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Thailand Electricity Security Assessment 2016

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The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
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Foreword

The International Energy Agency (IEA) and Thailand have long shared a strong mutual interest in enhancing energy security. This has been the foundation of an increasingly close relationship, leading to co-operation on topics such as emergency preparedness and improving data and statistics to inform the development of Thailand's energy policies. During the IEA Ministerial meeting in November 2015, Thailand became an "Association" country of the IEA, as did China and Indonesia. This represented an important milestone in an ongoing process of closer and deeper collaboration towards addressing shared energy-related challenges.

The IEA firmly believes that the transition to a clean energy system requires a new era of collaboration, on a scale the world has never seen. As part of this, the IEA is actively supporting Thailand's efforts to decrease the carbon intensity of its energy sector, which will be crucial to fulfilling its commitment to the UN climate conference in Paris in December 2015.

The electricity sector is fundamental to Thailand's continued economic development. Electricity security is therefore a key concern, as supply disruptions and black/brown-outs impose a considerable cost on the economy and influence private-sector investment decisions. These concerns are becoming even more important as efforts to decarbonise electricity supply raise new challenges for planning and operating power systems.

This study – a security assessment of Thailand's electricity sector – is the first IEA peer review engagement with Thailand. The IEA and Thailand chose to focus on the power sector because it is an area of key interest of Thailand, which aims to decrease its dependency on fossil fuels by diversifying its power supply and, in particular, increasing the penetration of renewables. Thailand's efforts will have wide-ranging impacts, given that it is a driving force behind the formation of a regional electricity market in Southeast Asia.

The primary aim of this report is to support Thailand in its quest for a secure, affordable and environmentally sustainable transformation of its electricity sector. It is my hope that it is the first of many joint studies between the IEA and Thailand, and that it contributes to a cleaner, more sustainable global energy system.

Dr. Fatih Birol

Executive Director

International Energy Agency

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Executive summary

Thailand is the second-largest economy in Southeast Asia. While most demand for electricity is concentrated in the Bangkok metropolitan area, Thailand also has a large industrial and manufacturing base and significant amounts of tourism in its other provinces. Thailand is a rapidly growing country with a large middle class, and as a result is set to undergo a structural transition, changing the nature and shape of electricity demand in the coming years.

Thai energy policy is driven by the three pillars of security, affordability and environmental sustainability. Concerns over fuel diversity underlie all three of these pillars and thus are a major driver of Thailand's current long-term outlook of power sector development. Natural gas-fired generation makes up two-thirds of the Thai generating fleet. Thailand's natural gas resources, however, are set to begin depleting rapidly, and the country is heavily dependent on natural gas imports from a single country: Myanmar. In addition to strengthening its gas supply infrastructure through the continued development of gas pipeline networks and LNG import terminals, Thailand is seeking to diversify its power sector over the next two decades. This diversification is expected to come mainly from two sources: an increase in coal generation and coal imports, and an increase in both domestic and imported renewables. In addition, Thailand is seeking to reduce the need for investment in generation and transmission by improving energy end-use and other forms of efficiency.

Thailand became an association country of the IEA in 2015, reinforcing its partnership with the IEA on energy security and sustainable development. In this study, the IEA explores the state of electricity sector development in Thailand within the framework of the IEA Electricity Security Action Plan, and provides policy recommendations to the government of Thailand on possible market design and regulatory changes to enhance the security and sustainability of its electricity system. It focuses mainly on long-term electricity security within the context of the most recent Power Development Plan, although it also discusses short-term electricity security issues where relevant.

Thailand has a number of both government and government-owned institutions that play key roles in the management and development of the Thai power sector. Policy goals set by the national government are developed by the Ministry of Energy (MoEN), and implemented and enforced by the Energy Regulatory Commission (ERC). The Electricity Generating Authority of Thailand (EGAT) is responsible for power system operations and planning for both generation and transmission, while the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) are responsible for the distribution and retail markets in the Bangkok metropolitan area and the rest of Thailand, respectively.

In 2007 Thailand began, but did not complete, the process of liberalising its power sector. Originally intending to move to a competitive power pool model, Thailand has instead implemented what it refers to as the "enhanced single buyer model". In addition to owning approximately 50% of Thai generation and the high-voltage transmission network, EGAT also acts as the country's central dispatcher of generation. The remaining generation is purchased from privately owned independent power producers (IPPs) located both within Thailand and in neighbouring countries. The possibility of moving to a power pool model remains under discussion, but at the time of writing no firm decision had been taken.

Development of the Thai power sector is managed through a set of plans that collectively cover all aspects of the electricity system. The most significant is the Power Development Plan, most recently updated in 2015 (PDP2015), which sets out a specific 21-year schedule for transmission and generation investments. Other relevant plans include the Alternative Energy Development Plan (which focuses on renewable resources), the Energy Efficiency Plan (which sets specific energy-intensity reduction targets), and the Gas Plan (which focuses on the development of both domestic and imported natural gas resources).

While these plans have historically been developed independently, Thailand has recently taken the important step of combining them into what it calls the Energy Master Plan. Under the Master Plan, individual plans are developed in parallel, allowing policy makers and system planners to better ensure that the plans collectively work toward meeting both general policy goals, sustainability and overall energy security. There has also been an associated increase in the overall transparency and inclusiveness of the planning processes.

The roles and responsibilities of the MoEN, the ERC, EGAT and other agencies are generally well defined, but there are areas of overlap and the potential for misaligned or conflicting policy objectives. An imbalance also exists between the respective organisations' independence and capacity, which could and should be resolved.

Diversifying the power sector

Thailand's focus on ensuring long-term electricity security is reflected primarily in its efforts to increase the diversity of its power system. Thailand plans to increase diversity by growing the share of coal and renewables in the generation mix. It also intends to increase the amount of hydropower imported from neighbouring countries, although the total share of all electricity imports into the Thai system will be capped at 15% from 2020 onward.

PDP2015 puts forward a very specific timetable for developing new generation. Under the current plan, the share of gas-fired generation will decline from 65% to 37% by 2036, while the share of coal-fired generation will increase from 20% to 23%. The share of domestic renewables will double from 10% to 20%, while imported hydropower will increase from 8% to 15%. Although increasing the share of coal will increase the level of carbon emissions, the relatively larger increase in both renewables and hydro means that the overall carbon intensity of the power system will decline over the timeline of the plan, relative to business as usual.

Thailand has experienced rapid growth in electricity demand, with peak load growing by nearly 50% over the past decade, and power consumption growing by 5% a year on average over the same period. Thailand expects demand to double over the period from 2015-36, so while the share of coal increases only marginally in proportional terms, in absolute terms it more than doubles from approximately 2 400 megawatts (MW) to nearly 7 400 MW. Domestic opposition to the development of new fossil generation is strong, leaving open the possibility of construction delays.

The Alternative Energy Development Plan (AEDP2015) sets out a target for renewables deployment that is among the most ambitious in Southeast Asia. Solar photovoltaics (PV) make up the largest portion of planned renewable generation (6 000 MW), followed closely by biomass (5 570 MW), and then onshore wind (3 000 MW). This would more than triple, in absolute terms, the amount of renewable capacity in the Thai system by 2036. While significant, the absolute quantity of planned generation is limited by existing constraints in the Thai power grid. This plan therefore has the potential to be more ambitious, should these constraints be reduced.

Thailand has implemented a number of support mechanisms for renewables, including various feed-in-tariff (FIT) schemes. While these have been successful in encouraging investment in renewables, the policies have to date been implemented in a somewhat inconsistent fashion. To a degree, investments have also been undermined by a relatively complex permitting process. Simplifying the support schemes and streamlining the application process could help Thailand more easily reach its ambitious goals.

Thailand's development plans are also key elements of its Intended National Determined Contribution (INDC), which it submitted to the UN climate meeting in December 2015. These plans must therefore also be considered within the context of broader climate change goals. Thailand has made reducing the carbon intensity of the power sector a key goal of PDP2015, with a minimum target of reducing power-related carbon dioxide (CO_2) emissions by 20% compared to business as usual by 2030, and a maximum target of 25%. As the agreement signed at the end of the Paris conference requires countries to submit INDCs that are increasingly stringent, this suggests that future PDPs will need to aim for an even higher reduction in emissions intensity. This may necessitate a re-evaluation of the absolute level of coal generation in the Thai fuel mix.

Imports in Thailand mainly take the form of IPP generation built with the explicit intent of selling power to EGAT. More than 5 400 MW of imported capacity has either already been developed or is under construction, and total imports will increase to more than 11 000 MW under the most recent PDP. The majority of these projects are hydroelectric dams located in Lao People's Democratic Republic (PDR). Imported generation is, for the most part, isolated from its respective domestic power system, meaning that generation from these projects must either be consumed within Thailand or exported into a neighbouring country via the Thai grid.

Historically, projects built outside Thailand have been developed to a lower environmental standard compared to projects built domestically, reducing their environmental sustainability. Extending the environmental standards applied to domestic projects to imported power would reduce the environmental impact of these projects while also reducing both domestic and international opposition to their development.

Lao PDR has also indicated that it would like to move away from projects that are tied directly to the Thai grid to a more general framework of grid-to-grid, or utility-to-utility, trading. While doing so would increase operational complexity from a Thai perspective, it would also allow Thailand to take better advantage of the significant resource diversity of the region, while at the same time allowing the export of power at times when it has excess capacity.

Energy efficiency to support electricity security

Thailand has experienced consistently rapid electricity demand growth, with peak load growing by nearly 50% over the past decade, and power consumption growing by 5% a year on average over the same period.

The generation and transmission schedule laid out in PDP2015 is based upon an assumption that power demand will continue to grow, albeit at a slower pace of 2.7% per year. Expected growth is lower than the historical average mainly due to anticipated improvements in energy efficiency. Whether and how these improvements will occur is of key importance to Thailand's long-term electricity security, as underestimating long-term growth could lead to an underinvestment in generating capacity.

Under the Energy Efficiency Plan (EEP), Thailand is implementing a suite of energy efficiency measures that seek to save nearly 90 terawatt hours (TWh) of electricity by 2036 – the equivalent to the annual output of more than 16 coal-fired power plants. The single largest measure is increasing its minimum energy performance standards (MEPS) and high energy performance standards (HEPS), although Thailand also expects to achieve significant savings through energy efficiency improvements in buildings and factories, through improved building codes, financial incentives and promoting the use of light-emitting diodes (LEDs). More than three-quarters of these gains will come from efficiency improvements in the commercial and industrial sectors.

The EEP lays out an ambitious and comprehensive plan for decreasing Thailand's energy intensity and, if implemented as planned, will certainly contribute to the country meeting its energy security goals. Historically, however, energy efficiency implementation in Thailand has met a number of stumbling blocks. Lack of co-ordination among relevant government agencies is one key obstacle, as well as the slow development of measurement, reporting and verification (MRV) systems, which has hindered the energy service company (ESCO) market. Tariff reform would also aid energy efficiency initiatives by improving the economic case for many projects.

Developing the grid for long-term growth

Increasing Thailand's generation diversity and, in particular, the share of variable renewable power, will require investment in, and a reshaping of, the Thai electricity grid. The majority of the Thai grid is located in the central and northern regions of the country, where most of the generation and load are also concentrated. At present, 13% of Thailand's grid is composed of 500 kilovolt (kV) high-voltage lines, and EGAT plans to extend this network to cover the entire geographical territory of the country by 2019. This high-voltage grid is an important step towards both realising Thailand's renewables potential and supporting development of generation more broadly.

Grid development is a major enabler of renewable technologies, which are less flexible in where they can be deployed as compared to conventional generation. Network constraints – particularly in the eastern portion of the country – have limited the deployment of grid-connected renewables to date. The perception of limits to grid capacity is one reason why the renewables goals laid out in the AEDP are not more ambitious.

Despite the move to integrate its various development plans, Thailand also does not currently co-optimise generation and transmission planning. Instead, the Transmission Development Plan is taken as a static input into the PDP. In addition to improving co-ordination, Thailand could consider taking an approach to grid planning that includes a greater degree of probability based scenario analysis, to better account for the variability of hydro and non-hydro renewable generation, and to consider the possible impact of unplanned network outages.

Thailand's regulatory framework has historically supported EGAT's network development activities, and that support is likely to continue for the plan laid out under PDP2015. As both the developer and operator of the transmission system, EGAT must balance electricity security goals with economic and environmental goals. Political and social pressure, however, may push the balance towards security at the expense of the other priorities. An independent and knowledgeable regulator is key to ensuring all three goals are properly balanced. At present, however, the ERC lacks the in-house expertise necessary to truly evaluate these plans. Furthermore, the ERC's independence is undermined by the fact that final approval for transmission projects lies with the Ministry of Finance.

Thailand's electricity security is aided by the significant flexibility of its generating fleet. Continuing to invest in the grid would also improve overall system flexibility, increasing the potential for renewables deployment. Thailand's long-term plans are well aligned with electricity security goals from a resource adequacy perspective, but a greater focus on how best to develop the Thai grid would also help to improve system security.

Recommendations

The government of Thailand should:

- Clarify roles and responsibilities among all relevant government agencies, and strengthen capacity within the MoEN and the ERC to help ensure the power sector develops in a secure and balanced fashion. In particular, the role of the regulator needs to be enhanced and further safeguarded from political influence. Capacities within the regulator should be developed so that it can properly evaluate the plans and actions of EGAT, MEA and PEA.
- Increase the ambition of the renewables target, in particular for solar PV. While Thailand's renewables target is ambitious, in particular relative to other countries in the Association of Southeast Asian Nations (ASEAN), there remains significant room for improvement. In particular, Thailand should look carefully at the potential for continued declines in costs, and develop improved financing schemes for solar and wind technologies.
- Energy efficiency measures could be improved by expanding the range of products covered by MEPS, HEPS and labels, and by making more of these measures mandatory. Current initiatives rely to a large degree on voluntary measures. Five products are covered by MEPS, of which only the ones for residential air conditioners and refrigerators are mandatory.
- Conduct a transparent cost-benefit analysis to assess grid development in areas that are rich in renewable resources. This, along with the timing and planning of network reinforcements, can help to ensure that network and generation development go hand in hand.
- Ensure that power sector development plans are consistent with future climate change obligations and local environmental pollution. The Paris agreement requires that countries submit INDCs ever five years that meet increasingly stringent climate change goals. Thailand's current INDC commits to the carbon reductions that would be achieved under the PDP and associated plans; this means the next INDC will need to exceed these targets. Investment decisions made over the next few years should be considered within the context of how they will contribute to future carbon reduction commitments.

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- Charoen Sompong Co., Ltd.
- D and J Clean Energy System Co., Ltd
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- Department of Energy Business
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- Electricity Regulatory Commission
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- Infinite Green
- Infratech Engineering and Services Co., Ltd.
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- Mitsui Thailand
- MP Alternative
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Introduction

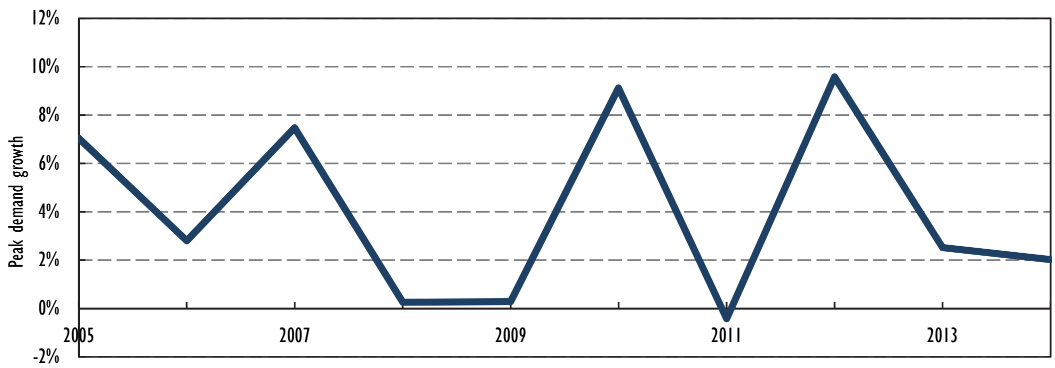
Thailand is the second-largest economy and the fourth-largest country by population in Southeast Asia, and a founding member of the Association of Southeast Asian Nations (ASEAN). Due to its relatively advanced development status and its strategic geopolitical position,[1] Thailand plays a major role in promoting regional co-operation and integration in ASEAN and beyond (ADB, 2016).

Thailand has been a constitutional monarchy since 1932, with the King serving as Head of State. A member of the so-called "tiger economies", Thailand experienced rapid growth in the 1990s – growth that stopped abruptly with the Asian financial crisis in 1997/98. It soon recovered from this economic shock, rebounding to moderate but robust growth levels of approximately 5% per year from 2002 to 2007. This was followed by the negative impact of the global financial crisis of 2008/09, local floods in 2011, and the impact of political tensions and uncertainty in 2010 and again in 2013-15 (World Bank, 2015).

Despite internal political turmoil, significant economic shocks and major natural disasters, Thailand is a development success story and has achieved remarkable social and economic progress since the 1970s. In 2011 Thailand became an upper-middle income country, an achievement that is reflected in the fact that it reduced poverty rates from 67% in 1986 to 11% in 2014 (World Bank, 2015).

Thailand's economic success story has resulted in a steady and steep increase in its energy consumption and, as a consequence, a rising dependency on imported fuels and associated exposure to international commodity prices. As a recent example, average gross domestic product (GDP) growth of 3.6% per year between 2005 and 2010 translated into an increase in primary energy demand of 4.1% per year (ADB, 2015). Thai electricity demand increases and decreases in response to the country's economic circumstances. For example, in 2010 the Thai economy grew by 7.8% and peak electricity demand grew by 9.11% (Figure 1). During the 2008 and 2011 economic downturns, however, peak demand declined by 0.25% and 0.42%, respectively (EGAT, 2015).

Figure 1 • Year-on-year peak demand growth, 2005-2014



Source: EGAT, 2016

Secure and affordable electricity is vital to Thailand's continued development. Digital technologies, communication infrastructure and industrial processes all depend on the reliable and efficient supply of electricity. The majority of Thailand's generation is fuelled by natural gas, and domestic gas supplies are set to deplete rapidly. As a result, natural

[1] Thailand is at the centre of the Indochina peninsula, bordered by Myanmar and Lao PDR to the north, Cambodia to the east, and Malaysia to the south, the Gulf of Thailand to the east, and the Andaman Sea to the west.

gas imports are certain to rise, causing the government of Thailand to become increasingly concerned about the security and affordability of the power sector. The issue of affordability is of particular relevance, as tariffs are, at present, not fully cost reflective. Questions arise, therefore, as to how and whether an increase in natural gas costs would be passed on to consumers. This policy review comes at a time when the power sector globally is in the midst of a deep transformation that, if not properly managed, could lead to new electricity security challenges.

Traditional forms of power generation, such as natural gas and coal, are dispatchable technologies, which many system operators value from the perspective of electricity security. Their development in Thailand, however, faces significant obstacles due in part to their high emissions and their dependence on imported fuels. Nuclear power is dispatchable and does not come with any associated emissions, but has significant cost and public perception challenges. Hydropower generation is also dispatchable and free from significant levels of emissions,[2] but has other, potentially negative, environmental impacts. It is also subject to seasonable variability, an issue which may only grow as climate change affects rainfall and temperature levels in the Mekong and beyond.

At the same time, wind and solar power have made impressive technological progress and are being rapidly deployed around the world. But these technologies bring with them a new set of electricity system operation and security issues, and have the potential to affect the economics of other parts of the electricity system.

Thailand recovered from the negative impact that the recent political turmoil has had on the economy which resulted in a growth rate of only 0.9% in 2014, bit increased to 3.1% in 2015 and is expected to average annual growth rates of at least 3.6% between 2016 and 2020 (OECD, 2015). The key question for the Thai government, therefore, is whether existing policies, market design and regulatory frameworks will deliver reliable, efficient and progressively cleaner electricity supply in a timely manner.

General energy overview

Production and supply

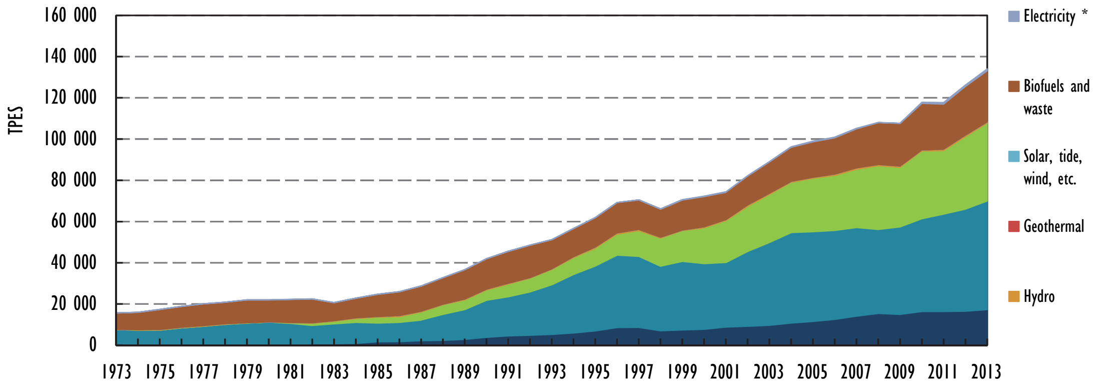
Total primary energy supply (TPES) in Thailand grew at an annualised rate of 4.17% between 2003 and 2013, giving a total increase of more than 50%. TPES reached a record high of 134.1 million tonnes of oil-equivalent (Mtoe) in 2013, a 6.24% increase compared to the previous year.

Oil is the largest source of energy in the country, accounting for 39.3% of TPES in 2013. Natural gas made up a further 28.2%, followed by bioenergy, biofuels and waste (18.4%) and coal (12.9%). Hydro accounted for 0.4%, while around 0.1% was supplied from solar and wind (Figure 2).

Together, fossil fuels represent 80.4% of TPES, while renewable energy sources account for the remainder. When compared to the 34 member countries of the Organisation for Economic Co-operation and Development (OECD), Thailand ranks 17th-highest with regard to the share of fossil fuels in TPES (Figure 3).

[2] While the generation of electricity from hydropower itself does not result in any emissions, methane emissions may result from the anaerobic decomposition of biomass after the reservoir is created.

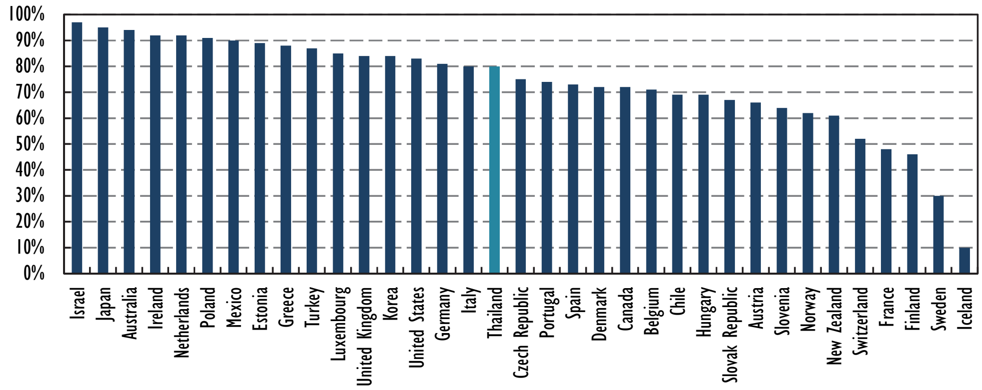
Figure 2 • Thailand's TPES, 1973-2013 (Mtoe)



* Negligible.

Source: IEA (2015a), Energy Balances of Non-OECD Countries 2014.

Figure 3 • Ranking of OECD member countries by share of fossil fuels in TPES, plus Thailand, 2013



Source: IEA (2015a), Energy Balances of Non-OECD Countries 2014.

Over the decade to 2013, Thailand's energy mix saw significant growth in the supply of coal, natural gas, and biofuels and waste. As such, the share of coal in TPES increased from 10.8% in 2003 to 12.9% in 2013, the share of natural gas increased from 26.1% to 28.2%, and the share of biofuels and waste in TPES increased as well from 17.1% to 18.4% over the same period. This was balanced by a decrease in the share of oil.

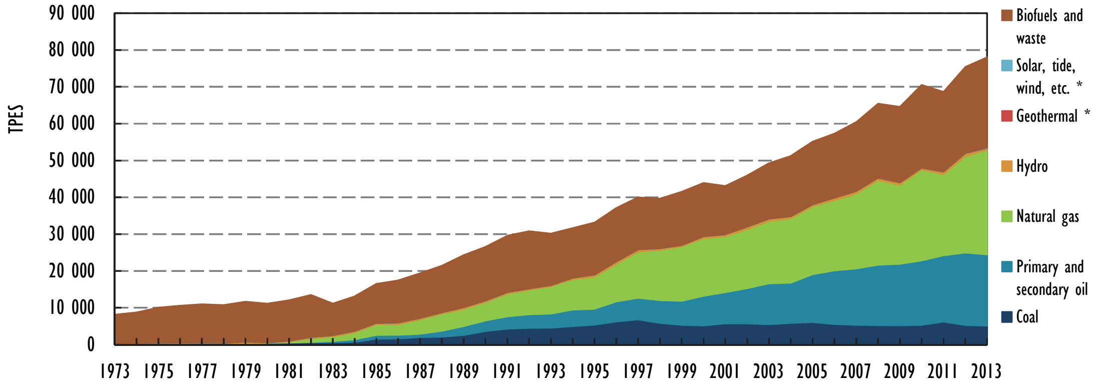
Thailand remains a significant producer of energy, with total energy production of 78.1 Mtoe in 2013. Natural gas accounts for 36.3% of all production, followed by biofuels and waste (31.5%), oil (24.8%), and coal (6.5%). The country also produces hydro, wind and solar, albeit at a small share of around 0.8% of production for all of them combined.

Crude oil production has increased by 74.4% since 2003, from 11.1 Mtoe to 19.4 Mtoe, while natural gas production has grown at a similar rate, up by 67.5% from 16.9 Mtoe in 2003 to 28.4 Mtoe in 2013. Additionally, the production of biofuels and energy from waste has increased by 62.2% to reach 24.6 Mtoe in 2013. Conversely, the production of coal has fallen by 6.6% over the same period. Electricity production from hydro has fluctuated over the years but overall has remained at a relatively consistent level. The first solar photovoltaic (PV) and wind generators were commissioned in 2006.

Total energy exports amounted to 13.9 Mtoe in 2013, made up almost entirely of oil products (87.5%) and crude oil (11.2%). Exports increased by 73.6% in the ten years to 2013, growing faster in relative terms than total production of energy, which increased by 58.3% over the same period (Figure 4).

Imports totalled 70.7 Mtoe in 2013, made up of crude oil (64.0%), coal (16.7%), natural gas (13.4%), oil products (4.2%), and electricity (1.5%). Imports to Thailand have increased by 38.9% in the ten years after 2003.

Figure 4 • Energy production in Thailand by source, 1973-2013 (Mtoe)



* Negligible.

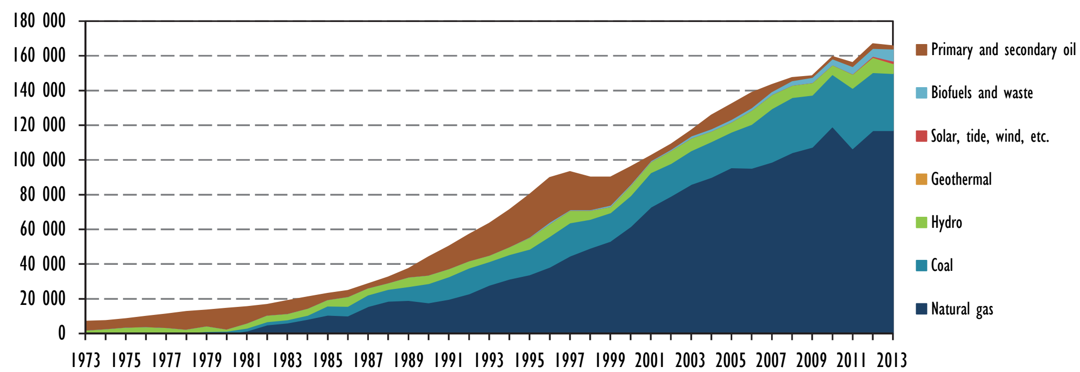
Source: IEA (2015a), *Energy Balances of Non-OECD Countries 2014.*

Electricity supply and demand

Electricity generation

Electricity generation in Thailand amounted to 165.7 terawatt hours (TWh) in 2013 (Figure 5). This represents a slight decrease of 0.7% compared to the previous year, and is 41.7% higher compared to 2003. Electricity production has been on a steady upward trend for decades, increasing at an annualised rate of 5.9% since 1990.

Figure 5 • Domestic electricity generation by source (GWh)



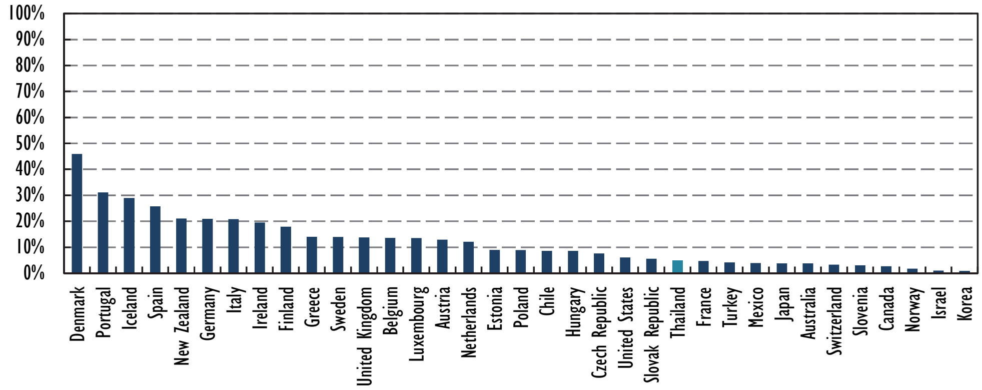
Note: GWh = gigawatt hour.

Source: IEA (2015a), Energy Balances of Non-OECD Countries 2014.

Fossil fuels account for 91.5% of total domestic generation. Gas is the dominant fuel source at 70.6%, a share which has remained quite stable over the last decade, declining slightly from 73.5% in 2003. Approximately 19.9% of electricity comes from coal, with the remainder mostly from renewable energy sources.

Renewable energy sources represent 8.5% of generation, made up mainly of biofuels and waste (4.2%), domestic hydropower (3.5%), and solar and wind (0.8%). Electricity production from solar PV has expanded over the last few years, starting in 2006 and reaching 1 080 GWh in 2013. When compared to OECD member countries, Thailand ranks 28th for the share of non-hydro renewables in electricity generation (Figure 6). Internationally Thailand ranks 42nd, and 101st if hydroelectric power is included.

Figure 6 • Ranking of OECD member countries by share of electricity generation from non-hydro renewables, plus Thailand, 2013



Source: IEA (2015a), Energy Balances of Non-OECD Countries 2014.

Demand

Thailand's energy demand has increased over the past two decades as a result of its rapidly expanding economy. TPES equalled 134 Mtoe in 2013, while total final consumption (TFC) reached 92 Mtoe. Both have been increasing steadily since 2002. Between 1990 and 2010, Thailand's GDP grew at an average annual rate of 4.5% and between 2011 and 2013 at 3.2%. Energy demand kept a similar pace, growing at an average of 4.4% per year and is predicted to grow at a higher rate over the next decade (OECD, 2015 and EPPO, 2013). TPES in 2012 was three times the amount it was in 1990.

Thailand has a mixed economic structure. The majority of the country's national income is driven by the manufacturing and service sectors, although the agricultural sector still employs 49% of the working population. Among services, wholesale and retail trade, transport, and tourism and travel-related activities are the largest contributors to GDP, maintaining significant shares of employment (ADB, 2013; World Bank, 2015).

Manufacturing, which is the most energy-intensive sector, makes up 34% of the Thai economy, a larger proportion than in all of its regional competitors. Thailand is the world's 17th-largest manufacturer and 14th-largest car producer. Industry value-added in Thailand rose from 18.5% of GDP in 1960 to a high of 44.7% in 2007 (Oxford Business Group, 2014,).

Energy consumption growth rates in the manufacturing and commercial sectors have been much higher than the GDP growth rate, with increases of 3.0 and 3.7 times respectively compared with consumption in 1990 (EPPO, 2013). Industry's rising energy demand has primarily been driven by the increasing share of manufacturing in the economy and use of inefficient industrial plants. The transport sector's high energy demand is mainly due to the country's heavy reliance on road transport and lack of fuel economy standards.

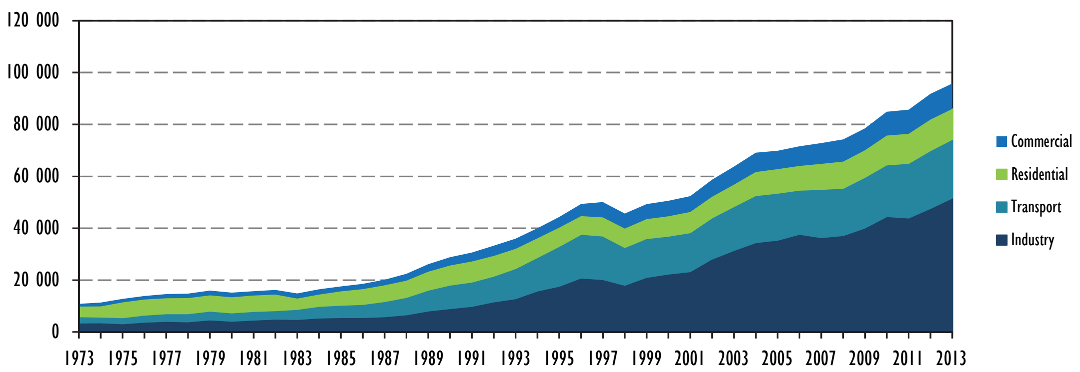
Electricity demand in any given year, however, is heavily dependent on both the state of the economy and the weather. For example, peak demand in 2005 grew at a rate of 2.8%, compared to 7% the previous year, because of a tsunami that made landfall in Thailand on December 25, 2004. From 2007 to 2008, Thailand was affected by the global financial crisis, resulting in essentially no demand growth.

Demand for electricity was also static in 2009, due perhaps in part to an outbreak of swine flu, as well as significant political protests, particularly in Bangkok. The Thai economy recovered in 2010, leading to demand growth of approximately 9%. In 2011, however, Thailand experienced a year of unusually cool weather, plus significant flooding, resulting in a decline in electricity demand of 0.4%. This was followed by a year of strong demand growth: 9.6% in 2012 compared to 2011. Since 2012, however, demand has grown more slowly at closer to 2% per year.

Thailand's industry and business activities are at present concentrated in the Bangkok Metropolitan Area. The service area of the Metropolitan Electricity Authority (MEA), comprising Bangkok, Nonthaburi and Samut Prakarn, accounts for two-thirds of Thailand's electricity demand.

TFC reached a record high of 95.8 Mtoe in 2013, 50.2% higher than in 2003 (Figure 7). The industrial sector is the largest consumer of energy, accounting for 31.2% of TFC, plus an additional share of 22.7% from non-energy use, bringing industry's total share of TFC to 53.9%. Transport accounts for 23.6%, followed by residential with 12.2%. The smallest consuming sectors are commercial/public services and agriculture, with respective shares of 6.0% and 4.1% of TFC (Figure 5).

Figure 7 • TFC by sector, 1973-2013



Notes: Commercial includes commercial and public services, agriculture/fishing and forestry; industry includes non-energy use.
Source: IEA (2015a), *Energy Balances of Non-OECD Countries 2014*.

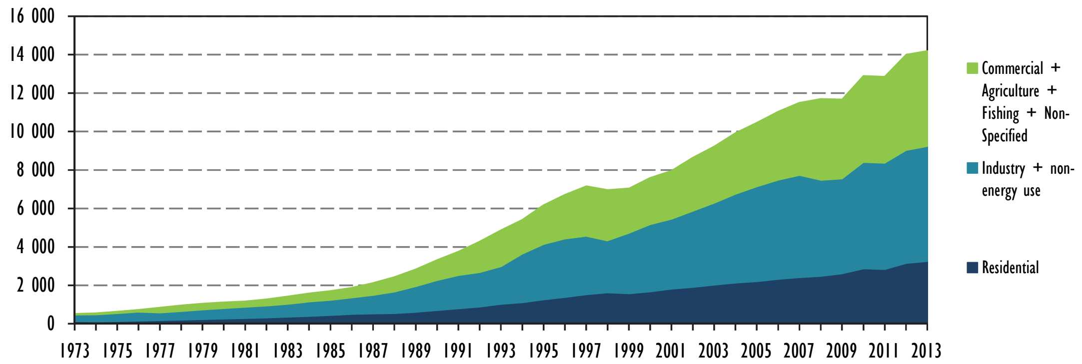
In the ten years to 2013, demand grew faster in the industrial sector, with overall growth of 64.3% over that period. By comparison, demand from households increased by only 38.9% during that time.

The industrial sector is the main consumer of electricity in Thailand, accounting for 41.8% of consumption in 2013. The commercial and public sector represents 35.2% of consumption, while residential accounts for the remaining 23.0%.

The commercial and public sectors experienced the strongest growth in demand for electricity over the decade to 2013, growing at an annualised rate of 5.3%. Consumption in the residential sector increased at an annualised rate of 4.9%, while industry growth was the slowest at 3.4% per year. Consequently, the share of industry in electricity consumption has fallen from 45.9% in 2003 to 41.8% in 2013. Conversely, the relative share of residential and commercial use has increased (Figure 8).

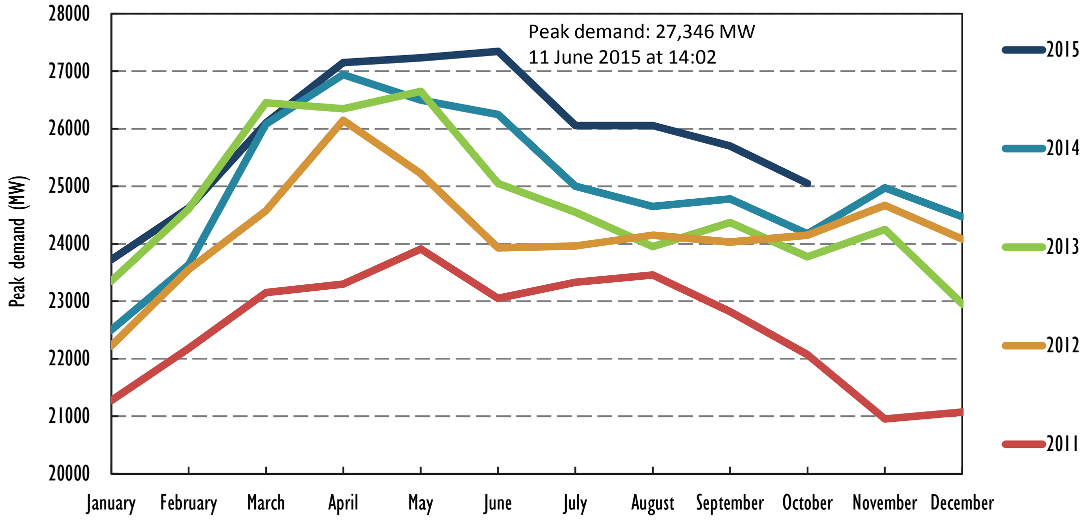
Electricity demand is increasing in general. Annual peaks in demand are seasonal, historically occurring from March to May. However, this is changing as weather conditions change, possibly as a result of climate change. In 2015 peak demand occurred in June, reaching 27 gigawatts.

Figure 8 • Electricity consumption by sector (TWh)



Source: IEA (2015a), Energy Balances of Non-OECD Countries 2014.

Figure 9 • Monthly peak demand since 2011



Note: MW = megawatt.
Source: EGAT, 2016.

Power sector governance

Electricity market development

Thailand's electricity sector began with the private Danish company, Siam Electricity Company (SECO),[3] which commissioned the Wat Lieb power plant in 1901 to supply power to the southern areas of Bangkok. As electricity came to be considered a critical component of infrastructure, national security concerns and natural monopoly considerations led the government of Thailand to take over the operation of SECO when the Danish concession expired in 1958. In its place the Thai government created the Metropolitan Electricity Authority (MEA), which exists to this day.

Following the creation of MEA, the government of Thailand (through the Ministry of the Interior) created the Provincial Electricity Authority (PEA) in 1960 to oversee the electrification of the largely rural provinces. In 1969, Thailand created a fully integrated electricity utility – the Electricity Generating Authority of Thailand (EGAT) – for the nationwide provision of generation and transmission services, while MEA and PEA were given responsibility for electricity distribution in their respective areas. This led to an organisational model of the electricity market where generation and transmission are separated from distribution and retail supply, similar to electricity market structures in Germany and the Philippines at the time.

The structure of the power market started to change in the 1980s, when the government of Thailand was increasingly unable to finance the massive investments in generation and transmission required to meet rapidly increasing demand for electricity. In 1993, Thailand followed the Philippines by beginning a process to allow the participation of private investors in the market, in the form of independent power producers (IPPs).

While attracting IPPs into Thailand during the 1990s was initially considered a success, it later became apparent that governance failures, insufficient regulatory frameworks and lack of regulatory oversight – combined with the consequences of the Asian financial crisis – resulted in a failure of the IPP model. Thailand had been highly attractive to outside investors because of the generous terms provided to the IPP developers. Typical power purchase agreements (PPAs) were designed to minimise the risk borne by investors at the expense of their counterparts. Governments and domestic utilities typically had to bear the risks associated with market demand, exchange rates, fuel costs, retail tariff and sovereign risk. As a consequence, from the investor's perspective IPPs were virtually risk-free.

Electricity reform continued both during and after the Asian financial crisis. In fact, in countries receiving structural adjustment loans (SALs) from the World Bank (viz. Thailand, the Philippines and Indonesia), electricity reforms were usually part of the negotiated loan conditions. In Thailand, the "national champion" policy under the Thaksin administration abandoned reform plans that called for an electricity sector organisation similar to the power pool model adopted in the United Kingdom (Jarvis, 2010). Instead, the Thaksin administration implemented what is known as the enhanced single buyer model in 2003, which is still in place.

Thailand's enhanced single buyer model

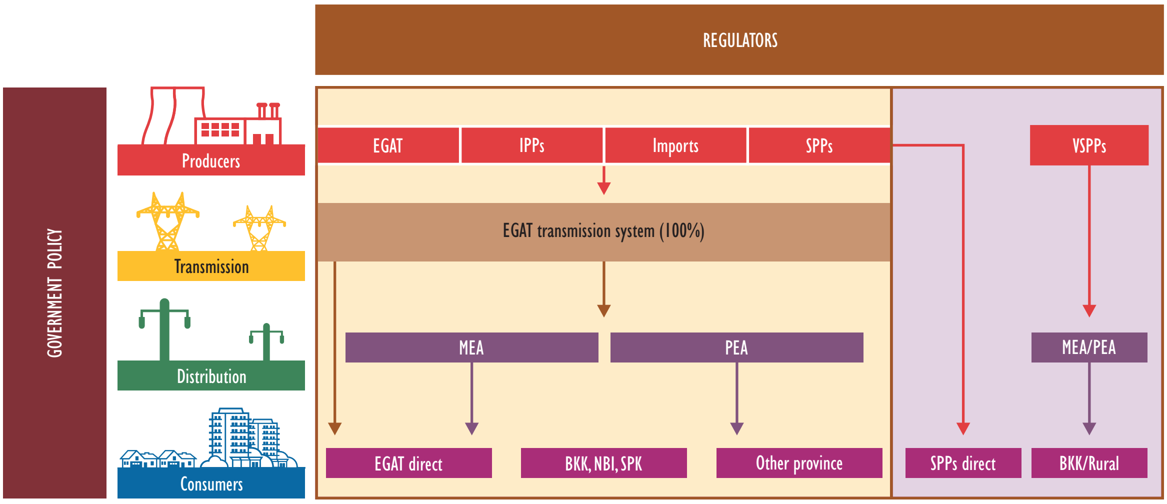
As implemented in Thailand, the enhanced single buyer model consists of a single vertically integrated utility, EGAT, owning and managing a portion of the generation fleet, the entirety of the transmission network, and a portion of the retail market (Figure 10). In addition to its own

[3] Since 1939, Thai Electric Corporation Limited.

generation fleet, EGAT purchases electricity from IPPs, small power producers (SPPs), and imports from other countries (which are generally structured as IPPs).

While large customers may purchase power directly from EGAT, smaller commercial and residential consumers purchase power from the two distribution companies: MEA and PEA. SPPs may also sell electricity directly to consumers. In addition, Very Small Power Producers (VSPPs) sell electricity directly to MEA and PEA. Real-time co-ordination between EGAT, MEA and PEA is managed through various regional dispatch control centres, as well as a single national control centre.

Figure 10 • Structure of the Thai power market



Notes: BKK = Bangkok; NBI = Nonthaburi; SPK = Samut Prakan; these three provinces make up the service area of MEA.
Source: IEA, Thailand Questionnaire, 2015.

Current market reform activities are focused on improving the single buyer model. Discussions on full liberalisation and the establishment of a competitive power market are, however, ongoing in government circles. The current government may well decide to finish the stalled reforms that were begun in 2007.

Institutions

Key government institutions

The institutional framework that guides energy policy (both electricity and natural gas) in Thailand is developed by the National Energy Policy Council (NEPC), with the Ministry of Energy (MoEN) as a key participant (Figure 11). The Energy Regulatory Commission (ERC) has responsibility for ensuring that the policies are enacted and followed as intended.

The **NEPC** consists of the Prime Minister as Chairman, a Deputy Prime Minister designated by the Prime Minister as Vice-Chairman, the Ministers for Energy, Transport, Interior, Defence, Foreign Affairs, Finance and Agriculture, and the Secretary-General of the NEPC. The NEPC devises the National Energy Policy and the National Energy Management and Development Plan. To enhance efficient energy sector management, the Committee on Energy Policy Administration (CEPA) has been established to assist with the work of the NEPC.

The government of Thailand also organises a working group on electricity that consists of the Energy Policy and Planning Office of the MoEN, EGAT, the ERC, MEA, PEA, and various outside experts.

The **MoEN** is the principal actor in the governance of the energy sector. It drafts and proposes all policies related to energy, including electric power and renewable energy policies. It is composed of two offices and three departments, which have different responsibilities and missions.

The **Energy Policy and Planning Office** (EPPO) recommends energy policies, including the Power Development Plan, energy management and development plans of the country, acts as Secretariat to the NEPC and Secretary to the CEPA, administers the MoEN energy information technology system and national energy trend forecasts, and manages energy funds.

The **Office of the Permanent Secretary** (OPS) co-ordinates departments/offices in the MoEN and functions as the interface with international organisations, such as the IEA, International Energy Forum (IEF) and Asia-Pacific Economic Cooperation (APEC).

The **Department of Mineral Fuel** (DMF) grants concessions, regulates, and facilitates international co-operation for oil and gas exploration and production, and aims to enhance gas supply security.

The **Department of Alternative Energy Development and Efficiency** (DEDE) promotes clean energy production and use, the commercialisation of clean energy technology, and energy conservation. It also prepares and implements short-term oil demand restraint measures and develops energy conservation regulation.

The **Department of Energy Business** (DOEB) grants licences for oil and gas trading, storage stockpiling and transport, controls safety standards, and defines and controls oil and gas quality standards.

The **ERC** is a regulatory agency established in 2008 under the Energy Industry Act of 2007. It operates separately from the MoEN and other government departments, but works within the policy framework of the NEPC. The ERC is modelled on the UK's Office of Gas and Electricity Markets (OFGEM) and fulfils the following (non-exhaustive) list of functions:

- regulate energy industry operations to ensure they are compliant with the Act and policies established by the MoEN
- issue operational licences for the energy industry
- ensure that the power system is secure and reliable
- establish regulations and criteria for power purchases
- provide an opinion on various energy development plans, including the Power Development Plan
- promote energy efficiency and the use of clean energy
- approve the electricity tariff
- set standards for safety in energy industry operations
- oversee energy network systems and operators
- protect energy consumers
- set the pipeline tariff for natural gas.

Despite the ERC operating as a separate entity, the MoEN retains certain key authorities over the ERC – in particular, consideration of the agency's operating plan and budget, and nominations for ERC commissioners. As a result, the ERC cannot be considered a fully independent regulatory authority.

The **Ministry of Finance** (MoF) also plays a key role in the power sector, as it must approve all public electricity-related investment projects. Investment decisions must, therefore, meet the approval of two main Thai ministries: the MoF and the MoEN.

The **Ministry of the Interior** (MoI) is involved in the energy sector as state-owned enterprises are established under its authority and regulated by it. In addition, the development of the provincial electricity sector was formerly undertaken under the authority of the MoI.

The **Ministry of Industry** is involved in the electricity sector as it supervises and co-ordinates the activities of industrial business operations, including power generation, by applying the guidelines on environmental protection, safety, hygiene and energy efficiency. Discussions have been ongoing in Thailand regarding the size at which small generation activities should be registered as industrial business operations.

State-owned enterprises

EGAT is a state-owned, vertically integrated utility and plays the key role in electricity generation and transmission in the Thai power sector. EGAT owns 48% of Thailand's total generation capacity and has the exclusive rights to purchase electricity that is produced by IPPs and SPPs, and to sell it to the two distribution companies. While the ERC regulates power purchases, the ultimate authority for setting policy on power sector procurement lies with the NEPC, and so EGAT's monopoly on power purchases ultimately derives from that authority. EGAT also makes limited direct sales to certain large retail customers. The MoEN is responsible for overseeing the activities of EGAT.

EGAT is sole owner of the transmission system, including transmission lines with voltages of 500 kilovolts (kV), 230 kV and 115 kV, as well as the high-voltage direct current (HVDC) power exchange (300 kV HVDC link) between the southern part of Thailand and Malaysia.

In addition to owning and operating its own generation fleet and transmission network, EGAT is responsible for system operations, including dispatch of the generating fleet. To maintain transparency and to ensure that IPPs are dispatched equally with EGAT-owned generation, system operations are ring-fenced from the rest of the company (although it remains within the EGAT corporate structure). EGAT has set up a National Control Center (NCC) and five Regional Control Centers (RCCs), comprising Metropolitan, Central, Northern, Northeastern and Southern areas.

MEA engages in the distribution of electricity in Thailand. The company supplies electricity to customers in Bangkok, Nonthaburi, and Samut Prakarn, which together account for two-thirds of Thailand's electricity demand. MEA owns no generation itself, but instead purchases from EGAT or directly from VSPPs. It is, however, directly responsible for the high-voltage distribution network within its service territory, and is involved in the design, installation and maintenance of high-voltage as well as low-voltage electrical systems.

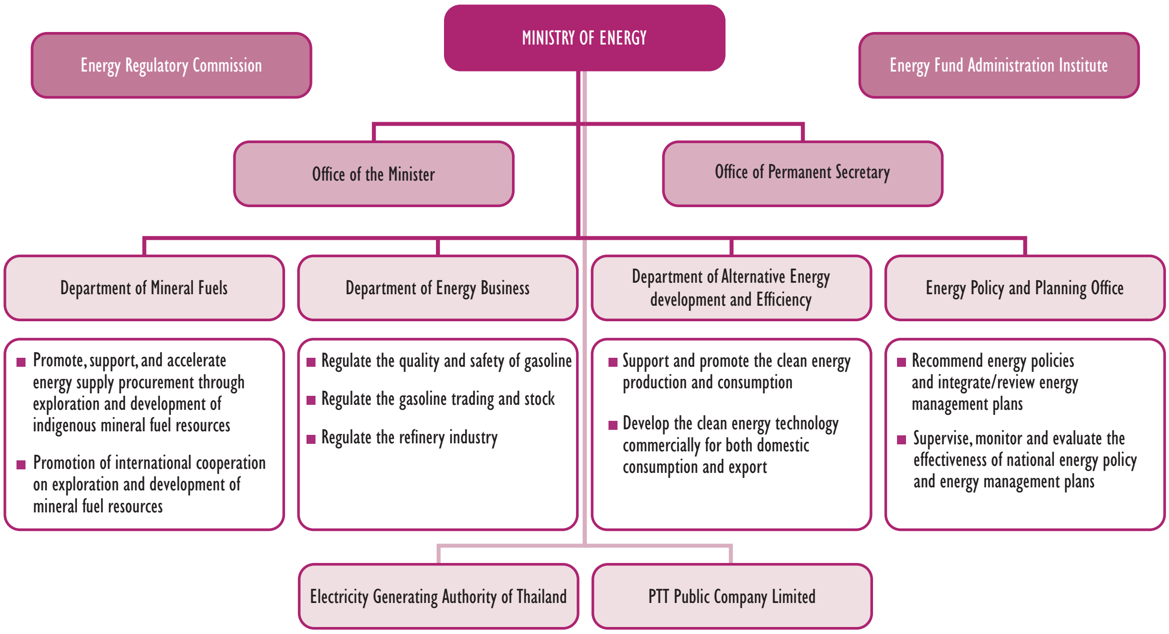
MEA is also involved in: the deployment of centralised air-conditioning systems; safety and security systems; design of landscape and exterior lighting systems; manufacture and distribution of electrical products; and operation of a fibre optic telecommunication network and data centres. Responsibility for oversight of MEA lies with the MoI.

PEA is also attached to the MoI. PEA's primary responsibilities include generation, procurement, distribution and sale of electricity to the public, business and industrial sectors in 74 provinces, over a nationwide area of 510 000 square kilometres or 99.4% of Thailand. PEA does not own or control any of the high-voltage lines within its service territory. As with MEA, responsibility for oversight of PEA falls to the MoI.

PTT Public Company Limited (PTT) is a fully integrated oil and natural gas company in Thailand, which conducts upstream exploration and production, the import and export of crude oil, condensate, petroleum feedstock and petrochemical products, refining and the marketing of refined products. The MoF holds a majority stake in PTT (51% of the total shares).

As approximately two-thirds of Thailand's generating fleet is natural gas-fired, PTT plays a key role in ensuring the fuel supply for the majority of Thailand's power plants.

Figure 11 • Relationship of key Thai institutions as regards energy



Notes: EFAI = Energy Fund Administration Institute; Bangchak = Bangchak Petroleum Company Limited.
Source: IEA, Thailand Questionnaire, 2015.

Electricity policies

Energy Industry Act 2007

The regulatory framework for the Thai energy sector was reformed in December 2007 with the passage of the Energy Industry Act. The Act established the principles of the regulatory framework for the power and gas sectors, and the institutional arrangements for the separation of policy and regulation. The establishment of the ERC was one of its cornerstones.

The Act is impressive in its scope and comprehensiveness. In addition to covering important aspects of the power and natural gas sectors, such as the issuance of licences and the setting of tariffs, the Act explicitly calls for the full utilisation and development of renewable sources of energy, with a particular emphasis on reducing the reliance on imports. In addition, the Act establishes an explicit requirement for third-party access (TPA) to electricity and gas networks. In practice, however, this requirement has not been exercised, and no entities currently benefit from TPA to either the electricity or gas grids.

The Act introduced the notion that tariffs should be cost reflective, should ensure efficient and adequate supply, but should be fair, and should allow for explicit support of the poor. In this regard, the Act also established a Power Development Fund, with the aim of supporting development at the local level and the promotion of renewable energy, among other objectives.

Energy Master Plan

Thailand has, for the first time, combined its various energy development plans into a single set of plans for the energy sector: the Energy Master Plan, sometimes also referred to as the Integrated

Energy Plan (2015-36). The Plan is not, however, a single integrated plan. Instead it is a set of five plans that are developed in parallel, which collectively cover all relevant aspects of the Thai energy sector. It includes the Power Development Plan, the Energy Efficiency Plan, the Alternative Energy Development Plan, the Gas Plan and the Oil Plan. Of these, the Power Development Plan, the Energy Efficiency Plan and the Alternative Energy Development Plan are also key components of Thailand's Intended Nationally Determined Contribution (INDC), which was submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in advance of the 21st Conference of the Parties (COP21), which was held in Paris in December 2015.

Thailand's INDC

In the run-up to COP21, each participating country submitted a document (the INDC) listing the actions they intend to take post-2020 to reduce emissions and mitigate the impact of climate change.

Thailand's INDC presents an economy-wide contribution covering the timeframe 2021 to 2030. The INDC does not develop a new climate plan for Thailand, but instead leverages existing plans that will, either directly or indirectly, reduce the emission of carbon dioxide, methane and other climate gases. Specifically, the INDC was based on the following plans that are "already approved or in the pipeline for approval by the Cabinet" (UNFCCC, 2015):

- National Economic and Social Development Plans
- Climate Change Master Plan B.E. 2558-2593 (2015-50)
- Power Development Plan B.E. 2558-2579 (2015-36)
- Thailand Smart Grid Development Master Plan B.E. 2558-2579 (2015-36)
- Energy Efficiency Plan B.E. 2557-2579 (2015-36)
- Alternative Energy Development Plan B.E. 2558-2579 (2015-36)
- Environmentally Sustainable Transport System Plan B.E. 2556-2573 (2013-30)
- National Industrial Development Master Plan B.E. 2555-2574 (2012-31)
- Waste Management Roadmap.

Of these, the Power Development Plan, the Smart Grid Master Plan, the Energy Efficiency Plan and the Alternative Energy Development Plan will all affect the power sector in one way or another.

Notably, the agreement signed at COP21 requires each member country to submit a new INDC approximately every five years that is more stringent than the previous plan. This suggests that Thailand's future development plans will have to reduce the emissions intensity of the power sector beyond current objectives.

Power Development Plan

Legislative/regulatory background

The Power Development Plan (PDP) details a 21-year investment strategy for the power sector, including the types of generation to be developed and a detailed schedule for development. The guiding principles of the PDP are:

- **Security,** which in this context means ensuring adequate supply and increasing the overall diversity of the generation fleet.
- **Economy,** which means ensuring that all relevant costs can be recovered via the tariff and that the development plan is affordable.
- **Ecology,** which means limiting the environmental impact of the generation fleet as a whole.

The PDP2015 targets a long-term reserve margin of 15%. The current reserve margin is 25%, well above that target. This excess is due mainly to recently commissioned IPP and SPP projects, although it is also the result of lower-than-expected demand. Thailand expects, however, that future demand growth will be relatively strong. This, combined with the need to replace approximately 27 gigawatts (GW) of capacity that is expected to retire over the timeframe of the PDP, means that it will be necessary to build new generation despite the current position of excess capacity.

Many relevant agencies and organisations are involved in the development of the PDP, including the MoEN, EPPO, EGAT and DEDE. While there is no single entity responsible for final evaluation of the PDP, EGAT (which has the most significant technical capacity and expertise on this topic) certainly plays a key role. For example, cost assumptions for relevant technologies – a major driver of the final results of any power development plan – are developed by EGAT (although fuel price assumptions are provided by PTT). EGAT also determines the Loss of Load Expectation (LOLE)/Loss of Load Probability (LOLP) target. This reliability standard is statically determined, and does not, for example, directly take into account the willingness on the part of consumers to experience outages – that is, the value of lost load (VoLL) (see Box 1).

Box 1 • Value of Lost Load (VoLL)

Reliability standards must balance the desire on the part of consumers for reliable electricity supply with the overall cost of the power system. While of course consumers prefer power to be available at all times, in practice the cost of ensuring that the power system is 100% reliable is more than most consumers are willing to pay. An ideal reliability standard is one that can deliver sufficient reliability to all consumers at least cost.

The difficulty lies in determining what "sufficient" means in this context. One useful concept to help quantity the reliability target is the value of lost load (VoLL). The VoLL – typically expressed in terms of USD per megawatt hour (MWh) – is the price that a typical customer would pay to avoid an outage. VoLL can inform the cost-benefit analysis of power development plans to determine the appropriate level and balance of generation, transmission and distribution investments. It can also be used in an operational capacity, for example by helping to establish real-time rules with regard to resource adequacy.

In practice, the VoLL depends heavily on a number of factors, including the type of consumer and the timing of the potential outage (for example, a business that only operates during the day may care less about outages that occur in the evening, whereas a household may have the opposite view). Typical figures used in many countries range around 10 000 USD/MWh, with some countries using higher values up to 20 000 USD/MWh (IEA, 2016). Determining the appropriate VoLL for a given country is generally done through one of four methodologies: revealed preference surveys; stated choice surveys; macroeconomic analysis; and case study analysis. There is no one answer as to which methodology is most appropriate in a given situation, and in many cases multiple methodologies are employed.

The PDP is currently developed with a target LOLP of less than 24 hours of outages per year. This is relatively high compared to targets typically used in member countries of the Organisation for Economic Co-operation and Development (OECD). For example, the North American Electric Reliability Corporation (NERC) in the United States recommends a one day in ten years standard, and most markets within the United States meet or exceed that standard. However, a one-day-per-year standard is comparable to many other OECD non-member economies.

Content of the plan and linkage to other plans

The PDP development process is conducted with the involvement of the general public via a limited number of stakeholder meetings and open consultations. The PDP must be reviewed by the ERC before it can be presented to the NEPC and the Cabinet.

The most recent PDP was completed in 2015 (PDP2015), and has been presented to the NEPC and Cabinet for approval. The main objective of PDP2015 is to better manage the fuel ratio in new electricity generation and to reduce Thailand's dependency on the use of natural gas in electricity production. To this end, PDP2015 aims to increase both the proportion of coal-fired generation as well as renewable energy generation. The plan also includes nuclear development, though only at the end of the plan, as development of nuclear is at present not feasible. The PDP is developed on the basis of a least-cost optimisation methodology, although adjustments are made after the fact to account for specific policy priorities (namely security, cost and environment – in that order).

Renewables costs are not directly included in the PDP, but instead are taken as a given based on targets developed by DEDE. Similarly, energy efficiency and demand response are taken as exogenous to planning.

There is concern among some market participants in Thailand that IPPs – and, in particular, the long-term nature of the PPAs – reduce the flexibility of system planning. One issue is that PPAs are negotiated without input from EGAT, but EGAT (as the system operator) is required to integrate IPPs into both its planning and dispatch decisions. These PPAs are also designed without allowing for much flexibility over the lifetime of the contract. In addition, there is a need to more explicitly integrate IPP contracting and EGAT power development within the PDP itself, as at present it is not clear which planned generation will be built by EGAT and which will be developed by IPPs.

Alternative Energy Development Plan

Thailand has put forward one of the most ambitious renewable energy plans in Southeast Asia. The Alternative Energy Development Plan (AEDP) contains a target of 30% of final energy consumption from renewable energy sources by the end of 2036 (DEDE, 2015a). The plan sets a target of 20 GW of installed capacity by 2036 or, in generation terms, enough to meet approximately 20% of load. Table 1 shows the current AEDP and compares it against past renewable energy plans.

Thailand's process for establishing a new renewable energy plan has been improved over time to incorporate new technological capability and resource assessment methods. Since 2009, the Thai government has proposed four versions of its renewable energy plans. The increasing targets for each type of renewable energy in each subsequent plan reflect growing confidence in renewable energy technologies, as well as increasing estimated potential. For the latest renewable energy plan, DEDE determined renewable energy potential and subjected the targets to EGAT's PDP planning and grid constraints. The potential calculation has also recently been conducted by geographical area, detailed to the provincial level and overlaid by grid capacity. The government held several public hearings in different regions of the country, as well as workshops to solicit comments from stakeholders

Unlike previous renewable energy plans, AEDP2015 establishes priorities for renewable energy support, or the so-called "merit order" for renewable power generation (Table 2). This establishes an order for the grid connection of renewables when EGAT declares grid constraints. For example, in the planned feed-in tariff (FIT) bidding scheme, different renewable energy plants will compete for the FIT rates but the connections will be granted in order of priority. Once the reserved feeder capacity is full, then lower order renewables cannot be connected even if their price is lower. Waste-to-energy is prioritised because of the Thai government's policy to support waste utilisation and farming communities.

Table 1 • Thailand's renewable energy plans

Type of renewable energy	REDP 2008-22 (MW)	AEDP2011 (2008-21) (MW)	AEDP2013 (2012-21) (MW)	AEDP2015 (2015-36) (MW)
Solar	500	2 000	3 000	6 000
Wind	800	1 200	1 800	3 002
Hydro (domestic)	324	1 608	324	3 282
Hydro >15 MW	0	0	0	2 906
Hydro ≤ 15 MW	324	1 608	324	376
Biomass	3 700	3 630	4 800	5 570
Biogas	120	600	3 000	1 280
Napier grass	0	0	3 000	0
Energy crops	0	0	0	680
Wastewater	0	0	0	600
Waste-to-energy	160	160	400	550
Others	3	3	3	0
Total	**5 607**	**9 201**	**13 927**	**19 684**

Notes: MW = megawatt; REDP refers to the Renewable Energy Development Plan; the target for hydropower above 15 MW is based on existing domestic capacity.

Sources: EPPO (2008); EPPO (2012); DEDE (2015a), Alternative Energy Development Plan: AEDP 2015, www.dede.go.th/download/files/AEDP2015_Final_version.pdf.

Table 2 • Merit order for renewable energy support

Priority (highest to lowest)	Technology
1	Waste-to-energy
2	Biomass
3	Biogas from waste/wastewater
4	Micro hydro
5	Biogas from energy crops
6	Wind
7	Solar PV
8	Geothermal

Source: DEDE (2015a), Alternative Energy Development Plan: AEDP 2015, www.dede.go.th/download/files/AEDP2015_Final_version.pdf.

The new AEDP is a crucial building block to secure Thailand's electricity needs and move to a low-carbon electricity sector, particularly given the country's aim of decreasing the proportion of gas-fired generation in the power sector by, in part, adding more renewable energy sources to the electricity mix. AEDP2015 aims to triple Thailand's renewable generation.

Energy Efficiency Plan

Thailand's Energy Efficiency Plan (EEP) covers the period 2015-36 and is a cornerstone of the country's approach to improving electricity security, addressing projected demand growth, and reducing the need for additional generation and related state-backed investment. Under the EEP, Thailand is implementing a package of measures that seeks to save a total of nearly 90 terawatt hours by 2036, a reduction in energy intensity of 30% compared with 2010.

The EEP outlines five strategic approaches to improving energy efficiency, including strengthening and expanding the following:

- Mandatory requirements with rules, regulations and standards
- Energy conservation promotion and support
- Public awareness of energy efficiency and behaviour change
- Promotion of technology development and innovation
- Development of human resources and institutional capacity.

The policy measures included in the EEP range from minimum energy performance standards (MEPS) and energy efficiency resource standards (EERS) to energy management systems in buildings and industry. Policies also seek to expand the market for light-emitting diodes (LEDs) and lighting systems and to promote energy efficiency through increased financial incentives.

Distribution Network Development Plans

Both MEA and PEA develop five-year Distribution Network Development Plans (DNDPs). The most recent is DNDP 11, covering the period 2012 to 2016. Each plan contains a five-year target and annual action plans to meet that target. The development plans rely on the macro-level load forecast developed by the load forecast committee, as well as a micro-level forecast developed by EGAT.

DNDP 11 has a budget of approximately THB 55 billion for MEA for the entire five-year period, and THB 30-40 billion per year for PEA. Investment projects must be approved by ERC as well as the MoEN and MoF. MEA's investment budget in the next five-year plan is expected to increase to approximately THB 125 billion, with the increase in expenditure deriving mainly from the higher cost of installing underground cables. The need to develop underground transmission is a significant obstacle to investment in the MEA system, and a major reason for MEA's explicit responsibility for its own high-voltage network.

Smart Grid Masterplan

The Thailand Smart Grid Masterplan also covers the period 2015-36. It sets out the guidelines and regulatory framework for the implementation of the smart grid roadmaps by EGAT, PEA and MEA. All three are now working on feasibility studies and pilot projects. Very little simulation has been done to date.

Gas Plan

Gas demand projections are based on PDP2015, and the infrastructure requirements of the Gas Plan are to be developed in parallel with the expansion of generation and the grid under PDP2015 and the Transmission Development Plan. The overriding principle is to prolong domestic production by reducing the gas production depletion rate in the Gulf of Thailand by 40% per year, increase the role of liquefied natural gas (LNG), and developing the necessary import and distribution infrastructure. In addition, Thailand aims to increase its gas reserves for emergencies.

In 2015, the NEPC approved plans for a natural gas transmission system and infrastructure for the first phase of natural gas pipeline network, acknowledging in principle the second and third phases of the network (Stage I), and extension of Thailand's LNG receiving facilities (Stage II). PTT was assigned to implement three projects under the plan, with a total budget of THB 13.9 billion.

Thailand also established a new framework for managing natural gas fields where concessions are about to expire, to ensure continuing maintenance and development of the fields.

Coal market policy

Thailand has no explicit policy on coal production or imports, and no government department is tasked with overseeing coal imports specifically. Coal mining and transport regulations, however, are in place. As Thailand has very limited domestic coal resources, the planned increase in coal-fired generation will necessitate an increase in coal imports. Given the fairly liquid global market for coal, this is unlikely to raise any supply concerns. There are, however, environmental concerns associated with coal, in particular the climate change impacts of emissions. As the agreement signed at COP21 in Paris in December 2015 requires future climate change targets to be more stringent than current targets, any coal generation developed in Thailand will have to coexist with increasingly ambitious climate goals. Any new coal generation should be high-efficiency, low-emissions (HELE), which, in addition to emitting significantly less CO2 emissions than subcritical units, could also potentially be retrofitted to include carbon capture and storage (CCS) at some later stage.

Electricity tariffs and financing

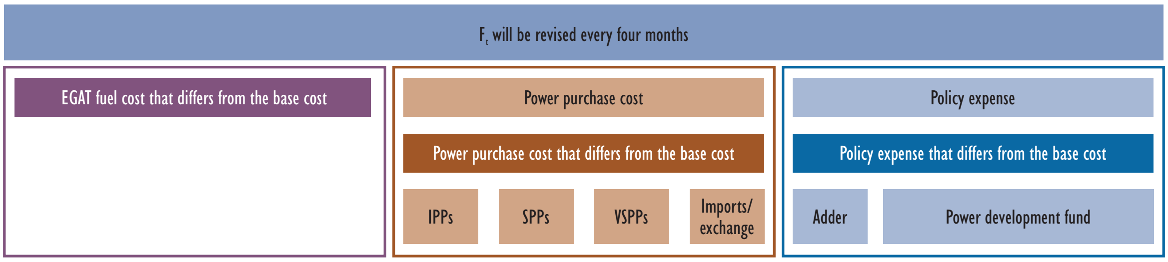
The ERC is mandated to establish criteria for determining the tariffs of power generation licensees. Tariffs paid to IPPs include a capacity component, which compensates generators for being available to produce power even if they are not dispatched, and a separate energy component which is paid per unit of power delivered. The availability payment is passed through to consumers via an adjustment component to the tariff, and dispatch decisions are made based on the energy component, which should reflect the marginal cost of production.

At the consumer level, Thailand has a uniform retail electricity tariff policy, meaning a single tariff structure is applied to the entire country. The retail tariff includes three components (each of which is charged on a per kilowatt hour [kWh] basis): a base tariff; a fuel adjustment mechanism (Ft) which captures fuel costs that differ from the base cost; and a value added tax (VAT). The base tariff reflects the investment costs of utilities in developing power plants, transmission lines, distribution lines and energy costs with certain assumptions pertaining to fuel prices, the inflation rate and exchange rates. The existing base tariff averages THB 2.2/kWh. This tariff is relatively low, and it is not clear the degree to which it accurately reflects all associated costs, such as network costs. Generation costs are the largest component of the tariff, followed by distribution and retail costs and then transmission costs.

As of July 2011, after the restructuring of the power tariff, the new base tariff includes the base fuel cost plus the cost incurred from the public service obligation (PSO), that is, a set quantity of electricity provided at no cost to residential consumers whose consumption does not exceed 50 kWh/month. The base tariff is reviewed every three to five years.

The Ft is reviewed every four months and is based on changes in the fuel cost and power purchase cost under the PPAs, including an environmental adder for promoting renewable energy and the cost incurred from contributions made to the Power Development Fund – the last two items constitute less than 3% of the Ft (Figure 12).

Figure 12 • Components of the Fuel Adjustment Mechanism



Source: IEA Thailand Questionnaire, 2015

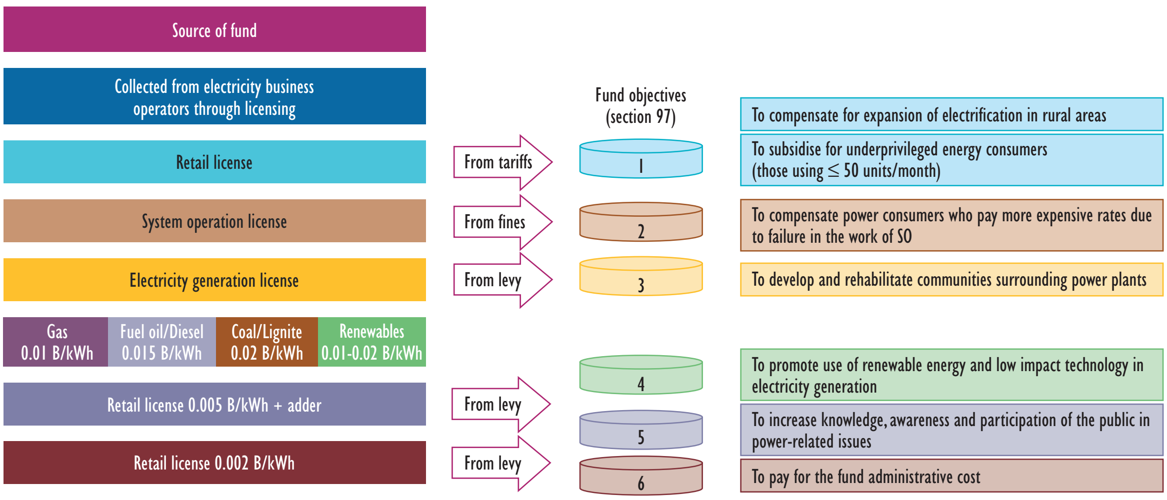
In 2012, these costs broke down as follows: 78.1% generation (including fuel cost, investment costs and power purchase costs – both energy and capacity); 13.1% distribution and retail; and 8.8% transmission (Ruangrong, 2012). The actual retail electricity tariffs vary depending on consumption and voltage level. The fuel cost component is adjusted every four months, and the VAT is currently 7% of the total electricity price.

Since MEA and PEA have different costs of service, the government has decided to subsidise PEA for the higher cost of rural electricity distribution to ensure uniform national electricity tariffs. PEA currently has approximate annual expenditure of THB 30-40 billion (approximately USD 0.8-1 billion). PEA's average recovery rate from tariff payments amount to THB 20-30 billion. The difference is then covered by the Thai treasury using general revenues.

The Power Development Fund

The Power Development Fund is made up of a number of components and funding sources to support different policy objectives, such as the PSO (Figure 13). The key levy is the revenue collected from retail licensees (MEA and PEA) to subsidise services to underprivileged consumers. Another important contribution is the levy imposed on generation licensees, which is used for the development and rehabilitation of communities affected by power plant operations.

Figure 13 • Power development fund



Source: IEA Thailand Questionnaire, 2015.

Electricity generation

Current supply mix

The Electricity Generating Authority of Thailand (EGAT) owns approximately 45% of generation in Thailand, while independent power producers (IPPs) own approximately 38% (excluding imports). The share of generation that EGAT is allowed to own is set by the Ministry of Energy (MoEN), which limits EGAT to less than 50% of total capacity. It should be noted, however, that the IPP figure obscures the fact that EGAT owns significant, though minority, shares in several large IPPs (Phongpaichit and Benyaapikul, 2013), a potential source of conflict of interest. The split in ownership between EGAT and the IPPs will remain largely the same under the 2015 Power Development Plan (PDP2015), with EGAT owning approximately 51% of new generation, and IPPs the rest.

Table 3 • Generating capacity by technology and type of owner (MW)

	Enhanced single buyer (ESB) (EGAT)					VSPP
	EGAT	IPP	SPP (firm)	Imports	SPP (non-firm)	
Hydro	3 444	0	0	2 104.6	12.2	58
Natural gas	9 534	11 160	2 927	0	235	0
Coal	0	2 007	367	0	53	0
Lignite	2 180	0	0	0	0	0
Oil	315	0	4.5	0	0	0
Diesel	4.4	0	0	0	0	47
Renewables	4.6	0	314	0	615	1 924
- Biomass	0	0	314	0	246	705
- Biogas	0	0	0	0	0	188
- Solar PV	1.6	0	0	0	175	973
- Waste	0	0	0	0	0	43
- Wind	2.7	0	0	0	180	11
- Other	0.3	0	0	300	14	4.4
Total	**15 482**	**13 167**	**3 615**	**2 405**	**915**	**2 029**
ESB total	**35 584**					
System total	**37 612**					

Note: imports consist of 2 105 MW of power purchases from Lao People's Democratic Republic (PDR) and a 300 MW high-voltage direct current (HVDC) link with Malaysia; MW = megawatt; PV = photovoltaic; SPP = small power producer; VSPP = very small power producer.

Source: DEDE (2015a), Alternative Energy Development Plan: AEDP 2015, www.dede.go.th/download/files/AEDP2015_Final_version.pdf.

IPP licences have been awarded to both international and domestic developers. Foreign investors include J-Power (Japan), GDF Suez (France), SPC Power Corporation (the Philippines), China Light and Power (Hong Kong, China), Mitsubishi (Japan), Tokyo Electric Power (Japan) and Marubeni (Japan). Recent contracts awarded to international developers include a contract for a USD 1 billion, 600 MW lignite-fired power plant awarded jointly to Marubeni and Alstom, to be built in Mae Moh (Thailand) for EGAT. Domestically, a consortium of companies led by Global Power Synergy – a subsidiary of PTT Public Company Limited (PTT) – is constructing a 400 MW natural gas-fired power plant in the Thilawa Special Economic Zone (UNCTAD, 2015).

Another large domestic developer is the Electricity Generating Public Company (EGCO), which invests in power plants both within Thailand and internationally. It operates 23 power plants in 5 countries, with a combined capacity of more than 3 700 MW. Most of these plants are located within Thailand, although it also has investments in Lao PDR, Indonesia and the Philippines. EGAT is a significant investor in EGCO, with an ownership stake of approximately 25%.

Privately owned SPPs account for 10% of generation, while imports and VSPPs make up the remainder. SPPs are projects of up to 90 MW that can contract to sell electricity to EGAT or directly to consumers. It takes approximately 45 days for a new SPP licence to be granted. One recent SPP contract is for an 8 MW solar plant in Sa Kaeo, being built by Conergy (a German firm) but to be operated by B.Grimm Power of Thailand (UNCTAD, 2015).

VSPPs can contract with the Provincial Energy Authority (PEA) and the Metropolitan Energy Authority (MEA), but not with EGAT and not directly with consumers. All VSPPs, regardless of technology, are considered non-dispatchable, in part because the system operator (EGAT) cannot see production from VSPP projects directly. Instead, PEA and MEA provide data on VSPP production to the Energy Regulatory Commission (ERC), which in turn passes that information on to EGAT.

EGAT manages day-to-day dispatch of IPPs, SPPs and its own generation through its various control centres. To ensure that resources will be available as needed, EGAT also develops a monthly dispatch schedule based on fuel prices. This schedule is distributed to the generating resources and to PTT, which is responsible for ensuring fuel deliverability.

EGAT has approximately 800 MW of balancing resources, 800 MW available for quick-start services, and 600 MW of capacity on standby.

Evolution of the supply mix under PDP2015

Thailand is anticipating continued and relatively sustained demand growth over the next two decades. As a result, despite the current excess of capacity, PDP2015 includes significant new investments in generation. Most of this generation is needed to meet new demand, although some is also needed to replace existing generators that are expected to retire. In particular, PDP2015 includes more than 57 gigawatts (GW) of new capacity, offset by retirements of around 25 GW – a relatively high proportion of Thailand's existing capacity. In total, this means Thailand will nearly double its installed capacity to more than 70 GW by 2036.

PDP2015 aims for a long-term reserve margin of 15%. While not stated directly, it is apparent that this reserve margin is meant to be a floor and not a floating target, as the reserve margin does not fall below 15% throughout the lifetime of the plan. In fact, it stays above 15% until 2032. Thailand's current available reserve margin is 25%.

Table 4 details the change in the generation mix over the course of the plan compared to the generation fleet as it stood in 2014. For the sake of comparison, it also includes the target share from the previous Power Development Plan (PDP), PDP2010.

Table 4 • Generating capacity by technology (MW)

Fuel type	PDP2015			PDP2010
	2015	2026	2036	2030
Natural gas	64%	51%	37%	58%
Coal	20%	23%	23%	19%
Renewables	10%	18%	20%	8%
Imported hydro	8%	8%	15%	10%
Nuclear	0%	0%	5%	5%

Source: IEA Thailand Questionnaire, 2015.

The most notable change is the reduction in natural gas generation, from the current 64% to a minimum of 30% and a maximum of 40% of generating capacity by 2036. This decline is offset by some new coal, but mainly from new imported hydro and new renewables.

Table 5 shows the breakdown in planned capacity by type of generation in 2036.

Table 5 • Generating capacity by technology (MW)

Type of capacity	Total (MW)	Number of plants
Natural gas (CCGT)	17 478	15
Natural gas (turbines)	1 250	5
Coal	7 390	9
Renewables	12 105	..
Pumped-storage hydro	2 101	..
Imported hydro	11 016	..
Co-generation	4 119	..
Nuclear	2 000	2

Notes: CCGT = combined-cycle gasification turbine; .. = data not available.

Source: IEA Thailand Questionnaire, 2015.

In absolute terms, certain technologies see particularly large increases. Coal capacity nearly quadruples from approximately 2 GW to 7.3 GW. Despite this, its relative share in the power mix remains fairly constant over the 20-year investment period, due to the expected increases in demand. The share of natural gas generation, on the other hand, decreases in absolute as well as proportional terms – a fact driven primarily by Thailand's stated goal of reducing its dependence on this fuel.

Natural gas-fired generation

Total demand for natural gas in Thailand in 2014 was 49.7 billion cubic metres (bcm). The power sector accounts for the majority of natural gas demand – 70.6% of the total – with the remainder split between industrial use, transport, and petrochemicals.

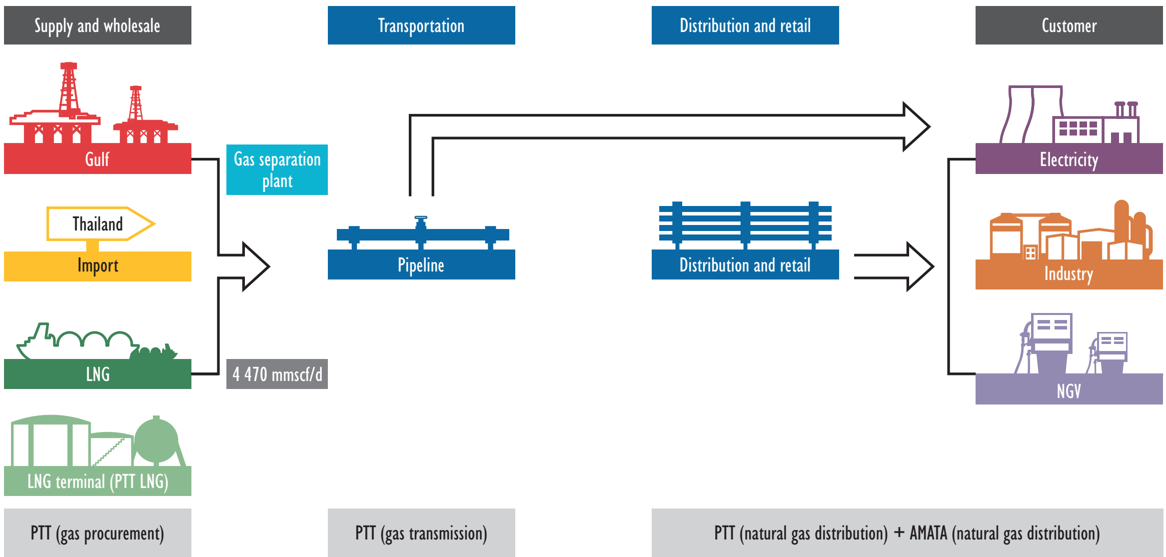
Total natural gas demand is expected to grow at an average annual rate of 1.1% through to 2036. For the power sector, however, natural gas use is expected to decline at an average annual rate of -1.0% over that same timeframe, as some natural gas generation is displaced by coal, renewables and hydropower imports.

Approximately 80% of natural gas-fired generators have a form of fuel-switching capability – either to fuel oil or to diesel. Under existing power purchase agreements (PPAs), plants with fuel-switching capability must demonstrate this ability by operating under the alternative fuel for at least three days in a row.

Fuel sources

The gas sector is regulated by the ERC and overseen by the Department of Mineral Fuel. PTT is responsible for procurement and transmission of natural gas for and within Thailand, while distribution is managed through PTT Natural Gas Distribution (NGD) and Amata NGD (Figure 14). While third-party access rules for the gas pipeline network are in place, in practice no capacity has been allocated to any outside party. Looking ahead, a greater reliance on liquefied natural gas (LNG) imports may result in opportunities for third-party access becoming available.

Figure 14 • Structure of the Thai gas industry



Note: mmscf/d = million standard cubic feet per day.
Source: IEA Thailand Questionnaire, 2015

Since becoming a gas importer in 1998, Thailand has experienced a steady increase in imports (which reached 13 bcm by 2014) (Figure 15). Development of the country's natural gas resources – particularly from the Gulf of Thailand – alongside the start of pipeline imports from Myanmar in the late 1990s, have supported robust growth in gas demand over the past 15 years. Since 2000, gas consumption has increased at an annual pace of almost 6%, driven by strong final energy demand and higher penetration of gas in both the power and transport sectors.

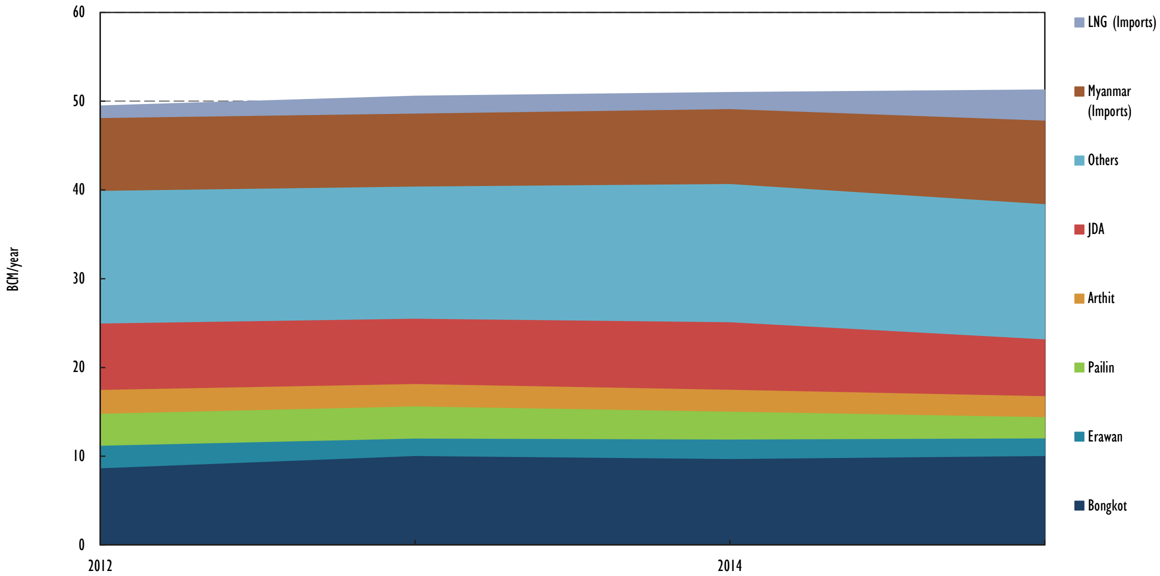
Thailand's demand forecast for natural gas is based on the PDP, the details of which have a significant impact on long-term natural gas plans. While long-term price forecasts are, of course, uncertain, the general preference on the part of the public for natural gas over coal as a fuel source means that reliance on natural gas as a primary fuel source is likely to continue.

The gas supply outlook for Thailand looks increasingly challenging. Growth in production has not been offset by new discoveries in recent years, leading to a rapid depletion of the country's proven gas reserves (which have almost halved since their peak in 2005). The country's reserve-to-production ratio now stands at just six years. Thailand has no long-term natural gas storage, and approximately three days of storage at the LNG terminal.

The maturity of the region's asset base is a major driver behind the small number of new discoveries, but other factors are also at play: uncertainty over the future of expiring domestic concessions and the potential for changes to the regulatory framework create additional investment risks for companies and weigh on the level of investment. At the same time, competition for capital across various producing regions is set to increase, as companies around the globe sharply reduce upstream spending in response to lower oil and gas prices.

Consequently, the IEA Medium-Term Gas Market Report 2015 projects a decline in Thai production over the next few years (IEA, 2015d).

Figure 15 • Thailand's natural gas supply by source, 2012-15



* January through October

Notes: JDA = Malaysia-Thailand Joint Development Area.

Source: IEA Thailand Questionnaire, 2015.

Thailand's gas imports are set to increase rapidly as a result. Domestic gas production has accounted for roughly three-quarters of incremental demand over the past ten years, which means that even much slower growth in consumption will require higher reliance on imports.

Today, Thailand imports gas from Myanmar and via LNG. Imports from Myanmar started in 1998 from the Yadana gas project, and were then expanded in 2000 when another gas pipeline was connected from the Yetagun gas field. In 2014 imports from Myanmar stood at 11.5 bcm, equal to roughly one-quarter of Thai gas consumption. Looking ahead, there is uncertainty over whether Myanmar will be able to export larger volumes to Thailand. While several companies are now starting exploring acreage that was awarded during a successful licensing round in 2013, a clear picture on both the size of the resources and timeline for development is yet to emerge. Moreover, Myanmar's domestic demand is set to increase very rapidly as the country electrifies and industrialises following a long period of international isolation, which could constrain the country's ability to export. In the short run, the start up of the Zawtika gas project will contribute to increasing Myanmar's production. The field – operated by PTT Exploration and Production (PTTEP) – has an anticipated peak output of 3 bcm. Production will serve both to increase exports to Thailand and to meet Myanmar's growing domestic demand. The field, however, is relatively small in relation to the size of the Thai gas market, and will have no meaningful impact on Thailand's expected increased reliance on LNG imports.

Thailand has a relatively sizeable and under-utilised LNG import capacity. The country's Map Ta Phut LNG receiving terminal was the first operating terminal in Southeast Asia and has a capacity of 6.8 bcm. To date imports have run well below capacity, peaking at 2 bcm in 2013 and falling to 1.9 bcm in 2014. Thailand has traditionally sourced all its LNG from the spot market. In 2015, however, it began importing LNG from Qatar based on a 20-year long-term contract for 2.7 bcm per year, which was signed by Qatargas and PTT in 2012. PTT expects LNG imports to supply approximately 20 bcm to 30 bcm by 2036.

In response to the uncertain supply outlook both for domestic production and imports from Myanmar, Thailand is planning to double the size of the Map Ta Phut LNG terminal to 13.6 bcm per year. State-owned PTT awarded the engineering, procurement and construction contract for the expansion in April 2014, with a scheduled start-up date of mid-2017. The company has also indicated it is considering building a second LNG import terminal.

With its reliance on LNG imports likely to increase, Thailand is also looking to secure access to long-term supplies. In addition to the long-term contract signed with Qatar, PTT is focusing on the potential to tap into new LNG production in Mozambique. In 2013, the company signed a preliminary deal with Anadarko to purchase 3.5 bcm of LNG per year from the planned Mozambique LNG project. PTT has also made a sizeable upstream investment in the project and owns an 8.5% equity stake via a subsidiary. A contractor for the project was appointed in May 2015 but a final investment decision has yet to be taken. The risk of delay has increased in light of prevailing poor market conditions. Even under optimistic assumptions, shipments to Thailand will not be available before the early 2020s.

Domestically, differences in the quality of gas between eastern and western Thailand limit the ability to ship gas within the country. As a result, pockets of congestion exist within the system that could potentially cause disruption, in particular if local issues with plant dispatch arise. PTT receives, on a weekly basis, a list of plants to be dispatched so it can plan for potential issues.[4]

Thailand's current high dependency on gas for its power generation raises concerns over fuel security and power generation costs over the longer run due to the expectation of rapidly falling domestic production. Imports of LNG are set to grow significantly, thus increasingly exposing the country's power sector to the dynamics of international gas markets.

Coal-fired generation

Coal-fired generation accounts for 19.9% of total power production in Thailand. In 2014, demand for coal amounted to 25.6 million tonnes of coal-equivalent (Mtce), and was evenly split between industrial and power generation uses (Table 6). Thailand expects demand for coal to increase at an average annual rate of 1.8% per year, reaching 36.1 Mtce by 2036. While increasing industrial demand accounts for some of this growth, the majority is due to increases in coal used for power generation.

Table 6 • Thai coal consumption by sector (Mtce)

Sector	2012	2013	2014	2015*
Power generation	12.9	12.9	13.6	10.3
Industry	10.6	9.7	12.0	10.3
Total	**23.4**	**22.6**	**25.6**	**20.7**

* January through October.

Source: IEA Thailand Questionnaire, 2015.

Thailand is in the process of replacing old and inefficient coal-fired generation units, such as the Khrabi power plant. This is being heavily opposed by the Thai public and non-governmental organisations, which fear detrimental health and environmental impacts from coal-fired generation. PDP2015 calls for additional replacements and new coal-fired generation in Thailand up to 2036.

In the face of domestic opposition, the government of Thailand and EGAT are building coal-fired generation units outside Thailand and importing the electricity generated via IPPs and PPAs. The

[4] Natural gas from onshore fields in the northeast on average contains 76% methane and 13% carbon dioxide (CO_2), while that from offshore fields in Myanmar contains 72.4% methane, 6.2% CO_2 and 16% nitrogen.

first such plant is the mine-mouth Hongsa power station in Xaignabouri, Lao PDR, with another planned in Myanmar. Hongsa is being developed by Ratchaburi Electricity Generating Holding, Banpu Power and Lao Holding State Enterprise (LHSE), and will export 1 473 MW of power to Thailand with EGAT as purchaser.

A similar project is under way in Myanmar, where PTT Energy and Ratchaburi Electricity Generating Holding plan to invest in a 600 MW coal-fired power plant in Kyaing Tong, of which about 500 MW would be exported to Thailand.

Fuel source

Thailand has approximately 30 years of domestic coal supply. While it does currently import some coal, the vast majority (~95% of imports) is used for industrial purposes. New coal plants would be likely to require additional imports, which would come from sources such as Indonesia, Australia, and perhaps even as far away as Colombia. Unlike for natural gas, no specific government office or policy focuses on coal imports and distribution infrastructure.

Technology

Thailand needs to choose carefully the technology for coal-fired power generation, as it will lock in cost and environmental burdens for decades to come. Choosing supercritical and ultra-supercritical technology, in particular to replace inefficient sub-critical plants, would lead to a much more efficient fleet.[5]

Improving the average fleet efficiency of existing power stations would lead to an important drop in emissions intensity, or the per-kilowatt hour (kWh) usage of coal. This would also have a positive impact on operating costs, and lessen the environmental impacts of coal-fired power. In addition, it would place less pressure on coal resources and reduce the impacts of the coal supply chain on the environment.

Almost all non-greenhouse gas pollutants can be controlled and reduced to low levels, similar to those of an equivalent-sized gas plant; the best-performing coal plants in China can meet air pollutant standards designed for gas-fired plants. Carbon dioxide, however, remains a problem. Any rise in emissions is best avoided, but achieving the highest possible efficiencies minimises this rise, and also steers a possible path to the successful and economic deployment of carbon capture and storage in the future. In addition demand side efficiency measures help to limit demand and generation growth and therefore avoid additional emissions.

Pulverised coal combustion (PCC) is the world's dominant coal-based power generation technology and is likely to remain so for the foreseeable future. Increasingly advanced cycles have improved the efficiency of PCC electricity generation from subcritical to supercritical and ultra-supercritical; research into advanced materials and steam-cycle conditions promises to maintain this trend (IEA, 2016).

[5] Definitions of subcritical, supercritical (SC) and ultra-supercritical (USC) can differ around the world, and will vary depending on the steam temperatures and pressures. As a general rule, stations designed with subcritical steam conditions operate at efficiencies at or below 39% on a lower heating value (LHV) basis; super and ultra-supercritical efficiencies can reach 46%. Advanced ultra-supercritical (A-USC) efficiencies aim to continue this trend with efficiencies approaching 50-52% but, as yet, commercially available technologies continue to undergo development. If successful, a plant operating at 50% efficiency would emit almost a third less CO_2 than a reasonable subcritical plant (at 35%), achieving massive savings in greenhouse gas emissions. In 2013, the weighted efficiency of the global coal-fired fleet was 36.4 %, and in the Southeast Asia was 33.4%.

Hydropower

Hydropower accounts for 3.5% of Thailand's domestic installed generation capacity. Under the Alternative Energy Development Plan (AEDP2015), Thailand aims to add 200 MW of new hydroelectric capacity, all of which will be small hydro (Table 7, Table 8).

Table 7 • Hydropower additions until 2036

Technology	AEDP 2036 target (MW)	Recent progress (MW)			
		2012	2013	2014	2015 (Jan-Aug)
Small hydro	376	102	109	142	172
Large hydro	2 906	0	0	0	2 906

Source: EGAT, 2016

Table 8 • Feed-in-tariff for small hydro (<200 kW)

FIT (THB/kWh)	Term	Premium for Southern Provinces (THB/kWh)
4.9	20 years	0.5

Source: EGAT, 2016

In addition, EGAT currently has 500 MW of pumped-storage hydropower and is planning to increase this capacity to 2 100 MW. As pumped-storage hydro can store electricity for use when there is an abundance of renewable power, it has the potential to become more valuable to the Thai system as the share of renewables increases. It should be noted, however, that much of the benefit of pumped-storage hydro can be provided by Thailand's existing hydropower fleet and relatively flexible (and abundant) natural gas-fired generating fleet.

Planning for hydropower is based on historical production patterns, and does not take into account any forecasts with regard to resource availability. EGAT is at present unconcerned about the possibility of climate change having a negative impact on the availability of hydro generation, although it is unclear whether this view is based on actual analysis of potential changes. One study by the Mekong River Commission found that the Mekong River Basin is likely to become wetter as a result of climate change, but that changes to rain patterns may affect the seasonal availability of hydroelectric power (MRC, 2009).

As Thailand's domestic capacity for additional hydropower is limited, the Thai government is encouraging companies to invest in hydropower generation in neighbouring countries, such as Lao PDR, Myanmar, China, and Vietnam.

Imports

As outlined above, Thailand aims to overcome the challenges of expanding coal-fired generation domestically and the limits imposed by its riverine systems by increasing in absolute terms electricity imports. In particular, it will invest in additional hydroelectric power. Institutionally such development is governed by memoranda of understanding (MoUs) between EGAT and Myanmar, China (signed in 1998 for 300 MW of imports), Lao PDR (7 000 MW), Cambodia and Malaysia (300 MW via a single HVDC transmission line).

All existing and planned imports into Thailand are connected directly to the Thai grid, and are generally islanded from their domestic markets. No grid-to-grid power is currently traded between Thailand and its neighbours, although excess power is on occasion exported to neighbouring countries under various MoUs. Table 9 lists projects that are currently subject to PPAs with EGAT (both existing and under construction).

Table 9 • Power purchases from neighbouring countries (existing and under construction, 2013-19)

Projects			
Completed	**Capacity**	**Under construction**	**Capacity**
Mai Khot, coal, Myanmar	220	Hongsa Lignite, coal, Lao PDR	1 473
Hutgyi, hydro, Myanmar	126	Nam Ngum 2, hydro, Lao PDR	354
Dawei, coal-fired, Myanmar	948	Nam Ngiep 1, hydro, Lao PDR	1 220
Pak Beng, hydro, Lao PDR	597	Nam Theun 1, hydro, Lao PDR	269
Xayaburi, hydro, Lao PDR	220		
Total	2 111		3 316
	5 427		

Source: EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

Beyond 2020, power imports into Thailand, which amount to 6.4% at present, will not be allowed to exceed 15% of total capacity.

The majority of Thailand's imported power comes from hydroelectric dams in Lao PDR. Thailand has a long history of importing electricity from Lao PDR, with power trading having gone on essentially uninterrupted for decades. Hydropower exports are a significant revenue source for Lao PDR, with 85% of power generation exported to other countries. For example, more than 90% of the power generated by Nam Theun 2 (a 1 GW hydro plant) is exported to Thailand under a 25-year concession agreement that is expected to provide the Lao government with approximately USD 2 billion in revenues over that timeframe. While these revenues are large relative to the Lao economy, in absolute terms they are fairly small, possibly reflecting the fact that this project was considered risky at the time it was developed. New projects are likely to be priced higher, and by 2020, the power sector could make up approximately 16% of Lao PDR's gross domestic product (UNCTAD, 2015).

Lao PDR has an estimated 23 000 MW of hydropower potential – a significant proportion of the Mekong River Basin's estimated total potential of 59 930 MW. Lao PDR is actively encouraging hydropower development and investment, as it provides significant revenue to the country.

While Lao PDR is still growing, and despite the fact that a significant proportion of the country remains unelectrified, with a population of only 6 million people, it is unlikely that the total amount of hydropower could be consumed domestically. According to its Power Development Plan, demand in Lao PDR will only reach 4 099 MW in 2022. The relative abundance of domestic resources compared to potential domestic demand is the reason that the country is considered the "battery of Southeast Asia", with the potential to be a significant source of low-carbon electricity for the entire region.

Lao PDR has 29 existing power plants that are under long-term PPAs with Thailand, totalling more than 3 000 MW of capacity and producing more than 16 000 gigawatt hours per year. Lao PDR exports power to Thailand via two transmission lines of 500 kilovolts (kV) and two of 230 kV. In addition, five transmission lines of 115 kV can be used for bidirectional power trades. Lao PDR's distribution network is also directly linked to that of PEA. In contrast to the high-voltage lines, these lines are used for exports from Thailand into Lao PDR.

Lao PDR currently has 45 generation projects under construction, which will add a total of 6 185 MW of new capacity. Most projects in Lao PDR are built either by Thai or Chinese developers (UNCTAD, 2015). Some potential for wind power exists near the Lao PDR-Viet Nam border, but it is physically difficult to build wind power in Lao PDR at present.

In addition to imports from Lao PDR, the potential exists to import hydropower from Myanmar. One question, however, is whether growing domestic demand within Myanmar will reduce the potential quantity of power available for export. Increasing industrialisation and electrification, combined with significant amounts of supressed demand, could mean that new hydropower developments within Myanmar are absorbed by domestic consumption. According to its Power Development Plan, demand in Myanmar in 2030 could range from a low of 9 100 MW to a high of 14 542 MW.

The price of Thailand's imports is fixed under the terms of each PPA. These costs are completely passed on to consumers. The ERC requires that imported power be cheaper than comparable domestic sources, and the regulator can force prioritisation of domestic resources over imported power if it is concerned about security of supply. For example, the ERC has mandated that a demand-response programme be implemented in southern Thailand, instead of expanding imports of power from Malaysia.

Non-hydro renewables

Status of renewable power

Thailand's renewable power has seen continuous growth due to supportive policy frameworks and incentive measures in the form of feed-in tariffs (FITs) and tax incentives. As of September 2015, total grid-connected renewable power stood at 4 348 MW, or 8.5% of total generation (ERC, 2015). Excluding domestic hydro, renewables accounted for 5% of installed generation (IEA Stats, 2015a). Table 10 shows the installed capacity by type of renewable energy, and Figure 16 shows the shares of different renewable power sources in Thailand's fuel mix.

Table 10 • Status of renewable power development in Thailand versus AEDP2015 target for 2036

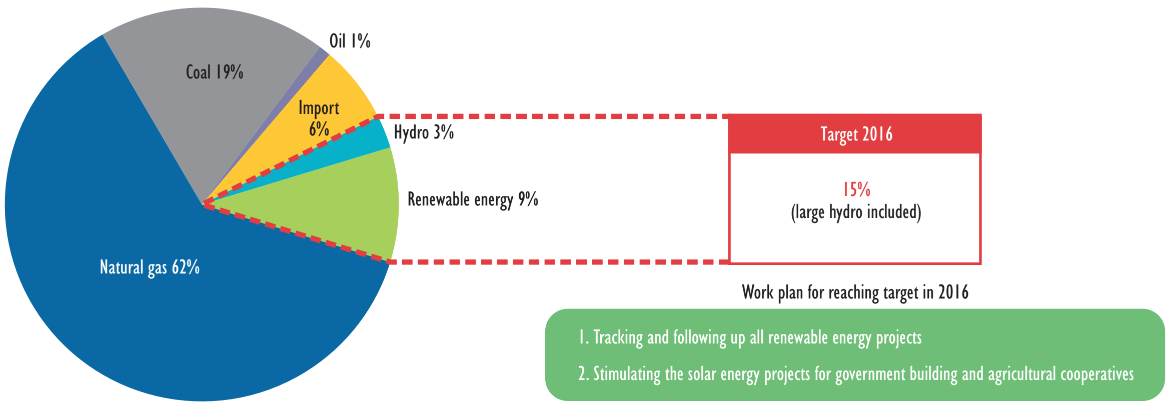
RE power status (MW)	AEDP 2036 target	Progress			
		2012	2013	2014	2015 (Jan-Aug)
Solar power	6 000	377	823	1 299	1 314
Wind power	3 002	112	223	224	225
Biomass	5 570	1 960	2 321	2 452	2 679
Biogas	600	193	265	311	359
Energy crops	680	0	0	0	0
Waste-to-energy	500	43	48	66	135
Total	**16 352**	**2 685**	**3 680**	**4 352**	**4 712**

Source: DEDE (2015b), "Performance on alternative energy policy (Jan-Aug 2015)", webpage, www.dede.go.th/download/state_58/sit_57_58/calendar_aug.pdf.

Between 2013 and 2015, solar power experienced the highest average yearly growth rate at 59%, followed by waste-to-energy power (51.5%), wind power (33.5%), biogas (23%), and biomass (11.1%).

Figure 16 • Share of Renewables in Thailand's Energy Mix

	Sep 2015	Target 2015	Target 2016	Target 2016-Sep15	COD in 2016
1. Community waste	134.72	143.80	187.00	52.28	66.34
2. Industrial Waste	-	-	-	-	-
3. Biomass	2 676.50	2 724.34	2 949.46	272.96	470.15
4. Biogas	365.10	365.09	375.00	9.90	113.94
5. Biogas (from Energy plant)	-	-	-	-	-
6. Small Hydropower	172.06	172.24	190.42	18.36	23.50
7. Wind Energy	225.37	225.93	255.79	30.42	865.45
8. Solar Energy	1 313.65	1 393.89	1 679.03	365.38	1 071.77
9. Large Hydro	2 906.40	2 906.40	2 906.40	-	-
MW	7 793.80	7 931.69	8 543.10	749.30	2 611.15
ktoe	1 464.00	2 385.01	2 574.02	1 110.02	591.33



Note: The table shows the actual renewable capacity reached in September 2015 and the capacity targets in 2015, 2016 and the capacity needed to reach the 2016 target as well as the capacity expected to come online in 2016.

Source: IEA Thailand Questionnaire, 2015

Policy and regulatory designs

AEDP2015 formulates three broad general strategies: 1) increasing preparedness on feedstock and technologies; 2) increasing renewable energy production and expanding the renewable energy market; and 3) increasing renewable energy awareness. Specific actions to support these strategies focus on stepping up efforts to increase investment, production and workforce participation in the renewable energy market.

The permitting process for renewables

The permitting process for VSPP projects is complex, involving significant documentation requirements, the involvement of a third-party contractor, and approval by MEA, PEA and the ERC. For a VSPP, the required permits include a generation licence, an industrial permit, a building permit, a zoning permit, and an environmental safety assessment for plants larger than 5 MW and less than 10 MW. A minimum timeframe of one year is to be expected to acquire all the permits. Discussions have been held about turning ERC into a one-stop-shop for VSPP licences.

Support measures

Thailand has put in place key support measures that have stimulated private-sector investment in renewable power.

FITs

The FIT programme has been in place since 2007 and is available to six types of technology: biomass, biogas, solar, wind, small/micro hydro, and waste-to-energy. In its original form, the FIT structure comprised a premium paid on top of prevailing wholesale electricity rates, and hence the programme was called the “Adder” programme. Currently, the programme has a “fixed FIT” structure, following the National Energy Policy Council’s resolution to change the price structure for solar projects in 2010 and for all other technologies in 2014. Two main types of FIT are available, as detailed below.

Fixed FITs for solar power

In 2013, Thailand introduced a FIT system for solar PV. This replaced the Adder programme that had been in place since 2007. The quota allocated by the government for this scheme was limited to 200 MW for residential, commercial and industrial-scale rooftop solar installations (Table 11).

Table 11 • FITs for rooftop solar

Technology	Power plant capacity	Period of time	Feed-in tariff rate in THB/kWh	Quota
Rooftop solar	0-10 kW	25 years	6.85	100 MW
	10-250 kW		6.40	100 MW
	250 kW-1 MW		6.01	

Notes: installations to be operational by December 2015; kW = kilowatt.

Source: DEDE (2015b), “Performance on alternative energy policy (Jan-Aug 2015)”, webpage, www.dede.go.th/download/state_58/sit_57_58/calendar_aug.pdf.

In addition, the government approved an 800 MW quota for ground-mounted solar systems for communities. The programme was modified between 2014 and 2015 to allocate 400 MW to agricultural co-operatives and 400 MW to government properties (Table 12).

Table 12 • FITs for ground-mounted solar for agricultural co-operatives and government properties

Technology	Period of time	FIT rate in THB/kWh	Quota
Ground-mounted solar for agricultural co-operatives and government properties	25 years	5.66	800 MW

Note: installations to be operational by September 2016.

Source: DEDE (2015b), “Performance on alternative energy policy (Jan-Aug 2015)”, webpage, www.dede.go.th/download/state_58/sit_57_58/calendar_aug.pdf.

Fixed FITs for non-solar renewables

In 2014, the government of Thailand widened the new FIT programme to non-solar renewables (Table 13).[6] The FITs for non-solar are granted for 20 years, except those for biogas power from landfill gas which have a duration of 10 years. These changes put the application process for all non-solar renewables on hold for nearly a year.

The new FITs for non-solar renewables comprise three components:

- FIT(F) is the fixed portion of remuneration.
- FIT(V) is the variable portion of the remuneration, adjusted according to the inflation rate.
- FIT(P) is the feed-in premium that is split according to the fuel type and location of the installation.

Renewable power procurement under this programme will be conducted by a competitive bidding process, whose detailed regulation is scheduled to be released early in 2016. According to the latest version of the draft regulation, details of the competitive bidding schemes are as follows.

[6] The design principles are taken from the draft regulation and could still change.

Table 13 • Announced FIT rates for non-solar renewables (THB/kWh)

						FIT(P)	
Technology	Capacity	FIT(F)	FIT(V)	Total calculated FIT	Period of support	For bioenergy (8 years)	Southern Provinces
Waste (e.g. incineration, gasification)	<1 MW	3.13	3.21	6.34	20 years	0.70	0.50
	1 MW-3 MW	2.61	3.21	5.82			
	>3 MW	2.39	2.69	5.08			
Waste (landfill gas)	x	5.60	x	5.60	10 years	x	
Biomass	<1 MW	3.13	2.21	5.34	20 years	0.50	
	1 MW-3 MW	2.61	2.21	4.82		0.40	
	>3 MW	2.39	1.85	4.24		0.30	
Biogas (from waste products)	x	3.76	x	3.76		0.50	
Biogas (from energy crops)	x	2.79	2.55	5.34			
Hydropower	<200 kW	4.90	x	4.90		x	
Wind	x	6.06	x	6.06		x	

Note: x = not applicable.

Source: DEDE (2015b), "Performance on alternative energy policy (Jan-Aug 2015)", webpage, www.dede.go.th/download/state_58/sit_57_58/calendar_aug.pdf.

The first round of competitive bidding will include three types of renewables: biomass, biogas (from waste/wastewater and energy crops), and wind.

The ERC will announce a quota for each type of renewables in each region (i.e. North, Northeast, Central, East, West, South, and Bangkok).

Projects will compete for capacity allocation under the appropriate quota based on the level of FIT that each project offers. After considering the merit order, the winning bidder will be the one that offers the highest discount from the announced FIT(F), e.g. a 5% discount on FIT(F).

The bidding process for each region will finish when the total quota for each type of renewables in each region is filled. The policy framework for FIT bidding is in place, but at the time of writing the application process had not begun. The FIT bidding application process awaits the implementation of the solar programme for agricultural co-operatives and government properties, completion of which would enable the utilities to allocate remaining grid capacity to the FIT bidding programme.

Net metering

In January 2015, the National Reform Committee approved a proposal for a net-metering project for rooftop solar power. The project, entitled "A Project to Support Rooftop Solar Installations", is designed to be open to rooftop solar PV systems smaller than 500 kW for an indefinite period of time without any quota. Solar PV systems should be designed for self-consumption, and excess electricity fed into the grid will either be rewarded a payment or credited to the next billing cycle. Details of the regulation on net metering have not yet been released. The National Reform Committee expects this project to add 1 000 MW of rooftop solar PV over the next five years and a total of 10 000 MW over the next 20 years. Given the size of the Thai system this will require careful system planning and upgrades to the distribution system. (IEA, 2016)

However, the current pause in FIT support and the absence of net metering regulations mean that rooftop solar PV systems have faced a gap in support since 2013.

Permitting challenges for grid-connected rooftop solar PV systems

The Thai government has continuously improved the process for acquiring permits for rooftop solar PV systems. Between 2013 and 2014, rooftop solar PV systems were required to acquire the same number of permits as large-scale solar farms. However, in March 2014 the government lifted the requirement for factory permits and in October 2015 the need for building permits for smaller-scale rooftop systems. Nevertheless, the process of acquiring all remaining permits could be simplified and benchmarked against international best practice. Key features of streamlined permitting should be included, such as the creation of an online permitting portal and the narrowing down of the inspection window (see for example NREL, 2013). The process of reducing the number of permits should also not compromise safety. In this regard, the government should initiate a contractor certification programme. Pre-approved contractors can not only help with fast-tracking the permitting process, but also help ensure safety throughout the lifetime of the systems (see for example Northwest SEED et al., 2012).

Nuclear

While Thailand has no direct experience of building or operating nuclear power plants, it has included nuclear in successive PDPs. In each case development has been postponed. PDP2015 includes 2 000 MW of new nuclear capacity, although it is highly unlikely that it will come online within the timeframe of PDP2015.

The development of nuclear power requires significant regulatory intervention. In particular, regulations should be in place to ensure safety during construction, the safe storage and management of nuclear fuel, and the safe management and storage of the radioactive waste products, as well as the day-to-day operations of the plants. Strong regulatory regimes and, in particular, strong oversight of the development and operation of the nuclear facility, are vital. Nuclear power development also requires the continuous training of nuclear safety experts that can operate a power plant. This adds further costs and requires the establishment of education programmes and training centres years ahead of time.

Nuclear plants take a long time to develop compared to other technologies, even under ideal conditions. In countries that have no experience of building nuclear technologies, delays are to be expected because of the technical complexity of such projects, and the potential for strong local opposition.

Nuclear technologies are also very capital intensive, and therefore require significant upfront investment. Globally, most recent nuclear projects have been developed in regulated markets, where costs can be directly passed on to consumers. Even in these cases, however, some kind of government-provided financial support has been required, for example in the form of loan guarantees. Under current circumstances, a key obstacle to financing nuclear in Thailand will be the ability of such costs to be passed through to consumers via the tariff, as the PDP calls for the affordability of electricity costs for consumers.

Electricity demand

Energy demand

The future direction of Thailand's economy will have serious implications for its energy demand, as consumption levels and intensities in each sector are very different. A move away from heavy industry towards the service sector may come with an associated decrease in both energy intensity and demand.

However, further income growth will go hand in hand with an increase in car, air conditioning and electrical appliance ownership at the household level, partially offsetting decreases in the industrial sector. Continued growth in the tourism and retail sectors may also contribute to increases in electricity demand (Figure 17). It is important to note that Thailand's shopping malls are very large electricity consumers. In addition, the economic development of Thailand's northern and southern regions could add further to increases in demand.

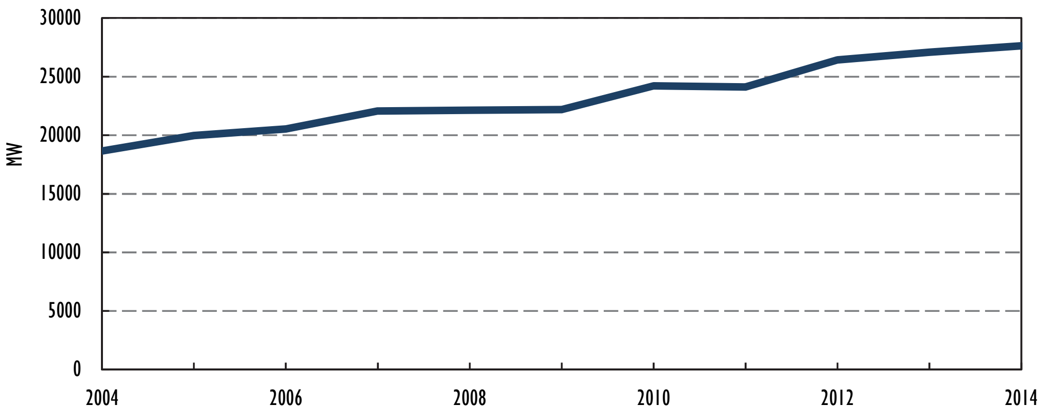
Energy consumption growth rates in the manufacturing and commercial sectors are significantly higher than rates of growth in gross domestic product (GDP), with increases of 3.0 and 3.7 times respectively compared with consumption in 1990 (EPPO, 2013). Industry's rising energy demand is primarily driven by the increasing share of manufacturing in the economy and use of inefficient industrial plants (Figure 22).

Thailand's rapid economic expansion over the past two decades has spurred the need for generation capacity to keep pace with higher electricity demand. Growth in overall power consumption has averaged approximately 5% a year over the past decade.

Peak demand

In line with general consumption growth, Thailand's peak electricity demand has increased by 48% over the last ten years (Figure 17).

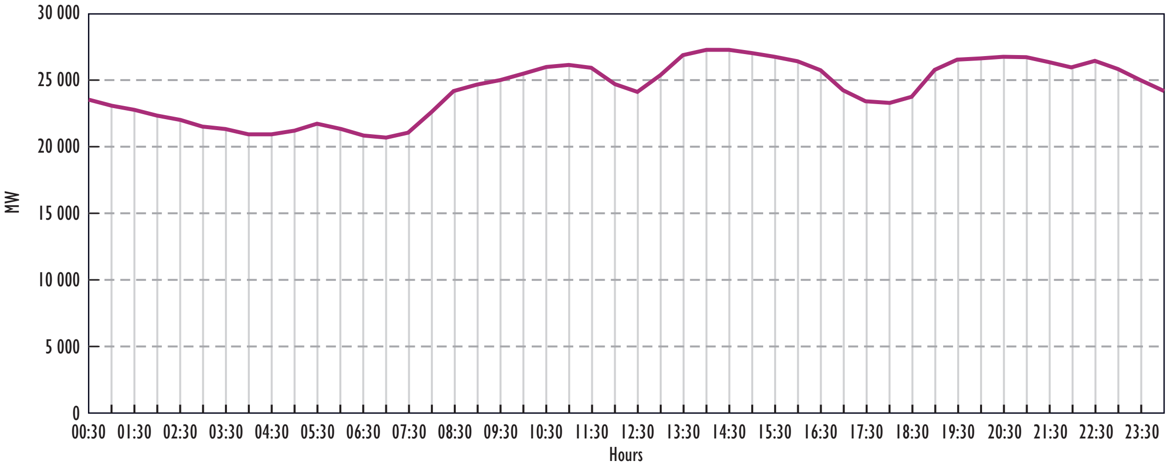
Figure 17 • Thailand's growth in peak demand for electricity (MW)



Source: EGAT, 2016.

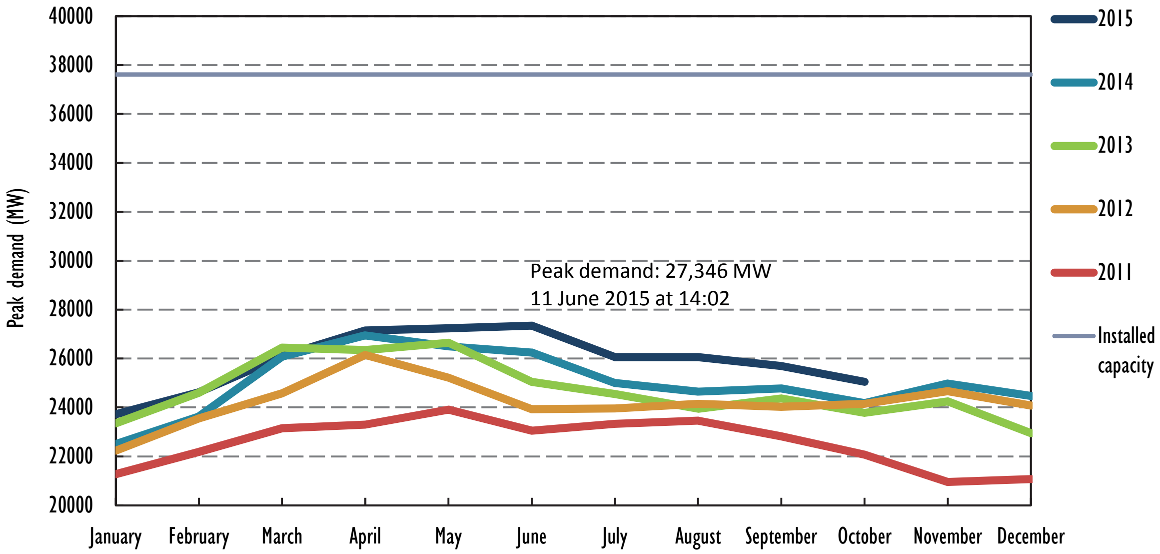
A typical daily load curve has three peaks: morning, afternoon (the largest) and evening (Figure 18). There is relatively little seasonal variation, although power demand has traditionally peaked during March to May.[7] This has recently been prolonged to June due to changing weather conditions that conform to the expected impacts of climate change (Figure 19).

Figure 18 • Typical daily load curve



Source: EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

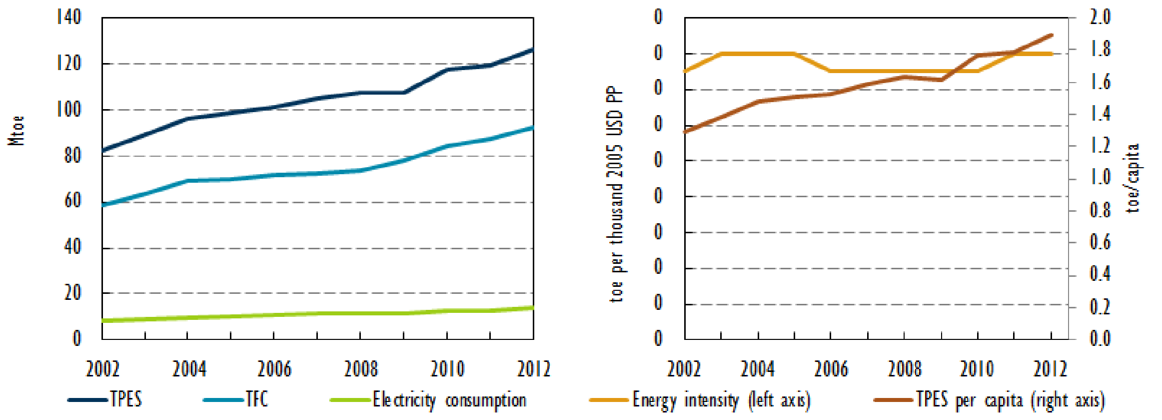
Figure 19 • Monthly peak demand, 2011-15



Source: EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

[7] 2015 was an unusual year in that peak demand occurred in June. EGAT is investigating the specific cause of the unusually timed peak, although it is most likely the result of unusual weather patterns, lack of small power plant production, or some combination of the two.

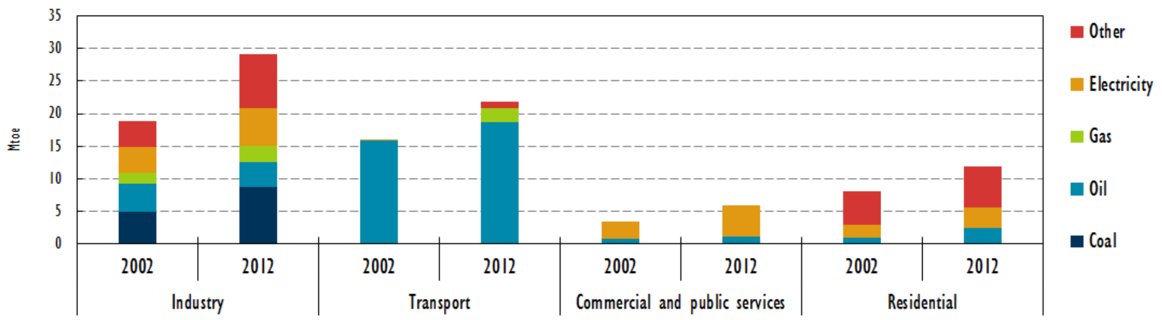
Figure 20 • TPES, TFC, electricity consumption, energy intensity, and TPES per capita for Thailand, 2002-12



Notes: Mtoe = million tonnes of oil-equivalent; PPP = purchasing power parity; TFC = total final consumption; toe = tonne of oil-equivalent; TPES = total primary energy supply.

Source: IEA Thailand Questionnaire, 2015.

Figure 21 • TFC by sector and by energy source, 2002 and 2012



Source: IEA Thailand Questionnaire, 2015.

Demand forecast

Energy demand growth is expected to continue over the next twenty years. Under a business-as-usual scenario, TFC is expected to reach 151 Mtoe, an annual average growth rate of 3.9%, under the assumption that GDP will grow at an annual average rate of 4.2% (EPPO, 2013). GDP growth is forecast to average 3.6% per year between 2016 and 2020 (OECD, 2015).

Power demand is forecast to continue to grow at an average annual rate of 2.7%, slower than expected TFC growth. This is lower than the historical rate due to expected improvements in energy efficiency. At this rate of growth, peak demand in 2020 would be approximately 34 808 MW, and in 2030 would be 44 424 MW.

The load forecast is developed by the Load Forecast Committee, which is chaired by the Permanent Secretary of Energy and includes participants from the Energy Policy and Planning Office (EPPO), the Department of Alternative Energy Development and Efficiency (DEDE), the National Economic and Social Development Board, the Thailand Development Research Institute, the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Energy Authority (MEA), the Provincial Energy Authority (PEA), the Association of Private Power Producers, the Federation of Thai Industries, and the Board of Trade of Thailand.

Energy efficiency measures

Scaling up energy efficiency is an essential part of Thailand's strategy to mitigate energy demand growth, improve energy security, decrease greenhouse gas emissions and promote economic and social prosperity.

As mentioned earlier in this report, as part of its Energy Efficiency Plan (EEP) (2015-36), Thailand is implementing a package of measures that seeks to save a total of nearly 90 terawatt hours by 2036. This level of savings is a 30% decrease in energy intensity in 2036 compared to 2010, and is equivalent to the annual output of more than 16 coal-fired power plants.

The EEP outlines five strategic approaches to improving energy efficiency, including strengthening and expanding:

- mandatory requirements via rules, regulations and standards
- energy conservation promotion and support
- public awareness of energy efficiency and behaviour change
- promotion of technology development and innovation
- human resources and institutional capacity development.

The policy measures included in the EEP range from minimum energy performance standards (MEPS) and energy efficiency resource standards (EERS) to energy management systems in buildings and industry (Table 14). Policies also seek to expand the market for light-emitting diode (LED) lighting systems and to promote energy efficiency through increased financial incentives. These include subsidies of 20% of the cost of energy efficiency measures with a payback period of fewer than 7 years in designated buildings and factories, and tax credits for the purchase of more than 19 products, most of which have received the highest energy rating possible (5 out of 5).

Table 14 • Expected energy savings by measure (2015-36)

Expected energy-saving measure	Electricity (GWh)
Energy consumption management in designated building/factory	19 649
Building energy code (BEC)	13 686
HEPS and MEPS	23 760
Financial incentives	15 074
Promoting greater use of LEDs	11 632
EERS	5 872

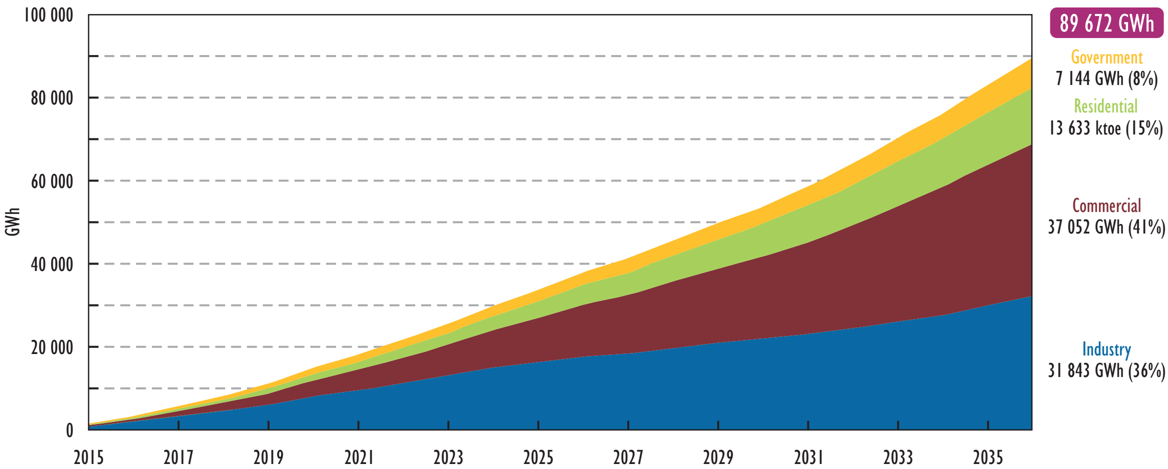
Notes: GWh = gigawatt hour; HEPS = high energy performance standards.

Source: DEDE (2015a), Alternative Energy Development Plan: AEDP 2015, www.dede.go.th/download/files/AEDP2015_Final_version.pdf.

The commercial sector is expected to account for the largest share of energy efficiency improvements (41%), followed by industry (36%) and the residential sector (15%) (Figure 22).

Figure 22 • Share of energy savings by sector (2015-36) compared with business-as-usual energy demand

Measure	Residential	Commercial	Industry	Total (Gwh)
Enforcement of energy conservation standards in designated factories / buildings	0	10,814	8,834	19,649
Building Energy Code (CODE) for new buildings	0	0	13,686	13,686
Energy Labelling	8,936	6,226	8,598	23,760
Energy Efficiency Resource Standards (EERS) for large energy producers and distributors	1,343	2,367	2,162	5,872
Financial incentives and support for energy performance achievement	0	9,133	5,914	15,672
Promoting greater use of LED	3,355	3,303	4,975	11,632
Total	13,633	14,516	44,196	89,672
Or total savings				



Source: IEA Thailand Questionnaire, 2015.

Although not listed here, given this report's focus on electricity, the EEP also seeks energy savings in the transport sector equivalent to around 37 000 thousand tonnes of oil equivalent (ktoe).

MEPS and energy labels

According to the EEP, MEPS and HEPS are the measures that will lead to the greatest electricity savings. MEPS are set by DEDE, under the Ministry of Energy (MoEN), and regulated by the Thai Industrial Standards Institute (TISI) under the Ministry of Industry. The following products are currently covered by MEPS: residential air conditioners, refrigerators, ballasts, fluorescent lamps and compact fluorescent lamps (CFLs). MEPS are only mandatory for residential air conditioners and refrigerators. They are voluntary for the other products. MEPS fail the 3% least energy-efficient products on the market.

Products certified under voluntary MEPS carry a blue logo, while products certified under mandatory MEPS carry a red label (Figure 23).

Figure 23 • Voluntary and mandatory MEPS certification labels, Thailand

Source: Asawutmangkul (2015), Thailand's Energy Efficiency Policy and Promotion Measures.

HEPS are voluntary and are set in collaboration with DEDE and EGAT. The top 20% most efficient products on the market receive the highest HEPS designation – number 5. HEPS cover eight products including air conditioners, refrigerators, electric fans, chillers, glazing, electric water heaters, rice cookers and electric pots.

DEDE and EGAT also run voluntary labelling programmes for products. EGAT's programme (Figure 24, left-hand label) covers 25 appliances, including refrigerators, air conditioners, CFLs, electric fans and electric rice cookers. DEDE's programme (Figure 24, right-hand label) covers eight non-appliance products, including liquefied petroleum gas stoves, fibreglass insulation, variable speed drives (VSDs), windows, diesel engines, three-phase induction motors and gasoline engines.

Figure 24 • EGAT and DEDE voluntary labels

Source: Asawutmangkul (2015), Thailand's Energy Efficiency Policy and Promotion Measures.

Energy Conservation Promotion (ENCON) Act

In addition to the EEP, the government has introduced various energy conservation measures, including the Energy Conservation Promotion (ENCON) Act, B.E. 2535, which entered into force in 1992. The ENCON Fund has annual inflows of approximately USD 200 million (WB, 2010) from a small levy on petroleum products. This fund is used for research, development, demonstration, incentives (grants and soft loans) and capacity building. Programmes financed by the ENCON Fund include the Energy Efficiency Revolving Fund (EERF) and the ESCO Revolving Fund.

Introduced in 2002, the EERF provided credit lines to 11 participating banks in Thailand at an interest rate of 0% in the range of USD 2.5 million to USD 10 million to finance energy efficiency projects. Among the requirements stipulated by the revolving fund was that the interest rate charged to borrowers was to be no more than 4% (compared to the 2002 market rate of 9%). Local banks were able to provide low-interest loans, which covered up to 100% of project costs but were limited to USD 1.4 million per project. In cases where a project required finance of over USD 1.4 million, the commercial banks could provide their own funds to cover the remaining amount.

By the close of the EERF in 2011, the total investment leveraged was USD 521 million, which consisted of USD 236 million from the EERF and USD 285 million in debt financing from local banks. It is estimated that the energy savings achieved were worth USD 154 million per year, with an average payback period of approximately three years (World Bank and NESDB, 2011; CCAP, 2012).

The ESCO Revolving Fund was established in 2008 to allow for joint investments by the government with private operators in energy efficiency and renewable energy projects. It is essentially a government co-investing scheme, with funding of THB 500 million from government plus THB 500 million from the private sector. Investment can be provided through equity finance, credit guarantee facility, venture capital, equipment leasing, carbon market investment and technical assistance (EEF, 2016).

Since its start, the ESCO Revolving Fund has supported 85 projects worth approximately THB 600 million, of which 73 were energy efficiency projects and 12 were renewable energy projects. Examples of funded energy efficiency projects include chiller, VSD and lighting replacement programmes, and were financed through equipment leasing worth at least THB 318 million. On average, each energy efficiency project was worth THB 4.4 million.[8]

[8] Overall the ESCO Revolving Fund financed 12 renewable energy projects through equity investment and one project through venture capital, in total worth an overall THB 250 million. On average, each renewable energy project was worth THB 23.5 million. Large renewable energy projects clearly prevail over small energy efficiency projects in the ESCO Revolving Fund, although it is gradually moving towards funding more energy efficiency projects and fewer renewable energy projects, which may be attributable to the MoEN's increasing focus on energy efficiency.

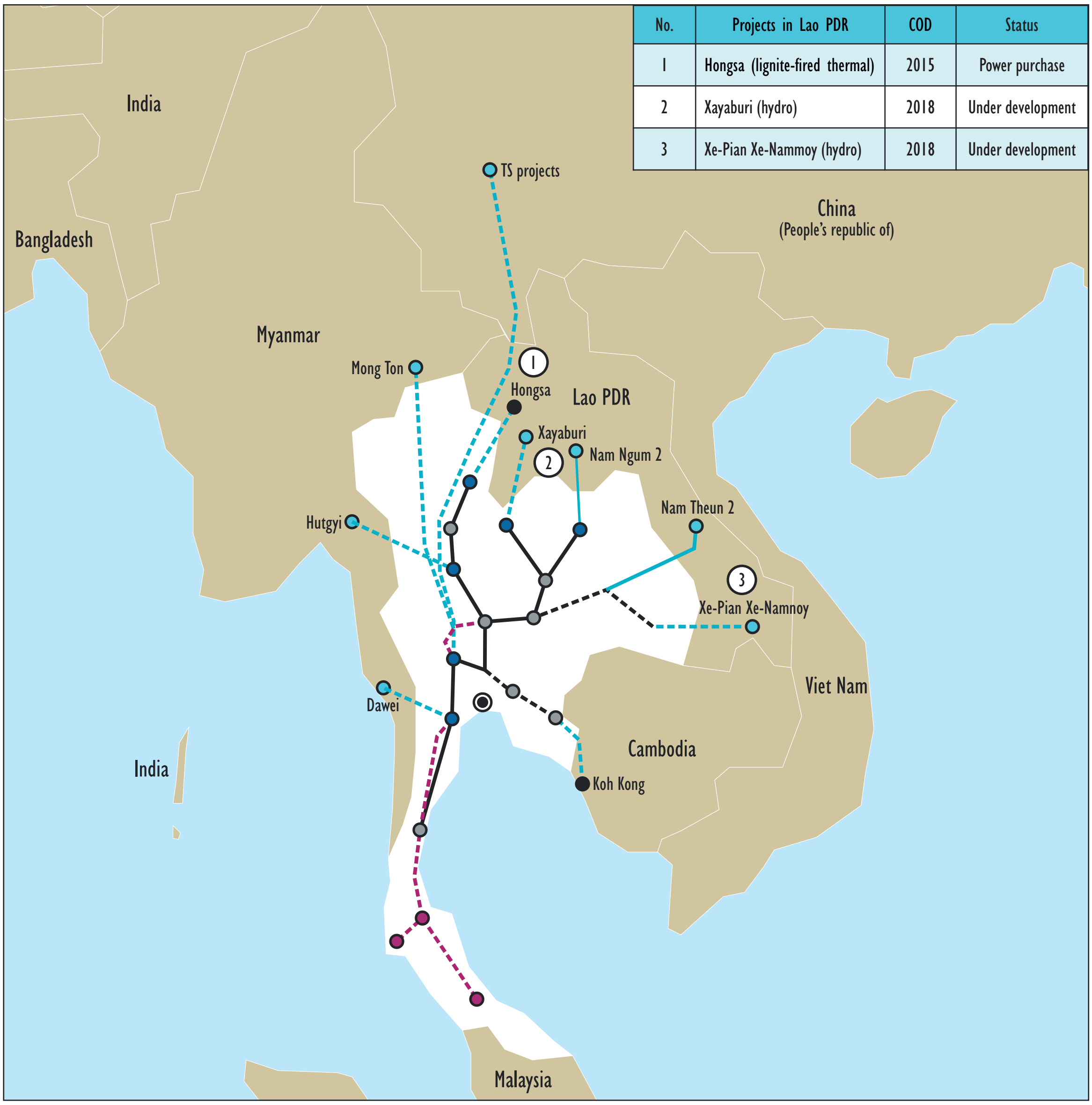
Electricity transmission and distribution

Overview of the system

The Electricity Generating Authority of Thailand (EGAT) has a transmission system comprising transmission lines of different voltages, with the vast majority operating at 500 kilovolts (kV), 230 kV, and 115 kV, all at a frequency of 50 Hertz (Figures 25 and 26). Approximately 13% of Thailand's transmission network is made up of 500 kV lines. By 2019, EGAT expects that the 500 kV network will extend across all of Thailand. As of August 2015, the country had a total of 33 242 circuit-kilometres of transmission and distribution lines at all voltage levels.

Figure 25 • Map of the transmission system of Thailand

No.	Projects in Lao PDR	COD	Status
1	Hongsa (lignite-fired thermal)	2015	Power purchase
2	Xayaburi (hydro)	2018	Under development
3	Xe-Pian Xe-Nammoy (hydro)	2018	Under development



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: solid line = existing; dashed line = planned or under construction.

Source: EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

Table 15 • The Thai transmission system

Voltage level (kV)	Aug 2015					
	Line length (Circuit-kilometres)	%	Number of Substations	%	Transformer capacity (MVA)	%
500	4 746	14	13	6	22 450	24
300	23	0.07	0	0	388	0.42
230	14 651	44	76	35	54 460	59
132	9	0.03	0	0	133	0.14
115	13 829	42	126	59	14 580	16
69	19	0.06	0	0	0	0
Total	33 242	100	215	100	92 011	100

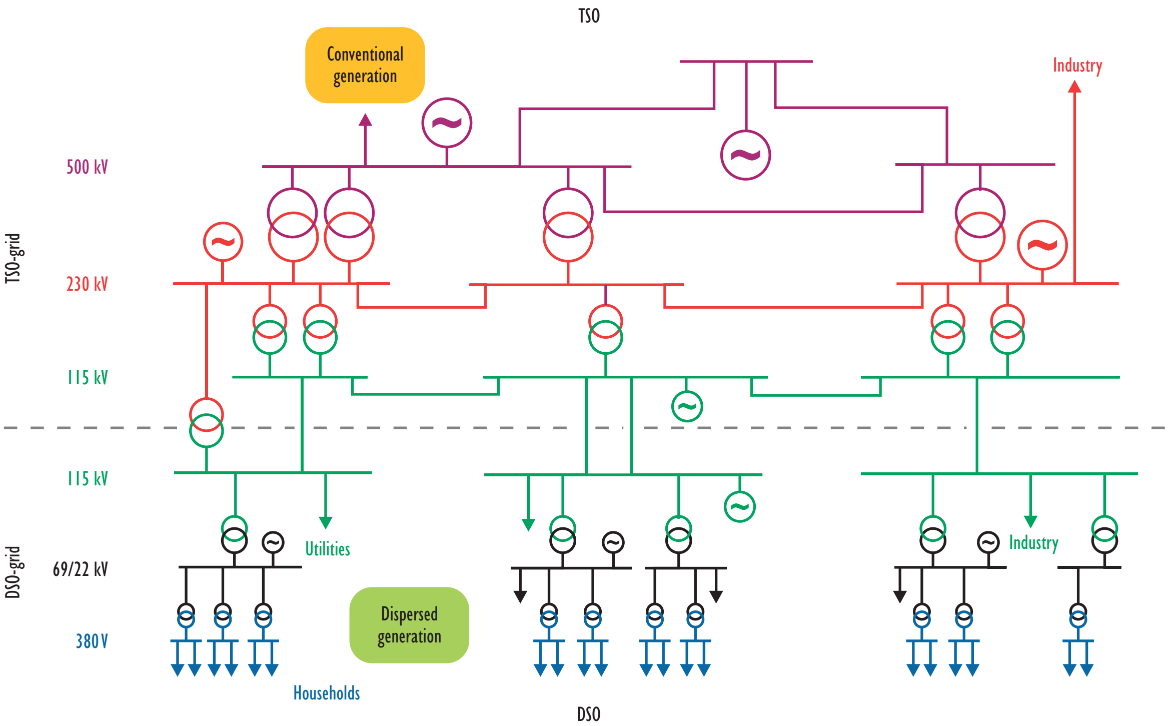
Note: MVA = megavolt-ampere.

Source EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

EGAT (the transmission system operator [TSO]) sells electricity to two distributing authorities, namely the Metropolitan Electricity Authority (MEA, one of two distribution system operators [DSOs]) and the Provincial Electricity Authority (PEA, the second DSO), which deliver electricity to retail customers in their respective areas.

MEA and PEA are responsible for lines with a voltage of 115 kV and below (although MEA does also own and operate certain higher-voltage connections). EGAT, MEA and PEA therefore have a close relationship, as close co-ordination is a necessary part of planning processes as well as network operations.

Figure 26 • Structure of electrical power system



Source: EGAT (2016), "Grid governance and management", presentation to IEA Review Team.

EGAT also sells electricity to the power utilities of neighbouring countries, namely Lao People's Democratic Republic (PDR) using 115 kV and at 22 kV lines, and Malaysia using 300 kV high-voltage direct current (HVDC) lines (EGAT, 2014).

In 2014, 53 forced outages occurred. Of these, 7 were the result of transmission line failures and 46 resulted from problems with substation equipment. The interruptions were caused mainly by malfunction of substation control and prevention equipment (16 times), by animals (16 times), by human error (either staff or outside people, 9 times), by the environment (6 times), by weather (twice), and by unidentifiable reasons (4 times). Table 16 shows the performance indicators of the transmission grid. The Thai system's performance is very good compared to similar markets and systems. It is comparable to Eastern European OECD countries.

Table 16 • Performance indicators transmission grid 2014

System interruption severity (MW-minutes/MW)	0.73431
System average interruption frequency index (SAIFI)	0.18282
System average interruption duration index (hours)	2.61577
System availability (%)	99.9701
Transmission circuit availability (%)	99.99550
Transformer availability (%)	99.75207

Note: MW = megawatt.

Source: EGAT (2014), Annual Report 2014, www.egat.co.th/en/images/annual-report/2014/egat-annual-eng-2014.pdf.

Regulation

Among other tasks, the Energy Regulatory Commission (ERC) is responsible for ensuring sufficient power supply to meet Thailand's consumption needs and for the regulation of power distribution nationally. The ERC also reviews and approves all transmission and distribution-related projects proposed by EGAT, MEA and PEA. Network planning, investment and usage are all major factors that influence network costs and therefore final tariffs. The ERC currently lacks significant in-house engineering expertise, and so relies on EGAT, MEA, PEA and outside experts to evaluate projects proposed by the utilities and transmission and distribution companies.

The ERC is involved in the creation of the Transmission Development Plan (TDP), the Power Development Plan (PDP) and the Smart Grid Development Plan, as it sits on the respective committees. It also has a responsibility to provide opinions on these plans under the Energy Industry Act 2007.

Nevertheless, due to the lack of in-house expertise on transmission network management and operation, the ERC has been unable to conduct, in particular, a thorough assessment of the TDP. The ERC is, furthermore, currently unable to assess the interdependencies between the different development plans, interdependencies that are heavily influenced by the TDP. Ultimate responsibility for approving actual investments in transmission and distribution networks does not lie with the ERC, but is in fact held by the Ministry of Finance. Consequently, the ERC has a weakened position not only relative to EGAT, but also to MEA and PEA, the ministries and planning committees. The network planning and investment decisions are taken in other institutions, while the conversion of costs into tariffs is left to the ERC.

Network adequacy

The bulk of the Thai transmission network is in the northern and central regions of Thailand, which have both a high share of generation (more than 85%) and high levels of energy consumption. Generation in the north has historically served load in that region. Transmission network reinforcements are necessary to enable imports from Lao PDR and Myanmar, so as to ensure security of energy supply at least cost. Increasing demand in cities and the decreasing acceptance of generation is driving a change in the transmission network structure. A shift from conventional generation towards increased deployment of renewables and smart networks will require even more investment in the existing network infrastructure. The implications of such a transition are difficult to assess. Nevertheless, due to significant opposition to developing new domestic conventional generation, the increasing importance of carbon emission targets (in particular after the agreement signed at the 21st Conference of the Parties [COP21] in Paris), the declining cost of renewable technologies, and an increase in dependence on imported power, renewable generation will play an increasingly important role in Thailand's power sector. These developments present major challenges for both the transmission and distribution networks, which need to be taken into account in network planning.

Relationship to generation planning

Network constraints within the Thai system have an impact on generation planning. This is in particular the case for renewables, which are less flexible in where they can be developed. In particular, network constraints in eastern Thailand mean EGAT is not currently able to both increase imports and integrate significant shares of variable renewables.

Security of energy supply consists of different components being brought together by the transmission and distribution network. In this context, network planning should be regarded as a possible alternative to a certain amount of investment in generation. Being able to transfer electricity across wider areas reduces the need for generation investments. Cost-benefit analysis is a helpful tool to assess the relationship between the cost of investment in transmission and distribution networks and generation costs. Thailand does not currently co-optimise generation and transmission planning. Instead, the TDP is taken as an input into the PDP. A lack of co-optimisation can lead to significant detachment between generation and transmission planning – a potentially significant issue (for more on this topic, see Liu et al., 2013).

Network and imports

Imports are, for the most part, sourced by means of contracts with independent power producers (IPPs), especially from Lao PDR, the largest source of imports. These are synchronised to the Thai grid and are fully dispatchable by EGAT. From EGAT's perspective, therefore, they function essentially as domestic resources. Of the more than 20 high-voltage interconnections between Lao PDR and Thailand, only 5 can be considered true grid-to-grid connections allowing for bidirectional flows of electricity. A small number of medium-voltage lines also link provinces in Lao PDR to provinces in Thailand. Lao PDR has expressed an interest in moving toward more grid-to-grid operations, although there are no specific plans at this point to do so.

While most power flows from Lao PDR to Thailand, Lao PDR does in fact import up to 140 MW of power from Thailand, mainly during the dry season. These power trades are netted out over time – either by balancing out flows so they net to zero, or through explicit payment by Lao PDR.

Transmission projects under development include: a USD 106 million 500 kV line connecting Nabong in Lao PDR to Udon Thani in Thailand, which will deliver approximately 1 500 MW of power into Thailand from numerous hydropower projects; a proposed 115 kV interconnection that will connect Thailand and Cambodia (again via Lao PDR); and a USD 278 million interconnection with Vietnam (transiting Lao PDR) that is expected to "introduce a step change in the development of a regional power market and lead to reduced reserve margin requirements, lower costs and enhanced confidence in the regional power market" (UNCTAD, 2015).

From the perspective of Lao PDR, grid-to-grid operations may make more sense than the current arrangement, in particular as the Lao economy continues to develop. As of 2010 the electrification rate of Lao PDR was 71%, and this is likely to reach nearly 100% over the next few years. Moving toward power trade between utilities would allow Lao PDR to utilise both domestic hydroelectric power and excess generation in Thailand to meet growing domestic demand.

From the perspective of Thailand, however, such an arrangement could potentially mean a loosening of control over generation that currently makes up a significant portion of the Thai power mix. This could have an impact on the way in which Thailand measures its own electricity security, and therefore its own power sector planning. Given the high level of historical co-operation between Thailand and Lao PDR, however, such issues could be alleviated through appropriate contract arrangements. Goals for renewables could be more ambitious under such arrangements, with grid-to grid connections allowing surplus electricity from wind farms or solar panels to be stored as pumped storage, for example in Lao PDR, especially during the dry season.

Network and renewables

Transmission network planning and renewables integration, particularly in respect of onshore wind and solar, can in most countries be seen as a chicken and egg problem. Transmission networks face long planning and licensing periods due to problems of acceptance and environmental issues. In the case of Thailand, building a new HVDC line is likely to take up to ten years.[9] In contrast to this, the building of renewables is generally easier. Public acceptance is higher and renewables can be built within a few years, or even months, in designated areas. Therefore identifying suitable areas and network limitations pose the greatest barriers to the development of renewables.

Thailand's Alternative Energy Development Plan (AEDP2015) suggests that renewables will have potentially large impacts on the future development of the transmission network, as suitable locations for renewables are not always close to load centres. Over the course of the development of AEDP2015, existing network constraints in eastern Thailand led to reductions in the renewable targets, as EGAT claimed that it was not able to both increase imports and integrate significant shares of variable renewables.

With regard to the connection of energy industry operators and other licensees, the Energy Industry Act 2007 states that energy network operators are not to discriminate against third parties. The only restrictions on new connections are that the security, safety and quality of the energy system are maintained, other energy customers and the public are not disadvantaged, and technical connection specifications are clear, technically feasible and do not impose an undue burden on the person who requests utilisation of or connection to the energy network.

Smart grid plan

Thailand has put forward an ambitious smart grid strategy in order to foster efficient use of existing and newly built network infrastructure. The smart grid plan's early timeframe includes pilot projects that are already being undertaken or are envisaged to be undertaken in the near future. Due to the fact that these are pilot projects and, more generally, a lack of experience with

[9] See for example the Field Survey of the Transmission System and Substation Development Project by the Japan International Cooperation Agency (JICA) from 2004, which found that transmission projects took 7-12 years (JICA, 2004). www.jica.go.jp/english/our_work/evaluation/oda_loan/post/2005/pdf/2-01_full.pdf.

communication infrastructure in the distribution and transmission system, co-ordination between EGAT, MEA and PEA to enable bi-directional flows of energy between transmission and distribution systems remains limited.

As the use of smart grid technologies to manage renewables is not foreseen in the near future, Thailand has begun to implement various demand response (DR) programmes. As of April 2015 the DR programme had 500 MW of capacity, meaning that EGAT can call on demand-side customers to reduce demand by as much as 500 MW in aggregate if needed. EGAT estimates that its DR programme could be increased to approximately 2 000 MW.[10] EGAT is also considering the development of a new, DR-focused control centre, under the authority of the system operator, but no firm decision has yet been taken.

Future plans and programmes by the ERC and EGAT should allow for the inclusion of DR in day-ahead dispatch planning. In the near-term, however, the question of how exactly DR should be controlled needs to resolved.

Flexibility in support of variable renewables integration

Communication between PEA, MEA and EGAT as operator of the transmission network is an important issue. Current grid codes in Thailand do not allow reverse power flows from the distribution network to the transmission network. However, with an increasing share of distributed renewables, this position is unlikely to remain tenable. Therefore, it is necessary on the one hand to increase the responsibilities of renewables to support grid stability as far as practicable, and on the other hand to overcome obsolete practices in network operation.

Efforts are under way to improve grid codes so as to allow for the more efficient integration of renewables throughout the system, including requiring renewables to be controllable by the transmission operator. Allowing reverse power flows is one area that should be tackled in order to increase system security.

Role of Thailand in the Power Integration Project

Thailand lies at the heart of the ongoing pilot by the Association of Southeast Asian Nations (ASEAN) to initiate cross-border power trade from Lao PDR to Singapore under the Lao PDR, Thailand, Malaysia and Singapore (LTMS) Power Integration Project (PIP). The pilot is intended to complement existing work towards realising the ASEAN Power Grid (APG) and the ASEAN Economic Community (AEC), by creating opportunities for electricity trading beyond neighbouring borders. The project should help identify and resolve issues affecting cross-border electricity trading in ASEAN, and demonstrate the technical viability of cross-border power trade of up to 100 MW from Lao PDR to Singapore through existing interconnections. This includes the examination of policy, regulatory, legal and commercial issues relating to cross-border electricity trading (ASEAN, 2015).

Thailand would be a key country in this project from a grid/network perspective, as all electricity from Lao PDR to Malaysia or Singapore would have to transit through Thailand. This raises additional challenges and questions regarding Thailand's distribution system capacity.

[10] Based on an EGAT survey of 60 large customers.

Conclusions and recommendations

Power sector governance

Thailand's power market and institutional structure aligns well with its strong commitment to electricity security. Guided by national objectives set by the National Energy Policy Council (NEPC), the Ministry of Energy (MoEN) has primary responsibility for developing policies related to the electricity sector. Responsibility for implementing and enforcing policies lies with the Energy Regulatory Commission (ERC), while the Energy Generating Authority of Thailand (EGAT), which remains government owned, has primary responsibility for operations and power sector planning.

Experiences among member countries of the International Energy Agency (IEA) have shown that the clear allocation of power sector roles and responsibilities is vital to maintaining both near-term and long-term electricity security. Prior work by the IEA has identified a number of best practices in implementing policy and regulatory frameworks to support electricity security, among which the following are relevant to Thailand:

- clarify individual and shared responsibilities for electricity security
- align accountabilities with functional responsibilities
- ensure the boundaries of authority to act are clearly specified for all parties, and that the authorities granted are sufficient to meet their responsibilities
- provide strong incentives for effective co-ordination and information exchange
- create transparency and objectivity
- strengthen coverage, accountability and enforcement to help reinforce incentives for providing electricity security, and to improve the credibility of the policy and regulatory framework
- apply policies and regulations consistently throughout the power system.

Thailand meets many of these best practices. In particular, Thailand's recent work to interlink its energy policy plans is an important step toward ensuring secure, clean and affordable electricity provision. It does this by improving transparency and objectivity within the planning processes, increasing the consistency of policies throughout the power system, and improving the overall credibility of the plans.

Nevertheless, there are opportunities for improvement. Power sector development plans are best developed in an open, transparent fashion, where responsible parties are given sufficient capacity and an appropriate level of independence. As long as policy goals are clearly articulated and responsibilities clearly delineated, the resulting plan should strike an appropriate balance between security, economy and environment. In particular, there must be clear lines of authority between the relevant government ministries and the ERC, in particular with respect to EGAT.

While roles are, in general, clearly allotted between the relevant agencies, at a practical level there are overlaps and potential misalignments. For example, while the MoEN is ultimately responsibility for finalising the Power Development Plan (PDP), and ERC is ultimately responsible for ensuring the plan is implemented properly, much of the technical capacity for both developing and evaluating the PDP lies within EGAT. Capacity building in both the MoEN and the ERC would allow for a more objective and balanced process for developing and implementing each PDP.

Increasing the independence of the ERC would also help to improve oversight of the power sector. Established under the Energy Industry Act of 2007, the ERC is separate from the MoEN but not explicitly declared to be independent. Furthermore, portions of the Act may undermine the possibility of explicit independence. For example, section 14 of the Act establishes requirements for the composition of the Screening Committee, which is responsible for reviewing potential candidates for the Commission. Of the nine Committee members, four must be former members of a relevant ministry – a fact that can potentially undermine their independence. The Act also provides a rather broad range of reasons why a sitting member of the Commission may be dismissed. That the range is broad is not necessarily a problem, but regulators should at least be assured that, if they are dismissed, the reasons for the dismissal are clearly stated, that the decision is made in an open and transparent fashion, and that they are afforded an opportunity to appeal a decision not made in their favour.

Thailand has also recognised the interlinkages between security, economy and environmental concerns as guiding principles of the PDP. These three principles align well with the primary definition of electricity security. However, meeting all of these goals equally is, from a practical perspective, at present impossible. For example, increasing fuel diversity or decreasing environmental impact may require additional expenditure that makes it hard to meet the principle of economy. Thailand has, in its own planning processes, prioritised security above economy and environment.

The focus on security is the most likely basis for one relatively conservative aspect of PDP2015 – namely the fact that reserve margins remain well above the 15% target through to 2032. A reserve margin of 15% is typical for countries that have a high dependence on thermal power. In North America, for example, the North American Reliability Council (NERC) suggests a default reserve margin of 15% for thermal-based power systems. NERC also suggests a 10% reserve margin for power systems dominated by hydropower (NERC, 2015). However, reserve margin requirements in hydro-dominated systems should reflect the availability of hydroelectric power throughout the year. In systems such as Thailand's, which sees significant seasonal variations in hydropower, more sophisticated approaches to planning generation adequacy may be warranted.

Deterministic reserve margin targets, such as a fixed target of 15%, have the advantage of being simple to understand and to implement. However, a fixed target may not necessarily reflect the actual needs of the system given the actual probability of an outage. A probabilistic framework uses stochastic modelling techniques to estimate the likelihood that supply (with a given generation mix) will fail to meet load. It has the advantage of providing a more accurate and relevant assessment of reliability than what would be determined based on a static analysis. For example, the reserve margin could be tied explicitly to the loss of load expectation (LOLE) target – which, for Thailand, is no more than 24 hours per year. One advantage to developing a reserve margin target based on the LOLE is that the reserve margin could be easily revised if the LOLE were ever changed.

Having a high reserve margin may be entirely appropriate for the Thai power system, in particular if the expectation is that reliability standards are to be tightened in the future. However, front-loading generation investments in the expectation that they will be needed later could lead to overinvestment. This is, in particular, a possibility should the cost of renewables decline more rapidly, or demand not rise as quickly, as expected.

An additional complexity of the Thai power system is the fact that only a proportion of projects are directly owned and operated by EGAT. Approximately half of domestic generation and all projects developed outside of Thailand involve independent power producers (IPPs) contracted under long-term power purchase agreements (PPAs). EGAT, however, also has minority stakes in certain IPPs through its various subsidiaries.

This split in ownership structure between EGAT and the various IPPs has the potential to create uncertainty, both in terms of investment and in terms of operations if not properly co-ordinated. Conflicts of interest – for example, the prioritisation of generation fully or partially owned by EGAT over other generation – could potentially undermine both the investment environment and the security of day-to-day operations.

The relative inflexibility of PPAs can also affect long- and short-term electricity security. Long-term, fixed-price PPAs offer a degree of certainty to both the investor and the purchaser (in this case, EGAT), but limit the ability of developers and system planners to respond to market developments. This is particularly challenging in an environment that mixes utility-owned generation (which is, by its nature, relatively isolated from market forces) and IPPs. In Thailand, the situation is compounded by the fact that PPAs are negotiated by the MoEN, but EGAT is responsible for integrating IPPs into the power system. Over the short term, such PPAs may lead to inefficient dispatch decisions due to an increase in anticipated fuel costs and/or if anticipated demand growth is being overestimated, which could potentially result in power system instability.

The relevant parties in Thailand should also carefully consider the varying motivations for investment. Typically, investment decisions are driven by one or more of four motivating factors: market-seeking; resource-seeking; efficiency-seeking; and strategic asset-seeking (UNCTAD, 2015). For a government-owned entity such as EGAT, the primary motivation for investment is likely to be resource-seeking (e.g. ensuring sufficient generating resources to meet demand) or efficiency-seeking (e.g. seeking to reduce overall cost or to make better use of existing resources). For an outside investor, the primary motivation is more likely to be market-seeking (e.g. aiming to sell power domestically or to a neighbouring market, in order to earn a profit) or strategic asset-seeking (e.g. to position themselves as being necessary to serve rapidly growing Thai demand). Of course, it is possible for any given investment to have multiple motivating factors.

From the perspective of the Thai government, resource- and efficiency-seeking motivations are more likely to match policy objectives. Nevertheless, the involvement of outside investors should be encouraged. Ideally, all PPAs should be entered into through an open tender process, to help ensure that power needs are met at low cost. In addition, it is worth looking into ways to make the PPAs themselves more flexible. For example, PPAs for variable renewable power could be structured around specific time of delivery blocks, such as work days versus weekends or seasons. Alternatively, PPAs could simply include automatic adjustment mechanisms that reflect actual market conditions beyond simple fuel-price adjustments, or the performance of the IPP itself. Increasing the flexibility of the PPA process, however, must be balanced against the need for investors to obtain project financing.

There is also the question of relative cost. It is important that the full cost of both EGAT and IPP projects be considered in a fair and consistent fashion. In addition, how those costs are allocated to consumers should be carefully reviewed before either an IPP or an EGAT-owned project is approved. The MoEN should also work to ensure the project approval process is transparent and efficient to ensure that investments are made in a timely fashion.

The PDP and Alternative Energy Development Plan (AEDP) do not consider alternative fuel-mix scenarios. The initial renewable energy targets proposed by the Department of Alternative Energy Development and Efficiency (DEDE) were reduced after incorporating the need to increase baseload generation, including coal and nuclear power plants, and the increase in imported power from neighbouring countries. This conventional approach to resource planning ignores technological capabilities that are available today for increasing renewable energy in the fuel mix.

Electricity security is possible regardless of market structure, as long as the power sector is properly governed (IEA, 2015c). As a first priority, therefore, Thailand should focus on improving power sector governance. The future evolution of Thailand's power market design, however, remains an open question, which may be a source of investment uncertainty. Thailand should therefore take a firm decision as to whether or not it will move away from the enhanced single buyer model to a full power pool model. Which direction Thailand chooses is less important than giving all power market participants an increased degree of certainty with regard to the direction of future reforms.

Implementing a power pool is not a precondition to ensuring resource adequacy or the stability of the power system. However, following a full power pool model could potentially improve both the investment and operating environments in Thailand – in particular by expanding opportunities for third-party developers and laying the foundation for multilateral power trading with utilities and generators in neighbouring countries, which could also be allowed to participate in the power pool. Conversely, it would also reduce the ability of policy makers to direct investments in the power sector and would require a significant restructuring of the main market participants, in particular EGAT. Moving to a power pool model would require the unbundling of EGAT's generating assets (the transmission assets would remain under the control of a regulated monopoly).

Pure cost-of-service ratemaking – which seeks to compensate the utility purely for the cost of their investment and operating needs – is simple to implement, but creates an incentive for the utility to maximise capital-intensive investments and sales, potentially at the expense of investments that would improve productivity. By implementing PBR, regulators are able to directly incentivise the utility to meet specific policy goals – for example, reducing outage rates –in effect by fining the utility if the goals are not met, and rewarding the utility (in the form of additional revenues) if the goals are exceeded. By combining PBR with integrated resource planning (IRP), it is possible for power sector plans to more efficiently scale up renewables while scaling down fossil-fuel plants.

Implementing PBR puts an additional burden on the regulator, which must be able to set goals that are realistically achievable, but which can improve system operations and security while simultaneously allowing the utility an additional degree of operational freedom. If Thailand continues to keep EGAT as a government-owned entity, however, it is more important to focus on ensuring efficient and effective corporate governance, and to resolve any potential conflicts of authority at the ministerial and regulatory level.

Finally, regardless of the market environment, establishing a "one-stop shop" for the licensing of new power plants would also improve the investment environment – in particular for very small power producers (VSPPs). This would allow for the streamlining of the licensing process without undermining the necessary checks to ensure new projects meet all necessary regulations. Implementing such a one-stop shop is already under discussion in Thailand. This conversation should be supported.

Recommendations

Clarify roles and responsibilities among all relevant government agencies, and strengthen capacity within the MoEN and the ERC to help ensure the power sector develops in a secure and balanced fashion. In particular, the role of the regulator needs to be enhanced and further safeguarded from political influence. Capacities within the ERC should be developed so that it can properly evaluate the plans and actions of EGAT, the Metropolitan Energy Authority (MEA) and the Provincial Energy Authority (PEA).

Establish a clear, rule-based consultation process for all energy sector plans. Thailand has an excellent institutional foundation on which to build and maintain a secure power system. These institutions could be further strengthened by increasing overall transparency, reviewing committee memberships to ensure they include a representative group of participants, and engaging in open and regular consultation with stakeholders.

Consider moving to fully integrated resource planning. The current co-ordinated planning approach and the development of the Energy Master Plan are a significant step forward, and are to be commended. There is a need, however, for more dynamic and integrated planning across all sectors, in particular to ensure that future plans appropriately include renewable energy and energy efficiency. Moving away from development plans to an integrated resource plan approach would improve the efficiency and sustainability of the power sector without compromising security.

Continually evaluate the reserve margin requirement and consider moving to probabilistic framework. The current reserve margin target of 15% may be appropriate given current market conditions, but without a full understanding of system needs and a view of how the system may evolve over time, it is difficult to know for sure. Moving to a probabilistic framework for determining the reserve margin would allow for more responsive – and therefore more secure – power development plans.

Create a one-stop shop for the licensing and approval of new generation, in particular for VSPPs. Such an office could streamline the application process to improve development timeframes while increasing overall transparency.

Make a firm decision on whether or not to replace the enhanced single buyer model with a power pool model. Moving to a power pool model is not a necessary condition for ensuring electricity security over the long run. Properly implemented, however, a power pool model could increase both system security and overall system efficiency. If Thailand does move to a power pool model, it will need to carefully consider how to handle existing PPAs and the divestment of EGAT-owned generation.

Create incentives for EGAT to improve system performance and, depending on market reforms, implement performance-based ratemaking to incentivise efficiency improvements and increase system security. Rates can be explicitly tied to security performance targets, or even non-security related targets, such as explicit goals for deploying renewables or implementing side measures.

Electricity generation

One of the core issues PDP2015 attempts to address is the question of fuel diversity. Heavy reliance on natural gas generation puts Thailand in a potentially precarious spot, from both a security and an economic perspective. The highly liquid global market for liquefied natural gas (LNG) means that Thailand is unlikely to face any major supply disruptions. Nevertheless, there is value in increasing the diversity of the generating fleet.

Generation diversity is expected primarily to come from two sources: increased investment in coal-fired generation, and increased production from renewable technologies (including imported hydro).

A major concern relating to the development of domestic fossil generation is construction delays. This is relevant to the PDP, which lays out a very specific timeline for plant construction, but is also a concern from the perspective of near-term reliability. EGAT has determined that, by 2019, two new coal plants will be needed to replace ageing generation. It is possible that construction delays could lead either to existing plants being operated beyond their rated lifetimes, or to a situation of capacity shortage (although the fact that the reserve margin is well above the 15% target should somewhat reduce such concerns).

A significant unresolved question is the order and timing of generator retirement. Decisions on timing can have a significant impact on where and when new investments are needed, and can therefore affect the financing of new generation and the operation of existing plants. Developing a plan for retirements – for example, by focusing first on the most inefficient generation – would help alleviate investment and operational uncertainty.

Domestic opposition to the development of new fossil generation is strong, in particular for new coal plants. Local opposition can potentially delay or disrupt the development of a significant proportion of the generation planned in the PDP. One impact of local opposition has been to push the development of certain fossil plants across the border into neighbouring countries. While the development of coal plants in these countries may create relatively less opposition, Thailand should bear in mind the very real possibility that attitudes in the future may change.

New coal projects should therefore seek to meet the highest environmental standards, whether they are located within or outside Thailand.

Indeed, Thailand should take advantage of its relative position of wealth and authority to encourage sustainable and socially responsible development throughout the region. One way to do this would be to commit that all generation built in neighbouring countries for import into Thailand should meet the same standards for development as domestic generation.

The fact that the majority of Thailand's generation is natural gas-fired is a potential cause for concern, at least from the perspective of fuel security. Decreasing domestic supplies also mean that, over time, Thailand will become more exposed to international natural gas prices – potentially increasing costs. It is therefore reasonable to include fuel diversification as part of the PDP.

Diversity, however, can come from many places and take many forms. For example, currently around 80% of Thailand's natural gas generation has some form of fuel-switching capability. Fuel switching could be improved by extending the dual-fuel requirement to the entire natural gas fleet, or by increasing the number of days' worth of backup fuel required to be kept on hand.

Thailand could also invest in natural gas storage facilities. Currently the only storage available is at the LNG terminal – approximately three days' worth. Increasing domestic storage would better insure against the possibility of long-term disruptions. Domestic gas fields which are, or which soon will be, depleted could be converted to storage. Improvements could also be made to the domestic pipeline network – in particular, resolving the gas quality issues that make it harder to transport gas between eastern and western Thailand.

Diversifying away from natural gas also means losing some of the benefits of gas-fired generation. In particular, natural gas is cleaner than coal, emitting fewer particulates and less carbon. While modern coal technologies are more flexible than their predecessors, natural gas generators tend to be more flexible still, making them more useful for balancing variable renewable generation. Ideally, increasing the diversity of the generation fleet should not come at the expense of the flexibility of the overall system.

Experiences in IEA member countries have shown that increasing the share of renewables can increase the diversity of the power system without undermining power system reliability (IEA, 2014). From a security standpoint, the policy-making process should focus on the ability to incorporate renewable power as much as possible in the long-term PDP.

The current AEDP represents an advance over previous renewable energy plans in incorporating resource potential as well as constraints, but the interlinkage with the PDP process should be enhanced. Both the current PDP and the AEDP lack clear statements of objectives. A statement of objectives can help hold decision makers and implementers accountable for their decisions by making progress easier to evaluate (Wood et al., 2014). Clear objectives also help with the development of focused strategies and actions for the plan's implementation. For example, were one of the objectives a reduction in dependence on fossil fuels, one of the actions would be to increase the system's capability to integrate and balance renewables. At present, the various energy development plans do not have an explicit set of objectives, an indication that the linkages between them may be weak.

Considering the prevalent trend of decreasing costs seen in many types of renewable power plants, the AEDP targets could be more ambitious. Worldwide, average generation costs for new plants built between 2010 and 2015 have declined by 30% for onshore wind plants and by 67% for utility-scale solar photovoltaic (PV) power plants (IEA, 2015c, p.16). In the next five years, the IEA forecasts that these two technologies' costs will continue to go down by an additional 10% for onshore wind and 25% for solar PV. Furthermore, in Thailand, certain biomass power plants based on agricultural residues and biogas plants can produce electricity at costs that are now competitive with wholesale power costs. A redesign of support measures could potentially ramp up renewable capacity from various sources in such a way that they enhance Thailand's electricity security.

As a result, Thailand can afford to be more ambitious in its renewables goals. In particular, the target of 6 000 megawatts of solar PV is quite low compared to what is possible – both from the perspective of cost and impact on the system. Thailand should take advantage of the rapidly declining costs of solar PV and the inherent flexibility of its power system by significantly increasing its renewables target.

To ensure that various renewable resources can be more effectively utilised to help support the system's security, the government should revamp the current feed-in tariff (FIT) programmes. As discussed earlier, FIT incentives are currently separated into two programmes. The current solar FIT programme takes the form of a fixed rate to an allocated quota. A FIT bidding scheme is held on an ad hoc schedule for non-solar types of renewables. Ideally, renewables support schemes should be technology neutral and should encourage development that works best from a system perspective. This means encouraging the deployment of renewables that are both geographically optimal (taking into account both renewable resource potential and grid constraints) and temporally optimal from a system perspective (e.g. those that provide a maximum contribution to peak load). For example, separating support according to project scale would better enable continuous support while ensuring adequate grid capacity allocation. Specifically, the support schemes should be separated into two: an SPP scheme, and a VSPP scheme:

An SPP bidding scheme with firm and non-firm contracts: Instead of receiving FITs, large-scale renewable SPPs should be allowed to bid in annual or twice-yearly auctions in designated grid zones. This proposal is in line with the government's recent attempts to take into account renewable potential and grid capacity. A bidding scheme enables low-cost plants to compete against each other on price in areas with high transmission capacity and high load. The government could even separate the auction process and contracts by technological characteristics – firm (non-variable) and non-firm (variable). The non-variable types of renewable energy, such as biomass, would bid for and sign firm contracts that provide for an availability payment and an energy payment in the tariff structure. This design would ramp up the capacity of renewable SPPs that can guarantee a fixed amount of capacity for specified hours in the year, thereby allowing EGAT to plan ahead. The variable types of renewable energy would bid for the lowest tariffs and sign non-firm contracts with the utilities. In a competitive environment the winning bids would better match technology cost trends, lowering the subsidy burden on bill payers. Ideally the SPP bidding scheme would have a fixed schedule, for example annually or twice yearly for the next 10 years.

A VSPP open application process for FITs: The current FIT bidding scheme is operated on an ad hoc basis. If the government were to revert to a process in which VSPPs that are ready can apply for FITs on a first-come, first-serve basis, this would bring certainty back to the market, allow prepared developers to plan and complete their projects, and bring capacity to the grid on a continuous basis. This would preferably be coupled to a simplified and streamlined permitting process and strict enforcement of commercial operation deadlines.

Combining these two new schemes would encourage the expansion of renewables capacity over the next decade, as would supporting the development of rooftop solar by developing simple rules for the installation of residential and commercial systems. While plans to build new fossil-fuel plants face uncertainty, prioritising renewables during this period would allow new capacity to come online quickly and with more certainty. And as the government has no need to add further fossil-fuel capacity, it has sufficient time to better match demand with new generation capacity.

All of these renewable support schemes, and the PDP more generally, must be considered within the context of the agreement signed at the 21st Conference of the Parties (COP21) in Paris. Thailand's Intended Nationally Determined Contribution (INDC) puts forward an intended carbon reduction target of 20% relative to business as usual by 2030, with the possibility of a 25% target. This is consistent with reductions to be achieved under PDP2015 and other relevant plans (in particular the AEDP, the Energy Efficiency Plan [EEP] and the Smart Grid Development Plan, but also the Climate Change Master Plan 2015-50, the Environmentally Sustainable Transport System Plan 2013-20, and the National Industrial Development Master Plan 2012-31).

The agreement reached in Paris requires that countries submit new INDCs every five years that strengthen the emissions reduction targets set out in the previous INDC. This means that, in 2020, Thailand must submit a new INDC that sets a target above 20%, and perhaps even above 25%. As these targets are explicitly tied to the plans that make up the Energy Master Plan, investment plans made under PDP2015 have the potential to conflict with future emission goals. This is something that should be explicitly considered as investment decisions are made over the next few years, and in particular as Thailand prepares its next Master Plan.

Imports

Concerns about the reliability of electricity imports have led to a relatively conservative approach to the development and integration of generation located outside of Thailand. Most imported power is generated by IPPs that are directly tied to the Thai grid.

Moving from unidirectional imports to utility-to-utility (or grid-to-grid) trading can add additional complexity to daily operations, but offers significant long-term benefits. In particular, by increasing regional trade, Thailand would be able to take advantage of the significant resource diversity of the Greater Mekong Subregion (GMS) (and the Association of Southeast Asian Nations [ASEAN] more broadly), both geographically and temporally. Significant seasonal variation in hydro generation occurs within the GMS. As the majority of Thailand's power imports are hydroelectric, Thailand must have enough domestic resources to meet domestic demand during the dry season. This means the potential exists for significant amounts of excess domestic capacity to be exported during the wet season.

Moving to regional power trading would allow Thailand to take better advantage of thermal and other non-hydro renewable resources located in neighbouring countries, lessening the need for investment in domestic generation. It would also allow Thailand to export more power in times when it has excess capacity. As the economies of neighbouring countries grow, electricity demand will rise, and grid-to-grid trading would allow for more optimal use of Thai generating resources over the long term.

Facilitating power trade among neighbouring countries, however, requires the development of regional institutions that do not currently exist within ASEAN. In particular, the establishment of a regional regulator would aid the development of an efficient power exchange among the countries of the GMS. Discussions with regard to establishing such a regulator are ongoing, a positive development that should be encouraged.

Recommendations

Prioritise the replacement of inefficient generation. A significant proportion of the Thai generating fleet is expected to retire over the next 20 years. Inefficient plants should be retired first, to be replaced by more efficient plants. If resource adequacy becomes a concern, these plants could be mothballed instead of being completely decommissioned.

Ensure that power sector development plans are consistent with future climate change obligations. The Paris agreement requires that countries submit INDCs every five years that meet increasingly stringent climate change goals. Thailand's current INDC commits to the carbon reductions that would be achieved under the PDP and associated plans, which means the next INDC is likely to need to exceed these targets. Investment decisions made over the next few years should be considered within the context of how they will contribute to future carbon reduction commitments.

Increase the amount of natural gas storage to offset the possibility of fuel disruptions. Three days of natural gas storage is insufficient, particularly given that domestic supplies are set to deplete rapidly. Converting depleted natural gas fields to storage would give Thailand a significant hedge both against possible disruptions and future price increases. Related to this, consideration should be given to increasing the amount of liquid fuel that natural gas plants with dual-fuel capabilities are required to keep in stock.

If coal generation is to be built, commit to developing only the most advanced technologies economically feasible. Increasing the fuel diversity of the Thai power system is an important step toward improving electricity security. New coal generation, however, brings a new set of potential environmental concerns. Using best available emissions reduction technologies would reduce the environmental impact and improve public acceptance of new development.

Commitments to reduce the environmental impact of new generation should also be extended to new imports. Thailand is a leader in the ASEAN community and an important example for developing economies around the world. Ensuring that new plants developed for the purpose of importing power into Thailand – in particular, coal and hydro – meet the same standard as domestic generation is a key way to encourage the development of sustainable and socially inclusive generation throughout the region.

The power sector as a whole should be developed with an eye toward maintaining flexibility, both for long-term investment needs and short-term power sector management. The PDP should be re-evaluated on a regular basis to ensure that the investment mix makes full use of the potential for renewables, while leveraging the flexibility inherent in a power system that has significant quantities of natural gas-fired generation.

Assess the potential for any new generator to become a stranded asset. Investment decisions made under the PDP are expected to last for decades. It is therefore important to evaluate how the economics of these investment decisions may change as the needs of the Thai power sector evolve. In particular, were demand growth to be lower than expected because of improvements in energy efficiency, or were the economics of the power mix to change because of movement in the cost of renewables or fuel prices, it is possible that it would be uneconomic to keep some newly built generation online. The economics of new generators should be evaluated under a range of scenarios, so that the potential for early retirement can be accounted for.

Renewables

Increase the ambition of the renewables target, in particular for solar PV. Thailand's AEDP lays out an ambitious renewables goal, in particular compared to other countries in ASEAN. Taking into account the trend for declining costs of solar and wind technologies, significant room for improvement remains.

Redesign the support schemes for renewable energy, with the goal of bringing new renewable capacity online and scaling down plans for new fossil-fuel plants over the next decade.

Separate renewable energy support measures into at least two channels, one for SPPs and another for VSPPs. SPPs should compete on price via annual or twice-yearly auctions. VSPP support, meanwhile, should revert to a first-come, first served FIT with annual degression. For rooftop solar PV systems, simple rules should be developed to facilitate installation.

To support more ambitious renewable targets, **establish renewable performance targets for EGAT in terms of share of grid-connected renewables.** Moving to performance-based ratemaking would allow EGAT to be directly compensated for the cost of meeting – or exceeding – any such target.

As a further step, **re-think the zoning approach for the deployment of renewables.** Current restrictions on where new renewables can be deployed based on the capacity limits of the grid create a negative feedback loop, whereby investors avoid potentially promising regions within Thailand, reducing the incentive for grid improvements. Loosening restrictions on where new renewables can be developed would allow the investment community to identify the best places to build new renewable generation, allowing grid investments to be targeted where they are needed the most. A cost-benefit analysis comparing potential generation and transmission investments could aid in guiding investment decisions. Thailand is prioritising system-friendly renewables, which will have positive impacts for transmission planning as long as they are visible to EGAT.

Increase the visibility of renewables for EGAT with respect to the real-time output of distributed generation. As the penetration of renewables increases, it has the potential to undermine the stability of the power system. Increasing EGAT's view of the distribution network in real-time would help to alleviate this.

Energy efficiency and demand

As an economy situated within ASEAN, the relative performance of Thailand compared to its neighbours is an important consideration with respect to the nature of domestic demand. Competition from countries such as Myanmar – which is relatively less developed but which is undergoing reforms that may increase economic development in the near term – may force Thailand to move up the economic value chain. If so, this could change the nature of electricity demand within the country, potentially reducing or even breaking the link between economic growth and growth in electricity consumption. Indeed, it is possible that the economy of Bangkok may have already experienced such a decoupling. Certain parts of Thailand, however, remain relatively underdeveloped. It is therefore possible that a decline in demand growth in some parts of Thailand could be offset by an increase in demand growth elsewhere.

The Thai government should therefore be commended for taking a strong and serious approach to energy efficiency. Energy efficiency combines all the guiding principles of PDP2015, and is a key component of improving Thailand's electricity security. The EEP is ambitious and comprehensive and, if implemented as planned, will decrease Thailand's energy intensity and increase demand for energy-efficient products and services. Achieving the reduction targets outlined by the EEP would avoid the equivalent of 16 new coal plants, and decrease greenhouse gas and other environmentally destructive emissions.

Yet a number of factors continue to constrain the implementation of energy efficiency markets in Thailand. First, a lack of co-ordination between government agencies could have an impact on the effectiveness of policies and programmes, as could a lack of energy efficiency finance, particularly for small and medium-sized enterprises.

Other challenges include the need to promote the development of measurement, reporting and verification (MRV) systems, particularly as the energy service company (ESCO) market relies on access to and use of MRV standards and protocols. Finally, while energy providers have taken an active role in demand-side energy efficiency, sustaining and expanding this role requires a system that would make reducing energy demand, and capturing the other benefits of energy efficiency, a viable business opportunity.

Barriers to energy efficiency include a lack of manpower, lack of awareness on the part of the public, the relative expense of more efficient technologies, the length of payback periods (which are too long, due in part to Thailand's relatively low electricity tariffs), and the opportunity cost of installing energy-efficient equipment versus avoiding associated downtime.

Experts within Thailand have expressed concern that the easiest energy efficiency measures have already been exploited, and that it is becoming more difficult to find projects with a high enough internal rate of return to justify investment. This is partly because the economics of energy efficiency programmes are undermined by Thailand's relatively low electricity tariffs. The country's tariff structure already differentiates between peak and off-peak periods. As a further step, Thailand could move to providing more granular real-time pricing (in particular to large consumers, who may be in a better position to react to real-time price changes than smaller consumers). Thailand should also work to ensure that tariffs are truly cost-reflective.

Aside from tariff reform, the Thai government could leverage the revolving funds to provide more, and more targeted, low-interest loans. In addition, minimum energy performance standards (MEPS) could be extended to commercial equipment, particularly air conditioning systems in shopping malls. Moreover, only two of the five MEPs are currently mandatory. Requiring MEPS for a larger range of products could significantly improve energy efficiency. Thailand could also aid ESCOs by providing more detailed load profile information, to help them target relevant customers.

Obstacles to district cooling extend beyond the difficulty in developing new infrastructure in high-density areas. Many building owners prefer to control their own cooling systems, in part because they are concerned about reliability issues, but also because costs can be passed on to building tenants. Thailand can help by developing stronger building codes and appliance standards, in particular for cooling technologies.

Improving MRV is also an area for potential reform. Incentives currently focus on financial support for the deployment of energy efficiency. Without proper MRV regimes in place, however, it will not be clear whether energy efficiency measures that have been deployed are delivering the promised savings. Supporting additional MRV – for example by helping to develop standard protocols, or by direct financial support of MRV programmes – could both aid the deployment of energy efficiency (by providing measurable evidence that promised savings are real and sustainable) and improve system planning by increasing the accuracy of load forecasts.

Finally, with regard to demand forecasts, certain parties outside government are concerned that current projections overestimate long-term growth rates. If actual demand growth is lower than projections suggest, this could have a profound impact on the relevance of the PDP.

Recommendations

Energy efficiency should be more explicitly tied to energy security by recognising the key role it can play in supporting resource adequacy targets. Poorly implemented energy efficiency policies or policies that are not viewed as achievable can create uncertainty, potentially affecting demand forecasts and resource adequacy. The government of Thailand should make energy efficiency a core component of its power sector plans. Energy efficiency measures could be improved by expanding the coverage of products covered by MEPS, high energy performance standards (HEPS) and labels, and make more of these measures mandatory. Current efforts rely to a large degree on voluntary measures. Five products are covered by MEPS and only two of these are mandatory.

Improve co-ordination between ministries and relevant agencies on the topic of energy efficiency by developing more lines of communication and clarifying roles and responsibilities. The development of EEP is an importance step to developing closer co-operation on the topic of energy efficiency, but it does not by itself eliminate some of the structural issues that may prevent energy efficiency improvements. Defining clear roles and responsibilities within the Thai government and improving communication and transparency can go a long way to supporting energy efficiency measures throughout the country.

Focus efforts on Thailand's metropolitan areas, where most of the demand is and where there is the greatest potential for improvement. For example, the government should implement mandatory MEPS for commercial air conditioners in malls and commercial buildings, and eliminate loopholes that allow owners to avoid energy efficiency upgrades when updating or retrofitting a building. In addition, regulations are needed to incentivise the deployment of energy efficiency in common areas of large residential and commercial buildings.

Allow verifiable energy efficiency projects to compete directly with supply-side options in resource procurement. Moving to fully integrated resource planning would allow energy efficiency programmes to be directly compared on an economic basis to generation and transmission alternatives.

Further develop energy efficiency MRV systems in order to support and improve the ESCO market in Thailand. The development of a robust ESCO market requires consumers to be confident that the services they are paying for will result in real savings. Improving MRV practices in Thailand would build consumer confidence and reduce the ability of poorly performing ESCOs to tarnish the market.

Set up a steering mechanism with the mandate and powers to request information from responsible agencies and that will regularly publish the interim results of EEP implementation. A first action of such steering structure should be to define clearly which agencies bear first responsibility for development of energy efficiency instruments, and which agencies have first responsibility for implementation and/or reporting energy savings. The steering structure should also insist on annual reporting by these responsible agencies on activities undertaken and energy savings realised.

Electricity transmission and distribution

As system operator, EGAT has various responsibilities that relate directly to the three policy priorities of the Thai government – namely, safeguarding the security of the electricity network, ensuring cost-efficient investment, and minimising environmental impact. As noted earlier, it is not possible to achieve each of these goals equally. This creates a potential conflict of interest for EGAT with regard to its major role not only in planning the transmission infrastructure, but also in shaping Thailand's future generation mix. As EGAT is the most visible Thai entity with responsibility for keeping the lights on, it may favour improving security at the expense of the other two goals. EGAT has an incentive to overinvest in supply while keeping the share of renewables in the Thai transmission system relatively low. Increasing the capacity and independence of the ERC is one way to ensure a balanced achievement of all three goals.

Moving to a probability-based approach for the assessment of the transmission and distribution network (in addition to doing so for the development of the overall reliability standard) is another way to reduce the potential for bias toward a particular solution. By examining how the Thai grid would perform under different scenarios – for example, extreme weather conditions, changes in consumption patterns or unexpected losses – and comparing those to a variety of possible prevention measures, EGAT could be encouraged to develop solutions that would improve reliability at least cost.

In this context, it is especially important for transmission network planning and operation to carefully consider the actual utilisation rates of the high-voltage network, in order to better understand where investments are needed. Under a probability-based approach, correlations between different generators can be better assessed, and the transmission network developed accordingly. For example, hydroelectric power is generally seasonal. As a result, associated transmission lines may only see heavy use during certain months of the year. Existing transmission assets can potentially be used more efficiently if new generators are allowed to use them in addition to hydro imports from Lao People's Democratic Republic (PDR).

A probabilistic approach should consider scenarios experienced in the past, e.g. the gas shortage in 2013, as well as invented scenarios, taking into account the increase in smart grids due to be implemented in the Thai network. In particular, the rise in renewables deployment and changes in consumption patterns could have profound impacts on transmission utilisation rates in the future.

To avoid the potential for stranded network investments, network planning should be amended in line with envisaged changes to the generation and demand structure. It would be very sensible for EGAT to assess different possible scenarios for the generation mix, as well as the potential location of future generation (in particular renewables), in order to develop those lines which have the highest likelihood of being exploited intensively.

With regard to the envisaged increase in co-ordination and co-operation in the ASEAN region, future network planning should consider interconnectors to neighbouring countries in long-term planning. Transmission planning currently does not fully consider the possibility of grid-to-grid connections with neighbouring countries. While Thailand is considering joint grid planning with Lao PDR, there are currently no explicit plans to take this forward. Despite the stated goal among ASEAN countries to develop the so-called ASEAN Power Grid, grid-to-grid planning is hampered in part by a lack of policy frameworks and supporting institutions at the ASEAN level.

In relation to PDP and AEDP, the Transmission Development Plan is of fundamental importance as it enables the actual transfer of generated electricity. Thorough co-ordination is therefore essential. Renewables are relatively limited in where they can be deployed due to their weather dependency; gas and coal generation need suitable access to gas and coal transfers, which also limits their choice of location. Transmission network investments can cause environmental impacts and usually have low public acceptance, increasing their cost where mitigation is required. Therefore, before deciding on a certain generation mix, all these impacts need to be considered as far as possible by thorough cost-benefit analysis of different options available. This will also increase public acceptance as the relationship between risk, costs and possibilities can be clearly depicted in such an analysis.

Grid constraints and integrating and balancing renewables

The major mechanism for integrating renewables in Thailand today is based on transmission system reinforcement. This approach is a logical response to a trend in which renewables have tended to be deployed in places of relatively little load. Historically, the private sector's selection of renewable energy project location has been based on project economics without taking into account the project's impact on the grid. Such development fails to prioritise higher-value locations from the grid's perspectives, for example areas of high demand and low supply. Instead, these projects are often sited in renewable energy "hotspots" – i.e. areas rich in renewable energy resources and where land costs are low. These areas are often areas of limited local demand. Renewable energy facilities therefore tend to concentrate in certain areas, such as the northeastern part of Thailand, taking up transmission system availability and causing grid congestion. Increased congestion means new renewable energy projects have to wait until transmission system reinforcement has been completed.

A decrease in long-term renewables targets due to network constraints, however, creates a vicious circle. Limiting the share of renewables in the AEDP due to network constrains increases the perceived need for new natural gas and coal development. Mid- and long-term renewables targets should be assessed based on the combined cost of renewables development and network enforcement, as compared to the benefits that come from reduced dependency on imported fuels and the achievability of carbon emission targets.

Network reinforcement does not happen in discrete steps – it is necessary to have long-term goals for network enforcement. Network constraints should only reduce renewables deployment over the long term if the cost of network reinforcement is out of proportion to the benefits of the renewables. Therefore, joint planning of renewables deployment and transmission and distribution network investment is essential.

In order to enable the ERC, policy makers and potential operators of conventional and renewable generation to make informed decisions, detailed information on the transmission and distribution network should be made public, in particular regarding its current capability and planned reinforcement in the next five to ten years. Transmission and distribution network codes should also be updated regularly in order to adapt to innovations, especially in renewable generation (e.g. controllability of renewables and limitations on the size of the renewable feeder to be connected to the distribution network). It will be equally important to factor the new standards for renewable energy generators into future network and generation planning to avoid an oversupply of service capacity.

From the perspective of electricity security, the policy and regulatory framework can be improved so as to align incentives to encourage development in higher-value areas with encouragement for innovative ways of planning and balancing renewables. A number of options exist that can increase the flexibility of the power system's flexibility, thereby enhancing the ability to integrate more renewables (see, e.g. Cochran et al., 2014). Flexibility considerations can be integrated into all steps of the utility planning process, from planning to system operation. In the short term, flexibility considerations can be integrated into the existing FIT mechanism, such as by basing support on location of generation, provision of frequency support, alignment with demand, and/or integration into dispatch optimisation. In the long term, the PDP process should include the assessment of various possible levels of renewable generation that can happen without jeopardising reliability. Policy makers should also determine the right combination of tools to enable system flexibility.

Recommendations

Develop a regular evaluation cycle to evaluate the status of the various network development plans. Doing so would allow both policy makers and market participants to respond to development delays or shifting market conditions. It is also important to pay close attention to how the grid plans are progressing relative to other development plans, such as the PDP.

Conduct a transparent cost-benefit analysis to assess grid development in areas that are rich in renewable resources. This, along with the timing and planning of network reinforcements, would help to ensure that network and generation development go hand-in-hand.

Introduce probabilistic calculations in the network development plans. In addition to helping with the development of reliability standards and operational practices, introducing a set of probability-based scenarios into grid planning would help increase both the reliability and the cost-effectiveness of the grid.

Allow reverse power flows as soon as it is technically possible to do so. Investing in new technologies to support reverse power flows would help in the integration of distributed variable renewables.

Focus on increasing interconnection capacities as a way of overcoming barriers to development, such as difficult terrain. New generation development will require additional investment in the grid. Geographic and social obstacles, however, can delay or even prevent the development of new lines. Increasing the capacity of existing lines would help to reduce the need for greenfield investments.

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Acronyms, abbreviations and units of measure

Acronyms and abbreviations

ADB	Asian Development Bank
AEC	ASEAN Economic Community
AEDP	Alternative Energy Development Plan
APG	ASEAN Power Grid
ASEAN	Association of Southeast Asian Nations
CEPA	Committee on Energy Policy Administration
CFL	compact fluorescent lamp
DEDE	Department of Alternative Energy Development and Efficiency
DMF	Department of Mineral Fuel
DNDP	Distribution Network Development Plan
DOEB	Department of Energy Business
DR	demand response
EEP	Energy Efficiency Plan
EERF	Energy Efficiency Revolving Fund
EERS	energy efficiency resource standards
EGAT	Electricity Generating Authority of Thailand
EGCO	Electricity Generating Public Company
ENCON	Energy Conservation Promotion
EPPO	Energy Policy and Planning Office
ERC	Energy Regulatory Commission
ESB	enhanced single buyer
FIT	feed-in-tariff
GDP	gross domestic product
GMS	Greater Mekong Subregion
HEPS	high energy performance standards
HVDC	high-voltage direct current
IEA	International Energy Agency
INDC	Intended National Determined Contribution
IPP	independent power producer
IRP	integrated resource planning
JICA	Japan International Cooperation Agency
Lao PDR	Lao People's Democratic Republic
LED	light-emitting diode
LHSE	Lao Holding State Enterprise
LOLE	loss of load expectation
LOLP	loss of load probability
LTMS	Lao PDR, Thailand, Malaysia, Singapore
MEA	Metropolitan Energy Authority
MEPS	minimum energy performance standards
MoEN	Ministry of Energy
MoF	Ministry of Finance
MoI	Ministry of the Interior
MoU	memorandum of understanding
MRV	measurement, reporting and verification
NCC	National Control Center
NEPC	National Energy Policy Council

NERC	North American Reliability Council
NGD	Natural Gas Distribution
OPS	Office of the Permanent Secretary
PBR	performance-based ratemaking
PCC	pulverised coal combustion
PDP	Power Development Plan
PEA	Provincial Energy Authority
PIP	Power Integration Project
PPA	power purchase agreement
PSO	public service obligation
RCC	Regional Control Center
SAL	structural adjustment loan
SECO	Siam Electricity Company
SPP	small power producer
TDP	Transmission Development Plan
TFC	total final consumption
TISI	Thai Industrial Standards Institute
TPA	third-party access
TPES	total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
VAT	value added tax
VoLL	value of lost load
VSD	variable speed drive
VSP	Pvery small power producer

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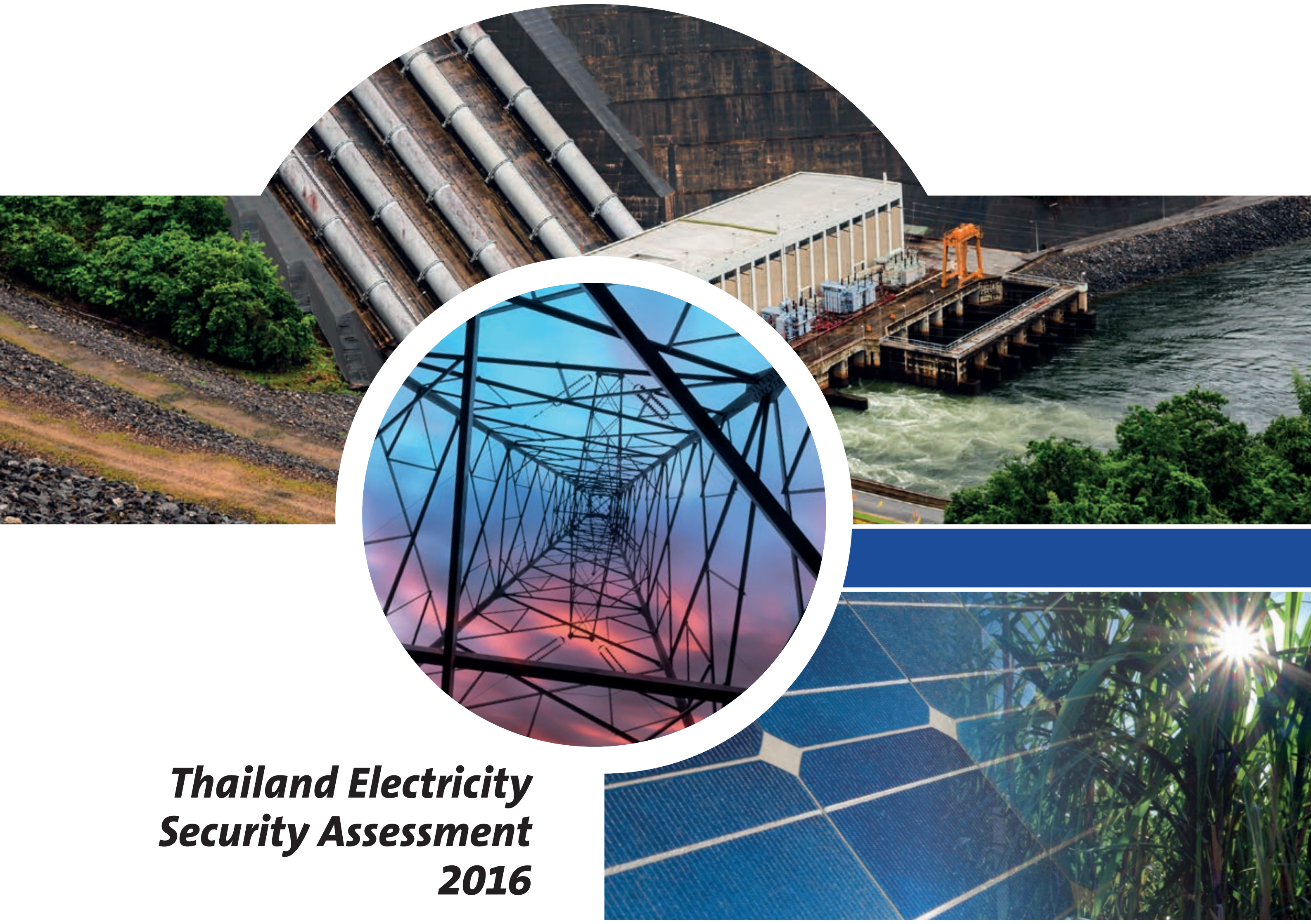

Thailand Electricity Security Assessment 2016

Thailand's remarkable social and economic development since the 1970s has resulted in a steep and steady increase in energy consumption and, as a consequence, a rising dependency on imported fuels and associated exposure to international commodity prices. Electricity demand is currently concentrated in the Bangkok metropolitan area and driven by a large industrial and manufacturing base and significant amounts of tourism. But Thailand is a growing country with a large middle class, and a structural transition may change the nature and shape of electricity demand.

Thai energy policy is driven by three pillars: security, affordability and environmental sustainability. Concerns about fuel diversity underlie all three pillars and as a result are major factors in long-term plans for power generation. Thailand's electricity sector is at a turning point similar to that of many International Energy Agency (IEA) member countries, as it transitions to low-carbon power sources. Thailand must decide how to finance massive investments in new generation assets, transmission and distribution networks, as well as the steps to improve system operations and scale up energy efficiency.

Partner Country Series – Thailand Electricity Security Assessment 2016 analyses the challenges the country faces, including how regulatory and market arrangements can adapt to best realise the opportunities from potentially disruptive distributed resources like wind and solar photovoltaics. This study draws on IEA member countries' experiences as well as Agency analysis to recommend policy improvements for a more secure and sustainable electricity sector in Thailand.