กระทรวงพลังงาน
MINISTRY OF ENERGY

IRENA
International Renewable Energy Agency

THAILAND POWER SYSTEM FLEXIBILITY ASSESSMENT

IRENA FLEXTOOL CASE STUDY

May 2019

FlexTool Engagement Process

The FlexTool engagement process for Thailand started with a formal invitation from the International Renewable Energy Agency (IRENA) to the focal point entity for Thailand, the Ministry of Energy, and more specifically the Department of Alternative Energy Development and Efficiency (DEDE), which is the department in charge of promoting sustainability and energy efficiency in Thailand. The invitation presented the possibility to carry out a power system flexibility assessment using the FlexTool that IRENA was developing at the time (IRENA 2018a, 2018b).

This engagement process was facilitated in parallel to IRENA's collaboration with energy officials and experts from the country in developing the *Thailand Renewable Energy Outlook* (IRENA, 2017a), in which IRENA's Renewable Energy Roadmap (REmap) and Renewables Readiness Assessment (RRA) methodologies were applied in a co-ordinated approach.

After the completion of the *Outlook* study, the Minister of Energy expressed his appreciation for the work done as input to Thailand's renewable energy policy formulation and asked for IRENA's help in assessing grid capacity to integrate more renewables, along with the economic impact. In response to this request, IRENA worked with DEDE to develop such an analysis based on data from the Power Development Plan 2015-2036 (EGAT, 2015).

DEDE requested the necessary data to build the FlexTool model from the Electricity Generating Authority of Thailand (EGAT), the Energy Regulatory Commission and the Royal Irrigation Department. Additionally, DEDE provided information and guidance on the details of the Thai power system. All of this information was consolidated in a database by IRENA.

Regarding the future generation mix in 2036, two scenarios were considered for Thailand: a reference scenario based on the Alternative Energy Development Plan (Ministry of Energy, 2015) with insights from the Power Development Plan (EGAT, 2015), and a REmap scenario based on the *Thailand Renewable Energy Outlook* (IRENA, 2017a), which considers higher renewables deployment and lower thermal generation capacity.

After the Ministry of Energy and DEDE sent the data to IRENA, the results were shared at various stages, as well as discussed in Abu Dhabi in January 2018 with representatives of the Thai institutions. This brochure summarises the main findings from the FlexTool's application in Thailand.

Figure 1 shows the main challenges identified before starting the assessment as well as the relevant analysis undertaken to cope with these challenges.

Figure 1: Main challenges of the Thai power system and FlexTool analysis done

Country challenges

» Limited experience in operating systems with high shares of variable renewable energy (VRE)

» Weak interconnection with other countries

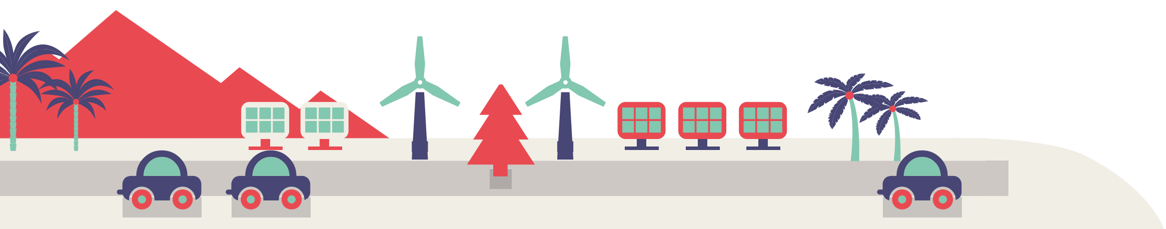
» Peak load after sunset

Analysis undertaken

» Simulation of different VRE penetration scenarios (reference and REmap)

» Assessment of the optimal power-generation capacity mix (including storage)

» Long-term planning for possible increase in VRE share, mostly with solar PV



Thailand's Power System

Thailand's power system is characterised by a large share of natural gas-fired generation capacity (around 60% of installed capacity), hydropower generation with storage and some pumping capabilities, and a small amount of variable renewable energy (VRE; less than 4%). The Thai development plan (Ministry of Energy, 2015) calls for an additional 7.5 gigawatts (GW) of VRE capacity by 2036, mostly from solar photovoltaics (PV) (2036 reference scenario). The REmap scenario for 2036, recognising greater capacity, sees the installation of another 21.7 GW of VRE, mostly solar PV. By 2017, actual installed solar PV capacity had reached 2.7 GW (IRENA, 2017b).

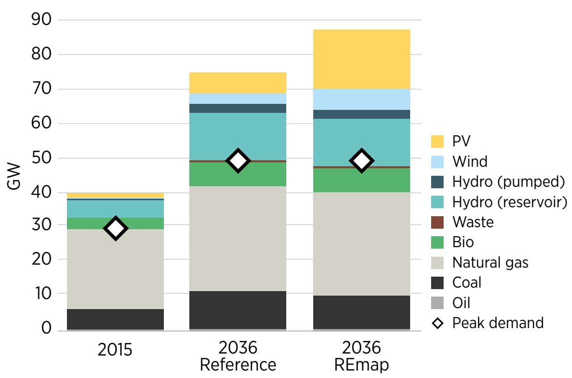
Thailand's peak energy demand was around 30 GW in 2015 and is expected to grow to 51.5 GW by 2036. Annual electricity demand is expected to grow 70% from 2015 to 2036 (EGAT, 2015; Ministry of Energy, 2015).

As EGAT plans to boost generation capacity by 2036 to cope with this rapid demand growth, generation adequacy issues are not expected[1] (see Figure 2).

Given limited details, the power system is modelled as a single node. Part of Thailand's electricity demand is met by power plants in the Lao People's Democratic Republic (Lao PDR) and Myanmar; however, these plants are modelled as part of the Thai system and not treated as interconnection capacity. Thus, for modelling purposes, there is no active cross-border electricity exchange.

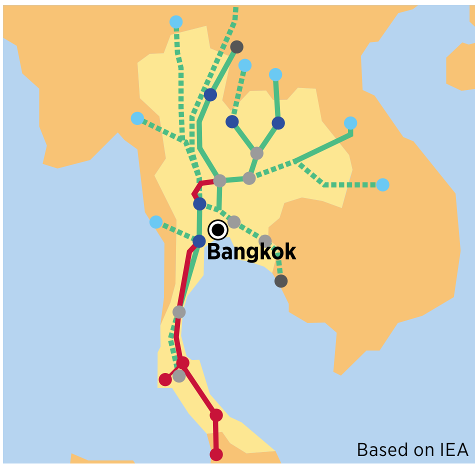
Table 1 lists enablers of flexibility in Thailand's power system based on historical information and on the latest generation and transmission expansion plans (EGAT, 2015; Ministry of Energy, 2015).

Figure 2: Expected evolution of Thailand's generation capacity mix, 2015-2036



Note: "2036 Reference" refers to the expected capacity mix based on existing plans and policies.

Figure 3: Thailand's transmission network



Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Table 1: Flexibility enablers in Thailand's power system*

Flexibility enablers	High	Medium	Low
Interconnection capacity vs. average demand			●
Generator ramping capabilities	●		
Matching of demand with VRE generation		●	
Hydro inflow stability		●	
Strength of internal grid		N/A	
Storage vs. annual demand (MWh)		●	
Geographical dispersion of VRE generation and demand		N/A	
Minimum demand vs. VRE capacity	●		

* These flexibility enablers are defined in IRENA (2018b). "High" flexibility enabler values indicate very good conditions; "medium" levels indicate normal conditions; and "low" levels indicate significant challenges or poor conditions for increasing power system flexibility at present. Some are N/A (not applicable) because the system was modelled as a single node.

[1] In the simulations, generation adequacy issues might be identified. This is because VRE sources do not have 100% firm capacity and hydro resources have limited energy; therefore, issues could appear if VRE production is low and the year of analysis is dry. However, the flexibility assessment also can be performed for specific cases where low rainfall or low wind might create adequacy challenges, and the tool is capable of addressing them by investing in a least-cost mix of technologies.

Highlights from the Analysis

Flexibility analysis in Thailand's 2036 power system

Using the information provided by the Thai agencies, the 2036 reference and REmap scenarios were simulated and no flexibility issues were identified (see Table 2). This suggests that the power system has enough flexibility to cope with higher shares of VRE, a conclusion in line with the Thailand Grid Renewable Integration Assessment and other studies (IEA, 2018).

If both scenarios are compared, changes in the dispatch and annual generation can be quantified (see Figure 4), with the REmap scenario yielding a decline in generation costs of USD 700 million per year and a 12% reduction in carbon dioxide (CO_2) emissions. Figure 4 shows annual shares of power generation by technology, as well as dispatch in the week with the highest VRE penetration for the two scenarios.

Table 2 presents the main flexibility indicators. With all indicators amounting to zero, Thailand should face no flexibility issues in 2036.

This is mainly because EGAT and the Ministry of Energy are actively considering VRE integration in line with REmap estimates.

Key measures include:

- 2.1 GW of additional pumped hydro capacity;
- Additional hydro plants in Lao PDR (2 GW) and Myanmar (6.3 GW), connected to Thailand's power system;
- Around 7 GW of net natural gas-fired capacity (mostly combined-cycle).

Figure 4: Power generation (annual share) and hourly dispatch over a week in 2036 with the highest VRE penetration: Reference and REmap scenarios

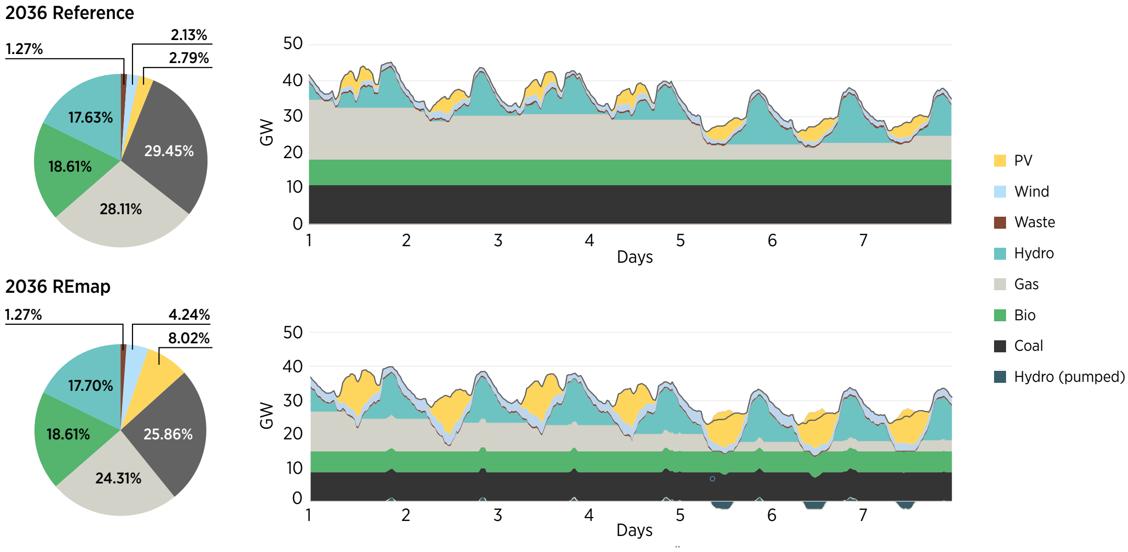


Table 2: Main flexibility indicators for Thailand's power system in 2036 reference and REmap scenarios: No flexibility issues identified

	2036 Reference		2036 REmap	
	Total (GWh)	Peak (MW)	Total (GWh)	Peak (MW)
Curtailment	0	0	0	0
Loss of load	0	0	0	0
Spillage	0	0	0	0
Reserves inadequacy	0	0	0	0

Note: These flexibility indicators are defined in IRENA (2018b). GWH = gigawatt-hours; MW = megawatts.

EVALUATING ADDITIONAL INVESTMENTS FOR OPTIMAL CAPACITY MIX

Since no flexibility issues were identified in the 2036 reference and REmap scenarios, a sensitivity analysis was performed to check if there could be cost-efficient additional investments[2]. The expansion mode of FlexTool identified that the minimum total system cost is achieved in the REmap scenario by adding 15 GW of wind, 23.8 GW of solar and 2 GW of biomass (see Figure 5). This increases the VRE share from 12.3% to 33.4% (see Figure 7) and the renewable energy share from 49% to 74%.

Figure 5: Generation capacity in 2036 REmap scenarios with and without investments for optimised system costs

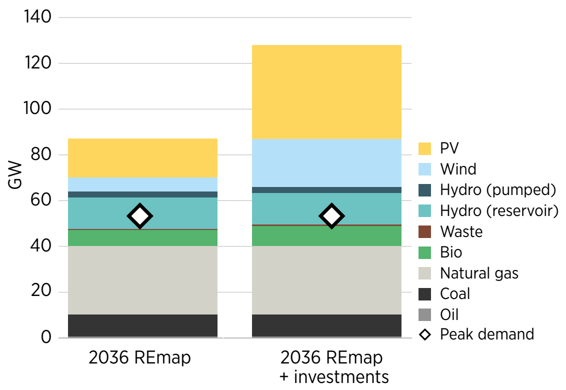
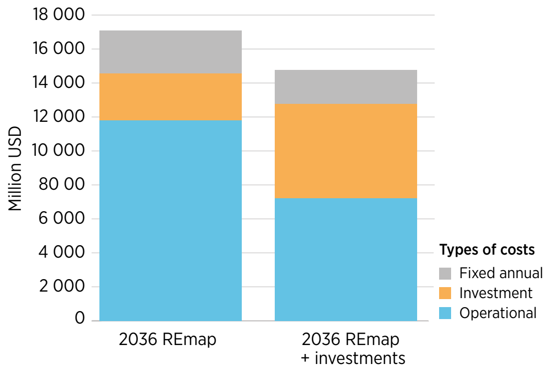


Figure 6 shows the total system costs with and without additional investments. Investments in wind, solar and to a lesser extent biomass – as well as curtailment costs (there is a 2% curtailment in the scenario with investments[3])

Figure 6: Annualised cost comparison between 2036 REmap scenarios with and without investments for optimised system costs



– are covered by savings in operational costs from fossil-fuelled capacity[4].

Finally, additional flexibility indicators were estimated to measure the flexibility that remains in the system after the additional investments. Table 3 presents the values of these indicators for the REmap scenario with optimised capacity mix, from the FlexTool investment mode.

The Thai power system still has remaining flexibility to handle a higher penetration of VRE in the 2036 REmap scenario with optimised investments (and thus also in the reference scenario). However, investing in VRE beyond the levels in the "REmap + investments" scenario is not economically viable under the current assumptions on technology costs and fuel prices.

Table 3: Remaining flexibility indicators for the 2036 REmap scenario with optimised investments: Annual average and most critical period*

	Average	Most critical*
Residual ramping capability (MW/min)	663.6 MW/min	272.0 MW/min
Share of time when transmission is not congested (%)**	N/A	N/A
Remaining interconnection capacity (%)**	N/A	N/A
Unused hydro reservoirs capacity (%)	74.9%	25.9%

*Most critical period represents the worst conditions for each of the indicators under the modelled scenario. Period, or time interval, is half an hour in the Thai FlexTool model.

**N/A (not applicable) because the system was modelled as a single node with no interconnection capacity.

Note: These remaining flexibility indicators are defined in IRENA (2018b).

[2] In the case of Thailand, the expansion includes only renewable energy capacity.

[3] This amount of curtailment is low and does not imply a flexibility issue in the system.

[4] Fuel price assumptions are: coal (USD 23 per megawatt-hour, MWh), natural gas (USD 60 per MWh) and oil (USD 80 per MWh).

Gradually integrating more solar and wind power into the system

For sensitivity analysis, solar PV and wind are gradually added to test the system's flexibility limits. In total, 34 VRE scenarios were simulated. Figure 7 shows VRE curtailment given different VRE shares for 26 of the simulated scenarios.

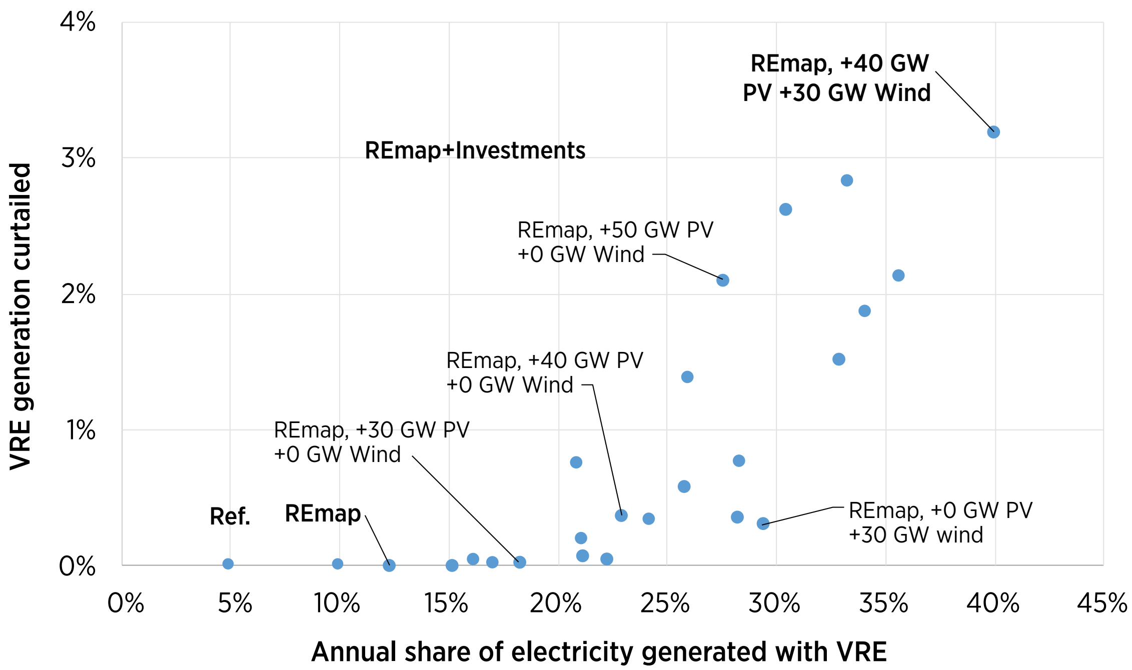
In the reference scenario, the installed capacity is 6 GW for solar PV and 3 GW for wind, resulting in no curtailment and no flexibility issues. Meanwhile, the annual VRE share is 5%, and the renewable share is 41%. When installed capacity increases to REmap scenario levels (17 GW solar PV and 6 GW wind), the annual VRE share is around 12% and the renewable share is around 49%. Flexibility issues still do not appear. Therefore, the system could accommodate more VRE than in the REmap scenario.

When installed capacity reaches 40 GW for solar PV (with REmap wind levels), or 30 GW for wind (with REmap PV levels), VRE curtailment starts to appear, but at a reasonable level (less than 0.5%).

The REmap scenario with optimised investments puts solar PV capacity at 41 GW and wind capacity at 21 GW, yielding 1.9% VRE curtailment, a 33% VRE share and a 74% renewable energy share. Considering Thailand's peak demand in 2036 (51.5 GW) the curtailment level with this high penetration of VRE (62 GW) could seem very low. However, the good match between demand and VRE profiles, together with the 2.6 GW of pumped hydro storage installed in the system, greatly reduces the expected VRE curtailment.

From this scenario onwards VRE curtailment starts to increase rapidly as VRE installed capacity increases. In this analysis, Thailand is modelled as a single node due to lack of data. Thus, curtailment due to transmission congestion may appear at lower VRE penetration than what is presented in this analysis. If transmission capacity is expanded to avoid congestion, results are not likely to change using a multi-node model.

Figure 7: VRE curtailment at different levels of solar and wind penetration in 2036



Conclusions and Recommendations

In 2015 the Thai power system had a low VRE share and the capacity mix had enough flexibility to cope with net load variations; thus flexibility is not yet an issue. In 2036 the VRE share will grow according to the Power Development Plan and the Alternative Energy Development Plan, for which Thailand is expected to have enough flexibility.

For this reason, an additional scenario was simulated using the VRE potential from REmap, where there is an increase in solar PV capacity with respect to the reference scenario. In this scenario the Thai power system is still flexible enough to cope with the variability introduced by VRE. This is mainly because, apart from the existing flexible power plants in Thailand, the country plans to install 2.1 GW of pumped hydro storage and to connect to its power system 8.3 GW of hydro plants in Lao PDR and Myanmar.

Based on the results of the analysis, the IRENA FlexTool suggests that additional investments in renewable capacity, mainly in solar PV and wind, are technically and economically viable. Moreover, the FlexTool suggests investing in around 2 GW of additional biomass capacity in both scenarios when the optimal capacity mix is investigated through the investment mode. These investments help reduce both the total system costs and CO_2 emissions. The optimal amount of solar PV identified is 41 GW and of wind is 21 GW.

Additional investments beyond the identified optimal mix can be accommodated in case they occur independently from planned capacity, for instance through customer rooftop PV installations. This study concludes that if VRE installed capacity goes beyond the identified optimum, additional flexibility solutions beyond the existing ones should be identified to further integrate VRE into the system.

An increase in pumped hydro storage capacity, the addition of interconnection and sector coupling are among the options that could be considered in a further analysis with the IRENA FlexTool. Further analysis, using higher grid resolution, is still needed to identify the investments that would be required, if any, to ensure the viability of the proposed solutions.

Impact

DEDE, which forms part of Thailand's Ministry of Energy, affirms the usefulness of the FlexTool for assessing the system's readiness for higher shares of variable renewables.

After the co-ordinated application of IRENA's REmap and RRA methodologies, country representatives asked IRENA to study the power system in more depth. They were especially interested in analysing the grid's ability to accommodate more renewables – and the economic implications of this – by applying the IRENA FlexTool.

Specifically, they proposed using the Alternative Energy Development Plan and the Power Development Plan 2015-2036 as the two main references for the FlexTool analysis.

The study indicates that flexibility will not be an issue and that the Thai power system can cope with the variability introduced by solar and wind power. Further investment in solar PV and wind power would be feasible and even economically optimal. Investing in more biomass would also boost Thailand's energy security.

Further Reading

- **EGAT (2015)**, *Thailand power development plan 2015-2036*, Electricity Generating Authority of Thailand, Bangkok, https://www.egat.co.th/en/images/about-egat/PDP2015_Eng.pdf.
- **IEA (2018)**, *Thailand renewable grid integration assessment*, International Energy Agency, Paris.
- **IRENA (2018a)**, *Power system flexibility for the energy transition, Part I: Overview for policy makers*, International Renewable Energy Agency, Abu Dhabi.
- **IRENA (2018b)**, *Power system flexibility for the energy transition, Part II: IRENA FlexTool methodology*, International Renewable Energy Agency, Abu Dhabi.
- **IRENA (2017a)**, *Renewable energy outlook: Thailand*, International Renewable Energy Agency, Abu Dhabi.
- **IRENA (2017b),** Data and Statistics – IRENA REsource, http://resourceirena.irena.org/gateway/dashboard/?topic=4&subTopic=19 (accessed 10 October 2018).
- **Ministry of Energy (2015)**, *Alternative energy development plan*, Thailand Ministry of Energy, Bangkok, http://www.eppo.go.th/images/POLICY/ENG/AEDP2015ENG.pdf.

ISBN: 978-92-9260-088-4

Acknowledgements

IRENA appreciates the support of the Government of Japan, which contributed to the preparation of this report. This case study benefited greatly from the reviews and input of experts in Thailand, including Munlika Sompranon (DEDE) and Pipatpon Mitasit (EGAT), as well as the Energy Regulatory Commission (ERC) and the Royal Irrigation Department (RID). Dolf Gielen, Nicholas Wagner and Yong Chen (IRENA) also provided valuable input.

Contributing authors: Emanuele Taibi, Carlos Fernández and Laura Gutiérrez (IRENA), with Tomi J. Lindroos and Juha Kiviluoma (VTT).