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Optimization of Malaysia's power generation mix to meet the electricity demand by 2050

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Abstract

The Malaysian Government has been introducing fuel diversification policies over the past decade by considering other sources of fuel such as alternative and renewables into the electricity mix as a measure to lengthen the oil and gas reserves against premature depletion. Since electricity consumption forms about a fifth of the total energy consumption, and directly impacts the country's economy and people's well-being, it is necessary to pay emphasis on Malaysia's long-term power sector planning by identifying sustainable options which will enhance Malaysia's energy security and mitigate climate change. This paper presents an analysis of the long-term power generation options for Malaysia by deploying the integrated MARKAL-EFOM system (TIMES) model. The examined scenarios are business as usual (BAU) and optimized least cost scenarios which include: existing technology, plus renewable, plus nuclear as well as, plus photovoltaic (PV) and storage. The results indicated that Malaysia has sufficient renewable energy resources to meet the projected electricity demand by 2050 and fossil fuels can be fully replaced with electricity sourced from large hydropower and combination of other indigenous sustainable energy sources. The variability issue of renewables can be stabilized with the integration of storage systems into the grid. This analysis also demonstrated that installation of 8.57 GW solar PV panels on existing rooftops combined with 3.6 GW large-scale pumped heat energy storage (PHES) system can generate electricity comparable to a 2.0 GW nuclear plant at a lower system cost of $102.4 billion. Hence, if Malaysia were to adopt a sustainable policy, then nuclear power would not be an ideal option as uranium fuel relies on continuous imports.

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Keywords: Malaysia; Optimization; Power generation mix; Renewable energy; Scenario analysis; TIMES model.

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1. Introduction

The power sector in Malaysia has been heavily dependent on conventional fossil resources, according to 2013 available capacity data indicated that 88.4% came from fossil fuels and 11.4% is from hydropower. To be distinct, the 88.4% accounts for 53.3% natural gas, 30.5% coal, 2.8% fuel oil and 1.8% diesel. The penetration of renewables in the generation mix has been rather laid back despite the implementation of the feed-in tariff and renewable smart targets. The contribution of renewables aside from hydro in the electricity mix in 2013 was only 0.2%[1]. Malaysia is also one of the largest carbon dioxide (CO_2) emitters in South East Asia, ranked third after Indonesia and Thailand. In 2013, the CO_2 emission marked a tremendous four-fold increase to 236.5 Mt compared to 56.6 Mt in 1990. Furthermore, in 2013 power sector alone contributed 54.8% of total CO_2 emissions [2]. Malaysia has also ratified the Paris agreement to reduce 45% of greenhouse gas (GHG) emissions relative to 2005 levels by 2030, in which 35% reduction is on unconditional terms and 10% is upon receipt of climate finance, technology transfer and capacity building from advanced countries. At current production to reserve rate, oil and gas reserves are showing signs of depletion, oil may last for 30 years, while gas may hold about 40 years. Malaysia needs to restructure her electricity generation mix to cater for the aforementioned challenges of climate change and diminishing fossil fuel. As part of the solution, the government has laid plans to commission a 2.0 GW Nuclear Power Plant which is scheduled to be in operation by 2030. Malaysia Nuclear Power Corporation (MNPC) was established and entrusted to lead this initiative, their current focus is to set up the legal framework for nuclear power in the country [3]. Nevertheless, after the Fukushima Daiichi nuclear disaster in 2011, led some European countries to shut down their nuclear reactors as a safety obligation towards their citizens. This incident has enhanced the awareness of the Malaysian public that nuclear technology is associated with inherent risks, and thus the idea of sourcing power from nuclear is no longer intriguing to the public. Thus there is a need to explore other long term sustainable options for power generation in Malaysia. This type of long term foresight studies are still lacking for Malaysia and optimization models are known to be able to provide an objective evaluation of future generation technologies and fuel mix selection. These studies are not only limited to power sector analysis but can cover the whole energy system as well which have been performed by *M.A.H. Mondal et al* (2014), *Mallah and Bansal* (2010) and U.*K. Rout et al* (2011) [4-6]. However, these studies are often unique owing to application of country-specific data, the research objectives may vary upon factors such as policies of national interest, demand or technology-driven or maybe linked to environmental concerns. Hence, this study will assess the optimized least cost selection of future power generation technologies in Malaysia for a period from 2013 until 2050 by evaluating a few scenarios namely the optimized least cost on existing technology, plus renewables, plus nuclear, also plus PV and storage which will be contrasted to the business as usual (BAU) scenario. The electricity demand projection, capacity levels, and electricity generation by technology, the CO_2 emission profile, as well as the total system cost for all scenarios will be presented.

2. Methodology

The methods used in this study involves base year data collection from secondary sources published by the Energy Commission of Malaysia [1]. The growth rates predicted by the Energy Commission as in Table 1 [7] were applied to determine the electricity demand projection up to 2050. The impact of energy efficiency initiatives, higher electricity prices and the slowdown in industrial sales were among the contributing factors to the decreasing trend in electricity demand growth rates. TIMES was selected as the simulation tool for modeling the different scenarios as it is the upgraded version of the MARKAL model. This simulator was developed by the Energy Technology Systems Analysis Program (ETSAP) under the auspices of the International Energy Agency (IEA). TIMES is a specialized energy modeling generator suitable for long term power sector assessment [8]. It is a bottom up, partial equilibrium, linear programming, and least-cost optimization system. Thus, TIMES is an ideal scenario simulator and the perfect tool for foresight analysis. The modeling framework requires the full spectrum of processes from the supply of primary fuels through the conversion technologies to meet the end user demand sectors. The simple reference energy system (RES) for Malaysia is illustrated in Fig. 1.