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Powering the future:
Malaysia's energy policy challenges

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Executive summary

- The energy industry is changing fast and in multiple directions, with important consequences for energy-rich countries. Malaysia is also experiencing unprecedented political changes with the election of the Pakatan Harapan (PH) coalition on May 9 of 2018, the first alternation of power since the country's independence. Some of the key promises made by the PH's manifesto are related to the energy sector, including a fast growth of renewable generation and the promotion of green technologies. **This paper discusses the global energy scenario, Malaysia's energy policy challenges, and explains why it is important to put energy innovation at the forefront of the national development strategy.**

- In the last decade, the energy industry has been affected by two important factors: the growth of unconventional oil and gas (O&G) production and renewable sources of energy. The former **brought abundance of fossil fuels**, starting from the United States but with potential to spread to other countries. The latter represents **alternatives to fossil fuels**, which can be key to diversifying the energy sources and upholding commitments to limit greenhouse gas emissions as called for by governments that signed the Paris Agreement (2015), which includes Malaysia.

- In terms of total contribution to the world energy supply, unconventional O&G far exceeds the growth of modern renewables such as wind and solar. In 2017, unconventional O&G (from shale and tight oil), in the United States alone, added 12.8 million barrels of oil equivalent per day (MMBOE/d). In contrast, solar and wind energy provided equvalent to 2.1 MMBOE/d, globally, in 2016. However, **renewables have shown impressive gains in competitiveness in recent years** and, in some cases, are the cheapest sources for electricity generation. In addition to these dramatic cost reductions, **renewable sources are poised to gain** from the electrification of energy demand (e.g., electric vehicles), climate change-related policy activism that discourages fossil fuels, and consumers' pressure in favor of low carbon alternatives.

- Both the abundance of fossil fuels unlocked by new technologies and the increasingly competitive alternative energy sources will disrupt business models of firms that rely on the extraction of conventional O&G, as well as the public finances of oil-rich countries like Malaysia.

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- **Unlike the rest of the world, Malaysia's energy matrix is becoming more carbon-heavy:** in terms of primary energy share, coal has increased from 5% in 1996 to 20% in 2016. In electricity production, coal has replaced natural gas as the main source of energy and now accounts for 46% of electrical energy generation. Meanwhile, modern renewable sources (solar and wind) make up less than 1%.

- Malaysian policymakers will need to devise policies to expand the supply and generation of natural gas (to replace coal) and drastically incentivize low-carbon sources of energy such as solar in order to de-carbonize the energy matrix and reach the target of 20% of renewable energy by 2025 as promised by the PH manifesto.

- Both objectives can be facilitated by a national innovation system that prioritizes the research and development (R&D) of the energy sector. Malaysia's high-cost and complex O&G resources need to continuously innovate to remain competitive in a world of fossil fuel abundance and to unlock new gas fields that can replace the growing coal consumption. Incentives for local R&D and collaboration between lead firms, suppliers and universities are also key to building capabilities in renewables.

1. Introduction

The energy industry is changing fast and in multiple directions: the United States overtook Saudi Arabia in 2014 as the world biggest oil producer, thanks to unconventional oil production; electric cars and e-bikes are now mass market products and not gadgets for early-adopters, threatening the internal combustion engine and the demand for liquid fuels; and the price of solar photovoltaics generation is rapidly decreasing and becoming market competitive, pushing solar adoption regardless of subsidies. Recent technological gains have unlocked more oil and gas (O&G) reserves as well as alternative energy sources. Amidst increasing concerns with the environmental impact of fossil fuels and a change in the demand profile towards electrification, there is a possibility that oil reserves will be left on the ground, resulting in a loss to resource-rich countries, including Malaysia.

In addition to global developments, Malaysia's landscape is also changing. The election of the Pakatan Harapan (PH) coalition on May 9, 2018 represented the first change of government since the country's independence. Elections in Malaysia were already increasingly competitive, and going forward, politicians will be increasingly pressured to accede to distributive demands that may be key to winning and retaining government. Some of the key promises made by PH in its manifesto presents examples of political demands with fiscal costs and impact on the energy sector, such as: increasing royalties to oil-producing states to 20%; subsidizing and "stabilizing" petrol prices; enabling the purchase of a first car with reduced prices to low income families; and abolishing highway tolls. Furthermore, the replacement of the GST with the reintroduction of the SST will result in a predicted tax revenue shortfall of RM21 billion to be partially compensated with oil revenues.[1] At the same time, PH promised to increase renewable energy supply from 2% to 20% by 2025 and to "focus on green technology development and renewable energy" (Pakatan Harapan 2018, p. 86). This is a challenging governing agenda that involves a series of tradeoffs and compromises.

[1] The Sun Daily, "SST to be set at 6% for services, 10% for sales," July 16, 2018.

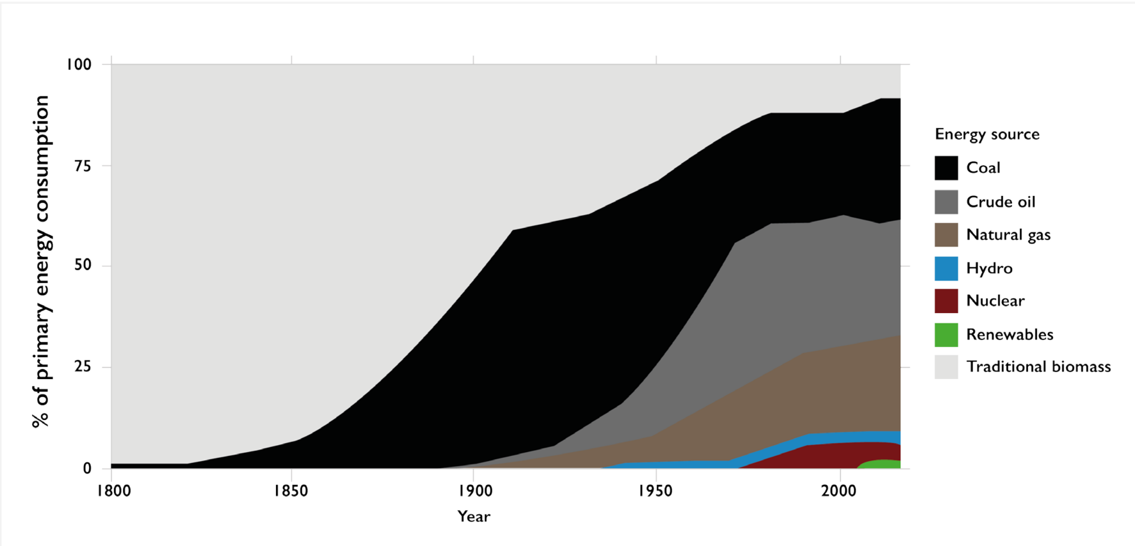
This paper discusses the challenges ahead for Malaysia's energy sector and makes policy suggestions to the method by which the country can position itself to build a strong, innovative and financially sustainable energy industry amidst the emerging domestic and global environment. It starts by presenting key trends in the global energy industry that are disrupting the status quo and leading to new entrants and business models. It follows with an analysis of Malaysia's energy sector, with particular attention to the O&G industry. It then argues for an energy innovation system in Malaysia: a series of interconnected institutions and market players from the public and private sectors working in collaboration to develop and deploy technologies and to foster the creation of new companies. Such an innovation system will be key to maintaining the strength of the current O&G industry by extending the life of current fields and supporting new discoveries; by promoting knowledge spillovers from energy-based research (such as material sciences, biotechnology, data analytics, etc.) to non-energy sectors, helping to further diversify Malaysia's economy and tax base; and by preparing the nation for an economy where fossil fuels play a diminishing role and it becomes increasingly unfeasible to base a large share of the national budget on O&G revenues.

This study concludes that with the right policy mix, Malaysia can be well positioned in the future energy scenario. The task for policymakers is to provide a clear vision of direction followed by calibrated policy instruments that promote the long-term objectives of developing the country's innovation and institutional capacity, which will foster a competitive and sustainable energy sector.

2. From scarcity to abundance: the role of technology in powering the future

The spectacular global economic growth witnessed since the industrial revolution – when global GDP per capita jumped from less than $1000, where it had been stagnant for centuries, to over $10,000 as registered most recently[2] – has been fueled by hydrocarbons. First, it was led by coal, and in the 20th century, by oil. Oil has several advantages: it can "pack" lots of energy in a comparatively small volume (high energy density), it is cheap, easy to store and transport, and is a versatile raw material for a number of fuels and petrochemicals. Given its technical qualities, oil allowed the expansion of the internal combustion engine, as well as everyday plastics and synthetic fibers that are now embedded in contemporary society. By replacing less efficient forms of energy, such as wood and crop residues (traditional biomass), oil helped to create modern life and global trade that most of us may take for granted. Figure 1 highlights these energy transitions and also shows how modern renewables (wind and solar) are still negligible in terms of total world energy consumption. Albeit, renewables are growing fast, as elaborated later in the paper.

Figure 1: Primary energy consumption by main sources (1800-2015)



Source: Smill (2017)

The omnipresence of oil use is contrasted with its uneven global distribution. Few countries have large oil reserves and are net exporters. To complicate things further, proliferous giant oil fields tend to be in politically unstable and undemocratic countries – a relationship that is unlikely random but rather a consequence of the easy access to oil riches and the politico-economic incentives it creates to retain, rather than peacefully alternate, power. In fact, few resource rich countries have managed to utilize their endowment blessing as a developmental advantage, which is what led to a large literature in social science on the "resource curse." About 70% of total oil reserves and 43% of oil production (BP, 2018) come from the Organization of Petroleum Exporting Countries (OPEC), an association which features some of the most autocratic regimes.[3] For the most part, the oil found in OPEC countries tend to be plentiful and technically easy to extract, which makes them the lowest cost of production in the world and the most able to collect high revenues per barrel sold. Through a variety of channels, the abundance of an easy-to-extract resource also made these countries less likely to diversify their economies.

[2] For historical statistics see Maddison (2001) and for most recent data The World Bank (2018).

[3] The following countries are present members of OPEC: Algeria, Angola, Congo, Ecuador, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

For many years, the combination of both the high inelasticity of demand for oil along with its production concentration in a handful of large exporters had led to profound geopolitical and economic consequences, notably the U.S. interest in the Middle East to secure a source of energy to its economy.

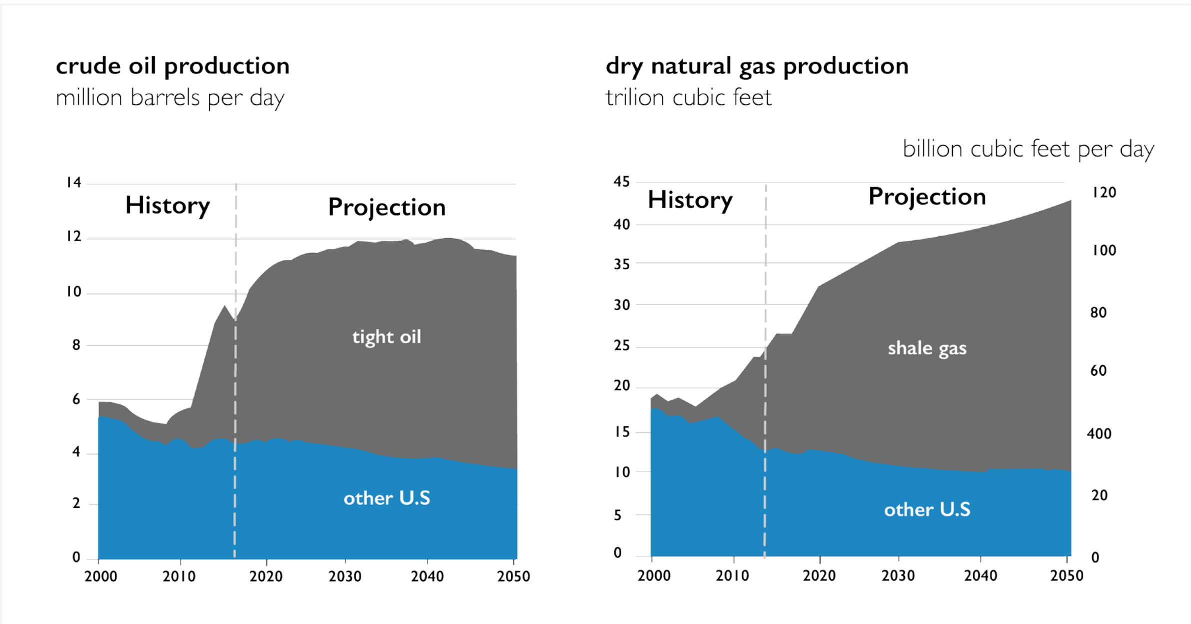
The U.S. is a large, resource-rich nation, which was an oil pioneer. However, production peaked in 1970 at 11.3 million barrels per day (mb/d) and reached a bottom of 6.7 mb/d in 2008. From that year onward, production started to grow consistently and reached a record-high of 13 mb/d of crude oil in 2017. Since 2009, the U.S. has surpassed Russia as the world's top producer of natural gas, and since 2014 displaced Saudi Arabia as the world's leading crude oil producer (BP, 2018).

How was it possible that in a period of less than a decade, the U.S. almost doubled its total oil production and contributed to the world oil market supply the equivalent to **nine times of Malaysia's total crude oil production in 2017 (0.7 mb/d)**?

The answer lies in the combination of resource availability (i.e., geology); technological advancements, particularly the combination of horizontal drilling with hydraulic fracturing; and institutional differences, including private property rights for the subsoil and a strong capital market that financed oil entrepreneurs. It has been known for years that large parts of the U.S. territory had O&G trapped in formations that were too costly to extract because conventional production techniques yielded very low recovery volumes. The high oil prices that prevailed in the 2000s created incentives for entrepreneurs to experiment solutions to tap these *unconventional* resources.

Figure 2, from the U.S. Energy Information Agency, shows the dramatic gains in production from tight oil and shale gas (EIA, 2018). In 2017 alone, these unconventional sources added 12.8 million barrels of oil equivalent per day (MMBOE/d). The figure also shows EIA's growth projection - most likely under baseline scenarios - up to 2050, with the U.S. featuring as a net energy exporter.

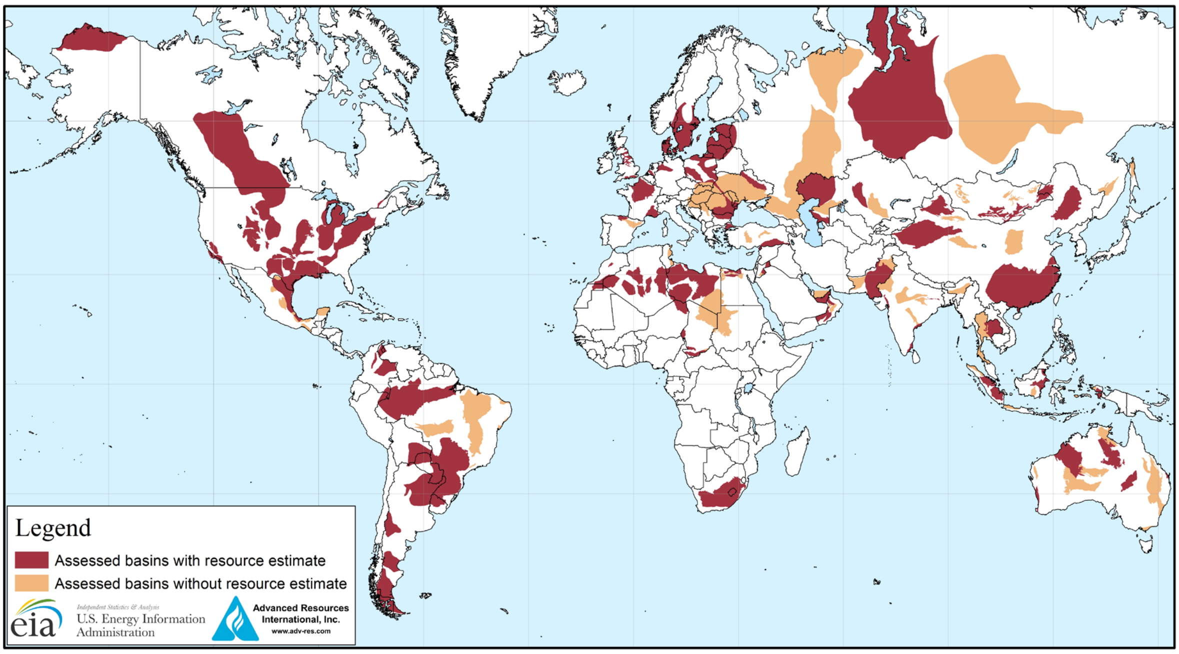
Figure 2: U.S. crude oil and dry natural production



*Noted: Shale gas production includes associated natural gas from tight oil plays
Source: U.S energy Information Administration, Annual Energy Outlook 2018 Reference case

While the U.S. had all the necessary factors to be a pioneer in unconventional O&G, it is far from being the only country with these types of resources. In 2015, an assessment made by EIA on the global potential of technically recoverable shale resources shows 418 billion barrels of crude oil and 7,576 trillion cubic feet of natural gas in a multitude of countries – including Australia, Argentina, France, Indonesia, Poland, etc. (see Figure 3). To give a sense of proportion, the total world reserve as of 2017 was1,696.6 billion barrels, with a crude oil consumption of 92.6 million barrels per day, or 33.3 billion barrels per year, which leads to over 50 years of available reserves given the current level of consumption (BP, 2018). The technically recoverable tight oil from shale, as mentioned, can add another 12 years to that already sizable length of time. In addition, when the technologies used for shale begin to be deployed in conventional fields, available resources will also grow by enabling higher recovery rates from current producing fields (Aguilera and Radetzki, 2016). It is surprising for those outside the O&G sector to know that in most oil fields in the world, only 20% to 40% is actually extracted (Muggeridge et al., 2013). While in most cases it is technically possible to extract more oil from a mature field with "enhanced oil recovery" techniques, production will stop when it does not make economic sense to do so, i.e., when the marginal cost of extraction per barrel from a given field is higher than the price it can be sold. As the bundle of technologies that enabled the shale revolution spreads to the rest of the world and new ones are developed, more oil can be extracted from today's conventional fields.

Figure 3: Assessed basins based on EIA (2015)



The growth of O&G production from shale is not the only remarkable technological advancement in the industry lately. Another source of production growth has been from deepwater offshore wells. Thanks to advancements in 3-D and 4-D seismic analysis, subsea systems, and drilling under challenging high pressure conditions, oil companies have been increasingly able to master the challenges of extracting O&G from water depths that go even beyond 2km. In 2007, for example, Petrobras and the Brazilian government announced the discovery of a new oil play with initial estimates of 70 billion barrels of resources below a thick layer of salt and in water depths of over 2km located 200km away from the coast. This pre-salt area, as it came to be known, was the result of decades of investment in R&D to discover and develop challenging resources, with the participation of state-owned and private companies as well as local and international research institutions (see Box 1).

Box 1: Brazil's leadership in deep offshore oil

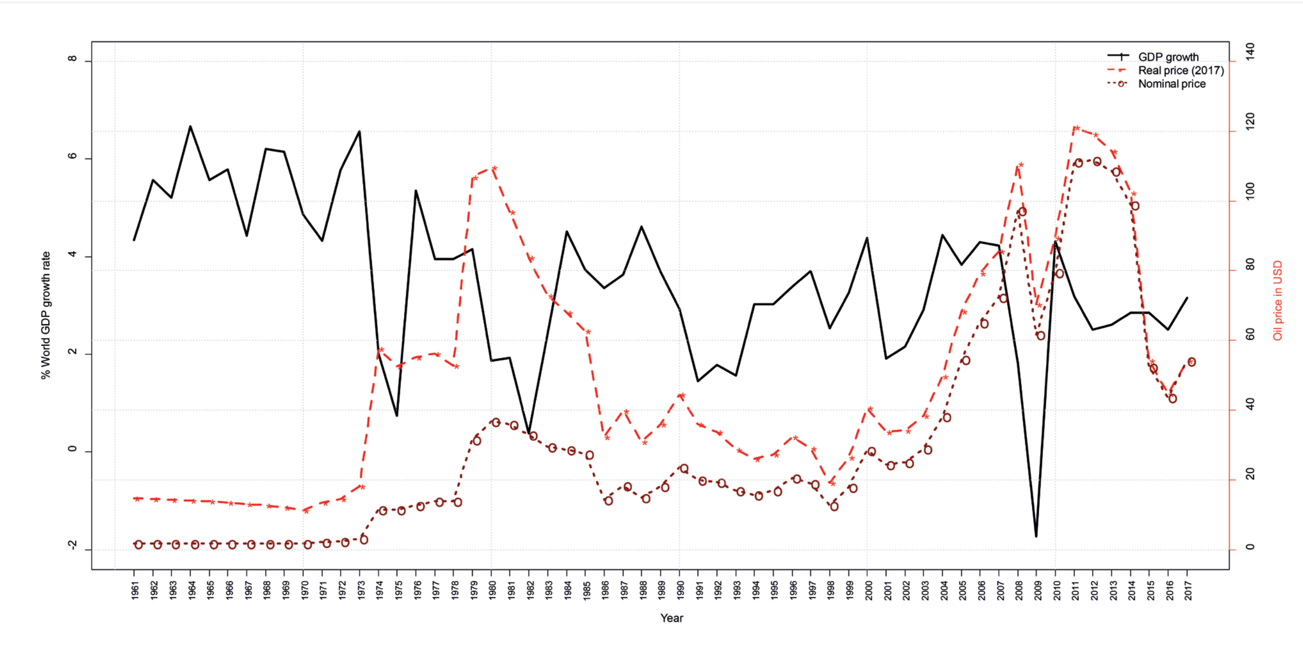
Since Brazil opened its oil sector for private investment in the mid-1990s with the first bidding round in 1999, production has increased from 1.132 mb/d in 1999 to 2.734 mb/d in 2017 (BP, 2018). Brazil's Petrobras is a global leader in deepwater offshore oil production, a feat made possible with a mission-driven R&D investment program called Procap, which started in the 1980s and was designed to master deepwater and ultra-deepwater offshore oil production. Lawmakers and regulators introduced specific rules during the opening of the country's oil sector to channel oil revenues to local R&D by public universities and private companies. Up to 1% of the gross value of the oil production from highly productive fields had to be spent on local R&D investment in the areas of oil, natural gas and biofuels. The amount was to be used in universities and research centers, and up to 50% in internal R&D centers of oil companies and suppliers with local R&D operations. More recently, contracts from 2013 reserved 10% of the earmarked resources to supplier development programs. The opening of the oil sector allowed Petrobras to partner with private firms and raise the capital necessary to invest in deepwater offshore fields, which carried high price tags and geological risks. Petrobras is the only national oil company (NOC) to have received three OTC Distinguished Achievement Awards (1992, 2001, 2015), which is a prize that recognizes technological innovations in the segment (Lima-de-Oliveira, 2017).

Unfortunately, the Brazilian oil company was also in the spotlight recently due to a major corruption scandal revealed in 2014 that led to the arrest of former directors, senior executives from supply companies and high-level politicians, including a former speaker of the house, a finance minister and a former president. The scandal involved the payment of kickbacks from suppliers to fund political campaigns and was a major blow to the image of the company. Thankfully, the independence of public prosecutors and Brazilian courts revealed the full extent of the corruption scheme and held the participants accountable by imposing fines and criminal convictions. Petrobras also received back part of the losses in judicial agreements with suppliers.

The high oil prices that prevailed during the latest commodity super-cycle (from 2004 to 2014) provided a clear incentive to the development of energy-related technologies such as those that allowed the expansion of unconventional oil production. Another incentive was the lack of low-cost reserves available to international oil companies (IOC). National oil companies (NOC) own about 90% of the world's reserves (Victor et al., 2012). Oil operators that are left with less-than-good acreage had to invest to overcome technical challenges and cost barriers to bring to market the barrels that come from high-cost assets. These resources, however, have high breakeven price and are the first investments to be halted when prices decline, such as in 2014.

Figure 4 shows GDP growth and oil prices (real and nominal) per year. In real prices, the commodities super-cycle observed in the 2000s was marked by higher oil prices than in previous periods of oil shocks, such as in the 1970s. Therefore, oil prices between $40 to $60, as observed recently, are not low prices, but rather historically high. Secondly, GDP growth is decoupling from oil prices as the economy becomes more knowledge-intensive and service-sector-based rather than energy-intensive and manufacture-driven.

Figure 4: GDP growth and oil prices (1960-2017)

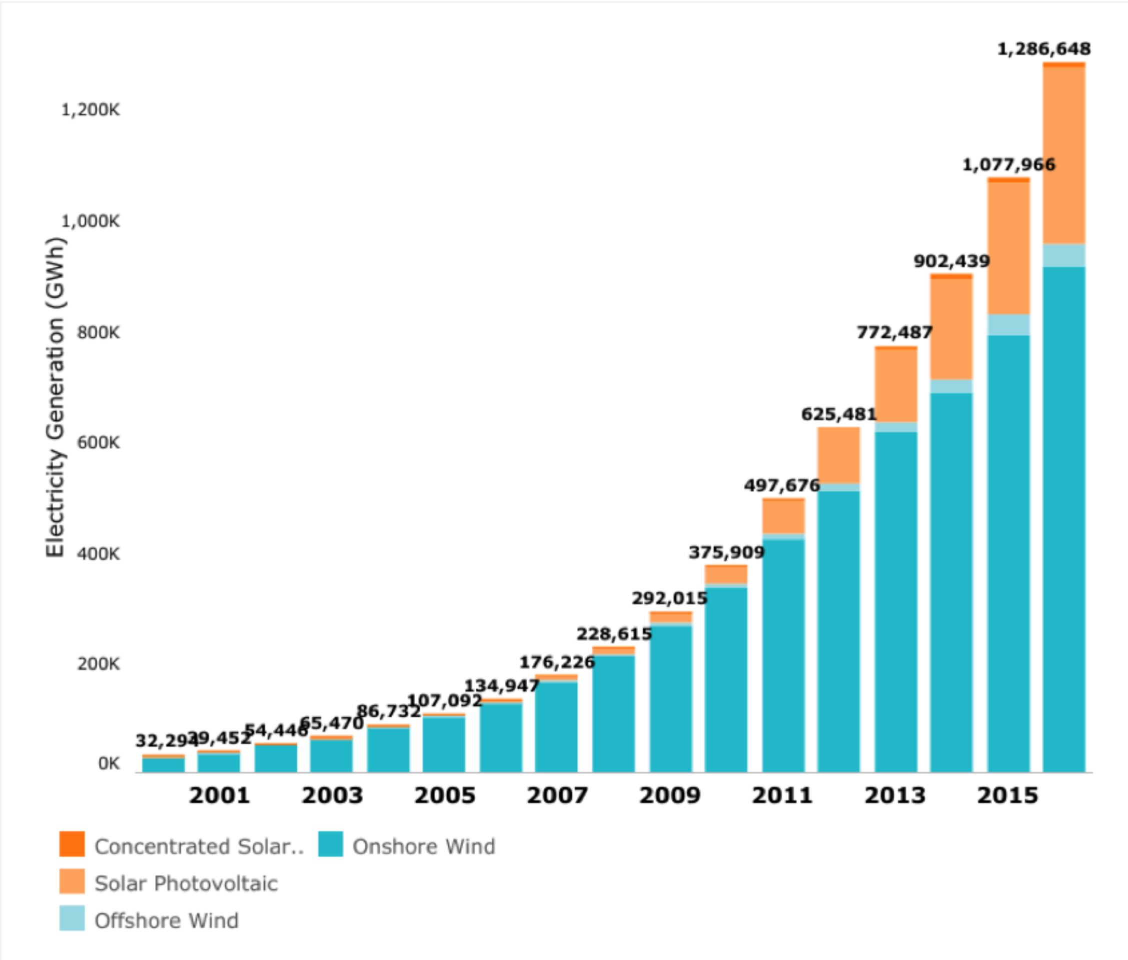


Source: BP 2018 and World Bank Development Indicators

The share of renewables

High oil prices and a growing concern over the environmental impact of fossil fuels also stimulated the search for substitutes. The current commercially available wind and solar energy generators are updated versions of technologies that have been around for decades. Yet, the installed capacity of solar and wind increased from a slim 18,163 MW in 2000 to 903,119 MW in 2017 (IRENA, 2018a). Installed capacity is a tricky indicator for renewable energies because the sun is not always shining nor the wind always blowing. Nevertheless, when taking into account total energy generation, the growth has been from 32,294 GWh to 1,286,648 GWh from 2000 to 2016. To put this into perspective, in 2016, solar and wind energy provided the same as 2.1 MMBOE/d of energy for a year – about Norway's crude oil production and about one-sixth of U.S. unconventional O&G in 2017 (EIA, 2018).

Figure 5: Trends in Renewable Energy (Electricity Generation in GWh)



Source: IRENA 2018a

Renewable energies are still a green drop in a black ocean, since fossil fuels currently account for about 80% of total primary energy consumption in the world. However, there are good reasons to believe that a combination of factors is poised to favor renewable energy production in the coming years:

1. Dramatic cost reductions

In addition to incremental innovation, wind and solar energy projects have benefited tremendously from scale economies and learning-by-doing in manufacturing. This has been particularly true with solar photovoltaic (PV). Scientists involved with the MIT Energy Initiative have noticed that "the cost of solar power tends to be lower than expected, and the deployment of solar power tends to be higher than expected" (Brown et al. 2017). For instance, in 2011, the U.S. Department of Energy launched the SunShot initiative with the aim of accelerating cost reduction in solar deployment so it could be competitive with conventional sources of electricity generation (i.e., coal and natural gas) without subsidies, which required slashing costs by 75%. The target set for 2020 was achieved in 2017 for utility scale solar (a levelized cost of electricity of $0.06 per kWh[4]) and a new initiative, for 2030, was launched with a target to further reduce costs by 50% ($0.03 per kWh)(U.S. DOE ,2017).

Recent energy auctions in different markets showed renewables on cost parity or even cheaper than natural gas and coal (IRENA, 2018b). However, this does not necessarily mean that we can now quickly reduce the share of fossil fuels in the energy matrix. Due to the intermittent nature of the most deployed modern renewable energies, wind and solar PV, system stability requires backup generators that can be dispatched to the system – most of the time fueled by natural gas and coal. Utility-scale energy storage would solve this issue, but cost reductions and technological improvements in this area are still limited. One of the focus areas of the SunShot 2030 initiative is to achieve comparably low costs in concentrated solar thermal power (CSP), a solar technology that, unlike solar PV, can store energy and dispatch it to the grid when needed.

2. Electrification of energy demand

The digital economy has the potential to shift energy demand in multiple fronts, including: growing usage of equipment powered by electricity; decentralization of energy production, with consumers also playing the role of generators; and a shift in the consumer base from passive to active through smart meters and internet-of-things that manage load and add flexibility to the energy grid. Some of the impacts are more speculative, such as gradual reduction of global physical trade through decentralized manufacturing via 3D-printing or widespread deployment of more efficient logistics through driverless cars and trucks, both of which have the potential to reduce liquid fuel consumption (Helm 2017).

From energy-hungry data centers that serve as cloud storage to mobile phones at the hands of hundreds of millions of users, the digital economy is powered by electricity. The backbone of the contemporary economy runs on electricity, even for intensive and perhaps spurious usage, such as purely bitcoin mining.[5]

[4] Measured as the levelized cost of electricity (LCOE) for an area of average climate in the U.S. LCOE is a convenient measure to compare costs among different sources of energy by incorporating the net present value of capital and operational costs over the lifetime of a given project. It can be interpreted as the break even price of the project or "the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate" (IRENA 2012, p. 3).

[5] A recent paper that assessed the feasibility of cryptocurrencies serving as dominant mean of exchange pointed to the energy consumption as one of the barriers for large scale adoption. The study estimated that the total electricity use of bitcoin mining amounted to the consumption of a country like Switzerland, resulting in an environmental disaster, so the authors claimed (BIS 2018).

Presently, oil is rarely used to generate electricity; instead, it is dominant (94%) in transportation (BP, 2018). If demand for transportation goes down, either by increased efficiency with driverless cars or 3D-printing reducing the intercontinental flow of goods, oil stands to lose. It also stands to lose if transportation switches from the internal combustion engine to electric vehicles. On this front, the penetration of electric vehicles is gaining momentum: sales of electric vehicles reached 1 million units in 2017 (IEA, 2018a).

Since 2016, investments in electricity generation surpassed oil and gas – US$750 billion versus US$715 billion, respectively, for 2017 (IEA 2018b). Electricity can be generated from multiple sources and coal has traditionally been dominant in many countries due to it being cheap and widely available, despite its environmental, and largely unpriced, cost from high emissions of nitrogen oxides (NOx), sulfur oxides (SOx) and greenhouse gases. Coal is gradually being displaced due to the stricter environmental laws and cost competition from renewables and natural gas (particularly in the U.S., thanks to the shale revolution). It is now commonplace to see natural gas as a "bridge fuel" for a greener future because it can generate electricity with 50% less CO_2 emissions than coal and can also provide dispatchable thermoelectric generation when needed, compensating the intermittency of wind and solar PV generation.

3. Policy activism and consumer's preference

Most scientists and politicians agree that the rate of CO_2 emissions and other greenhouse gases are linked to a warming of the planet and if we are to keep it below a rise of 2°C above pre-industrial levels, the world needs to drastically move away from carbon-based sources of energy. This is reflected in the objectives of the Paris Agreement (2015), the latest in a series of summits and meetings that seek to coordinate a unified response to the challenge of global warming.

The Paris Agreement is based on voluntary cooperation. It has no enforcement mechanism and already suffered a major blow with the election of Donald J. Trump in the United States, who announced the withdrawal of the US from the agreement. Despite the fragility of a global agreement to limit carbon emissions, at the country and state level, policies can accelerate energy transition.

In the U.S., although the Trump administration is reversing regulations set by the Environmental Protection Agency (EPA) to benefit the coal and oil industries, activists turned to state level politics to enforce their green agenda. States like California and Massachusetts have their own clean energy and pollution reduction targets.

When politics fail, citizens concerned with environmental impact can also influence the energy demand through their purchasing power. To differentiate products and promote sustainable consumption, some companies are investing in carbon offsetting schemes, signaling to consumers that they are doing their part in mitigating climate change.

It is hard to predict the exact impact that the stick of local regulations or the carrot of consumers favoring environmentally sustainable suppliers will have on business practices. Nonetheless, the combination of policy activism and consumers' preference towards sustainable products are forces that energy firms based on fossil fuel will have to reckon with as it can increase their cost of doing business.

Energy transition and its political effects

For most of the 20th century, policymakers from oil-rich countries were able to reasonably expect that the combination of high oil demand, lack of a real substitute and limited reserve availability secured an intrinsic value to their subsoil wealth. They did not need to hurry to take oil out of their ground – oil produced tomorrow would be worth more than oil produced today, since reserves would get increasingly scarce, and prices would be driven up over time. Output could be managed according to the fiscal needs of the producing countries, the time horizon of the rulers, and the quotas set by OPEC. NOCs could then play the role of custodians of the nation's underground wealth.

A new energy scenario challenges this conventional approach and poses serious threats to oil-rich countries such as Malaysia. The increasingly lower cost of renewables is bringing competitive alternatives to energy generation. The electrification of the economy, including the transportation sector, can reduce the demand for liquid fuels. Technological advances in horizontal drilling, fracking and deepwater offshore production have unlocked vast new reserves outside OPEC countries and challenged the idea of peak oil and increasingly higher oil prices. Finally, policy and consumer pressures can accelerate the shift towards a lower carbon footprint in the economy.

Because of these factors, oil consumption may reach a peak in the coming decades, whereby natural gas and renewables gradually displace oil products, even if total energy consumption goes up. To keep their market share in the world energy matrix and slow down the energy transition, oil-rich countries may react by increasing their production capacity and try to undercut, by lowering prices, the expansion of renewables and electric forms of transportation. In this likely scenario, oil prices would stay lower in the medium- to long-term – with occasional short-term fluctuations to adjust supply and demand and react to geopolitical shocks.

The gradual decline of oil in the energy matrix will have deep repercussions and it is a challenge to oil companies, particularly NOCs. It puts pressure in countries that base a large share of their fiscal revenues on oil sales and have not diversified their economy. It will be particularly hard for countries and regions that base their economy on the sole extraction of natural resources and have not invested in human capital and innovation capabilities.

The good news to oil-rich countries is that energy transitions take time and the current production from renewables is still miniscule. Policy decisions taken today can have a deep impact in shaping the future. In the next section, the paper addresses Malaysia's energy system and provides policy suggestions that allow the country to seize the opportunities brought by the incoming global energy changes.

3. Malaysia energy outlook

This section starts by describing the main players in Malaysia's energy system, particularly PETRONAS in O&G and Tenaga Nasional Berhad in electric energy. It follows with an analysis of Malaysia's energy matrix and energy transition challenges.

PETRONAS and the O&G sector

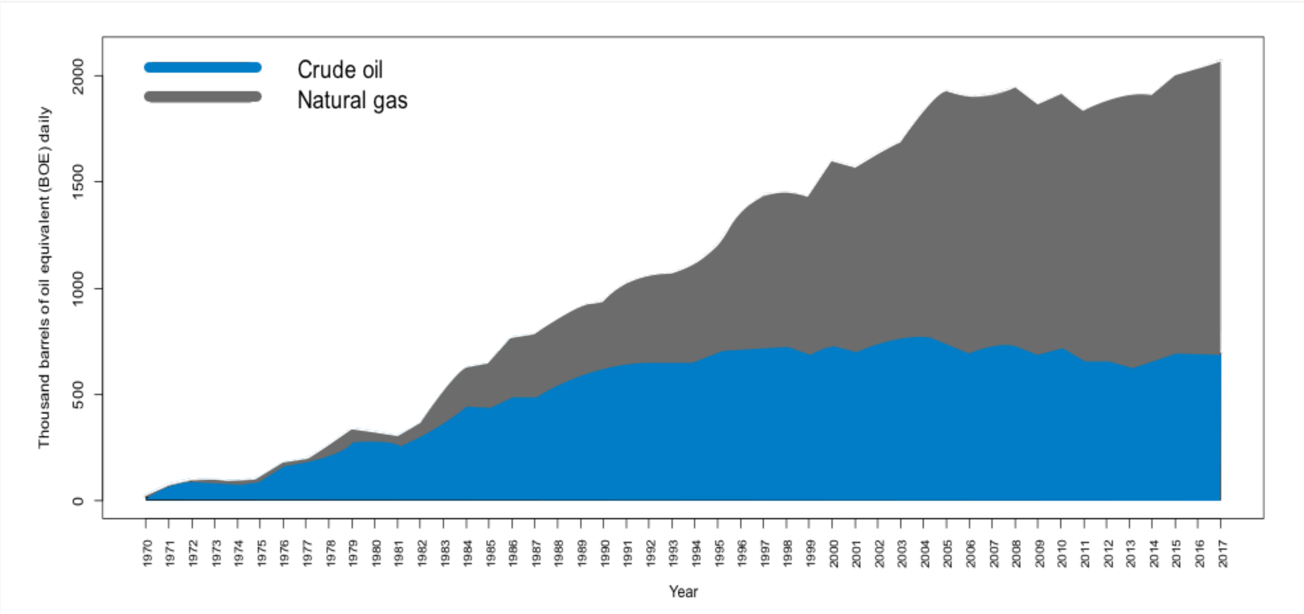
The big wave of contract renegotiations and later oil nationalizations between the 1950s and 1970s shifted most of the economic rent from international oil companies to host countries (Mommer, 2002; Maugeri, 2006). With traditional markets closed or severely taxed, oil companies sought to explore resources outside OPEC countries. This led to the economically counterintuitive move of developing more costly sources of oil before exhausting the cheap ones, which are predominantly found in OPEC countries. New areas for oil exploration and production included the North Sea, Alaska, and offshore Brazil and Malaysia.

In the late 1960s, Shell and Esso started offshore oil exploration in Malaysian waters but production was miniscule, amounting to less than 10k bpd in the 1960s. Yet, it had potential and the Malaysian government decided to revamp the legal framework by centralizing regulatory and ownership rights from states, and negotiating new contracts with oil companies that would increase the taxes from oil production. PETRONAS, created in 1974 through the Petroleum Development Act (PDA), reflected the spirit of the time. Globally, oil scarcity drove companies to find new markets and host governments expected high returns. Nationally, PETRONAS would serve as a vehicle to promote a Bumiputera business class, in accordance with the principles of the New Economic Policy (NEP), which was enacted in 1971 following the 1969 ethnic riots.

More than just a rent-collector, PETRONAS sought to develop national capabilities in human resources and in the supply chain through regulations built into the Production Sharing Contracts (PSCs) that foreign oil companies signed. By requiring companies to transfer knowledge from foreign workers to locals and by sponsoring scholarships, PETRONAS developed, over the years, a pool of qualified human capital apt to operate in all activities of the O&G value chain. It also created incentives for the localization of goods and services in Malaysia by requiring oil companies to buy from local licensed companies. Starting in 1978, PETRONAS took the risk of operating a field by itself by setting up a subsidiary (Carigali) that undertook the development of an area relinquished by Conoco (the Duyong field). With time, PETRONAS became a fully integrated O&G company with a strong international footprint (Hashim, 2004; Lima-de-Oliveira, 2017; Lopez, 2012).

Domestically, PETRONAS still takes the role of a regulator (through the Malaysian Petroleum Management (MPM) division) and operator (Carigali) in the upstream. Natural gas represents about two-thirds of Malaysia's upstream production with 1.372 mboe/d in 2017. Since the mid-1990s, crude oil production has stabilized around 700 kbp/d (See Figure 6). Several companies are involved in upstream exploration and production in Malaysia, such as Shell, Exxon, Murphy Oil, ConocoPhillips, Sapura Energy, Hibiscus, etc. As the custodian of the nation's O&G resources with full regulatory powers, PETRONAS dominates the country's sector and determines the conditions of entry through closed biddings, selecting which areas are put for exploration and under what fiscal terms. It also holds a minimum 15% equity stake in upstream PSCs.

Figure 6: Crude oil and gas production of Malaysia (1970-2017)



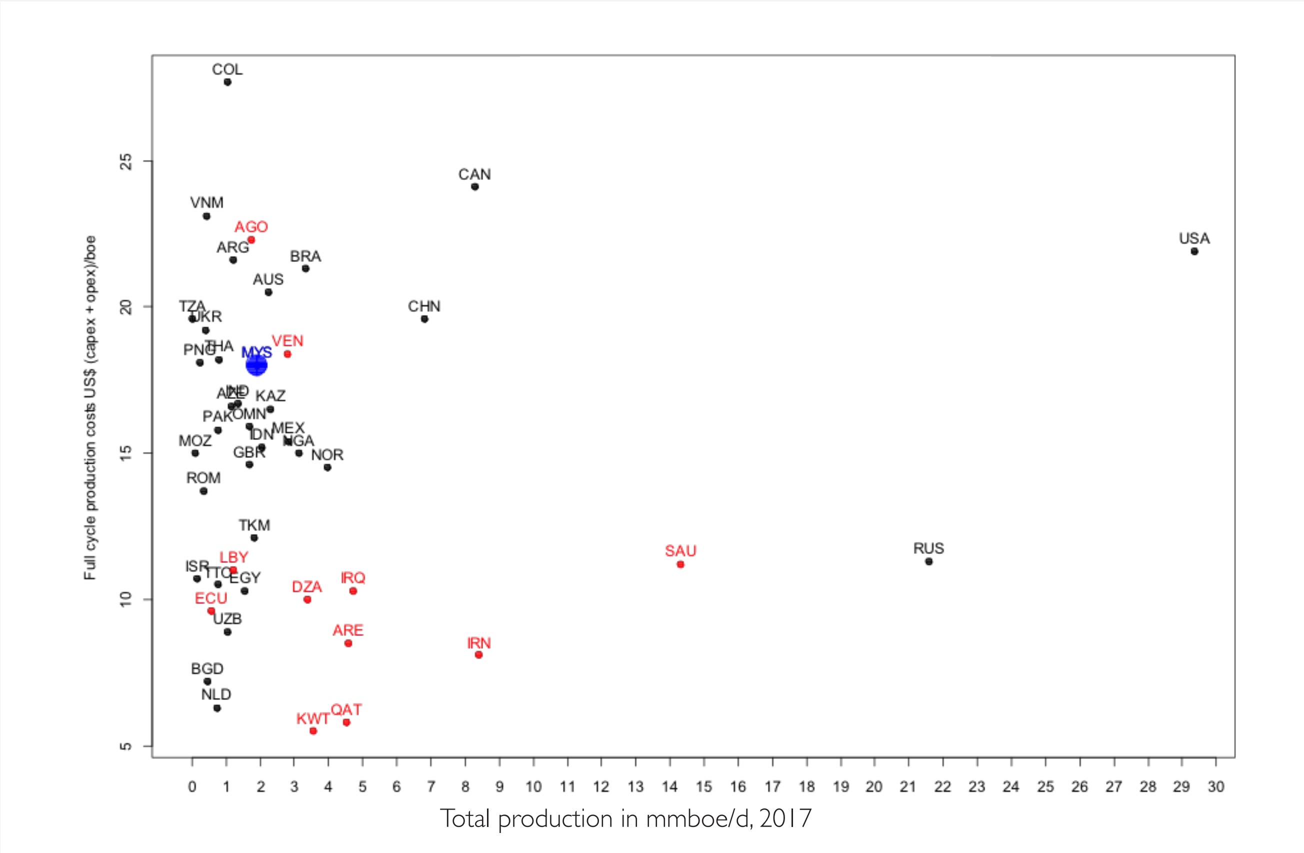
Source: BP 2018

The rate of growth of domestic O&G production has been below the country's economic progress and Malaysia has struggled to add to reserve capacity. The fall of oil prices in 2014 hit Malaysia particularly hard as the country's geological endowment is of high-cost offshore O&G with fields of limited size. Figure 7 shows full cycle production costs (capital and operational expenditures per boe[6]) and total O&G output for a group of 45 countries.[7] With US$18/boe of cost, Malaysia is situated among the countries with high cost of production. Accordingly, since the contracts have been signed in 1976, subsequent contracts have offered more attractive fiscal terms to partners (1985 PSC, deepwater PSC, R/C PSC). In 2011, PETRONAS awarded six Risk Service Contracts (RSC) to develop clusters of marginal fields. Despite an initial interest, most of them had been returned following the decline of oil prices after 2014 as they have an estimated breakeven costs of $60 per barrel (BMI, 2018).

[6] These estimates do not include exploration and appraisal costs. Sedimentary basins with higher geological risk, most of which are outside of OPEC countries, will have higher expected costs.

[7] All countries that hold more than 2 billion boe of reserves.

Figure 7: Full cycle production costs and total output in selected countries



* Author's calculation based on GlobalData Upstream Analytics

According to IEA (2017), about half of the country's recoverable resources are in fields smaller than 100 million barrels. Unless prices go (and stay) up, in order to profitably exploit these small fields, it will be necessary to invest in cost-reduction technologies and devise even more attractive fiscal regimes. Malaysia's high fiscal dependence on oil revenues – frequently over 20% of the federal budget – and dwindling reserves represent a critical challenge to the PH government. To boost future capacity, the O&G industry in Malaysia will need to: (a) increase exploration in deepwater offshore areas; (b) maximize the recovery factor of existing oil fields (through the deployment of enhanced oil recovery techniques); and, (c) monetize small, marginal fields. All three routes represent cost challenges and likely require lower government take per barrel to attract investments.

In sum, while O&G production in Malaysia while O&G gas production in Malaysia has been stable or slightly growing since the mid-2000s, the current institutional framework has not been successful in meeting the country's economic growth rate and the need to add reserves to match the demand. It should be noted that PETRONAS has been investing heavily in the downstream sector with the Pengerang Integrated Complex (PIC), a US$27 billion project in partnership with Saudi Aramco that will process Saudi crude. However, the economics of downstream are significantly different: it is a highly competitive segment with low margins. The growth in the downstream segment is unlikely to compensate, in fiscal contributions, the upstream sector – which makes the strengthening of the latter critical.

The electrical energy market

If in O&G, PETRONAS is the crown jewel of the country, in electrical generation Tenaga Nasional Berhad (TNB) is the dominant player. However, the electrical energy market is more diverse and has been subject to recent changes towards opening and competition.

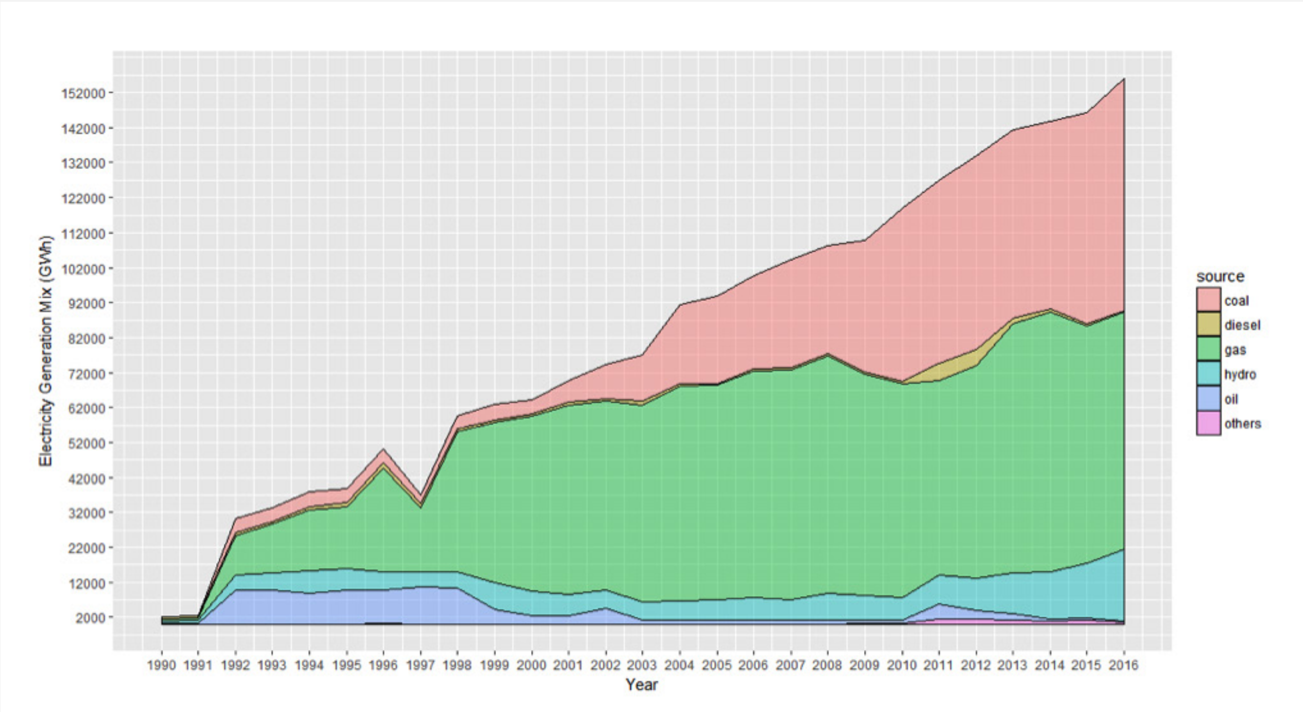
With a near monopoly in Peninsular Malaysia, TNB is the biggest electricity provider in the country. TNB is publicly-listed and the government controls it through Government Linked Investment Companies (GLICs) like Khazanah and Permodalan Nasional Berhad (PNB). In Borneo, the electrical utility role is performed by Sabah Electricity, which is majority-owned by TNB with minority participation by the state of Sabah, and Sarawak Energy. About 60% of the country's generating capacity comes from TNB with Malakoff (23%), Powertek (8%) and YTL Power (6%) playing sizable roles.

Malaysia adopts a single buyer model with independent power producers (IPPs). Policy is set by the Energy Commission, established in 2001, and the Ministry of Energy, Technology, Science, Climate Change and Environment (MESTECC) – which, as the long name signals, is a ministry with no shortage of issues to deal with.

Malaysia has signed and ratified the COP21 Paris Agreement and committed to cut its greenhouse gas emissions. In the government-issued Green Technology Master Plan (2017-2030), it aspired to reduce 45% of emission intensity by 2030 (KeTTHA, 2017). Increasing the mix of renewable energy in the country is a necessary condition and different policy instruments have been deployed to promote renewable energies in Malaysia. This includes the establishment of Greentech Malaysia in 2010 to coordinate the initiative and the creation of incentives that include targeted subsidies in the form of feed-in tariffs and loan guarantees, as well as other incentives such as technology grants, etc. Furthermore, the PH manifesto pledged to increase renewable energy supply to 20% by 2025.

In light of these state policy priorities and the fact that Malaysia is a gas-rich country, it is surprising to note that Malaysia is becoming a more, and not less, carbon-intensive economy. Coal may be dying in the rest of the world, but not in Malaysia: in terms of primary energy share, coal has increased from 5% in 1996 to 20% in 2016. Most of coal consumed in Malaysia is imported and used to generate electricity. Beginning in the late 1990s (see Figure 8), **Malaysia has made a strong bet on coal** by raising consumption more than 17-fold – from 964 ktoe in 1998 to 17,101 ktoe in 2016 (Energy Commission 2017). As a share of electrical energy generation, coal supplied 46% of the total 150,442 GWh in 2016, with a negligible participation of modern renewables like solar and wind.

Figure 8: Electricity generation mix (in GWh) of Malaysia (1990-2016)



The combination of fast national economic growth, slow progress in domestic hydrocarbon output (particularly gas fields in offshore Peninsular Malaysia) and political pressure to keep domestic energy prices low under subsidized rates has resulted in an explosion of coal consumption.[8] The availability of natural gas would make it a perfect fuel for domestic electric energy generation, as has been happening in the United States with the shale revolution. However, Malaysia's natural gas can be more profitably sold elsewhere than domestically consumed, mainly due to subsidized energy prices and long-term contracts.

In Malaysia, 60% of the total gas production that is exported as Liquefied Natural Gas (LNG) follows market prices, while the gas consumed domestically has a lower rate that is regulated by the government. The difference between the LNG price and the domestic one is a subsidy which is borne by PETRONAS. Since the adoption of this policy, in 1997, PETRONAS has forgone RM241.4 billion of revenues (Malaysian Gas Association, 2017). Malaysia's premier oil company is required to commercially sell its production in order to generate much needed revenues for the public budget, which, in part, ends up paying for energy subsidies. In 2010, energy subsidies for electricity and transport fuel accounted for 4.1% of the GDP (ERIA, 2016). Although Malaysia had been phasing out subsidies since 2014, the PH government signaled that it plans to keep consumer energy prices low through this politically friendly, but environmentally and fiscally costly, policy.

As shown in Figure 8, Malaysia's energy balance is carbon-heavy, and decarbonization – as called for by the Green Technology Master Plan and the PH manifesto – will require greater investments in technologies and new public policies to unlock more natural gas and support the expansion of renewable sources. Malaysia has been gradually implementing policies to promote renewables but they have yet to move the needle in the direction of less carbon.

[8] The growing domestic demand with limited natural gas supply can generate systemic risks and extra costs. For instance, a curtailment of natural gas from offshore Peninsular Malaysia due to platform maintenance resulted in an energy crisis in 2011 and 2012, which led to a spike in the use of fuel oil and diesel (see Figure 8). Since May 2013, with the completion of a regasification terminal in Melaka, Peninsular Malaysia gained more energy security. However, in 2016, only 20 cargoes of LNG were imported through this terminal while 420 cargoes were exported from Bintulu, Sarawak (Malaysian Gas Association 2017).

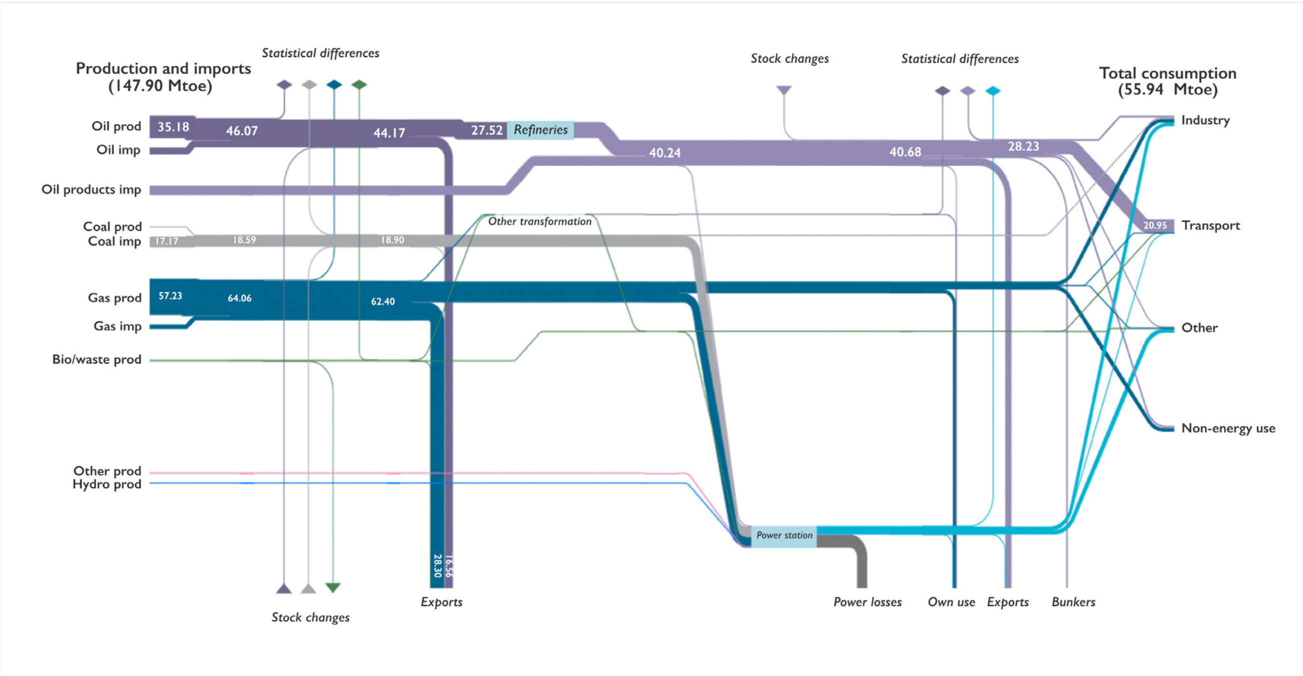
Box 2: The TN50 Oil and the energy long-term aspirations

In 2017, the Malaysian government launched the "Transformasi Nasional 2050" (TN50) initiative which had the aim of making Malaysia a top-20 nation in socio-economic development and innovation by 2050. The initiative involved several stakeholders from diverse sectors of the society – including IDEAS – in meetings that debated both the long-term aspirations for the country as well as the policies necessary to make them a reality. PETRONAS led the initiative of the TN50 for the oil, gas and energy (OGEE) sector.

Malaysia is no stranger to such long-term planning exercises and the TN50 built upon a rather surprisingly successful national tradition of aspiring to hard-to-reach goals that includes the New Economic Policy (NEP) (1971-1990) and Vision 2020 (1991-2020), which were planning efforts that achieved a fair share of success, albeit not without controversy. Planning so far ahead in the future (2050) is doomed to result in mistakes or unrealistic targets because technology is constantly disrupting business models. However, the initiative was able to capture the thinking of major stakeholders of the industry and how they wanted or saw the sector evolving in the future.

In July 19, 2018 the TN50 OGEE secretariat shared with stakeholders their conclusions, which had been formulated in a white paper delivered to the new PH government. It called for a fully liberalized market in the energy sector (but not in O&G), increase of renewables in the energy matrix, and more investments in energy innovation (to reach 3% of GDP by 2050 from less than 1% currently).

Figure 9: Sankey diagram of Malaysia's energy balance (2016).



Source: IEA (https://www.iea.org/Sankey/#?c=Malaysia&s=Balance)

4. Energy innovation: a framework for Malaysia's future

Technological innovations are reshaping the energy sector with profound economic and geopolitical implications. After a decade of more hype than reality, renewable energies are catching up and becoming cost-competitive, without subsidies, in generating electricity. Electricity is also gaining ground in total energy consumption with the digital economy and electric transportation options. In O&G, the US shale revolution has unlocked vast amounts of new sources of fuel with the potential to keep hydrocarbon prices low in the medium to long term. Oil-dependent countries, particularly OPEC members, will have to cope with the double challenge of increased supply from shale and more cost-competitive alternative energy sources. Given their fiscal dependency on oil revenues, and domestic political challenges, oil-rich countries may well react by pumping more O&G out of ground before it is too late – before their reserves get stranded. This can further depress oil prices in the medium- to long-term.

This likely scenario will be particularly challenging to Malaysia. Given its high cost of production (see Figure 7) and relatively small fields, lower oil prices can seriously affect the domestic oil industry, which has already struggled to maintain production levels. Higher royalties, such as those demanded by oil-producing states, can equally depress new investments. The combination of economic growth, political pressures to keep energy prices low and limited natural gas output has already impacted the national energy matrix by increasing the usage of coal, which now accounts for 46% of the electrical energy produced in Malaysia (Energy Commission, 2017). This contrasts with the commitments made by Malaysia under the Paris Agreement to limit carbon emissions and make the PH manifesto promise to increase renewable energy utilization to 20% even more challenging.

Despite a diversified economy, the O&G industry is still a key pillar of Malaysia's economy. The country has a heavy reliance on O&G revenues to fund its public budget – it was 15% in 2017 from a peak of 49% in 2009 (EPU, 2017). Furthermore, the dependence is expected to increase again in 2018 to cover the revenue shortfall from the replacement of GST to SST tax system. The sector's economic contribution has been estimated as RM203 billion for a total national GDP of RM 1,353 billion, or 14.7% of the GDP (EPU, 2017), and it pays the highest salaries in the country, with an average of RM13,310 (Department of Statistics Malaysia, 2017).

It is vital, therefore, to sustain the national O&G industry and invest in building capabilities to smoothly transition to renewables and seize the green jobs of the future. The path forward passes through increasing Malaysia's innovative capacity, using revenues from O&G to invest in cost reduction innovations in order to maintain the current industry and help to unlock more natural gas that can replace coal, and also in renewable technologies. In this regard, there is much to achieve, as detailed in the following sections.

Energy innovation in Malaysia

How is Malaysia ranking in terms of energy innovation? Patents are an imperfect but widely used metric for innovation output and can provide a snapshot of the country's effort in this activity. In both O&G as well as renewables, the numbers do not fare well internationally.

Table 1 presents the number of international patents registered by a list of 15 NOCs. The company selection was based on the list of firms studied by Victor et al. (2012). In addition to the total number of patents, I followed Cavalheiro et al. (2014) and also provide information on patents that match the E21B technical area of the International Patent Classification (IPC) scheme which encompasses upstream technologies.

PETRONAS occupies the median position – behind seven other NOCs, but ahead of most Middle Eastern, African and Indian competitors, which basically do not engage in R&D. In addition, of its 287 patents, only 10 are directly related to upstream technologies (E21B category). This is in stark contrast to the leading NOCs like CNPC, Statoil/Equinor and Petrobras.

Table 1: International patents by selected NOCs (from 1970 to 2017)

Company	Origin	patents (total)	patents (upstream)
CNPC	China	10034	5274
Statoil	Norway	2818	1182
Petrobras	Brazil	2744	716
Gazprom	Russia	1263	458
PDVSA	Venezuela	1210	158
Saudi Aramco	Saudi Arabia	1061	272
Pemex	Mexico	859	63
PETRONAS	Malaysia	287	10
ONGC	India	12	4
ADNOC	Abu Dhabi	2	1
NIOC	Iran	2	2
Sonatrach	Algeria	1	0
KPC	Kuwait	0	0
NNPC	Nigeria	0	0
Sonangol	Angola	0	0

Source: Author's calculation based on the European Patent Office search

Table 2 shows data on cumulative patent applications, from 2000 to 2015, for renewable technologies for a selected group of countries.[9] Measured by patents per population, Malaysia shows room for improvement.

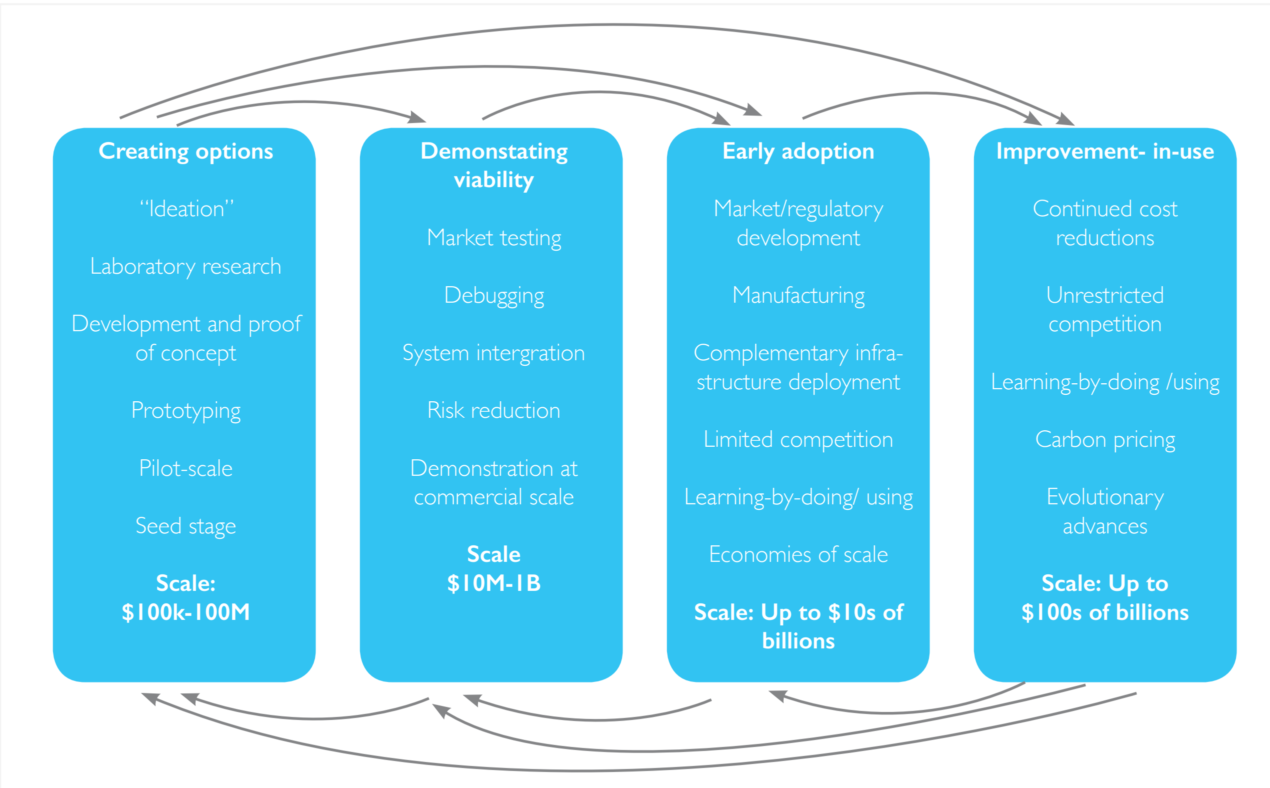
Table 2: Cumulative number of patents filled for renewable technologies (2000-2015)

Country	Patents	Population	Patent per million population
Singapore	1809	5,535,262	326.81
United States	102680	319,929,162	320.95
Spain	9682	46,397,664	208.68
China	169181	1,397,028,553	121.10
South Africa	2238	55,291,225	40.48
Mexico	4488	125,890,949	35.65
Brazil	6752	205,962,108	32.78
Malaysia	562	30,723,155	18.29
Turkey	516	78,271,472	6.59

Source: IRENA and UN

The energy sector is one of the pillars of Malaysia's economy but it is not innovating enough to face the technical and political challenges. This study suggests to Malaysian policymakers to put energy innovation at the forefront of their sectoral policy. Following Lester and Hart's (2012) energy innovation framework (see Figure 10), Malaysia needs to strengthen its national innovation system from the stage of creating options to incrementally greater stages of innovation.

Figure 10: Stages of energy innovation (Lester and Hart 2012)



[9] The list includes patents for ocean energy, heat pumps, geothermal energy, fuel from waste, biofuels, bioenergy, hydropower, wind energy, wind power, PV - thermal hybrid, solar photovoltaics, solar thermal, cross-cutting.

The national O&G sector can play a much stronger role in promoting innovation given its magnitude in the share of the economy and the technical challenges that it faces. Lima-de-Oliveira and Sturgeon (2017) show that the O&G industry has its own innovation system, characterized by intense collaboration between the main actors. Oil operators tend to conduct in-house R&D for subsurface research and more asset-specific questions. These lead firms influence the development of technologies, which are more applied in nature, by working with their Tier 1 suppliers like the oilfield service companies Schlumberger and Halliburton. Operators also keep close links with universities and research and technology organizations (RTOs) for recruitment, the development of technologies that are less asset specific and have broad applicability, and in answering questions that are outside their core expertise. In O&G, no single technology determines the competitive advantage of an oil company. Instead, firms gain their competitive edge by building capabilities to bundle and deploy an integrated set of technologies. Another key finding from Lima-de-Oliveira and Sturgeon (2017) is that public policies can influence the scale of local R&D, attract global research labs to where international oil companies have a sizable presence (co-location), and promote knowledge linkages between foreign and domestic oil companies, local suppliers and universities.

Malaysia has a very centralized energy innovation model, with PETRONAS at the top. The national oil company has its own internal R&D and also partners with universities - its own Universiti Teknologi PETRONAS as a case in point. PETRONAS has also been experimenting with innovation challenges through crowdsourcing for specific solutions. Such centralized mode, however, is not ideal in promoting collaboration between the diverse range of actors of the O&G value chain or attracting global in-house R&D from other companies. International oil companies, like Shell and Exxon, participate in the extraction of resources in Malaysia, but not in the production of new knowledge. Along with other national players like Sapura Energy, they could be incentivised to produce and share such knowledge given a framework that created incentives towards R&D application in Malaysia. Public policies to promote innovation and collaboration can include matching funds, research consortiums, high-technology government procurement, innovation calls and supplier development programs.[10] They could be structured towards particular challenges in increasing the domestic O&G production (e.g., maximizing resource recovery, dealing with contaminants) as well as involve the development and integration of renewables. In short, an innovation policy is needed to strengthen the O&G industry, as well as help develop the local talent and capabilities in renewables energies, which would reduce the national dependency on O&G.

The energy world is in transition: energy companies are re-evaluating their business strategies and countries are rethinking their policy frameworks. As a country rich in natural gas, Malaysia would be well equipped to make a transition towards a less carbon intensive energy system, given the role of natural gas as a bridge fuel. However, because of the slow growth rate of domestic O&G, particularly in Peninsular Malaysia, natural gas output is being prioritized to external markets, while coal is being used to generate electricity to Malaysian citizens – carrying with it all the negative externalities from coal generation including disease-causing particulate matter. At the same time, there is recent political pressure to redistribute more revenues from O&G production to oil producing states, to compensate revenue losses in switching from GST to SST, and to provide subsidized petrol. Considering Malaysia's high cost of production and a future global scenario of fossil fuel energy abundance that would keep prices down in the medium- to long-run, the sustainability of the energy sector is under threat. This paper calls for policies that put innovation at the forefront with instruments that promote wide collaboration between the multiple stakeholders.

[10] Both PETRONAS and the Malaysia Petroleum Resource Corporation (MPRC) have supplier development programs. This task is critical to upgrade local players into higher value-added activities.

5. Conclusion

"More important than the riches from natural resources are the artificial riches of education and technology".

- Roberto Campos (1917-2001), former Brazilian Ambassador -

The history of modern Malaysia has been shaped by its natural resource endowments, such as rubber, palm oil, and particularly, O&G. Malaysia's fossil fuel endowment has provided the country with a tax source to pay for investments; affordable energy that has benefitted consumers; and an important manufacturing and service sector led by PETRONAS and other O&G extracting companies. Furthermore, PETRONAS became an icon of the country – beyond a touristic hotspot and a F-1 sponsor – due to its leadership in business ranks and example of an NOC that built capabilities to internationalize and compete shoulder-to-shoulder with major players.

These are true accomplishments but one should not rest on their laurels. The energy sector is passing through profound challenges – coming from environmental pressures, technological disruptions, and changes in consumption patterns. All of these can put at risk the arrangement that so far has been beneficial to Malaysia. In the domestic front, ageing fields with increasing costs of production can seriously limit the competitiveness of the local O&G sector in an era of global fossil fuel abundance. Equally important, Malaysia's politics is passing through unprecedented changes, with the election for the first time of a governing coalition (Pakatan Harapan) not led by UMNO and Barisan Nasional. With increased political competition and party fragmentation, distributive demands like petrol subsidies, low energy prices and lower taxation can be intensified, bringing additional challenges to the fiscal stability of the country.

In summary, both the global energy industry and Malaysia are in flux, which calls for a reflection of the prevailing institutional arrangement and how to best seize the opportunities brought by a shifting energy business environment.

This study suggests that Malaysia can be well placed to face the coming energy challenges, but doing so may require new institutions and public policies. Malaysia is richer in natural gas than in crude oil. Gas has historically been a less noble by-product of the search for oil but currently is the only fuel predicted to grow in share of the world energy matrix. Natural gas is considered to be a bridge fuel: it has lower carbon content per unit of energy generated and can be stored and dispatched upon demand – characteristics not currently available to most renewables, such as solar and wind, which are intermittent sources of energy. However, domestic resources have not grown to the rhythm of the country and Malaysia has deployed more and more coal in its energy matrix.

For the energy sector to continue as one of the pillars of the Malaysian economy it is necessary to invest more in the future, to which innovation is key. Incentives for local R&D and collaboration between lead firms, suppliers, and universities can be targeted to reduce domestic production costs of O&G, unlock more natural gas that can replace coal consumption, and build capabilities in renewables.

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