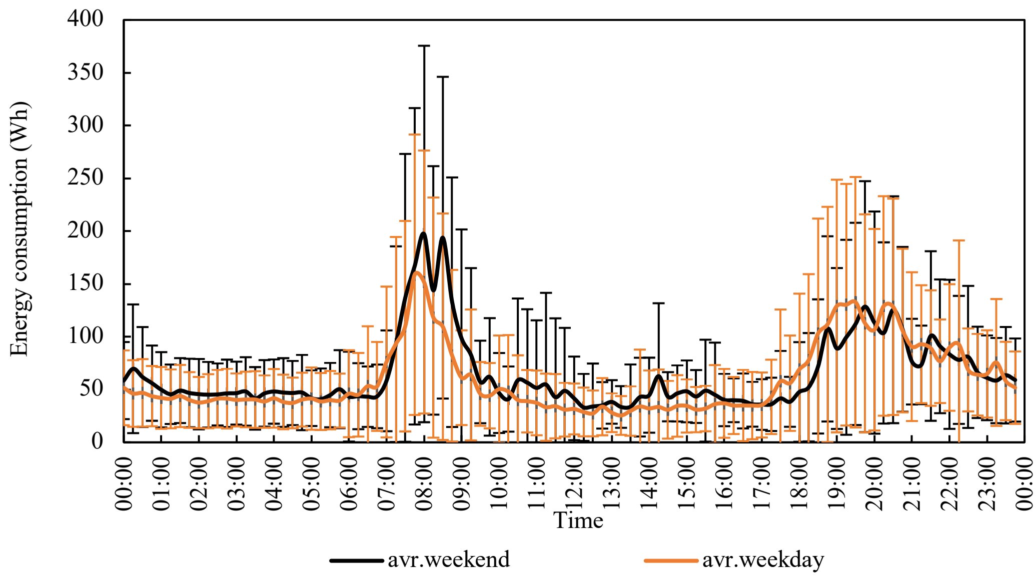


Figure 4.22 Average energy consumption in HH2 (Weekday/Weekend)

The information about the characteristics and energy usage behaviors within the second-phase community hospital residential buildings, it is evident that there is no significant difference in daily energy usage behaviors statistically. That is to say, there are similar usage behaviors during the same time period, but with varying usage quantities. This includes both weekday and holidays, which demonstrate energy usage behaviors and residential occupancy within the buildings. This is due to the fact that energy usage during the evening period is consistently high for a longer duration, unlike in the morning period where usage is higher but for a shorter period. Furthermore, analysis of the behaviors of residents with the same number of occupants during all time periods indicates that if the amount of energy usage for each activity is the same in two time periods, there is a higher frequency of usage in the morning compared to the evening, resulting in a higher cumulative energy usage in the shorter time period. This is because the average energy usage value is similar.

3.1.2 Office building

3.1.2.1 School office

From the data on energy consumption within the office-type building of the school (SCO), as shown in Figure 4.23, it was found that there was no clear difference in energy usage throughout the day. However, there was a characteristic of energy consumption quantities that had a high standard deviation from the mean value throughout the day. Specifically, during the time periods of 6:15-9:00 and 16:15-19:00, the average energy consumption within the building was found to be 10.93 Wh and 10.30 Wh, respectively, which was higher than the average energy consumption throughout the day, which was 9.49 Wh. When analyzing the correlation level of energy usage within the building over the time periods, it was found that the two data sets were not statistically correlated.

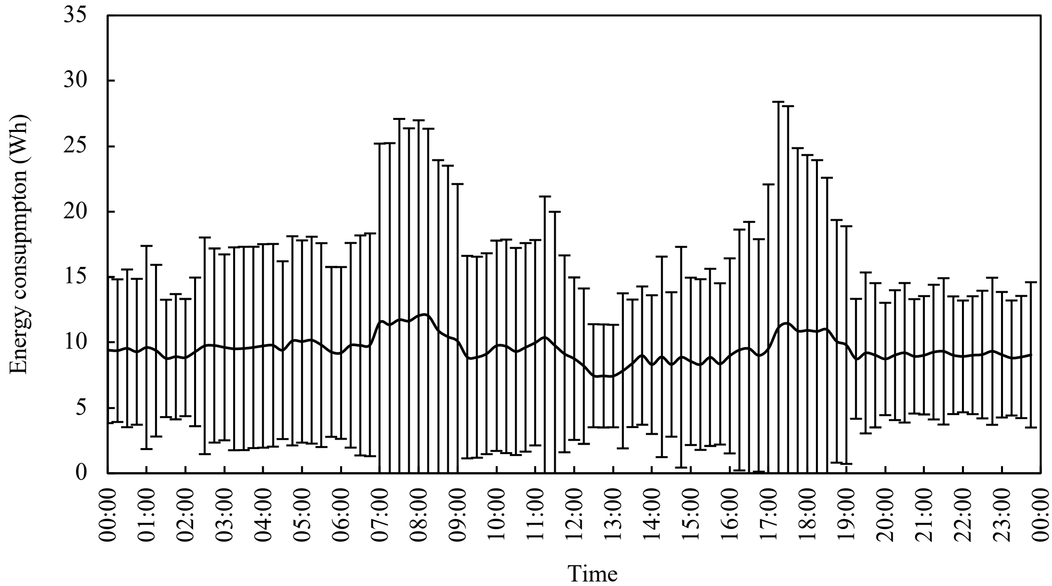


Figure 4.23 Average energy consumption in SCO

After analyzing the average energy usage per day of the week, as shown in Figure 4.24, it was found that during periods of high data variability for each day, there were distinctive patterns in energy consumption for different buildings. Specifically, when examining energy usage patterns on Sundays, it was observed that between 6:45-8:00 am, there was a noticeably lower amount of energy consumption than during the same time period on other days. However, when analyzing the cumulative energy usage every 15 minutes throughout the entire day, from Sunday to Saturday, it was found that the average values did not differ significantly and were equal to 8.55, 10.25, 10.04, 8.48, 8.93, 10.48, and 9.36 Wh, respectively, with corresponding standard deviations of 5.13, 8.09, 7.75, 4.36, 5.00, 9.90, and 7.46.

Further analysis of the relationship between energy consumption and time of day revealed that there was no statistically significant correlation between the two variables, but they did exhibit opposite directions of variability with a correlation coefficient of 0.435.

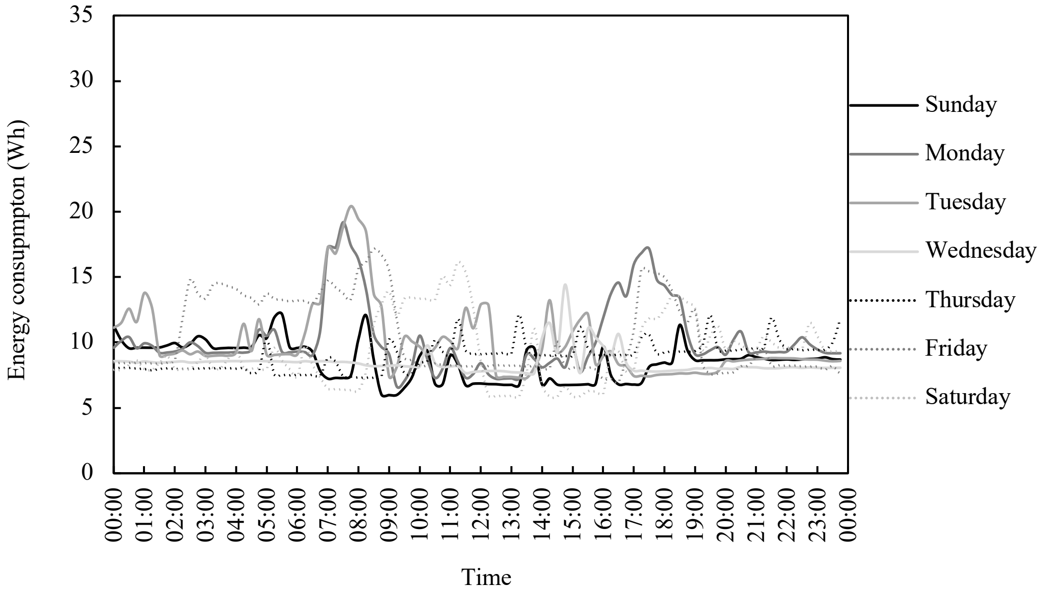


Figure 4.24 Average energy consumption in SCO (day of the week)

The analysis of energy consumption within SCO, when dividing the data set into weekday and weekend, reveals that the energy consumption pattern within the building throughout weekday has a higher average than weekend. Based on data collected every 15 minutes, the average energy consumption within the building on weekday is 9.66 Wh, which is higher than weekend with an average energy consumption of only 8.98 Wh. By referring to Figure 4.25, which shows the average data for each day, it is found that during the time interval of 6:30-8:00, the electricity consumption on weekday increases, while during the same time interval weekend, there is a decrease in energy consumption. However, there is an increase in energy consumption at around 9:00 on both weekday and weekend. Furthermore, when considering the energy consumption from 16:00 onwards, it is found that the behaviour of energy consumption on both days tends to increase at a similar rate and energy consumption reaches its peak at 19:00 on both weekday and weekend.

The analysis of the energy consumption data separated into weekday and weekend shows a negative correlation between the amount of energy consumption and time used. The correlation coefficient is 0.051, which is statistically significant at the 0.01 level. Additionally, the covariance in the opposite direction is 0.319.

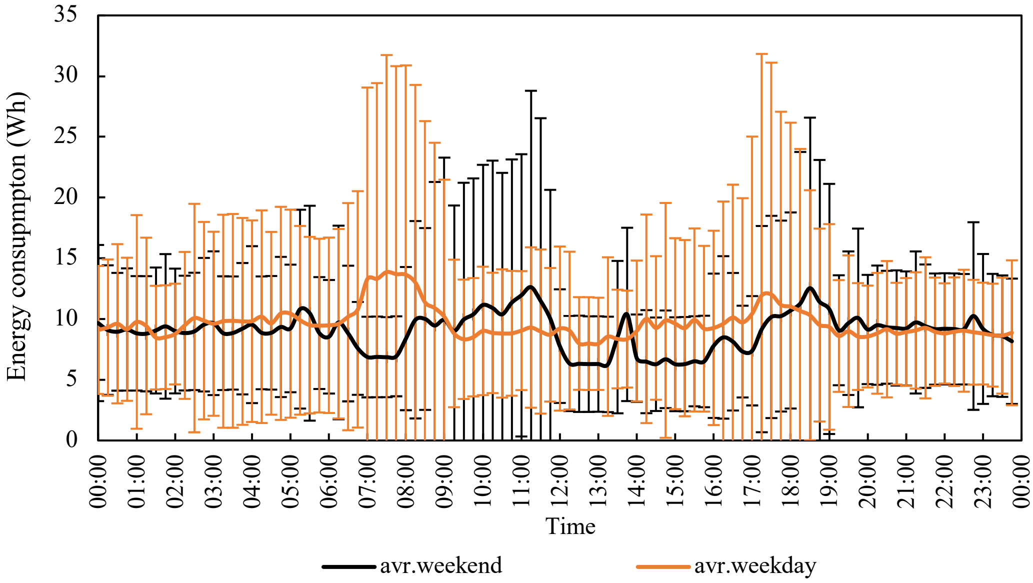


Figure 4.25 Average energy consumption in SCO (Weekday/Weekend)

The data on energy usage behavior within an office building in a school, it was found that there is high variability in energy usage during two time periods: 7:00-8:30 and 17:00-19:00. Upon analyzing the data by building function and location, it was observed that the building in question is designed to support the teaching activities of school teachers. Specifically, the building is primarily used before the start of classes at 8:30 AM and after the end of classes at 16:30, which is consistent with the observed energy usage patterns.

3.1.2.2 Community hospital office

The data on energy consumption within the community hospital office building, as shown in Figure 4.26, demonstrates the average energy usage every 15 minutes. The graph depicts an increase in energy usage starting from 7:00 until it stabilizes at approximately 8:30, followed by a slight decrease in electricity usage within the building between 11:30 and 12:30. Subsequently, energy usage rises again during the afternoon and decreases twice more, ultimately returning to a consistent energy consumption level around 17:00. Additionally, it was found that the majority of energy consumption within the building occurs between 8:00 and 16:45, during which the energy usage is higher than the daily average of 144.75 Wh. During this period, the average energy usage is 223.54 Wh, with a standard deviation of 141.89 for the same time range.

The relationship between the energy consumption data within the community hospital office building and time usage, it was found that the two datasets have a positive correlation with a Pearson's correlation coefficient of 0.040, which is statistically significant at the 0.01 level.

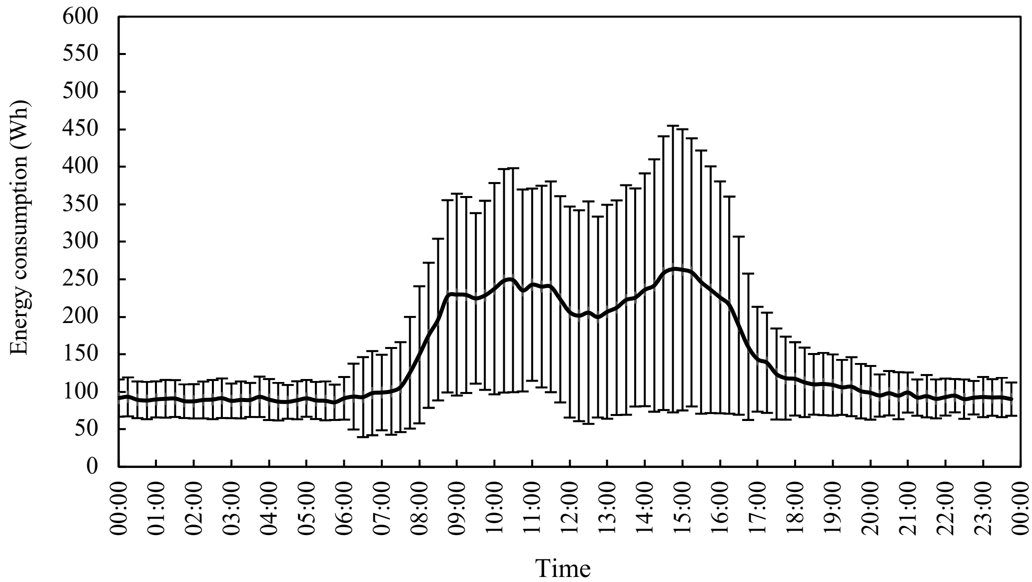


Figure 4.26 Average energy consumption in CHO

The energy consumption behavior within the building on a daily basis, it was found that the amount of energy used in the building varies slightly on Sundays and Saturdays. Figure 4.27 displays the energy consumption data within the building on Sundays, with increased energy usage occurring only during the time period from 8:00 to 12:00. This time period marks the day with the highest energy usage within the 7-day week cycle. The energy consumption data on Saturdays shows a clear division into two time periods, with energy usage starting higher than the normal level from 8:00 to 15:30, but then a brief stoppage in usage occurs from 11:30 to 12:00. These patterns are in contrast to the patterns observed from Monday to Friday. Moreover, when the average energy usage from 8:00 to 16:45 on each day was analyzed, it was found that the average energy consumption on Sundays and Saturdays was lower than that of Monday to Friday, with the average energy consumption being 105.97, 221.07, 267.68, 284.84, 288.67, 260.64, and 137.30 Wh for Sundays to Saturdays, respectively.

The relationship between each day of the week and energy consumption during each time period, it was found that the two variables had a significant negative correlation with a statistically significant level of Correlation at the 0.01 level.

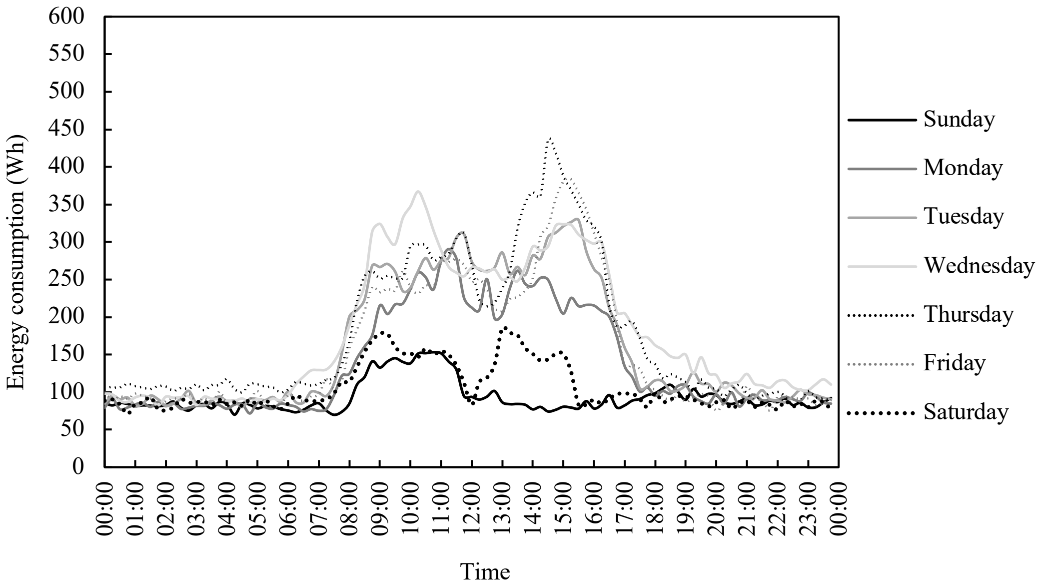


Figure 4.27 Average energy consumption in CHO (day of the week)

The energy consumption data is aggregated into weekday and weekend, as shown in Figure 4.28, it is evident that the amount of energy used within the building on weekday is higher than on weekend. When considering the standard deviation values of energy consumption on weekday, it can be observed that the minimum energy usage opportunity in the building is at the level of constant energy usage, and it varies according to the time of day. However, when considering the energy usage behavior on weekend during the time period of 0:00-12:00, the energy usage behavior and SD values are in the same direction and close in value. However, between 12:00-15:30, a higher standard deviation value is found due to the fact that the energy consumption data inside the building on Sundays and Saturdays shows that there is energy usage during that time on Saturdays, but not on Sundays, which affects the higher SD value.

The average energy consumption within the building separately for weekday and weekend, it was found that it was equal to 163.42 Wh with an SD value of 74.23 on weekday, and 98.61 Wh with an SD value of 40.91 on weekend. Specifically, when considering only the time periods with higher than normal energy usage, the average energy usage was 265.60 Wh with an SD value of 139.72 on weekday, and 119.97 Wh with an SD value of 66.34 on weekend. When analyzing both datasets for their correlation, it was found that they were significantly negatively correlated at the 0.01 level of statistical significance, with a correlation coefficient of 0.107.

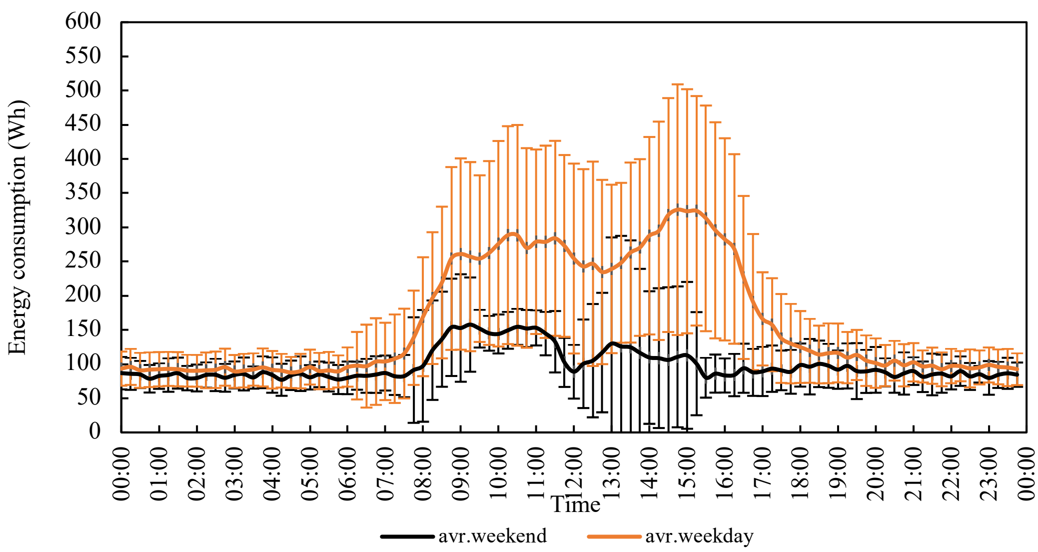


Figure 4.28 Average energy consumption in CHO (Weekday/Weekend)

The data regarding energy usage within the community hospital office building, it has been found that the time of day, day of the week, and type of work day all have significant impacts on the amount of energy consumed within the building. The quantity of energy usage within the building is dependent on the electrical appliances present within the building, as well as the manner in which the building is utilized.

3.1.3 Commercial

3.1.3.1 Coffee shop

The energy usage characteristics of a commercial building, specifically a beverage selling business (COF), as presented in Figure 4.29, reveal that energy consumption occurs only during specific time periods, between 5:30 and 19:15. This is evident from the graph showing the peak energy usage times during the early hours of each day, where the rate of energy consumption rapidly increases, averaging 32.73 Wh/15 min at 5:30 and reaching its highest daily usage rate of 134.33 Wh at 6:15, after which energy consumption reduces and stabilizes at a nearly constant rate throughout the day.

When considering three distinct time periods, namely the period with the lowest energy consumption rates or usage below the daily average of 20.69 Wh, which occurs from 0:00 to 5:30 and from 17:00 to 23:45, the period with the highest energy consumption rate, which is from 5:30 to 6:45, and the final period, which has energy usage rates that are similar to the constant average throughout the day and occurs between 6:45 and 17:00, it is found that energy consumption rates are 1.84 Wh/15min, 72.03 Wh/15min, and 37.42 Wh/15min, respectively.

From the energy consumption behavior during the peak usage periods at the start of the day, it is evident that this is when electrical appliances are being turned on and used simultaneously within the building. This includes the operation of coffee makers, lights, and boiling water for the tea shop.

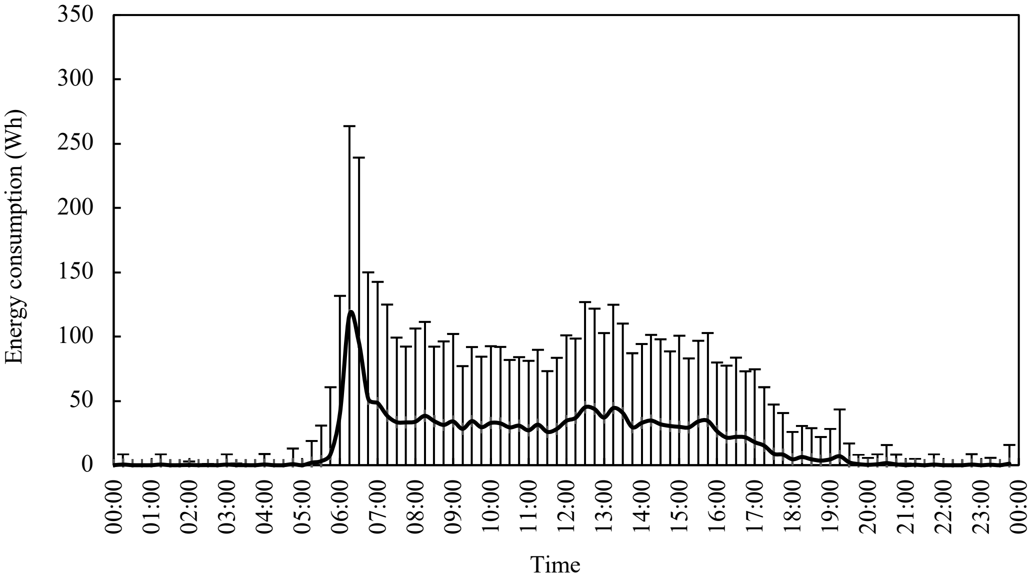


Figure 4.29 Average energy consumption in COF

The relationship between energy use inside buildings and time of day, when categorized by day type for energy use behavior analysis in a week as shown in Figure 4.30, it can be observed that on Sundays and Saturdays during high energy consumption periods, the average energy usage is lower than that of weekdays, which is clearly evident. The average energy consumption inside buildings on Sundays and Saturdays during the aforementioned period is only 45.24 Wh and 49.49 Wh respectively, which is lower than weekdays, where the average energy consumption during the same period is 81.93, 92.98, 80.88, 82.50, and 71.17 Wh respectively. However, when considering the period between 6.45am to 5.00pm, it was found that the average energy consumption was similar on all days from Sunday to Saturday, with values of 39.67, 36.74, 36.88, 37.05, 39.63, 35.79, and 36.23 Wh, respectively. Additionally, the standard deviation (SD) of energy use is found to change in the same direction as the energy consumption, which means that high energy use periods in buildings affect the high SD value, where the average SD value throughout the day is 53.02. Moreover, analyzing the relationship between energy consumption on each day, it was found that the amount of energy consumption has a statistically significant negative correlation with the day of the week at the 0.01 level, which is consistent with the direction of the joint variance level, with a value of 0.002 in the opposite direction.

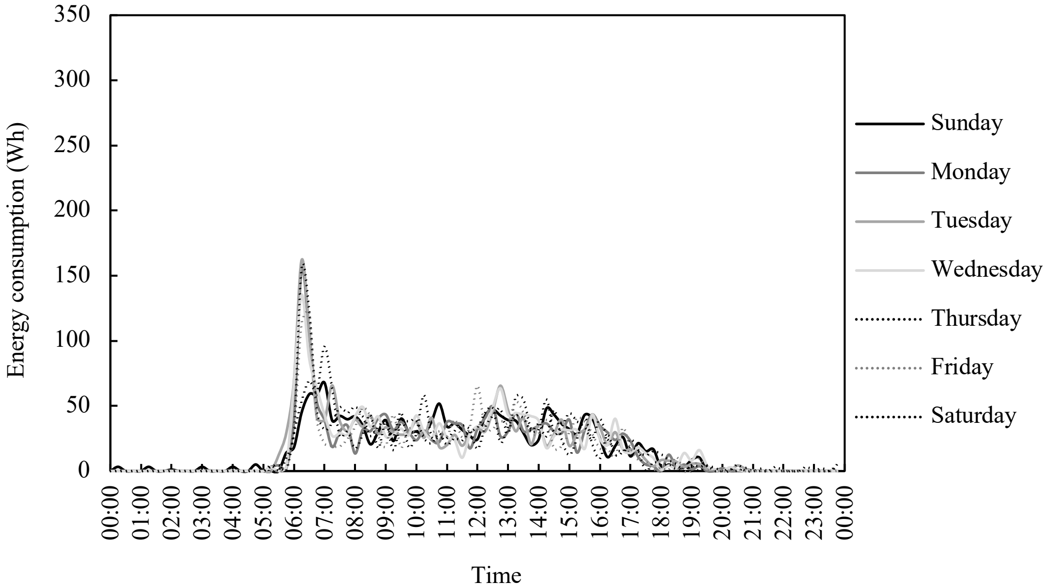


Figure 4.30 Average energy consumption in CHO (day of the week)

When categorizing the days into weekday and holidays, it is clear that the energy usage patterns exhibit distinct differences, as shown in Figure 4.31. Upon examining the energy consumption behavior separately for weekday and holidays during three time periods, similar to the previous analysis, it is observed that the time period with the lowest average energy usage is 1.39 Wh on weekday and 2.13 Wh on holidays. The time period with the highest energy usage is 71.46 Wh on weekday and 40.76 Wh on holidays. The continuous energy usage time period averages 32.48 Wh on weekday and 32.65 Wh on holidays. Furthermore, when considering the daily overall averages of weekday and holidays, they are found to be close to each other at 18.31 Wh on weekday and 17.18 Wh on holidays. Upon analyzing the correlation levels, it is found that there is a statistically significant negative correlation at the 0.01 level, with a correlation coefficient of 0.031.

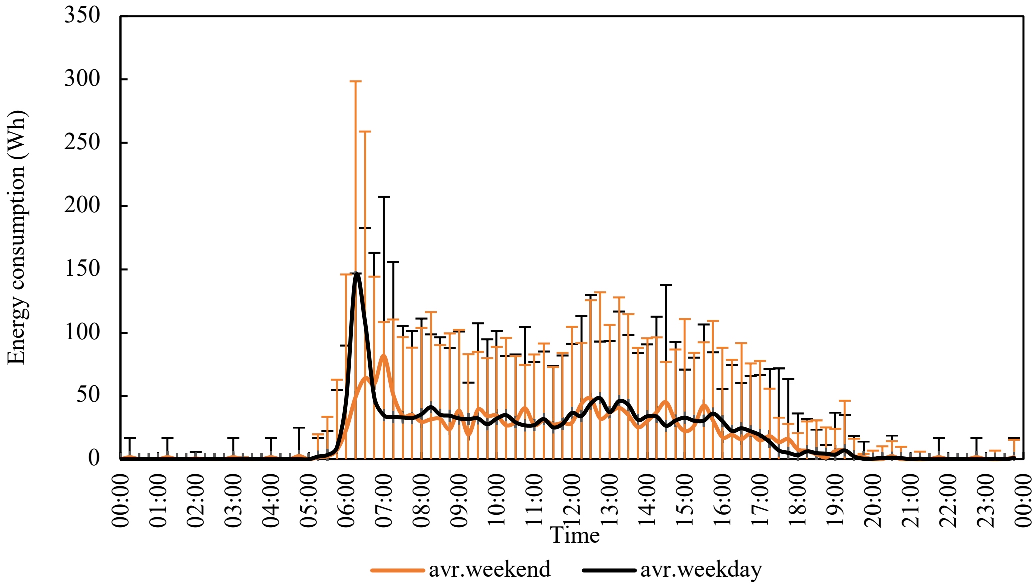


Figure 4.31 Average energy consumption in CHO (Weekday/Weekend)

The data on energy consumption in a beverage shop building, it was found that there is only one pattern of energy use. This pattern starts at around 5:30 a.m. and ends at approximately 6:00. The average duration of energy stoppages in the building varies depending on each day. It usually occurs during the period between 6:00 and 8:00. Moreover, data shows that there is high energy consumption during the initial phase of usage every day due to the simultaneous use of various heating equipment such as hot water boilers, coffee makers, etc. These devices require energy for preparation in readiness for daily use. In contrast, the energy consumption during high-usage periods on weekends is lower than that of weekdays due to the shorter operating hours or longer preparation time for the equipment and the reduced usage of devices.

Analyzing the energy use during the constant period of 8:00 to 17:00, it was found that the majority of the energy consumption comes from heating water, brewing coffee, and using fruit juicers. The average energy consumption of each device is consistent with its energy demand.

3.2 Water

Data on water consumption in every building is gathered by the system through measuring the total water usage every 15 minutes. The volume of water consumed during each period is then calculated based on this measurement, enabling monitoring of the building's water usage patterns. The assessment of water consumption is segmented into three components: the overall average water consumption behavior of the building, water usage patterns during weekdays and weekends, and water usage patterns by the days of the week. The water usage behavior within buildings can be categorized into three types based on the building type, namely residential buildings, office buildings, and commercial buildings.

3.2.1 Residential

The water usage characteristics of residential buildings are generally consistent in the same direction on each roof. There is high water usage behavior in the morning and evening of each day. When the water use characteristics of the aforementioned buildings were examined, it can be observed that the amount of water usage has a relatively uncertain behavior. This depends on the behavior that changes daily, but there is still a consistent amount of water usage in the same direction, as shown in Figure 4.32. In general, the average water usage in the first public housing building throughout the day is 10.75 liters, with a standard deviation of 23.42 The period of highest water usage is during the morning between 6:00 and 7:30 am, with an average water usage during that time of 45.46 liters, with a standard deviation of 57.10 When analyzing the relationship between water usage data inside the building and the time used, it was found that the water usage in GH1 has a statistically significant correlation with time, with a positive direction and a correlation coefficient of 0.050 at the 0.01 significance level, as shown in Table 4.29.

Normally, the behavior of water usage within residential buildings of the housing type follows a similar pattern. Data on water usage within all residential buildings of the housing type are displayed in Figure C1 to Figure C15, which show the quantity of water usage within the buildings GH2, SH1, SH2, HH1, and HH2, respectively. It is evident that the behavior of water usage within all residential buildings of the housing type can be clearly divided into two distinct ranges that are consistent with the data on water usage in GH1. The average quantity of water usage per house throughout the day is 6.75, 2, 2, 2, 2, 3, and 5 liters, with standard deviations of 5.33, 2, 3, 4, and 5, respectively. Additionally, the maximum cumulative water usage every 15 minutes in the morning is 39.28 liters at SD 56.60 of GH2, 2 liters at SD 2 of

SH1, 3 liters at SD 3 of SH2, 5 liters at SD 4 of HH1, and 15 liters at SD 5 of HH2. Furthermore, the maximum cumulative water usage every 15 minutes in the evening is 1 liter at SD 15 of GH2, 2 liters at SD 2 of SH1, 3 liters at SD 3 of SH2, 5 liters at SD 4 of HH1, and 15 liters at SD 5 of HH2.

Upon analyzing the relationship between water usage quantity and time of usage regardless of day, it was found that nearly all residential buildings exhibited a positive correlation at a significant level of 0.01. Specifically, the correlation coefficients were 0.020 for SH1, 0.064 for SH2, 0.065 for HH1, and 0.041 for HH2, as shown in Table C1. The analysis did not consider the specific day of usage.

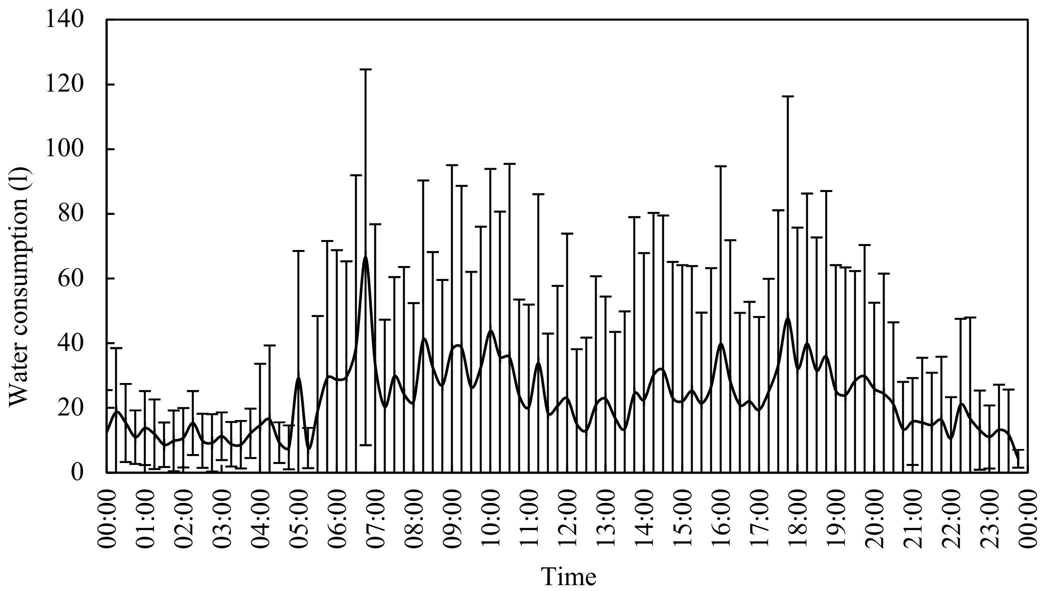


Figure 4.32 Average water consumption in GH1

Table 4.29 Correlation between time and water consumption in GH1

		Time	Water consumption
Time	Pearson Correlation	1.000	0.050**
	Sig. (2-tailed)		0.000
	Covariance	0.083	0.368
	N	10,225	10,225

Table 4.29 (Cont.)

		Time	Water consumption
Water consumption	Pearson Correlation	0.050**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.368	650.113
	N	10,225	10,225

**. Correlation is significant at the 0.01 level (2-tailed).

After analyzing the amount of water used inside buildings by considering the day of the week, it was found that the usage behavior did not vary significantly within GH1 building as shown in Figure 4.33. The accumulated water consumption every 15 minutes for each day of the week inside GH1 building had an average of 13.58, 7.05, 11.27, 8.48, 11.47, 12.08, and 11.63 litters, respectively, with standard deviation (SD) of 20.29, 13.38, 17.83, 13.71, 18.56, 19.84, and 16.66 for Sunday to Saturday. When comparing the accumulated water consumption every 15 minutes for two time periods with the highest usage behavior, it was found that the highest water consumption occurred during the daytime on Sundays to Saturdays, with a maximum of 60.55, 34.42, 74.58, 44.67, 109.67, 60.75, and 63.18 litters, respectively in the same order.

The data of water usage behavior within residential buildings of a sample building, it was found that when analyzed on a day-to-day basis within a week, the behavior of water usage inside the building was not clearly differentiated by days and had statistically significant correlations between the amount of water usage and the time of usage. Most of these correlations were negative to a small extent, and statistically insignificant in all buildings except for building HH2, where a statistically significant correlation of 0.027 at the 0.05 significance level was observed, as shown in Table C1.

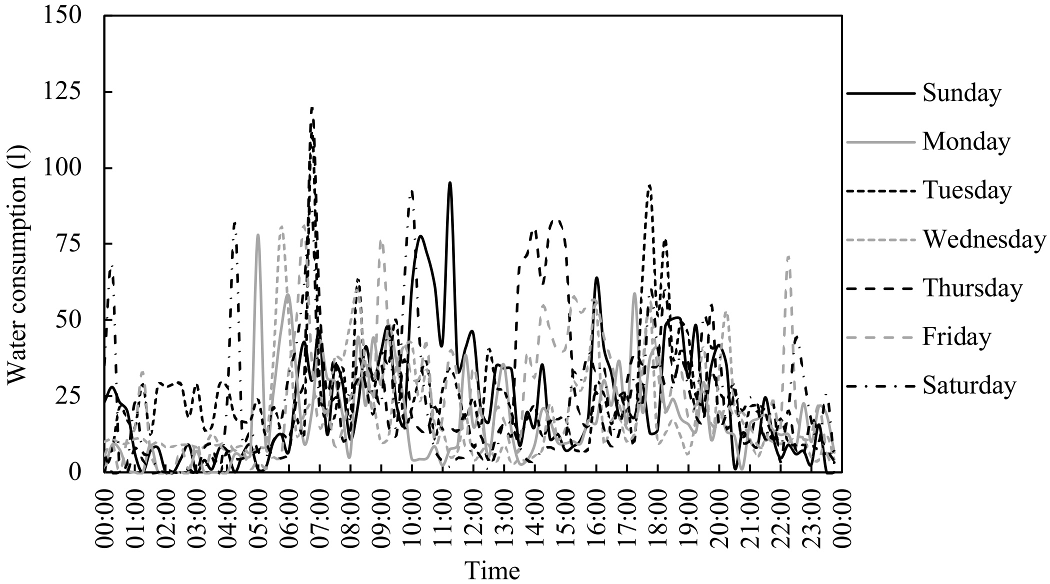


Figure 4.33 Average water consumption in General public house 1 (day of the week)

Table 4.30 Correlation between Time-day and water consumption in GH1

		Time-day	**Water consumption**
Time-day	Pearson Correlation	1.000	0.021*
	Sig. (2-tailed)		.034
	Covariance	4.050	1.074
	N	10,225	10,225
Water consumption	Pearson Correlation	0.021*	1.000
	Sig. (2-tailed)	0.034	
	Covariance	1.074	650.113
	N	10,225	10,225

*. Correlation is significant at the 0.05 level (2-tailed).

Upon analyzing the water usage behavior within the building, it was found that there was a slight difference in the usage patterns between weekday and weekends. It was observed that there was a lower volume of water usage during weekends. Furthermore, the highest water usage period was in the morning, approximately 1 hour after waking up, and the water usage behavior in the evening was highly variable, but the average volume of water usage was similar to that of weekday. The water usage data segregated according to weekday and weekends for building GH1 is presented in Figure 4.34. The analysis of the data revealed that the average water usage on weekday was 7.65 liters with a standard deviation (SD) of 19.76, while the average water usage on weekends was 8.94 liters with an SD of 20.24. Furthermore, the correlation analysis of the two data sets showed a significant negative correlation between the water usage and time of day, with a statistically significant correlation coefficient of 0.047 at the 0.05 level, as shown in Table 4.31.

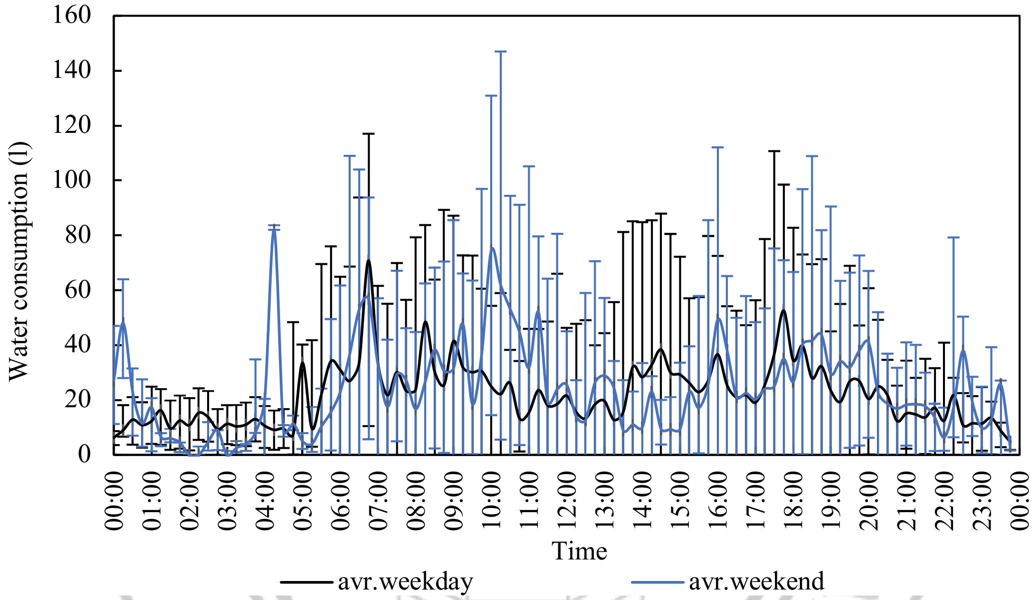


Figure 4.34 Average energy consumption in General public house 1 (Weekday/Weekend)

Table 4.31 Correlation between Weekday/weekend and water consumption in GH1

		Time-week	Water consumption
Time-week	Pearson Correlation	1.000	0.047**
	Sig. (2-tailed)		0.000
	Covariance	0.285	0.640
	N	10,225	10,225
Water consumption	Pearson Correlation	0.047**	1.000
	Sig. (2-tailed)	0.000	
	Covariance	0.640	650.113
	N	10,225	10,225

**. Correlation is significant at the 0.01 level (2-tailed).

When considering the weekday and weekend of residential buildings, it was found that there was a consistent pattern in the water usage behavior across all buildings, as shown in Figure C3, Figure C6, Figure C9,Figure C12, and Figure C15. Both types of days had similar levels of water usage in each building

When the water usage data within each building was separated by weekday and weekend, it was found that some buildings had statistical relationships. These included the SH1 and HH2 buildings, which had a negative correlation between water usage per time considering weekday and weekend, with correlation coefficients of 0.059 and 0.036, respectively. The correlation was significant at the 0.01 level. Additionally, the GH2 and HH1 buildings had a negative correlation, while the GH1 and SH2 buildings had a positive correlation. All four buildings had low correlation coefficients, indicating that there was no statistical relationship between them.

From the water usage data of residential buildings, it was found that the water usage behavior within the buildings occurred mostly during two time periods, namely between 7:00-9:00 and 17:00-22:30 in every building, with accumulated water usage being highest during these times. When considering the water usage patterns and correlation levels of water usage according to weekdays and weekends for one week, it was found that most residential buildings did not have statistically significant correlations with each other. Therefore, it can be concluded that residential buildings have time-dependent water usage behavior, regardless of the type of day. In other words, residential buildings have similar water usage patterns every day.

3.2.2 Office building

It was found that water usage behavior within office buildings differs significantly from that of residential buildings, as evidenced by the data presented in Figure 4.35 which depicts water usage patterns within a school office building (SCO) during a single day from 6:30 to 19:30. The volume of water usage peaked initially and then decreased over time. The average daily water usage within the building was 5.79 liters, which is higher than the standard deviation of 4.37. When considering only periods of water usage within the building, the average cumulative water usage every 15 minutes was 8.31 liters, which is similar to the standard deviation of 9.13. Similar water usage patterns were also observed in the community hospital office building depicted in Figure C16, where water usage started at 8:00 and ceased at 16:30.

The data on the water consumption within office buildings, it can be observed that there is a high volume of water usage during a specific time period, which is during midday or working hours. It is essential for this group of buildings to support the work of teachers within schools, who work between the hours of 7:00 to 17:30 during working days. Additionally, community hospital office buildings must accommodate and provide convenience for patients who receive hospital services, with working hours from 8:00 to 17:00 on working days.

Upon analyzing the relationship between water usage data and time of usage within office buildings of both groups without considering the day, it was found that if considered throughout the day, time did not significantly affect the water consumption within the building, as indicated by the statistics. The data shows negative correlations between the amount of water usage and time of usage, with a level of 0.003 for school office buildings and 0.013 for community hospital office buildings. In other words, an increase in time during each day will lead to a decrease in the amount of water usage within the building, as shown in Table C1.

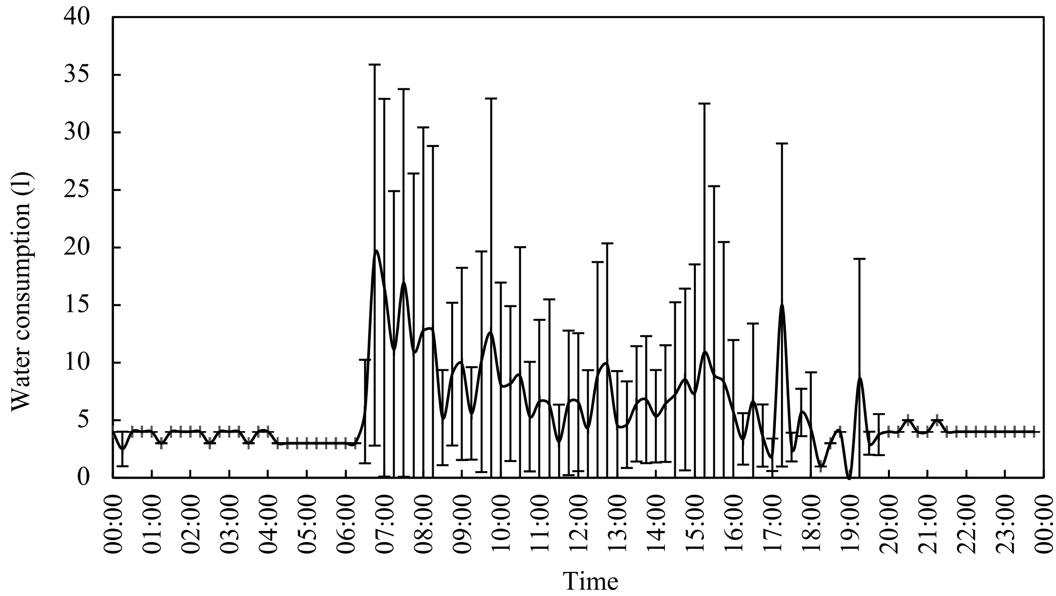


Figure 4.35 Average water consumption in SCO

If the water usage data within the office building is analyzed on a weekly basis, it can be found that the usage varies slightly every day. The wastewater data of the SCO building separated by day of the week, as shown in Figure 436, indicates that the average water usage during the time periods of typical water usage behavior from Monday to Friday are 3.10, 2.73, 4.42, 5.23, and 4.75 liters, respectively, with standard deviations of 2.30, 1.84, 3.12, 3.43, and 3.78 liters, respectively, in the order of the days of the week, and decreases to 0.71 liters on Saturday and 0.27 liters on Sunday, with SDs of 0.03.

Similarly, the water usage data within the CHO building separated by day of the week, as shown in Figure C17, which shows the water usage behavior within the building in the same direction from Monday to Friday, indicates that the accumulated average water usage is highest in the morning and decreases as time passes, with an average water usage during the time period of 7:30 am to 5:00 pm of 62.27, 60.09, 61.72, 53.71, 50.26, 37.31, and 31.08 liters, respectively, with standard deviations of 13.52, 17.32, 17.93, 17.97, 17.25, 16.81, and 14.27 liters, respectively, in the order of the days of the week. From the water usage data of both types of office buildings, it can be observed that the average water usage on Saturdays and Sundays is lower than that from Monday to Friday.

Moreover, when analyzing the relationship between the water usage data separated by the day of the week and time, it was found that there is no significant correlation between the water usage of both buildings and the time of usage, although it should be noted that there are some small variations in the data.

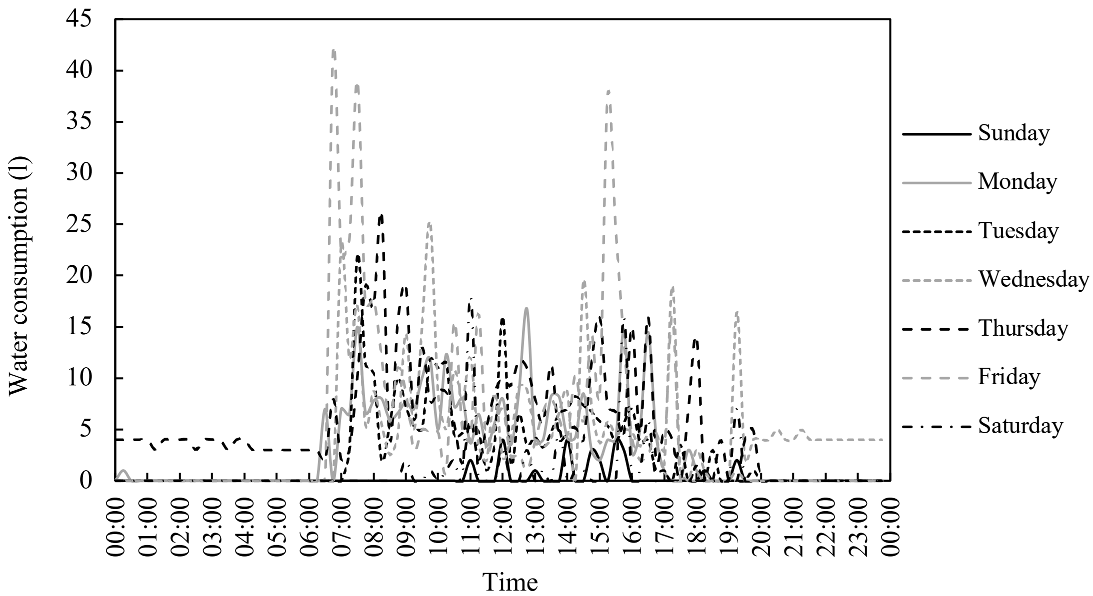


Figure 4.36 Average water consumption in SCO (day of the week)

The data on water usage separated by day of the week, it is evident that the amount of water used within the buildings on Saturdays and Sundays differs from other days. When the data is classified into two groups, working days and weekends, it is clear that the water usage behavior within both buildings differs significantly. Figure 4.37 shows the amount of water usage within the School Office (SCO) building separated by working days and weekends, where on working days, the amount of water usage within the building is significantly higher than on weekends. The average cumulative water usage within the building on working days is 42.94 liters, which is higher than the average cumulative water usage within the building on weekends, which is only 32.48 liters, with standard deviation values of 24.24 and 11.32, respectively. When considering the water usage behavior, it is found that there is an increase in water usage when the time increases on weekends, which is different from working days where water usage decreases. This behavior differs slightly from the water usage pattern on weekends in the hospital building, which has a water usage behavior within the building during the time frame of 8:30-12:00. When comparing the building characteristics, it is found that on Saturdays, there is still usage within the building in the morning, which affects the amount of water used within the building. Upon analysis of the quantity of water usage within the building in relation to time of usage, considering both working days and non-working days, it was discovered that time has a significant statistical negative effect on the quantity of water usage within the building. The correlation coefficients were found to be -0.064 for SCO and -0.041 for CHO, and the significance level of the correlation was 0.01. It can be observed from the data on water usage behavior within office buildings that the behavior tends to be similar within buildings of the same type. Moreover, the quantity of water usage within a building varies over time, depending significantly on the type of working day and day off, as indicated by statistically significant correlations.

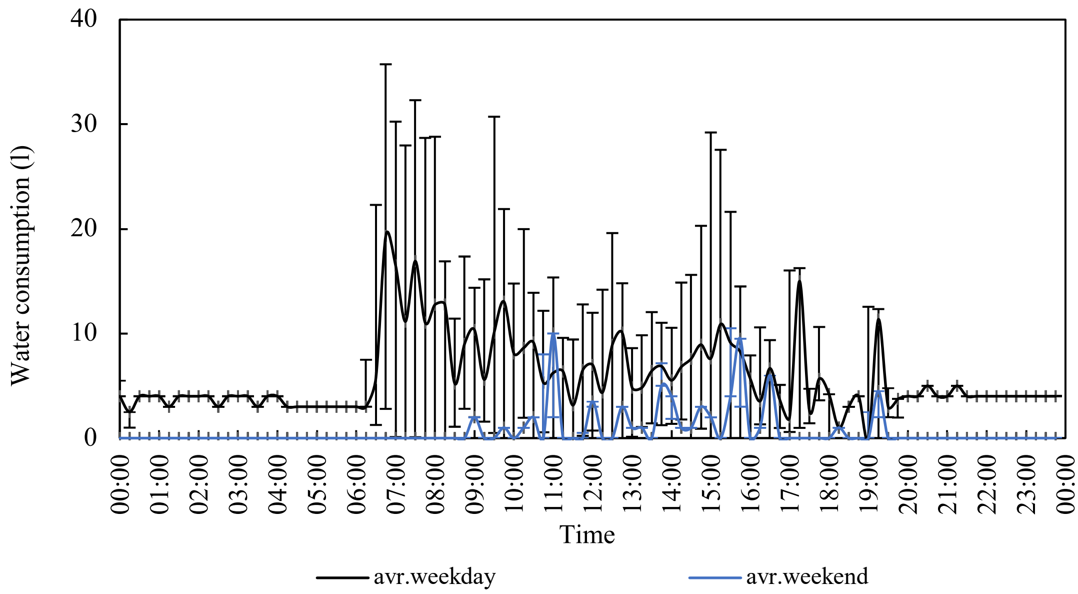


Figure 4.37 Average energy consumption in SCO (Weekday/Weekend)

3.2.3 Commercial

For commercial buildings, water usage behavior is similar to that of office buildings, but there are differences in the pattern of consumption. Specifically, in commercial buildings, such as shopping malls, water usage is lower at the beginning and end of the day, and higher during the middle of the day. This pattern is based on data from water usage behavior in a coffee shop (COF), as shown in Figure 4.38. The average daily water usage from 6:00 to 20:00 is 0.58 liters, with a standard deviation of 0.60. However, when considering only the period of high water usage, the average is 0.94 liters, with a standard deviation of 0.97. Furthermore, when examining water usage during the morning hours (6:00 to 8:30), the behavior is more variable and irregular due to the cleaning and sanitation of equipment and containers, which are necessary for maintaining product quality and safety.

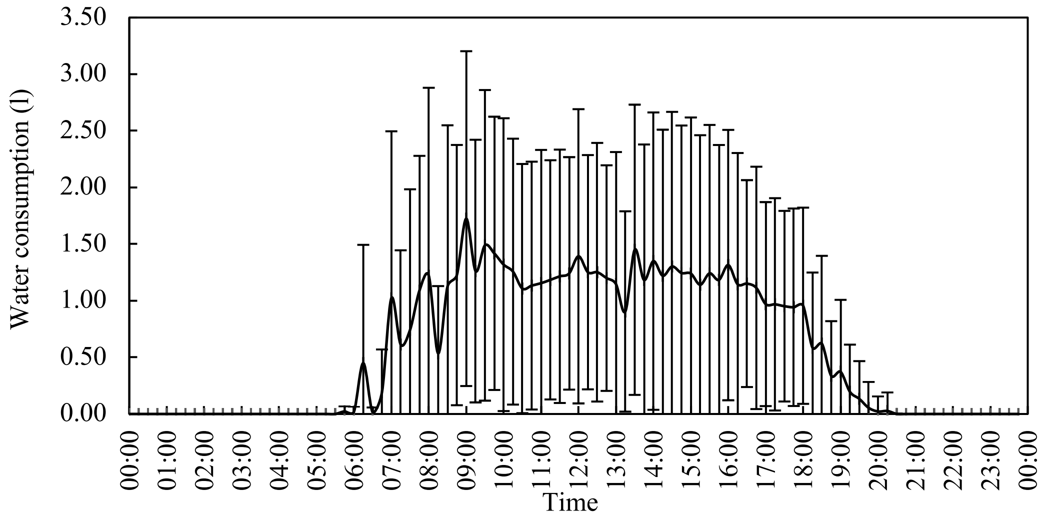


Figure 4.38 Average water consumption in COF

When the data on water usage within the building is analyzed to separate the usage amounts for each day of the week, it is found that there is no observable difference in water usage patterns within the building. The average cumulative water usage for Sunday through Saturday is 1.01, 0.83, 0.81, 0.94, 1.07, 0.80, and 0.90 liters, respectively, with standard deviations of 1.02, 0.72, 0.82, 0.79, 0.92, 0.76, and 0.94, respectively.

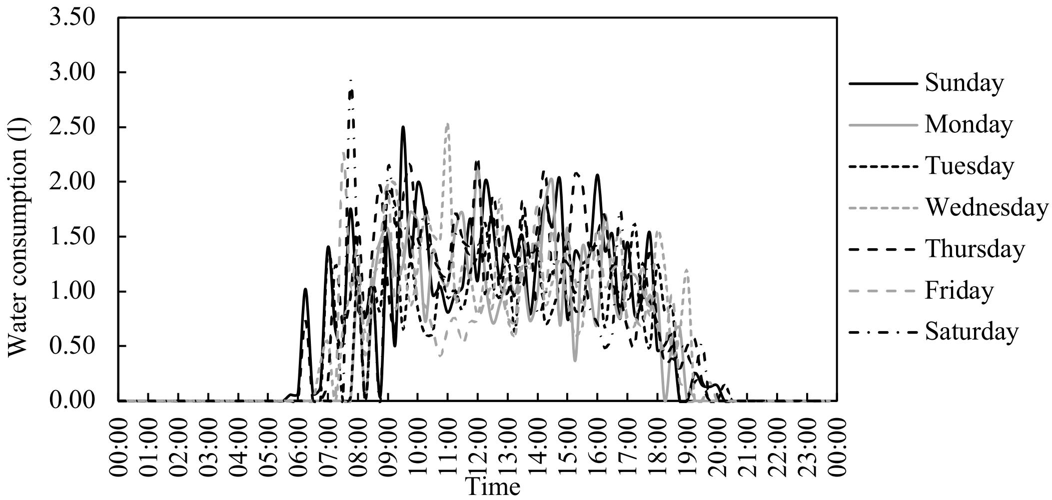


Figure 4.39 Average water consumption in COF (day of the week)

Upon considering the water consumption separated by workdays and holidays, it was found that the pattern of water usage was consistent in terms of both usage periods and consumption levels, as shown in Figure 4.40. Furthermore, when analyzing the relationship of water consumption according to workdays and holidays, no statistically significant difference was found. Thus, it can be concluded that the water consumption within commercial buildings does not show a difference in usage when considering the days of operation.

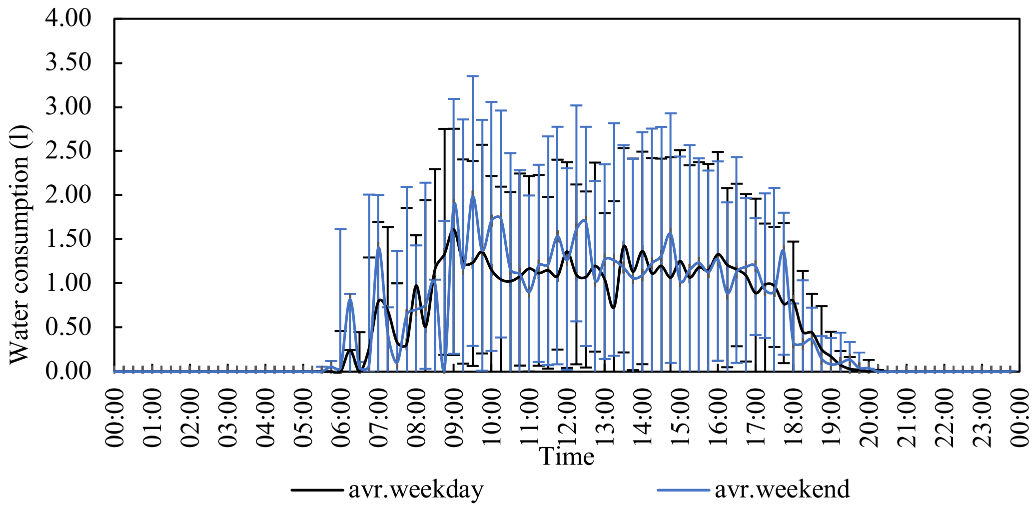


Figure 4.40 Average energy consumption in COF (Weekday/Weekend)

3.3 Waste

3.3.1 Residential

The average waste generation within a General Public House 1 building, as illustrated in Figure 4.41, exhibits an unclear waste disposal pattern in terms of both time and the quantity of waste disposed within the building. It was found that the average values of general waste, organic waste, and recyclable waste accumulated every 15 minutes were equal to 0.01 for all types of waste. The maximum average waste disposal quantities for each type were 0.04 kg at 16:45 for general waste, 0.02 kg at 4:45 for organic waste, and 0.05 kg at 22:00 for recyclable waste. Upon examining the relationship between the waste generation within the building and time, it was revealed that all three types of waste had a slightly significant statistical relationship with the time of day, particularly general waste with a correlation coefficient of 0.023 at a correlation significant at the 0.01 level, and recyclable waste with a coefficient of 0.081 at a correlation significant at the 0.01 level, both in a positive direction. However, the quantity of each type of waste had a significant statistical relationship with the corresponding waste disposal, as demonstrated in Table 4.32.

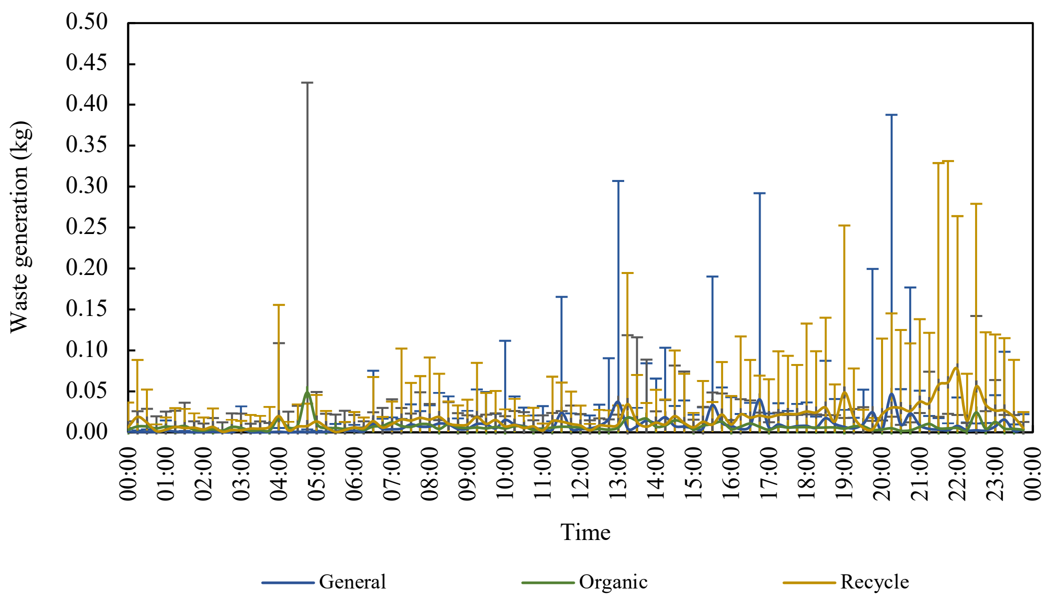


Figure 4.41 The average amount of waste accumulated at a frequency of 15 minutes in General public house 1

Table 4.32 Correlation between time and waste creation in GH1 (15m)

		Time	Gen	Org	Rec
Time	Pearson Correlation	1.000	0.023**	0.001	0.081**
	Covariance	0.084	0.000	0.000	0.002
	N	16,357	16,357	16,357	16,357
Gen	Pearson Correlation	0.023**	1.000	0.061**	0.277**
	Covariance	0.000	0.005	0.000	0.002
	N	16,357	16,357	16,357	16,357
Org	Pearson Correlation	0.001	0.061**	1.000	0.229**
	Covariance	0.000	0.000	0.001	0.001
	N	16,357	16,357	16,357	16,357
Rec	Pearson Correlation	0.081**	0.277**	0.229**	1.000
	Covariance	.002	0.002	0.001	0.006
	N	16,357	16,357	16,357	16,357

**. Correlation is significant at the 0.01 level (2-tailed).

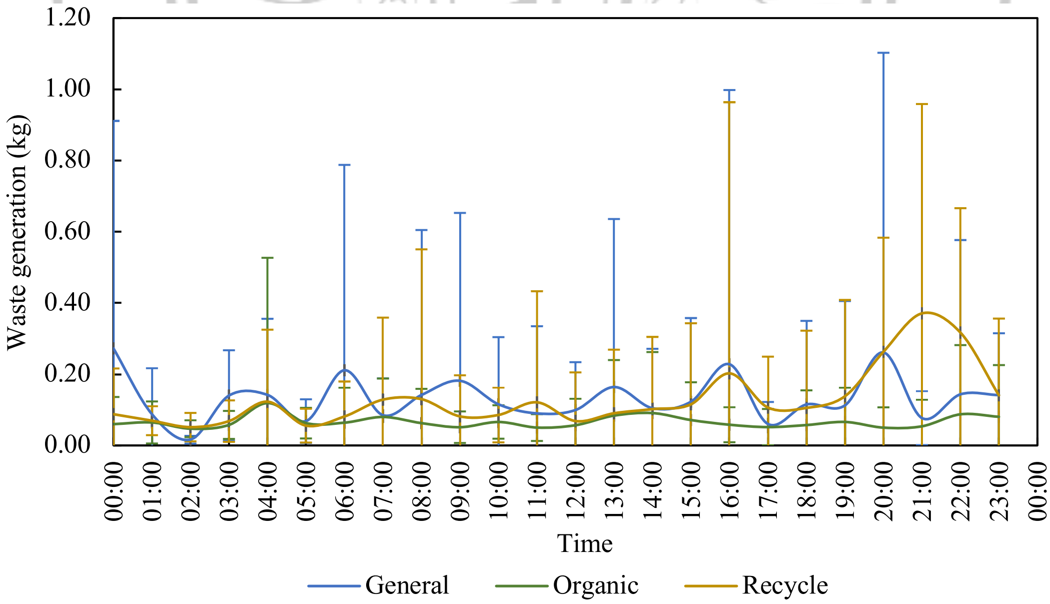


Figure 4.42 The average amount of waste accumulated at a frequency of 1 hour in General public house 1

The average accumulated waste generation within the building every hour, it was found that the data showed a clearer trend of waste generation within the building. This is because the waste generation at the 15 minute accumulated frequency level had relatively low quantities, which might affect the reliability of the measuring device that can detect a minimum waste mass of only 0.01 kg, consequently impacting the uncertainty of the measured data. When analyzing the data at a 1 hour accumulated frequency as shown in Figure 4.42, it was observed that general waste disposal occurs throughout the day but has higher quantities than the daily average during the morning and evening periods. This differs from organic waste and recyclable waste, which have higher waste disposal quantities only during the morning for organic waste and during the evening for recyclable waste. Upon examining the average waste disposal quantities throughout the day, it was found that general waste had an average quantity of 0.15 kg, organic waste had 0.07 kg, and recyclable waste had 0.13 kg, with standard deviations of 0.32, 0.10, and 0.22, respectively.

The correlation levels of waste quantities of each type in relation to the waste generation time within the building revealed that only the recyclable waste quantity demonstrated a significant positive correlation to the time of day at a level of 0.079 (Correlation is significant at the 0.01 level). Furthermore, waste quantities of each type exhibited positive correlations among themselves at levels of 0.076 between general waste and organic waste, 0.071 between general waste and recyclable waste, and 0.264 between organic waste and recyclable waste. From the correlation level data within each waste type, it was observed that recyclable waste had a relationship with the waste generation quantities of all types within the building. The correlation level data of accumulated waste quantities at a frequency of 1 hour is presented in Table 4.33.

Table 4.33 Correlation between time and waste creation in GH1 (1h)

		Time	Gen	Org	Rec
Time	Pearson Correlation	1.000	0.007	-0.018	0.079**
	Covariance	0.083	0.000	0.000	0.002
	N	4081	4081	4081	4081

Table 4.33 (Cont.)

		Time	Gen	Org	Rec
Gen	Pearson Correlation	0.007	1.000	0.076**	0.071**
	Covariance	0.000	0.007	0.000	0.001
	N	4,081	4,081	4,081	4,081
Org	Pearson Correlation	-0.018	0.076**	1.000	0.264**
	Covariance	0.000	0.000	0.001	0.001
	N	4,081	4,081	4,081	4,081
Rec	Pearson Correlation	0.079**	0.071**	0.264**	1.000
	Covariance	0.002	0.001	0.001	0.012
	N	4,081	4,081	4,081	4,081

**. Correlation is significant at the 0.01 level (2-tailed).

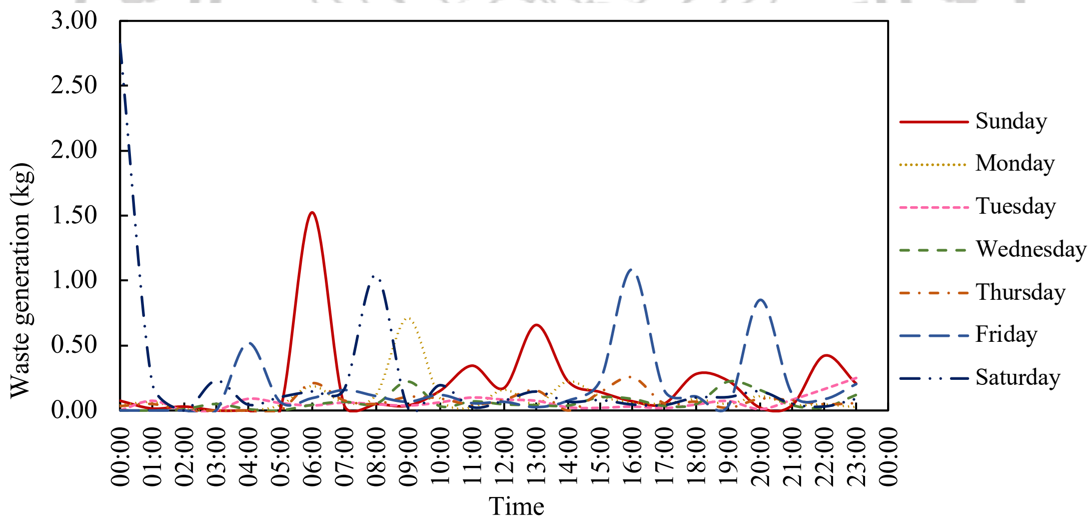


Figure 4.43 The average amount of waste accumulated at a frequency of 1 hour in General public house 1 (Day of week)

When considering the average waste quantity per day over a week, it was found that there were no noticeable differences in waste disposal behavior for each day on average across all waste types, as shown in Figure 4.43. However, the data indicated that the average waste generation within residential-type buildings tended to have higher waste disposal during Fridays, Saturdays, and Sundays. Upon analyzing the average waste disposal quantities from Sunday to Saturday, it was found that the daily average waste quantities were 0.20, 0.10, 0.06, 0.06, 0.07, 0.18, and 0.25 kg/hour for general waste; 0.08, 0.06, 0.05, 0.07, 0.06, 0.08, and 0.07 kg/hour for organic waste; and 0.13, 0.09, 0.13, 0.15, 0.11, 0.16, and 0.14 kg/hour for recyclable waste, respectively.

The waste disposal quantity into two groups, weekdays and weekends, as depicted in Figure 4.44, it was observed that the general waste and recyclable waste disposal behaviors differed between the two groups of days. During weekdays, there was an increase in the disposal of general waste in the middle of the day compared to the average waste disposal quantity. However, on weekends, it was found that the disposal of general waste was higher than the average in the evening at 20:00. In contrast, for recyclable and organic waste, the waste disposal behavior followed the same direction for both weekdays and weekends.

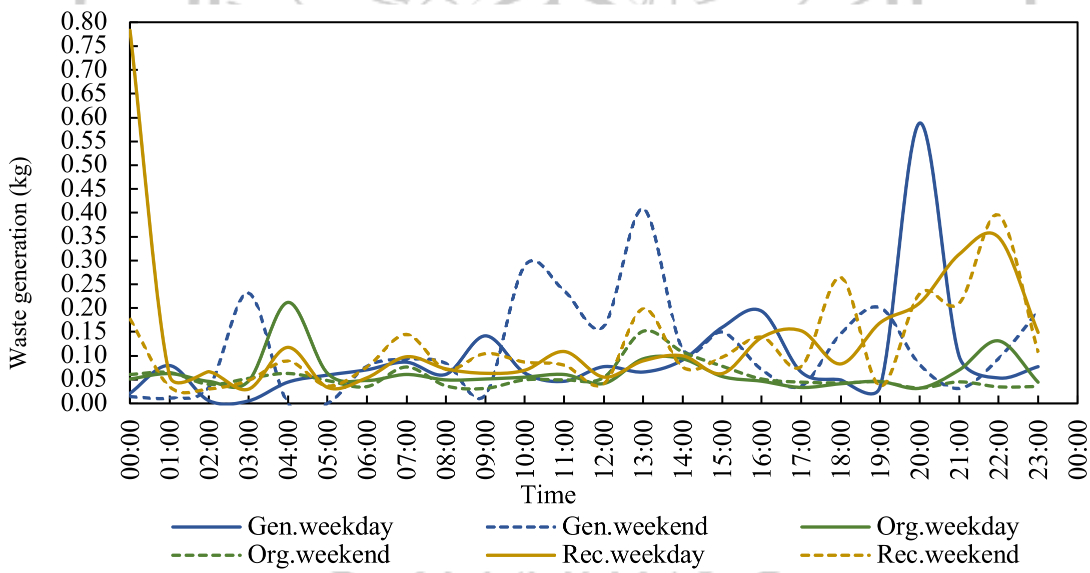


Figure 4.44 The average amount of waste accumulated at a frequency of 1 hour in General public house 1 (Weekday/Weekend)

From the data on waste generation behavior for different types of waste occurring within residential buildings, it was found that waste generation followed the same direction throughout the day. However, variations were observed depending on age groups, gender, and the number of building occupants. In general, it was discovered that buildings of the same type exhibited similar waste generation behaviors.

3.3.2 Office building

Waste disposal patterns within office buildings were found to involve varying quantities of each waste type during working hours, or between 7:00 – 17:00. An example of waste quantities for a community hospital office is presented in Figure 4.45, which shows average hourly accumulated waste quantities of 0.01 kg for general waste, 0.02 kg for organic waste, and 0.01 kg for recyclable waste. Upon analyzing the data according to time intervals, it was observed that waste disposal behaviors for each type of waste generated within the building had higher frequency and quantity during two periods: 8:00 – 10:00 and 13:00 – 16:00. These periods corresponded to the highest number of service users accessing the building. Consequently, the waste disposal behaviors occurring within the building were significantly correlated with the number of people accessing the services of the building.

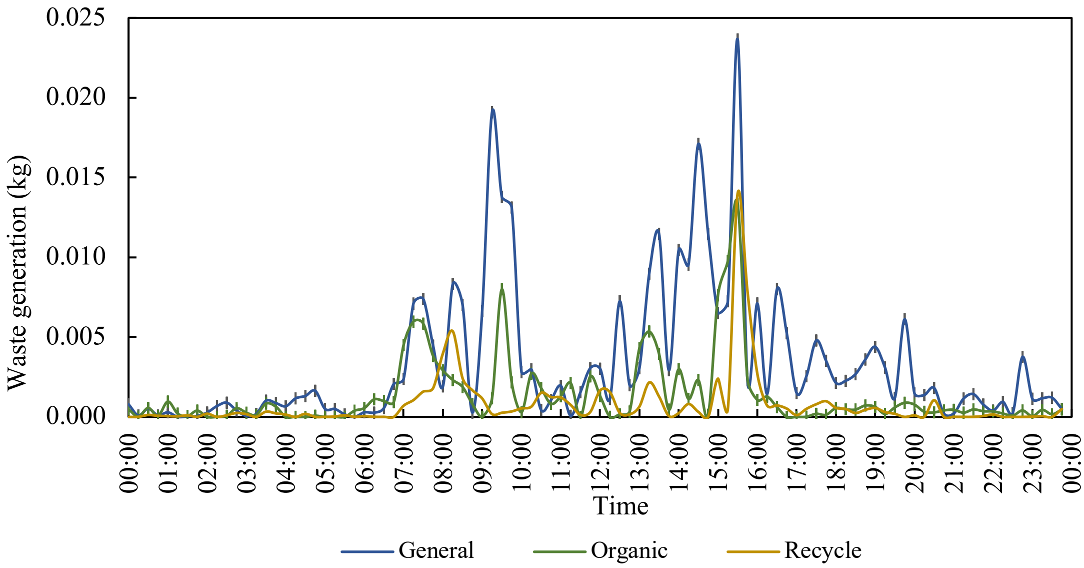


Figure 4.45 The average amount of waste accumulated at a frequency of 15 minutes in Community hospital office

Upon analyzing waste disposal patterns by day of the week, it was found that waste disposal behaviors on each day did not exhibit statistically significant differences with respect to the time of waste disposal. The characteristics of waste quantities generated within the building, separated by days from Sunday to Saturday, as shown in Figure 4.46, revealed that waste disposal behaviors could not be differentiated by individual days within a week for analysis, as the day of the week did not influence the changes in waste disposal behaviors within the building. The data indicated that average general waste quantities during working hours were 23.17, 42.58, 31.24, 31.30, 4.97, 17.47, and 20.96 g/hour; organic waste quantities were 23.93, 16.06, 15.60, 14.00, 22.30, 7.25, and 5.68 g/hour; and recyclable waste quantities were 7.13, 8.14, 16.39, 12.24, 10.65, 8.96, and 4.04 g/hour for Sunday through Saturday, respectively. Furthermore, the analysis of the correlation between different types of waste disposal behaviors within the building and the time of waste disposal revealed that each type of waste exhibited a positive relationship with one another and a significant positive relationship with time.

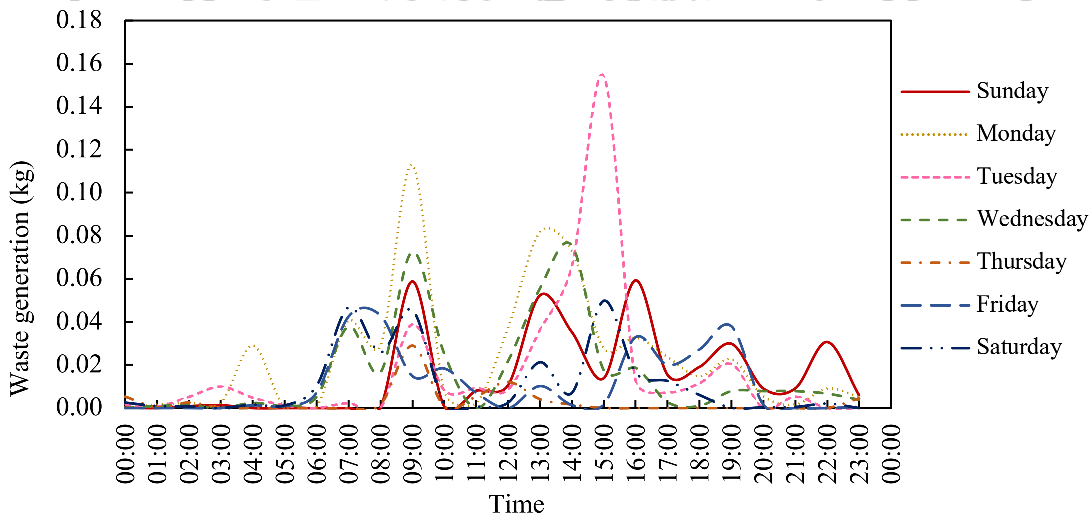


Figure 4.46 The average amount of waste accumulated at a frequency of 1 hour in Community hospital office (Day of week)

waste disposal behaviors for each type of waste when separated by working days and non-working days, as shown in Figure 4.47, it was found that all three types of waste exhibited similar disposal patterns on both working and non-working days, with frequency and quantity of waste disposal occurring in the two aforementioned time periods for general waste and recyclable waste. For organic waste, a high quantity of waste was generated only during the average evening working days. When considering the overall data correlation, it was determined that the waste quantities generated, separated by working and non-working days, did not exhibit any relationship with the time of occurrence. However, the increasing quantities of each type of waste were found to be correlated with one another.

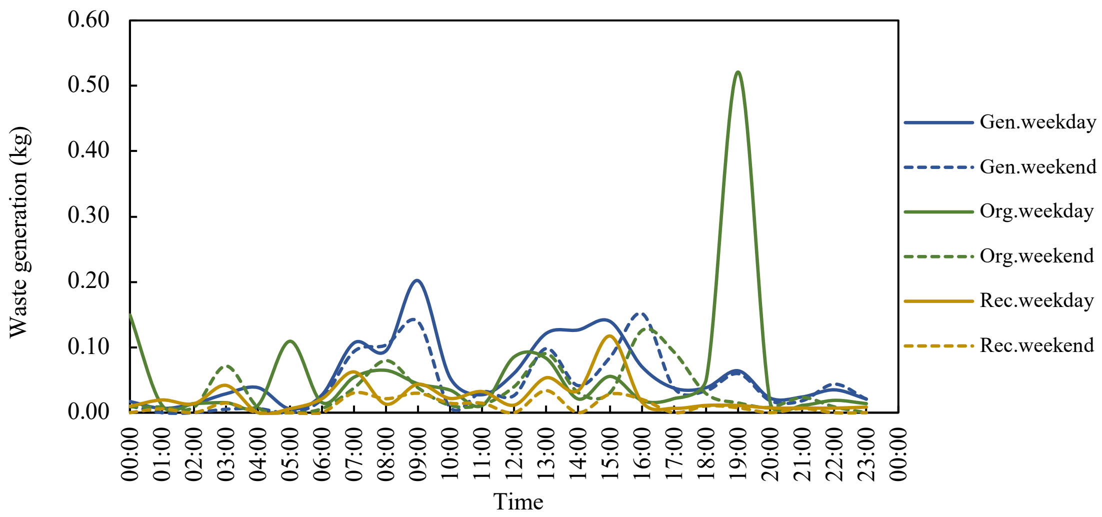


Figure 4.47 The average amount of waste accumulated at a frequency of 1 hour in Community hospital office (Weekday/Weekend)

4. Building activity profile

The Building Activity Profile study is an investigation of the behavior and characteristics of activities that occur within a sample building. It is used to compare and analyze energy usage, water consumption, and waste generation characteristics of each building activity. The building activity profile analysis is divided into three phases, which include determining and integrating the building activity profile, studying the relationship of building activity, and verifying the activity profile. The results of the study are as follows:

4.1 Determine and integrated of the building activity profile

The results of this process can be divided into two steps. The first step involves studying the patterns of activities occurring within the building, utilizing questionnaire tools. The second step, "Identification of activity," involves combining data from the questionnaire with data collected from Smart meters measuring energy, water, and waste consumption.

4.1.1 Building activity (Questionnaire)

The analysis of activities taking place within all buildings was conducted using data collected through a questionnaire from the sample of residents living in the buildings equipped with a smart meter. The process of data collection involved documenting all activities that occurred within the buildings and presenting their characteristics and abbreviations in Table 4.4. The analysis of building activities was divided into two main parts: the first being the frequency analysis of each activity that occurred in the building, and the second being the time analysis of each activity that took place. Additionally, the activities were classified based on the characteristics of each consumer to identify the trends and patterns of activity behavior within the building. This involved identifying the consumer characteristics and analyzing their behavior within the building.

4.1.1.1 Residential

General public house 1: The data regarding activities that occurred within GH1 for occupants 1 and 2 exhibit similar behavioral patterns, with activities occurring during two distinct time periods per day: morning and evening. For the occupants of the first unit, there were a total of 16 activities per day, as detailed in Figure 4.48, which included RE, FA, LT, TL, WD, ET, BA, TV, MI, CK, GN, WR, IC, WC, WB, RC, and HD. Notably, the RE activity was continuously executed throughout the day due to its necessity as an electrical appliance. Furthermore, all activities were characterized by specific details. For instance, the FA activity was divided into three time intervals per day: 00:00-5:45, 12:00-13:45, and 20:00-23:45, with an average usage time of approximately 11 hours per day. Additionally, the LT activity occurred twice per day during specific time intervals, from 6:00-7:45 and 18:00-23:45, with an average duration of approximately 420 minutes per day.

The TL frequency of activities is six times per day, in three time slots, namely 5:00-6:45, 16:00-18:15, and 20:00-21:45, with an average duration of approximately one minute per occurrence. The frequency of occurrence of activities for WD is twice per day, in two time slots, namely 7:30-10:15 and 18:00-18:45, with an average duration of approximately 15 minutes per occurrence. The frequency of occurrence of activities for ET is twice per day, in two time slots, namely 9:00-10:15 and 17:00-18:45, with an average duration of approximately 25 minutes per occurrence. The frequency of occurrence of activities for BA is twice per day, in two time slots, namely 6:00-6:45 and 19:00-20:45, with an average duration of approximately 10 minutes per occurrence. The frequency of occurrence of activities for TV is approximately three times per week, during the time slot of approximately 19:00-20:45, with an average duration of approximately 60 minutes per occurrence.

The MI group has an average frequency of approximately 5 activities per week, divided into 3 time slots: 6:00-6:45, 12:00-12:15, and 17:00-17:15, with an average activity duration of approximately 2 minutes per occurrence. The CK group has an average frequency of 1 activity per day during the time slot of 17:00-18:45, with an average activity duration of approximately 45 minutes per occurrence. The GN group has an average frequency of 4 activities per week during the time slot of 7:30-8:45, with an average activity duration of approximately 30 minutes per occurrence. The WR group has an average frequency of 1 activity per month during the time slot of 9:00-10:30, with an average activity duration of approximately 30 minutes per occurrence. The IC group has an average frequency of 2 activities per week during the time slot of 7:00-8:00, with an average activity duration of approximately 60 minutes per occurrence. The WC group has an average frequency of 2 activities per week during the time slot of 7:00-7:45, with an average activity duration of approximately 60 minutes per occurrence. The WB and RC groups have an average frequency of approximately 1 activity per day during the time slot of 6:00-6:45, with an average activity duration of approximately 15 minutes per occurrence for WB and 20 minutes per occurrence for RC. Finally, the HD has an average frequency of 4 activities per week during the time slot of 20:00-20:30, with an average activity duration of approximately 5 minutes per occurrence.

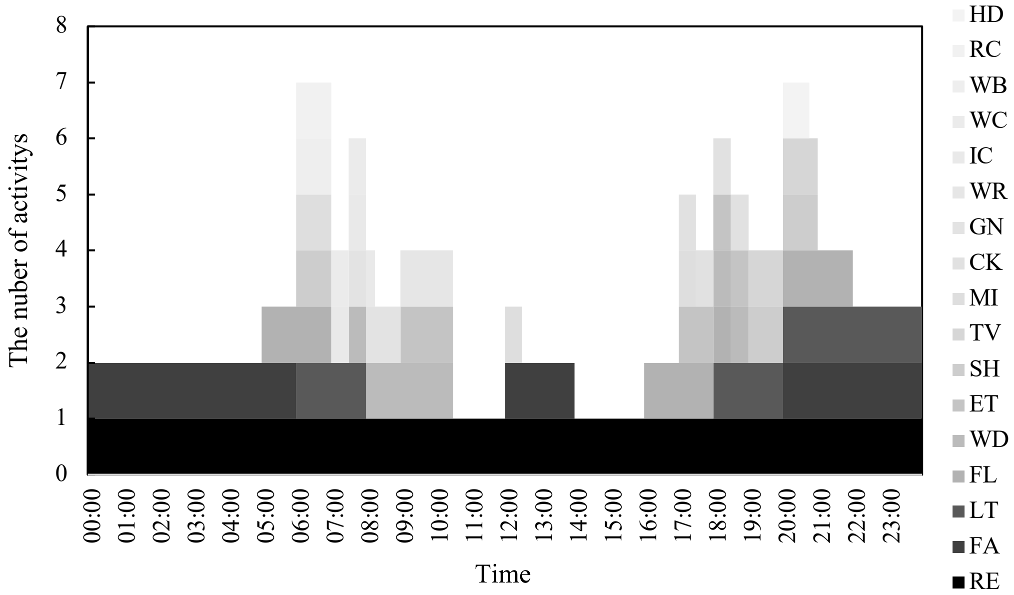


Figure 4.48 The number of events in GH1 of the 1st consumer

The details of the activity data within the second resident's building are presented according to the time intervals shown in Figure 4.49, consisting of 12 activities, namely RE, CF, LT, ET, MI, WC, BA, CK, RC, IC, WB, and HD. Two of these activities, RE and CF, are continuously carried out throughout the day due to their dependence on the use of electricity. Each activity has the following details: LT occurs twice daily for an average duration of approximately 14 hours, between 6:00-8:00 and 18:00-23:45; ET occurs twice daily for an average duration of approximately 30 minutes per occurrence, between 9:00-10:30 and 17:00-19:00; MI occurs approximately four times per week, divided into three time intervals, 8:00-8:30, 12:00-12:30, and 18:00, with an average duration of approximately 10 minutes per occurrence; and WC occurs three times per week for an average duration of approximately 45 minutes per occurrence, between 7:00-7:45. The BA activity occurs twice a day, at two different time periods, namely 7:30-7:45 and 19:00-19:30, with an average activity duration of approximately 15 minutes per occurrence. The CK activity has an average frequency of 2 occurrences per day, during the time periods of 6:00-6:30 and 18:00-18:30, with an average activity duration of approximately 45 minutes per occurrence. The RC activity has an average frequency of 5 occurrences per week, during the time periods of 6:00-6:30 and 18:00-18:30, with an average activity duration of approximately 30 minutes per occurrence. The IC activity has an average frequency of 2 occurrences per week, during the time period of 7:45-8:00, with an average activity duration of approximately 60 minutes per occurrence. The WB activity occurs once a day, at approximately 7:00-7:15, with an average activity duration of approximately 5 minutes per occurrence. Finally, the HD activity has an average frequency of 3 occurrences per week, during the time period of 19:00-19:30, with an average activity duration of approximately 10 minutes per occurrence.

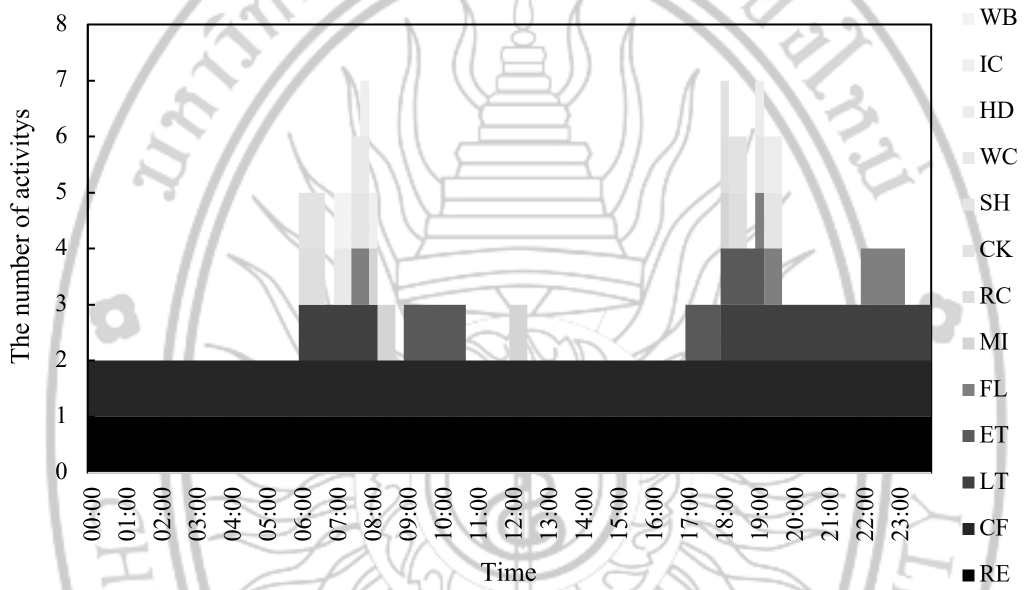


Figure 4.49 The number of events in GH1 of the 2nd consumer

The data on the activities of both consumers within GH1 reveals that there are activities that are continuously utilized and shared within the building, namely RE, and one activity that is utilized continuously within the building, namely CF. Therefore, in analyzing the collective activities within the building, data from both activities will be used. Upon examination of the activities that occurred within the building from both residents, it was found that in the morning (6:00-10:30), there were LT at 6:00-7:45, RC at 6:00-3:60, WC at 7:00-7:45, IC at 7:30-8:00, and ET at 9:00-10:15. During midday, there was only one activity, namely MI at 12:00-12:30, and in the evening, there were four activities, namely LT at 18:00-23:45, ET at 17:00-18:45, CK at 18:00-18:30, and BA at 19:00-19:30. Moreover, upon considering the activities that occurred within the building from only one resident, there were the following activities: FA at 00:00-5:45, 12:00-13:45, and 20:00-23:45, TL at 5:00-6:45, 16:00-18:15, and 20:00-21:45, BA at 6:00-6:45, 7:30-7:45, and 19:45-20:45, WD at 7:30-10:15 and 18:00-18:45, MI at 6:00-6:45, 8:00-8:30, 17:00-17:15, and 18:00, CK at 6:00-6:30 and 17:00-17:45, RC at 18:00-18:30, TV at 19:00-20:45, GN at 7:30-8:45, WR at 9:00-10:15, WB at 6:00-7:15, and HD at 19:00-19:30 and 20:00-20:30.

Upon examining the data on energy usage, water usage, and waste generation for GH1, it was found that there was no significant difference between weekdays and weekends. Therefore, activities that occur less frequently than once per day within the building may have a negligible impact on energy usage, water usage, and waste generation. If we consider activities that occur less frequently than once per day, we find that there are five such activities: HD, WC, IC, MI, and WR, with average activity durations of 6.67 minutes, 35 minutes twice per week, 60 minutes twice per week, 4.67 minutes 4.67 times per week, and 30 minutes once per month, respectively.

General public house 2: The data on activities occurring within GH1 for residents 1 and 2 displays similar behavior patterns based on survey responses. The activities are divided into two time periods per day, morning, and evening, and are detailed in Figure 4.50 and Figure 4.51. There are a total of 13 activities, including RE, FA, LT, TV, ET, WD, CK, AC, GN, HD, TL, BA, and WB. Only one activity, RE, is performed continuously throughout the day, while the other activities, FA is divided into three time periods per day, 00:00-03:00, 12:00-13:00, and 20:00-23:45, with an average duration of approximately 9 hours per day. LT occurs twice per day at 5:00-6:30 and 17:00-19:00, with an average activity duration of approximately 300 minutes per day. TV occurs once per day, around 18:00-21:00, with an average activity duration of approximately 180 minutes. ET, WD, and CK each occur twice per day at 6:00-7:00 and 18:00-19:00, with an average activity duration of approximately 25 minutes per occurrence for ET and WD and 60 minutes per occurrence for CK. AC activities occur once a day during the period of approximately 20:00-21:30. However, this behavior is dependent on external temperature factors, and as such, the frequency of use by building occupants is typically around five times per week during the hot season (March-June). GN activities occur once a day on average during the time period of 17:00-18:30, with an average duration of approximately 30 minutes per occurrence. HD activities occur once a day on average during the time period of 6:00-6:30 or 18:00-18:30, with an average duration of approximately 5 minutes per occurrence. TL and BA activities occur during the same time periods of approximately 6:00-6:30 and 18:00-18:30. TL has an average duration of approximately 3 minutes per occurrence and occurs four times per day, while BA has an average duration of approximately 30 minutes per occurrence and occurs twice per day. Finally, WB activities occur once a day on average during the time period of approximately 6:00-6:45, with an average duration of approximately 15 minutes per occurrence. The average duration of WB activities is approximately 5 minutes, and they occur once per day during the time period of 6:00-6:30.

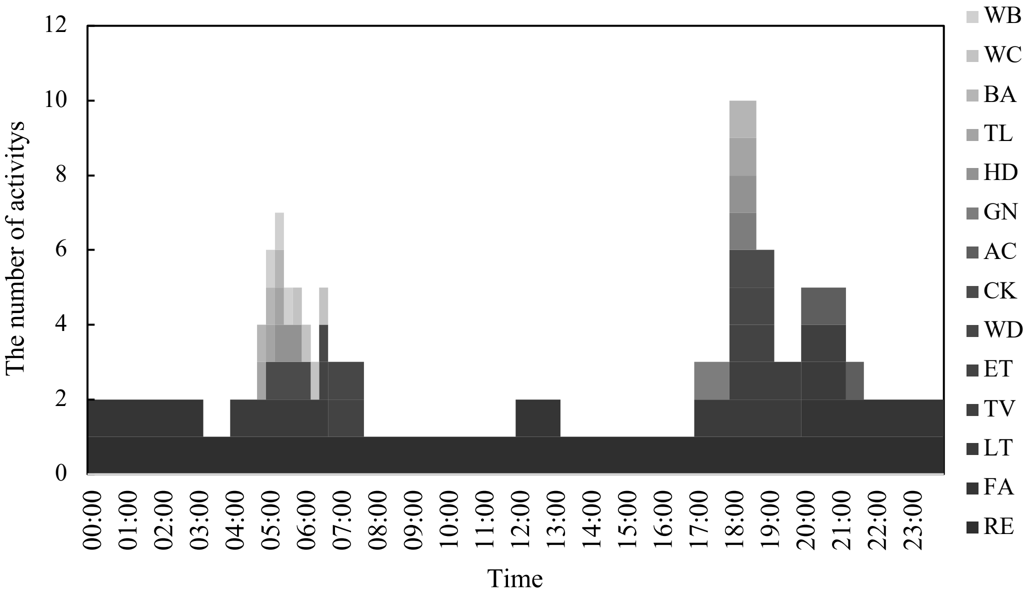


Figure 4.50 The number of events in GH2 of the 1st consumer

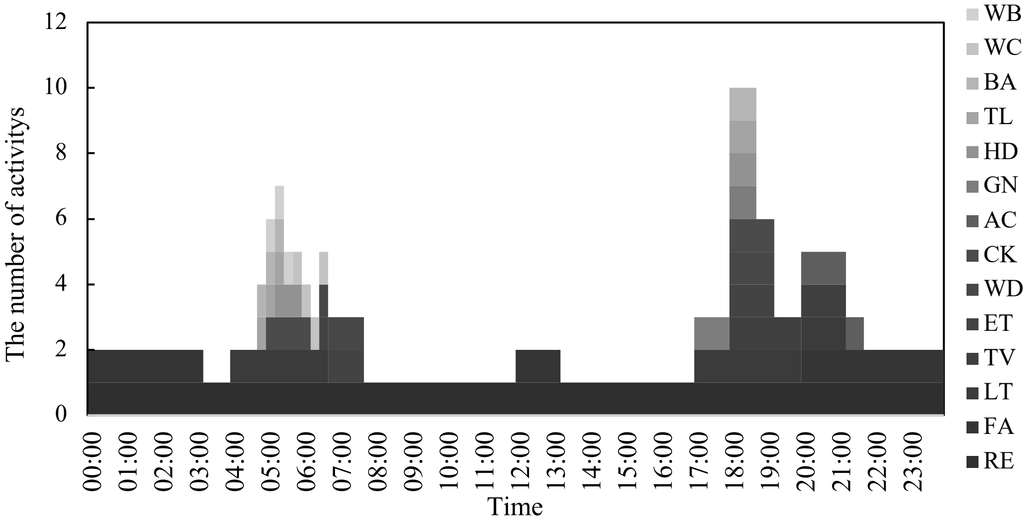


Figure 4.51 The number of events in GH2 of the 2nd consumer

School house 1: The activities within the female resident number 1 of SH1, aged between 51 and 60, are detailed in Figure 4.52, consisting of a total of 10 activities: LT, TL, MI, BA, WB, ET, WD, MI, HD, and IC. Each activity has behavior patterns for their occurrence within the building as follows: LT occurs twice daily at two different times, from 6:00 to 7:00 and 18:30 to 22:30, with an average activity duration of approximately 5 hours per occurrence. TL occurs four times daily at three different times, namely from 6:00 to 6:30, 18:30 to 19:00, and 22:00 to 22:30, with an average activity duration of approximately 2 minutes per occurrence. MI occurs approximately twice weekly at two different times, from 6:30 to 7:00 and 18:30 to 19:00, with an average activity duration of approximately 5 minutes per occurrence. BA and WB occur simultaneously at two different times, namely from 6:30 to 6:30 and 19:00 to 19:30, with an average activity duration of approximately 10 minutes per occurrence for BA and 3 minutes per occurrence for WB. ET occurs twice daily at approximately 6:30 to 7:00 and 19:00 to 19:30, with an average activity duration of approximately 20 minutes per occurrence. WD occurs twice daily with an average activity frequency of 2 times per day and an average activity duration of 5 minutes per occurrence, occurring after ET at approximately 7:00 to 7:30 and 19:30 to 20:00. MI activities occur on average twice per day, with two time intervals: 6:30-7:00 and 18:30-19:00. The duration of each activity is approximately 5 minutes. On the other hand, HD activities occur on average once per week, during the 19:30-20:00 time interval, with each activity lasting around 5 minutes. Lastly, the IC activities occur on average once per week, during the 19:00-19:30 time interval, with each activity lasting around 10 minutes.

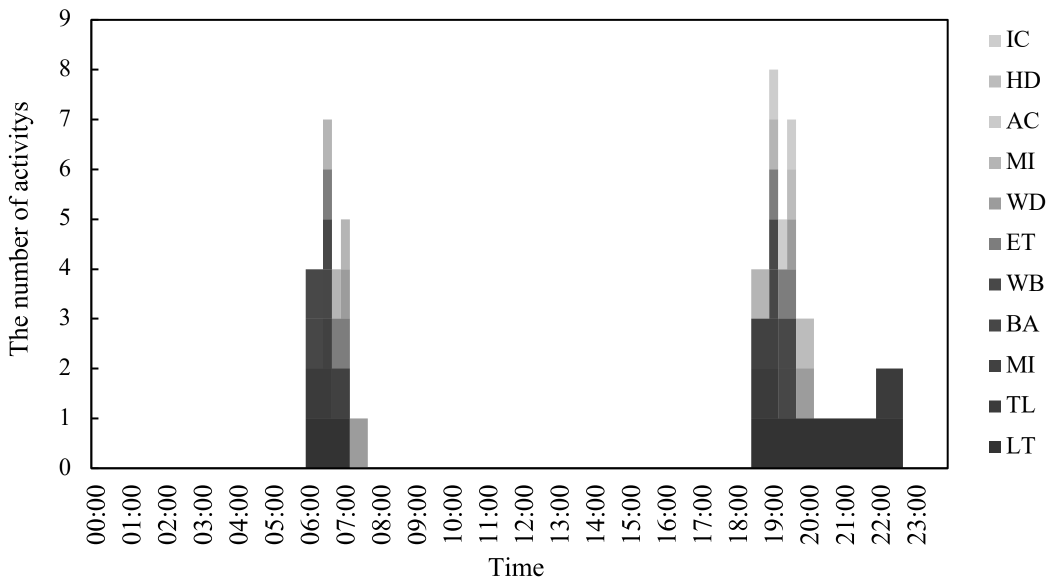


Figure 4.52 The number of events in SH1 of the 1st consumer

From Figure 4.53, the characteristics of activities that occur within SH 1 of male residents aged between 41 and 50 years old, who are resident number 2, are shown. The findings reveal that there are six activities that occur among all consumers, namely FA, LT, BA, MI, ET, and WD. The behaviors of the activities occurring within the building are divided into two periods: from 0.00 to 8.00 and from 17.00 to 23.45, which are outside of working hours. The details of each activity are as follows: FA occurs once a day in both periods, from 00.00 to 7.00 and from 17.00 to 23.45, with an average duration of 14 hours per day. This activity is the longest occurring activity because consumers primarily use fans as a device to adjust the indoor air condition, and the fans also help with the air circulation system, which directly affects the comfort level inside the building. Additionally, since the building is not a private residence, it cannot adjust the environmental conditions that affect the air circulation inside the building, which is the reason why the fans are used for an extended period. LT occurs twice a day in both periods, from 5.00 to 8.00 and from 18.00 to 23.00, with an average duration of 8 hours per day. BA has two periods of activity, which are from 6.00 to 7.00 and from 20.00 to 21.00, with an average duration of approximately 15 minutes per occurrence. MI, ET, and WD occur twice in the same time period, with two occurrences of each activity per day.

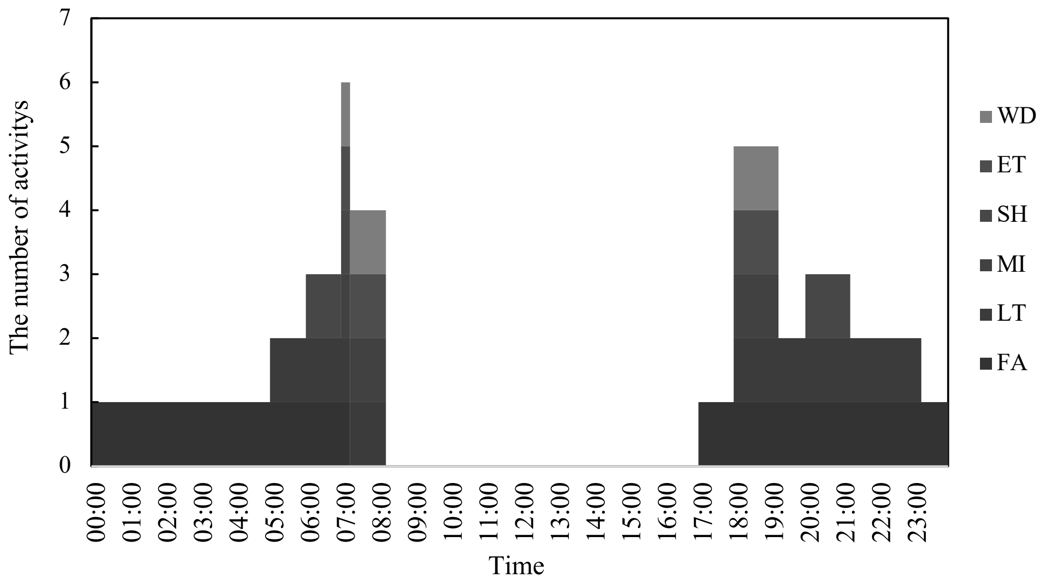


Figure 4.53 The number of events in SH1 of the 2nd consumer

For the third resident of SH1 who is male and aged between 31-40 years old, there are detailed activities within the building as shown in Figure 4.54. There are a total of nine activities comprising of RE, FA, LT, TL, BA, CK, MI, ET, and WD. It was found that there is one activity that occurs throughout the day, which is RE, due to the requirement of continuous use of electricity. The consumer has specified that this activity was carried out by the third consumer of SH1, as it occurred or utilized equipment in their private living quarters and not in the common area of the building. Other activities carried out by the consumer include FA, which occurs once a day during two time periods, from 0.00-6.00 and 23.00-23.45, with an average duration of 6 hours per day. LT occurs once a day during the time period of 18.00-23.00, with an average duration of approximately 4 hours per day. TL and BA occur twice a day during the same time periods, from 7.00-7.30 and 21.00-21.30, with each activity occurring twice per day and an average duration of 10 minutes for BA and 2 minutes for TL. BA also occurs four times per day during three time periods, which are 7.00-7.30, 12.00-13.00, and 21.00-21.30.

There are four activities, CK, MI, ET, and WD, which occur in close proximity to each other. All four activities are performed sequentially, beginning with food preparation and microwaving, followed by meal consumption, and concluding with dishwashing. These four activities are performed twice daily, during the time periods of 7:00-7:30 and 20:00-20:30. The average duration of each activity is as follows: CK, 35 minutes; MI, 2 minutes; ET, 25 minutes; and WD, 1 minute.

Characteristics and behavior of activities within the SH1 of all consumers within the building reveal a total of 12 activities occurring during two distinct time periods within a given day. Necessary activities that require constant energy usage throughout the day, regardless of occupancy, such as refrigeration, were not included. During the first time period, or morning hours, most activities occurred in close proximity to one another, beginning with the FA activity that occurred with two residents and commencing with additional activities around 5:00. The first time period ended at 8:00 with the final LT activity that occurred between 5:00 and 8:00, followed by BA and TL activities that occurred at roughly 6:00-6:30 and 7:00-7:30, respectively. This was followed by the WB activity at 6:00-6:30, and then the breakfast period, which began with CK and MI for meal preparation, followed by ET for meal consumption, and WD for dishwashing, with breakfast occurring between 6:30 and 8:00. The highest level of concurrent consumer activities within the building occurred during the breakfast period, particularly around 7:00-7:30. There was a second occurrence of activities within the building after 5:00, with the longest duration being for the lighting system (LT) and the air conditioning system (FA). This was followed by a period of dinner consumption activities (CK, MI, WB, ET, and WD), which did not occur in close proximity to one another like the morning activities, but still occurred during a relatively short time period.

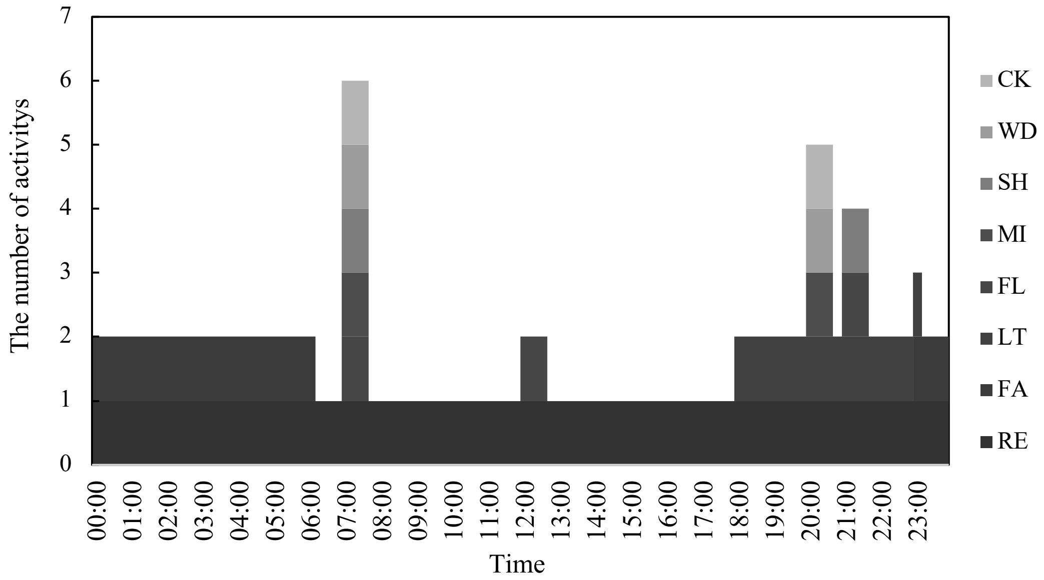


Figure 4.54 The number of events in SH1 of the 3rd consumer

The data, it was found that the quantity of behavioral characteristics that occur within the building changes in two periods of the day: weekday and weekends. According to the correlation data of energy, water, and waste within the building, it is seen that the estimated use of energy and water within the building has a significant correlation with the time and type of working day. Additionally, the data within the building shows that the amount of energy used is also correlated with the amount of water used, and the amount of water used has an impact on the amount of waste generated within the building, which is statistically significant. Therefore, it can be concluded that the behavior of activities that occur within the building has an impact on the quantity of resources used within the building.

School house 2: The activities that occurred within the building by 1st consumer, a female aged between 21-30 years old, consisted of a total of nine activities, namely RE, LT, FA, TL, BA, WC, ET, WD, and IC, as shown in Figure 4.55. The most frequent activity that occurred throughout the 24-hour period was the refrigerator. It was found that the majority of the activities occurred between 17:00-23:45, accounting for eight out of the nine activities. In the morning, only three activities occurred during the period of 6:30-7:45, including lighting, bathing, and toilet.

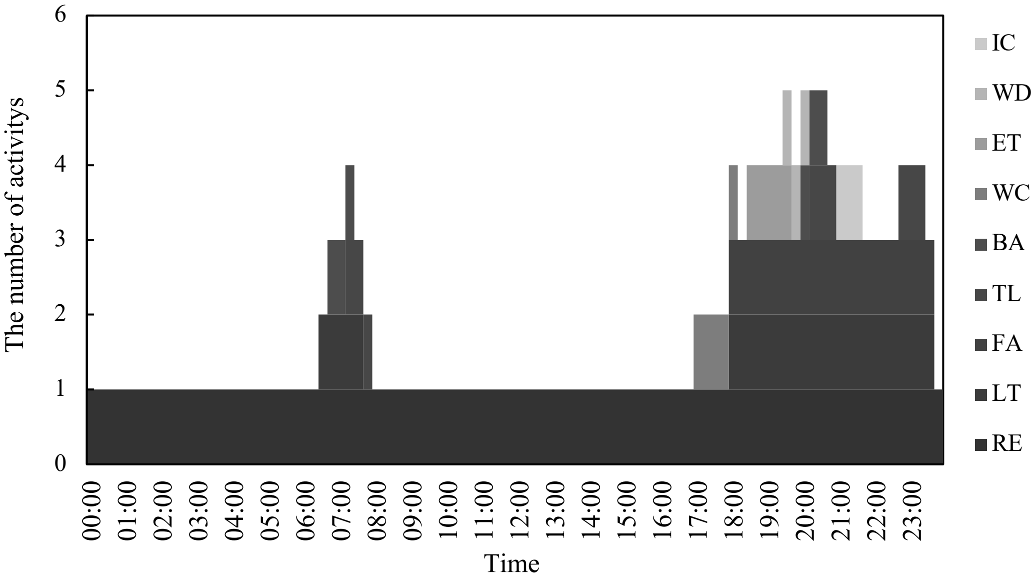


Figure 4.55 The number of events in SH2 of the 1st consumer

Upon analysis of the characteristics of each activity, it was determined that the activity denoted as lighting took place twice per day, between the hours of 6:30-7:30 and 18:00-23:30, with an average daily usage time of 720 minutes. The activity associated with turning on the fan took place once per day on average, during the period of 18:00-23:30, with an average usage time of approximately 690 minutes per day. The activity labeled as toilet occurred during three distinct time periods, namely 7:15-7:45, 20:15-20:45, and 22:45-23:15, with a frequency of three times per day and an average duration of 2 minutes. Bathing took place twice per day, during the periods of 6:45-7:15 and 20:00-20:30, with an average duration of 30 minutes per occurrence. The activity associated with eating occurred once per day on average, with an average duration of 20 minutes during the period of 18:30-19:30. Washing dishes took place after mealtime, during the period of 19:30-20:00, with an average duration of 5 minutes and occurring once per day. The activity denoted as laundry took place once per week, during the period of 17:00-18:00, with an average duration of 60 minutes.

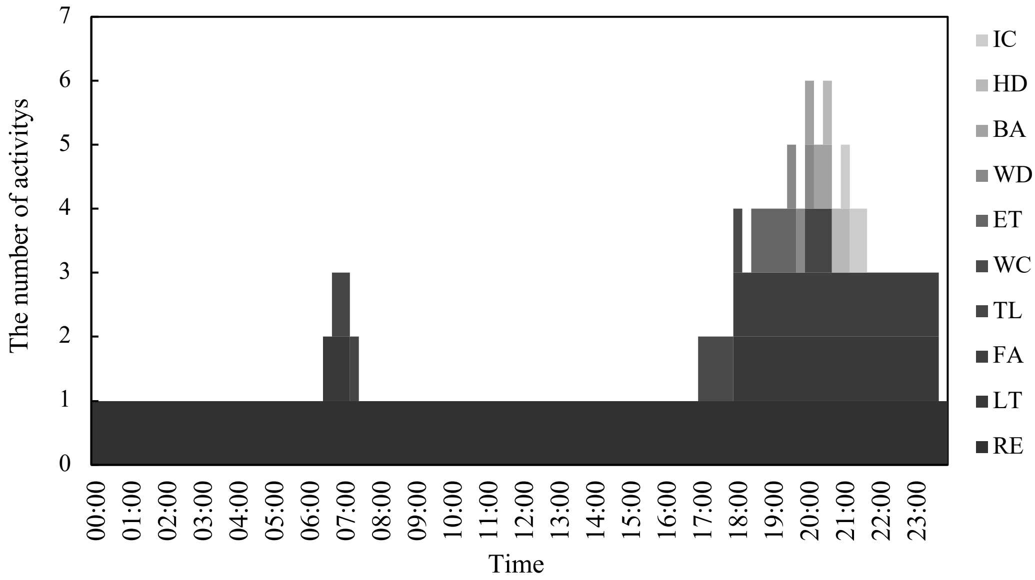


Figure 4.56 The number of events in SH2 of the 2nd consumer

After examining the activities that occurred within the building by female consumers between the ages of 21-30, a total of 10 activities were identified, including RE, LT, FA, TL, WC, ET, WD, BA, HD, and IC, which were similar to those of Consumer 1, with the addition of one activity, namely hair drying, as indicated in Figure 4.56. It was found that the refrigerator was the activity that occurred throughout the 24-hour period, and that most activities occurred between 17:00-23:45, with a total of 8 activities. Only 2 activities occurred in the morning, namely lighting and toilet, which occurred between 6:30-7:45.

The characteristics of daily activities indicate that there is a lighting period from 6:30 to 7:00 in the morning, followed by restroom use from 6:45 to 7:15. Evening activities consist of lighting periods from 18:00 to 23:30, coinciding with the use of fans, with an average lighting time of approximately 390 minutes per day and an average fan usage time of approximately 327 minutes per day. This is followed by a mealtime period from 18:30 to 19:30, which lasts approximately 25 minutes and occurs once per day, followed by dishwashing from 19:30 to 20:00, which takes approximately 5 minutes and occurs once per day.

Bathing and restroom use occur simultaneously from 20:00 to 20:30, with an average of one bath per day taking approximately 25 minutes and two restroom uses per day taking approximately 1 minute each. This is followed by hair drying from 20:30 to 21:00, which takes approximately 5 minutes and occurs once per day, and ends with laundry wringing from 21:00 to 21:30, which takes approximately 5 minutes and occurs once per day. Laundry washing occurs only once per week during the time period of 17:00 to 18:30, taking approximately 50 minutes.

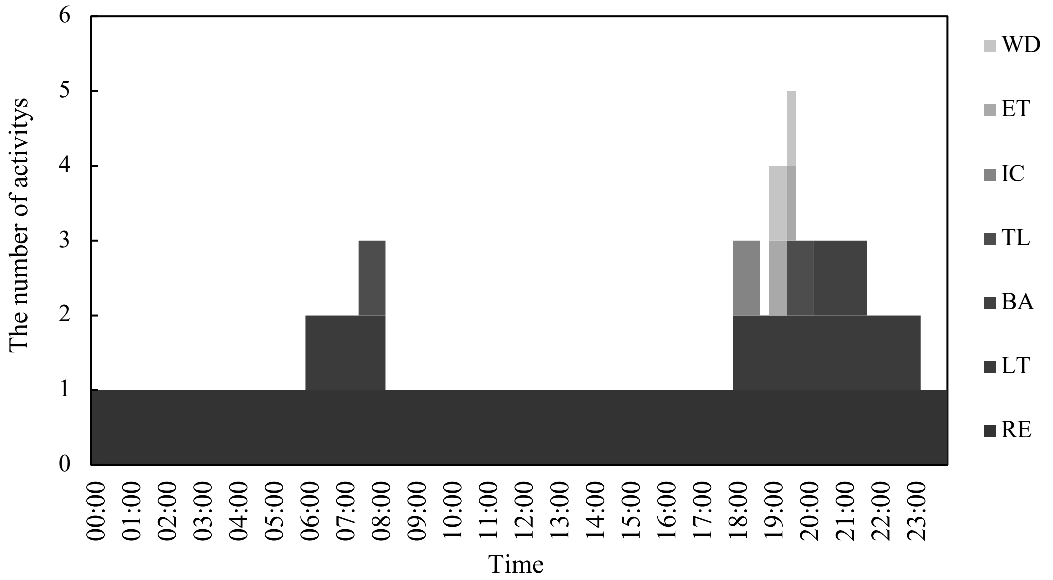


Figure 4.57 The number of events in SH2 of the 3rd consumer

Within the building, activities of female consumers aged between 21 and 30 years were recorded and categorized as RE, LT, BA, TL, IC, ET and WD, as shown in Figure 4.57. The activities occurring over 24 hours were examined and it was found that the most prevalent activity was the use of the refrigerator, with the majority of activities taking place between 18:00 and 23:00. Only two activities, lighting and toilet use, occurred in the morning, specifically between 6:00 and 8:00.

Further analysis revealed that lighting activities occurred during two distinct time periods: between 6:00 and 8:00 and between 18:00 and 23:00. The average duration of lighting use per day was found to be 420 minutes. Bathing activities occurred between 20:15 and 21:30, with an average duration of 30 minutes per session, once per day. Toilet use was found to occur with a high frequency of three times per day, on average taking one minute per use, during two time periods: 7:30-8:00 and 19:30-20:00. Laundry activities occurred between 18:00 and 18:30, with an average duration of five minutes per session, once per day. Eating and dishwashing activities occurred at the same time, specifically between 19:00 and 19:30, with an average duration of 25 minutes for eating and five minutes for dishwashing. Both activities occurred within the building once per day on average.

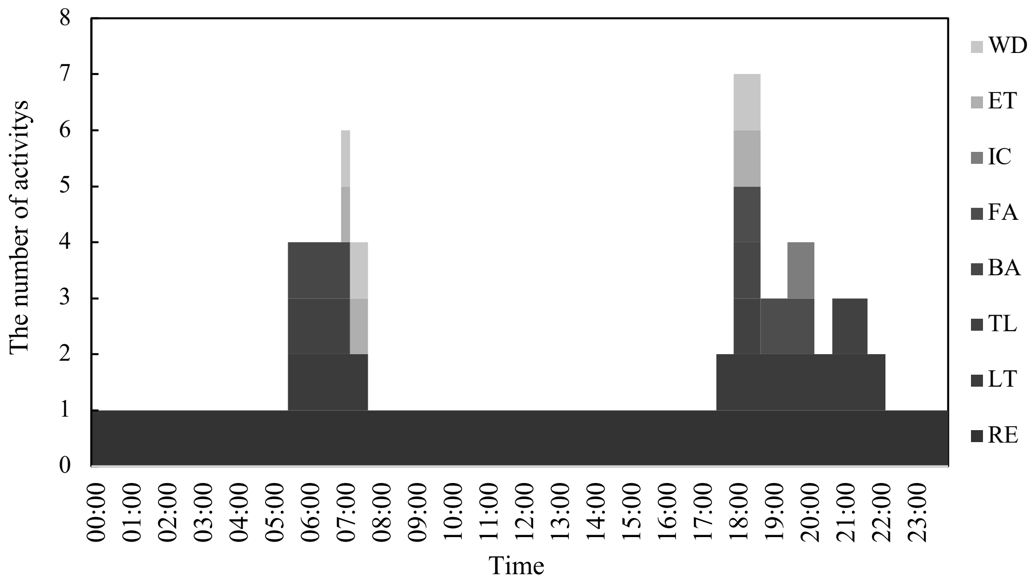


Figure 4.58 The number of events in SH2 of the 4th consumer

For the 4th consumer of the residential building for teachers, who is a female aged between 41-50 years old, as shown in Figure 4.58, there are a total of 8 activities within the building, namely RE, LT, TL, BA, FA, IC, ET, and WD. From the data, it was found that there is 1 activity that occurs continuously for 24 hours, which is the refrigerator activity. It was found that the activity of turning on the lights occurs twice a day, between 5:30-7:30 and 17:30-22:00, averaging about 420 minutes per day. The activity of taking a shower occurs twice a day, in the time periods of 5:30-7:00 and 18:00-18:30, averaging 15 minutes per occurrence, with a frequency of 2 occurrences per day. The activity of using the bathroom occurs in 3 time periods, with the first 2 periods occurring at the same time as the shower activity, and the third period occurring between 20:45-21:30, averaging 1 minute per occurrence, with a frequency of 3 occurrences per day.

The activity of using the fan occurs once a day within the building, with an average duration of 120 minutes, in the time period of 18:00-20:00. The activity of doing laundry occurs once a day within the building, averaging 5 minutes in duration, in the time period of 19:30-20:00. The last two activities occur simultaneously, which are the activity of eating and dishwashing, which occur twice a day in the time periods of 7:00-7:30 and 18:00-18:30, averaging 2 occurrences per day with a duration of 15 minutes for eating and 5 minutes for dishwashing.

The characteristics and behaviors of activities conducted within SH2 building, as observed by 4 consumers, are shown to comprise a total of 9 activities. These activities include the use of a refrigerator, the operation of a fan, the turning on of lights, bathing, the use of a restroom, hair drying, swimming, eating, dishwashing, and laundry washing and drying. These activities mostly occur between 18:00 and 23:30, with only the activities of turning on lights, bathing, using the restroom, having meals, and washing dishes happening between 5:30 and 8:00 in the morning. The most frequently encountered behaviors in the morning are turning on lights between 6:00 and 7:30, bathing from 6:45 to 7:00, and using the restroom from 6:45 to 7:45, occurring more than twice a day. The analysis of activity frequencies in the evening indicates that simultaneous activities mostly involve turning on lights between 18:00 and 23:30 and operating fans between 18:00 and 23:30. Among the evening activities, meal consumption occurs between 18:30 and 19:30, dishwashing from 19:30 to 20:00, bathing and restroom usage from 20:00 to 20:45, hair drying from 20:00:30 to 21:00, and laundry washing, ironing, and fabric drying from 21:00 to 21:30.

The average duration of each activity that occurs within the building was found to be as follows: the activity of turning on the lights had an average usage time of 465.00 minutes once per day; the activity of using the hair dryer had an average usage time of 379.00 minutes 0.75 times per day; the activity of taking a shower had an average duration of 25.00 minutes 1.50 times per day; the activity of using the restroom had an average duration of 1.25 minutes 2.75 times per day; the activity of blow drying hair had an average duration of 5 minutes 0.25 times per day; the activity of eating had an average duration of 21.25 minutes 1.25 times per day; the activity of washing had an average duration of 5 minutes 1.25 times per day; and the activity of doing laundry had an average duration of 55 minutes 0.5 times per week.

The activities observed within the building are typical of those that occur in a residential facility where people carry out their daily routines. For example, the need to turn on the lights and use household appliances is common to all homes. Similarly, personal care activities such as taking a shower and using the restroom are also typical daily routines for individuals living in a residential facility. Meals are also a regular activity that occurs in all households, and doing laundry is a necessary task that needs to be performed periodically. Therefore, the observed activities are not unexpected and reflect the daily routines of the occupants in the building.

Community hospital house 1: Activity within the first residence building of Community hospital house 1 from the first occupant shows the time range of activities as depicted in Figure 4.59. It is found that there are eight activities that occur within the building, which include using the refrigerator, lighting, fan, toilet, bathing, eating, washing dishes, and ironing clothes. The activity that occurs for the longest period within the building is the refrigerator, which is in use 24 hours a day. Additionally, activities related to turning on the lights occur during multiple time periods, including 0:00-2:00, 7:00-8:00, 12:00-12:45, and 18:30-23:45, and on average, last 300.00 minutes per day. Activities related to turning on the fan occur during the time periods of 0:00-3:00, 7:30-8:00, 19:00-19:30, and 22:00-23:45, and on average last approximately 300.00 minutes per day. Bathing activities occur during the time periods of 7:00-7:30 and 20:30-21:00, and on average take 10 minutes to complete, twice per day. Entering the toilet is a high-frequency activity that occurs four times per day and lasts approximately 1 minute per occurrence, during the time periods of 0:00-0:30, 7:00-7:30, 12:15-12:45, and 21:00-21:30. Eating occurs three times per day and on average takes 30 minutes per occurrence during the time periods of 0:00-0:30, 12:15-12:45, and 19:00-19:30. Lastly, washing dishes occurs twice per day during the time periods of 0:00-0:30 and 12:15-12:45, and on average takes 10 minutes per occurrence. The last activity that occurs within the building from this occupant is ironing clothes, which occurs once per day and on average takes approximately 10 minutes to complete.

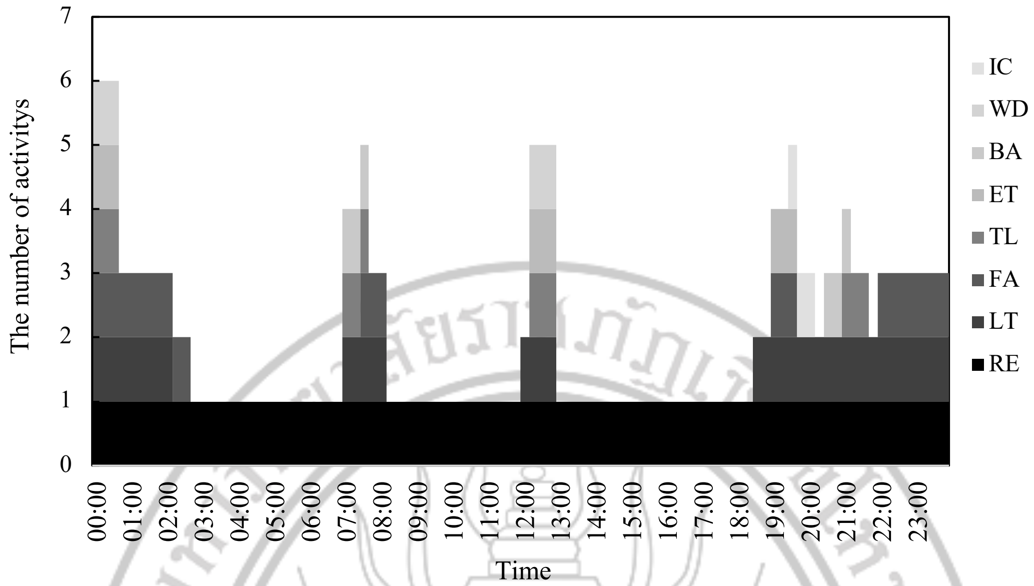


Figure 4.59 The number of events in HH1 of the 2nd consumer

Within the community hospital house 1, resident number 2, who is female and aged between 21-30 years old, demonstrated the activities as shown in Figure 4.60. A total of nine activities were identified, including the use of the refrigerator, fan, lighting, toilet, bathing, ironing clothes, washing clothes, using a hair dryer, and electric water heater. The refrigerator was found to be active 24 hours a day. If we consider each activity that occurs within the building, it was found that turning on the fan occurs twice a day for a total of 120 minutes on average, during the time periods of 0:00-2:15 and 18:00-23:45. The activity of turning on the lights occurred during the time periods of 6:00-8:00 and 18:00-23:00, averaging 300 minutes per day. The activity of bathing and using the restroom occurred during two time periods, which are 6:00-6:30 and 19:00-13:90. Additionally, a water heater was used in the morning for approximately 10 minutes twice a day. The water heater was used only once in the morning, averaging 10 minutes per day. Furthermore, the activity of using the restroom increased by one time period, which is 23:00-23:30, with an average time of 2 minutes and occurring three times per day. Hair drying occurred once a day during the time period of 20:00-20:30, averaging 3 minutes per day. Finally, the activity of washing and ironing clothes occurred only once a week, with an average time of 45-60 minutes per instance.

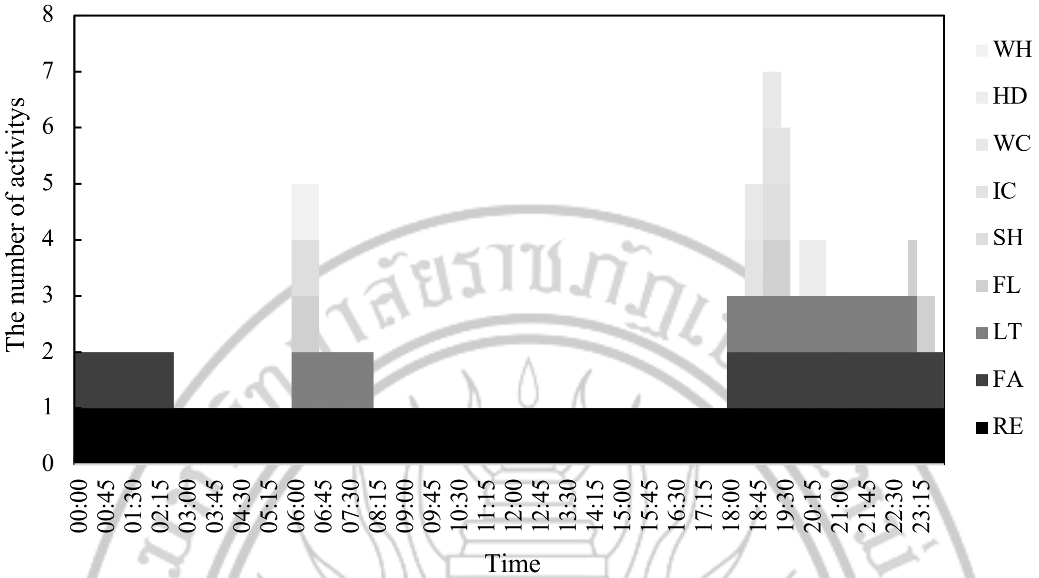


Figure 4.60 The number of events in HH1 of the 1st consumer

The activity data from 2 consumers within community hospital house 1, it was observed that the activities occurring within the building were divided into 4 time intervals, namely 0:00-2:30, 6:00-8:00, 12:00-12:45, and 18:00-23:45. The activities during interval 1 included turning on the lights, turning on the fan, using the bathroom, having meals, and washing dishes. The activities during interval 2 included turning on the lights, turning on the fan, using the bathroom, and having meals. The activities during interval 3 included turning on the lights, using the bathroom, having meals, and washing dishes. The activities during interval 4 included turning on the lights, turning on the fan, using the bathroom, taking a shower, having meals, and blow-drying hair.

On average, the lights were turned on for 300.00 minutes per day, the fan was turned on for 210 minutes per day, showering occurred twice a day for an average of 10 minutes each time, using the bathroom occurred 1.5 minutes per visit, meals were consumed three times a day for an average of 30 minutes each time, dishes were washed for an average of 10 minutes twice a day, hair was blow-dried for an average of 3 minutes 0.5 times per day, and clothes were laundered for an average of 35 minutes, four times per week.

The activity data, it is apparent that the building under observation serves as a residential facility where people conduct their daily activities. The activities are broadly classified into three categories, namely personal care, household chores, and meals. The personal care activities, which include showering and blow-drying hair, take place during the last time interval of the day, between 18:00-23:45. On average, showering occurs twice daily, and each session lasts 10 minutes, while hair is blow-dried for an average of 3 minutes 0.5 times per day. Household chores, such as turning on lights and fans, using the bathroom, and washing dishes, are carried out in various time intervals during the day. Turning on the lights and fans is a recurrent activity that takes place in all time intervals. On average, the lights are on for 300 minutes and fans for 210 minutes daily. Bathroom use takes approximately 1.5 minutes per visit and occurs throughout the day. Washing dishes lasts for an average of 10 minutes twice a day. The third category of activities is meals, which are consumed three times a day and each time lasts for 30 minutes. Laundry is done four times a week, with each occasion taking approximately 35 minutes. The observations suggest that the occupants conduct their activities in typical residential routines. The timing and duration of each activity provide insights into the occupants' daily lives.

Community hospital house 2: Activity within the second community hospital house from consumer 1, who is male, aged between 21-30, was examined based on the time period of each activity as shown in Figure 4.61. The findings revealed a total of 10 activities, including the refrigerator, lighting, fan, bathing, toilet, hair wash, clothes washing, eating, dishwashing, and TV. The time periods in which activities occurred were divided into 2 time periods. The activity that lasted the longest was the refrigerator, which was used for 24 hours. The fan activity occurred in two time periods, between 00:00-8:30 and 17:30-23:45, with an average duration of 900 minutes per day. The lighting activity was used for approximately 900 minutes per day, occurring between 1:00-8:00 and 17:00-23:45. Bathing activity occurred twice a day, averaging 30 minutes each time, between 5:30-7:30 and 20:00-22:00. Bathroom and hair drying activities occurred at the same time, twice a day, averaging 1 minute for bathroom use and 5 minutes for hair drying, between 5:30-7:30 and 20:00-22:00. Meal consumption and dishwashing activities occurred twice a day, between 7:45-8:30 and 19:00-19:45, with an average duration of 15 minutes for meal consumption and 5 minutes for dishwashing. TV viewing occurred once a day for an average of 60 minutes, between 19:30-21:00. Finally, clothes washing occurred once a day, on average 45 minutes, between 19:00-21:30.

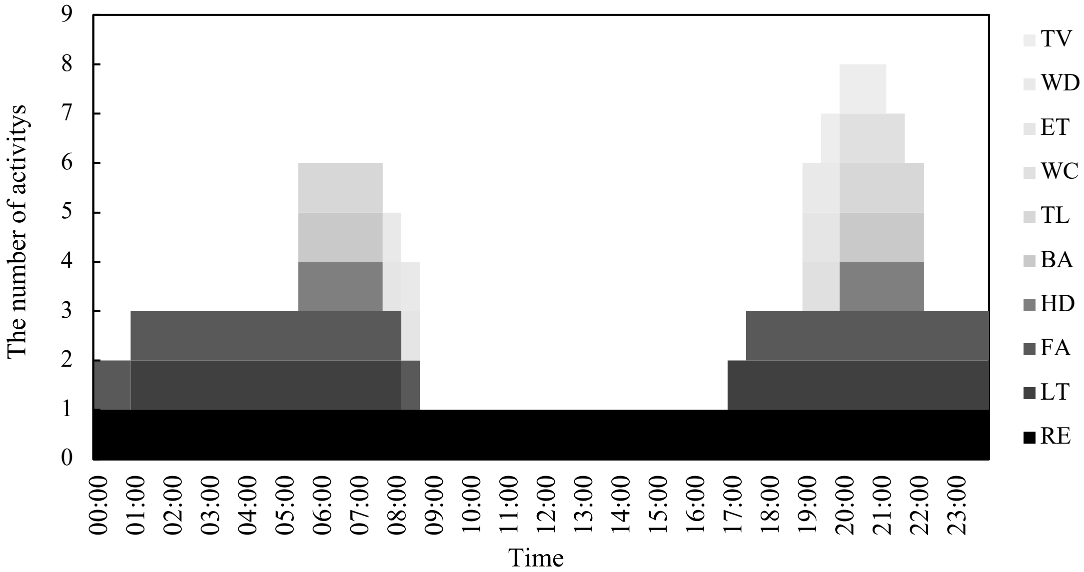


Figure 4.61 The number of events in HH2 of the 1st consumer

The second consumer of the building are males aged between 31 to 40 years old. Their activity patterns within the building at different times, as shown in Figure 4.62, reveal a total of 10 activities: refrigerator, fan, lighting, bathing, electric water heater, toilet, microwave, eating, dishwashing, and TV viewing. Activities involving the use of lighting and fans occur frequently throughout the day, except for the refrigerator which is an essential electrical appliance that operates 24 hours a day. The duration of lighting and fan usage during 0:00-7:00 and 17:30-23:45 averages 780 minutes per day. Additionally, during the morning period, high activity levels were observed for bathing and the use of a water heater from 5:30-7:30, using the common bathroom from 6:00-6:45. The same three activities occurred again in the evening from 19:00-21:00, with an average duration of 30 minutes for each occurrence, twice a day for bathing and water heater usage, and an average of 2 minutes per occurrence, twice a day for toilet usage. During the evening period, there was also a microwave usage activity for food heating and a communal meal from 19:00-20:30, with an average duration of 30 minutes per occurrence for microwave usage and 20 minutes per occurrence for meal consumption, with a frequency of 5 times per week. Dishwashing occurred twice a week during the time of 20:00-21:00, with an average duration of 20 minutes per occurrence. TV viewing activity occurred between 21:00-23:00, with an unspecified duration.

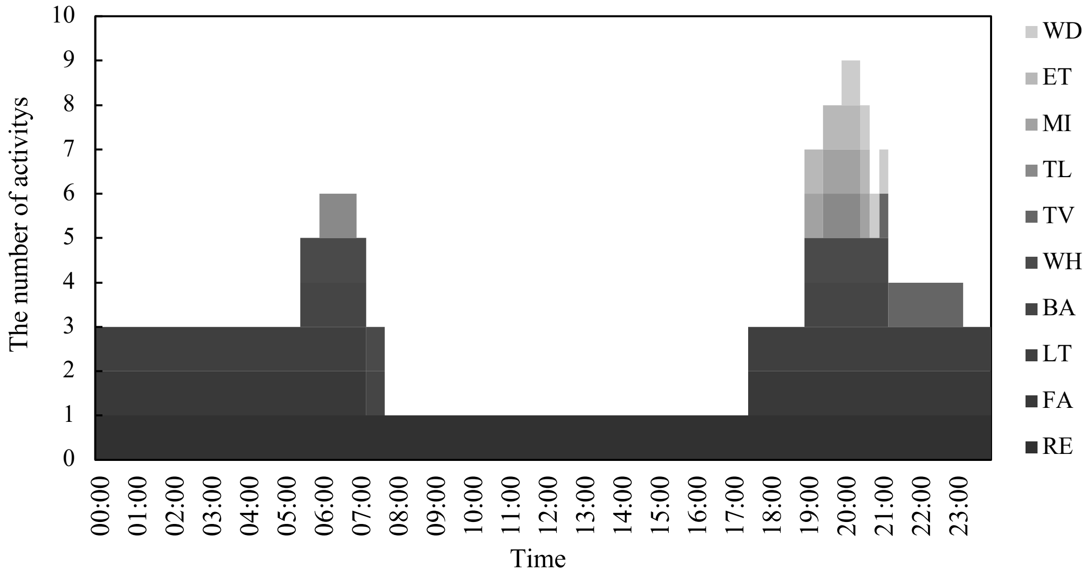


Figure 4.62 The number of events in HH2 of the 2nd consumer

From the activities that occurred within Community hospital house 2, it was found that the activities can be divided into two time periods. The use of electricity and fans would exceed the limit during the hours of 0:00-8:00 and 17:30-23:45, with an average duration of 840 minutes per day. Shower activities would occur during the morning at the same time between 5:30-7:30 and during the evening between 20:00-21:00, with an average duration of 30 minutes, twice a day. During these same time periods, the activity of using the restroom would also occur, with an average duration of 1.50 minutes per instance, 2.5 times per day. Hair drying activities would occur during the same time period as showering activities between 5:30-7:30 and 20:00-22:00, with an average duration of 5 minutes, once a day. The activity of warming food using a microwave, consuming food, and dishwashing would occur during the morning at 7:45-8:30 and during the evening at 19:00-20:30, with an average duration of 30 minutes, 2.50 times per week for warming food with a microwave, 17.50 minutes, 1.36 times per day for consuming food, and 12.50 minutes, 1.14 times per day for dishwashing. The activity of watching television would occur within the building for one time period per day, during the hours of 19:30-23:00, with an average duration of 90 minutes, once a day.

The functions taking place within Community hospital house 2 are indispensable for the daily functioning of its inhabitants. The use of electricity and fans during the hours of 0:00-8:00 and 17:30-23:45 is fundamental to ensuring a comfortable and healthy living environment. Sanitation and personal hygiene are critical, and thus, the use of showers and restrooms is indispensable. Furthermore, hair drying activities are necessary for personal grooming during the same time periods as showering activities. The activities of warming food using a microwave, consuming food, and dishwashing are imperative for daily sustenance and maintaining good health. Lastly, the activity of watching television serves as a source of entertainment and relaxation for the occupants during the hours of 19:30-23:00. In summary, the nature of these activities in Community hospital house 2 is rationalized as they are essential for the daily life and well-being of the occupants.

4.1.1.2 Office building

With regards to the characteristics of activities that take place inside office buildings, the group of consumers or residents living within the building are not identified because of the building's constant flow of consumers entering and exiting throughout the day. As a result, a comprehensive analysis is conducted on the potential collective activities that may transpire within the building, which can have significant implications for energy consumption, water utilization, and waste production.

School office: The nature of activities occurring within a school office building were found to take place between the hours of 7:00 and 19:00, as shown in Figure 4.63. An analysis of all potential activities within the building was conducted, which may impact energy consumption, water usage, and waste generation. Eight activities were identified, namely, refrigerator use, lighting, hot water boiling, fan use, microwave use, meal consumption, dishwashing, and watering of plants. The refrigerator was found to be in constant operation 24 hours a day. Lighting usage began at 7:00 and ended at 18:30, with an average usage time of 300.00 minutes per day. Fans were used twice a day between 11:00 and 14:00, with an average usage time of 60 minutes. Hot water boiling occurred between 7:30 and 18:00, with an average usage time of 600.00 minutes per day. The microwave was used three times a day at 7:30-9:00 and 18:00-19:00, with an average usage time of 3.00 minutes per usage. Meal consumption occurred twice a day for an average of 60 minutes per meal at 7:00-8:00 and 11:30-12:30. Dishwashing occurred twice a day for an average of 10 minutes per session at 7:30-8:00 and 12:00-12:30. Lastly, watering of plants occurred once a day for an average of 30 minutes between 8:00-8:30.

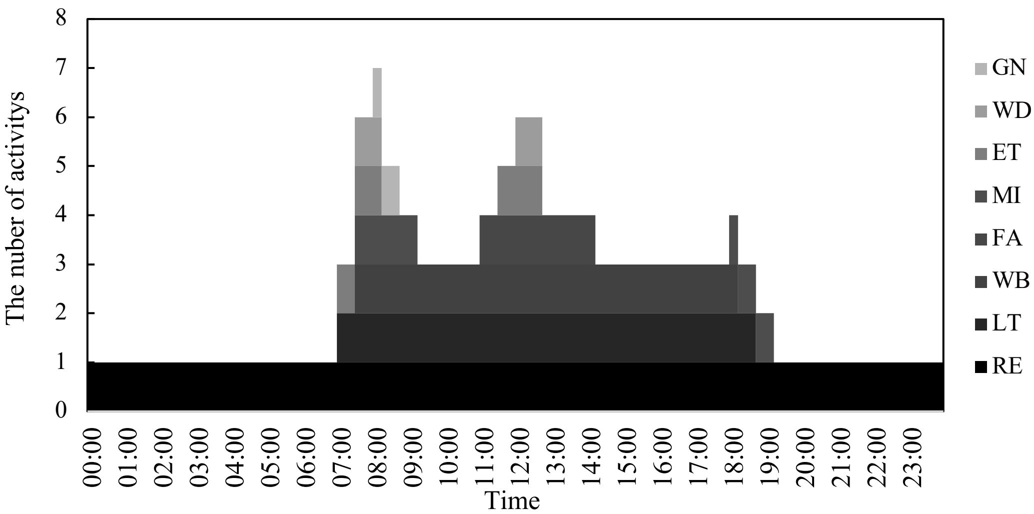


Figure 4.63 The number of events in SCO

The activities taking place within a school office building are deemed imperative for the smooth operation of the premises. Among these activities, the refrigeration of food and other perishable items is necessary to sustain their freshness. Adequate lighting ensures visibility within the building, while fans are employed to promote air circulation, enhancing occupants' comfort levels. The availability of hot water is essential for various functions, such as preparing tea or coffee, and dishwashing is indispensable for cleaning utensils used during meals.

In addition, microwaves serve the purpose of heating food, while meal consumption occurs during stipulated meal times. Moreover, watering plants is a requisite to maintain an attractive and healthy environment. The aforementioned activities play a pivotal role in the proper functioning of a school office and in meeting the demands of its occupants. However, these activities are associated with energy and water consumption, as well as waste generation, warranting the need for an analysis of their usage and the implementation of strategies to mitigate their environmental impact.

Community hospital office: The activities that occur within the community hospital office building comprise only five activities, which include the use of refrigerators, fans, lighting, restrooms, and other medical activities that require energy, as shown in Figure 4.64. The entire time frame during which these activities take place is divided into two periods, between 8:00-12:00 and 13:00-18:30, except for the use of the refrigerator, which is in constant operation 24 hours a day.

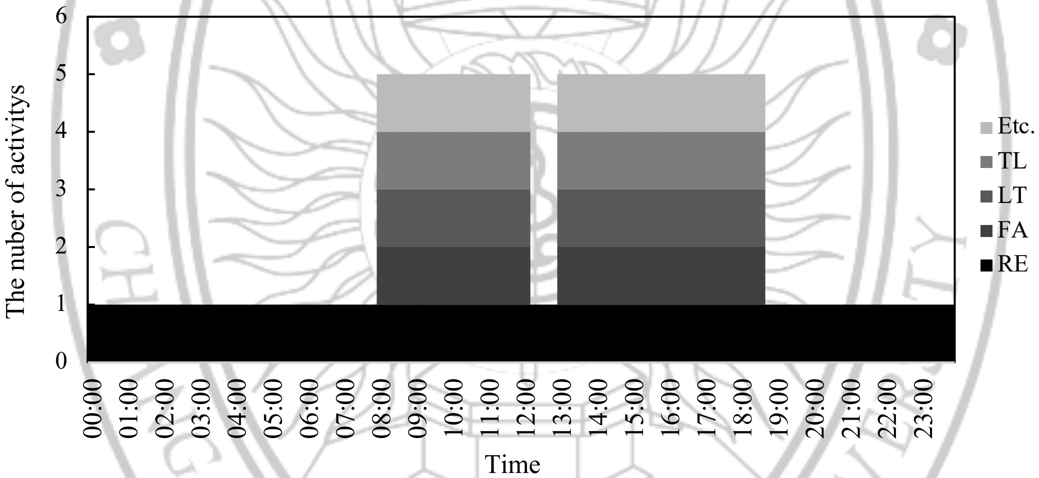


Figure 4.64 The number of events in CHO

The listed activities for the community hospital office building are crucial for the effective functioning of the building and the safety of its occupants. The use of refrigerators is necessary to store perishable medical items, while fans maintain a comfortable environment and reduce humidity, which is crucial in a medical facility. Lighting is critical for visibility and effective performance of staff, and proper restroom facilities are crucial for hygiene and the prevention of the spread of infections.

Additionally, other medical activities requiring energy, such as the use of medical equipment, are essential for the treatment and care of patients. All in all, these activities are necessary for the proper functioning of the community hospital office building and the health of its occupants.

4.1.1.3 Commercial

Coffee shop: The characteristics and number of activities that occur within a commercial building that sells drinks or coffee were investigated, and it was found that there were only five activities: turning on lights, boiling water, using a blender, washing dishes, and brewing coffee with a coffee maker. The time intervals for each activity are presented in Figure 4.65. The frequency and duration of each activity were examined, it was found that the activity with the longest duration was boiling water, which occurred between 6:30 and 18:30, averaging 12 hours per day. The second activity, washing dishes, occurred at similar intervals, starting from 7:00 to 18:00, with an average duration of 1 minute and occurring about 50 times per day. The third activity, brewing coffee, took approximately 1 minute per brew and occurred about 10 times per day between 7:30 and 15:15. The fourth activity, turning on lights, occurred twice a day at 6:30-9:45 and 17:15-19:00, averaging 240 minutes per day and happening twice a day. Finally, the last activity, using a blender to make drinks, occurred between 12:00 and 16:30, averaging 3 minutes per blend and occurring about 20 times per regular day and approximately 40 times on weekends.

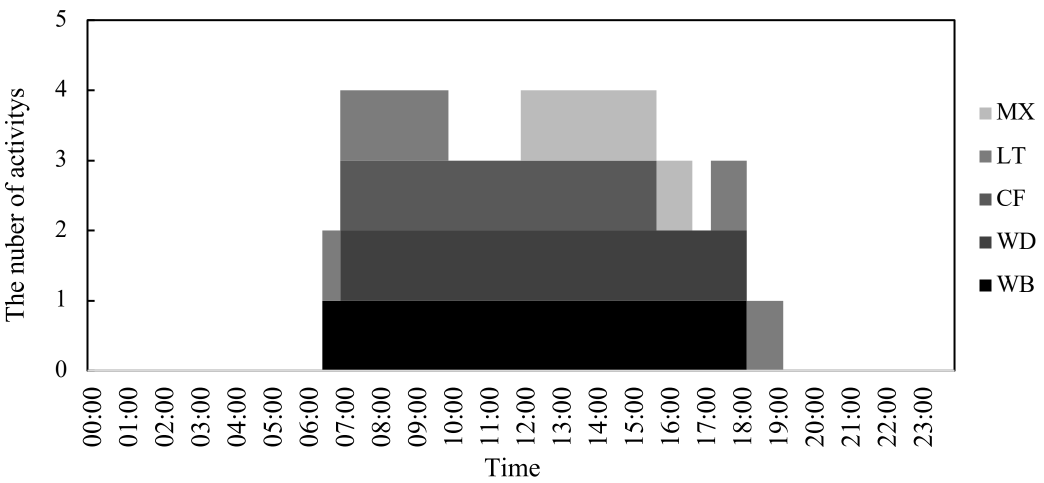


Figure 4.65 The number of events in COF

The behavior of the activities occurring within a commercial building that sells drinks or coffee has been investigated, and it has been found that boiling water has the longest duration among the activities due to its multiple uses, including making tea, and coffee. dishes and glasses occur at similar intervals to boiling water since maintaining hygiene is crucial in coffee shops, and customers tend to visit at various times throughout the day. Turning on the lights during operational hours is essential to provide proper visibility for customers and employees, and the timing of this activity is based on the opening and closing hours of the coffee shop. The use of a blender is most frequent during the afternoon and especially at weekends when the majority of the student population is off work.

4.1.2 Identification of activity

To present the frequency of activities in each building, a detailed breakdown of data presentation is provided for each sector, categorized by individual buildings. Energy-related data can be classified into two categories: activities or electrical appliances that continuously require energy usage, and activities that consume energy over a long period, such as refrigerators, freezers, lighting systems, televisions, fans, air conditioning systems, as well as other short-term activities like bathroom use, cooking, and bathing. To determine the activities that occur, peak loads for each sector are considered to identify patterns or behaviors of normal usage, or activities that may use resources in a coordinated manner. The frequency of activities that occur in each building varies accordingly.

The process of activity identification involves the utilization of data on energy consumption, water usage, and waste generation obtained from smart meters to confirm the peak load period for each activity. Questionnaires are utilized to determine the timing of each activity, and the analysis is divided based on consumer profiles, as illustrated in Table 4.25. By comparing the data from both groups, the behavior of each consumer profile can be ascertained. It is important to separate the data on the quantity of energy consumption, water usage, and waste generation of each activity that occurs in each building, which is a summary of data for all consumers within the building, as shown in Table 4.34, to identify each individual consumer. Therefore, data quantification needs to be separated to identify each individual consumer.

Table 4.34 Consumer profile of people living in each building

Community profile	Building								
	GH1	**GH2**	**SH1**	**SH2**	**HH1**	**HH2**	**SCO**	**CHO**	**COF**
CP1									
CP2						✓			
CP3			✓			✓			
CP4			✓						
CP5									
CP6		✓							
CP7									
CP8									
CP9				✓✓✓	✓✓				
CP10									
CP11	✓		✓	✓					
CP12	✓	✓							
CP13									
CP14									

An analysis of the behavioral characteristics that occur within the building with respect to the quantity of energy usage, water consumption, and waste generation, when compared to the frequency of each activity that occurs from each individual consumer as shown in Figure 4.66 which illustrates the percentage frequency of each activity within the building from the first consumer in building GH1, and Figure 4.67 which provides details of the second consumer, it can be concluded that.

Upon analyzing the energy consumption quantity from Figure 4.66 (a) and Figure 4.67 (a) depicting the average daily energy consumption within the building over different time intervals, it becomes evident that the amount of activity occurring during each time interval is directly proportional to the energy consumption quantity within the building. As observed from the graph, the energy consumption quantity is influenced by the activities taking place within the building, just like the water consumption quantity shown in Figure 4.66 (b) and Figure 4.67 (b). The time intervals with a higher frequency of activities contribute to a greater water consumption quantity, which is dependent on the individual usage patterns of the consumers.

The quantity of waste generated within a building, as illustrated in Figure 4.66, does not necessarily have a significant impact on the occurrence of waste generation for each activity during different time periods within the building. This is different from the amount of waste that is actually generated, which is of considerable importance. The average daily amount of waste disposed of for (c) General, (d) Organic, and (e) Recyclable waste, by Consumer 1 in house GH1. Similarly, Figure 4.67 (c)-(e) shows the same for Consumer 2. It was found that the time periods with the highest average amount of waste disposed of did not correspond to the time periods with the highest occurrence of activities within the building.

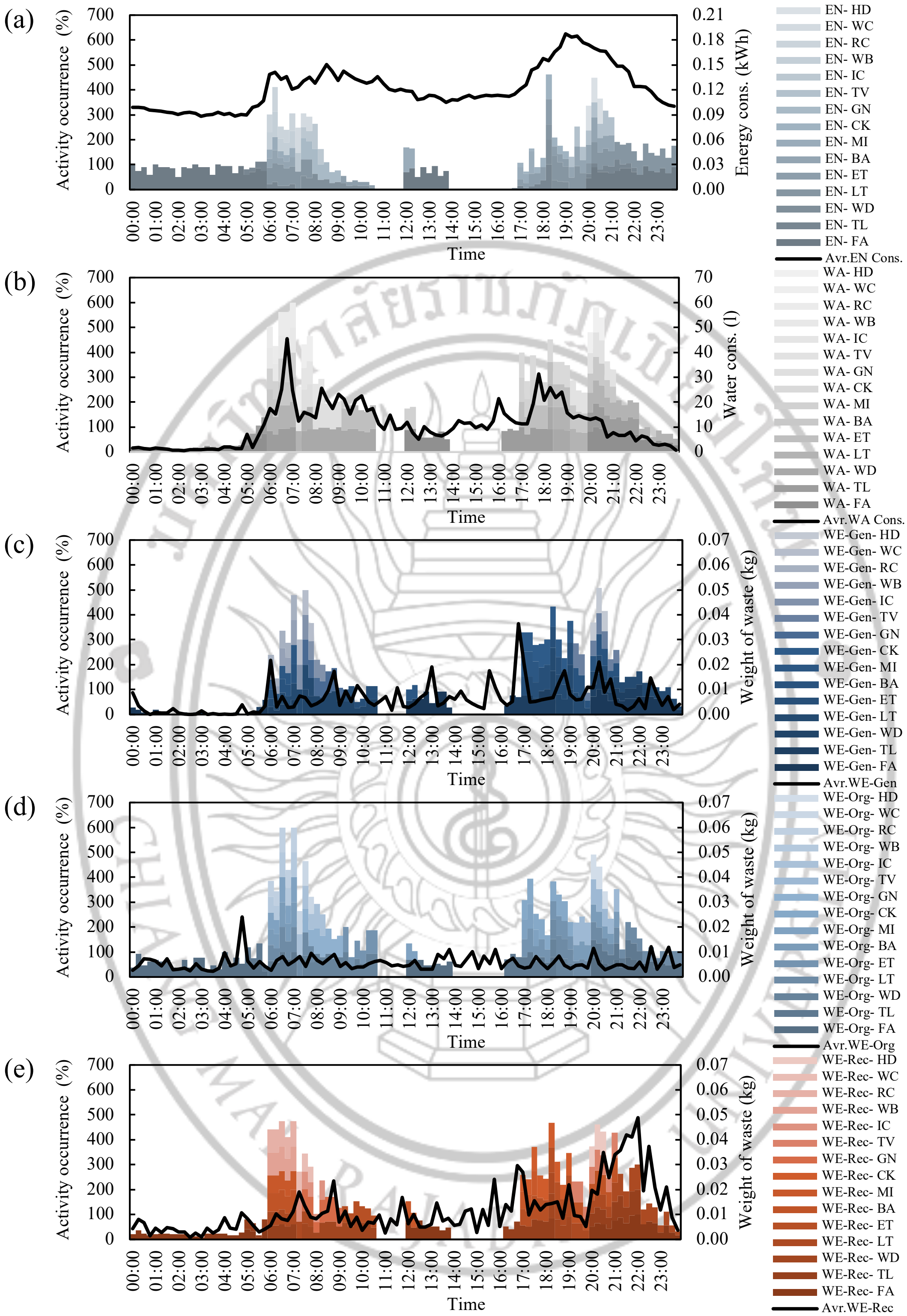


Figure 4.66 The activity occurrence in GH1 of 1st consumer with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

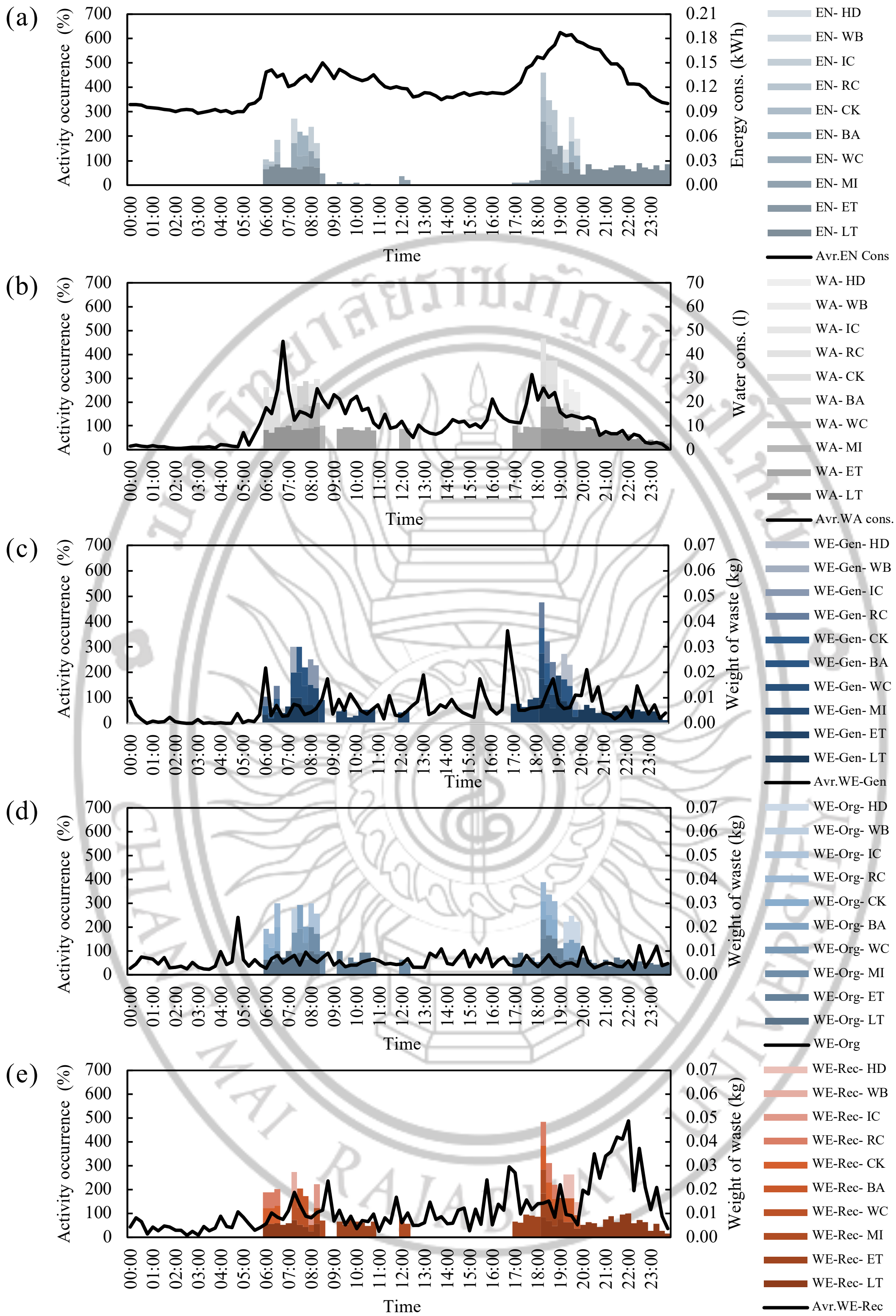


Figure 4.67 The activity occurrence in GH1 of 2nd consumer with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

Table 4.35 Size, number, proportion, and total consumption of appliances in each sample building

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9**	**CP9**	**CP9**	**CP11**	**CP9**	**CP9**	**CP2**	**CP3**
Lighting	LED	Size (W)	18.00	18.00	10.00	10.00	22.00	15.00	15.00	15.00	15.00	15.00	15.00	10.00	10.00	12.00	12.00
		Unit	10.00	12.00	9.00	9.00	1.00	2.00	2.00	8.00	8.00	8.00	8.00	8.00	8.00	3.00	3.00
	Fluorescent	Size (W)	23.00	-	12.46	12.46	-	41.00	41.00	-	-	-	-	-	-	18.00	18.00
		Unit	1.00	-	13.00	14.00	-	1.00	1.00	-	-	-	-	-	-	3.00	3.00
	Total load (W)		203.00	216.00	252.00	264.46	22.00	71.00	71.00	120.00	120.00	120.00	120.00	80.00	80.00	90.00	90.00
Fan	Ceiling	Size (inch)	16.00	16.00	16.00	16.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	4.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Wall mounted	Size (inch)	-	-	16.00	16.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	-	3.00	3.00	-	-	-	-	-	-	-	-	-	-	-
	Table	Size (inch)	14.00	18.00	16.00	16.00	18.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
		Unit	1.00	2.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
	Total load (W)		70.00	245.00	353.25	353.25	64.00	50.25	50.25	50.25	50.25	50.25	50.25	50.25	50.25	100.50	100.50
AC	Conv.	Size (BTU)	-	-	18,000	18,000	-	-	-	-	-	-	-	-	-	-	-
		Seer	-	-	15.00	15.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (Wh)		-	-	1,200.00	1,200.00	-	-	-	-	-	-	-	-	-	-	-
Refrigerator	Conv. Single-d	Size (ft^3)	6.40	5.50	6.40	6.40	5.20	5.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00	-	-
		Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-
	Inv. Single-d	Size (ft^3)	-	-	-	-	-	-	-	-	-	-	-	-	-	3.40	3.40
		Unit	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00

Table 4.35 (Cont.)

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9	CP9	CP9	CP11	CP9	CP9	CP2	CP3
Refrigerator	Conv. Double-d	Size (ft^3)	-	7.70	6.40	6.40	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Inv. Double-d	Size (ft^3)	6.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		265.50	332.90	331.75	331.75	123.73	122.32	122.32	122.32	122.32	122.32	122.32	196.42	196.42	65.55	65.55
Heater	Electricity	Size (w)	4,500.00	4,500.00	4,311.00	4,311.00	-	-	-	-	-	-	-	4,500.00	4,500.00	3,500.00	3,500.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	1.00	1.00	1.00	1.00
	Total load (W)		4,500.00	4,500.00	4,311.00	4,311.00	-	-	-	-	-	-	-	4,500.00	4,500.00	3,500.00	3,500.00
Hair dry		Size (W)	1,000.00	1,000.00	1,350.00	1,350.00	-	-	-	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	-	1,200.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00
	Total load (W)		1,000.00	1,000.00	1,350.00	1,350.00	-	-	-	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	-	1,200.00
Rice cook	Conv.	Size (L)	1.80	1.80	-	-	-	-	-	-	-	-	-	1.80	1.80	-	-
		Unit	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00	-	-
	Total load (W)		630.00	630.00	-	-	-	-	-	-	-	-	-	630.00	630.00	-	-
Microwave		Size (W)	1,300.00	700.00	800.00	800.00	1,500.00	1,800.00	1,800.00	-	-	-	-	-	-	1,200.00	1,200.00
		Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	1.00	1.00
	Total load (W)		1,300.00	700.00	800.00	800.00	1,500.00	1,800.00	1,800.00	-	-	-	-	-	-	1,200.00	1,200.00
Water boiler	Kettle	Size (l)	-	-	-	-	0.50	-	1.70	1.00	1.00	1.00	1.00	-	-	-	-
		Unit	-	-	-	-	1.00	-	1.00	1.00	1.00	1.00	1.00	-	-	-	-

Table 4.35 (Cont.)

Building			GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile			CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9	CP9	CP9	CP11	CP9	CP9	CP2	CP3
Water boiler	Thermos	Size (l)	2.50	-	1.80	1.80	-	-	-	-	-	-	-	-	-	-	-
		Unit	1.00	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		700.00	-	657.15	657.15	1,000.00	-	1,500.00	1,510.00	1,510.00	1,510.00	1,510.00	-	-	-	-
Blender		Size (W)	-	1,400.00	800.00	800.00	-	-	-	-	-	-	-	-	-	-	-
		Unit	-	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Total load (W)		-	1,400.00	800.00	800.00	-	-	-	-	-	-	-	-	-	-	-
Washer	Twin tub	Size (kg)	11.00	11.00	11.00	11.00	-	-	-	8.00	8.00	8.00	8.00	-	-	-	-
		Unit	2.00	2.00	2.00	2.00	-	-	-	1.00	1.00	1.00	1.00	-	-	-	-
	Top load	Size (kg)	-	-	-	-	-	-	-	-	-	-	-	8.00	8.00	8.00	8.00
		Unit	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00	1.00	1.00
	Total load (W)		952.42	952.42	952.42	952.42	-	-	-	390.00	390.00	390.00	390.00	350.00	350.00	350.00	350.00
Iron		Size (W)	1,000.00	1,500.00	1,000.00	1,000.00	-	-	1,200.00	1,500.00	1,500.00	1,500.00	1,500.00	1,200.00	1,200.00	-	-
		Unit	1.00	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-
	Total load (W)		1,000.00	1,500.00	1,000.00	1,000.00	-	-	1,200.00	1,500.00	1,500.00	1,500.00	1,500.00	1,200.00	1,200.00	-	-
TV	LED	Size (inch)	32.00	32.00	55.00	55.00	-	-	-	-	-	-	-	-	-	32.00	32.00
		Unit	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00
	Total load (W)		45.00	45.00	108.33	108.33	-	-	-	-	-	-	-	-	-	45.00	45.00

Table 4.36 Activity time, Frequency, and period of each consumer and building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Lighting	Time (min)	840.00	420.00	300.00	300.00	240.00	480.00	300.00	720.00	390.00	420.00	330.00	300.00	300.00	900.00	780.00
	Frequency (Times)	1.00	2.00	2.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
Fan	Time (min)	600.00	660.00	540.00	540.00	360.00	840.00	5.00	690.00	327.00	-	120.00	300.00	120.00	900.00	780.00
	Frequency (Times)	2.00	2.00	-	-	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	2.00	1.00	1.00
	Period	Day	Day	-	-	Day	Day	Day	Day	Day	-	Day	Day	Day	Day	Day
Bathing	Time (min)	15.00	10.00	30.00	30.00	10.00	15.00	10.00	30.00	25.00	30.00	15.00	10.00	10.00	30.00	30.00
	Frequency (Times)	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
Toilet	Time (min)	1.00	1.00	1.00	1.00	2.00	-	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00	2.00
	Frequency (Times)	10.00	6.00	4.00	4.00	4.00	-	3.00	3.00	2.00	3.00	3.00	4.00	3.00	3.00	2.00
	Period	Day	Day	Day	Day	-	-	Day	Day	Day	Day	Day	Day	Day	Day	Day
Hair drying	Time (min)	10.00	5.00	15.00	15.00	-	-	5.00	-	5.00	-	-	-	3.00	5.00	-
	Frequency (Times)	0.43	0.57	1.00	1.00	-	-	0.14	-	1.00	-	-	-	1.00	2.00	-
	Period	Day	Day	Day	Day	-	-	Day	-	Day	-	-	-	Day	Day	-
Washer	Time (min)	45.00	30.00	-	50.00	-	-	-	60.00	50.00	-	-	-	45.00	45.00	-
	Frequency (Times)	3.00	2.00	-	2.00	-	-	-	1.00	1.00	-	-	-	1.00	1.00	-
	Period	Week	Week	-	Week	-	-	-	Week	Week	-	-	-	Week	Week	-
Iron	Time (min)	60.00	60.00	-	-	-	-	10.00	5.00	5.00	5.00	10.00	10.00	60.00	-	-
	Frequency (Times)	2.00	2.00	-	-	-	-	1.00	7.00	7.00	7.00	7.00	7.00	1.00	-	-
	Period	Week	Week	-	-	-	-	Week	Week	Week	Week	Week	Week	Week	-	-

Table 4.36 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Rice cook	Time (min)	30.00	20.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	0.71	2.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Period	Day	Day	-	-	-	-	-	-	-	-	-	-	-	-	-
Microwave	Time (min)	10.00	2.00	2.00	2.00	2.00	6.00	5.00	-	-	-	-	-	-	-	30.00
	Frequency (Times)	4.00	5.00	1.00	1.00	14.00	14.00	2.00	-	-	-	-	-	-	-	5.00
	Period	Week	Week	Week	Week	Week	Week	Week	-	-	-	-	-	-	-	Week
Water boiling	Time (min)	5.00	15.00	5.00	5.00	-	-	3.00	5.00	-	-	-	-	-	-	-
	Frequency (Times)	1.00	1.00	1.00	1.00	-	-	2.00	1.00	-	-	-	-	-	-	-
	Period	Day	Day	Day	Day	-	-	Day	Day	-	-	-	-	-	-	-
Mixer	Time (min)	10.00	-	3.00	3.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	5.00	-	0.50	0.50	-	-	-	-	-	-	-	-	-	-	-
	Period	Week	-	Week	Week	-	-	-	-	-	-	-	-	-	-	-
TV	Time (min)	-	60.00	180.00	180.00	-	-	-	-	-	-	-	-	-	60.00	120.00
	Frequency (Times)	-	0.43	1.00	1.00	-	-	-	-	-	-	-	-	-	1.00	1.00
	Period	-	Day	Day	Day	-	-	-	-	-	-	-	-	-	Day	Day
Eating	Time (min)	30.00	25.00	25.00	25.00	25.00	30.00	20.00	20.00	25.00	25.00	15.00	30.00	-	15.00	20.00
	Frequency (Times)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00	3.00	-	2.00	0.71
	Period	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	-	Day	Day
Washing dish	Time (min)	10.00	15.00	5.00	5.00	1.00	5.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00	5.00	20.00
	Frequency (Times)	2.00	2.00	2.00	2.00	2.00	2.00	-	1.00	1.00	1.00	2.00	2.00	2.00	2.00	0.29
	Period	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	Day	Day	Day	Day	Day

Table 4.36 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Community profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
Gardening	Time (min)	-	30.00	30.00	30.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	-	0.57	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Period	-	Day	Day	Day	-	-	-	-	-	-	-	-	-	-	-
Wash car	Time (min)	-	30.00	-	-	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-
	Period	-	Week	-	-	-	-	-	-	-	-	-	-	-	-	-
Pet	Time (min)	30.00	-	30.00	30.00	-	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	1.00	-	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
	Period	Week	-	Week	Week	-	-	-	-	-	-	-	-	-	-	-
Cooking	Time (min)	45.00	45.00	60.00	60.00	35.00	-	-	-	-	-	-	-	-	-	-
	Frequency (Times)	2.00	1.00	2.00	2.00	2.00	-	-	-	-	-	-	-	-	-	-
	Period	Day	Day	Day	Day	Day	-	-	-	-	-	-	-	-	-	-

An analysis was conducted on the amount of energy usage, water consumption, and waste generation for each individual consumer within a building, in order to distinguish usage patterns and create customer profiles for all buildings with regards to their resource consumption. The quantity of energy usage and waste generation was compared across all customer profiles. To conduct this analysis, activity, and device usage data from each individual consumer at the time of measurement was collected, as presented in Table 4.35 and Table 4.36. The percentage of energy usage and waste generation was then determined and adjusted accordingly for each individual consumer. The analysis was performed using two methods: analyzing usage patterns for each individual consumer with respect to the type of community resource consumed, and analyzing activities in which energy, water, and waste were generated by each individual consumer through the use of community resources.

An analysis was conducted on the energy consumption of consumer 1 within GH1, as shown in Figure 4.68. It was found that the activity with the highest and most sustained energy usage was the use of the refrigerator (GH1CP12-RE), with an average consumption of 32.75 Wh (SD = 5.99) throughout the day. The next activity with the highest energy consumption was the use of electric lighting (GH1CP12-LT), which occurred during 6:00 – 8:00 and 18:00 – 23:45 with an average electricity consumption of 10.19 Wh (SD = 4.98). The third activity was the use of a fan (GH1CP12-FA), which was divided into three time periods according to the frequency of the activity occurring within the building, with an average energy consumption of 4.02 Wh (SD = 2.12) during each period. Other activities with lower energy consumption included bathing (2.15 Wh, SD = 0.82), cooking rice (1.27 Wh, SD = 0.30), laundry (1.18 Wh, SD = 0.28), washing clothes (0.40 Wh, SD = 0.07), hair drying (0.27 Wh, SD = 0.05), TV viewing (0.16 Wh, SD = 0.05), and using a microwave (0.16 Wh, SD = 0.05).

It should be noted that the quantity of energy used within a building by the first consumer is generally higher than that of the second consumer, with almost all activities except for the use of refrigerators. This is due to the fact that the second consumer has an additional cake refrigerator, which is an electrical appliance that operates continuously and has a relatively high power consumption rate. Consequently, this has an impact on the energy usage pattern of the second consumer, as depicted in Figure 4.69. The average energy consumption for the refrigerator throughout the day was found to be 26.12 Wh with a standard deviation (SD) of 4.77, while for the cake refrigerator, it was 52.15 Wh with an SD of 9.53. On the other hand, the average energy consumption for other activities throughout the day was found to be 9.53, 4.15, 1.00, 0.83, 0.71, 0.31, 0.30, and 0.24 Wh with SDs of 4.73, 0.95, 0.15, 0.15, 0.21, 0.06, 0.08, and 0.02, respectively, in the order of turning on lights, taking a shower, washing clothes, doing laundry, cooking rice, blow-drying hair, using a microwave, and boiling water.

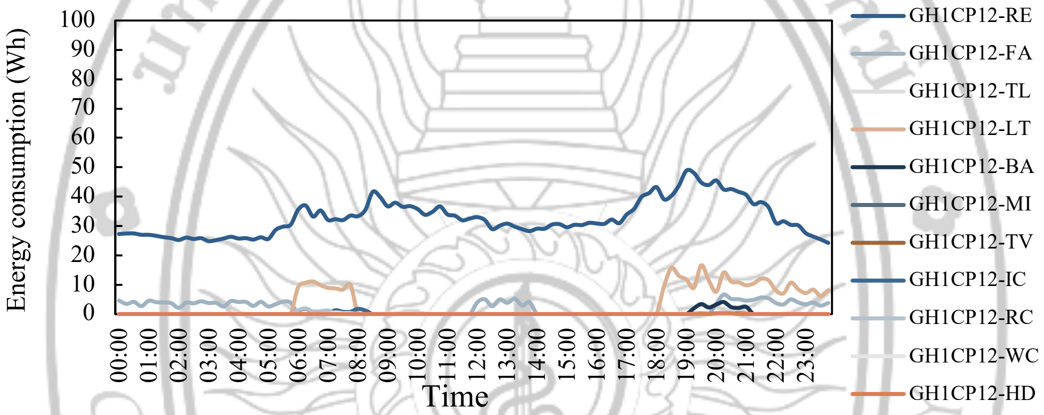


Figure 4.68 Energy consumption of each activity by 1st consumer in GH1

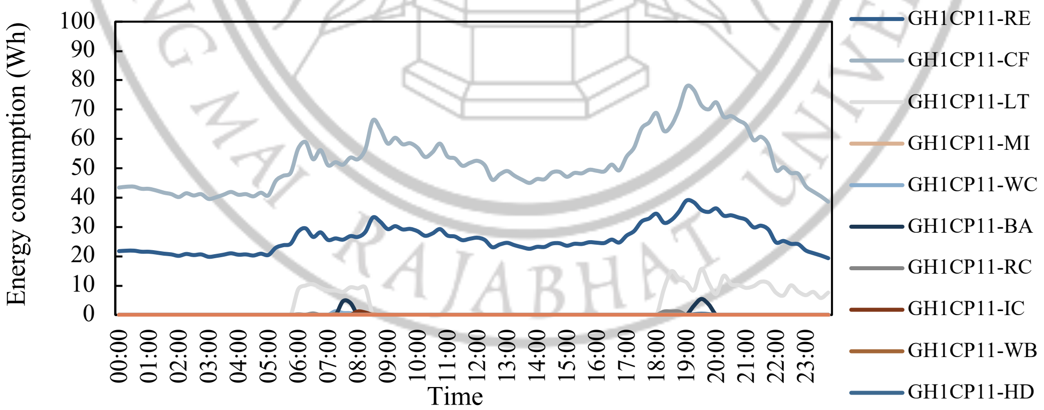


Figure 4.69 Energy consumption of each activity by 2nd consumer in GH1

Water consumption quantities of each activity by each user as shown in Figure 4.70 and Figure 4.71, it was found that water was used during activity periods within the buildings by all users. Upon considering the average water usage of the first user for each of the 10 activities, namely watering and caring for plants, boiling water, cooking rice, bathing, cooking, dishwashing, eating, using the bathroom, doing laundry, and washing the car, the values were 6.05, 5.91, 5.91, 5.07, 4.51, 4.21, 3.78, 3.08, 3.07, and 2.86 liters, respectively, with a standard deviation of 1.77, 1.57, 1.57, 2.01, 1.47, 1.92, 1.57, 2.39, 0.57, and 0.72. However, for the second user, water was used in all 6 activities within the buildings, namely using the bathroom, cooking rice, eating, doing laundry, bathing, and cooking, with an average water usage of 3.71, 3.66, 2.63, 2.61, 2.13, and 0.49 liters, respectively, and a standard deviation of 1.22, 0.90, 1.12, 0.52, 0.49, and 0.12, respectively. Upon analyzing the water usage quantities of the same activity by both users, it was found that the first user used slightly more water than the second user. It should be noted that the water usage quantity for each activity varied depending on the activity duration.

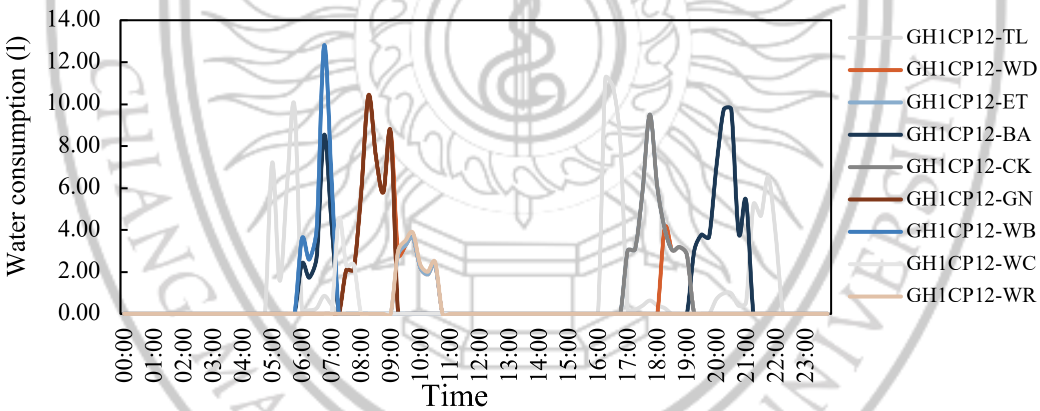


Figure 4.70 Water consumption of each activity by 1st consumer in GH1

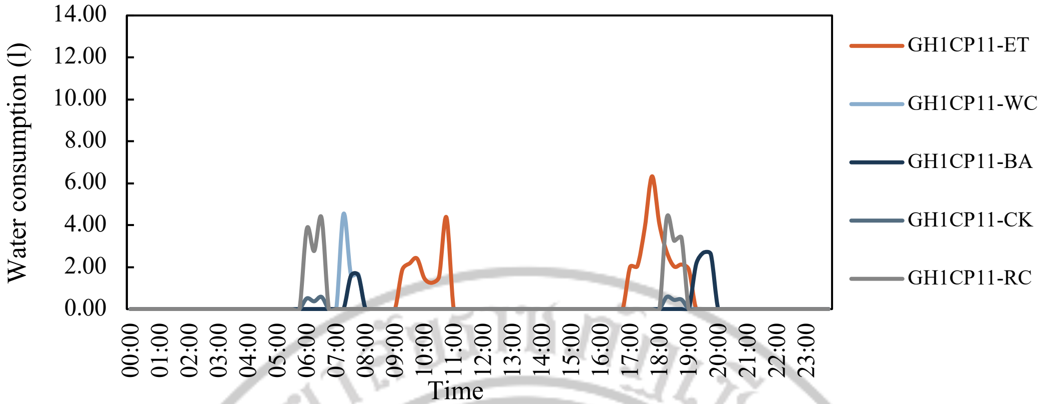


Figure 4.71 Water consumption of each activity by 2nd consumer in GH1

The quantity of waste generated within the building by each user, classified by waste type as depicted in Figure 4.72 and Figure 4.73, was analyzed. The average general waste generated for user 1 and user 2 was found to be 0.01 kg and 0.006 kg, respectively. Figure 4.74 and Figure 4.75 display the amount of organic waste generated, whereas Figure 4.76 and Figure 4.77 show the amount of recyclable waste. The quantity of waste generated fluctuates considerably and varies according to the timing of different activities carried out within the building. The average organic waste generation of 0.001 kg and recyclable waste generation of 0.002 kg for both users showed similar patterns of variability in waste generation.

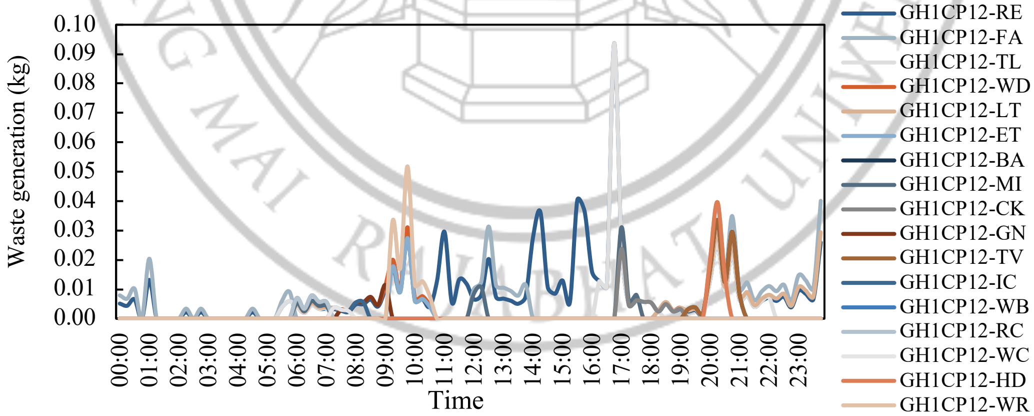


Figure 4.72 General waste generation of each activity by 1st consumer in GH1

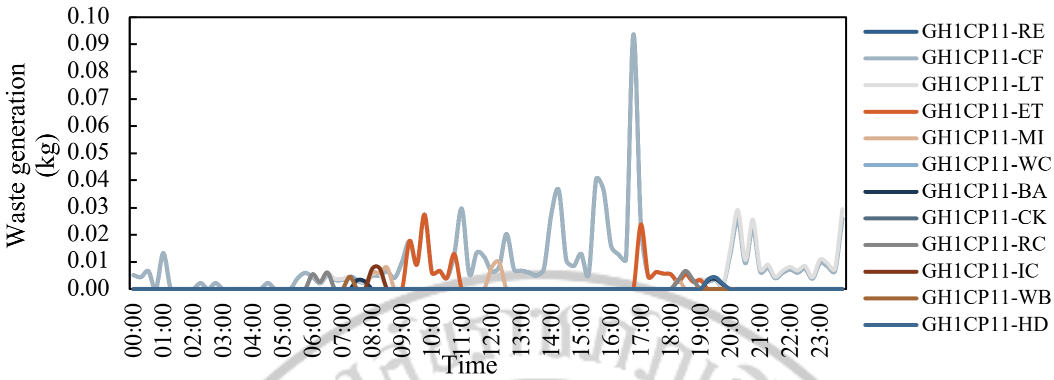


Figure 4.73 General waste generation of each activity by 2nd consumer in GH1

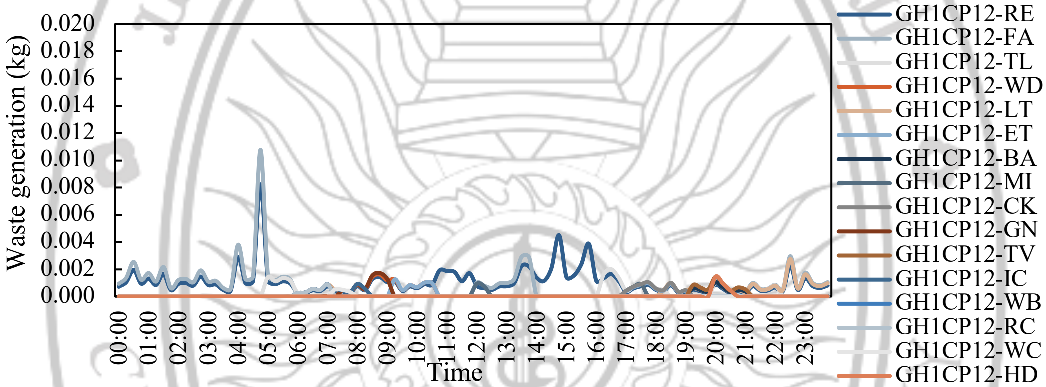


Figure 4.74 Organic waste generation of each activity by 1st consumer in GH1

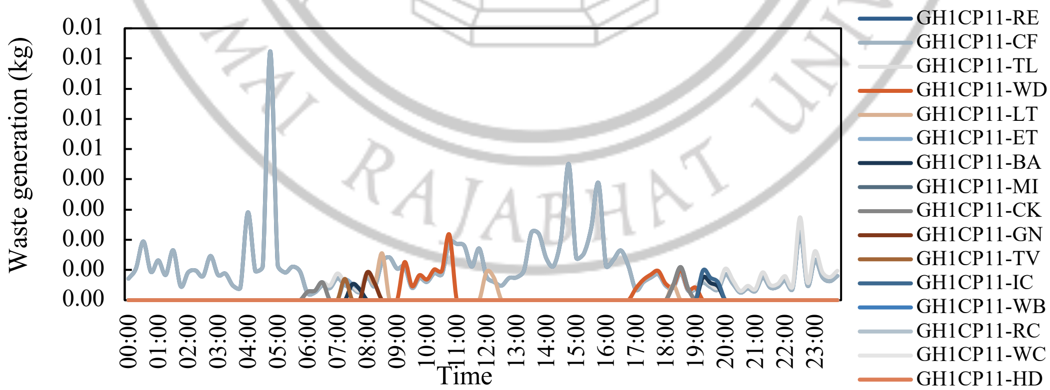


Figure 4.75 Organic waste generation of each activity by 2nd consumer in GH1

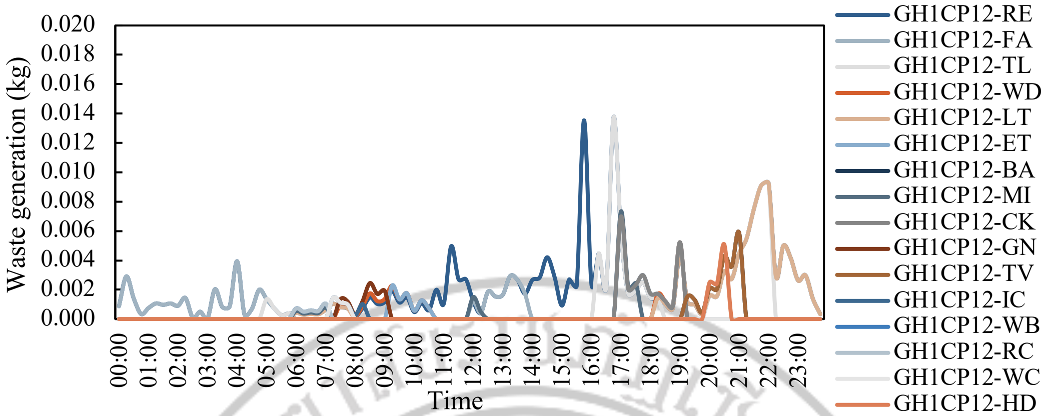


Figure 4.76 Recycle waste generation of each activity by 1st consumer in GH1

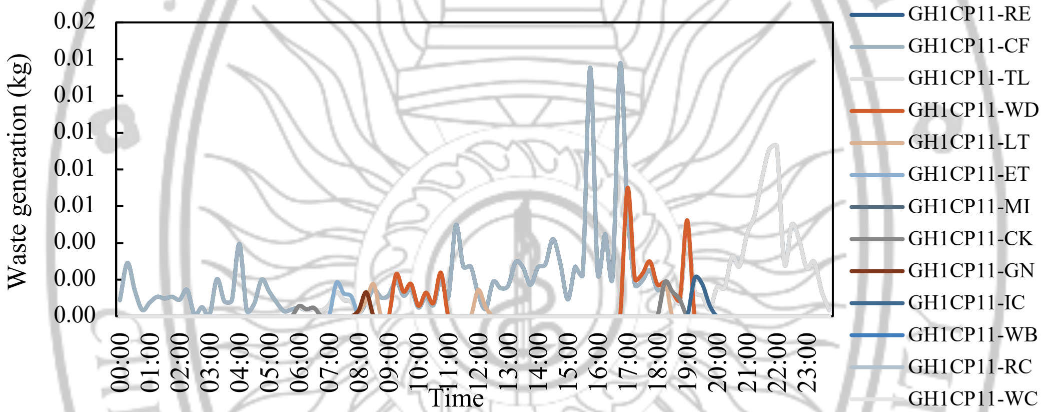


Figure 4.77 Recycle waste generation of each activity by 2nd consumer in GH1

The quantities of energy consumption, water usage, and waste generation that arise from the activities of each individual user residing in each building are displayed in the data. These quantities are calculated from the usage behaviors of both energy and water, as indicated by the trends of the data sets that point in the same direction within each group of buildings. These quantities are presented in Table 4.37. It should be noted that the amount of energy consumed by users residing in the same building and engaging in similar activities is likely to be similar due to the shared use of certain types of electrical appliances, although it may vary among users due to differences in the duration of their activities.

Table 4.37 Energy consumption of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	26.12	32.75	11.38	11.38	21.05	-	-	10.10	10.10	10.10	11.20	15.62	15.62	21.48	17.98
	SD	4.77	5.99	5.88	5.88	8.98	-	-	2.68	2.68	2.68	4.11	5.89	5.89	11.89	9.80
FA	Avr.	-	4.02	1.97	1.97	1.08	1.55	-	1.32	0.62	-	10.10	0.36	0.40	9.27	8.83
	SD	-	2.12	0.98	0.98	0.51	0.90	-	0.57	0.27	-	2.68	0.19	0.19	6.42	4.67
TL	Avr.	-	0.00	0.00	0.00	0.01	-	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
	SD	-	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
WD	Avr.	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-
LT	Avr.	9.55	10.19	5.63	5.90	0.92	0.83	3.85	6.55	3.51	3.46	-	1.19	1.09	16.55	15.68
	SD	4.74	4.98	2.87	3.02	0.40	0.44	1.70	3.02	1.59	1.63	-	0.64	0.63	11.29	8.37
ET	Avr.	-	-	-	-	-	-	-	-	-	-	2.53	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	1.41	-	-	-	-
BA	Avr.	4.17	2.15	5.83	5.83	-	-	-	-	-	-	-	2.56	2.33	26.24	13.60
	SD	0.95	0.82	1.45	1.45	-	-	-	-	-	-	-	0.71	0.64	11.39	3.50
MI	Avr.	0.30	0.04	-	-	1.04	1.09	0.59	-	-	-	-	-	-	-	-
	SD	0.08	0.01	-	-	0.25	0.33	0.15	-	-	-	-	-	-	-	-
CK	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GN	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.37 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		**CP11**	**CP12**	**CP6**	**CP12**	**CP3**	**CP4**	**CP11**	**CP9,1**	**CP9,2**	**CP9,3**	**CP11**	**CP9,1**	**CP9,2**	**CP2**	**CP3**
TV	Avr.	-	0.16	0.87	0.87	-	-	-	-	-	-	-	-	-	0.79	0.76
	SD	-	0.05	0.32	0.32	-	-	-	-	-	-	-	-	-	0.21	0.27
IC	Avr.	1.00	1.18	-	-	-	-	0.42	0.60	0.59	0.60	-	0.77	0.98	-	-
	SD	0.15	0.28	-	-	-	-	0.07	0.11	0.10	0.10	-	0.19	0.17	-	-
WB	Avr.	0.24	-	0.15	0.15	-	-	1.64	-	-	-	0.65	-	-	-	-
	SD	0.02	-	0.03	0.03	-	-	0.43	-	-	-	0.22	-	-	-	-
RC	Avr.	0.71	1.27	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.21	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	0.84	0.40	-	0.38	-	-	-	0.25	0.21	-	-	-	-	0.68	0.34
	SD	0.16	0.07	-	0.08	-	-	-	0.06	0.05	-	-	-	-	0.22	0.07
HD	Avr.	0.31	0.27	0.88	0.88	-	-	-	-	0.41	-	-	-	-	-	1.64
	SD	0.06	0.05	0.22	0.22	-	-	-	-	0.07	-	-	-	-	-	0.42
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	52.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	9.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.38 Water consumption of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FA	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TL	Avr.	3.71	3.08	0.12	0.12	2.35	3.57	2.01	7.75	1.98	2.73	2.73	18.69	11.92	0.87	0.34
	SD	1.22	2.39	0.04	0.04	0.79	0.88	0.67	3.06	0.91	0.90	0.90	8.66	8.34	0.46	0.09
WD	Avr.	-	4.14	2.72	1.81	1.33	1.23	2.01	1.88	2.14	1.20	1.20	-	17.09	11.11	3.78
	SD	-	1.92	1.27	0.85	0.35	0.41	0.63	0.36	0.40	0.21	0.21	-	4.16	3.33	1.22
LT	Avr.	-	-	-	-	2.84	2.80	2.24	-	-	-	-	-	-	-	-
	SD	-	-	-	-	1.35	1.87	1.14	-	-	-	-	-	-	-	-
ET	Avr.	2.63	3.78	2.72	2.72	1.33	1.23	2.73	9.62	7.20	6.02	3.61	-	26.08	11.11	5.67
	SD	1.12	1.57	1.27	1.27	0.35	0.41	0.83	2.57	1.65	1.06	0.64	-	7.70	3.33	1.84
BA	Avr.	2.13	4.63	1.23	1.84	1.95	2.57	1.63	20.71	10.02	19.08	9.54	33.16	64.02	8.68	5.03
	SD	0.49	1.95	0.40	0.61	0.56	0.96	0.43	5.53	1.76	5.16	2.58	8.89	15.64	4.57	1.34
MI	Avr.	-	-	-	-	1.33	1.23	2.58	-	-	-	-	-	-	-	-
	SD	-	-	-	-	0.35	0.41	0.83	-	-	-	-	-	-	-	-
CK	Avr.	0.49	4.51	2.88	2.88	1.33	-	-	-	-	-	-	-	-	-	4.25
	SD	0.12	1.47	1.22	1.22	0.35	-	-	-	-	-	-	-	-	-	1.30
GN	Avr.	-	5.87	3.75	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	1.76	1.39	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.38 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IC	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB	Avr.	-	5.91	3.93	1.31	-	-	1.63	-	-	-	-	-	-	-	1.51
	SD	-	1.57	0.69	0.23	-	-	0.43	-	-	-	-	-	-	-	0.27
RC	Avr.	3.66	5.91	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.90	1.57	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	2.61	2.61	6.72	6.72	-	-	-	8.60	7.22	-	-	43.06	-	10.20	4.47
	SD	0.52	0.52	1.37	1.37	-	-	-	2.02	1.70	-	-	9.47	-	3.47	0.83
HD	Avr.	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	0.32	-	-	-	-	-	-	-	-
WR	Avr.	-	2.86	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.72	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.39 General waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0107	0.0107	0.0217	0.0217	0.0026	-	-	0.0075	0.0075	0.0075	0.0075	0.0027	0.0027	0.0035	0.0020
	SD	0.0123	0.0123	0.0383	0.0383	0.0040	-	-	0.0101	0.0101	0.0101	0.0101	0.0037	0.0037	0.0053	0.0019
FA	Avr.	-	0.0133	0.0079	-	0.0002	0.0017	-	0.0026	-	-	-	0.0017	0.0007	0.0020	0.0032
	SD	-	0.0085	0.0063	-	0.0000	0.0023	-	0.0016	-	-	-	0.0014	0.0005	0.0019	0.0018
TL	Avr.	-	0.0119	0.0030	0.0030	0.0009	0.0009	0.0002	0.0032	-	0.0032	0.0032	0.0030	0.0009	0.0011	0.0010
	SD	-	0.0106	0.0008	0.0008	0.0004	0.0003	0.0001	0.0013	-	0.0010	0.0010	0.0011	0.0004	0.0005	0.0002
WD	Avr.	-	0.0081	0.0037	0.0037	0.0010	0.0008	0.0009	0.0026	-	0.0043	0.0043	-	0.0011	0.0025	0.0016
	SD	-	0.0043	0.0019	0.0019	0.0003	0.0004	0.0003	0.0005	-	0.0008	0.0008	-	0.0003	0.0008	0.0007
LT	Avr.	0.0079	0.0080	0.0075	0.0075	0.0002	0.0004	0.0004	0.0046	-	0.0048	0.0048	0.0005	0.0006	0.0017	0.0008
	SD	0.0056	0.0056	0.0069	0.0069	0.0001	0.0004	0.0003	0.0050	-	0.0051	0.0051	0.0005	0.0006	0.0017	0.0004
ET	Avr.	0.0090	0.0087	0.0037	0.0037	0.0010	0.0008	0.0012	0.0182	-	0.0043	0.0043	-	0.0011	0.0025	0.0016
	SD	0.0045	0.0044	0.0019	0.0019	0.0003	0.0004	0.0004	0.0047	-	0.0008	0.0008	-	0.0004	0.0008	0.0007
BA	Avr.	0.0029	0.0104	0.0030	0.0030	0.0011	0.0006	0.0001	0.0113	-	0.0027	0.0027	0.0034	0.0014	0.0011	0.0010
	SD	0.0007	0.0051	0.0008	0.0008	0.0003	0.0003	0.0000	0.0048	-	0.0007	0.0007	0.0010	0.0004	0.0005	0.0002
MI	Avr.	0.0068	0.0088	-	-	0.0010	0.0008	0.0010	-	-	-	-	-	-	-	-
	SD	0.0017	0.0037	-	-	0.0003	0.0004	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0045	0.0066	0.0207	0.0207	0.0010	-	-	-	-	-	-	-	-	-	0.0011
	SD	0.0012	0.0027	0.0110	0.0110	0.0003	-	-	-	-	-	-	-	-	-	0.0004
GN	Avr.	-	0.0058	0.0042	0.0042	-	-	-	-	-	-	-	-	-	-	0.0010
	SD	-	0.0017	0.0013	0.0013	-	-	-	-	-	-	-	-	-	-	0.0003

Table 4.39 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	-	0.0139	0.0080	0.0080	-	-	-	-	-	-	-	-	-	0.0009	0.0017
	SD	-	0.0051	0.0046	0.0046	-	-	-	-	-	-	-	-	-	0.0003	0.0007
IC	Avr.	0.0076	0.0044	-	-	-	-	0.0001	0.0040	-	0.0221	0.0221	0.0029	0.0015	-	-
	SD	0.0011	0.0010	-	-	-	-	0.0000	0.0007	-	0.0043	0.0043	0.0007	0.0003	-	-
WB	Avr.	0.0045	0.0062	0.0498	0.0498	-	-	0.0001	-	-	-	-	-	-	-	0.0018
	SD	0.0005	0.0014	0.0094	0.0094	-	-	0.0000	-	-	-	-	-	-	-	0.0003
RC	Avr.	0.0045	0.0062	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0012	0.0014	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	0.0036	0.0036	0.0246	0.0246	-	-	-	0.0432	-	-	-	0.0022	-	0.0011	0.0013
	SD	0.0006	0.0006	0.0087	0.0087	-	-	-	0.0084	-	-	-	0.0006	-	0.0005	0.0003
HD	Avr.	0.0033	0.0249	0.0213	0.0213	-	-	0.0002	0.0017	-	-	-	0.0024	-	0.0011	0.0011
	SD	0.0006	0.0047	0.0094	0.0094	-	-	0.0000	0.0003	-	-	-	0.0005	-	0.0005	0.0003
WR	Avr.	-	0.0224	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0067	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0107	-	-	0.0079	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0123	-	-	0.0063	-	-	-	-	-	-	-	-	-	-	-

Table 4.40 Organic waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0011	0.0011	0.0334	0.0334	0.0029	-	-	0.0026	0.0026	0.0026	0.0026	0.0019	0.0019	0.0014	0.0021
	SD	0.0010	0.0010	0.0376	0.0376	0.0048	-	-	0.0013	0.0013	0.0013	0.0013	0.0023	0.0023	0.0018	0.0026
FA	Avr.	-	0.0014	0.0381	0.0381	0.0006	0.0005	-	0.0009	0.0008	-	-	0.0013	0.0017	0.0008	0.0018
	SD	-	0.0013	0.0108	0.0108	0.0003	0.0004	-	0.0002	0.0001	-	-	0.0009	0.0015	0.0007	0.0012
TL	Avr.	0.0007	0.0008	0.0026	0.0026	0.0005	-	0.0007	0.0009	0.0120	0.0013	0.0013	0.0015	0.0028	0.0005	0.0007
	SD	0.0004	0.0004	0.0006	0.0006	0.0002	-	0.0003	0.0001	0.0012	0.0002	0.0002	0.0004	0.0017	0.0002	0.0002
WD	Avr.	0.0008	0.0008	0.0050	0.0050	0.0005	0.0008	0.0006	-	-	-	-	-	0.0012	0.0011	0.0006
	SD	0.0004	0.0004	0.0012	0.0012	0.0001	0.0003	0.0002	-	-	-	-	-	0.0002	0.0004	0.0002
LT	Avr.	0.0009	0.0007	0.0213	0.0213	0.0013	0.0006	0.0005	0.0031	0.0036	0.0028	0.0028	0.0015	0.0013	0.0006	0.0007
	SD	0.0002	0.0004	0.0108	0.0108	0.0007	0.0004	0.0003	0.0012	0.0012	0.0012	0.0012	0.0015	0.0015	0.0004	0.0004
ET	Avr.	0.0005	0.0007	0.0050	0.0050	0.0005	0.0008	0.0011	0.0008	0.0008	-	-	-	0.0007	0.0011	0.0006
	SD	0.0001	0.0003	0.0012	0.0012	0.0001	0.0003	0.0003	0.0001	0.0001	-	-	-	0.0002	0.0004	0.0002
BA	Avr.	0.0005	0.0005	0.0026	0.0026	0.0004	0.0009	0.0013	0.0120	-	0.0007	0.0007	0.0001	0.0059	0.0005	0.0007
	SD	0.0001	0.0002	0.0006	0.0006	0.0001	0.0003	0.0003	0.0012	-	0.0001	0.0001	0.0000	0.0026	0.0002	0.0002
MI	Avr.	0.0005	0.0006	-	-	0.0005	0.0008	0.0009	-	-	-	-	-	-	-	-
	SD	0.0001	0.0002	-	-	0.0001	0.0003	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0005	0.0007	0.0026	0.0026	0.0005	-	-	-	-	-	-	-	-	-	0.0007
	SD	0.0001	0.0002	0.0006	0.0006	0.0001	-	-	-	-	-	-	-	-	-	0.0003
GN	Avr.	0.0007	0.0010	0.0314	0.0314	-	-	-	-	-	-	-	-	-	-	0.0009
	SD	0.0001	0.0003	0.0113	0.0113	-	-	-	-	-	-	-	-	-	-	0.0003

Table 4.40 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	0.0007	0.0008	0.0005	0.0005	-	-	-	-	-	-	-	-	-	0.0005	0.0008
	SD	0.0001	0.0002	0.0001	0.0001	-	-	-	-	-	-	-	-	-	0.0001	0.0003
IC	Avr.	0.0008	0.0006	-	-	-	-	0.0018	0.0007	0.0007	-	-	0.0005	0.0002	-	-
	SD	0.0001	0.0001	-	-	-	-	0.0002	0.0001	0.0001	-	-	0.0002	0.0000	-	-
WB	Avr.	-	0.0005	0.0056	0.0056	-	-	0.0013	-	-	-	-	-	-	-	0.0012
	SD	-	0.0001	0.0009	0.0009	-	-	0.0003	-	-	-	-	-	-	-	0.0002
RC	Avr.	-	0.0005	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0001	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	-	0.0005	-	-	-	-	-	0.0013	0.0013	-	-	0.0007	-	0.0005	0.0009
	SD	-	0.0001	-	-	-	-	-	0.0001	0.0001	-	-	0.0002	-	0.0002	0.0002
HD	Avr.	-	0.0009	0.0031	0.0031	-	-	0.0054	-	-	-	-	0.0056	-	0.0005	0.0007
	SD	-	0.0002	0.0006	0.0006	-	-	0.0008	-	-	-	-	0.0006	-	0.0002	0.0002
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0010	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.41 Recycle waste generation of each activity in sample building

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
RE	Avr.	0.0022	0.0022	0.0150	0.0150	0.0032	-	-	0.0074	0.0032	0.0032	0.0032	0.0009	0.0009	0.0012	0.0010
	SD	0.0024	0.0024	0.0163	0.0163	0.0036	-	-	0.0089	0.0039	0.0039	0.0039	-	-	0.0018	0.0011
FA	Avr.	-	0.0022	0.0021	0.0021	0.0025	0.0015	-	0.0034	0.0015	-	-	0.0098	0.0079	0.0001	0.0008
	SD	-	0.0019	0.0005	0.0005	0.0014	0.0015	-	0.0014	0.0006	-	-	-	-	0.0001	0.0005
TL	Avr.	0.0025	0.0032	0.0007	0.0007	0.0015	-	0.0010	0.0020	0.0009	0.0019	0.0019	-	0.0008	0.0001	0.0000
	SD	0.0019	0.0023	0.0001	0.0001	0.0006	-	0.0003	0.0005	0.0002	0.0005	0.0005	-	-	0.0000	0.0000
WD	Avr.	0.0022	0.0015	0.0203	0.0203	0.0005	0.0007	0.0010	0.0136	0.0018	0.0057	0.0057	-	0.0009	0.0002	0.0001
	SD	0.0011	0.0007	0.0081	0.0081	0.0001	0.0002	0.0003	0.0024	0.0003	0.0010	0.0010	-	-	0.0001	0.0000
LT	Avr.	0.0011	0.0026	0.0076	0.0076	0.0007	0.0008	0.0010	0.0033	0.0015	0.0016	0.0016	0.0004	0.0019	0.0001	0.0001
	SD	0.0003	0.0019	0.0062	0.0062	0.0003	0.0006	0.0005	0.0014	0.0006	0.0007	0.0007	-	-	0.0001	0.0001
ET	Avr.	0.0014	0.0022	0.0203	0.0203	0.0005	0.0007	0.0011	0.0045	0.0030	0.0057	0.0057	-	0.0009	0.0002	0.0001
	SD	0.0002	0.0010	0.0081	0.0081	0.0001	0.0002	0.0003	0.0010	0.0007	0.0010	0.0010	-	-	0.0001	0.0000
BA	Avr.	0.0014	0.0019	0.0007	0.0007	0.0008	0.0007	0.0007	0.0029	0.0009	0.0026	0.0026	-	0.0011	0.0001	0.0000
	SD	0.0003	0.0009	0.0001	0.0001	0.0002	0.0002	0.0002	0.0006	0.0002	0.0004	0.0004	-	-	0.0000	0.0000
MI	Avr.	0.0009	0.0017	-	-	0.0005	0.0007	0.0011	-	-	-	-	-	-	-	-
	SD	0.0003	0.0008	-	-	0.0001	0.0002	0.0003	-	-	-	-	-	-	-	-
CK	Avr.	0.0009	0.0028	0.0021	0.0021	0.0005	-	-	-	-	-	-	-	-	-	0.0001
	SD	0.0003	0.0010	0.0007	0.0007	0.0001	-	-	-	-	-	-	-	-	-	0.0000
GN	Avr.	0.0008	0.0015	0.0244	0.0244	-	-	-	-	-	-	-	-	-	-	0.0002
	SD	0.0001	0.0004	0.0062	0.0062	-	-	-	-	-	-	-	-	-	-	0.0001

Table 4.41 (Cont.)

Building		GH1		GH2		SH1			SH2				HH1		HH2	
Consumer profile		CP11	CP12	CP6	CP12	CP3	CP4	CP11	CP9,1	CP9,2	CP9,3	CP11	CP9,1	CP9,2	CP2	CP3
TV	Avr.	0.0018	0.0027	0.0011	0.0011	-	-	-	-	-	-	-	-	-	0.0001	0.0001
	SD	0.0002	0.0009	0.0002	0.0002	-	-	-	-	-	-	-	-	-	0.0000	0.0000
IC	Avr.	0.0015	0.0011	-	-	-	-	0.0007	0.0097	-	0.0019	0.0019	0.0002	-	-	-
	SD	0.0003	0.0003	-	-	-	-	0.0001	0.0010	-	0.0003	0.0003	-	-	-	-
WB	Avr.	-	0.0007	0.0079	0.0079	-	-	0.0007	-	-	-	-	-	-	-	0.0000
	SD	-	0.0002	0.0014	0.0014	-	-	0.0002	-	-	-	-	-	-	-	0.0000
RC	Avr.	-	0.0007	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-
WC	Avr.	-	0.0014	0.0041	0.0041	-	-	-	0.0077	0.0030	-	-	0.0002	-	0.0000	0.0000
	SD	-	0.0002	0.0006	0.0006	-	-	-	0.0023	0.0010	-	-	-	-	0.0000	0.0000
HD	Avr.	-	0.0033	0.0040	0.0040	-	-	0.0009	0.0059	0.0043	-	-	0.0015	-	0.0001	0.0000
	SD	-	0.0006	0.0006	0.0006	-	-	0.0002	0.0010	0.0004	-	-	-	-	0.0000	0.0000
WR	Avr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	Avr.	0.0022	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SD	0.0024	-	-	-	-	-	-	-	-	-	-	-	-	-	-

5. Relationship of building activity

The relationship between energy, water, and waste is analyzed in two parts in this study, which include the overall relationship and the relationship within activities. Specifically, the relationship between energy, water, and waste data with respect to each building is examined, as well as the relationship between energy, water, and waste data based on the activities that occur within each building.

5.1 The relationship in each building

When data related to energy consumption, water usage, and waste generation across various consumer groups are analyzed, the relationships between these factors are often studied. Such an analysis can be divided into four distinct groups: the relationship between Energy and Water, Energy and Waste, Water and Waste, and the overall relationship between Energy, Water, and Waste.

To study the patterns and trends in the relationships between energy, water, and waste data, statistical techniques are used by researchers to identify correlations between the variables. Correlations help to identify the strength and direction of the relationship between two variables. For example, a positive correlation between energy and water usage would suggest that as energy usage increases, so does water usage. In contrast, a negative correlation between energy and waste generation would suggest that as energy usage increases, waste generation decreases.

When data within different buildings or consumer groups are compared, different patterns of correlations are often found by researchers. For example, in a study of six different buildings, it was found that there was a correlation only between energy and water at a level of 0.109 in GH1. In contrast, GH2 had a negative correlation between energy and waste generation at a level of 0.028. Similarly, two positive correlations were found in SH1: one between energy and water usage at a level of 0.022 and another between water usage and waste generation at a level of 0.023. SH2 had three different correlations: energy to water usage at a level of 0.082, energy to waste generation at a level of 0.037, and water usage to waste generation at a level of 0.023. HH1 and HH2 also had two positive correlations each: one between energy and water usage at levels of 0.102 and 0.300, respectively, and another between water usage and waste generation at levels of 0.090 and 0.018, respectively.

Furthermore, it is important to note that the relationships between energy, water, and waste usage within each building or consumer group also have external relationships with other buildings or consumer groups. For instance, energy usage in one building may be correlated with energy usage in other buildings, whereas water usage in one building may not be as strongly correlated with water usage in other buildings. When correlation pairs across all six buildings are examined, it is found that all three variables have statistically significant relationships, which form a complex web of interrelated factors.

In conclusion, valuable insights into patterns of resource usage and sustainability are provided by studying the relationships between energy, water, and waste usage across different consumer groups and buildings. The use of statistical techniques to identify correlations between variables can help researchers to identify areas where improvements in resource usage can be made.

5.2 The relationship based on the activities

From the data on energy consumption, water usage, and waste generation of each activity by each user, when analyzed for the relationship between energy, water, and waste as shown in Table 4.42 to Table 4.45, the behavior of actual activities within the building can be divided into two groups. The first group consists of activities that have continuous and long durations, such as using a refrigerator, turning on a fan, turning on lights, and watching television. The second group consists of activities that occur at certain intervals, such as taking a shower, using the bathroom, blow-drying hair, cooking, and eating. When analyzed, it can be seen that activities with long durations are the only ones that use electricity exclusively, which affects the amount of energy consumed within the building. When data from all three areas are analyzed, it is found that all three activities have a statistically significant relationship with each other, since the behavior of using water and disposing of waste within the building occurs during the aforementioned activities, leading to an increase in the level of correlation. Based on the data, it is found that energy usage within the building has a statistically significant relationship with waste generation within the building from activities such as using a refrigerator, turning on a fan, and turning on lights, with a mostly positive correlation. Furthermore, all three activities have a statistically significant relationship with waste generation within the building for all three types of waste, based on the data.

Upon consideration of the activities of the second group that occurred during a short period, it can be observed that each activity from each user had a different relationship level between energy, water, and waste. This is due to the type of housing, occupation, and age range, which differ as stated in the above information. These characteristics indicate that all individuals have an impact on the quantity and behavior within the building that affects the relationship level. From the activity data of using the bathroom and showering, it was found that all of them had a positive relationship level in all directions, both energy-water, energy-waste, water-waste, as well as the relationship between each type of waste, which is statistically significant.

Cooking activities have a relationship only in terms of water and waste. The relationship between water and waste is positive, and there is a significant relationship between each type of waste. This is due to the behavior of the residents within the building who mostly choose to use LPG gas as a fuel for cooking, which does not affect the amount of electricity used during the activity significantly. Therefore, it affects the relationship level between water and waste and waste to a moderate level. However, the use of fuel for cooking and lifestyle behavior still affects the relationship between energy, water, and waste that occur in rice cooking activities, as rice cooking activity is an activity that requires energy, water, and creates waste in a small amount, but this activity occurs frequently.

It was found that both the activity of boiling water and the use of a microwave had a significant statistical relationship with energy, water, and waste. Furthermore, there was a correlation between the different types of waste generated during each activity. Upon considering the activity of eating and dishwashing, it was found that both activities had a significant positive statistical correlation with water and waste, but there was little correlation between the two activities with respect to energy. Analyzing the conducted activities revealed that, in the sample group, the majority engaged in the activity of eating followed by dishwashing, and both activities were carried out by disposing of the remaining waste generated during eating before washing the utensils used for eating with water. From this observed behavior, it is evident that the activities were conducted only with the presence of water and waste. The low correlation with respect to energy is due to the fact that the activities do not require much energy, except for the use of light in the building. It is noteworthy that both eating and dishwashing activities typically occur in conjunction with turning on the lights, according to the behavioral data collected within the building. Therefore, the two activities have little statistical correlation with energy consumption.

The activity of laundry washing is another activity that has a relationship between energy and water, exclusively in a positive direction without any relationship to waste generation. Upon analysis of the activity characteristics, it can be observed that only two resources are utilized: water for cleaning clothes and electricity-powered washing machines to assist in the activity. This directly affects both relationships. Additionally, the relationship data shows that each type of waste generated during the activity is not affected by other factors and has its own level of correlation. Furthermore, the analysis of the laundry washing activity reveals that a significant amount of energy is utilized, resulting in waste generation during the activity. This is evident from the relationship data between energy and waste generated during the laundry washing activity, which shows a positive correlation. However, each type of waste generated during the activity is not correlated with each other, as observed from all user data. Consequently, the laundry washing activity only has a relationship between energy and waste generation in general.

The activity of watering plants has a relationship between energy and waste, water and waste, and the relationship within each type of waste. This is data that shows that all three relationships have a positive correlation. This is due to the fact that plant care activities involve using a large and continuous amount of water, which affects the amount of water used during the activity period. In addition, such activities involve trimming, weed removal, as well as rice collection or house cleaning, which increases the amount of waste in all three categories. However, due to the fact that the water used inside the building does not use a water pump that requires energy, this has an impact on the amount of energy used in such activities that is not related to energy.

Furthermore, data on energy consumption, water usage, and waste generation during hair blow-drying and dishwashing activities indicate that there is no correlation between energy, water, and waste in these activities. Statistical analysis concludes that both activities consume resources but are not related to each other.

Table 4.42 Energy, Water, Waste relationship in activity of refrigerator, fan toilet, and washing dish

Building (Consumer)	Resource	RE					FA					TL					WD				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-			-0.295**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	0.398**	-	-	-	-	-	-
	Gen-WE	-	-	-	-	0.540**	-	-	-	-	0.540**	-	-	-	-	-	-	-	-	-	-
	Org-WE	-0.295**	-	-	-	-	-	-	-	-	-	-	0.398**	-	-	0.567**	-	-	-	-	0.618**
	Rec-WE	-	-	0.540**	-	-	-	-	0.540**	-	-	-	-	-	0.567**	-	-	-	-	0.618**	-
GH1 (CP12)	EN	-	-	-	-0.295**	-	-	-	0.389**	0.328**	0.399**			0.337**	-	-	-	-	0.675**	0.253*	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.407**	0.800**	0.587**	-	-	0.419**	0.783**	0.606**
	Gen-WE	-	-	-	-	0.540**	0.389**	-	-	-	0.381**	0.337**	0.407**	-	0.519**	0.685**	0.675**	0.419**	-	0.689**	0.456**
	Org-WE	-0.295**	-	-	-	-	0.328**	-	-	-	0.292**	-	0.800**	0.519**	-	0.540**	0.253*	0.783**	0.689**	-	0.648**
	Rec-WE	-	-	0.540**	-	-	0.399**		0.381**	0.292**	-	-	0.587**	0.685**	0.540**	-	-	0.606**	0.456**	0.648**	-
GH2 (CP6)	EN	-	-	-	-	-	-	0.522**	-	-	0.222**	-	-	-	0.998**	-	-	-	-	0.994**	-
	WA	-	-	-	-	-	0.522**	-	-	-	-	-	-	0.693**	-	0.661**	-	-	0.765**	-	0.487**
	Gen-WE	-	-	-	-	-	-	-	-	-	0.488**	-	0.693**	-	-	-		0.765**	-	-	0.863**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.998**	-	-	-	-	0.994**	-	-	-	-
	Rec-WE	-	-	-	-	-	0.222*	-	0.488**	-	-	-	0.661**	-	-	-	-	0.487**	0.863**	-	-
GH2 (CP1)2	EN	-	-	-	-	-	-	0.522**	-	-	0.222**	-	-	-	0.998**	-	-	-	-	0.994**	-
	WA	-	-	-	-	-	0.522**	-	-	-	-	-	-	0.693**	-	0.661**	-	-	0.765**	-	0.487**
	Gen-WE	-	-	-	-	-	-	-	-	-	0.488**	-	0.693**	-	-	-	-	0.765**	-	-	0.863**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.998**	-	-	-	-	0.994**	-	-	-	-
	Rec-WE	-	-	-	-	-	0.222*	-	0.488**	-	-	-	0.661**	-	-	-	-	0.487**	0.863**	-	-
SH1 (CP3)	EN	-	-	-	0.392**	-	-	-	-	0.335**	0.378**	-	-	-	0.248*	0.327**	-	-	-	0.330**	0.838**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.486**	0.5911**	0.779**	-	-	0.490**	0.803**	0.454**
	Gen-WE	-	-	-	-	0.510**		-	-	-	-	-	0.489**	-	0.664**	0.467**	-	0.490**	-	0.674**	0.377**
	Org-WE	0.392**	-	-	-	-	0.335**	-	-	-	0.689**	0.248**	0.591**	0.664**	-	0.674	0.334**	0.803**	0.674**	-	0.674**
	Rec-WE	-	-	0.510**	-	-	0.378**	-	-	0.689**	-	0.327**	0.779**	0.467**	0.674**	-	0.838**	0.4554**	0.377**	0.674**	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	0.219*	0.409**	0.408*	-	-	0.925**	-	-	-	-	-	-	0.396**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.482**	0.625**	0.841**
	Gen-WE	-	-	-	-	-	0.219*	-	-	-	0.709**	-	0.925**	-	-	-	-	0.482**	-	0.57**	0.446**
	Org-WE	-	-	-	-	-	0.409**	-	-	-	-	-	-	-	-	-	-	0.625**	0.574**	-	0.720**
	Rec-WE	-	-	-	-	-	0.408**	-	0.709**		-	-	-	-	-	-	0.396**	0.841**	0.446**	0.720**	-
SH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	0.729**	0.545**	0.455**	0.788**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.729**	-	0.504**	0.605**	0.925**	-	-	0.550**	0.936**	0.922**
	Gen-WE	-	-	-	-	-	-	-	-	-	-	0.545**	0.504**	-	-	0.745**	-	0.550**	-	0.761**	0.621**
	Org-WE	-	-	-	-	-	-	-	-	-	-	0455**	0.605**	-	-	0.389**	-	0.936**	0.761**	-	0.925**
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.788**	0.25**	0.754**	0.389**	-	-	0.922**	0.621**	0.925**	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	0.455**	-	0.360**	-	0.663**	0.594**	0.255*	0.679**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.663**	-	0.262**	0.344**	0.525**	-	-	0.908**	-	0.909**
	Gen-WE	-	-	-	0.355**	-	0.455**	-	-	0.219*	0.528**	0.594**	0.262**	-	-	0.242**	-	0.908**	-	-	0.976**
	Org-WE	-	-	0.355**	-	-	-	-	0.219*	-	0.203*	0.255*	0.344**	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	0.360**	-	0.528**	0.203*	-	0.679**	0.525**	0.242**	-	-	-	0.909**	0.976**	-	-

Table 4.42 (Cont.)

Building (Consumer)	Resource	RE					FA					TL					WD				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.509**	-	0.356**	0.639**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.509**	-	-	-	0.502**	-	-	-	-	0.927**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	0.356**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.639**	0.520**	-	-	-	-	0.927**	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.578**	0.661**	0.397**	0.858**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.578**	-	0.770**	0.854**	0.767**	-	-	0.909**	-	0.994**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	0.661**	0.770**	-	0.864**	0.678**	-	0.909**	-	-	0.906**
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	0.397**	0.854**	0.864**		0.676**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	0.858**	0.767**	0.678**	0.676**	-	-	0.994**	0.906**	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0..770**	0.854**	0.764**	-	-	0.909**	-	0.994**
	Gen-WE	-	-	-	0.355**	-	-	-	-	-	-	-	0.770**	-	0.864**	0.678**	-	0.909**	-	-	0.906**
	Org-WE	-	-	0.355**	-	-	-	-	-	-	-	-	0.854**	0.864**	-	0.676**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	0.767**	0.678**	0.676**	-	-	0.994**	0.906**	-	-
HH1 (CP9)	EN	-	-	0.369**	-	-	-	-	-	0.369**	-	-	-	0.665**	0.246*	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.369**		-	-	-	-	-	0.369**	-	-	0.665**	-	-	0.429**	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.223*	-	-	-	-	-	0.246*	-	0.429**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	0.223*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.369**	-	-	-	-	-	-	-	-	-	0.481**	-	-	-	-	0.534**	0.247**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.369**	-	-	-	-	-	-	-	0.347**	-	0.481**	-	-	0.272**	0.582**	0.534**	-	-	0.224*	0.829**
	Org-WE	-	-	-	-	0.223*	-	-	-	-	-	-	-	0.272**	-	-	0.247*	-	0.224*	-	-
	Rec-WE	-	-	-	0.223*	-	-	-	0.347**	-	-	-	-	0.582**	-	-	-	-	0.829**	-	-
HH2 (CP2)	EN	-	-	-	-	0.215*	-	-	0.341**	0.412**	0.489**	-	-	-	0.271**	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.666**	0.714**	0.560**	-	-	0.863**	0.453**	0.718**
	Gen-WE	-	-	-	0.660**	0.718**	0.341**	-	-	0.245*	0.229*	-	0.666**	-	0.544**	0.298**	-	0.863**	-	0.721**	0.780**
	Org-WE	-	-	0.660**	-	0.650**	0.412**	-	0.245*	-	0.227*	0.271**	0.714**	0.544**	-	0.314**	-	0.453**	0.721**	-	0.498**
	Rec-WE	-0.215*		0.718**	0.650**	-	0.489**	-	0.229*	0.227*	-	-	0.560**	0.298**	0.314**	-	-	0.718**	0.780**	0.498**	-
HH2 (CP3)	EN	-	-	-	-	-0.240*	-	-	0.295**	0.579**	-	-	-	-	0.659**	-	-	-	-	0.611**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	0.343**	0.654**	0.829**	-	-	0.680**	0.685**	0.687**
	Gen-WE	-	-	-	0.273**	0.244*	0.295**	-	-	0.379**	0.349**	-	0.343**	-	0.509**	-	-	0.680**	-	0.476**	0.269**
	Org-WE	-	-	0.273**	-	0.234*	0.579**	-	0.379**	-	0.524**	0.659**	0.654**	0.509**	-	0.533**	0.611**	0.685**	0.476**	-	0.649**
	Rec-WE	-0.240*	-	0.244*	0.234*	-	-	-	0.349**	0.524**	-	-	0.829**	-	0.533**	-	-	0.687**	0.269**	0.649**	-

Table 4.43 Energy, Water, Waste relationship in activity of lighting, eating, bathing, and microwave

Building (Consumer)	Resource	LT					ET					BA					MI				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	0.645**	-	-	-	-	-	-	-	-	0.989**	0.981**	0.937**	0.927**	-	-	0.702**	0.218*	0.510**
	WA	-	-	-	-	-	-	-	0.633**	-	-	0.959**	-	0.936**	0.959**	0.910**	-	-	-	-	-
	Gen-WE	0.645**	-	-	-	-	-	0.633**	-	-	-	0.981**	0..936**	-	0.964**	0.979**	0.702**	-	-	-	-
	Org-WE	-	-	-	-	0.844**	-	-	-	-	0.995**	0.937**	0.959**	0.964**	-	0.976**	0.218*	-	-	-	0.865**
	Rec-WE	-	-	-	0.844**	-	-	-	-	0.995*	-	0.927**	0.910**	0.979**	0.976**	-	0.510**	-	-	0.865**	-
GH1 (CP12)	EN	-	-	0.539**	0.713**	0.620**	-	-	0.671**	0.315**	-	-	0.729**	0.825**	0.884**	0.709**	-	-	0.751**	0.466**	-
	WA	-	-	-	-	-	-	-	0.418**	0.767**	0.712**	0.729**	-	0.608**	0.685**	0.746**	-	-	-	-	-
	Gen-WE	0.539**	-	-	0.608**	0.348**	0.617**	0.418**	-	0.712**	0.542**	0.825**	0.608**	-	0.763**	0.565**	0.751**	-	-	0.716**	0.659**
	Org-WE	0.713**	-	0.608**	-	0.569**	0.315**	0.767**	0.712**	-	0.603**	0.884**	0.685**	0.763**	-	0.559**	0.466**	-	0.716**	-	0.504**
	Rec-WE	0.620**	-	0.348**	0.569**	-	-	0.712**	0.542**	0.603**	-	0.709**	0.746**	0.565**	0.559**	-	-	-	0.659**	0.504**	-
GH2 (CP6)	EN	-	-	0.357**	-	-	-	-	-	0.994**	-	-	0.742**	0.462**	-	0.396**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.765**	-	0.487**	0.742**	-	0.693**	-	0.661**	-	-	-	-	-
	Gen-WE	0.3587**	-	-	-	0.207*	-	0.765**	-	-	0.863**	0.462**	0.693**	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.670**	0.994**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	0.207*	0.670**	-	-	0.487**	0.863**	-	-	0.396**	0.661**	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	0.357**	-	-	-	-	-	0.994**	-	-	0.742**	0.462**	-	0.396**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.765**	-	0.487**	0.742**	-	0.693**	-	0.661**	-	-	-	-	-
	Gen-WE	0.357**	-	-	-	0.207*	-	0.765**	-	-	0.863**	0.462**	0.693**	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	0.670**	0.994**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	0.207*	0.670**	-	-	0.487**	0.863**	-	-	0.396**	0.661**	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	0.688**	0.435**	0.525**	0.751**	-	-	-	0.334**	0.838**	-	-	-	0.396**	0.727**	-	0.842**	0.599**	0.846**	0.832**
	WA	0.688**	-	0.670*	0.550**	0.719**	-	-	0.490**	0.803**	0.454**	-	-	0.410**	0.427**	0.497**	0.842**	-	0.490**	0.803**	0.454**
	Gen-WE	0.435**	0.670**	-	0.426**	0.470**	-	0.409**	-	0.674**	0.377**	-	0.410**	-	0.807**	0.519**	0.599**	0.409**	-	0.674**	0.377**
	Org-WE	0.525**	0.550**	0.426**	-	0.455**	0.334**	0.803**	0.674**	-	0.674**	0.396**	0.427**	0.807**	-	0.851**	0.846**	0.803**	0.674**	-	0.674**
	Rec-WE	0.751**	0.719**	0.470**	0.455**	-	0.838**	0.454**	0.377**	0.674**	-	0.727**	0.497**	0.519**	0.851**	-	0.832**	0.454**	0.377**	0.674**	-
SH1 (CP4)	EN	-	0.539**	0.416**	0.490**	0.518**	-	-	-	-	0.396**	-	-	-	-	0.403**	-	0.763**	0.522**	0.441**	0.737**
	WA	0.539**	-	-	0.526**	0.815**	-	-	0.482**	0.625**	0.841**	-	-	0.838**	0.850**	0.780**	0.763**	-	0.482**	0.625**	0.841**
	Gen-WE	0.416**	-	-	0.445**	0.212*	-	0.482**	-	0.574**	0.446**	-	0.838**	-	0.610**	0.516**	0.522**	0.482**	-	0.574**	0.446**
	Org-WE	0.490**	0.526**	0.445**	-	0.457**	-	0.625**	0.574**	-	0.720**	-	0.850**	0.610**	-	0.621**	0.441**	0.625**	0.574**	-	0.720**
	Rec-WE	0.518**	0.815**	0.212*	0.457**	-	0.396**	0.841**	0.446**	0.720**	-	0.403**	0.780**	0.516**	0.621**	-	0.737**	0.841**	0.446**	0.720**	-
SH1 (CP11)	EN	-	0.795**	0.522**	0.554**	0.829**	-	-	-	-	-	-	-	-	-	-	-	0.770**	0.663**	0.675**	0.870**
	WA	0.795**	0.778**	0.778**	0.709**	0.849**	-	-	0.926**	0.873**	0.925**	-	-	0.256*	0.885**	0.902**	0.770**	-	0.944**	0.889**	0.911**
	Gen-WE	0.522**	0.778**	-	0.567**	0.502**	-	0.925**	-	0.717**	0.795**	-	0.256*	-	-	0.427**	0.663**	0.944**	-	0.718**	0.828**
	Org-WE	0.554**	0.709**	0.567**	-	0.513**	-	0.873**	0.717**	-	-	-	0.885**	-	-	0.646**	0.675**	0.889**	0.817**	-	0.743**
	Rec-WE	0.829**	0.849**	0.502**	0.513**	-	-	0.925**	0.795**	0.719**	-	-	0.902**	0.427**	0.646**	-	0.870**	0.911**	0.828**	0.743**	-
SH2 (CP9)	EN	-	-	0.370**	-	0.629**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.408**	0.306**	0.812**	-	-	0.779**	0.652**	0.385**	-	-	-	-	-
	Gen-WE	0.370**	-	-	0.920**	-	-	0.408**	-	-	0.685**	-	0.779**	-	0.963**	-	-	-	-	-	-
	Org-WE	-	-	0.920**	-	-	-	0.306**	-	-	0.543**	-	0.652**	0.963**	-	-	-	-	-	-	-
	Rec-WE	0.692**	-	-	-	-	-	0.812**	0.685**	0.543**	-	-	0.385**	-	-	-	-	-	-	-	-

Table 4.43 (Cont.)

Building (Consumer)	Resource	LT					ET					BA					MI				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	0.691**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	0.564**	0.988**	-	-	-	-	0.675**	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	0.564**	-	-	0.535**	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.691**	-	-	-	-	-	0.988**	-	0.535**	-	-	0.675**	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	0.378**	-	0.627**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.909**	-	0.994**	-	-	0.822**	0.207*	0.570**	-	-	-	-	-
	Gen-WE	0.378**	-	-	0.924**	-	-	0.909**	-	-	-	-	0.822**	-	0.672**	0.316***	-	-	-	-	-
	Org-WE	-	-	0.924**	-	-	-	-	-	-	-	-	0.207*	0.672**	-	-	-	-	-	-	-
	Rec-WE	0.627**	-	-	-	-	-	0.994**	0.906**	-	-	-	0.570**	0.316**	-	-	-	-	-	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	0.232*	0.215*	-	0.235*	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	0.232*	-	0.909**	-	0.994**	-	-	0.822**	0.207*	0.570**	-	-	-	-	-
	Gen-WE	-	-	-	0.924**	-	0.215*	0.909**	-	-	0.906**	-	0.822**	-	0.672**	0.316**	-	-	-	-	-
	Org-WE	-	-	0.924**	-	-	-	-	-	-	-	-	0.207*	0.672**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	0.235*	0.994**	0.906**	-	-	-	0.570**	0.316**	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.226*	0.416**	-	-	-	-	-	-	-	-	0.523**	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.226*	-	-	0.210*	-	-	-	-	-	-	0.523**	-	-	0.722**	-	-	-	-	-	-
	Org-WE	0.416**	-	0.210*	-	-	-	-	-	-	-	-	-	0.722**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	0.348**	0.345**	-	-	-	0.454**	0.274*	-	-	-	0.635**	0.6748**	0.308**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.348**	-	-	0.307**	-	0.454**	-	-	-	0.710**	0.635**	-	-	0.458**	0.688**	-	-	-	-	-
	Org-WE	0.345**	-	0.307**	-	-	0.247*	-	-	-	-	0.648**	-	0.458**	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	0.710**	-	-	0.308**	-	0.688**	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	0.258**	0.331**	0.534**	-	-	-	-	-	-	0.726**	0.627**	0.622**	0.566**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.863**	0.453**	0.718**	0.726**	-	0.666**	0.714**	0.560**	-	-	-	-	-
	Gen-WE	0.285**	-	-	-	-	-	0.863**	-	0.712**	0.780**	0.627**	0.666**	-	0.544**	0.298**	-	-	-	-	-
	Org-WE	0.331**	-	-	-	-	-	0.453**	0.721**	-	0.498**	0.622**	0.714**	0.544**	-	0.314**	-	-	-	-	-
	Rec-WE	0.534**	-	-	-	-	-	0.718**	0.780**	0.489**	-	0.566**	0.560**	0.298**	0.314**	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	0.583**	0.635**	0.324**	-	-	-	0.611**	-	-	0.776**	0.466**	0.735**	0.600**	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.680**	0.685**	0.687**	0.776**	-	0.343**	0.654**	0.829**	-	-	-	-	-
	Gen-WE	0.583**	-	-	0.422**	0.417**	-	0.680**	-	0.476**	0.269**	0.466**	0.343**	-	0.509**	-	-	-	-	-	-
	Org-WE	0.635**	-	0.422**	-	0.330**	0.611**	0.685**	0.476**	-	0.649**	0.735**	0.654**	0.509**	-	0.533**	-	-	-	-	-
	Rec-WE	0.324**	-	0.417**	0.330**	-	-	0.687**	0.269**	0.649**	-	0.600**	0.829**	-	0.533**	-	-	-	-	-	-

Table 4.44 Energy, Water, Waste relationship in activity of cooking, gardening, TV, and ironing

Building (Consumer)	Resource	CK					GN					TV					IC				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.980**	-	-
	WA	-	-	0.945**	0.866**	0.874**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.945**	-	0.933**	0.799**	-	-	-	-	-	-	-	-	-	-	0.980**	-	-	-	-
	Org-WE	-	0.866**	0.933**	-	0.865**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.971**
	Rec-WE	-	0.874**	0.799**	0.865**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.971**	-
GH1 (CP12)	EN	-	-	0.828**	0.425**	-	-	-	0.923**	0.326**	-	-	-	0.689**	0.485**	-	-	-	0.923**	0.955**	0.552**
	WA	-	-	0.312**	0.816**	0.694**	-	-	0.336**	0.812**	0.836**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.828**	0.312**	-	0.664**	0.503**	-	0.336**	-	0.628**	0.395**	0.689**	-	-	0.788**	0.564**	0.923**	-	-	0.774**	0.300*
	Org-WE	0.425**	0.816**	0.664**	-	0.623**	0.326**	0.812**	0.628**	-	0.874**	0.485**	-	0.788**	-	0.643**	0.955**	-	0.774**	-	0.679**
	Rec-WE	-	0.694**	0.503**	0.623**	-	-	0.836**	0.395**	0.874**	-	-	-	0.564**	0.643**	-	0.552**	-	0.300**	0.679**	-
GH2 (CP6)	EN	-	-	-	0.998**	-	-	-	-	0.667**	-	-	-	0.491**	0.503**	0.319**	-	-	-	-	-
	WA	-	-	0.303**	-	0.621**	-	-	0.762**	0.317**	0.528**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.303**	-	-	0.892**	-	0.762**	-	0.552**	0.772**	0.491**	-	-	-	-	-	-	-	-	-
	Org-WE	0.998**	-	-	-	-	0.667**	0.317**	0.552**	-	0.731**	0.503**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.621**	0.892**	-	-	-	0.528**	0.772**	0.731**	-	0.319**	-	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	-	0.998**	-	-	-	-	0.667**	-	-	-	0.491**	0.503**	0.319**	-	-	-	-	-
	WA	-	-	0.303**	-	0.621**	-	-	0.762**	0.317**	0.528**	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.303**	-	-	0.892**	-	0.762**	-	0.552**	0.772**	0.491**	-	-	-	-	-	-	-	-	-
	Org-WE	0.998*	-	-	-	-	0.667**	0.317**	0.552**	-	0.731**	0.503**	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.621**	0.892**	-	-	-	0.528**	0.772**	0.731**	-	0.319**	-	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.829**	0.558**	0.947**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.829**	-	-	-	0.607**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.558**	-	-	-	0.764**
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.647**	-	0.607**	0.764**	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.938**	0.551**	0.572**
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.938**	-	-	0.775**	0.304**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.551**	-	0.775**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.572**	-	0.304**	-	-

Table 4.44 (Cont.)

Building (Consumer)	Resource	CK					GN					TV					IC				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.563**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.563**	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.585**	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.585**	-	-	-	0.606**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.606**	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.702**	0.362**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.702**	-	-	0.418**	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.361**	-	0.418**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.874**	0.592**	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.874**	-	-	0.814**	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.592**	-	0.814**	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	-	-	-	-	-	-	-	-	-	-	0.229*	0.655**	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	0.229*	-	-	-	0.275**	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	0.655**	-	-	-	0.429**	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	0.275**	0.429**	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	-	0.522**	-	-	-	-	0.462**	-	-	-	0.221*	0.617**	-	-	-	-	-	-
	WA	-	-	0.640**	0.677**	0.531**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.640**	-	0.542**	0.395**	-	-	-	0.469**	0.507**	0.221*	-	-	0.436**	0.455**	-	-	-	-	-
	Org-WE	0.522**	0.677**	0.542**	-	0.560**	0.462**	-	0.49**	-	0.304**	0.617**	-	0.436**	-	0.455**	-	-	-	-	-
	Rec-WE	-	0.531**	0.395**	0.560**	-	-	-	0.507**	0.304**	-	-	-	0.430**	0.455**	-	-	-	-	-	-

Table 4.45 Energy, Water, Waste relationship in activity of water boiling, rice cooking, wash clothes, hair dying, and car wash

Building (Consumer)	Resource	WB					RC					WC					HD and WR				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
GH1 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	0.980**	0.973*	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	0.756*	-	-	0.980**	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	0.756*	-	-	-	0.973*	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GH1 (CP12)	EN	-	0.201*	0.986**	0.804**	0.447**	-	-	0.896**	-	-	-	-	0.999**	-	-	-	-	-	-	-
	WA	0201*	-	0.249*	0.623**	0.778**	-	-	-	-	-	-	-	-	-	0.939*	-	-	-	-	-
	Gen-WE	0.986*	0.249*	-	0.835**	0.480**	0.896**	-	-	-	-	0.999**	-	-	-	-	-	-	-	-	-
	Org-WE	-	0804**	0.623**	0.835**	0.835**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.447**	0.778**	0.480**	0.835**	-	-	-	-	-	-	-	0.939*	-	-	-	-	-	-	-	-
GH2 (CP6)	EN	-	-	-	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	0.586**	-	0.606**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.586**	-	-	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.606**	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GH2 (CP1)2	EN	-	-	-	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	0.586**	-	0.606**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	0.586**	-	-	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.996**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	0.606**	0.989**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP4)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH1 (CP11)	EN	-	0.770**	0.735**	0.441**	0.891**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	0.770**	-	0.256*	0.885**	0.902**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.735**	0.256*	-	-	0.427**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	0.441**	0.885**	-	-	0.646**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	0.891**	0.902**	0.427**	0.646**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.45 (Cont.)

Building (Consumer)	Resource	WB					RC					WC					HD and WR				
		EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE	EN	WA	Gen-WE	Org-WE	Rec-WE
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	0.834*	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	0.834*	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SH2 (CP11)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH1 (CP9)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP2)	EN	-	-	-	-	-	-	-	-	-	-	-	-0.673*	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-0.673*	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.647*	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-0.647*	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH2 (CP3)	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Org-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rec-WE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

6. Verification of consumer profile

The results of the verification of consumer profiles were obtained by grouping the usage behavior data of a sample community according to the characteristics of each group, with a total of 14 groups. This grouping was performed for the purpose of adjusting the quantities of energy, water usage, and waste generation based on the usage behavior data from the second sample group, within a building that has been equipped with Smart meters. The results of the data analysis were divided into two stages as follows:

6.1 The activity occurrence consumer profile

The amount of energy, water, and waste consumption of each consumer, it will be analyzed from the consumer data and the measured usage from the smart meter. Then, the set of consumption data will be expanded to each consumer group, from CP1 to CP14, with activity data that occurred within each consumer group building, as shown in Figure 4.78 - Figure 4.91.

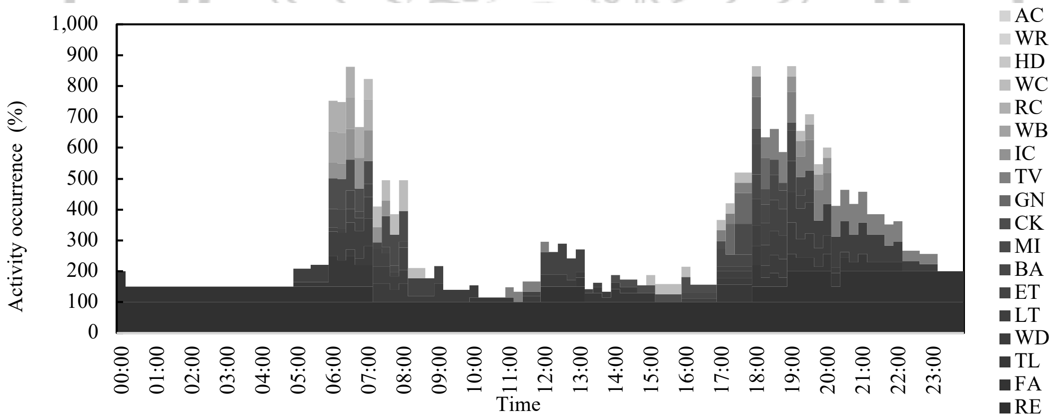


Figure 4.78 The activity occurrence consumer profile 1

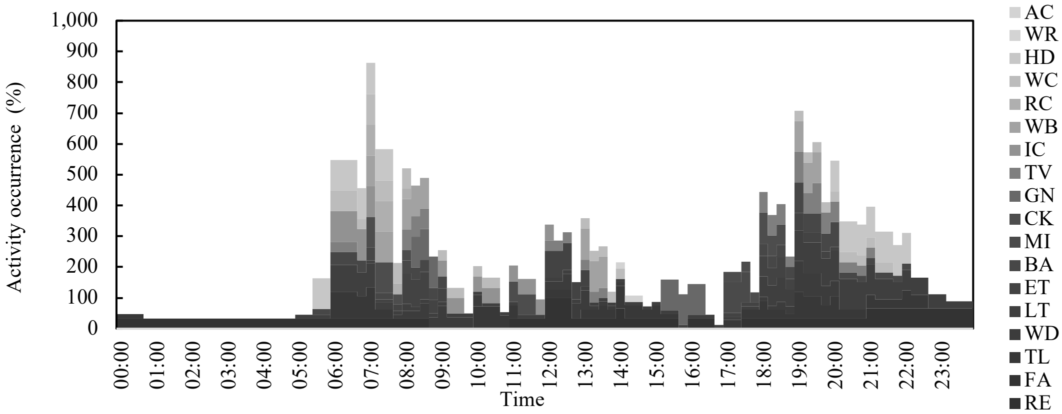


Figure 4.79 The activity occurrence consumer profile 2

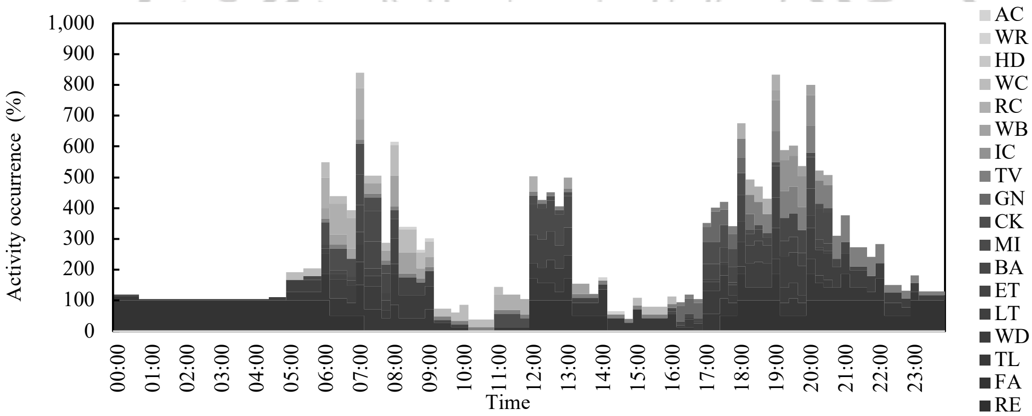


Figure 4.80 The activity occurrence consumer profile 3

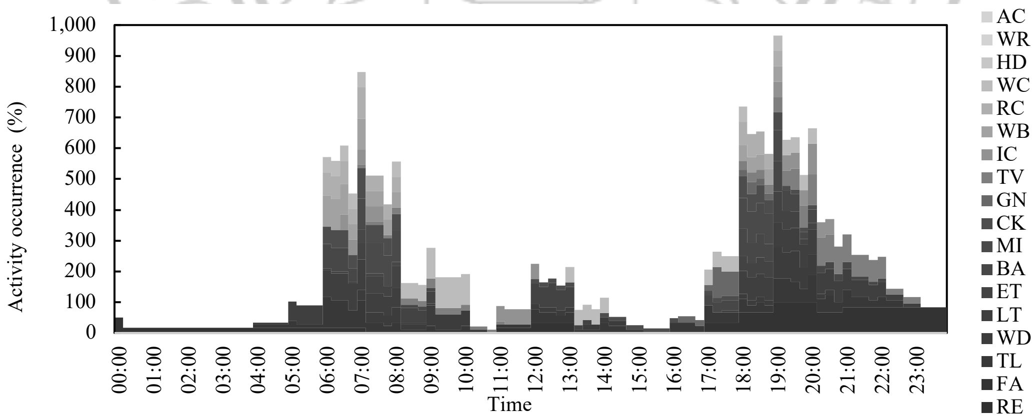


Figure 4.81 The activity occurrence consumer profile 4

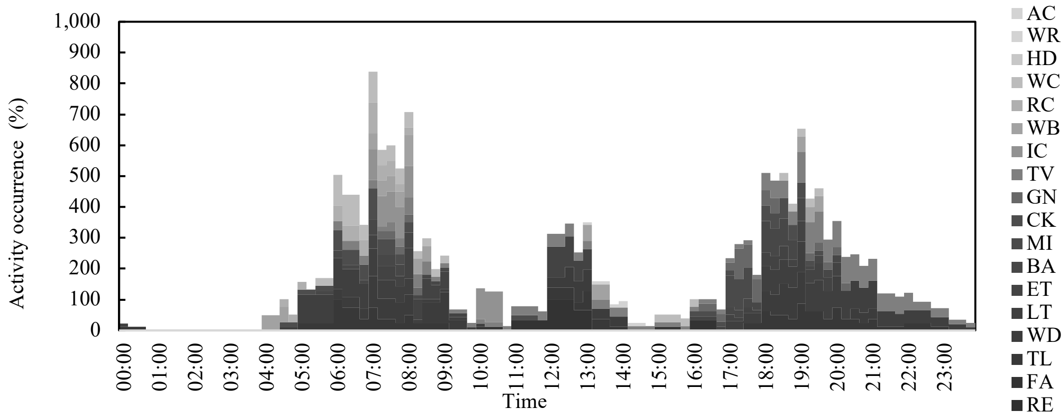


Figure 4.82 The activity occurrence consumer profile 5

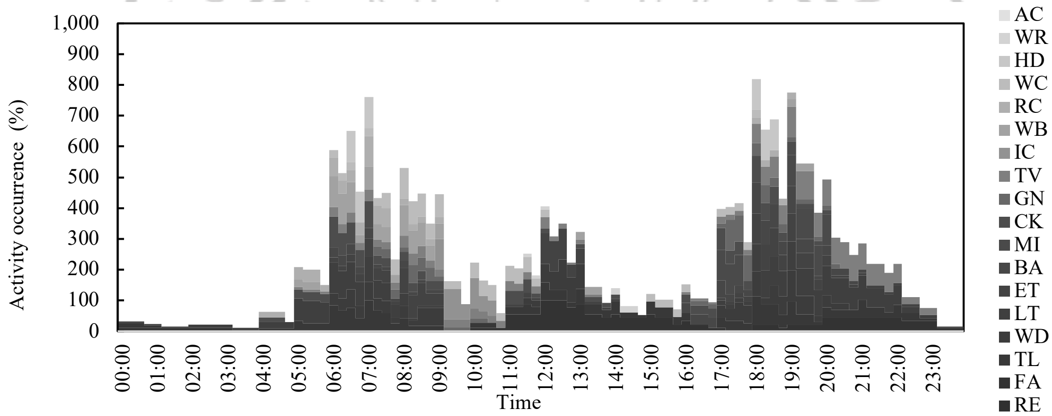


Figure 4.83 The activity occurrence consumer profile 6

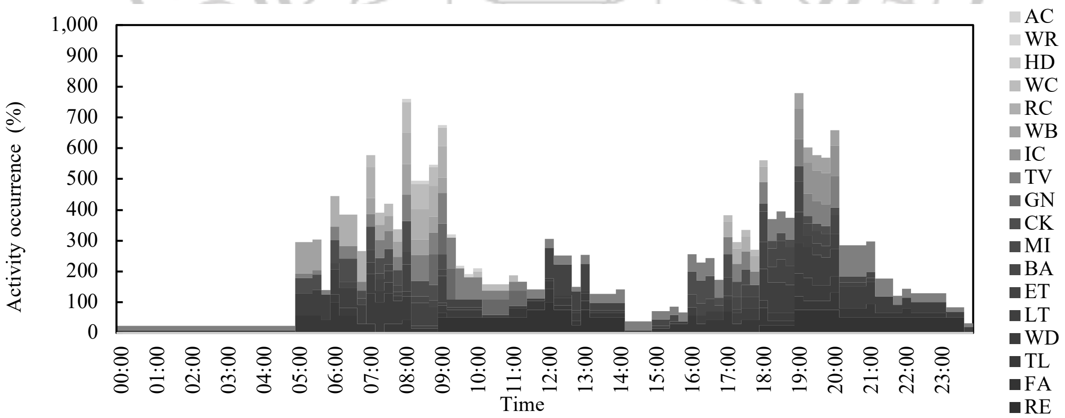


Figure 4.84 The activity occurrence consumer profile 7

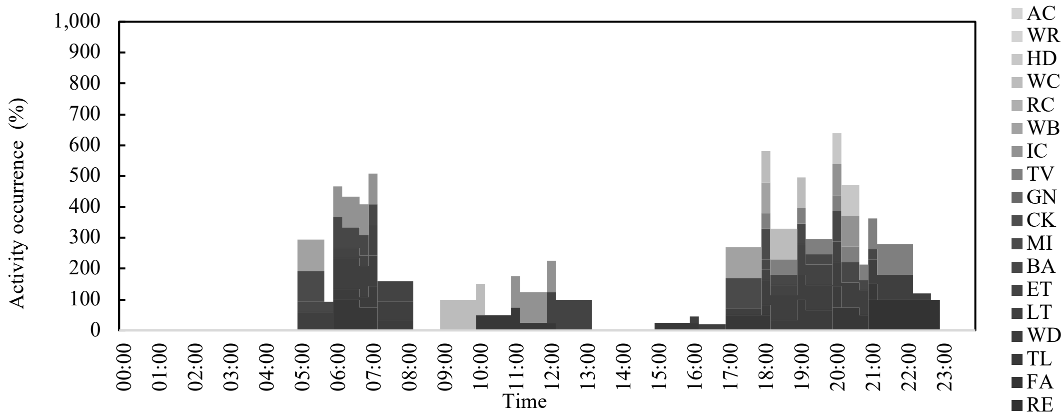


Figure 4.85 The activity occurrence consumer profile 8

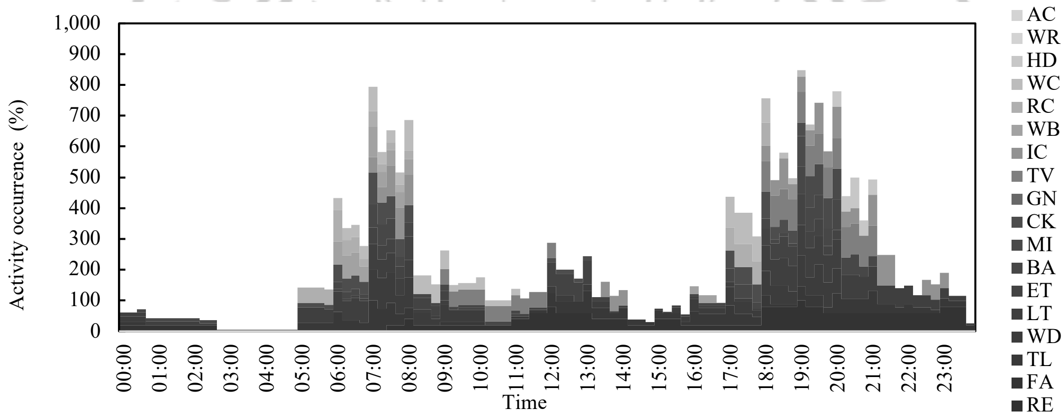


Figure 4.86 The activity occurrence consumer profile 9

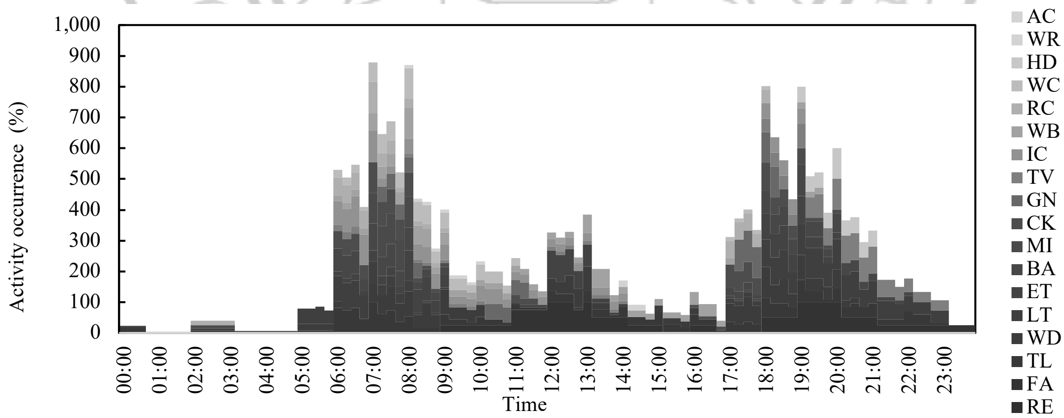


Figure 4.87 The activity occurrence consumer profile 10

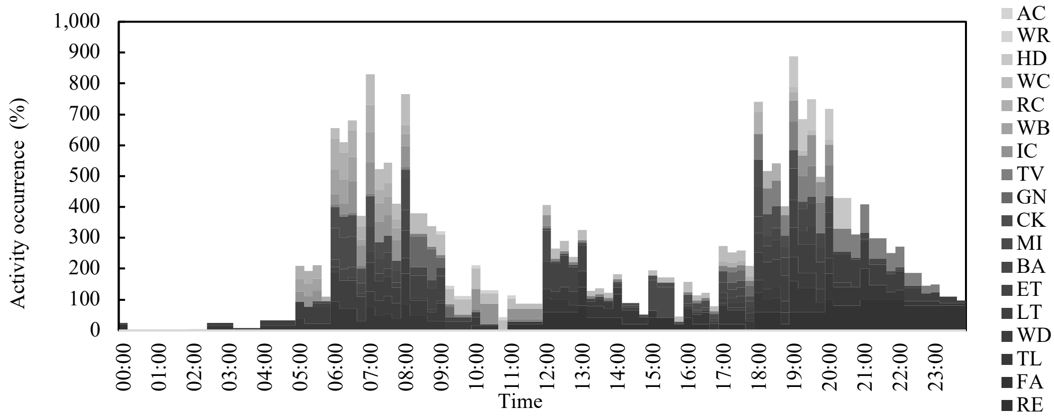


Figure 4.88 The activity occurrence consumer profile 11

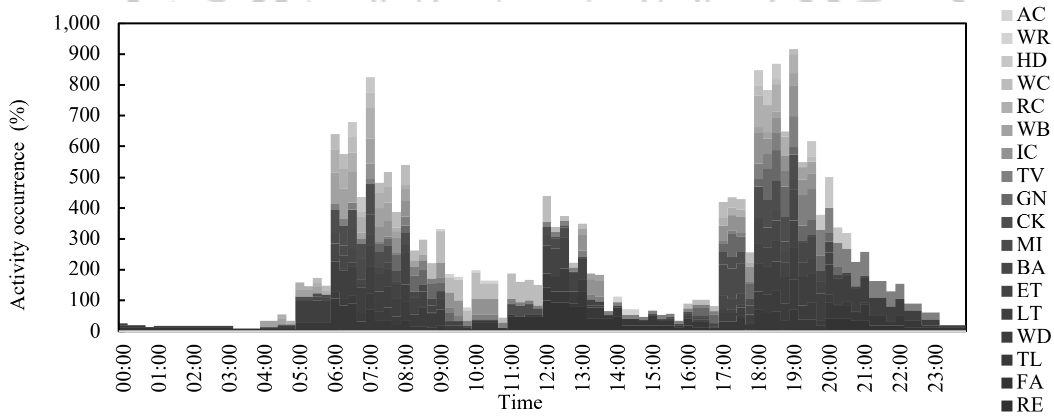


Figure 4.89 The activity occurrence consumer profile 12

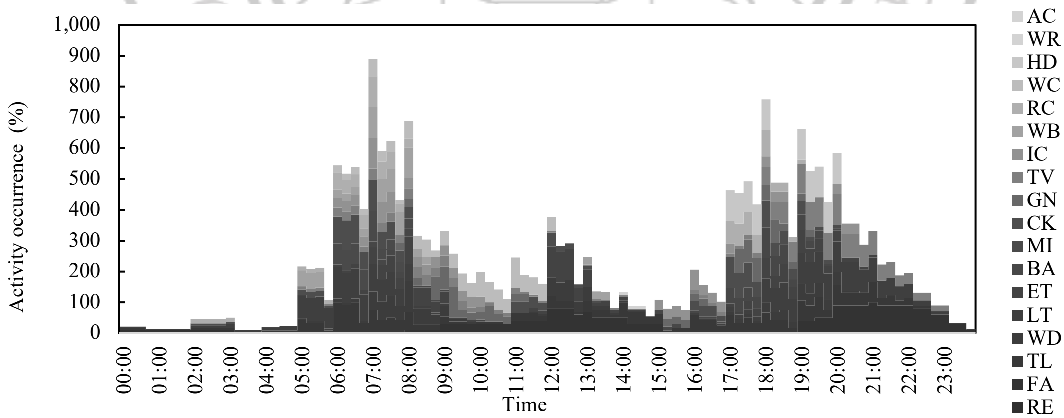


Figure 4.90 The activity occurrence consumer profile 13

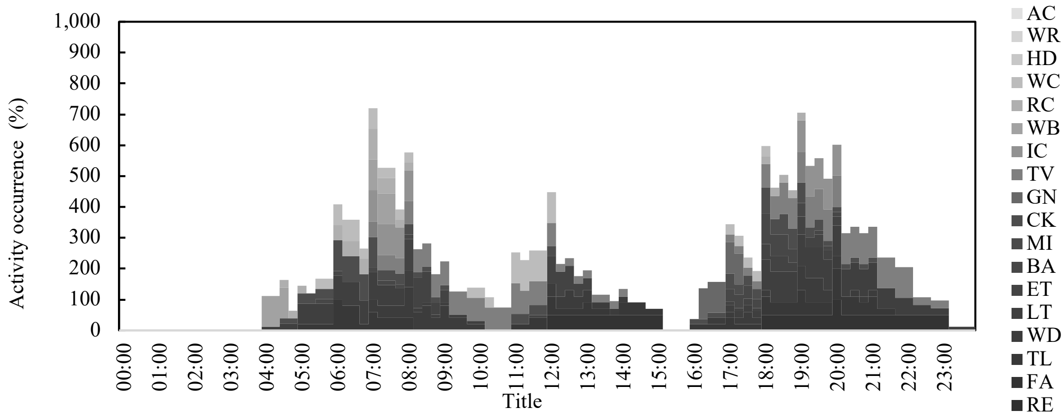


Figure 4.91 The activity occurrence consumer profile 14

Table 4.46 Appliances in each building and for each customer profile, including their size, quantity, and percentage of sample group

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Lighting	LED light	Size (W)	11.13	17.13	16.57	13.54	8.17	11.39	16.80	29.25	14.15	13.64	11.54	12.73	13.71	9.33
		Number (Unit)	5.78	7.33	5.57	7.54	8.17	7.11	5.91	9.75	6.59	8.38	6.13	7.36	6.16	5.86
		Percentage	90.00	69.23	77.78	76.47	46.15	79.17	91.67	80.00	89.47	68.42	85.71	75.76	86.21	70.00
	Fluorescent	Size (W)	23.71	24.50	18.92	25.00	18.67	22.47	25.67	16.67	18.40	22.25	22.50	20.70	23.95	24.00
		Number (Unit)	2.71	4.00	5.08	3.73	5.14	5.64	5.33	4.00	4.80	5.42	4.20	5.13	4.79	4.83
		Percentage	70.00	46.15	72.22	64.71	53.85	58.33	50.00	60.00	52.63	63.16	53.57	69.70	65.52	60.00
	Incandescent	Size (W)	25.00	-	25.00	18.00	-	31.05	18.00	-	25.20	25.00	18.00	14.00	42.60	-
		Number (Unit)	1.00	-	1.00	11.00	8.00	9.75	11.00	-	25.00	4.50	9.50	8.33	14.50	-
		Percentage	10.00	-	5.56	11.76	7.69	16.67	8.33	-	5.26	10.53	7.14	9.09	6.90	-
	Total Power Consumption (W)		105.45	132.17	142.58	161.63	82.48	188.48	175.94	268.15	163.01	166.21	123.42	155.60	190.57	107.87
Fan	Ceiling	Size (Inch)	15.00	17.00	17.00	16.67	18.00	16.43	-	17.00	16.00	17.50	16.67	16.60	16.67	-
		Number (Unit)	1.00	3.00	7.33	1.00	1.00	7.00	-	3.00	1.00	3.00	2.00	4.00	9.50	-
		Percentage	10.00	15.38	16.67	11.76	7.69	25.00	-	40.00	15.79	10.53	10.71	36.36	6.90	-
	Wall mounted	Size (Inch)	16.75	-	12.40	17.20	16.00	16.30	17.00	-	16.80	15.00	17.14	14.50	16.25	18.00
		Number (Unit)	2.00	1.00	2.25	1.17	3.00	3.25	1.00	-	1.20	1.60	1.57	2.11	3.22	1.00
		Percentage	50.00	7.69	22.22	35.29	7.69	50.00	25.00	-	26.32	26.32	25.00	27.27	31.03	30.00
	Table	Size (Inch)	14.89	15.40	16.47	16.65	16.73	15.06	16.44	16.40	16.00	16.47	15.68	16.00	15.96	16.75
		Number (Unit)	2.11	2.18	2.40	2.06	2.18	2.56	2.20	2.80	2.06	3.00	1.96	2.22	2.26	2.00
		Percentage	90.00	84.62	83.33	100.00	84.62	75.00	83.33	100.00	89.47	78.95	89.29	96.97	93.10	90.00
	Total power consumption (W)		192.46	144.89	117.26	271.99	112.71	212.55	120.28	161.73	122.06	211.32	195.67	121.76	192.46	144.89

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Air conditioner	Inv.	Size (BTU)	10,600.00	12,200.00	9,000.00	12,200.00	10,600.00	10,600.00	8,500.00	-	9,000.00	9,800.00	10,600.00	10,600.00	10,600.00	-
		SEER	2,250.00	22.50	-	2,250.00	22.50	22.50	-	-	-	22.50	2,250.00	22.50	2,250.00	-
		Number (unit)	1.50	1.00	1.00	2.00	1.00	1.25	1.00	-	2.00	1.00	1.50	1.00	2.00	-
		Percentage	20.00	15.38	5.56	5.88	15.38	16.67	16.67	-	5.26	21.05	7.14	12.12	6.90	-
	Conv.	Size (BTU)	9,000.00	-	9,000.00	-	-	12,000.00	-	20,000.00	-	14,500.00	12,000.00	12,100.00	-	-
		SEER	-	-	-	-	-	14.00	-	-	-	-	13.00	14.58	-	-
		Nmber (unit)	1.00	-	1.00	-	-	1.00	-	1.00	-	1.00	1.00	1.00	-	-
		Percentage	10.00	-	5.56	-	-	20.83	-	20.00	-	10.53	7.14	12.12	-	-
	Total power consumption (W)		292.55	83.39	83.40	87.48	86.95	317.77	90.25	400.00	63.12	272.45	138.22	175.41	93.17	-
Refrigerator	Conv. Single-door	Size (ft^3)	4.46	5.38	5.11	5.32	5.48	5.47	5.80	4.00	5.87	5.53	5.31	5.33	5.43	5.23
		Number (unit)	1.60	1.00	1.20	1.44	2.00	1.27	1.40	1.00	1.43	1.38	1.79	1.47	1.21	1.67
		Percentage	50.00	46.15	55.56	52.94	30.77	62.50	41.67	40.00	73.68	42.11	50.00	51.52	65.52	60.00
	Inv. Single-door	Size (ft^3)	-	4.20	3.40	-	5.00	12.00	5.00	-	12.00	5.00	8.03	5.00	9.25	5.00
		Number (unit)	-	1.00	1.00	-	1.50	1.00	1.00	-	1.00	1.50	1.33	1.67	1.00	1.00
		Percentage	-	15.38	5.56	-	15.38	4.17	8.33	-	5.26	10.53	10.71	9.09	13.79	10.00
	Conv. Double-door	Size (ft^3)	6.90	9.65	6.73	7.45	8.25	7.53	7.20	8.50	7.54	8.20	7.81	7.46	7.62	7.45
		Number (unit)	1.00	1.50	1.00	1.50	1.00	1.00	1.00	1.00	1.20	1.00	1.14	1.08	1.00	1.00
		Percentage	10.00	15.38	16.67	23.53	30.77	20.83	33.33	20.00	26.32	21.05	25.00	39.39	31.03	20.00
	Inv. Double-door	Size (ft^3)	9.20	7.70	9.20	9.00	8.20	8.70	-	8.55	-	8.72	8.60	7.96	8.50	-
		Number (unit)	1.00	1.00	1.00	2.00	1.00	1.00	-	1.00	-	1.40	1.00	1.00	1.00	-
		Percentage	20.00	15.38	11.11	11.76	7.69	8.33	-	40.00	-	26.32	7.14	15.15	6.90	-
	Total power consumption (W)		166.68	148.16	138.83	199.61	170.75	162.93	135.70	167.70	200.35	189.44	198.20	208.66	190.94	174.16

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Water-heater	LPG	Number (unit)	-	-	1.00	-	-	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	-
		Percentage	-	-	5.56	-	-	8.33	8.33	20.00	-	10.53	-	3.03	3.45	-
	Electricity	Size (W)	3,850.75	3,660.00	3,567.17	3,260.00	3,000.00	3,647.03	600.00	3,500.00	4,134.45	3,233.83	3,240.00	3,281.10	2,914.76	2,460.67
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.17	1.00	1.00	1.00	1.00
		Percentage	40.00	38.46	33.33	35.29	23.08	41.67	8.33	20.00	15.79	31.58	35.71	30.30	20.69	30.00
	Total power consumption (W)		1,540.30	1,407.64	1,188.94	1,150.45	692.40	1,519.72	49.98	1,400.00	652.83	1,191.45	1,157.00	994.17	603.06	738.20
Hair dry		Size (W)	900.00	1,100.00	1,050.00	-	-	1,687.50	1,000.00	2,600.00	1,000.00	937.75	1,000.00	1,137.50	1,316.67	1,000.00
		Number (unit)	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Percentage	10.00	23.08	11.11	-	-	16.67	8.33	20.00	21.05	21.05	14.29	12.12	13.79	10.00
	Total power consumption (W)		1,540.30	90.00	253.88	116.66	-	-	281.31	83.30	520.00	210.50	197.40	142.90	137.87	181.57
Rice cook	Conv.	Size (L)	1.41	1.49	1.53	1.64	1.59	1.52	1.33	1.70	1.69	1.63	1.60	1.66	1.51	1.39
		Number (unit)	1.00	1.00	1.00	1.07	1.00	1.05	1.00	1.00	1.00	1.13	1.00	1.00	1.04	1.00
		Percentage	90.00	69.23	66.67	82.35	53.85	79.17	83.33	80.00	84.21	78.95	78.57	72.73	89.66	80.00
	Digital	Size (L)	-	-	-	-	-	2.40	1.80	-	-	-	2.38	1.80	-	-
		Number (unit)	-	-	-	-	-	1.00	1.00	-	-	-	1.00	1.00	-	-
		Percentage	-	-	-	-	-	8.33	8.33	-	-	-	14.29	6.06	-	-
	Total power consumption (W)		501.77	396.54	387.34	529.03	317.81	551.36	516.49	486.70	511.53	535.12	585.44	486.02	536.59	442.13
Microwave		Size (W)	1,500.00	884.00	986.67	1,300.00	1,000.00	1,262.50	800.00	220.00	-	906.67	1,014.29	1,157.78	966.67	-
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	-
		Percentage	20.00	38.46	33.33	23.53	7.69	33.33	8.33	20.00	-	15.79	28.57	27.27	24.14	-
	Total power consumption (W)		300.00	339.99	328.86	305.89	76.90	420.79	66.64	44.00	-	143.16	289.78	315.73	233.35	-

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Water boiler	Kettle	Size (L)	1.20	-	1.50	1.70	2.10	1.40	-	2.00	1.27	1.40	1.23	1.60	1.58	2.40
		Number (unit)	1.00	-	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.20	1.00
		Percentage	30.00	-	16.67	23.53	23.08	8.33	-	20.00	31.58	21.05	28.57	18.18	17.24	20.00
Water boiler	Thermos	Size (L)	1.50	1.93	6.60	2.07	2.83	1.62	2.19	1.90	1.35	5.11	2.28	2.16	3.40	1.00
		Number (unit)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Percentage	20.00	53.85	27.78	52.94	23.08	54.17	66.67	40.00	31.58	52.63	46.43	45.45	62.07	20.00
	Total power consumption (W)		568.64	382.63	546.49	760.49	568.05	520.49	466.44	634.41	691.49	744.52	728.89	610.46	760.77	521.50
Air fryer		Size (W)	-	-	-	-	-	-	-	-	800.00	220.00	1,100.00	-	220.00	-
		Number (unit)	-	-	-	-	-	-	-	-	1.00	1.00	1.00	-	1.00	-
		Percentage	-	-	-	-	-	-	-	-	15.79	5.26	7.14	-	3.45	-
	Total power consumption (W)		568.64	382.63	546.49	760.49	568.05	520.49	466.44	634.41	691.49	744.52	728.89	610.46	760.77	521.50
Washing machine	Twin tub	Size (kg)	12.86	11.75	12.42	12.83	13.05	12.08	11.63	12.50	12.14	13.04	12.94	12.52	12.82	10.78
		Number (unit)	1.00	1.13	1.00	1.00	1.20	1.18	1.00	1.00	1.00	1.00	1.05	1.17	1.00	1.00
		Percentage	70.00	61.54	72.22	82.35	76.92	70.83	75.00	80.00	73.68	68.42	67.86	87.88	79.31	90.00
	Top load	Size (kg)	15.00	9.00	8.00	-	13.00	7.50	12.00	15.00	7.00	13.33	12.50	12.00	5.00	-
		Number (unit)	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-
		Percentage	10.00	15.38	5.56	-	7.69	8.33	8.33	20.00	15.79	15.79	21.43	9.09	3.45	-
	Front load	Size (kg)	-	-	-	-	-	-	-	-	-	-	15.00	-	15.00	-
		Number (unit)	-	-	-	-	-	-	-	-	-	-	1.00	-	1.00	-
		Percentage	-	-	-	-	-	-	-	-	-	-	3.57	-	3.45	-
	Total power consumption (W)		457.66	423.68	419.61	468.73	572.21	478.75	430.50	562.23	452.64	477.23	586.61	617.16	530.16	436.66

Table 4.46 (Cont.)

Consumer profile			CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
Gender			Male							Female						
age			11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71	11 – 20	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	> 71
Iron		Size (W)	728.00	1,036.67	480.00	1,041.82	732.86	773.33	1,400.00	794.00	1,253.33	770.77	1,038.75	918.70	808.57	1,100.00
		Number (unit)	1.00	1.14	1.17	1.00	1.00	1.00	1.33	1.20	1.00	1.21	1.00	1.04	1.00	1.00
		Percentage	50.00	53.85	33.33	70.59	53.85	66.67	50.00	100.00	63.16	73.68	64.29	75.76	55.17	30.00
	Total power consumption (W)		364.00	637.99	186.65	735.42	394.64	515.58	933.33	952.80	791.61	689.60	667.81	723.84	446.09	330.00
TV	Conv.	Size (inch)	20.50	32.75	22.50	37.00	29.67	24.25	20.67	27.00	26.67	25.50	31.33	26.29	24.80	20.00
		Number (unit)	1.00	1.40	1.50	1.00	1.00	1.00	1.00	1.67	1.00	1.50	1.00	1.29	1.00	1.00
		Percentage	20.00	38.46	22.22	11.76	23.08	16.67	33.33	60.00	15.79	21.05	21.43	21.21	17.24	20.00
	LCD	Size (inch)	32.00	37.00	33.25	34.00	-	38.00	36.00	-	41.00	35.00	36.00	33.33	36.50	32.00
		Number (unit)	1.00	1.00	1.00	1.00	-	1.00	1.43	-	1.00	1.60	1.00	1.00	1.22	1.00
		Percentage	20.00	15.38	22.22	23.53	-	16.67	58.33	-	10.53	26.32	25.00	9.09	31.03	20.00
	LED	Size (inch)	33.80	30.80	40.25	32.70	31.80	37.93	32.00	31.50	34.00	34.67	34.58	34.21	35.00	34.50
		Number (unit)	1.40	1.00	1.00	1.20	1.33	1.20	1.50	1.00	1.13	1.10	1.31	1.14	1.25	1.00
		Percentage	50.00	38.46	44.44	58.82	46.15	62.50	16.67	40.00	42.11	52.63	46.43	63.64	55.17	40.00
	Total power consumption (W)		65.54	125.44	73.05	81.72	63.53	77.14	111.73	135.72	55.13	100.89	89.30	76.35	90.35	49.27

Table 4.47 Comparison of activity time, Frequency, and period of consumer profile between community population (1st sample group) and consumer in sample building (2nd sample group)

Profile	CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
LT T	246.00	-	252.50	900.00	241.18	510.00	171.18	480.00	194.33	-	236.54	300.00	353.33	-	105.00	-	273.95	426.00	189.11	-	245.36	490.00	212.42	360.00	265.00	-	251.00	-
F	1.70	-	1.62	1.00	1.93	1.00	1.65	2.00	1.85	-	1.65	2.00	1.67	-	1.75	-	1.42	1.00	1.82	-	1.61	1.00	1.88	2.00	2.07	-	1.60	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
AC T	-	-	25.00	-	-	-	-	-	20.00	-	56.67	-	260.00	-	-	-	-	-	160.00	-	400.00	-	116.67	-	-	-	-	-
F	-	-	1.50	-	-	-	-	-	2.00	-	1.33	-	1.50	-	-	-	-	-	2.00	-	1.33	-	1.33	-	-	-	-	-
P	-	-	Day	-	-	-	-	-	Day	-	Day	-	Day	-	-	-	-	-	Day	-	Day	-	Day	-	-	-	-	-
FA T	172.00	-	218.33	900.00	225.56	570.00	216.67	840.00	30.00	-	141.54	540.00	78.89	-	150.00	-	254.63	287.40	113.00	-	232.86	241.67	149.25	600.00	143.75	-	110.00	-
F	1.20	-	1.83	1.00	1.11	1.00	1.11	1.00	1.33	-	1.50	-	0.88	-	1.00	-	1.50	1.00	1.20	-	1.14	1.33	1.42	1.00	1.13	-	1.50	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-
BA T	18.33	-	17.08	30.00	20.63	20.00	13.75	15.00	16.15	-	15.75	30.00	18.33	-	20.00	-	17.37	21.00	19.72	-	16.15	13.33	16.21	20.00	13.28	-	15.00	-
F	1.44	-	1.62	2.00	1.56	2.00	1.44	2.00	1.54	-	1.43	2.00	1.42	-	1.75	-	1.68	1.60	1.83	-	1.62	2.00	1.52	1.50	1.21	-	1.13	-
P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
TL T	6.61	-	7.25	1.00	3.60	2.00	3.50	2.00	9.92	-	4.88	1.00	6.28	-	1.00	-	3.44	1.40	4.95	-	6.18	1.00	4.31	1.00	4.48	-	4.00	-
F	3.86	-	5.78	3.00	4.15	3.00	3.14	2.00	4.08	-	4.00	4.00	2.89	-	3.33	-	3.82	3.00	4.47	-	4.24	5.33	4.17	5.00	3.05	-	3.43	-
P	Day	-	Day	Day	Day	-	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	Day	Day	Day	Day	-	Day	-
HD T	-	-	5.00	5.00	15.00	2.50	-	-	-	-	15.00	15.00	1.00	-	10.00	-	7.67	1.60	11.67	-	10.00	5.00	7.50	10.00	10.00	-	-	-
F	-	-	1.29	2.00	0.29	1.00	-	-	-	-	1.00	1.00	-	-	1.00	-	0.86	0.40	0.48	-	0.71	0.19	0.46	0.79	0.57	-	-	-
P	-	-	Day	Day	Day	-	-	-	-	-	Day	Day	-	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	-	-
WC T	39.17	-	36.67	45.00	43.00	-	40.45	-	42.50	-	56.82	-	41.25	-	51.67	-	46.56	31.00	44.72	-	58.40	15.00	41.61	40.00	46.67	-	35.00	-
F	3.17	-	2.33	1.00	3.50	-	2.18	-	2.50	-	3.55	-	3.38	-	3.00	-	2.50	0.60	5.22	-	2.32	1.00	4.25	2.00	2.88	-	2.78	-
P	Week	-	Week	Week	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	Week	Week	-	Week	-
IC T	16.25	-	25.00	-	32.50	-	28.33	-	25.00	-	30.83	-	15.50	-	22.50	-	19.58	17.00	48.85	-	26.39	26.67	26.54	30.00	18.82	-	16.67	-
F	3.25	-	2.29	-	4.25	-	3.17	-	1.25	-	2.45	-	2.63	-	5.50	-	3.33	5.80	5.00	-	2.63	3.33	1.85	1.00	2.11	-	3.00	-
P	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	Week	Week	-	Week	Week	Week	Day	Week	-	Week	-

Table 4.47 (Cont.)

Profile		CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
RC	T	26.67	-	23.33	-	27.50	-	32.86	-	28.33	-	26.82	-	41.67	-	30.00	-	23.33	-	30.42	-	32.75	10.00	22.50	10.00	31.50	-	25.00	-
	F	0.71	-	1.17	-	0.79	-	1.14	-	0.71	-	1.05	-	0.84	-	2.00	-	0.92	-	1.10	-	1.01	0.24	1.17	1.00	0.87	-	1.25	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-	Day	-
MI	T	1.00	-	10.67	-	11.00	16.00	6.00	6.00	25.00	-	10.67	2.00	-	-	-	-	20.00	-	10.50	-	8.33	5.00	12.71	2.00	20.00	-	-	-
	F	14.00	-	4.67	-	11.00	9.50	14.00	14.00	1.13	-	3.33	1.00	-	-	-	-	3.00	-	8.00	-	8.33	2.00	3.46	3.00	7.00	-	-	-
	P	Week	-	Week	-	Week	Week	Week	Week	Week	-	Week	Week	-	-	-	-	Week	-	Week	-	Week	-	Week	Week	Week	-	-	-
WB	T	10.00	-	10.00	-	15.00	-	17.00	-	13.75	-	13.89	5.00	45.00	-	30.00	-	9.29	1.00	27.86	-	17.22	2.67	11.30	10.00	21.11	-	15.00	-
	F	1.00	-	2.00	-	1.33	-	1.20	-	1.50	-	1.14	1.00	2.00	-	2.00	-	1.00	0.20	1.43	-	1.22	1.00	1.40	1.00	1.03	-	1.00	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
TV	T	168.00	-	55.71	60.00	179.09	60.00	132.50	-	175.00	-	161.82	180.00	297.00	-	110.00	-	160.00	-	173.64	-	124.50	-	164.00	120.00	166.40	-	180.00	-
	F	0.86	-	1.49	1.00	1.03	0.50	1.08	-	1.38	-	1.41	1.00	1.43	-	1.00	-	1.00	-	1.43	-	1.08	-	1.38	0.71	1.51	-	1.71	-
	P	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
ET	T	17.50	-	21.36	15.00	20.71	22.50	19.41	30.00	23.18	-	20.48	25.00	17.50	-	16.67	-	20.59	20.00	17.50	-	19.60	21.67	19.52	25.00	21.96	-	18.13	-
	F	2.64	-	2.49	2.00	2.77	1.36	2.71	2.00	3.00	-	2.85	2.00	2.50	-	3.00	-	2.58	1.20	2.53	-	2.56	2.00	2.87	2.00	2.63	-	2.75	-
	P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	Day	Day	-	Day	-
WD	T	9.00	-	9.17	5.00	12.44	10.50	10.00	5.00	12.78	-	11.54	5.00	18.75	-	9.00	-	7.12	7.00	15.00	-	11.36	6.67	9.14	10.00	12.78	-	11.88	-
	F	2.29	-	2.71	2.00	2.04	1.14	1.56	2.00	2.22	-	2.36	2.00	1.38	-	1.40	-	2.08	1.40	2.00	-	2.00	1.33	2.39	2.00	2.31	-	2.38	-
	P	Day	-	Day	Day	Day	Day	Day	Day	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	Day	-
GN	T	11.67	-	30.00	-	40.00	-	14.44	-	20.00	-	26.25	30.00	15.00	-	-	-	15.25	-	32.50	-	17.22	-	18.64	30.00	30.00	-	27.50	-
	F	1.67	-	0.25	-	1.39	-	0.75	-	0.74	-	0.97	1.00	1.00	-	-	-	0.38	-	1.04	-	1.03	-	0.74	0.79	0.72	-	0.57	-
	P	Day	-	Day	-	Day	-	Day	-	Day	-	Day	Day	Day	-	-	-	Day	-	Day	-	Day	-	Day	Day	Day	-	Day	-
WR	T	30.00	-	30.00	-	55.00	-	25.71	-	27.50	-	38.57	-	28.33	-	-	-	20.00	-	46.00	-	45.00	-	30.00	15.00	20.00	-	-	-
	F	0.25	-	0.42	-	1.06	-	0.82	-	0.88	-	0.71	-	0.83	-	-	-	1.00	-	0.60	-	0.44	-	0.44	0.13	0.25	-	-	-
	P	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	Week	-	-	-	Week	-	Week	-	Week	-	Week	Day	Week	-	-	-
Pet	T	-	-	-	-	-	-	25.00	-	-	-	17.33	30.00	15.00	-	-	-	20.00	-	-	-	30.00	10.00	23.00	15.00	17.00	-	20.00	-
	F	-	-	-	-	-	-	1.13	-	-	-	3.33	1.00	2.00	-	-	-	0.50	-	-	-	1.00	0.33	3.50	0.50	3.00	-	2.00	-
	P	-	-	-	-	-	-	Week	-	-	-	Week	Week	Week	-	-	-	Week	-	-	-	Week	-	Week	Day	Week	-	Week	-

Table 4.47 (Cont.)

Profile	CP1		CP2		CP3		CP4		CP5		CP6		CP7		CP8		CP9		CP10		CP11		CP12		CP13		CP14	
Sample	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
CK T	35.00	-	31.67	-	33.89	35.00	35.00	-	30.00	-	31.54	60.00	32.14	-	-	-	35.63	-	31.43	-	33.53	45.00	36.11	52.50	36.92	-	52.86	-
F	2.25	-	2.67	-	2.00	2.00	2.13	-	1.86	-	2.00	2.00	1.71	-	-	-	1.88	-	1.79	-	1.88	2.00	2.15	1.50	2.19	-	2.29	-
P	Day	-	Day	-	Day	Day	Day	-	Day	-	Day	Day	Day	-	-	-	Day	-	Day	-	Day	Day	Day	Day	Day	-	Day	-

From the comparative activity behavior data of each customer profile between the data from sample population 1 from the community and sample population 2 residing in buildings equipped with Smart Meters as shown in Table 4.47, it was found that sample population 2 had a total of 7 customer profiles, consisting of CP2, CP3, CP4, CP5, CP6, CP7, CP8, CP9, CP10, CP11, and CP12. Considering group CP2, the activity of turning on lights occurred in the same manner in both sample groups, with 9 activities, as follows: the activity duration of sample population 1 was longer than sample population 2. It was found that the first sample group turned on lights for an average of 407.88 minutes per day, which was lower than the second sample group that turned on lights for an average of 900 minutes per day. The same was true for the activity of using fans, which had an average activity time of 400.28 minutes per day for sample population 1 and 900.00 minutes per day for sample population 2. As for the activity of bathing, the frequency of this activity was slightly lower in sample population 1 compared to sample population 2, with a frequency of 1.62 times per day and an average duration of 17.08 minutes per time for sample population 1, which was lower than sample population 2 that had an average frequency of 2 times per day and 30 minutes per time. However, the activity of using the bathroom (TL) had a longer activity time in sample population 1 with an average duration of 725 minutes per time, which occurred 5.78 times per day, which was higher than sample population 2 that had an activity duration of only 1 minute per time and occurred 3 times per day. The hair drying activity (HD) is characterized by a similar duration of activity of 5 minutes per session, with a slightly different frequency observed between the two sample groups, where Sample Group 1 exhibited an average frequency of 1.29 times per day, which is lower than Sample Group 2 that had an average frequency of 2 times per day. With regards to the clothes washing activity (WC), Sample Group 1 had a longer duration of activity than Sample Group 2, with an average time of 85.56 minutes per week and an average frequency of 2.33 times per week, compared to Sample Group 2 which only had an average time of 45.00 minutes per week and an average frequency of 1 time per week. As for the TV watching activity, both groups had a similar duration of activity per session, with Sample Group 1 and Sample Group 2 having an average time of 55.71 minutes and 60.00 minutes, respectively. However, Sample Group 1 exhibited a lower frequency of activity than Sample Group 2, with an average frequency of 1.49 times per day and 1 time per day, respectively. Finally, for the eating (ET) and dishwashing (WD) activities, Sample Group 1 had a longer duration of activity and a higher frequency of activity than Sample Group 2. The average duration of activity for Sample Group 1 was 21.36 minutes per session, with an average frequency of 2.49 times per day for the eating activity and 9.17 minutes per session, with an average frequency of 2.71 times per day for the dishwashing activity, which were both higher than those observed in Sample Group 2. The first sample group conducted activities within a building that differed from all of the activities conducted by the second sample group. The activities included the use of air conditioning, clothes ironing, rice cooking, microwave usage, hot water boiling, plant watering, car washing, and food preparation. It was found that the average activity duration for each activity was 25.00, 23.33, 10.00, 30.00, and 31.37 minutes per occurrence, respectively, while the average frequency of each activity was 1.50, 1.17, 2.00, 0.25, and 2.67 times per day for AC, RC, WB, GN, and CK, respectively. For IC, MI, and WC, the corresponding activity durations were 25.00, 10.67, and 30.00 minutes per occurrence with an average frequency of 2.29, 4.67, and 30.00 times per week, respectively.

A total of 10 activities were performed by two CP3 groups that conducted similar activities. These activities included turning on lights, turning on fans, taking a shower, using the restroom, blow drying hair, using a microwave, watching TV, having meals, washing dishes, and cooking. The first sample group exhibited higher frequencies and longer durations for each activity compared to the second sample group. Specifically, the first group spent an average of 241.18 minutes and performed the activity 1.93 times per day for turning on lights, 225.56 minutes and 1.11 times per day for turning on fans, 20.63 minutes and 1.56 times per day for taking a shower, 3.60 minutes and 4.15 times per day for using the restroom, 15.00 minutes and 0.29 times per day for blow drying hair, 11.00 minutes and 11.00 times per week for using a microwave, 179.09 minutes and 1.03 times per day for watching TV, 20.71 minutes and 2.77 times per day for having meals, 12.44 minutes and 2.04 times per day for washing dishes, and 33.89 minutes and 2 times per day for cooking. In contrast, the second sample group spent only 510.00 minutes once per day for turning on lights, 570.00 minutes once per day for turning on fans, 20.00 minutes and 2 times per day for taking a shower, 2.00 minutes and 3 times per day for using the restroom, 2.50 minutes and once per day for blow drying hair, 16.00 minutes and 9.50 times per week for using a microwave, 60.00 minutes and 0.50 times per day for watching TV, 22.50 minutes and 1.36 times per day for having meals, 10.50 minutes and 1.14 times per day for washing dishes, and 35.00 minutes and 2 times per day for cooking, respectively. The activities that occurred were specific to sample group 1, consisting of 6 activities, namely clothing washing, fabric ironing, rice cooking, watering plants, car washing, and pet care. The average time spent on these activities was 43.00 minutes per session, 3.50 sessions per week, 32.50 minutes per session, 4.25 sessions per week, 27.50 minutes per session, 0.76 sessions per day, 15.00 minutes per session, 1.33 sessions per day, 40.00 minutes per session, 1.39 sessions per day, and 55.00 minutes per session, 1.06 sessions per week, respectively.

A total of seven activities were observed to occur simultaneously in CP4. These activities consisted of turning on the lights, turning on the fan, taking a shower, using the bathroom, using the microwave, eating, and washing dishes. From the data, it was found that both sample groups had similar durations and frequencies of activities. Sample group 1 spent an average of 171.18 minutes, or 1.65 times per day, on all activities combined. Sample group 2 spent an average of 480.00 minutes, or 2.00 times per day, on all activities combined. For turning on the lights, sample group 1 spent an average of 216.67 minutes, or 1.11 times per day, while sample group 2 spent an average of 480.00 minutes, or 1.00 time per day. For turning on the fan, sample group 1 spent an average of 13.75 minutes, or 1.44 times per day, while sample group 2 spent an average of 15.00 minutes, or 2.00 times per day. For taking a shower, sample group 1 spent an average of 3.50 minutes, or 3.14 times per day, while sample group 2 spent an average of 2.00 minutes, or 2.00 times per day. For using the bathroom, sample group 1 spent an average of 2.00 minutes, or 2.00 times per day. Both sample groups used the microwave for an average of 6 minutes, 14 times per week. For eating, sample group 1 spent an average of 19.41 minutes, or 2.71 times per day, while sample group 2 spent an average of 30.00 minutes, or 2.00 times per day. For washing dishes, sample group 1 spent an average of 10.00 minutes, or 1.56 times per day, while sample group 2 spent an average of 5.00 minutes, or 2.00 times per day. It should be noted that sample group 1 had an additional nine activities that occurred, which sample group 2 did not perform, namely washing clothes, ironing, cooking rice, boiling water, watching television, watering plants, washing the car, looking after pets, and cooking, with an average time of 40.45 minutes and a frequency of 2.18 times per week, 28.33 minutes and a frequency of 3.17 times per week, and 32.86 minutes, respectively. From the behavioral data of each user group, a comparison is made with the activity dataset and the characteristics of each user group from section CHAPTER 42 Building activity. This is done in order to compare and adjust the quantities of energy consumption, water usage, and waste generation from the sample group 2 to align with the overall behavior of each customer profile.

When all the data on energy consumption, water usage, and waste generation are analyzed, it can be seen that only refrigerators have an impact on energy consumption throughout the day. The energy usage characteristics of refrigerators are the amount used by each building according to the size of the equipment and the activity data that occurs within the building. This is because the energy usage characteristics of refrigerators are consistent with the time and number of activities that occur throughout the day, as shown in the example in Figure 4.92, which shows the average energy consumption throughout the day of User 1 's refrigerator usage in a doctor's dormitory. The behavior of refrigerator usage is consistent across all buildings and all users. When the data on the amount of energy used per appliance in each building is considered according to each user, it can be determined.

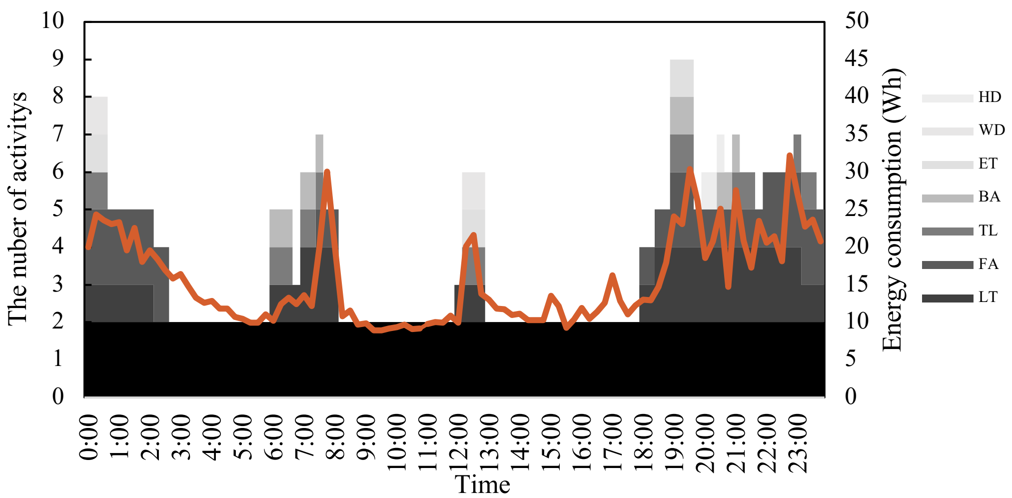


Figure 4.92 The energy consumption of the refrigerator by 1st customer in HH1

When the data on electrical appliance usage for each activity was calculated to find the average energy consumption within 15 minutes, it was found to be consistent with the previously analyzed data. The coefficient of variation calculated from the data measured by the smart meters of each user, each building, and each activity was lower than the calculated average by 15.27%. Therefore, when considering the amount of electricity consumed by each activity based on the electrical appliance data, it is necessary to calculate a reduction from the aforementioned calculated values for all activities.

As for the data on water usage, it will be considered based on the average rate of water usage per 15 minutes throughout the day and the duration of each activity. It was found that the average water consumption in residential buildings was 3.60 liters per 15 minutes. When calculated the duration of each activity, the average amount of water consumption is shown in Table 4.48, which also displays the energy and waste generated per person per 15 minutes. The waste is measured in Wh/15 min per person, the water consumption is measured in liters/15 min per person, and the waste generated is measured in grams/15 min per person. All of this data will be used to create the consumer profile for the next phase.

Table 4.48 Energy, Water, Waste in activity by customer profile

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
RE	EN	35.31	31.38	29.41	42.28	36.17	34.51	28.75	35.52	42.44	40.13	41.98	44.20	40.45	36.89
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.89	0.24	0.17	0.11	1.18	2.36	2.39	0.49	0.37	1.19	1.72	2.20	1.61	1.88
	Org-WE	0.01	0.00	0.00	0.00	0.02	0.03	0.06	0.01	0.00	0.01	0.00	0.02	0.06	0.09
	Rec-WE	0.01	0.01	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.03	0.05
FA	EN	1.91	2.18	3.19	2.31	0.26	2.83	0.65	2.34	2.25	1.34	2.09	2.32	2.07	0.99
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	28.38	2.29	0.60	0.41	30.40	17.50	43.91	4.47	1.25	4.44	3.05	27.82	16.41	29.77
	Org-WE	0.30	0.03	0.01	0.04	1.69	0.74	2.55	0.26	0.01	0.30	0.03	0.41	1.17	2.69
	Rec-WE	0.05	0.01	0.02	0.01	0.33	0.05	0.42	0.09	0.03	0.17	0.03	0.05	0.21	0.39
TL	EN	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01
	WA	1.90	2.08	1.03	1.00	2.85	1.40	1.80	0.29	0.99	1.42	1.77	1.24	1.28	1.15
	Gen-WE	93.15	28.28	28.83	6.30	18.39	96.25	67.06	462.37	72.21	130.94	76.94	337.45	192.27	358.12
	Org-WE	0.67	0.27	0.25	0.07	0.11	0.73	0.77	5.98	0.60	0.90	0.25	0.61	1.14	0.04
	Rec-WE	0.53	0.17	0.43	0.31	0.47	0.25	2.35	5.29	0.24	0.55	0.29	0.83	2.71	4.00
WD	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	6.65	6.78	9.20	7.39	9.45	8.53	13.86	6.65	5.26	11.09	8.40	6.76	9.45	8.78
	Gen-WE	94.79	27.56	7.80	2.05	28.55	50.88	42.87	40.52	35.81	11.16	62.56	126.66	58.65	86.66
	Org-WE	0.68	0.27	0.09	0.04	0.18	0.59	0.55	0.38	0.09	0.21	0.11	0.49	0.58	1.31
	Rec-WE	1.82	0.22	0.05	0.16	0.65	3.29	2.13	2.34	0.45	0.68	0.27	2.22	4.22	7.68

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
LT	EN	6.49	7.93	9.78	6.70	4.35	10.84	15.24	7.25	9.33	8.43	7.16	9.14	15.39	6.37
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	2.38	0.57	0.15	0.04	1.45	3.03	2.37	2.55	0.65	4.37	3.03	3.82	2.80	4.19
	Org-WE	0.03	0.01	0.00	0.01	0.04	0.07	0.09	0.10	0.00	0.01	0.01	0.04	0.11	0.25
	Rec-WE	0.03	0.01	0.00	0.00	0.02	0.04	0.05	0.08	0.00	0.00	0.00	0.02	0.07	0.15
ET	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	4.31	5.26	5.10	4.78	5.71	5.05	4.31	4.11	5.07	4.31	4.83	4.81	5.41	4.47
	Gen-WE	47.39	11.83	5.54	1.06	3.93	28.67	22.42	52.75	36.84	87.28	67.36	62.58	43.91	60.97
	Org-WE	0.39	0.12	0.05	0.02	0.09	0.33	0.55	0.29	0.02	0.21	0.07	0.23	0.84	1.44
	Rec-WE	0.00	0.09	0.03	0.08	0.42	1.86	2.74	1.68	0.10	0.25	0.14	1.08	3.45	6.83
BA	EN	4.15	3.54	3.61	2.33	1.65	3.52	0.13	4.12	1.67	3.46	2.75	2.37	1.18	1.63
	WA	3.97	3.70	4.46	2.98	3.50	3.41	3.97	4.33	3.76	4.27	3.50	3.51	2.87	3.25
	Gen-WE	37.48	12.00	4.96	1.06	16.94	29.85	33.92	48.84	26.01	59.41	32.34	80.76	128.54	145.00
	Org-WE	0.22	0.11	0.05	0.03	0.09	0.23	0.31	0.63	0.15	0.34	0.09	0.15	1.01	1.36
	Rec-WE	0.00	0.07	0.04	0.06	0.25	0.08	0.55	0.12	0.06	0.23	0.10	0.15	0.33	0.13
MI	EN	0.09	0.36	0.84	0.54	0.05	0.31	0.00	0.00	0.00	0.25	0.42	0.29	0.69	0.00
	WA	0.48	1.70	4.14	2.88	0.96	1.22	0.00	0.00	2.05	2.88	2.38	1.51	4.79	0.00
	Gen-WE	1,030.80	73.60	5.71	1.71	74.59	242.55	0.00	0.00	69.49	1.74	107.12	275.00	59.73	0.00
	Org-WE	0.86	0.25	0.06	0.05	0.12	0.17	0.00	0.00	0.00	0.00	0.13	0.15	0.12	0.00
	Rec-WE	0.92	-0.03	0.06	0.09	1.04	0.41	0.00	0.00	0.01	0.00	0.10	0.49	0.34	0.00

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
CK	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	2.04	1.85	1.98	2.04	1.75	1.84	1.87	0.00	2.08	1.83	1.95	2.10	2.15	3.08
	Gen-WE	12.19	0.47	2.91	3.49	47.77	102.75	96.45	0.00	19.61	28.63	37.05	74.08	65.91	58.33
	Org-WE	0.09	0.06	0.03	0.02	0.04	0.11	0.25	0.00	0.02	0.14	0.03	0.07	0.20	0.28
	Rec-WE	0.16	0.03	0.03	0.03	0.17	0.12	0.58	0.00	0.02	0.00	0.03	0.13	0.50	0.52
GN	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	3.80	1.46	10.89	2.11	2.89	5.00	2.93	0.00	1.14	6.58	3.47	2.70	4.20	3.07
	Gen-WE	236.42	188.00	5.60	0.00	1.76	25.75	66.34	0.00	76.17	33.57	87.66	71.10	40.35	47.65
	Org-WE	0.77	0.40	0.10	0.16	0.84	1.69	2.80	0.00	0.00	0.00	0.07	1.81	2.43	5.68
	Rec-WE	2.04	0.95	0.03	0.18	0.78	1.79	4.08	0.00	0.64	0.00	0.05	1.75	4.15	9.85
TV	EN	1.62	1.03	1.92	1.59	1.64	1.84	4.88	2.20	1.30	2.58	1.64	1.84	2.21	1.30
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.29	2.11	2.13	0.77	1.61	11.29	1.08	42.80	4.13	9.52	3.29	13.06	11.28	15.18
	Org-WE	0.01	0.03	0.00	0.00	0.00	0.00	0.02	0.08	0.02	0.03	0.01	0.01	0.00	0.02
	Rec-WE	0.01	0.02	0.01	0.01	0.03	0.01	0.04	0.04	0.01	0.05	0.01	0.02	0.10	0.06
IC	EN	0.40	0.77	0.54	1.39	0.26	0.82	0.80	2.48	1.09	3.54	0.97	0.75	0.37	0.35
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	392.60	128.22	15.54	1.90	37.94	31.04	107.00	31.11	78.54	24.77	274.02	121.88	42.18	83.77
	Org-WE	0.18	0.22	0.04	0.05	0.08	0.06	0.53	0.03	0.03	0.06	0.16	0.13	0.17	0.89
	Rec-WE	0.06	0.00	0.12	0.08	0.84	0.47	1.50	0.09	0.25	0.15	0.14	0.29	0.38	0.28

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
WB	EN	0.84	1.13	1.61	2.28	1.72	1.22	6.18	5.60	0.94	4.36	2.26	1.42	2.44	1.15
	WA	0.26	0.52	0.52	0.53	0.54	0.42	2.35	1.57	0.24	1.04	0.55	0.41	0.57	0.39
	Gen-WE	99.53	8.97	28.63	20.81	200.89	491.93	78.46	54.38	157.87	0.00	30.29	346.90	228.56	513.35
	Org-WE	0.97	0.13	0.14	0.06	0.31	0.49	0.29	0.57	0.65	0.00	0.10	0.30	1.53	3.84
	Rec-WE	0.95	0.10	0.14	0.06	0.31	0.93	0.29	0.21	0.09	0.00	0.04	0.51	1.45	3.41
RC	EN	1.41	1.59	1.23	2.92	0.95	2.29	2.67	4.30	1.62	2.62	2.84	1.89	2.16	2.03
	WA	4.57	6.52	5.18	9.00	4.85	6.76	8.43	14.38	5.15	7.98	7.91	6.33	6.55	7.49
	Gen-WE	199.05	45.59	14.97	0.10	10.30	5.35	7.61	12.13	22.28	27.63	37.66	46.19	33.95	34.50
	Org-WE	0.05	0.06	0.03	0.01	0.01	0.01	0.05	0.00	0.00	0.00	0.05	0.03	0.37	0.00
	Rec-WE	0.00	0.03	0.15	0.03	0.18	0.23	0.21	0.01	0.03	0.11	0.04	0.05	0.10	0.18
WC	EN	1.19	0.76	1.33	0.87	1.28	2.03	1.26	1.83	1.11	2.34	1.67	2.29	1.49	0.89
	WA	4.25	2.93	5.15	3.02	3.64	6.90	4.77	5.31	3.99	8.00	4.64	6.05	4.59	3.33
	Gen-WE	1.34	12.19	18.96	18.89	139.92	134.16	175.60	154.40	131.20	42.02	50.27	109.28	149.03	319.52
	Org-WE	0.06	0.15	0.03	0.04	0.02	0.02	0.12	0.00	0.04	0.00	0.08	0.03	0.41	0.00
	Rec-WE	0.37	0.07	0.09	0.10	0.37	0.27	1.05	0.41	0.13	0.16	0.14	0.20	1.33	2.48
HD	EN	0.00	0.24	0.07	0.00	0.00	0.62	0.00	0.76	0.20	0.16	0.15	0.07	0.15	0.00
	WA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gen-WE	0.00	31.89	110.01	0.00	0.00	222.39	0.00	168.67	29.95	64.02	66.66	1,297.88	842.65	0.00
	Org-WE	0.00	0.30	0.75	0.00	0.00	0.28	0.00	1.48	0.48	1.22	0.25	0.89	2.44	0.00
	Rec-WE	0.00	0.19	0.43	0.00	0.00	0.50	0.00	1.42	0.34	1.56	0.12	1.96	1.17	0.00

Table 4.48 (Cont.)

Activity	Resource	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14
WR	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WA	0.20	0.34	1.59	0.58	0.66	0.74	0.64	0.00	0.54	0.75	0.54	0.36	0.14	0.00
	Gen-WE	0.00	75.36	53.30	69.35	545.81	941.50	919.10	0.00	301.01	334.31	942.50	2,337.49	4,954.64	0.00
	Org-WE	10.12	1.45	0.26	0.43	2.22	4.39	8.71	0.00	1.86	0.64	0.73	4.25	52.07	0.00
	Rec-WE	0.00	0.53	0.37	0.31	0.99	1.95	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.2 Consumer profile

In the process of creating a consumer profile, it is necessary to analyze the factors that influence personal consumption of energy, water, and waste in households. This analysis revealed that increased access to electricity does not necessarily result in increased usage among low-income households and may actually widen the gap in energy use between high- and low-income households. Moreover, household characteristics such as education level, head of household, household size, and housing quality and efficiency were identified as significant factors affecting electricity consumption (Son & Yoon, 2020). Additionally, it was found that there are direct and indirect drivers of resource use behavior in buildings, which can be categorized into direct and indirect drivers (Jorgensen et al., 2009).

The direct drivers of household water consumption can be classified into various categories, including incentives or disincentives provided through tariff structures, pricing mechanisms, or rebates on water-saving technologies. Furthermore, regulations and ordinances such as water restrictions and local government planning regulations play a significant role in influencing household water consumption. The characteristics of the property, such as lot size, pool, bore, tank, house size, and age, also impact the water usage patterns. In addition, household characteristics such as the composition of the household, household income, availability of water-saving technology, and water supply technology are crucial in determining the amount of water consumed. Finally, personal characteristics such as an individual's intention to conserve water and their knowledge of water conservation methods also play a role in influencing water consumption patterns in households. By understanding these direct drivers, policymakers and water management authorities can develop effective strategies to promote water conservation and sustainable water use practices in households.

The indirect drivers of water conservation behavior are factors that are less directly linked to water use but can still have a significant impact on the decision-making processes that drive water consumption. These drivers include various personal characteristics, such as subjective norms, behavioral control, and attitudes towards water conservation. Another important indirect driver is trust, both in the water provider and in other consumers. Additionally, perceptions of fairness in decision-making processes related to water management, including restrictions, tariffs, and infrastructure development, can impact water conservation behavior. Environmental values and conservation attitudes are also relevant, as is the principle of intergenerational equity. Socio-economic factors, such as household income, composition, age, gender, and education level, are also important drivers of water conservation behavior, as they can impact the availability of water-saving technologies, the affordability of water bills, and the knowledge and awareness of water conservation strategies.

The conditions and all factors that affect energy consumption, water usage, and waste generation resulting from each activity of each consumer group, it is possible to create a total of 14 profiles as illustrated in Figure 4.93 to Figure 4.106

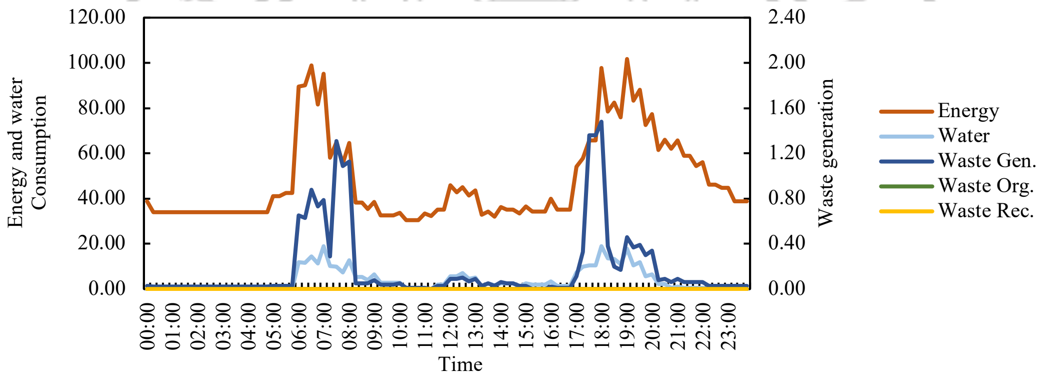


Figure 4.93 Consumer profile 1

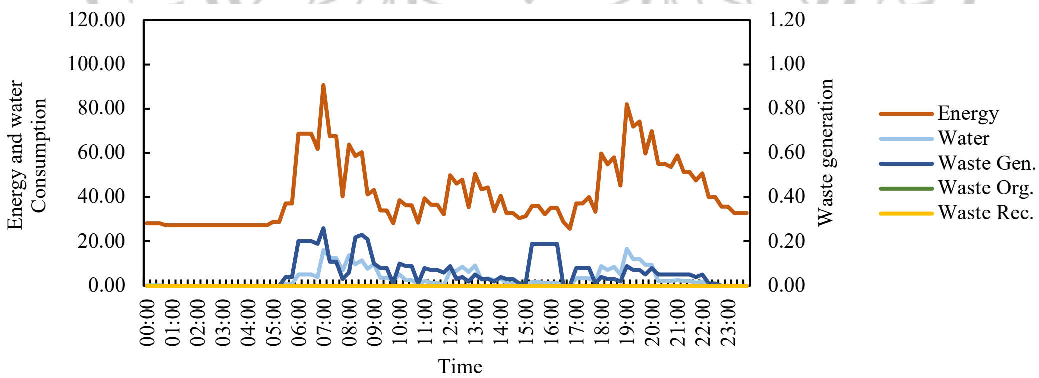


Figure 4.94 Consumer profile 2

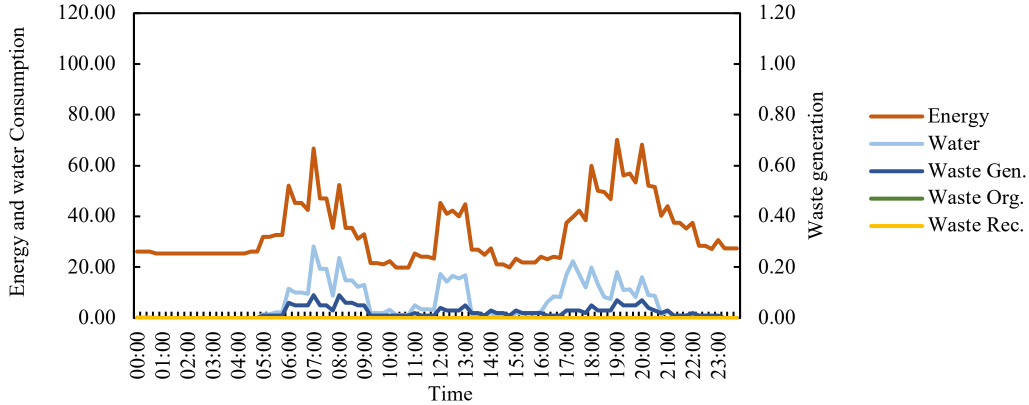


Figure 4.95 Consumer profile 3

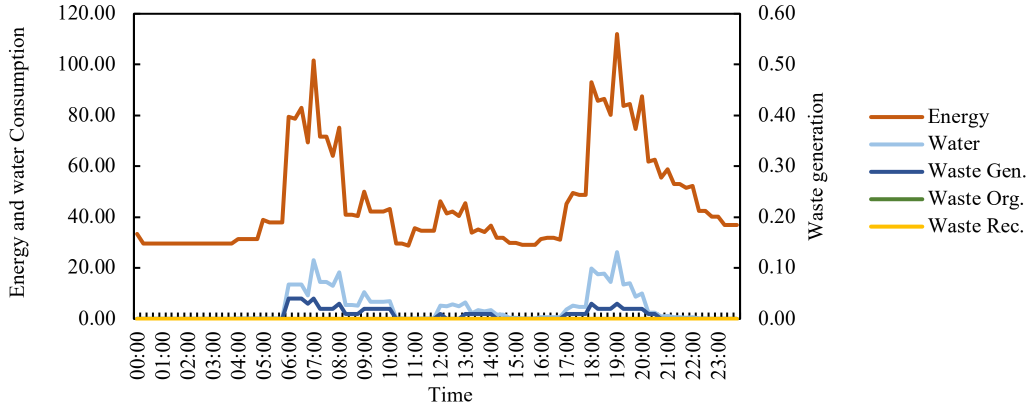


Figure 4.96 Consumer profile 4

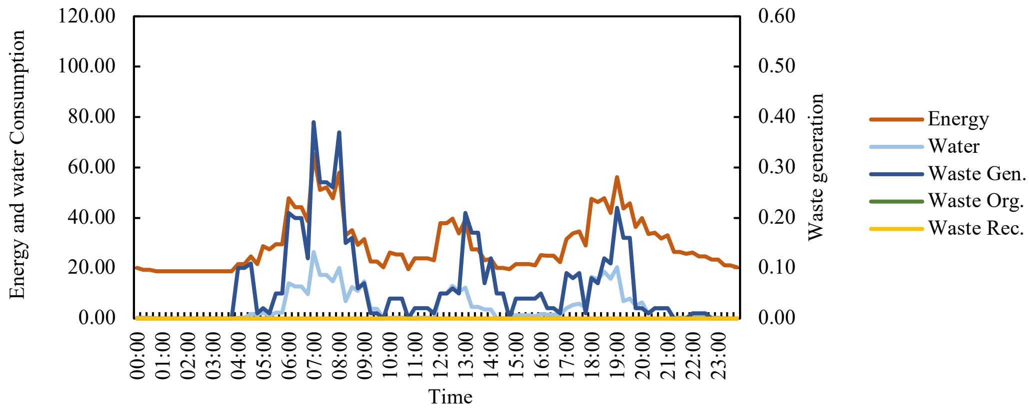


Figure 4.97 Consumer profile 5

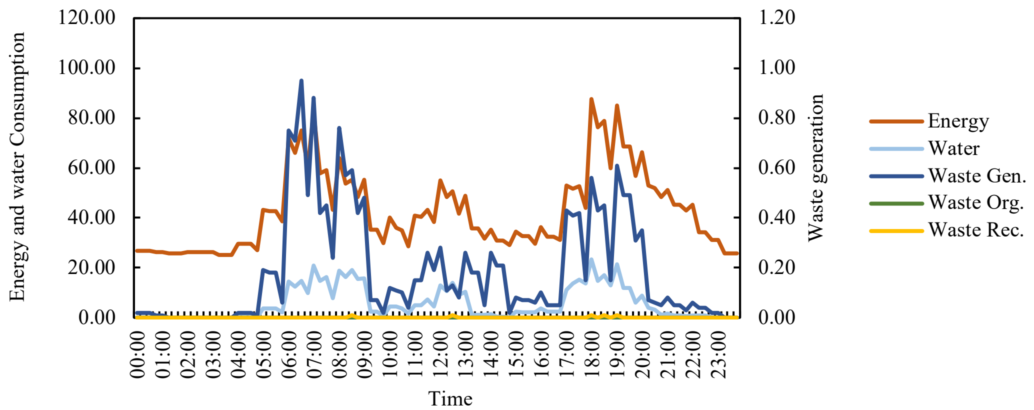


Figure 4.98 Consumer profile 6

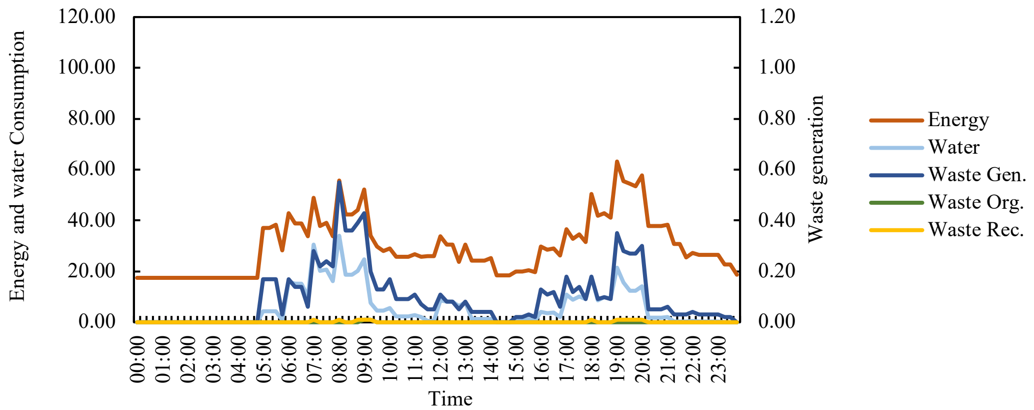


Figure 4.99 Consumer profile 7

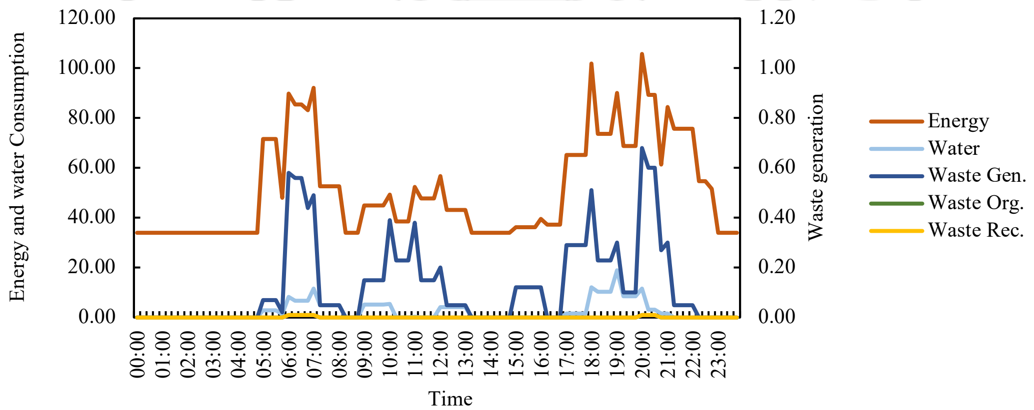


Figure 4.100 Consumer profile 8

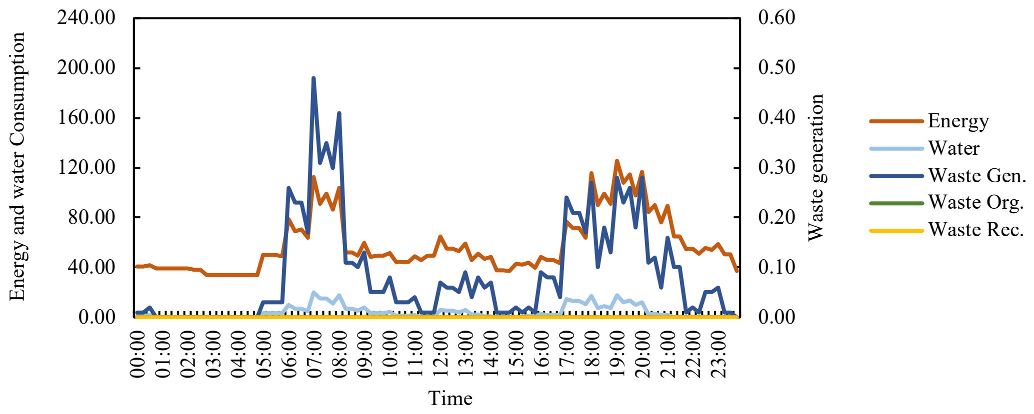


Figure 4.101 Consumer profile 9

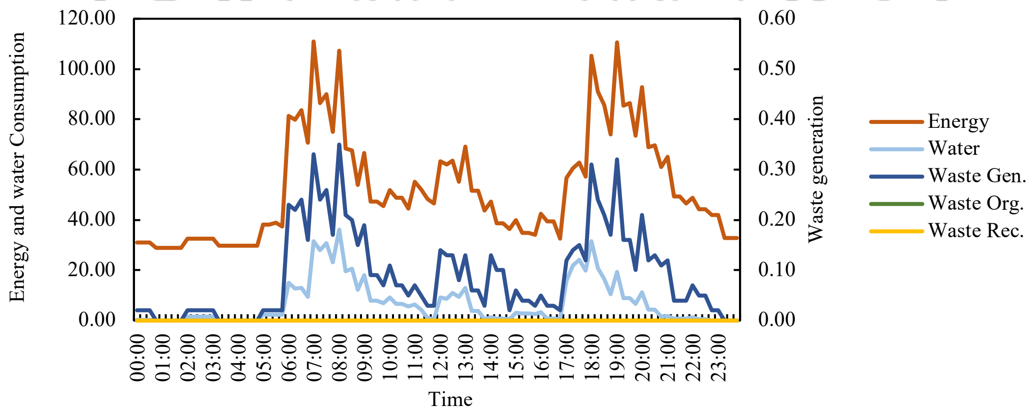


Figure 4.102 Consumer profile 10

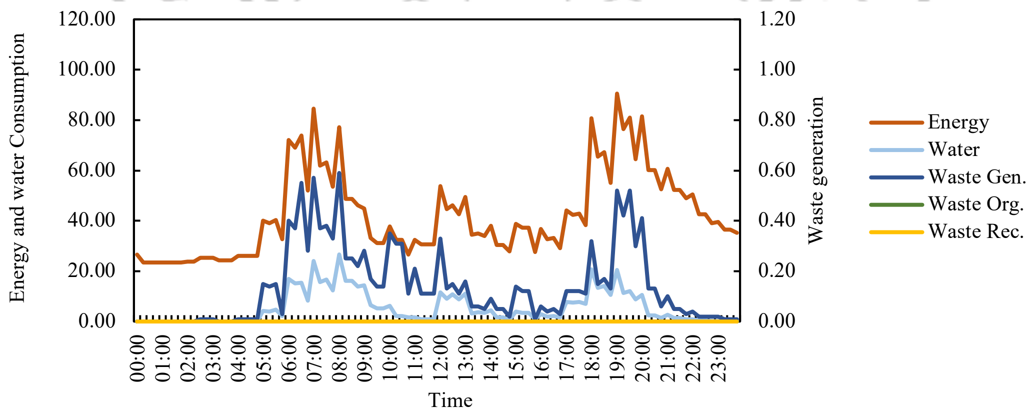


Figure 4.103 Consumer profile 11

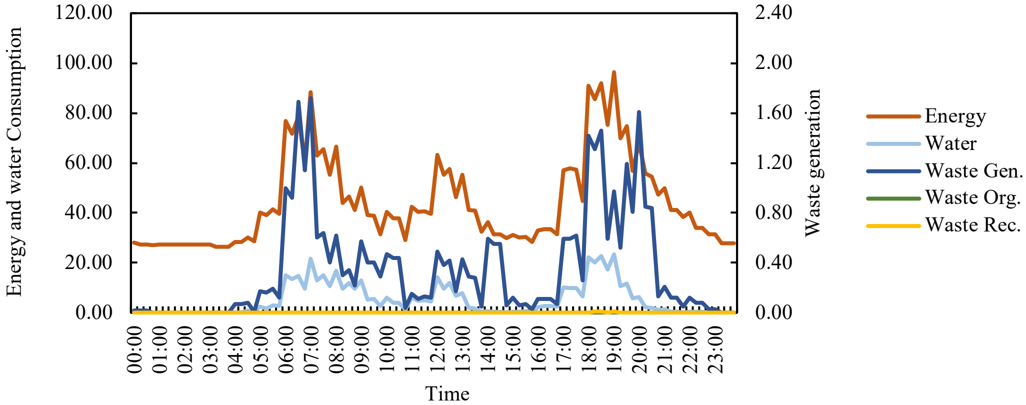


Figure 4.104 Consumer profile 12

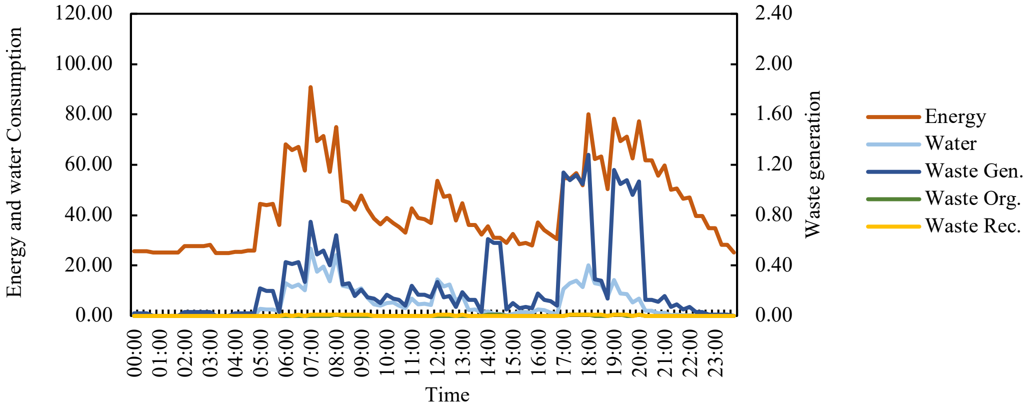


Figure 4.105 Consumer profile 13

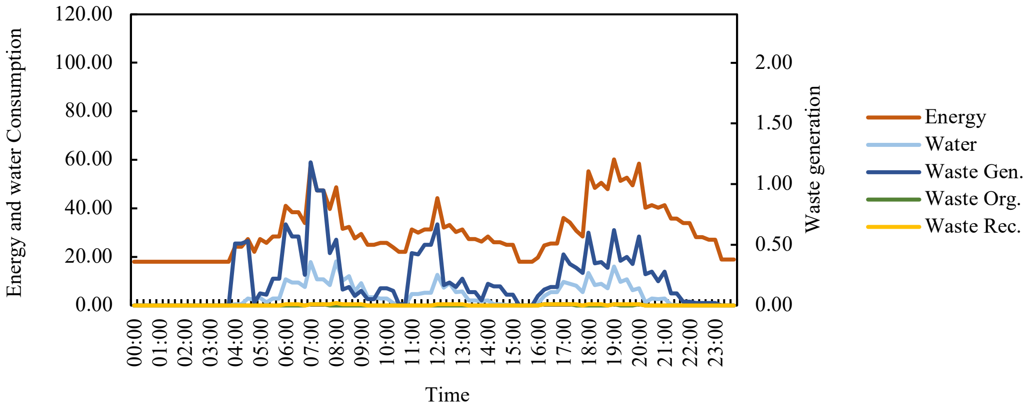


Figure 4.106 Consumer profile 14

Community load

From the population data of approximately 760 individuals in the community, consisting of 375 males and 380 females, the distribution among 16 consumer groups is as follows Table 4.49.

Table 4.49 Mae Tha Man community population

Profile symbol	Personal data		Community population	
	Gender	Age (Year old)	(Number)	(Percentage)
-	Male	< 10	45	5.92
CP1		11-20	55	7.24
CP2		21 - 30	68	8.95
CP3		31 - 40	53	6.97
CP4		41 - 50	53	6.97
CP5		51 - 60	47	6.18
CP6		61 -70	27	3.55
CP7		>71	16	2.11
-	Female	< 10	64	8.42
CP8		11-20	44	5.79
CP9		21 - 30	65	8.55
CP10		31 - 40	62	8.16
CP11		41 - 50	63	8.29
CP12		51 - 60	45	5.92
CP13		61 -70	40	5.26
CP14		>71	13	1.71
Total (Person)			**760**	**100.00**

The population data of the community, multiplying it by the amount of energy, water usage, and waste generation per profile yields the average usage and generation per day as shown in Figure 4.107 to Figure 4.109. These figures depict the quantity of energy, water, and different types of waste generated during different times of the day. Analysis of the data reveals that the average daily energy consumption is 1451.69 kWh/day, with the maximum electricity consumption of 29.29 kWh occurring at 19:30 and the minimum consumption of 9.78 kWh at 13:30. The average electricity consumption throughout the day is 15.12 kWh. Regarding water usage, the data show that the average daily consumption is 307,887.22 liters, or 405.11 liters per person per day, which is higher than the average water usage. The time of highest estimated water usage is at 6:45, with a total consumption of 10,189.22 liters for the entire community, while the lowest water usage occurs at 12:15 with a consumption of 1396.03 liters. The average daily water usage for the community is 3,207.16 liters. Examining the waste generation of the community, the data indicate high variability during the early morning hours, and the amount of waste does not correspond with energy and water usage patterns. The average waste generation of the community is 3057.34 kilograms per day, consisting of 1694.82 kilograms of general waste, 1004.86 kilograms of organic waste, and 357.66 kilograms of recyclable waste.

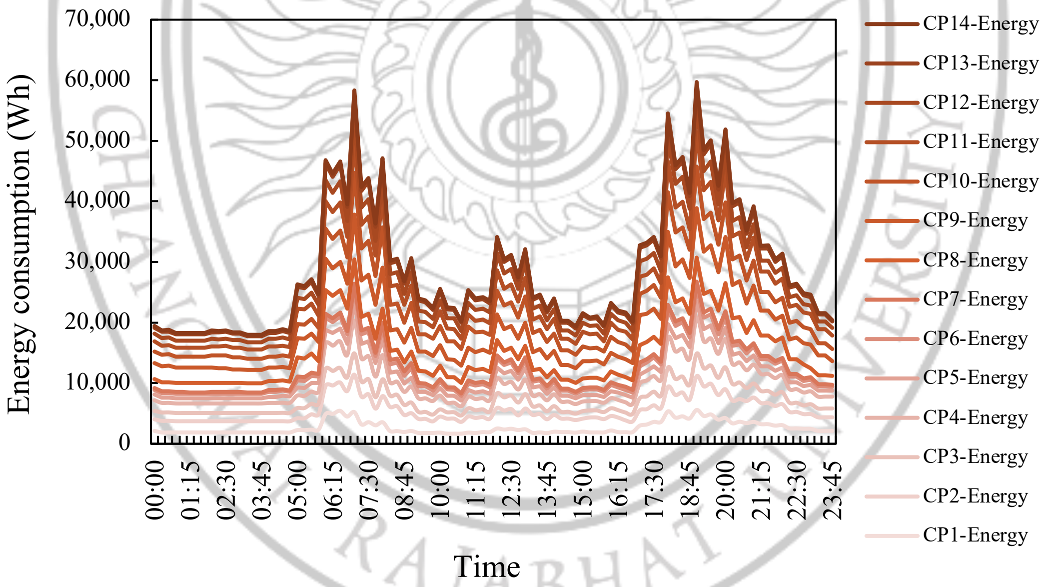


Figure 4.107 The average daily energy consumption of community

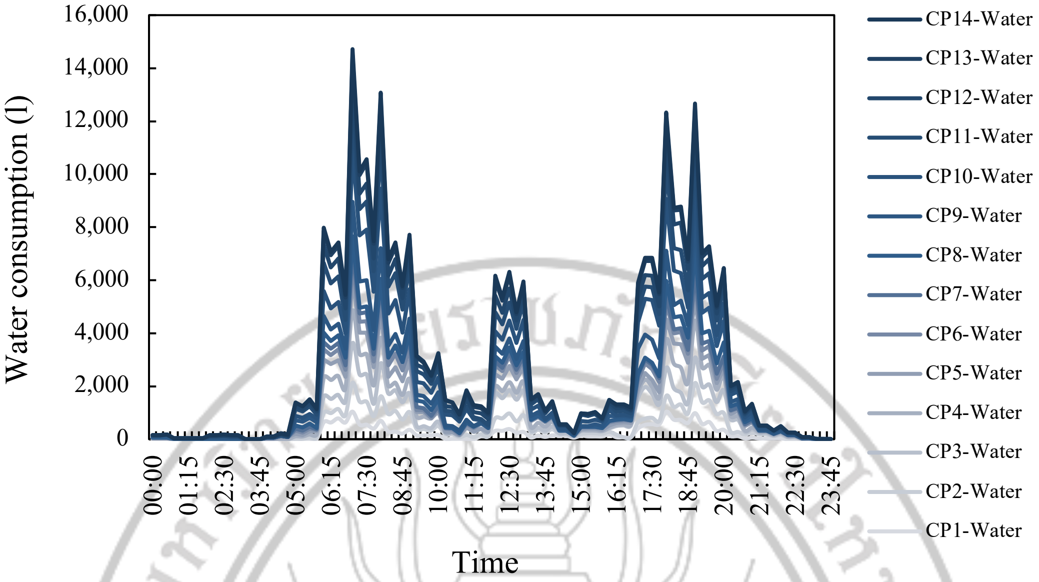


Figure 4.108 The average daily water consumption of community

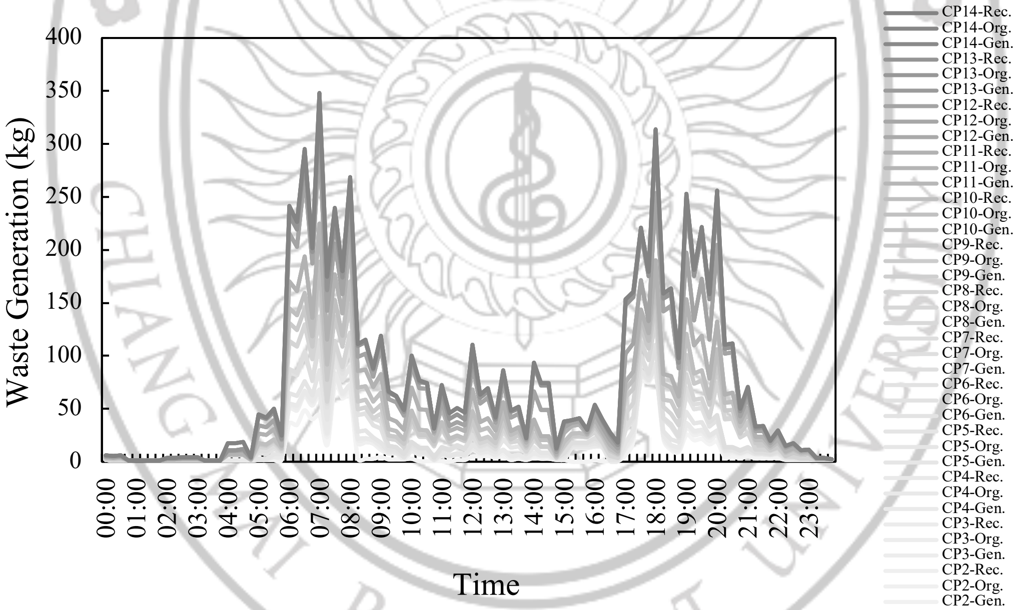


Figure 4.109 The average daily waste generation of community

When analyzing the quantity of energy, water usage, and waste generation within the community on a monthly basis, it is necessary to consider the environmental conditions of the community since the data on energy usage and water consumption within the buildings is retrospective. When comparing the average energy and water usage for each time period throughout the month, it varies in the same direction as the environmental conditions, as shown in Figure 4.110. Additionally, the positive correlation between water usage within the buildings and energy usage within the buildings causes the water usage within the buildings to also vary directly with the external temperature, similar to the energy usage. However, the generation of waste does not have a statistically significant correlation with energy and water usage, and thus, the analysis of accumulated waste did not consider environmental factors.

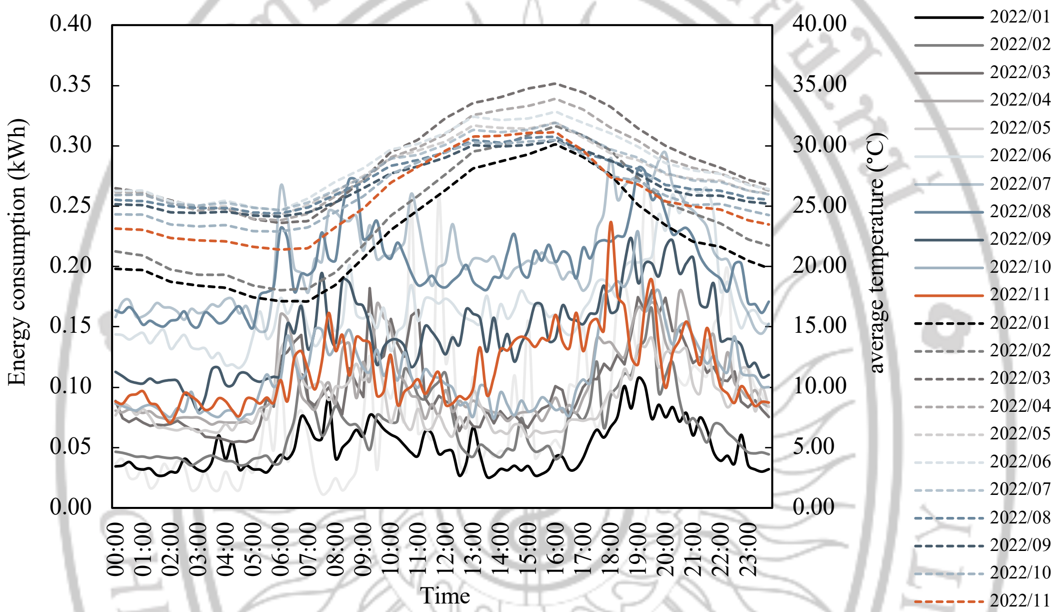


Figure 4.110 The average of energy consumption in CH1 and outdoor ambient temperature in community

The analysis revealed that, when analyzing the amount of energy, water usage, and waste, it was found that the total amount of energy used by the community in one year was as follows: 84,947.24, 88,839.21, 119,988.03, 116,469.74, 131,999.19, 118,090.05, 105,681.56, 110,074.08, 107,450.75, 105,931.00, 97,528.94, and 99,806.62 kWh per month, for the months of January to December 2022.

Development of smart community frameworks

1. Analysis of community potential

1.1 Energy sector

It was found from the data on solar irradiance intensity in the community that the level of irradiance was higher than 900 W/m2 during the period from February to October. When considering the potential for electricity production, it was found to be equal to 2,729.61, 2,716.84, 2,347.43, 1,923.32, 1,816.43, 1,741.49, 1,844.76, 1,749.13, 1,573.23, 1,686.07, 1,658.88, and 1,637.05 kWh/m^2/month, respectively, as a quantity of potential electricity production from solar radiation from January to December.

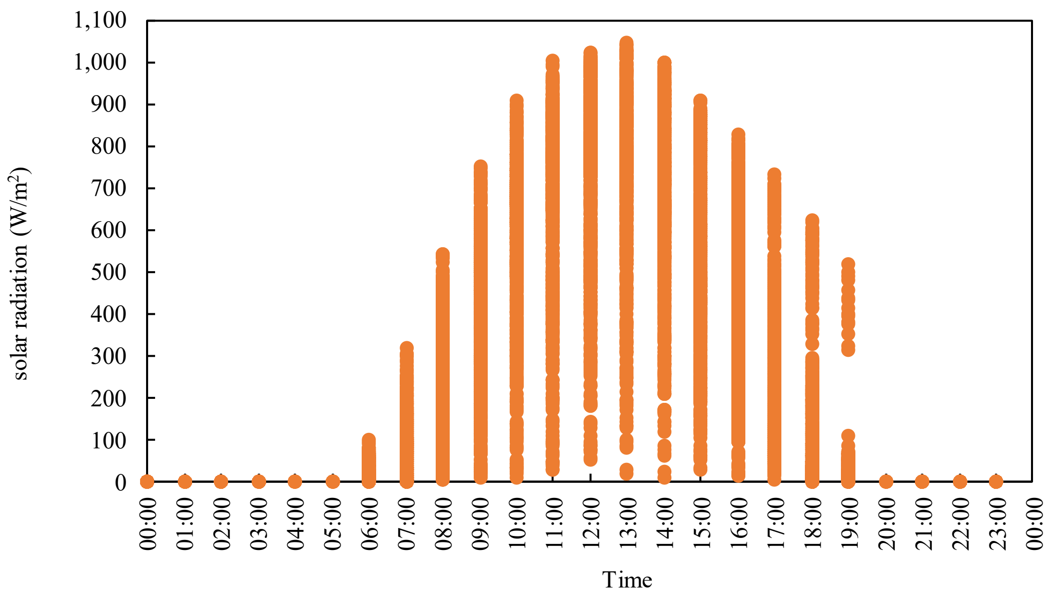


Figure 4.111 Solar radiation in community

Wind potential in the area, the average wind speed is found to be approximately 5.40 m/s. By considering the wind speed to assess the potential size of wind turbines that could be installed for electricity generation within the community, it is observed that the amount of electricity generated by a wind speed of 5.4 m/s is contingent upon both the size of the wind turbine and its efficacy in generating electricity. Typically, wind turbines utilized for community installations range in size from 10 kW to 100 kW. It is assumed that a 50 kW wind turbine with a 40% efficiency has the capacity to generate an approximate amount of 26.38 kWh of electricity. Thus, with the implementation of a 50 kW wind turbine possessing a 40% efficiency, a wind speed of 5.4 m/s has the ability to generate 26.38 kWh of electricity per hour.

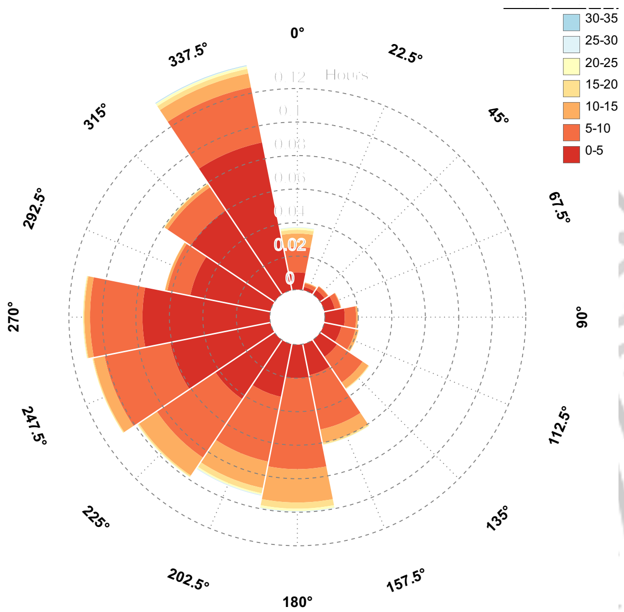


Figure 4.112 Wind speed and direction in community

1.2 Water sector

The community's necessary water source within the village is a natural water source that is mainly used by the community. The data obtained from the survey on water usage and demand from a sample group, it is evident that a large portion of residential buildings, specifically residential homes, already have two water systems in place, namely the community tap water system and the natural water source system. However, from the data, it was found that the water system derived from the natural water source cannot be used during the period between months, due to the natural water source being dry and experiencing turbidity.

1.3 Waste sector

Derived from the waste generation data in the Mae Tha Man community based on the consumer profile of the entire village, it was found that general waste was produced at 7.59 kg, wet waste at 0.01 kg, and recyclable waste at 0.02 kg. Upon aggregating the data, it was determined that the average waste disposal per capita per day in the Mae Tamarn community was 0.01 kg, which is considerably lower than the national average for Thailand, which stands at 1.15 kg per capita per day.

Upon examining the community context, it was discovered that the Mae Tamarn community has been actively engaged in waste management with societal participation. This social process involves raising community awareness about the current waste situation, fostering understanding, and discussing suitable waste management strategies for the community. Prior to implementing the participatory waste management plan, the Mae Tamarn community had an average waste generation of 1.05 kg per capita per day. Following the initiation of the community-based waste management process, the waste generation was reduced by 0.02 kg per capita per day. The obtained data, it can be observed that waste reduction has been consistently achieved over time. Thus, it can be concluded that the waste generation data analyzed from the consumer profile closely aligns with the reality.

2. Development of smart community framework

2.1 Energy sector

Upon assessing the total energy demand of the village, divided into one-hour intervals and juxtaposed with the solar and wind energy potential in the area, several observations have been made. It has been ascertained that electricity production from solar energy exhibits potential primarily during the morning hours and is sufficient to meet the energy demand between 10:00 to 16:00. The capacity of solar panels to address energy requirements during this period is limited, accounting for only 30.28% of the total energy demand. However, when analyzing the energy consumption potential throughout the day, a significant finding emerges. It has been determined wind energy possesses the capability to replace up to 83.99% of the total energy demand. This discovery underscores the importance of leveraging both solar and wind energy resources to optimize the village's energy management strategies and harness the full potential of renewable energy sources. That show in Figure 4.113.

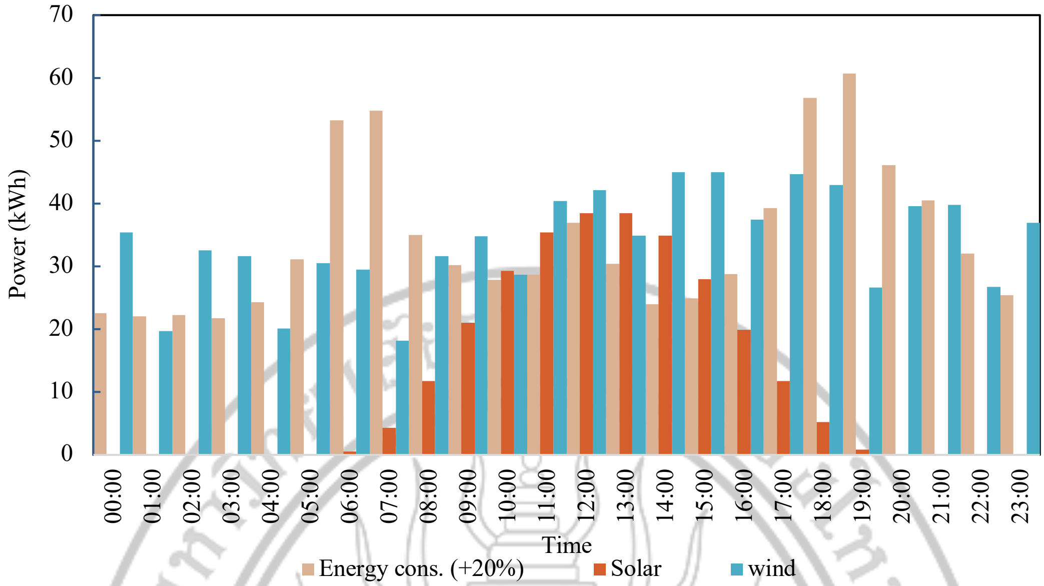


Figure 4.113 The energy production over time from the community's solar and wind potential

2.2 Water sector

To analyze the investment for a clean water production system for the community, it is crucial to consider both the initial investment and the ongoing operational costs. The clean water production system must operate for 12 months to provide clean water during the six months when the natural water source is turbid. The investment for the clean water production system will depend on the system's type, size, and installation and maintenance costs. Operational costs will include energy, chemical, and maintenance expenses. Conducting a feasibility study is necessary to determine the most appropriate and cost-effective system for the community's requirements.

If the cost of the clean water production system is affordable and feasible, it will provide the community with access to clean water year-round, decrease the risk of water-borne diseases, and enhance overall health and well-being. It will also reduce the community's dependence on the natural water source during the six months when the water is turbid, ensuring a consistent supply of clean water.

2.3 Waste sector

The daily waste generation data in the community revealed a mere 7.63 kg/day from all individuals in the village, which is considered to be an insufficient amount for practical utilization. Consequently, it can be concluded that this particular community does not yet necessitate waste management interventions.

3. Economic analysis of smart community guideline

3.1 Energy

The cost of solar energy systems is an important factor in evaluating the financial feasibility of a solar energy project. The cost of the solar system installation is generally measured in terms of the cost per watt. For instance, the cost of the 52.25 kW solar system installation mentioned in the example is calculated at THB 40 per watt, resulting in an initial cost of THB 2,090,000.

The net present value (NPV), internal rate of return (IRR), and payback period are all financial metrics used to assess the financial feasibility of solar energy projects. These metrics are calculated the initial cost of the solar system installation and the estimated future cash inflows and outflows associated with the project.

A positive NPV, higher IRR, and shorter payback period all indicate that a solar energy project is financially viable. In the example given, the NPV of the solar system installation is found to be positive, the IRR is higher than before, and the payback period is approximately 1.74 years, all of which suggests that the project is financially viable. Financial metrics can help investors or businesses make informed decisions regarding solar energy projects and their financial returns.

The cost of installing a wind power system is calculated by multiplying the total wattage by the cost per watt, which in this case is THB 90 per watt. With an assumed total wattage of 20 kW, the initial cost of the wind power system is THB 1,800,000. To determine the profitability of the wind power system, the NPV, IRR, and payback period are calculated the assumption that the system can save around THB 3,334,402.62 per year.

The NPV of the wind power system installation is calculated to be THB 39,338,262.03, which is positive and indicates that the project is profitable based on the assumptions made. The IRR of the wind power system installation is 58.45%, which is high and indicates that the project will generate a high return the assumptions made. The payback period for the wind power system installation is approximately 0.54 years, which means that the project will pay for itself in approximately 0.54 years based on the assumptions made.

These calculations show that a wind power system can be a profitable investment with a relatively short payback period. However, it is important to note that these calculations are certain assumptions and may not be applicable to all situations. Factors such as location, wind patterns, and maintenance costs may affect the actual costs and benefits of a wind power system.

The cost per watt is used to measure the cost of solar system installation. The net present value (NPV), internal rate of return (IRR), and payback period are financial metrics used to assess the financial feasibility of solar energy projects. A positive NPV, higher IRR, and shorter payback period suggest that a solar energy project is financially viable. The same method is used to calculate the cost of wind power system installation, and the profitability of the system is determined by the NPV, IRR, and payback period. The calculations show that wind power systems can be profitable with a relatively short payback period, but it is important to consider other factors such as location, wind patterns, and maintenance costs.

3.2 Water

Investing in a clean water production system for the community is a feasible approach to provide year-round access to clean water. However, a feasibility study is necessary to determine the most appropriate and cost-effective system. To estimate the cost of installation and operation of a clean water production system, several factors such as the type of system, capacity, location, and maintenance requirements must be considered. The cost of installation can vary widely depending on the system type and location. For instance, a simple filtration system with a capacity of 304,000 liters/day may cost between 100,000 to 500,000 baht, whereas a more advanced reverse osmosis system with the same capacity may cost between 500,000 to 1,500,000 baht.

Operational costs may include electricity, maintenance, and labor costs. The electricity costs depend on the system's capacity and energy efficiency, ranging from 20,000 to 50,000 baht per month. Maintenance costs vary with system complexity and maintenance frequency, estimated to be around 10,000 to 30,000 baht per month. Labor costs depend on the number of staff required to operate and maintain the system, ranging from 20,000 to 50,000 baht per month. Overall, the cost of installation and operation of a clean water production system can range from 150,000 to 2,000,000 baht, depending on several factors. Conducting a feasibility study is necessary to determine the most suitable system type, location, and operation model to optimize cost-effectiveness.

Smart community framework

A framework for the development of smart community based on the quantification of energy demand, water consumption, and waste generation within the community has been proposed. This is achieved by comparing the community's potential with the collected and analyzed data from the community, as illustrated in Figure 4.114. The development framework and analysis are divided into three data sources: data obtained from surveys, data measured by smart meter, and data from public databases, with details as follows:

Data from surveys, which are obtained through on-site collection from a sample group within the community for the purpose of analyzing behavioral patterns in building activities by age and gender, consist of four main components: user characteristics, electrical devices and appliances within the building, frequency and duration of each activity, and historical expenditure data. This information is gathered from two sample groups: a majority or at least 35% of the community population, and a sample group of residents living in representative buildings.

Data from smart meters are derived from measurements of energy consumption, water usage, and waste generation of various types (general waste, recyclable waste, and organic waste) within buildings in real-time, with data collection frequency every 15 minutes. These devices are installed in three groups of representative buildings, including residential buildings, office buildings, and commercial buildings. The increased number of buildings with installed smart measuring devices contributes to the reliability of the data used in the analysis of user profiles.

Public database information comprises general data accessible from both government agencies and private organizations. This data includes the total population of the area, categorized by age and gender groups, and current and historical information on the community's fundamental potential, such as solar radiation intensity, wind speed and direction, as well as the quantity and size of water sources in the area. This information is utilized for comparative analysis with the community's needs.

Upon obtaining data from all three sources, management, and analysis yield four sets of data, which include: 1. Behavioral data within the community from the sample population and residents living in representative buildings; 2. Real-time energy, water, and waste generation data; 3. Community context data categorized by age and gender groups; and 4. Community potential data, with details as follows:

Behavioral data within the community from the sample population is obtained by analyzing the frequency and probability of behaviors and activities occurring within buildings for each profile group. This data is used to adjust and compare with values obtained from representative buildings to ensure accuracy and precision. The behavioral data of residents living in representative buildings is used to create activity profiles for each activity occurring within the buildings, which can be utilized for prediction or user profile creation.

Real-time energy, water, and waste generation data within representative buildings are used to identify quantities derived from activities occurring during the time periods when residents are engaged in their respective activities within each building. This data is combined with information from questionnaires to create user profiles.

Community context data, categorized by age and gender groups, is used to analyze the quantity of energy and water consumption and waste generation within all buildings. This analysis determines the potential and costs associated with resource management.

Community potential data assesses the readiness of the area to support current community needs and accommodate future community expansion. This data indicates the feasibility of local resources to accommodate the development of the community towards a smart community.

The provided information, an analysis is conducted using the data obtained from the activities occurring within the sample population, in conjunction with the activity profile data. This analysis aims to identify the energy, water, and waste generation quantities of each activity, in order to create and adjust user profiles for accuracy and reliability. Additionally, the data from the entire community population is used to calculate community needs, taking into consideration the user profiles.

Subsequently, the potential of the community in three aspects is analyzed to determine its suitability. Generally, solar energy can generate an average of 30% of the estimated daily energy demand, while areas with wind energy potential can generate an average of 80% or more, depending on the community's location. The suitability of a community is calculated using the investment costs for installing solar energy systems at approximately 40 THB/watt, and wind energy systems at an average of 90 THB/watt, with the system size depending on the community's energy demand. The clean water production system is calculated by the average daily water consumption at a rate of approximately 3.50 THB/liter. The expenses for waste management, which the community cannot handle independently, are on average between 800 and 2,500 THB/ton, depending on the area and transportation distance.

The appropriateness of community development towards a smart community for energy, water, and waste management is determined by considering the investment value for the preparedness and management of energy, water, and waste in the entire area, divided by the costs that the community can reduce. If all three aspects have a low payback period, it indicates that the community has the potential to develop towards a smart community.

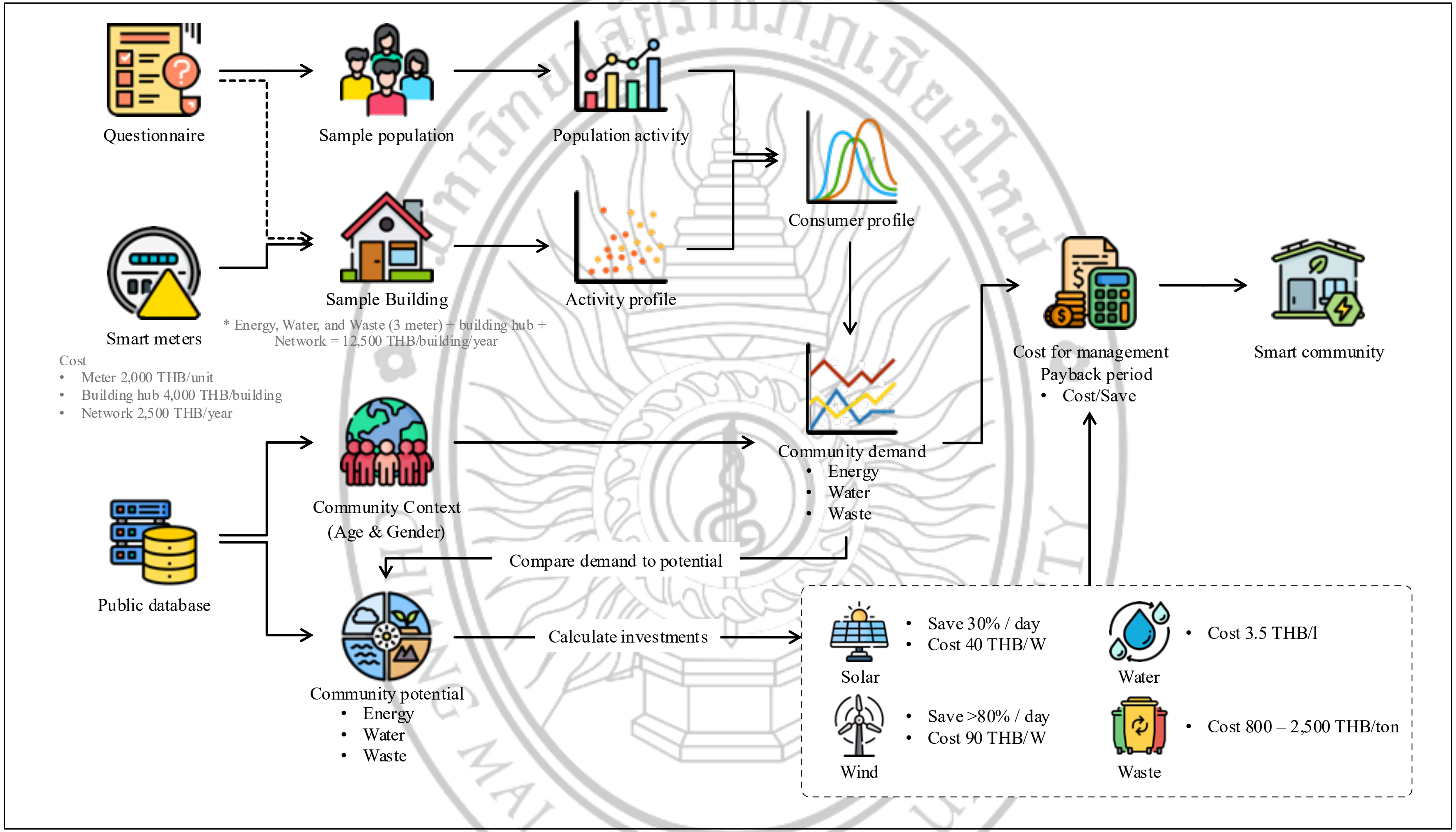


Figure 4.114 Smart community framework infographic

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Community context

In conclusion, this study provides valuable insights into the building characteristics and activity behavior of the Mae Tha Man Community in northern Thailand. The correlation analysis highlights the impact of age on education, occupation, and income, while education and occupation were found to be positively correlated with monthly income. The study also highlights the importance of understanding building characteristics to identify potential areas for energy conservation in communities, with LED lighting being the most commonly used lighting equipment and fans being the primary device used to regulate room temperature. Additionally, the analysis of building activities identified 23 different activities and their frequency, duration, and time intervals, which can be used to develop a dataset that comprehensively captures patterns of energy, water, and waste resource usage. Overall, this information can be instrumental in developing policies and programs aimed at improving the living standards of the community and addressing their specific needs.

Building consumption and activity profile

In conclusion, the analysis of the building activity profile involves studying the features of the building's data on energy, water, and waste consumption, as monitored by SM. This data collection enables the understanding of community resource consumption and the prediction of future community demand. This sector involves two main steps, namely analyzing building consumption data and creating a building activity profile. Regarding building consumption data, the collection focuses on measuring the consumption of all three resources, namely energy, water, and waste disposed of inside the building. Specifically, the data on energy consumption involves monitoring the quantity of power utilized in each building every 15 minutes, which is used to calculate the total electricity used throughout each period. The assessment of energy consumption is categorized based on three characteristics, namely the building's general average energy consumption behavior, energy consumption characteristics by weekday and weekend, and energy consumption characteristics by days of the week.

1. Consumption

The data collected from the various buildings, it can be concluded that energy and water usage patterns within buildings vary depending on the type of building and the behavior of its occupants. Residential buildings have energy usage concentrated in two time periods, the morning and evening of each day, but the quantity and duration of energy usage vary depending on the occupants' characteristics. In contrast, commercial buildings such as coffee shops, office buildings, and even physician residences have energy, water, and waste production concentrated during working hours or mid-day. However, there is only a slight difference in resource usage between weekdays and holidays.

The study found that energy consumption behavior within a building is consistent throughout the week, with two periods of high energy usage occurring at the same times on weekdays and weekends. This behavior suggests that the amount of energy usage within the building is related to both weekdays and weekends, and there is consistent energy consumption behavior in the same direction. Moreover, the study concluded that energy usage behavior was directly affected by the building's occupants. Thus, further factors such as consumer information, occupation, and individual preferences may play a crucial role in determining the amount of energy consumed. Overall, these findings suggest that to develop effective energy-saving measures, it is essential to consider not only the type of building but also the behavior of its occupants.

2. Activity

The information provided in the message is a summary of the activities and behavior patterns observed in different households. The focus is mainly on the frequency and duration of various activities such as washing, bathing, and lighting, and their correlation with energy usage, water usage, and waste generation. The conclusion drawn from the data is that activities in the building should be consistent with energy usage patterns to reduce waste generation. The data also shows that infrequent activities such as washing and physical training have little effect on energy consumption, water usage, and waste generation, but they are still significant in terms of the larger interrelated picture.

In conclusion, the analysis of energy usage, water consumption, and waste generation within each building is crucial to identify consumption patterns and determine the amount of energy, water, and waste consumption of each individual consumer. The process of activity identification involves the use of data from smart meters, questionnaires, and analysis of peak loads to identify patterns or behaviors of normal usage. The frequency of activities within each building is directly proportional to the energy consumption quantity within the building, and the energy consumption quantity is influenced by the activities taking place within the building. The amount of waste generated within a building does not necessarily have a significant impact on the occurrence of waste generation for each activity during different time periods within the building. The method of determining the energy, water, and waste consumption can identify the consumption patterns of each consumer, and the set of consumption data can be expanded to each consumer group for further analysis. Overall, understanding energy usage patterns and consumption data is essential for implementing energy-efficient practices and reducing energy consumption in buildings.

Relationships of energy, water, and waste

In conclusion, the analysis of energy consumption, water usage, and waste generation within a building reveals a complex and varied relationship between these factors. The correlation between the variables can be divided into two groups of activities: those with long durations and those that occur at certain intervals. The behavior of these activities is influenced by various factors such as user behavior, activity type, and building characteristics. The findings suggest that targeted interventions may be necessary to reduce energy consumption and waste generation within the building. Future research could focus on identifying specific interventions and strategies to improve the relationships between energy, water, and waste in buildings.

Community load profile

this study provides valuable insights into the usage and generation of energy, water, and waste within a community. The findings indicate that the average daily energy consumption of the community was 1451.69 kWh/day, with a maximum consumption occurring at 19:30 and a minimum consumption at 13:30. Similarly, the average daily water consumption for the community was estimated to be 307,887.22 liters, or 405.11 liters per person per day, which was higher than the average water usage. Waste generation within the community showed high variability during the early morning hours and was not directly correlated with energy and water usage patterns.

Moreover, the study highlights the importance of considering environmental factors when analyzing monthly energy and water usage, as these factors influence the consumption patterns. However, waste generation did not show a statistically significant correlation with energy and water usage, and therefore, environmental factors were not considered in the analysis of accumulated waste.

Finally, the analysis of the total energy used by the community over one year revealed monthly variations, with the highest energy consumption occurring in May and the lowest in November. Overall, this study provides valuable information for policymakers and community planners to make informed decisions regarding energy, water, and waste management within their communities.

Frameworks for optimization of the smart community

1. community potential

In conclusion, the Mae Tha Man community has great potential for renewable energy production through solar irradiance and wind speed. The community's natural water source system needs to be augmented to meet the water demands of the population during dry and turbid months. The community has been actively involved in waste management, and the participatory waste management plan has proven to be successful in reducing waste generation over time. The data obtained from the consumer profile is reflective of the actual waste generation in the community. Overall, the analysis of the community's potential in the energy, water, and waste sectors will help in developing sustainable strategies for the community's future growth and development.

2. smart community framework

The development of a smart community framework requires a thorough analysis of the energy, water, and waste sectors to optimize the use of resources and improve the overall quality of life for the community. The assessment of the energy sector revealed that a combination of solar and wind energy resources could replace a significant portion of the community's energy demand. The water sector analysis highlighted the importance of investing in a clean water production system to provide year-round access to clean water, decrease the risk of water-borne diseases, and enhance overall health and well-being. Finally, the waste sector analysis concluded that the community's waste generation rate was insufficient to necessitate waste management interventions. Overall, this smart community framework could serve as a blueprint for other communities seeking to optimize resource utilization and improve the quality of life for their residents.

The economic analysis of the smart community guidelines highlights the importance of considering financial feasibility when investing in renewable energy and clean water production systems. The cost per watt, net present value, internal rate of return, and payback period are essential financial metrics used to evaluate the profitability of solar and wind power systems. The profitability of a clean water production system depends on several factors, such as the system type, location, and operational costs. Therefore, conducting a feasibility study is necessary to determine the most suitable and cost-effective clean water production system. Overall, implementing renewable energy and clean water production systems can bring long-term benefits to the community and the environment.

This research is to develop a process for the implementation of a Smart Community in rural areas where the average monthly income is less than 10,000 baht. One of the main objectives is to understand the behavior and activities of the community members, which can be correlated with their age and gender profiles. It is important to note that the amounts of energy use, water consumption, and waste production can differ significantly between different profile groups. Therefore, it is necessary to gather data from the installed Smart Meters to understand these patterns and trends.

The relationship between energy and water use is present at the building level, meaning that it is possible to determine how much energy and water a particular building is using. On the other hand, the relationship with waste production is at the activity level, which means that it is necessary to understand how much waste is being produced by different activities in the community, such as cooking, cleaning, and waste disposal. To collect community energy, water, and waste data, a combination of smart meters and surveys can be conducted. This approach can help to reduce the cost of equipment and provide a more accurate understanding of the community's needs. Additionally, the data management framework that is established through this process can be applied to the planning of community expansion in the future.

Overall, the development of a process for the Smart Community in rural areas can provide significant benefits to the community members, including access to clean energy, water, and waste management systems. By gathering data on community behavior and activities, it is possible to design and implement effective systems that meet the specific needs of the community while also reducing costs and promoting sustainable development.

Smart community framework

The framework for developing smart community through the quantification of energy demand, water consumption, and waste generation provides a comprehensive approach to sustainable resource management. By collecting data from various sources, including surveys, smart meters, and public databases, the framework enables the creation of accurate and reliable user profiles and facilitates the analysis of community needs and potentials.

The analysis of the community's potential in terms of energy generation, water production, and waste management allows for informed decisions on investments and the feasibility of developing towards a smart community. By considering the payback period for investments in energy, water, and waste management systems, the community can assess its suitability for development into a smart community.

Ultimately, the proposed framework presents a practical and systematic approach to managing resources and promoting sustainable growth within communities. By integrating smart technologies and data-driven decision-making, communities can achieve better resource efficiency, reduce their environmental impact, and improve overall quality of life for their residents.

Recommendation

1. The community data collection by the questionnaire

The use of data from surveys for analyzing energy usage, water consumption, and community waste generation behaviors is a critical tool for confirming the accuracy of actual behaviors. It is essential to collect data on load and activity obtained from surveys, which must be verified for accuracy because data users may not know the details of the devices or the exact time of activities. This can affect the accuracy and reliability of the data used for analysis.

2. The monitoring system

The importance of real-time monitoring systems in collecting community data, particularly for remote areas, highlights the need for a reliable network communication system. In this research, internet-based communication was chosen, and in the initial stages, the existing internet infrastructure within the smart meter installation sample building was utilized. However, due to the remote and unstable nature of the area, which is at the end of the power and internet distribution line, the data collected could not be transmitted to the database completely. To address this issue, the researchers developed a private internet network to ensure complete and accurate data collection.

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APPENDIX

APPENDIX A

Questionnaire for community activity collection

แบบสอบถามข้อมูลการใช้ทรัพยากรชุมชน

ด้านพลังงาน น้ำ และขยะในการดำเนินกิจกรรมในครัวเรือน

คำชี้แจงทั่วไป

แบบสอบถามนี้จัดทำขึ้นเพื่อเป็นข้อมูลประกอบการทำดุษฎีนิพนธ์ เรื่อง "การศึกษาแนวทางการจัดการข้อมูลพลังงาน น้ำ และขยะ เพื่อมุ่งสู่ชุมชนอัจฉริยะ กรณีศึกษา หมู่บ้านแม่ตะมาน ตำบลกึ้ดช้าง อำเภอแม่แตง จังหวัดเชียงใหม่"เท่านั้น โดยไม่มีการเปิดเผยข้อมูลเฉพาะบุคคลแต่อย่างใด จึงหวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จากท่าน และขอขอบพระคุณมา ณ โอกาสนี้

<u>คำชี้แจง</u> แบบสอบถาม ประกอบด้วย 4 ตอน ดังนี้

ตอนที่ 1 ข้อมูลพื้นฐานผู้ให้ข้อมูล

ตอนที่ 2 ข้อมูลลักษณะอาคาร และอุปกรณ์เครื่องใช้ในอาคาร

ตอนที่ 3 ข้อมูลกิจกรรมการใช้พลังงาน น้ำ และขยะ ในครัวเรือน

ตอนที่ 4 ข้อมูลค่าใช้จ่ายสำหรับการใช่และจัดการพลังงาน น้ำ และขยะในครัวเรือน

ตอนที่ 1 ข้อมูลพื้นฐานผู้ให้ข้อมูล

คำชี้แจง กรุณาทำเครื่องหมาย ✓ ในช่องที่ตรงกับความเป็นจริงของท่านที่สุด (ทุกกลุ่มตัวอย่าง)

1.1 เพศ

☐ ชาย ☐ หญิง

1.2 อายุ

☐ ต่ำกว่า 10 ปี ☐ 31 - 40 ปี ☐ 61 - 70 ปี

☐ 11 - 20 ปี ☐ 41 - 50 ปี ☐ 71 - 80 ปี

☐ 21 - 30 ปี ☐ 51 – 60 ปี ☐ มากกว่า 81 ปี

1.3 การสำเร็จการศึกษา/กำลังศึกษาอยู่

☐ ต่ำกว่าระดับประถมศึกษา ☐ ประถมศึกษา ☐ มัธยมศึกษา/ปวช.

☐ ปวส. ☐ ปริญญาตรี ☐ สูงกว่าระดับปริญญาตรี

1.4 อาชีพ

☐ เกษตรกร ☐ พนักงานเอกชน ☐ รับจ้างทั่วไป

☐ นักเรียน นิสิต นักศึกษา ☐ ธุรกิจส่วนตัว / ค้าขาย ☐ พ่อบ้าน/แม่บ้าน

☐ ข้าราชการ/พนักงานรัฐวิสาหกิจ ☐ อื่นๆ (ระบุ) ....

1.5 รายได้ต่อเดือน

☐ 10,000 บาท หรือต่ำกว่า ☐ 10,001 - 20,000 บาท ☐ 20,001 - 30,000 บาท

☐ 30,001 - 40,000 บาท ☐ 40,001 - 50,000 บาท ☐ 50,001 บาท ขึ้นไป

ตอนที่ 2 ข้อมูลลักษณะอาคาร และอุปกรณ์เครื่องใช้ในอาคาร

คำชี้แจง กรุณาทำเครื่องหมาย ✓ ในช่อง ☐ และ ○ ที่ตรงกับความเป็นจริงของท่านที่สุด พร้อมทั้งระบุรายละเอียดให้ชัดเจน (เฉพาะกลุ่มตัวอย่างที่ 1 และ 2 เท่านั้น)

2.1 ประเภทอาคาร

☐ บ้านพักอาศัย ☐ อาคารสำนักงาน ☐ อาคารพาณิชย์

2.2 ตำแหน่งอาคาร/เลขที่ ....

2.3 รายการและรายละเอียดของอุปกรณ์และเครื่องใช้ภายในอาคาร

☐ หลอดไฟ

○ หลอด LED ขนาด .... วัตต์ จำนวน .... หลอด

ขนาด .... วัตต์ จำนวน .... หลอด

ขนาด .... วัตต์ จำนวน .... หลอด

○ หลอดตะเกียบ/ฟลูออกเรสเซ็นต์ ○ บัลลาสต์ธรรมดา ○ บัลลาสต์อิเล็กทรอนิกส์

ขนาด .... วัตต์ จำนวน .... หลอด

ขนาด .... วัตต์ จำนวน .... หลอด

ขนาด .... วัตต์ จำนวน .... หลอด

○ หลอดไส้ ขนาด .... วัตต์ จำนวน .... หลอด

ขนาด .... วัตต์ จำนวน .... หลอด

☐ พัดลม

○ แขวนเพดาน ขนาด .... นิ้ว จำนวน .... เครื่อง

○ แขวนผนัง ขนาด .... นิ้ว จำนวน .... เครื่อง

○ ตั้งพื้น ขนาด .... นิ้ว จำนวน .... เครื่อง

○ Tower ขนาด .... นิ้ว จำนวน .... เครื่อง

☐ เครื่องปรับอากาศ

○ แบบ Invertor ขนาด .... BTU

SEER ....

จำนวน .... เครื่อง

○ แบบทั่วไป ขนาด .... BTU

SEER ....

จำนวน .... เครื่อง

☐ ตู้เย็น

- ○ 1 ประตู แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ 1 ประตู แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ 2 ประตู แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ 2 ประตู แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ อื่นๆ ....
  ขนาด .... คิว จำนวน .... เครื่อง

☐ ตู้แช่เครื่องดื่ม

- ○ 1 ประตู แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ 1 ประตู แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ 2 ประตู แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ 2 ประตู แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ อื่นๆ ....
  ขนาด .... คิว จำนวน .... เครื่อง

☐ ตู้แช่แข็ง

- ○ ประตูทึบ แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ ประตูทึบ แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ ประตูใส แบบธรรมดา ขนาด .... คิว จำนวน .... เครื่อง
- ○ ประตูใส แบบ Invertor ขนาด .... คิว จำนวน .... เครื่อง
- ○ อื่นๆ ....
  ขนาด .... คิว จำนวน .... เครื่อง

☐ เครื่องทำน้ำอุ่น

- ○ แบบใช้แก๊ส LPG
- ○ แบบใช้ไฟฟ้า ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ เครื่องเป่าผม ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ หม้อหุงข้าว

- ○ แบบธรรมมดา ขนาด .... ลิตร จำนวน .... เครื่อง
- ○ แบบดิจิทัล ขนาด .... ลิตร จำนวน .... เครื่อง

☐ ไมโครเวฟ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ หม้ออบ/หม้อทอดลมร้อน ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ กาต้มน้ำร้อน/กระติกน้ำร้อนไฟฟ้า

- ○ แบบกาต้มน้ำ ขนาด .... ลิตร จำนวน .... เครื่อง
- ○ แบบกระติก ขนาด .... ลิตร จำนวน .... เครื่อง

☐ ตู้อบ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ เครื่องปั่น ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ เครื่องล้างจานอัตโนมัติ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ เครื่องกรองน้ำ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ เครื่องซักผ้า

- ○ แบบ 2 ถัง ขนาด .... กก. จำนวน .... เครื่อง
- ○ แบบ 1 ถัง (ฝาบน) ขนาด .... กก. จำนวน .... เครื่อง
- ○ แบบ 1 ถัง (ฝาหน้า) ขนาด .... กก. จำนวน .... เครื่อง
- ○ แบบ 1 ถัง (รวมอบ) ขนาด .... กก. จำนวน .... เครื่อง

☐ เครื่องอบผ้า ขนาด .... กก. จำนวน .... เครื่อง

☐ เตารีด ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ ปั้มน้ำ

- ○ หอยโขง ขนาด .... HP จำนวน .... เครื่อง
- ○ อัตโนมัติ ขนาด .... วัตต์ จำนวน .... เครื่อง
- ○ แรงดันคงที่ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ โทรทัศน์

- ○ แบบจอแก้ว ขนาด .... นิ้ว จำนวน .... เครื่อง
- ○ แบบ LCD ขนาด .... นิ้ว จำนวน .... เครื่อง
- ○ แบบ LED ขนาด .... นิ้ว จำนวน .... เครื่อง

☐ มอเตอร์ไฟฟ้าประตูอัตโนมัติ ขนาด .... วัตต์ จำนวน .... เครื่อง

☐ อื่นๆ (ระบุ)

- ○ .... ขนาด .... จำนวน .... เครื่อง
- ○ .... ขนาด .... จำนวน .... เครื่อง
- ○ .... ขนาด .... จำนวน .... เครื่อง
- ○ .... ขนาด .... จำนวน .... เครื่อง
- ○ .... ขนาด .... จำนวน .... เครื่อง
- ○ .... ขนาด .... จำนวน .... เครื่อง

2.4 ความถี่ในการเกิดกิจกรรมภายในอาคาร

☐ เปิดไฟฟ้า ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ใช้เครื่องปรับอากาศ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ เปิดพัดลม ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ อาบน้ำ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ กดชักโครก ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ เป่าผม ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ใช้เครื่องกรองน้ำ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ซักผ้า ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ อบผ้า ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ รีดผ้า ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ปั๊มน้ำ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ หุงข้าว ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ไมโครเวฟ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ต้มน้ำร้อน ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ หม้ออบ/หม้อทอดฯ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ตู้อบ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ เครื่องปั่น ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ดูทีวี ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ รับประทานอาหาร ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ล้างจาน ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ รดน้ำต้นไม้ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ล้างรถ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ อาบ/เปลี่ยนน้ำสัตว์ ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน
☐ ....ครั้งละ..............นาที จำนวน ....ครั้ง/ ○ วัน ○ สัปดาห์ ○ เดือน

ตอนที่ 3 ข้อมูลกิจกรรมการใช้พลังงาน น้ำ และขยะ ในครัวเรือน (อย่างละเอียด)

คำชี้แจง กรุณาทำเครื่องหมาย ✓ ในช่องที่ตรงกับความเป็นจริงของท่านที่สุด (เฉพาะกลุ่มตัวอย่างที่ 1 เท่านั้น)

3.1 กิจกรรมที่เกิดขึ้นในครัวเรือน <u>วันจันทร์ – วันศุกร์</u>

กิจกรรม	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
เปิดไฟฟ้า																								
ใช้เครื่องปรับอากาศ																								
เปิดพัดลม																								
อาบน้ำ (น้ำอุ่น+ฝักบัว)																								
อาบน้ำ (น้ำอุ่น+ขัน)																								
อาบน้ำ (น้ำปกติ+ฝักบัว)																								
อาบน้ำ (น้ำปกติ+ขัน)																								
กดชักโครก																								
เป่าผม																								
ใช้เครื่องกรองน้ำ																								
ซักผ้า																								
อบผ้า																								
รีดผ้า																								
ปั๊มน้ำ																								
เปิดประตูรั้ว																								

กิจกรรม	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
ทำอาหาร																								
หุงข้าว																								
อุ่นอาหาร (ไมโครเวฟ)																								
ต้มน้ำร้อน (กาน้ำร้อน)																								
หม้ออบฯ/หม้อทอดฯ																								
ตู้อบ																								
เครื่องปั่น																								
ตู้เย็น																								
ดูทีวี																								
รับประทานอาหาร																								
ล้างจาน																								
รดน้ำต้นไม้																								
ล้างรถ																								
อาบ/เปลี่ยนน้ำสัตว์เลี้ยง																								

3.2 กิจกรรมที่เกิดขึ้นในครัวเรือน <u>วันเสาร์ – อาทิตย์ และวันหยุด</u>

กิจกรรม	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
เปิดไฟฟ้า																								
ใช้เครื่องปรับอากาศ																								
เปิดพัดลม																								
อาบน้ำ (น้ำอุ่น+ฝักบัว)																								
อาบน้ำ (น้ำอุ่น+ขัน)																								
อาบน้ำ (น้ำปกติ+ฝักบัว)																								
อาบน้ำ (น้ำปกติ+ขัน)																								
กดชักโครก																								
เป่าผม																								
ใช้เครื่องกรองน้ำ																								
ซักผ้า																								
อบผ้า																								
รีดผ้า																								
ปั๊มน้ำ																								
เปิดประตูรั้ว																								
ทำอาหาร																								
หุงข้าว																								
อุ่นอาหาร (ไมโครเวฟ)																								

กิจกรรม	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
ต้มน้ำร้อน (กาน้ำร้อน)																								
หม้ออบฯ/หม้อทอดฯ																								
ตู้อบ																								
เครื่องปั่น																								
ตู้เย็น																								
ดูทีวี																								
รับประทานอาหาร																								
ล้างจาน																								
รดน้ำต้นไม้																								
ล้างรถ																								
อาบ/เปลี่ยนน้ำสัตว์เลี้ยง																								

ตอนที่ 4 ข้อมูลค่าใช้จ่ายสำหรับการใช้และจัดการพลังงาน น้ำ และขยะในครัวเรือน

คำชี้แจง กรุณากรอกรายละเอียดในช่องว่างให้ครบถ้วน (ทุกกลุ่มตัวอย่าง)

4.1 ค่าใช้จ่ายและปริมาณการใช้พลังงานภายในอาคาร

- พฤษภาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- มิถุนายน 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- กรกฎาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- สิงหาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- กันยายน 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- ตุลาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- พฤศจิกายน 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- ธันวาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- มกราคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- กุมภาพันธ์ 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- มีนาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- เมษายน 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- พฤษภาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- มิถุนายน 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- กรกฎาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- สิงหาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- กันยายน 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- ตุลาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- พฤศจิกายน 255 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย
- ธันวาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณการใช้งาน .... หน่วย

4.2 ค่าใช้จ่ายและปริมาณการใช้น้ำภายในอาคาร

• พฤษภาคม 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• มิถุนายน 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• กรกฎาคม 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• สิงหาคม 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• กันยายน 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• ตุลาคม 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• พฤศจิกายน 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• ธันวาคม 2564	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• มกราคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• กุมภาพันธ์ 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• มีนาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• เมษายน 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• พฤษภาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• มิถุนายน 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• กรกฎาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• สิงหาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• กันยายน 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• ตุลาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• พฤศจิกายน 255	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย
• ธันวาคม 2565	ค่าใช้จ่าย	....	บาท	ปริมาณการใช้งาน	....	หน่วย

4.3 ค่าใช้จ่ายสำหรับการจัดการขยะภายในอาคาร (หน่วย .... ถุง/กก. .... ลิตร)

- พฤษภาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- มิถุนายน 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- กรกฎาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- สิงหาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- กันยายน 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- ตุลาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- พฤศจิกายน 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- ธันวาคม 2564 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- มกราคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- กุมภาพันธ์ 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- มีนาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- เมษายน 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- พฤษภาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- มิถุนายน 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- กรกฎาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- สิงหาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- กันยายน 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- ตุลาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- พฤศจิกายน 255 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย
- ธันวาคม 2565 ค่าใช้จ่าย .... บาท ปริมาณขยะ .... หน่วย

APPENDIX B

Smart meter detail

B1 Energy smart meter

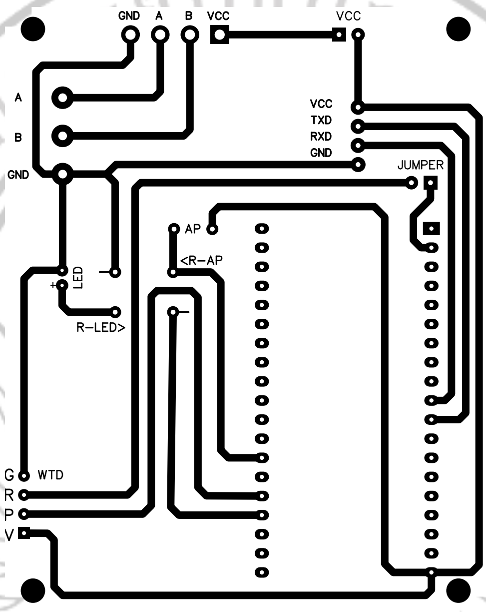


Figure B1 Printed circuit board diagram of energy smart meter

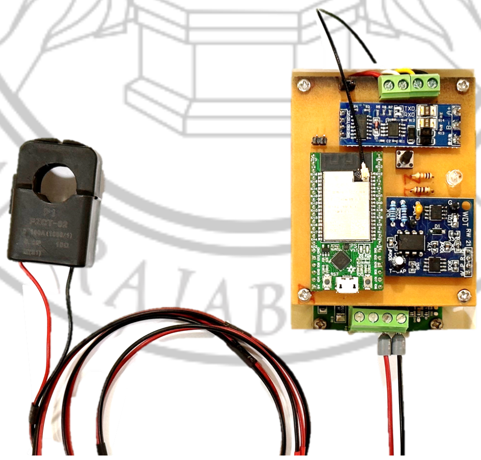


Figure B2 Energy smart meter prototype

B2 Water smart meter

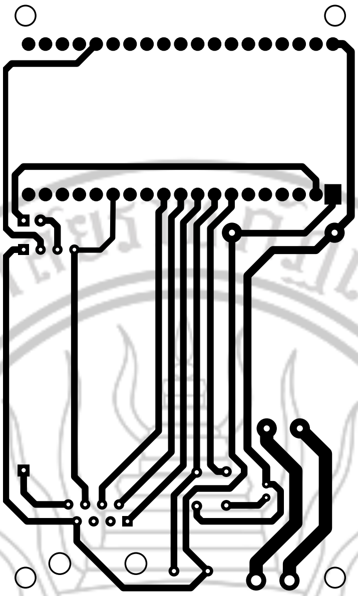


Figure B3 Printed circuit board diagram of water smart meter

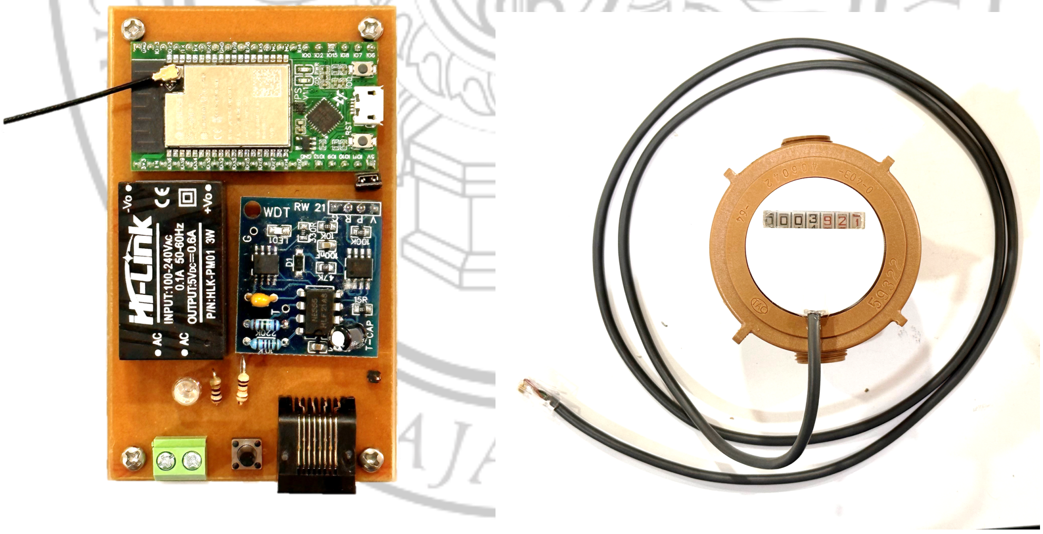


Figure B4 Water smart meter prototype

B3 Waste smart meter (Smart bin)

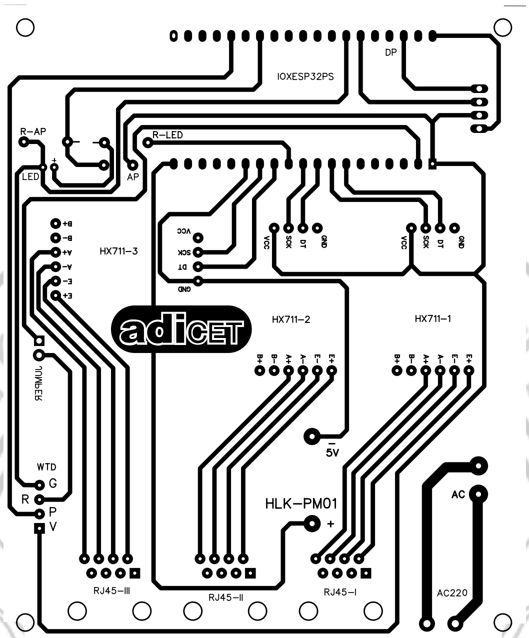


Figure B5 Printed circuit board diagram of waste smart meter (Smart bin)

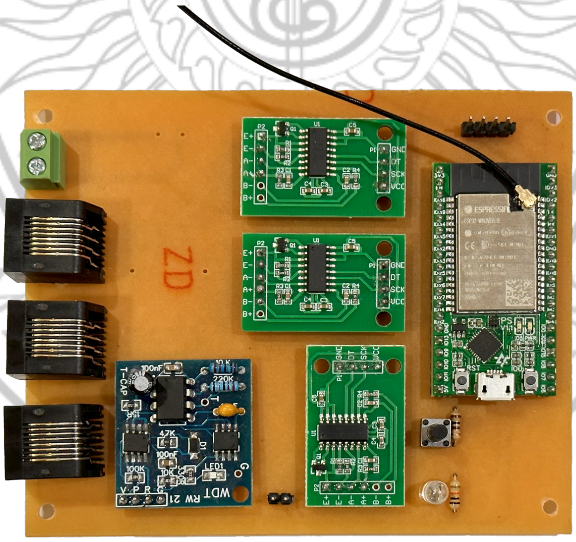
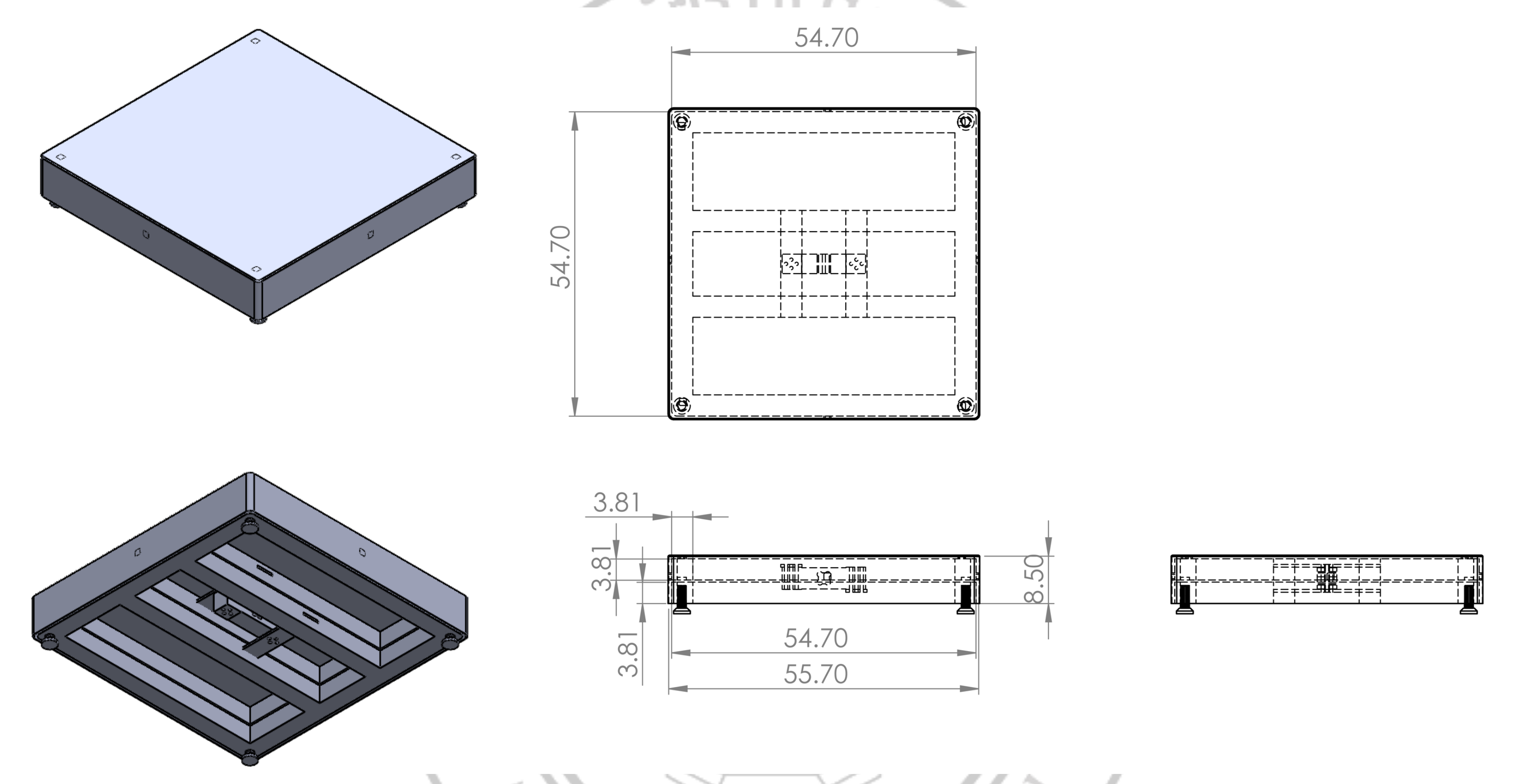
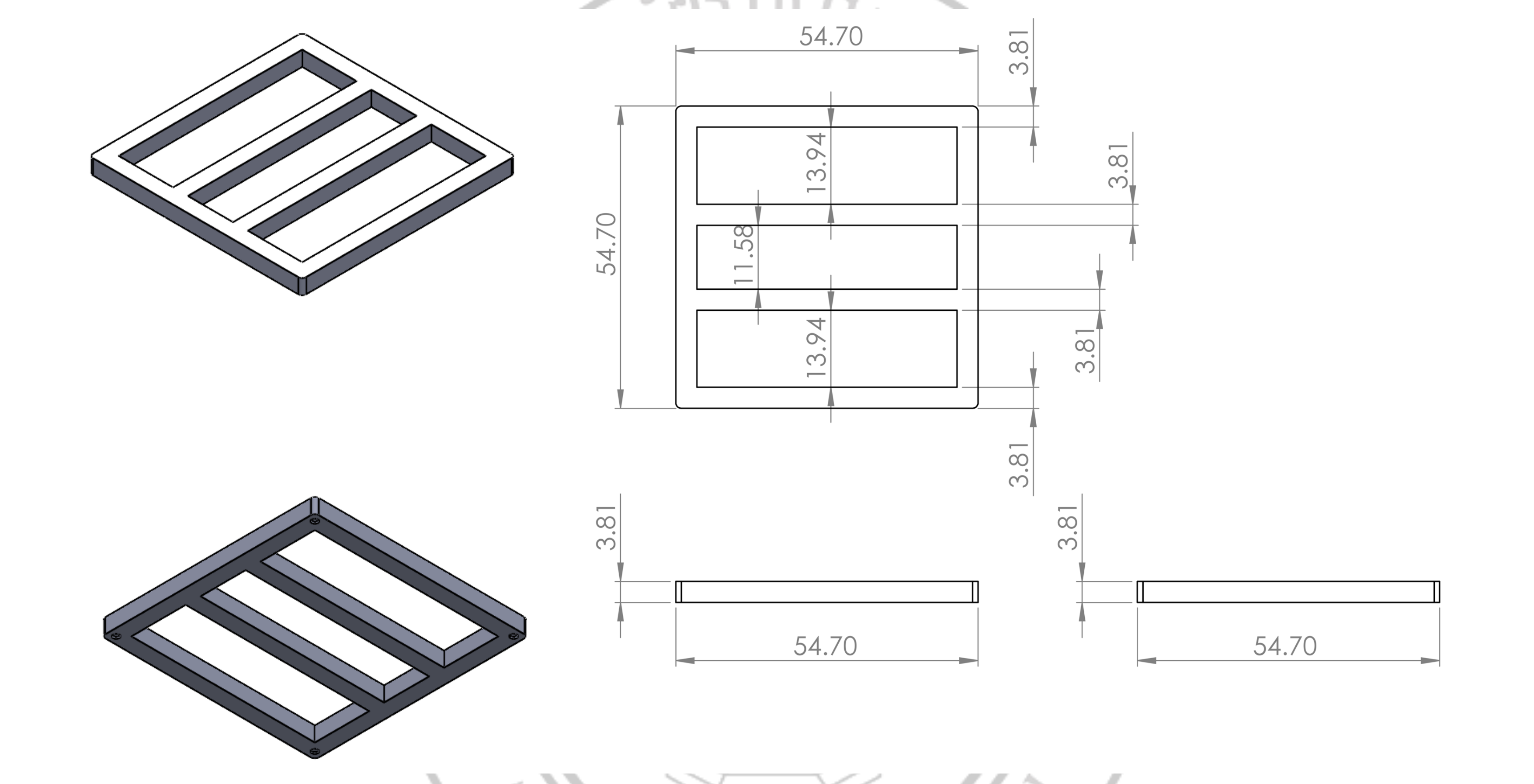


Figure B6 Smart bin prototype



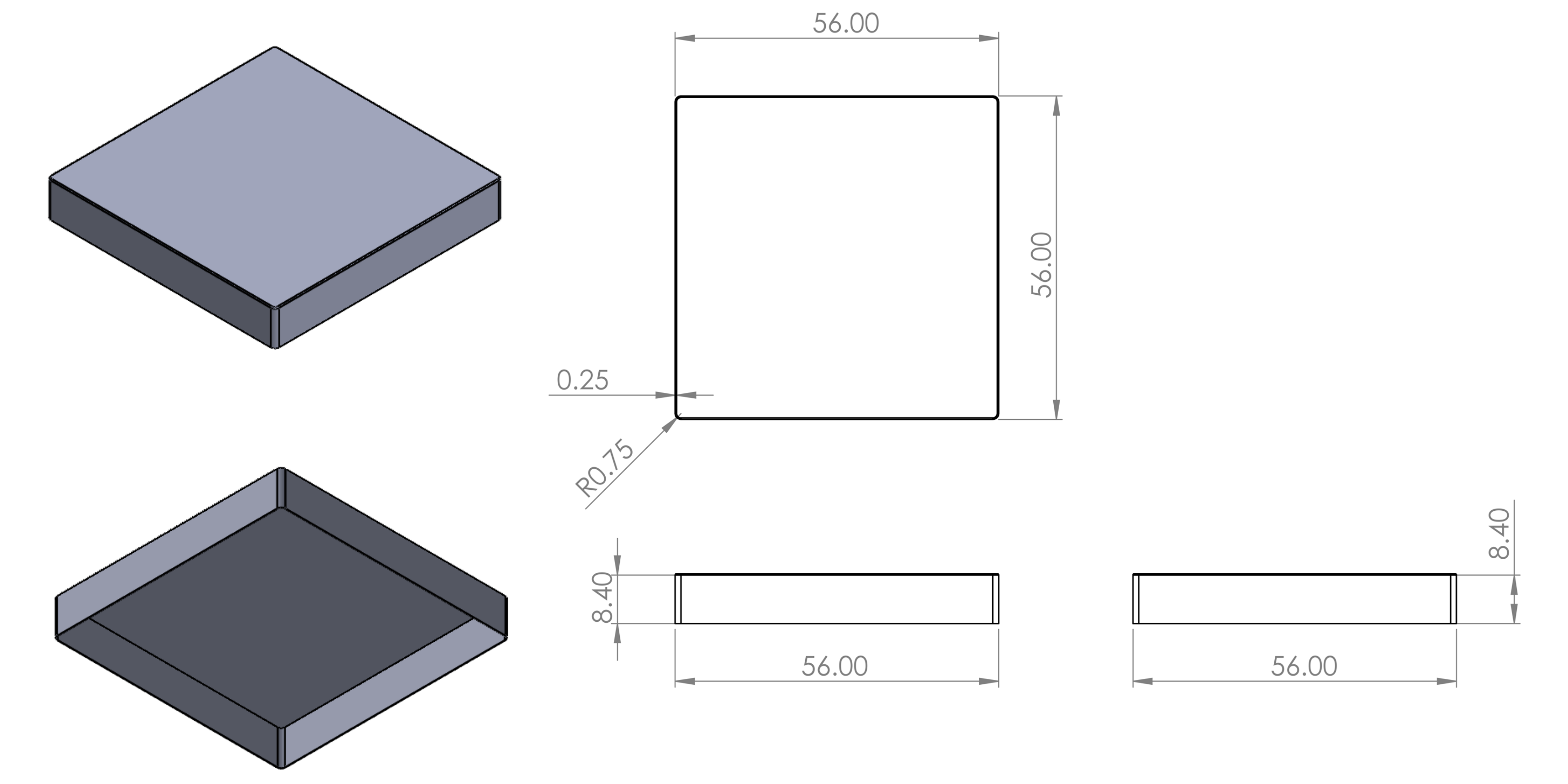
adiCET	Asian Development College for Community	Material	Metal (iron)	Size A4	Unit cm
	Economy and Technology	Design/Draft	Thananchai Sataklang	Scale	1:100
	Chiang Mai Rajabhat University	Product name	Smart bin model	Number	1 of 4

Figure B7 Smart bin model



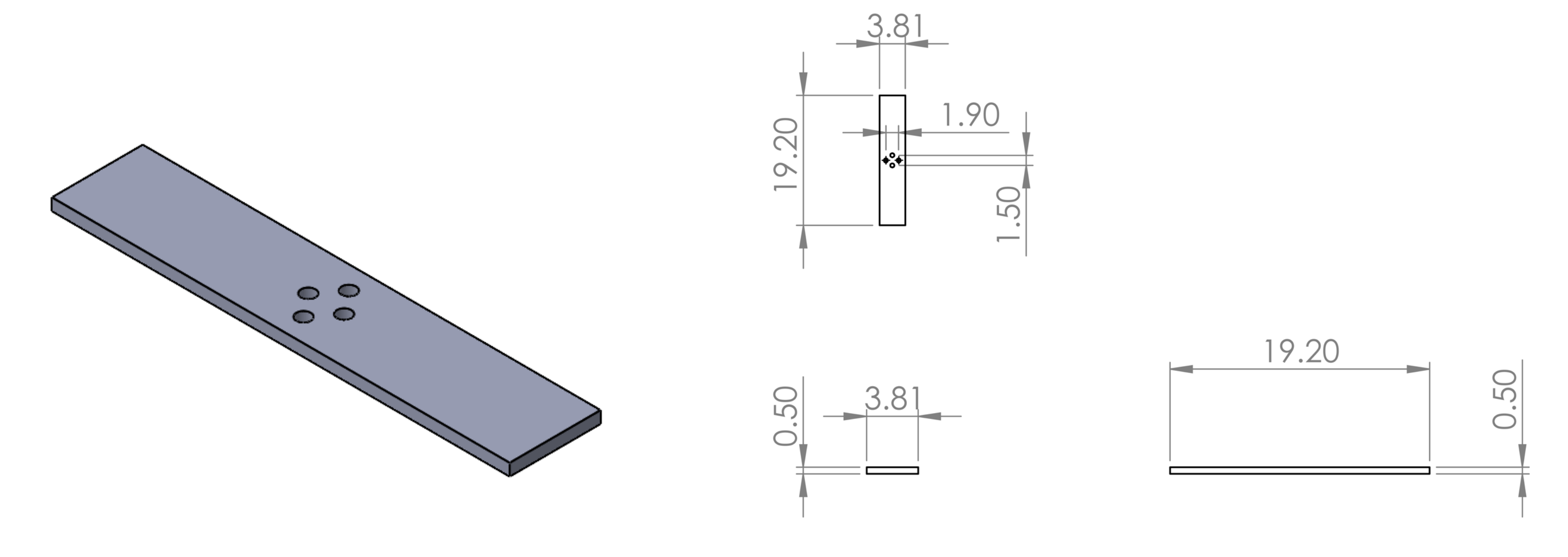
adiCET	Asian Development College for Community Economy and Technology Chiang Mai Rajabhat University	Material	Metal (iron)	Size A4	Unit cm
		Design/Draft	Thananchai Sataklang	Scale	1:100
		Product name	Load bearing structure	Number	1 of 4

Figure B8 Internal load bearing structure of smart bin



adiCET	Asian Development College for Community Economy and Technology Chiang Mai Rajabhat University	Material	Metal (iron)	Size A4	Unit cm
		Design/Draft	Thananchai Sataklang	Scale	1:100
		Product name	Structural covering	Number	3 of 4

Figure B9 Structural covering of smart bin



adiCET	Asian Development College for Community	Material	Metal (iron)	Size A4	Unit cm
	Economy and Technology	Design/Draft	Thananchai Sataklang	Scale	1:100
	Chiang Mai Rajabhat University	Product name	Load cell support plate	Number	4 of 4

Figure B10 Load cell sensor support plate of smart bin

APPENDIX C

Community consumption data and correlation

C1 Water consumption

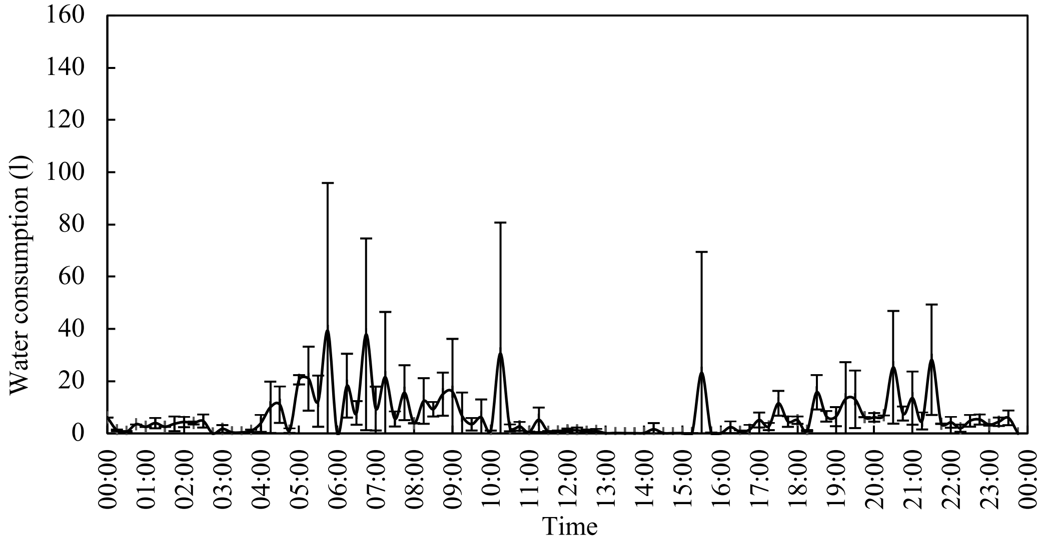


Figure C1 Average water consumption in GH2

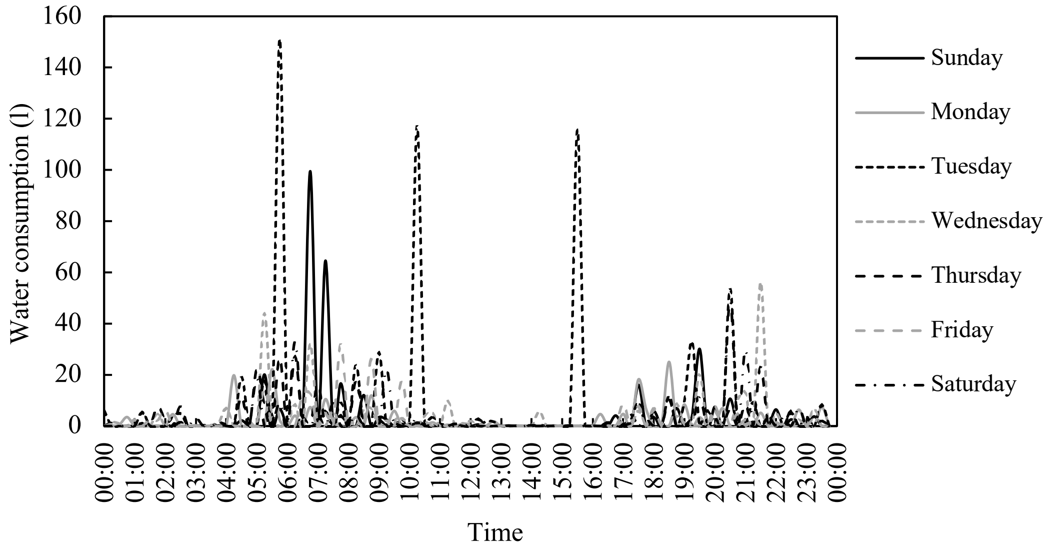


Figure C2 Average water consumption in GH2 (day of the week)

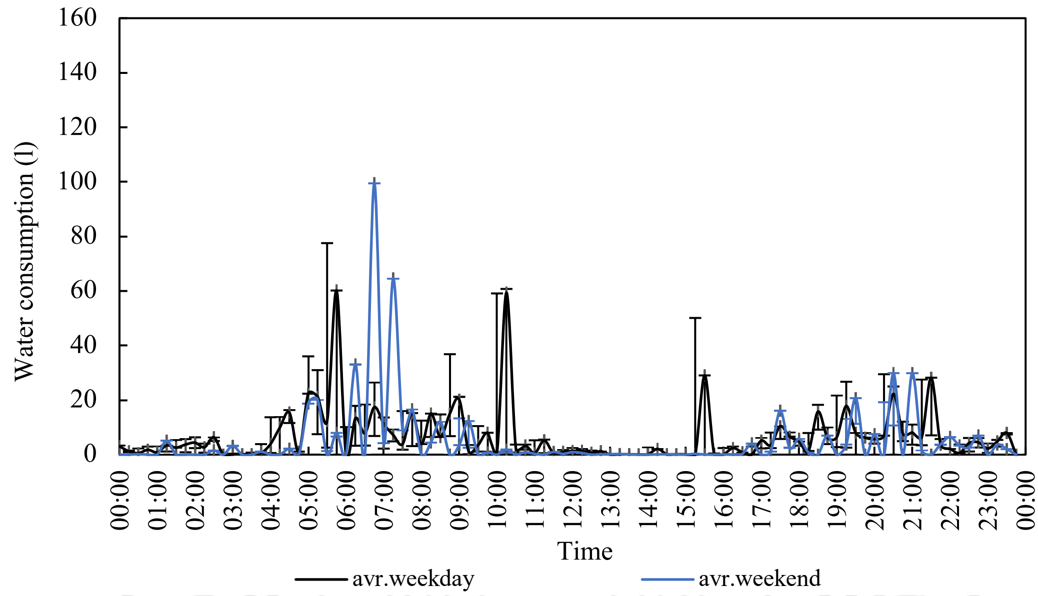


Figure C3 Average water consumption in GH2 (Weekday/Weekend)

Average water consmumption in school house 1

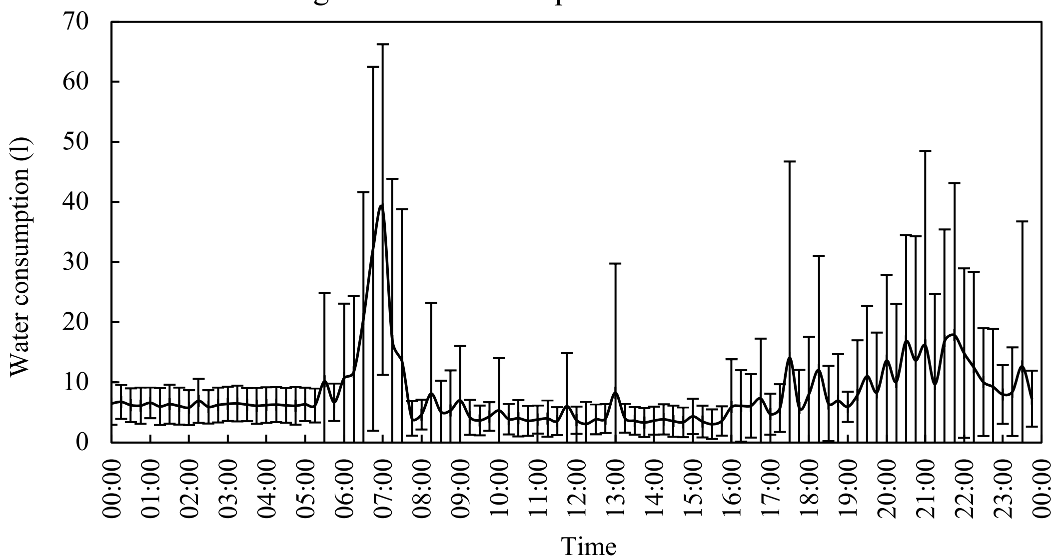


Figure C4 Average water consumption in SH1

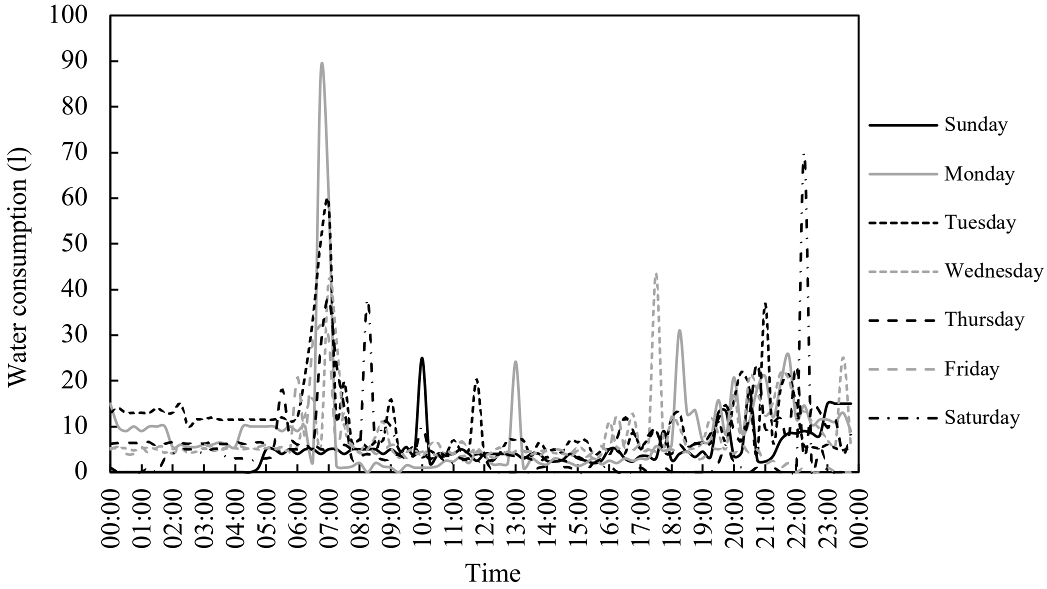


Figure C5 Average water consumption in SH1 (day of the week)

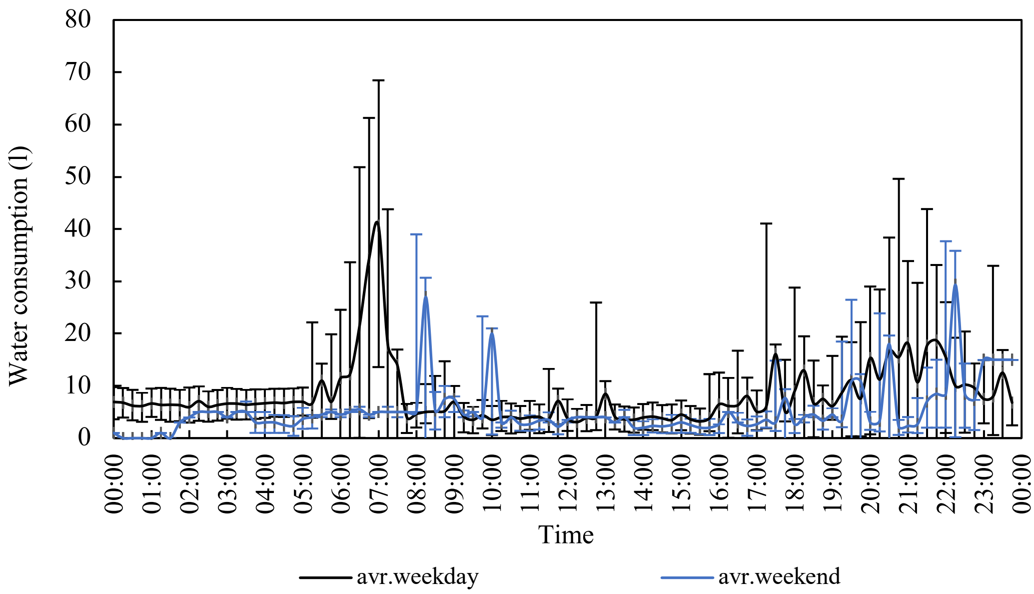


Figure C6 Average water consumption in SH1 (Weekday/Weekend)

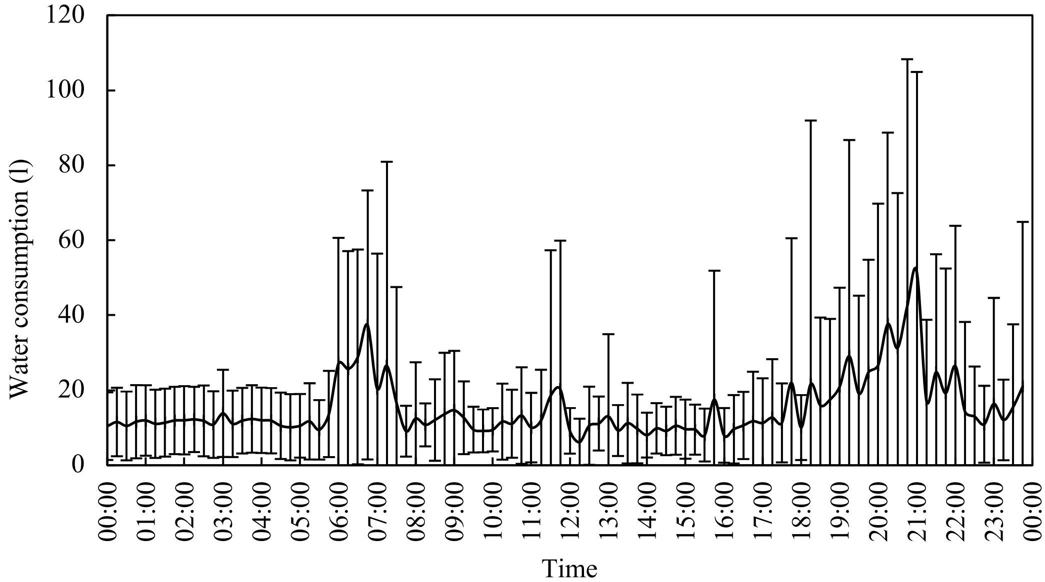


Figure C7 Average water consumption in SH2

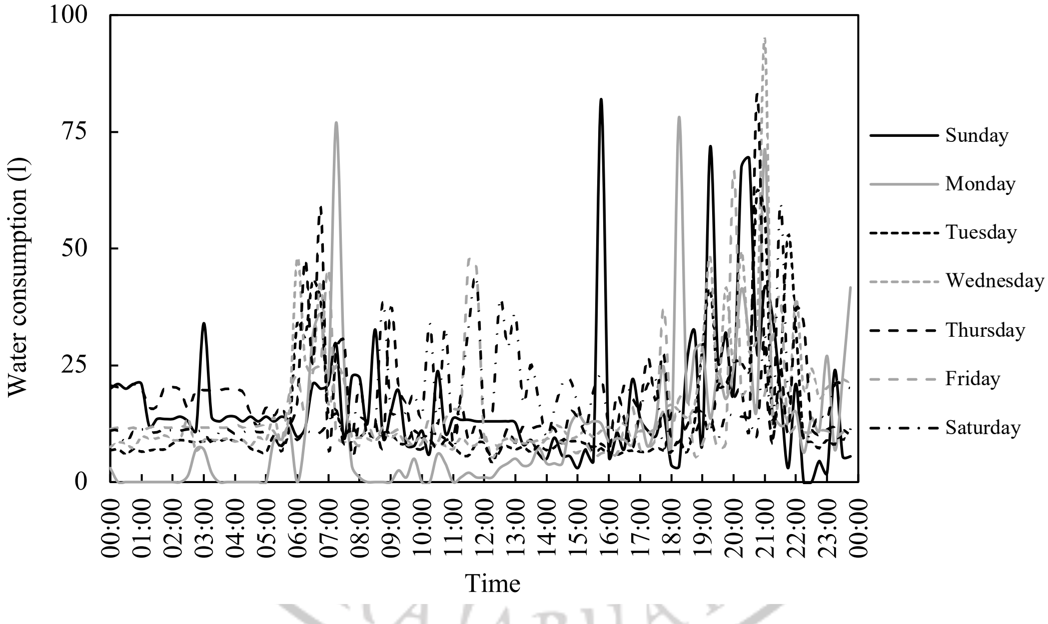


Figure C8 Average water consumption in SH2 (day of the week)

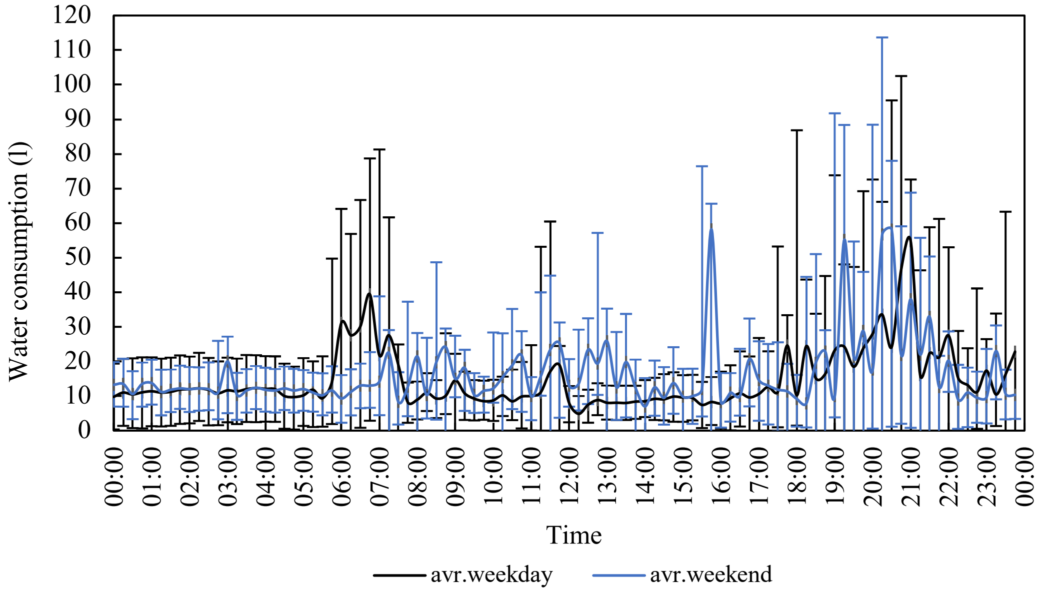


Figure C9 Average water consumption in SH2 (Weekday/Weekend)

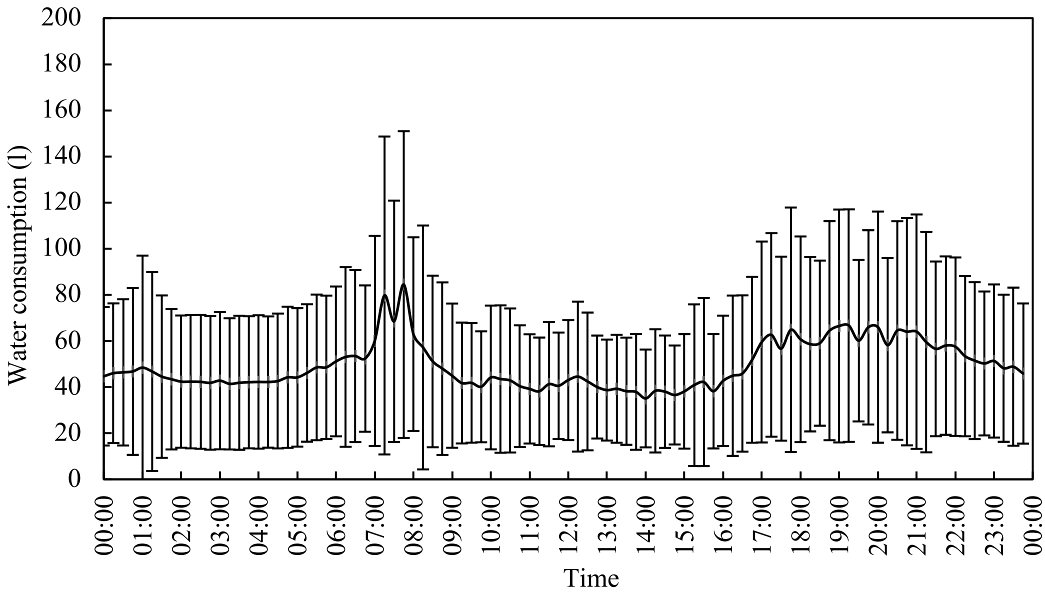


Figure C10 Average water consumption in HH1

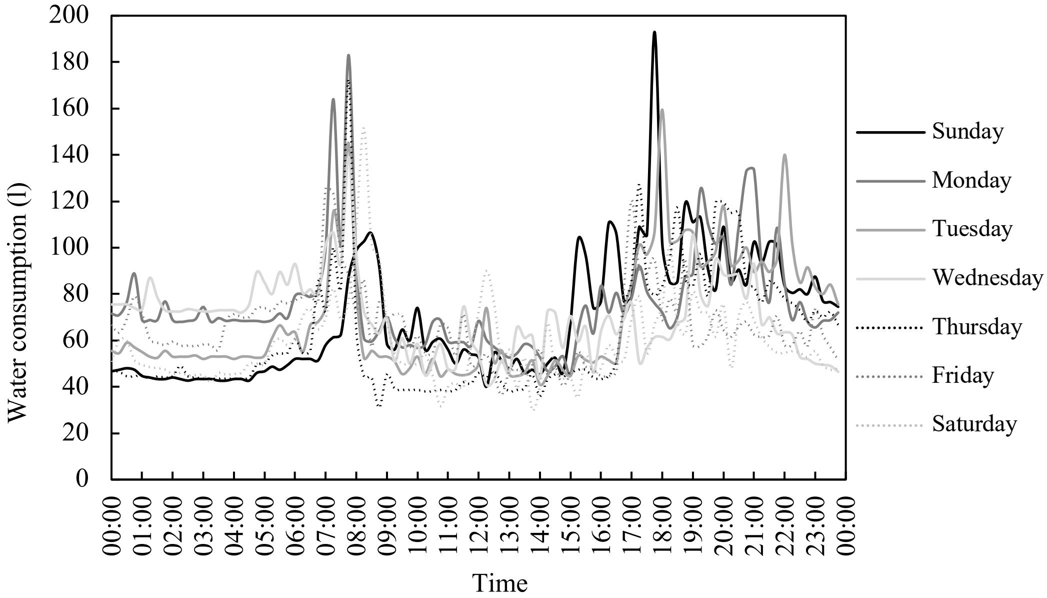


Figure C11 Average water consumption in HH1 (day of the week)

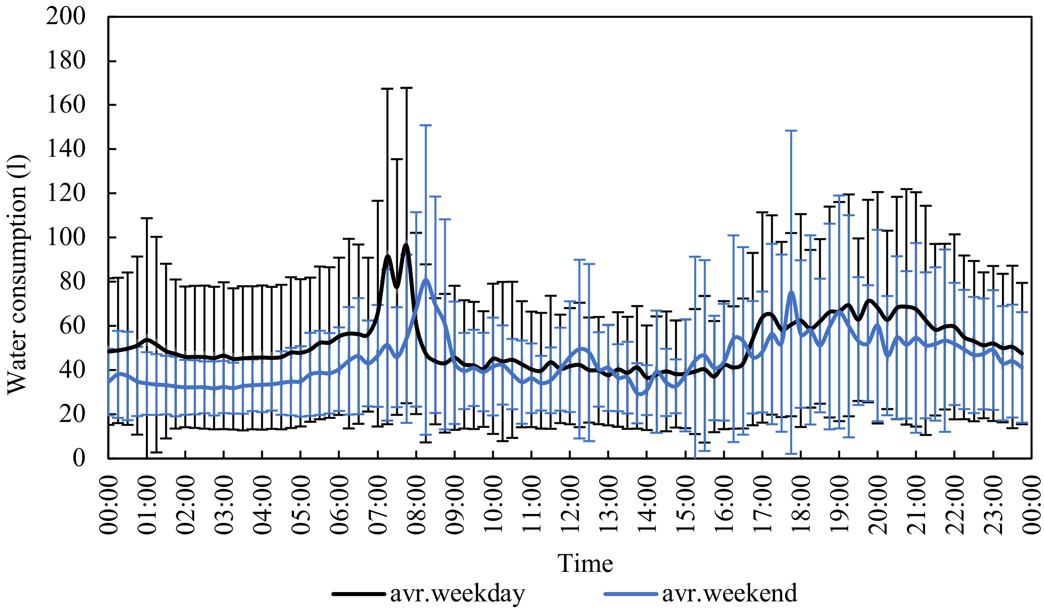


Figure C12 Average water consumption in HH1 (Weekday/Weekend)

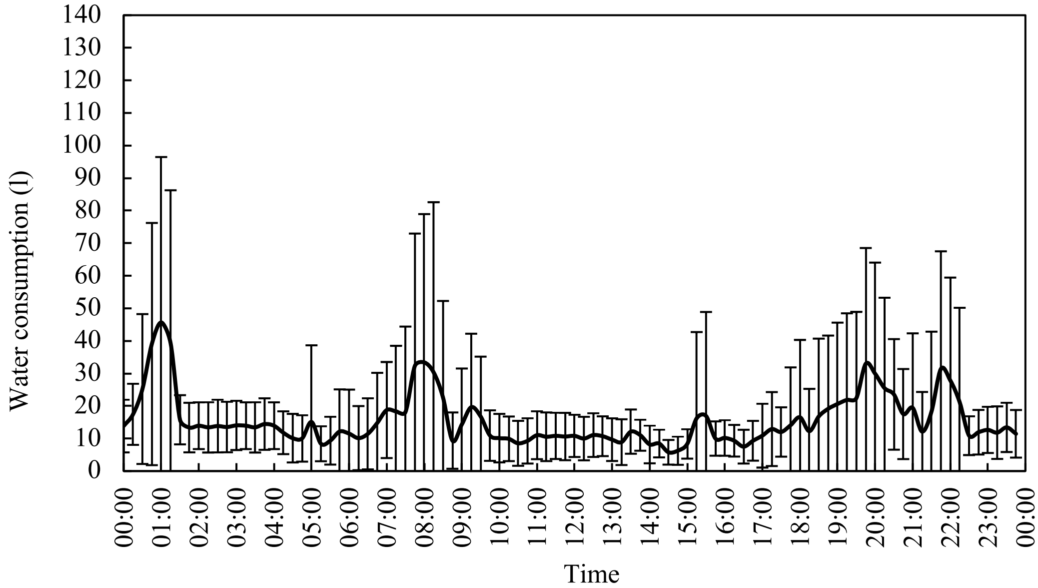


Figure C13 Average water consumption in HH2

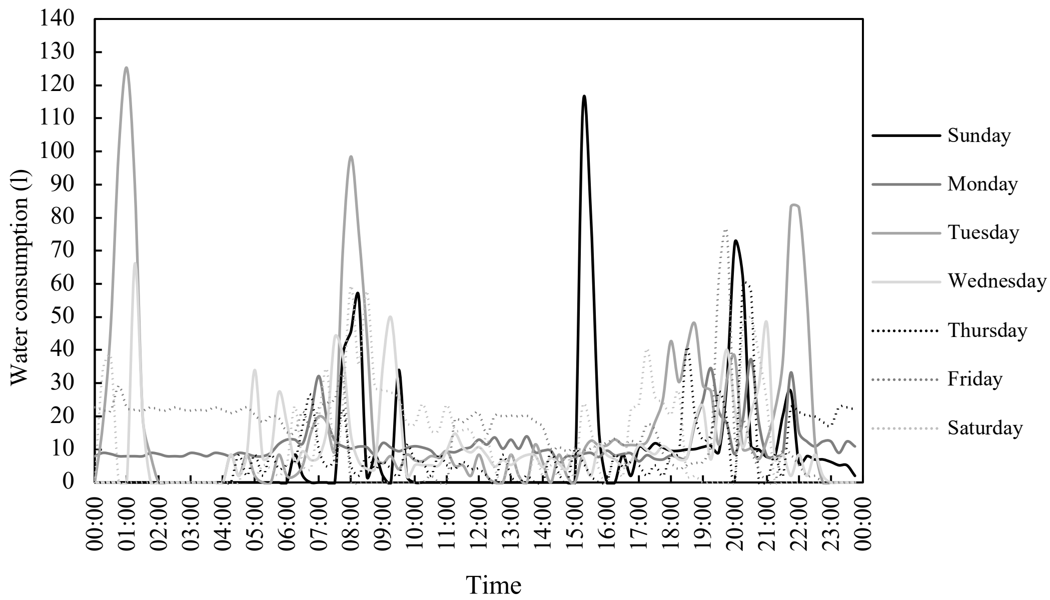


Figure C14 Average water consumption in HH2 (day of the week)

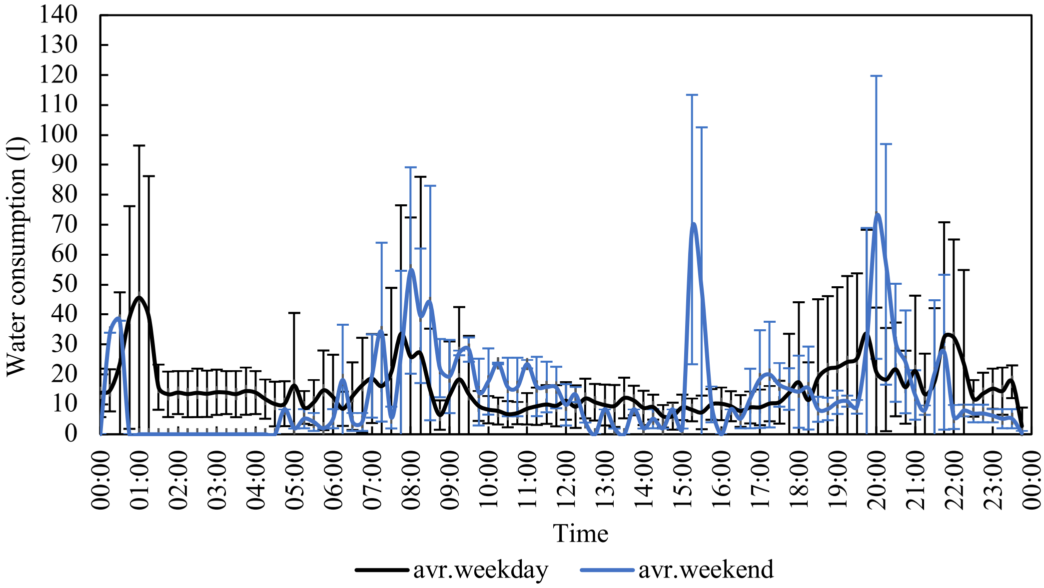


Figure C15 Average water consumption in HH2 (Weekday/Weekend)

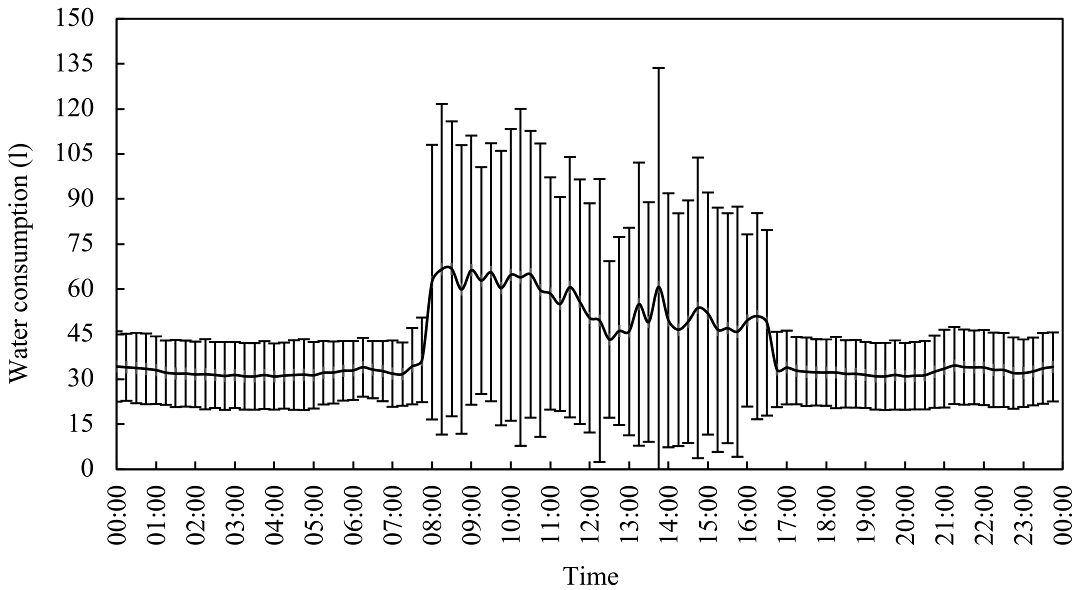


Figure C16 Average water consumption in CHO

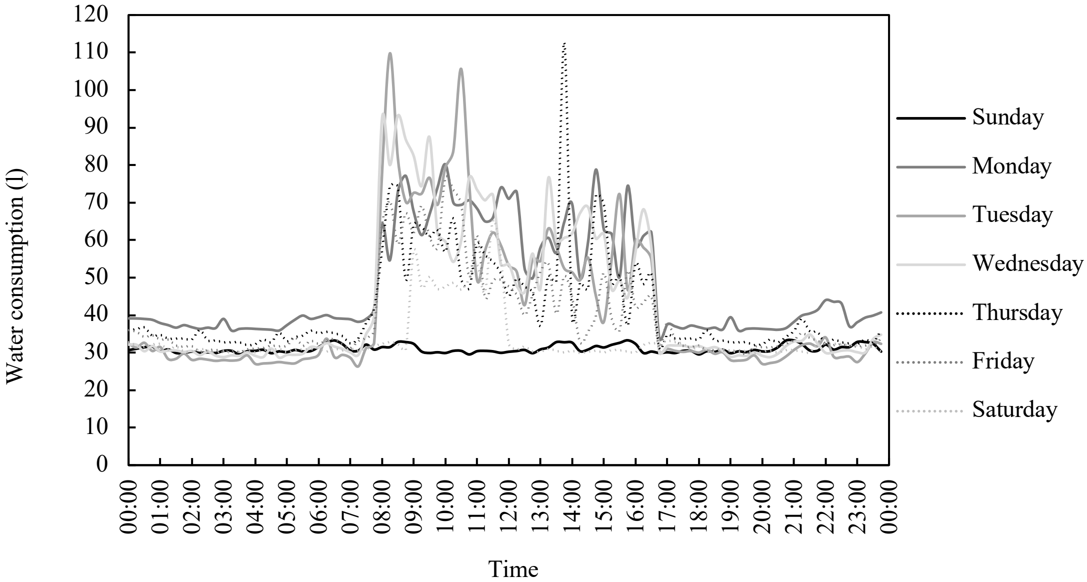


Figure C17 Average water consumption in CHO (day of the week)

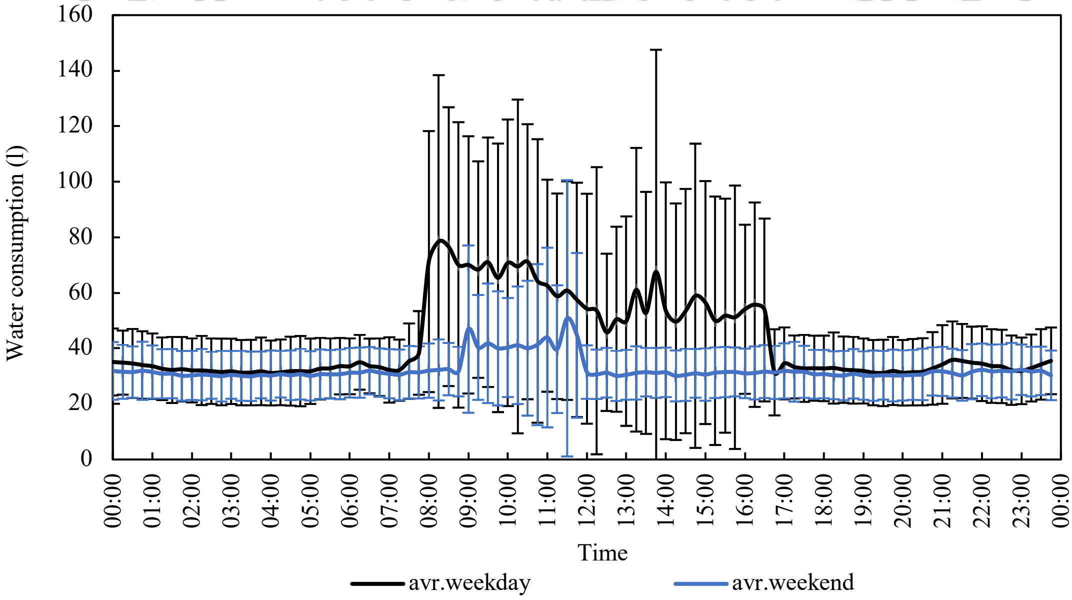


Figure C18 Average water consumption in CHO (Weekday/Weekend)

C2 Waste generation

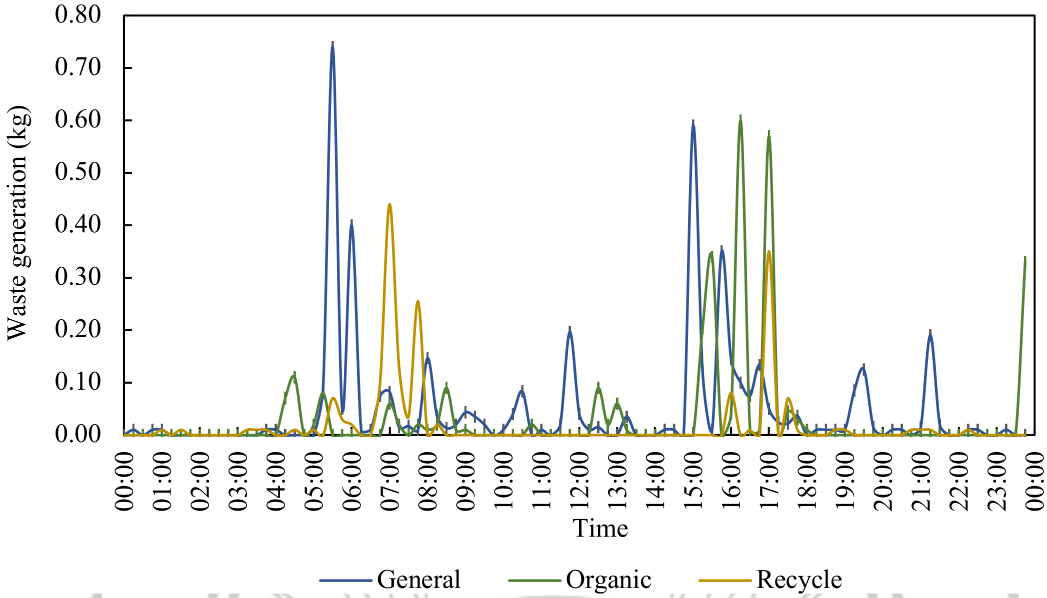


Figure C19 Average waste generation in GH2

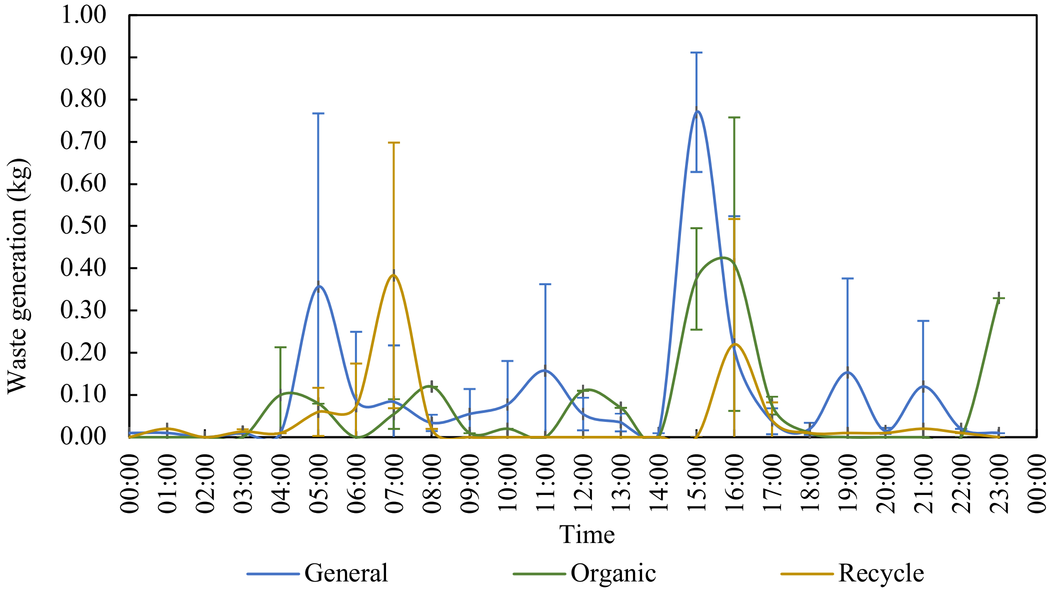


Figure C20 Average waste generation in GH2 (day of the week)

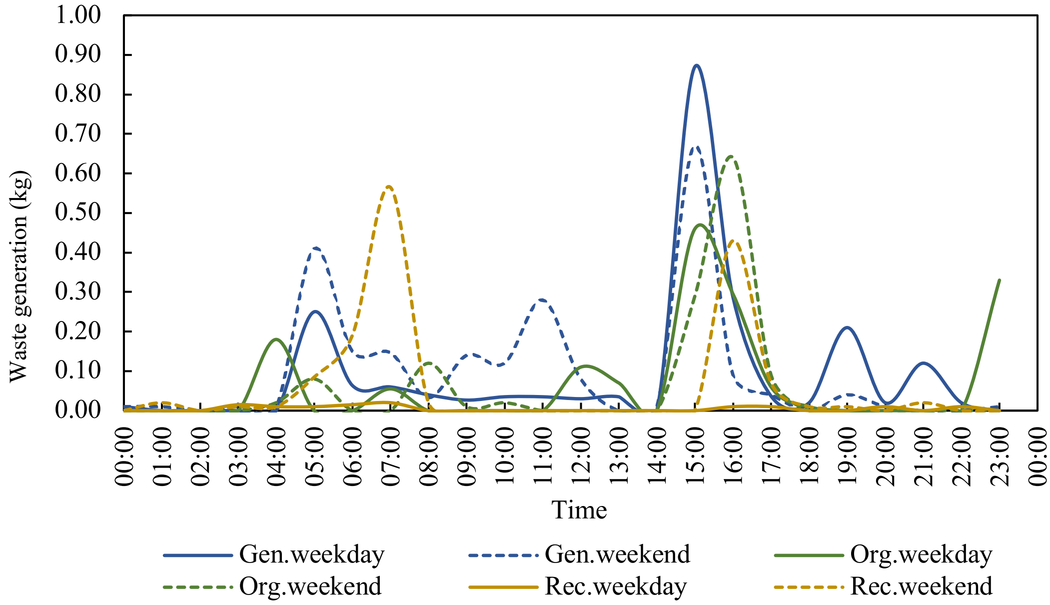


Figure C21 Average waste generation in GH2 (Weekday/Weekend)

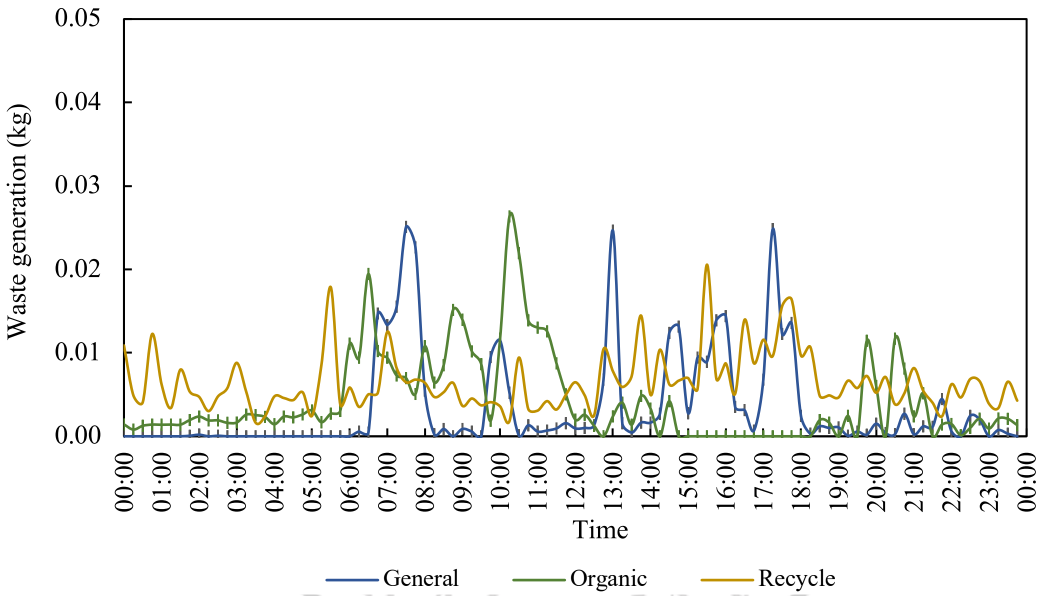


Figure C22 Average waste generation in SH1

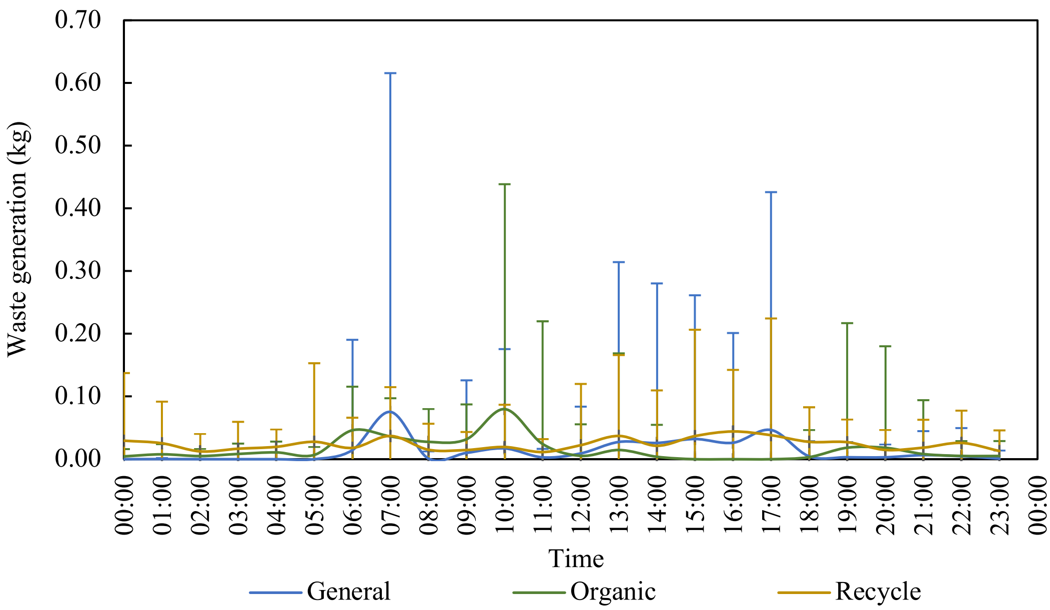


Figure C23 Average waste generation in SH1 (day of the week)

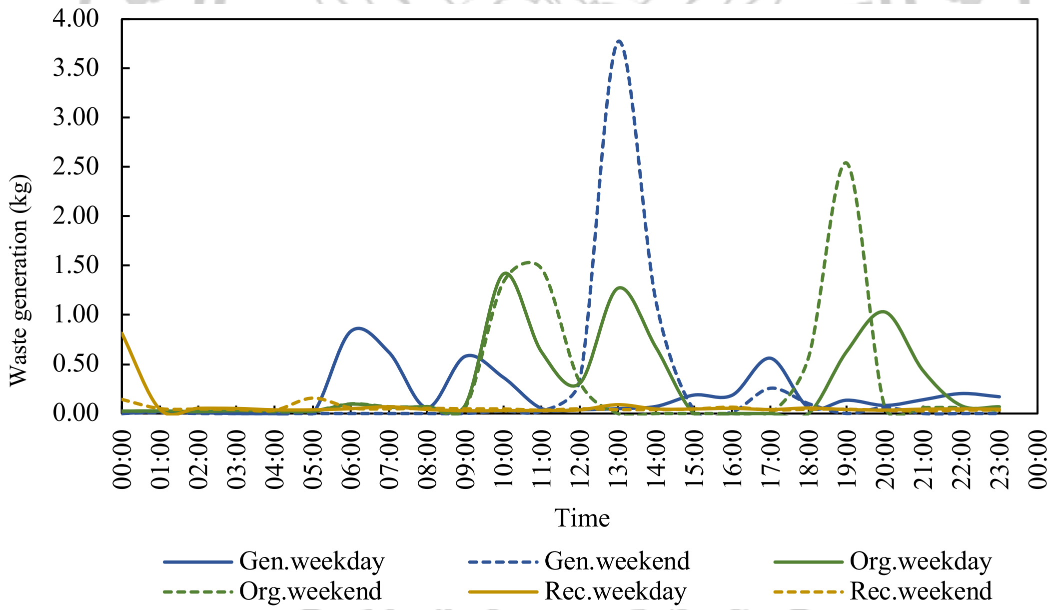


Figure C24 Average waste generation in SH1 (Weekday/Weekend)

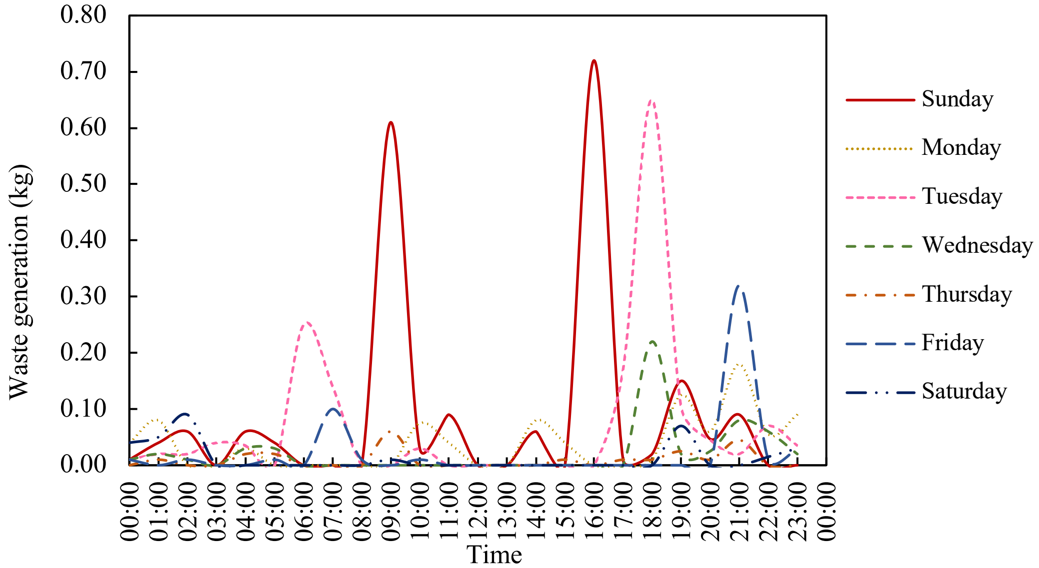


Figure C25 Average waste generation in SH2 (day of the week)

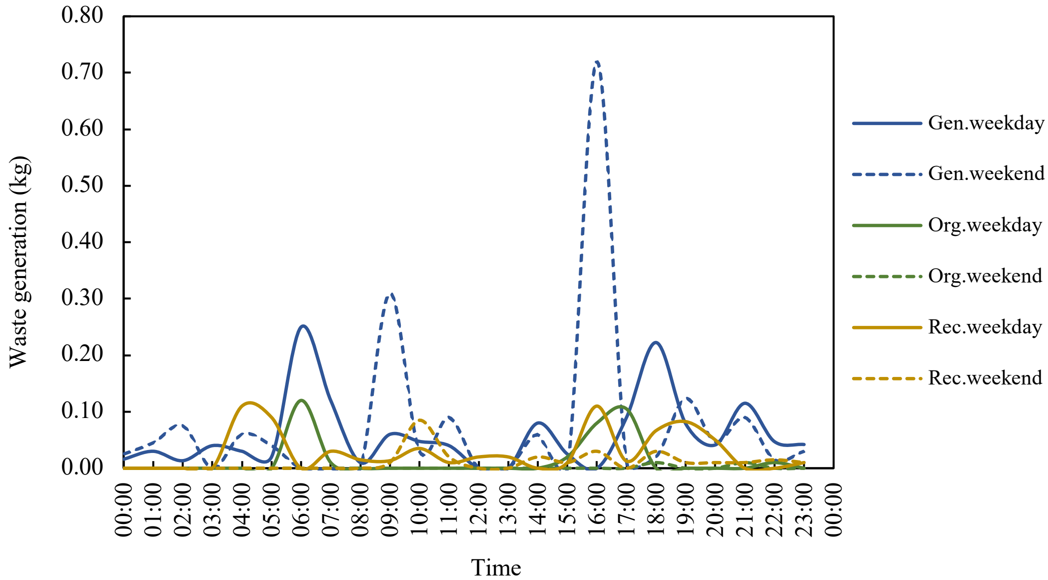


Figure C26 Average waste generation in SH2 (Weekday/Weekend)

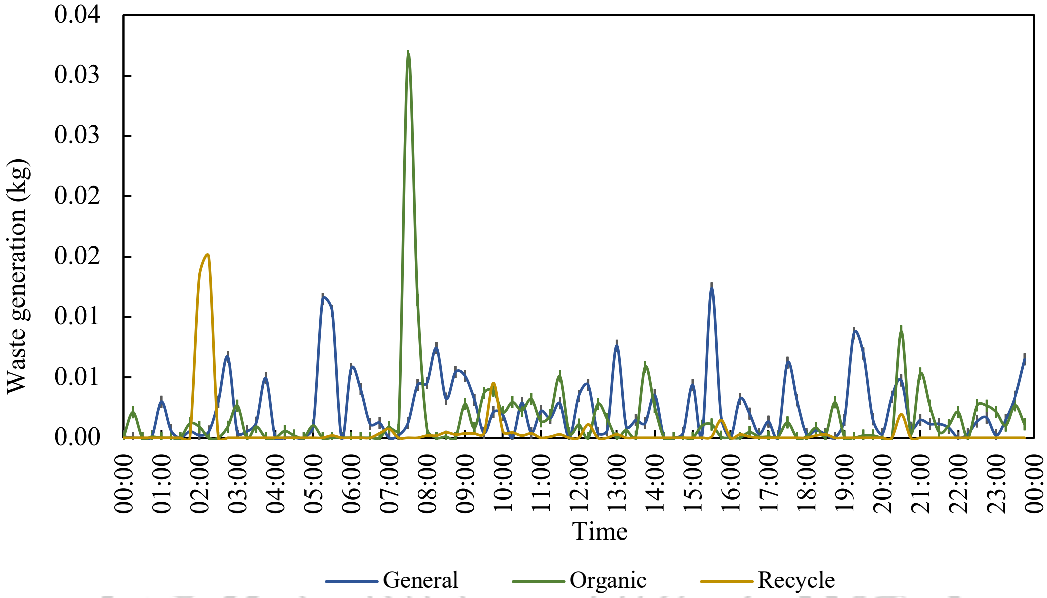


Figure C27 Average waste generation in HH1

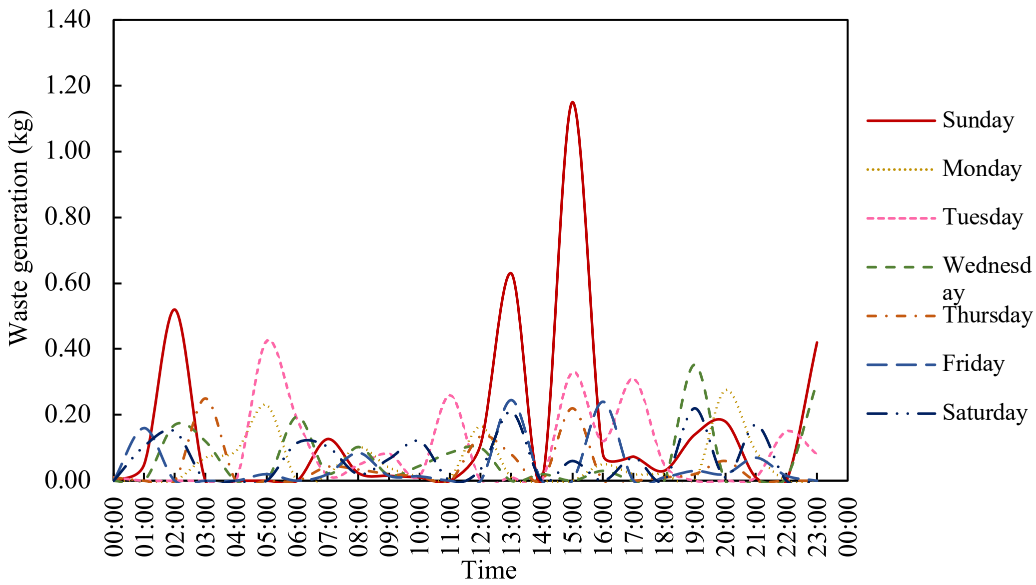


Figure C28 Average waste generation in HH1 (day of the week)

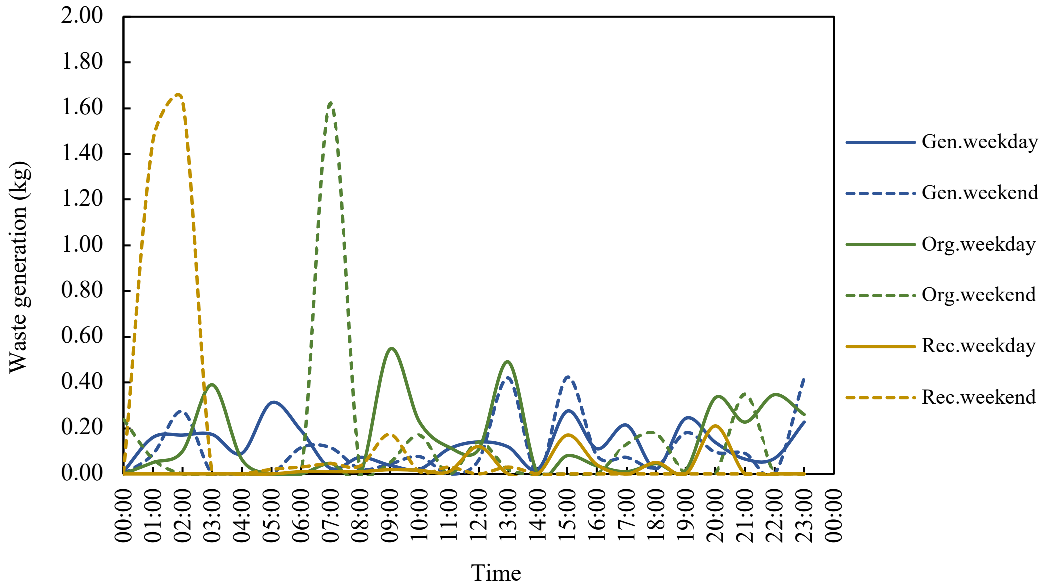


Figure C29 Average waste generation in HH1 (Weekday/Weekend)

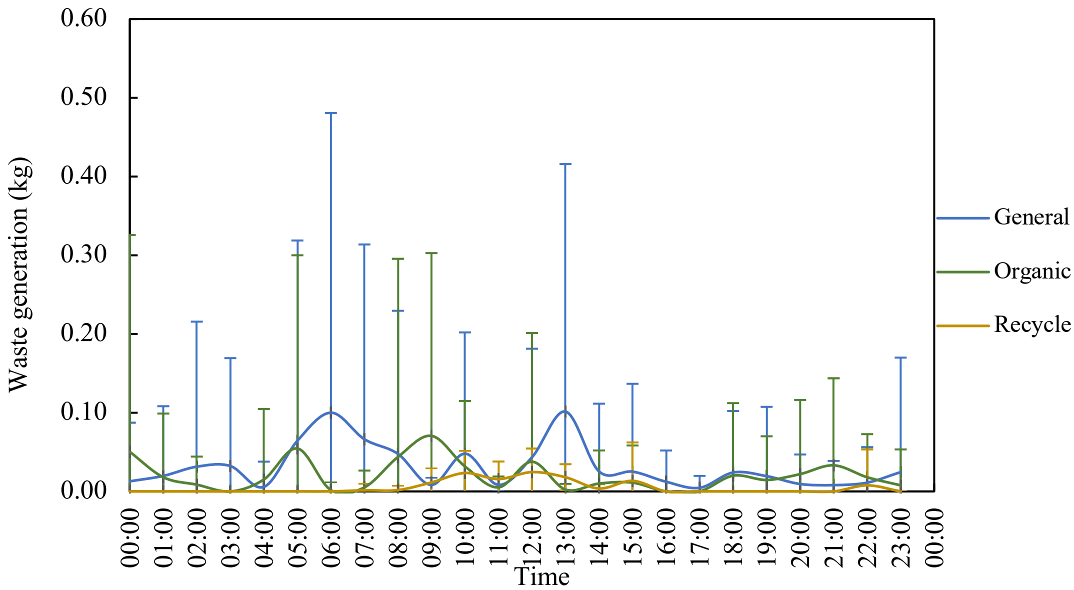


Figure C30 Average waste generation in HH2

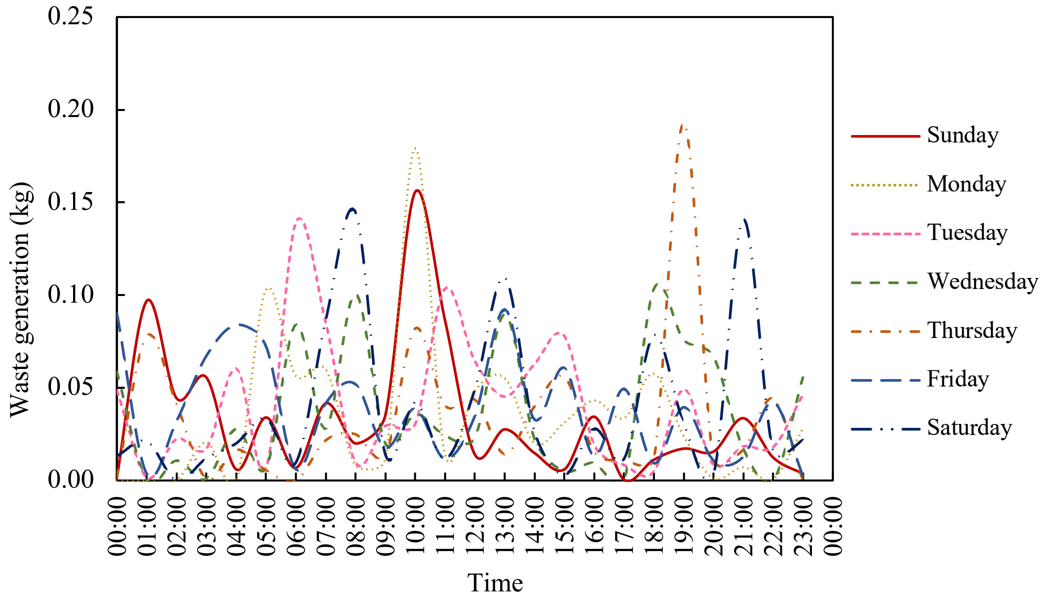


Figure C31 Average waste generation in HH2 (day of the week)

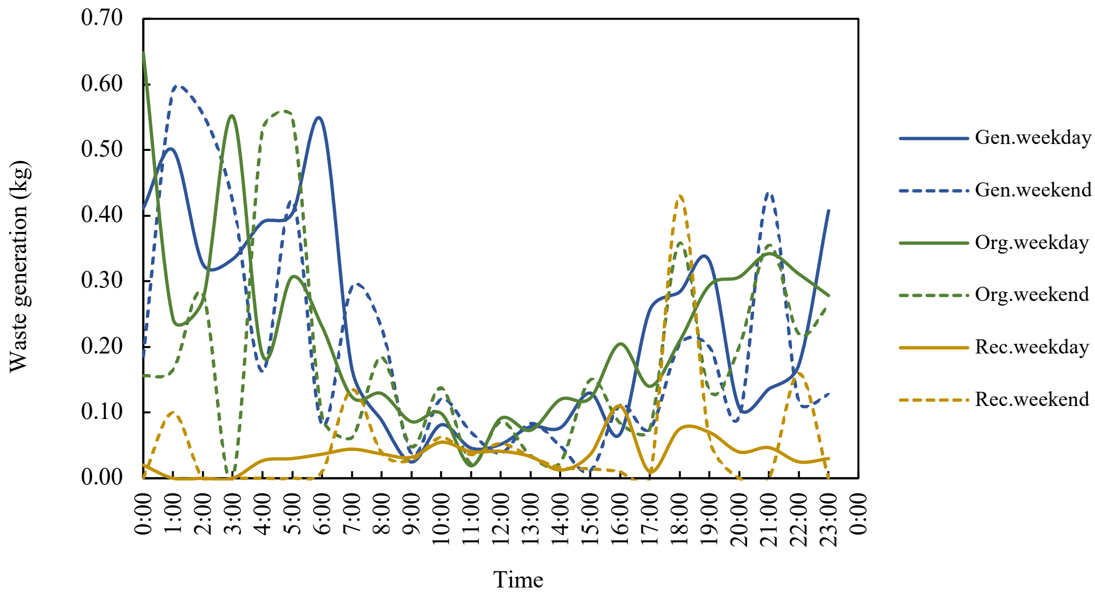


Figure C32 Average waste generation in HH2 (Weekday/Weekend)

C3 Correlation of energy, water, and waste data

Table C1 The correlation and covariance between energy and water data on time of consumption

Building		Energy consumption			Water consumption		
		Time	Time-D	Time-W	Time	Time-D	Time-W
GH1	Cor.	0.151 **	-0.033 **	0.090 **	0.050 **	0.021 *	0.047 *
	Cov.	0.004	-0.006	0.005	0.368	1.074	0.64
GH2	Cor.	0.109 **	-0.007	0.063 **	-0.012	-0.012	-0.006
	Cov.	0.001	0.000	0.001	-0.01	-0.068	-0.01
SH1	Cor.	0.100 **	0.003	0.047 **	0.020 **	-0.004	-0.059 **
	Cov.	0.001	0.000	0.001	0.03	-0.037	-0.166
SH2	Cor.	0.114 **	-0.004	0.040 **	0.064 **	0.000	0.004
	Cov.	0.002	-0.001	0.001	0.228	-0.005	0.025
HH1	Cor.	0.023	0.019 **	-0.015	0.065 **	-0.019	-0.007
	Cov.	0.000	0.002	0.000	0.749	-1.477	-0.147
HH2	Cor.	0.141 **	0.034 **	0.085 **	0.041 **	-0.027 *	-0.036 **
	Cov.	0.003	0.005	0.003	0.136	-0.618	-0.22
SCO	Cor.	-0.011	-0.018	-0.051 **	-0.003	0.013	-0.064 **
	Cov.	-0.036	-0.435	-0.319	-0.002	0.069	-0.092
CHO	Cor.	0.040 **	-0.024 **	-0.107 **	-0.013	-0.001	-0.041 **
	Cov.	0.000	0.000	0.000	-0.118	-0.087	-2.715
COF	Cor.	-0.044 **	-0.015 *	-0.031 **			
	Cov.	-0.001	-0.002	-0.001			

*. Correlation is significant at the 0.05 level (1-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX D

The activity occurrence with energy, water consumption, and waste generation

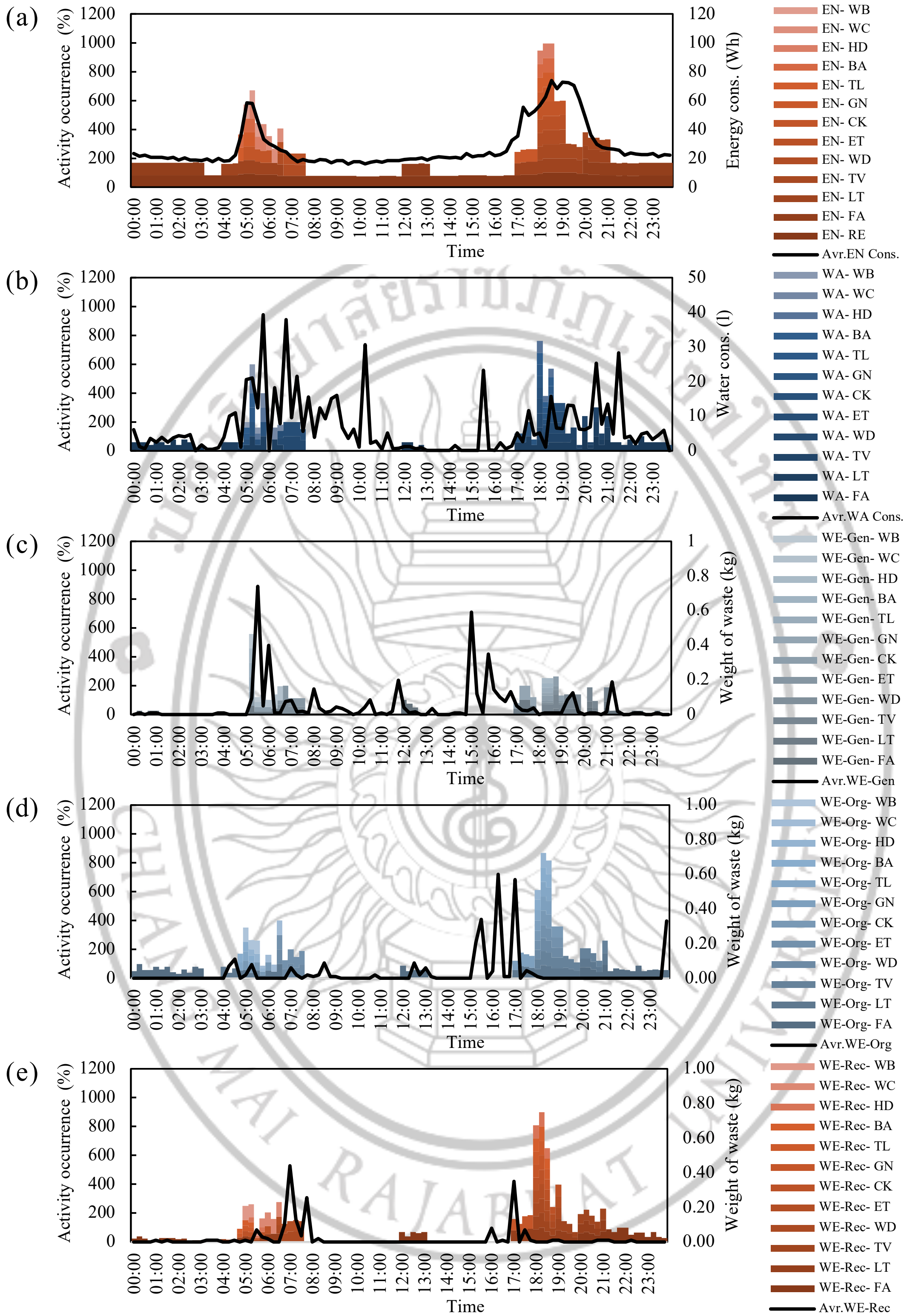


Figure D1 The activity occurrence in GH2 of all consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

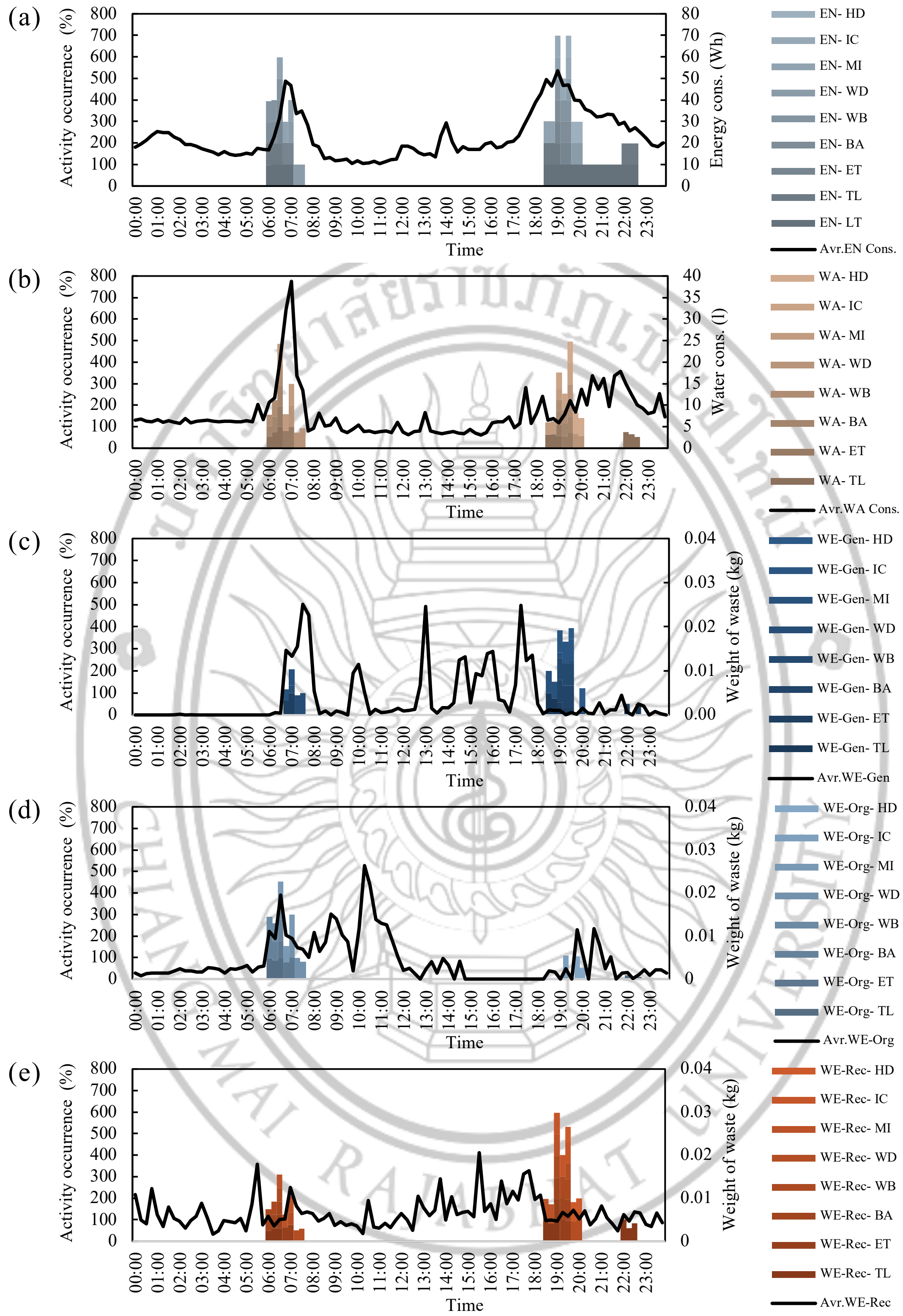


Figure D2 The activity occurrence in SH1 of 1st consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

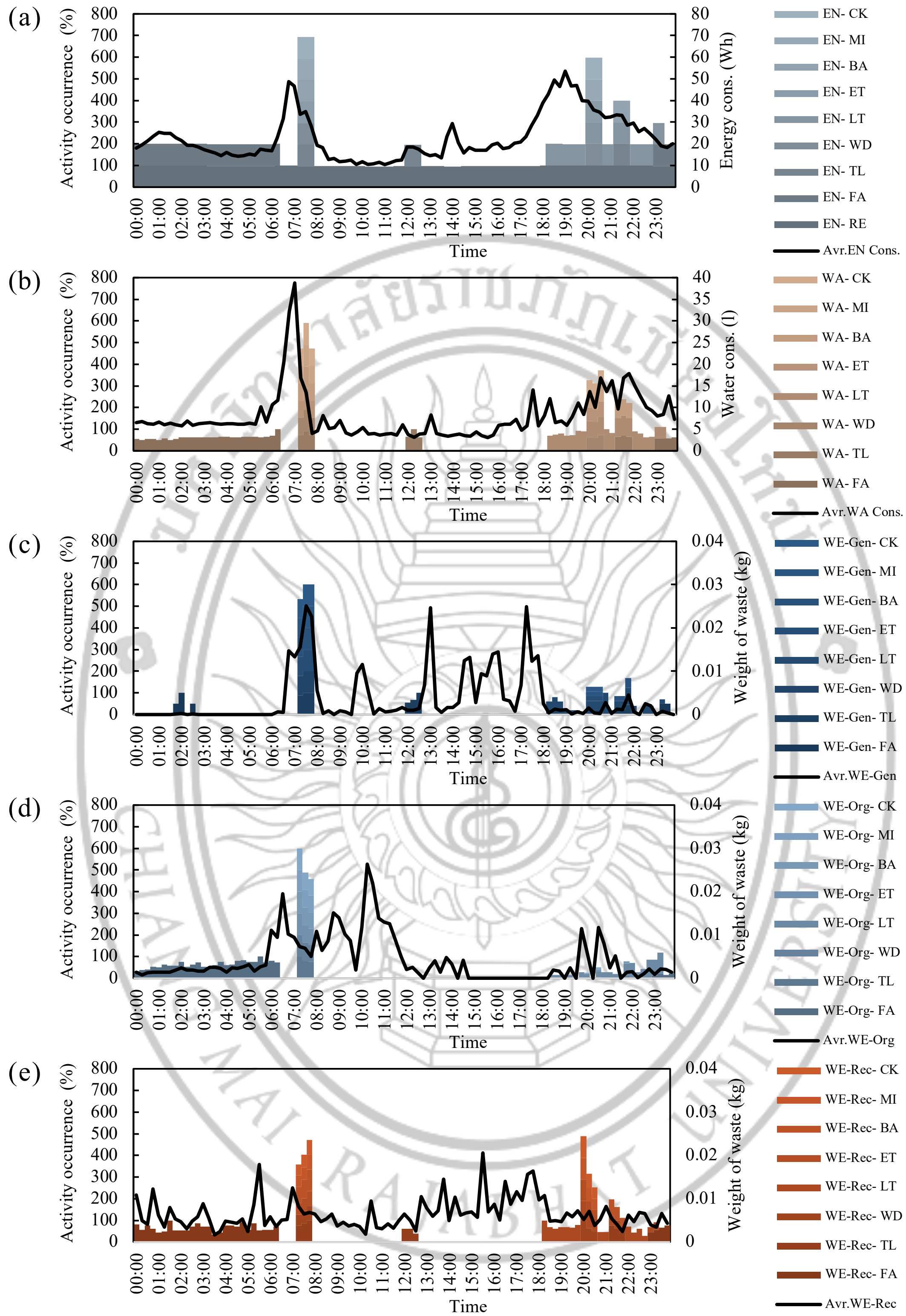


Figure D3 The activity occurrence in SH1 of 2nd consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

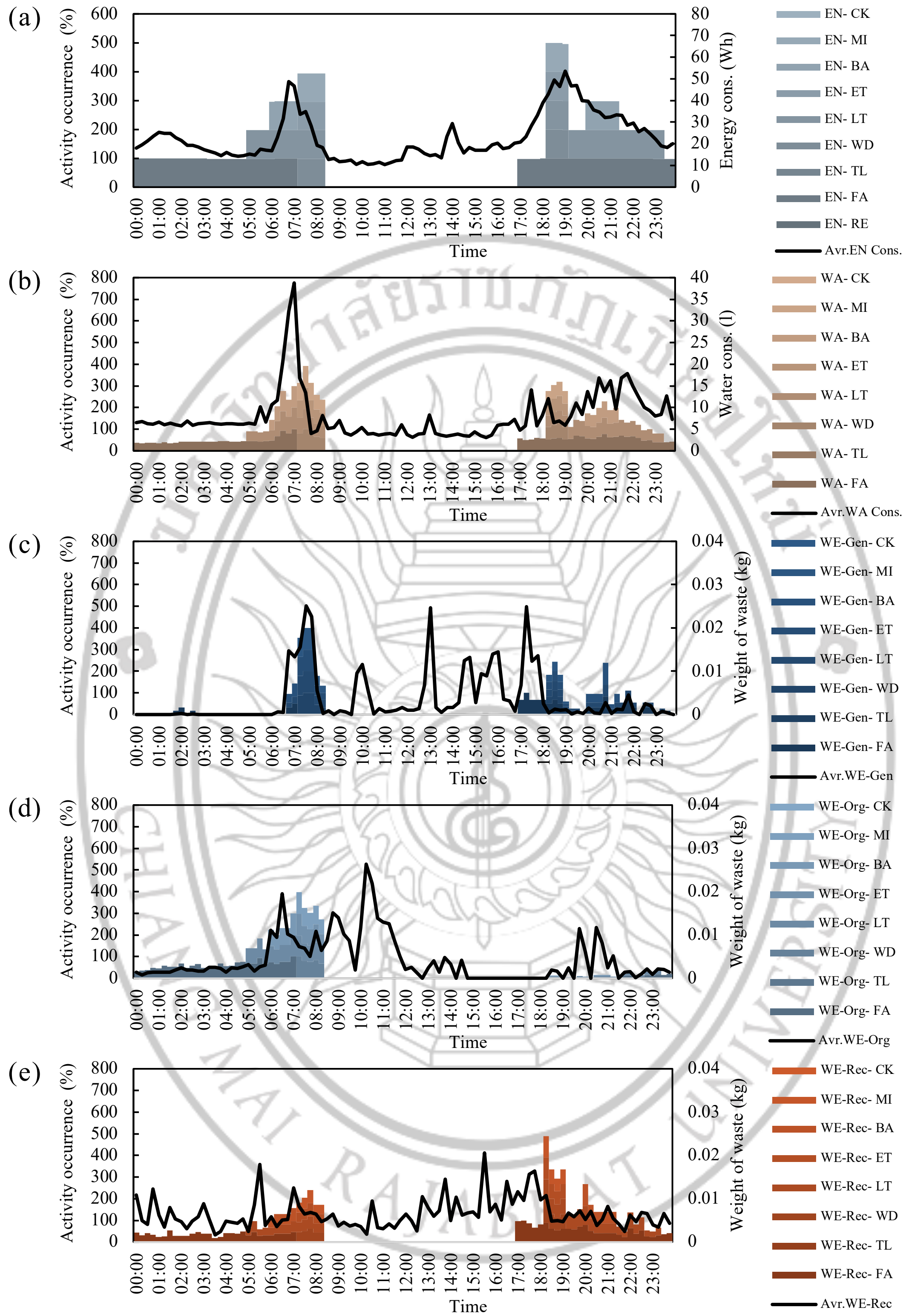


Figure D4 The activity occurrence in SH1 of 3rd consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

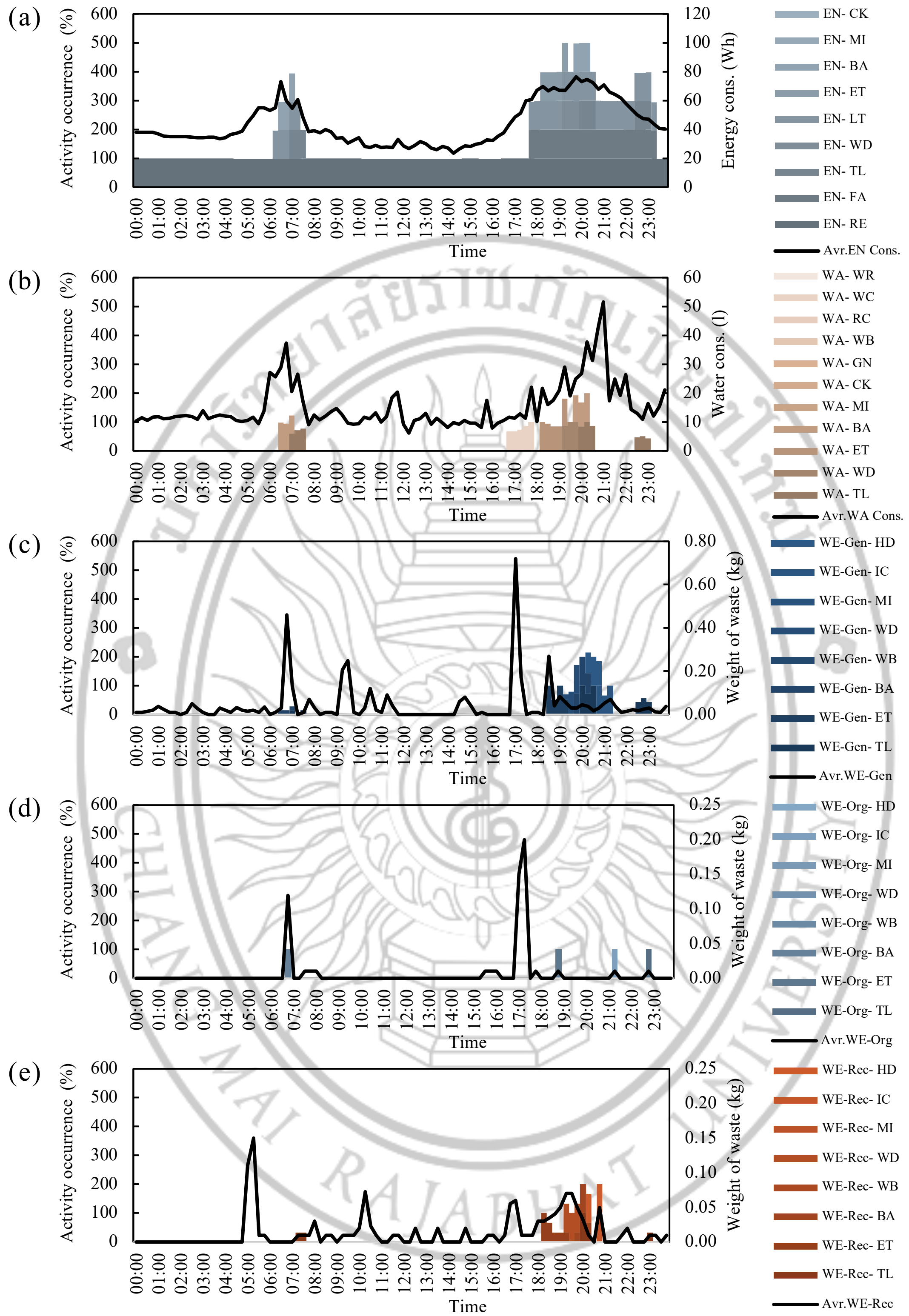


Figure D5 The activity occurrence in SH2 of 1st consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

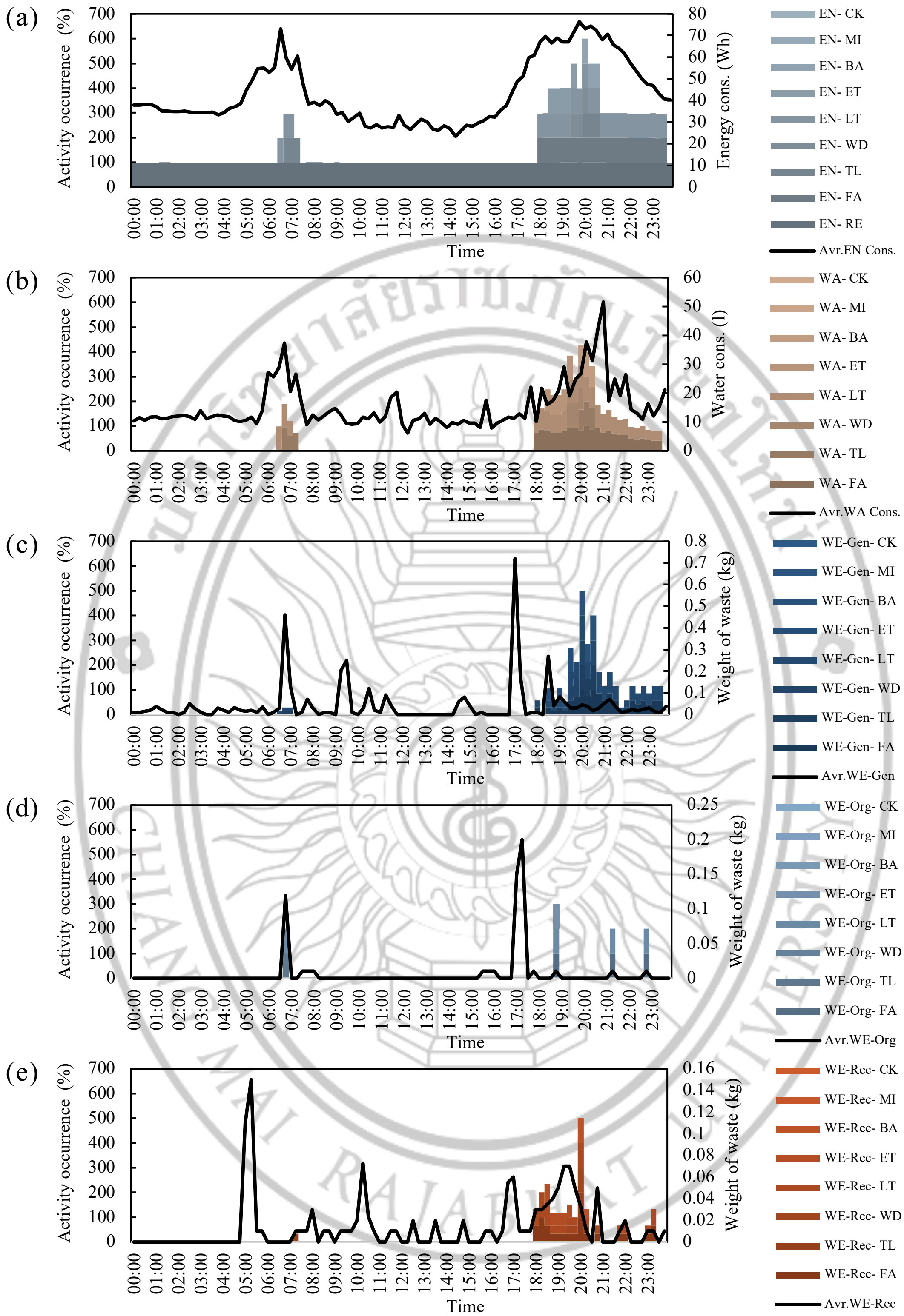


Figure D6 The activity occurrence in SH2 of 2nd consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

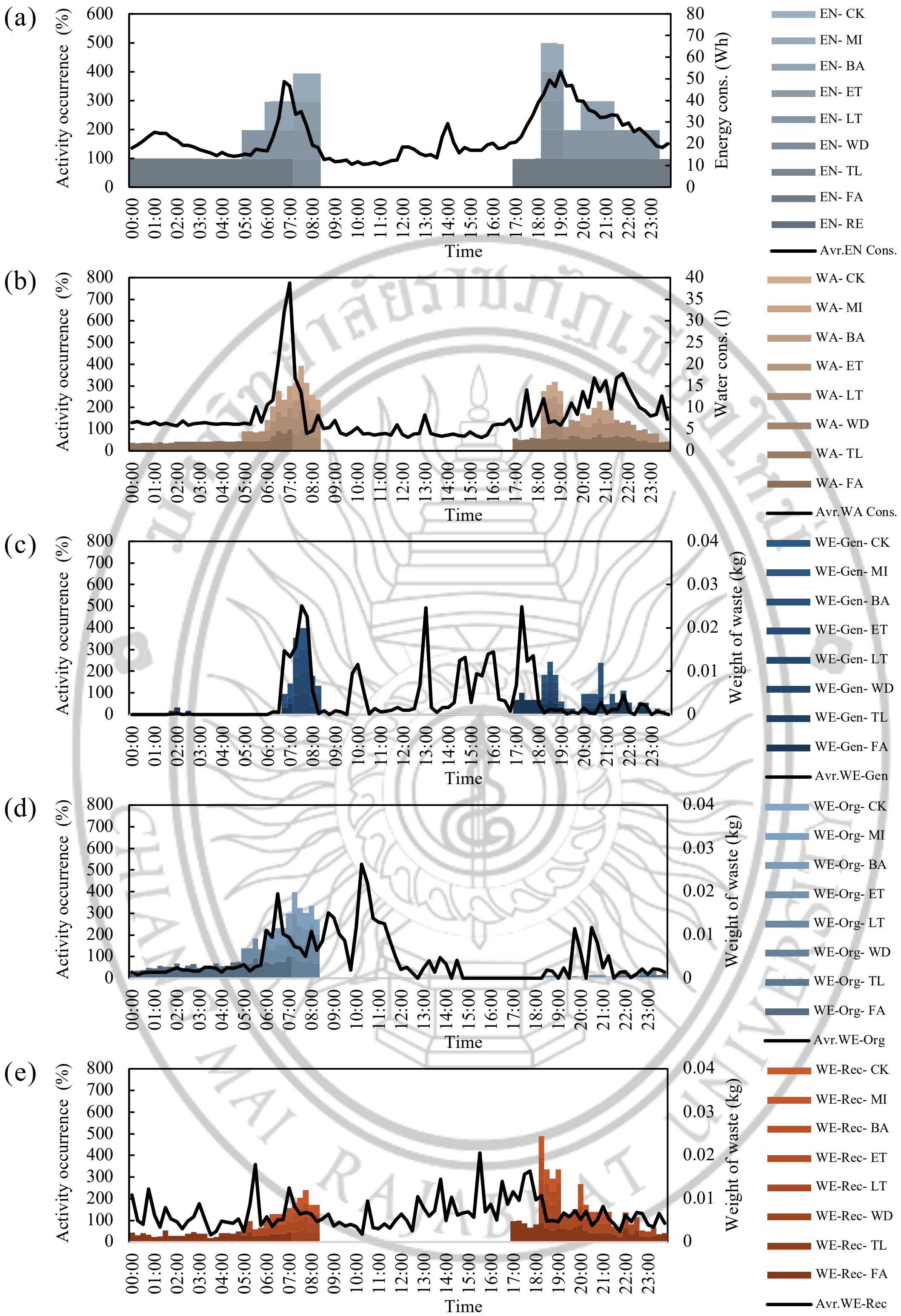


Figure D7 The activity occurrence in SH2 of 3rd consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

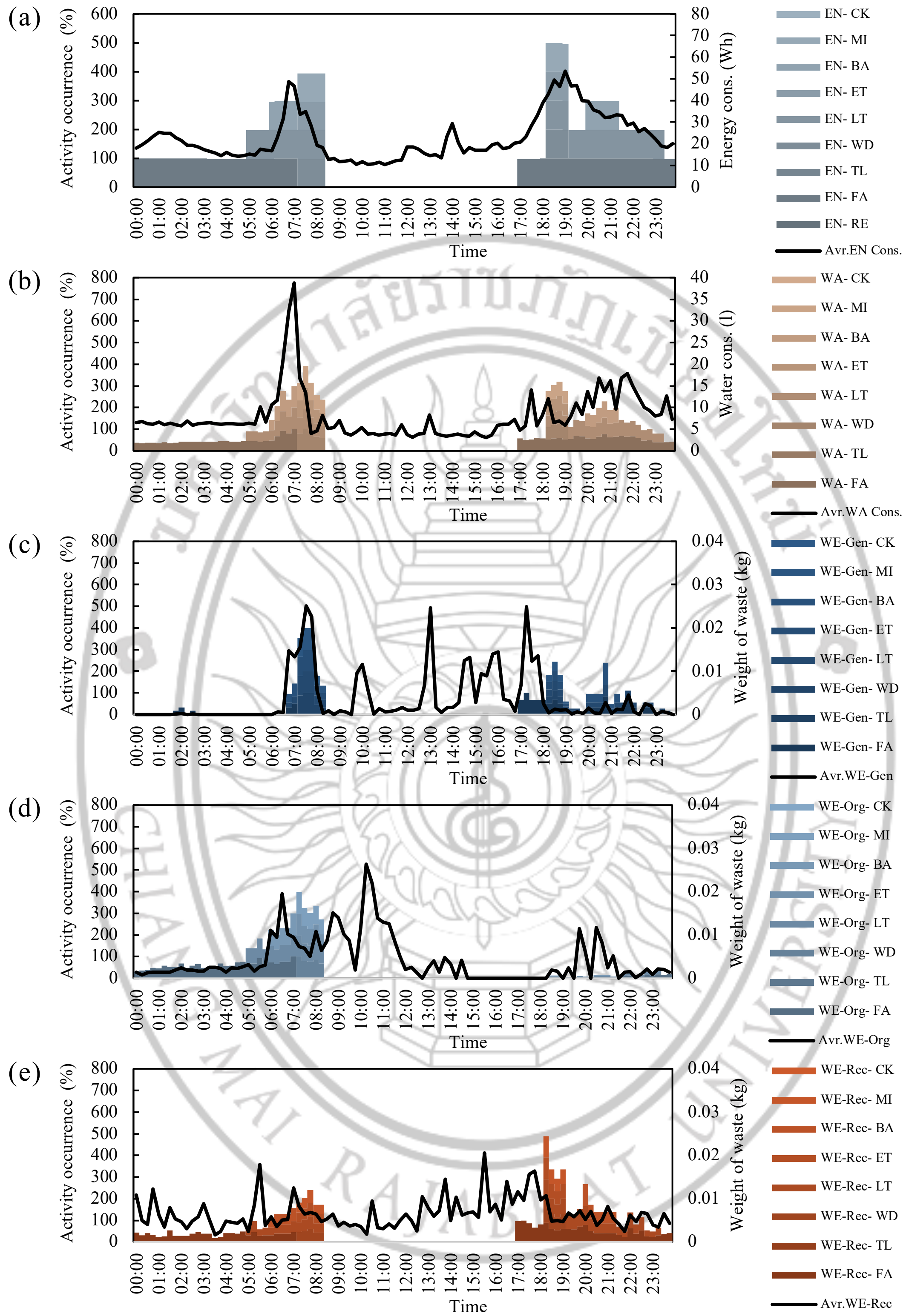


Figure D8 The activity occurrence in SH2 of 4th consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

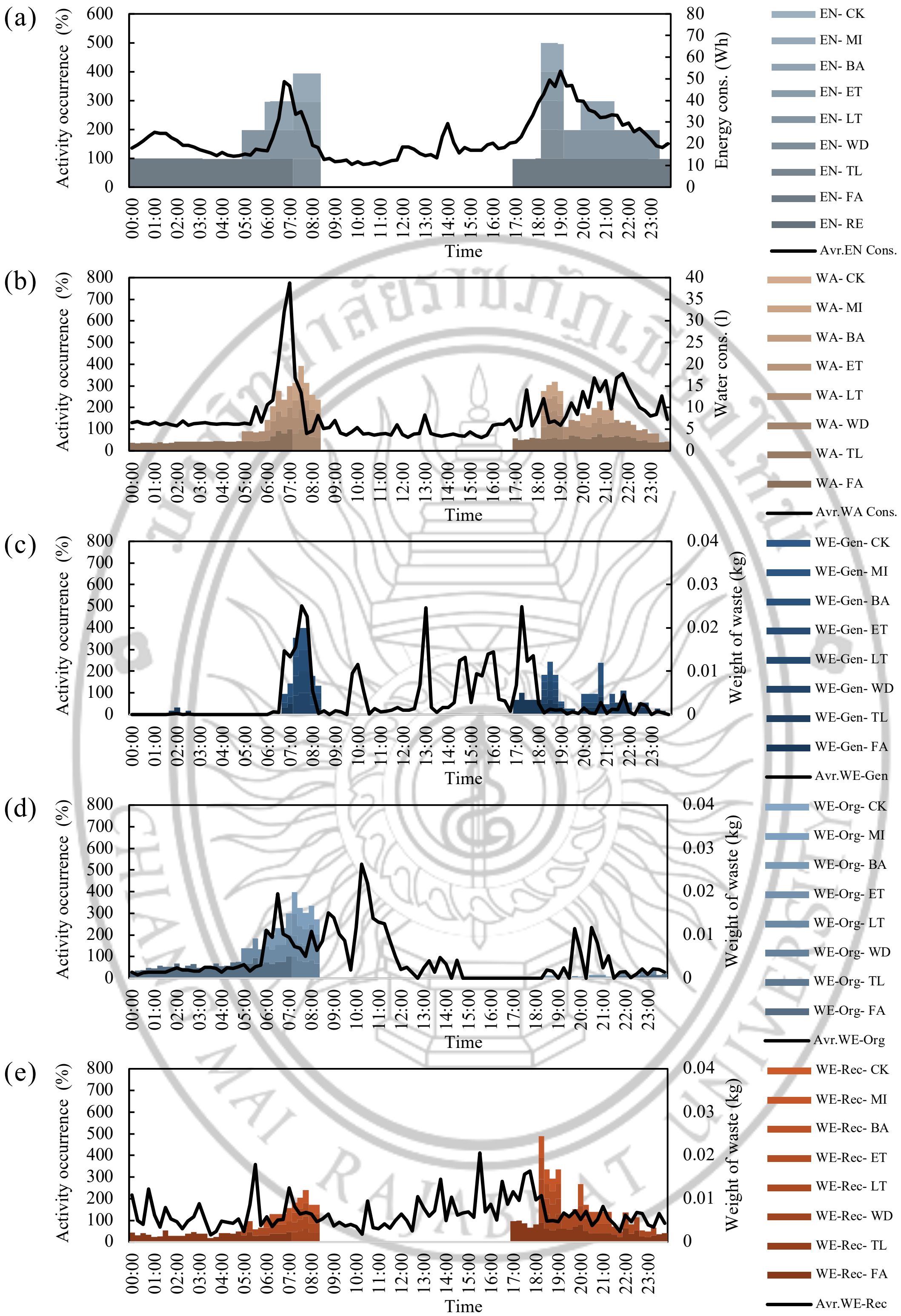


Figure D9 The activity occurrence in HH1 of 1st consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

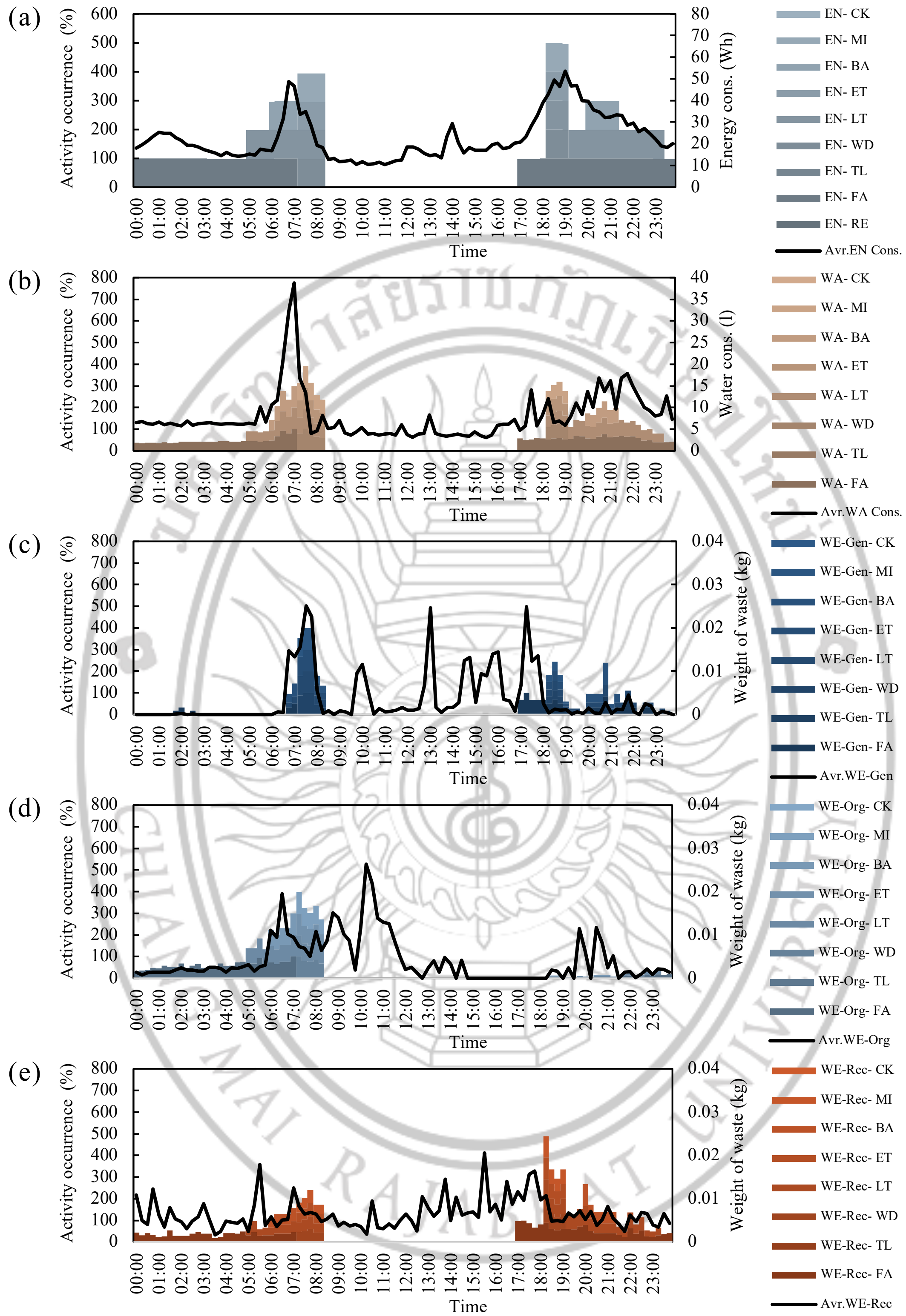
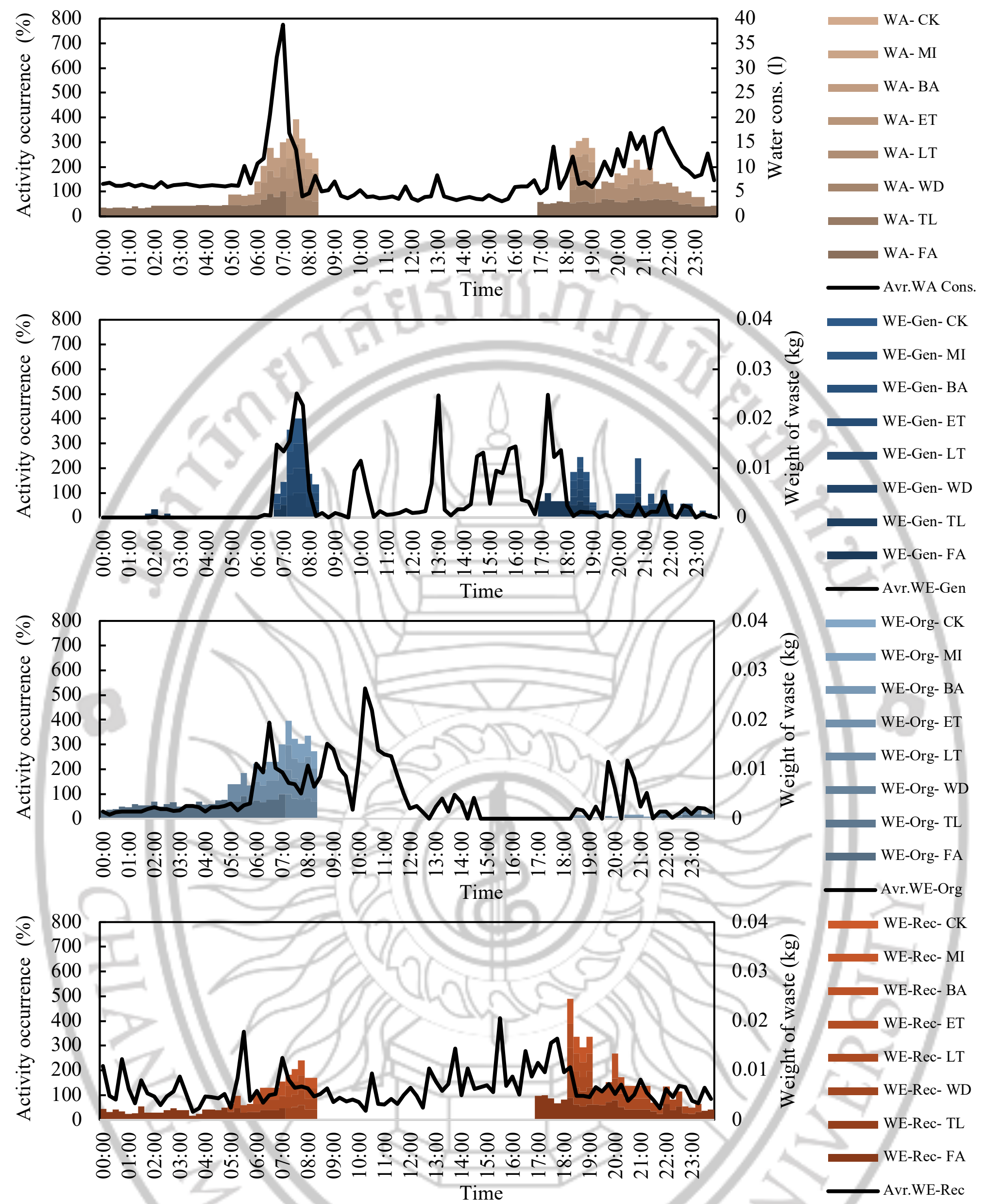


Figure D10 The activity occurrence in HH1 of 2[nd] consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

(a)

(b)



(c)

(d)

(e)

Figure D11 The activity occurrence in HH2 of 1st consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

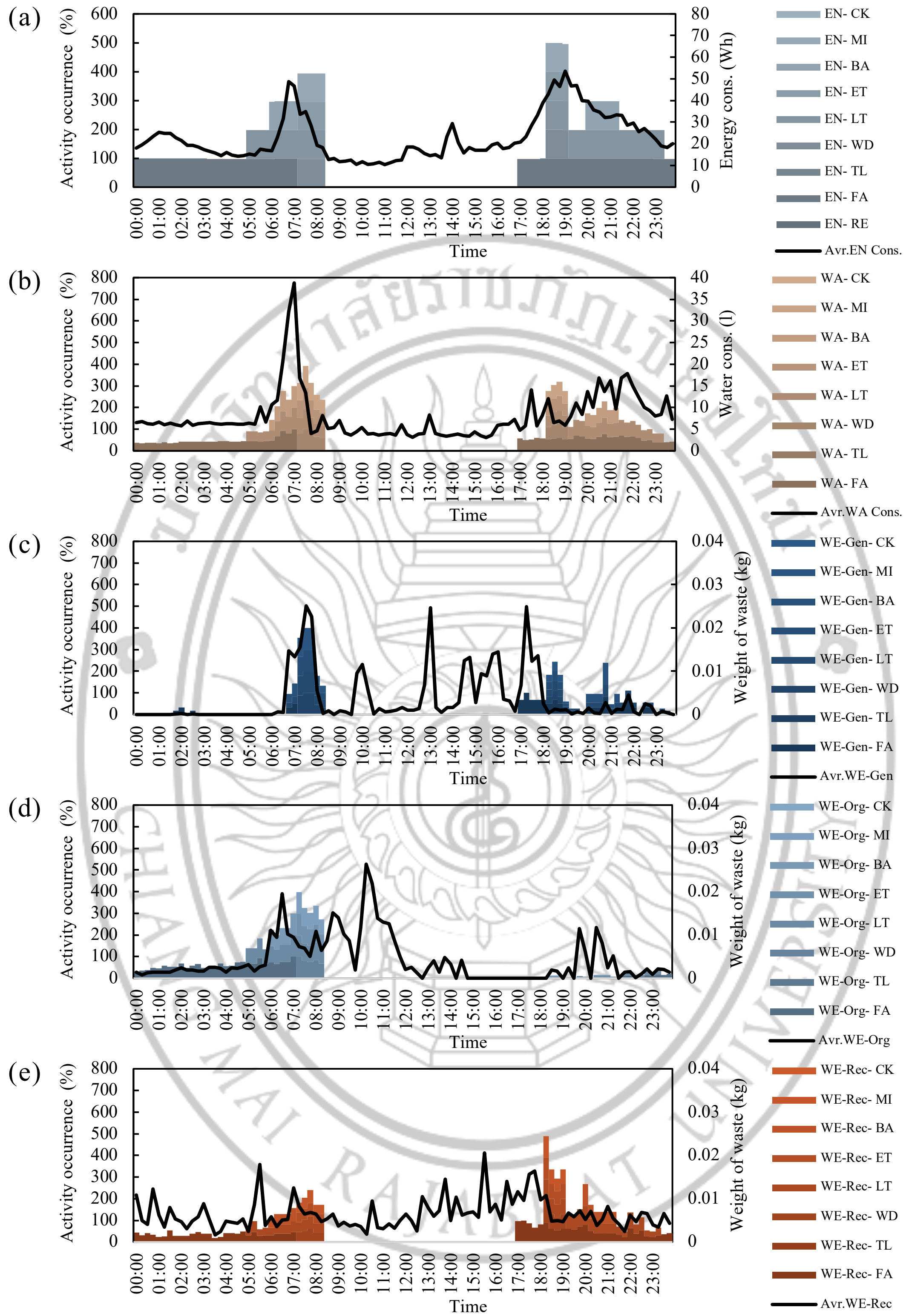


Figure D12 The activity occurrence in HH2 of 2nd consumers with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

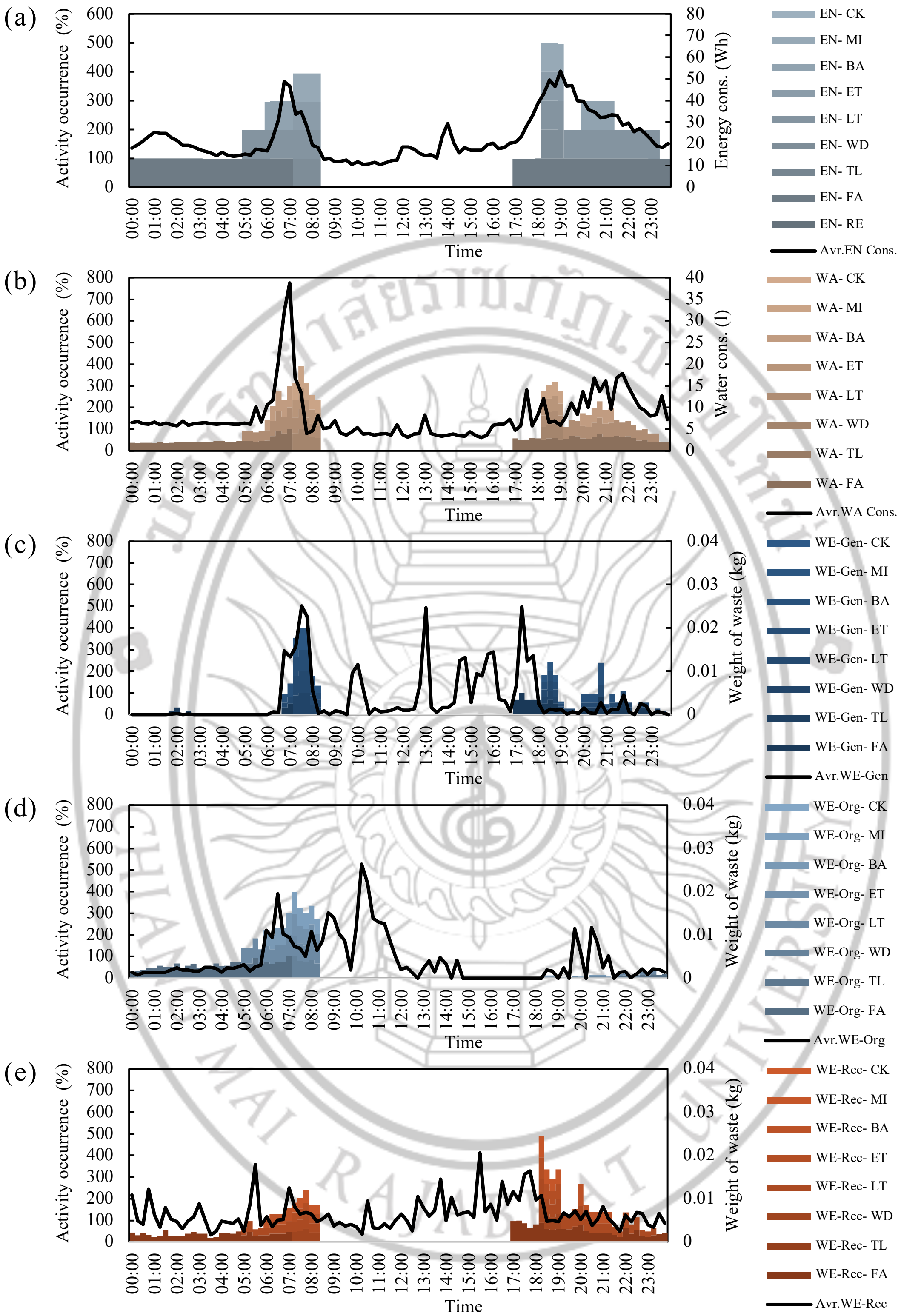


Figure D13 The activity occurrence in SCO with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

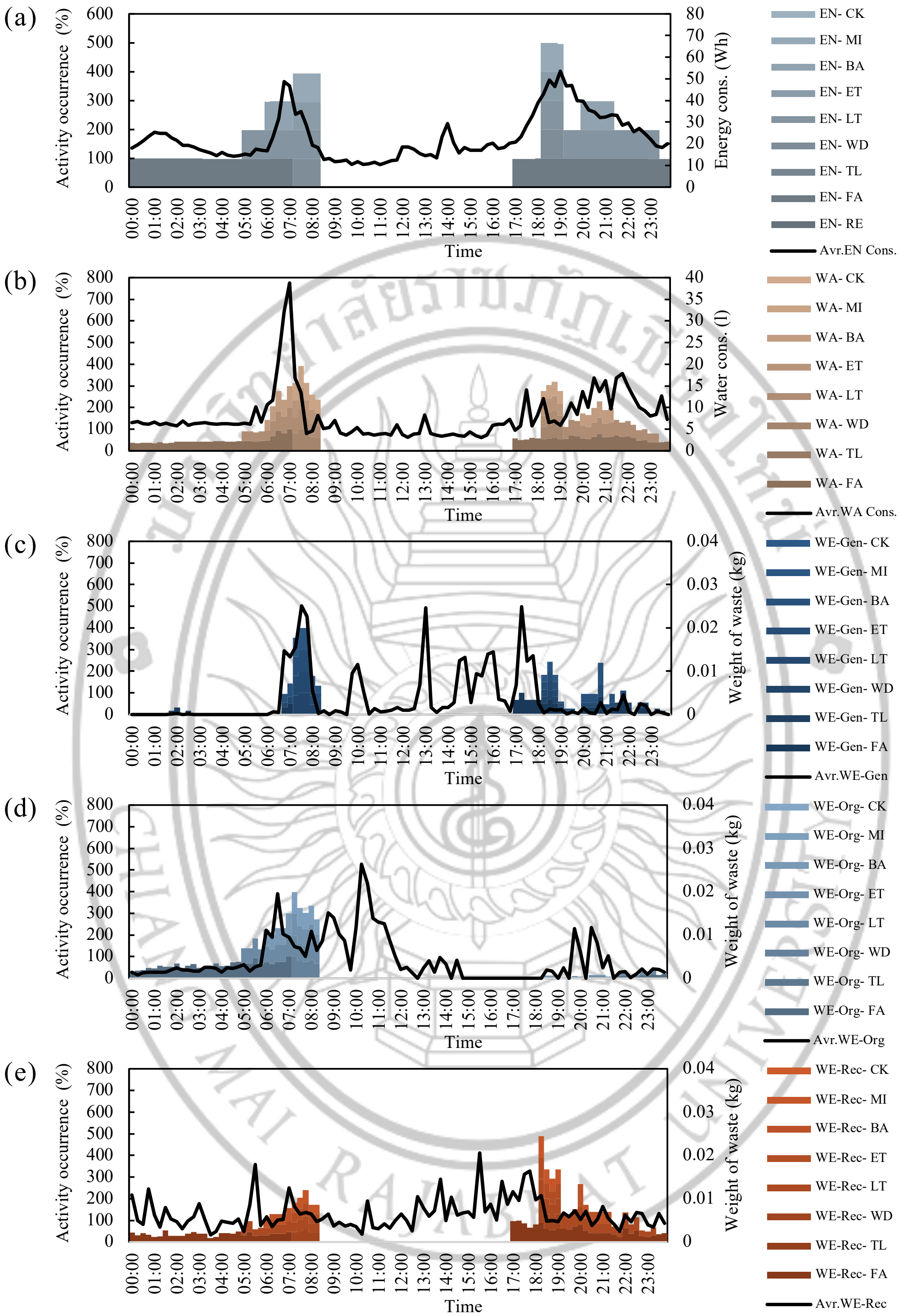


Figure D14 The activity occurrence in CHO with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

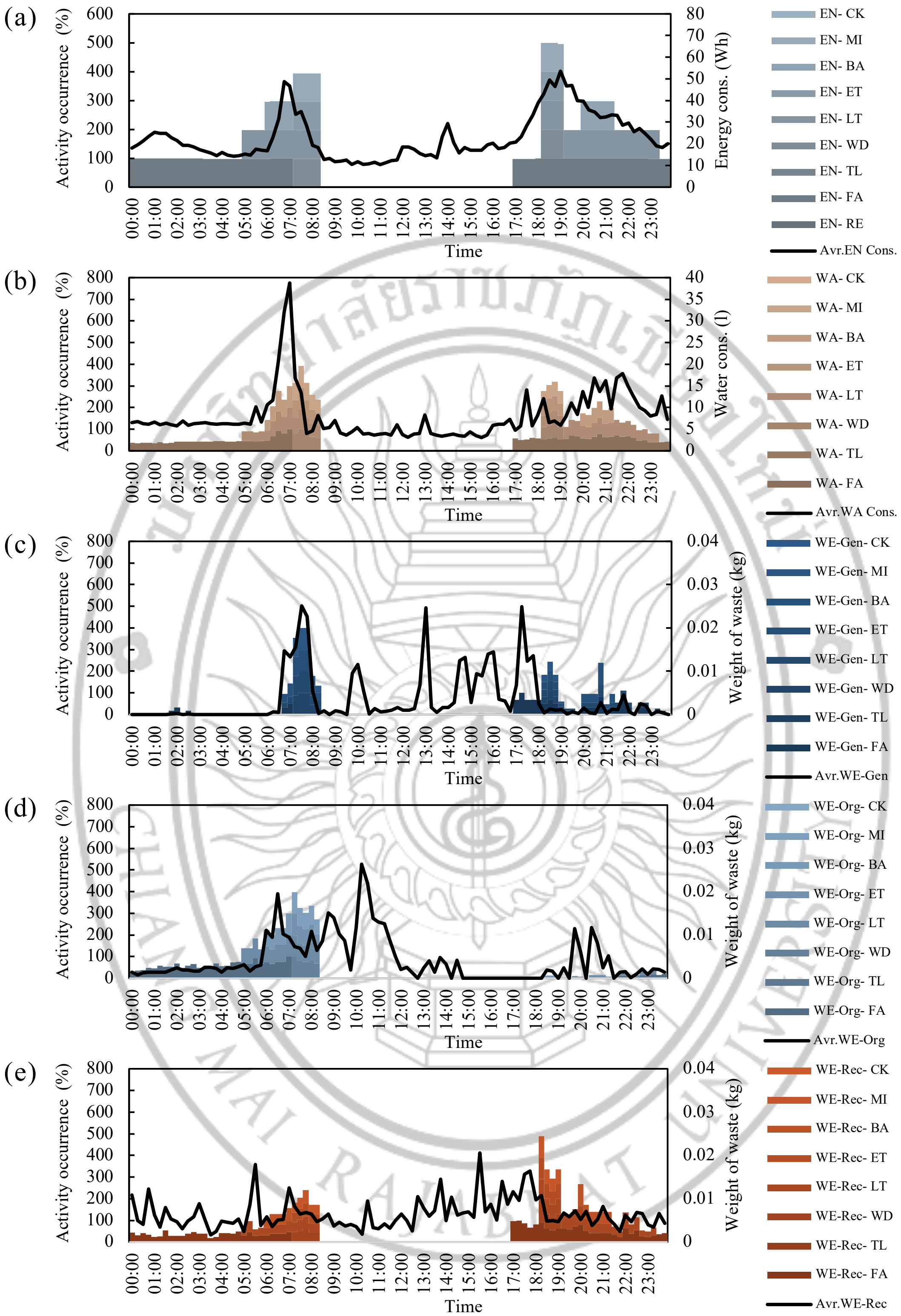


Figure D15 The activity occurrence in COF with consumption of (a) Energy (b) Water and creation of (c) General (d) Organic and (e) Recycle waste

APPENDIX E

Power consumption of appliances

Table E1 The average power consumption of appliances in building

Appliances	Type	Size	Unit	Average power consumption (W)
Fan	Ceiling	16.00	inch	45.00
		18.00	inch	65.00
		48.00	inch	109.25
		56.00	inch	142.50
	Wall mounted	16.00	inch	52.50
		18.00	inch	77.00
		22.00	inch	163.50
	Table	12.00	inch	38.00
		16.00	inch	50.25
		18.00	inch	64.00
Refrigerator	Conv. Single-door	6.70	ft^3	147.50
		6.80	ft^3	185.00
		7.00	ft^3	117.50
		7.20	ft^3	117.00
		7.50	ft^3	123.00
		8.00	ft^3	107.00
		8.30	ft^3	156.00
		9.50	ft^3	174.00
	Inv. Single-door	5.00	ft^3	92.02
		6.00	ft^3	109.48
		7.00	ft^3	102.50
		8.00	ft^3	144.41
		9.00	ft^3	161.87

Table E1 (Cont.)

Appliances	Type	Size	Unit	Average power consumption (W)
Refrigerator	Conv. Double-door	8.90	ft^3	219.00
		9.50	ft^3	198.50
		11.00	ft^3	258.00
		12.00	ft^3	214.00
		12.50	ft^3	214.50
		15.00	ft^3	229.00
		22.20	ft^3	253.00
	Inv. Double-door	8.30	ft^3	143.00
		9.18	ft^3	194.00
		10.31	ft^3	194.00
		12.01	ft^3	207.00
Rice cook	Conv.	0.27	L	210.00
		0.60	L	300.00
		1.00	L	491.67
		1.30	L	536.00
		1.50	L	550.00
		1.80	L	630.00
		2.00	L	645.00
	Digital	0.54	L	360.00
		1.00	L	585.00
		1.50	L	720.00
		1.80	L	801.25
Water boiler	Kettle	0.80	L	1,000.00
		1.00	L	1,510.00
		1.50	L	2,000.00
		1.70	L	1,500.00
		1.80	L	1,800.00
		2.50	L	1,850.00
Water boiler	Thermos	2.50	L	700.00
		2.80	L	670.00
		3.30	L	700.00
		4.50	L	750.00

Table E1 (Cont.)

Appliances	Type	Size	Unit	Average power consumption (W)
Washing machine	Twin tub	7.00	kg	250.00
		7.50	kg	340.00
		8.00	kg	390.00
		10.00	kg	425.00
		10.50	kg	540.00
		14.00	kg	573.33
		16.00	kg	650.00
		18.00	kg	760.00
	Top load	8.00	kg	350.00
		12.00	kg	500.00
		15.00	kg	580.00
		18.00	kg	703.81
		25.00	kg	1,100.00
	Front load			2,000.00
TV	LCD	24.00	inch	50.00
		32.00	inch	70.00
		37.00	inch	80.00
		42.00	inch	120.00
		50.00	inch	160.00
	LED	32.00	inch	45.00
		37.00	inch	65.00
		42.00	inch	80.00
		50.00	inch	100.00
		65.00	inch	125.00
		82.00	inch	262.00

(avjo, 2022; Home Product Center Public Company Limited, 2023; Panasonic, 2023; W. Y. Park et al., 2017)

APPENDIX F

Energy water consumption and waste generation of each activity by consumer in building

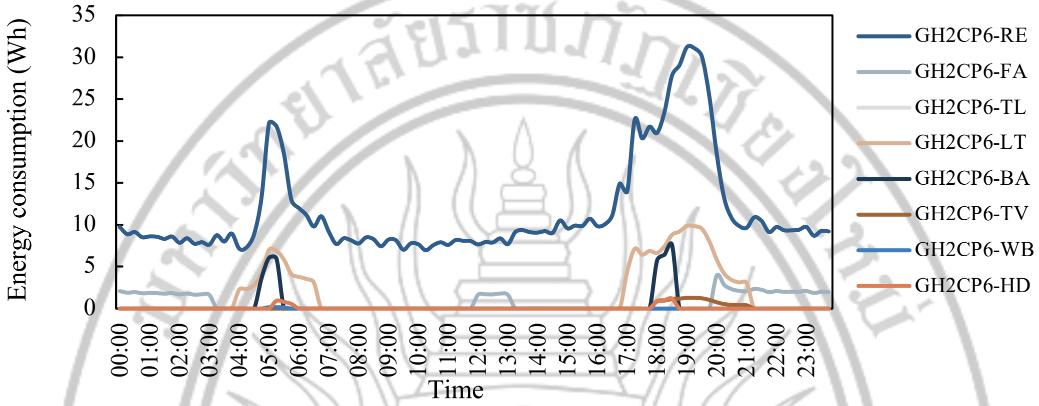


Figure F1 Energy consumption of each activity by 1st consumer in GH2

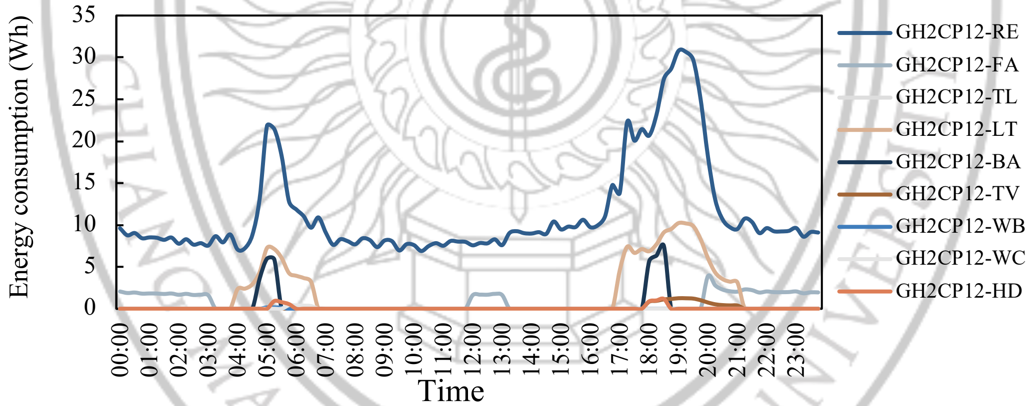


Figure F2 Energy consumption of each activity by 2nd consumer in GH2

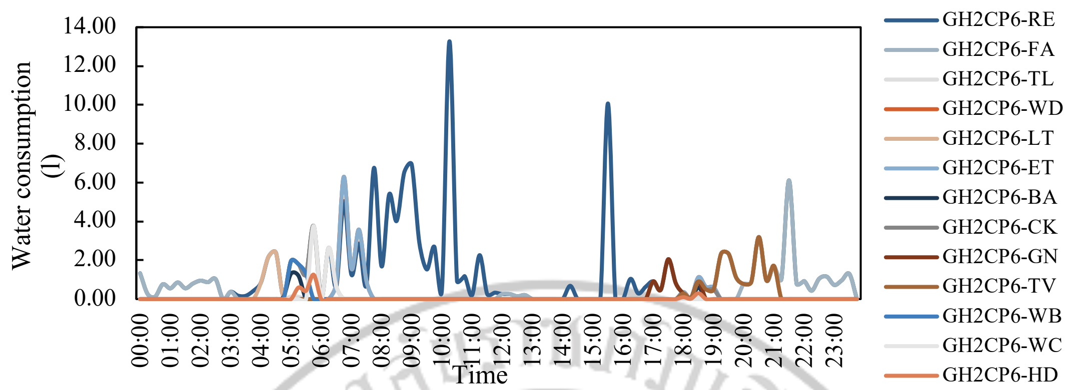


Figure F3 Water consumption of each activity by 1st consumer in GH2

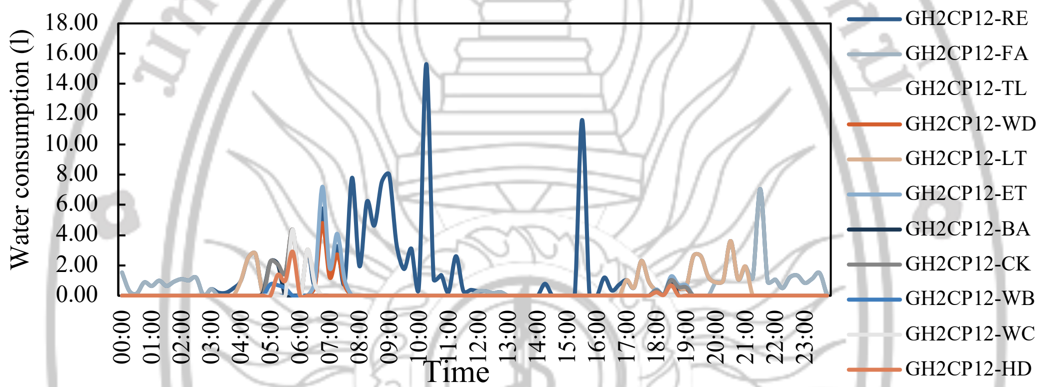


Figure F4 Water consumption of each activity by 2nd consumer in GH2

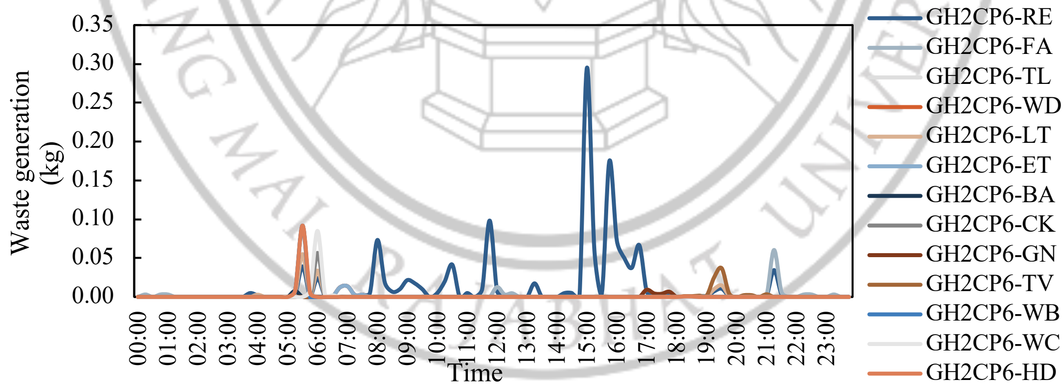


Figure F5 General waste generation of each activity by 1st consumer in GH2

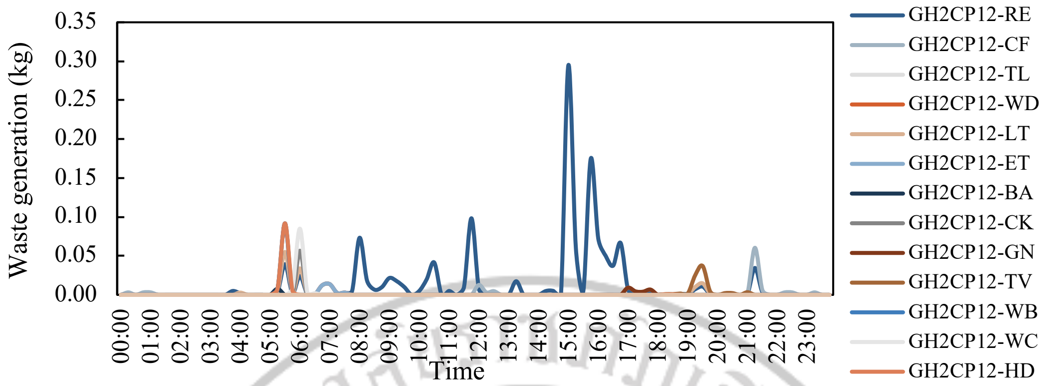


Figure F6 General waste generation of each activity by 2nd consumer in GH2

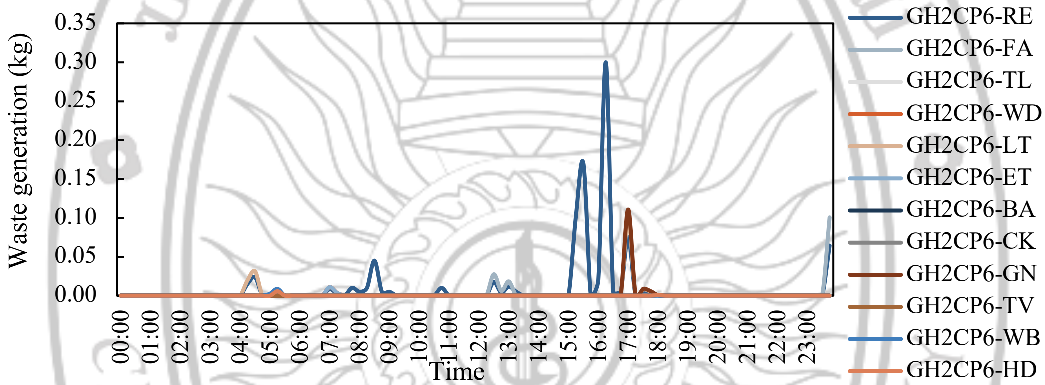


Figure F7 Organic waste generation of each activity by 1st consumer in GH2

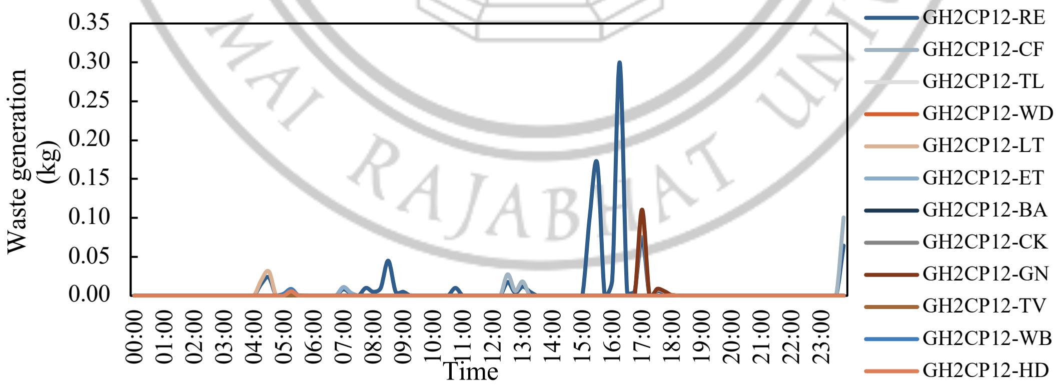


Figure F8 Organic waste generation of each activity by 2nd consumer in GH2

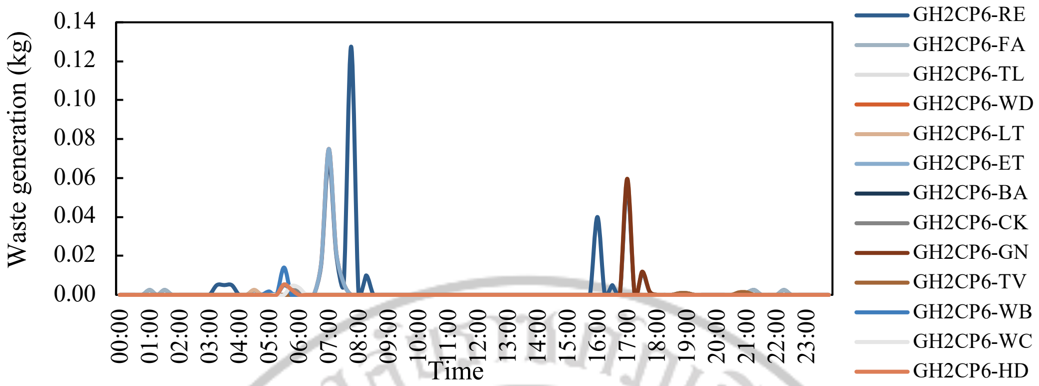


Figure F9 Recycle waste generation of each activity by 1st consumer in GH2

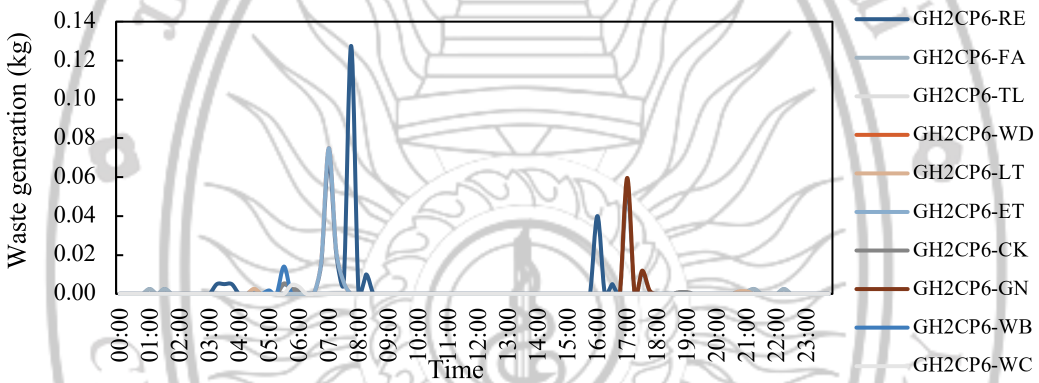


Figure F10 Recycle waste generation of each activity by 2nd consumer in GH2

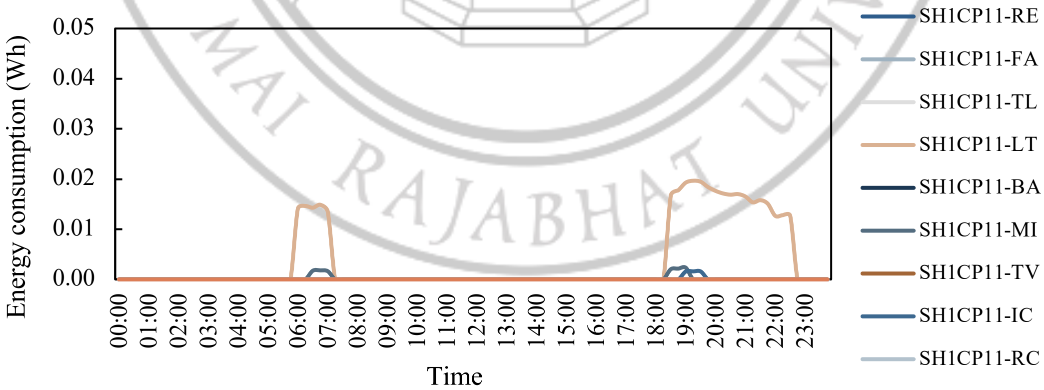


Figure F11 Energy consumption of each activity by 1st consumer in SH1

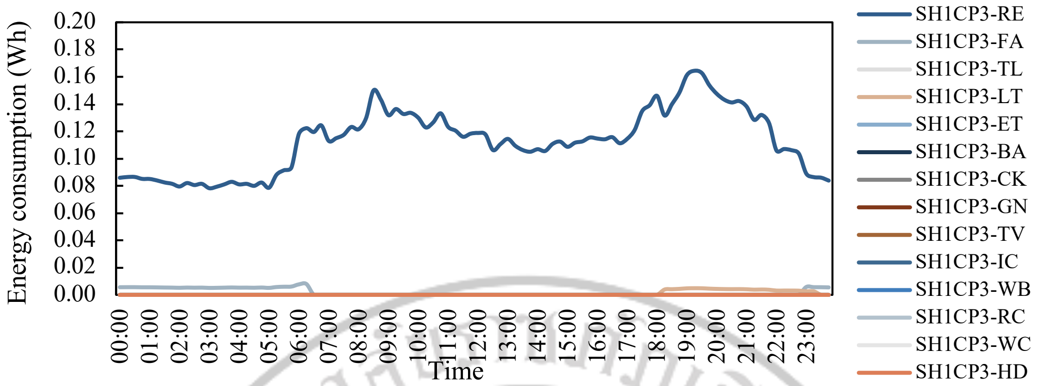


Figure F12 Energy consumption of each activity by 2nd consumer in SH1

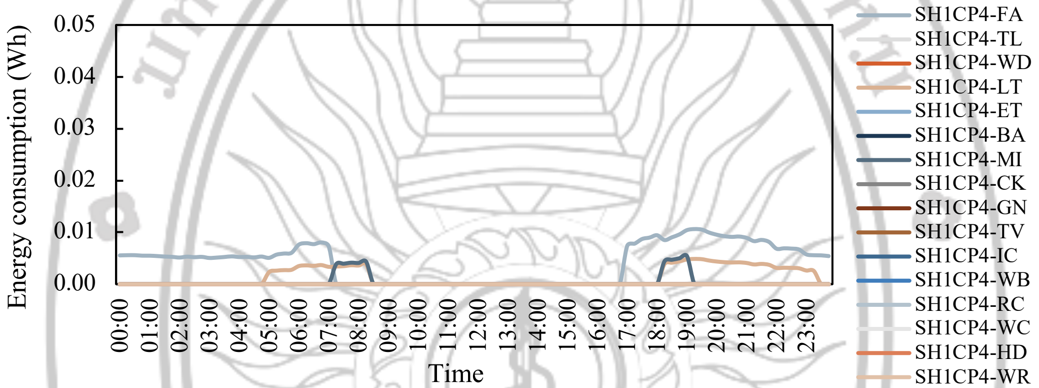


Figure F13 Energy consumption of each activity by 3rd consumer in SH1

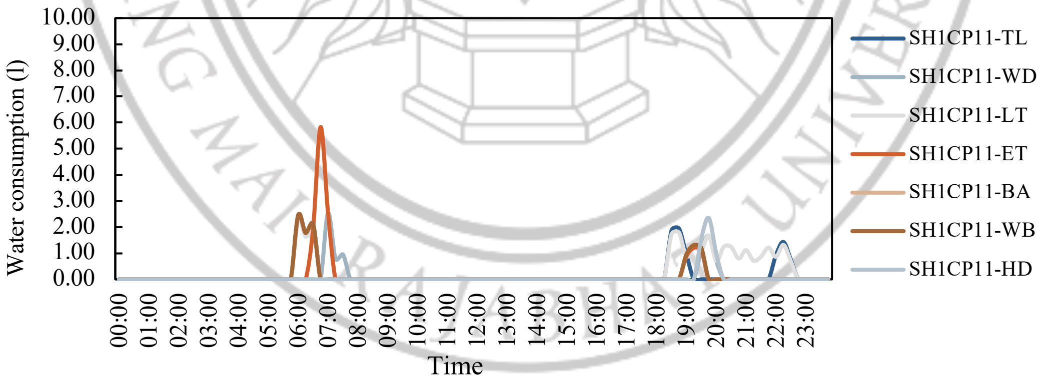


Figure F14 Water consumption of each activity by 1st consumer in SH1

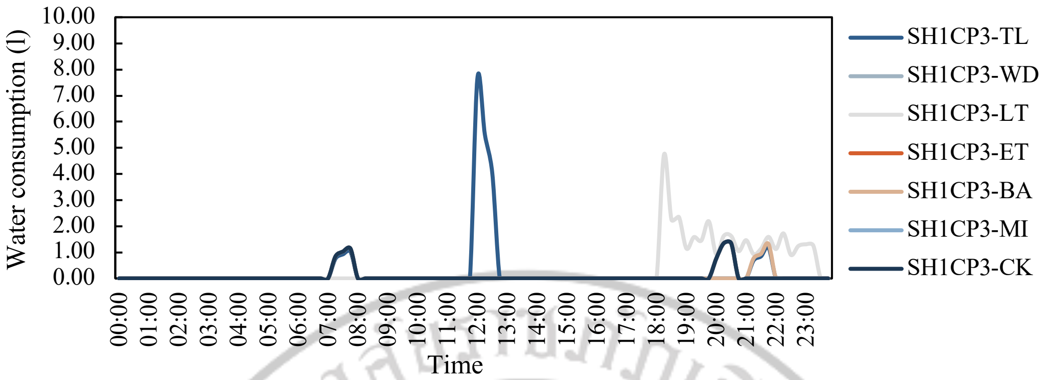


Figure F15 Water consumption of each activity by 2nd consumer in SH1

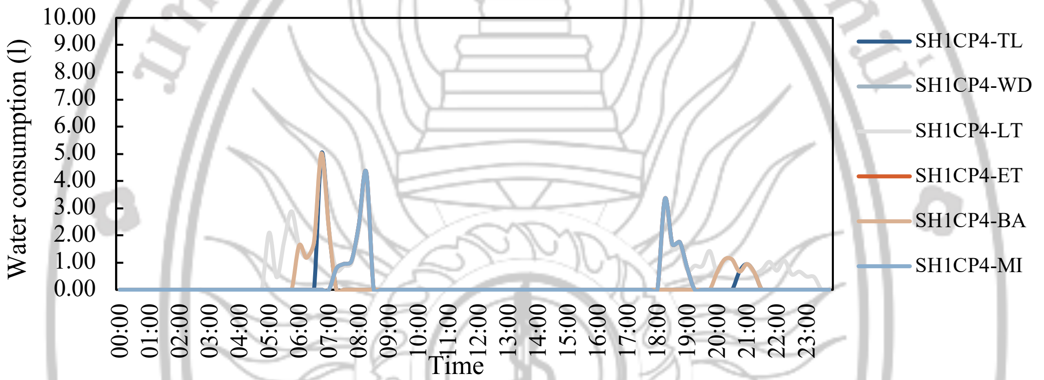


Figure F16 Water consumption of each activity by 3rd consumer in SH1

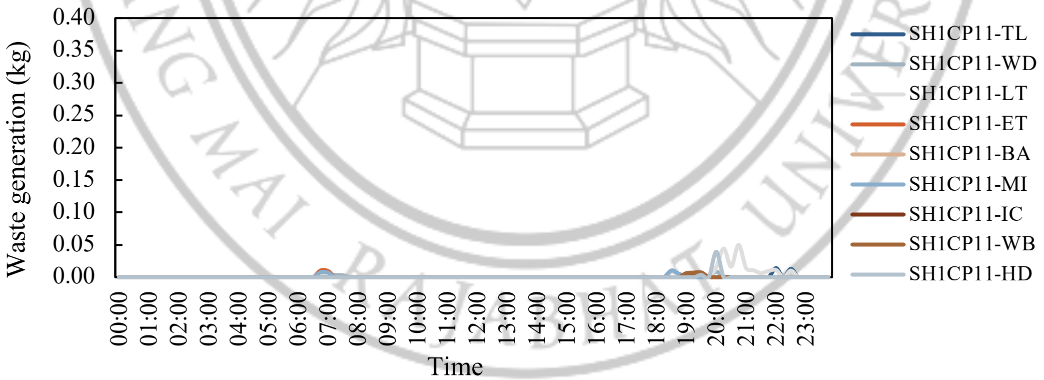


Figure F17 General waste generation of each activity by 1st consumer in SH1

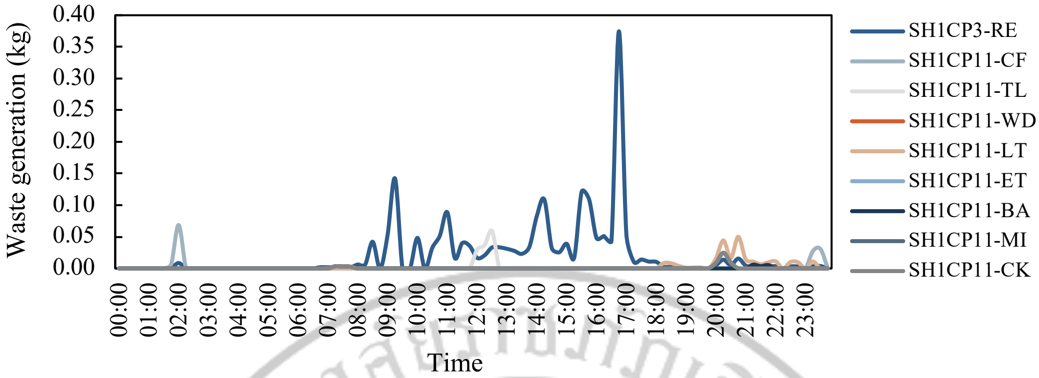


Figure F18 General waste generation of each activity by 2nd consumer in SH1

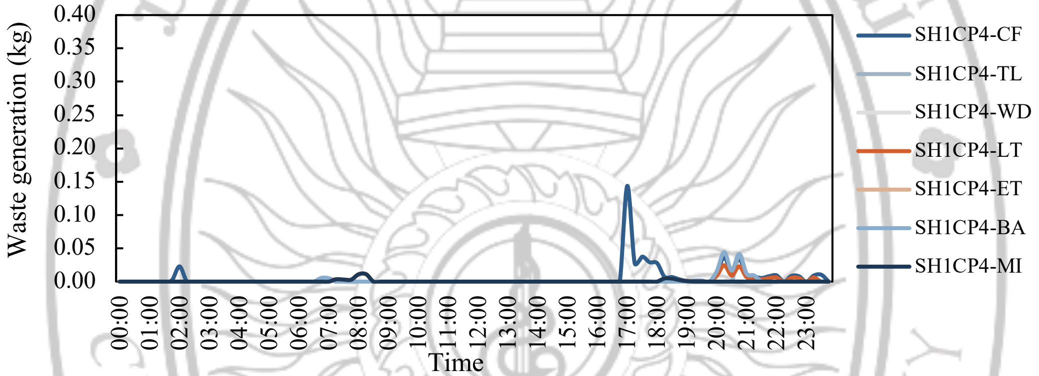


Figure F19 General waste generation of each activity by 3rd consumer in SH1

APPENDIX G

Smart community framework

กรอบแนวทางสำหรับการพัฒนาชุมชนอัจฉริยะจากข้อมูลปริมาณความต้องการใช้พลังงาน ปริมาณน้ำ และปริมาณขยะที่เกิดขึ้นภายในชุมชน โดยเปรียบเทียบกับศักยภาพของชุมชนจากการเก็บ และวิเคราะห์ข้อมูลของชุมชน แสดงในภาพถัดไป ที่แสดงกรอบการพัฒนาชุมชนและวิเคราะห์ออกเป็น 3 แหล่งข้อมูล ประกอบด้วยข้อมูลที่ได้จากการเก็บข้อมูลจากแบบสอบถาม ข้อมูลที่ตรวจวัดได้จากอุปกรณ์ตรวจวัดอัจฉริยะ และข้อมูลจากฐานข้อมูลสาธารณะ ซึ่งมีรายละเอียดดังนี้

ข้อมูลจากแบบสอบถาม เป็นข้อมูลที่ได้จากการลงพื้นที่เก็บแบบสอบถามจากกลุ่มตัวอย่างในชุมชนเพื่อสำหรับการวิเคราะห์พฤติกรรมการทำกิจกรรมภายในอาคารแยกตามกลุ่มอายุและเพศ ซึ่งได้จากข้อมูลทั้งหมด 4 ส่วน ประกอบด้วย ข้อมูลลักษณะผู้ใช้งาน อุปกรณ์และเครื่องใช้ไฟฟ้าภายในอาคาร ความถี่และระยะเวลาสำหรับการทำกิจกรรมแต่ละกิจกรรม และข้อมูลค่าใช้จ่ายย้อนหลัง ทั้งนี้ข้อมูลจากการเก็บแบบสองถามจะเก็บจาก 2 กลุ่มตัวอย่าง คือ กลุ่มตัวอย่างจากประชากรภายในชุมชนส่วนใหญ่หรืออย่างน้อยร้อยละ 35 จากจำนวนประชากรในพื้นที่ทั้งหมด และกลุ่มตัวอย่างจากประชากรที่อาศัยอยู่ภายในอาคารตัวอย่าง

ข้อมูลจากอุปกรณ์ตรวจวัดอัจฉริยะ เป็นข้อมูลที่ได้จากการตรวจวัดปริมาณการใช้พลังงาน ปริมาณการใช้น้ำ และปริมาณการทิ้งขยะแต่ละชนิด (ขยะทั่วไป ขยะรีไซเคิล และขยะอินทรีย์) ที่เกขึ้นภายในอาคารในเวลาที่เกิดขึ้นจริงที่ความถี่ของการเก็บข้อมูลสะสมทุก 15 นาที ที่ติดตั้งภายในอาคารตัวอย่างทั้ง 3 กลุ่มอาคาร ประกอบด้วยอาคารบ้านพักอาศัย อาคารสำนักงาน และอาคารเชิงพาณิชย์ ทั้งนี้มีจำนวนอาคารที่ทำการติดตั้งอุปกรณ์ตรวจวัดอัจฉริยะมากขึ้นจะส่งผลต่อความน่าเชื่อถือข้อมูลที่ใช้ในการวิเคราะห์โปรไฟล์ของผู้ใช้งาน

ข้อมูลจากฐานข้อมูลสาธารณะ เป็นข้อมูลทั่วไปที่สามารถค้นหาได้จากทั้งทางหน่วยงานของภาครัฐ รวมถึงหน่วยงานเอกชน ซึ่งประกอบด้วยข้อมูลประชนกรทั้งหมดของพื้นที่โดนแยกประเภทตามกลุ่มอายุและเพศ และข้อมูลศักยภาพพื้นฐานในชุมชนในปัจจุบัน และย้อนหลัง เช่น ระดับความเข้มของรังสีอาทิตย์ ความเร็วและทิศทางลม รวมถึงข้อมูลปริมาณและขนาดแหล่งน้ำในพื้นที่ เพื่อนำมาใช้สำหรับการวิเคราะห์เปรียบเทียบต่อความต้องการของชุมชน

เมื่อได้ข้อมูลจากทั้ง 3 แหล่งข้อมูล นำมาจัดการและวิเคราะห์จะได้ชุดข้อมูลทั้งหมด 4 ชุดข้อมูล ได้แก่ 1. ข้อมูลพฤติกรรมที่เกิดขึ้นภายในชุมชนจากกลุ่มตัวอย่างประชากรและประชากร

ที่อาศัยภายในอาคารตัวอย่าง 2. ข้อมูลการใช้พลังงาน น้ำ และการสร้างขยะในเวลาที่เกิดขึ้นจริง (Real-time) 3. ข้อมูลบริบทชุมชนที่แยกตามกลุ่มอายุและเพศ และ 4. ข้อมูลศักยภาพของชุมชน โดยมีรายละเอียดดังนี้

ข้อมูลพฤติกรรมที่เกิดขึ้นภายในชุมชนจากกลุ่มตัวอย่างประชากร ได้จากการวิเคราะห์ปริมาณความถี่และโอกาสของการพฤติกรรมและกิจกรรมที่เกิดขึ้นภายในอาคารขากแต่ละกลุ่มโปรไฟล์ ใช้สำหรับการปรับเทียบกับค่าที่วิเคราะห์ได้จากอาคารตัวอย่าง ให้มีความถูกต้องและแม่นยำมากขึ้น และข้อมูลพฤติกรรมของประชากรที่อาศัยภายในอาคารตัวอย่าง จะใช้สำหรับการสร้างโปรไฟล์กิจกรรมแต่ละกิจกรรมที่เกิดขึ้นภายในอาคาร เพื่อใช้สำหรับการทำนายหรือสร้างโปรไฟล์ผู้ใช้งาน

ข้อมูลการใช้พลังงาน น้ำ และการสร้างขยะในเวลาที่เกิดขึ้นจริงภายในอาคารตัวอย่าง จะใช้สำหรับการระบุปริมาณจากกิจกรรมที่เกิดขึ้นในช่วงเวลาที่มีการทำกิจกรรมของผู้ที่อาศัยอยู่แต่ละคนที่อยู่ภายในแต่ละอาคาร เพื่อสร้างโปรไฟล์ผู้ใช้งานร่วมกับข้อมูลจากแบบสอบถาม

ข้อมูลบริบทชุมชนที่แยกตามกลุ่มอายุและเพศ ใช้สำหรับการวิเคราะห์ปริมาณความต้องการใช้พลังงาน น้ำ และปริมาณการสร้างขยะแต่ละชนิดที่เกิดขึ้นภายในอาคารรวมทั้งหมด เพื่อวิเคราะห์ศักยภาพและค่าใช้จ่ายสำหรับการบริหารจัดการทรัพยากร

ข้อมูลศักยภาพของชุมชน จะเป็นข้อมูลความพร้อมของพื้นที่สำหรับรองรับความต้องการของชุมชนในปัจจุบัน รวมถึงรองรับการขยายตัวของชุมชนในอนาคต ทั้งนี้ข้อมูลศักยภาพของชุมชนจะเป็นตัวระบุระดับความเป็นไปได้ของแหล่งทรัพยากรในพื้นที่ว่ามีความเหมาะสมต่อการพัฒนาชุมชนไปสู่ชุมชนอัจฉริยะหรือไม่

จากข้อมูลข้างต้นจะนำข้อมูลกิจกรรมที่เกิดขึ้นภายในจากกลุ่มประชากรตัวอย่างมั้งหมดมาวิเคราะห์เปรียบเทียบร่วมกับข้อมูลโปรไฟล์กิจกรรมเพื่อระบุปริมาณการใช้พลังงาน น้ำ และการสร้างขยะของแต่ละกิจกรรมเพื่อสร้างและปรับโปรไฟล์ผู้ใช้งานให้มีความถูกต้องและมีความน่าเชื่อถือ และนำข้อมูลกลุ่มประชากรในชุมชนทั้งหมดมาคำนวณความต้องการของชุมชนโดยพิจารณาด้วยโปรไฟล์ผู้ใช้งาน จากนั้นนำข้อมูลศักยภาพของชุมชนทั้ง 3 ด้านมาวิเคราะห์หาความเหมาะสม โดยทั่วไปพลังงานแสงอาทิตย์จะสามารถสร้างพลังงานได้เฉลี่ยเพียงร้อยละ 30 จากประมาณความต้องการตลอดทั้งวัน และหากพื้นที่มีศักยภาพของพลังงานลมจะสามารถสร้างพลังงานเฉลี่ยได้ประมาณร้อยละ 80 หรือมากกว่า ทั่งขึ้นอยู่กับพื้นที่ตั้งของชุมชน โดยการพิจารณาความเหมาะสมของชุมชนนั้นจะคำนวณโดยใช้เงินลงทุนของการติดตั้งระบบผลิตไฟฟ้าจากแสงอาทิตย์ที่ราคาประมาณ 40 บาท/วัตต์ และระบบการผลิตไฟฟ้าจากพลังงานลมเฉลี่ย 90 บาท/วัตต์ โดยขนาดของระบบขึ้นอยู่กับปริมาณความต้องการของชุมชน รวมถึงระบบการผลิตน้ำสะอาด

นั้นโดยจะคำนวณจากปริมาณการใช้น้ำเฉลี่ยต่อวันที่ราคาประมาณ 3.50 บาท/ลิตร และค่าใช้จ่ายสำหรับการบริหารจัดการขยะที่ชุมชนไม่สามารถจัดการเองได้นั้นจะอยู่ที่เฉลี่ยประมาณ 800 – 2,500 บาท/ตัน ขึ้นอยู่กับพื้นที่และระยะทางการขนส่ง

ความเหมาะสมของการพัฒนาชุมชนไปสู่ชุมชนอัจฉริยะเพื่อการจัดการพลังงาน น้ำ และขยะของชุมชน จะพิจารณามูลค่าการลงทุนสำหรับการเตรียมความพร้อมและการบริหารจัดการพลังงาน น้ำ และขยะในพื้นที่ทั้งหมดหารด้วยค่าใช้จ่ายของชุมชนที่สามารถลดได้ หากพิจารณาทั้งสามส่วนพบว่ามีระยะเวลาคืนทุนที่ต่ำ แสดงว่าชุมชนมีความเป็นไปได้ต่อการพัฒนาไปสู่ชุมชนอัจฉริยะ

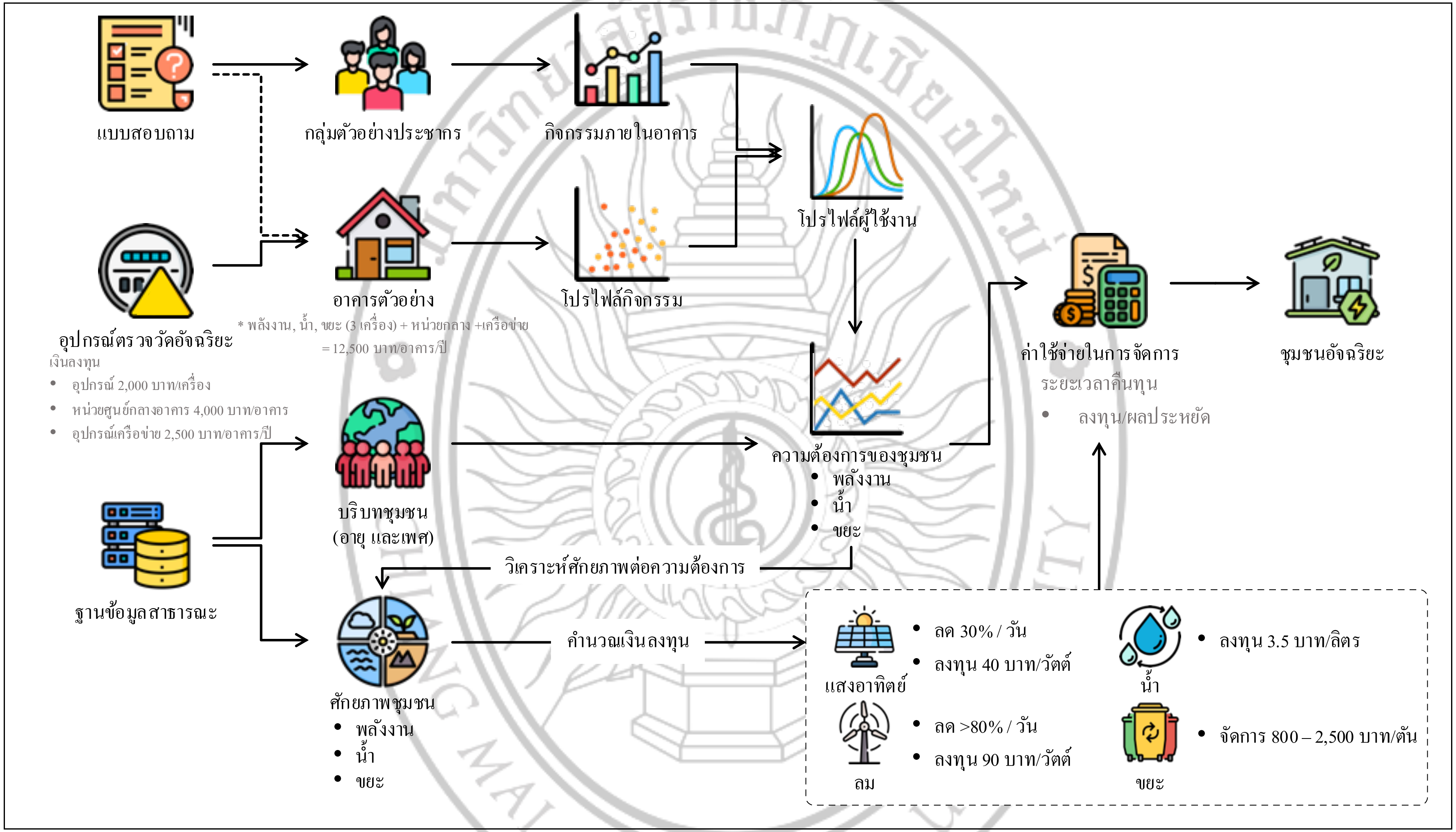


Figure G20 Smart community framework infographic

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