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Electricity supply industry reform and design of competitive electricity market in Malaysia

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1. Introduction

1.1 Introduction

Malaysia is a member state of the Association of Southeast Asian Nations (ASEAN)[1] and is classified as an upper middle-income economy[2] (WB, 2020). The country is divided into three main regions: Peninsular Malaysia, Sabah, and Sarawak (see Figure 1.1). Sarawak and Sabah are located on the island of Borneo and are separated from Peninsular Malaysia by the South China Sea. Peninsular Malaysia shares a land border with Thailand and a maritime border with Singapore, while Sabah and Sarawak share land borders with Indonesia and Brunei.

Figure 1.1: Map of Malaysia: Peninsular Malaysia, Sabah, and Sarawak

Source: www.worldatlas (2020)

Since the 1990s, Malaysia has been in the process of restructuring its electricity sector with the aim of improving the efficiency, governance, and administration of the sector, maintaining/enhancing the security of electricity supply, and encouraging the growth of low-carbon technologies (see Chapter 2). The country has faced a number of challenges in all elements across the electricity supply chain and this led to the creation of the Malaysian Electricity Supply Industry (MESI 1.0) reform initiatives. This reform aimed at awarding tenders to competive independent power producers (IPPs), incentive based regulation (IBR) with imbalance cost pass through (ICPT), accounting unbundling, and the gradual rationalization of gas subsidies.

In the years following MESI 1.0 a range of new industry megatrends – such as digitalization (examples: smart energy network using digital technologies), decentralization (examples: customer participation and integration of distributed resources), and electrification (examples: increase in electricity demand due to electric vehicles and other appliances) – led to the MESI 2.0 reform initiative (MESTECC, 2019). MESI 2.0 aims to make the power sector more efficient, reliable, and sustainable.

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[1] ASEAN member states: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.

[2] Upper middle-income economies with a Gross National Income (GNI) per capita between USD4,046 and USD12,535 (WB, 2020),

The objective of this research is to examine electricity supply industry reform challenges and analyse market design issues and options in Peninsular Malaysia. It is envisaged that the research findings will contribute to the design of electricity industry reform and new regulatory rules to accommodate renewables, and will enable consumer participation and design of renewable support schemes.

1.2 Research questions

The research questions were designed to address issues related to the reform model, decentralization of the electricity market, and the design of suitable support schemes for renewables in Peninsular Malaysia. These questions are as follows:

1. What is the most suitable reform model for the Malaysian electricity sector which will promote competition, security of supply, and sustainability while at the same time being compatible with the country's own context and government objectives?
2. How does decentralization (distributed generation, storage, demand response, and energy efficiency) affect the Malaysian electricity sector?
3. How do renewable support schemes need to be designed and implemented in order to avoid or minimize distortion in the market?

1.3 Methodology

The methodology used in this study is a combination of semi-structured interviews and analysis of existing literature, governmental proposals, and current data on the electricity sector. Two approaches have been used to collect the data required to address the research questions.

i. Secondary data collection
- Secondary data and statistics have been collected from national publications (such as the National Energy Balance and the Malaysian Energy Statistics Handbook), the Malaysia Energy Information Hub (MEIH) database, the Energy Commission (EC), and Single Buyer websites.

ii. Interview sessions with the following stakeholders:
- TNB Renewable,
- TNB Grid Division,
- TNB Distribution Network,
- TNB Retail,
- Ministry of Energy, Science, Technology, Environment & Climate Change (MESTECC)[3],
- Energy Commission (EC),
- Sustainable Energy Development Authority (SEDA),
- Federation of Malaysian Manufacturers (FMM).

1.4 Outline of the research

The outline of the study is as follows. The next chapter offers a brief background on the electricity sector in Malaysia, discusses the summary of energy policies implemented, outlines the motivation for the restructuring of the electricity supply industry, and highlights challenges as well as opportunities in reforming the power sector in Malaysia.

Chapter 3, which is structured to address the first research question, analyses power market design and transition towards the hybrid market structure. This chapter also discusses requirements in terms of policies and regulations towards market liberalization.

Chapter 4 focuses on the second research question and examines the implications of decentralization for the electricity system. It first analyses how decentralization affects the power system in terms of net load variability and the need for flexibility. The chapter then discusses the implications of

[3] Currently known as Ministry of Energy & Natural Resources

decentralization for the electricity market and highlights the requirements of an efficient network tariff design.

Chapter 5, which addresses the last research question, focuses on renewable support design, as well as the effect of renewable support schemes on wholesale electricity markets. It analyses the trade-off faced by policy makers in reconciling investors' incentives with market compatibility when designing renewable support schemes.

The concluding chapter provides a summary of key findings of the research

2. Electricity supply industry background

2.1 Historical development of the electricity sector in Malaysia

The Malaysian power sector framework had been undergoing continuous change since the country's independence in 1957. The first electricity board – the Central Electricity Board (CEB) – was established in 1949 to develop power plants and grid infrastructure in the country. In 1967 the CEB was renamed the National Electricity Board (NEB) and was charged with managing the power sector. By the 1980s, the NEB was responsible for supplying electricity in Peninsular Malaysia.[4] The government then established a successor company to corporatize NEB under the Electricity Supply (Successor Company) Act 1990. This decision was in parallel with the government's strategy on privatization policy (Malay Mail, 2020). The national electricity utility company, Tenaga National Berhad (TNB), was formed in 1990 and became a public listed company in 1992. The government was the major shareholder and it proposed critical decisions for the industry to: decentralize the power system, expand power capacity, and revise the electricity tariffs. In 1993, the government decided to introduce Independent Power Producers (IPPs), who were to be contracted to supply at least 30 per cent of the nation's electricity demand in Peninsular Malaysia. The decision to introduce IPPs signalled the initial stage of power sector liberalization. The management unbundling of TNB was implemented in an effort to further reform the Peninsula's electricity sector, and this will be discussed in the following section. The Energy Commission (EC) was formed in 2001 as an independent body to regulate the power sector, enforce rules on licensees' electricity supply infrastructure, and to be responsible for administration of the Single Buyer Rules (SB, 2017). The process of liberalizing the power sector has been ongoing, and the country is aiming to revise the structure of the power sector to create a competitive and efficient electricity market system in the future.

2.2 Context and motivation for power sector liberalization

The text book model of electricity sector restructuring often includes the corporatization of national utilities, the introduction of competition through unbundling the sector into its functional components (generation, transmission, and distribution), allowing the entry of private power producers and distributors, the establishment of independent regulatory institutions, and the creation of competitive power markets, by stages, in the future. In Malaysia, some of these components have already been implemented: for instance, the national utility TNB has been corporatized, and private producers are allowed in generation.

Like many other countries, the power sector in Malaysia had originally been a vertically integrated monopoly system and has gone through different stages of the liberalization process. In line with the government initiative on introducing its privatization policy, the power sector was privatized to secure an adequate supply for the Peninsula through attracting investments and improving efficiency and productivity in the system. The government also encouraged the participation of IPPs to improve security of electricity supply and to address the shortage of generation capacity to meet demand in Peninsular Malaysia. In 2009, the government endorsed the Malaysia Electricity Supply Industry (MESI) 1.0 initiatives; these aimed, in the years 2010–14, to transform the power sector. The objectives were:

[4] History of TNB: https://www.tnb.com.my/about-tnb/history.

to improve the tariff mechanism, enhance fuel supply and security, and achieve governance effectiveness in managing the power sector. The MESI 1.0 initiatives prompted the establishment of the ring-fenced Single Buyer model.

In 2018, the government announced the second stage of reform initiatives and the country plans to transform its electricity industry through the implementation of the MESI 2.0 objectives (although the government recently decided to review this initiative[5]). This reform aimed for changes such as the introduction of new suppliers of coal and gas, and alternative retailers and gentailers (retail energy suppliers who also own generation assets). The initiative also envisioned the establishment of a wholesale market (including a capacity market) as well as the setting up of Single Buyer and Grid System Operators as independent entities. The key driver favouring liberalization is the need to improve governance and decentralize and revise the regulations of the power structure (NST, 2018).

The evolution of a competitive gas market in Malaysia is closely related to the design of a competitive electricity market in the country. Gas is one of the main fuels consumed in the power sector;[6] hence gas industry liberalization would impact gas consumption and gas pricing in the power sector. The government is motivated to liberalize the power sector by creating a third-party access framework to supply fuel sources (for example the TPA framework for gas supply enforced in 2017), together with access to grid infrastructure and the retail market by third parties.[7] The government anticipated that the reform of this sector would encourage and facilitate the supply of green energy in the country. As Malaysia plans to integrate renewables in the electricity system based on the Green Technology Master Plan, the country also needs to address the critical challenges of designing suitable renewable support schemes (KeTTHA, 2017–2030), such as: de-risking investments by awarding long-term contracts,[8] facilitating consumer participation in electricity market by reforming end-user tariffs,[9] and enhancing the flexibility of the power system to deal with the intermittency of renewables. The design of an electricity market also needs to be compatible with a mix of zero marginal cost renewables and non-zero marginal cost conventional generators. Table 2.1 summarizes the past and current motivation for power sector liberalization.

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[5] In July 2020, MESI 2.0 was reportedly being reviewed by the federal government. See 'Putrajaya to review MESI 2.0 power sector reform', *Edge Markets*, 22 July 2020, available at: https://www.theedgemarkets.com/article/govt-review-mesi-20-power-sector-reform.

[6] Gas as fuel input to power stations was 31.7% of 37,510 ktoe and coal input was 50.6% of 37,510 ktoe in 2017 (EC, 2019a). In the existing arrangement, coal is 100% imported for the power sector by Tenaga National Berhad Fuel (TNBF) from Indonesia, Australia, Russia, and South Africa; gas is sourced from Petroliam Nasional Bhd. (Petronas).

[7] MESI 2.0 contained new rules for fuel sourcing which could allow power generators to obtain coal and gas from other sources. (Energywatch, 2019).

[8] As we mention later in Chapter 5, there is a trade off between de-risking investment through support schemes and market compatibility of the scheme. Eventually, there will be a need for an exit strategy as technologies become mature.

[9] Reforming end user prices is the first step in removing the barriers to consumers' participation in the electricity market. This is because it allows for demand response and efficient investment and consumption decisions by consumers.

Table 2.1: Summary of past and current motivation for power sector reform

	Malaysia Energy Supply Industry 1990s–2010	Malaysia Energy Supply Industry 2018–current
Motivation for reform	• Privatize TNB to create transparency in power market system. • Establish ring-fenced Single Buyer model (Single buyer and Grid system operator within TNB but separate financial account and operation) which happened in 2009 as part of MESI 1.0. • Encourage participation of IPPs in power generation sector to improve supply security and expand power capacity.	• Implement competitive electricity tariff by removing distortions, modifying the tariff structure, and increasing integration of renewables in the system. • Encourage third-party access to distribution and transmission system. • Decentralize and move towards capacity and energy market model to allow for more efficient and flexible use of resources.

Source: Author's summary

2.3 Existing and planned future power sector structure in Peninsular Malaysia

2.3.1 Existing power sector structure

Before the establishment of the Single Buyer model, the role of, and responsibilities for, electricity procurement in Peninsular Malaysia were embedded within TNB. TNB operated as the off-taker for power plant capacity and energy contracts. The responsibility of least-cost dispatching of generation capacity was also integrated within TNB. The current power sector structure in Peninsular Malaysia is known as the ring-fenced Single Buyer model. The model involves maintaining a separate set of Single Buyer's accounts as well as the separation of its operations. The Single Buyer is the entity authorized by the government under the Electricity Supply Act (ESA) 1990. The primary function of this model is to procure electricity from IPPs and TNB Generation and execute least cost dispatch schedules (SB, 2019). With the formation of the ring-fenced Single Buyer, system planning and operations are more transparent, under the supervision of the Energy Commission as the regulator (Zamin et al., 2013). The government also set up a ring-fenced Grid System Operator, with the responsibility of day-to-day real time operation and the management of the Peninsular grid system.

2.3.2 Planned future power sector structure

There are several key initiatives planned by the government to restructure the power sector in the coming years. One initiative is to establish a third-party access framework and system access charges for the grid, to allow new players to use the transmission and distribution infrastructures.[10] The producers could participate in electricity distribution, and retailers would be able to bid competitively in the energy market.[11] Transmission and distribution network assets, however, will remain a natural monopoly.

Fuel cost plays a significant deciding factor in deriving the base electricity tariff structure in Peninsular Malaysia, making up 42 per cent of electricity tariffs[12] in 2018 (MESTECC, 2019). One of the government initiatives in reforming the power sector is to create fuel source procurement options in the future.[13] Another initiative taken by the government through the Energy Commission (EC) is to consider governance reform of the Single Buyer (SB) and Grid System Operator (GSO), in which both ring-

[10] According to MESTECC (2019), the Energy Commission had scheduled the establishment of a TPA framework and network charges in 2019.

[11] As a separate initiative outside MESI 2.0 a pilot phase, in which a peer-to-peer energy trading sandbox was created and approved by the Energy Commission, operated between November 2019 until June 2020, to encourage energy trading between net energy metering (NEM) prosumers and consumers (SEDA, 2019).

[12] Electricity tariff in 2018: 0.395 RM/kWh (MESTECC, 2019).

[13] https://www.mestecc.gov.my/web/wp-content/uploads/2019/11/MESI_2.0_IGEM19-web.pdf

fenced departments are to be independent of TNB's structure in the future. Furthermore, the government is due to outline the capacity and energy market rules. Based on the 10-year MESI 2.0 masterplan announced in September 2019, delivery of the first new build under the capacity market is scheduled in 2029.[14] In parallel to the establishment of this capacity and energy market, the government will still be honouring the long-term PPAs that are currently in place.

2.4 Challenges and opportunities in liberalizing the power sector

The country is facing a number of critical challenges in reforming the electricity market at different levels – including fuel supply, capacity addition, enabling access to grid infrastructure by third-party players, and making retail prices competitive. Figure 2.1 summarizes the key challenges that the power sector faces in liberalization.

- **Market design and energy transition**: One of the key challenges is to design the short-term and long-term electricity market for Malaysia. The designing of the electricity market needs to consider issues related to wider policies about renewable energy and security of electricity supply. The experiences of other countries show that when renewables are added to a power market that is designed for traditional resources, it might lead to price signal distortion and require subsequent market reforms by the government. Therefore, it is crucial to design the electricity market in a way that is consistent with national decarbonisation objectives in the energy sector. In addition, it needs to be in harmony with efforts to establish a competitive fuel market, and legacy PPA contracts. Currently, there is no fuel price risk to power producers (such as IPPs) due to the terms of their PPAs. The Imbalance Cost Pass Through (ICPT) mechanism reflects variations in the Base Generation Costs, whereby any saving or additional costs will be passed through to the consumers via rebate or surcharge. Hence, there is a lack of incentives for IPPs to find alternative fuel suppliers. In 2017, the amendment of the Gas Supply Act to introduce a third-party access (TPA) framework created an opportunity for new gas players to access gas infrastructure and supply gas at a competitive price. This arrangement could benefit the power sector by finding alternative fuel suppliers. See Chapter 3 on market design for the Malaysian power sector.
- **Retail market**: In the current tariff structure across the value chain in Peninsular Malaysia, the retail segment contribution is about 1 Sen/kWh (2 per cent) in deriving the base electricity tariff.[15] The government is facing challenges on how to reform the retail segment to allow for greater price differentiation and, by extension, greater consumer choice in switching their electricity provider, and how to reform commercial and industrial tariffs to encourage more efficient energy consumption across consumer segments. The reform of the retail market is one step towards reforms creating opportunities for customers to respond to price signals, and for power producers to be more efficient in providing the service.[16]The introduction of smart metering could provide a platform to transform the way the retail market operates to benefit customers. See Chapter 3 for details on the retail market.
- **Decentralization of the power sector:** It is a challenge to introduce TPA to grid infrastructure, as the grid needs to support a high number of generators (for example distributed energy resource generators), accommodate a diversity of generation technology (such as renewables), and integrate new technologies (smart meters, battery storage, electric vehicles, among others). The government has initiated a revision of its access rules for grid infrastructure, to facilitate new power producers and smart energy networks using digital technologies. The TPA framework provides opportunities for decentralized generators to sell electricity to customers. See Chapter 4 on the potential for, and impacts

[14] This timeline on introducing the entry of a capacity market, or any other implementation of MESI 2.0 initiatives, is subject to the government's decision and the evaluation of financial implications to the government. For example, the government would have to bear the cost of PPAs with a total of RM60–80 billion if the government takes over these agreements from TNB (Aziz 2020).

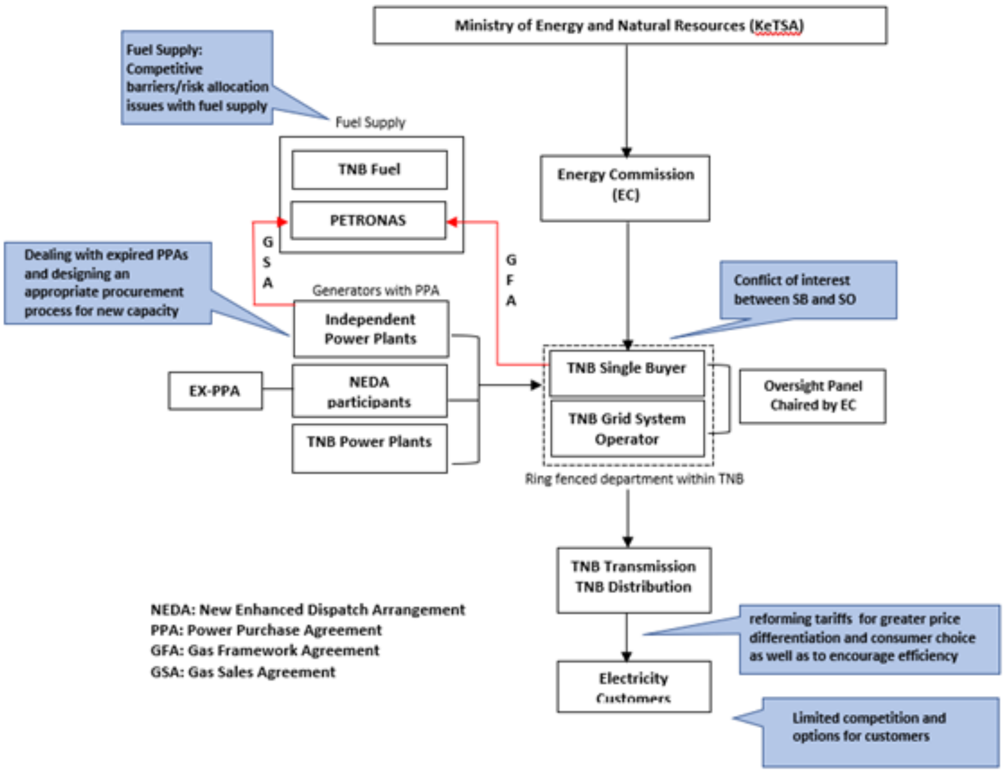
[15] Electricity tariff in 2018: 0.395 RM/kWh (MESTECC, 2019).

[16] As retail tariffs are a small proportion of the overall tariff, other measures (described earlier) are needed in the generation segment to complement the effectiveness of reforms.

of, power sector decentralization, as well as the implications of decentralization for network tariff design.

- **Renewable support scheme designs**: Despite the introduction of renewable energy policies and targets in the country, renewable integration in the power sector is a challenge, and fossil fuel consumption still dominates the power sector. The introduction of renewable direct support schemes such as Feed-in tariff (FiT), Net Energy Metering (NEM), and the Large-Scale Solar (LSS) programme has encouraged the participation of renewable producers in the system. See Chapter 5 on designs for renewables in the context of the Malaysian power sector and the implementation of renewable support schemes in wholesale markets.

Figure 2.1: Key challenges in the power sector in Malaysia



Source: Author's summary based on interview respondents

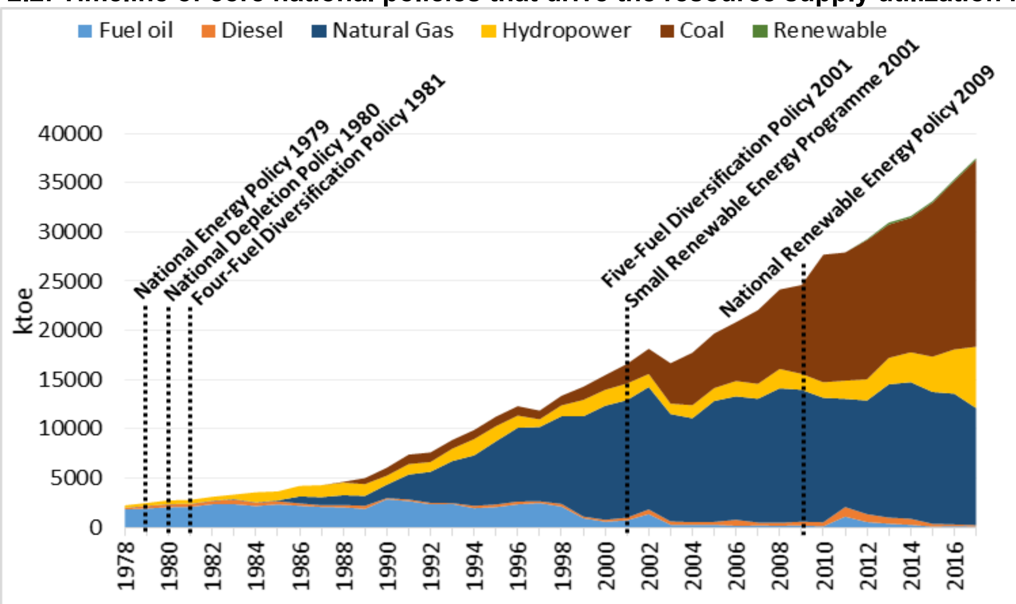
2.5 Review of energy and environmental policies for the power sector

The trend of fuel consumption in the power sector has changed over time with the implementation of energy policies in the country (Figure 2.2). In the 1980s, the implementation of the National Energy Policy, the National Depletion Policy, and the Four-Fuel Diversification Policy changed the landscape of oil consumption trends in the power sector. Following the international oil crises in 1973 and 1979, the government decided to diversify energy resources to prevent over-dependency on oil. The National Depletion Policy was introduced in 1980 to preserve oil and gas resources for future supply security. This policy implementation limited crude oil production to an average of 630,000 barrels per day (bpd) and natural gas production to 2,000 million standard cubic feet per day (mmscfd), leading to regulated fuel consumptions in the power sector (Khor and Lalchand, 2014).

In 1981, the Four-Fuel Diversification Policy was implemented to decrease dependence on oil as the principal energy source and to create alternative fuel resources of oil, gas, hydro, and coal to be used in electricity generation. The dependence on oil for electricity generation was gradually reduced and eventually decoupled from the electricity sector in Peninsular Malaysia. The use of oil gradually decreased from 1980 until 2017 (from 2,097 ktoe to 99 ktoe in 2017) which shifted the dependence towards domestic gas for electricity generation. Gas input for electricity generation increased from 59 ktoe in 1983 to 11,872 ktoe in 2017, since the discovery of gas in 1983. At the same time coal consumption also increased, starting with coal supply of 71 ktoe from 1988 and reaching 18,967 ktoe in 2017.

In 2001, the Five-Fuel Diversification Policy was introduced to incorporate renewable energy as the fifth fuel after oil, gas, coal, and hydro. The objective was to reduce reliance on fossil fuels, support the efficient use of natural resources, and to seek new alternatives in the energy sector – especially in harvesting renewable resources (Rahman Mohamed and Lee, 2006; Oh et al., 2010). The government also introduced the Small Renewable Energy Programme (SREP) in 2001 to facilitate grid-connected renewable energy, and the National Biofuel Policy (NBP) in 2005 to support and promote the development of biofuel production. In 2009, the National Renewable Energy Policy was implemented to further harvest renewable energy resources such as solar, biomass, and biogas. As of December 2017, the total installed capacity of renewables as reported in the National Energy Balance (NEB) was about 1,206 MW (NEB, 2017). Furthermore, a target to achieve a 20 per cent renewable generation mix by 2025 was announced in 2018 by the government, to increase the renewable share. Table 2.2 outlines the list of core national policies and the objectives of these policies.

Figure 2.2: Timeline of core national policies that drive the resource supply utilization in Malaysia



Source of data: NEB (2017), EC (2017a)

Malaysia was also committed to reducing greenhouse gas emissions (GHG) by ratifying the Kyoto Protocol in 2002. The country pledged a voluntary reduction of up to 40 per cent in terms of emissions intensity of GDP by 2020 compared to 2005 levels. This commitment was announced at the 15th Conference of Parties (COP15) in 2009. The target was reviewed and a revised pledge made: reducing CO_2 emissions per unit of GDP by up to 45 per cent by 2030, from 2005 levels (UNFCCC, 2015). This revised target was announced at the Paris Climate Conference and Conference of Parties (COP) 21. These commitments directly reduced the dependency of fossil fuels in the power sector (UNFCCC, 2000; UNFCCC, 2018). The Malaysian Electricity Supply Industry (MESI) has been going through many stages of restructuring since the introduction of the government's initiatives to reform the power sector, through the MESI 1.0 and MESI 2.0 phases. The initiatives on decentralization, digitalization, and retail options were also included under MESI 2.0 objectives.

Table 2.2: Summary of energy related national policies in Malaysia

Policies	**Objectives**
National Petroleum Policy (1975)	To ensure optimal use of oil resources, regulation of ownership, management, and operation, and safeguard exploitation of petroleum due to fast-growing petroleum industry.
National Energy Policy (1979)	Formulated with guidelines on three energy objectives: • Supply – ensure the provision of adequate, secure, and cost-effective energy supplies through developing indigenous energy resources. The resources include non-renewable and renewable energy resources using least-cost options and diversification of supply sources. • Utilization – promote efficient utilization of energy and discourage wasteful and non-productive patterns of energy consumption. • Environment – minimize the negative impacts of energy production, transportation, conversion, utilization, and consumption on the environment.
National Depletion Policy (1980)	To safeguard against over-exploitation of oil and gas reserves. Oil consumption in the power sector gradually reduced following this policy.
Four Fuel Diversification Policy (1981)	Designed to avoid over-dependence on oil as the primary energy resource and aimed to increase gas, hydro, and coal consumption in the electricity generation mix.
Electricity Supply Act (1990)	To regulate the licensing of electricity generation, transmission, and distribution.
Five Fuel Diversification Strategy (1999)	To include oil, gas, hydro, coal, and renewable energy in the electricity generation mix.
Fifth Fuel Policy (2000)	To harvest potential renewable energy resources such as biomass, biogas, municipal waste, solar, and mini-hydro for electricity generation.
National Green Technology Policy (2009)	To provide for green technology development, which includes implementation of innovative economic instruments, as well as the establishment of effective fiscal and financial mechanisms to support the growth of green industries.
National Renewable Energy Policy and Action Plan (2009)	To utilize indigenous renewable energy (RE) resources with a cumulative target of 11 GW by 2050, which aims to contribute towards national electricity supply security and sustainable socio-economic development.
Green Technology Master Plan Malaysia (2017–2030)	To promote and establish the role of the green economy and green technology, focusing on energy, manufacturing, transport, building, waste, and water sectors.
Renewable Energy Transition Roadmap (RETR)	To determine the strategies and comprehensive action plans of renewables, as well as to evaluate the impact of renewable strategies using indicators having measurable economic, social, and environmental benefits.

Source adapted from Khor and Lalchand (2014)

3. Electricity market reform model for Malaysia

3.1 The current generation market design and proposed reform initiatives

3.1.1 Current market design

Globally, the objectives of power sector reform and restructuring have generally been to provide a competitive environment in the power sector and increase efficiency (Poudineh et al., 2018). The reform of the Malaysia Electricity Supply Industry (MESI) was initiated in 1992 with the introduction of Independent Power Producers (IPPs). Since then, MESI has evolved by adopting new elements, which include the Single Buyer model framework.

Single Buyer model

The Single Buyer model is a market framework in which a government-backed central agency is responsible for the procurement of electricity from generators, often through term contracts. This is in contrast to fully liberalized electricity markets, in which there are multiple competing buyers and sellers. In Malaysia, the Single Buyer was established as a ring-fenced regulated department within TNB in September 2012, based on the Electricity Supply Act (ESA) of 1990, in order to conduct electricity planning, and to manage electricity procurement services for Peninsular Malaysia. The Single Buyer department oversees least-cost dispatch scheduling, managing the PPAs and the settlement process (Aris et al., 2019). It also monitors the adequacy of gas and coal supply as well as hydro levels, to ensure that they meet the week-ahead and the three-months-ahead dispatch schedules, and are able to respond to any unexpected curtailment or disruption to the planned supply and delivery of forecast quantities of gas and coal. The Electricity Supply (Amendment) Act 2015 defines ring fencing of the Single Buyer as identifying and isolating the activities, assets, costs, revenues, and service obligations of Single Buyer from the licensee, TNB, through accounting, financial, or legal separation. Ring-fencing of the Single Buyer is further fortified by the Guidelines on Ring-Fencing Practices and Procedures for Single Buyer (Peninsular Malaysia). The ring-fencing requirement is an important aspect of the Energy Commission's regulatory framework, to ensure that the Single Buyer can meet its functions in a fair and non-discriminatory manner.

The Single Buyer buys electricity from generators based on a least-cost approach, such that the lowest marginal cost generating unit is dispatched first, followed by the next-lowest marginal cost generating unit, until all demand is met. This approach is also consistent with the terms and conditions of Generator Contracts, Daily Heat Rate, and Variable Operating Rate Bids or Daily Price Bids (EC, 2015), as required by the Single Buyer Market Rules and the New Enhanced Dispatch Arrangement (NEDA) Rules.[17] The Single Buyer takes into consideration the generation and transmission network constraints and configuration, and all relevant system security and safety parameters as specified in the Grid Code for Peninsular Malaysia. The Grid Code is a regulatory instrument used to coordinate the various electricity supply activities of electricity producers, the operator, distributors, and consumers.

The short-term adequacy of supply is based on the three-months-ahead dispatch schedule, the week-ahead dispatch schedule, and the day-ahead dispatch schedule.

- The purpose of the three-months-ahead dispatch schedule is to provide information to generators to assist them with their fuel planning and purchase decisions.
- The week-ahead dispatch schedule aims to optimize weekly scheduling and fuel mix, and to provide forecast scheduling information to generators, while ensuring that operating reserve requirements, transmission constraints, generation constraints, and fuel availability are met.

[17] NEDA, which was supplementary to the Single Buyer Rules, introduced short-run competition in daily generation dispatch among IPPs with PPAs, TNB Generation with Service Level Agreement, and merchant generators without PPAs. It aimed to enhance cost efficiency in generation through short-run competition, enable energy-efficient options such as co-generation to participate in the electricity market, and provide the opportunity to non-PPA/SLA generators to sell electricity to the Single Buyer to enhance their business options by maximizing the use of existing facilities for the advantage of both the electricity supply industry and the consumer, in a cost-efficient way (EC, 2016b).

- The day-ahead dispatch schedule fulfils the same requirements but on a shorter time scale, whereby the generators submit their daily availability declarations, the NEDA participants submit their bids, the Grid System Operator submits transmission outage plans to the Single Buyer, and the Single Buyer outlines the load forecast to ensure the security of fuel supply.

The Grid System Operator (GSO) is a ring-fenced entity within TNB; it is responsible for operational planning, real-time re-scheduling, dispatch, and control of the Peninsular grid system in compliance with the provisions of the Grid Code.

To maintain the security of supply, the Single Buyer identifies gaps in short-term resource adequacy based on the three-months-ahead dispatch schedule and the week-ahead dispatch schedule and informs the Energy Commission (EC) if any supply shortfall is identified (EC, 2016a). The Single Buyer also notifies the EC about future new generation capacity requirements based on long-term capacity projection. The Energy Commission then develops requests for tendering for new generation capacity, taking into account the forecast shortfall, the generation type (for peaking or baseload), the type of fuel, as well as the requirements for ancillary services.

Payments and costs in Single Buyer market

In Malaysia, a Power Purchase Agreement (PPA) is an agreement between IPPs and TNB, on behalf of the power sector, whereby the duration of the contract for gas-fired power plant is 21 years and 25 years for coal power plants. IPPs are awarded licences to operate by the Energy Commission, based on the terms of power purchase agreements with TNB. A PPA between TNB and IPPs operates on a fully dispatchable basis – in other words, all capacity must be available to the national grid at any time, except during scheduled maintenance or forced outages. The payments by the Single Buyer to generators consists of an energy payment and a capacity payment.

Capacity payments are a means to achieve resource adequacy when there is a possibility of inadequate electricity supply as a result of, for example, lack of investment, increased demand, and/or retirement of old power plants. Capacity payments in Malaysia comprise the Capacity Rate Financial (CRF) (a fixed element to cover debt service) and a fixed operating rate, which covers fixed operating costs (JT, 2008). The payment (which is subject to availability requirements being met) in RM/kW/month is for capital and fixed costs that are not covered by the price of energy per kWh, and it also provides incentives for generators to be available at times when the system needs generation capacity. An allowable rate of return is included in this component (JT, 2008).

Energy payments are expressed in RM/kWh, and cover the fuel cost incurred by generators as well as other variable operating expenses. IPP fuel cost is fully passed through under the incentive-based regulation (IBR). Variations in the forecasted fuel cost factored into the base tariff are accounted for in the Imbalance Cost Pass Through (ICPT) surcharge mechanism as allowed for in the PPA. Total TNB and IPP fuel costs represent about 40 per cent of TNB's total operating cost in Peninsular Malaysia. (Parliamen Malaysia, 2016). The Energy Commission establishes the two components of Single Buyer Tariff arrangements for the purchase of electricity, under the IBR framework:

i. Single Buyer Generation Tariff, which includes:
    - energy payments, available capacity payments, fuel, and any other payments from the Single Buyer to the generators;
    - costs of importing electricity;
    - arrangements for the pass-through of fuel and additional generation-specific costs, with more frequent adjustments to the Single Buyer Generation Tariff to account for the relatively higher level of volatility for fuel-related costs.

ii. Single Buyer Operations Tariff includes:
    - forecasts of efficient operating costs, excluding any costs incurred or revenues received as part of the Single Buyer Generation Tariff Component;
    - a return on the Single Buyer's regulatory asset base reflecting an efficient market-based cost of capital;
    - forecasts for efficient depreciation.

To supplement the Single Buyer Rules, NEDA is designed to enhance short-run competition (namely on the basis of scheduling and dispatch) and cost efficiency as well as to incentivize the power generators to be more efficient. The objective of NEDA is to provide the opportunity for non-PPA/SLA (service level agreement)[18] generators (which include expired PPA/SLA generators receiving power sector fuel) to operate as Merchant Generators and sell energy to the Single Buyer through competing in the new system of daily bidding for electricity prices (EC, 2016b). This arrangement enables small merchant generators such as co-generators, small RE generators, and franchise utilities below 30 MW to participate as Price Takers, while also enabling participation of large merchant generators (for example co-gen plant, renewable plants, and franchise utilities) above the export capacity of over 30 MW (MPI, 2017).

Generators that have signed PPAs are also allowed to compete in the NEDA system based on variable operating rates (VOR), rather than the fixed rate in their PPAs or SLAs (Aris et al., 2019). Therefore, generators can decide to bid for a VOR that is lower than their PPAs/SLAs, in exchange for more dispatch hours. Hence, better managed and more efficient power plants are able to generate more money as compared to their competitors. This, however, will not affect the capacity payment (Aris et al., 2019). The active generators need to declare their daily availability, which is used by the Single Buyer, together with the PPA/SLA rates, to produce the day-ahead dispatch schedule based on the least-cost dispatch methodology (MPI, 2017). By opening the market to power generators with existing and expired agreements, NEDA aims to decrease the cost of electricity in the country (Aris et al., 2019).

Fuel supply in Peninsular Malaysia

Power plants do not have any direct financial benefit from the subsidized cost of gas. The fuel supply mechanism permits the IPP holder to perform its sole duty as the generator of electricity. Two companies supply coal and gas to power plants in Peninsular Malaysia: TNB Fuel Services (TNBF) for coal and Petroliam Nasional Berhad (PETRONAS) Energy & Gas Trading (PEGT)[19] for natural gas, under the terms of the relevant PPAs. TNB Fuel has been in operation since September 1998; it supplies 100 per cent imported coal to IPPs (including Kapar Energy Ventures, TNB Janamanjung, Tanjung Bin, and Jimah Energy Ventures)[20] based on Coal Supply and Transportation Agreements (CSTA).

Coal power plants are entirely owned and operated by IPPs, with the exception of a few that are fully owned, joint ventures, or subsidiaries of TNB (total installed capacity of coal power plants – 9.1GW of 25.4 GW) in Peninsular Malaysia. In FY2019, 65 per cent of coal supplies were imported from Indonesia, 21 per cent from Australia, Russia (11 per cent), and South Africa (2 per cent) (TNB, 2019). Total coal consumption by power plants in Peninsular Malaysia was 28.8 million metric tonnes in FY2019, generating roughly 68 TWh of coal-fired electricity (TNB, 2020). Under the terms of the PPAs, IPPs were guaranteed capacity and energy payments and this arrangement did not incentivize IPPs to source cheaper fuel, as the cost of fuel will ultimately be passed on to end consumers. With imported coal purchases also subject to exchange rate risks, price volatility becomes a potential concern for end consumers in this regard.

PEGT is the only company that supplies gas to TNB and IPP-owned gas power plants.[21] Of the total 10.98 GW gas power plants installed in Peninsular Malaysia (excluding co-generation and self-generation), 33 per cent are owned by TNB and 67 per cent by IPPs (NEB 2016). TNB, on behalf of the power sector, has PPAs/SLAs with all power generation plants (including its own). Gas Supply Agreements (GSA) are required to execute PPAs, and while individual power plants could sign a GSA

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[18] As opposed to IPPs who sign a power purchase agreement with the single buyer, TNB owns generation contracts with the single buyer based on Service Level Agreements (SLAs).

[19] In the effort to liberalize the gas market and to prepare for Third-Party Access (TPA), Petronas was unbundled and restructured to establish PETRONAS Energy & Gas Trading (PEGT) as the shipping licence holder, and PETRONAS as gas producer and supplier.

[20] Coal plants in the system according to TNB in 2020: Kapar Energy Ventures, Jimah Energy Ventures, TNB Janamanjung (Unit 1–3), Manjung Four, Manjung Five, Tanjung Bin (1–3), Tanjung Bin Energy, and Jimah East Power.

[21] In October 2019, an LNG trial cargo arrived in Malaysia to test the TPA arrangement via the Regasification Terminal (RGT).

contract with any gas supplier, PETRONAS has been the sole supplier so far – thus, all GSA contracts as of 2019 are with PETRONAS.

Gas Framework Agreements (GFAs) and Gas Sales Agreements (GSAs) govern the terms of the supply of gas to generators. GSAs are contracts that govern the supply of gas to individual generators by PEGT. However, under the current PPA structure, generators are not in direct control of their dispatch (and hence gas offtake), as all dispatch instructions are under the purview of SB and Grid System Operator (GSO). Additionally, in 2013, with the introduction of the regasification terminal in Melaka, the Economic Council decided on a two-tier pricing mechanism (Regulated and Market Price) for gas prices to the power sector. In light of these developments, the GFA was proposed to act as an overarching agreement between PEGT and TNB to recognize the roles of SB and GSO, as the central body in managing the gas supply to the power sector. The GFA would manage, amongst its other duties, the gas supply risks, gas differential payments, and the two-tier pricing mechanism for the power sector as a whole. The gas price to the power sector follows a single tier pricing mechanism, beginning in 2020.

The price of gas sold to IPPs by PEGT is uniform, shielding them from price volatility. The prevailing gas price paid by the plants to PEGT is called the Reference Market Price (RMP), and it is used to determine the energy payment to IPPs. Any savings (namely the difference between the forecasted RMP in the base tariff and the actual RMP charged to the power sector) are adjusted in the Imbalance Cost Pass Through (ICPT) mechanism under the IBR framework. At the time of writing, PEGT had started to declare a gas price-based Reference Market Price (RMP), as the regulated gas price had reached and converged with the market parity level. Therefore, the previous two-tier gas pricing mechanism will no longer be used as, starting from January 2020, only single-tier gas pricing based on RMP will be declared by PEGT to the power sector.

Transmission and distribution system in Peninsular Malaysia

TNB owns the transmission and distribution system in Peninsular Malaysia. The transmission system comprises double-circuit 500 kV, 275 kV, and 132 kV transmission lines connecting power stations and demand centres. The grid system is operated by a ring-fenced entity, GSO, which manages the grid and coordinates all parties connected to the transmission network. When a power plant seeks to connect to the grid system, it has to meet several conditions and criteria that are set out in PPAs and fixed by the Energy Commission and the grid owner based on Malaysia's Grid Codes. These stipulations are usually placed before any actual connections are made, to ensure that the connection-seeking generator meets all the requirements necessary, which include producing electricity with an acceptable power quality, in order to minimize grid management costs.

The distribution network refers to parts of the grid that operate below 132 kV (66 kV, 33 kV, 22 kV, 11 kV, 6.6 kV and 400 V)[22] and is comprised of electric lines, cables, substations and associated equipment. Similar to the transmission system, there are regulations and technical requirements (namely a Distribution Code) that need to be met by all parties involved in the planning, managing, and maintenance of the distribution network, in order to ensure security, safety, and reliability at all time. An emerging trend in power systems around the world, driven by the adoption of renewables (for example rooftop solar) and battery storage, is increasing decentralization – implying more generally that the importance of the distribution network is likely to increase in the medium-term future.

3.1.2 Challenges in the current market model and proposed reform initiatives

Malaysia currently has a single-buyer market model for electricity, whereby generators sell their electricity to the buyer at the price agreed in their PPAs. This also means that competition, if any, is only present at the generation (upstream) level. In general, the main advantages of a single-buyer model have been identified as providing a relatively simple first step toward higher levels of competition. However, single-buyer models require a higher level of regulatory complexity than more competitive market structures, as they need to be supplemented/supported by a comprehensive regulatory framework to ensure that all players are incentivized to act efficiently. In addition, competitive market

[22] In Malaysia, 132 kV and above is for transmission network (EC, 2016a).

structures naturally align with optimal operation of the different segments of the electricity sector – generation and retail supply are amenable to efficient operation under competition, whereas networks are amenable to being operated as regulated natural monopolies.[23]

Besides the regulatory complexity associated with the single buyer, there are other challenges in the Malaysian electricity market. The early encouragement of IPPs and private investment from 1993, while injecting immediate competition into the electricity sector via the generation segment and placing top priority on uninterrupted and reliable power supply for business, also inadvertently led to the buildout of excess capacity. For instance, by 2003, the power sector had reached a reserve margin of 56 per cent – considered higher than the efficient threshold – as demand slowed, in part due to the economic slowdown during 1997–99.

To reduce excess capacity, in 2005, the government initiated a 10-year programme. It was decided that all IPP licences would be tendered out by the Energy Commission (EC) to attain an optimum price for generating electricity (Hisyam, 2014; Choon, 2016). Tendering not only controlled capacity deployment, but also had the benefit of lowering the IPPs' cost of generating electricity, which had been higher in the past when compared to generators owned by TNB (Aris et. al., 2019; Choon, 2016). Overall, surplus capacity (in Peninsular Malaysia), which peaked at an all-time high of 56 per cent in 2003, declined to 53 per cent in 2009 and stood at 36 per cent in 2017 (NEB, 2017; Choon, 2016).

The absence of a liberalized market also has potential adverse extended impacts on other parts of the industry, such as fuel suppliers. For example, Petronas has to forego earnings – the opportunity cost – if it could have otherwise sold gas at higher market prices instead of at the determined price to IPPs.

Power sector reforms, as described in subsequent chapters, aim to resolve these issues and focus on improving efficiency in terms of the governance, industry structure, fuel supply and security, and tariff. With the liberalization of the power sector, competition is expected to be made more extensive with the presence of more industry players (retailers) to bid and purchase electricity from the power producers. The objectives of MESI 2.0 are to increase the industry's efficiency, to future-proof the industry, structure, regulations, and key processes, and to empower the consumers (Aris et al., 2019). The single-buyer model will evolve into a more competitive wholesale electricity market and competition is expected to be extended beyond the generation level along the value chain. Retailers who purchase electricity from power producers in the wholesale market will be selling it to the end users who are allowed to choose their preferred retailers, thus creating competition at the retail level – in other words, the retail market.

Figure 3.2 shows the government initiative to liberalise the electricity market under MESI 2.0 (currently under review) as compared to previous electricity market structure (Figure 3.1). One objective of liberalization is to have market-based competition throughout the value chain, as opposed to the current model in which competition only exists at the generation level (Aris et. al. 2019). Another objective is to promote cross-border trade with neighbouring ASEAN countries to enhance efficiency of operations. The transmission grid is connected with neighbouring countries, while Peninsular Malaysia has arrangements to procure electricity from Laos and Thailand – further commercial arrangements with neighbouring countries to increase electricity trade could be put in place. Through the interconnection, surplus capacity can potentially be exported to other countries in the future and vice versa, hence creating cross-border competition, and improving overall efficiency. However, unbundling (structural, accounting, and legal separation of the electricity sector into its functional components – generation, transmission, and distribution) is the prerequisite to the creation of such a competitive market (Thomas, 2006). This is why, under the current reform initiative (MESI 2.0), a third-party access (TPA) framework is envisioned for the transmission and distribution networks in order to facilitate competition in generation and retail supply markets, by allowing buyers and sellers to participate more actively and directly in the system while avoiding duplicative infrastructure costs. TNB will still own the transmission

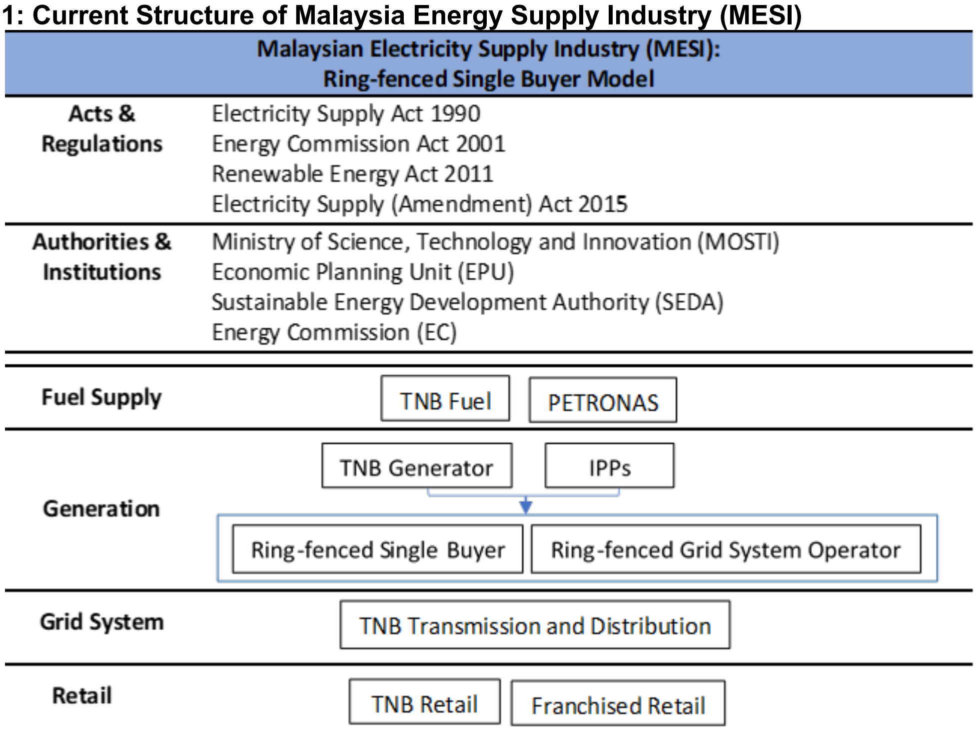
[23] See Poudineh et al. (2018) for further exposition.

and distribution networks, but the grid system will be opened for third-party access by other generators, subject to an access regime.

The reform initiative in the previous round of reforms imposed competitive tendering for new IPPs commencing in 2010, and renegotiation of existing IPPs on PPA extensions (due to delays in the commissioning of new power plants), which impacted the level of the reserve margin. For example, the reserve margin reduced to 25 per cent in 2014, compared to between 31 and 45 per cent in the period 2001–2013. Although high reserve margins can guarantee uninterrupted electricity supply to consumers, the cost of unused capacity will ultimately be transferred to the consumers. According to the previous Minister of Energy, Science, Technology, Environment and Climate Change (MESTECC), around 30 per cent of the electric bill is for capacity payment, which depends on electricity supply reserve margin and the terms in the power purchase agreement with the IPPs. In 2018, the electricity reserve margin in Malaysia was at 32 per cent and continuation of new IPPs with PPAs will increase the reserve margin, which will lead to an increase in the capacity payment (Kumar and Zainuddin, 2018).

Other important reform initiatives include third-party access (TPA) to the gas network (this preceded MESI 2.0), as well as lifting the monopoly over coal supply. Under the 10-year masterplan (currently under review), the government is looking into enabling IPPs to procure their own coal, through an incentive mechanism to encourage players to purchase fuels competitively and share the savings. Thus, IPPs could find alternative coal suppliers – currently, coal is 100 per cent supplied by TNB Fuel Services Sdn. Bhd. (TNB Fuel)[24] to coal power plants. In the gas industry, the Gas Supply Act (Amendment) 2016 was implemented to enable the participation of third parties in the gas industry and access to regasification terminals and gas pipelines. A TPA pilot phase was introduced in 2019, under which a maiden Liquefied Natural Gas (LNG) trial cargo arrived in Malaysia in October 2019 to test the TPA arrangement via the Regasification Terminal (RGT).

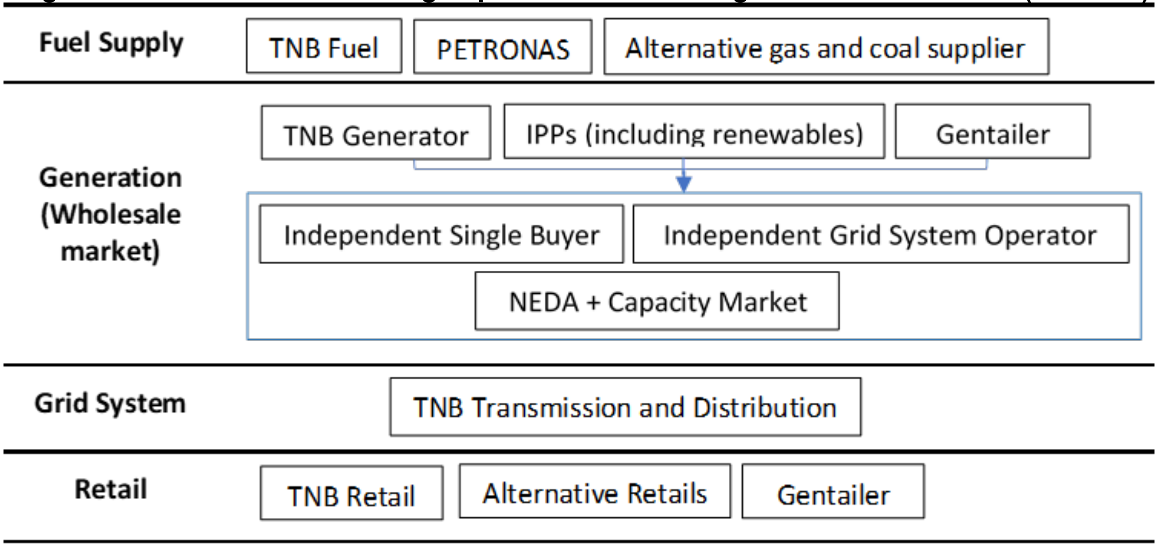
Figure 3.1: Current Structure of Malaysia Energy Supply Industry (MESI)



Source: EC (2013), Zamin et al. (2013)

[24] TNBF was established following the Cabinet Decision to purchase coal for the power sector, taking into account the cost-effectiveness of procurement.

Figure 3.2: Planned restructuring of power sector under government initiatives (MESI 2.0)



Source: EC (2013), EC (2017b)

The government also intends to further reform the SB and GSO into independent entities. In July 2015, the Electricity Supply Act (ESA) 1990 was amended (Electricity Supply (Amendment) Act 2015) to allow the functions of the SB and the GSO to be ring-fenced from TNB. This Act also includes separation of the activities, assets, costs, revenues, service obligations, and functions of the SB and GSO from those of licensees (such as IPPs), to ensure independence and enhance transparency and competition. The Amendment is another step forward for the SB and GSO, en route to becoming an independent single buyer (ISB) and an independent grid system operator (IGSO). A report on the enhanced governance of SB and GSO was expected to be published in 2020. However, this current restructuring plan to reform the power sector in stages under a 10-year programme is subject to some uncertainty, in large part due to a reprioritization of economic policy to focus on the economic recovery following a government-mandated lockdown since March 2020 to control the spread of COVID-19.

The government also aims to empower consumers by giving them more control and flexibility in deciding what works best for them regarding their electricity consumption, as well as in determining how much their electricity bill will be. For example, the option to have time-of-use tariffs, peak and off peak, is already available for industrial and commercial customers through the Enhanced Time of Use (ETOU) scheme that encourages demand-side management. However, the rate is fixed for domestic consumers regardless of the time of day, and savings are only possible through consumers changing their consumption between different tariff tiers. A time-of-use tariff can enable flexible users to benefit from shifting their consumption to low-price hours. This not only lowers their own costs but also those of the power system.

3.2 Development of generation market design and market transition towards hybrid market

Countries around the world have adopted different approaches to electricity market liberalization, based on their context, and with varying degrees of success. On a global scale, decarbonization and renewables integration are catalysing a shift in the technological fundamentals of the electricity system, opening up possibilities for new commercial and business models around which markets need to reorganize. Uncertainty over the end point of this shift implies that the ‘ultimate’ or the ‘ideal’ electricity sector model is as yet unknown (Poudineh et al., 2020b). However, a trend can be seen in electricity markets around the world, post liberalization, towards hybrid structures in which short-term dispatch markets are combined with a market for long-term contracts.

As discussed earlier, Peninsular Malaysia's electricity reforms aim to restructure its electricity sector, taking into account not just economic growth but also the emerging trends around digitalization which are likely to shape the electricity system of the twenty-first century. Since 2009, many changes have already been introduced and implemented towards this end; these include competitive tendering for generation, followed by the IBR framework and Imbalance Cost Pass Through (ICPT) in 2015 (to bring prices more closely in alignment with cost variations), and changes in governance structures to enhance sector operations (including ring fencing of the SB and GSO). The goal since 2018 has been to continue extending reforms to improve the efficiency of operation of the sector and market competitiveness, to provide consumers with retail options, and to accommodate an increasing share of renewables in the system. The aim is to start the enrgy and capacity markets for the new capacity additions while maintaining the existing PPAs until they are expired. A fully competitive wholesale market is envisioned by 2029 over a 10-year staged timeframe. These planned reforms are currently being reviewed by the government. The key parts of these steps are third-party access to grid infrastructure and competitive fuel supply of gas and coal.

The current (2020) electricity market structure in Malaysia is such that TNB Generation and independent power producers own and operate power plants, while IPPs sign PPAs or SLAs with TNB on the basis of some technical and commercial terms. Given the timeframes required to establish competitive structures,[25] the next step for Malaysian electricity market reform is to establish a hybrid market structure – a structure combining market-based incentives while retaining some regulatory features – before further reform towards a fully liberalized market post-2029, as outlined by the Malaysian Electricity Supply Industry (MESI 2.0). A 'hybrid' structure would also be more adaptable to the eventual outcome of electricity transition (Poudineh et al., 2020b). The following subsections describe the three main components of a hybrid market structure:

- short-term electricity markets,
- long-term electricity contracts (and the interaction between the two),
- the ancillary services market.

They also discuss further sector reforms relating to these components, which are relevant for Malaysia's efforts in making effective policies and regulations, and building stakeholders' 'capabilities towards market liberalization'.

3.2.1 Short-term electricity market design

Short-term electricity markets are defined as markets that take place within one day of delivery; these include day-ahead, intra-day, and real-time balancing markets. Short-term markets are essential tools for dealing with demand variability in the system. In recent years, with the growth of variable renewables in the generation mix, the importance of short-term markets has increased because the system's variability is increasing due to the limited controllability and predictability of intermittent renewable resources such as wind and solar. The following subsections highlight the key elements in designing short-term electricity markets.

Pool versus decentralized market

A pool-based short-term electricity market is coordinated by a market operator and provides a foundation for building an open-access bid-based spot market. It is built on the principles of economic dispatch and creates a setting in the wholesale market for competition among the market participants (Hogan, 1998). A pool can be operated as a day-ahead market (for example the former England and Wales Pool) or as a close to real-time market (for example five minutes-ahead, such as in Australia). It is also possible to combine a range of market combinations, such as day-ahead, intra-day, and five minutes-ahead (Barroso et al., 2005). In a power pool, all generators offer price–quantity pairs for the supply of electricity, from which an aggregated supply curve can be determined (Barroso et al., 2005). The prices that are offered can be based on predetermined variable costs (for example Cost-Based Pools) or the generators can offer any price they like (for example Price-Based Pools) (Barroso et al., 2005).

[25] Typically, 10 years, based on European or UK experience.

The pool model allows for more accurate pricing, namely Locational Marginal Pricing (LMP), or a price per location instead of one uniform price. This price per location is based on the marginal cost of supplying the next increment of electric energy demand at a specific location (for example at each node, or based on a wider zonal approach) in the electric power network, accounting for both generation and network characteristics (Barroso et al., 2005). A pool model with LMP for every node is often regarded as an ideal short-term market model, as the nodal prices perfectly show the total costs of electricity supply at given nodes and manage congestion, while sending clear signals to market participants regarding requirements for new generating capacity or transmission lines in a specific location (Barroso et al., 2005).

Nodal pricing has one drawback – it results in significant variation in electricity prices across consumers based on their location, even though consumers are essentially consuming what is a homogenous commodity (electricity, or electrons). Hence it can create consumer dissatisfaction. If a nodal price mechanism was implemented in Peninsular Malaysia, there may be differences in terms of pricing for consumers in different regions or states. For example, one region (for example Kelantan) may have a higher electricity tariff as compared to other districts in the country, as it needs to build infrastructure to reduce congestion.

Some jurisdictions (such as Italy and the Nordic market) have adopted zonal pricing (a simplified version of nodal prices) rather than nodal pricing (which may not be immediately accepted by all electricity consumers, due to the price differentials). The apparent advantage of zonal pricing is the increased liquidity of a zonal market, as more parties can compete with each other on equal terms, as long as the congestion costs are considered. The disadvantage is that a zonal approach averages the nodal prices within a zone, making the price signals less efficient (Barroso et al., 2005).

It is also possible to have a voluntary power pool, in the form of a 'power exchange'; this differs from a power pool, as in the latter all generating companies offer price–quantity pairs for the supply of electricity to form an industry supply curve, whereas participation in an exchange is voluntary. Power exchanges have existed in Europe since liberalization, with the objective of increasing the liquidity of electricity trading, allowing for more efficient price formation. Power exchanges can also facilitate cross-border trade between countries, or between jurisdictions with similar electricity industry structures and regulations. Malaysia can consider initiating the adoption of a pool market for power trading with neighbouring countries that also have the same objectives. Yet, the case for a power exchange market with neighbouring countries is only possible if extensive reforms of the electricity supply industry are implemented to enable many sellers (producers) and many buyers (transmission system operators, distributors, and retailers/suppliers) to join the market (Aris et. al. 2019).

The alternative to a power pool model is a decentralized market mechanism based on physical bilateral contracts – hence sellers (generators) and buyers (retailers and eligible large consumers) freely enter into bilateral contracts for power supply (Barroso et al., 2005). However, generators could also become buyers (for example if they have a shortage of generation) and consumers can become sellers (if they have surplus and/or flexibility to offer); further, brokers often act as an intermediary between buyers and sellers dealing with contracts, and these types of transactions are referred to as Over the Counter (OTC) transactions (Barroso et al., 2005).

In reality, there will always be differences between the contracted volumes and the actual metered volumes (Barroso et al., 2005). Power systems are subject to several network constraints, depending on the actions of every market participant because each participant can impose an externality on others using the power system. For example, the ability of customer A to purchase power from generator B depends on the performance of generator C or of consumer D (Sioshansi et al., 2009). These complexities have raised the question of whether decentralized markets are able to efficiently and effectively commit and dispatch units while respecting power system constraints, as happens in centralized markets operated by a system operator (Sioshansi et al., 2009).

The UK market started with a centralized market in the original Electricity Pool, moved to a more decentralized design under the New Electricity Trading Arrangements (NETA), and then to subsequent reforms under the British Electricity Trading and Transmission Agreements (BETTA), which were intended to overcome some of the problems experienced under the original centralized pool design (Sioshansi et al., 2009). In the UK's decentralized electricity market, market participants only provide physical notifications on the amount of electricity they will generate or consume during the following period up to one hour before the gate closure. Any deviation from the contract, after the gate closure, will be dealt with in the balancing market. The price in the balancing market can be very high, to incentivize market participants to take a balanced position.

Market power

The exercise of market power in a generation market has the following harmful effects on overall economic welfare (Biggar and Hesamzadeh, 2014). In the short run, customers may choose to reduce their consumption, even though their marginal value is above the actual marginal cost of electricity supply at that time. Similarly, some generators might choose to increase their production, even though their marginal cost is above the actual marginal cost of electricity supply. Overall, there is a reduction in allocative efficiency – that is, the total output could be produced at a lower cost had prices not diverged from marginal costs. In the longer run, some generators may choose to invest in expanding their capacity even though it is inefficient to do so. Similarly, customers may be reluctant to invest in assets that increase their reliance on electricity as an energy source.

The incentive to exercise market power increases when there is a tight supply and demand balance, because prices can rise significantly. Electricity, as a commodity, also has characteristics that exacerbate the issue of market power – such as the difficulty of storing electricity, the steepness of the supply curve at peak times, and the lack of responsiveness of most customers to the wholesale price (Cretì and Fontini, 2019). In a conventional large power system, most small or medium-sized electricity consumers and the smallest generating units cannot impact on the wholesale market price through a change in consumption/output, and therefore have no market power. On the other hand, the largest generators might have a degree of market power, especially at peak times. These generators can strategically withhold capacity and thus raise market prices beyond the efficient level.

The issue of market power needs to be taken account when Malaysia establishes a wholesale market. Market power can happen both under centralized and decentralized market models, but the effect is more acute under a centralized market in which market participants can engage in a strategic behaviour to influence the spot price. A factor which has a very strong influence on the incentive to exercise market power is the hedge portfolio of a generator (Biggar, 2011). If the volume associated with the hedge portfolio at the profit-maximizing level of output is well below the profit maximizing level of output, the generator has a strong incentive to raise the market price above the generator's marginal cost curve. If the volume associated with the hedge contract at the profit-maximizing level of output is above or equal the profit-maximizing level of output, the generator does not have an incentive to raise the market above its marginal cost because it will not benefit from it. The generator can choose a hedge contract which has different levels of hedge cover at different prices.

This was one of the reasons that the UK moved from a centralized pool to decentralized bilateral contracts. Under the UK electricity market model, generators and suppliers need to have a balanced position (in other words, to have a bilateral contract for all the generation/consumption they give notification of to the national grid) and thus have no incentive to influence market prices. In a pool market, on the other hand, generators can exercise market power either by increasing their price bids or by making their inframarginal capacity unavailable, so that units with higher marginal costs set the market price.

Energy only versus energy & capacity market

From the perspective of commodity trading, there are two ways to arrange an electricity market. One is an energy-only electricity market in which energy (MWh) and ancillary services are the only commodities that are traded in the market. The other approach is to trade capacity (MW) in a separate market, or to have a mechanism that remunerates capacity in the existing market in addition to energy (MWh) and ancillary services. There are several key differences between these two models.

The energy-only market approach leaves generation expansion decisions to market participants, although price formation is still influenced by regulatory decisions (for example price caps in energy and reserves markets) (Botterud and Auer, 2018). Moreover, the energy-only market provides strong operational incentives, as generators cannot rely on income from mechanisms other than energy and reserves markets to recover their costs. They are also heavily penalized, in terms of losing money, if they are not available during scarcity situations when prices and scarcity rents are high. In a competitive energy-only market, generators bid their short-run marginal costs, and the hourly market-clearing price equals the marginal cost of the last generating capacity that clears the market, given that the demand does not exceed the available capacity. The fixed costs of the dispatched generators are recovered through two mechanisms: (i) inframarginal rents and (ii) scarcity rents. Inframarginal rents are reflected in the difference between market clearing prices and marginal costs of generation. Scarcity rents, again, are reflected in the difference between scarcity prices that are charged when demand exceeds the generation available in the market, and the marginal costs of the last available unit in the system.

A well-designed energy-only market, on paper, should be sufficient to guarantee resource adequacy. The main objective of the market designer is thus to improve price formation in energy and reserve markets.

One of the most important factors that affects price formation is price caps, in energy and reserve markets. The risk of market-power abuse during scarcity conditions often forces regulators to set a price cap in the energy-only market. Capped scarcity prices, however, may cause a missing money problem – a situation where electricity prices are not high enough at times of peak demand to recover the fixed costs of power plants and incentivize new investments (Joskow, 2006). The missing money can be caused by other issues too. For example, the failure to identify the issues and revise traditional approaches for procuring reserves and other balancing services by the system operator in a state-owned monopoly environment can cause a missing money problem (Hogan, 2016). A further cause of missing money, according to Hogan (2016), is the policies put in place to support investment in new resources – for example, renewables or nuclear – with the intention of introducing zero-carbon resource investment. Yet, such policy measures could distort energy price formation.

Apart from increasing or removing the price cap, another factor that contributes to price formation is enabling demand response (namely a reaction by consumers to price signals causing them to alter their demand). However, consumer participation in the electricity market – either directly, or indirectly through retail suppliers – has proved to be difficult. This is because of transaction costs and various other regulatory and market imperfections that prevent consumers from responding to price signals. In the absence of extensive demand participation, a move from fixed operating reserve requirements to demand curves for operating reserves can introduce some demand flexibility and improve short-term pricing, particularly during scarcity conditions (Hogan, 2005). However, generally improving scarcity pricing is not straightforward. In addition to the challenges of limited demand flexibility, price caps, and strict reliability standards, factors such as the growth of zero marginal cost resources may prevent optimal price formation in energy-only markets.

Given the issues with price formation in energy-only markets, another way to overcome the missing money problem is to establish a separate revenue mechanism known as the capacity remuneration mechanism (CRM) (Hogan, 2016). The objective of capacity remuneration mechanisms is to ensure the profitability of existing power plants and to support investments in new power plants by restoring the missing money of the energy-only market. By providing stable revenues for power producers, capacity mechanisms aim to increase both the short-run reliability and the long-run resource adequacy of power supply (Cramton and Ockenfels, 2012; De Vries, 2007; Joskow, 2008).

The capacity remuneration mechanism, however, operates outside energy and balancing markets. The system operator, or another central agency, often gauges how much capacity is needed to meet the reliability standard. The mechanism guarantees payments to providers of that quantity of dependable capacity, ideally above the providers' expected earnings in the energy and balancing services markets. There are different types of capacity remuneration mechanism such as:

(i) capacity payments which are explicit payments to power producers that are set administratively;

(ii) capacity auctions that are procurement auctions through which the system operator remunerates winners of auctions for capacity contracts;

(iii) capacity obligations placed on retail suppliers to hold or contract enough capacity to serve the load;
(iv) strategic reserves, capacity that is withdrawn from the market and made available to the system operator in exchange for a predetermined remuneration

(Andreisa et. al., 2020).

In Europe, the missing money problem in energy-only markets has triggered discussion on the need for additional markets to ensure that there is enough capacity to meet future demand and to back up increasing proportions of renewable energy sources (RES) in the long term (Brunekreeft and Meyer, 2011; Nicolosi, 2012; Cepeda and Finon, 2013). This has motivated numerous EU member states to consider moving towards an energy-plus-capacity market model (CREG, 2012). Capacity mechanisms have been implemented, or are in the process of being implemented, in several EU member states, and in the UK. The European Commission has approved, under EU State aid rules, electricity capacity mechanisms in Belgium, France, Germany, Greece, Italy, and Poland to ensure security of supply.

European countries have adopted different capacity mechanisms. For example, Belgium and Germany have chosen their security of supply risks to be addressed by strategic reserves. For Belgium, the strategic reserve is needed to mitigate the supply risks due to Belgium's high reliance on an ageing nuclear fleet and electricity import. For Germany, the strategic reserve is needed to ensure security of supply during the ongoing reform of the German electricity market and to manage the phase-out of nuclear electricity generation. In Spain, the capacity payment mechanism is determined on the basis of the system's long-term needs related to investment and technology availability. Meanwhile, in Ireland, a price-based mechanism is adopted by the regulator with annual funding. In the UK, a market-wide capacity market is adopted, in which capacity contracts are awarded through auction. The UK capacity mechanism was adopted to encourage sufficient investment in reliable capacity and to cope with the country's increasing reliance on unpredictable wind and solar generation.

The experiences of European countries can provide helpful insights in designing the market model for Malaysia. The conditions under which energy-only markets provide efficiency are quite restrictive, and it is very likely that barriers to price formation in the energy-only wholesale market do not allow resource adequacy to be achieved through the short-term price signal. Therefore, it is very likely that Malaysia will need to adopt additional instruments in addition to the energy-only spot market. One particular approach that has emerged in many countries around the world is the so-called hybrid electricity market model. In this design, the short-term electricity market is combined with a market for allocation of long-term contracts. The long-term contracts can be designed and awarded by a central agency such as an independent system operator. In the next subsections we discuss how this mechanism works.

3.2.2 Long-term contracts and separation of investment incentive from spot market price signal

One of the key challenges of power sector reform is that liberalized wholesale electricity markets might fail to ensure sufficient investment in generation capacity. Theoretically, an efficient electricity market design revolves around the reliance on market price signals to influence both short-term coordination for the dispatching of different resources, and long-term coordination to drive investment in adequate generation capacities to maintain security of supply (Roques and Finon, 2017). In the short term, it ensures the efficient operation of the total fleet of plants. In the long term, it signals a scarcity of capacity for different technologies via price signals that orient investors' long-term decisions. Consistency between short-term and long-term market coordination will be created when there is pure competition, perfect information, and no risk aversion (Roques and Finon, 2017). However, there are market imperfections – such as market power, information asymmetry, and risk aversion – that cause the short-term signal to fail, removing the incentive for long-term investment.

To correct for the inadequacy of short-term markets and to provide incentive for long-term investment, a combination of a cost-based spot market along with fixed-price forward contracts is provided to be effective (Joskow 1997). These long-term contracts can be procured by a central agency, such as the Single Buyer or the System Operator, or from generators and other resources who can provide resource adequacy. Alternatively, they can be imposed as obligations on retail electricity suppliers to secure contracts for the level of their demand. The counterparties to the fixed-price forward contracts sold to the electricity retailers, or offered by the central entity, will have a strong financial incentive to find the least-cost mix of new generation capacity to supply the energy they have sold in these forward contracts.

The short-term market can provide a mechanism for settlement of the imbalance between the price and amount of energy of the forward contract (if the quantity is also fixed in the forward contract) and actual generation in the spot market. In other words, the cost-based short-term market assures that generators will be paid, or will pay, for differences between the price of energy/amount of energy of the hourly production of their generation units and the price of energy/amount of energy that they have sold in a fixed-price forward contract during that hour. Electricity retailers can use this short-term market to clear hourly imbalances between the amount of energy they withdraw from the transmission network and their fixed-price forward contract obligation.

The fixed-price forward contract solution is the standard approach used to ensure a real-time supply and demand balance in markets for products with high fixed costs of production (Strbac and Wolak, 2017). The prospect of a high real-time price for the product provides incentives for customers to hedge this real-time price risk through a fixed-price forward contract. A supplier benefits from signing such a contract because it has greater quantity and revenue certainty. The potential for short-term prices at or near the price cap provides a strong incentive for electricity retailers and large customers to purchase their electricity through fixed-price forward contracts, rather than face the risk of extreme short-term prices. Purchasing these fixed-price (and fixed-quantity) forward contracts far enough in advance of delivery enables new entrants to compete to provide the energy, and ensures that retailers will receive a competitive forward market price for their purchase. These forward market purchases, far in advance of delivery, also ensure that the seller of the contract has sufficient time to construct the new generation capacity needed to meet the demand purchased through fixed-price forward contracts

The following subsection discusses the commodity (energy or capacity) to be used in a long-term contract; the subsequent one focuses on auctions design for the allocation of long-term contracts.

Commodity for long-term contract: energy or capacity?

A hybrid regime combines short-term markets with some form of centralized planning and long-term risk transfer arrangements to support investment in new capacity. The application of long-term contracts is not new and there has been some convergence between different long-term modules in the past decade, in particular in Latin America in the early 2000s, but also in the UK. The second wave of Latin American electricity market reforms in the early 2000s introduced long-term contracts to support and coordinate investment, in response to investment market failures (Batlle et al., 2010; Moreno et al., 2010; Rudnik et al., 2002, 2006). Long-term investment decision-making is henceforth largely driven by the auctioning of long-term contracts on capacity, as in Colombia (Larsen, 2004; Harbord and Pagnozzi, 2012), on energy, as in Chile and Peru, or on both, as in Brazil.

Long-term capacity contracts have the advantage that they focus strictly on capacity, and thus can ensure sufficient resources are available to meet current and future demand. They can also easily incorporate demand response and any contribution from power interconnection with other countries. However, the downside is that a capacity market cannot be integrated with a short-term energy-only market, because the two traded commodities are different (in other words, a short-term market only trades energy, whereas a capacity market trades capacity). An advantage of a long-term energy contract, however, is that it can be easily integrated with a short-term market through instruments such as a Contract for Difference (CfD).[26] Another advantage of an active forward market for energy is that other hedging instruments, such as 'swap contracts' – where a supplier and a retailer agree to a fixed price at a location in the transmission network for a fixed quantity of energy – are also possible. The

[26] CfDs incentivize investment in energy by providing project developers facing high upfront costs and long lifetimes with direct protection from volatile wholesale prices. They protect customers from paying increased support costs when electricity prices are high. CfDs have been used to support low-carbon energy buildout in the UK. A special UK entity, the Low Carbon Contracts Company (LCCC), acts as counterparty to the contracts awarded in CfD allocation rounds (auctions); its primary role is to issue the contracts, manage them during the construction and delivery phase, and make CfD payments (BEIS, 2020).

disadvantage of energy contracts, however, is that they might not ensure sufficient capacity in the system.

In Malaysia, a liquid forward market is yet to be developed and the government expects that the NEDA platform would create market liquidity to aid participants in managing short-term price exposure. In terms of the choice between capacity or energy for a long-term contract, the country needs to strike a balance between short-term market compatibility and the incentive to maintain or enhance the system's resource adequacy.

Auction design for allocation of long-term contracts

If long-term contracts are awarded by a central agency, they are usually allocated through an auction mechanism. Therefore, auction design will play a key role in releasing the objectives of resource adequacy. Inadequate auction design can have unintended outcomes. For example, according to Kruger et al. (2018), Malaysia (450 MW awarded solar PV capacity)[27] and Thailand (36 MW biomass and 5 MW biogas) have struggled to achieve some desirable price and timely investment outcomes, partly due to poor auction design (for example, ownership requirements; small project sizes; short bidding and implementation timelines) and implementation choices (for example political and regulatory uncertainty; poor quality documentation; poor governance).[28]

Auction design for the allocation of long-term contracts needs to cater for the structure of the electricity sector, the maturity of the power market, and the level of technology deployment. The increasing interest in auction schemes for the allocation of long-term contracts is driven by the ability to achieve deployment of technologies in a well-planned, cost-efficient, and transparent manner. Good auction design also provides opportunity for real price discovery, greater certainty in price and quantity, as well as ability to guarantee commitments. Another feature of auction design is that it offers regulatory certainty to investors in terms of minimizing the risk of challenge to investors' remuneration *ex post* as the market and policy environment changes. Furthermore, the risk of overpayment by consumers can be minimized by ensuring a competitive auction process.

The level of technology diversity is among the important factors that determines the level of competition in the auction. In technology-neutral auctions, different technologies compete among each other, which enables the deployment of the least-cost technologies. For example, in Brazil, renewable energy technologies were competing with natural gas power plants in the energy auctions. Apart from increasing competition, technology-neutral auctions reduce the risk of under contracting, due to the high level of participation by potential project developers in the bid. Technology-specific auctions, on the other hand, do not have the same efficiency effect as technology-neutral auctions, but they do provide guidance to developers and enable government to have some control over deployment of generation technologies. For example, auctions held under India's National Solar Mission focused on concentrated solar power and photovoltaic specifically. As such, India committed to a systematic auctioning scheme that promoted competition within each technology (IRENA and CEM, 2015).

Overall, there are key critical elements in auction design that need to be considered such as: bid design format, volume forecast, prequalification and non-compliance penalties, and discriminating policies with respect to existing and new generation plants.

There are various methods of bid design in the auction including: first-price and second-price sealed bid auctions, pay-as-bid and pay-as-clear sealed bid auctions, and descending clock auction. The choice between different formats of bidding depends on the various trade-offs that an auction designer faces with respect to balancing between efficiency versus revenue sufficiency and the possibility of collusion among bidders.

[27] The Energy Commission awarded 450 MW of PV capacity in its first Large-Scale Solar (LSS 1) tender round (Joshi, 2018).

[28] Other reasons were that some players didn't find a business case as solar panel costs were still high. At the same time, financing of these facilities was not easy.

Auction volume can be determined according to forecasted demand plus a reserve margin. Auctioning large volumes via a single auction may lead to rapid development of new capacity, but at the cost of reduced competition and higher prices. As bid prices are a function of supply and demand, volume caps may be implemented in order to ensure that the volume offered in a given auction remains below the total volume that the market can absorb (Poudineh and Hochberg, 2018).

Prequalification and penalties also have crucial implications for auctions in terms of overall efficacy. However, setting them at an appropriate level is not straightforward. For example, increasing the penalties for non-compliance and tightening prequalification criteria increases the probability of delivery, but at the same time reduces competition due to the reduction of eligible bidders.

Finally, auction design must not discriminate against existing capacity or new capacity, and must be carried out in a way that maximizes efficiency.

3.2.3 Interactions between short-term and long-term electricity markets

Long-term and short-term electricity markets have an impact on each other. First, the lead time of long-term contracts impacts upon types of generation that participate in the short-term market. A fixed-price forward contract for energy or capacity a day, month, or even a year ahead of delivery limits the number of firms and technologies that are able to provide this energy (Strbac and Wolak, 2017). For example, a contract negotiated one day in advance limits the sources of supply to only existing generation unit owners who can produce energy the following day. Even a year in advance limits the sources that can compete with existing generation unit owners, because it takes longer than 18 months to site and build a substantial new utility-scale generation plant in virtually all wholesale electricity markets around the world. Second, the lower the price spikes in the short-term market, the lower will be the incentive of market participants to enter into long-term contracts and to protect themselves from having price exposure (Strbac and Wolak, 2017).

To obtain the most competitive prices, at a minimum, most of the fixed-price forward contracts should be negotiated far enough in advance of delivery to allow new entrants to compete with existing suppliers. A restructured market will achieve long-term resource adequacy if a liquid forward market for energy exists at a time horizon of two to three years into the future before delivery, and there is adequate demand for energy at this time horizon (Strbac and Wolak, 2017). A liquid forward market at the two to three years delivery horizon implies less need for regulatory intervention into shorter-term forward markets. The regulator can raise the offer cap on the short-term market to allow price spikes to reflect the true scarcity rents. This will stimulate the demand for hedging products at various delivery horizons. By purchasing a hedge against the spot price risk at locations in the network where retailers or large consumers withdraw energy, buyers can obtain their energy at the lowest possible cost, relying on the financial incentive that the seller of the contract has.

3.2.4 Ancillary services market

Ancillary services are a set of services needed for the operational security of the electricity system, and consequently for the stability of electricity supply; they range from voltage and frequency support to system strength and black start. Conventionally, TSOs have utilized a combination of resources – such as thermal power plants, storage (examples: pumped hydro storage, capacitors), and reactive power control equipment (examples: synchronous or static compensators or capacitor banks) – to obtain ancillary services (Singh and Papalexopoulos, 1999) and to maintain grid frequency and voltage at desired levels, while provisioning some generation capacity as a reserve for contingency events (Stoft, 2002).

The key issues for system operators in relation to operational security have been sudden generation or load trip and extreme weather conditions. However, in recent years there has been an increased recognition that deployment of variable renewable generation sources (VRE) such as wind and solar introduces variability and uncertainty into power system operation. There are two questions when it comes to ancillary services: how these services can be procured, and what resources can be used.

Securing efficient procurement of ancillary services Traditionally, the obligation to procure these services is placed on a central agency, such as the system operator (transmission and/or distribution) which procures system services on both a short-term and long-term basis. It is also possible to have a decentralized model through stringent connection and access protocols that require participants to mitigate or eliminate the system security risks of their connection. A better approach is perhaps a hybrid model in which responsibilities and obligations for procuring system security services are split between new connecting generators and central agencies (Billimoria et al., 2020). Connecting generators need to make sure that they do not harm the system as part of their network access framework. The central agency is responsible for (1) procuring services that are unable/unlikely to be procured through access frameworks and (2) residual procurement of services for security conditions that were not anticipated in connection processes.

Resources used for ancillary services In terms of types of resources, the ancillary service market should be open to both traditional and non-traditional participants such as: large-scale renewable generators, battery storage, providers of distributed energy resources (DERs) including demand response, small-scale battery storage, and distributed generation.

In Germany, renewable energy generators, battery storage systems, and industrial loads were allowed – alongside conventional generators – to participate in the balancing markets in 2009. Between 2009 and 2015, the balancing market size in gigawatts (GW) decreased by 20 per cent and ancillary service procurement costs by TSOs decreased by 70 per cent. During the same period, system stability increased, which acted as one of the enablers of higher renewable deployment, resulting in an increase of 200 per cent of installed capacity of VRE. This experience indicates that allowing new resources to participate in ancillary service markets can help increase system stability while reducing costs. For example, devices such as solar PV or battery storage, which have an inverter-based interface with the power system, can provide reactive power support which can be introduced as a product in the ancillary services market (Ela et al., 2012). Reactive power support from large-scale wind and solar generation connected to the grid via inverters is also important in places where high-quality primary energy-based resources are far from the main load centres and connect to main load centres via 'weak' networks. Designing proper mechanisms to ensure that these assets contribute to reactive power control is also relevant. According to IRENA (2019a), such mechanisms can include effectively designed connection requirements (and grid codes) which might slightly increase capital costs for generators and thus guide investment decisions, as well as incentives designed specifically for the procurement of reactive power as a separate product.

Another example, distributed energy resources – such as rooftop solar systems, behind-the-meter battery storage systems, plug-in electric vehicles, and commercial and industrial loads – can provide ancillary services to system operators through price-based incentives, often referred to as 'explicit demand response'. By increasing liquidity and competition in the ancillary service markets, DERs can also help lower ancillary service procurement costs. DERs may be allowed to participate independently or through aggregators or retailers, depending on the market design in place.

According to IRENA (2019a), two key factors need to be considered in enabling new ancillary services:

> The first is to separate capacity and energy products. Separating balancing capacity products from balancing energy products can help to discover cost-effective resources in real time, while allowing VRE resources and other DERs to offer their energy flexibility in such markets. For this, the acquisition of balancing energy has to shift from yearly to monthly, or even daily, procurement. This will increase VRE resources and DER participation in ancillary service markets, thereby increasing system flexibility while leading to increased deployment of such resources.
> Balancing capacity gives TSOs the possibility of activating a certain amount of balancing energy in real time. For instance, automatic frequency restoration reserve (FRR) markets in Denmark and Spain, and manual and automatic FRR markets in Germany follow this approach (IRENA, 2017). However, only those generators that can offer balancing capacity can offer balancing energy in real time. If the procurement is only based on capacity products it does not reveal the most cost-effective resources in real time. It also restricts the

participation of various DERs, including VRE, because such products are procured well in advance and most VRE resources or DERs cannot commit capacity earlier than in real time.

The second is to separate upwards and downwards balancing products. The frequency up and down regulations should be procured as separate products. For instance, a combined-cycle plant operating at its minimum generation point could provide only regulation up, whereas a wind plant operating at its maximum generation could provide only regulation down. However, neither resource would be able to participate in the ancillary service market, which procures regulation up and down as a single service. Therefore, frequency up and down regulations should be procured as separate products. This will enable VRE resources, as well as DERs, to participate in ancillary service markets, thereby increasing system flexibility and resource deployment.

Based on an interview in 2019, Malaysia planned to achieve a target of 20 per cent renewable installed capacity[29] between 2020 and 2025, with a total renewable target of 3,758 MW (solar: 2,172 MW and non-solar: 1,586 MW). It will be possible to achieve this target with a Large-Scale Solar (LSS) programme in place if there is commissioning of solar installed capacity of 500 MW each year. In 2018, renewables in the system were 2,057 MW (off-grid and on-grid) which was approximately 6 per cent of total installed capacity in that year. The detailed shares of renewable installed capacity in 2018 were: 37 per cent biomass, 36 per cent solar, 23 per cent small hydro (<100 MW) and 4 per cent biogas (data provided by the interview respondent).

The provision of ancillary services, including primary and secondary operating reserves, is already embedded within the PPAs of existing generators, but with further growth of renewables, an appropriate market design could gradually be put in place with new ancillary services products as described above, in order to ensure the continued stability of the system. A market mechanism for ancillary services could provide incentives for more efficient resource allocation, potentially offsetting some of the requirement for enhancing grid infrastructure. Germany offers an example of a suitable ancillary services regime (Energy UK, 2017). There are four transmission operators in Germany, and all operators share a combined market platform for the procurement of ancillary services. The market is broadly designed into primary, secondary, and tertiary control products, which vary by required response time after an event that causes a net frequency imbalance. Primary and secondary control is used to provide both frequency response and balancing. Generation, DSR, and storage are able to bid into any or all of these products.

Malaysia can adopt a hybrid ancillary service market approach, where the system operator takes on the role of procuring residual quantities of system services that were not provided as part of grid connection access requirements (for example, if unanticipated system strength issues emerged in Malaysia's transmission grid, due to increasing integration of intermittent renewables). Formal approaches to residual procurement could involve contracting, organized auctions, or regulated self-build of equipment that provides operational security services. Given that the network is subject to asset-based economic regulation, it may be naturally incentivized towards asset buildout, though this could be balanced by regulatory performance incentive schemes. Regulations could also mandate specific procurement mechanisms, such as requiring network owners to contract, rather than self-build, equipment that provides system security services.

3.2.5 Retail electricity market

The Malaysian government is aiming to empower consumers by offering them greater control over their electricity consumption and supplier choice. This, however, requires unbundling to take place more extensively at the lower level (downstream) to create a retail market that allows independent retail companies to compete with incumbents for consumer demand. The consumer then can choose to

[29] 'Report on Peninsular Malaysia Generation Development Plan 2019 (2020 – 2030)', Energy Commission, February 2020. Available at: https://www.st.gov.my/en/contents/files/download/169/REPORT_ON_PENINSULAR_MALAYSIA_GENERATION_DEVELOPMENT_PLAN_2019_(2020_%E2%80%93_2030).pdf.

purchase her electricity from licensed independent retailers or from the main utility companies, based on preferences on price, quality of service, and other parameters.

To date, a few initiatives have been taken to facilitate retail choice in Malaysia. For example, the government recently announced the grid's 'green rider initiative', and a pilot for the opening up of retail has been initially scheduled for 2021, following the roll out of a retail regulatory framework.[30] The evolution of the electricity market towards greater retail choice is a gradual process, expected to take up to 10 years, depending on the progress of unbundling, the market designs and restructuring, TPA implementation, and participation of new players in the market.

In theory, retail competition puts pressure on both the sourcing costs of electricity (including the costs of hedging) as well as on the operating costs of retail (such as billing, metering, and credit assessment) (Poudineh, 2019). In the absence of consumers' switching costs, and low costs of entry and exit for independent suppliers, retail competition should result in cost-reflective tariffs that move with wholesale prices.[31] In principle, therefore, retailers must keep their margins to a minimum and pass savings to consumers when wholesale prices are falling, if they wish to maintain or enhance their market share. In the Malaysian context, retail competition would need to be preceded by other reforms (such as correcting the structure of tariffs) rather than being implemented in isolation.

Although the retail electricity market, in theory, provides efficiency, achieving a competitive retail market is not always straightforward. The experience of European countries shows that consumer disengagement is one of the most critical challenges facing the creation of a competitive retail electricity market. There are a range of issues that impede engagement, such as complexity of the retail market and electricity tariffs, transaction costs, uncertainty about the service quality of new suppliers, perceived barriers, and behavioural biases. Suppliers also face barriers to entry such as economy of scale, economy of scope, sunk costs, social and environmental obligations, and regulatory requirements. Furthermore, the retail margin is often very low, which can disincentive new entry. In Peninsular Malaysia, out of the RM0.395 per kilowatt-hour that customers pay on the average electricity tariff, the retail margin is actually only RM0.01. Hence, the efficiency gained is limited, especially for smaller users.

Achieving a competitive retail market for small users is particularly difficult. If there is a wish to target vulnerable consumers, a scheme could be devised to cover low-consumption consumers. However, these may not necessarily be vulnerable, as the household may consist of an individual or of a few people with relatively low consumption, or cover premises with small footage area or which benefit from self-generation.

Thus, it might be more effective if the retail electricity market is opened to competition initially for large consumers and only at a later stage for small users. This is because the cost of acquiring information and participating in a retail market is lower for large consumers compared with smaller ones. Over time, as information and communication technologies advance, the transaction cost of participation in the market for small users might decline, and it thus becomes easier to establish a competitive retail electricity market which includes all types of users. Apart from transaction costs, there is a range of behavioural biases such as choice overload, default bias, risk averseness, and time inconsistency, that act as barriers for the participation of small users in a retail market. Thus, there is a need for continuous education of consumers and awareness-improving campaigns.

There are also other pathways by which the benefits of market liberalization can be transferred to small consumers, such as households. Indeed, consumer empowerment can also be attained by encouraging small consumers to generate (renewably) their own energy and thus become prosumers. This, however, requires an appropriate incentive mechanism. Net energy metering (NEM), for example, would allow excess electricity generated from renewables to be exported back to the grid. It not only

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[30] At the time of writing the reform was under review.

[31] However, it is possible to have subsidized tariffs along with a retail market. The prerequisite for retail market competition is low barriers to entry for new suppliers and low barriers to switching for consumers.

increases the renewable share in the electricity generation mix, but also encourages consumers to participate at the retail level. The drawback of NEM is that it is the relatively better-off consumers who generally tend to opt for self-generation through, for instance, rooftop solar PV, thereby leaving a smaller pool of less well-off grid-connected consumers who then disproportionately bear the costs of the network, leading to problems around equity of access to the network, which needs to be evaluated and managed.

3.3 Policies, regulations and stakeholders' capabilities towards market liberalization

There are several capabilities that need to be created as prerequisites in a country or jurisdiction that wishes to liberalize its electricity sector.

Regulatory capabilities The first set of capabilities relates to regulatory capabilities, and includes: transparency of rules and regulation, independent and fair appraisal of market outcome, and an effective and independent regulatory system. International experience has shown that in jurisdictions lacking in these capabilities, market reforms often lead to undesired outcomes and sometimes even to a stalling or reversal of reforms. A major impediment to effective regulation in many countries has been the politicized nature of electricity within their different institutional contexts, implying that regulators often struggle to implement reforms such as tariff revisions (increases) (Rufin, 2003; Poudineh et al, 2020a). Rules and regulations need to be transparent from the outset, based on international best practices, with a clear, and ideally an independent, remit for the agencies responsible for their enforcement.

International experience provides some lessons. For instance, Thailand's Electricity Regulatory Commission (ERC) was established in its Energy Act of 2007 – and by definition was a quasi-government body. The Energy Act prescribes the role of the ERC to:

> 'promote competition in the energy industry and prevent abusive use of dominance in the energy industry operation and to promote fairness and transparency of the service provision of the energy network systems, without unjust discrimination' (Wisuttisak, 2012).

However, Thailand's electricity sector had been dominated by state-owned enterprises, and the Energy Act somewhat contradictorily tasked the ERC with 'supporting' the position of these enterprises. Thus, although the ERC was tasked with engendering competition in the sector, institutional problems, alongside a sometimes-volatile political environment, impeded the progress of reform (Sen et al., 2018). Regulatory capabilities can also influence the effectiveness of Third-Party Access regimes. For example, Indonesia's 2009 Electricity Law allowed full private participation in the supply of power for public use and open access for generation and distribution. However, the Law still provided Indonesia's state-owned electricity company – PLN – with priority rights to conduct its business throughout the country, and as it was the sole owner of transmission and distribution assets, this limited the effectiveness of TPA in practice (Sen et al., 2018). Regulatory capabilities may also need to expand for future electricity systems, to other parts of the energy sector in which the silos between different energy vectors and carriers (for example gas and electricity) are likely to dissipate; this has also been referred to as the 'systems' approach to energy sector policy and is being actively considered, for instance, in countries that have ambitious decarbonization targets (O'Malley et al., 2016).

Malaysia has arguably made a lot of headway in laying the ground for these regulatory capabilities, through legislation, the IBR and subsequent mechanisms enshrined within it. The 2015 amendment to the Malaysian Electricity Supply Act (ESA) recognizes the Single Buyer and the Grid System Operator as ring-fenced entities. The current institutions involved in electricity sector governance are the Energy Commission (EC) and the Ministry of Energy and Natural Resources (KeTSA);[32] these institutions develop policies and regulations. The overall objective of power sector reform initiatives has been to create an incentive-driven energy landscape. The government aims to enhance the governance of the

[32] MESTECC has been renamed KeTSA as of 2020.

SB and the GSO, enhance the capabilities of market facilitators and the regulator, as well as amending the Electricity Supply Act to accommodate electricity sector liberalization. Currently, the EC reports to the KeTSA. According to an interview respondent, the EC only regulates the gas and electricity sectors; however, about 60 per cent of the energy regulation of other sectors – such as industry or transportation – is not covered by the EC. In future it might be more efficient, in terms of planning, to establish a single governance system or entity that oversees the entire energy sector. The next step is ensuring the independence of the regulator, and perhaps merging the Sustainable Energy Development Authority (SEDA) – which is currently regulating and monitoring renewables – with the EC. The independence of the regulatory system is a critical prerequisite to a robust competitive policy framework, and there is a variety of regulatory governance models around the world from which Malaysia can draw. An independent regulator should ideally sit outside the purview of the incumbent government – that is, it should be an arm's length entity. An effective regulator must constantly monitor the market outcomes and only engage in an explicit regulatory intervention if there is a legitimate concern – and where the side-effects of regulatory intervention are lower than those of non-intervention in the market.

Knowledge-based capabilities Among other capabilities, Strbac and Wolak (2017) state that international experience in the industrialized and developing world has revealed some factors that are crucial to achieving lasting improvements in electricity industry performance and tangible economic benefits for its consumers. These include:

(1) the match between the short-term market used to dispatch generation units and how the actual electricity network operates,
(2) effective market and regulatory mechanisms to ensure long-term generation and transmission resource adequacy,
(3) appropriate mechanisms to mitigate system-wide and local market power,
(4) mechanisms to allow active involvement of final demand in the short-term market.

Often, apart from the design of these mechanisms, their effectiveness also requires that market participants are aware of the rules and regulations and that they have the knowledge of how to trade in newly established electricity markets. Training programmes for market participants are therefore also a prerequisite, in terms of establishing knowledge-based capabilities.

Institutional interface capabilities A third set of capabilities relates to the interface between generators, utilities, and financial institutions that closely engage with the power sector. An endemic hurdle affecting market liberalization and power sector reform in many Asian countries has been contract enforcement. The typical problem here is that distribution companies that are also responsible for retail supply in these countries may delay contractual payments to generators who are often private IPPs. This can create an atmosphere of acrimony and uncertainty and will often lead to a debt/liquidity crisis, impeding power sector liberalization. This has been seen in the past in countries such as India, Pakistan, the Philippines, and Thailand. For instance, in India, the latest amendment to the Electricity Act (2020) establishes a contract enforcement agency to ensure that payments to generators are made to the agreed schedule. Payment delays are often caused because distribution/retail supply utilities cannot recover the costs of their supply from revenues, and hence face problems paying their generators. However, the issue is not solely one of the creditworthiness of distribution and retail supply utilities, but rather, one of structural problems in these countries, relating to the interface of financial institutions with power sector entities. State-owned financial institutions often find themselves exposed to a large amount of 'bad debt' (NPAs) in the power sector, as distribution/retail utilities frequently need to tap state financial institutions to rescue them from debt crises. This set of capabilities should therefore target familiarizing financial institutions with the operations of the power sector, alongside contractual enforcement.

Stakeholder engagement capabilities A final set of capabilities relates to stakeholder consultation and policy evolution. The history of the power sector is one of change. Prior to the 'first wave' of power sector reforms in the 1990s, the sector was seen as best organized around large vertically integrated structures which supported economies of scale in electricity generation. Post the 1990s and in the 2000s, it became evident that the sector was more efficiently organized around the unbundled operation of competitive (namely generation and retail supply) and natural monopoly (transmission and distribution network) segments. As we move into the twenty-first century, it is very likely that future power systems will need to evolve further, and the process of policy evolution will continue. The trend towards decentralization in OECD countries (for example Europe) through the adoption of EVs, rooftop solar, and other disruptive technologies, for instance, indicates that consumer buy-in and stakeholder participation will be key factors in determining the outcomes of policy reform measures. Policy stability and policy change must therefore be ensured through establishing an enduring mechanism for stakeholder consultations – which can be at the national or local level. For example, India's state electricity regulators hold 'open meetings' with consumers prior to passing any regulatory orders – especially those related to tariff reforms (Sen et al., 2018).

Table 3.1 provides a summary of options for the reform of Malaysia's electricity market.

Table 3.1: Summary of options available for reform of electricity market in Malaysia

Element of electricity market	Options for reform
Wholesale electricity market	A wholesale electricity market can be designed as a pool in which all transactions happen in a centralized way – in other words, a system operator operates both the grid and the market. Alternatively, it can be designed in a decentralized way such that the system operator only operates the grid and balancing market, while most transactions happen between parties in a bilateral way or through power exchanges. A centralized model can easily accommodate locational marginal pricing but is susceptible to market power. The decentralized model, however, is less exposed to market power but it cannot accommodate locational marginal pricing for the purpose of dealing with congestion. With respect to trading, the options are an energy-only market versus an energy+capacity market.
Resource adequacy	It is unlikely that an energy-only short-term market can be sufficient to provide signals for both efficient investment and operation. Thus, a short-term electricity market can be combined with a market for allocation of long-term contracts. These contracts can be awarded through auction by a central body such as the system operator. The underlying product for the long-term contract can be capacity or energy. If long-term energy contracts are awarded, the short-term market can be a settlement mechanism for the long-term contracts.
Retail electricity market	Retail is one of the most challenging elements of a liberalized electricity market. It is not straightforward to establish a fully competitive and efficient retail market for all types of consumers right at the outset of restructuring. Therefore, a gradual approach to the opening of the electricity market to retail choice is recommended. A retail market can be started with large consumers first, and then over time it can be extended to other smaller consumers when these users gain sufficient experience about participating in the market. Policy makers also need to remove barriers to entry for independent suppliers, and barriers to switching for consumers.

4. Implications of decentralization for the Malaysian electricity sector

As Malaysia's electricity sector plans to integrate an increasing share of distributed energy resources, it is important to understand how these decentralized technologies might affect the requirements of grid management, wholesale market operation, system cost recovery, and investment. The following sub-sections discuss the potential for decentralized generation technologies, the impact of the growth of decentralization on the electricity market, and the implications of decentralization for electricity network tariff design.

4.1 Potential for distributed resources in Malaysia

There are multiple examples of 'distributed' resources:

- small-scale power generation units connected to the grid at the distribution level,
- demand-side response (alteration of consumption patterns by large- and small-scale electricity consumers in response to a market price signal),
- storage technologies (including battery systems and Electric Vehicles),
- other controlled loads.

Several factors have contributed to the growth of these resources. These include: electricity market liberalization, advances in distributed generation technologies (leading to better learning curves for these technologies and rapid cost declines), constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity supply, and concerns about climate change (IEA, 2017).

Among various distributed resources, distributed generation in particular is widely deployed in power systems around the world. Decentralized distributed generation can be defined as:

> generating plants that serve customers on site, or provide support to a distribution network and connect to lower-level voltages (IEA, 2002).

As decentralized generation plants are an alternative to large central generating plants, they will increasingly take over a range of services that are necessary for the operation of the power system (such as energy, capacity, and ancillary services) but which are traditionally provided by centralized generation (Jenkins et al., 2010). There are different types of distributed generation technologies, but the majority of them are based on renewable energy such as solar PV, small hydro and wind turbines, and more recently, solar rooftop tiles which obviate the need for solar panels (Mokhtari et al., 2017; CleanMalaysia, 2016). There are also fuel-based distributed generation technologies such as combustion engines, microturbines, fuel cells, diesel generators, and biomass. In what follows we discuss the potential for distributed resources in Malaysia.

4.1.1 Solar PV

Malaysia has significant potential for renewable energy-based distributed technologies such as solar PV. According to Sopian et al. (2005), the estimated technical potential for building-integrated photovoltaic (BIPV) power in Malaysia, based on available commercial, industry, and residential building surfaces, is about 11,000 Megawatt peak (MWp), which could generate about 12,000 GWh of electricity annually. Based on annual household electricity sales by TNB in Peninsular Malaysia of 24,828 GWh in 2017 (TNB had a total of 7.2 million household consumers in 2017), this would meet at least half of the total household electricity requirements. In 2019, the Ministry of Energy, Science, Technology, Environment and Climate Change stated that there are over 4.12 million buildings with solar rooftop potential in Peninsular Malaysia that could generate 34,194 megawatts (MW) of electricity if they are fitted with solar PV systems (Thomas, 2019). The solar PV systems are not only a means of promoting efficiency and reliability in the electricity system, but they can also be used for rural electrification – such as in pockets of rural Sabah and Sarawak. In countries such as Brazil, Cambodia, South Africa, China, Bangladesh, and India, solar PV has been used extensively to electrify rural areas which are far from the main grid, and for which the cost of grid extension is prohibitive, given the relatively smaller size of demand (Niez, 2010).

Malaysia's previous efforts to expand solar PV go back to the national SURIA-1000 programme, which was introduced in 2007 with a target of 1,000 kWp of BIPV, in order to enhance the development of renewable energy technology in the residential and commercial sector (Haidar et al., 2011). However, the process of solar PV installation has gained a new momentum in recent years. The Malaysian Building-Integrated Photovoltaic Project (MBIPV) was introduced in 2015 to encourage the installation of the building-integrated PV system (Hussin et al., 2012). In June 2019, the Seberang Perai Municipal Council (MPSP) in the northern state of Penang became the first municipal council in the country to install solar panels on the rooftops of public markets and some state government offices. In September 2019, a chain retailer in Ipoh, Mydin Mohamed Holdings Berhad (Mydin), installed 324 kilowatt-peak (kWp) of solar PV and expected to save up to RM3.24 million (US$773,000) in electricity bills throughout the system's 25-year lifespan (Thomas, 2019). In July 2020, Tesco Malaysia announced that 15 of its 62 Malaysia stores would be powered by solar PV, collectively generating about 18 GWh of clean energy each year (Wong, 2020).

The main business models for deployment of solar photovoltaic (PV) that are emerging in Malaysia are: solar leasing, solar power purchase agreements (SPPAs), or a hybrid of both. These models can be in the form of a bilateral contract between a solar investor and a client, or a tripartite agreement which includes Tenaga Nasional Berhad (TNB) under the Supply Agreement for Renewable Energy (SARE) programme. Other types of financing structures for solar PV include loans from financing institutions (of course, outright purchases without such loans are also possible, if capital is available).

The solar leasing programme is a popular approach, because it offers a low-cost option that makes it more attractive for customers to install solar PV. For example, GSPARX Sdn. Bhd. is a wholly-owned subsidiary of TNB that focuses on green retail generation, enabling investment in rooftop solar PV for all retail customers. Under the Net Energy Metering Scheme (NEM), GSPARX offers a solution for customers interested in solar PV self-generation and selling the excess of solar energy. If there is an excess or balance of energy, it will automatically flow to the TNB grid. And if consumers package their installation with NEM, they get credit for the excess energy to further reduce their bill, with the same rate for buying and selling to TNB.

Another example is Solarvest Energy Sdn. Bhd. which currently has a solar leasing option called the PowerLease Programme for commercial and industrial consumers that will negotiate a monthly payment plan for a specified period of time (often 20–25 years) (Tan, 2018). Under this leasing agreement, the consumer would pay the lessor for the electricity produced by the solar PV system at a rate 5–10 per cent lower than the TNB tariff. At the end of the period, the system will be owned by the consumer. If the consumers choose to work with TNB, the utility will collect the monthly payments from them and remit these funds to the solar investor in exchange for a fee (Tan, 2018).

As seen from the above, the installation of rooftop solar PV can potentially reduce the monthly bill of end users by committing to a fixed tariff offered by solar leasing companies. Since this tariff is fixed, it is shielded from any tariff hike for the term of the agreement. Customers committed to rooftop solar panel installations are also automatically signed up for the Malaysian government's revised Net Energy Metering 2.0 (NEM 2.0) mechanism of 2019. The concept of NEM is that the energy produced from the installed solar PV system will be consumed first, and any excess will be exported to TNB on a 'one-on-one' offset basis. The new NEM mechanism offers the same tariff for selling and buying electricity (see Table 4.1), and from the consumers' perspective this gives an incentive to opt for solar PV. In other words, were the buying rate to be higher than the selling rate, a consumer would face a disincentive to inject power in the grid. Conversely, were the selling rate to be higher than the buying rate, consumers may be incentivized into selling into the grid at a level that is sub-optimal from the system perspective, creating problems for the distribution network – for example congestion. Thus, the new mechanism is meant to encourage more customers to install rooftop solar and register with NEM. The quota for this mechanism is up to 500 MW on a first-come, first-served basis, and the mechanism will end by 31 December 2020 even if the quota is not reached. Following the success of Net Energy Metering (NEM) 2.0, in 2021, the Energy and Natural Resources Ministry (KeTSA) introduced the Net Energy Metering (NEM) 3.0 programme to encourage more users to install Solar PV systems on their rooftops for electricity bill reduction. For the NEM 3.0 the same quota size as the previous one is offered from

February 1, 2021 to December 31, 2023, entailing all energy consumers (e.g., residents, commercial and industrial)[33].

Apart from small-scale and distributed solar PV, the government of Malaysia introduced the Large-Scale Solar (LSS) programme in 2016 in order to expand the share of this resource in the generation mix. The Energy Commission (EC) of Malaysia has started the competitive bidding process for LSS to offer a total of 434 MW for Peninsular Malaysia, with a tariff ranging from 39.95 to 44.95 sen/kWh (Abdullah et al., 2019). The first round of LSS offered 434 MW. The second round of LSS bidding by EC offered 506 MW. The third round of LSS took place in 2019 with a total capacity of 491 MW awarded in Peninsular Malaysia. In 2020, Malaysia opened competitive bidding for 1 GW of solar plants worth about RM4 billion, the largest capacity offered under its LSS scheme – two packages offered through the tender are 500 MW for capacity between 10 MW and 30 MW, and another 500 MW for capacity between 30 MW and 50 MW (NST, 2020). These initiatives are expected to increase the share of solar PV in the generation mix of Malaysia significantly.

Table 4.1: Old NEM scheme (2016) and revised New NEM scheme (2019)

<table>
<tr><th>Old NEM scheme (2016)</th><th>Revised NEM scheme (2019)</th></tr>
<tr><td>• Any surplus energy sold to the utility will be credited in the next billing at displaced cost.</td><td>• Any surplus energy sold to the utility will be credited in the next billing at retail rate.</td></tr>
<tr><td>• Displaced cost in Peninsular Malaysia:
a. for low voltage (< 1kV): RM 0.31/kWh)
b. for medium voltage (1kV-50kV): RM 0.238/kWh)</td><td>• Domestic/gazetted tariff:<table><tr><th>Tariff Category (kWh)</th><th>Unit price (cent/kWh)</th></tr><tr><td>1-200</td><td>21.80</td></tr><tr><td>201-300</td><td>33.40</td></tr><tr><td>301-600</td><td>51.60</td></tr><tr><td>601-900</td><td>54.60</td></tr><tr><td>>900</td><td>57.10</td></tr></table></td></tr>
<tr><td>• Net Billing = [Energy consumed from distribution licensee (kWh) x Gazetted tariff (RM)] - [Energy exported to distribution licensee (kWh) x Displaced cost (RM)]</td><td>• Net Charge Amount = [Energy imported from distribution licensee (kWh) x Gazetted tariff (RM)] – [Energy Exported to distribution licensee (kWh) x Gazetted tariff (RM)]</td></tr>
</table>

Source: Adapted from TNB, SEDA, EC (2019b) and Razali et al. (2019)

4.1.2 Small hydro

Another distributed technology based on renewable energy is small hydro, one type of which is deployed in places where there is a flow of water or other fluids, such as a sewage outlet (Mokhtari et al., 2017). A small-scale hydropower station in the form of a run-of-river plant enables high efficiency to be reached over a wide range of water flows through spinning blades that control active power generation (Márquez et al., 2010). According to Heris and Ivatloo (2017), the significant advantages of small hydro systems are the elimination of the cost of transmission line construction and power loss, mitigation of environmental constraints, an increment of network stability, and peak load reduction.

In Malaysia, implementation of small hydro plants (defined as run-of-river schemes up to 30 MW in capacity), has been spurred on by the Renewable Energy (RE) Act 2011. Small hydropower plants often exist in three different sizes: full scale, mini, and micro. A full-scale small hydropower plant has a capacity of 10–30 MW, whereas mini hydro plants are typically in the range of 500 kW to 10 MW. Micro hydro, on the other hand, can range from 5 kW to 500 kW. Due to their small size, mini hydro plants in general do not supply electricity to national grids, but rather to groups of houses or local communities, using batteries.

The development plan for small hydro plants presented at the APEC Energy Working Group (APEC, 2013) recommended that the energy provided by small hydro schemes be increased substantially, from

[33] https://themalaysianreserve.com/2020/12/30/govt-offers-500mw-until-2023-in-energy-scheme/

60 MW in 2011 to 490 MW by 2020 (APEC, 2013). Small hydropower development is in line with the country's Small Renewable Energy Programme (SREP), which encourages the development of electricity generation from renewable sources. Under the SREP, owners of small renewable energy plants can apply to sell the electricity to the national utility through the distribution grid system. A separate yet complementary mechanism (administered by SEDA), the Feed-in tariff (FiT) scheme that was adopted in December 2011, provides a route for smaller RE plants to sell electricity to the utility through an RE Power Purchase Agreement (REPPA) (Nasab, 2012). As of 2020, the installed capacity of small hydro under the country's FiT programme reached 20 MW, and the plants in progress were about 84 MW.

The share of mini hydro and micro hydro is also improving. As of 2017, TNB operated 21.96 MW of small hydro capacity. Overall, small hydro plants constitute an important part of Malaysia's renewable energy strategy, in meeting the local small-scale electricity demand. However, development of small hydro schemes in this country is not free from challenge. The issues range from unexpected water flows resulting from dry seasons, to regulatory requirements such as land acquisition, environmental impact assessment, as well as financial support (APEC, 2013).

4.1.3 Wind power

Small-scale wind turbines, as a distributed generation technology, are potential sources of renewable power for local communities and small group of homes (Mokhtari et al., 2017). However, the potential for development of this technology has not yet been entirely explored in Malaysia. Exell and Fook (1986), studying wind energy potential in Malaysia, find that the overall prospects for the application of wind energy in Malaysia do not appear to be very good. They suggested that small wind turbines could be used to provide electricity on the relatively underdeveloped east coast of West Malaysia and the offshore islands. Sopian et al. (1995) suggested that Mersing and Kuala Terengganu have the most significant wind power potential in Malaysia due to the Northeast monsoon. They concluded that small-scale wind turbines could be used to provide electricity for under-developed areas and for those regions which are not connected to the national grid. In 2007, a pilot wind power plant was developed in Terengganu. Yet the project was not successful, due to the failure of the wind turbine to generate the desired level of electricity, most likely because of the choice of turbine technology (Albani and Ibrahim, 2017). It is suggested that suitable technology for low wind conditions needs to be explored in Malaysia, to harness the untapped potential of wind power (Abdullah et al., 2019).

Apart from the need for wind resource-compatible turbine technology, a robust regulatory framework is required to unlock the potential of wind technology in Malaysia (Ho, 2016). Support and incentives from the government are especially important at the initial stage of deployment of wind power (Abdullah et al., 2019). The absence of wind power technology in the feed-in tariff support scheme in Malaysia, for example, makes it difficult for these projects to achieve economic viability.

4.1.4 Combined heat and power (CHP)

Cogeneration, or combined heat and power (CHP), is a distributed generation technology with high fuel efficiency and low incremental capital costs for heat-recovery equipment. CHP plants make use of the waste heat from thermal electricity generation for either industrial process or space heating and this increases the overall energy efficiency (Jenkins et al., 2010). Around the world, more than 80 per cent of CHP capacity is in large industrial applications, mostly in four industries: paper, chemicals, petroleum refining, and food processing (IEA, 2002). CHP plants can be oil-fired or diesel-fired engines (designed principally to meet peak electricity demand). They can also be in the form of gas or steam turbines or be biomass based. CHP plants have been extensively used in many places such as the EU, due to government-supported policies.

The Malaysian government promotes the use of CHP in industry. By 2017, 23 private licences and ten public licences had been issued by the Malaysian Energy Commission in Peninsular Malaysia (EC, 2017c). These licences were for installing CHP for industrial cogeneration, fully integrated cogeneration, and district cooling (Hashim et al., 2010). According to MEIH statistics, examples of large CHP plants in Malaysia are Malaysian Refining Company Sdn. Bhd. in Melaka and Centralised Utility Facilities (CUF) in Terengganu as well as in Pahang. Another example is the Pengerang Cogeneration Plant, situated in the Pengerang Integrated Complex, Johor (EC, 2017c). In 2014, Gas Malaysia Berhad, a gas distribution company, entered into a joint venture with Energy Advance Co. Ltd. (Enac) of Japan to develop CHP plants (The Edge, 2014). The plan was for CHP plants to use gas as the primary source of energy to generate electricity, steam, or heat for customers to use in their production, with the aim of reducing energy, particularly electricity, costs. Relative to gas, biomass residues (such as palm oil residues and municipal solid waste) for electricity generation and cogeneration are underutilized in Malaysia, due to various factors that make it impractical to utilize all of the available residues for conversion into solid fuel, as well as financing reasons, and the opportunity cost of producing biomass power (Shafie et al., 2012). Although biomass and biogas have significant potential, stronger incentives may be required to catalyse investments in the sectors. Palm oil mills may not see this investment as worthwhile, as most mills harness biomass as a cheaper alternative for bioenergy. Mills also tend to lack grid access, while those that have access find the FiT rates unattractive given the heavy investments required. Biomass fibres also have an export market, which competes with the market opportunity for bio-power. (Edge Markets, 2020).

The use of CHP is very economical in industries with demand for both heat and power in Malaysia, yet its full potential has not been achieved. According to the Energy Commission, the demand for cogeneration plants is not high and is mainly driven by specific industries such as pulp and paper products, iron and steel, and chemicals (including petroleum and plastic products). Furthermore, the energy commission considers cogeneration plant applications more stringently and encourages their development for self-generation, or use of energy for own-consumption, in the first place. Only if there is a surplus waste of heat and steam could it then be distributed to other users, or sold to the grid in the form of electricity.

4.1.5 Energy storage

In recent years there has been a growing interest in energy storage in order to deal with the variability of renewable generation and to provide services to the grid (Akbari et al., 2019). Energy generated by solar and wind is intermittent and highly dependent on season and weather. Energy storage technologies store energy in various forms (such as electricity, heating, cooling, potential energy, kinetic energy, and magnetic field) and release or convert them to electricity when needed. This contributes towards grid stabilization, power quality and reliability, and load shifting; it also supports the integration of intermittent renewable energy sources (Walawalkar and Apt, 2008).

In terms of services provided to the grid, energy storage technologies can be divided into three categories (Fthenakis and Nikolakakis, 2012).

- *Power quality storage technology* regulates frequency and stabilizes the voltage of the electricity grid. Flywheels, electric double-layer capacitors, and superconducting magnetic storage are classified under this category.
- *Bridging power storage technology*. Examples of this category are lithium-ion (Li-ion) and flow batteries used for contingency reserves and ramping.
- *Energy management storage technologies* address variability in the system, which is manifested by peak and off-peak demand. Examples are pumped hydro energy storage and compressed air energy storage.

Among energy storage technologies, batteries are being used extensively by both residential and commercial consumers (Pimm et al., 2017). For example, lithium-ion batteries paired with solar panels are now frequently used for rural electrification, which allows households to use electricity for low-power applications such as lighting or mobile phone charging (Diouf and Avis, 2019). In Australia, a 100 MW lithium-ion battery is used with a wind farm to stabilize the electricity grid and address challenges of renewable variability (Hornsdale Power Reserve, 2017).

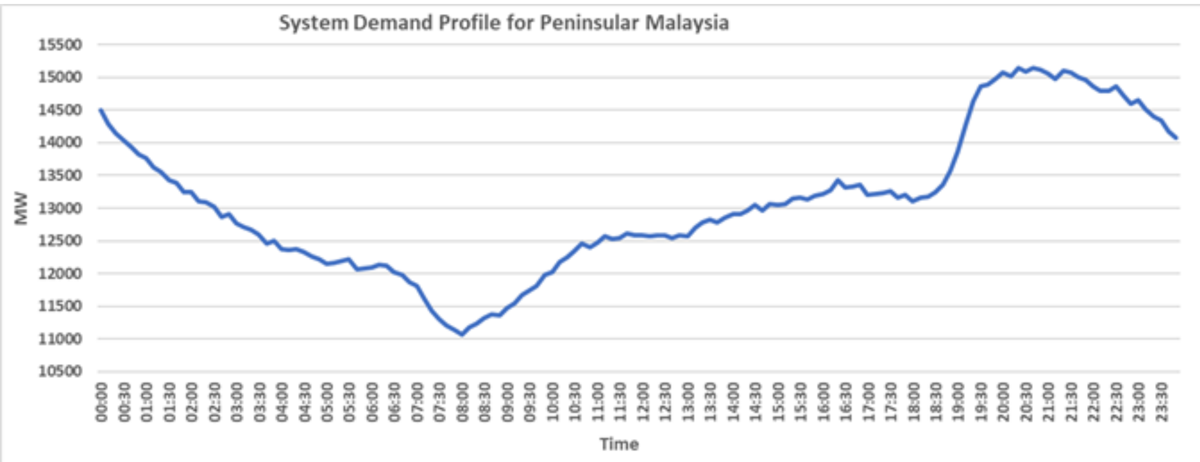
As of yet, there is no significant storage capacity in the electricity system of Malaysia. However, the country has potential for expansion of energy storage technology as it aims to become the marketing hub for electric vehicles (EVs) under the National Electric Mobility Blueprint (EMB). This could also enable Malaysia's plans to expand solar energy, while helping to minimize adverse impacts on system stability. Electric Vehicles also feature in Malaysia's National Automotive Plan 2020 – which outlines plans over the next 10 years to develop standards for EV interoperability (charging protocols, energy management system for the EV ecosystem, and safety standards for critical components) (Carsifu, 2020). According to Borneo Post (2017), Malaysia is targeting 100,000 electric cars,[34] 125,000 charging stations, 2,000 electric buses, and 100,000 electric motorcycles on the road by 2030. Along with promoting the use of electric vehicles, the government also initiated the ChargEV programme. This programme aims to give the public more convenient access to EV charging stations. By the end of 2018, there were 250 public EV chargers installed at shopping malls, hotels, Petronas petrol stations, and other selected public places (MGTC, 2019). In 2018, the ChargEV network recorded 254,802 kWh of electricity consumption.

With appropriate incentives (such as time-of-use electricity tariffs), electric vehicles can be incentivized to charge during the off-peak period in order to prevent them from exacerbating the existing demand profile of Malaysia (see Figure 4.1). As shown in Figure 4.1, the system demand in peninsular Malaysia starts to rise in the late afternoon and peaks in the evening, which is the same time at which the majority are returning from work. Thus, coordinated charging is necessary to avoid congestion in the grid.

Electric vehicles can also be used as a back-up storage during periods of grid failure or spikes in demand, using vehicle-to-grid (V2G) technology (Uddin et al., 2018). The city of Utrecht in the Netherlands is operating an ingenious storage system utilizing a Vehicle to Grid (V2G) system that uses electric vehicles' batteries as a storage unit for excess energy. Alongside innovative solar-powered electric vehicle charging stations, this technology could integrate with a more comprehensive smart grid to provide a resilient and creative energy generation and storage opportunity. Furthermore, second-hand EV batteries can be used as grid-scale storage when EVs are taken off the road. For example, 2,000 batteries from retired Mercedes Benz EVs in Germany have been used to create a stationary grid-sized battery and as second-hand storage that can hold almost 9 MWh of energy (EESI, 2019).

In sum, storage technologies are essential to increase the reliability and flexibility of current networks and to accommodate the projected high penetration of solar and wind energy in future decarbonized grids (Fthenakis and Nikolakakis, 2012).

Figure 4.1: System Demand Profile in Peninsular Malaysia (16 September 2020)



Source: Grid System Operator

[34] These targets are very ambitious given the current level of EV penetration in the country. The infrastructure is also not ready yet. As of September 2018, there were only 400 charging stations against the target of 3,000 by the end of 2018. 'Green transport the way forward', *New Straits Times*, 17 October 2019. Available at: https://www.nst.com.my/cbt/2019/10/530681/green-transport-way-forward.

4.1.6 Smart grids

Decentralization is not just about distributed resources. It is also about networks and especially distribution networks, which are becoming smarter. Smart grids are intelligently controlled active networks that facilitate the integration of distributed resources, such as distributed generation, residential micro-generation, storage, demand response, and EVs, into the power system (Janaka et al., 2012). A smart grid monitors and manages the delivery of power in real-time, enables bidirectional control and information flow to customers, and provides an ideal foundation for innovative solutions to the integration of renewables.

Many countries have initiatives to modernize their power system infrastructure while enabling the integration of low-carbon energy resources. For example, China is developing smart grid in the context of rapid economic growth, uneven geographical distribution of electricity generation, and increasing consumption (Yuan et al., 2014). In the UK, the smart grid is being developed to provide flexibility to the current electricity system and facilitate a secure transition to a low-carbon energy system (Jenkins et al., 2015; Xenias et al., 2015). The European Union (EU) incentivizes smart grid with the aim of integrating more of the low-carbon generation technologies, as well as encouraging the demand side to play an active part in the power system.

In Malaysia, TNB has targeted the investment of RM2.7 billion into smart grid technologies as part of its ‘Grid of the Future’ initiative. The amount is part of the RM18.8 billion (USD4.7 billion) capital investment in the transmission and distribution grid which was secured under the second regulatory period (2018–2020) (Energy Malaysia, 2018); it is expected to improve grid reliability and efficiency, energy efficiency, enhance demand-side management, and increase customer participation in the system (Largue, 2018). TNB also has a 10-year transmission grid strategy framework focusing on six key objectives over 2019–29, and a five-year distribution network strategy to address the expected industry changes as a result of MESI 2.0, by focusing on nine key areas (TNB Annual Report, 2019). These strategic initiatives envision the ‘grid of the future’ as fully automated and digitalized, supporting bidirectional flow in a decentralized system that empowers self-generation and greater energy efficiency among consumers (TNB Annual Report, 2019). It also helps with improving visibility and control by the System Operator over distributed resources, in order to manage intermittent renewable resources.

Experience of other countries shows that deployment of smart grid requires a clear national strategy and road map as well as regulatory systems to integrate this technology within the existing centralized generation and transmission system (Xenias et al., 2015; Yuan et al., 2014). Restructuring of the power sector into its competitive (generation and retail supply) and natural monopoly (transmission and distribution network) components is also required to provide efficient and excellent service to generators, retailers, and customers, as this will enable clearer price signals for different parts of the sector, to incentivize all agents to operate efficiently from a system perspective. Furthermore, to enable efficient participation of the demand-side in the electricity markets (which by definition is likely to form a significant part of distributed energy resources, and thus impact upon both grid operation and revenues), pricing reform is needed to align retail tariffs with the cost of energy service to different customers. Moreover, efficient network pricing arrangements are required for distributed technology to compete successfully with existing central generation in a smart grid environment (Jenkins et al., 2010).

4.2 Impacts of growth of decentralization on the electricity market

The implications of distributed resources for the electricity system depend on the type of decentralized technology. They also depend on whether the system operates in a grid-connected (GC) or a stand-alone (SA) mode (AlMuhaini, 2017). For example, it is possible to have decentralization at the industrial level, whereby the power generated as a by-product of the industrial process is used for own consumption, with any surplus being fed into the grid. On the other hand, a stand-alone system comprises most installations which are not connected to the electricity grid, either because the installation is in a remote region or it is solely used to satisfy the owner’s demand. In the case of Malaysia, the government is planning to increase the share of distributed resources in the power system, mainly through rooftop solar and large-scale solar (LSS). The following sub-sections discuss some of the key issues pertaining to an increase in the share of distributed resources in the power system mix. These include the problem of over-generation and renewable curtailment, the need for an increase in system flexibility to accommodate renewables, and finally, the need to facilitate the participation of distributed resources in the wholesale power market.

4.2.1 Over generation due to growth of solar PVs

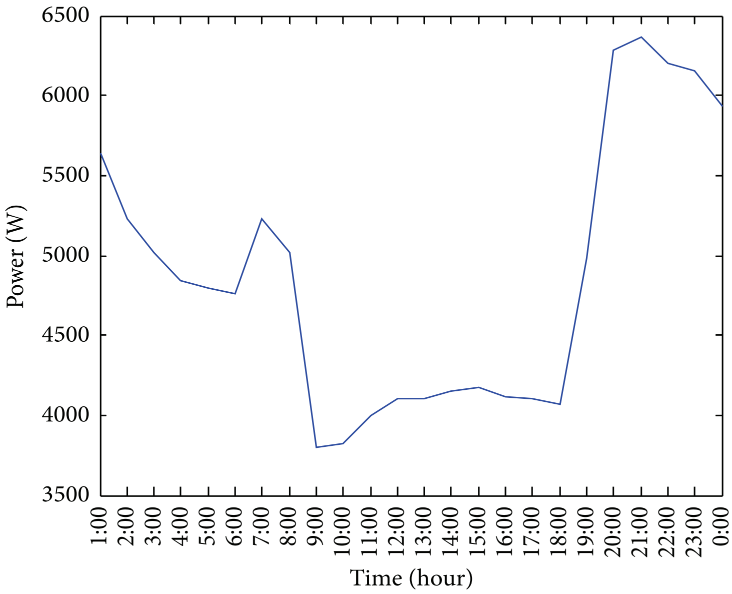
The high penetration of solar PV significantly impacts the operation of the power system. Solar plants create an increased requirement for frequency-regulating reserves, sub-hourly net load-following plants to address the variability caused by transient clouds, and the hourly net load ramps of increasing magnitude caused by aggregate solar production ramps at the beginning and end of the sunlight hours (Helman, 2014). The experience of other countries shows that as integration of solar PV increases, the shape of the net-load curve changes, and thus the demand for flexible resources in the system increases (Hou et al., 2019). For example, the California Independent System Operator (CAISO) has observed that at certain times of the year, net-load curves produce a 'belly' appearance in the mid-afternoon that quickly ramps up to create an 'arch' similar to the neck of a duck (California ISO, 2016). This shape of net-load curve which is named a 'duck curve' is widely used to describe the timing imbalance between peak demand and PV generation.

The net-load curve reaches the bottom by noon, increases sharply during sunset and peaks in the evening. The dramatic changes in net load indicate that the duck curve would place considerable peaking and ramping regulation stress on conventional dispatchable generators. Similar issues are also observed in Hawaii (John, 2014). Distributed solar PV on the island of Oahu, Hawaii, has had a considerable penetration due to strong incentives. The system is now experiencing solar over-generation on sunny days, which drives the system-wide demand curve below zero on certain peak days. The key challenge for the system is thus to find ways to manage such large penetrations of customer-owned generation, which is outside the utility's control, and mostly unmonitored by utilities and grid operators.

Malaysia would have to consider these issues, as the country is planning to increase the share of solar PV in the power system. Peninsular Malaysia receives about six hours of sunshine per day and the solar radiation ranges from 6.5 kWh/m^2 in January to 6.0 kWh/m^2 in August (Shavalipour et al., 2013). In May 2020 the government announced that the Energy Commission (EC) would offer a solar quota of 1 GW via a competitive bidding process under the Large-Scale Solar (LSS) programme (LSS-4) by Malaysian Electricity Industry to attract renewable investment (Arif, 2020). Besides the LSS programme, the government has also planned to offer incentives to customers to install solar panels on the rooftops of their buildings. The aim is to have solar integrated into the grid system. If there are large penetrations of customer-owned generation into the system, there is a high possibility that energy supply will exceed energy demand at certain times – for example, there is a high availability of solar between 10 a.m. and 2 p.m. in Malaysia (Wan Nik et al., 2012), yet there is not much demand from the residential sector during this time, as shown in Figure 4.2. According to Figure 4.2, residential daily load in Malaysia varies significantly during the day. The level of demand during working hours, which coincides with the period between sunrise and sunset, is significantly lower than the level of demand in the evening. This would raise the issue of balancing energy supply and demand, as experienced in California or Hawaii.

There are many strategies that can be adopted to improve the power system's flexibility and to mitigate the impact of the duck curve, which will be discussed in the next sub-section.

Figure 4.2: Residential daily load of Malaysia



Source: Adapted from Aljanad and Mohamed (2016)

Renewable curtailment and the increasing need for system flexibility

The growth of distributed resources such as solar PV raises concerns about supply and demand balance and the stability of the grid system. The issue could be acute, particularly on days characterized by the duck curve – whereby the conventional power system is unable to accommodate the ramp rate and range needed to utilize solar energy fully. The imbalance could result in renewable curtailment if there is not sufficient system flexibility. The variable generation is curtailed by either reducing output from the inverter or disconnecting the plant altogether. NREL (2015) conducted a study, focusing on California, to explore the duck curve in detail, examining how much PV might need to be curtailed if additional grid flexibility measures are not provided, and how curtailment rates can be decreased by changing grid operational practices. For instance, considering measures to ‘fatten’ the duck (in other words by deploying and utilizing flexibility in the system through calling on ramping plants or increasing the balancing area) or conversely, by ‘flattening the duck’ (by deploying and drawing on backup capacity, storage, and load shifting). This is explained further in the paragraphs below. The study argues that by allowing distributed PV and storage to provide grid services, system flexibility could be significantly enhanced.

There are various resources and approaches that can enhance the operational flexibility of the power system. These include both physical (namely flexibility-enabling assets) and other elements, including institutional design such as operating rules and market structure (Boscan and Poudineh, 2016). In addition to generators, which have traditionally been the main sources of flexibility, other resources such as storage (for example, pumped hydro and batteries), interconnections with neighbouring networks, and demand-side management can all be instrumental in addressing variability in the power system. The electricity network, on its own, does not provide additional flexibility, but it severely limits the provision of flexibility if sufficient transmission capacity is unavailable. Market and contract design are another relevant element that can enable flexibility: in the absence of adequate trading mechanisms, market participants are unable to trade flexibility even if sufficient physical resources exist (Boscan and Poudineh, 2016).

Apart from grid flexibility, other measures can be adopted to influence the shape of the load curve. In the case of California, it is identified that deployment of energy efficiency and demand response resources is necessary to change the net-load shape and ensure reliable grid management (California ISO, 2013). Another study comprehensively outlined ten specific strategies to mitigate the challenges of the duck curve and suggested that policies such as targeting energy efficiency to the hours when the load ramps up sharply, or deploying electrical energy storage in targeted locations, could streamline the duck curve and change its shape (Lazar, 2016). Other possible measures are: to implement aggressive demand-response programmes, or to retire inflexible generating plants with high off-peak must-run requirements.

4.2.2 Facilitating participation of distributed resources in the electricity market

New technologies such as solar PV, battery storage, micro-grids, or electric vehicles create a customer-engaged market and significantly enhance system reliability and resilience (Advance Energy Economy, 2019). According to IRENA (2019b), facilitating the participation of distributed resources in the electricity market is crucial to unlocking demand-side flexibility. The flexibility provided by these resources enables stacking revenues from the services offered in the market and thus improves the economics of distributed resources. Apart from flexibility, distributed resources can also provide other services. Overall, depending on the market arrangement, distributed resources can offer energy, capacity, and ancillary services in the electricity market.

The growth of distributed resources gives rise to new business models which are intelligent, diverse, and which incentivize consumer engagement (Löbbe, and Hackbarth, 2017). For example, in Germany, the value of generation has partially migrated from central production to the customer's premises, and the end user is becoming the focal point of the system. These alternative business models are very different from the historical business model of the electricity system. Traditionally, utility companies have owned and operated the entire value chain from generation to customer supply. However, the convergence of market restructuring, distributed technology, and customer engagement has changed the traditional business model (PwC, 2016). For example, a virtual utility model (or 'virtual power plant') can combine the services from various distributed resources and act as the intermediary between electricity market and end users. In this model, the utility can integrate distributed resources with their own generation, thus not only providing a route to the market for those resources but also expanding their asset portfolios.

In some jurisdictions such as California, new market rules have been introduced that facilitate the participation of distributed energy aggregations in real-time and day-ahead wholesale electricity markets (Gundlach and Webb, 2018). 'Aggregation' of distributed resources refers to the pooling of different distributed resources that can be managed collectively to provide energy, capacity, or ancillary services (Migden-Ostrander et al., 2018). For example, biomass-based power generation or co-generation from industrial consumers and air conditioners or rooftop solar PV from residential consumers can be managed as an aggregated portfolio. In such a model, the aggregated virtual power plant could act like a conventional power plant with similar technical attributes, such as minimum/maximum capacity and ramp-up and ramp-down criteria.

Participation of a significant amount of distributed resources in the wholesale electricity market increases efficiency, as these resources can be aggregated and thus compete with conventional generation plants which provide energy and ancillary services (IRENA, 2019b). The aggregation of distributed resources could also be utilized to manage congestion and delay grid reinforcement investments. In the UK, for example, some distribution network operators tap into rooftop solar PV and batteries owned by households to manage peak demand and congestion (Hill, 2018).

In the case of Malaysia, the Energy Commission (EC) and market operators (not yet established, as currently it is a Single Buyer market) would need to consider adopting rules and practices that are conductive to integration of distributed resources into the wholesale market. The current policy direction for Malaysia has no clear timeline on the establishment of independent market operators and distribution system operators. The distributed resources are connected to the distribution grid, thus a distribution system operator would need to consider active management of decentralized resources, due to risks of over-voltage, under-voltage, and grid congestion caused by the penetration of these resources. Although Malaysia is still at the early stages of deploying distributed resources such as rooftop solar PV, it is crucial to implement its power sector reform with the anticipation of an increasing share of decentralized and variable distributed resources. This specifically includes market rules, product definition, and the operating models of distribution networks. A framework is required for integrating these resources into the power system as a source of energy, capacity, and ancillary services, as well as for incentivizing distribution network operators to utilize customers' resources such as rooftop solar or electric vehicles, to manage the grid actively.

4.3 Implications of decentralization for electricity network tariff design

The benefits of distributed resources will not be realized if network tariffs are inefficient. In other words, the aggregation of distributed resources provides value to the system only when tariffs are in line with the efficient operation of these resources. This especially pertains to distribution network tariffs, as distribution system operators need to transform their operating procedures and consider distributed resources flexibility as a real and effective alternative to grid investments (IRENA, 2019b). An effective regulatory framework, however, is required to remove barriers to efficient aggregation and promote fair competition among all market participants, to provide energy and grid-related services (IRENA, 2019b).

Decentralization of the power sector allows end users to become active participants in the electricity market. However, an inadequate network tariff design would lead to the unfair distribution of system fixed costs, and would also be a barrier to achieving efficient decentralization. Incorrect network pricing would lead to consumers reacting more strongly or more weakly to incentives for the adoption of distributed resources (Schittekatte, 2019). For example, high volumetric network charges with net metering could over-reward users who install solar PV. This would lead to more injection of solar PV than would be optimal for a system. While this reduces network fees paid by distributed resources' owners, the overall network costs are not equally reduced. This means that regulators would have to increase network volumetric charges to recover network costs in the next tariff review, and this would impact users who did not install distributed resources, as they face higher rates for the same electricity consumption.

Overall, the rise of distributed energy resources offers increased opportunities to exploit the existing system of network charges in ways that were not originally envisaged. Therefore, if network tariff design does not anticipate the new sets of actions available to consumers with the growth of decentralization, the Distribution System Operator's grid-cost recovery, and a fair allocation of costs, are at risk (Pollitt and Anaya, 2016).

In a traditional power system – in which electricity was primarily supplied by centralized generation and consumers were mainly passive recipients of power – the network charges tended to be predominantly designed to recover network costs. However, the electricity system has been revolutionized with the adoption of technologies such as smart grids, self-generation, and storage. In the case of the residential sector, consumers are displaying diverse and less predictable demand patterns with the growth of solar PV, storage, and electric vehicles (EVs). These mean that network tariff design in the decentralization era needs to go beyond cost recovery, by encouraging flexibility and by incentivizing consumers to draw value from new opportunities, when it is efficient to do so. At the same time, tariff design should ensure an appropriate balance of charges between traditional consumers and more innovative active consumers.

The electricity distribution network tariff design often involves a combination of fixed, capacity, and volumetric charges. Network tariffs ranges between more fixed costs that are relatively unrelated to the capacity or volume a consumer demands, and more variable charges which varies according to capacity or volume (ClientEarth, 2019). The main criteria for network charges during the decentralization era are:

(i) revenue sufficiency (funds collected via network tariff must equal the regulated network costs);

(ii) allocative efficiency (incentivizing efficient response by network users while minimizing economic distortions).

(MIT, 2016)

When distribution networks become congested, the actions of users not only impact the operating costs of the network, but also indicate the need for new network investments. Although Location Marginal Pricing (LMP) ($/kWh) has not been implemented at distribution level anywhere around the world, it is theoretically proven to be the most effective way of inducing short-term efficiency (MIT, 2016). However, LMP is not sufficient to recover full network costs. Thus, long-term marginal or incremental costs of network expansion need to be recovered through a separate mechanism. A peak-coincident network capacity charge ($/kW) can thus be used to guide long-term capacity utilization of the distribution network and recover parts of its costs.

An important point here is that the peak-coincident capacity charge can be positive or negative, depending on whether a user injects or withdraws electricity from the grid during peak demand or peak production (MIT, 2016). For example, a user who withdraws from the network during peak demand or injects power during peak production is subject to a positive peak-coincident capacity charge. Conversely, a user who injects power during peak demand or withdraws power during peak production is subject to a negative peak-coincident capacity charge, which can be either in the form of monetary reward or credit on the bill.

Any residual network costs, along with policy and other costs that the government applies to network tariffs, should be recovered through a mechanism that does not distort economic efficiency. A flat volumetric rate (per KWh regardless of the time or the location) can result in a significant loss of economic efficiency, as the signal changes the price of energy. On the other hand, a fixed charge in the form of a lump sum – determined annually by the regulator for each customer and charged monthly – does not create distortion, but it raises equity issues. This is because it increases the average bill of low consuming users. The fixed charge can thus be differentiated on the basis of the level of consumption, so those who consume more pay a higher share of fixed costs.

5. The design of renewable support schemes for the Malaysian electricity sector

There are several overarching policies that incentivize the deployment and utilization of renewable energy in Malaysia. These include the Renewable Energy Policy Act 2011, the National Green Technology Policy 2009, the National Biofuel Policy 2006, the Green Technology Masterplan (2017–30), and the Small Renewable Energy Power (SREP) programme. The government has also introduced a target of 20 per cent renewable energy in the capacity mix by 2025, to accelerate implementation of the renewable project. These primary policies introduced by the government will further drive the implementation of support schemes such as the feed-in tariff (FiT). However, support schemes not only need to be effective to provide incentives for investment, but they also need to be compatible with operation of the electricity market. The following sections discuss the various approaches to the design and implementation of renewable support schemes. We use classification defined in Poudineh et al. (2017) to categorize support policies as 'direct' and 'indirect'.

Although renewable support schemes can be gradually introduced as part of an electricity sector that is reforming towards a liberalized market, the ultimate objective of policymakers is often to move to a liberalized market structure, as there are structural hurdles to the efficient deployment and operation of renewable sources in a single buyer market structure, particularly where a vertically integrated utility is the single buyer. This is because renewable sources, when deployed in a decentralized way (for example roof top solar PV, battery storage, or EVs), tend to affect the return on assets of the single buyer, as they effectively transfer generation assets away from the utility and to consumers. Even in the case of investor-owned utility-scale projects, unless robust and clear regulatory frameworks are in place, there is some incentive for the single buyer to prioritize its own generation assets over independent resources, slowing down the deployment of renewables. To the extent that these problems apply to the context of Malaysia, the country's power market reforms will therefore need to be designed to anticipate some of these hurdles, and the ensuing paragraphs discuss various measures.

5.1 Indirect support policies for renewables

'Indirect policies', as the name suggest, are policies that aim at increasing the cost of fossil fuels or restricting their use, thus they indirectly benefit the implementation of renewables. Indirect policies can be divided into emission reduction schemes and regulations on reducing fossil fuels.

- Emission reduction schemes could be price-based (for example taxing carbon), or quantity-based (such as carbon cap and trading). Implementation of carbon tax, however, is not straightforward. This is because a carbon tax is visible compared to cap and trade in which carbon price is the result of the carbon market outcome. However, irrespective of the model, carbon pricing model might reduce the dispatch of convetional plants and increase the electricity prices.

- Regulation, on the other hand, places a direct constraint on the use of fossil fuels. An example of this is the Large Combustion Plants Directive in the EU region, which mandates an emission limit for power plants.

Long prior to the Paris Agreement (COP21), Malaysia had ratified the Kyoto Protocol in 2002 and had committed to participating in the Clean Development Mechanism (CDM) voluntarily, to reduce greenhouse gas (GHG) emissions as a developing country (also known as non-Annex I country), giving it (as a non-Annex I country) the possibility of supplying carbon credits under the CDM project. These carbon credits could then be traded with industrialized countries (also known as Annex I countries). Eligible projects under the CDM include renewable energy sources (such as wind, hydro, and biomass), as well as projects relating to improving energy efficiency (forestry, waste management, transport,[35] and agriculture[36]). The overall contribution of the CDM projects in Malaysia to GHG emissions reduction has not been significant; however, they encouraged some industries to adopt alternative energy resources through their participation in these projects. The motivation was mainly to benefit from the sale of carbon credits on top of the revenue from the sale of plant outputs.

The Bera 10 MW biomass power plant is an example of a grid-connected plant registered with the UNFCCC as a CDM project.[37] Other biomass plants registered under the CDM project include Lahad Datu Edible Oils (LDEO) biomass power plant, Sandakan Edible Oils (SEO) biomass power plant, Johor Bundled biomass steam plant, and Bentong biomass plant. These projects supplied carbon credits for Malaysia as a non-Annex I country (Xin-Le and Wei-Haur, 2014). Malaysia generated a total of 9,844,435 tradable Certified Emission Reductions (CERs) between 2008 and 2012 (NRE, 2015), which were traded with Annexe I countries. According to an NRE report in 2015, the CDM projects potentially have contributed 23.95 million tonnes CO_2eq of emissions reduction in the country between 2008 and 2012.

The CDM initiative created the incentive for some industries to adopt low-carbon technologies instead of fossil fuel alternatives. For example, Hartalega Sdn. Bhd. replaced conventional boilers with biomass boilers (which use biomass residues from palm oil mills) to generate a large amount of heat to produce rubber gloves for the food and medical industries. As another example, Panasonic Electronic Devices Malaysia Sdn. Bhd. (an electric and electronic manufacturer) implemented energy-efficiency improvement measures such as installing efficient pump motors, vacuum pumps, or air compressors at their facilities.

5.2 Direct support policies for renewables

Direct policies to support renewables are either production-based or investment-based schemes (Poudineh et al., 2017).

- Production-based schemes, remunerate investors per unit of energy produced, so they have a direct impact on emission reduction. These schemes can be further classified as either price- or quantity-based.

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[35] CDM project related to efficiency improvements for vehicles. An example of a CDM project for the transport sector is the Nittsu Fuel Efficiency Improvement with Digital Tachograph Systems on Road Freight Transportation in Malaysia.
[36] CDM project related to composting of agriculture wastes. An example of a CDM project for the agriculture sector is the Kedah ENCO Biomass Energy Plant.
[37] Details of Malaysia Biomass Power Plant Project: https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/UJLT1C2B653DNVMGXESHFRW0YAIQP7/view.

- Investment-based support schemes subsidize the capital asset, or partially finance the project, in return for equity ownership. Similar to production-based programmes, these schemes can be categorized as price-based or quantity-based.

5.2.1 Production oriented price-based scheme

There are various models of production-oriented price-based renewable support schemes. The most widely used schemes include: feed-in tariff (FiT), feed-in premium, and net metering. Malaysia has adopted FiT and net metering. FiT currently exists for small-scale (up to 30 MW in size) renewable projects under the Renewable Energy Act 2011. In terms of funding, there are two sources of funds to cover the payment to Feed-in Approval Holders (FiAH): an initial FiT fund of RM300 million provided by government, and a subsequent fund, introduced in 2011, which was financed through a 1.6 per cent surcharge on consumer bills. Renewable generators are eligible to sell electricity at the FiT rates for 16 years in the case of biomass, and 21 years for biogas resources, small hydropower, and solar photovoltaic technologies. The quota for FiT is determined on the basis of availability of funding for FiT, which will be reviewed every six months by the government for the next three years. The allocated quotas for biomass, biogas, and small hydro under the FiT scheme (as of September 2020) are summarized in Table 5.1. There is no allocation of quota for solar under this scheme.

Table 5.1: Allocated quota for renewable resources under FiT scheme

	2020	2021	2022	2023	2024
Biomass (MW)	8	12.4	0	27.3	0
Biogas (MW)	1.2	0	59.64	0	0
Small hydro (MW)	171.25	338	0	0	176.8

Source: SEDA[38]

The Net Energy Metering (NEM) scheme was implemented in 2017, focusing on solar rooftop PV installation by domestic and non-domestic customers. Customers with solar PV generate electricity for their own consumption and any excess electricity is sold to the grid in the form of credit. The new (2019) NEM mechanism offers the same tariff for selling and buying electricity. This scheme aims to achieve a target capacity of 500 MW by 2020. In September 2020, as per the SEA–NEM Dashboard, approximately 234 MW of schemes had been allocated in Peninsular Malaysia.[39] The mechanism will end in December 2020, even if the quota is not reached.

5.2.2 Production-oriented quantity-based schemes

Production-oriented quantity-based support schemes can be introduced through tendering or quota obligation. Malaysia has been implementing tendering under its Large-Scale Solar (LSS) initiative over the last few years, whereby projects are selected in a bidding process. Successful project bidders are required to sign a power purchase agreement (PPA) with the utility company as the off-taker for 21 years, with fixed energy prices throughout the contract duration. The PPA of LSS is an energy-only agreement with priority dispatch. The solar developers build, own, and operate these solar power plants. The first cycle of the tender was announced in 2016 for commercial operation date (COD) in 2017/2018 and a total capacity of 434 MW awarded in Peninsular Malaysia.[40] The second cycle for COD in 2019/2020 awarded a capacity of 506 MW,[41] whereas the third cycle for COD in 2021 awarded

[38] Data published on SEDA portal: Available at: http://www3.seda.gov.my/?omaneg=00010100000001010101000100001000010001000101110000 (as of 24 September 2020).

[39] For dashboard see: https://services.seda.gov.my/nem/quota/dashboard.

[40] 'Request for Proposal (RFP) for the Development of Large Scale Solar Photovoltaic (LSSPV) Plants in Peninsular Malaysia and Sabah for Commercial Operation in 2017–2018 – Announcement of Shortlisted Bidder', Energy Commission. Available at: https://www.st.gov.my/en/contents/highlight/2016/Announcement_RFP_Results.pdf.

[41] 'Request For Proposal (RFP) for the Development of Large Scale Solar Photovoltaic (LSSPV) Plants in Peninsular Malaysia, Sabah and Labuan for Commercial Operation in 2019–2020 – Announcement Of Shortlisted Bidders', Energy Commission. Available at: https://www.st.gov.my/en/contents/article/industry/2017/LSS/Announcement_of_Shortlisted_Bidder_For_The_Development_LSSPV_Plants_2019-2020.pdf.

a total capacity of 491 MW[42] in Peninsular Malaysia. The fourth cycle was announced by the Ministry of Energy and Natural Resources through the Energy Commission in May 2020, with a plan to award a total capacity of 1,000 MW to be operational by 2023. As of Q1 2020, a total of 689.78 MW awarded since 2017 is in operation, meanwhile other capacities awarded are still in the process of completion.[43]

5.2.3 Investment-oriented price-based schemes

Examples of investment-oriented price-based schemes are investment tax credit, tax reduction, loans, and grants. Malaysia introduced the Green Technology Tax Incentive in 2013 to support the purchase and implementation of green technologies in sectors such as power, transport, or building. The government hopes that the scheme will encourage companies to purchase green technologies and/or become green technology service providers. Thus, this mechanism is not related to energy production but to investment in renewable technology, as tax exemption is applied on the capital cost of technology.

The Green Investment Tax Allowance (GITA) and Green Income Tax Exemption (GITE) are two major green initiatives introduced under the Green Technology Tax Incentive. One of the incentives under GITA offers a tax allowance against 70 per cent of statutory income in the assessment year. The GITA scheme, which is applicable to initiatives qualified as GITA assets and GITA projects, aims to motivate companies investing in renewables, energy efficiency technologies, and green buildings.

The GITE scheme, on the other hand, encourages companies to promote green services related to renewables, electric vehicles, or green certification of products. Under this scheme, eligible companies can claim income tax exemption equal to 100 per cent of their statutory income from the assessment year.

In addition to tax schemes, another investment-based support model has been introduced by the Malaysian government; it is known as the Green Technology Financing Scheme (GTFS). In 2018, the second phase of GTFS was reinstated for two years (2019–20) with an offer of 2 per cent per annum interest rate subsidy for the first seven years. Under this scheme, the government also guarantees 60 per cent on project financing.

The Supply Agreement on Renewable Energy (SARE) includes a ‘Solar Leasing’ concept whereby consumers are able to lease solar panels and install them at their households without the need to pay for the system. With this policy, users have no upfront cost to install PV panels, and payment for the monthly leasing fee, or solar energy usage, can be made to the solar company involved, via TNB’s bills.[44]

5.3 Revenue sufficiency, stability, and burden sharing of renewable support schemes

A renewable support scheme needs to be effective, efficient, and equitable. ‘Effectiveness’ in this context means that the scheme needs to create sufficient incentive for investment by providing a stable revenue. It needs to do it at the lowest possible cost (efficiency) and distribute the cost of policy fairly among rate payers or taxpayers (equity).

5.3.1 Revenue sufficiency of renewable support schemes

If the entire revenue of a renewable project is going to come from a renewable support scheme, it needs to be sufficient to cover the cost of capital and operating costs. Malaysia has had a history of ineffective renewable support schemes. For example, when the FiT scheme was first introduced under the Small Renewable Energy Power (SREP) Programme in 2001, there were issues related to revenue sufficiency

[42] ‘Request For Proposal (RFP) for the Development of Large Scale Solar Photovoltaic (LSSPV) Plants in Peninsular Malaysia for Commercial Operation in 2021 – Announcement of Shortlisted Bidders’, Energy Commission. Available at: https://www.st.gov.my/contents/2019/LSS/Announcement%20of%20Shortlisted%20Bidder%20for%20the%20Development%20of%20Large%20Scale%20So....pdf.
[43] LSS Progress by region, Energy Commission. Available at: https://www.st.gov.my/en/web/industry/details/2/17
[44] Solar Information Panel, NEM Solar Malaysia. Available at: http://nemsolarmalaysia.com/sare-malaysia/.

due to the low SREP tariff rate, which was only enough to cover the operation costs of the facilities. The FiT rate offered under SREP in Peninsular Malaysia for the solar project was USD0.08 per kWh, and USD0.064 per kWh for biomass and biogas in 2007 (Sovacool and Drupady, 2011; Chua et al., 2011). Investors were unable to recoup their revenues to cover their project costs under this scheme, due to the differential between the FiT and the market price of electricity, forcing them to seek alternative ways to raise revenue. For example, investors had to obtain carbon credits through Clean Development Mechanism (CDM) participation to cover project costs.

5.3.2 Burden sharing of renewable support schemes

Since the implementation of the FiT scheme under the SREP programme was not successful across all RE projects, changes were applied in 2011. The special tariff under the Renewable Energy (RE) Act 2011 (to aid the deployment of renewable energy), was financed by the RE fund. As a result, a surcharge of 1.6 per cent was imposed on customers' electricity bills towards funding for renewable projects (Joshi, 2018). These surcharges were imposed on customers from residential, commercial, and industrial sectors. Only those residential customers that have an electricity consumption of 300 kWh per month or less are exempted from the surcharge. The RE fund is thus a mechanism introduced to share the burden of the renewable support scheme between the government and consumers, without affecting lower-income groups. When SEDA determines that a particular renewable energy installation has achieved grid parity (the time at which the FiT rate applicable to the relevant installation is equal to or less than the displaced cost[45] – namely the average cost of generating and supplying 1 kWh of electricity from non-renewable resources) the following actions will take place:

(a) the Feed-in Approval Holders (FiAH) concerned will cease to be entitled to be paid the FiT but will be paid based on the prevailing displaced cost for the remaining duration of the effective period; and

(b) the distribution licensee will not be entitled to recover from the RE Fund the amount it has paid to the FiAH for the purchase of electricity generated by the relevant installation or to be paid administrative fees pertaining thereto.
(Lexology, 2019; AGC 2011)

Similar financial burden-sharing initiatives were effectively implemented in the Netherlands, Germany, Austria, and Denmark in various sectors. A key question is: how to distribute the cost of renewable support schemes in a way that protects low-income groups. Germany had introduced surcharges on household customers to finance renewable projects, however, Cludius et al. (2015) argue that customers who account for higher levels of electricity consumption – who were also higher-income consumers – did not bear a proportionately higher burden of the cost of support schemes, relative to customers who consumed less (and who were also in lower-income groups). Policy makers can apply a uniform surcharge on electricity consumption in an equal manner, or scale the surcharge based on the volume of consumption. This is a political decision in essence, because it involves re-distribution among rate payers.

There is also the issue of stability. Although several adjustments (such as the RE fund which aimed to decrease the financial burden of the government) have been made to address the issues with renewable support schemes in Malaysia, changes must not compromise the stability of the scheme in the eyes of investors. Changes need to be predictable, and the mechanism for such modification needs to be determined and communicated properly to stakeholders. For example, the FiT rates in Malaysia change on the basis of annual degression rates. The annual degression rate was changed from 8 per cent to a flat rate of 10 per cent effective in 2014 for solar capacity of below 24 kW, meanwhile the annual degression rate for biogas and biomass changed from 0.5 per cent to a flat rate of 0 per cent effective in 2013.[46] These annual degression rate changes affect cost recovery by investors so they need to be determined prior to investors making investment decisions. This is to avoid compromising the stability of the scheme in the long term, and affects the perception of future investors in renewable energy.

[45] Feed-in Tariff, SEDA. Available at: http://www.seda.gov.my/reportal/fit/.

[46] 'FiT Rates for Solar PV (Community) (21 years from FiT Commencement Date)', SEDA. Available at: http://www3.seda.gov.my/iframe/.

5.4 The effect of renewable support schemes on wholesale electricity prices

As of 2017, the total installed capacity of renewables (solar, biomass, biogas, and hydro) in Peninsular Malaysia, which was deployed through the FiT scheme, was 426.1 MW (EC, 2019a). It is expected that the share of renewable resources, both large and small, will increase. Renewables are incentivized through various support schemes and thus it is crucial to understand how these schemes would impact a future, fully functioning wholesale power market. In a liberalized electricity market, wholesale prices vary during the day depending on the electricity demand and the cost of marginal power supply. Retailers bid on behalf of end users, while power generators specify the amount of electricity they would be able to supply at their offered price. The market operator then evaluates bids and offers and set the market price according to the marginal cost.

A generator in a liberalized market would produce electricity profitably if its marginal cost is less than the wholesale price (Borenstein, 2000). However, evidence from Germany (Hirth, 2013), Portugal (Macedo et al., 2020), Denmark (Djørup et al., 2018), and Australia show that renewable support schemes affect wholesale electricity prices due to zero or low marginal costs and the dispatch priority of renewables. For example, Csereklyei et al. (2019) show that the increase in wind and solar generation dispatched in the Australian wholesale market decreases the wholesale prices due to the negligible marginal costs of these resources. Renewable support schemes with fixed tariff and priority dispatch not only reduce the wholesale prices but also influence the investments of conventional power plants, as they push expensive fuel-based plants out of the merit order (Sensfuß et al., 2008).

However, designing a support scheme that provides sufficient incentive for investors while at the same time being market compatible, is not straightforward. The following sub-sections discuss the trade-off between market compatibility and incentives for investors, taking into account the influence of renewable support schemes on wholesale electricity prices.

5.4.1 The trade-off between market compatibility and investors' incentive

Policy makers have two ways of designing production-based renewable support schemes: making the price paid per unit of energy fixed (either administratively or through an auction) or linking the price paid to the wholesale electricity market price. Each way has its own implications in terms of the impact on the market and the incentive for investors. For example, Poudineh et al. (2020b) argue that the FiT scheme is not market compatible, as such schemes protect power producers from market price risk. Thus, renewable generators produce irrespective of market conditions. This situation can lead to over generation and consequently further impact market prices and the profitability of conventional power plants. Nonetheless, FiT attracts investors, as the scheme guarantees a fixed tariff per unit of energy over a long term, which is often 15 or 20 years.

Although FiT existed in Malaysia as early as 2004, it was not until 2011 (after the Renewable Energy Bill was enacted) that a full-featured renewable tariff scheme was launched. FiT is a fixed tariff with priority dispatch in a single buyer market environment. Thus, there is no market risk involved and there is a guarantee that the offtaker accepts the renewable generator's output. As the fixed price tariff paid is not related to the market price, price risk does not exist for the duration of the contract (which is often multi decades), even if the market is liberalized before the contract expires. Therefore, although the FiT scheme is an effective approach to achieving the renewable generation target, this scheme could encourage a production pattern by renewable plants that is inconsistent with the outcome of the market. It also can affect wholesale market prices. In what follows we discuss alternative support schemes and factors that affect the choice of optimum scheme.

5.4.2 Electricity market and renewable support scheme: feed in tariff versus fixed feed in premium

Introduction of the renewable support scheme, especially the FiT, increased the deployment of renewable technology in Malaysia. The implementation of a support scheme might be necessary until renewables achieve grid parity – the point at which the cost of RE generation becomes equal to or lower than the cost of conventional power plants (SEDA, 2020). A possible scenario for achieving grid parity could be when the generation cost of renewables decreases to parity with that of fossil fuels (including the internalization of externalities). Once grid parity is reached, the renewable producer would be paid based on the displaced cost for the remainder of the renewable power purchase agreement – where ‘displaced cost’ is the average cost of generating and supplying a kWh of electricity from resources other than renewables (namely fossil fuels). The FiT scheme is independent of market price, as it is a fixed rate decided for a certain period and does not fluctuate according to the actual market conditions. This scheme guarantees revenues for the investors and lowers the cost of capital, due to the lower risk imposed on the investors (SEDA, 2020).

On the other hand, in a feed-in premium (FiP) scheme, remuneration to the renewable generator is made partially from the market price of power and partially from a premium on top, and thus it could be market compatible while still exposing the investors to market price risks. A FiP fluctuates according to spot electricity prices and thus generators’ revenues are market price-dependent in a wholesale markets scenario. The revenue also depends on the premium offered above electricity market prices, which is a payment additional to the wholesale market price. This scheme could be introduced as an option for specific renewable technologies. For example, Poland had only small biogas and hydropower technologies under the FiP scheme (RES LEGAL Europe, 2019). Another example is Greece, which introduced ‘technology specific’ tendering for a feed in premium scheme. Some other countries, such as Hungary, the Netherlands, Luxembourg, and Italy, have also adopted the premium scheme (CEER, 2018). The premium scheme is compatible with a deregulated market environment, whereby renewables and conventional plants compete to sell electricity on the spot market. Furthermore, it can encourage new generation participation if the premium is attractive or there is the possibility of electricity market price rises.

As mentioned above, a FiP is market compatible but may not create sufficient incentive for investment. There are, however, countries that have introduced both mechanisms. For instance, Spain has introduced both FiT and FiP to balance between market signals, low risks, and the sharing of responsibility between renewable producers and the system operator (Hiroux and Saguan, 2010).

5.4.3 Choosing the optimum support scheme for renewables

According to the Council of European Energy Regulators (CEER), a support scheme for renewables could be decided through administrative approaches or through competitive bidding procedures (for example tender or auction) (CEER, 2016). The level of these support schemes depends on the renewable target set by the government and on the cost-efficient financial support needed for investments in renewable technologies (CEER, 2016). The key approach in applying the administrative procedures is to recover the costs and to account for the positive externalities of the renewables, which would determine the level of support. In the administrative approach, the prices of renewable production are decided by the government or regulator to drive renewable technology development. On the other hand, the approach taken in determining the level of support in competitive procedures is usually an auction, which determines the level of support per kWh or MWh. A key issue in designing renewable support schemes is to get the balance right between encouraging investment in renewables and avoiding excessive payment to generators. Auctions, if designed adequately, are an effective price discovery mechanism that can achieve efficiency, so they are superior to administrative approaches.

A key question, however, is whether support schemes should entirely shield renewable generators from market price exposure or not. The answer to this question depends on the type of renewable technology. It is likely that nascent technologies require stronger risk mitigation compared with mature technologies and thus fixed-price schemes are effective in facilitating the uptake of nascent resources. This means that policy makers can differentiate between support schemes based on the type of resources and the level of technology maturity. If various technologies are supported, then a combination of different support schemes can be adopted. However, a mechanism needs to be designed to transition toward market-compatible support instruments, as renewable technologies mature, and renewables eventually become subsidy free.

There are countries that have adopted a combination of various support schemes for renewables. For example, Poland, which depends on coal as the primary source of fuel for power generation, has gradually introduced several support schemes to comply with the commitment to generate at least 15 per cent of renewable energy by 2020 and thus fulfil its EU emission reduction obligations and Kyoto protocol targets (Flanders, 2019; Ignaciuk, 2019). The support systems implemented are FiT, FiP for biogas and hydropower for up to 1 MW, and a tender system with a guaranteed price (pay-as-bid) for 15 years. Another example is Hungary, a country that mainly depends on nuclear, coal, and gas for power generation. Besides the feed-in tariff, Hungary has introduced two types of green premium schemes (Antal, 2019; Szabo, 2019). The first green premium scheme focuses on renewable plants of less than 1 MW and the tariff for the scheme is decided by the government through a market reference price and an administrative premium which is paid by the grid operator. The second type of green premium scheme applies to renewable plants with a capacity of more than 1 MW and awards are made through a tendering system.

The examples from Poland and Hungary show that support schemes can be adopted in combination, to incentivize the deployment of renewables by investors, and the adoption of different renewable technologies by consumers. The main reason for combining different support schemes is to account for heterogeneity among renewable energy technologies. We have technologies such as onshore wind and solar PV that are already considered mature in some markets. We have also technologies that are nascent. Thus, applying one support policy to all types of renewables can lead to inefficient outcomes because it may provide weak incentives for some technologies and strong incentives for other technologies. For example, a scheme such as auctioning cannot be applied to small resources because of the transaction cost involved. Furthermore, as technologies become mature, they do not require to be completely shielded from the market price. Overall, when there is a variation in the stage of market maturity of renewables, a combination of incentive schemes is likely to be more effective than a single scheme. Nonetheless, it is important that a policy designed to target one sphere does not contradict another.

There are many other countries with a different combination of renewable support schemes in the EU. Yet, Poland and Hungry have been selected as these countries have a similar energy situation to Malaysia. These countries mainly consume fossil fuels in the power sector and have renewable targets, for example, Poland has committed to achieving at least 15 per cent of renewable energy generation by 2020. A combination of renewable support schemes has been introduced in a fossil-fuel-based electricity generation environment in both these countries. In Hungary, the FiT is not subject to tendering for installed capacity between 50–500 kW and is available for all renewable resources. Meanwhile, a green premium scheme for capacities greater than 1 MW is subject to tendering and is technology-specific. The investors could combine FiT with loan or grants through subsidy programmes such as the Environment and Energy Efficiency Operative Programme. Hence, these renewable schemes could complement another scheme, for example FiT schemes, premium schemes, or green certificates to promote renewables.

Apart from the issue of efficiency and effectiveness of renewable support schemes, there is also the question of how to distribute the cost of renewable funds. Financing renewable support schemes could be achieved through general taxation or by surcharges collected via electricity bills (CEER, 2018). Both approaches are used in European countries. For example, Denmark and Finland impose a general electricity tax on all citizens to support renewable funds (Larsen, 2011; OECD, 2019). Meanwhile, countries such as Belgium, Estonia, and Italy impose surcharges on customers through their electricity bills (KPMG, 2015). The surcharges could be decided by government, regulator, or transmission system operator. While they can be designed to mimic very similar outcomes, the difference between the two methods is nuanced: electricity taxes may be uniformly applied to all consumers, with oversight on revenues coming through the general budget of the country, making it easier to administer and manage. A surcharge could be discriminatory (in a positive or negative way) in terms of differentiating between specific groups of consumers (for example based on the type of consumer) and the oversight for surcharges may also lie with government, or alternatively with regulators or transmission system operators.

Finally, apart from the issue of investment incentive and market compatibility, the optimum support scheme for renewables depends on dedicated overarching energy policies implemented by a country to achieve its renewable targets and to meet international obligations for reduction of carbon emissions. In the case of Malaysia, the voluntary commitment to reduce the greenhouse gas (GHG) emission intensity of GDP by 45 per cent by 2030 relative to 2005 necessitates introducing renewable targets to diversify the generation mix in the power sector. Other factors involved in choosing the appropriate support schemes for renewables are the level of electricity and fossil fuel subsidies and the expected path for the decline in the cost of the renewable technology (REKK, 2012; Johannes, 2016).

While fossil fuel price subsidies (specifically for gas) have been gradually removed in Malaysia,[47] the country can also benefit from rapid global cost declines in renewable energy technologies which have made renewables competitive with fossil fuels in many markets that have fully priced in the externalities of fossil fuel consumption (for example the UK; countries in the EU). Malaysia can adopt a combination of renewable support schemes to encourage the continued deployment of renewable energy in pursuit of its 2025 target. In addition to FiPs, for instance, FiTs (already in place in Malaysia) can be considered for specific renewable technologies that are considered to be less 'mature', alongside the development of a competitive market and market-oriented electricity pricing. The FiT is particularly helpful for technologies that have shown potential for cost reductions through increasing scale. FiP, however, can be adopted for mature technologies such as CHP plants or biomass/biogas facilities, as this would be compatible with a liberalized market and could encourage competition between renewable and conventional generators. Eventually subsidies can be gradually withdrawn, as technology cost declines further, in order to progressively expose a larger proportion of participants in the electricity market (generators and consumers) to market price signals.

5.5 Approaches to harmonize the operation of renewables with the electricity market

It is essential to harmonize the operations of renewable plants with the electricity market, in order to prevent distorted market outcomes. In the early stages of renewable market integration, harmonization could be agreed between generators and system operators through bilateral agreements. In a complex system, however, harmonization approaches would incorporate regulatory frameworks, market rules, grid codes, and transmission tariffs (IRENA, 2019c). These would also include dispatch rules, renewable curtailments, balancing responsibility, and the gate opening and closure times for trading in the wholesale electricity markets, as discussed in the following subsections.

5.5.1 Priority dispatch versus economic dispatch

Priority dispatch ensures that renewables are dispatched when these resources are available and guarantees that dispatch of these renewables is not constrained by the operation of the electricity market. Renewable dispatch priority, which ignores the merit order for dispatching generators, is applied to encourage producers to invest in renewables (WindEurope, 2016). This is the case in Malaysia, whereby renewables connected to the grid are given priority to be dispatched compared to conventional power plants. However, priority dispatch is not needed in a mature market if the market has adapted to rules according to renewable characteristics (for example variability and availability uncertainty of renewables to the system) and enforced an adequate level of market transparency (EWEA, 2014). This also would be the situation where the market has clear and unbiased rules for renewable curtailment.

The priority dispatch rule can prevent an efficient market outcome. Economic dispatch, on the other hand, is based on efficiency, as it starts with the dispatch of least-cost generators followed by the expensive ones. Integration of renewables has caused issues in the practice of economic dispatch and operation of fossil fuel-based power plants. The variability and uncertainty associated with renewables have required flexible generation resources to ramp up and down stronger and more frequently (DOE, 2012). Furthermore, it has also impacted the cost of balancing the system in real time given the uncertainty in the availability of intermittent renewables. The additional cost to balance the system, by having power plants such as nuclear or coal operational at minimum outputs and available for peak hours, would impact electricity prices.

[47] Other developments include: increasing distributed renewable generators connected to grid through third-party access to the grid system and alternative fuel suppliers of coal and gas.

In a fully liberalized market, priority dispatch for renewables such as solar and wind is not needed, as these resources have zero marginal cost and thus have priority by default. However, this does not mean that renewables are always dispatched, as the electricity price provides a signal for generators to decide about their commitment and production level. Out of market payments (namely renewable support schemes such as FiT) will impact this decision and this is one of the reasons that renewable support models distort the market outcome. Overall, priority dispatch should be applied with careful consideration for operation of the electricity market (see Section 5.5.3). At the beginning of renewable deployment, and when the electricity market is not fully liberalized, priority dispatch may help renewables gain market share; however, in the long term, such a practice may not benefit the electricity sector.

The action to curtail renewable generation when these resources are available is considered as an economic loss, as near-zero marginal cost renewables are not used. Curtailment of renewables usually takes place when there are barriers related to a grid system fault, market stability, or excess energy produced by renewables (Jacobsen and Schroder, 2012). The approach to curtailment could be on a voluntary or involuntary basis. According to a WindEurope report, the curtailment needs to be considered as a market-based service of downwards regulation offered through the balancing market (WindEurope, 2016). For example, wind generators in Denmark and the United Kingdom provide a downward regulation service through the balancing markets. Hence, the market-based service of downwards regulation could be an economically efficient way to reduce curtailment, which can be combined with greater operational flexibility and improved resources forecasting, to integrate a higher share of renewables (Bird et al., 2016).

5.5.2 Balancing responsibility for non-dispatchable renewables

Renewable support policies are benefiting investors, yet with the increase in the share of renewables, dispatch priority and renewable subsidies could create an imbalance in the system. For instance, system operators would have to deal with issues related to the decrease in load factor of conventional back-up plants, uncertainty in the level of operational reserves from traditional power plants, and risk to the security of supply. Given the existence of support schemes and priority dispatch, along with the lack of balancing responsibility for renewables, these generators have no incentives to improve their output forecast or to firm up, for example, by partnering with storage technologies or demand-response providers. Therefore, the electricity market needs to be designed in a way to prevent renewable support policies from distorting the efficient market outcome and increasing the electricity cost for customers (Chaves-Ávila and Fernandes, 2015). Furthermore, factors such as flexibility of the system, higher reserves, and capacity upgrading of the grid system also help in managing the unpredictability of renewable generation.

An effective method to minimize the balancing cost is to make all parties in the market responsible for meeting their balancing requirements (ENTSOE, 2011). This approach requires an appropriate market design that allows renewables to act as balancing service providers. The renewable generators in Malaysia do not bear the balancing responsibility. The cost of addressing intermittency is paid for by the system operator, thus there is no risk of balancing cost for renewable generators. The renewable support scheme thus needs to be enhaced with rules for imbalance charges, in order to improve balancing signals and reduce balancing costs. This creates a level playing filed for all generators and improves the efficiency of addressing renewables' intermittency.

5.5.3 Reducing the time between gate closure and real time dispatch

Other measures that can improve the integration of renewables are the choice of optimum lead time between gate closure and real time dispatch, as well as the dispatch interval in competitive wholesale electricity markets. There are no specific rules for determining the gate closure lead time; however, deciding an appropriate time gives operators and generators adequate time to manage the variability and uncertainty of renewables. At the same time, the reduced timing could increase certainty about the forecasted generation and minimize the imbalance of the system.

In a similar manner, a shorter dispatch interval improves economic efficiency by enabling responsive bidding based on the latest price information. This is because a shorter interval improves price signals and better directs investments towards renewables (IRENA, 2019c). Overall, shorter dispatch intervals benefit the power system as they allow for frequent scheduling of generators and optimization of capacity investment, and provide incentives for investments in flexible generation.

6. Conclusion

This study has aimed to identify and analyse the challenges and solutions facing electricity supply industry reform in Peninsular Malaysia. It is envisaged that these research findings will contribute to electricity market reform strategy in this country, which is planned with the aim of creating competitive power markets through the restructuring of the existing ring-fenced single buyer model. In order to carry out a systematic analysis of the issue, this project posed three research questions as follows:

1. What is the most suitable reform model for the Malaysian electricity sector which will promote competition, security of supply, and sustainability while at the same time being compatible with the country's own context and government objectives?
2. How does decentralization (distributed generation, storage, demand response, and energy efficiency) affect the Malaysian electricity sector?
3. How do renewable support schemes need to be designed and implemented in order to avoid or minimize distortion in the market?

In addition to the introduction and background chapters, each research question was analysed in a specific chapter. The main findings of the research, which are summarized and grouped by research question, are presented in this chapter.

6.1 Design of Malaysian electricity reform model

Research Question 1: What is the most suitable reform model for the Malaysian electricity sector which promotes competition, security of supply, and sustainability while at the same time being compatible with the country's own context and government objectives?

To answer this question, the paper analysed the existing and planned reform initiatives in the Malaysian electricity supply industry and then highlighted the options available for wholesale market design and, overall, electricity market structure (see Chapter 3 for the details).

The main finding with respect to the above question is that relying on the short-term market for both short-term efficiency as well as long-term resource adequacy may not be the best way forward for Malaysia, at least at the early stage of the reform. Thus, the paper suggests a hybrid market structure for the Malaysian power sector. The hybrid market structure is a design that combines the short-term market for dispatch with a market for long-term contracts. The short-term market achieves operational efficiency based on economic dispatch and system marginal cost pricing, whereas a long-term contract market achieves investment efficiency by providing a mechanism of risk sharing between consumers and generators. Such a design is also compatible with the Malaysian government's power sector policies, which aim to enhance security of supply while at the same time to reduce carbon emissions. Several elements, however, need to be considered in the design of the hybrid electricity market, as summarized in Table 6.1.

Malaysia also needs to integrate new ancillary service products in the system. For example, the participation of distributed energy resources in an ancillary service market can contribute to system flexibility. A hybrid ancillary service market can be adopted whereby the system operator (besides being involved in operational management, power balancing, or voltage control) could also organize auctions or be involved in the contracting of system services beyond what generators deliver as part of their grid-connection requirements.

Table 6.1: Summary of findings on suitable reform model for the Malaysian electricity sector

Components	**Elements to consider for market designs**	**Interaction between short-term markets and long-term contracts**
Short-term market design	• *pool-based* (where all trading happens in an auction-based pool market) versus *decentralized market* (where trading is based on bilateral contracts), • market power influencing electricity spot price (a generator could influence prices by increasing price bids in a pool market), • *energy only* (where energy and ancillary services are the only commodities traded in the market) versus *energy+capacity* (a capacity renumeration mechanism in addition to energy trade in order to incentivize new investment). The actual choice between these designs is constrained by existing institutions and PPA agreements. It also, to some extent, depends on whether the NEDA system can eventually become the main platform for all short-term electricity trade.	• If an increasing share of generators' revenue comes from long-term contracts, short-term markets become irrelevant. • The price in the short-term market can be affected by long-term contract markets and vice versa. • Overall, long-term resource adequacy is achieved if liquid forward markets exist as complementary to the short-term market.
Long-term contract	• The choice of an underlying product for long-term contracts (for Malaysia, the choice between capacity or energy depends on the need to balance short-term market compatibility, for example NEDA, to create market liquidity and manage price volatility) and incentives provided to enhance resource adequacy. • In the absence of a forward market for bilateral contracts, the contracts can be awarded through auction. With respect to auction design for long-term contracts, the key issues that need to be considered are: • auction structure (for example sealed bid vs. descending clock vs. hybrid auction), • pricing rule (pay-as-bid vs. pay-as-clear), • generation technology eligibility (technology-specific vs. multi-technology vs. technology-neutral auctions), • volume determination (volume as a function of energy, capacity, or budget) Policy makers must also determine auction frequency, participant qualification and non-compliance penalties, grid connection cost model, and whether participant sellers will be responsible for balancing.	

6.2 Decentralization of Malaysian electricity sector

Research Question 2: How does decentralization (distributed generation, storage, demand response, and energy efficiency) affect the Malaysian electricity sector?

To answer this question, the paper first explored decentralized technologies that are relevant in the context of the Malaysian electricity sector and then investigated how decentralization affects the Malaysian electricity market (see Chapter 4 for a detailed discussion). There are two key aspects to consider in relation to decentralization: one is the impact of integrating distributed resources on the electricity system and the other concerns the implications of decentralization for distribution network tariff design.

Malaysia has been actively promoting renewable resources, mainly through initiatives such as the Large-Scale Solar (LSS) programme and Feed-in-Tariff (FiT). An issue that may arise with the growth of distributed resources such as solar is the mismatch between peak solar production and peak demand, which can give rise to a difficult-to-handle shape of net load known as the 'duck curve'. The experience of other countries shows that as variable and uncertain distributed resources grow in the system, there is a resulting shape of net load that requires steep ramping and higher cycles from conventional generation. The problem is exacerbated when decentralized resources replace conventional resources and thus reduce the amount of online flexibility. These issues mean that the power system needs to improve and enhance the flexibility of existing resources, as well as ensure that future plants seeking grid connection can meet the requirements of a grid with a high level of distributed resources. There are various sources of flexibility on both supply and demand sides. It is also possible to have 'virtual power plants (VPPs)' through creating a network of power generators, demand-side resources, and storage technologies. In the context of Malaysia, pooling of gas power plants (Peninsular Malaysia has an estimated 11 GW of gas installed capacity)[48] and battery storage and demand response to provide reliability and flexibility, can significantly improve system flexibility.

With the increasing integration of distributed resources, there is also a need for adequate network tariff design to ensure cost recovery of network companies and, at the same time, efficient operation of decentralized resources. The role of the distribution network operators (DNOs) might need to extend to include distribution system operation (DSO) to better manage peak load and network congestion. A DSO will actively manage congestion in the distribution network using distributed resources, as opposed to a DNO which relies on network reinforcement only. A DSO model of distribution networks in Malaysia can enhance grid flexibility and reduce network investment with the integration of distributed resources.

Table 6.2 summarizes the key points about the way in which decentralization affects the Malaysian electricity sector.

[48] Installed gas capacity as of 2019 was 11,050.43 MW and for 2020 was 9,817.43, as per estimates obtained by author from TNB. Installed capacity for 2020 as of 31 December excludes SPG (1,440 MW) – one unit (720 MW) was targeted to achieve COD in late December 2020 and another unit (720 MW) in early January 2021.

Table 6.2: Summary of findings for the effect of decentralization on Malaysian power sector
Table 6.2a: The impact of distributed resources on the power system

Scope	How decentralization could affect electricity sector	Addressing impact & implications	Government initiatives on distributed resources
Penetration of distributed resources such as solar PV	• Timing imbalance between peak demand & solar-based generation (for example, 'duck-curve' in California and Hawaii). • Peak and ramp regulation stress on conventional dispatchable generators to manage net load.	• Grid flexibility options (for example, fast ramp natural gas plants along with modifications to short-term dispatch schedules to respond to variable supply renewables). • Deployment of energy storages (for example batteries) to provide flexibility and improve efficiency. • Demand response resources. • Retiring inflexible plants with high off-peak running requirements.	• A part of LSS programme (2016–20) at medium voltage level. • Peer-to-peer solar energy trading between NEM prosumers & consumers (2019–June 2020).
Integration and participation of distributed resources	• The gradual shift of the system from a primarily centralized system to a model in which both centralized and decentralized resources co-exist. • A shift towards renewables may impact operation of thermal power plants or increase the risk of renewable curtailment due to grid congestions and instability.	• Pooling of different distributed resources (for example virtual power plant integrating CHP, solar PV, and flexible customers. In future: electric vehicles and battery storage). • New market rules introduction (for example regulatory rules to incentivize flexible resources to offer their services in the market). • Active risk management to address over-voltage, under-voltage, grid congestions, and other operational security issues.	• FiT schemes (biomass, biogas, small hydro, and solar PV, Net Energy Metering). • CHP licenses.

Table 6.2b implications of decentralization for network tariff design

Scope	How decentralization could affect network	Addressing impact & implications
Network tariff design	• Distribution networks will likely experience more variable load as well as congestion. • Networks may also experience challenge in recovering their costs due to the tariff structure which is heavily linked to energy usage while network costs are mainly fixed.	• When distribution networks become congested, the actions of users not only impact the operating costs of the network but also indicate the need for new network investments. Locational Marginal Pricing (LMP) ($/kWh) is an effective way of inducing short-term efficiency. • This can be combined with a peak-coincident network capacity charge ($/kW) to guide long-term capacity utilization of the distribution network. • Policy makers can consider implementing an approximate version of LMP at distribution level, in order to avoid the practical changes of having too many price nodes. • The residual network costs can be recovered through a fixed charge ($/customer). Policy makers can differentiate for fixed charge based on the level of consumption to make it more equitable.

6.3 Renewable support schemes design for Malaysian power sector

Research Question 3: How do renewable support schemes need to be designed and implemented in order to avoid or minimize distortion in the market?

This question considered issues related to the design of renewable support schemes and their effects on wholesale prices (see Chapter 5 for details). The design of an appropriate support scheme is primarily a balance between market compatibility of the scheme and generators' incentives for investment. For instance, fixed price schemes such as feed-in tariff (whether the price is set administratively or through an auction) are effective means to provide incentives for investors in new capacity, as these schemes provide a guaranteed tariff for a sufficiently long period of time. Nonetheless, fixed price schemes can lead to distortion of wholesale electricity market prices. On the other hand, schemes which link the renumeration of the renewable generator to spot electricity prices (such as feed-in premium) are market compatible, but they expose generators partially to electricity market price volatility, thus reducing the incentive for investment.

Overall, the choice of support scheme depends on many factors including the characteristics of the electricity market and requires careful consideration to be given to the trade-offs involved. The renewable support scheme can be technology-neutral or technology-specific. It can focus on the supply side of the market (such as feed-in tariff and tendering) or demand side (for example, tradeable green certificates). From a policy perspective, a renewable support scheme needs to provide sufficient incentive for renewable investment (in other words, it needs to be effective) and cost reduction (namely, it should be efficient), and it needs to operate in harmony with the market system in which it is implemented. Other issues that need to be considered in designing renewable schemes are burden-sharing between government and customers, and scheme stability. When renewable costs are transferred to electricity users though surcharge, the retail price of electricity increases; this might create incentives for self-generation and grid defection, with remaining on-grid customers needing to shoulder the fixed cost of the system. Also, an administrative approach to support schemes makes them susceptible to political intervention through price adjustment or policy change (for instance abandoning support), and this sends a signal of policy instability, much to the detriment of the investment climate. On the other hand, competitive schemes ensure only the most efficient investors are awarded the contract. Therefore, competitive schemes, when feasible, need be prioritized over non-competitive approaches.

Table 6.3 provides a summary of key issues in relation to design of renewable support schemes.

Table 6.3: Summary of findings for research question on renewable support scheme design and implementation

Design of renewable support schemes		
Scope	**Factors to consider in designing**	**Current Government initiatives on renewable schemes**
Direct and indirect renewable schemes	• Revenue sufficiency to cover capital and operating costs. • Burden sharing between government and customers. • Scheme stability to attract investors. • Compliance with overarching national policies.	• Indirect schemes: CDM. • Direct schemes: FiT, NEM, LSS, GITA, GITE, and GTFS.
Implementation of renewable support schemes in electricity market		
Scope	**Elements contributing to effect on wholesale prices**	**Factors to harmonize operation of renewables**
Wholesale electricity prices and renewable operations	• The guaranteed nature of plants' renumeration via support schemes whether the price is set through administrative approaches or competitive bidding will have an impact on wholesale market prices. • Tradeoff between investment incentive and market compatibility (for example FiT vs FiP). • Fossil fuel subsidies (for example cross subsidies for fuel and electricity in Malaysia).	• Partially linking the remuneration of renewables to wholesale electricity prices for mature technologies. • Modifying dispatch rule decisions in the wholesale market (for example, priority dispatch for renewables distorts efficient market outcome) RE priority dispatch in Malaysia may not be needed in future when market becomes mature. • Balancing responsibility for renewables, to minimize balancing cost. • Choosing the optimal time between gate closure and real-time dispatch.

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