A Mini Review on Energy System Modelling for Enhancing Energy Efficiency in Malaysia

M A F A Aziz\textsuperscript{1}, P Y Liew\textsuperscript{1,2}\textsuperscript{*}

\textsuperscript{1}Department of Chemical and Environmental Engineering, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia Kuala Lumpur, Malaysia.

\textsuperscript{2}Process System Engineering Center (PROSPECT), Research Institute of Sustainable Environment (RISE), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia.

*Corresponding author: pyliew@utm.my

Abstract. Energy efficiency is an important energy consumption parameter to indicate the efficient use of energy. Through enhancing energy efficiency, the harvested energy (fossil or non-fossil) could be used in the most impactful manner, which reduces the energy wastage and carbon emission. This study performs a critical review of energy system modelling, which involves the modelling studies of renewable energy and energy efficiency measures for the national energy sector. The energy value chain is typically related to the national energy policies. Thus, this study continues with a review of the national energy policies from several countries. This study concludes with comprehensive comments and analysis on the feasibility of the national energy system modelling perspective for Malaysia to achieve the 8% of energy efficiency savings by 2025 for sustainable energy development.

1. Introduction

Energy efficiency plays a vital role in sustainable energy development towards affordable and clean energy as indicated by United Nation under Sustainable Development Goal 7. Achieving the energy efficiency will help to reduce the energy operational expenditure, mitigate the greenhouse gas emission, decrease the imports of conventional fuel sources and most importantly meeting the energy demand [1].

This paper reviews various energy modelling systems studied from the other countries and institutions in providing the analysis and insight for national energy efficiency. The research gap in the energy modelling system is identified for effective energy efficiency framework driven by policy. A preliminary assessment is proposed for the Malaysia energy modelling system especially for energy efficiency to complement various existing national energy efficiency policies in Malaysia and to anticipate the adoption of new policies adopted.

2. Malaysia Energy Efficiency Policy

American Council for an Energy-Efficient Economy (ACEEE) performed a critical study on the rating for the country energy efficiency policy metrics & performance executed at buildings, industry,
transportation, and overall national energy efficiency [1]. In 2018, ACEEE developed a methodology in evaluating the country’s ranking based on 36 metrics with point allocations of 59 for policy while the remaining 41 for performance covering from sectoral level up to national context. Figure 1 shows the overall rankings for top countries based on the ACEEE approach.

The approach adopted by ACEEE to produce the energy efficiency ranks was based on the evaluation of the selected countries based on the top 25 energy consumers worldwide published by the International Energy Agency (IEA) in 2014. Despite the data of Malaysian energy consumption was not being highlighted among the top 25 energy consumer by IEA, the national energy consumption for Malaysia in 2014 was at 52,210 ktoe [3]. This was comparable to the 51,244 ktoe of energy consumption [2] by United Arab Emirates (UAE) that was ranked at 25th place. This provide a message that Malaysia is also categorized among the top energy consumers globally and requires more efforts towards the deployment of energy efficiency. The motivation of energy efficiency can be achieved at the consumption level by reducing the energy used to provide similar energy services or to use the equal energy amount to provide more energy services.

Malaysia has set a national target in achieving 20% of renewable energy mix generation and 8% saving from energy efficiency in 2025 [4]. National Energy Efficiency Action Plan (NEEAP) published in 2015, introduced by Ministry of Energy and Natural Resources aims to reduce electricity demand and improve load profile via electricity saving. The potential total of energy capacity savings is 2,526 MW by end of the period of 2025 [5]. NEEAP policy highlights on the main barriers of energy efficiency in Malaysia such as low energy prices due to the fuel subsidies. Furthermore, Malaysia are lack in terms of few aspects such as financing, overall national planning, real champion to drive the initiatives and lack of consistency in embarking on the energy efficiency. NEEAP outlines the thrusts on the implementation of energy efficiency action plan such as strengthens the institutional framework capacity development and training for implementation of energy efficiency. Others including establishes a sustainable funding mechanism to implement energy efficiency initiatives and promoting private sector investment in the energy efficiency initiatives. Actions proposed in the NEEAP include the establishment of a special section to monitor implementation of NEEAP in Energy Commission, funding for energy efficiency, government-led initiatives, capacity building and research & development. There are several initiatives strategized in NEEAP that consist of 5 key programmes covering for 3 sectors for 10 years period of implementation with potential savings, such as the promotion of 5 star rated appliances (9,720 GWh), minimum energy performance standards (MEPSI) (4,391 GWh), energy audits and energy management in buildings and industries (34,832 GWh), promotion of co-generation (3,276 GWh) and energy efficient building design (15 GWh). The analytical approach of energy modelling for energy efficiency is crucial to ensure that the targets can
be achieved within the stipulated time. The following section discusses the energy modelling studies in detail for a few countries.

3. Global Practices on the National Energy System Modelling

There are various applications of national energy modelling system applied globally to address the issues by providing strategic insights on the energy industry development via different techniques based on the architecture system and framework [6]. The Integrated MARKAL-EFOM System (TIMES) is a tool used to assess the energy system in a large economic sector via linear optimisation to determine the most affordable energy system costs for the regional economy based on the investment and energy operation. UCL Energy Institute developed a national energy system model based on the UK TIMES Model (UKTM) built originally by IEA-ETSAP. In UKTM, the TIMES model integrates with the series of upgrading version of strategic document established by UK MARKAL. UK MARKAL has strong records in spearheading the national energy policies, including the Energy White Papers (EWP) and Climate Change Bill etc [8]. The reference energy system for the UKTM consists of eight sectors with the breakdown of three supply-side (resources and imports, electricity, processing) and five from the demand side (residential, services, industry, transport and agriculture). The UKTM model featured with TIMES model & VEDA model system is to determine the energy system in relation to the service demand side as shown in Figure 2. Energy model is generated from the energy data input using TIMES and the model solution is determined according to the environment using the General Algebraic Modelling System (GAMS). Then, VEDA back end (VEDA BE) processes the preliminary results of the models to produce the final output in a form of text, tables and graphs. The UKTM requires calibration of user’s database prior to model generation. The UKTM would be strong with the linkage of behavioural modelling and spatial as well as the temporal modelling [7].

![Figure 2. UK TIMES Energy System Model with the integration of TIMES & VEDA](image)

A national energy system modelling is also developed to support the energy and climate policy decision-making for the future energy system in Sweden known as TIMES-Sweden [8]. The model is featured with various characteristics such as energy system model, optimisation model, bottom-up model, technology-rich, energy-economic, partial equilibrium, time dimension, dynamic, perfect foresight, and regional coverage. Few main assumptions are being applied such as energy service demand, primary resources potential, techno-economic parameters, environmental parameters and policy settings to generate the models with main data sources of time dimension, demand projections, national energy balance, resources, emission, fuel price, policy assumption and technology database. Techno-economic contribution of Combined Heat Power (CHP) in the context of national energy system models is being simulated to reduce the demand from the primary energy. The modelling analysis is also linked with the national CGE model (EMEC) to provide robust and transparent energy
analysis as both models aim different angles of the contribution of energy scenario and economy development. Future research improvement is highlighted focusing on the heating and cooling demand due to substantial consumption which may contribute towards the European energy efficiency target. Besides, the cross-border energy trade with the neighbouring countries needs to be incorporated into the TIMES-Sweden to project the accurate energy demand.

A study demonstrates on the application of Scottish TIMES model for the energy efficiency policy analysis based on six different scenarios indicates the strength and limitation of the modelling approach at the strategic level for few sub-sectors [9]. TIMES has a limitation to provide analysis for energy efficiency in which it is solely suitable for the technology substitution of using more efficient equipment for required energy service and its require know-how on the specific policies and objectives to be tested. The energy service demand can be achieved via the synchronization of energy conversion technologies and energy conservation technologies. Few studies incorporate direct analysis on energy efficiency such as via input energy constraints by reducing the amount of input fuels, demand changes by reducing energy service demand associated with the users’ behaviour or technological progress. Besides, it includes technology adoption constraints by executing energy efficiency and conservation initiative to reduce the input fuel requirements. Sample cases of residential energy efficiency for gas and electricity consumption were conducted by adopting two different scenarios of input energy constraint and technology adoption constraints. It is found that both scenarios’ approach produced a different result for gas and electricity consumption. Thus, this recommends the best method by applying TIMES to conduct the energy efficiency analysis. Input constraint scenario reduces the gas consumption while the technology constraint scenario reduces the electricity consumption compared with the base case scenario. This indicates the consequences and implication from the policy being imposed or the best policies to be applied to achieve the target by the policy makers and to select the ideal modelling approaches for the energy efficiency required.

A model of energy efficiency evaluation guideline established in United States of America (USA) to provide model approaches for gas and electric utilities and regulators to determine the energy demand and emission of reduction from the energy efficiency. This will contributes towards National Action Plan for Energy Efficiency driven by the key policies. The guideline serves as standardized frameworks consist of the calculation of gross energy and demand savings, net energy and demand savings and the avoided air emission from the energy efficiency. This quantify process of measurement and verification will provide a baseline to evaluate the impact from the energy efficiency activities for future planning [10].

Energy Information Administration (EIA) applied National Energy Modelling System (NEMS) to project the energy, economics, environmental and security factors to the USA driven by alternative energy policies and assumptions on the energy markets [11]. It integrates sets of energy modules such as demand modules, electricity market module, oil and gas supply modules and liquid fuels market modules as shown in Figure 3. As NEMS is a computer-based module for energy economy, it represents the energy markets and interaction with the national economy for the balancing of demand and supply. NEMS is also connected with the macroeconomy activity modules to produce more significant economic outcomes at various levels. The demand module structures such as residential, industrial, transportation and commercial defined the detail components and the relation with the supply and market modules.

A modelling analysis partnership for renewable energy and efficiency known as REMAP was developed by National Renewable Energy Laboratory (NREL). It demonstrates the system outputs based on different models, technology and market assumptions and relates to the developed scenarios, which are unaligned Base Case and aligned Tier 1 Case, for a certain percentage of penetration for renewable energy generation by 2025. REMAP utilize the data from the NEMS as a data reference and other local reputable sources. This study found that it is essential to conduct the due diligence by the policy makers and not depending on single model analysis since the assumptions made will produce different outcomes. It is therefore recommended to utilize similar assumptions with different
modelling for better comparison and analysis. Sensitivity analysis can provide comprehensive findings on how the outcomes respond with the variation of technology cost and market consumption [12].

![Diagram](figure3.png)

**Figure 3.** Overall view of National Energy Modelling System [11]

TIMES modelling and CGE model SNOW-NO (Statistics Norway World model) are also being applied to assess the energy efficiency for the residential sector in Norway and evaluates accordingly to understand the similarities and differences between both models. A baseline scenario of energy projection until 2030 is developed and the policies of the energy efficiency is tested based on specific target such as reduction of the household heating energy consumption by 2030. This study incorporates the technology adoption constraints in modelling by having energy conversation technologies. The TIMES model will inform on how the energy efficiency can be achieved via the application of various technologies and energy products in comparison with SNOW-NO where the options for the technology is limited. This resulting towards the low consumption of the energy from households as the consumption is restricted. The researchers suggested the policy makers to be flexible in using various tools to simulate the modelling of energy efficiency [13].

Based on the TIMES for China, building sector may contribute towards reducing the carbon emission via the adoption of renewable energy sources of solar PV and complements the energy efficiency standards by simulating the demand projections from the energy service demand. The study tested four different scenarios for energy efficiency modelling [14]. TIMES is applied to analyse the six energy efficiency scenarios in Germany to measure the energy savings, development of the technology, cost and the emission factors. The study measured the CO₂ emission from every scenario and concludes that national energy efficiency target can be significantly achieved by using biofuels and methanol for the road transports compared to the other energy demands. For the residential, there is an opportunity by replacing the conventional boilers with the condensing gas boilers [15]. Another analysis was also conducted by researchers to understand the contribution of the industrial sector on the energy efficiency in the UK context by using the TIMES modelling based on five scenarios. It shows that both TIMES modelling and analysis on the energy efficiency in Germany and UK imposed constraints on the energy input and emission reduction [16].

Optimization of Malaysia’s power generation mix is demonstrated to study the energy generation in meeting the electricity demand by 2050 based on the few tested scenarios. The scenarios are business as usual (BAU) of existing technology, existing technology, plus renewable, plus nuclear as well as plus photovoltaic (PV) and storage [17]. By using the TIMES, this analysis established a few key parameters and assumptions for all the scenarios based on the readiness of local context. The study found that Malaysia will have the capability to meet the energy demand by depending on the renewable energy resources substantially from the hydropower, solar PV and stored electricity. This is aligning with the sustainable policy and complementing the national commitment towards the Paris agreement on the CO₂ emission. This study also described the ramification of energy demand sectors
comprising of industry, commercial, residential, agriculture and transport. Based on all the reviews in this section, the findings on energy modelling and energy efficiency are summarized in Table 1.

| Country     | National EE Target          | Main National EE Policy                      | Studied Energy Modelling | EE Assessment |
|-------------|-----------------------------|---------------------------------------------|--------------------------|--------------|
| UK [8]      | Reduce 20% by 2020          | UK NEEAP                                   | UKTM                     | Direct       |
| Sweden [9]  | Reduce 50% by 2030          | 4th NEEAP                                  | TIMES & CGE EMEC         | Indirect     |
| Scotland [10]| Reduce 12% by 2020         | Energy Efficiency Action Plan (EEAP)        | TIMES                    | Direct       |
| U.S.A [11], [12], [13]| Reduce 20% of electricity & 12% natural gas by 2030 | Energy Efficiency Resource Standard (EERS) | NEMS & REMAP            | Direct       |
| Norway [14] | Reduce 25% by 2030          | Climate Policy & Energy White Papers        | TIMES & CGE SNOW NO      | Direct       |
| China [15]  | Reduce 15% by 2020          | Energy Savings under series of Five-Year Plan | TIMES                    | Direct       |
| Germany [16]| Reduce 50% by 2050          | National Action Plan on Energy Efficiency   | TIMES                    | Direct       |
| Malaysia [18]| Reduce 8% by 2025         | Malaysia NEEAP                             | TIMES                    | Not Measured |

4. Preliminary Analysis and Critical Appraisals
Based on the reviews on the national energy system, it is observed that there are various methods being adopted from the other countries to assess and monitor the energy efficiency implementation. TIMES has a wide application for simulating energy system, however, most of the applications of TIMES are not directly measuring the energy efficiency performance at the strategic national level. There are very limited studies that provide direct measurements and analysis of energy efficiency based on the projected scenarios to achieve the specific outcomes.

For Malaysian context, previously, there were few approaches and attempts done by Malaysian to embrace the various types of energy models including WASP, ENPEP, LEAP, MARKAL and MAED. It is found that those models are not suitable to be applied for the analysis and modelling of unique Malaysia energy landscape. This is due to the data availability, huge investment needed, gap exists between the model structure and local energy system requirement i.e model purpose versus user objective [18]. To date, Malaysia government is adopting forecasting technique to conduct the energy projection and data collection of the national energy balance empowered by the energy modelling tool of PLEXOS. The PLEXOS model is based on commercial linear mixed-integer power sector model developed by Energy Exemplar that suits with the issue of data constraints face by clients and flexible for the framework development.

There is no specific national modelling applied to analyse the energy efficiency progress in Malaysia despite few policies are in place in stimulating the energy efficiency in Malaysia. Some of the energy efficiency policy available in Malaysia are:

- Electricity Supply Act 1990,
- Energy Commission Act 2001,
- Energy Audit Conditional Grants (EACG),
- Energy Performance Contracting (EPC),
- Efficient Management of Electrical Energy Regulation 2008 (EMEER),
- Building Sector Energy Efficiency Project (BSEEP),
- National Energy Efficiency Action Plan (NEEAP)
- Minimum Energy Performance Standards,
- Incentive for Energy Efficiency Project via Investment Tax Allowance (ITA)

This indicates that there is an opportunity for Malaysia to establish national energy modelling, which can support the policy direction focussing on the energy efficiency by incorporating the unit operation level up to the entire energy economy. This model should simulate the combination of Process System Engineering and Energy Economics for better decision-making hierarchy. Development of a framework for the national energy efficiency modelling at the strategic level will provide better insights for the policy makers on the implementation of the energy efficiency and the efficacy of the policy imposed from top-down approach. Furthermore, this will also provide open collaboration on how the various category of energy demands and consumers at the operational level can also support towards achieving the national target of the energy efficiency in more practical ways based on the bottom up approach. In this context, the energy demand is defined as an end-use sector where the energy is consumed to provide the energy services consist of industry, transportation, residential, commercial and agriculture sector. Sankey diagram is applied to trace the energy flows from the primary source to end-use based on the energy consumption in Malaysia [20].

5. Conclusion
The development of the national energy modelling for energy efficiency based on the bottom-up and top-down approach is very crucial to assess the progress of the energy efficiency in Malaysia towards achieving the national targets of 8% savings by 2025. Energy policies should be simulated to determine the efficacy of the policy transition and this can also be applied for the new policy and market instruments. Malaysia is implementing Energy Efficiency and Conservation Act (EECA), which aims to contribute towards the CO$_2$ reduction, energy savings and ultimately the economic impacts. It is foreseeing that it will drive the implementation of energy efficiency and complement the thermal energy efficiency, which is currently lacking in terms of the adoption due to the uncertain direction. A good national energy modelling provides high agility towards simulating the energy efficiency (electricity and heating) and complement the innovations. The future development of national energy modelling will require strong support from each key players and stakeholders in Malaysia to ensure consistency and accuracy of the modelling result as various sources of data and set of policies are available from different agencies. Further study will consider the actual data on the implementation of energy efficiency (electricity and heating) to simulate the data into the framework modelling in order to measure contribution in the energy efficiency target for sustainable energy development.

Acknowledgement
The authors would like to thank for the financial supports from Universiti Teknologi Malaysia (UTM) and Ministry of Education Malaysia (MOE) through the Fundamental Research Grant Scheme (R.K130000.7843.5F075; FRGS/1/2018/TK02/UTM/02/26) and MRUN Translational Research Grant Scheme (R.K130000.7843.4L883).

References
[1] Castro-Alvarez, F., Vaidyanathan, S., Bastian, H. and King, J., 2018. The 2018 International Energy Efficiency Scorecard. ACEEE Report I, 1801.
[2] International Energy Agency, 2018, World Energy Balance Sankey Diagram 2014, IEA (International Energy Agency), France.
[3] Energy Commission, 2017, National Energy Balance 2015, Energy Commission, Malaysia.
[4] Special Report on Initiatives by Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC), 2019, MESTECC, Malaysia.
[5] Ministry of Energy, Green Technology and Water, 2015, National Energy Efficiency Action Plan (NEEAP), Ministry of Energy, Green Technology and Water (MEGTW), Malaysia.
[6] H-Holger Rogner, 2017, Introduction to Energy System Modelling, International Institute for Applied System Analysis (IIASA), Royal Institute of Technology (KTH), Stockholm, Sweden.

[7] Hannah E. Daly & Birgit Fais, UK TIMES Model, UCL Energy Institute, 2014.

[8] Riekkola A.K., 2015, National Energy System Modelling for Supporting Energy and Climate Policy Decision- Making: The Case of Sweden, Department of Energy and Environment, Chalmers University of Technology, Sweden.

[9] Calvillo C, Turner K, Low R, McGregor P, Bell K., 2018, Energy efficiency policy analysis with TIMES: Assessment of energy efficiency modelling approaches and their potential impact on policy. Glasgow: University of Strathclyde, 2018. 86 p, Glasgow, Scotland.

[10] Schiller S.R., 2007, Model Energy Efficiency Program Impact Evaluation Guide, US Environmental Protection Agency, US.

[11] US Energy Information Administration, 2019, The National Energy Modelling System: An Overview 2018, U.S. Energy Information Administration, U.S.

[12] Blair N., 2009, Renewable Energy and Efficiency Modelling Analaysis Partnership (REMAP): An Analysis of How Different Energy Models Addressed a Common High Renewable Energy Penetration Scenario in 2025, National Renewable Energy Laboratory (NREL), U.S.

[13] Rosnes O., Brita B., Kari E., Taran F., Eva R., 2017, Energy technology and energy economics: Analyses of energy efficiency policy in two different model traditions, 15th IAEE European Conference, Vienna, Austria.

[14] S. Jingcheng, C. Wenying, Y. Xiang, 2016, Modelling building’s decarbonization with application of China TIMES model. Applied Energy, Elsevier, vol. 162(C), pages 1303-1312.

[15] Blesl M., Anjana D., Ulrich F., Uwe R., 2007, Role of energy efficiency standards in reducing CO2 emissions in Germany: An assessment with TIMES, Energy Policy, Elsevier, vol. 35 (2), pages 772-785, February.

[16] Fais B., Nagore S., Neil S., 2016, The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets, Applied Energy, Elsevier, vol. 162(C), pages 699-712.

[17] Haiges R., Wang Y., Ghoshray A., Roskilly A., 2017, Optimization of Malaysia’s power generation mix to meet the electricity demand by 2050. Energy Procedia. 142. 2844-2851.

[18] Yusof, M. A., The Development of Integrated Malaysia Energy Model: A Reference Energy System (RES) Approach, 2010, Proceeding The Malaysian National Economic Conference (PERKEM) V, vol. 2 (2010) 350-356, ISSN: 221-962X.

[19] Subramanian A. S. R., Truls G., Thomas A. A., 2018, Modelling and Simulation of Energy Systems; A review, Process 2018, 6, 238.

[20] C. Chong, W. Ni, L. Ma, P. Liu, Z. Li, 2015, The Use of Energy in Malaysia: Tracing Energy Flows from Primary Source to End Use. Energies. 8. 2828-2866.