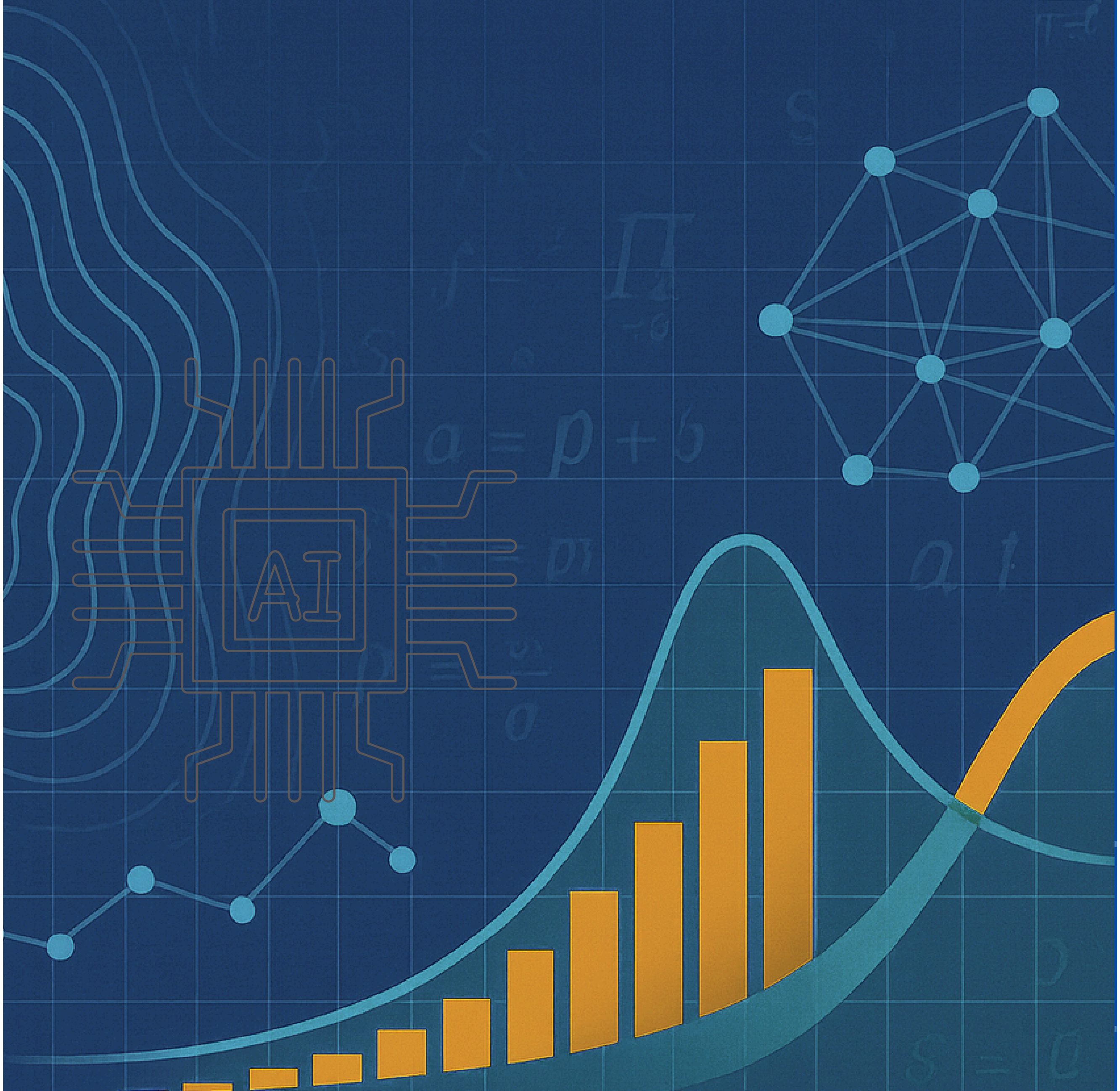
UNIVERSITI TEKNOLOGI MARA

MATHEMATICS AND STATISTICS

UNDERGRADUATE RESEARCH PROCEEDINGS 2025



UiTM CAWANGAN NEGERI SEMBILAN

HOME ENERGY MANAGEMENT FOR HOME APPLIANCES USING KNAPSACK MODEL

Nor Aishah Md Noh, Fatin Nur Liyana Mohd Ridzuan
Faculty of Computer and Mathematical Sciences,
Universiti Teknologi MARA Negeri Sembilan Branch, Seremban Campus, 70300 Seremban, Negeri Sembilan, Malaysia.
*nor_aishah@uitm.edu.my

Abstract

In recent months, increasing electricity bills have led to the need for consumers to manage their energy consumption efficiently. This study used the knapsack model for home energy management for home appliances to solve this problem. The aims are to adapt an optimization approach for daily appliance usage using the knapsack model for home energy management of home appliances and to compare the cost of electricity bills per day before and after using the knapsack model. The model was developed using IBM CPLEX software where the knapsack model will prioritize essential appliances for continuous use while nonessential devices are scheduled based on the cost budget limit. The results indicate that the knapsack model reduced daily electricity costs by RM0.22–RM0.66. This corresponds to monthly savings of RM6.60–RM19.80, representing approximately 4–12% compared to the actual daily costs. In conclusion, the model not only ensures optimal energy consumption but also provides consumers with a sustainable and cost-effective solution for managing household electricity usage.

Keywords: Energy consumption, appliances, knapsack model, IBM CPLEX

Introduction

The knapsack model is a combined optimization method where the goal is to maximize the total value of the items put into the bag without exceeding the weight of the bag [1]. Researchers often use the knapsack model in their studies, especially in solving optimization problems most efficiently. It shows that in home energy management (HEM), the knapsack model can optimize energy consumption (EC) to effectively meet household demand. This is one of the ways of HEM to maximize the EC in the home by using the knapsack model. HEM is the practice of managing EC in the home effectively and efficiently to reduce the cost of EC [2]. The cost of EC needs to be controlled because, in recent months, an increase in the price of electricity bills has been an issue that is getting more attention in the community. Consumers need to understand the factors that lead to this increase, as it helps manage their budget successfully while minimizing the impact on their quality of life.

The management of household EC has become a crucial issue in the modern period, due to the growth of home appliances for daily functions [3]. Efficient EC not only lowers utility expenses but also helps protect the environment by lowering carbon emissions. HEM has some difficulties in terms of assigning weights, since various appliances have different energy consumption levels appliances have different weights. That means managing appliances with varying weights complicates the optimization challenge. Determining the right weights needs detailed information about each appliance's EC, consumption patterns, and significance to the home, which can be difficult to gather perfectly. The knapsack model can help solve EC problems which are often used for optimization and offers a systematic way to divide limited resources for maximum benefit. In HEM, these models help households prioritize EC for different appliances based on immediate needs, consumer preferences, and energy efficiency ratings. However, this knapsack also has its weaknesses. The data used must be in a large amount to ensure that the result made is more accurate [4].

The objective of this study is to adapt an optimization usage of appliances per day using the knapsack model for home energy management of home appliances. Next, to compare the cost of electricity bills per day before and after using the knapsack model. This study focuses on the knapsack model to address HEM for home appliances in urban areas of Malaysia. This study focuses on urban Malaysia, where EC patterns differ from rural areas [5]. Besides, instead of analyzing EC weekly, this study will do it daily to produce a more accurate and detailed representation of consumption patterns which include increases and decreases in energy demands and wants. The daily analysis enables easier optimization and ensures that energy efficiency closely corresponds with the lifestyle of urban residents.

The significance of this study comes from its potential to address critical issues related to energy efficiency, cost savings and sustainability in households. EC accounts for a large portion of household expenses, so it needs to be managed properly so that the price of the electricity bills can be reduced. It is very important to implement an effective HEM strategy to minimize energy waste and maximize energy efficiency. The use of the knapsack model helps consumers reduce their electricity bills by optimizing the scheduling and operation of appliances based on factors such as EC rates and tariff structures. Carbon emissions and environmental degradation are the effects of household EC. Households can reduce their carbon emissions and contribute to environmental sustainability by optimizing EC with the knapsack model.

Literature Review

The knapsack model is a well-known optimization method for dealing with multiple issues. It is widely used in situations where a group of objects with related weights and values must be chosen to maximize the overall value while keeping to a total weight limit [6]. The main purpose of the knapsack model is to determine the maximum amount of profit that can be brought with the maximum capacity of the knapsack. Each appliance has its own weight and profit [7]. This study used the knapsack model because it offers several advantages over other optimization algorithms. The knapsack model helps to achieve optimal consumption of limited resources by selecting appliances that maximize the overall value within the cost budget. Next, the basic idea of the knapsack model is easy to understand. Beginners and experienced users can use it because of its simplicity [8]. By integrating the knapsack model into home energy management (HEM), energy consumption (EC) can be optimized without exceeding the cost budget.

Besides the knapsack model, other optimization methods such as the greedy algorithm and brute force algorithm have also been used in problem solving. The greedy algorithm makes decisions step by step by choosing what looks most profitable at that moment. This method is simple and fast. However, it only provides locally optimal solutions and does not always guarantee the best overall outcome, which limits its suitability for energy management problems [4-9]. The brute force algorithm, on the other hand, tries all possible solutions systematically to find the best result. Although it ensures accuracy, it is highly resource-demanding and inefficient for large datasets. It is because it relies heavily on computing power [4]. The knapsack model offers a more balanced approach compared to these methods. It requires less computation than brute force and produces better-quality solutions than the greedy algorithm. These strengths make the knapsack model both practical and effective for scheduling household appliances within a limited cost budget.

HEM is the process of planning, managing, and controlling the EC in a house efficiently and effectively. It involves the use of methods that aim to reduce energy waste, increase awareness of EC, and reduce the negative impact on the environment. The purpose of HEM is to schedule household appliances to reduce electricity bills [10]. Electricity bills have increased because the increased mobility contributes to higher EC, with people using more electrical devices in different places [11]. Consumers can use renewable energy at home to reduce electricity bills. However, it is difficult to install it, especially for the B40 group [12], but it is not an obstacle for consumers to reduce the cost of their electricity bills. Consumers can use various other methods to reduce their electricity bills such as unplugging devices and turning off the standby mode. Consumers can also set EC prioritize and limits for each appliance based on factors such as immediate needs, consumer preferences, and energy costs.

Methodology

Data Collection Method

Primary data was obtained through a questionnaire conducted using Google Forms. The questionnaire was used as a survey instrument to obtain the socioeconomic profile of households and the type of electrical appliance consumption. This study will use a convenience sampling technique where the selected respondents are from 18 years old to 50 years old and live in urban areas. This sampling technique can minimize selection bias and be representative of the population [13]. The sample of 30 respondents used for this study is all Malaysians in all states who live in urban areas. This study collects 30 respondents as a sample due to cost limitations and the time required to collect data from a larger population. The sample was considered sufficient to obtain an initial view of household energy usage within the scope and resources available for this study. Table 1 shows the data about the percentage of respondents who have those appliances out of 30 respondents and the average duration of usage per day.

Table 1: Summary of the respondents' appliances used with average usage time from the survey

Appliances Parameter (i)	Description of Appliances	Appliances' User (% out of 30 respondents)	Average Usage Time (hours per day)
1	Refrigerator	100	24
2	Fan	100	24
3	Lamp	100	12
4	Charger Device	100	3

Continue to the next page

Continue from the previous page			
5	Washing Machine	100	2
6	Iron	100	1
7	Rice Cooker	86.67	1
8	Television	83.33	5
9	Freezer	66.67	24
10	Air Fryer	56.67	1
11	Vacuum	53.33	1
12	Water Purifier	50	24
13	Wi-Fi	50	24
14	Pressure Cooker	50	1
15	Air Conditioning	43.33	8
16	Microwave	23.33	1

For secondary data, the data were obtained from previous studies and used the power rating information. The data used is obtained from the journal [8-14] and Tenaga Nasional Berhad (TNB). Table 2 shows data about the power rating for each appliance, the duration of usage for each appliance, and a list of all appliances to be used. The duration of usage is taken from the average time the respondents use the appliances daily. The cost of appliances is calculated using (1) and the cost for each time slot is RM0.198.

$$C_i = \sum_{i=1}^{n} P_i \, x_i \, C_S \tag{1}$$

where,

C_i	=	Cost of appliances i (RM/hour)
i	=	Appliance
n	=	The total number of appliances
P_i	=	The power rating of the appliances i (kilowatts)
x_i	=	The duration of usage for the appliances i per day (hours)
C_S	=	The cost for each time slot (RM/kWh)

Table 2: Initial parameter for knapsack appliances

Appliances Parameter (i)	**Description of Appliances**	**Power Rating (kilowatts)**	**Duration of Usage (hours per day)**	**Cost of Appliances, C_i (RM per hour)**
1	Refrigerator	0.400	24	0.0792
2	Fan	0.054	24	0.0107
3	Lamp	0.030	12	0.0059
				Continue to the next page

Continue from the previous page				
4	Charger Device	0.005	3	0.0010
5	Washing Machine	0.425	2	0.0842
6	Iron	1.000	1	0.1980
7	Rice Cooker	0.300	1	0.0594
8	Television	0.100	5	0.0198
9	Freezer	0.140	24	0.0277
10	Air Fryer	1.400	1	0.2772
11	Vacuum	0.600	1	0.1188
12	Water Purifier	0.300	24	0.0594
13	Wi-Fi	0.006	24	0.0012
14	Pressure Cooker	1.000	1	0.1980
15	Air Conditioning	0.750	8	0.1485
16	Microwave	0.700	1	0.1386

Implementation of the Knapsack Model

The knapsack problem is an optimization model used to determine the best appliance combination based on weight and value. The objective is to maximize the total value while ensuring the total weight does not exceed the capacity limit. The objective can be formulated as (2). By applying the knapsack model, this study optimizes home energy management by prioritizing appliances that provide the most benefit within the given energy constraints.

$$\text{Maximize } E = \sum_{i=1}^{n} v_i \, x_i \tag{2}$$

$$\text{Subject to } = \sum_{i=1}^{n} w_i \, x_i \leq W$$

where,

E	=	Total energy consumption per day
i	=	Appliance
n	=	Total number of appliances
v_i	=	Energy consumption of appliances i for each hour
x_i	=	Duration of usage for the appliances i per day
w_i	=	Cost of appliances i for each hour
W	=	Cost budget per day

Everyone has different home appliances based on their needs, lifestyle, and financial capabilities. These differences cause different energy consumption (EC) for each home. Therefore, this study took three respondents as a case to represent the variation in the use of home appliances. These respondents were selected based on specific criteria, such as their energy usage patterns and appliance ownership to provide useful information about the impact of the knapsack model on home energy management (HEM). The goal of these cases is to analyze the variety of possibilities regarding the duration of usage of the appliances per day, as well as the uses for those cases that are subject to constraints. Table 3 shows the list of available appliances based on respondents' feedback. This sample selection allows for a deeper analysis of how each consumer makes decisions in managing home appliances. In the context of the knapsack problem, each consumer needs to make the best choice to use certain appliances based on the available cost budget and their daily needs. This involves considering basic needs and the desire to use more advanced appliances that use more energy.

Table 3: List of available appliances based on three different cases

Appliances Parameter (i)	Description of Appliances	Case 1	Case 2	Case 3
1	Refrigerator	✓	✓	✓
2	Fan	✓	✓	✓
3	Lamp	✓	✓	✓
4	Charger Device	✓	✓	✓
5	Washing Machine	✓	✓	✓
6	Iron	✓	✓	✓
7	Rice Cooker	✓	✓	✓
8	Television	✓	✓	✓
9	Freezer	✓	✓	✓
10	Air Fryer	✓	✓	✓
11	Vacuum		✓	✓
12	Water Purifier	✓		
13	Wi-Fi		✓	✓
14	Pressure Cooker	✓	✓	✓
15	Air Conditioning		✓	✓
16	Microwave			

In this study, CPLEX was used to maximize the EC of the selected appliances without exceeding the cost budget. CPLEX was used in this study because it can quickly and efficiently suggest the duration of usage for the appliances with minimal user involvement [15]. Below is the implementation and the constraints listed for each variable for three different cases with a cost budget, is RM4.75 and RM5.00. RM4.75 per day because based on [8], each operation hour is set as 1kWh. For one day, it is equal to 24kWh equivalent to RM4.75. RM5.00 per day because this study rounded the budget cost of RM4.75 to the nearest Ringgit Malaysia (RM). After inserting the constraints into the CPLEX and running the coding process, the software will suggest the optimal duration of usage of each appliance per day that can be used without exceeding the cost budget. The results from these two cost budgets will be compared to see the difference in the suggested usage time. This equation is based on (2).

$$\begin{aligned}\text{Maximize} = {} & 0.400x_1 + 0.054x_2 + 0.030x_3 + 0.005x_4 + 0.425x_5 + 1.000x_6 + \\ & 0.300x_7 + 0.100x_8 0.140x_9 + 1.400x_{10} + 0.600x_{11} + 0.300x_{12} + \\ & 0.006x_{13} + 1.000x_{14} + 0.750x_{15} + 0.700x_{16}\end{aligned}$$

Subject to:

$$\begin{aligned}& 0.0792x_1 + 0.0107x_2 + 0.0059x_3 + 0.0010x_4 + \\ & 0.0842x_5 + 0.1980x_6 + 0.0594x_7 + 0.0198x_8 + \\ & 0.0277x_9 + 0.2772x_{10} + 0.1188x_{11} + 0.0594x_{12} + \\ & 0.0012x_{13} + 0.1980x_{14} + 0.1485x_{15} + 0.1386x_{16} \le W\end{aligned} \quad ; \quad \text{Cost of appliances for each hour}$$

Table 4 is the list of constraints based on the available appliances for three different cases. Compulsory appliances needed means everyone has the appliances. All three cases use the same constraints. However, there are different constraints for some appliances because of the availability of the appliances. If the consumers did not have the appliances, it would equal to 0. Range of the duration of usage for the appliances based on the average respondents use the appliances from the questionnaire.

Table 4: List of constraints based on the available appliances for three different cases

	Compulsory appliances needed	**Appliances to use when necessary**	**Do not have the appliances**
Case 1	$x_1, x_9, x_{12} = 24$ $8 \le x_2 \le 24$ $5 \le x_3 \le 24$ $1 \le x_4, x_8 \le 4$	$0 \le x_{10}, x_{14} \le 2$	$x_{11}, x_{13}, x_{15}, x_{16} = 0$
Case 2		$0 \le x_{10}, x_{14} \le 2$	$x_{12}, x_{16} = 0$
Case 3		$1 \le x_5, x_6, x_7, x_{11} \le 2$	$x_{10}, x_{13}, x_{14}, x_{15}, x_{16} = 0$

Performance Evaluation

This study will compare before and after using the knapsack model for the total cost consumed by the appliances per day. Real-time monitoring is used to produce comprehensive assessments. The total cost consumed by the appliances per day can be calculated by (3). The cost for each time slot, C_i is RM 0.198 after adjusting the tariff rate and Imbalance Cost Pass-Through (ICPT) rebate.

$$C_T = \sum_{i=1}^{n} P_i \, x_i \, y_i \, C_i \tag{3}$$

where,

C_T	=	Total cost consumed by the appliances per day
i	=	Appliance
n	=	The total number of appliances
P_i	=	The power rating of the appliances i (kilowatts)
x_i	=	The duration of usage for the appliances i per day (hours)
y_i	=	The decision variable for appliance i (1 if selected, 0 otherwise)
C_i	=	The cost for each time slot (RM/kWh)

Total cost for case 1,

$$\begin{aligned} C_T = {} & P_1x_1y_1C_1 + P_2x_2y_2C_2 + P_3x_3y_3C_3 + P_4x_4y_4C_4 + P_5x_5y_5C_5 + P_6x_6y_6C_6 + \\ & P_7x_7y_7C_7 + P_8x_8y_8C_8 + P_9x_9y_9C_9 + P_{10}x_{10}y_{10}C_{10} + P_{11}x_{11}y_{11}C_{11} + \\ & P_{12}x_{12}y_{12}C_{12} + P_{13}x_{13}y_{13}C_{13} + P_{14}x_{14}y_{14}C_{14} + P_{15}x_{15}y_{15}C_{15} + P_{16}x_{16}y_{16}C_{16} \end{aligned}$$

$$\begin{aligned} = {} & 0.400(24)(1)(0.198) + 0.054(24)(1)(0.198) + 0.030(12)(1)(0.198) + \\ & 0.005(3)(1)(0.198) + 0.425(2)(1)(0.198) + (1.000)(1)(1)(0.198) + \\ & 0.300(1)(1)(0.198) + 0.100(5)(1)(0.198) + 0.140(24)(1)(0.198) + \\ & 1.400(1)(1)(0.198) + 0.600(1)(1)(0.198) + 0.300(24)(0)(0.198) + \\ & 0.006(24)(1)(0.198) + 1.000(1)(1)(0.198) + 0.750(8)(1)(0.198) + \\ & 0.700(1)(0)(0.198) \end{aligned}$$

$$= \text{RM } 5.32$$

Total cost for case 2,

$$\begin{aligned} C_T = {} & P_1x_1y_1C_1 + P_2x_2y_2C_2 + P_3x_3y_3C_3 + P_4x_4y_4C_4 + P_5x_5y_5C_5 + P_6x_6y_6C_6 + \\ & P_7x_7y_7C_7 + P_8x_8y_8C_8 + P_9x_9y_9C_9 + P_{10}x_{10}y_{10}C_{10} + P_{11}x_{11}y_{11}C_{11} + \\ & P_{12}x_{12}y_{12}C_{12} + P_{13}x_{13}y_{13}C_{13} + P_{14}x_{14}y_{14}C_{14} + P_{15}x_{15}y_{15}C_{15} + P_{16}x_{16}y_{16}C_{16} \end{aligned}$$

$$
\begin{aligned}
&= 0.400(24)(1)(0.198) + 0.054(24)(1)(0.198) + 0.030(12)(1)(0.198) + \\
&\quad 0.005(3)(1)(0.198) + 0.425(2)(1)(0.198) + (1.000)(1)(1)(0.198) + \\
&\quad 0.300(1)(1)(0.198) + 0.100(5)(1)(0.198) + 0.140(24)(1)(0.198) + \\
&\quad 1.400(1)(1)(0.198) + 0.600(1)(1)(0.198) + 0.300(24)(0)(0.198) + \\
&\quad 0.006(24)(1)(0.198) + 1.000(1)(1)(0.198) + 0.750(8)(1)(0.198) + \\
&\quad 0.700(1)(0)(0.198)
\end{aligned}
$$

$$= \text{RM } 5.23$$

Total cost for case 3,

$$
\begin{aligned}
C_T &= P_1x_1y_1C_1 + P_2x_2y_2C_2 + P_3x_3y_3C_3 + P_4x_4y_4C_4 + P_5x_5y_5C_5 + P_6x_6y_6C_6 + \\
&\quad P_7x_7y_7C_7 + P_8x_8y_8C_8 + P_9x_9y_9C_9 + P_{10}x_{10}y_{10}C_{10} + P_{11}x_{11}y_{11}C_{11} + \\
&\quad P_{12}x_{12}y_{12}C_{12} + P_{13}x_{13}y_{13}C_{13} + P_{14}x_{14}y_{14}C_{14} + P_{15}x_{15}y_{15}C_{15} + P_{16}x_{16}y_{16}C_{16} \\
&= 0.400(24)(1)(0.198) + 0.054(24)(1)(0.198) + 0.030(12)(1)(0.198) + \\
&\quad 0.005(3)(1)(0.198) + 0.425(2)(1)(0.198) + (1.000)(1)(1)(0.198) + \\
&\quad 0.300(1)(1)(0.198) + 0.100(5)(1)(0.198) + 0.140(24)(1)(0.198) + \\
&\quad 1.400(1)(0)(0.198) + 0.600(1)(1)(0.198) + 0.300(24)(1)(0.198) + \\
&\quad 0.006(24)(1)(0.198) + 1.000(1)(0)(0.198) + 0.750(8)(0)(0.198) + \\
&\quad 0.700(1)(1)(0.198)
\end{aligned}
$$

$$= \text{RM } 5.13$$

Results and Discussions

The results of this study provide an analysis of the duration of usage for each appliance using the knapsack model. By using energy consumption (EC) as the value of the appliances and the cost of appliances as the weight, this study gets the optimal solution for the duration of usage for each appliance without exceeding the cost budget which is RM4.75 and RM5.00. The objective is to choose the combination of appliances that stay within the set budget while maximizing EC. For all cases, the optimal duration of usage of appliances that can stay within the cost budget is shown in Table 5. It shows the comparison between the actual total cost of electricity per day and the suggested total cost of electricity per day after using the knapsack model.

Table 5: Summary of the results from CPLEX for the cost budget

		Cost Budget (RM)			
		4.75		5.00	
	Actual Cost	Suggested Cost	Saving Cost	Suggested Cost	Saving Cost
Case 1	5.32	4.66	0.66	4.91	0.41
Case 2	5.23	4.66	0.57	4.91	0.32
Case 3	5.13	4.66	0.47	4.91	0.22

For all cases, the suggested total cost per day is RM4.66, which is less than the cost budget of RM4.75 while RM4.91 for the cost budget of RM5.00 per day. The cost savings range is from RM0.22 to RM0.66 per day and RM6.60 to RM19.80 per month. It shows that this model can help control the monthly electricity bills by ensuring daily EC is within a set budget range. This model also maximizes energy efficiency by prioritizing appliances, such as lights and fans, over less efficient appliances such as air fryers. This not only saves costs but also increases consumer awareness of responsible EC. This can make consumers more enjoyable with a sustainable and budget-friendly lifestyle. The results of CPLEX for each case are shown in Table 6. From the table, it shows that the knapsack model successfully identifies the most energy-efficient appliances within the cost constraints. An important insight is the adaptability of the model to different cost constraints. When the budget increases, the model includes more high EC appliances such as fan and lamp. On the other hand, selecting cheaper and energy-efficient appliances is preferred by those with smaller budgets. This flexibility shows how the knapsack model can be used to address a variety of home energy management (HEM) needs.

Table 6: Summary of the results from CPLEX for the duration of usage for the appliances per day

		Cost Budget (RM)					
		4.75			5.00		
		Duration of Usage for the Appliances per Day (hours)					
Appliances Parameter (i)	**Description of Appliances**	**Case 1**	**Case 2**	**Case 3**	**Case 1**	**Case 2**	**Case 3**
1	Refrigerator	24	24	24	24	24	24
2	Fan	22	10	10	23	22	22
3	Lamp	5	5	5	16	21	5
4	Charger Device	3	4	4	1	3	2
5	Washing Machine	1	1	1	1	1	2
6	Iron	1	1	1	1	1	1
7	Rice Cooker	1	2	1	1	1	1
8	Television	3	1	2	2	1	4
9	Freezer	24	24	24	24	24	24
10	Air Fryer	0	0	0	0	0	0
11	Vacuum	0	1	1	0	1	1
12	Water Purifier	24	0	24	24	0	24
13	Wi-Fi	0	24	24	0	24	24
14	Pressure Cooker	0	1	0	0	0	0
15	Air Conditioning	0	8	0	0	8	0
16	Microwave	0	0	0	0	0	0

Conclusion and Recommendations

The knapsack model helps to get efficient energy resource allocation based on consumer preferences and the energy efficiency of appliances. The first objective of this study was to adapt an optimization usage of appliances per day using the knapsack model for home energy management (HEM) of home appliances. The focus of home appliances is to optimize energy efficiency and balance the household energy load. Some appliances such as refrigerator, water purifier, freezer and wi-fi must be used continuously which is 24 hours and always prioritized while other appliances are scheduled based on the capacity limit which is the cost budget of RM4.75 and RM5.00. Appliances such as air fryer, pressure cooker and microwave will be selected if the total cost consumed by appliances does not exceed the cost budget.

The second objective is to compare the cost of electricity bills per day before and after using the knapsack model. The findings show that strategically scheduling appliance usage with the model enhances energy efficiency, potentially reducing electricity costs. This analysis shows the significance of optimization in household energy management and emphasizes the benefits of efficient appliance scheduling. Overall, the results support the knapsack model as a valuable tool for reducing electricity costs while ensuring essential energy needs are met.

The knapsack model is one of the effective models to solve problems related to optimization. Future studies can include more appliances with varying energy demands to improve the knapsack model's performance. This addition will allow for more accurate and efficient management overall energy consumption (EC). Besides, renewable energy such as solar panels may be considered in the optimization process. The knapsack model may produce specific energy management solutions that encourage increased efficiency and support sustainable energy practices by adjusting to both conventional and renewable energy systems, especially in different weather conditions

Acknowledgments

The author would like to express their heartfelt appreciation to everyone who contributed to this study, with special attention to the family, supervisor, all the respondents, and friends for their dedication, efforts, invaluable guidance and support throughout this journey.

References

[1]Shivanaganna, N., & Murali, V. (2022). Energy routing based optimal solution for residential peak power reduction with photovoltaic and electric vehicle penetration. Energy Sources. Part A, Recovery, Utilization, and Environmental Effects, 44(3), 5682–5698. https://doi.org/10.1080/15567036.2022.2085824

[2]Qayyum, N., Amin, A., Jamil, U., & Mahmood, A. (2019). Optimization Techniques for Home Energy Management: A Review. 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET). https://doi.org/10.1109/icomet.2019.8673435

[3]Hischier, R., Reale, F., Castellani, V., & Sala, S. (2020). Environmental impacts of household appliances in Europe and scenarios for their impact reduction. Journal of Cleaner Production, 267, 1-12. https://doi.org/10.1016/j.jclepro.2020.121952

[4] Balogun, O. A., Dosunmu, M. A., & I.O Ibidapo. (2022). An Explanatory Comparison of Brute Force and Dynamic Programming Techniques to Solve the 0-1 Knapsack Problem. Zenodo (CERN European Organization for Nuclear Research), 7(2), 660-664. https://doi.org/10.5281/zenodo.6345484.

[5]Wong, J. C. Y., Blankenship, B., Urpelainen, J., Balani, K., Ganesan, K., & Bharadwaj, K. (2022). Understanding electricity billing preferences in rural and urban India: Evidence from a conjoint experiment. Energy Economics, 106, 1-12. https://doi.org/10.1016/j.eneco.2021.105735

[6]Kumabe , S., & Yoshida, Y. (2022). Average Sensitivity of the Knapsack Problem. 244(14), 1–75. https://doi.org/10.4230/LIPIcs.ESA.2022.75

[7] Boes, D. F., Dewanto, K. P., Raushanfikir, M. I., Handoyo, A. T., & Nurhasanah, N. (2023). Analyzing The Most Effective Algorithm For Knapsack Problems. 172-176. https://doi.org/10.1109/icon-sonics59898.2023.10434966

[8] Anzar, M., Iqra, R., Kousar, A., Ejaz, S., Alvarez-Alvarado, M. S., & Zafar, A. K. (2017). Optimization of Home Energy Management System in Smart Grid for Effective Demand Side Management. https://doi.org/10.1109/irsec.2017.8477255

[9]Chen, X. (2022). A Comparison of Greedy Algorithm and Dynamic Programming Algorithm. SHS Web of Conferences, 144, 1-5. https://doi.org/10.1051/shsconf/202214403009

[10]Malik, S. A., & Ayop, A. R. (2020). Solar energy technology: Knowledge, awareness, and acceptance of B40 households in one district of Malaysia towards government initiatives. Technology in Society, 63, 1-7. https://doi.org/10.1016/j.techsoc.2020.101416

[11]Siebra, C., Costa, P., Da Silva, F. Q., Santos, A. L., & Mascaro, A. (2013). The hardware and software aspects of energy consumption in the mobile development platform. International Journal of Pervasive Computing and Communications, 9(2), 139–162. https://doi.org/10.1108/ijpcc-04-2013-0007

[12]Shewale, A., Mokhade, A., Lipare, A., & Bokde, N. D. (2023). Efficient Techniques for Residential Appliances Scheduling in Smart Homes for Energy Management Using Multiple Knapsack Problem. Arabian Journal for Science and Engineering, 49(3), 3793–3813. https://doi.org/10.1007/s13369-023-08178-w

[13]Iliyasu, R., & Etikan, I. (2021). Comparison of Quota Sampling and Stratified Random Sampling. Biometrics & Biostatistics International Journal, 10(1), 24–27. https://doi.org/10.15406/bbij.2021.10.00326

[14] Ali, S. S. S., Razman, M. R., & Awang, A. (2020). The Estimation and Relationship of Domestic Electricity Consumption and Appliances Ownership in Malaysia Intermediate City. International Journal of Energy Economics and Policy, 10(6), 116–122. https://doi.org/10.32479/ijeep.8358

[15]Lu, Y., & Vasko, F. J. (2019). A comprehensive empirical demonstration of the impact of choice constraints on solving generalizations of the 0–1 knapsack problem using the integer programming option of CPLEX®. Engineering Optimization, 52(9), 1632–1644. https://doi.org/10.1080/0305215x.2019.1658748