

# ***LONG-TERM DECARBONISATION ENERGY PATHWAYS FOR MALAYSIA USING A HYBRID DEMAND-SUPPLY MODEL***

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## **Overview**

Along with many countries battling to reduce emissions, at the 2015 Paris Climate Summit, Malaysia also pledged to reduce its greenhouse gas (GHG) emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005 (UNFCCC 2015). This re-pledged the commitment made earlier during the 2009 Copenhagen Climate Summit. The pledge shows that Malaysia is seriously considering incorporating environmental issues into the process of energy planning and policy-making. Many policies and measures have been initiated to diversify the utilisation of fuel resources and adaptation of new technologies, especially renewables in the power sector, in an effort to reduce emissions (Oh, Pang et al. 2010).

Therefore, it is vital to conduct research looking into modelling perspective of the fuel resources diversification and the adaptation of new technologies, taking into account future economic and population growth. Much of the current literature highlights the challenges faced in supply-demand energy systems in Malaysia (Zamzam Jaafar, Shekarchian, Moghavvemi et al. 2011, Ali, Daut et al. 2012, Khor and Lalchand 2014), yet not many studies focus on national energy systems modelling using optimisation models (Fairuz, S. M. C., et al 2013 , Koh, S. L., et al. 2011).

To conduct this analysis, a novel hybrid model (MAED-OSEMOSYS) has been developed to examine the demand-supply energy system and to further analyse the fuel combustion emissions in the energy sector. The detailed demand model (MAED) captures the range of possible future energy service demands in a fast developing country like Malaysia. The energy systems supply model (OSEMOSYS) captures technological and resources characteristic of Malaysia as well as its geographical aspects via a multi-regional approach. It is a challenge to obtain the extensive data set required to build the complete energy system model. Also, the lack of current good models are significant issues for both Malaysia and all other developing countries. Hence, this is an important work and contribution in the field of energy systems modelling for developing countries.

In this paper, the hybrid model is used to analyse fuel-switching of end-use technologies, especially electrified technologies in the Industry, Transportation, Household and Services sectors when gradual carbon emission constraints are imposed until 2050. This paper further focuses on the alternative technologies needed in the power sector to meet the country's increasing electricity demand as well as satisfying the carbon emission constraints. The power sector has been the major contributor towards CO<sub>2</sub> emissions since 2000 due to fossil fuel combustion. Its contribution is growing annually as the fossil fuels consumption increases in this sector (NRE 2011). Therefore, it will be interesting to examine the energy sector contribution towards the national commitments in reducing carbon emissions. The main research question addressed in the paper is to explore and analyse decarbonisation pathways up to 2050 and how the country's low carbon electricity transitions are evolving to meet the imposed emission constraints.

## **Methods**

Two models (MAED and OSEMOSYS) are soft-linked to conduct this analysis. The Model for Analysis of Energy Demand (MAED) is developed to generate sectoral (Industry, Transportation, Household and Services) energy demands for Peninsular Malaysia, Sabah and Sarawak separately based on two key drivers, the Gross Domestic Product (GDP) and population growth. The demand projection has also incorporated demographic changes, urbanisation levels and policy changes.

The final sectoral energy demand projections (2013-2050) obtained from MAED are soft-linked with the OSEMOSYS model. The OSEMOSYS model is developed for Malaysia with three regions (Peninsular Malaysia, Sabah and Sarawak), incorporating the supply-demand side balances for the period 2013-2050. The model also captures the required network infrastructure and connectivity for electricity trade between these three regions. The details of these technologies are based on the ETSAP supply-demand technology database. The OSeMOSYS model takes into account the domestic resources, fuel imports, fuel prices, power plant technologies, technology efficiencies, renewable potentials, network infrastructure and sectoral end-use technologies. Industrial technologies in the model are divided into fossil fuel machinery and equipment technologies (oil, gas, coal, LPG and electrical machineries & equipment) and Electrical technologies. Transportation technologies are divided into Road transportation, Rail, Air and Sea. Road transportation (car travel) technologies are divided into gasoline, biodiesel, NGV hybrid and Electric hybrid cars. Road transportation (light/heavy buses and trucks) are divided into

Diesel/NGV hybrid buses and trucks. Rail technologies are divided into electric and diesel rail networks. Household technologies are divided into cooking appliances (gas/electrical hob) and electrical appliances. Services technologies are divided into cooking appliances ( gas/electrical hob), General equipments (oil motor power/electric equipments) and Air conditioners (gas/electric air conditioner).

Currently, this hybrid model is used to evaluate decarbonisation pathways for the country and to analyse technological changes in the power sector as well as other sectors to meet the carbon emission constraints. This hybrid model will be further modified to explore the near-optimal investment strategies by relaxing the objective function in the OSEMOSYS model.

## Results

The carbon emission projection produced in the Reference (REF) scenario is used as a new constraint to generate four different emission scenarios. This REF carbon emission projection gradually decreased beginning with the year 2030 to reach 20%, 40%, 60% or 80% emission reduction levels by 2050. The results show that tightening the emission constraints leads to radical changes in the technology mix with profound implications for overall electricity production and trade across the three regions. The end-use technologies in the Industry, Transportation, Household and Services sectors switches from fossil fuels to electrified technologies as the percentage of the emission constraints increased. With the 20% reduction, the fuel transitions are visible in year 2040 – 2050. The results suggest that gas-cooking technology switches to electrified stoves in 2050 for Household and Services sectors. The gas vehicles further substituting petrol vehicles in the transportation sector. In industry sector, the coal and oil based machines are replaced with gas technologies. The fuel transitions to gas or electrified technologies are noticeable by the year 2030 in the 40% and 60% reduction scenario. With 80% reduction, most of the fossil fuel based technologies are electrified by 2050, especially in the household, commercial and industrial sectors.

The demand for electricity gradually increases from 12% (20% emission scenario) to 68% (80% emission scenario) as compared to the REF scenario. To meet the country's increasing electricity demand and its emission constraints respectively, fossil fuel technologies in the power sector are slowly replaced with hydro imports from Sarawak, renewables and nuclear energy. Further, the technology constraints imposed in the power sector shows the preferences of hydro imports, renewables and nuclear energy based on costing.

## Conclusions

The results illustrate that the more stringent the emission constraint imposed, the cost structure of future technologies becomes more expensive. It is also interesting to examine the transition of new low carbon technologies in the energy systems at different stages. Initially, the oil and coal based technologies are replaced with gas technologies. Eventually, most of these technologies are electrified, which instigate the building of more power plants to fulfil this increased electricity demand. In the power sector, Sarawak hydro imports to Peninsular Malaysia, renewables and nuclear energy are selected. This paper contributes towards the modelling of end-use technologies as well as exploring the country's commitment towards emission reductions.

## References

- Ali, R., et al. (2012). "A review on existing and future energy sources for electrical power generation in Malaysia." *Renewable and Sustainable Energy Reviews* 16(6): 4047-4055.
- Fairuz, S. M. C., et al. (2013). "Long term strategy for electricity generation in Peninsular Malaysia - Analysis of cost and carbon footprint using MESSAGE." *Energy Policy* 62: 493-502.
- Khor, C. S. and G. Lalchand (2014). "A review on sustainable power generation in Malaysia to 2030: Historical perspective, current assessment, and future strategies." *Renewable and Sustainable Energy Reviews* 29(0): 952-960.
- Koh, S. L., et al. (2011). "Cost Effective Options for Greenhouse Gas (GHG) Emission Reduction in the Power Sector for Developing Economies — A Case Study in Sabah, Malaysia." *Energies* 4(5): 780-803.
- NRE (2011). *Malaysia's Second National Communication to the UNFCCC*. Putrajaya: Ministry of Natural Resources and Environment.
- Oh, T. H., et al. (2010). "Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth." *Renewable and Sustainable Energy Reviews* 14(4): 1241-1252.
- Shekarchian, M., et al. (2011). "A review on the pattern of electricity generation and emission in Malaysia from 1976 to 2008." *Renewable and Sustainable Energy Reviews* 15(6): 2629-2642.
- UNFCCC (2015). *Intended Nationally Determined Contribution (INDC) of The Government of Malaysia*. Paris Summit 2015.
- Zamzam Jaafar, M., et al. (2003). "Greener energy solutions for a sustainable future: issues and challenges for Malaysia." *Energy Policy* 31(11): 1061-1072.