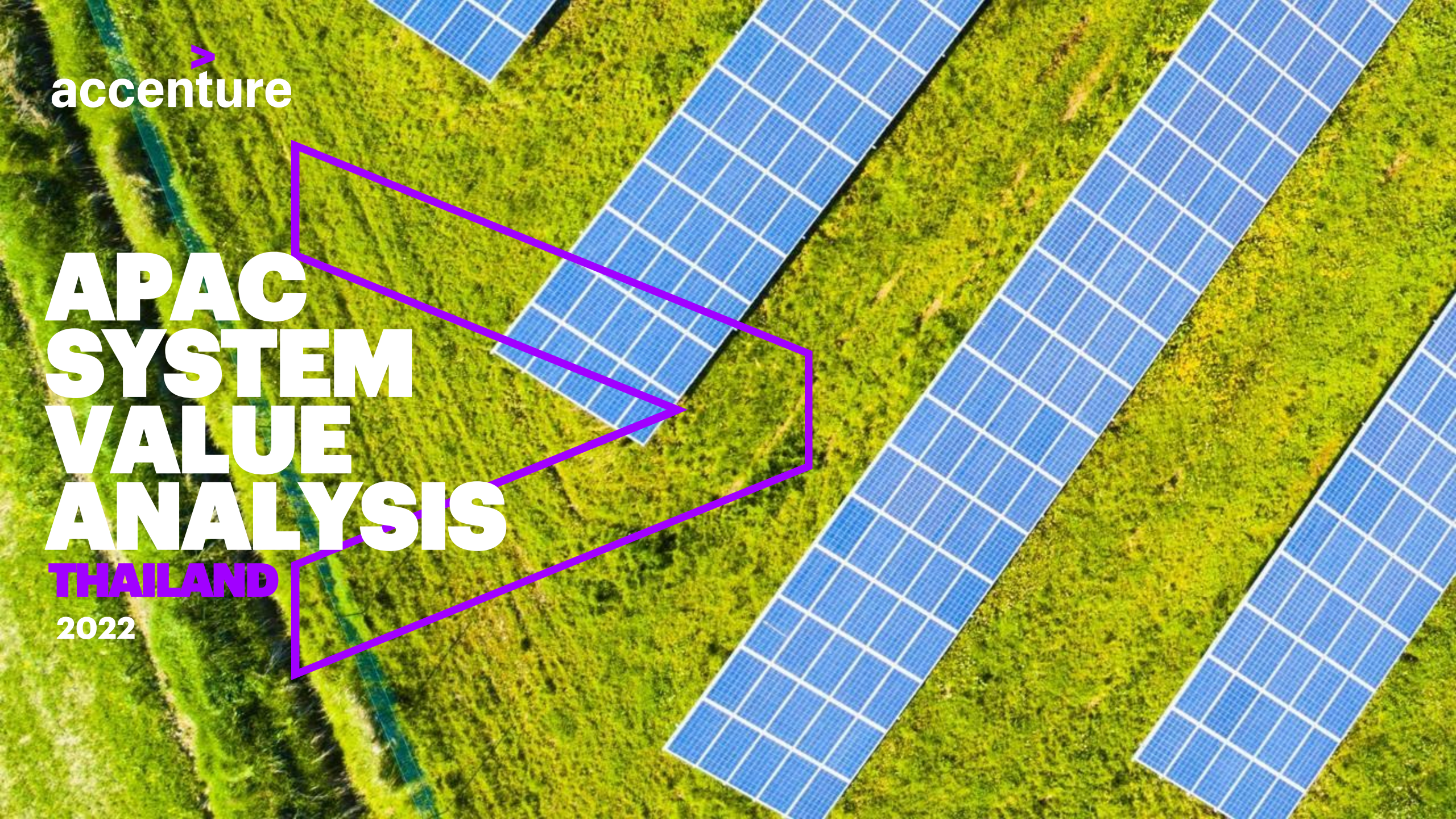


accenture

APAC SYSTEM VALUE ANALYSIS

THAILAND

2022

AGENDA

1

Executive Summary

2

Market Analysis

3

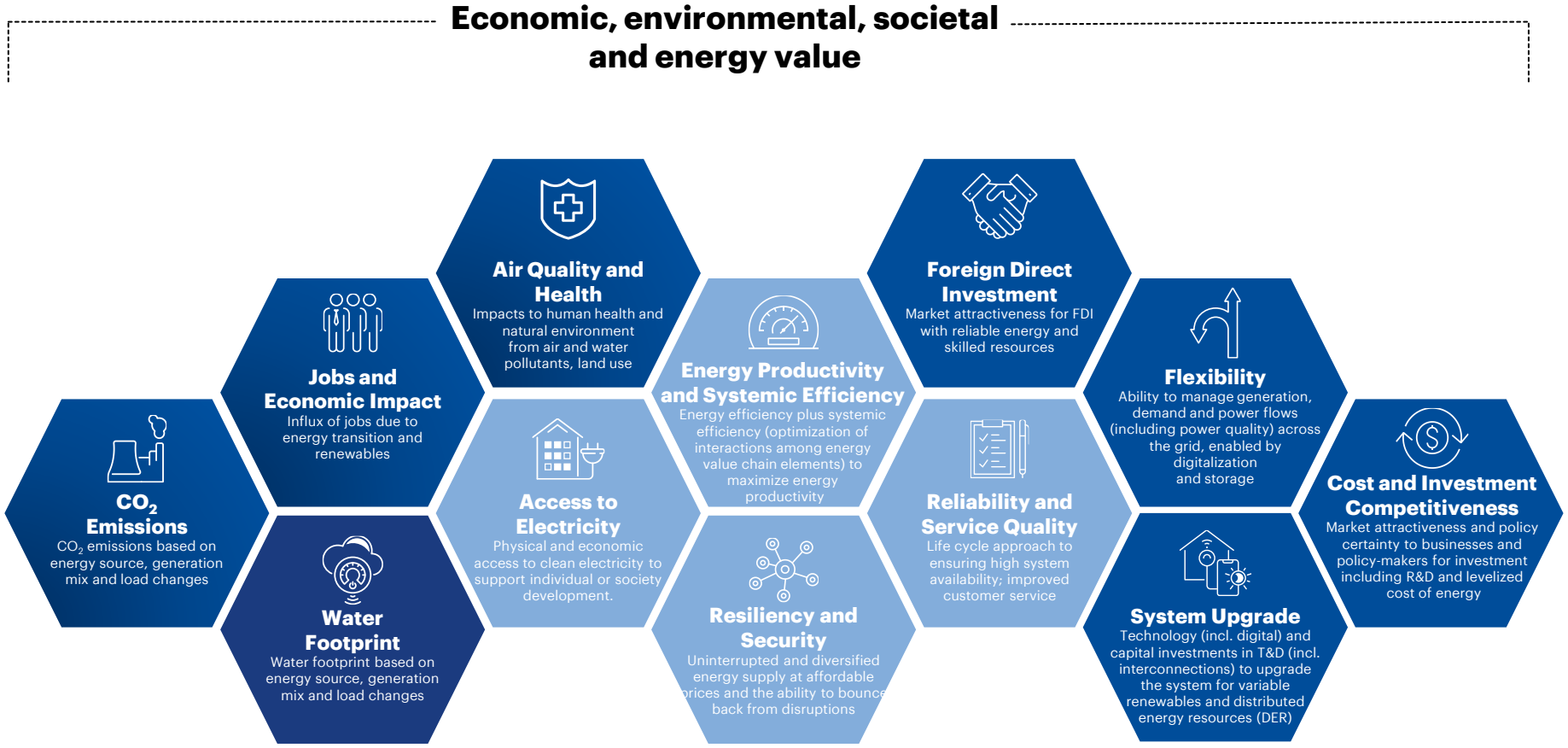
Solutions

System Value of the clean energy transition

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to **shift political and commercial focus beyond cost to include value**.

Using the System Value framework, the World Economic Forum, supported by Accenture and a group of global electricity companies, conducted analysis across several geographies as part of market evaluations that examined recovery opportunities to accelerate economic growth and the clean energy transition.

The flexible nature of the framework allows inclusion of both quantitative and qualitative analysis. The relevance of System Value dimensions may vary by geography and over time horizons.



Priority outcomes for Thailand

System Value of Thailand's clean energy transition

System Value dimension with quantitative analysis

System Value dimension with qualitative analysis

Priority System Value dimension

	CO_2 Emissions: CO_2 emissions based on energy source, generation mix and load changes	Water Footprint: Water footprint based on energy source, generation mix and load changes	Access to Electricity: Physical and economic access to clean electricity to support individual or society development	Jobs and Economic Impact: Influx of jobs due to energy transition and renewables	Air Quality and Health: Impacts to human health and natural environment from air & water pollutants, land use	Resiliency and Security: Uninterrupted and diversified energy supply at affordable prices and the ability to bounce back from disruptions	Energy Productivity and Systemic Efficiency: Energy efficiency plus systemic efficiency to maximize energy productivity	Foreign Direct Investment: Market attractiveness for FDI with reliable energy and skilled resources	Reliability and Service Quality: Life cycle approach to ensuring high system availability; improved customer service	Flexibility: Ability to manage generation, demand and power flows (incl. power quality) across the grid, enabled by digitalization and storage	System Upgrade: Technologies (incl. digital) and capital investments in T&D to upgrade the system for variable renewables and DERs	Cost and Investment Competitiveness: Market attractiveness and policy certainty for investment incl. R&D and levelized cost of energy
1. Replace planned new coal with Utility-scale Solar	**127 MMT**	**210 bn L**	◑	**88K**	**$ 2 bn**	●	○	●			◑	●
2. System flexibility enhancement to allow up to 30% VRE	**315 MMT**	**487 bn L**	◑	**358K**	**$2.6 bn**	●	●	◑	●	●	●	◑
3. Leverage Industrial Clusters to build sustainable ecosystems	**136 MMT**	○	○	**843K**	**$0.08 bn**	●	●	●	◑	◑	◑	●
4. Drive EV Adoption	**215 MMT**	○	○	○	**$0.03 bn**	○	●	●		◑	◑	◑

Analysis performed for given System Value dimension and recovery solution. For more detail, please see specific solution and/or relevant System Value dimension slide(s).

System Value dimension not as relevant to geographic market or not considered with given recovery solution.

Relative System Value dimension benefit for given recovery solution within market

● High benefit ◑ Medium benefit ○ Minimal-to-no benefit

Note(s): 1-Impacts are calculated as delta from the base case during the year 2022 – 2037.; 2-Solution 1 and 2 are step solutions. For example, impacts indicated in 2 are the result of implementing solution 1, and 2 altogether.; 3-Solution 3 and 4 are stand alone.

Market Analysis | Executive Summary

77 GW Total planned **installed capacity** at the end of 2037 as per PDP (from 48 GW in 2018)

53% Target **Gas-based** generation in 2037 as per PDP (from 63% in 2018) [1]

11% Target **Coal-based** generation in 2037 as per PDP (from 19% in 2018) [1]

20% **Renewable Energy** generation in 2037 as per PDP (from 10 % in 2018)[1]

~7.5% Target VRE **(solar and wind)** in **2037** generation mix as per PDP (at **~7%** and **0.5%** respectively), with high competitiveness of solar compared to wind generation.

20% Target reduction of **greenhouse gas emission** from 2030 BAU case as per NDC

27 GW The look ahead **gap in 2037 between forecasted demand and already contracted capacity** (As of 2021), allowing room for **green portfolio management**.

~15% **VRE** can be **technically integrated** in the grid, given high spinning reserves & load-following ability of existing Hydro & CCGT capacity

30% Share of **Industrial Sector** in total CO_2 **emissions** in 2018, with 36% from Light industries

15 Mn Targeted **Electric vehicles on the road** by 2035 (compared to 210,000 in 2020) and **80,000** Public Charging Stations by 2035; Target to sell only ZEV[2]s from 2035 onwards

18 Mn Targeted **Electric vehicles Production** by 2035 (compared to 551 in 2020)

Sources: Smart Grid Plan, Power Development plan 2018 revision, Alternative Energy Development Plan, White Paper on Next-Generation Automotive, IRENA, LNG Trading, Electricity market liberalization, Solar rooftop

Notes: 1-The remaining are 6% from interconnection and EEP, 9% from import, fuel oil and diesel; 2-ZEV: Zero Emission Vehicle; excludes hybrid EVs

4 Solutions for Thailand's Energy Transition

1. Replace planned new coal with Utility-scale Solar

All of the new Coal capacity planned in the Power Development Plan could potentially be replaced by Solar. Priority access for Renewable Energy Companies could help drive investment in new solar capacity.

127MMt (6%)
Less CO_2 emissions from electricity generation through 2037

210 bnL (5%)
Less water consumption from electricity generation through 2037

$2 bn
Human health benefits from air quality improvements through 2037

88K (19%)
Additional jobs in electricity generation through 2037

2. System flexibility enhancement to allow up to 30% VRE

Contractual flexibility enhancement in both PPA and fuel supply, as well as technical flexibility enhancement through Interconnection and storage implementation would allow higher VRE penetration, thus resulting in some planned new gas to be replaced by solar.

315MMt (16%)
Less CO_2 emissions from electricity generation through 2037

487 bnL (13%)
Less water consumption from electricity generation through 2037

$2.6 bn
Human health benefits from air quality improvements through 2037

358K (80%)
Additional jobs in electricity generation through 2037

3. Leveraging Industrial Clusters to build Sustainable ecosystems

Thailand's existing Industrial Cluster ecosystem can be leveraged to achieve national climate goals by focusing on circularity & waste management, and direct electrification of light industries powered by on-site renewable energy

136MMt(7%)
Less CO_2 emissions from electricity generation and transport through 2037

43 bnL (1%)
Less water consumption from electricity generation through 2037

$0.08 bn
Human health benefits from air quality improvements through 2037

843K(11%)
Additional jobs in electricity generation and transport through 2037

4. Drive EV Adoption

EV Adoption can be driven by reduction of Total Cost of Ownership, Improving Consumer Perception, Financing and Development of EV Charging Infrastructure while minimizing negative grid impact.

215MMt(68%)
CO2 emissions reduction in 2037 compared to base case

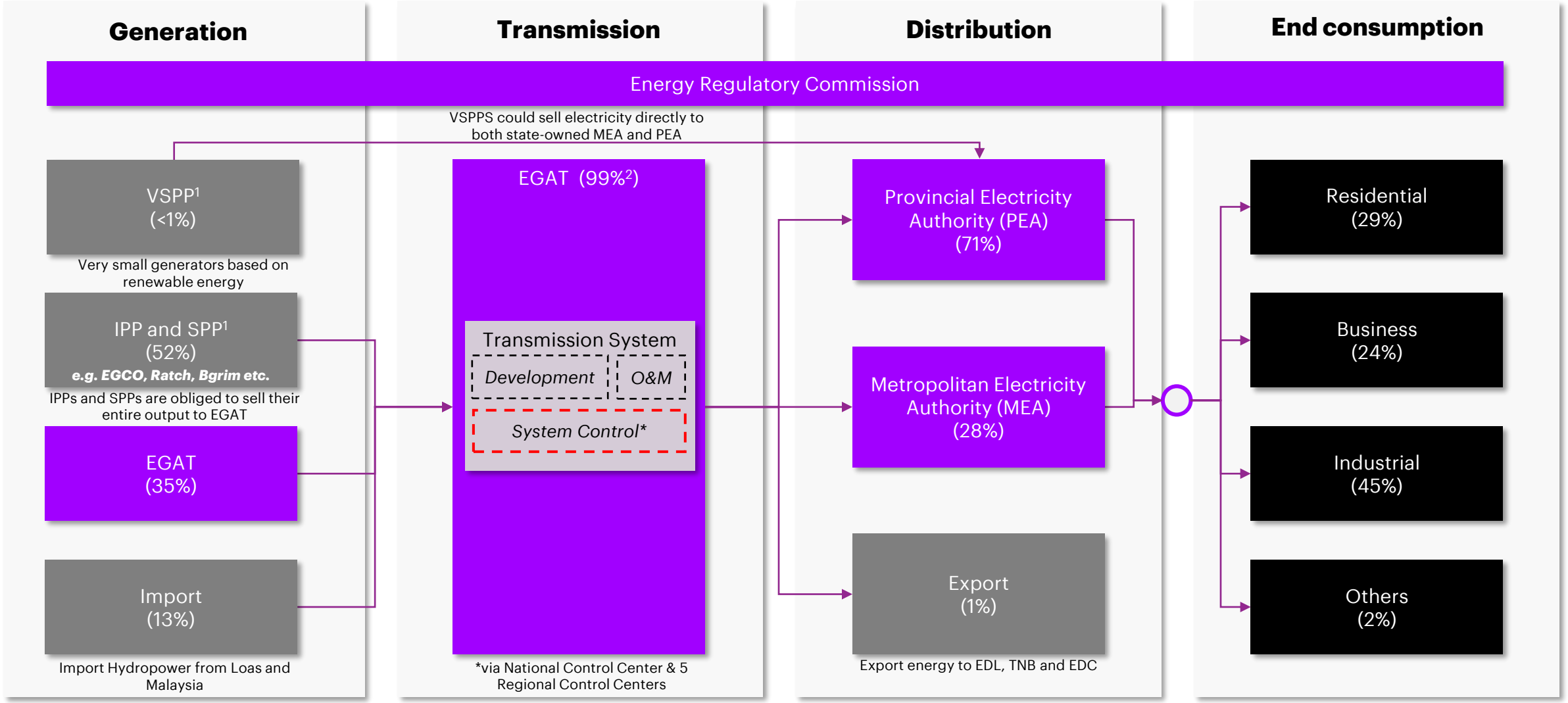
6 bn L
Slight increase in water consumption compared to base case through 2037

$0.03 bn
Human health benefits from air quality improvements through 2037

Note(s): 1-Impacts are calculated as delta from the base case during the year 2022 – 2037.; 2-Solution 1 and 2 are step solutions. For example, impacts indicated in 2 are the result of implementing solution 1 and 2 altogether.; 3-Solution 3 and 4 are stand alone.

Thailand's Electricity Market Structure

Thailand's energy market is centered around the state-owned Electricity Generating Authority of Thailand (EGAT), which is responsible for generating, transmitting and wholesaling electricity.



Source(s): EGAT, Energy Policy and Planning Office and EMIS
Note(s): 1. IPPs are power producers w/contracted capacity > 90 MW, SPPs 10-90MW and VSPPs <10MW
2. While 100% of transmission infra is owned by EGAT, ~1% of power is sold by VSPPs directly to MEA/PEA, and not through EGAT

Legend: Private companies | Government companies

Overview of Thailand Electricity Market

Thailand's base case scenario is PDP 2018 (Revision 1), forecasting 20% of RE[1] generation share by 2037. Gas is expected to remain the source of power security as per PDP.

Market Structure Components

- Thailand electricity market is enhanced single buyer model with EGAT as a **generator** (35% of total generation) and **TSO**.
- MEA and PEA are **retailers**, responsible for **distribution system**.
- Majority of power is generated by IPPs, SPPs while some power is imported. A small portion is generated by VSPPs.

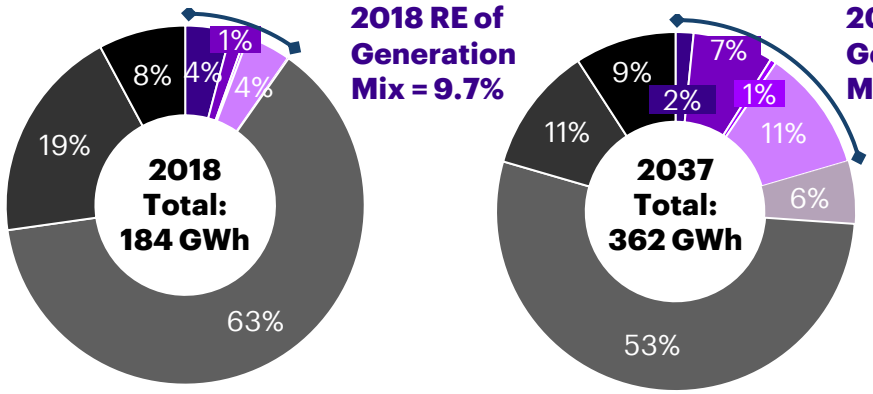
Supply and Demand Dynamics

- Electricity **supply** in 2037 will be at 362 TWh which will be **~2x of 2018** while the **installed capacity** in 2037 would be 77 GW which will be **1.6x of 2018**.
- Thailand is reported to have a 99.9% electrification rate. However, some rural areas experience power quality and reliability issues.

Energy Transition Targets

- **20% Renewables** in the generation mix by 2037
- **CO_2 reduction** as per **PDP** @28.35 $MtCO_2e$ is **ahead of DNC[2]** by **4.35 $MtCO_2e$.**

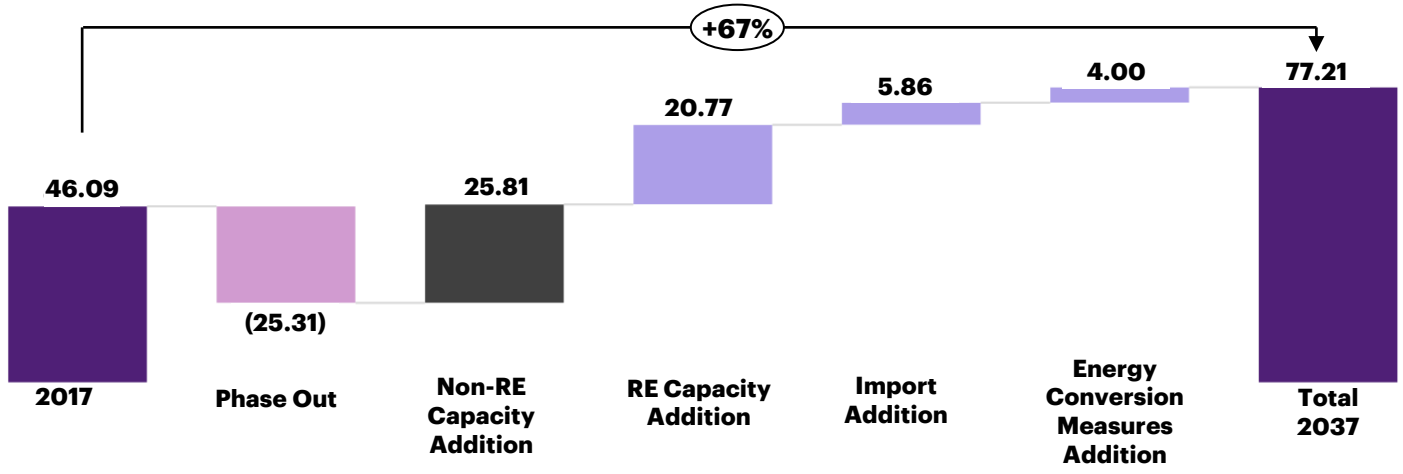
Thailand Generation from 2018-2037



CAGR 2018 – 2037

-1.29%	Hydro
13.29%	Solar
7.75%	Wind
9.43%	Biofuel
30.56%	Others[3]
2.79%	Natural Gas
0.81%	Coal
4.54%	Import & oil

Thailand Capacity Expansion from 2017-2037 (GW)



Source(s): PDP2018 Rev.1; IEA Thailand Power System Flexibility Study; Accenture Analysis; World Bank 2019 Greater Mekong Subregion Power Market Development report
Note(s): 1 – RE generation share includes domestic hydro; 2-DNC: Thailand Nationally Determined Contribution Roadmap on mitigation 2021-2030; 3-including EEP and interconnection

Overview of System Flexibility

Thailand grid infrastructure overall is at a very high level of flexibility. High reserves margin, along with hydropower and CCGT as planned in PDP can technically manage 15% VRE.

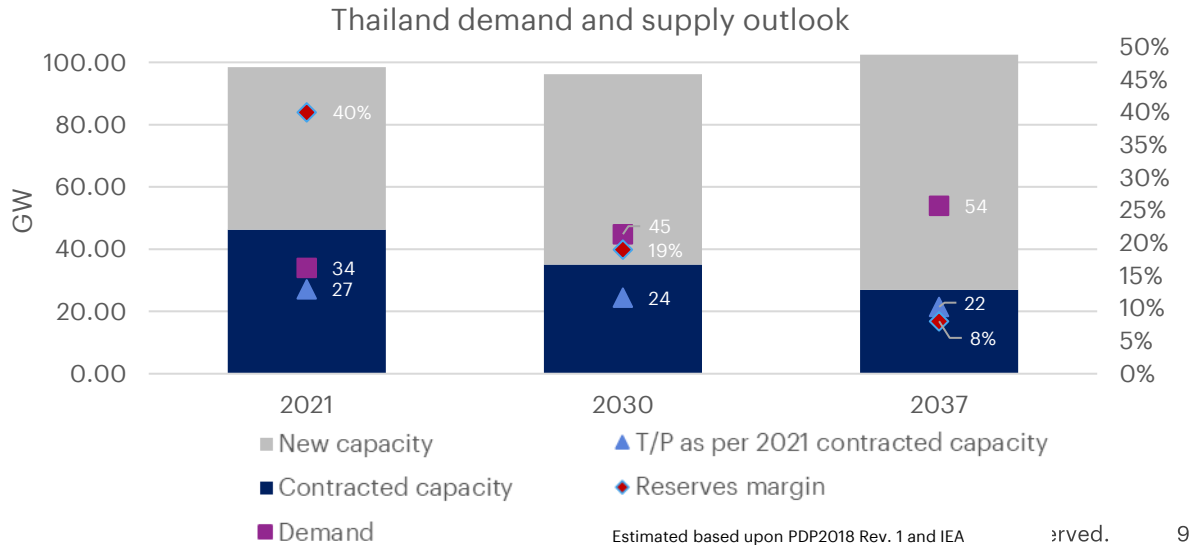
Because the dispatch ability is tied with the minimum take-or-pay and gas supply contract, contractual limitation is the issue. Also, higher VRE penetration would require higher flexibility by storage and interconnection implementation.

VRE and System Flexibility

- **2037** generation share of VRE as per PDP 2018 Rev. 1 will grow to **7.28%** from 2021 share at 2.01% resulting in both uncertainty and variability causing:
  - **Higher ramping requirement**
  - **Larger gap between daily min and peak demand**.
- IEA study simulates load and generation as per PDP 2030 (6% VRE), it was found that **15% VRE** can be **technically manageable** by hydropower and CCGT as per PDP in terms of **both power and ramp rate requirement** across different time scale.
- In terms of technical **curtailment**, IEA study, in-line with IRENA, states the annual VRE curtailment rate is just 0.05% (20 GWh) for 15% VRE share in 2030 and 2036.
- The same study also suggests that the additional PV and wind at **~50% VRE penetration** would cause technical **curtailment ~2%** which is **acceptable**.

Reserves Margin

- Thailand grid infrastructure overall has high level of flexibility in terms of high reserves margin at **40% in 2021, down to 8% in 2037**. (international standards ~10-15%)
- **2037 demand, 54 GW, is 59% growing from 2021.** PDP specifies planned new capacity from both fossil and RE to serve such growth.
- The Take-or-Pay shown in the below figure is from already contracted capacity in 2021 only. This Take-or-Pay will rise upon more new capacity to be signed.
- The **gap between demand and current Take-or-Pay level** allows possibility of balanced portfolio management and **higher VRE penetration**.



Estimated based upon PDP2018 Rev. 1 and IEA

Source(s): EGAT, IEA Thailand Power System Flexibility Study, IRENA Thailand Power System Flexibility Assessment

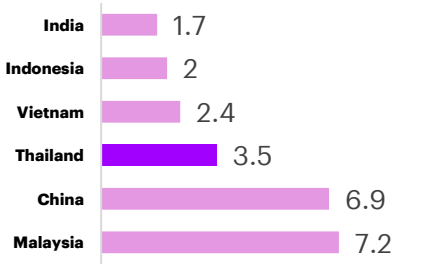
Note(s): Reserves Margin is estimated based upon published dependability in PDP2018 Rev.1, dependability-high.

Thailand CO_2 Emission Reduction

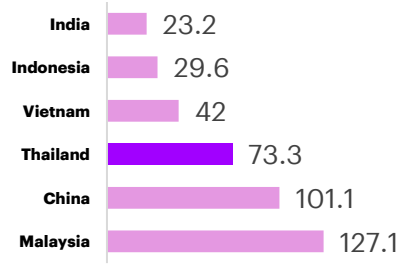
Thailand is to reduce 20.8% total GHG emission in 2030 from of its BAU, or 115.6 of its 555 $MtCO_2e$ (all sectors). GHG reduction target for electricity generation sector is reasonable as PDP2018 Rev.1 emission forecast is 18% (4.35 $MtCO_2e$) less than emission roadmap.

CO_2 Emission and Energy Consumption

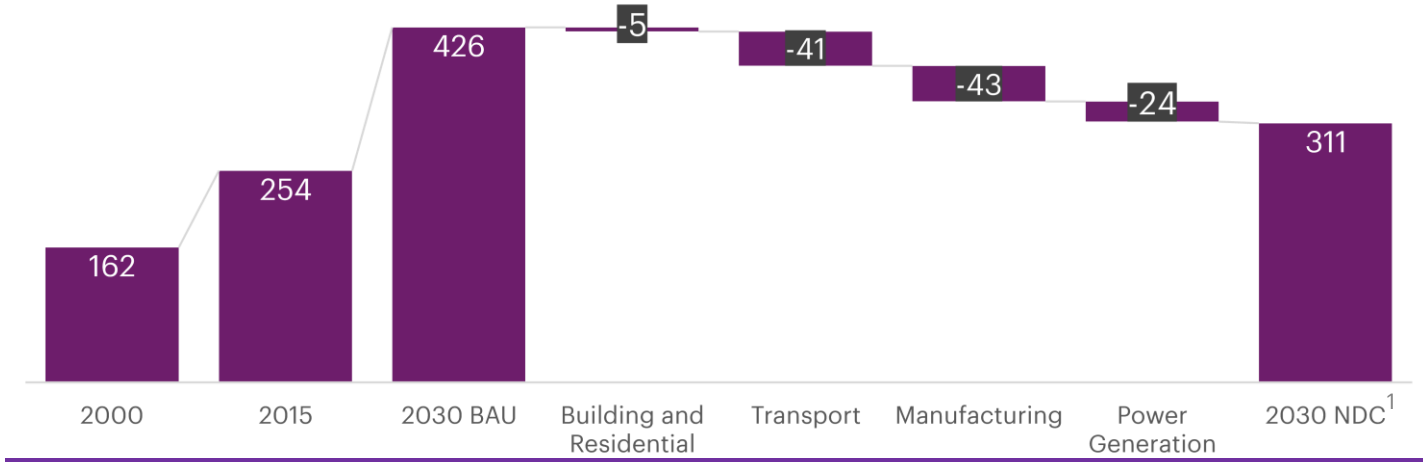
CO_2 Emissions per capita (MT) 2020



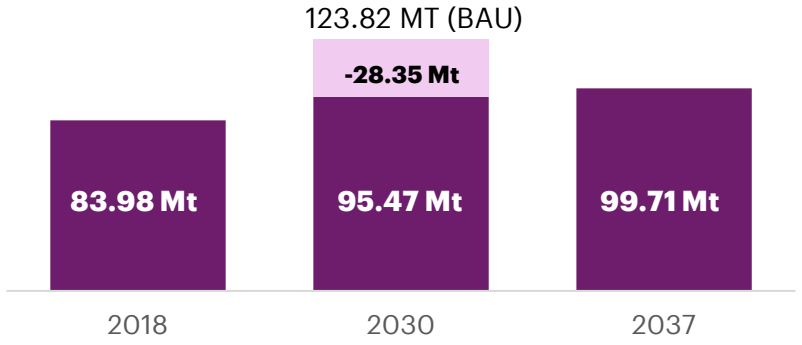
Energy Consumption per capita (GJ) 2020



National Roadmap of CO_2 Emission 2000-2030 Following Paris Agreement (Energy sector, $MtCO_2e$)



Carbon Emission Projection from Electricity Generation (PDP 2018)



Commentary

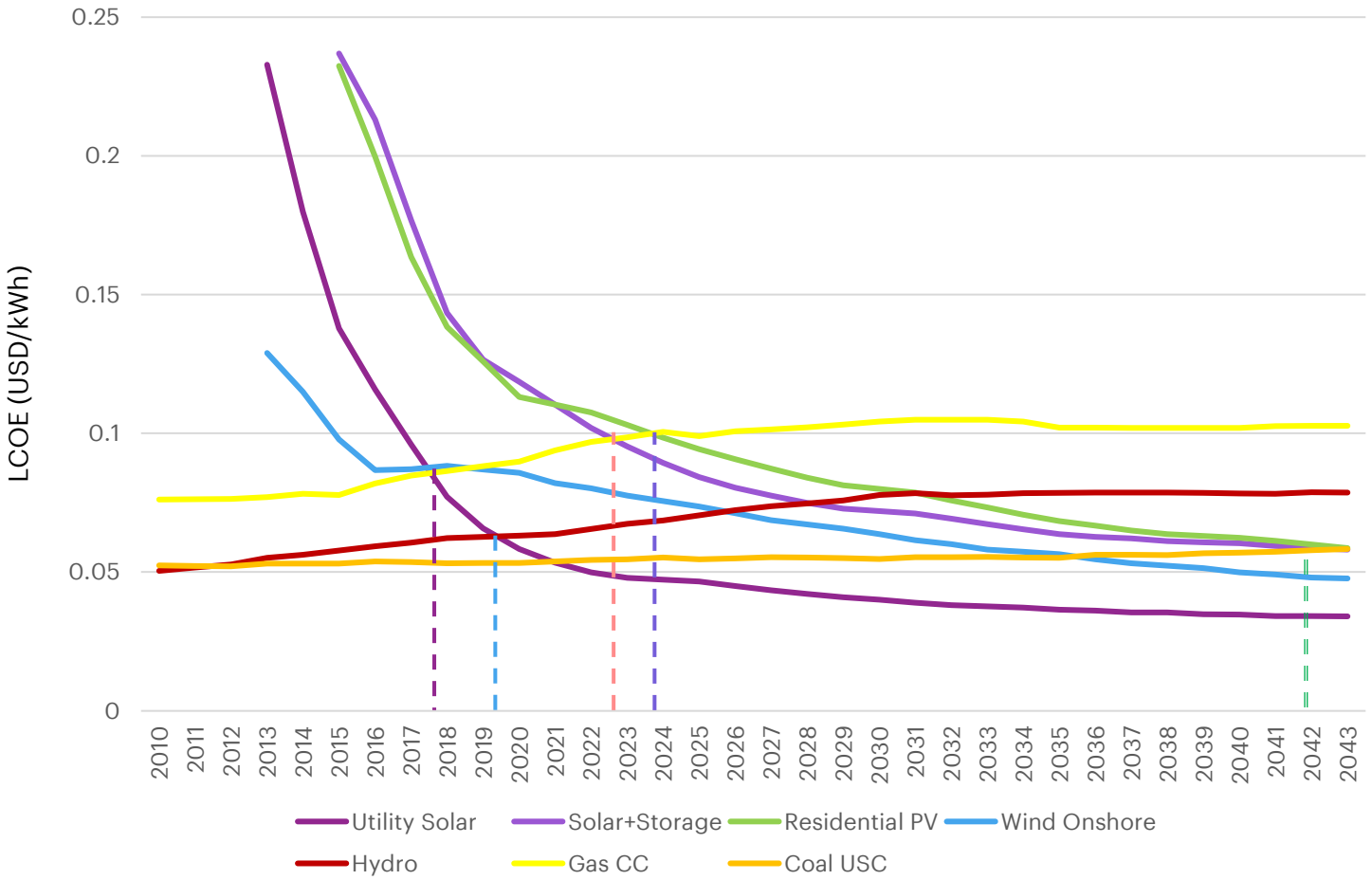
- Thailand announced commitment to net-zero by 2065 during COP 26 (2021).
- PDP only considers carbon emission from fossil fuel generation, no emission from renewables.
- EPPO[2]'s actual carbon emission from power generation number for 2018 is significantly higher than forecasted in PDP. This suggests possible reduction failure.
- Thailand NDC was created and submitted in 2015, based on PDP2015. The reduction target in power generation sector is at 24 $MtCO_2e$ from BAU.
- Upon the latest 2018PDP Rev.1, the emission is forecasted to decrease from 2015PDP by 4.35 MtCO2e, equivalent to a total of 28.35 MtCO2e reduction from BAU. Therefore, up to 25% reduction for Thailand is possible if all other sectors meet their target reduction.

Source(s): IEA: Putting a price on carbon-Thailand; PDP 2018 Rev.1; Reuters: Philippines raise carbon emission target to 75% by 2030; World Resource Institute; British Embassy Bangkok; UNFCCC; IEA: The Potential Role of Carbon Pricing in Thailand's Power Sector; MIT; bp Statistical Review of World Energy 2021
Note(s): 1- NDC: Thailand Nationally Determined Contribution Roadmap on mitigation 2021-2030, 2-EPPO: Energy Policy and Planning Office

RE LCOE Evolution for Thailand

Thailand RE LCOE (except hydro) is forecasted to decline significantly. Importantly, Thailand has the second-lowest solar LCOE in ASEAN.

LCOE Evolution of Main Energy Sources for Thailand from 2010 – 2037 (USD/kWh)



Commentary

- Utility Solar LCOE is already at grid parity with natural gas & is expected to be at grid party with Coal in the near future. This was spurred further by the Asian Energy crisis, with average spot market fuel prices driving up coal & gas power cost in Thailand by 19% and 46% respectively in 2021 compared to 2020.
- Recent supply-chain issues have led to increase in Solar PV costs since 2021, however the trend of cost advantage of Solar over coal is expected to continue in the longer term.
- Solar + Storage is expected to be at price parity with Gas by 2023 and with Coal by 2042.
- Currently, Utility Solar LCOE in Thailand is second lowest in ASEAN making it one of the best contender for solar power producer/exporter in the region.
- LCOE for hydro is largely driven by CAPEX & therefore expected to rise over the next decade as new hydro projects built in challenging sites are operationalized. Beyond 2030, significant investment in newer (and more difficult) hydro sites unlikely due to economic feasibility concerns as competition from Gas would set a price ceiling
- Biomass LCOE in Thailand is ~0.0884 USD/kWh (2019), already lower than EGAT average, which shows promising potential for future RE.

Grid Parity

- Solar vs Gas: **2018**
- Wind vs Gas: **2019**
- Solar + Storage vs Gas: **2023**
- Wind vs Coal: **2035**
- Solar + Storage vs Coal : **2042**

Source(s): WoodMackenzie Battle for future 2020; USAID-NREL: Exploring Renewable Energy Opportunities in Selected Southeast Asian Countries; ERIA (2019), Bloomberg NEF

Note(s):

Solar and Wind LCOE for Thailand vs ASEAN

Thailand solar LCOE is the second-lowest in ASEAN, whereas wind LCOE is higher than ASEAN average LCOE. Thus, solar is considered high potential for scaling in Thailand, especially in provinces with high solar irradiance.

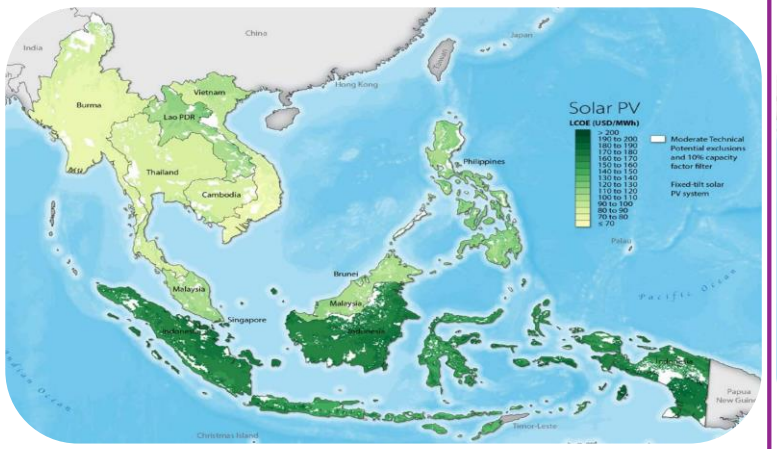
Solar

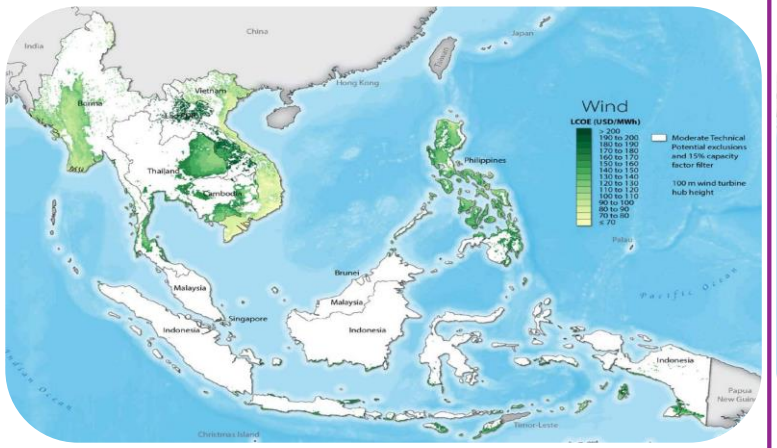
- Thailand's solar LCOE is No.2 lowest in ASEAN at 0.0864 USD/kWh making it one of the best contender for solar power producer/exporter.
- Solar LCOE is cheaper in the central and northeastern region upon higher efficiency from higher irradiance.
- Combining with existing stronger geographical advantage, grids and infrastructure than other countries with similar LCOE (Myanmar, Cambodia, and Vietnam), Thailand has a very high potential for being regional PV hub.

Wind

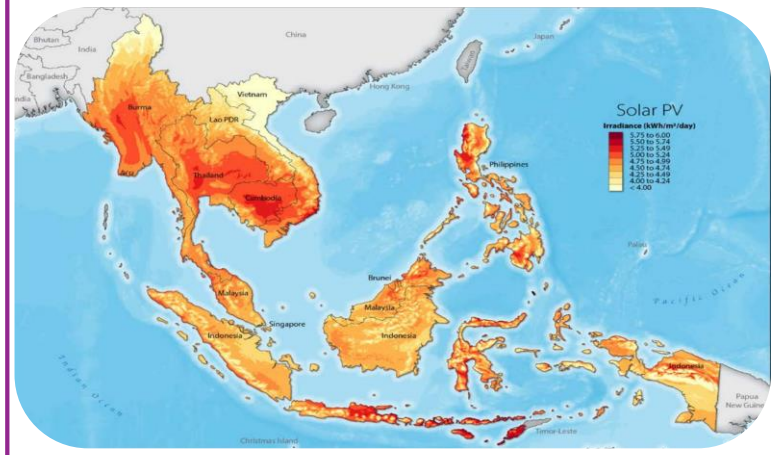
- Thailand's wind LCOE on the other hand ranks 6th in ASEAN due to relatively low wind speeds compared to top rankers, indicating lower investment competitiveness.
- Southern region has higher wind speeds than other regions, making it suitable for wind farms. However, solar LCOE is still cheaper than wind LCOE even in this region.

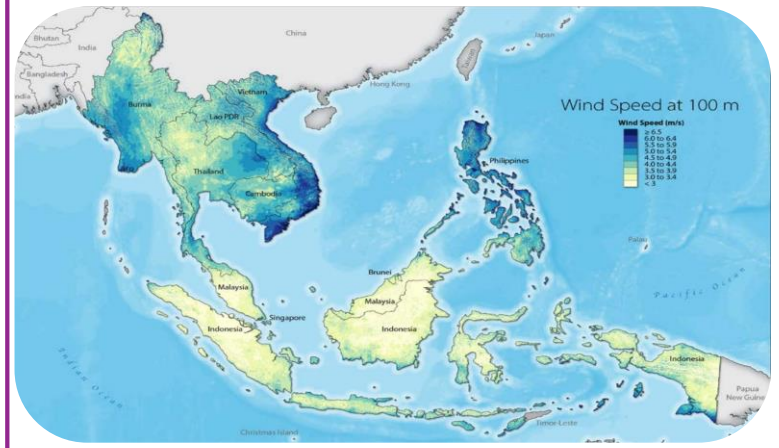
LCOE





Irradiance/wind speed





Source(s): USAID-NREL: Exploring Renewable Energy Opportunities in Selected Southeast Asian Countries; Accenture Analysis

Industrial Cluster Overview

Thailand has a robust Industrial Cluster ecosystem, and existing initiatives aim to achieve more sustainable industrial development. However more could be done to align and leverage these efforts to achieve national climate change goals.

Industrial Estates

Industrial areas developed and managed by state authorities that provide integrated services such as approvals/licensing as well as utility services for operations

63

Total no. of Industrial Estates that are currently operational in Thailand, with additional estates under development and a few in the planning stages

Eco-Industrial Town program

EIT, launched by IEAT in 2010 to transform Industrial Estates to sustainable communities, with a focus on Circularity & Waste Management and Renewable Energy development

IEAT

Industrial Estate Authority of Thailand, a govt. enterprise under Ministry of Industry that develops and manages IEs either on its own, or in a JV with private partners

Automotive, Steel , Electronics

Top industry groups, along with Rubber & Plastic, Engine & Machinery, that expressed interest in investing in Thai industrial estates in 2020

Green Industry program

Accreditation program for factories/companies committed to creating sustainable operations. Accredited companies are promoted through government channels and benefit from MoIn's financial support programs

Sustainability Investment trend in IEs

- Japanese firms Toyota, Kansai Electric & Osaka Gas to invest in RE businesses at the Smart Park IE incepted to support targeted industries like robotics, aviation, medical & digital development
- MoU signed by GULF with PEA on a pilot EMS using AMI to develop smart grid & P2P energy trading, intended to support increasing electricity demand in EEC.
- Impact Solar Ltd, a Thailand-based clean energy company, developing Thailand's largest private microgrid at Saha Industrial Estate in Sri Racha.

Source: https://www.bangkokpost.com/sponsored/ieat/#images

Source(s): IEA, IEAT, BoI, EPPO

EV Adoption Outlook

While Thailand has set ambitious targets on becoming ASEAN's EV hub, it's meagre EV production and penetration levels at present show that it would be a steep road ahead

Thailand's E-mobility goals till 2035

- In 2015, the Thai govt initiated a policy to support the **electrification of Transportation Fleet,** setting aside a budget of 5,000 million baht to be used BMTA. It is a 3-phase plan to expand EV usage and infrastructure.
- As of September 2020, Thailand's Board of Investment (BOI) allowed foreign companies to set up electric vehicle production bases by investing a total of 15,625 million Baht in BEV projects alone and thereby**, producing 125,140 Battery Electric vehicles per year**.
- **30/30 Policy:** The National EV Policy Commission announced that **ZEVs** will contribute to at least **30% of total domestic vehicle production by 2030** and Thailand will be equipped with 12,000 public fast-charging points by that time

15.5 Mn.
EVs on the road by 2035

18.41 Mn.
EVs produced by 2035

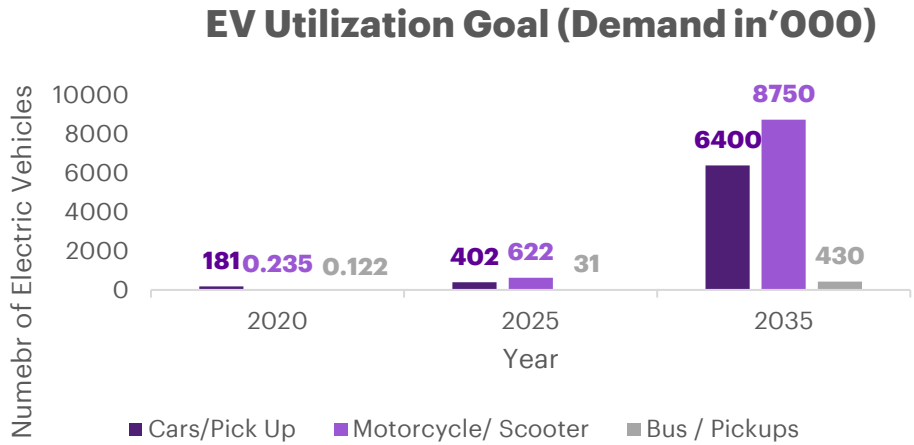
50%
EVs sold should be locally produced by 2030

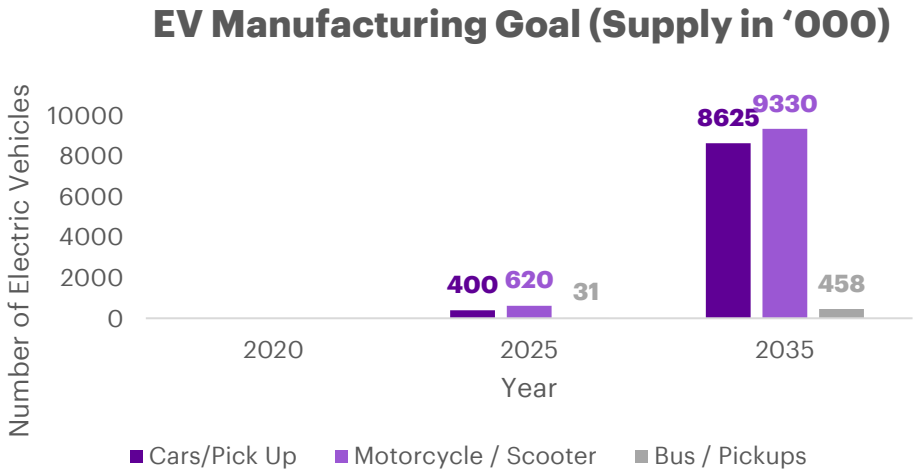
100%
Of public fleet to be ZEVs by 2030

12,000
Public fast-charging points by 2030

Thailand's Current Position

- While Thailand is in a stronger position compared to its peers in terms of EV penetration, the current **penetration (1%)** and total **EVs manufactured (0.03%)** till now are still small amounts (of motorized vehicles).
- There are a total of **1,900 publicly available charging stations** nationwide.





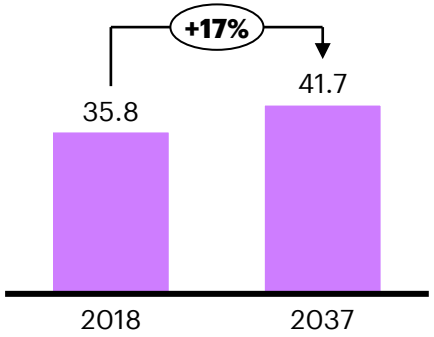
Source(s): IEA Global Data Explorer, EVAT Thailand, Thailand Automotive Industry Ministry

Market Analysis Insights

We have identified four key insights for Thailand based on the base case in the PDP 2018 Rev.1 as well as other market data sources. They form foundation for analysis and solutioning.

1. Coal continues to be added and dependence on Gas remains high even in 2037

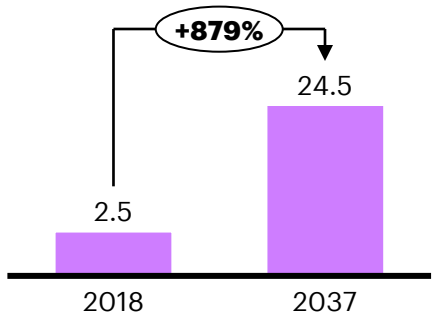
PDP 2018 Coal Generation Volume (TWh)



- **Coal generation to increase by 17%** from 2018 to 2037.
- However, more aggressive coal switching is likely given Paris Agreement global coal phaseouts (e.g. Climate Analytics modelled **non-OECD Asia to phase out coal by 2037**)
- Share of Gas in Generation remains significantly high at 54% in 2037

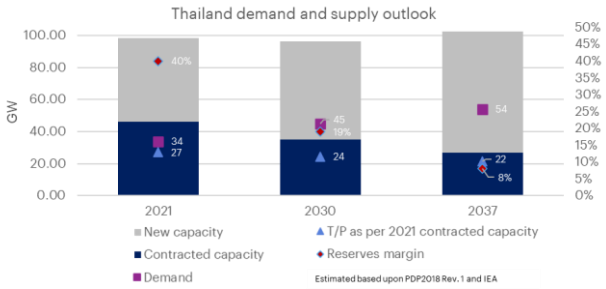
2. Solar constitutes small portion despite significant potential and competitiveness

PDP 2018 Solar Generation Volume (TWh)



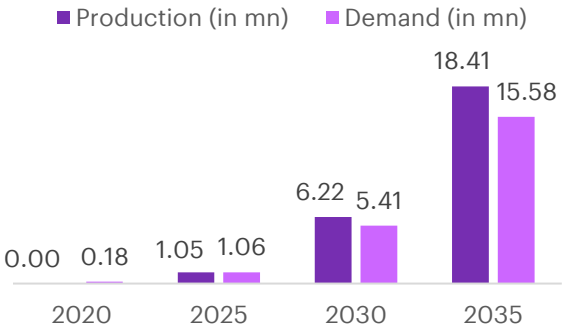
- **Solar constitutes only 7%** of **generation in 2037** despite significant potential.
- **Revised PDP does not break down Solar capacity target** by type, except for 2.7GW of floating solar targeted to be added by 2037.
- While **current policy focuses** on **Residential Rooftop** PV, **uptake** has been very **slow.**

3. Good technical Flexibility and high reserves margin to accommodate VRE



- Thailand grid infrastructure overall is at a very high level of flexibility in terms of **high reserves at 40%** in 2021 down to 8% in 2037. (international standards ~10-15%)
- However, challenges lie in commercial structure.

4. Ambitious targets for EV adoption and production by 2035



- Thailand targets **15 million EVs on the road** and a **production of 18.41 million** units **by 2035**.
- Target to have **50% of automobiles manufactured as EVs** while current proportion is **only 0.03%** (~550 EVs produced till 2020).
- The current penetration of EVs is just 0.18 million **(1%** of motorized vehicles)
- While the policy targets are quite ambitious, the slow uptake at present shows adoption is challenging path.

Source(s): Thailand Power Development Plan 2018 – 2037 (Revision 1); IRENA RE Outlook: Thailand (2017); Climate Analytics: Global and regional coal phase-out requirements of the Paris Agreement; Accenture Analysis

Key Question

How might Thailand realign its energy mix to achieve its energy transition targets?

1. Replace new coal with Utility-scale Solar

With high solar irradiance and high existing system flexibility, Thailand can set much more aggressive Solar targets. With a 'No new Coal' policy, Utility-scale Solar, both ground-mounted & floating, can replace generation from planned new coal capacity, reaching 14% VRE by 2037 without the need for Storage

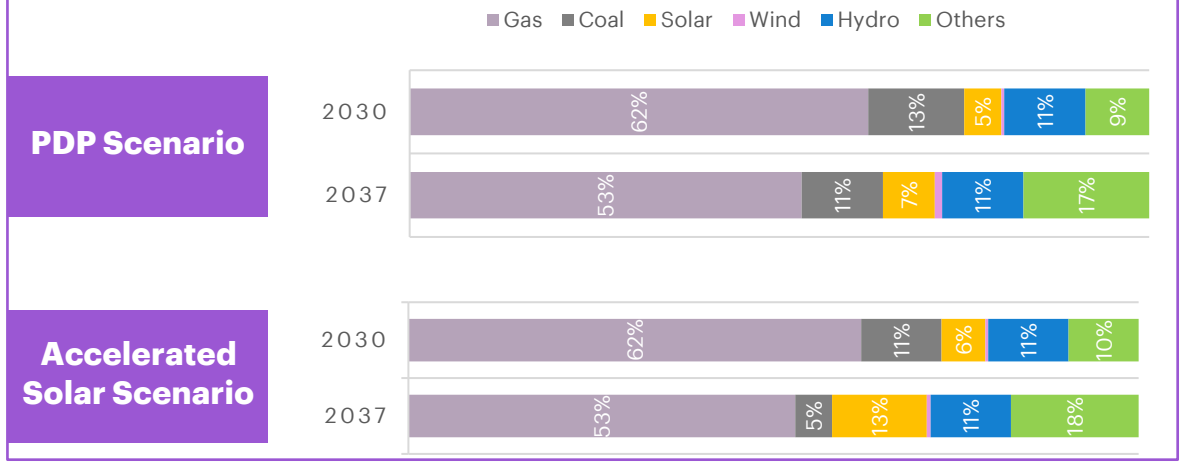
Overview

- Current **overcapacity** in the system is a **major barrier to Solar investment** with **reserve margin** currently ~**40%.** The PDP outlines plans for adding **1.2GW** & **2GW of coal** plants by **2030** & **2037,** respectively.
- With growing consensus on need for immediate halting of new coal for a Net Zero future, all the planned **new coal capacity could be replaced** instead **with Solar.**
- In this **proposed case**, Solar would constitute **6% of generation in 2030 & 13% in 2037,** corresponding to additional 2.6 GW & 12.3 GW of Utility-scale solar. **These levels can be integrated without storage due to high technical flexibility of the existing grid.**
- **Utility-scale Solar PV** is at **price parity with Gas and expected to be at par with Coal soon.**
- With **existing coal plants** planned to operate at **full capacity** in the PDP period, **replacing new Coal capacity with Solar** will lead to a **corresponding shift in generation** to Solar.

Opportunity

- A **'No new coal' policy** would allow proposed additional **Solar generation to replace planned generation from Coal** while encouraging investments in new Solar capacity.
- Incorporating **advanced VRE forecasts** in load dispatch and having **dedicated Renewable Energy Control Centers**, would be cost-effective **accelerators** to support **integration of higher levels of Solar** at existing levels of system flexibility.
- Providing **priority access for RE investments** and **scaling down investment incentives** for **fossil fuel generation** could be policy initiatives in the short & medium term to help reclaim Thailand's RE leadership status in SEA in the face of **growing attractiveness** of **other RE markets** like **Vietnam**.
- With most of **competitive Solar** located in **North East & Central** regions and most of the **coal** in **the North & Central regions**, increasing Solar generation at the cost of Coal will require **revising transmission network & interconnection expansion plans.**
- Phased **mothballing** of **existing coal plants** with the ability to call them into operation with advance notice of up to 6 months, as is being done in Germany & Japan, could further accelerate coal phase out in the longer term while **maintaining** required **Reserves margin.**

Generation Mix in Base & Accelerated Scenario



System Value Impacts - Benefits

CO2 emissions

↓ 127 MMT

Cumulative CO_2 emissions reduction between 2022-2037 compared to PDP case

Water footprint

↓ 210 bn L

Cumulative reduction of water consumption between 2022-2037 compared to PDP case

Job impact

↑ 88 K

Cumulative job increase between 2022-2037 compared to PDP case

↓ **12K** *lesser jobs in coal /gas*

↑ **100K** *more jobs in Solar*

Air quality & health

↑ $2 bn

Human health benefits between 2022-2037 compared to PDP case

Source(s): PDP; IEA; EGAT Thailand Transmission Planning Perspective; Wood Mackenzie Report – Battle for 2050; Accenture Research; Bloomberg NEF

Note(s): Solution 1-3 are step solutions where impact is calculated cumulatively. For example, impact indicated in 2(a) are the result of implementing solution 1, 2(a) and 2(b).

2(a). Contractual flexibility in both PPA & fuel supply + Solar

In order to allow higher VRE penetration without curtailment, contract restructuring is required both in power and fuel supply.

Overview

Energy transition will result in more RE. Recent focus has been placed on **VRE, i.e., wind and solar**, due to **rapidly decreasing cost** of these technologies. Thailand's grid infrastructure overall has high levels of technical flexibility in terms of reserves, minimum stable load (MSL), ramp rate and start-up time. Several studies have found that **15-18% VRE is technically feasible** in the grid, helped by a good share of hydropower & CCGT in the capacity mix, in terms of both power and ramp rate requirement across different time scales. However, the **bottleneck lies in contractual structures** (power and gas supply) due to **minimum take-or-pay** clauses, restricting cost-optimized dispatchability.

Opportunity

Due to existing high minimum take-or-pay and inflexible gas supply contracts, dispatch is not based on merit order or cost-optimized. Reforming commercial and contractual structures would allow current assets to be operated/dispatched more flexibly and cost effectively.

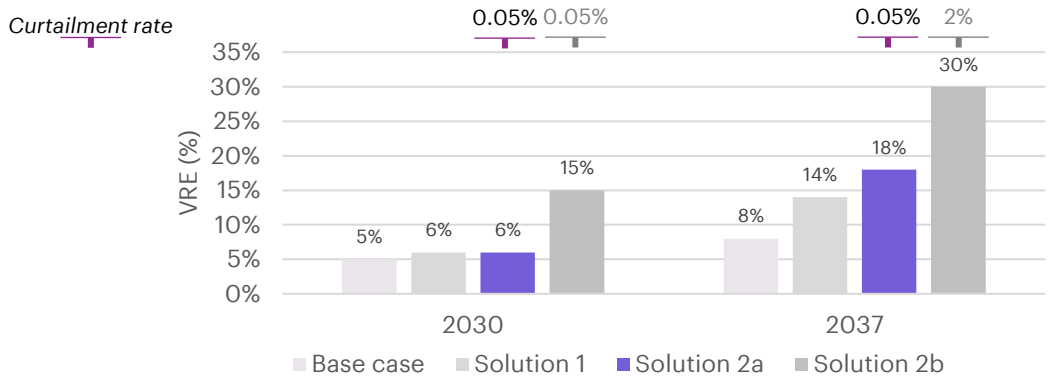
a) Existing fuel and power contracts can be renegotiated for **longer observation period**. Authorities may introduce dynamic adder and reduction to the non-RE energy payment **upon the RE seasonal potential** using nonprofit fund or other means. This would automatically incentivize power plants to sell the electricity during RE low production season.

b) All new power (hydro & CGGT) and gas/LNG contracts should be termed with:
   - i. **longer observation period**, e.g., quarterly or annually so that optimum dispatch is allowed.
   - ii. **Lower minimum take-or-pay**, on domestic power plants and hydro import.
   - iii. **Balancing long-short term gas/LNG Portfolio procurement** to allow greater flexibility and equilibrium of flex-cost-security.

c) Promotion of **grid third-party-access, bilateral contract** and higher level of **decentralized market**, e.g., market liberalization/wholesale market/short-term markets.

With bottleneck relieved, Thailand could replace 2.4 GW of new gas with solar, enabling **18% VRE** (17% solar or 35 GW) penetration by 2037.

VRE penetration for proposed scenarios



System Value Impacts - Benefits

CO2 emissions

141 MMT

Cumulative CO_2 emissions reduction between 2022-2037 compared to PDP case

Water footprint

232 bn L

Cumulative reduction of water consumption between 2022-2037 compared to PDP case

Job impact

109 K

Cumulative job increase between 2022-2037 compared to PDP case

↓ **15K** *less jobs in coal/gas*

↑ **124K** *more jobs in Solar*

Air quality & health

$2.2 bn

Human health benefits between 2022-2037 compared to PDP case

Source(s): IEA, EGAT Thailand Transmission Planning Perspective; ASEAN Energy Market Integration (AEMI); Thomson Reuters: Practical Law; TenneT

Note(s): Fuel price assumptions are: coal (USD 23 per MWh), natural gas (USD 60 per MWh) and oil (USD 80 per MWh);
Solution 1-3 are step solutions where impact is calculated cumulatively. For example, impact indicated in 2(a) are the result of implementing solution 1, 2(a) and 2(b).

2(b). Interconnection and Storage + Solar

Upon implementation of interconnection and/or storage, more solar can be utilized, replacing some of the planned new Gas.

Overview

- To accelerate energy transition, **storage and/or interconnection** is required **to avoid congestion and curtailment.**
- As of 2021, **Laos-Thailand-Malaysia 100 MW interconnection** pilot project (the 1st phase of LTMS-PIP[1]) is on-going with further plan to expand to Singapore.
- Currently (2021), 1 GW PSH capacity is in place, with 500 MW planned (PDP2018 Rev. 1).
- Thailand's **generation mix** has **high dependence on Gas** at **63% (2021)** and will remain **53% in 2037.** PDP[2] outlines plans for adding **15GW of new gas capacity** in 2018 – 2030 and additional 5GW by 2037. More power import is expected for both for domestic consumption (depleting gas reserves) and to serve Thailand as ASEAN electricity hub.
- **Solar + Storage** is expected to achieve **price parity with Gas** in Thailand as early as **2023.**

Opportunity

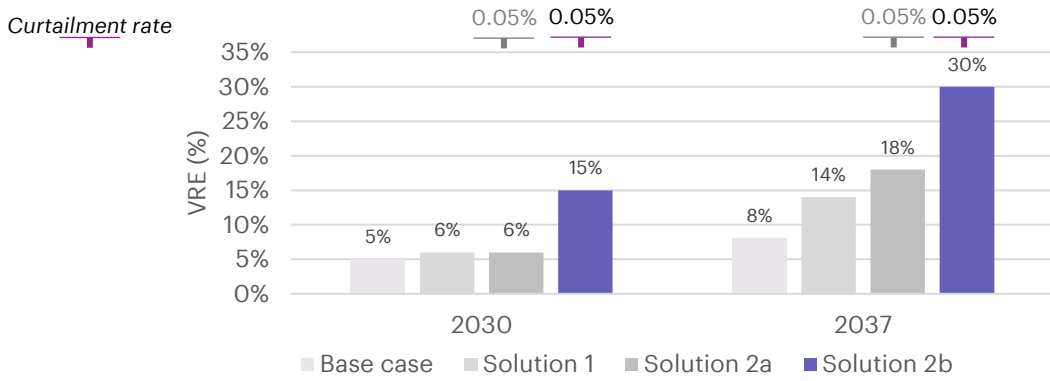
a) With **interregional** (within Thailand)**/international interconnections**, power dispatch can be more flexibly managed, **reducing transmission congestion**. More, Pumped Storage Hydropower (PSH) resources could be internationally shared, esp. by Laos.

International interconnection is a key strategy for Thailand to be ASEAN electricity hub. Thailand must accelerate this initiative, despite several various **political, technical and institutional minimum requirements.**

b) Upon **NE** region being the highest potential area for VRE, **Storage up to 9.6 GW** could be installed in these regions. This would partly substitute capacity and network reinforcement investment. Utility scale Solar + Storage is expected to reach price parity with Gas in 2023, with coal in 2043. While Thailand has **significant** domestic PSH potential, local resistance could be a challenge with 1/3rd population involved in agriculture. Therefore, **BESS** investment could play a **key role in flexibility enhancement** and **long-term capacity expansion.** Enablers for storage include investment incentives and regulatory framework.

Additional flexibility would allow system to accommodate **up to 30% VRE** (~60 GW Solar) by 2037. For this, Solar capacity must grow aggressively @18% CAGR. Interconnection & storage up to 9.6 GW will absorb curtailment and congestion. With this, good reserves margin (9-23% at 2037) is maintained.

VRE penetration for proposed scenarios



System Value Impacts - Benefits

CO2 emissions

↓ 315 MMT

Cumulative CO_2 emissions reduction between 2022-2037 compared to PDP case

Water footprint

↓ 487 bn L

Cumulative reduction of water consumption between 2022-2037 compared to PDP case

Job impact

↑ 358 K

Cumulative job increase between 2022-2037 compared to PDP case

↓ ***41K*** *less jobs in coal /gas*

↑ ***400K*** *more jobs in Solar*

Air quality & health

↑ $2.6 bn

Human health benefits between 2022-2037 compared to PDP case

Source(s): IEA, EGAT Thailand Transmission Planning Perspective; ASEAN Energy Market Integration (AEMI); Thomson Reuters: Practical Law; TenneT

Note(s): 1-LTMS-PIP (Laos, Thailand, Malaysia and Singapore Power Integration Project); 2-PDP2018 Rev. 1; 3-Sol 2(b) assumes storage could supply peak demand at 50% of its capacity; Fuel price assumptions are: coal (USD 23 per MWh), natural gas (USD 60 per MWh) and oil (USD 80 per MWh); Solution 1-3 are step solutions where impact is calculated cumulatively. For example, impact indicated in 2(a) are the result of implementing solution 1, 2(a) and 2(b).

Summary of solutions 1 and 2

Solution 1 (Replace planned new Coal with Solar)

By 2030

With planned new coal of 0.6 GW in the PDP, solution 1 suggests eliminating it from the plan with corresponding additional supply by utility-scale solar of 2.6 GW.

By 2037

With planned new coal of 2 GW (between 2031 – 2037), solution 1 suggests to further eliminate this. The corresponding demand can be supplied by additional utility-scale solar of 9.7 GW.

Scenario	Year	Coal		Gas		Solar		VRE	Curtailment rate	Reserves Margin[1]
		+/-	Total	+/-	Total	+/-	Total			
Base case	2030	-	4.85	-	33.22	-	7.94	5%	0.05%	14-19%
	2037	-	4.84	-	32.11	-	14.75	8%	0.05%	2-8%
Solution 1	2030	-0.6	4.25	-	33.22	2.6	10.57	6%	0.05%	15-20-21%
	2037	-2.6	2.24	-	32.11	12.3	27.09	14%	0.05%	6-13-15%
Solution 2(a)	2030	-	4.25	-	33.22	-	10.57	6%	0.05%	15-20-21%
	2037	-	2.24	-2.4	29.71	8.1	35.17	18%	2%	8-15-18%
Solution 2(b)	2030	-	4.25	-4.7	28.48	14.8	25.35	15%	0.05%	19-24-27%
	2037	-	2.24	-9.6	22.47	24.4	59.54	30%	0.05%	9-16-23%

+/-: Cumulative additional or reduction from **new** gas/coal/solar; Unit: GW

Solution 2(a) (Contractual flexibility)

By 2030

Existing fuel and power contracts could be renegotiated for longer observation period. For any new contracts, it is suggested to keep longer observation period and have low Take or Pay (T/P) levels.

By 2037

The room between demand and T/P (as of 2021) will be 33 GW and is expected to increase as a result of the above action (if implemented). For any new contracts, solution 2(a) suggests to keep lower Take or Pay (T/P) levels to allow dispatch of additional 8.1 GW solar capacity on top while reducing 2.4 GW of new Gas capacity from the PDP plan.

Solution 2(b) (Interconnection and Storage)

By 2030

Solution 2(b) suggests addition of 14.8 GW utility solar while reducing planned new gas by 4.7 GW. The development of interconnection and storage will help reduce curtailment levels arising from interregional bottlenecks and gap between daily local peak demand/supply.

By 2037

Solution 2(b) suggests addition of 9.6 GW utility solar GW (between 2031 – 2037) while reducing new gas by 4.9 GW in this period. Further, development of interconnection and storage up to 9.6 GW will help reduce curtailment arising from any interregional bottlenecks and gap between daily local peak demand/supply.

Note(s): 1-Reserves Margin decreases due to new gas/coal reduction from the plan, and increases with added utility solar. This does not account the storage implementation which would result in higher reserves margin. Reserves Margin is estimated based upon published dependability in PDP2018 Rev.1. (low-mid-high: dependability-low capacity & dependability-low added solar – dependability-high capacity & dependability-low added solar – dependability-high & dependability-high added solar); 2-Sol 2(b) assumes storage could supply the peak demand at 50% of its capacity.

3(a). Leveraging Industrial Clusters to build sustainable ecosystems

Thailand could leverage its existing Industrial Estate ecosystem to transform its industrial zones to sustainable industrial communities. The Eco Industrial Town program aims to achieve more sustainable industrial development, but more could be done to leverage these efforts to achieve climate change goals

Overview

- **Industrial Clusters** help deployment of **low-carbon technologies** by enabling **sharing of risks & resources** and harnessing potential **synergies** of **co-located plants**.
- **Industrial CO_2 emissions** account for about **30%** of Thailand's total emissions. With Thailand's high annual emissions growth rate of 10% in the past 2 decades being attributed to **rapid industrialization**, the share of Industrial emissions is expected to go up further.
- About **36%** of Thailand's Industrial Emissions are from **Light Industries** such as Food & beverages, Textiles & clothing, Wood & furniture, Paper & printing etc.
- Thailand has a **robust Industrial Estate ecosystem** and an integrated sustainability program – **the Eco-Industrial Town program** – to drive sustainability in Industrial Estates.
- Of the **4 solution groups** of the **Industrial Cluster framework**, the **EIT program** currently **focuses** on **Circularity & Waste Management** and driving **RE use** in Industrial Estates.
- While Thailand has a **pilot 1.2 MW Wind-Hydrogen** project, Green Hydrogen is expected to be **commercially feasible only in the long term** with cost of green hydrogen currently being 2-3 time of blue/brown hydrogen

Opportunity

- The EIT program currently **lacks specific & measurable environmental** targets**, especially in linkage with national climate change goals.** The program could be **integrated with Thailand's** larger efforts under its **National Determined Contributions.**
- The program could be expanded to set **commitments for industrial clusters** to achieve **Net Zero** within a **specified timelines,** in line with Thailand's national net zero targets.
- **Electrification** of **light industries** and using **on-site generated or PPA-based renewable energy** to power processes, could be another area of focus under the EIT program.
- **Rooftop PV** and **Corporate PPAs** could be **focused initiatives** under the **EIT program helped by regulatory support,** given that the C&I segment has shown **high adoption propensity** for **Solar PV** and has **45% power consumption share** in Thailand.
- With **Carbon Border Tax** planned in the **EU from 2026** & proposed in other developed economies as well, **emission reduction** could become a **priority for exporting industries**.

Net Zero Solution Framework for Industrial Clusters

1. Systemic efficiency and circularity

Increase circularity via cross-entity waste utilization. Integrate processes to share energy, material streams, and provide cost-effective benefits.

2. Direct electrification and renewable heat

Electrify low-to-medium temperature and pressure processes. Generate low-cost, renewable electricity and heat onsite and pursue shared infrastructure.

3. Carbon capture, utilization and storage

Capture carbon from energy/hydrogen production and use for industrial and manufacturing processes

4. Hydrogen

Produce low-to-zero-carbon hydrogen economically. Use as alternative fuel and for storage/grid balancing.

System Value Impacts - Benefits

CO2 emissions	Water footprint	Resiliency & Security	FDI
↓ **145MMT** Cumulative CO_2 emissions reduction between 2022-2037 compared to PDP case	↓ **87 bn L** Reduced water footprint through shared waste-water recycling infrastructure	↑ Reduced reliance on imported energy supply through on-site RE farms and microgrids	↑ Net-zero clusters attract FDI benefitting from the cluster's integrated partnership approach

Source(s): IEA, IEAT, BOI, EPPO, Accenture Reseearch

3(b). Setting up Electric Vehicle Manufacturing Clusters

As Thailand aims to become the EV Hub in ASEAN, it requires transition to EV manufacturing, scaling up production with a focus on circular economy and clean energy use for its supply chain and value chain

Overview

- Thailand, a globally leading automotive producer, plans on becoming ASEAN's EV manufacturing hub producing **18 million EVs** by 2035. Automotive & logistics has been a priority investment area in its Industrial clusters. But with current production (only ~550 EVs manufactured domestically till 2020) **lagging far behind the desired state**, it requires large scale investments in manufacturing capabilities & charging stations.
- The massive deployment of EVs globally is also raising **concerns around the sustainability** of practices including **availability of minerals** needed for the batteries, the **ability to reuse and recycle existing batteries**, potential human rights and **environmental threats** associated with mineral extraction and production.

Opportunity

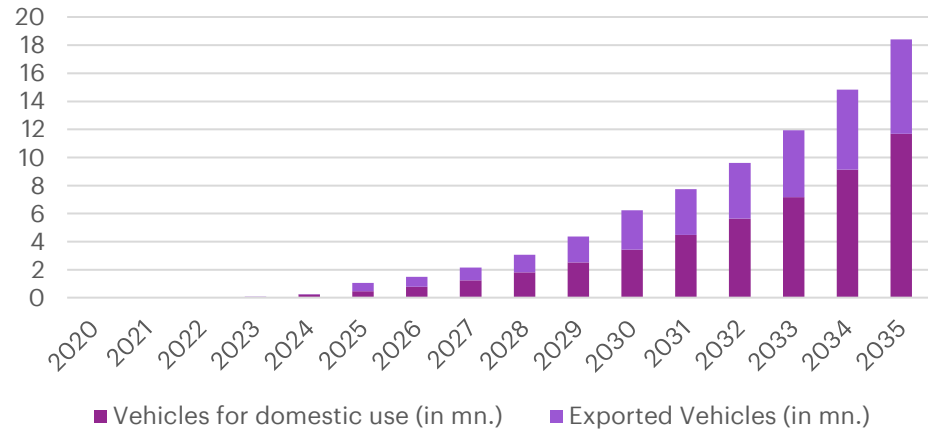
Scaling up EV manufacturing

1. **Attracting Investments for Local EV Manufacturing:** Thailand needs to generate both local and foreign investments in e-mobility. It must attract FDI for knowledge transfer (reskilling employees) or import of EVs (to accelerate consumer adoption) and provide financial (tax) incentives to encourage PE/VCs to **invest in e-mobility start-ups.**
2. **Gradual phasing-in of import taxes/duties:** Setting the initial import taxes to 0% would incentivize investment in the EV ecosystem in early years. Larger financial incentives for local manufacturers for this time would boost domestic manufacturing. Once local EV manufacturing is at a competitive level, import taxes can gradually be phased in.
3. **Mandates for existing automakers to produce a given percentage of EVs.** It could also enforce taxes based on vehicles' energy efficiency, performance, cost competitiveness

Developing and enforcing a sustainable value chain

1. **Circular economy design:** Industry leaders could design batteries proactively for disassembly (enabling recycling and reuse). Focus from industry leaders, govt. to build regional infrastructure/regulatory certainty for battery recycling & transportation
2. **Industry-wide sustainability standards:** Eco-industrial standards as minimum to ensure greater applicability of industry-defined sustainability best practices across the EV value chain; Govt. to support through financial incentives for follow-up on initiatives
3. **Powering with clean energy:** Establishing responsible manufacturing plants for EVs powered by clean energy sources like solar to minimize CO_2 footprint of the process

EV Manufacturing Targets: Domestic Use and Exports



System Value Impacts - Benefits

CO2 emissions	Water footprint	Job impact	Air quality & health
↑ **9 MMT**	↑ **44 bn L**	↑ **843 K**	↑ **$0.08 bn**
Cumulative CO2 emissions reduction between 2022-2035	Cumulative increase in water consumption between 2022-2035	Cumulative job increase between 2022-2037 from new jobs created or reskilling ICE related employees	Human health benefits between 2022-2035

Source(s): IEA, EVAT Thailand Electric Vehicle Outlook 2021; NRGI USA

4. Drive Electric Vehicle Adoption

For Thailand to bring the desired number of EVs on the road, it needs focus on reducing the total cost of ownership and improving consumer perception, building sufficient charging capacity while minimizing negative impact on the grid

Overview

Thailand plans on bringing in an ambitious target of **15 million EVs on the road by 2035** with only ZEVs being sold from 2035 onwards. At present, there are 210,000 EVs in a total of ~42 million vehicles. To achieve this target, Thailand must focus on Reduction of the Total Cost of Ownership and building sufficient EV Charging/Support Infrastructure with minimum negative Grid Impact.

Existing measures announced by the government include financial incentives like R&D investments, tax exemptions (registration tax, road tax, VAT), clean vehicle conversion rebates and rebates on setting up charging stations.

Opportunity

Reducing Total Cost of Ownership and Improving Consumer Perception

- Thailand has an existing Free Trade Agreement (FTA) with China (hence, import tax for China is 0%). Policy to **reduce import tax and excise duty to 0%** for other countries will reduce the current purchase cost.
- The revenue lost would not be significant since the number of imported EVs being imported at present is not very high. Increasing the taxes on **new** ICEs (import/excise tax, VAT) could compensate this loss while encouraging switching to EVs
- Gradual **phase-in of import tax** would allow EV uptake while supporting competitiveness
- **Soft loans for EV purchase** could also help increase affordability of EVs for the public

Financing and Development of EV Charging Infrastructure

- **~215,000** public charging points to encourage adoption
- Interoperable charging points: standard operating guidelines**, roaming** b/w operators
- **Financial Incentives for Investors:** Subsidizing charging station investment, preferential electricity selling rates for charging stations, renting public space at lower cost to build charging stations, and the use of a **"stop-loss mechanism"** where the state compensates the private investors for losses incurred beyond a certain level
- Building an EV ecosystem requires initiatives by **govt., service providers & consumers**

Reduction of EV Impact on Grid

- In the long run, this could be managed by setting up **ToU regulation** and use of **Smart chargers** responding to ToU. This would efficiently enable V2G and VRE management. EVs would then help **reduce curtailment, balance the grid, manage grid congestions.**

Impact of Solutions for EV Adoption

Annual savings in TCO on purchase of an electric car v/s an ICE

~ 154,000 baht

Peak load and grid investments down by nearly

90%

Number of projected Public Charging points by 2035

215,000 points

Projected Available Capacity from Public Charging in 2035

17 GW

System Value Impacts - Benefits

CO2 emissions

215 MMt

Cumulative CO_2 emissions reduction between 2022-2037 compared to PDP case

Water footprint

6 bn L

Cumulative increase of water consumption between 2022-2037 compared to PDP case

Air quality & health

$0.03 bn

Human health benefits between 2022-2037 compared to PDP case

Source(s): IEA, EVAT Thailand Electric Vehicle Outlook 2021; IEA Global EV Outlook 2020;

Acknowledgement | Thailand System Value Analysis Peer Reviewers

	Company	Peer Reviewer
1	**EGAT**	Warit Rattanachuen, Dr. Thanawat Nakawiro
2	**IVL**	Sunil Fotedar, Jom Madan, PC Kamar, Thana Amornsirinukroh
3	**PEA**	K. Pradit Fuangfoo
4	**PTT**	Waraporn Witthayasinthana, Paramate Hoisungwan, Supreeya Virakul Wattanasuttiwong, Ake Piyamaikongdech
5	**SCG**	Thammasak Sethaudom, Attapong Sathitmanothum, Dr. Kriengkrai Suksankraisorn, Samarnorn Jariyawiroj

Thank you