E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23 January 2025
PTDI, UiTM Cawangan Johor Kampus Pasir Gudang

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Electrical Engineering Studies, College of Engineering
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Editors

Aznilinda Zainuddin

Maisarah Noorezam

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PREFACE

It is with great pleasure that we present the e-proceedings of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), which compiles the extended abstracts submitted to the International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), held on 23 January 2025 at **PTDI, Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.** This publication serves as a valuable resource, showcasing the intellectual contributions on the invention and innovation among students, academics, researchers, and professionals.

The International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), organized under the theme "Fostering a Culture of Innovation and Entrepreneurial Excellence," is designed to inspire participants at various academic levels, from secondary students to higher education students and professionals. The competition emphasizes both innovation and entrepreneurship, encouraging the development of product prototypes that address real-world problems and have clear commercialization potential. By focusing on technological and social innovations, i-TIEC 2025 highlights the importance of turning creative ideas into viable, market-ready solutions that can benefit users and society. The extended abstracts in this e-proceedings book showcase the diverse perspectives and depth of research presented during the event, reflecting the strong entrepreneurial element at its core.

We extend our sincere gratitude to the contributors for their dedication in sharing their innovation and the organizing committee for their hard work in ensuring the success of the event and this publication. We also appreciate the support of our collaborators; Mass Rapid Transit Corporation Sdn. Bhd. (MRT Corp), Universitas Labuhanbatu, Indonesia (ULB), Universitas Riau Kepulauan, Indonesia (UNRIKA) and IEEE Young Professionals Malaysia, whose contributions have been instrumental in making this event and publication possible.

We hope that this e-proceedings book will serve as a valuable reference for researchers, educators, and practitioners, inspiring further studies and collaborations in both innovation and entrepreneurship. May the knowledge shared here continue to spark new ideas and market-ready solutions, advancing our collective expertise and fostering the growth of entrepreneurial ventures.

B-ST010 - B-ST152

B-ST010: INDEPENDENT VARIABLES COMBINATION SELECTION USING BEST SUBSET SELECTION METHOD IN A MULTIPLE LINEAR REGRESSION BASELINE ENERGY MODEL FOR EDUCATIONAL BUILDING'S ENERGY CONSUMPTION PREDICTION

Rijalul Fahmi Mustapa, Atiqah Hamizah Mohd Nordin, Muhammad Ashraf Hairuddin, and Mohd Ezwan Mahadan
Electrical Engineering Studies, College of Engineering, Universiti Teknologi MARA, Johor Branch, Pasir Gudang Campus, Masai, Malaysia

Corresponding author: rijalulfahmi@uitm.edu.my

ABSTRACT
A baseline energy model (BEM) establishes a relationship between energy consumption and its governing independent variables, serving as a foundation for predicting energy usage. Typically, baseline energy models often rely on multiple linear regression due to its simplicity and effectiveness in estimating energy consumption based on selected variables. However, traditional baseline models may suffer from reduced performance when too many independent variables are included, as not all variables have a strong impact on energy consumption. This can lead to overfitting and decreased predictive accuracy. To address this issue, this project introduces an enhanced baseline energy model that integrates the best subset selection method. This approach identifies the most impactful independent variables, ensuring a more accurate and efficient model for energy consumption prediction. The enhanced model demonstrates superior performance, with a mean squared error (MSE) of 255.00 kWh compared to 255.34 kWh to the traditional model. This improvement highlights the model's ability to choose relevant variables, delivering better prediction accuracy. The model offers significant advantages, including improved energy-saving planning and operational optimization. With strong commercialization potential, it can be applied to buildings with similar characteristics, fostering sustainable energy management and contributing to socio-economic and environmental benefits.

Keywords: Baseline, Prediction, Model, Regression, Accuracy

1. Product Description
A baseline energy model (BEM) correlates energy consumption with relevant independent variables, such as occupancy and temperature. It enables building owners to predict energy usage and quantify savings from energy efficiency measures. Multiple Linear Regression (MLR) is widely used in baseline energy modeling due to its simplicity and ability to incorporate multiple variables. However, not all variables significantly impact energy consumption, and including irrelevant ones can reduce model accuracy. Available studies just consider all combinations of variables without systematically identifying the best subset, leading to low accuracy of prediction. This work introduces an innovative approach by applying the best subset selection method to identify the optimal combination of independent variables for the MLR model in an educational building. This method

systematically evaluates variable combinations to select those with the strongest relationship to energy consumption, ensuring a more reliable and efficient model. By focusing only on impactful variables, the MLR model achieves improved prediction accuracy compared to previous methods. The refined BEM provides a practical approach for modelling educational building's BEM, offering better energy consumption predictions. This improvement supports building owners in managing energy usage more effectively and accurately quantifying savings from energy efficiency initiatives.

2. Figures

2.1 Innovation Block Diagram

Figure 1 illustrates a BEM developed using a multiple linear regression model. This model will be named as traditional BEM. The case studies that will be used is an one block of an educational building that is the Electrical Engineering Studies Building in UiTM Johor Branch, Pasir Gudang campus. The inputs of the model are Staff Occupancies, Students in Classrooms, Students in Laboratories, Temperature, Lecturers in Classrooms, and Lecturers in Laboratories. The output is the predicted energy consumption. The independent variables were selected based on the assumption that they significantly impact energy consumption. Once the BEM is developed, it will be used to predict the building's energy consumption.

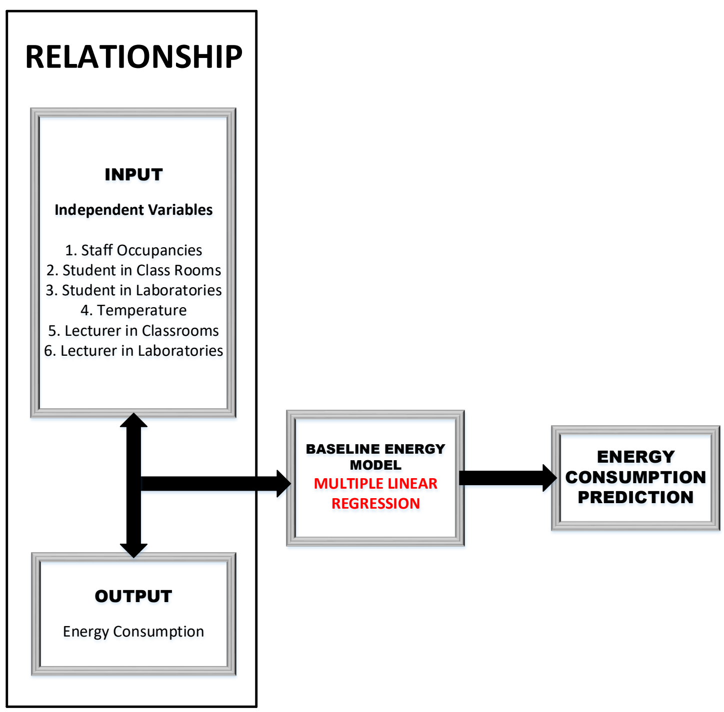

Figure 1. Traditional Baseline Energy Model Using a Multiple Linear Regression Model.

Figure 2, meanwhile, illustrates the innovation introduced in the development of a BEM using a multiple linear regression model with the incorporation of Best Subset Selection metho. This model will be named as enhanced model to depict that Best Subset Selection method were used for independent variables selection purposes. The inputs—Staff Occupancies, Students in Classrooms, Students in Laboratories, Temperature, Lecturers in Classrooms, and Lecturers in Laboratories—are fed into the Best Subset Selection method. This method selects and combines the most impactful independent variables that significantly influence energy consumption. The selected combination of variables is evaluated using the coefficient of determination (R^2) and adjusted R^2. Once the process identifies the best combination of variables, BEM will be developed in order to have accurate energy consumption predictions.

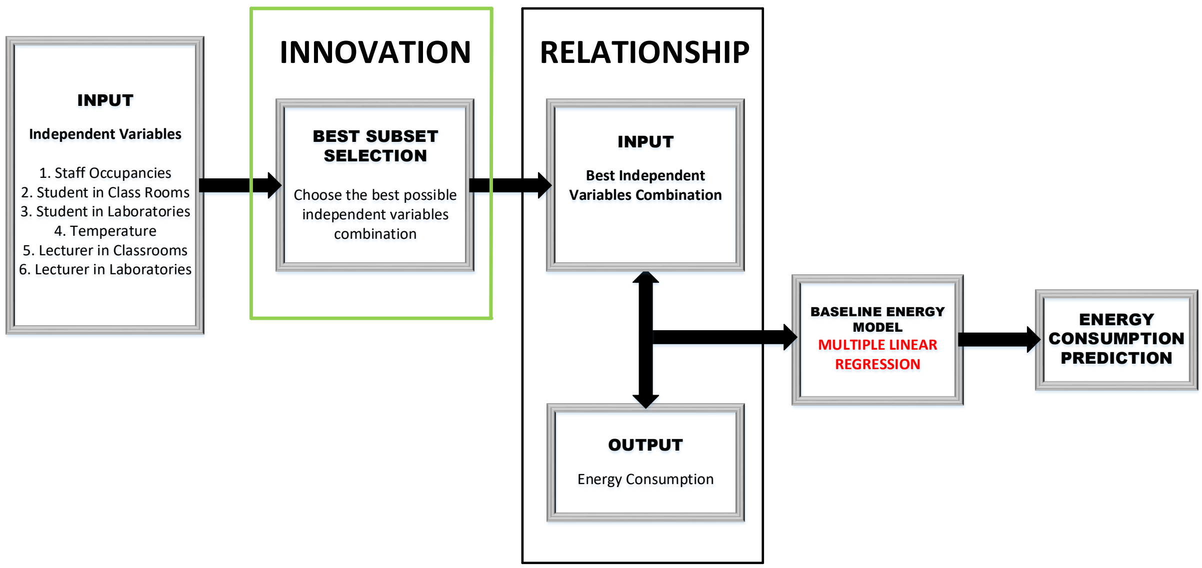

Figure 2. Enhanced Baseline Energy Model Using Multiple Linear Regression Model with Best Subset Selection Method

2.1 Innovation Results

The results demonstrate that the Enhanced Baseline Energy Model (BEM), which incorporates the Best Subset Selection method, outperforms the Traditional BEM in terms of prediction accuracy. By selecting only the most impactful independent variables that is Staff Occupancies, Students in Classrooms, and Temperature. The Enhanced BEM achieves a reduction in both Mean Squared Error (MSE) and Root Mean Square Error (RMSE). Specifically, the MSE decreases from 259.45 kWh to 255.00 kWh, and the RMSE decreases slightly from 16.10 kWh to 15.97 kWh. This improvement indicates that the Enhanced BEM provides more precise energy consumption predictions while maintaining the same R^2 value of 0.842 as the Traditional BEM. Additionally, the Mean Absolute Percentage Error (MAPE) improves from 41.12% to 40.83%, reflecting a lower percentage of error.

Table 1. Prediction Results from Traditional Baseline Energy Model and Enhanced Baseline Energy Model

Metric	*Traditional BEM*	*Enhanced BEM*
Mean Squared Error (MSE)	259.45 kWh	255.00 kWh
Root Mean Squared Error (RMSE)	16.10 kWh	15.9689 kWh
R-squared (R^2)	0.842	0.842
Mean Absolute Percentage Error (MAPE)	41.12%	40.83 %

3. Novelty and uniqueness

The Enhanced BEM introduces a novel approach by incorporating the Best Subset Selection method, which sets it apart from the Traditional BEM. The Traditional BEM uses all available variables indiscriminately, assuming equal significance, while the Enhanced BEM uniquely identifies and selects only the most impactful predictors. This not only reduces redundancy but also optimizes the model's performance. The uniqueness lies in systematically evaluating variable combinations to find the best subset, ensuring improved model accuracy and efficiency. The results highlight this innovation, with the Enhanced BEM achieving a lower MSE (255.00 kWh), RMSE (15.97 kWh), and MAPE (40.83%) compared to the Traditional BEM (MSE = 259.45 kWh, RMSE = 16.10 kWh, MAPE = 41.12%), while maintaining the same R^2 (0.842). Despite the modest error improvements, the novelty of the Enhanced BEM lies in its ability to systematically eliminate irrelevant variables, avoiding overfitting and improving reliability. This unique integration of the Best Subset Selection method results in a more efficient and optimized baseline energy model, making it a more robust tool for energy consumption prediction and management in educational buildings.

4. Benefit to mankind

The benefit of the Enhanced Baseline Energy Model (BEM) to mankind lies in its ability to optimize energy management, leading to significant economic, environmental, and societal advantages. By incorporating the Best Subset Selection method, the Enhanced BEM improves the accuracy of energy consumption predictions by focusing only on the most impactful variables. This allows building owners, particularly in educational institutions, to better understand and control their energy usage, resulting in reduced energy waste and cost savings. Lower energy consumption directly translates into reduced greenhouse gas emissions, supporting global efforts to combat climate change and promoting environmental sustainability.

5. Innovation and Entrepreneurial Impact

From an innovation and entrepreneurial perspective, this approach drives smarter energy management solutions, enabling the development of resource-efficient buildings and cities. By serving as a replicable model, the Enhanced BEM opens opportunities for businesses and entrepreneurs to create energy-efficient tools and services that minimize operational costs while reducing environmental impact. The optimized BEM empowers decision-makers to implement data-driven strategies, fostering innovation in energy technologies, predictive analytics, and sustainable solutions. This innovation not only addresses the growing demand for energy efficiency but also paves the way for entrepreneurial ventures to capitalize on emerging markets, contributing to economic growth while supporting global sustainability goals.

6. Potential commercialization

As for commercialization potential, The Enhanced Baseline Energy Model (BEM) can be developed into a user-friendly software or platform for energy management in buildings. It can help building owners, educational institutions, and facility managers predict energy consumption accurately and identify areas for energy savings. Businesses can license or sell this tool to organizations looking to reduce operational costs and improve energy efficiency. Additionally, the model can be offered as a service (Energy Audit Solutions) where professionals analyze and optimize energy usage for clients. Its scalability allows it to be applied across various sectors, such as offices, factories, and commercial buildings, making it a valuable product for promoting energy-efficient practices.

7. Acknowledgment

The authors would like to express their sincere gratitude to everyone who contributed to the success of this work. The authors also appreciate the collaboration and insightful feedback provided by colleagues and team members. Further acknowledgment goes to the technical staff and participants who assisted in installing data loggers at the main switch room of the educational buildings.

8. Authors' Biography

Rijalul Fahmi Mustapa received his PhD in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia, in 2021. He is a senior lecturer at the Universiti Teknologi MARA (UiTM) Pasir Gudang campus. His research interests include energy measurement and verification, energy prediction, and artificial intelligence applications.

Atiqah Hamizah Mohd Nordin received her PhD in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia, in 2022. She is a senior lecturer at the Universiti Teknologi MARA (UiTM) Pasir Gudang campus. Her research interest includes renewable energy, solar photovoltaic sustainability, and life cycle assessment (LCA).

Muhammad Asraf Hairuddin received his PhD in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia, in 2014. He is a senior lecturer at the Universiti Teknologi MARA (UiTM) Pasir Gudang campus. His research interests include image processing, artificial intelligence, and deep learning applications.

Mohd Ezwan Mahadan was born in Malaysia on 9 November 1986. He received his Bachelor of Electrical Engineering (Hons.) and Master of Electrical Engineering from Universiti Tun Hussein Onn Malaysia (UTHM) in 2010 and 2013, respectively. He is currently enrolled as a PhD student at Universiti Teknologi MARA, (UiTM).