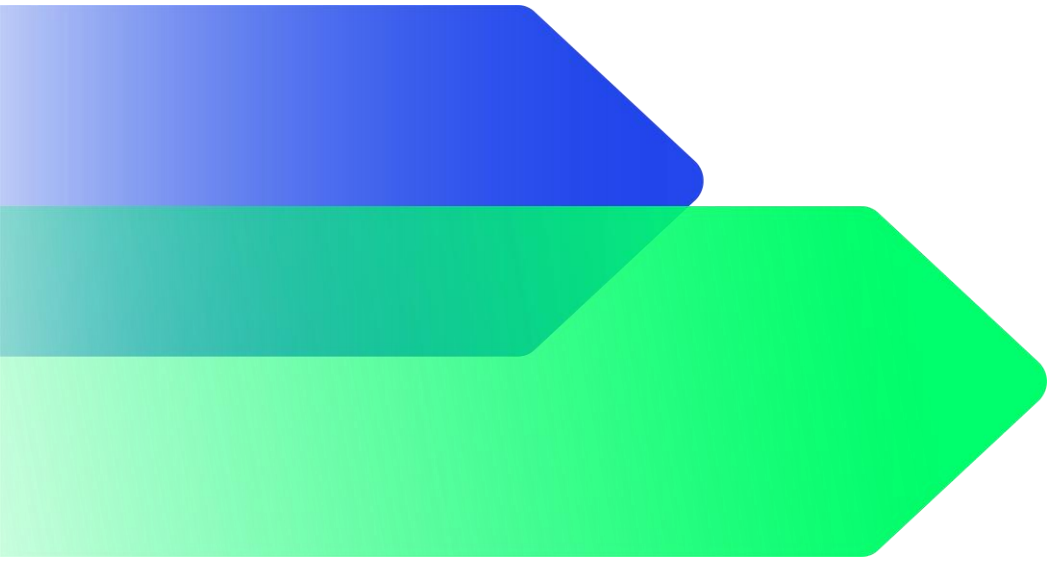
Foreign, Commonwealth & Development Office

REPORT

Roadmap for Thailand's Renewable Energy Ambition

March 2022



Acknowledgments

The Carbon Trust wrote this report based on an impartial analysis of primary and secondary sources, including expert interviews.

The Carbon Trust would like to thank everyone that has contributed their time and expertise during the preparation and completion of this report.

This report has been commissioned by South Asia Research Hub, Foreign, Commonwealth and Development Office, Government of United Kingdom. However, the views expressed in the report do not necessarily reflect the official policies of the Government of United Kingdom.

Who we are

We are a trusted, expert guide to Net Zero, bringing purpose led, vital expertise from the climate change frontline. We have been pioneering decarbonisation for more than 20 years for businesses, governments, and organisations around the world.

We draw on the experience of over 300 experts internationally, accelerating progress and providing solutions to this existential crisis. We have supported over 3,000 organisations in 50 countries with their climate action planning, collaborating with 150+ partners in setting science-based targets, and supporting cities across 5 continents on the journey to Net Zero.

The Carbon Trust's mission is to accelerate the move to a decarbonised future.

Authors

The Carbon Trust

Mauricio Riveros Senior Manager

Aurore Penillard Senior Associate

Hazim Rosli Associate

Natalie Tay Analyst

Rhys Watt Analyst

The Carbon Trust collaborated with Creagy Co. Ltd in the delivery of this project. The Creagy team include:

Boonrod Yaowapruek Director

Kannikar Srithunyalucksana Senior Manager

Nontaya Kraikish Senior Manager

Kornkanok Laoprasertsuk Senior Consultant

Preechaya Rassadanukul Consultant

Contents

Tables

Figures

Abbreviations

ADB	Asian Development Bank
ADE	Association for Decentralised Energy (United Kingdom)
AEDP	Alternative Energy Development Plan
ASEAN	Association of South East Asian Nations
BAU	Business-as-Usual
BEIS	Department for Business, Enterprise, and Industrial Strategy (United Kingdom, Ministry of Energy)
BESS	Battery Energy Storage Systems
BOT	Bank of Thailand
CCC	Climate Change Committee (United Kingdom)
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
COP26	Conference of Parties, 26th edition
DEDE	Department of Alternative Energy Development and Efficiency
DNO	Distributed Network Operators
DPA	Dispatchable Power Agreement
DSO	Distribution Systems Operator
DSR	Demand Side Response
EA	Energy Absolute Public Company Limited
EEC	Eastern Economic Corridor
EEP	Energy Efficiency Plan
EGAT	Electricity Generating Authority of Thailand
EGCO	Electricity Generating Company
EHRDD	Energy Human Resource Development Division
ENTEC	National Energy Technology Centre
EPPO	Energy Policy and Planning Office
ERC	Energy Regulatory Commission
ERI	Energy Research Institute, Chulalongkorn University
ESB	Enhanced Single Buyer
ESC	Electricity Settlements Company
ESO	Electricity System Operator
ESS	Energy Storage Systems
ETP	Energy Trading Platform
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric Vehicles
FCDO	Foreign, Commonwealth and Development Office
FCO	Foreign and Commonwealth Office (erstwhile name of FCDO prior to merger with the Department for International Development)
FiT	Feed-in Tariff
FTI	Federation of Thai Industries
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GO	Guarantees of Origin

GPSC	Global Power Synergy Public Company Limited
GW	Gigawatt
ICT	Information and Communications Technology
IEA	International Energy Agency
IEAT	Industrial Estate Authority of Thailand
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
KMUTT	King Mongkutt University of Technology
KPI	Key Performance Indicator
LCCC	Low Carbon Contracts Company (United Kingdom)
LCOE	Levelised Cost of Energy
LT-LEDS	Long Term Low Emissions Development Strategy
MEA	Metropolitan Electricity Authority
MM	Market mechanisms
MOU	Memorandum of Understanding
NEP	National Energy Plan
NEPC	National Energy Policy Council
NETA	New Electricity Trading Arrangements
NETP	National Energy Trading Platform
NG ESO	National Grid Electricity Systems Operator
NSTDA	National Science and Technology Development Agency
ONEP	Office of Natural Resources and Environmental Policy
OTP	Office of Transport Policy and Planning
P&R	Policy and Regulation
P2P	Peer-to-Peer
PDP	Power Development Plan
PDU	Professional Development Units
PEA	Provincial Electricity Authority
PPA	Power Purchase Agreement
PV	Photovoltaics
R&D	Research and Development
RE	Renewable Energy
REC	Renewable Energy Certificate
REGO	Renewable Energy Guarantee of Origins (UK)
RES	Renewable Energy Sources
RETA	Regulatory Energy Transition Accelerator (UK)
RO	Renewable Obligation
ROC	Renewable Obligation Certificates
SEG	Smart Export Guarantee
SET	Stock Exchange of Thailand
SME	Small and Medium-sized Enterprises
SPP	Small Power Producers
SSEN	Scottish and Southern Networks
TDRI	Thailand Development Research Institute
TGO	Thailand Greenhouse Gas Management Organisation
TSO	Transmission System Operator
UK	United Kingdom
UKIB	UK Infrastructure Bank

UKRI	UK Research and Innovation
UNFCCC	United Nations Framework Convention on Climate Change
VALCOE	Value-adjusted Levelized Cost of Electricity
VISTEC	Vidyasirimedhi Institute of Science and Technology
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
VSPP	Very Small Power Producer
4D1E	Digitalization, Deregulation, Decarbonisation, Decentralization and Electrification

Executive Summary

Introduction

Thailand aims to boost the proportion of renewable energy in new power generation

Thailand's National Energy Plan (NEP), announced in August 2021, has set the target of achieving 50% of renewables share in new power capacity in support of the country's ambition of achieving carbon neutrality sometime within 2065-2070. Contributing more than 70% of the country's total greenhouse gas (GHG) emissions, the energy sector must take a leading role in Thailand's decarbonisation efforts.

However, at the United Nations Climate Change Conference of Parties (COP26) in Glasgow in November 2021, the Prime Minister of Thailand Prayut Chan-O-Cha announced that Thailand will be raising its ambition, aiming to be carbon neutral by 2050 and achieve net zero GHG emissions by 2065. The NEP was developed prior to the announcement at COP26. Therefore, it remains to be seen whether the 50% of renewables share in new power capacity target will be similarly brought forward to meet the new timeline for carbon neutrality. Regardless, it is clear that Thailand aims to boost the proportion of clean and renewable energy (RE) aggressively in new power generation.

While the overall objective is clear, there is no clear implementation plan to outline how the 50% share of renewable in new power capacity will be met. It is therefore crucial that a Roadmap of actions be developed to support updates to the Power Development Plan.

UK FCDO commissioned the development of a Roadmap to support the Power Development Plan

The Foreign, Commonwealth and Development Office of the United Kingdom commissioned the Carbon Trust and Creagy to support the development of this Roadmap. This Roadmap lays out recommendations that support Thailand to achieve the goal of 50% renewables share of new power capacity and is intended for government agencies in Thailand with power system-related responsibilities. It sets out the strategic actions and measures to be implemented over the immediate, short, medium and long-term timescales.

Methodology

Robust framework covering policy and regulations, market mechanisms, infrastructure innovation, and human capacity underpins the development of the Roadmap

A three-step methodology was undertaken to develop the roadmap. The steps and their overall aims are summarised as follows:

- Step 1: Characterisation of Thailand's Power System – to understand the current status of the power system
- Step 2: Opportunity identification – to identify challenges and develop a longlist of recommendations
- Step 3: Roadmap development – to phase and sequence longlist of recommendations

This methodology strongly relied on desk-based literature review and engagement with stakeholders, both in Thailand and internationally. The following lists the engagement activities and the stakeholders engaged:

- *Bilateral engagements with Thai stakeholders:* Energy Regulatory Commission (ERC), Energy Policy and Planning Office (EPPO), Department of Alternative Energy Development and Efficiency (DEDE), Electricity Generating Authority of Thailand (EGAT), Renewable Energy Club of the Federation of Thai Industries
- *Engagement at multi-stakeholder workshops:* In addition to those listed in the above bullet, workshop participants included state-owned enterprises (Metropolitan Electricity Authority, Provincial Electricity Authority), government agencies (Office of Natural Resources and Environmental Policy and Planning, Office of Transport Policy and Planning, Thailand GHG

Management Organisation), private sector (Symbior Solar, SCG Chemicals, Energy Absolute, and Gunkul Engineering) and academia (Energy Research Institute, Thammasat University).

- *Bilateral engagements with UK stakeholders:* Association for Decentralised Energy, National Grid, Scottish and Southern Energy Networks, and UK Research and Innovation).

A five-pillar framework was developed to systematically guide these three steps and frame the analysis. These pillars are:

1. Policy and Regulation**:** refers to the policy instruments and regulatory environment, including RE plan, as set out by the Thai government to promote and develop RE.
2. Market Mechanisms**:** refer to means of remunerating providers and consumers with an open and understood system of value and trade-offs to optimize distribution of power services in the most economically efficient manner.
3. Infrastructure: refers to physical infrastructure, such as transmission and distribution lines, battery storage, and virtual infrastructure such as a trading platform to facilitate and accommodate RE.
4. Innovation: considered at the system-level, covering enabling technologies, business models, regulations and market design to transform the power system.
5. Human Capacity: refers to the associated know-how and knowledge needs within the workforce of the power sector which will be important in ensuring successful implementation of the RE plans and measures.

Landscape for high share of renewable energy penetration in Thailand

Thailand has developed many plans to support its low carbon development. However these need to be revised to align with recent announcements at COP26.

Thailand has developed various energy and climate change plans include the Power Development Plan, Alternative Energy Development Plan, Thailand's Smart Grid, Development Masterplan and many others. These plans have lay out targets that the government aims to achieve typically over a 20-year timeframe. The National Energy Plan is new and aims at combining and integrating the various energy plans together. However, the targets and trajectories in all these plans must be reconsidered to ensure that they support the new carbon neutrality and net zero targets announced at COP26.

Some key measures to be included in the refreshed plans include actions that support the transition from the enhanced single buyer model to a decentralised one, regulatory amendments to allow private sector direct access to the grid, and development of market mechanisms.

While there are few market mechanisms in place at the moment, there is interest to develop this to facilitate private sector participation.

Adder and feed-in-tariff schemes have supported RE deployment in Thailand, with 9,330MW capacity registered as of January 2022. These schemes however target a small amount of deployment, with the remainder expected to be installed purely by achieving price parity. Other mechanisms are currently being explored including shifts towards a market-based approach. Financing RE projects is not a problem in Thailand for many large corporates, many of which have raised capitals through equities and green bonds. However, small and medium-sized corporates may face struggle to secure loans from financial institutions due to collateral issues.

There has been significant investment in behind-the-meter RE projects under the corporate power purchase agreements where the off-takers are corporates who want to increase their RE consumption. RECs have received increasing interest from private players, but it is unclear if they can drive the deployment of RE.

Infrastructure upgrades are being carried out both physically and virtually.

The transmission and distribution grid lines are being expanded. Other physical infrastructure improvements include development of RE forecast centres and RE-based micro grids in remote areas as a priority. Virtual platforms such as exchanges are also currently being explored.

Executive Summary

Many innovation activities are ongoing in Thailand, especially in new business models and the technologies such as energy systems storage and hydrogen.

ERC launched a sandbox programme to test new business models and new power system management that correspond with the National Energy Plan. The campaign was opened for project proposals in 5 areas: 1) new power market structure, 2) new tariff structure, 3) innovative technologies, 4) new models of power system operation and management, and 4) new energy business models. Many of these sandboxes had good outcomes but require scaling up to the national level to increase their impact. In addition to this, many innovation activities on virtual power plants, prosumer peer-to-peer trading, bioenergy and energy storage systems have been undertaken. Hydrogen is fast becoming a popular area of research in Thailand.

Training courses and degree programmes on RE and power systems are widely available. Nonetheless, more can be done to prepare the workforce to continually upgrade in the context of a fast-evolving power system.

There are many technical institutes, universities and programmes that build capacity in the workforce on various topics relating to the power system. These range from degree-granting programmes to professional courses covering RE and smart grids, for example. DEDE is also active in training the workforce on a wide range of topics relating to RE. However, more can be done to ensure that the skillsets of the domestic workforce remain relevant in a fast-changing power system.

Challenges & Recommendations

Policy & Regulations

Clarifying policy targets and trajectories, tailoring supporting policy instruments, fostering private sector participation through policy and regulatory changes, and developing policy guidance for market mechanisms to scale up synergies are recommended to guide Thailand's power system transition

Policy and regulations are fundamental to Thailand's power system transition. Policymakers set the target based on robust on scenario planning, from which various interventions are designed and implemented to support the target. Regulations are often formed or amended in support of policies, providing explicit specifications that guide the achievement of targets and boundaries within which market players operate.

The main policymaking and regulation setting actors in Thailand's power system are the National Energy Policy Council (NEPC), Energy Policy and Planning Office (EPPO) and the Energy Regulatory Commission (ERC). NEPC is the agency responsible for developing, managing and regulating national energy policy and makes the final decisions on all energy-related policies, plans and activities in Thailand. EPPO is an agency under the Ministry of Energy which acts as a secretariat to the NEPC, and recommends energy policies to the NEPC. It is also responsible for integrating, reviewing, monitoring, and evaluating the national policy and plans. ERC operates independently from the Ministry of Energy with guidance from the NEPC. ERC is the energy regulator and is responsible for regulating electricity tariffs, and power procurement, among others.

The policy and regulatory environment in Thailand needs to evolve to facilitate the integration of higher shares of RE. Through the characterisation of Thailand's power system, ambitions and engagement with stakeholders, several policy and regulation challenges have been identified:

1. **Uncertainties over the targets and trajectory to achieve targets.** Many plans relating to the power system have been developed but it is unclear how these plans align with one another. At COP26, Thailand announced its commitment to achieve carbon neutrality by 2050 and net zero GHG emissions by 2065. However, the NEP targets, released several months before COP26, were developed based on the previous targets where Thailand aimed to achieve carbon neutrality sometime between 2065 and 2070. PDP2018 (Rev.1) which covers plans up until 2037 need to be extended and updated to align with these new targets.

Additionally, existing targets in the NEP and PDP2018 (Rev.1) are in terms of installed capacity (in GW units). This leaves large uncertainties on the actual share of RE power generation as it does not account for capacity factors which affect RE sources and curtailment due to regulatory constraints.

2. **Concerns regarding the costs of transition.** The cost of achieving Thailand's RE target is not limited to the cost of developing RE assets. A high penetration of variable RE in the Thai energy system will imply costs to the underlying infrastructure supporting its operation. Stakeholder engagement revealed that there is no consensus on who should bear the costs of RE in Thailand. This uncertainty is detrimental to investor confidence, and adversely impacts Thailand's power system transition.
3. **Regulatory and contractual clauses impose constraints that deter private investments.** Current power purchase agreements (PPAs) with EGAT requires RE installations to either provide steady power generation by embedding energy storage in (in the case of firm PPAs) or to enter into non-firm PPAs where offtake volumes, and therefore revenue, are uncertain. Existing regulation also prohibit export of privately generated electricity from RE installations to the grid and impose a high wheeling charge for export through EGAT. These constraints increase the investment cost and risk premium of RE projects that deter further private investment.
4. **Limited avenues for remuneration for RE installations.** RE installations will only be built if project developers and owners are able to generate revenue. The current system organisation around the enhanced single buyer model and the lack of access to the grid mean that private RE projects cannot access purchasers of power to generate revenues. While prosumer participation has been recognised as a large enabler for RE deployment, it faces the same challenge as prosumers cannot be renumerated when there is surplus generation.

To address these challenges, four recommendations have been developed. They are:

- PR Recommendation 1 [PR1]: Develop trajectories towards the targets and elaborate on the means to achieve them
- PR Recommendation 2 [PR2]: Tailor support schemes to Thailand's ambitions
- PR Recommendation 3 [PR3]: Foster private sector participation: reduce constraints, develop revenue opportunities and maintain confidence
- PR Recommendation 4 [PR4]: Open and provide direction to markets to enable public-private synergies

PR1 will provide clarity for all actors in the system and set the basis for underlying actions. The trajectories are of immediate priority and thus phased in the immediate term but extends out to the short term to ensure that robust implementation plans are developed to support them. PR2 is dependent on investor confidence which will improve with clear plans. Thus, this is phased to commence in the middle of the immediate term after a clear trajectory has been set. Similarly, PR3 and PR4 are activities that follow after clear trajectories and plans have been developed. These are key to ensure the private sector participates in deploying RE. Table ES.1 summarises this timeline.

Table ES.1. Timescales for implementing policy and regulations recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
PR1				
PR2				
PR3				
PR4				

Executive Summary

Market Mechanism

Recommendations relating to the development of supporting frameworks, tailoring market mechanisms to need, formalising REC trading, facilitating the participation of distributed and small RE actors, contributing to the regional ASEAN Power Grid and integrating the power system to a potential carbon market are put forward to boost the deployment of RE.

Market mechanisms are tools to remunerate providers and consumers with an open system of value and trade-offs to optimize distribution of power services in the most economically efficient manner. The development of competition and markets in Thailand is a necessary step toward achieving Thailand's RE target as it will facilitate the participation of private actors in the power system.

The outcomes of market mechanisms will be directly driven by the participation conditions, product specifications and optimised market settlement. The design of market mechanisms will impact their contribution to Thailand's RE and decarbonisation targets. As introduced in the Policy and Regulation chapter, guidance by policymakers and regulatory frameworks is key in providing direction to the market mechanisms.

While there is a clear need for market mechanisms to open up competition, its development and implementation is complex. Several challenges linked to market mechanisms have been identified as part of Thailand's power system transition:

1. **Unclear path to opening the power markets.** A reform to the enhanced single buyer model, accompanied by clear policy and regulations is necessary to enable private players to compete on both the generation and supply sides. The transition from this model is currently unclear.
2. **Unclear outcomes of market mechanisms under development.** Market mechanisms can accelerate the deployment of RE installations. However, there are limitations. Market mechanisms may exclude technologies that are not yet cost-competitive, and revenues may sometimes be insufficient to improve the economics of certain RE technologies. Higher RE penetrations in the energy mix requires increased flexibility, however the design for flexibility markets remain an emerging effort globally.
3. **Development of an ASEAN-wide power market relies on the development and alignment of national markets.** Thailand has ambitions of being a power system hub in the ASEAN Power Grid. While the development of a regional market framework can provide benefits, the development of such an initiative will rely on cooperation between neighbouring markets and alignment of the policy and regulatory frameworks.
4. **Carbon pricing mechanisms impact assets and consumers' economics.** Several laws (Greenhouse Gas Reporting Law and Emission Trading System Law) have been developed to be considered for inclusion in Thailand's draft Climate Change Act. However, the official establishment of a carbon pricing mechanism is unclear, increasing the uncertainties relating to the economics of RE projects.

To address these challenges, six recommendations have been developed. They are:

- MM Recommendation 1 [MM1]: Establish guidelines, frameworks, and platforms to enable market development
- MM Recommendation 2 [MM2]: Develop tailored power market mechanisms for different purposes
- MM Recommendation 3 [MM3]: Formalise trading of renewable energy certificates
- MM Recommendation 4 [MM4]: Enable the participation of distributed and small actors
- MM Recommendation 5 [MM5]: Contribute to efforts seeking to develop markets at the regional scale
- MM Recommendation 6 [MM6]: Implement existing plans of developing a carbon market

Executive Summary

MM1 is a key foundational activity to be done in the immediate term as it could unlock the other recommendations. MM3 should also be undertaken in the immediate term as there are various trials and pilots on RECs that have been done; it now requires scaling up. MM2 involves identifying relevant market mechanisms and developing them. Studies to support their development should be done in the immediate term so that the market mechanisms can be implemented as soon as possible It is recommended to continue to the long term as continuous revisions are needed to ensure it accounts for new technologies, needs and actors. Enabling the participation of distributed and small actors should be implemented (MM4) in the short term once guidelines and frameworks on broader market mechanisms have been developed. Cooperating and aligning with nine other countries will be challenging. Coupled with Thailand's own power system transition, MM5 is phased as an activity in the medium term that will continue to the long term. Carbon markets (MM6) is an important tool that can reduce GHG emissions beyond the energy sector and is therefore a recommendation that should be implemented in the short term. It is recognised that Thailand has undertaken a lot of work on the topic and have drafted several laws to support its implementation. Table ES.2 summarises these timelines.

Table ES.2. Timescales for implementing market mechanism recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
MM1				
MM2				
MM3				
MM4				
MM5				
MM6				

Infrastructure

Thailand's power system infrastructure needs to offer increased flexibility, especially from existing assets, be planned through a whole-system view that ensures a fair distribution of cost and integrate digital tools

Substantial evolutions in Thailand's physical and virtual power system infrastructure are needed to ensure the system remains reliable with increasing RE integration. The grid infrastructure needs to be upgraded to connect with the RE installations and ensure the transport of electricity from generation to demand sites. As the RE installations are expected to be increasingly connected to the distribution grid, transformations in the operation of both the transmission and distribution networks in Thailand will be needed.

Digital tools will also need to be developed as part of infrastructure development. This is important to support greater access to data and improved communication that will be increasingly more important as the power system evolves and decentralises.

Infrastructure development is a key part of the power system transition. Several challenges linked to it have been identified:

1. **Present infrastructure operation has limited flexibility which can restrict variable RE deployment.** The present flexibility of the Thai power system, and in particular of existing large conventional assets, appears constrained due to both technical and contractual constraints. Independent power producers who wishes to install large RE installations can enter into firm PPAs with EGAT where their output to

the grid must remain steady despite the inherent variability of RE sources. RE installations that enter into non-firm PPAs will not have guaranteed offtake which will impact their viability.

2. **Existing infrastructure was not designed for a high share of variable, distributed RE.** Significant infrastructure development will be needed to maintain the stability and reliability of the grid, ensure the offtake, transport and supply of the RE generation from producers to consumers, and enable the participation of decentralised actors.

To address these challenges, three recommendations have been developed. They are:

- IF Recommendation 1 [IF1]: Increase flexibility from existing assets to facilitate penetration of renewable energy
- IF Recommendation 2 [IF2]: Characterise the infrastructure development needs and costs
- IF Recommendation 3 [IF3]: Enhance digitalisation to enable a grid operation with high penetration of distributed variable RE.

IF1 does not rely on significant infrastructure deployment and has the potential to significantly facilitate RE penetration. We recommend that it is implemented in the immediate term. IF2 includes actions to support the development of infrastructure that can support the power transition; therefore, it should be undertaken in the immediate to short terms. IF3 builds on activities introduced in Thailand's Smart Grid Master Plan and Grid Modernisation of Transmission and Distribution Plan. We concur with the Plans that these activities should be undertaken in the short to medium terms. Table ES.3 summarises the timescales for implementing these recommendations.

Table ES.3. Timescales for implementing infrastructure recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
IF1				
IF2				
IF3				

Innovation

Three recommendations focusing on prioritisation, raising existing efforts to the system-level and leveraging international partnerships are put forward to enhance the research, development and deployment ecosystem and environment for power systems innovation.

Innovation has driven cost reductions in key technologies such as solar and onshore wind globally, and has made solar energy a cost-competitive energy source in Thailand. Innovation is a continuous process which has no end point. Its focus must go beyond technologies, but to wider system components such as business models, regulation, system, and market design. Innovation can support Thailand's recovery from the Covid-19 pandemic while simultaneously helping increase Thailand's future competitiveness in international markets.

The main actors in Thailand's innovation system are the National Innovation Agency (NIA), National Science and Technological Development Agency, and the Thailand Research Fund. These agencies are collectively responsible for driving national innovation and accelerating science and technology, and providing the necessary funding for research, development, and deployment activities.

Executive Summary

Innovation underpins the country's Thailand 4.0 policy, which excludes energy and power system and themes related to it as a priority sector. This has led to several challenges for innovation:

1. **Institutional arrangement does not sufficiently facilitate coordination between various innovation actors.** Many different actors, including academia, public and private sector, are involved in energy and power systems innovation in Thailand. However, they tend to operate in siloes and rarely collaborate with one another. The NIA's is the lead innovation agency and has the responsibility of convening various innovation actors to co-create, test and demonstrate ideas. However, it appears that NIA has not taken such a role as energy and power systems is not deemed as a national priority innovation area, resulting in poor coordination between various innovation actors.
2. **Weak system-level approach to energy and power systems innovation.** While it is commendable that the scope of existing sandbox programmes appears cross-cutting and includes technological, business model and market design elements, engagements with stakeholders revealed that current innovation activities do not sufficiently occur at the higher order system level. Research has mostly been conducted with the purpose of publishing academic papers to boost academia credentials, many of which does not contribute to innovation.
3. **Insufficient government support for energy and power systems innovation.** Thailand's total expenditure on innovation is below the average for middle income countries. Trends indicate that the government is reducing its support to innovation; state contributions to innovation fell by 8 percentage points between 2015 and 2019. Where there are support schemes, these are too fragmented and uncoordinated with a disproportionate amount channelled to the public sector.
4. **Pilot projects, and sandbox programmes need to be translated into implementable actions.** Many sandbox programmes and pilot projects have been undertaken in Thailand. While these programmes have yielded many good outcomes, they are often not scaled up nor implemented at a larger scale, largely due to barriers related to existing policies and regulations.

To address these challenges, three recommendations have been developed. They are:

- IV Recommendation 1 [IV1]: Elevate energy and power systems to a national innovation priority.
- IV Recommendation 2 [IV2]: Promote integrated systems-level innovation.
- IV Recommendation 3 [IV3]: Leverage international partnerships to maximise impact of domestic innovation

IV1 is a key first step to raise the priority of energy and power system in the Thai Government's agenda and therefore must be undertaken in the immediate term. With greater priority, more resources can be pushed to the topic area, thereby facilitating higher order system-level innovation (IV2), phased to commence in the middle of the immediate term. An enabling innovative environment requires efficient leverage of knowledge transfer from the international community (IV3). This is phased continuously from the middle of the immediate term to the medium term as countries accelerate the decarbonisation of their power systems. Table ES.4 summarises the phasing of these recommendations.

Table ES.4. Timescales for implementing innovation recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
IV1				
IV2				
IV3				

Human Capacity

Recommendations focus on increasing the capacity of policymakers, taking proactive steps to plan for and assess human capacity needs, and increasing collaboration across different stakeholders to develop a workforce capable of supporting a future power system with higher shares of RE.

Human capacity is an essential component that covers multiple facets of the power ecosystem, cutting across all pillars of activity. Capacity is needed in policymakers to enable design of robust policy, regulations and market mechanisms that can facilitate high penetrations of RE in the grid. It is also needed in the private sector who are responsible for the development of RE infrastructure. End consumers also need to have relevant knowledge and capabilities to respond to changes in policies such as the promotion of distributed energy generation or prosumer trading.

Human capacity needs are not static and will evolve as the power system evolves as Thailand transits to achieve net zero GHG emissions. Capabilities need to be built across the energy value chain to ensure a smooth transition. Several challenges that could hinder this smooth transition have been identified:

1. **Capacity of policymakers to design policies, regulations and mechanisms that facilitate higher penetrations of RE.** There is a general lack of know-how among policymakers on the approach to amending existing new policies and regulations, the design of new market mechanisms, and how to transition away from existing policy instruments. Stakeholder engagements revealed that this lack of know-how is a key underlying barrier preventing the rapid development of RE infrastructure.
2. **Workforce capacity is likely to be lower for novel technologies and lags between skill gap identification, upskilling and delivery**. The power system is rapidly evolving. However, there are no concrete plans to equip the workforce with the relevant skills to adapt to the changing power system. While stakeholders generally agreed that the workforce is sufficiently skilled to facilitate high deployments of RE, there are existing skills gap in areas such as power system optimisation modelling, and enabling technologies such as energy storage and hydrogen.
3. **Insufficient knowledge transfer across different stakeholders.** Investments by incumbent private utility players such as Global Power Synergy's first SemiSolid energy storage unit factory, and Energy Absolute's lithium-ion battery plant demonstrate that the private sector has sufficient capacity in future power systems. However, there is insufficient knowledge transfers from the private sector to SMEs, public actors and stakeholders involved in training and higher education.

To address these challenges, three recommendations have been synthesised. They are:

- HC Recommendation 1 [HC1]: Increase capacity of policymakers to design policies, regulations and market mechanisms that facilitate higher penetrations of renewable energy
- HC Recommendation 2 [HC2]: Take proactive steps to plan for and assess existing and future human capacity needs
- HC Recommendation 3 [HC3]: Increase stakeholder engagement and collaborations

HC1 has been phased for the immediate to long terms. This is a priority action that should start in the immediate term and continue into the long-term as constant training of policymakers is a key building block for enabling a regulatory environment that supports high RE. This is especially important given the fast-evolving nature of energy systems. HC2 has been phased for the mid-immediate term to the short term as it is relatively urgent to appoint a dedicated nationwide entity to manage training. The skills gaps assessment and updating of curricula delivered by education institutions would require more time and hence extend into the short-term. HC3 has been phased across the mid-immediate to mid-short term as

engaging local stakeholders and faciliating collaborations can be achieved in a short timespan. Table ES.5 summarises the phasing of these recommendations

Table ES.5. Timescales for implementing human capacity recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
HC1				
HC2				
HC3				

Conclusion

Many of the recommendations are cross-cutting in nature, therefore, we strongly emphasize the need for policymakers to take a systems-level approach to actioning the recommendations.

Energy and power systems is a highly complex issue that involve various interactions, between policy and innovation, policy and human behaviour, innovation and human capacity among many others. Recommendations in the policy and regulation pillar cuts across all others, setting the tone and direction for them. Clear policy is needed to unlock the development of market mechanisms and promote infrastructure upgrades. Innovation is also closely linked to policy. Without strong policy, innovation efforts could be de-prioritised as the benefits tend to be intangible in the short term and often only accrue in the long term. For example, many of the sandbox programmes implemented by ERC in Thailand are not scaled up due to policy and regulatory barriers. Policy is also needed to set innovation priorities, specifically in areas that can generate a competitive advantage for Thailand, and to drive activities related to it. Innovation can facilitate infrastructure development in Thailand, such as in battery and energy storage. Outputs from system level innovations take a birds' eye view to problems beyond technological ones and include business model innovation. Innovation and human capacity are closely linked as well. Close industry-academia collaborations enable mutual benefit by providing industries a chance to steer academic curricula tailored to skillsets and expertise needed in the industry. Universities also provide a supporting environment for industries to access top research talent that can support with innovation activities.

Developing clear targets aligned with COP26 announcements, and the associated trajectories is the number one priority. Regular monitoring and evaluation is important to enable proper tracking and performance assessment.

Many actions are phased in the immediate and short terms because Thailand is still in the early phases of transitioning its power system. Many recommendations related to policy and regulations are phased to happen in the short term because they are key to unlocking follow-on activities in the other pillars. Developing clear targets and trajectories is the number one action that needs to be undertaken to ensure alignment with the commitments announced at COP26. A common action across the recommendation is the need for regular monitoring and evaluation. This is crucial to ensure interventions continue as planned and informs whether alternative or supplementary interventions need to be developed. It can also lead to new recommendations being formed over time.

There are many areas that Thailand can learn from the UK given the latter's deep experience in transitioning its power system. This include topics such as driving energy systems innovations, designing market mechanisms and support schemes, and taking an integrated approach to climate and energy planning

1. Introduction

1.1. Overview

At the 2021 UN Climate Change Conference (COP26) in Glasgow, the Prime Minister of Thailand, Prayut Chan-o-Cha, announced the country's ambition to be carbon neutral by 2050 and to achieve net zero greenhouse gas emissions by 2065. These ambitions expectedly focus on the energy sector, whose greenhouse gas emissions account for 72% of the country's total in 2016[1,2]. To drive emission reduction in the country, the government of Thailand is currently developing a National Energy Plan (NEP) to guide the country to achieve these goals.

There are four key policies outlined in the NEP[3]:

1. Boosting the proportion of clean and renewable energy aggressively in new power generation
2. Promoting electric vehicles to move towards use of green electricity in transport
3. Improving energy efficiency through using innovative energy management approaches
4. Supporting Thailand's energy transition by implementing the principles of **4D1E** - **Digitalization** (use of digital technology and data to manage to the power system), **Deregulation** (restructuring of power system to allow a free market and increase competition), **Decarbonisation** (reducing carbon-intensive fossil fuel power generation), **Decentralization** (distributed power generation) **Electrification** (replacing technologies that use fossils fuels with that using electricity)

The NEP has set the goal of achieving 50% of renewables share in new power capacity. Although the NEP has set ambitious RE targets, there is no clear implementation plan to outline how this target will be met. To reach the commitment of these ambitions, an updated RE roadmap and pathway is needed to bring Thailand's PDP in line with the NEP. The roadmap needs to involve all stakeholder groups and cover the broad policy and regulatory, financial, technical, and economic considerations that ensure the successful build out of RE including the market mechanisms to enable sufficient deployment of flexibility to ensure a secure, safety and cost-effective decarbonisation of the power systems, and take advantage of the potential opportunities that can bring a green recovery to the Thai economy post-COVID.

There also remains significant barriers around access to grid, permitting, licensing, and power purchase agreements that would make achieving this target challenging. Therefore, a more innovative ecosystem, enabling regulatory and policy environment, advanced technologies such as smart grid for transmission and distribution, de-risking instruments, and supportive mechanisms must be included in this roadmap.

1.2. Roadmap Objectives

The project team, comprising the Carbon Trust and Creagy, was commissioned by the UK Foreign, Commonwealth and Development Office's (FCDO) Research and Evidence Directorate, to develop a roadmap that supports the new PDP. The objective of this roadmap is to provide Thailand with recommendations that support the government in achieving the goal of 50% renewables share of the country's new power capacity. It sets out the strategic actions and measures that should be implemented

[1] Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy, 2021.

[2] Energy sector here refers to energy use for power generation, heat generation, transportation.

[3] Energy Policy and Planning Office. National Energy Plan 2022 (NEP) Framework, 2021.

over the immediate, short, medium, and long-term timescales; and are organised according to a five-pillar framework that reflect key elements of a mature power system capable to support high penetrations of RE. The roadmap is intended for government agencies in Thailand with power-related responsibilities.

To develop recommendations for a mature power system with high RE penetration, the project team drew upon the UK and international learnings and experiences. UK experience is highlighted as it has one of the highest RE penetration rates in the world, with RE accounting for 43% of the UK's domestic power generation in 2020.[4]

1.3. Roadmap Structure

This report has been structured in chapters as follows:

Chapter 1 – Introduction provides a brief background of the project and its objectives, and the aims of the roadmap, which are to inform decision making for Thailand to reach its target of 50% of new power capacity being derived from RE.

Chapter 2 – Methodology describes the three-pronged approach the project team undertook to develop the roadmap. It details the approach in understanding and characterising the power system in Thailand, identification of challenges and corresponding opportunities. The methodology rests on a five-pillar framework (i.e., Policy and Regulations, Market Mechanisms, Infrastructure, Innovation, Human Capacity) developed by the project team as it reflects key pillars of a mature power system capable of supporting a high share of RE.

Chapter 3 – Landscape for High Shares of Renewable Energy Penetration in Thailand explores in further detail Thailand's status quo and initiatives/activities in relation to each pillar of the five-pillar framework.

Chapters 4 to 8 – Challenges and Recommendations (one for each pillar) builds on the characterisation and identifies challenges across the Policy and Regulation (Chapter 4), Market Mechanism (Chapter 5), Infrastructure (Chapter 6), Innovation (Chapter 7), and Human Capacity (Chapter 8) pillars that are hindering the scale up of RE in Thailand, and corresponding recommendations to address these challenges. Where available, UK and international experience and learnings have been drawn upon to develop and inform the recommendations. The recommendations have also been phased according to an immediate, short, medium, and long-term timescale to provide a time-bound roadmap for Thailand to implement.

Chapter 9 – Conclusion summarises our key findings and recommended actions for Thailand. Immediate next steps are emphasised to make clear what the government needs to kickstart the power system transition. Several research limitations have also been identified.

Appendices provide supplementary background material on the characterisation of Thailand's power system, stakeholder engagements questions, case studies from UK and international experience, and Mentimeter poll results from the Mid-project Workshop.

[4] UK targets power from 100% renewable sources by 2035.

2. Methodology

The methodology undertaken to develop the roadmap can be broken down into the three activities as seen in Figure 1. Understanding the importance of including Thai stakeholders' views and their buy-in for decision-making in Thailand, the project team engaged these stakeholders throughout the project. Further, given the UK's extensive experience with incorporating high RE into the current power system, learnings from the UK inform the opportunities identified and recommendations for Thailand.

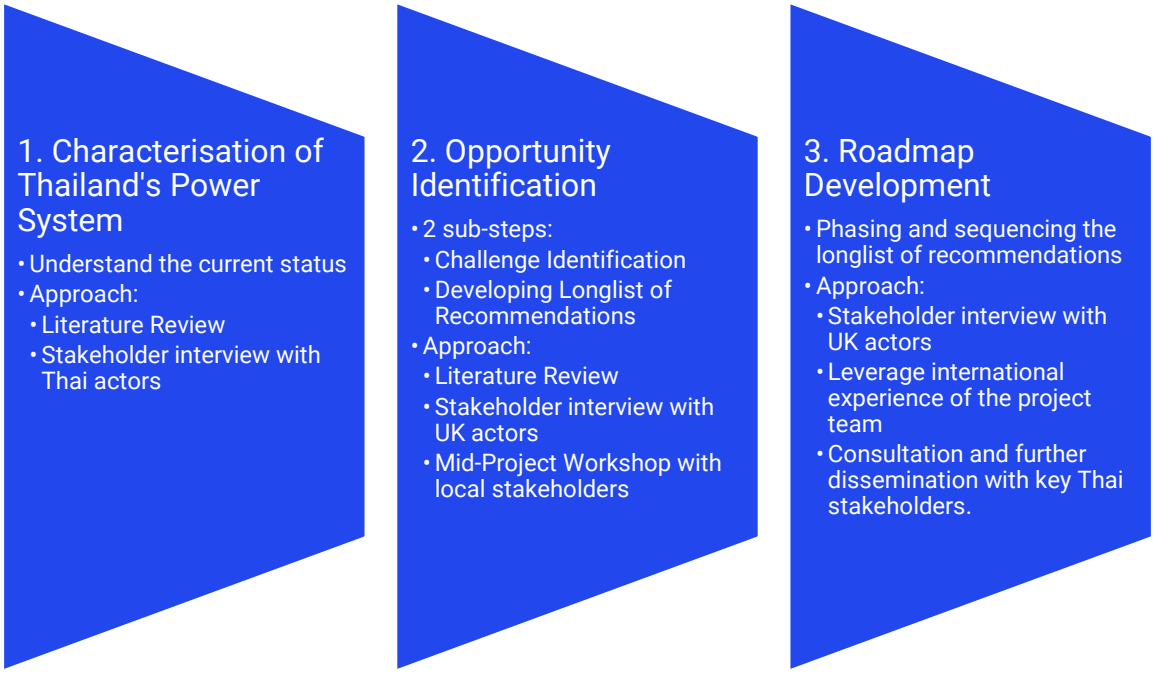


Figure 1: Methodology adopted in the Roadmap development

To guide the above activities and identify the strategic actions for the roadmap, a five-pillar framework was developed. These pillars reflect a mature power system capable of supporting a high share of RE. They are:

1. **Policy and Regulation**: refers to the policy instruments and regulatory environment, including RE plan, as set out by the Thai government to promote and develop RE.
2. **Market Mechanisms:** refer to means of remunerating providers and consumers with an open and understood system of value and trade-offs to optimize distribution of power services in the most economically efficient manner.
3. **Infrastructure:** refers to physical infrastructure, such as transmission and distribution lines, battery storage, and virtual infrastructure such as a trading platform to facilitate and accommodate RE.
4. **Innovation**: innovation here is considered at a systems level, which includes innovation in technologies, business models and market design to transform the power system.
5. **Human Capacity:** refers to various facets, including technical expertise and knowledge within the workforce of the power sector and capacity of country policymakers to develop the appropriate policy or market designs to support RE.

2.1. Activity 1: Characterisation of Thailand's Power System

The objective of this activity was to characterise Thailand's power system and identify challenges in increasing RE in the country's power generation. The project team undertook a literature review and a series of stakeholder engagements to set the scene and understand the landscape of the Thai power industry, as guided by the five-pillar framework. The characterisation also included an outline of its make-up in terms of generation capacity by source, transmission, distribution, and consumption characteristics; policy and regulations that govern power system development and operation; the energy market; and the institutional arrangements.

Characterising Thailand's power system was crucial in identifying the challenges hindering the Thai RE power system as it laid the foundation for the roadmap development.

2.1.1. Literature Review

Several key documents and literature were reviewed to build a comprehensive understanding of the current state of the Thai power system, including future RE scenarios, targets, and objectives. The following lists the key reports reviewed:

- Energy Policy and Planning Office, 2021, *National Energy Plan 2022 (NEP) Framework*.
- Energy Policy and Planning Office, 2021, *Study on the development of hydrogen production and consumption for enhancing the application of renewable energy*
- Energy Regulatory Commission, 2021, *Study on Wheeling Charge for Third Party Access (TPA)*
- Energy Research Institute, Chulalongkorn University. King Mongkut's University of Technology North Bangkok, 2021. *Study on an impact on the power system (generating system, transmission system and distribution system) from electricity generation from renewable energy and solutions*
- Energy Research Institute, Chulalongkorn University, 2021. *Study on an impact on the power system and the electricity trading business model from transformative technology*
- Energy Research Institute, Chulalongkorn University, 2021. *Study on suitable factors and business models for developing the Prosumer under the P2P electricity market in Thailand*
- Energy Research Institute, Chulalongkorn University, 2020. *Study on suitable fuel options for Power development plan (PDP) to prepared for the trend of Prosumer market*.2020
- Federation of Thai Industries, 2019. *Study on grid energy storage for Thailand*.
- Ministry of Energy, 2020. *Alternative Energy Development Plan 2018–2037 (AEDP 2018)*.
- Ministry of Energy, 2020. *Thailand's Power Development Plan 2018–2037 (PDP 2018 Revision 1)*.
- Ministry of Energy, 2015. *Thailand's Smart Grid Master Plan (2015–2036)*.
- Ministry of Natural Resources and Environment, 2021. *Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy*.
- Thailand Development Research Institute, 2018. *Market outlook of distributed PV and energy storage in Thailand*

2.1.2. Stakeholder Engagement

The project team identified and mapped stakeholders from the government, academia and think tanks, state-owned enterprises, private sector renewable energy players and financiers. One-to-one virtual interviews with several stakeholders were conducted to better understand the Thai power system context and the challenges of increasing RE. The stakeholders interviewed were:

- Energy Policy and Planning Office

- Energy Regulatory Commission
- Department of Alternative Energy Development and Efficiency
- Electricity Generating Authority of Thailand
- Renewable Energy Club, Federation of Thai Industries

These interviews involved questions based on the five-pillar framework and the full list of questions can be found in Appendix 1.

2.2. Activity 2: Opportunity Identification

Building on the characterisation of the Thai power system in Activity 1, this activity aimed to further refine the list of challenges faced by the Thai power industry in scaling the deployment of RE and identify opportunities for achieving the target. A long list of challenges and opportunities was developed by the project team through continued literature review, international experience, and learnings, as well as feedback from Thai stakeholders in a mid-project stakeholder workshop.

2.2.1. Literature Review

International literature and research were reviewed to supplement and identify challenges, opportunities, and international experience that Thailand can learn from. In particular, the following reports were reviewed:

- International Energy Agency (IEA), 2019, Southeast Asia Energy Outlook 2019
- International Renewable Energy Agency (IRENA), 2016, Renewable Energy Outlook for ASEAN
- IRENA, 2017, Renewable Energy Outlook: Thailand
- IEA, 2018, Thailand Renewable Grid Integration Assessment
- IEA, 2021, Thailand Power System Flexibility Study
- IEA, 2021, The Potential Role of Carbon Pricing in Thailand's Power Sector
- Energy Reports 6, 2020, Marginal Abatement Cost of Electricity Generation from Renewable Energy in Thailand
- Energies 2021, 14, 4203, Success Factors for the Implementation of Community
- Renewable Energy in Thailand
- Energies 2021, 14, 5420, Factors Influencing Consumer's Adoption of Renewable Energy [in Thailand
- Asian Development Bank (ADB), Increasing Penetration of Variable Renewable Energy: Lessons for Asia and the Pacific
- Renewable Energy Integration, Energy Storage and the Need for Flexibility on the Grid

Numerous other literatures were reviewed to provide further insights and analysis on the UK experience. The source documents for these are referenced in the corresponding chapters.

2.2.2. International Experience

The project team capitalised on its extensive knowledge and experience of the UK power system to draw on learnings that could be applied to the Thai context. Additionally, the team sought learnings through a series of one-to-one interviews with key UK power industry players. The stakeholders interviewed were:

- National Grid Electricity Systems Operator (NG ESO), the national system operator

- UK Research and Innovation (UKRI), the UK Governmental body responsible for setting the policy in Innovation
- The Association for Decentralised Energy (ADE)
- Scottish and Southern Networks (SSEN), one of the Distribution Network Operators in the UK.
- Regulatory Energy Transition Accelerator (RETA), and
- Office of Gas and Electricity Markets (OFGEM), the UK regulator

The full list of questions can be found in Appendix 2.

2.2.3. Mid-Project Workshop

From our extensive experience, we know it is vitally important to engage market players through any roadmap development. This exponentially increases buy-in and the success and usefulness of any roadmap document. The project team held a mid-project Workshop to seek the views of a broad range of stakeholders active in the power industry who are critical to the success of Thailand's energy transition. They included actors from government, state-owned enterprises, private sector, academia and think tanks. Held virtually on 3rd March 2022, the objectives of the workshop were to:

- Test identified challenges and proposed actions with stakeholders
- Understand how stakeholders prioritise these challenges and opportunities
- Gather insights into other challenges and opportunities/measures not previously considered

Challenges and opportunities were discussed across all five pillars. This was achieved primarily by using Mentimeter, an interactive software that allowed the project team to pose a series of poll questions that participants could respond to through their electronic devices. These questions were structured in ways to gather their views on the identified challenges and how Thailand should prioritise needed actions. Open-ended questions and question and answer sessions also allowed participants to express their views freely and suggest challenges or opportunities that had not been identified previously.

2.3. Activity 3: Roadmap Development

Based on interviews with UK experts that highlighted learnings and priority actions, prioritisations from stakeholders during the mid-project Workshop, and the project team's expertise and knowledge, the project team synthesised the key strategic actions across the five pillars and phased the roadmap into measures and actions to be implemented in the immediate-, short-, medium- and long-term timescales.

The outcomes of the final draft of the roadmap will be presented to the key stakeholders during a Dissemination Workshop in the second half of April 2022.[5] The aim of this workshop would be to solicit a final round of feedback and insights from stakeholders on the project team's proposed opportunities for Thailand, developed according to the timescales of immediate, short-term, medium-term, and long-term.

[5] The dissemination workshop has not been delivered at the time of writing.

3. Landscape for High Share of Renewable Energy Penetration in Thailand

This chapter describes the status of Thailand's power sector that can affect the commitment of RE targets through the five-pillar framework introduced in the methodology.

3.1. Policy and Regulation

Key national plans and their high-level targets related to RE deployment are described within this chapter and more detail about these key plans are in Appendix 4.

Thailand has introduced a series of climate change and power plans shaping the development of the country's power industry and RE uptake. Figure 2 below summarises the key climate change and energy plans, and their associated timelines. Namely, they are the:

- **National Energy Plan (2023-2070):** the NEP is the latest energy plan that aims to harmonise and align the five energy plans (i.e. PDP, AEDP, Energy Efficiency plan, Oil plan and Gas plan), and is the main plan driving forward the aim of 50% of new installed power capacity from RE.
- **Masterplan on Thailand's Smart Grid Development (2015-2036):** provides the framework for the development of smart grids that will increase flexibility of the grid and accommodate more variable RE generation.
- **Grid Modernisation of Transmission and Distribution Plan (2018-2037):** Provides an update of the short-term plan established in the Smart Grid Master Plan and aims to enable integration of advanced technologies throughout the power system.
- **PDP2018 (Rev.1) 2018-2037:** The main national plan governing the power system, including the development of new power plants. It focuses on (1) energy security (2) economy to maintain reasonable cost of power generation into the long term, and (3) reduce carbon emissions from power generation and increase RE generation. The plan projects that 77,211 MW of new capacity will be installed by 2037, of which 18,696 MW will be from RE.
- **AEDP2018 (2018-2037):** The main plan governing alternative energy in Thailand (i.e. non-conventional energy of fossil fuels). The plan covers electricity, heat, and biofuels, and aims to increase the share of RE in total energy consumption of these three areas to 30% collectively.
- **Energy Efficiency Plan (2018-2037):** Prepared by Department of Alternative Energy Development and Efficiency, the Energy Efficiency Plan 2018-2037 (EEP2018) outlines a target for energy intensity (EI) reduction of 30% by 2037 compared to the 2010 baseline.
- **Climate Change Master Plan (2015-2050):** Short, medium, and long-term strategic actions for both climate change adaptation and mitigation. It includes high-level measures for the RE sector as a whole and for power sector. Its key missions are: (i) building climate resilience by integrating policies and measures in all sectors, (ii) creating mechanisms to reduce GHG emissions, leading to sustainable low carbon growth, (iii) building readiness by enhancing capacity and awareness of stakeholders and (iv) developing a database, knowledge, and technology to support climate change adaptation and mitigation.
- **Nationally Determined Contributions (NDC, Updated 2020):** Prepared by Office for Natural Resources and Environmental Policy and Planning (ONEP), the NDC commits to the Paris Agreement to reduce GHG emissions by 20% from the BAU level by 2030.
- **Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy (2021-2065):** Provides high-level targets and measures to achieve net zero by the second half of the century.

- **Announcements at COP26 (2021):** The latest climate change targets were announced at COP26, where Thailand aims to achieve carbon neutrality by 2050 and net zero by 2065 at the latest.

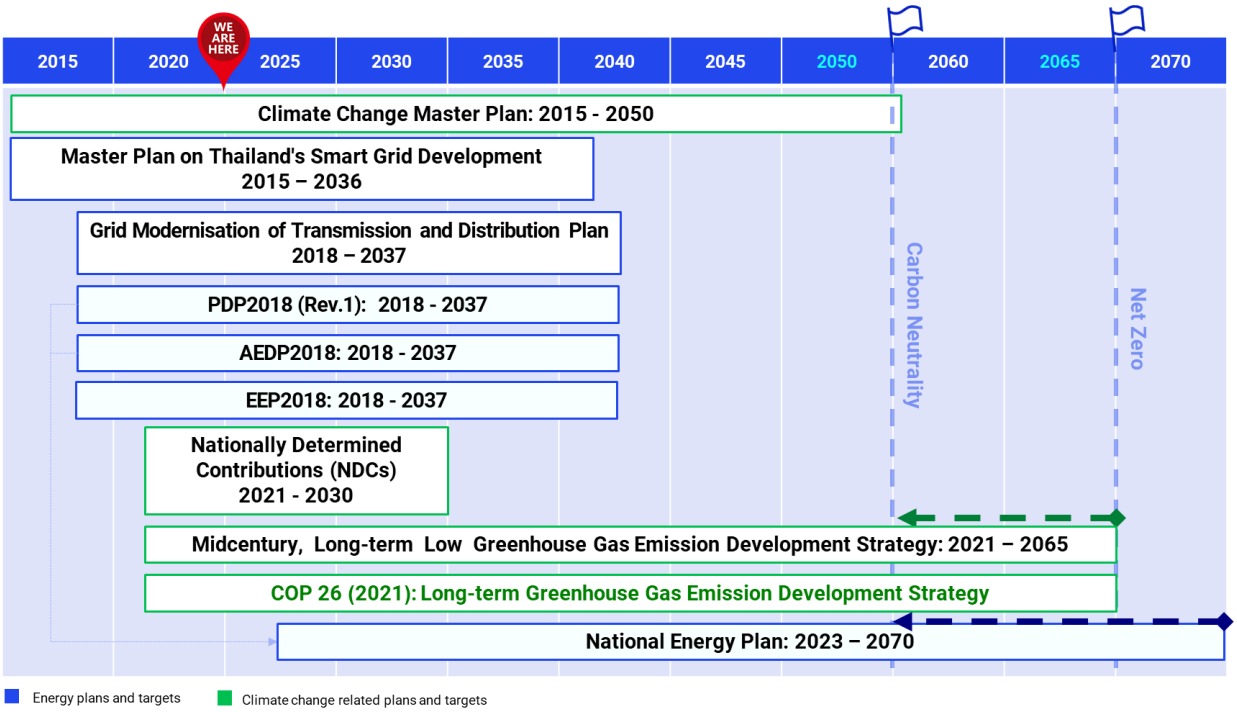


Figure 2:Timescales of the national climate change and energy plans.[6]

With several national plans, there are ongoing efforts to align and synchronise all targets and plans to provide clearer strategic direction. Figure 2 summarises some important RE targets and ambitions across the plans.

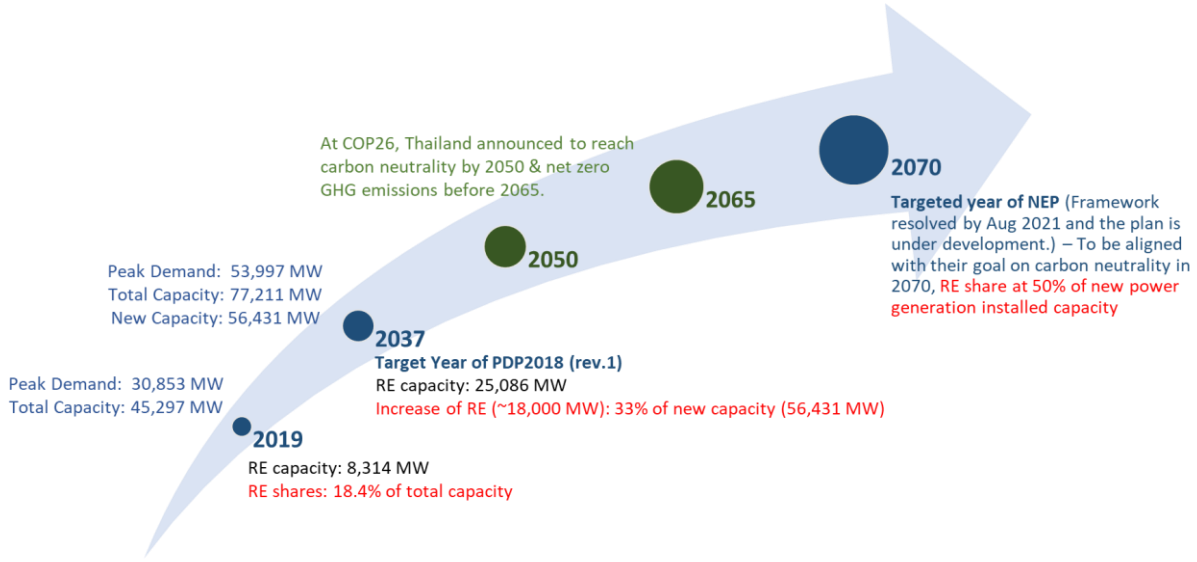


Figure 3: Thailand's RE targets and ambitions in the power sector[7]

[6] Chart developed by project team based on information in the listed national climate change and energy plans.

[7] Created by the author using data from PDP 2018 (Rev. 1) and NEP (www.eppo.go.th)

Thailand aims to achieve a high penetration of RE in the power system in its efforts to achieve carbon neutrality and net zero. Specifically, the target set in Thailand's NEP is 50% RE share in new power capacity by 2070, in line with Thailand's original target year to achieve carbon neutrality. However, Thailand announced revised targets at COP26 and committed to be carbon neutral by 2050 and net zero by 2065. This suggests that the 50% RE share in new power capacity target might be brought forward to 2050.

The PDP2018 projects that more than 18 GW of new RE capacity will be added by 2037, of which solar PV represents the largest share. This will increase the share of RE to 33% of the new total installed capacity by 2037. Furthermore, the PDP indicates existing support schemes, primarily feed-in tariffs (FiTs), would be allocated for about 2.5 GW of additions, while no financial support schemes are specified for the remaining capacity additions of 16.2 GW and the economic competitiveness of these assets is expected to drive their commissioning.

In parallel, a transformation of the power system organisation is expected from the enhanced single buyer (ESB) model towards a decentralised organisation in which numerous players are active on the supply and demand sides, with the purpose of facilitating the integration of RE.

Engagement with stakeholders in Thailand confirmed that increased competitiveness of RE translates into private sector willingness to develop installations, as well as into appetite for "green" renewable power from consumers. Enabling the private sector to invest and participate in the power system through regulatory amendments and development of market mechanisms is expected to enable the deployment of RE.

In addition, as the share of distributed generation is expected to rise, models identified as enablers of the smooth penetration of decentralised RE such as virtual power plants (VPP) and peer-to-peer (P2P) trading, are expected to play a significant role in the achievement of Thailand's RE target. Facilitating the emergence of these models through regulatory, market and technology evolutions is identified as a key element of the power system evolution.

The transformation of the Thai power system is two-fold: while the energy plans and ongoing initiatives set the basis of the trajectory, the literature review and engagement with Thai stakeholders led to the identification of challenges which could hinder the delivery of the desired transition and targets.

3.2. Market Mechanisms

Market mechanisms refer to means of remunerating providers and consumers with an open and understood system of value and trade-offs to optimize distribution of power services in the most economically efficient manner.

The cost of RE has reduced significantly over the last few years and has become competitive to fossils, particularly for solar and wind. However, other RE technologies and small-scale RE are not as commercially viable and require support.

Market mechanisms for RE deployment

Existing RE installed capacity (9,330 MW as of January 2022) have been subsidized either in the form of Adder or feed-in-tariffs (FiT).[8] This has acted as a good incentive for RE deployment, but it is intended to only be operated initially to incentivise investors for the engagement needed or for some advanced RE technology or projects that are not financially viable. Community power plants, waste-to-energy and biomass power plants such as those in the Southern region of Thailand have been considered to receive FiT, as outlined in the PDP2018. Other RE promotional mechanisms are being considered, either through the development of the existing Adder or FiTs or a new mechanism, such as shifts towards a market-based approach with no or limited subsidy and take-and-pay contract.

Based on stakeholder interviews, access to capital is not an issue that prevents RE investment from large corporates. The financial institutions and banking sector in Thailand have extensive experience in both corporate and project financing. Many power producers are publicly listed companies and have direct experiences in raising capitals from both equities, green bonds, and corporate loans. There are many green bonds for solar and wind projects in Thailand. However, small-and-medium-size corporates may face some collateral issues when applying loans from banks.

There is some government financial support to reduce RE investment costs, but most RE penetration is expected by achieving price parity. For instance, there is government support to stimulate RE through manufacturing and upgrading of technology or machinery for energy conservation and alternative energy utilisation, as well as promoting research and development (R&D) in engineering design. This is promoted through the Board of Investment No. 9/2560 Measures to Promote Improvement of Production Efficiency.[9]

Interviews with stakeholders have also pointed towards other existing mechanisms such as the green tax, green funding, green bonds for large projects, and carbon border adjust mechanism (CBAM) which remains to be implemented more widely in the future. Furthermore, the Crowdfunding platform and P2P lending for financial support had been launched by the Stock Exchange of Thailand (SET), Bank of Thailand (BOT) and the private-owned company called Sinwattana Crowdfunding.

However, there is no market mechanism to support access to the grid and zero exports, as current regulations and the ESB model do not allow smaller players to supply RE to the grid. Therefore, there are not many private players entering the market or potential private players in Thailand are mostly large corporates, and they are likely to become monopoly (or only few players).

There has been significant investment in behind-the-meter RE projects under the corporate power purchase agreements where the off-takers are corporates who want to increase their RE consumption. For corporates that have limited direct access to RE on site, they will consider purchasing Renewable Energy Certificates (RECs).

EGAT is the issuing authority of RECs in Thailand, under the International REC Standard (I-REC). The REC market in Thailand formally began in 2019/2020 when Toyota bought EGAT's first 10,000 RECs. Between June 2019 to May 2020, 761,923 RECs had been issued. According to EGAT, approximately 3.9 million

[8] Adder is an additional tariff provided on top of the normal tariff to electricity from RE power plants selling to the grid for 7-10 years from their Commercial Operation Date (COD).

[9] Board of Investment, 2017. Announcement of the Board of Investment No. 9/2560 Measures to Promote Improvement of Production Efficiency (unofficial translation)

RECs can be produced per year in Thailand.[10] As of 2021, there were 64 registered REC projects in Thailand with a total installed capacity of 809MW. In terms of installed capacity, 53% of the total installed capacity are attributed to solar projects, followed by 39% to wind, 4% to biomass, 2% to biogas and the remaining 1% to hydro.[11] Most notably, in 2020, a REC trading marketplace was also established in Thailand.

Figure 4 below provides a breakdown of renewable energy projects registered under the I-REC standard.

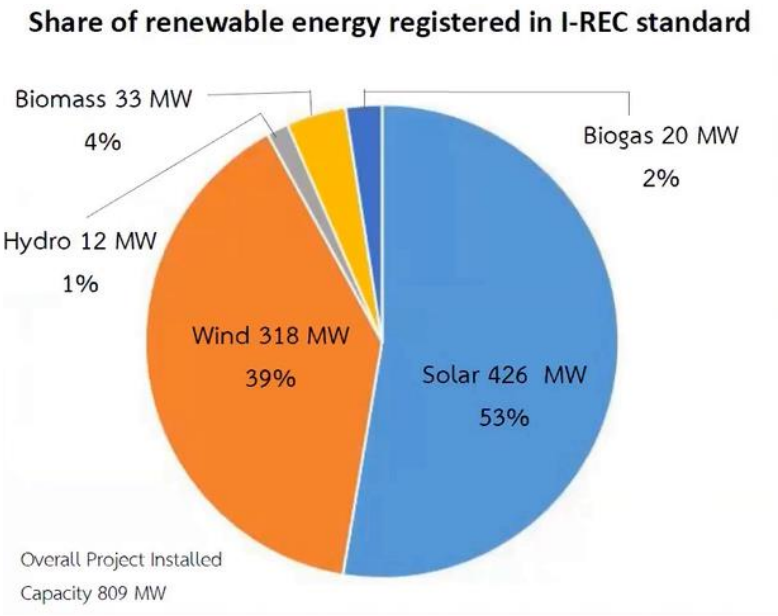


Figure 4: **Breakdown of REC projects in Thailand by RE technology**[12]

3.3. Infrastructure

Infrastructure improvements and changes are required to facilitate a higher penetration of variable RE within the grid and mitigate its impact on grid security and stability. Stakeholder feedback from the mid project workshop indicated that existing Transmission and Distribution infrastructure is relatively inadequate to support a higher level of RE penetration such as the level targeted on the energy plans.

Smart grids development

Currently, the smart grid plan is under execution of the activities established in its mid-term phase (2022 - 2031), corresponding to the phase of smart grid development including the following activities: energy tariff structure improvement (development of Real Time Pricing), RE and energy storage system (ESS) forecasting data centre development, domestic software and hardware development, tax and financial support mechanism implementation, infrastructure, and technologies investment by power utilities.

[10] EGAT I-REC Issuer

[11] The International REC Standard, 2021. Webinar: Renewable Energy Certificate Market in Thailand

[12] As above

The Grid Modernisation of Transmission and Distribution Plan also outlines the government's plans for a big data centre that will enable better data integration among the three utilities. This will improve data analytics, cyber security, and data privacy. Further, this will help to develop demand response.

According to the Smart Grid Master Plan (Medium term, in 2022-2024), Thailand will focus on the RE-Based Micro Grid development targeting the remote area as a priority (off-grid with an autonomous full-service 24/7), piloting an on-grid microgrid particularly with prosumer integration. The plan will expand to a commercialised model such as a community and industrial microgrid.

Energy Trading Platforms (ETP)

Energy trading platforms have been under discussion by the Thai government and plans for these can be found in various energy plans, including the Grid Modernisation of Transmission and Distribution Plan to introduce ETP/National Energy Trading platforms (NETP).

In 2019, SEC and EGAT had entered an MOU regarding a study on developing a reliable platform to accommodate an emerging wholesale electricity market. The study aims at the importance of this mechanism which enable effective power management for the benefits of both producers and users. Further, EGAT and the Industrial Estate Authority of Thailand (IEAT) had selected Pinthong Industrial Estate, to become a Smart City: Energy Digital Platform Sandbox. This project aims at the development of next generation of power and the use in industrial plants of the future. The new model of power management will embrace those of alternative energy such as solar rooftop, battery storage management, power exchanging platform, etc.

In 2020, Power Ledger (an Australian blockchain firm) and Thai company BCPG, launched a trading platform for RECs. The platform was developed in conjunction with the Thai Digital Energy Development. This marketplace and trading platform is not limited to Thailand and includes the broader Southeast Asia region.[13]

3.4. Innovation

Innovation focuses on new developments and research into novel technologies, system design and business models. It goes beyond new, or less conventional, RE technologies, also focusing on cross-cutting developments on relatively novel ideas to improve the current power industry.

To support this, ERC launched a sandbox programme to test new business models and new power system management that correspond with the National Energy Plan. The campaign was opened for project proposals in 5 areas: 1) new power market structure, 2) new tariff structure, 3) innovative technologies, 4) new models of power system operation and management, and 4) new energy business models. The eligible participants are government agencies, local academic institutions, or private companies registered in Thailand.

In the first phase which launched in 2019, a total of 183 project proposals were received, which can be categorized into eight activities as follows:

1. Peer-to-Peer Energy Trading

[13] Eco-Business, 2020. Australian and Thai firms team up to launch renewable energy credit marketplace spanning Southeast Asia

2. Bilateral Energy Trading
3. Microgrid
4. Energy Storage
5. Study on New Tariff Structure
6. Innovative Business Model
7. Natural Gas
8. Other Trial Business and Innovations

34 projects will be implemented under the regulatory sandbox campaign and includes major energy players from the private and public sectors, such as BCPG and PTT Group.

Other key actors in the energy innovation ecosystem in Thailand include national agencies and academic institutions. They are National Science and Technology Development Agency (NSTDA), EGAT, ERC, and DEDE and research institutes including the Energy Research Institute in Chulalongkorn University and Thailand Development Research Institute (TDRI) and Sustainable Energy and Low Carbon Research Unit of Thammasat University, among other universities. The latter had also partnered with EGAT on the ERC Sandbox: TU EGAT ENERGY project expansion to develop "Smart Energy Solutions". This indicates that ecosystem for innovation and R&D are in place, and several initiatives to test new ideas.

Virtual Power Plants (VPPs)

Digitalisation of grids such as Virtual Power Plants (VPPs) allows distributed energy resources to be linked to create a cloud-enabled "smart grid" which can help achieve flexibility. Technology studies and pilot projects are underway. EGAT has cooperated with King Mongkut's University of Technology Thonburi (KMUTT) to conduct a study on VPP development which divided the study into three phases: 1) 2020, designing the model for operation of a power generation in a form of VPP with a selected pilot power plant; 2) 2021-2022, the develop in electricity trading agreement system and test the power plant command system; 3) 2023-2024, the experiment on calculating system of the production and electricity trading units in the target area by using EGAT's power plants as the main power plant. It is expected that by 2030, there will be a virtual power plant business model in Thailand with a total capacity of more than 400 megawatts.[14]

Prosumer/P2P Trading Model

Thailand is currently exploring new business models beyond the ESB model and self-consumption model for most of the distributed renewable energy generation assets such as solar rooftop projects. Research on new business models include P2P trading models.

ERI had also conducted research on business models and related regulations of peer-to-peer (P2P) energy trading for prosumer electricity market, with recommendations for a model where the existing distribution operators (PEA and MEA) act as scheme operators. The excess electricity is exported from one prosumer and distributed though the national grid system operated by the operators to the end user. All participating in this P2P model will have to register themselves on an online channel. The PPA will be mutually agreed and signed between the seller and the purchaser.

Bioenergy

[14] Electricity Generating Authority of Thailand

Power from bioenergy is a key source of RE for Thailand and accounts for a majority of the current RE power generation. Such bioenergy includes biomass, biogas (solid waste, wastewater, energy crops).

While the AEDP2018 has laid out plans for research and development for bioenergy, these largely focus on biofuels (e.g., Improve the quality of refuse-derived fuels, strains with high yields, appropriate technology transfer, and increasing agricultural crop yield for biofuel production through plantation zoning). This suggests that Thailand's innovation in bioenergy focuses on biofuels for vehicle usage and transportation.

Energy Storage System (ESS)

Currently, the use of ESS in Thailand is not widespread due to high costs and limited opportunities to generate income due to limited regulations or market mechanisms that remunerate storage.

In the Smart Grid Master Plan, the ESS has been emphasized as a key technology to support the operation and management of the microgrid system to increase the power system's reliability. It targeted the implementation of 3-5 pilot projects within the year 2020.

In the short-term smart grid action plan progress report, it was reported EGAT's study on RE forecast for the RE power plant was completed, covering RE forecast for the power system control centre and included a model with the ESS integration. The ESS can be integrated into any part of the system - the microgrid system, the distribution system to support the energy management of DSO (PEA/MEA), or in the transmission/sub-station of EGAT to support an overall energy management.

According to the Smart Grid Master Plan's 3rd Pillar, the Ministry of Energy has indicated the Key Performance Indicators (KPI) under this pillar to all three electricity utilities. EGAT, PEA, and MEA have laid out and implemented pilot microgrid & ESS projects in different types of area (i.e., special economic zone, smart city, and remote area) such as Smart City: Energy Digital Platform in the Eastern Economic Corridor, Microgrid in remote areas (such as Mae Hong Son, Chiang Mai, Lamphun, and Yala provinces), High Voltage Substation (Chaiyaphum and Lopburi provinces)[15]. The ESS were integrated into the microgrid in different functions with different type of ESS, such as Battery Energy Storage System (BESS) and Pumped-Hydro Energy Storage.[16]

In 2021, several private sector companies had also launched projects and operations to accelerate ESS and to lead in battery technologies and the power storage industry. For instance, Global Power Synergy Public Company Limited, (GPSC PCL) kicked off operations at its ASEAN's first SemiSolid energy storage unit factory, aiming to enhance its power generation capacity from renewable energy to supply power plants, large industrial factories, and SMEs as well as further develop its production plan for electric vehicle batteries.[17] In the same year, Energy Absolute (EA) launched the lithium-ion battery plant and power storage system of Energy Absolute Group. The project has an initial capacity of 1 GWh per year in the Eastern Economic Corridor (EEC) development project area, with the expansion plan with the production capacity to 50 GWh per year.[18]

---

[15] Battery Energy Storage: EGAT's New Dimension on Electricity Management System

[16] ระบบสมาร์ทกริด – Thai smartgrid

[17] Press Releases | Global Power Synergy Public Company Limited (GPSC)

[18] EA announces the success of grand opening of the first Gigafactory, the largest integrated battery factory in ASEAN

ESS research has also been underway, with Vidyasirimedhi Institute of Science and Technology (VISTEC) investigating the feasibility and capabilities of ESS for multiple applications.[19] VISTEC is focusing on many energy storage technologies e.g., Lithium sulfur batteries, advanced lithium and sodium ions batteries, supercapacitors, and Li- and Na-capacitors. [20] Similarly, the National Energy Technology Center (ENTEC) under the National Science and Technology Development Agency has been playing an active role in ESS R&D, which aims to support energy storage industries with state-of-the-art research on advanced/beyond Li-ion batteries, high energy density storage materials and systems, supercapacitors, hydrogen storage/fuel cell, and thermal storage.[21]

Hydrogen

Hydrogen production is another RE enabling technology that has not reached commercialization due to high costs and lack of specific technical skills but is also being researched and piloted by the government. Research on production of hydrogen and the use to promote renewable energy is being conducted.[22]

EGAT is implementing a pilot project such as the Lumtakong electricity plant on electricity generation from a wind-hydrogen hybrid. As electricity generated from wind turbines does fluctuate, electricity generation from wind turbines (pilot project) is promoted along with electrolyser and an efficient energy storage system (fuel cell system) that potentially supplies electricity generated from wind turbines to the system in a stable manner.[23]

Other private-public partnerships include a Thai (EGCO, EGAT and ATE)-US (Bloom: supplier of hydrogen power generation), where an MoU was signed to enhance technology development and explore investment opportunity in Solid Oxide Fuel Cells and Electrolyser Technology (EGAT, 2021). In 2019, EGAT also signed an MoU with Phi Suea House (Chiang Mai province) that focuses on the study of hydrogen as an energy storage in the Green Mini-Grid Sandbox Project at EGAT's headquarters.[24]

3.5. Human Capacity

With new innovations and plans for higher RE shares in Thailand's power system, human capacity must be further enhanced to enable and facilitate the transition. AEDP2018 plans to strengthen knowledge and expertise in renewable energy, especially in solar power throughout the design, installation and commissioning stages. The plan also highlights human resource development in engineering and technical personnel in RE technologies and enhancing community participation in RE development.

Although various national plans recognise the need to scale up human capacity, there are few targeted actions and measures to facilitate this, which may suggest that this is not a key gap for Thailand Results

---

[19] Associate Professor Dr. Montree Sawangphruk

[20] VISTEC : Advanced Energy Storage Technology

[21] https://www.entec.or.th/rd/energy-storage/

[22] EPPO. โครงการศึกษาแนวทางการพัฒนาการผลิตและการใช้ไฮโดรเจนเพื่อส่งเสริมพลังงานหมุนเวียน (Project to study guidelines for the development of production and use of hydrogen to promote renewable energy). http://www.eppo.go.th/images/Infromation_service/procurement/2563/11_2563/SLK-KLG-2563-11-27_1TOR.pdf

[23] EGAT. (2017). ไฮบริดลำตะคอง นวัตกรรมเพื่ออนาคต พลังงานลมจับคู่กับเซลล์เชื้อเพลิง (Hybrid-Lumtakong Innovation for future, Hydrogen with fuel cell). https://www.egat.co.th/index.php?option=com_content&view=article&id=1984:20170522-article-01&catid=49&Itemid=251

[24] Electricity Generating Authority of Thailand

from polls conducted at the Mid-project Workshop also indicate that the workforce is sufficiently skilled to facilitate high deployment of RE (Appendix 5), but participants recognised that new training programmes need to be developed to increase the human capacity of the local workforce as the energy systems evolves.

There are several universities and technical institutes in Thailand that provide degree and professional training programmes. For example, the school of Electrical Engineering in Chulalongkorn University offers degree programmes in future energy systems, covering broad topics such as power and energy systems and smart grids and renewable energy technology, and more specific ones such as power electronics and high voltage insulation and transmission technology programmes.[25] Similar degree-granting programmes are provided by the School of Renewable Energy and Smart Grid Technology in Naresuan University, University of Phayao, Thammasat University, and Srindhorn Institute of Technology. Poll results suggest that universities and technical institutes sufficiently train and equip the local workforce with necessary skills (Appendix 5).

Institutes, such as the Engineering Institute of Thailand Under H.M. The King's Patronage[26], provide short-term technical training courses on RE to members, government officials, and the public. These courses are eligible for Professional Development Units (PDUs), and certain income tax exemptions on registration fees. Other examples include the Thailand Council of Engineers[27], and Institute of Electrical and Electronics Engineers Thailand Section who provide online seminars covering RE and smart grids.

Lastly, government agencies are also responsible for delivering capacity building. The Energy Human Resource Development Division (EHRDD) of DEDE is responsible for carrying out RE courses for both private and government sector.[28] As of 2018, EHRDD developed and conducted 19 training courses covering solar generation, biogas, biofuels, and general knowledge on RE.

[25] M. Eng Curriculum, School of Electrical Engineering, Chulalongkorn University

[26] The Engineering Institute of Thailand Under H.M. The King's Patronage. Training

[27] Thailand Council of Engineers. Committee Rules on Continuing Professional Development (CPD)

[28] Review Of Current Policy on Renewable Energy Training Development And Recommendations For DEDE, 2019

4. Policy and Regulation

Policy and Regulation set the foundations for trajectory of Thailand's ambitions.

Policymakers specify the targets for renewable energy and decarbonisation, from which supporting interventions are designed and implemented to achieve the targets. In addition, policymakers will influence the evolution of the power system's organisation from being centred around state-owned entities to a competitive market.

Regulation acts as a second layer, working in coordination with policy to provide explicit specifications that will ensure targets can be met.

This chapter describes the substantial policy and regulatory developments needed to meet Thailand's RE target. The characterisation of Thailand's power system and ambitions mean that policy and regulations (P&R) are needed to unlock the potential for RE deployment in Thailand.

4.1. Challenges

Through the characterisation of Thailand's power system ambitions and engagement with stakeholders in Thailand, policy and regulation challenges have been identified and are presented in the four paragraphs below.

4.1.1. Uncertainties over the targets and trajectory to achieve them

The broader challenge that was raised by multiple stakeholders to achieve Thailand's RE target relates to the uncertainty associated with the definition of the target and the trajectory to achieve it.

First, how the 50% target will be achieved is unresolved. The 2018 revised PDP target year is 2037 and plans an increase of RE capacity of about 18.7GW between 2018 and 2037. The existing plans currently do not develop how this will align with the 50% target. The PDP describes that existing support schemes will enable ~2.5GW of RE additions, while the remaining 16.2GW are expected to be delivered based on economics of projects. Uncertainty remains on whether players will indeed be willing to invest and build this capacity. Current regulatory constraints for grid access and absence of markets for energy trading have been raised as limiting factors from the private sector.

Second, ambitious targets related to greenhouse gas emissions have been stated since the definition of Thailand's RE target: at COP26, the Prime Minister of Thailand announced objectives to reach carbon neutrality by 2050 and net zero greenhouse gas emissions by 2065. It is however unclear how these objectives can be achieved. Considering that the energy sector accounted for more than 71.7% of Thailand's total GHG emissions in 2016, reaching carbon neutrality and net zero will require a deep decarbonisation of this sector. Thailand's RE target may need to be brought forward and reviewed to higher levels to be consistent with decarbonisation ambitions.

Third, Thailand's RE target aims to increase the installed capacity of RE, with high ambitions for solar PV notably. However, variable RE technologies do not generate electricity on a continuous basis as they depend on the resource availability (solar or wind for example). The share of electricity produced from RE

will be lower than the share of RE installed capacity in the mix[29]. Furthermore, as the power system in Thailand is not designed for high RE penetration, there is a risk of curtailment of RE production, i.e. of requiring RE installations to reduce or stop their production due to network or operational constraints. This adds a downwards risk on RE generation volumes.

Setting a target in terms of installed capacity leaves a strong uncertainty on the future share of RE in electricity production and consumption in Thailand.

4.1.2. Concerns regarding the costs of the transition

The cost of developing RE installations in Thailand is one of the major challenges of the energy transition, which should be achieved without over-burdening consumers. Although the cost of technologies such as solar and wind have decreased, the cost of achieving Thailand's RE target is not limited to the cost of developing RE power plants. A high penetration of variable RE in the Thai energy system will imply costs to the underlying infrastructure supporting its operation (e.g., cost of reserve, cost of grid development, etc).

Stakeholder engagement revealed that there is no consensus regarding who should bear the costs of RE within Thailand. Poll results at the mid project workshop reflected an equivalent number of agree and disagree responses when asked if it is agreed that the costs of RE penetration should be borne by those who desire to consume RE power. Furthermore, while consumers who want to buy renewable power (through Green Tariffs for example) can contribute to the development of RE capacity in Thailand, the sizing of this contribution compared to Thailand's RE target remains unknown.

Finally, the uncertainty regarding how the transition costs will be covered can be detrimental to market players' confidence and Thailand's transition.

4.1.3. Regulatory and contractual clauses impose constraints that deter private investments

Stakeholders in Thailand stated that current terms of regulation and contracts for RE installations impose constraints that limit the potential for RE development within Thailand.

Regarding the RE installations which sign power purchase agreements (PPAs) with EGAT, the constraints associated with the firm-PPAs (fixed output) are challenging for variable renewable installations. The solution to add potential storage or hybrid-capacity, necessary to enable a steady generation profile, increases the costs of projects. On the other hand, the non-firm PPAs translate into uncertain offtake volumes for the projects meaning uncertain revenues. This can reduce potential interest of project developers and translate into risk premiums being implemented in the costs of projects.

Furthermore, while PPAs can be signed between private power producers and state-owned organisations, Thailand's ambitions rely on the decentralisation of the power sector. In order to capture revenues by selling the power produced from RE installations, private actors need to be able to inject the electricity

[29] The IEA's 2021 Thailand Power System Flexibility Study estimates capacity factors of 18% and 28% for solar and wind respectively: this means that, in Thailand, a solar installation will generate on average 18% of its installed capacity and a wind installation 28% of its installed capacity.

generated to the grid. However, current rules impose either high wheeling charges for private installations or a zero export to the grid rule. While these rules can enable a secure operation of the grid, they imply that private RE installations experience barriers to dispatch production towards potential customers. Lifting barriers to access to the grid for RE projects was ranked as the first priority for policy and regulation, based on poll results from the mid-project workshop.

4.1.4. Limited avenues of remuneration for RE installations

RE installations will only be built if project developers and owners are able to generate revenue. The current system organisation around the ESB model and the lack of access to the grid mean that private RE projects cannot access purchasers of power to generate revenues. Developing a clear framework of policy and regulation to accelerate the reform of the power system organisation towards market opening and ensuring a level-playing field for small players was ranked as the second priority when sampling Thai stakeholder's opinions.

Furthermore, distributed solar PV is expected to develop in Thailand due to the low costs compared to retail tariffs. This will translate into the emergence of prosumers, who both produce and consume power. The participation of prosumers to the power system was raised as a large enabler for RE deployment in Thailand during the stakeholder engagement. To leverage this potential and trigger the deployment of small and distributed RE installations, it will be necessary to acknowledge the value of small sized installations and enable small players to fully benefit from installation of renewable assets. Enabling trading between small actors will trigger the development of new economic models and support the build out of these RE installations. The existing zero-export to the grid rule is however perceived today as a loss for RE owners: surplus generation cannot be exported and valued.

4.2. Recommendations

Challenges related to Policy and Regulation in Thailand are broad, from the uncertain trajectory to reach the targets to regulatory constraints and lack of remuneration opportunities for RE installations. The anticipated transformation of the Thai power system organisation also requires significant evolutions of the policy and regulatory framework in Thailand.

In order to address the identified challenges, four main recommendations have been derived for Policy and Regulation in Thailand, aiming to:

1. Develop clear and well-elaborated trajectories towards the targets
2. Tailor support schemes to Thailand's ambitions
3. Foster the private sector participation
4. Enable public-private synergies by opening and providing directions to markets.

While the first recommendation addresses the challenge of the uncertainty towards reaching the targets, others are expected to ease multiple challenges.

For example, a reviewed tailoring of support schemes to Thailand's ambitions will simultaneously enable a reduction in the cost of the transition, provide the opportunity for adjustments of current constraints to RE development in Thailand, and create remuneration avenues for technologies identified as relevant.

Table 1. Mapping of challenges against recommendations related to Policy and Regulation.

Policy & Regulation				
Challenges **Recommendations**	Uncertainties over the targets and trajectory to achieve them	Concerns regarding the costs of the transition	Regulatory and contractual clauses impost constraints that deter private investments	Limited avenues of remuneration for RE installations
PR1: Develop trajectories towards the targets and elaborate on the means to achieve them	✓			
PR2: Tailor support schemes to Thailand's ambitions		✓	✓	✓
PR3: Foster private sector participation: reduce constraints, develop revenue opportunities, and maintain confidence			✓	✓
PR4: Open and provide direction to markets to enable public-private synergies		✓	✓	✓

The following section details the recommendations and propose actions for Thailand's roadmap. UK and international experience are used to illustrate similar actions or challenges that have been encountered. Further details on the international experience are provided in Appendix 6.

Policy and Regulations Recommendation 1: Develop trajectories towards the targets and elaborate on the means to achieve them

Targets for renewable penetration, carbon neutrality and net-zero achievement have been set for Thailand. However, lack of clarity on the alignment between the different targets, their timeline, and the trajectory to their achievement, has been stated as a challenge. Assessing the potential trajectories towards these targets and introducing the means and expected roles of the different actors in the energy sector will be key to provide clarity for Thai stakeholders and improve the likelihood of success.

Sub-Recommendation 1: Set integrated targets and the accompanying milestones

The penetration of variable RE and high targets for renewable capacity deployment in Thailand will stress the need for flexibility across the system. Flexibility is defined as the ability to respond to unplanned

variance in the generation or demand. This will increase the total operating system costs and ultimately affect the realisation of the targets.

While targets are already set for renewable penetration in Thailand, the viability of reaching those targets needs to be assessed across the whole system. For example, it is important to assess the whole system impact and the possibility for broader flexibility provision across the whole system (i.e., from generation to the end consumers) because this could decrease the costs of flexibility provision and enable a more cost-effective decarbonisation of the power sector.

Analysing the potential ways of achieving the target across the whole energy system can contribute to the identification of realistic and desirable trajectories and clear milestones to reach.

UK EXPERIENCE

The UK Department for Business, Energy & Industrial Strategy (BEIS, Ministry of Energy) and Ofgem (Energy regulator) published the 2021 Smart systems and flexibility plan. The development of this plan relied on a substantial modelling effort to "understand the role and value of flexibility […] as well as identifying the amount and type of flexibility needed". The analysis explored the cost of the future electricity system through the use of detailed modelling under a range of assumptions and flexibility technologies. In addition to quantifying the role and value of flexibility ("up to £10bn a year by 2050" of cost reductions on the system could be achieved), the modelling effort also assessed the scale of low carbon flexibility that could be needed and sources to provide it: figures detailing the deployment of flexibility capacity between 2020 and 2050 were derived in coherence with the expected evolution of the energy system, notably the substantial increase of offshore wind capacity.

The following actions are identified for Thailand:

- Integrate Thailand's RE target (currently in terms of GW) and decarbonisation targets (currently in terms of GHG emissions) together; in particular, estimate the RE penetration compatible with Thailand's latest ambitions: carbon neutrality in 2050 and net-zero in 2065, and update the RE targets accordingly
- Characterise the potential trajectories towards the achievement of the RE target through scenario and modelling analysis. In particular,
    - the scenarios would identify RE capacity consistent with the target through 2050, with a potential breakdown by technology.
    - a detailed modelling of hourly generation and demand profiles in Thailand will enable the identification and quantification of potential supplementary technologies needed to ensure the power system balance: dispatchable capacity, storage and flexibility notably.
    - assessing induced carbon emissions will provide insights on the power sector contribution to Thailand's decarbonisation targets.

Sub-Recommendation 2: Provide visibility towards the actions to achieve the targets

In addition to setting targets, elaborating on the actions that will be undertaken to achieve them can increase confidence across the sector and ease the realisation of the desired transition. It is recommended that the government set clear action plans to deliver Thailand's decarbonisation ambitions to 2065. These plans and resources would provide a solid foundation to the strategy and transparency on the means which will be employed by the government to enable the transition.

The target being set, now a range of actions is needed to enable their achievement, such as providing funding, support schemes, or reforming markets and governance for example.

The following actions are identified for Thailand:

- Define action plans to support the achievement of Thailand's RE penetration targets
- Assess and define the potential increase in funds needed to support the development of specific RE technologies
- Assess support schemes for RE development and develop new schemes if needed
- Resolve pending uncertainties by providing decision making on policy matters, such as how the costs of RE installations will be distributed across consumers

Sub-Recommendation 3: Clarify the role of organisations in achieving the targets

Identifying clear responsibilities will increase the confidence in the feasibility of the target achievement in the whole energy sector, and trigger the necessary investments associated with the transition.

The UK experience illustrates how the definition of targets is accompanied by identification of the key players and their responsibility with the achievement of the targets. In this case, the Ministry of Energy (BEIS) has played a key role in defining the roles and responsibilities for the different players and OFGEM has been key in regulating the actions of these players.

It is important to consider that the transition might need the creation of new entities. For example, the role of players in the UK energy sector has evolved, and new organisations were created as needed. While the UK engaged in the liberalisation of its power sector, the government drove the evolution of each entity's roles across the whole value chain, from generation to consumers.

The following actions are identified for Thailand:

- Increase transparency and visibility towards the role of government agencies and broader energy sector stakeholders and their responsibility in achieving the target.
- Assess the need for dedicated bodies who will facilitate the trajectory towards Thailand' RE target by taking specific responsibilities such as: monitoring the trajectory, handling support schemes with the private sector, setting and operating new markets (e.g. ancillary service markets).

Sub-Recommendation 4: Monitor the trajectory

Understanding the progress towards the targets is key and will determine whether the resulting trajectory is on track with the ambitions, or whether potential supplementary or alternative actions may be needed. Implementing indicators and monitoring their evolution regularly is a fundamental enabler of the ambitions' achievement.

For example, measuring the evolution of installed capacity of RE technologies over time will inform whether the pace of capacity additions is in line with the targets. In addition, tracking the RE share in power generation will provide insights on the effective contribution of RE to satisfy demand in Thailand.

In the UK, this role is undertaken by the Committee on Climate Change (CCC). The CCC is a dedicated independent public body which has the responsibility to provide recommendations to the government on target-setting and their progress.

The following action is identified for Thailand:

- Develop indicators that enable tracking and regular updating of progress towards Thailand's targets

Policy and Regulations Recommendation 2: Tailor support schemes to Thailand's ambitions

A revision of the existing support schemes design is recommended to tailor the design of remuneration mechanisms according to the expected benefits associated with the public support of RE technologies in Thailand. This will involve assessing the actual competitiveness of the technologies identified as relevant to achieving Thailand's target in order to reach the optimum balance between public cost and expected benefits.

Also, a revision of the support schemes design can be the opportunity to ease the constraints for RE installations such as the requirements for firm generation profiles established in contracts with EGAT, which stakeholders have raised as a challenge to the development of RE in Thailand.

Sub-Recommendation 1: Provide support to technologies to enable their deployment

While targets are set for RE technologies in Thailand, their economics are expected to vary in time due to the evolution of technology costs and remuneration avenues. Some technologies, such as solar PV, are already competitive in Thailand and could be built without support schemes, while others remain uncompetitive but can display other benefits, such as small-scale biomass installations. Future market dynamics will also influence the economics of RE technologies and impact the need for support schemes to drive their development.

It is recommended to use the output of monitoring activities to adapt support schemes and remunerations accordingly. The UK experience below illustrates how the government reacted to the observation of a deficit of new installations for established technologies by re-instating public support.

UK EXPERIENCE

Acknowledging that the deployment of large onshore wind and solar PV installations was not keeping up with the pace of additions required to achieve UK targets, public support has been reinstated in 2021 for these established technologies for the first time since 2015: they are able to compete in the auctions for support in the form of Contracts for Difference.

The following action is identified for Thailand:

- Adapt support schemes accordingly to the results of the monitoring of projected deployment of RE installed capacity

Sub-Recommendation 2: Continuously revise support schemes

While support schemes can enable the development of RE capacity, it is necessary to remain agile to ensure they are fulfiling their objectives while remaining efficient.

Planning and undertaking a continuous revision of support schemes implemented in Thailand, Feed-in-Tariffs in particular, is recommended to ensure the minimisation of public cost: the sharp decline in established technologies costs in the past years means that the economic support needed is also lower.

In the UK, for example, revisions of Feed-in-Tariffs were implemented on an annual basis to ensure the decline in technology costs was also translated into a lower public support cost. Further details are provided in Appendix 6.

Moreover, supported RE installations may distort future market results. It is recommended for Thailand to ensure future support schemes are focused on incentivising the participation of RE installations to markets. Increasing competition for support allocation can incentivise project developers to lower their costs. For example, the introduction of Contract for Difference (CfD) to replace Renewable Obligation Certificates (ROC) in the UK enabled cost reductions by triggering competition and improving revenue visibility through the installation's lifespan for investors as explained in the UK experience below.

However, there is a risk that only the most competitive technologies will be developed. When introducing competition for the allocation of support schemes, ensuring various technologies can fairly compete is necessary too. It is also important to ensure that changes in support schemes do not introduce unnecessary uncertainty that deter investors. Therefore, changes need to be implemented progressively and without retroactive effect.

UK EXPERIENCE

For large-scale installations, the initial scheme was the implementation of a Renewable Obligation (RO) for electricity suppliers associated to the emission of ROC for producers of renewable power. In 2013, a 6-year period of transition was set up for the replacement of the RO scheme with the allocation of Contracts for Difference (CfD) through competitive tenders. Under the CfD, RE installations are responsible for selling their energy on markets and receive the difference between their contractual price in the CfD and the market revenues. The shift to the CfD scheme enabled to reintroduce a bound on the development of capacity and require RE installations to sell their energy on markets. In addition, it enabled cost reductions by triggering competition between project developers. Finally, a CfD contract guarantees that the generator receives a fixed price for the produced electricity through the length of the contract, usually 15 years. This long-term support mechanism provides investors with revenue visibility for a period comparable to the lifespan of the installations: in doing so, CfD contracts decrease the need for a risk-premium in the project financing, enabling a reduction of the capital cost (WACC) and eventually of the RE installation cost.

For small-scale installations, significant evolutions were also implemented: in 2019, the Smart Export Guarantee (SEG) scheme replaced the FiT: the SEG tariff rate is now proposed by energy suppliers instead of set by regulations, and only the surplus generation is remunerated.

The following actions are identified for Thailand:

- Review support schemes tariff rates and design regularly
- Introduce terms in the support schemes contracts that allow potential future evolutions and modifications of the scheme, for example:
    - clauses considering the potential revision of tariff levels in the event of high profitability of supported projects;
    - clauses enabling the revision of the energy volumes receiving support in the event of the emergence of alternative revenue streams on markets.
- Enhance competition where possible, in particular for established competitive technologies
- Adapt the complexity of schemes to the projects:
    - Support schemes such as CfDs which rely on a direct participation to markets require significant capability to enter markets and are better suited for large-scale installations;

- For small installations, especially domestic RE projects, simpler support schemes are recommended to prevent complexity from deterring private investment (such as FiT, or schemes where the retailer handles the energy injected).

Sub-Recommendation 3: Introduce mechanisms to frame the public cost of support schemes

The cost of the transition and its transfer to consumers has been expressed as an explicit concern by stakeholders in Thailand. While public support to RE technologies can enable the deployment of capacity, it can translate into substantial costs for consumers. In addition to optimising support schemes, introducing limits on the budget that can be engaged is a relevant safeguard to implement in Thailand. Such a safeguard has been introduced in the UK, where the cost of public support to RE technologies is passed on consumer's energy bills: the costs of the RO, FiT and CfD schemes are bounded by a predefined annual budget.

The medium through which the public support to RE will be passed on to Thailand's consumers can also impact the acceptability of supporting RE, and impact the achievement of Thailand's RE target. In the UK, the cost of public support to RE is passed onto electricity consumers. However, other countries such as France choose to rely on the government budget to finance the public support to RE. Recovering the costs of supporting RE through consumers' electricity bills would translate into an increased electricity price that risks deterring users from consuming electricity. To prevent this risk, the French government budget is directly engaged.

The following actions are identified for Thailand:

- Introduce bounds on the potential public budget engaged through support mechanisms: for example, the bounds can be in the shape of a maximum capacity deployment, as well as of a maximum potential budget allocated to the different schemes
- Assess the impact of financing support schemes by a levy on electricity consumers

Sub-Recommendation 4: Implement additional considerations within support schemes

The public support to technologies can trigger additional benefits for Thailand. Implementing conditions to the allocation of public support – such as the development of skills, creation of jobs, or development a supply chain within Thailand – would enhance the benefits associated to the RE capacity development.

For example in the UK every bid to apply for CfD support over 300MW of capacity is associated to the obligation to submit a supply chain plan demonstrating how the project will promote competition, innovation and skills in the sector's supply chain.

The following action is identified for Thailand:

- Consider the implementation of additional considerations when designing support schemes, especially for sectors emerging in Thailand

Policy and Regulations Recommendation 3: Foster private sector participation: reduce constraints, develop revenue opportunities, and maintain confidence

The private sector in Thailand communicates willingness – and demonstrated it through high participation in ERC's auctions – to finance and develop renewable projects. However, challenges were raised on (i)

existing constraints for access to the grid and (ii) the absence of markets that could create revenue streams for projects and driver the development of new business models.

Fostering the participation of the private sector to the development of RE capacity in Thailand can facilitate the achievement of Thailand's RE target. This will rely on enabling and de-risking the environment to create attractiveness for private actors. The following recommendations aim to adapt the policy and regulatory framework in Thailand to ease these challenges:

As a side-benefit, reducing the risk for investors will increase confidence and create attractiveness to develop RE projects, which is likely to translate into lower financing costs of projects. This would also contribute to the objective of lowering the cost of Thailand's transition.

Sub-Recommendation 1: Ensure access to the grid to renewable installations

Access to the network is fundamental to connect producers to consumers. It is recommended that Thailand should create a framework to ensure there is transparent and non-discriminatory access to the grid for private installations to engage Thailand's private sector participation in the renewable deployment.

UK EXPERIENCE

An extensive library of policy and regulatory decisions frames the integration of renewables in networks in the UK. Both the Electricity System Operator (National Grid) and the Distribution Network Operators (DNOs) are subject to this library. Distribution Network Operators are required to give access and propose connection to renewable installations, and the Grid Code sets the rules for this access provision.

Despite the mandatory grid-access, experience revealed obtaining access remains challenging for RE installations. Setting strict rules which limit the uncertainty for the RE projects is key to de-risk renewable projects from a lack of access to the grid. Furthermore, network and generation activities are separated in the UK: the firm controlling the networks is neutral to the owner of the generation facilities. This separation, also a strict rule in the European Union[30], provides a facilitating foundation for a non-discriminatory access for all players.

The following action is identified for Thailand:

- Enable access to the grid to private RE installations by pursuing revisions to the Grid Code
- The Grid Code should ensure the access to the grid is non-discriminatory for private RE installations

Sub-Recommendation 2: De-risk the injected volumes of renewable power generated

The possibility for the generator to inject the electricity produced into the grid is subject to the dispatch from the system operator and to network constraints.

[30] The EU 2009 Third Energy Package requires the legal unbundling for electricity and gas distribution activities (separated legal entities for network versus competitive activities), and ownership unbundling for electricity and gas transmission networks: a firm owning and operating a transmission network cannot be involved in competitive activities (production and supply of energy).

This means the output from a RE installation must be curtailed in response to a dispatch order or because of network constraints. This translates into forecasted revenue loss for the owner of the installation. The analysis conducted for the characterisation of Thailand's power system revealed that conventional assets in Thailand have limited flexibility, leading to potential reductions in RE installations dispatch. Furthermore, as the grid was not developed with a significant penetration of RE capacity in mind, it is likely that network constraints will emerge for RE installations.

The potential reduction in output injection to the grid, or curtailment, is a risk for RE installations owners as less generation translates into less revenues. The risk associated to curtailed volumes can translate into less capacity deployment or into there being a risk-premium which increases the costs of RE projects in Thailand. To mitigate the risk for RE installations it is recommended that both the dispatch and network constraints rules should be updated.

Such measures can also translate into increased RE production within Thailand, as less RE would be curtailed, leading to a cleaner electricity grid and contributing to the decarbonisation objective.

The UK and EU experiences below depict what regulatory measures have been implemented to de-risk project development for RE owners, both for dispatch and network constraints.

UK AND EU EXPERIENCES

Both the UK and European Union (EU) have introduced guaranteed access to the grid. They have also introduced a priority dispatch provision[31], or the obligation for the transmission system operators to dispatch energy from renewable generators ahead of other generators, as much as secure operation of the electricity system permits. This obligation has been an important lever to maximise the use of RE energy and ensure the integration of variable RE in the system. It has forced system operators to operate while adapting to RE generation and triggering the flexibility of dispatchable conventional assets first. In addition, it reduced the risks for RE generators by ensuring the energy can be sold to the market and fed to the grid. As renewable penetration grew, the regulatory frameworks evolved towards increasing the participation of variable RE assets to the system and markets' functionality. The priority dispatch model was removed for new RE installations from 2020. The underlying condition for this change was to ensure the Market Design and products adapted to enable the RE participation in the markets to receive revenues for such adjustments.

Furthermore, while a certain level of curtailment of RE output due to network constraint is considered acceptable in the UK, a compensation scheme is in place: curtailed volumes are compensated (paid) for to the RE owners by the network operators.

The following actions are identified for Thailand:

- Consider adapting the offtake contracts to the characteristics of RE generation profile, and reduce uncertainty on offtake volumes for small and very small private producers
- Consider implementing priority dispatch for RE installations to incentivise the system to be operated while integrating renewable energy if Thailand's infrastructure can accommodate to the share of variable RE
- Consider the compensation of RE installations for energy curtailed due to network constraints

[31] Priority dispatch for RE energy was introduced at EU level with the 2001 RES-e Directive, and further refined in the 2009 RES Directive

- These measures, relevant in the immediate term to facilitate RE deployment in Thailand, could be re-assessed in the medium-term: as RE share will grow in Thailand, the development of markets will enable RE installations to contribute to an optimised system and be remunerated for any downwards adjustment of their output.

Sub-Recommendation 3: Develop revenue opportunities

The development of RE in Thailand will depend upon project developers being able to generate revenues. Two streams of revenues can be identified and supplement one another: support schemes and market mechanisms. While Thailand's RE target sets ambitious RE penetration, future remuneration avenues for large and small scale RE installations would benefit from more transparency and visibility to attract the private sector.

Ensuring clarity on the evolution of support schemes needed to meet Thailand's RE target will provide long term visibility for investors. In addition, the design of a policy and regulatory framework helps identify potential revenue opportunities for RE assets. Renewable installations may be able to stack revenues from different markets in Thailand such as:

- Wholesale markets for the energy produced;
- Renewable energy certificates markets for the RE value of the energy; and;
- Market remunerating flexibility or services to the grid such as ancillary services.

The development of these markets and potential participation of RE installations need to be clarified to increase visibility of revenue opportunities for RE installations in Thailand.

Policy and Regulations Recommendation 4 further develops on the role of the policy and regulatory framework in providing direction to markets. The Market Mechanisms chapter further details the roles of potential markets to be developed in Thailand. The following action is identified for Thailand:

- Increase revenue opportunities for private RE projects, notably through opening the sector to competition and energy trading implementation

Policy and Regulations Recommendation 4: Open and provide direction to markets to enable public-private synergies

Thailand's power system is expected to evolve towards decentralisation but the details of market design is key to ensure a reliable, affordable, and decarbonised power sector.

The absence of market to trade power products and accompanying policy and regulatory framework is seen as a limitation for private RE deployment in Thailand. Private RE installations are subject to contracts with the state-owned utilities and do not have the opportunity to capture revenues on markets. A significant engagement with the public sector will be necessary for Thailand to open up and guide the market development process.

The Sub Recommendations of this section focus on the role of the public sector in enabling and providing directions to markets. Further details on market design and outcomes are provided in the Market Mechanisms chapter.

Sub-Recommendation 1: Set the path to decentralisation

Thailand aims to decentralise its power system and to increase competition between actors. A substantial transformation is needed from the current system centred around EGAT. Given the political dimension of such an evolution, a significant engagement of policymakers in Thailand will be necessary to drive the power system decentralisation.

In addition, the increased number of actors when the market is opened up will create the need for a robust set of regulations from the regulator ERC to ensure fair competition and benefits for consumers. It is recommended to adjust ERC's mandate as the regulator to include monitoring of market results, enforcing compliance from all market players, ensuring all consumers and actors are treated equally, and protecting consumers from uncertain market outcomes.

The following action is identified for Thailand:

- Update ERC's mandate to include monitoring and evaluating of market results, enforcing compliance from all market players, ensuring all consumers and actors are treated equally and protecting consumers from uncertain market outcomes.

Sub-Recommendation 2: Provide directions to electricity markets and assess market gaps through a policy and regulatory framework

Increased competition could provide multiple benefits for Thailand, such as lower costs from improved efficiency or increased innovation. Market mechanisms are optimisation tools: their design determines their delivery,

It is recommended for Thailand to design a clear policy and regulatory framework for power markets to ensure they deliver the desired outcomes. Markets should be designed to be agile, and the policy and regulatory framework should adapt to outcomes and potential gaps. Regular evaluations should be undertaken to analyse market performance and address potential limitations. Evaluations should be published in the form of a state of the markets report to provide transparency on the market's performance to market players.

UK EXPERIENCE

The opening of power markets in the UK started in 1989 and significant reforms are still occurring, with the Electricity Market Reform in 2013, followed by the implementation of a Capacity Market in 2014 and reforms to the Ancillary Services Market and price caps in 2017.
The regulator Ofgem is responsible for the publication of a State of the Energy Market report, in which competition in the markets and affordability of energy for consumers are assessed among others[32].
Several measures have been implemented to mitigate the gaps of market results in the UK: notably, the reintroduction of established RE technologies to the 2021 CfD auctions (introduced in Sub-Recommendation 2 of Policy and Regulations Recommendation 2) illustrates how the observation of a low deployment of assets compared to the policy ambitions was addressed. Significant measures have also been undertaken to ensure the decarbonisation ambitions are met. On top of the European Emissions Trading Scheme, the UK introduced a coal phaseout and a carbon price floor.

The following actions are identified for Thailand:

[32] State of the Energy Market 2019 | Ofgem

- Provide directions to power markets through tailored design and implementation of revisions based on the monitoring of market mechanisms' results
- Plan the development of a detailed analysis of market results by the regulator
- Assess gaps on what power markets can deliver and take supplementary measures identified as necessary to achieve the targets

Sub-Recommendation 3: Protect consumers from uncertain outcomes

The decentralisation and introduction of market mechanisms can create uncertainty and volatility in price levels, both on the wholesale and retail markets. As Thailand aims for a transition at the lowest cost for consumers, it is recommended that safeguards are introduced within the regulatory framework to guarantee consumer protection throughout the transformation of the Thai power system.

The following action is identified for Thailand:

- Embed consumer protection clearly into market regulatory frameworks such as:
  - setting a regulated cap on retail prices and maintaining the option for a regulated tariff to limit the risks for consumers
  - ensure consumer protection in the event of supplier failure

4.3. Phasing the recommendations

PR1 *Develop trajectories towards the targets and elaborate on the means to achieve them* will provide clarity for all actors of the system and set the basis for underlying actions such as the evolution of support schemes. This can be developed in conjunction with the National Energy Plan – phased in the immediate to short terms to allow the establishing a complex model to support the trajectory development. A continuous review will be necessary as targets and trajectories are likely to evolve.

PR2 *Tailor support schemes to Thailand's ambitions.* The design of support schemes is dependent on investor confidence as well as the potential costs for the Thai government. Continuous supervision is needed to ensure these schemes remain responsive to evolutions in the power sector – phased in the immediate-term and through the short term.

PR3 *Foster private sector participation: reduce constraints, develop revenue opportunities and maintain confidence* and PR4 *Open and provide direction to markets.* Resource should be allocated to immediately develop the framework that will enable the private sector to participate to the RE deployment and provide clear remuneration avenues that will facilitate the achievement of Thailand's RE target – phased in the immediate term.

Table 2. Timescales for implementing policy and regulations recommendations

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
PR1				
PR2				
PR3				
PR4				

5. Market Mechanisms

The development of competitive markets in Thailand is a necessary step toward achieving Thailand's RE target as it will facilitate the participation of private actors in the power system. Engagement during the mid-project workshop confirmed that stakeholders largely agree that market mechanisms can facilitate the energy transition in Thailand, and that increased competitiveness of RE technologies can drive RE deployment towards the targets. Furthermore, more competition in the power sector will incentivise players to optimise their operation and innovate to remain competitive.

Market mechanisms are tools to remunerate providers and consumers with an open system of value and trade-offs to optimize distribution of power services in the most economically efficient manner. The outcomes of market mechanisms will be directly driven by the participation conditions, product specifications and optimised market settlement. The design of market mechanisms will impact their contribution to Thailand's RE and decarbonisation targets. As introduced in the Policy and Regulation section, guidance by policymakers and regulatory frameworks is key in providing direction to the market mechanisms.

This chapter discusses challenges that are related to market mechanisms and provides recommendations to ensure they are fit for purpose and enable the achievement of Thailand's RE target.

5.1. Challenges

The main challenges raised towards market mechanisms in Thailand are linked to the establishment of potential markets.

5.1.1. Unclear path to opening the power markets

The first challenge for market opening is the organisation of the power system, centred around the ESB model. A reform of the organisation, accompanied by a clear policy and regulatory framework for markets is necessary to enable private players to compete. While the National Energy Plan emphasizes decentralisation, how this will be rolled out is unclear and acts as a barrier to the deployment of renewables.

In addition, while several trading platforms have been developed, both by state-owned and private actors, there is uncertainty among actors regarding a change or diversification of the current market platforms for power transactions. In the absence of official trading platforms for energy, renewable energy certificates or services to the grid such as ancillary services, market mechanisms and business model development cannot occur.

5.1.2. Unclear outcomes of power markets under development

While there appears to be consensus that market mechanisms can facilitate the transition in Thailand, a mixed response was observed when stakeholders were asked whether "market mechanisms alone can enable Thailand to achieve its RE targets". The disagreement to this statement underlines the uncertainty associated to allowing market mechanisms to be the main driver of the transition.

Market mechanisms can accelerate the deployment of RE installations. However, there are limitations. Three examples are presented here to illustrate the uncertain role of market mechanisms:

- While some RE technologies are competitive today, some others may not have sufficiently low costs to be commissioned based on market mechanisms only.
- The penetration of variable RE in the energy mix will be associated with an increased need for grid flexibility, including its provision through storage and demand-side response. While selling energy or RECs can lead to revenues for RE installations, remuneration for flexibility means there is a need to rely on additional markets. The design of such flexibility markets remains an emerging effort globally.
- There remains a pending question on the role of RECs to drive the commissioning of RE installations within Thailand. The appetite for green tariffs could increase the price of RECs in Thailand, and sufficiently high price levels can generate additional revenue improving the economics of RE projects, enabling their commissioning. While removing taxes on REC trading is proposed as a solution to improve the economics of such a mechanism, REC value in the UK or European Union remains too low (around $1.5 to $2/MWh) to be a driver of installations.

Additionally, countries with high levels of RE penetration are experiencing low prices during periods of high RE generation. As a consequence, a cannibalisation effect is observed. This is a situation where the revenues that RE assets receive on markets decrease as the penetration of RE rises. While such patterns occur when the share of RE with low marginal costs reaches high levels in the mix, these observations reveal another challenge for market mechanisms to drive the transition towards high decarbonisation of the power system in Thailand.

5.1.3. Development of an ASEAN-wide power market relies on the development and alignment of national markets

Thailand's energy plans and engagement with Thai stakeholders reveal an ambition for Thailand to play the role of a hub within a regional ASEAN Power Grid. While the development of a regional market framework can provide benefits, the development of such an initiative will rely on cooperation between neighbouring markets and alignment of the policy and regulatory frameworks.

5.1.4. Carbon pricing mechanisms impact assets and consumers' economics

Carbon pricing can increase the competitiveness of low-carbon technologies on power markets and increase the power price during hours where carbon-emitting technologies set the price, leading to higher revenues for assets selling their production.

On the other hand, carbon pricing mechanisms can result in higher prices for consumers by affecting the power prices. Redistributing revenues generated by carbon pricing can help limit rising costs for consumers.

Several pilots and voluntary programmes related to carbon pricing mechanisms have been implemented within Thailand driven by the World Bank and the Thailand Greenhouse Gas Management Office. It is recognised that several laws (Greenhouse Gas Reporting Law and Emission Trading System Law) have been developed to be considered for inclusion in the draft Climate Change Act. The official establishment of a carbon pricing mechanism remains uncertain, leaving an open question for the potential revenues of RE installations.

5.2. Recommendations

Thailand is decentralising its power system and opening the sector to competition and will enable players of the power system to interact and trade different products. However, engagement with stakeholders in Thailand highlighted that both the path to opening markets, their design, and outcomes remain uncertain. As such, the recommendations MM1 to MM4 seek to enable the development of functional and tailored power markets which will facilitate Thailand's trajectory to its targets while leveraging investments from the private sector in developing RE.

Recommendations that are not specific to power markets but that impacts the power sector have also been included. These recommendations look to mitigate the challenges associated to the establishment of a Carbon market and the development of markets at the ASEAN scale.

A mapping of how the recommendations address the challenges is presented in Table 3

Table 3. Mapping of challenges against recommendations related to Market Mechanisms.

Market Mechanisms				
Challenges **Recommenda-tions**	Unclear path to opening the power markets	Unclear outcomes of power markets under development	Development of an ASEAN market relies on the development and alignment of national markets	Carbon pricing mechanisms impact assets and consumers' economics
MM1: Establish guidelines, frameworks and platforms to enable market development	✓	✓		
MM2: Develop tailored power market mechanisms for different purposes	✓	✓		
MM3: Formalise trading of renewable energy certificates	✓	✓		
MM4: Enable the participation of distributed and small actors	✓			
MM5: Contribute To efforts seeking to develop markets				✓

at the regional scale				
MM6: Implement existing plans of developing a carbon market			✓	

Market Mechanism Recommendation 1: Establish guidelines, frameworks, and platforms to enable market development

The current organisation of the power system in Thailand relies on the Enhanced Single Buyer model with bilateral contracts between independent power producers and state-owned utilities. Pilots and sandboxes for the trading of power products have been developed in Thailand but their translation into established markets in Thailand remains uncertain and the lack of visibility is a substantial challenge for actors of the Thai power system.

The following Sub Recommendations propose actions for the establishment of market guidelines and platforms which will facilitate the entrance and participation of new players in Thailand's power system. Engagement with stakeholders during the mid-project workshop revealed that transiting from the Enhanced Single Buyer model and opening competition is a priority for Thailand, suggesting that such actions would receive buy-in from actors in Thailand.

Sub-Recommendation 1: Facilitate the entry of new players

Opening the power sector to competition will introduce new players in Thailand's power system. Firstly, EGAT owns a large share of the existing fleet of generation assets, and consumers rely on state-owned utilities for their electricity. New players will find it challenging to compete with well-established incumbent utilities. If there are a small number of players involved, this can lead to the possibility of 'market power', where a few organisations have the influence to strategically impact market outcomes. It will be important for Thailand to ensure the regulatory framework associated to market opening enables a fair competition between new players and dominant incumbents. 'Market power' behaviour was observed in the UK following the opening of the power sector to competition, but a suite of regulatory reforms were implemented in the UK that increased competition and facilitated entry of new players into the market. A co- benefit of this reform is to limit the opportunity for generators and producers to make excessive profits, and ensure competition leads to efficiency for consumers.

Secondly, the emergence of distributed, small-scale installations will mean an increase in the number of small players, especially aggregators or actors of P2P trading. It will be necessary to ensure a level-playing field for these new actors in Thailand's future power markets. The EU experience below provides an illustration of potential guidelines to ease P2P development.

EU EXPERIENCE

The 2018 Directive[33] specifies: "The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators."

[33] EU Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources

Criteria were also developed, indicating that consumers should be entitled to P2P trading without being subject to disproportionate or non-discriminatory (network) charges, fees, levies, taxes and procedures.

The following action is identified for Thailand:

- Limit the potential for market power through a clear regulatory framework, for example by:
  - Screening the behaviour (offers and bids) of markets participants against benchmarks such as cost of production, marginal price, or past bids and offers
  - In the event of observed market power of a participant, consider implementing specific regulations to frame its submitted bids and offer prices or sanctioning the participant
- Facilitate market entry of competitors by ensuring a level-playing field for all actors
  - Ensure market participants have the same rights and obligations when entering markets
  - Consider allowing installations and resources to participate in markets based on what services they can provide rather than their nature or type of technology.
  - Design standardised products based on the characteristics of all resources relevant to provide the services, including small assets

Sub-Recommendation 2: Develop Exchanges and display transparency

Market development relies on the existence of exchange platforms where buyers and sellers can interact. Scaling up existing pilots into official platforms is necessary. While several exchanges can be implemented for different markets, each should provide clear information which enable players to participate. In particular, guidance towards market access, participation and exit, specifications of traded products, and the methodology for the calculation of price and market settlement will be key to enable participation.

Furthermore, transparency on the market operation and access to market data will enable project developers to assess the true value of services and quantify potential revenues which can drive investment decisions. Market transparency also enhances the confidence of participants in competition. Access to market data will also enable the energy regulator to analyse market results and identify potential problems. Considering the current centralised organisation of the Thai power system, characterising current generation costs from EGAT and the associated pricing structure should be a first action to improve transparency and understand potential future market outcomes.

Finally, transparency in the governance and role of different actors in the development of markets is necessary to support the decentralisation of the Thai power system. While the government and regulator can provide inputs towards product development, expert organisations (such as the system operator EGAT) and market players are expected to provide valuable insights. These insights will strengthen the market design, thereby increasing the actors' confidence in the market operations. Public consultations with power market actors therefore be necessary.

The following actions are identified for Thailand:

- Establish official Exchanges for trading, including clear market rules and product design
- Ensure transparency and assign the energy regulator to monitor market results
- Characterise current generation costs and prices passed onto consumers
- Consult power market actors to collect inputs for market design specifications
- Clarify the roles in the market governance, and develop markets that serve policy objectives while integrating participants' contributions

Sub-Recommendation 3: Design standardised, tailored products and market operation

The design of the traded products will determine market participation in Thailand. As exchanges rely on standardised products, the product specifications and eligibility criteria will determine which players can participate and what products they can provide, eventually defining which assets or solutions can be included in the markets.

As Thailand's power sector is expected to evolve towards a higher share of variable, distributed RE associated with the emergence of small players, specific attention should be placed in ensuring standardised products and market operators enable the participation of such actors. For example, a low requirement for minimum capacity will open the door to small players, while enabling participants to adjust their bid at periods close to the delivery of power will be favourable to the participation of variable RE installations.

The UK experience described below shows challenges faced in the UK to adjust the market from conventional installations to enable new actors to emerge. The definition of products remains a continuous process as the delivery of market mechanisms (such as capacity additions) can be different from policy expectations.

As Thailand establishes market mechanisms to deploy distributed and variable installations, it is key to ensure that standardised products and the operation of markets enable the participation of all players. Again, policy and regulations are key to guiding markets as explained in Policy and Recommendations Recommendation 4.

UK EXPERIENCE

Power markets in the UK were initially designed for the participation of large, conventional technologies. As a result, the criteria were not adapted to enable the participation of smaller actors with different technical constraints. Reforms were implemented in the wholesale, capacity, and ancillary services markets to enable a larger range of options to compete in markets.

Furthermore, lack of standardisation has been expressed as a significant barrier for aggregators to enter the Ancillary Services Market. The 2017 reform of the ancillary services markets relied on input from market participants for the development of streamlined products.

In 2021, the UK government launched a Call for Evidence[34] for its Capacity Market. Based on the observation that the current design does not deliver results aligned with net-zero ambitions, actions were sought to increase the competitiveness of solutions towards a net-zero trajectory. Early propositions for market reform include reviewing the eligibility criteria, improving the consideration for projects with long-build times, and splitting auctions to open a window for low carbon capacity to compete.

The following action is identified for Thailand:

- Develop tailored, standardised products which take into account characteristics of expected participants: variable RE, storage technologies, and small players in particular

[34] Capacity Market: Improving delivery assurance and early action to align with net zero

Market Mechanism Recommendation 2: Develop tailored power market mechanisms for different purposes

Market design and the associated products determine who can participate and the technologies they deploy, which in turn impacts the overall market structure. The development of multiple market mechanisms in Thailand is needed to support the operation of a reliable and cost-effective power system.

The market mechanisms developed will differ across several parameters, such as:

- Geographical scale – local, area, national or ASEAN wide
- Participants – state-owned entities, private producers, suppliers or new distributed players
- Timescale - ensuring the instantaneous grid stability or the development of capacity in the power system
- Commodity exchanged - energy, capacity, REC, or GHG emissions allowances

Power assets and business models can be based on stacking revenues captured across multiple markets.

As the design of market mechanisms in Thailand remains to be established, the following Sub Recommendations are relevant for Thailand and introduce associated mechanisms established in the UK.[35]

It should be noted that the UK's primary focus to increase competition in generation evolved towards market segmentation, with market mechanisms developed at different stages in response to the trajectory of the UK power system. The development of capacity and flexibility market mechanisms can be associated to the rising penetration of RE in the UK. Considering that Thailand is opening market mechanisms to achieve high RE penetration ambitions, their development may be undertaken differently. There is an opportunity to plan the contribution of variable and distributed RE and flexibility assets from the first stages of market mechanism design.

Sub-Recommendation 1: Enable generators and suppliers to trade electricity

A first layer of exchange will be to enable generators to meet suppliers and trade electricity (energy). The wholesale markets enable suppliers to purchase energy from generators. The wholesale electricity market can be the first market mechanism to be developed in Thailand and pave the way for others in the future. Its development can be guided by the study conducted by EGAT and the Stock Exchange of Thailand on the development of a wholesale electricity market trading platform.

The following action is identified for Thailand:

- ➢ Establish a functional wholesale electricity market for trading of energy volumes based on results from the study conducted by EGAT and the Stock Exchange of Thailand.

Sub-Recommendation 2: Manage the power system's balance and stability

In order to maintain a reliable power system, it is necessary to balance the grid (matching supply and demand) in real time and maintain the grid frequency at a predefined level. As the share of variable and

[35] The UK markets introduced do not represent an exhaustive list of the markets in place in the UK, but illustrate different purposes that appear potentially relevant for Thailand.

distributed RE and actors connected to the grid increases, the challenge of maintaining the balance will become more prominent in Thailand. Providing the means for the system operator to maintain balance and frequency of the system in an economically efficient way can be approached through the development of an ancillary services market.

In addition, market mechanisms can incentivise market participants to balance their position and facilitate the operation of the power system. When the ESO balances the grid after the gate-closure of wholesale markets there is an opportunity to allow installations to adjust their position to ease the balancing which can provide economic gains for all players. The balancing mechanism can be designed to penalise actors for imbalances, which acts as an incentive for market participants to align their physical and market positions, as is illustrated in the UK experience below.

UK EXPERIENCE

In the UK, the balancing mechanism (and associated market) implies that suppliers and generators can provide 'offers' to adjust their output to regain system balance but are also charged for their imbalance (physical position differing from their market position). This mechanism incentivises players to balance their position to avoid financial penalties, enables an economic balance of the operation through an optimised settlement, and compensates the system operator for the measures taken to ensure real time supply and demand balance through the imbalance price.

The following actions are identified for Thailand:

- Pursue the implementation of ancillary services markets, with product design enabling the participation of distributed resources (potentially through their aggregation)
- Explore the implementation of balancing services to incentivise players to align their physical and market positions and optimise the costs of balancing supply and demand

Sub-Recommendation 3: Respond to security of supply concerns and influence the evolution of installed capacity

The economics of RE assets are expected to substantially evolve as Thailand's power system decentralises and decarbonises. The penetration of RE, or potential implementation of a carbon price, will be detrimental to the economics of conventional assets. As a result, the fleet of conventional generators in Thailand may experience falling revenues. New market players may also face the situation where power markets do not sufficiently remunerate them.

Remunerating RE installations for their capacity may be considered in the future in Thailand especially when there is uncertain system security. However, considering the high installed capacity in Thailand, and the uncertainty of the benefits of capacity markets over flexibility markets, assessing the role for a capacity market and its implementation could be delayed to the medium-term.

The UK experience below illustrates how the UK introduced a capacity market in response to security of supply concerns.

UK EXPERIENCE

The 2013 Electricity Market Reform saw the development of a capacity market, designed to ensure sufficient capacity remains in the UK grid to respond to demand. This market enables power assets to capture additional revenues for being available during peak periods in the UK. This additional revenue makes up for decreasing revenues associated to decreased load factors for conventional installations, and can enable the build of new installations. The capacity market is a mechanism significantly led by the UK government

to maintain capacity adequacy. The related call for evidence (introduced in Market Mechanism Recommendation.1) illustrates new government ambitions to align its delivery with the net zero target.

The following action is identified for Thailand:

- In the event of capacity adequacy concerns or to support new capacity deployment, estimate the benefits of the implementation of a capacity market and consider implementation

Sub-Recommendation 4: Trigger flexibility in the energy system

Flexibility needs are expected to grow as the amount of variable, distributed RE increases within Thailand. The mid-project workshop ranked the development of markets remunerating system flexibility and demand-side response as second in importance. As existing infrastructure in Thailand can unlock flexibility potential (as described in Infrastructure Recommendation 1) and flexibility market mechanisms remain globally immature, the development of a framework and associated business models for flexibility in Thailand should be seen as a first priority. This should be before the establishment of flexibility markets. It is important to work with the actors of the power system to identify barriers and tailor market design to facilitate their participation.

While the development of flexibility markets in the UK is still emerging[36], necessary reforms to current market design have been identified to facilitate the participation of flexibility actors. These reforms hint at remunerating flexibility services through market mechanisms such as capacity markets and CfD schemes.

The following actions are identified for Thailand:

- Support research and innovation on potential flexibility services and business models
- Engage with the sector to prepare the development of flexibility services in the medium-term
- Estimate the benefits of the implementation of flexibility markets and deliver their implementation based on the analysis conclusions

Market Mechanism Recommendation 3: Formalise trading of renewable energy certificates

A Renewable Procurement Scheme (RPS) was introduced in Thailand in 2003 associated with a 5% mandatory share of RE in the generation capacity of EGAT, which led to an increase of renewable capacity, especially hydroelectric power plants.

Today, as RE economics improve and customers in Thailand display interest for “green power” consumption, the opportunity to develop a market-based mechanism relying on Renewable Energy Certificates (RECs) to incentivise the development of RE is considered. The trade of RECs could translate into a promotional mechanism for RES: demand from customers for RECs would increase the value of RECs paid to RE generators and increase revenue potential and encourage investment in RE. Enabling the trade for REC could replace the need for public support schemes such as the feed-in-tariff and renewable procurement scheme, and green tariffs could be enablers of Thailand’s journey towards its ambitions.

[36] The UK Smart Systems and Flexibility Plan 2021 aims to facilitate flexibility in the UK through regulatory and market reform

Discussions with stakeholders in Thailand revealed that bilateral trading of REC is already implemented and managed by EGAT. Exchanges for multilateral trading of RECs have also been developed by several organisations in Thailand. However, stakeholder engagement informed that the final framework and market design for REC in Thailand remains to be defined and formalised. In the absence of a clear design, substantial uncertainty remains on the role RECs can play in facilitating RE deployment in Thailand. Tackling this uncertainty by elaborating on the design of RECs and their trading in Thailand is therefore necessary.

Two directions can be followed in Thailand: linking RECs to a mandatory procurement scheme through the long-term, or relying on appetite for green power to drive demand for REC. Both options have been introduced in the UK, each having a specific design and outcome, as illustrated below.

UK EXPERIENCE

Two distinct types of renewable energy certificates have been implemented in the UK: the Renewable Obligation Certificates (ROCs) and the Renewable Energy Guarantees of Origin (REGOs).

ROCs were implemented along with the Renewables Obligation (RO), which placed an obligation on suppliers to source a predefined proportion of their supply from RES sources (10% by 2010, 40% by 2018).

- *Initially, 1 ROC per MWh of renewable output was issued to RES generators. From 2009, differentiation of the quantity of ROCs allocated by technology and date of commissioning was implemented, to enable less mature technologies to develop,*
- *The 2019/20 price was ~£48/MWh,*
- *The generator received ROC value on top of the wholesale electricity price,*
- *The RO had no budget nor capacity cap: the cost of the scheme was not bounded.*

The Electricity Market Reform led to the replacement of the RO mechanism by the CfD scheme, perceived as better designed to enable the transition.

REGOs are the UK adaptation of the EU Guarantees of Origin, which were implemented as an accountability mechanism:

- *The Renewable Energy Guarantees of Origin (REGO) serve as an accountability tool to provide transparency to consumers about the proportion of electricity that suppliers source from renewable generation.*
- *1 REGO per MWh of renewable output is issued to RES generators*
- *The 2021 price of UK REGOs was ~£1/MWh*
- *The generators can trade the REGOs to value their production*
- *Electricity suppliers use REGOs to show customers the renewable content of electricity they have supplied each year and are especially used in "Green" tariffs.*

While REGOs are necessary for disclosure of the supply mix, they were not designed to support the build of RE installations: their value provides a supplement to potential valuation of renewable production on energy markets, but it remains too low compared to the costs of RE installations to trigger their commissioning. REGOs are also associated with potential perception for greenwashing[37]: the profile of consumption of physical power can be decorrelated from the RE generation profile; in addition, the REGOs of energy produced by RE installations that receive public support can be claimed by consumers who buy the REGOs only. This perception triggered reaction from the regulator Ofgem who will review the rules for green tariffs for more transparency to consumers on the role of green tariffs in providing environmental benefits.

[37] These observations are extended to the European Union Guarantees of Origin

The UK example shows that the definition of the REC and associated framework can significantly impact the value of RECs and their potential to be a RE promotion mechanism. It is recommended for Thailand to carefully design the REC framework to ensure the desired outcome.

Stakeholders in the mid-project workshop showed strong agreement across all stakeholder categories that a mandatory share of RE in supply will be needed to achieve the targets, which could ease the buy-in to such a mechanism. Learnings from the limitations of the RO in the UK provide insights on such a scheme and associated certificates design.

On the other hand, enabling private consumers to support RE through voluntary purchase of RECs will transfer them some costs of building RES and reduce the burden of public support on all Thai consumers. Uncertainty remains on the volume of demand for such tariffs, which will directly influence the RECs value and the development of RE capacity that could be achieved in comparison to Thailand's RE target. The UK experience shows such a market-mechanism should be supported by a robust design to enable the RECs to be an investment signal[38]: Notably, interaction with policies supporting the development of RES (and supply of RECs) can lower the value of REC.

The following actions are identified for Thailand:

- Provide transparency on the potential implementation of a mandatory share of RE in supply to drive the 50% RE target
- Quantify the interest from consumers for green tariffs in Thailand to understand their potential role in driving RE capacity deployment
- Consider the development of RECs standardised at the regional level (see Market Mechanism Recommendation 5)
- Ensure transparency for consumers on the role of RECs and green tariffs
- Enable multilateral trading of Renewable Energy Certificates through the implementation of an Exchange

Market Mechanism Recommendation 4: Enable the participation of distributed and small actors

Thanks to favourable economics, lifting regulatory barriers and opening markets could lead to the significant deployment of private distributed RE installations in Thailand. Ensuring the stability of the system at the distribution level will also be necessary when more RE assets are connected to the distribution grid. Market mechanisms which provide remuneration to distributed and small RE installations and also actors at the distribution level will ease the Thai energy transition.

Sub-Recommendation 1: Increase participation from distributed players

Distributed resources will play a significant role in the Thai energy transition, both in terms of generation and flexibility. While economics for distributed RE are already favourable for some RE technologies, it is expected that Energy Storage Systems will become increasingly competitive in the next decade. Demand-side response (DSR) services should also be considered as an economic solution to provide significant flexibility capacity in the future.

[38] Potential solutions would be to set a minimum REC price, or distinguish certificates depending on projects receiving or not public support.

The Aggregator model, which generates revenue by aggregating several assets (including DSR) into virtual units will also be particularly relevant in Thailand. While individual installations may not be willing, able, or skilled to contribute to complex markets, aggregators will bundle distributed installations and optimise their positions on markets. In addition to generating revenues for distributed installations, this will also economically ease the operation of the future power grid in Thailand.

Designing markets in a way that will enable small players and aggregators to participate and provide services will be key to facilitate Thailand's transition.

The following action is identified for Thailand:

- Enable participation of distributed players and aggregators to operate in markets by adapting market design and product definition
- Explore the development of local flexibility platforms where distributed network operators can remunerate services from distributed installations and small players that reduce the network costs

Sub-Recommendation 2: Facilitate active consumer and prosumer participation

Consumers can provide significant benefits to the future Thai power system by changing their behaviour to support the installation of RE.

For example, offering time-of-use tariffs, where the price of electricity varies in time, can lead consumers to react to prices and use electricity during low prices which are often associated with abundant, decarbonised supply. As a side-benefit, it will support a more flexible and sustainable system where RE energy integration is facilitated and peak demand can be lowered, decreasing the need for infrastructure development.

In addition, the peer-to-peer trading model[39], where consumers directly engage with producers to trade electricity, can allow a more proactive behaviour at the local scale and empower owners of distributed RE installations as well as consumers. Both actors can exchange power directly at an optimised price, which can generate economic benefits.

Enabling the prosumer behaviour and peer-to-peer trading relies on a clear regulatory framework including rules for grid access, the deployment of smart appliances, and development of innovative tariffs and energy services. The following actions rely on preliminary regulatory, market and infrastructure developments.

The following actions are identified for Thailand:

- Facilitate active consumer behaviour through the development of economic signals, such as dynamic retail pricing
- Enhance means for prosumer behaviour through the establishment of peer-to-peer trading

Market Mechanism Recommendation 5: Contribute to efforts seeking to develop markets at the regional scale

[39] Peer-to-peer (P2P) electricity trading is a business model, based on an interconnected platform, that serves as an online marketplace where consumers and producers "meet" to trade electricity directly, without the need for an intermediary. It allows local distributed energy generators to sell their electricity at the desired price to consumers willing to pay that price.

Thailand has the ambition to increase how much power they trade with neighbouring countries and become a hub within the ASEAN Power Grid project in the coming decades. The development of a regional power market can generate benefits for Thailand and other ASEAN countries, due to the potential exploitation of synergies between national supply mix and optimisation of the system operation.

Implementation of a regional power market relies on significant coordination between member states and will have an impact on Thailand's national policies and power system. Specific attention to the development of this regional market is recommended to ensure its implementation aligns with Thailand's energy transition.

As Thailand's power market is yet to be developed, the timeline for the establishment of the ASEAN Power Grid should be staged and coordinated with the development of markets within Thailand.

Sub-Recommendation 1: Progressively develop a regional market that will deliver common benefits

Regional markets can enable an enhanced optimisation of the dispatch: abundant or cheaper supply in a country can flow to satisfy demand in another country. In addition to the optimised dispatch of assets on regional market, two additional benefits can emerge should a significant integration of countries' power markets develop:

- The system operation can be optimised at the wider, regional level, reducing the costs for each country.
- The facilitated trade of electricity between zones of the market is a facilitator of RE integration as the electricity generated in one zone can be integrated into the supply mix of another country. This limits the cannibalisation effect at a smaller geographical scale and enables zones to benefit from the variable RE resources available in different areas.

The regional market will need a harmonised framework, relying on common regulations and trading rules and the coordination of market operators. In addition, the trade of power should be linked to the possibility for physical flow of electricity; cross-border interconnectors will be determinant of the development of the ASEAN Power Grid.

The EU experience presented in Appendix 6 provides further details on the development of the EU internal energy market.

Engagement with Thai stakeholders during the mid-project workshop revealed that developing an ASEAN-wide energy market is ranked as a low priority for market mechanisms. A first action in the near-term should be to pursue cooperation at the ASEAN level.

The following actions are identified for Thailand:

- Pursue cooperation with neighbouring countries to coordinate market design
- As market opening emerges in Thailand, pursue development of market operators' alignment and propose the establishment of an organisation dedicated to regional power systems coordination
- Assess the costs and benefits of increasing cross-border interconnection capacity and plan the potential development of interconnectors
- Develop market coupling where enabled by preliminary coordination
- Assess potential common dimensioning of power systems across the regional market

Sub-Recommendation 2: Assess the need for common REC development

An ASEAN Power Grid could enable physical flows of electricity between countries, the RE character of the power may be linked to Renewable Energy Certificates in Thailand and in other ASEAN countries. Subject to the establishment of RECs as the proof of the RE aspect of electricity across the regional, trading of RECs across ASEAN countries may be required for Thailand to sell the RE value of its electricity, or to buy RE electricity from neighbouring countries.

EU EXPERIENCE

To enable trading of renewable energy certificates at the EU scale, a standardisation has been established at the EU level: the Guarantees of Origin (GOs) are harmonised and are the only instrument that can be used to prove the origin of electricity generated from RES.

Based on this experience from the EU, the following action is identified for Thailand:

- Consider the potential establishment of standardised and common renewable energy certificates across members of the ASEAN Power Grid

Sub-Recommendation 3: Assess and monitor the ASEAN Power Grid interaction with Thailand's power system and market

Developing a regional power market could provide benefits but also increase interactions and interdependencies between national power systems. As a result, both policy and technical developments in one zone of the market could impact others. The two examples from the EU experience below show how localised physical constraints can impact the market at the regional scale:

EU EXPERIENCE

- *In the Winter 2016/17, nuclear outages in France resulted in spikes in power prices across the EU, with impact felt in the UK which has limited interconnection with other countries due to its geographical position, Central Western Europe, Italy and Scandinavia;*
- *In September 2021, an incident of the IFA interconnector between the UK and France led to decreased import capacity of 1GW for the UK: markets reacted with prices soaring to 2,500.01£/MWh for the peak hour on the day-ahead UK market*[40].

The two examples from the EU experience below show how the regional market can interact with national policies:

EU EXPERIENCE

- *In 2016, France announced its willingness to implement a carbon price floor on top of the European allowance (EUA, the carbon price being set by the EU Emissions Trading System). This unilateral decision was however withdrawn: increasing the cost of power generation in France only would translate into decreased competitiveness for French assets on the EU market compared to other assets in EU with potentially higher carbon emissions. While aiming to reduce emissions on the national ground, the impact of this unilateral national measure was a potential increase in carbon emissions at the EU level. The Netherlands implemented a national carbon price floor: analysis expect this to translate into lower generation from assets within the Netherlands, while units in neighbouring countries, coal plants in Germany in particular, increase their output and associated emissions.*

[40] Fire at French interconnector sends electricity prices soaring | E&T Magazine (theiet.org)

- *The trade of RE Guarantees of Origins across countries mean some countries may bear the costs of the RE capacity development, while others can buy the GOs to certify some share of RE supply in their mix. This leads to confusion on the role of GOs and can be detrimental to the public support to trading of both GOs and power at the European level.*

If there was an establishment of an ASEAN Power Grid, such interactions between national power systems and policies with the regional market are likely to occur. The following actions have been identified for Thailand:

- Assess developments of policies, market mechanisms and infrastructure related to the Thai power system in the context of the ASEAN Power Grid

Market Mechanism Recommendation 6: Implement existing plans of developing a carbon market

Thailand has developed trials of carbon pricing mechanisms but implementation of a carbon tax or a market mechanism remains uncertain, leaving an open question for the potential revenues of RE installations on markets.

A carbon pricing scheme covering Thailand's power sector could improve the competitiveness of RE assets, as well as trigger a switch from coal to gas generation in the merit order. Carbon pricing can directly contribute to Thailand's RE target and decarbonisation ambitions. The introduction of a carbon pricing scheme however is a policy decision. Engagement during the mid-project workshop revealed discrepancies across actors, participants associated to the government appearing more inclined towards setting carbon pricing mechanisms as a priority action. Both carbon taxes and a carbon market (Emissions Trading System, or ETS) have been proposed as solutions. More details are provided in Appendix 6.

Should the trials of carbon pricing mechanisms in Thailand be translated into the implementation of a carbon market, the following recommendations can be provided for the roadmap, to ensure the carbon market delivers efficient signals for RE deployment.

Sub-Recommendation 1: Design and maintain a market coherent with Thailand's long-term decarbonisation ambitions

When implementing a carbon market, Thailand should ensure its design is coherent with Thailand's long-term decarbonisation emissions. In particular, the ETS will rely on a definite number of allowances (or the right to emit greenhouse gases) which are then issued by the government. Ensuring the number of allowances issued is compatible with Thailand's long-term decarbonisation ambitions is necessary for the market to drive decarbonisation; a surplus of allowances would enable installations to emit more than the carbon budget associated with the trajectory.

In order to trigger low-carbon investment in the power system, the ETS in Thailand should cover installations of the power system. As the risk of carbon leakage (increased emissions in other countries that would replace activity in Thailand) remains limited for the power system, power installations can be subject to buying the allowances. This cost will then be transferred into the power price, improving the economics of RE installations on power markets.

Experience for the European Union ETS showed a surplus of allowances could be significantly detrimental to the price formation on an ETS. Ensuring the regulatory framework of Thailand's ETS includes measures that enable to review the volume of allowances is highly recommended.

The following actions are identified for Thailand:

- Design a carbon market with a trajectory in line with Thailand's decarbonisation ambitions
- Integrate the power system to a trading scheme, with power installations buying allowances to emit
- Introduce in the market design measures enabling the revision of the volume of allowances to tackle the potential surplus
- Monitor the market results and adapt the volumes of allowances issued

Sub-Recommendation 2: Assess and mitigate the impact of overlapping policies

For Thailand to ensure its potential carbon market to remain a strong decarbonisation tool, it is necessary to address the interactions between policies and the carbon market. Otherwise, the efficiency of the ETS to drive decarbonisation can be undermined.

The EU experience below illustrates how the overlap between policies supporting RE and the EU ETS caused challenges to the functioning of the EU ETS. It is recommended for Thailand to carefully integrate the design of its potential carbon market with the impact of RE subsidy schemes.

EU EXPERIENCE

The EU ETS aims to drive cost-optimised decarbonisation covering the EU power sector and large industrial installations. In addition to this market-based scheme, direct subsidies to the development of RE installations led to decreased emissions in the power sector 'outside' of the EU ETS. This generated a surplus of allowances as lower emissions were emitted by the power sector and contributed to low EUA price levels. Considering and mitigating the impact of the overlap of RE policies and the EU ETS is a repeated recommendation for the EU ETS.

The following actions are identified for Thailand:

- Integrate overlapping policies, especially towards RE, within the carbon market design and dimensioning
- Assess the level of emissions reductions associated to RE and other overlapping policy schemes and deduct them from the volume of available allowances

Sub-Recommendation 3: Plan the redistribution of revenues

The implementation of an ETS will generate revenues for the Thai government through the sale of allowances (or the right to emit greenhouse gases). Redistributing the revenues to consumers will increase the acceptance of a carbon pricing scheme. Furthermore, the revenues can be reinvested into low-carbon investments. The ETS then enables a transfer from high- to low-carbon technologies and would support Thailand's ambitions for a low-carbon economy.

The following actions are identified for Thailand:

- Ensure the revenues from allowances auctioned by the government are redistributed to support Thailand's low-carbon economy: the auction revenues can be allocated to dedicated funds

Sub-Recommendation 4: Propose the implementation of a regional carbon pricing or introduce an adjustment mechanism

The implementation of a carbon pricing mechanism will increase the production costs of installations that emit CO_2 in Thailand, for example of power generation assets and industrial installations should these sectors be covered under the scheme. As a result, the competitiveness of installations in Thailand would

decrease compared to countries that do not implement a carbon pricing mechanism, or where the carbon price is lower.

Considering the aim to develop the ASEAN Power Grid, a unilateral carbon pricing mechanism in Thailand will translate into a disadvantage for power installations in Thailand compared to other countries of the ASEAN Power Grid. The benefits of the carbon pricing scheme, to decrease emissions and create a signal for low carbon investment in Thailand, could be undermined.

The following actions are identified for Thailand:

- Engage discussions at the regional level for a potential regional carbon market, which would limit the risk of carbon leakage; this is particularly relevant in the context of an ASEAN Power Grid which would facilitate electricity trade and enhance competition between installations within and outside Thailand
- Subject to the development of a carbon market across the ASEAN region and Power Grid, explore the potential of introducing a carbon border adjustment mechanism

5.3. Phasing the recommendations

MM1 *Establish guidelines, frameworks, and platforms to enable market development* is a key activity that needs to be done to support the transition from the Enhanced Single Buyer model and open up competition – phased in the immediate term.

MM2 *Develop tailored power market mechanisms* that are identified as relevant to ensure optimal system operation as the Thai power system evolves and to provide a clear signal to investors. Assessments to understand the relevance of these market mechanisms and to tailor their development should be undertaken early on to prepare the power system's transition. Continuous revisions of the market design will also be necessary through the long-term journey as new technologies, needs and actors are likely to emerge – phased to commence in the immediate term but must also continuously happen through the long term.

MM3 *Formalise trading of renewable energy certificates.* The design of the REC and associated market will impact its role in the deployment of RE capacity in Thailand. Clarifying the design of RECs in Thailand should be undertaken as the initial stage – phased in the immediate term.

MM4 *Enable the participation of distributed and small actors.* Distributed energy generation and actors are expected to play an increasing role in Thailand as distributed RE installations will develop. Enabling their participation to markets should be implemented once the guidelines and frameworks on broader market mechanisms have been developed – phased in the short term.

MM5 *Contribute to efforts seeking to develop markets at the regional scale.* Developing an ASEAN regional market is an intervention that should happen, but is not an urgent priority. In the near-term, pursuing engaged cooperation at the ASEAN level will be helpful to harmonise market design and ensure future integration is facilitated. Harmonizing the standards across ten different countries with different geographies, challenges and at different levels of development will however be time-consuming. In addition, the power system in Thailand is expected to substantially evolve through the short-term – phased in the medium term and to continue in the long term.

MM6 *Implement existing plans of developing a carbon market.* Although mid-project workshop participants did not view a carbon market as an important mechanism as compared to others, carbon pricing is an

important tool to reduce GHG emissions beyond the energy sector. It is acknowledged that Thailand has undertaken a lot of work on this topic, and draft laws have been developed. Pricing mechanisms generally take a long time to implement – phased in the short term but to continue into the medium and long terms.

Table 4 summarises the timescales for implementing these market mechanism recommendations.

Table 4. Timescales for implementing market mechanism recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
MM1				
MM2				
MM3				
MM4				
MM5				
MM6				

6. Infrastructure

Substantial evolutions in Thailand's physical and virtual power system infrastructure are needed to ensure the system remains reliable with increasing RE integration. The grid infrastructure needs to be upgraded to connect with the RE installations and ensure the transport of electricity from generation to demand sites. As the RE installations are expected to be increasingly connected to the distribution grid, transformations in the operation of both the transmission and distribution networks in Thailand will be needed.

Conventional assets need to operate with increased flexibility to accommodate the variability of outputs from some RE installations to ensure continuous system equilibrium. New technologies for energy storage will be needed to store potential excess RE and satisfy power demand in periods of low RE generation.

The dynamic operation of the system will rely on the digitalisation of the infrastructure through the development of hardware, such as smart appliances and smart meters, as well as the associated software enabling data management and communication.

Assessing the future infrastructure needs to be done within the trajectory defined in setting Thailand's renewable capacity, carbon neutrality and net zero targets. This ensures the most relevant technologies are developed and operated in an optimised way.

6.1. Challenges

Infrastructure development in Thailand is expected to face challenges. The mid-project workshop confirmed that stakeholders in Thailand strongly agree that the increased penetration of variable RE can impact the reliability of the system, illustrating the perception of a risk which will need to be assessed on the trajectory towards the target.

The sections related to infrastructure in this report focus on the physical and virtual layers associated to the power system operation, the market mechanisms sections state the need for exchange platforms to be developed.

6.1.1. Present infrastructure operation has limited flexibility which can restrict variable RE deployment.

With increased penetration of variable RE, system flexibility will be key to absorb fluctuations in RE output and maintain the stability and reliability of the power system. However, the present flexibility of the Thai power system, provided exclusively by large conventional assets, is constrained due to both technical and contractual constraints.

Given this lack of flexibility, currently independent power producers who want to install large RE installations in Thailand can sign firm-PPAs, where the output to the grid has to remain steady with time despite the inherent variability of the RE asset. Alternatively, the non-firm PPAs proposed to small installations that don´t need to comply with this requirement of steady generation imply that there is no guaranteed offtake of the installation's output.

The first challenge identified related to infrastructure is to unlock the flexibility potential of the present infrastructure, which could enable easier implementation of variable RES.

6.1.2. Existing distribution grid was not designed for a high share of variable distributed RE

The second challenge identified through stakeholder engagement in Thailand is that the existing distribution infrastructure, both physical and virtual, was not built to integrate a high share of distributed and variable RE. It is worth adding that this is not a particular challenge that exclusively for Thailand. But as other countries aiming to reach high share of RE, significant infrastructure developments will be needed to:

- maintain the stability and reliability of the grid
- ensure the offtake, transport, and supply of the RE generation from producers to consumers
- enable the participation of decentralised actors in the power system.

Engagement through the mid-project workshop revealed that stakeholders in Thailand have varying opinions on whether existing transmission and distribution infrastructure can support high RE penetration.

Energy plans in Thailand however confirm that modernisation and digitalisation will be key to Thailand's energy transition.

6.2. Recommendations

Following the observation that the evolution of the infrastructure is acknowledged and planned in Thailand, three recommendations seeking to optimise the infrastructure evolution, both in its operation and dimensioning, have been derived. A mapping of how the recommendations address the challenges is presented in Table 5

Table 5. Mapping of infrastructure challenges against recommendations.

Infrastructure		
Challenges / **Recommendations**	Present infrastructure operation has limited flexibility which can restrict variable RE deployment	Existing infrastructure was not designed for a high share of variable, distributed RE
IF1: Increase flexibility from existing assets to facilitate penetration of renewable energy	✓	✓
IF2: Characterise the infrastructure development needs and costs		✓
IF3: Enhance digitalisation to enable a grid operation with high penetration of distributed variable RE.	✓	✓

Infrastructure Recommendation 1: Increase flexibility from existing assets to facilitate penetration of renewable energy

In order to accommodate to the penetration of variable RE, the Thai power system will need to operate with more flexibility, with an increasingly dynamic management of supply and demand balance. If significant shares of RE penetration can be challenging for the operation of a power system, the existing

infrastructure in Thailand, relying on substantial dispatchable capacity (coal, gas and hydropower especially) can contribute to the flexibility of the system and ease the penetration of RE.

In the current operation of the Thai power system, large RE installations are responsible for smoothing their generation profile (through firm-PPA contracting). However, this constrained on the output from RE can be reduced as other generation is available to provide flexibility.

While the Thai power system, were designed to connect and operate with large power plants, analysis of the Thailand Power System Flexibility from the International Energy Agency suggests that the existing system has latent technical flexibility to integrate up to 15% of variable RE by 2030 (compared to a 4% share of wind and solar in total generation in 2019).

Therefore, it appears relevant for Thailand to take actions which will develop this latent flexibility. The proposed sub-recommendations and actions discuss how such flexibility can be eased as a first step to adapt the Thai infrastructure to the growth of RE.

Sub-Recommendation 1: Trigger the flexible operation of conventional assets

Analysis of the Thai power system revealed that the flexibility of existing large conventional assets is constrained due to both technical and contractual constraints. Lifting these barriers to enhance the infrastructure flexibility is therefore recommended. Among five actions related to infrastructure submitted to participants of the mid-project workshop, "increasing the flexibility of existing conventional assets' operations" was ranked first in order of importance which suggests broad support from interviewed stakeholders.

Experience in the UK and EU revealed that incorporating a moderate share of variable RE in the power system was achievable without significant infrastructure developments. Difficulties emerged when only little dispatchable capacity (such as conventional thermal or hydropower generators) remain, or when levels of RE capacity can lead to network constraints or thermal issues.

The following actions are identified for Thailand:

- Review existing and future contractual arrangements of power assets to promote flexible operation (notably fuel procurement contracts)
- Identify power plants with greatest potential, or those that need retrofits, to provide more flexibility to the Thai power system
- Ease the technical flexibility of conventional assets (thermal and hydropower) through refurbishment or retrofits to lower potential minimum generation thresholds and increase ramp-up and down rates

Infrastructure Recommendation 2: Characterise the infrastructure development needs and costs

The absence of infrastructure adapted to a high share of distributed and variable RE in Thailand is a challenge, and the need for infrastructure development is recognised. Several plans have been developed to support infrastructure deployment in Thailand – the Smart Grid Master Plan and the Grid Modernisation of Transmission and Distribution Plan. The following recommendations have been derived from international best practices and optimise the characterisation and achievement of Thailand's infrastructure development.

Sub-Recommendation 1: Develop a whole-system view to enhance infrastructure deployment

While economics of RE technologies can drive the deployment of RE capacity in Thailand, it is recommended to assess the system as a whole and consider both the value and costs of technologies to understand the optimised infrastructure developments required.

A combination of solutions is expected to be relevant for the future power system in Thailand, in addition to the existing infrastructure:

- The development of the power grid, to enable the transport of RE power from the generation to the demand sites
- The development of storage capacity, both for short- and long-term storage, to maintain the supply-demand equilibrium as well as to contribute to system stability
- The mobilisation of consumers, relying on the development of smart technologies to enable communication and operation of distributed resources; infrastructure, both virtual and physical, to ensure cybersecurity and guarantee prosumers' protection is another underlying necessity
- The digitalisation of the entire infrastructure to permit flows of information between actors of the system.

Also, it is relevant to consider that some RE installations such as solar PV and wind farms will rarely generate electricity at maximum capacity, if at all due to their variable nature. Thus, dimensioning the whole system based on total installed capacity can lead to costs that do not provide significant benefits to RE penetration. Optimised dimensioning of the infrastructure, associated to potential flexibility from RE installations should be therefore assessed when planning grid reinforcements.

The UK experience below shows how the network dimensioning can be optimised at two distinct scales.

UK EXPERIENCE

In the UK, a trade-off between curtailing RE power and developing the infrastructure is in place. Network dimensioning is optimised to account for the low occurrences of maximum RE capacity being produced instead of sizing the grid to enable evacuate all potential RE generation. While this leads to some RE production being lost, savings in infrastructure investments can be beneficial. The network dimensioning can be optimised at two scales, by the project developer and at system level by the network planners:

- *While proposing the connection to RE installations is mandatory, some flexibility remains on the connection parameters which can ease, accelerate or lower the connection costs (for example, an accelerated connection without reinforcement of the grid can be proposed but associated to some curtailment of the electricity produced, which will be financially compensated for by the network operator). The terms and conditions remain the choice of the installation requesting the connection.*
- *At the system scale, a trade-off is determined between limiting the dimensioning of infrastructure (and associated costs) and curtailing some RE generation. Both in the UK and France, an efficient level of constraint is sought, where the value of curtailed RE generation meets the savings in infrastructure costs.*

The following actions are identified for Thailand:

- ➢ Assess all low-carbon and RE technologies, such as storage (short-and long-term), smart-charging, smart meters, solar, and heat pumps

- ➢ Consider both the cost and value of each technology in relation to the whole power system
- ➢ Develop planning with a whole-system consideration, to characterise the future functioning of the power system, understand the costs of potential trajectories, and identify technologies and actors involved
- ➢ Undertake infrastructure deployment following a detailed cost-benefit analysis, including through experimentations

Infrastructure Recommendation 3: Enhance digitalisation to enable a grid operation with high penetration of distributed variable RE.

The system operation will significantly evolve as the share of RE will increase in Thailand. Data collection and communication of information needs to evolve as the infrastructure shifts towards increasingly decentralised and dynamic assets.

The Thai power system has been built based on large-sized assets that are well monitored and managed by EGAT. It is now evolving towards a growing share of distributed assets that can be "invisible" and unpredictable for the network operators. Network operators at both levels of the grid will face the challenge of reduced information on the power flows and associated impacts on the system stability and reliability. As the growing share of distributed resources become the new normal, network operators in Thailand need solutions to mitigate reduced data availability.

- The roll out of smart meters will facilitate data collection and monitoring of power flows
- Enhancing the collaboration between RE project owners and system operators, through the communication of generation plans (and outages) will provide further data to understand the potential supply variations[41];
- Improving RE production forecasts will further enable the assessment of potential supply variations on the grid.[42] The development of RE forecast centres is particularly relevant in the context of the growth of variable RE in Thailand.
- Communication between actors will be necessary to trigger reactions and enable the smart operation of the system. The digitalisation of the system and development of smart appliances is necessary.

Engagement with stakeholders in the UK revealed that substantial evolutions in the infrastructure and its operation are challenging as both the culture and skills of the system operation need to evolve. Upskilling engineers of incumbent actors is key, as they can then provide technical guidance towards a modernised assessment and operation of the power system infrastructure (this is discussed further in Chapter 8).

The following actions are identified for Thailand:

- ➢ Ensure the development of data management and RE forecast centres

[41] Experience in the UK however showed receiving reliable information from small-size assets is challenging.

[42] Similarly, in France, only a low share of distributed assets generation is metered: instead, forecasts are extrapolated based on trends from assets metered and empirical modelling of potential RE generation.

- Ensure the development of the virtual and physical infrastructure necessary to the smart operation of the system

6.3. Phasing the recommendations

IF1 *Increasing the flexibility from existing assets to facilitate penetration of RE* does not rely on significant infrastructure deployment and will significantly facilitate RE penetration – phased as a recommendation to be undertaken in the immediate term.

IF2 *Characterise the infrastructure development needs, and cost* includes actions relating to integrating flexibility options, optimal dimensioning within the infrastructure development plans, and undertaking detailed assessment of costs and benefits. These are key activities to support the development of infrastructure that can support the power transition – phased as a recommendation to be undertaken in the immediate to short terms.

IF3 *Enhance digitalisation to enable a grid operation with high penetration of distributed variable RE* builds on activities introduced in Thailand's Smart Grid Master Plan and Grid Modernisation of Transmission and Distribution Plan (see Appendix 4). These plans include the development of digital infrastructure including RE forecast centres, domestic software and hardware, from now to 2030 – phased as a recommendation to be undertaken in the short to medium terms.

Table 6 summarises the timescales for implementing these infrastructure recommendations.

Table 6. Timescales for implementing infrastructure recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
IF1				
IF2				
IF3				

7. Innovation

Innovation plays a crucial role in driving the energy system transition. Innovation, through the mechanisms of learning-by-doing, learning-by-researching, and learning-by-interacting has led to significant reductions in the cost of renewable energy technologies, especially solar and onshore wind, to the extent many currently commercially available renewable energy generation technologies are cost-competitive with fossil fuels.[43] These cost reductions have contributed significantly to the rapid deployment of solar energy in Thailand.

Innovation is a continuous process which has no end point. It is a crucial activity that must be undertaken to enhance efficiency of existing technologies, to further drive cost reductions and create new solutions. Innovation must include enabling technologies that can support the energy system's transition but also other aspects of the energy value chain. This is key to ensure there are novel business models, updated policy and regulations, and market systems that create new value streams for the different actors in the energy value chain. This will facilitate their rapid uptake in a cost-effective manner.

Governments play a key role in fostering innovation. In Thailand, there are two key government agencies involved in innovation activities – National Innovation Agency (NIA) and National Science and Technology Development Agency (NSTDA). NIA is the agency responsible for supporting and developing Thailand's innovation system, driving national innovation by co-creation, networking, fostering, and partnering different organisation and fields.[44] NSTDA is the agency trusted with the task of accelerating science, technology and innovation development in order to respond to the needs of the industry and enhance the country's competitiveness.[45]

This chapter presents several innovation-related challenges followed by recommendations that have the potential to address these challenges.

7.1. Challenges

Based on literature review and engagements with local stakeholders, several challenges related to innovation were identified.

7.1.1. Institutional arrangement does not sufficiently facilitate coordination between various innovation actors

NIA leads the country's innovation efforts while NSTDA leads science and technological research. An energy technology development group exists within the NSTDA with the aim of addressing sustainable energy covering research in energy storage, diesel quality and solar energy.[46] Private sector players such as Energy Absolute and GPSC are also heavily involved in research and development especially on battery technologies and power storage. While battery storage is a common innovation topic, it remains unclear if there are intermediary actors that operate between the private sector and government agencies to coordinate the work undertaken by different actors.

---

[43] Renewables 2021, International Energy Agency.

[44] National Innovation Agency.

[45] Research Strategy, National Science and Technology Development Agency.

[46] Research Strategy, National Science and Technology Development Agency.

The sandbox programmes led by ERC and EGAT, agencies overseen by the Ministry of Energy, suggest that business model and regulatory innovations related to the power system are mostly conducted by these agencies, sometimes in partnership with the private sector. A 2020 report published by United Nations Development Programme highlighted that the Ministry of Energy is not an active actor in Thailand's innovation landscape.[47] This exclusion, coupled with energy systems being a theme that falls outside of the priorities and mandates of both NIA and NSTDA are potential reasons why there may be little to no coordination on these topics at the national level.

Beyond the institutional arrangement for energy systems innovation, Thailand's innovation system is relatively weak in comparison with other Asian countries of similar size and development level. According to the Global Innovation Index 2021, Thailand, ranked 43rd, is not only far behind Republic of Korea (ranked 5th) and Singapore (ranked 8th), but also ranks below Malaysia (ranked 36th). In characterising Thailand's national innovation system, the United Nations Conference on Trade and Development (UNCTAD) reported that political instability and a lack of policy continuity have weakened the ability of public institutions, many with overlapping responsibilities, to provide an enabling environment.[48]

7.1.2. Weak system-level approach to energy system innovation

The scope of existing sandbox programmes led by ERC and EGAT appears cross-cutting and includes technological, business model and market design elements. This is commendable as innovation should not be limited to technological ones as is often the case. Nonetheless, there is a need to strengthen the links drawn between the various innovation topics to ensure that they embed system-level analyses and to ensure more innovation areas consider a system-level lens. System-level innovation takes an integrated, whole-of-system view combining technological innovation with innovation in business models, in processes, and in market design and regulation to transform the energy system. It looks at the interactions between various verticals such as technology, business model, market design, policy, and regulations, etc.

It remains unclear if such efforts are in place. This sentiment was echoed by stakeholders at the mid-project workshop, many of them disagreeing when asked if they agreed that current innovation activities in Thailand occur at the system level. This is likely because energy systems has not been identified as a priority innovation area in Thailand.

In academia, stakeholders also lamented that most research has been conducted with the purpose of publishing academic papers to boost academia credentials, many of which does not contribute to innovation. This is likely a result of poor research management and the lack of an operating environment that facilitates scale up of research into demonstration and deployment. It is recognised that this challenge is closely linked to the previous; a more coordinated innovation institutional arrangement has the potential to scale innovations to the system-level.

7.1.3. Insufficient government support for energy systems innovation

Governments play a key role in facilitating innovation. Fiscal interventions such as subsidies, tax incentives, research and development contracts and public procurement are critical levers to promote innovation especially in the early stages where large uncertainties and high risks make it challenging to obtain private sector support.

Thailand's expenditure on innovation from both the public and private sectors was approximately 182 billion baht, or 1.11% of GDP, in 2018. This is lower than other upper middle-income countries whose

[47] Understanding Thailand's Innovation System, UNDP.

[48] Science, Technology & Innovation Policy Review – Thailand, UNCTAD.

innovation expenditure accounts for about 1.41% of GDP, and substantially lower than the 2.43% of GDP spend on innovation in high income countries. Trends also indicate that the government is reducing its support to innovation. State contributions to the country's innovation expenditure fell from 28% of total innovation spending in 2015 to 21% in 2019. The COVID-19 pandemic has slashed the government's innovation budget as funds are redirected to recovery.[49] Additionally, the various financial and non-financial support schemes have been reported to be too fragmented and uncoordinated, leveraging little research and development, and involving mostly other government agencies and a relatively small number of private sector organisations.[50]

While it is unclear what proportion of this expenditure is directed to the energy systems, it is reasonable to assume that there are insufficient government fundings support on energy systems innovation.

7.1.4. Pilot projects, and sandbox programmes need to be translated into implementable actions

Many sandbox programmes and pilot projects have been undertaken in Thailand as discussed in section 3.4. While these programmes have yielded many good outcomes, they are often not scaled up nor implemented at a larger scale. This is largely due to existing regulatory barriers. For example, existing third-party access prohibition limits the implementation of net metering programmes.

7.2. Recommendations

Challenges related to energy systems innovation in Thailand mostly relate to the lack of a facilitating operating environment. Innovation is key to prepare and support the energy system integrate higher shares of RE by developing novel solutions on key technologies, business models, regulations or system design. The following recommendations were synthesized based on the aforementioned challenges:

1. Elevate energy systems to a national innovation priority
2. Promote integrated system-level innovation
3. Leverage international partnerships to maximise impact of domestic innovation

The overall aim of these recommendations is to enhance the research, development, and deployment ecosystem for energy systems innovation.

A mapping of how the recommendations address the various challenges is presented in Table 7.

Table 7. Mapping of innovation-related challenges and recommendations.

Innovation				
Challenges **Recommendations**	Institutional arrangement does not facilitate coordination between various innovation actors	Weak system-level approach to energy system innovation	Insufficient government support for energy systems innovation	Pilot projects and sandbox programmes need to be translated into implementable actions

[49] Innovation is key to economic recovery, Thailand Development Research Institute

[50] Science, Technology & Innovation Policy Review – Thailand, UNCTAD.

IV1: Elevate energy systems to a national innovation priority	✓		✓	This is a cross-cutting innovation-related challenge that can be addressed through recommendations from other pillars such as policy and regulations, market mechanisms and infrastructure.
IV2: Promote integrated system-level innovations	✓	✓		
IV3: Leverage international partnerships to maximise impact of domestic innovation		✓		

Innovation Recommendation 1: Elevate energy systems to a national innovation priority

The Government of Thailand launched the Thailand 4.0 policy in 2016 to tackle the economic slowdown and to mitigate the risk of the country falling into the middle-income country trap.[51] Thailand 4.0 is a policy premised on an innovation-driven economy focusing on 10 target industries. These industries can be segmented into two segments as follows.[52]

First S-Curve: *Developing existing industrial sectors by adding value through advanced technologies*

1. Next-Generation Automotive
2. Smart Electronics
3. High-Income Tourism and Medical Tourism
4. Efficient Agriculture and Biotechnology
5. Food Innovation

New S-Curve: *Additional five growth engine industries that will accelerate Thailand's future expansion:*

1. Automation and Robotics
2. Aerospace
3. Bio-Energy and Bio-Chemicals
4. Digital
5. Medical and Healthcare

Sub-Recommendation 1: Refresh national innovation priorities and priorities within the energy systems topic area

Energy systems and themes related to it are not part of the 10 S-Curve industries. Recognising the important role it has to play in Thailand's sustainable – economic and climate – development goals, it is strongly recommended that energy systems is elevated as a national innovation priority.

Within energy systems, it is important to recognize the status of various innovation needs. The International Renewable Energy Agency (IRENA) strongly recommends that innovation needs be categorized in three groups - push, nurture and facilitate. 'Push' innovations relate to those that are on their way to being commercially viable but still require accelerating or adapting. 'Nurture' innovations relate to those that are potentially important, however, for which the developmental path is unclear and far from being commercially viable. 'Facilitate' refer to innovations that are developing well and where the

[51] Understanding Thailand's Innovation System, UNDP.

[52] Thailand 4.0 – A new value-based economy, Board of Investment.

market is sufficiently mature that private sector investment is likely to deliver.[53] Our recommendation would be that governments prioritise push innovations first, followed by nurture and facilitate equivalently.

Battery and energy storage is a priority innovation focus area in Thailand, as seen in chapter 3. It is an important topic for innovation as outcomes have the potential to improve system flexibility, which will become increasingly more important as the share of RE in the power system increases. Initial analysis suggests that it can be categorised as a push innovation. Other topics in Thailand include solar and biomass energy.[54] Solar is economically competitive and has generated strong investment interest from the private sector. Thus, it can be classified as a 'facilitate' innovation. This classification is broadly aligned with IRENA's grouping:[55]

- **Push:** battery storage, smart grids, concentrated solar power, geothermal, biopower
- **Nurture:** novel energy storage solutions, wave and tidal
- **Facilitate:** hydropower, solar PV, onshore and offshore wind

Participants at the mid project workshop also indicated that innovation should prioritise new business models for distributed RE, and digitalization of energy infrastructure. The following actions are recommended for Thailand in its efforts to refresh energy and power system innovation priorities:

- The Ministry of Energy, and the government agencies with energy-related responsibilities, should push for energy systems to be elevated as a national innovation priority.
- Assess the needs of various energy system innovations (technological, business model, system design and regulation) to classify them into push, nurture, or facilitate innovation categories. *This assessment could support the push for energy systems to be elevated as a national innovation priority.*

Sub-Recommendation 2: Increase government funding support to energy system innovations

The government plays an important role in setting the direction and supporting early-stage innovations, which are not yet at an appropriate readiness level to attract private sector investment. The Covid-19 pandemic has led to reductions in the Thai government's innovation budget as funds are being rechanneled to other purposes. However, it is crucial for the Thai government to increase, if not maintain, innovation budgets on energy systems innovation. Clean energy technology innovation supports pandemic recovery and its economic aftermath through several mechanisms.

Firstly, it can increase energy resilience and security of supply in the long term. A broader technology portfolio provides a means of diversifying the energy mix and energy supply chains. This is especially important for Thailand given its dependence on natural gas, whose price has increased tremendously since the second half of 2021. Secondly, continued innovation helps with future competitiveness. It can help companies come out of the pandemic better positioned to supply future domestic and international markets.

---

[53] Innovation priorities to transform the energy system: An overview for policymakers, IRENA.

[54] Research Strategy, National Science and Technology Development Agency.

[55] Innovation priorities to transform the energy system: An overview for policy makers

Continued innovation in emerging technologies can create new jobs that help with pandemic recovery. The IEA estimates that three to eight new jobs are created per million dollars invested in technology innovation on future energy systems. While manufacturing of emerging technologies is unlikely to provide large number of jobs in the near-term, employment effect can positively impact the supply chain and be future growth areas.[56]

The Thailand Research Fund (TRF) is a key funder of research and development projects, knowledge exchanges and capacity building programmes. While this provides a good foundation, more funding is needed to scale research and development activities into the demonstration and deployment stages. Several actions are recommended for Thailand to facilitate this:

- Launch innovation funding rounds continuously for the energy systems innovation priority areas identified in the earlier sub-recommendation.
- Lead energy systems innovation agency (see Innovation Recommendation 2, Sub-Recommendation 1) should map out innovation funding available domestically such as through the NIA, NSTDA, TRF, and the private sector. It should also seek out international support to fill funding gaps, such as through the Newton Fund.[57]

Innovation Recommendation 2: Promote integrated system-level innovations

The transformation of the power sector and increasing electrification of end-use sectors will require innovation beyond the verticals of technologies, business models, policy and regulation. Energy systems are fast evolving, underscoring the importance of prioritising activities and increasing the links and dependencies between different parts of the system. Innovation in energy systems policy therefore need to take a system-wide approach to ensure that innovations in various verticals such as technology, business models, system operation and market design are integrated to create solutions that allow higher shares of variable RE in the power system. A more connected approach is required to bridge this gap and pursue innovation that cuts across all power system verticals.

Sub-Recommendation 1: Revise the institutional arrangement surrounding energy system innovations

A clear institutional arrangement with defined roles and responsibilities for different actors are important. A lead government agency on energy systems innovation should oversee the development of innovation priorities and be responsible for providing funding support and developing a platform (physical and connections) where innovation actors can collaborate better. The role of the lead government agency is crucial as it reflects the transparency and consistency of government support which facilitate increased engagement from innovators and investors. The role of intermediaries, which includes knowledge brokering, providing institutional support, network building and innovation process management, should also be clarified.

UK EXPERIENCE

Innovate UK is the national innovation agency supporting business-led innovation in all sectors, technologies and UK regions. It provides grant and loan funding for various innovation opportunities that

[56] Sustainable recovery, IEA.

[57] Thailand, Newton Fund.

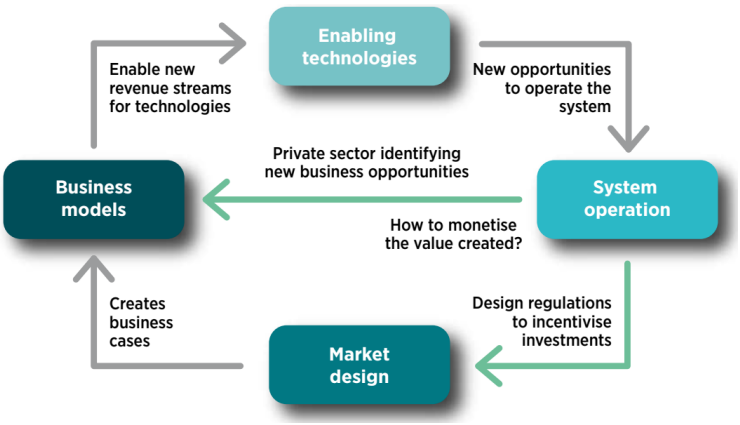
innovation actors can tap on.[58] It established the Catapult Network in the UK, which are physical centres with research and development infrastructures including hubs, laboratories, testbeds, and factories, as well as technical experts that prove and adopt breakthrough products, processes, services and technologies.[59] The Energy Systems Catapult is one of nine Catapult Networks, with the specific objective of driving the energy sector to net zero by supporting innovators to commercialise and helping design and deliver the future energy system. It leads a large part of the UK's business-led energy systems innovations and acts as an intermediary bringing together different innovation actors and provides technical, commercial and policy expertise to drive innovation across the whole energy system. The ESC was originally fully funded by the UK Government's Innovate UK but more recently has established revenue generating consultancy offer to increase their income, which is model UK Government is deploying more frequently.[60] Further information on ESC can be found in Appendix 6.

Referencing the development and role of ESC in the UK, the following actions are recommended for Thailand:

- EPPO, in collaboration with NIA and NSTDA, should develop a clear term of reference for the lead energy systems innovation agency, in consultation with existing innovation actors, to define the agency's role and decision-making power.
- A lead entity to coordinate national efforts on energy systems innovation and draw links between various innovation silos should subsequently be identified based on the developed terms of reference.
- Clarify actors that can act as intermediaries.

Sub-Recommendation 2: Promote systemic innovation

Systemic innovation takes an integrated, whole-of-system view combining technological innovation with innovation in business models, processes, and market design and regulation to transform the energy system as a whole. It accounts for the interactions and dependencies between and across various topics within the energy system. Figure 5 below illustrates the relationships between various innovation topics.[61]



[58] Innovate UK, UK Research and Innovation.

[59] Catapult Network.

[60] Energy Systems Catapult

[61] Innovation priorities to transform the energy system: An overview for policy makers

Figure 5. Illustration of the links between various energy systems innovation topics.[62]

The regulatory sandboxes are examples of efforts that consider the dependencies and interactions across various innovation verticals. Nonetheless, much more can be done to scale up existing innovation activities to the systemic level.

UK EXPERIENCE

The ESC is a platform that brings various innovators such as start-ups, industries, government, utilities, local places and intermediary actors such as the UK Energy Research Council to work together to bring new products and services more quickly to commercialisation. Being technology-agnostic, it provides support to actors on whole system modelling, systems engineering, integrating the transport and energy systems, markets, policy and regulations through activities such as test and demonstration, delivery of large-scale innovation trials, business model innovation, and harnessing digital and data. Through the ESC, many innovations have managed to scale up and commercialise.[63] *Further information on ESC can be found in Appendix 6. Platforms that bring together various actors working on different aspects of a similar challenge are important to enable co-creation of system-level solutions.*

The support provided by Thailand's NIA is similar to the ESC. While the support provided by the NIA may have to be expanded to include energy systems and to be strengthened, it provides a foundation from which efforts can be further scaled. Therefore, the following actions are recommended for Thailand:

- NIA should create an innovation programme focused on energy systems innovations that brings together various innovators and matches them with experts that can facilitate proposition design, business model innovation, test and demonstrations, and delivering large-scale innovation trials. In the short term, international experts can be brought in to support the development of the energy systems innovation network and to plug any innovation expertise gaps.

Innovation Recommendation 3: Leverage international partnerships to maximise impact of domestic innovation

Technology and knowledge transfer is a key part of Thailand's conditional NDC. Therefore, innovation in Thailand should leverage existing knowledge from the international community – both in terms of technical know-how and expertise that can facilitate innovation activities. While future energy systems is a relatively new topic, significant research and innovation has been done globally.

Many strong examples exist of collaboration across borders, and several international bodies and initiatives are facilitating such cross-border work on clean energy innovation. IRENA recommends that governments could make fuller use of such programmes and initiatives to complement and increase the impacts of their national programmes.[64]

Thailand, led by the NIA, already collaborates with global players on various innovation topics. However, international collaboration on energy systems innovation is a relatively unchartered area. The following actions are recommended for Thailand to enable this:

---

[62] Innovation priorities to transform the energy system: An overview for policymakers, IRENA.

[63] Annual Impact Review 2019-2020, Energy Systems Catapult

[64] Innovation Priorities to Transform the Energy System (2018)

- Based on Thailand's refreshed energy systems innovation priorities, the NIA, in collaboration with EPPO, NSTDA and other relevant agencies, should identify a clear list of existing innovation areas whose impact can be scaled through international partnerships.
- Seek out support from international actors such as the UK FCDO, IRENA, IEA, etc. For example, NIA could collaborate with ESC to scale up energy systems innovation in Thailand.
- Disseminate learnings from Thailand's innovation experience to other ASEAN countries through channels such as the ASEAN Centre for Energy. Thailand's experience may be more applicable to countries in the region that are in the earlier stages of the energy transition.

7.3. Phasing the recommendations

IV1 *Elevate energy systems to a national innovation priority.* This is a key first step to bring energy systems up the Thai Government's innovation agenda, which would potentially unlock more funding for energy systems innovation – phased as a recommendation to commence immediately and that would likely be actioned throughout the immediate term.

IV2 *Promote integrated system-level innovations.* Higher order system-level innovation is a foundational activity for a more holistic and integrated innovation outcome. It is recommended to run immediately after elevating energy systems into a national innovation priority so that a lead entity and intermediary innovation actors can be recognised as part of the institutional arrangement revision. – phased as a recommendation to commence at the middle of the immediate term through to the middle of the short term.

IV3 *Leverage international partnerships to maximise impact of domestic innovation.* An enabling innovative environment requires efficient leverage of knowledge transfer from the international community – phased as a recommendation to commence in the middle of the immediate term and that will run to the medium term as countries accelerate the decarbonisation of their power systems.

Table 8 summarises the timescales for implementing these innovation recommendations.

Table 8. Timescales for implementing innovation recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
IV1				
IV2				
IV3				

8. Human Capacity

Human capacity is an essential component that covers multiple facets of the power ecosystem, cutting across all pillars of activity. The capacity of policymakers to design appropriate policies to support the RE transition is the bedrock of any well-developed power system. Policies and mechanisms need to be fit for purpose and tailored to the country context. As policies and mechanisms take effect, all stakeholders should also have the knowledge and capabilities to respond to it.

When novel technologies are deployed at scale the technical expertise and knowledge of the workforce will also be essential to support their deployment. The AEDP2018 has outlines plans for human resource development in engineering and technical personnel in RE technologies and enhancing community participation in RE development. However, there are few targeted measures and actions to facilitate this. In addition to a potential skills shortage in more conventional engineering roles for RE development, the types of jobs and skills required in the sector are diversifying into digital and IT. The nature of future jobs will evolve as the energy system continues to evolve, further adding to the challenge of human capacity.

This chapter presents several human capacity-related challenges that were identified followed by recommendations that have the potential to address these challenges.

8.1. Challenges

Based on literature review and engagements with local stakeholders, several challenges related to human capacity were identified.

8.1.1. Capacity of policymakers to design policies, regulations and mechanisms that facilitate higher penetrations of RE

Thailand's RE plans outline commendable targets to support a higher RE penetration into the grid. Poll results from the mid project workshop indicated more support is needed for Thai policymakers and regulators in decision making. A key challenge for all countries is the development of capacity of policymakers to design and create appropriate policies, regulations and market mechanisms and being able to transition away from existing policy instruments. Ensuring the effective implementation of new policy is a universal challenge that must be considered in the early policy design phases.

8.1.2. Workforce capacity is likely to be lower for novel technologies and lags between skill gap identification, upskilling and delivery

The energy system is evolving with technological advancements. However, it is not currently clear how Thailand plans to equip the workforce to adapt to the changing energy system. Poll results from the mid project workshop indicated that while many agree that the workforce is sufficiently skilled to facilitate high deployment of RE, there are domains where skills are a limiting factor, especially in in power system optimisation modelling and trajectory development, and in emerging technologies such as battery storage and hydrogen.

It is crucial for Thailand to ensure that its workforce is ready to manage a fast-evolving energy system. The Thai public and private sector and academia need to establish programmes to improve workforce skills. These programmes can be internal or provided by external contractors and advisors. It is important

that this takes place soon, to avoid a skills gap which would reduce the effectiveness and success of RE deployment and energy system modernisation.

8.1.3. Insufficient knowledge transfer across different stakeholders

The year 2021 saw several big achievements from large, incumbent private utility players in Thailand. Global Power Synergy commenced operations at its first SemiSolid energy storage unit factory, aiming to become the leader in battery technology and total energy management solutions. The factory will enhance their power generation capacity from renewable energy to supply power plants, large industrial factories, and SMEs as well as further develop their production plan for electric vehicle batteries.[65] Energy Absolute launched a lithium-ion battery plant and power storage system, with an initial capacity of 1GWh per year with a view to expand this to 50GWh per year.[66] These achievements serve as clear testaments that knowledge of system operations and in current novel technologies lie in these large, private organisations.

However, a challenge exists in ensuring that such knowledge and expertise is shared with a wider group of actors, including smaller private and public actors and communicated to the stakeholders involved in training or higher education.

There is also a disconnect between those Government actors who have designed and developed policies/regulations/mechanisms and the local stakeholders on the ground who will be affected or involved in implementation. Stakeholders may not be kept up to date of changes, how they will be impacted or how their capabilities need to be refreshed or adapted. There is sometimes a lack of guidance on how policy changes will affect each stakeholder group and their roles in implementation. Such a disconnect could hinder the effective implementation and rollout of decentralisation and RE deployment.

8.2. Recommendations

Taking into consideration the key challenges discussed above, the project team has developed a set of recommendations to address them respectively. Table 9 provides a map of how the recommendations respond directly to the challenges.

Table 9. Mapping of human capacity-related challenges and recommendations

Human Capacity			
Challenges / **Recommendations**	Capacity of policymakers to design policies, regulations and mechanisms that facilitate higher penetrations of RE	Workforce capacity is likely to be lower for novel technologies and lag between skill gap identification, upskilling and delivery	Insufficient knowledge transfer across different stakeholders
HC. 1: Increase capacity of policymakers to design policies, regulations and market	✓		

[65] GPSC, 2021. GPSC's BOD approved an investment in a battery manufacturing plant in China to supply for electric vehicle market, which will enhance the company's competitiveness in all battery applications.

[66] The Nation, 2021. EA announces the success of grand opening of the first Gigafactory, the largest integrated battery factory in ASEAN

mechanisms that facilitate higher penetrations of RE			
HC 2. Take proactive steps to identify existing and future technical human capacity needs and assess skill gaps		✓	
HC 3. Increase stakeholder engagements and collaborations		✓	✓

Human Capacity Recommendation.1: Increase capacity of policymakers to design policies, regulations and market mechanisms

To address the challenge of a lack of capacity among policymakers to create appropriate measures and policies that can enable a higher RE penetration into the grid, it is important to build capacity and leverage on existing knowledge from the international community. This should be coupled with a process to gather learnings from the implementation of Thailand's policies.

Policymakers can gather insights and best practices from international training programmes and learning experiences partnerships with the wider global community. For instance, UNIDO and the European Academy Europe launched an 8-day long training programme on sustainable energy solutions for a targeted handful of 25 policymakers across 12 developing countries.

While important to capitalise on the wealth of knowledge in the global community, it is also key to assess current and past national policies and develop an understanding of what works best for Thailand. All policies should be evidence-based and be tailored to circumstances, undergoing a robust Monitoring and Evaluation (M&E) system. Learnings from experience should be applied during the process of designing new policies and measures for the energy industry.

As such, the following are recommendations for Thailand:

- EPPO and other key energy policymaking government agencies should actively seek out and participate in training programmes or learning partnerships with the international community, and ensure learnings are shared.
- EPPO and other policymaking agencies should ensure regular evaluation of national policies and mechanisms occurs through robust M&E system and learnings are applied during the policymaking process.

Human Capacity Recommendation.2: Take proactive steps to plan for and assess existing and future human capacity needs

To address the challenge of a lag between skill needs and availability policymakers should proactively plan for, and assess existing and future human capacity needs, and identify where skills gaps exist. This proactive assessment will enable policymakers to identify the skills that may become obsolete in the future, enabling efforts to be implemented to ensure workers can be re-skilled when their current jobs become redundant.

Sub-Recommendation 1: Appoint a dedicated nationwide entity to coordinate upskilling and capacity building for Thailand's net zero transition

Skills needs and development for green jobs have in the past been identified and developed primarily by the private sector and government agencies that do not directly manage skills and the labour policies, such as DEDE[67].

Thailand should take a whole-of-government approach to ensure the country achieves net zero GHG emissions by 2065. This includes appointing a nationwide entity dedicated to identifying the skills gaps in the net zero transition monitoring and reporting progress as Thailand's economy transitions. This entity could be led by agencies responsible for skills development and employment under the Ministry of Labour or a new entity can be established. Various stakeholder groups, including the public and private sectors, industry associations, unions, and academia, should be included in this national entity to ensure that views from all sections of society are taken into consideration to accurately identify the most pressing skills gaps.

UK EXPERIENCE

A Nationwide Body, UK

The Green Jobs Taskforce was established in November 2020 by Department for Business, Energy and Industrial Strategy (BEIS) and the Department of Education to better understand how the UK could take advantage of the Green Industrial Revolution's prospects. It conducted an impartial study of the possible skills and labour market consequences of the net zero transition, including how to ensure that green jobs are accessible to all and how to assist workers in making the transition to the green economy. The independent Taskforce included representatives from industry, trade unions, the skills sector and community organisations, published a report in July 2021 with 15 recommendations for government, industry and the skills sector.

One of the key recommendations from the Taskforce's analysis was that UK should establish a body with national representation to ensure momentum and coherence on workforce transition, and to liaise directly with local bodies. This body shall monitor, drive and report on the progress towards a net zero economy.

The key learning from this UK experience is the need to appoint a dedicated entity to manage the human capacity needs for the net zero transition. This is elucidated in both the UK's Green Jobs Taskforce and the Taskforce's own subsequent recommendation to create a national body to oversee the workforce transition to support the move to Net Zero. Dedicating a specific entity to oversee human capacity needs and development is a key first step, and the UK government has recognized this. Cohesiveness in approach is also critical and this is underscored by representation of the national government, industry, unions and other industry actors in this new national body by the UK.

It is recommended that Thailand adopt a similar approach, where the national entity should also take on the activities of Sub-recommendation 2. Specifically, the recommendations for Thailand are to:

- Appoint a nationwide entity with the mandate of monitoring and assessing skills and labour market consequences of the net zero transition (beyond the power sector). Representatives should include various stakeholder groups - public sector, private companies, industrial associations, unions and academia

[67] Friedrich-Ebert-Stiftung. Energy Transition in Thailand: Challenges and Opportunities

Sub-Recommendation 2: Undertake gap analysis on technical skills and adapt curricula

Building on the appointment of the nationwide entity described above, the immediate action would be understanding the likely trajectory of needs for the future energy system based on Thailand's net zero plans, areas where a skills gap exists and feedback from stakeholders on the ground. This assessment should also take an inclusive approach and ensure that the human capacity is developed across all sections of society.

This should translate into new or improved curricula offered by education institutes and training providers. Poll results from the Mid-Project Workshop also suggested that renewable energy courses could be established in all potential universities. Stakeholder engagements further revealed that skills gap exist in power system optimisation modelling and trajectory development, and in new technologies such as battery storage, hydrogen.

UK EXPERIENCE

BEIS and OFGEM: Transitioning to a net zero energy system – Smart Systems and Flexibility Plan 2021[68]

The Smart Systems and Flexibility Plan sets out to drive smart systems and flexibility, covering flexibility from consumers, flexibility on the grid, flexibility markets and digitalising the system. The plan recognises that the system is constantly evolving, thereby acknowledge that the measures to facilitate smart systems and flexibility will need to be adjusted frequently.

Among many other measures, the plan emphasises the need for a high-quality skilled workforce. A key action that will be undertaken by BEIS and OFGEM is to undertake a smart skills gap analysis which will clarify the skills and qualification levels that are needed to grow the smart and flexible energy sector. Outcomes from this gap analysis will be fed into the broader considerations on jobs and skills to help build pathways from education to industry for the sector.

As the power system constantly advances evolves, regular skills gap assessments and engagements with employers should be undertaken to enable the consideration of new skills that will be needed. This facilitates regular updates to the training curricula, ensuring training remains relevant and minimises the time lag between skills need and availability. As the training curricula will change with time, curricula developed to boost human capacity needs to be flexible and adaptable. To achieve this, the following actions are recommended for Thailand:

- The nationwide entity appointed from Sub-Rec 1 should develop a national plan to identify human capacity and skills relevant for the energy systems transition, mapping out the relevant skills and expertise needed.
- Oversee and undertake a skills gap assessment to understand areas that require capacity development based on the mapping in the national plan
- Translate outcomes from the skills gap assessment into tangible changes in the energy systems curricula in education institutions (e.g universities) and vocational training providers. This includes creating, revising, and sourcing for expertise to deliver the curricula

[68] Transitioning to a net zero energy system – Smart Systems and Flexibility Plan 2021

Human Capacity Recommendation.3: Increase stakeholder engagements and collaborations

Sub-Recommendation 1: Increase local stakeholder engagement and provide guidance and capacity building for their involvement

When new policies, regulations and other mechanisms are implemented, it is important to ensure that all stakeholders are aware of the changes, the implications to their group, and how they can support its effective implementation. Local actors may struggle with the introduction of new measures and have little understanding of what these measures mean for them. For example, the success of a potential distributed energy generation policy strongly depends on the end user's understanding of the policy and the benefits that can be gained. This requires a top-down and system-wide dissemination and communication of any changes, which should also include rural areas of the country.

As such, the following are recommendations for Thailand:

- EPPO should develop a structured approach to local engagement and dissemination when new measures are introduced.
- EPPO should develop guidance and training for local organisations who can, in turn, train end users on new policies that benefit the communities or individual households such as distributed energy generation. This should be supported with feedback from local stakeholders on where there are capacity needs and gaps.

Sub-Recommendation 2: Facilitate industry-academia collaboration

There is a wealth of knowledge, R&D and breakthrough activities concentrated within industry players and Thailand's research institutes respectively. Currently there is not enough knowledge and expertise being shared between these stakeholders. Not only do such partnerships ensure academia respond to the needs of the industry by adjusting their curricula, but they further stimulate innovation and research on future solutions. Additionally, the industry can also contribute by supporting academic institutions to deliver courses, transfer knowledge, and provide apprenticeships and valuable work-based learning and experience.

This recommendation is also linked to HC Recommendation 2, as insights and needs required by industry and employers could be being fed into curricula development.

To capitalise on the effectiveness collaboration, it is recommended that the Thai government help promote the benefits and ensure there is a platform for academia and industry to connect. This will help stakeholder groups to seek out and match expertise with needs on the ground. The following actions are recommended for Thailand:

- The nationwide entity appointed from HC Recommendation 1 shall work closely with the Office of The Higher Education Commission to develop a platform/programme that convenes industry and academia, specifically for energy systems. This platform/programme will allow actors to regularly present and share their new R&D, breakthroughs, activities, and outcomes. This will provide greater visibility on emerging R&D and upcoming activities occurring nationally.
- Within this platform, provide a channel within the platform for actors to seek out partners for R&D, and a channel for collaborations on course curricula (i.e. delivery, apprenticeships).
- Develop accompanying guidelines on the above, such as a framework for providing incentives to stimulate collaborations and frequency in which they should occur

8.3. Phasing the recommendations

HC1 *Increase capacity of policymakers to design policies, regulations and market mechanisms that facilitate higher penetrations of RE* recommendation has been phased for the immediate to long term. This is a priority action that should start in the immediate term and continue into the long-term as constant training of policymakers is a key building block for enabling a regulatory environment that supports high RE. Further, the nature of RE systems are constantly evolving and developing with time, as new innovations and breakthroughs occur, and policymakers need to be able to be responsive to this throughout.

HC2 Take proactive steps to identify existing and future technical human capacity needs and assess skill gaps has been phased for the mid-immediate term to the short term. The appointment of a dedicated nationwide entity to manage training is relatively urgent and quite simple to action. The skills gaps assessment and updating of curricula delivered by education institutions would require more time and hence extend into the short-term.

HC3 *Increase stakeholder engagements and collaborations* has been phased across the mid-immediate to mid-short term. Engaging local stakeholders and faciliating collaborations can be achieved in a short timespan and is simple to action.

Table 10 **Error! Not a valid bookmark self-reference.**summarises the timescales for implementing these innovation recommendations.

Table 10: Timescales for implementing innovation recommendations.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
HC1				
HC2				
HC3				

9. Conclusion

9.1. Cross-cutting nature of recommendations

Energy and power systems is a highly complex issue that involve various interactions, between policy and innovation, policy and human behaviour, innovation and human capacity among many others. In the preceding chapters, this report has attempted to classify the various issues into the distinct pillars of policy and regulations, market mechanisms, infrastructure, innovation, and human capacity. However, many of these issues cut across other pillars. Therefore, we strongly recommend policymakers approach energy and power systems from a holistic view.

Recognised as an individual pillar in this Roadmap, policy and regulations set the tone for the other pillars. Clear policy is needed to unlock the development of market mechanisms and promote infrastructure upgrades. For example, guidelines and regulatory frameworks to develop revenue opportunities discussed in PR3 *Foster private sector participation: reduce constraints, develop revenue opportunities and maintain confidence* are needed to pave the way for power markets such as wholesale or flexibility markets to develop in MM 2 *Develop tailored power market mechanisms*.

Innovation is also closely linked to policy. Without strong policy, innovation efforts could be de-prioritised as the benefits tend to be intangible in the short term and often only accrue in the long term. For example, many of the sandbox programmes implemented by ERC in Thailand are not scaled up due to policy and regulatory barriers. Policy is also needed to set innovation priorities, specifically in areas that can generate a competitive advantage for Thailand, and to drive activities related to it.

Policy must also be in place to ensure that the local workforce in Thailand can fulfil the jobs created by the industry. Innovation can facilitate infrastructure development. This analysis revealed that battery and energy storage systems is a priority innovation area in Thailand with many actors, public and private, involved. Innovations can improve the technological credentials of battery storage. IV2 *Promote system-level innovations* can help with MM4 *Enable the participation of distributed and small actors.* Outputs from system level innovations take a birds' eye view to problems beyond technological ones and include business model innovation. Such innovations can drive the participation of distributed and small actors.

Innovation and human capacity are closely linked as well. Close industry-academia collaborations enable mutual benefit by providing industries a chance to steer academic curricula tailored to skillsets and expertise needed in the industry. Universities also provide a supporting environment for industries to access top research talent that can support with innovation activities.

HC1 *Increase capacity of policymakers to design policies, regulations and market mechanisms* is fundamental to all the recommendations put forward under the policy and regulation, and market mechanism pillars. Without proper capacity, the interventions needed for Thailand's power system transition will not take place or be designed ineffectively.

Many of the recommendations are cross-cutting in nature and it is strongly emphasised that policymakers take a systems-level approach to actioning the recommendations put forward in this Roadmap.

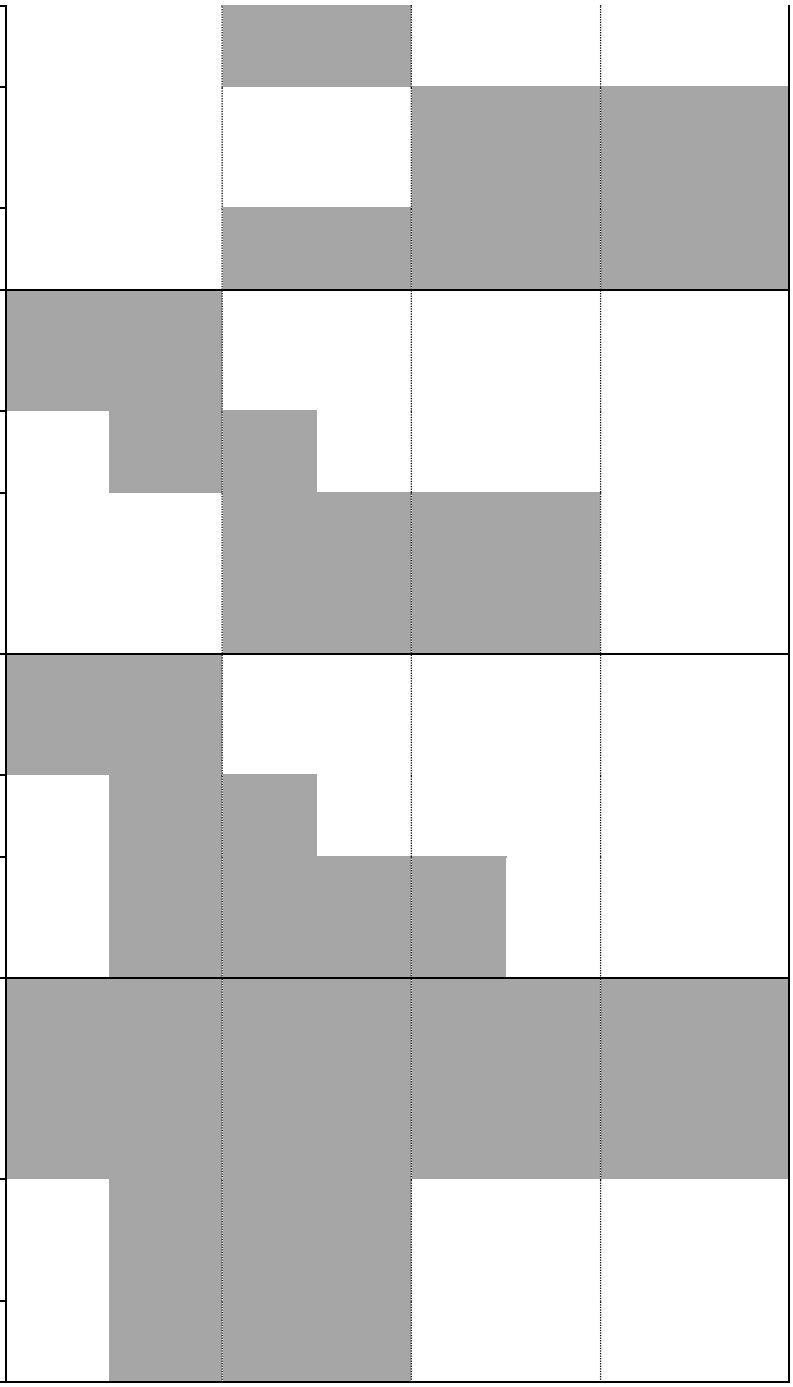
9.2. Immediate next steps

The Roadmap presents 19 recommendations for Thailand phased over the immediate (2022-2024), short (2025-2029), medium (2030-2037) and long (2037-2050) term timescales (Table 11). Many actions are phased in the immediate and short terms. This is because Thailand is still in its early phases of transitioning its power system. Many recommendations related to policy and regulations are phased to happen in the short term because they are key to unlocking follow-on activities in the other pillars. Developing clear targets and trajectories is the number one action that needs to be undertaken. This is especially important for several reasons – (i) to ensure alignment with the new targets announced at COP26; (ii) to give confidence to investors that the future is low-carbon – this will reduce uncertainties among investors and will direct the flow of investments to low carbon technologies; (iii) to support the development of follow-on mechanisms and schemes that can further facilitate increased action.

Other recommendations in the short term involve developing clear guidelines and framework to help define the role of mechanisms and schemes to be launched. They also include actions that can be perceived as low-hanging fruits such as formalising the trading of RECs which is already gaining popularity in Thailand and increasing flexibility from conventional assets. Elevating energy and power systems as a national innovation priority is crucial to ensure that it receives sufficient attention and funding which can build Thailand's future competitiveness. Increasing the capacity of policymakers is also key as it impacts many of the follow-on interventions that are designed to transition Thailand's power system.

Table 11. Summary of all recommendations phased over the immediate, short, medium, and long-term timescales.

Recommendation	Immediate (2022-24)	Short (2025 – 29)	Medium (2030-37)	Long (2037-50)
PR1: Develop trajectories towards the targets and elaborate on the means to achieve them				
PR2: Tailor support schemes to Thailand's ambitions				
PR3: Foster private sector participation: reduce constraints, develop revenue opportunities and maintain confidence				
PR4: Open and provide direction to market to enable public-private synergies				
MM1: Establish guidelines, frameworks, and platforms to enable market development				
MM2: Developed tailored power market mechanisms for different purposes				
MM3: Formalise trading of renewable energy certificates				

MM4: Enable the participation of distribution and small actors	
MM5: Contribute to efforts seeking to develop markets at the regional scale	
MM6: Implement existing plans of developing a carbon market	
IF1: Increase flexibility from existing assets to facilitate penetration of renewable energy	
IF2: Characterise the infrastructure development needs and costs	
IF3: Enhance digitalisation to enable a grid operation with high penetration of distributed variable RE	
IV1: Elevate energy and power systems to a national innovation priority.	
IV2: Promote integrated systems-level innovation	
IV3: Leverage international partnerships to maximise impact of domestic innovation	
HC1: Increase capacity of policymakers to design policies, regulations and market mechanisms that facilitate higher penetrations of renewable energy	
HC2: Take proactive steps to plan for and assess existing and future human capacity needs	
HC3: Increase stakeholder engagement and collaborations	

A common activity across all recommendations involves regular monitoring and evaluation. This is crucial as it provides an assessment of each intervention's performance. Where interventions have not succeeded, alternative or supplementary measures can be developed. Where interventions have been successful, learnings can be drawn and applied to other interventions. Constant reviews also enable the discovery of new interventions that may be required. Further recommendations can be added to the table over time with regular reviews and analysis.

The fast-evolving nature of the power and energy systems also mean that policymakers need to be nimble in their approach. Being agile and adaptable are key to ensure that interventions continue to push Thailand towards a low-carbon transition.

9.3. Limitations

Recommendations have been positioned with clear actions laid out for Thai policymakers taking a holistic view across policy, markets, infrastructure, and culture. However, several of the action will need more detail assessment regarding how to implement them and might involves more specific stakeholder engagement with other actors not engaged through this work.

This Roadmap synthesises recommendations for Thailand and is not intended to be a summary of UK experience. While we have described some UK experience in Appendix 6, they are a summary and should not be construed as detailed descriptions. The UK has implemented numerous interventions in transitioning its power system. Separate studies are needed to assess in more detail how the different aspects of the UK power system transitioned or was established.

Nonetheless, we do want to highlight that the UK strong experience form which Thailand could learn from. This includes driving energy systems innovations, developing market mechanisms for ancillary services and flexibility market trials, designing support schemes such as renewables obligation, and contracts-for-differences, taking an integrated approach to climate and energy planning.

.

Foreign, Commonwealth & Development Office

This report has been commissioned by South Asia Research Hub, Foreign, Commonwealth and Development Office, Government of United Kingdom. However, the views expressed in the report deck do not necessarily reflect the official policies of the Government of United Kingdom.

carbontrust.com

+44 (0) 20 7170 7000

Whilst reasonable steps have been taken to ensure that the information contained within this publication is correct, the authors, the Carbon Trust, its agents, contractors and sub-contractors give no warranty and make no representation as to its accuracy and accept no liability for any errors or omissions. Any trademarks, service marks or logos used in this publication, and copyright in it, are the property of the Carbon Trust. Nothing in this publication shall be construed as granting any licence or right to use or reproduce any of the trademarks, service marks, logos, copyright or any proprietary information in any way without the Carbon Trust's prior written permission. The Carbon Trust enforces infringements of its intellectual property rights to the full extent permitted by law.

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230 with its Registered Office at: 4th Floor, Dorset House, 27-45 Stamford Street, London SE1 9NT.

© The Carbon Trust 2022. All rights reserved.

Published in the UK: 2022