Journal of
Climate Policy
(JCP)

Accelerating the Energy Transition: Thailand's Strategic Pathways to Achieve Carbon Neutrality by 2050

CARI Journals

Journal of Climate Policy
ISSN: 2958-2431 (Online)
Vol.4, Issue No.1, pp 53– 78, 2025
www.carijournals.org

Accelerating the Energy Transition: Thailand's Strategic Pathways to Achieve Carbon Neutrality by 2050

Moaz Altaf[1,2*], Sebastien Bonnet[1,2], Nattapong Chayawatto[1,2]

[1]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

[2]Center of Excellence on Energy Technology and Environment, Ministry of Higher Education, Science, Research and Innovation, Bangkok 10140, Thailand

https://orcid.org/0000-0002-7569-3388

Accepted: 20th Mar, 2025, Received in Revised Form: 20th Apr, 2025, Published: 20th May, 2025

Abstract

Purpose: This study explores Thailand's strategic pathways towards achieving carbon neutrality in the energy sector by 2050. It aims to analyze the effectiveness and ambition of Thailand's existing mitigation policies and plans, particularly focusing on the Thailand Integrated Energy Blueprint (TIEB), in guiding a just, inclusive, and sustainable energy transition.

Methodology: A qualitative content analysis approach was employed to review national and sectoral policy documents, including Thailand's Nationally Determined Contributions (NDCs), the Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS), and the TIEB framework. The study critically assessed these plans against international decarbonization benchmarks and examined sectoral coherence, governance mechanisms, and implementation challenges.

Findings: The analysis reveals that while Thailand has taken commendable steps towards low-carbon development, significant gaps remain in policy integration, renewable energy scaling, and equitable transition planning. The study identifies a misalignment between policy ambition and implementation mechanisms, along with a need for stronger institutional coordination and stakeholder engagement. Moreover, the reliance on natural gas and carbon offsets may undermine long-term decarbonization goals.

Unique Contribution to Theory, Practice, and Policy: This paper offers a critical lens on Thailand's decarbonization efforts, contributing to the theoretical understanding of integrated climate-energy policy frameworks in Southeast Asia. It provides practical insights for policymakers on addressing institutional fragmentation, enhancing governance, and aligning national plans with global climate targets. For practitioners, it highlights the importance of inclusive stakeholder engagement and transparent monitoring systems to foster a just transition.

Keywords: *Decarbonization, Carbon Neutrality, Renewable Energy, Energy Transition. Climate Policy, Power Sector, Energy Blueprint, Climate Change Mitigation, Greenhouse Gas Reduction, Thailand*

1. Introduction

Climate change is a threat to ecosystem functioning and biodiversity in current times, with projected degradation of naturally existing resources that are pivotal to human and animal life (Kabisch et al., 2016). It has been a rising concern for authoritative bodies globally, considering it results from increased emission of greenhouse gases (GHG) like carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, leading to increased global temperatures and weather patterns over time. The (World Health Organization (WHO), 2023), for instance, argues that climate change is one of the most significant contributors to humanitarian emergencies, with almost half of the world's population (3.6 billion) living in areas highly susceptible to climate change impacts such as floods, tropical storms, hurricanes and heatwaves. This viewpoint among others shared by various scientists across the globe, underpin the increased need by the international community to develop collective actions towards mitigating climate change.

Global recognition of climate change and its devastating impacts necessitated international efforts, with countries globally coming together to develop actionable solutions with a common goal. These international efforts are shaped by landmark agreements that have guided global action on climate change over the years. The Montreal Protocol of 1987 marked the journey to international agreements on collective global action by signing a binding treaty that sought to eliminate the ozone-depleting elements gradually damaging the ozone layer (Fang et al., 2018; UNEP, 2012). Only 24 countries signed this protocol in 1987 (Fang et al., 2018; UNEP, 2012). However, its existence and intent for change on the climatic front successfully laid up the groundwork for the United Nations Framework Convention on Climate Change (UNFCCC), established in 1992 to address the global warming threat by managing human interference that would lead to stabilization of greenhouse gas emissions. The UNFCCC, learning from the Montreal Protocol, bound member states with the collective prioritization of human safety in the wake of scientific uncertainty surrounding climate change.

A key part of the UNFCC is the annual Conference of Parties (COP), where climate action negotiations would be conducted. The first COP (COP1) in Germany in 1995 laid the foundation for future meetings and set the process for dealing with the climate crisis as the new millennium approached. COP3 marked the earliest UNFCCC milestone by producing the world's first international treaty, known as the Kyoto Protocol, in 1997 to reduce global warming, with industrialized nations committing to reduce their greenhouse gas to 5% within 10-15 years in two commitment periods, 2008-2012 and 2013-2020 (Misila et al., 2020). However, this agreement was undermined by the United States' failure to commit and that India and China had not yet achieved industrialized status. Subsequent COP meetings focused on implementing the Kyoto Protocol, and in 2001 (COP7), 160 countries met and developed the Marrakesh Accords to further plan out the execution of the Kyoto Protocol (Benjamin & Wirth, 2021). Another milestone in the fight against climate change occurred in 2013 during COP19, popularly known as the Warsaw Mechanism for Loss and Damage, which formalized an international mechanism for dealing with loss and damage, especially for vulnerable nations (Benjamin & Wirth, 2021). Although several COP meetings took place before COP19, there were no binding accords even though the conferences produced some progress.

Nevertheless, 2015 was an important year because it yielded the Paris Agreement after an unsuccessful attempt to have a broad agreement that could be binding to all countries and act as an improvement of the Kyoto Protocol (Chaichaloempreecha et al., 2022). This agreement was significant because it marked a shift from the top-down Kyoto structures to the bottom-up NDCs where countries could set their own achievable emission goals in line with the international goals. The agreement's ambition is to limit global warming to below 2°C. It had also successfully brought significant emitters like the US, India, and China on board, which was not achieved with the Kyoto Protocol, making it a pivotal turning point in international climate policy. Table 1 below summarizes the plans and agreements concerning climate change mitigation.

Table 1. Global plans and agreements on climate change.

Agreement	Objectives	Key Features	Successes	Criticisms
Montreal Protocol (1987)	Address ozone layer depletion	Successful in phasing out ozone-depleting substances	Successful phase-out of ozone-depleting substances Ozone layer recovery	Focused on specific environmental issues rather than climate change
Kyoto Protocol (1997)	Reduce global GHG emissions to levels below 1990	Assigned emission reduction targets Flexibility Mechanisms	Raised awareness Established a framework	Limited scope Lack of legally binding commitments for developing countries
Marrakesh Accords (2001)	Set the rules for meeting the targets set out in the Kyoto Protocol	Created specific rules on how to meet the targets	Established sets of compliance and monitoring procedures	Lack of agreement on the text of compliance
Warsaw Mechanism for Loss and Damage (2013)	Formalization of international mechanism for dealing with losses and damage for vulnerable nations	Enhancing understanding of risk management approaches Strengthening dialogue Improving support and action to allow countries to address losses and damages	Created space and opportunity to understand multiple issues on climate change	Lack of leadership and political will from developing countries
Paris Agreement (2015)	Limit global temperature increase well below 2 degrees Celsius	NDCs Regular review mechanisms Global stock-take	Universal participation Emphasis on adaptation and finance	Insufficient emission reduction commitments Lack of precise enforcement mechanisms
Kigali Amendment (2016)	Phasing down hydrofluorocarbons (HFCs) Potent greenhouse gases	Addresses reduction of HFCs	Addresses a specific subset of potent greenhouse gases	Focused on reducing HFCs rather than a comprehensive climate strategy

Thailand, a country in Southeast Asia, is part of the countries that have committed to reducing its greenhouse gas emissions by 30% by 2030 and realizing carbon neutrality by 2050 after being ranked 13th in the "extremely at risk" category (ONEP, 2020a; Zhang et al., 2022). This ranking is evident in the devastating disasters faced by the country in the last three decades (Zhang et al., 2022). Thailand's commitment to this journey to carbon neutrality was first landmarked by joining the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty established in 1992 for global climate action. The country

has since been developing policies and regulations that govern its carbon emission levels. As evidenced by Thailand's Nationally Determined Contribution (NDC), which was first submitted to the UN in October 2020, the country aims to achieve carbon neutrality by 2050 after reducing the GHG by 30% in 2030 (ONEP, 2020a).

Thailand's government's commitment to reducing CO_2 emissions spans two decades since they joined the Kyoto Protocol. Outside the global commitments, the country has also had national mitigation actions that govern its carbon reduction journey, especially in industries/sectors with the highest emission levels: power, transport and industry (Zhang et al., 2022). It is evident that the rise in emissions is correlated with energy consumption in the country, and thus, the country has explicitly focused on the power sector to ensure they make strides towards reducing the emissions despite the energy consumed by shifting to renewable energy sources (Pita et al., 2020). As part of this initiative, in 2008, Thailand developed the National Energy Policy, intent on increasing energy security and encouraging the use of alternate sources and high-efficiency energy technologies to scale up on green energy alternatives (IRENA, 2017). This policy then evolved into the Thailand Integrated Energy Blueprint (TIEB) in 2015, which had five major plans for the country's 2015-2036 energy policy for the sector (IRENA, 2017). The five major plans covered under the TIEB are the Oil Plan, the Gas Plan, the Alternative Energy Development Plan (AEDP), the Power Development Plan (PDP) and the Energy Efficiency Plan (EEP), each with a differing focus in the overarching goal of ensuring green energy use and energy security in the country (IRENA, 2017). As a result, Thailand has made progress in some sectors, but the CO_2 emissions are still rising, and more needs to be done if the carbon neutrality by 2050 goal is to be achieved (ONEP, 2020a; Zhang et al., 2022). Thailand’s energy policy landscape, while robust in its ambition, still faces institutional and implementation challenges. Previous studies have emphasized the complexity of policy coordination across multiple agencies, and the difficulties in sustaining long-term energy efficiency reforms (Chemhengcharoen, Bonnet, & Puhl, 2014).

Furthermore, regional energy pooling frameworks, such as those proposed among China, Iran, Pakistan, Turkey, and Russia, demonstrate how shared energy infrastructure can help countries overcome national limitations and improve energy security (Altaf, 2022). Similarly, lessons drawn from stakeholder coordination and policy fragmentation observed in CPEC energy projects highlight the need for unified governance mechanisms and inclusive stakeholder engagement in Thailand’s decarbonization process (Altaf & Bonnet, 2025).

This review addresses the potential of achieving the national commitments made by Thailand in decarbonizing their country by 2050 through a detailed analysis of the power sector, reviewing the decadal achievements in the sector, and then addressing the potential hiccups in the journey. The review will focus on Thailand's efforts in addressing climate change issues and its steps towards mitigation, with a keen interest in the power sector's mitigation efforts, providing extensive analysis of the ambitious goal towards carbon neutrality by 2050. Thailand’s power sector is heavily intertwined with the energy sector, with plans and policies developed on production and consumption of power, cutting across the two sectors as they are dependent on one another. As such, while this review addresses the state, and goals of

Thailand's power sector, aspects of energy use and consumption (energy sector) which are key to the analysis and discussion are included.

2. Thailand's actions towards carbon emissions mitigation

2.1 Thailand's national contribution to CO_2 mitigation

Despite having less than 1% of the global carbon emissions, Thailand was ranked 8th in the most affected countries in the Global Climate Rick Index for the period 1999-2018 and 13th in 2022 (ONEP, 2020a, 2020b; Zhang et al., 2022). This ranking has forced the country to prioritize climate change and take actions that ensure it contributes to CO_2 mitigation. Thailand's first show of interest and commitment to climate change mitigation was joining the UNFCCC in 1991, one of the most significant international frameworks addressing climate change (Ministry of Natural Resources and Environment, 2021). It was ratified in 1994, and since then, climate mitigation strategies and actionable plans have been developed in line with the framework, focusing greatly on reducing GHG emissions. Later, Thailand ratified the Kyoto Protocol in 2002 and then the Paris Agreement in 2016. Each of these steps has shown the country's commitment to climate change, which has then shaped the policies developed in the country towards climate change mitigation plans across its various sectors and levels (Chunark et al., 2017). Since 2007, Thailand has consistently integrated climate change into its development plans across different sectors as part of the National Strategy (2018-2037) (Misila et al., 2020; ONEP, 2020b). The country's commitment to climate change mitigation is evidenced by the creation of a climate change policy known as Thailand's climate change master plan (2015-2050), within which the mitigation strategies that align with the global community agreements and the national strategy are encompassed (Ministry of Natural Resources and Environment, 2021).

2.2 Thailand's Climate Change Master Plan (2015-2050)

Thailand's Climate Change Master Plan (2015-2050) was developed in line with the National Strategy formulated in 2008 to help the country meet the global commitments to the Kyoto Protocol (ONEP, 2015). The policy, developed in 2015, focused on ensuring the country's priorities on decarbonization had a middle and long-term perspective and cut across all sectors (ONEP, 2015). The master plan had four primary purposes: providing a long-term national framework, providing a policy framework that guided the development of tools and mechanisms on national and sectoral levels, providing government agencies and other relevant organizations with a detailed framework for action plans, and ensuring budgeting agencies had a clear framework when allocating budgets (ONEP, 2015, 2020b).

The master plan's framework was developed using a Driving Forces-Pressure-State-Impact-Response (DPSIR) framework, which is a framework used to widely analyze the impacts and relationships between factors in a system (Buaban et al., 2021; ONEP, 2015). The framework focused on first addressing the driving forces of climate change, then the pressure points based on the human activities and conditions that lead to carbon emissions, and then the state of the climate based on changes experienced in weather, temperature patterns and sea levels. Impacts and responses were then focused on understanding the effects of climate change

on various sectors and then introducing approaches and responses to climate change based on the drivers, pressures and impacts (Buaban et al., 2021; ONEP, 2015).

The plan had three goals, covering two phases: the pre-2020 action plan and the post-2020 action plan. The goals were divided into the short-term, medium term and long-term, with the short and medium-term being part of the pre-2020 phase, while the long-term goals were covered under the post-2020 action phase. For each duration, there are three key components: climate change adaptation, mitigation and low carbon development, and enabling environment for climate change management (ONEP, 2015). Table 2 below summarizes the Climate Change Master Plan 2015-2050 goals in the three phases and the strategies under each component.

Table 2. Summary of Climate Change Master Plan goals.

Goals/ Strategies	Climate change adaptation	Mitigation and low carbon development	Enabling environment for climate change management
Short-term goals (Target 2016)	-Develop comprehensive climate change risk maps incorporating key socio-economic and environmental aspects. -Increase biodiversity conservation areas by at least 19% nationally, with at least 5000 rai/year mangrove forests. -Develop a comprehensive and ecologically sustainable coastal restoration plan in at least half of the country's coastal provinces. Develop a composite and sector-specific climate change resilience index.	-Define medium and long-term goals with targets and roadmaps for achieving GHG emissions. -Come up with integrated economic and legislative channels for low-carbon development.	-Develop databases across different sectors illustrating the business-as-usual scenario, the voluntary mitigation efforts and impacts, mandatory mitigation efforts, and the GHG emission reporting system for high industrial emitters. -Develop a national climate strategy with action plans to handle the above goal.
Medium-term goals (Target 2020)	-Set up comprehensive early warning measures across all sectors. -Set up a climate-based agricultural insurance scheme. -Increase national forest coverage to 40%. -All the short-term adaptations as well.	-Decrease GHG emissions in transport and energy sectors by 7-20% from the business-as-usual. -Boost renewable energy consumption in the national grid to 25% of total national energy consumption. -Increase green space per person to at least 10 square meters in more municipalities.	-Set up smart grid technology for use at a national level -Set up tools and mechanisms for climate change mitigation which correspond with the international goals at a national level.
Long-term goals (Target 2050)	-Prioritize agriculture, by ensuring there is soil and water conservation, increasing the water table, prioritizing farmer needs, and increasing the number of irrigation systems in the country. -Focus on reducing the impacts of natural disasters across the divide. -Ensure primary needs such as healthcare, disease surveillance, and malnutrition are decreased.	-Decrease GHG emissions by at least 25% from the business as usual by 2030. -Motivation increased usage of public transport and reduced GHG emissions from land transport. -Invest more in agriculture. -Reduce GHG emissions per GDG. -Invest in more low-carbon emission industries.	-Boost utilization of human resources development plans which align with climate change mitigation and low carbon development across the country.

The mitigation strategies in the Climate Change Master Plan are implemented through two mitigation actions: the NAMA for pre-2020 goals and the NDC for post-2020 goals.

2.3 Thailand's Mitigation Plans

2.3.1 The Nationally Appropriate Mitigation Actions (NAMA)

Thailand's international commitment to the global community is evidenced by efforts made in the national space. The first evidence of Thailand's commitment was its Nationally Appropriate Mitigation Actions (NAMA) plan submitted to the UNFCCC in 2014 in a voluntary capacity. It highlighted Thailand's endeavour to reduce GHG emissions by 7-20% of below the agreed-upon Business as Usual (BAU) values in 2020 through keen focus on the energy and transport sectors (Ministry of Natural Resources and Environment, 2021; ONEP, 2020b). The goal of the NAMA plan was to ensure the country had reduced their GHG emissions by at least 25% in 2030, in line with the international goals, in two phases: the pre-2020 phase and the post-2020 phase (Misila et al., 2020; ONEP, 2020b). In the pre-2020 phase, Thailand vowed to achieve a 7-20% goal in the energy and transportation sectors, and towards this, Thailand achieved a 15.76% reduction of GHG emissions to the BAU in 2018, showcasing their progress towards the achievement of the 2020 goal (ONEP, 2020b). In the second phase, the country would focus on the 2030 goals, targeting a 30% reduction, and this is covered in their Intended Nationally Determined Contribution (INDC), which later became NDC and was also submitted to the UNFCCC in 2020 following the Paris agreement (ONEP, 2017, 2020b). Table 3 below shows the contents of the NAMA roadmap, the area of focus, and the achieved outcome between 2016 and 2020.

Table 3: Summary of NAMA roadmap.

Nationally Appropriate Mitigation Actions (NAMA) mitigation plans							
NAMA Mitigation measure	**Target**	**Mitigation policy**	**Carbon emissions reduction (MtCO2eq)**				
			2016	**2017**	**2018**	**2019**	**2020**
Ensure electricity is generated from natural renewable energy	Increase the total amount of electricity generated from renewable energy to 20% of total generated electricity by 2036	Promoting renewable energy to generate electricity under the Alternate Energy Development Plan (AEDP)	3.99	5.53	7.27	7.74	6.41
Ensure electricity generation from bio-renewable energy	Increase the total amount of electricity generated from renewable energy to 20% of total generated electricity by 2036	Promoting renewable energy to generate electricity under the AEDP	9.86	9.95	11.10	11.56	11.11
Generate heat from natural renewable energy (solar)	Increase the total amount of heat produced from renewable energy to 30-35% of total heat demand by 2036	Promoting renewable energy to generate heat under the AEDP	0.02	0.03	0.03	0.04	0.03
Generate heat from bio-renewable energy (biogas and biomass)	Increase the total amount of heat produced from renewable energy to 30-35% of total heat demand by 2036	Promoting renewable energy to generate heat under the AEDP	23.46	24.04	26.55	25.61	23.01
Enhance consumption of Biodiesel in transport	Boost biodiesel consumption to 14 million litres/day by 2036	Promoting diesel consumption in vehicles under the AEDP	3.32	3.76	4.18	6.51	5.04
Enhance consumption of Ethanol in transport	Boost Ethanol consumption to 11.3 million liters/day by 2036	Promoting ethanol consumption in gasoline vehicles under the AEDP	2.92	3.13	3.34	3.39	3.27
Improve energy efficiency using thermal power plants	Meet the timelines of the power development plan (PDP) for power plants	Boost the thermal power plant's heat rate under the PDP	0.12			0.78	0.82
Improve energy efficiency using clean technology power plants	Meet the timelines of the power development plan (PDP) on clean technology power plants	Boost clean technology power plants' heat rate under the PDP	1.37			4.54	6.34
Improve energy efficiency using thermal power plants through natural gas and Lignite.	Meet the timelines of the power development plan (PDP) for power plants	Boost thermal power plants' heat rate under the PDP		4.56	4.62	6.89	6.34
Develop standard energy efficiency labelling for electric devices	Save 4149 ktoe of electricity using high-efficiency devices that are approved by energy efficiency standards before 2036.	Promote energy efficiency standards for electric devices under the EEP.	0.62	0.72	0.75	0.89	0.82
Total			45.68	51.72	57.84	64.20	56.54

As seen in Figure 1 below (and Table 3 above), Thailand achieved its NAMA pre-2020 phase of 7-20% reduction, with a 15.64% reduction by 2020 (ONEP, 2022a). Instead of shifting to the post-2020 phase, the NDC developed following the 2016 Paris Agreement kicked in.

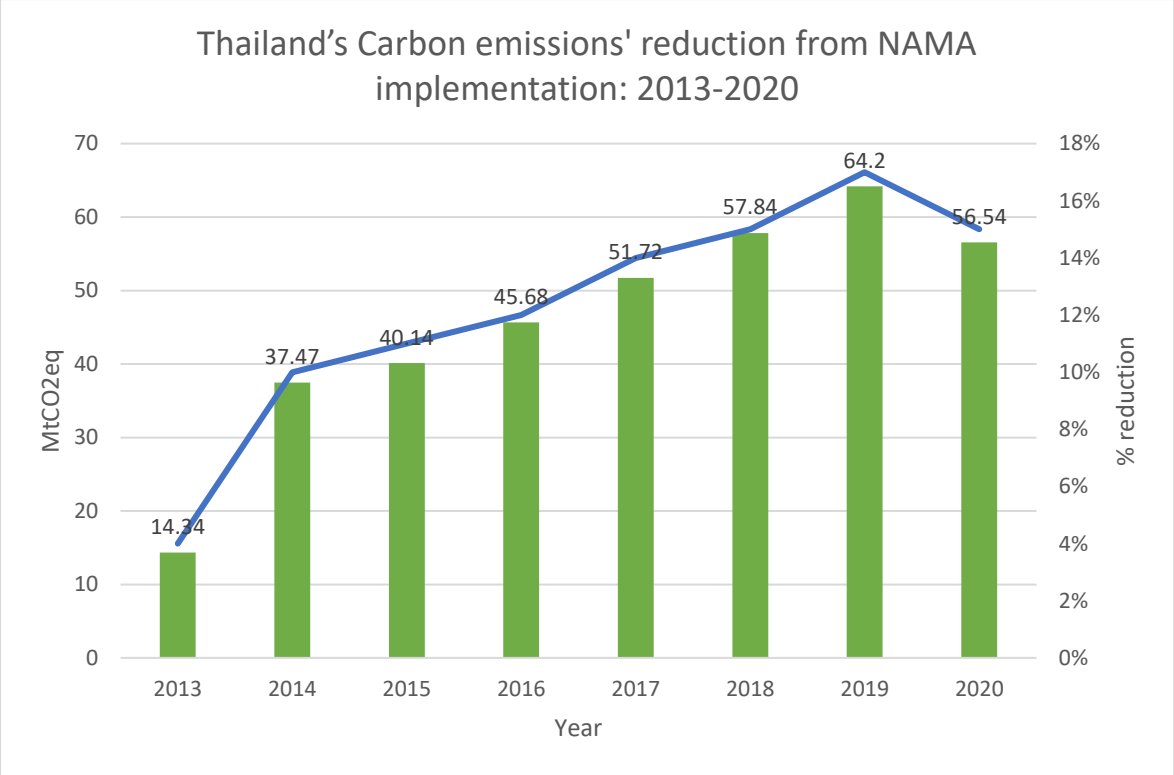

Figure 1. Thailand's Carbon emissions reduction goals through the implementation of NAMA 2013-2020.

2.3.2 Thailand's Nationally Determined Contribution (NDC)

Thailand's NDC was first developed in 2015, following the country's commitment to the Paris Agreement, made in COP21, and later edited and submitted to the UNFCCC in 2020 (ONEP, 2020a). After that, the second NDC was developed and submitted to the UNFCCC in 2022, which covers Thailand's post-2020 (2020-2050) climate mitigation strategy. The NDC is focused on the energy, transport, waste management and industrial sectors and developed based on the goals set in the following plans: The Climate Change Master Plan, Energy Efficiency Plan, Alternative Energy Development Plan, Thailand Smart Grid Development Master Plan, Master Plan for Sustainable Transport System and Mitigation of Climate Change Impact, Waste Management Roadmap, and the National Industrial Development Master Plan (ONEP, 2022b). The next section addresses the energy/power sector related plans and what they entail as the main focus of this analysis. The target is to achieve carbon neutrality by 2050 by reducing GHG emissions by 2030 and then further addressing other limitations to ensure the country's goals are achieved by 2050 and the country is at net zero by 2065 (ONEP, 2022b).

Policy is considered the first step towards enacting change, especially when addressing public issues. Policies, especially in regard to public interest, are developed by the government and often geared towards ensuring involved bodies are legally bound and, therefore, have to

comply with the policy terms (Porter et al., 2018). This has been the approach explored by Thailand's government in the mitigation of climate change and working towards decarbonizing the country, with a keen interest in sectorial roles. The energy sector, as seen in the NAMA summary, is a priority for the country, with all the policies and goals in the national strategy founded on ensuring there is clean energy developed, use of renewable energy, or biodegradable sources of fuel (Misila et al., 2020; ONEP, 2020b). The increased focus on the power sector is founded on the recognition that there has been an increase in energy consumption across the country's economic pillars. For instance, total final energy consumption in the economic sector increased by 95.6% during 2000-2017 (Misila et al., 2020). More importantly, energy consumption in the industrial and transport sectors accounted for three-quarters of the total energy consumption in the past ten years, as indicated in Figure 2 below (Department of Alternative Energy Development and Efficiency, 2020). Nevertheless, Thailand has made concerted efforts toward CO_2 mitigation in the energy sector.

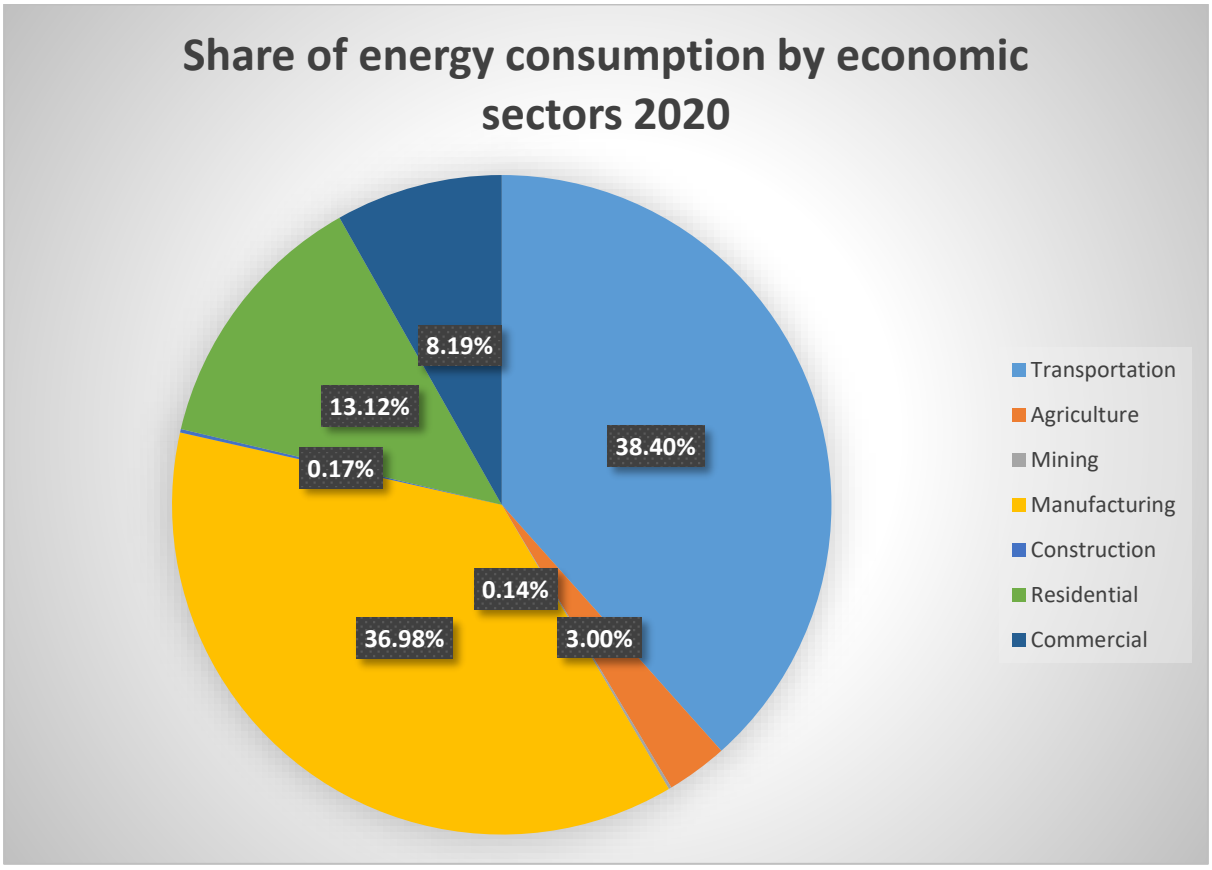

Figure 2. Share of final energy consumption in Thailand by economic sectors by 2020 according to the Department of Alternative Energy Development and Efficiency (DEDE) 2020.

3. Analysis of Thailand's efforts to decarbonize the power sector: Thailand Integrated Energy Blueprint (TIEB)

In order to decarbonize the power sector, Thailand's government developed a Thailand integrated Energy Blueprint (TIEB), which is a policy with five energy plans, focusing on achieving energy security, economic affordability and environmental sustainability, by developing ways of reducing the consumption of carbon-emitting fuels or generation of carbon-

emitting power systems. The five major plans in the policy are the Oil Plan, the Gas Plan, the Alternative Energy Development Plan (AEDP), the Power Development Plan (PDP) and the Energy Efficiency Plan (EEP), each with a differing focus in the overarching goal of ensuring green energy use and energy security in the country all developed in 2015, with a short term 5-year plan ending in 2020, then a medium term 10-year plan ending in 2027, and a long term 20-year plan that ends in 2036 or 2037 (IRENA, 2017). The objectives of TIEB using these plans are to secure the supply of electricity, ensure Thailand has cost competitiveness in the region, protect the environment by using renewable and clean energy sources, ensure the country has an energy support sustainability, and facilitate socio-economic support needed for people in the various sectors (IRENA, 2017). Figure 3 below shows how these objectives were distributed across the different plans:

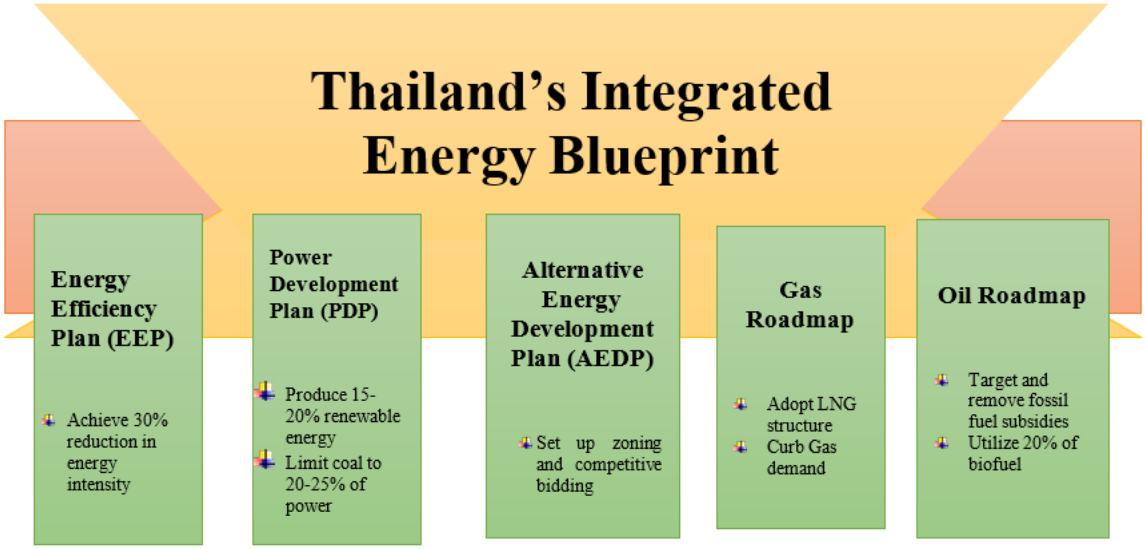

Figure 3: TIEB plans to achieve set objectives.

Focusing purely on the power sector, Thailand's strategy is threefold: come up with a way to use energy efficiently, hence reduce consumption, focus on energy production and supply that is secure with increased interest in renewable energy generation and distribution, and come up with ways to increase the energy generated from renewable and energy sources. The three plans, AEDP, PDP, and EEP, which cover this threefold strategy, are analyzed below.

3.1 Power Development Plan (PDP)

The PDP is the country's master plan for power generation and supply aimed at strengthening the security of the power system and ensuring it is adequate to meet the growing consumption needs in the country (Electricity Generating Authority of Thailand (EGAT), 2020; Ministry of Energy, 2020b). this plan, developed based on public opinions and feedback held by the Ministry of Energy, to ensure the country's interest from different perspectives was catered for in the new power policy, and stakeholders from different sectors were involved as it affects them (Electricity Generating Authority of Thailand (EGAT), 2020). The PDP 2015 has three priorities: ensuring security in power produced, ensuring there is a fair cost of the power produced that all citizens can afford, and ensuring the power being generated is society

and environment-friendly (Ministry of Energy, 2020b). Table 5 below summarizes the PDP goals across the different sources of energy that the government believes will provide affordable, safe and secure power for the country by 2036. The table is developed based on data from the Ministry of Energy (2020b) PDP plan.

Table 5. Summary of the PDP goals on energy generation by 2036.

Power source	2018	2023	2029	2036
Natural gas	58%	48%	48%	37%
Imported hydropower	6%	8%	12%	15%
Coal/Lignite	21%	26%	21%	23%
Renewable energy sources	15%	18%	19%	20%
Nuclear power	0	0	0	5%
Other sources	0.2%	0.1%	0.1%	0.1%

These goals were to be achieved using the exploration of alternative energy sources for production that could replace the fossil fuels in use.

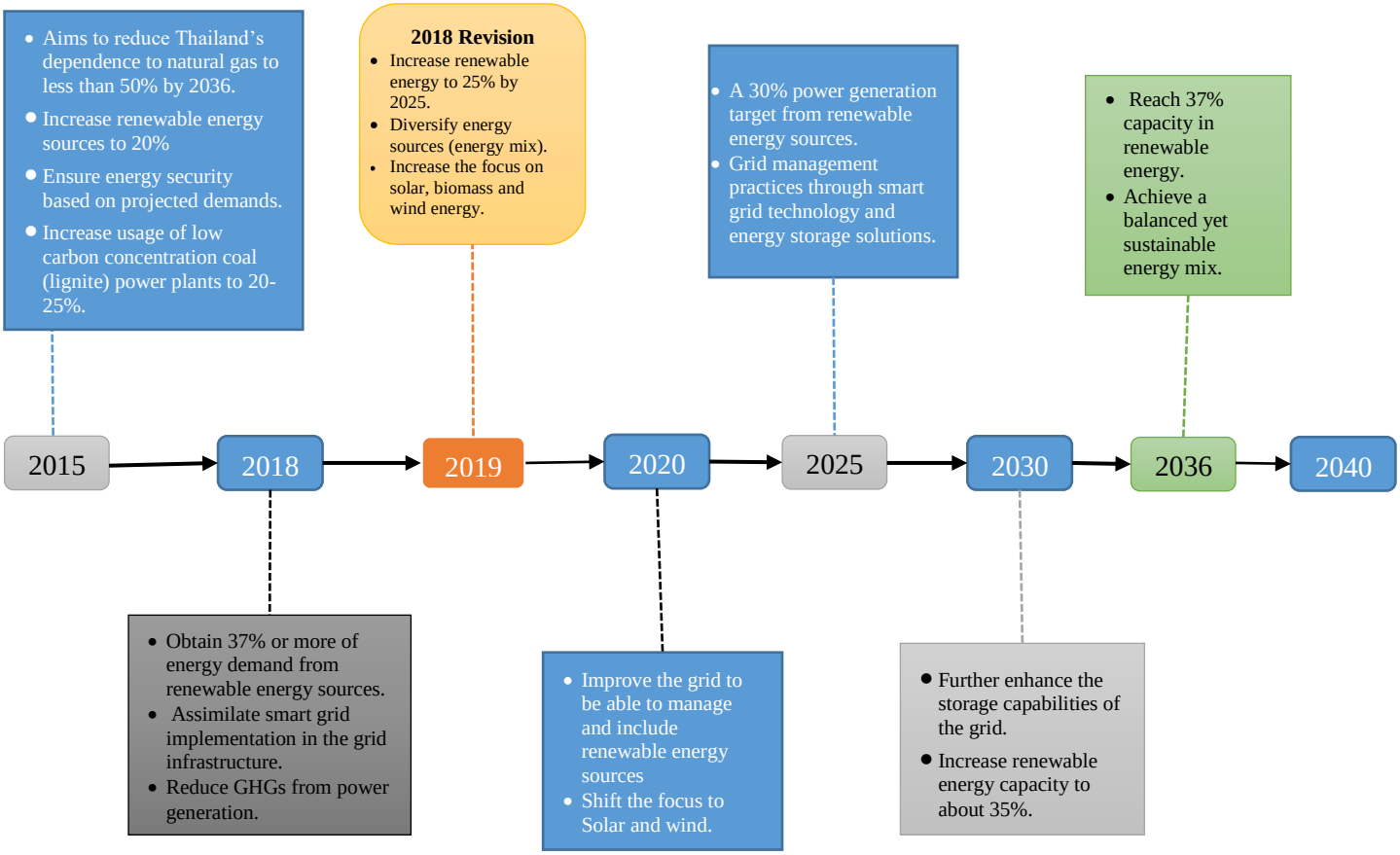

Figure 4: Timeline of Thailand's PDP

3.2 Alternative Energy Development Plan (AEDP)

The AEDP plan was developed to motivate increased production and utilization of renewable energy by 2037, in line with the PDP 2015 goals (Ministry of Energy, 2020a). Upon

review of the past activities by both the government and the country, it was apparent that the country's source of energy was energy sources such as crude oil, which, upon processing, had increased carbon emissions, and thus the need to shift to energy sources that had lower carbon emissions to the atmosphere, as part of their journey to carbon neutrality (Ministry of Energy, 2020a). In 2018, the country's consumption of conventional (non-renewable energy sources) energy was at 85%, with alternative energy consumption only at 15%, and the AEDP plan intends for this to shift to a 30% increase by 2037 in alternative energy consumption, a change that would reduce their use of fossil fuels by almost 40,000 ktoe, and manifest in an equivalent GHG emissions reduction of about 140 million tonnes of carbon (KPMG, 2020; Ministry of Energy, 2020a). Figure 5 below shows the ambitious goals of the AEDP plan and the types of power generation sources that are to aid with that goal if the reduction intended for carbon emissions by 2037 is to be achieved.

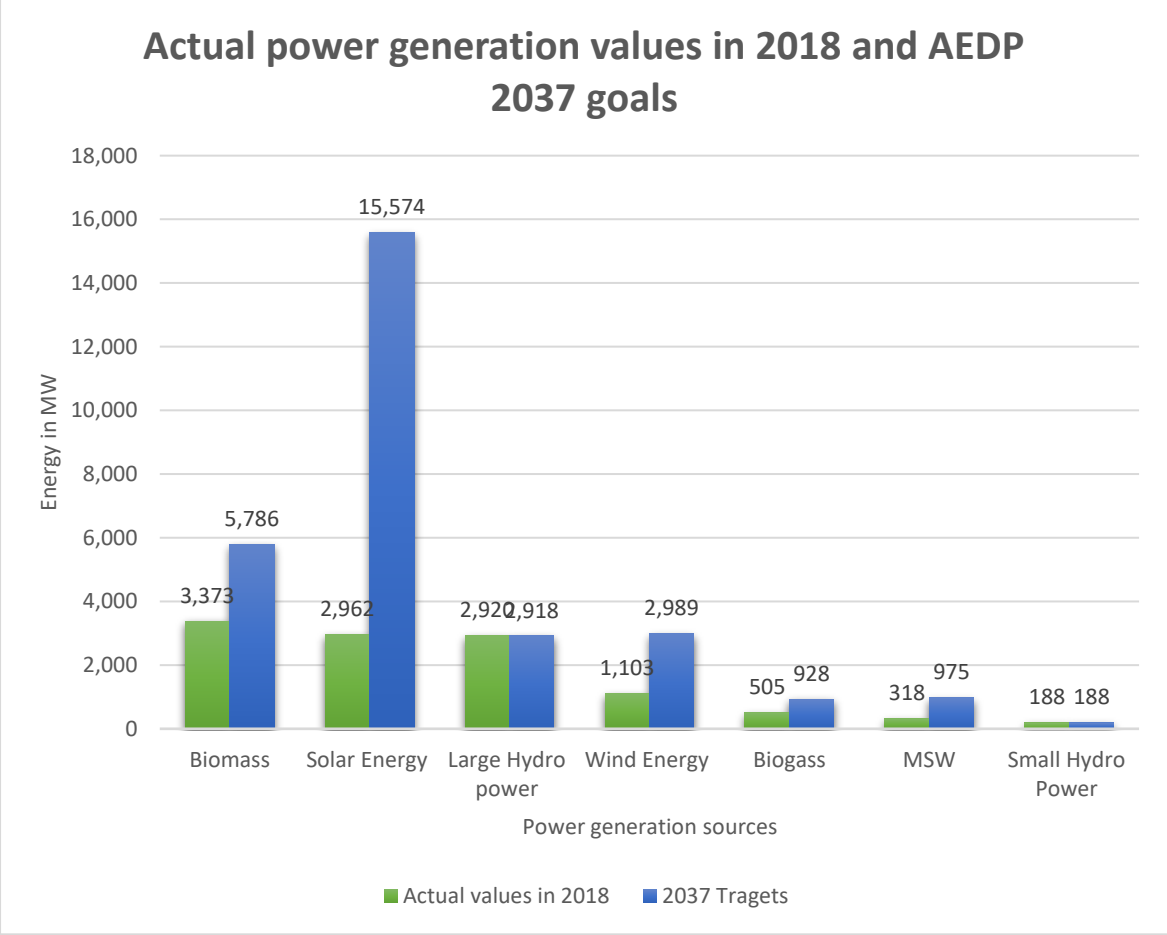

Figure 5: AEDP 2018 actual values and 2037 targets for power generation in the energy sector according to data by KPMG (2020).

If the above goals are achieved, the electricity consumption in the country from alternative energy would be 33%, with solar energy providing the largest portion, at 15,000MW, as seen above. Thailand is keen on this diversification, as it ensures the country has reliable renewable energy sources to enhance their carbon emission reduction goals. As a result, the government intends to invest in different energy sources, as seen in Figure 5 above,

to ensure the goals that the NAMA had already achieved in the pre-2020 phase are further enhanced towards the carbon neutrality journey. This plan is still in place, with efforts to discover new forms of renewable and clean energy production. The AEDP plans on power generation and consumption pathways for carbon neutrality goals also extend to the transport sector in terms of fuels, with the exploration and production of Biodiesel, Ethanol and compressed biomethane gas being pivotal in the development of biofuels they can use as diversified sources of energy (KPMG, 2020; Ministry of Energy, 2020a).

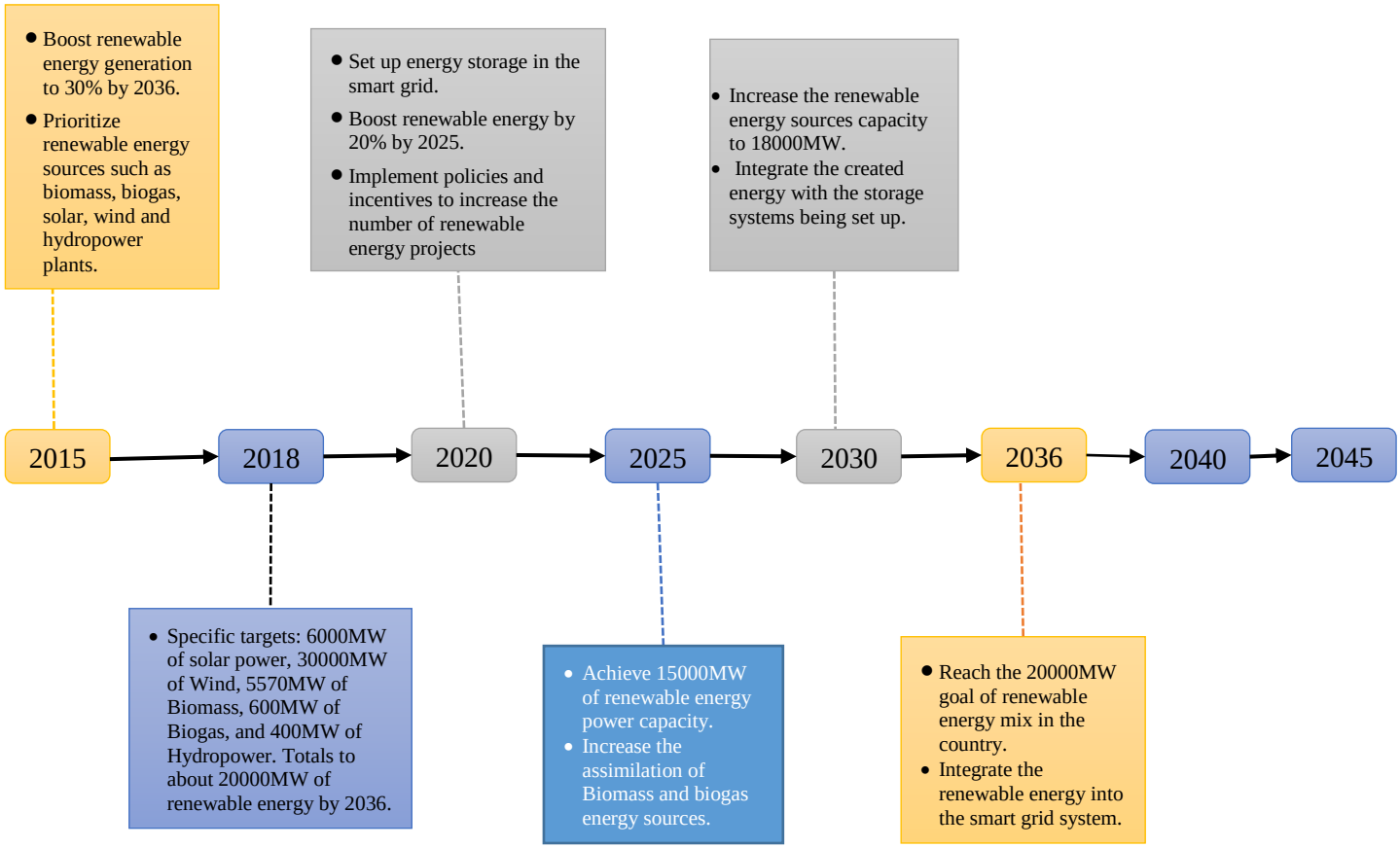

Figure 6: A timeline of Thailand's AEDP

3.3 Energy Efficiency Plan (EEP)

The EEP is a build-up from the other two plans, with the PDP providing grounds for the infrastructure mix and the AEDP enhancing ways of maximizing the energy mix. The EEP is more of an all-encompassing plan, which focuses on maximizing the impacts of the PDP and the AEDP by ensuring there is reduced intensity of the energy on the economy by reducing the amount of energy consumed per GDP while still maintaining the initial GDP output, while also ensuring there is conservation of energy across all the key sectors; business, industry, residential and transportation (Ministry of Energy, 2018). This plan is very diverse and focuses on different sectors, and is thus to be achieved through a detailed integration of different pathways across the sectors, ensuring a 30% intensity reduction in the power sector.

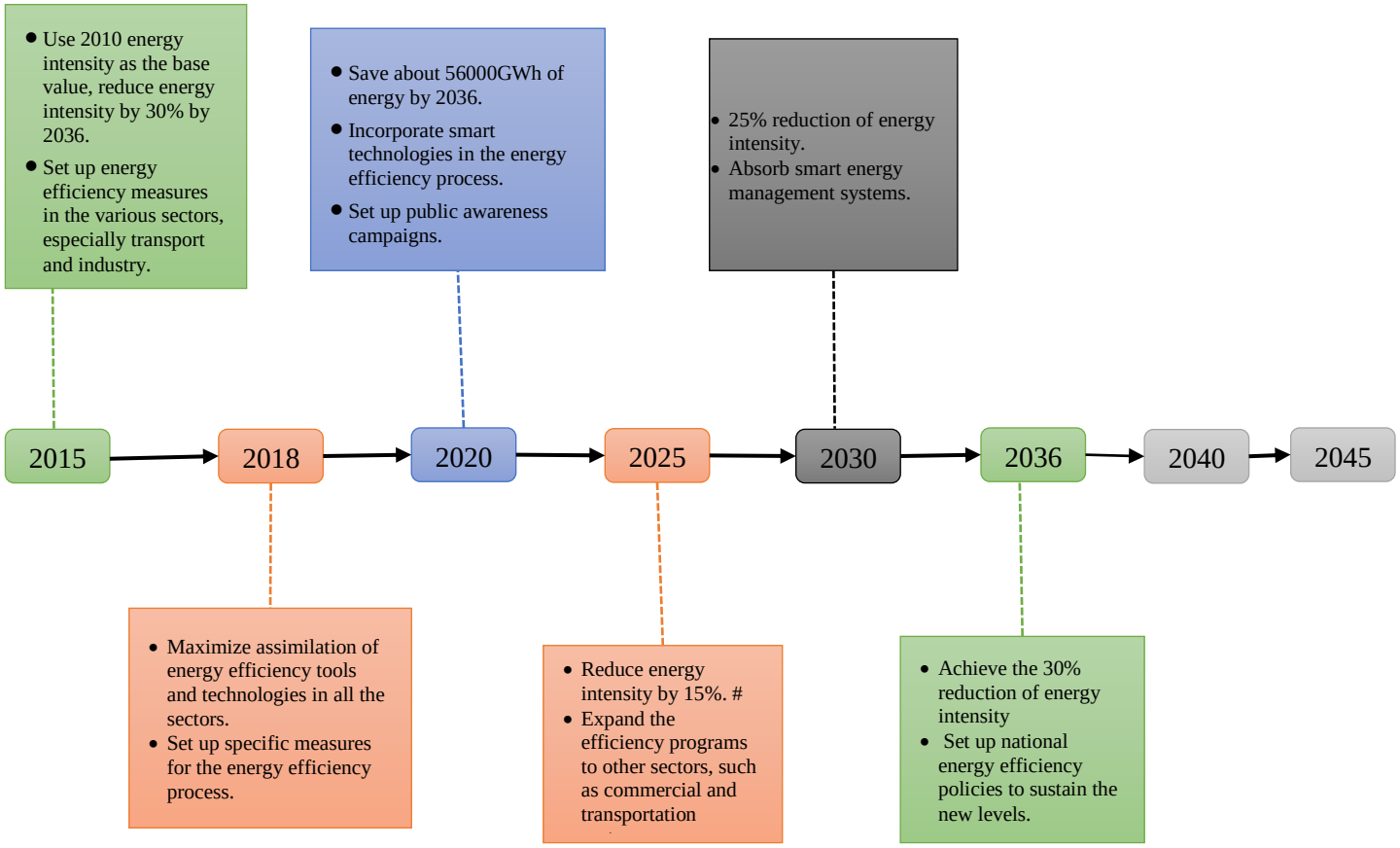

Figure 7: A timeline of Thailand's EEP

A comparison of PDP, AEDP and EEP is given in Table 6.

Table 6: Comparison of Thailand's EEP, PDP, AEDP.

	PDP	AEDP	EEP
Source	Ministry of Energy Thailand	Department of Alternative Energy Development and Efficiency, Ministry of Energy (Thailand)	Department of Alternative Energy Development and Efficiency, Ministry of Energy (Thailand)
Economic sector	Power	Energy, Power	Energy, Power
Energy types	All: Coal, Oil, Power, Gas, Renewable, Hydropower, Other, as it covers a universal base.	Power, Renewable, and Bioenergy, as it only focuses on producing clean energy.	It covers all energy types covered by the TIEB plan, be it power, energy, gas or oil, as long as they relate to power generation and consumption.
Goals	-Come up with a strategy for coping with increasing power demand such that the country still develops through diversifying fuel sources. -Maintain a sustainable energy cost from power generation -Lessen the carbon footprint through environmentally friendly energy sources.	-To explore the full potential of domestic renewable energy sources. -Create renewable energy generation streams that enable the reduction of carbon emissions from the use of fossil fuels.	Has seven core measures for increasing the country's energy efficiency and ensuring power produced can adequately meet the country's needs: -Enhancing energy efficiency improvements in industrial facilities -Conducting energy-saving housing promotions -Enforcing mandatory application of the Energy Efficiency Resource Standard. -Promoting efficiency for electric appliances and eco-stickers. -Providing soft loans for energy efficiency improvements -Promoting LED use. -Promoting energy efficiency in the transportation sector.
Target	-Increase power capacity to 56,431 MW with renewable energy being 37% (20766 MW).	-Increase the renewable energy and alternative energy sources proportion in electricity, biofuels and heat, to 30% by 2037.	-Reduce energy intensity in the country by 30% by 2037, which is a reduction in the commercial energy consumption to 49,064 ktoe. This would ensure the country is able to sustain their production and consumptions needs with the power generated, without need to import power from neighboring countries.

3.4 Critical evaluation of Thailand's efforts to decarbonize the energy sector

Thailand's efforts towards climate change mitigation, especially in the power sector, have been tenfold, as shown by the policies and plans the country has explored above. The plans and policies cover different areas of focus, ensuring that they enhance the government's journey towards carbon neutrality by 2060. The plans, therefore, showcase the government's and related stakeholders' strong commitment to transform the power sector and mitigate the potential impacts of climate change on a country such as Thailand, which is at high risk. However, the plans and policies will only work if they are centrally poised to address the issues at hand. Thus, this section evaluates the strengths and challenges associated with these policies and what that means for the country.

3.4.1 Strengths in the plans and policies employed for energy sector

Thailand's plans and policies reflect the country's interest in diversifying its energy sources to increase the share of renewable energy it can generate. The three plans covered the above transition from the goals to develop a strategy to increase power generated by

diversifying the fuel and energy sources under the PDP to exploring renewable energy generation streams under the AEDP (Ministry of Energy, 2020a, 2020b). This diversification is integral towards achieving their decarbonization goals, as well as providing energy security for the country as a result of different resources to use for energy generation. Kumar (2016) highlights this as one of the most powerful solutions to climate mitigation, increasing the potential for Thailand's success in the long run. Energy security, which comes alongside the use of cleaner energy sources, ensures the country is not only successfully implementing an energy mix, but one that is capable of having more benefits for the country no matter the outcome.

Reviewing the PDP, the plan has been refined to ensure the long-term outcome for the country is energy security, by reviewing the country's climate change vulnerability from the mitigation perspective and a sustainability gap (Ministry of Energy, 2020b). The energy security plan that the PDP focuses on established potential generation solutions but further enhances it by predicting the growing demand to ensure the country is also growing in capacity to align with the new demands despite changing their power generation tactics. This is integral when developing a plan for decarbonization because the challenge is not just replacing the existing sources with high carbon emissions but also ensuring that, based on projected numbers, the new power sources can meet the country's demand. This is important when developing carbon mitigation practices by generation of renewable energy, because it enhances the potential for success (Kumar, 2016). The strength of this plan is further enhanced by the fact that the strongest approach to achieving highly ambitious goals of decarbonization, as Thailand has envisioned, is through creating an energy system where low carbon power is generated that can meet the rising demand in the country, without requiring capping on electricity usage when it comes to final consumption (Chaichaloempreecha et al., 2022). Thailand's plans have mastered this concept.

Further, Thailand's plans and policies play a supportive role to one another. The government has developed plans that highlight the goals. However, these plans cannot be implemented successfully without policies that ensure the respective sectors are bound to the identified goals, and thus, each plan has accompanying mitigation action and policies that define what is to be done, by whom and the duration in which that progress is expected (Chaichaloempreecha et al., 2022). The AEDP, EEP, and PDP are key plans for Thailand's achievement of its international climate change mitigation goals highlighted in the NDC (Puree & Praiphol, 2017). This means Thailand's commitments to the NDC as part of its global contribution are planned for and implemented nationally, as they have developed each of their plans in line with the NDC commitments (Puree & Praiphol, 2017). These policies and mitigation actions help embed energy efficiency, security and sustainability across different sectors without hindering the commitment to the global community. This alignment between the national and global commitments further enhances the potential for success.

3.4.2 Barriers to the existing policies and plans for the decarbonization of the energy sector

Despite the policies and plans Thailand has set up being very extensive and clear on the goals the country has, several barriers have the potential to derail the journey to carbon

neutrality. First, the authorities in charge of the plans and policies are fragmented, which presents the opportunity for weak governance due to a lack of coordination. Table 6, for instance, shows that while the PDP is developed and presented by the Ministry of Energy (MOE), the AEDP and the EEP are developed by the Department of Alternative Energy Development and Efficiency alongside the MOE. This then creates a challenge in regard to the coverage of and governance of PDP policies, which the Department of Alternative Energy Development and Efficiency is not a part of, despite being in charge of developing the strategy for energy security and sustainable growth during the carbon mitigation process (Ministry of Energy, 2018, 2020a, 2020b; Puree & Praiphol, 2017). This is alongside other sectors and ministries that also have to be included as the policies in these plans affect those ministries, which creates a long list of stakeholders that need to be in alignment for the policies to function effectively (Puree & Praiphol, 2017). This increases the potential for poor implementation due to lacking cohesion between the different departments.

The Ministry of Energy recognizes that the policies have to be a collective effort between the public/citizens, the public sector, the private sector and non-governmental organizations as well, if the decarbonization goals will be realized (Ministry of Energy, 2018, 2020a, 2020b; ONEP, 2015). Despite this, the MOE has only sought the international community as well as the public sector to fund these efforts highlighted in the carbon mitigation plans, especially those for the energy transition process as identified in the three plans (Ministry of Energy, 2018, 2020a, 2020b; ONEP, 2015). The challenge with this is the public sector has not been able to continuously fund the projects, which now require intervention by the private sector, but there has been a limitation in the nature of cohesiveness between the two parties to ensure this is realized (Chaichaloempreecha et al., 2022; Puree & Praiphol, 2017). Unless there are forums where both public and private sectors feel involved, the lack of infrastructure to support the mitigation and decarbonization plans will last in the country.

4. Discussion: Implications of carbon neutrality by 2050 goals for the power sector

4.1 Thailand's Pathway towards Carbon Neutrality

4.1.1 Thailand's Current Decarbonization Efforts

In 2020, Thailand increased its emissions reduction objectives by announcing a net zero greenhouse gas emissions target in 2065 and carbon neutrality by 2050 (International Energy Agency, 2023). Given that the power sector is the largest contributor to the country's emissions and plays a vital role in decarbonizing other sectors, carbon neutrality is only possible when the power sector is decarbonizing. Therefore, this section focuses on carbon neutrality of Thailand's power sector and energy sector by extension, because the consumption of generated power is a key part of the policies and plans set to achieve carbon neutrality in power generation and consumption processes. The workings of Thailand’s power sector are dependent on energy intensity, efficiency, and demand, which is then dependent on the utilizations of energy by various sectors (Limmeechokchai et al., 2023). Pongthanaisawan et al. (2023) illustrates this relationship through the analysis of the energy sector, and the role changes in energy demand from the transport, residential/commercial and agriculture sector would have on power generation for consumption. As a result, to navigate the carbon neutrality goals in the power

sector, the energy consumption pathways have to be reviewed, and their role and impact on the power generation and consumption process redefined. Thailand has identified these sectors, residential (and commercial), transport, and agriculture, and developed incentives that help with reduction of carbon emissions by changing the type of energy consumed across these sectors. The country's model of climate change mitigation shifts the focus to power generation, consumption and energy efficiency systems as seen through the TIEB.

One way Thailand can achieve carbon neutrality, especially in the residential and commercial sector, is by investing in the prosumer market, which has a promising future. According to (Pongthanaisawan et al., 2023), rooftop solar panels and energy storage have attracted investors due to falling production costs and advanced technology associated with them, providing ground for affordable power generation and consumption. As such, Pongthanaisawan et al. (2023) further notes that Thailand has established solar power installation-related incentives to encourage people to invest in the prosumer market. The incentives were in the form of feed-in-tariffs, which are policies developed to boost development of renewable energy sources, through provision of guaranteed, above-market prices for the producers (Tongsopit, 2015). The government first developed the tariffs in 2007 and retained them till 2013, which helped increase the power production and consumption with a generation capacity of about 782MW by the end of 2013 (Tongsopit, 2015; Tongsopit et al., 2019). While the government promoted self-production and self-consumption of power as an economically viable venture (with high rates of return), the greater incentive was to shift as many people to renewable energy sources in one of the sectors with high consumption (residential) resulting in reduced power generation requirements, and hence lower carbon emissions from reduced generation using carbon emitting sources (Tongsopit et al., 2019). Besides the policies, the country is running pilot projects to encourage power purchases and sales among consumers in both private and public sectors (Kokchang et al., 2020). Between 2007 when the policies first began and 2020, solar power systems has grown from 1.6MWp to almost 4000MWp (Department of Alternative Energy Development and Efficiency, 2020). Further, between 2014 and 2020, Thailand recorded a 543% growth in distributed solar power systems (Tongsopit et al., 2024). These documented growth of solar power installation and consumption, demonstrate a significant growth over the decade, and illustrate potential for tremendous growth of Thailand's prosumer market in coming years, further driving the carbon neutrality goals.

Thailand's government has also set a clear target of promoting electric vehicles for the transport sector, to realize carbon neutrality by 2050. Pongthanaisawan et al. (2020) report that the electric vehicle market is expected to grow in the next five years, and all vehicles on the road are expected to be electric from 2035. However, the author points out that the switch to all-electric vehicles could take longer than expected since vehicles in Thailand usually have a lengthy lifespan. Another pathway to carbon neutrality in Thailand is through biomass and waste-to-energy strategy. Jusakulvijit et al. (2021) report that 40% of the total population in Thailand works in the agricultural sector, and 46.5% of the country's area is farmland, which presents a high potential for bioenergy. Although biomass and waste-to-energy have only been explored in the residential sector and Thailand is yet to consider them for power generation and

industrial sectors, Peerapong and Limmeechokchai (2016) highlight that biomass and waste-to-energy are likely to present Thailand with high electricity efficiency (about 40% each), while also leading to reduced carbon dioxide emissions from electricity generation, further driving the path to carbon neutrality.

Additionally, hydrogen has emerged as a potential renewable energy source for the future, due to its ability to generate high energy while burning cleanly (Reda et al., 2024). As a result, various countries have considered the benefits of using Hydrogen, especially in the transport and industry sectors, to replace the use of gasoline, natural gas and other traditional fuels as a source of energy for these sectors (Reda et al., 2024). Thailand is no exception, and set a target for use of hydrogen over oil imports in the transport sector since 2017 at 100,000kg (Deloitte, 2023). While the benefits are evident, the associated high costs in large scale where the production cost of hydrogen is very high, have led to hydrogen not being used as an energy source in the country (El-Emam & Özcan, 2019; Reda et al., 2024). Nevertheless, it is a path that Thailand is considering come 2030, as a part of their journey to carbon neutrality by 2050, and has potential to further reduce the number of carbon emissions through reduction of power generation needs especially from natural gas, which the country largely depends on (Deloitte, 2023).

4.1.2 Challenges to Thailand's journey to carbon neutrality

Despite Thailand's extensive efforts towards achieving carbon neutrality, the country still faces some challenges and limitations. According to ONEP (2022b), a recurring challenge in achieving this carbon neutrality is the financial costs to fund their mitigation strategies. Thailand is a developing country, which places it in a challenging position in terms of affording the necessary tools to successfully meet its goals in relation to the successful implementation of the strategies. For instance, there is a lot more cost associated with the technology and infrastructure necessary for the development of nuclear plants or setting up the financial institutions to successfully coordinate the use of the resources already available to them (ONEP, 2022b). Exploring renewable energy resources is expensive, especially when done by a developing country (Chaichaloempreecha et al., 2017; Srithiam et al., 2015). This exposes Thailand as a country to potential challenges in achieving the eventual goal, largely because there is a limit to the options the country can explore when they do not have funds to explore them. This also limits the country's reach as it lacks infrastructure and technology advanced enough to meet the needs it envisions in the project (Chaichaloempreecha et al., 2017; Srithiam et al., 2015). While the country has launched several tax incentives, tariffs and investment grants to increase the potential investors in these developments, the country is still a long way to go (ONEP, 2022b; Vivatpinyo & Pharino, 2019). New investors would shift the outcomes of the above efforts.

Another challenge, as identified by the country's energy sector experts, is the lack of success stories in climate mitigation to serve as pilot guidelines in the development of renewable energy sources on a national scale as Thailand intends (ONEP, 2022b; Vivatpinyo & Pharino, 2019). Unlike other countries, Thailand emits less than 1% of global GHG emissions, which also means the country is focused on mitigation, while other countries such

as the US, China, India, and Russia invest in managing climate change are largely focused on practices such as carbon capturing and carbon sequestration as they have quite high GHG emissions both for their country, and as per their global contributions (Crippa et al., 2023). As a result, Thailand is left exposed in regards to the carbon neutrality journey, where they are working on solutions while the other countries are working on control mechanisms. The US for instance, which contributes about 11% of the total GHG emissions globally, is focused on reduction of carbon emissions in the power sector using carbon capture method, and exploration of technologies that can enable the country to retrofit their power system with carbon-pollution free electrical systems (UNFCC, 2021). While the US strategy could work, it requires a huge capital, and access to infrastructure through funding, which Thailand lacks. This means that unless funded, Thailand does not have the capacity to explore such processes, and have no buffer to check whether their own strategies have/could work before investing in them, thus, the country has to be on the frontline in seeking solutions (Srithiam et al., 2015; Vivatpinyo & Pharino, 2019). On a global scale, ONEP (2022b) states that the UNFCCC has to take charge and work on developing solutions to this barrier; otherwise, it risks exposing developing countries to inadequacies as compared to the developed ones in implementing the agreed-upon solutions.

Thailand's goals are ambitious, and this is reflected in the country's goal to increase renewable generated to 20% of total generated energy, with 37% of the total power capacity being renewable energy. The achievement of this goal is founded on the policies the country has in place working, which would then materialize in reduced carbon emissions, and eventual carbon neutrality. However, the success of these strategies, beyond the lack of funding and direction as the approaches are based on Thailand's need to take change, require a lot of cooperation from the country's population, private and public sectors. The covered mitigation policies above reflect this, with the NAMA policies, the Climate change master plan, and the TIEB all reflecting that more than one sector is central to the carbon neutrality journey, and that shifting the power generation sources will not resolve the challenge. As such, beyond the individual strategies, cooperation is a necessity that Thailand and the many sectors need to explore to achieve carbon neutrality goals, else the efforts in the power sector will not reflect in the carbon footprint. As Limmeechokchai et al. (2023) posits, Thailand's strategy to decarbonize the country by 2050 is ambitious but achievable, based on the level of cooperation the country is able to master.

5. Conclusions and Recommendations

5.1 Conclusions

Thailand's power sector has set ambitious yet achievable goals to reduce greenhouse gas emissions by 30% by 2030, achieve carbon neutrality by 2050, and reach net-zero emissions by 2060. The government has developed a range of strategic plans and policies, such as the Power Development Plan (PDP), Alternative Energy Development Plan (AEDP), and Energy Efficiency Plan (EEP), to support this transition. These efforts reflect a strong commitment to decarbonization, although challenges remain due to Thailand's developing status and limited access to global pilot models or advanced technologies. The power sector's transformation is

deeply connected to energy consumption patterns across the transport, industrial, residential, and agricultural sectors. Therefore, a whole-of-society approach is essential, with active engagement across sectors and stakeholders. The review highlights the need for stronger governance, intersectoral cooperation, and international support to overcome financial and institutional barriers. Further research and targeted investment are vital to ensure Thailand successfully navigates its complex path toward a low-carbon future.

5.2 Recommendations

Thailand's commitment to carbon neutrality by 2050 is evident through its sectoral mitigation plans and policies, yet effective implementation requires stronger coordination. A key recommendation is the establishment of a Centralized Energy Transition Authority to manage and streamline efforts under the Thailand Integrated Energy Blueprint (TIEB), reducing policy fragmentation and improving inter-agency coherence. Public participation is currently lacking, and thus the development of a robust public engagement strategy is crucial to build trust, encourage behavioral change, and foster inclusive climate action. To overcome financial constraints, Thailand must mobilize green financing through instruments like green bonds, climate funds, and incentives for renewable energy developers and prosumers. Investment in technological innovation and infrastructure, such as smart grids, hydrogen technologies, and energy storage, is essential to meet future demands sustainably. Moreover, cross-sectoral policy integration is vital to embed climate goals into broader national planning and ensure holistic progress. Finally, capacity building and workforce development must be prioritized to equip stakeholders with the skills needed for managing the transition to a low-carbon economy.

References

Altaf, M. (2022). Pooling Regional Energy between China, Iran, Pakistan, Turkey, and Russia. Policy Perspectives, 19(1), 35–64.

Altaf, M., & Bonnet, S. (2025). Navigating Barriers: A Stakeholder Analysis of China-Pakistan Economic Corridor (CPEC) Energy Projects Implementation. GMSARN International Journal, 19, 609–620.

Benjamin, L., & Wirth, D. A. (2021). From Marrakesh to Glasgow: Looking backward to move forward on emissions trading. *Climate Law, 11*(3-4), 245-264.

Buaban, S., Nitivattananon, V., Shrestha, S., & Szabo, S. (2021). Exploring the Factors Associated with Climate-Related Issues in a Special Economic Development Zone: Application of a DPSIR Framework. *International journal of sustainable development and planning, 16*(8), 1529-1540. https://doi.org/10.18280/ijsdp.160814

Chaichaloempreecha, A., Chunark, P., Hanaoka, T., & Limmeechokchai, B. (2022). Thailand's mid-century greenhouse gas emission pathways to achieve the 2 degrees Celsius target. *Energy, Sustainability and Society, 12*(1), 1-20. https://doi.org/10.1186/s13705-022-00349-1

Chaichaloempreecha, A., Winyuchakrit, P., & Limmeechokchai, B. (2017). Assessment of renewable energy and energy efficiency plans in Thailand's industrial sector. *Energy procedia, 138*, 841-846. https://doi.org/10.1016/j.egypro.2017.10.105

Chemhengcharoen, S., Bonnet, S., & Puhl, I. (2014). A Review of Energy Efficiency Policy Development and Challenges for Implementation in Thailand. Journal of Sustainable Energy & Environment, 5, 127–130.

Chunark, P., Limmeechokchai, B., Fujimori, S., & Masui, T. (2017). Renewable energy achievements in CO2 mitigation in Thailand's NDCs. *Renewable Energy: Part B, 114*, 1294-1305. https://doi.org/10.1016/j.renene.2017.08.017

Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., E., S., Becker, W., Monforti-Ferrario, F., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Brandao De Melo, J., Oom, D., Branco, A., San-Miguel, J., & Vignati, E. (2023). GHG emissions of all world countries. *Publications Office of the European Union*. https://edgar.jrc.ec.europa.eu/report_2023#intro

Deloitte. (2023). Hydrogen market research in Malaysia and Thailand. *Deloitte Consulting Southeast Asia, November 2023*. https://www.nedo.go.jp/content/100974275.pdf

Department of Alternative Energy Development and Efficiency. (2020). Thailand PV Status report 2020. https://pvgis.kmutt.ac.th/pvstatus2020/downloads/PV_status_report_2020_Eng.pdf

Electricity Generating Authority of Thailand (EGAT). (2020). Power for Thai Happiness. https://www.egat.co.th/home/en/wp-content/uploads/2022/03/0211.pdf

El-Emam, R. S., & Özcan, H. (2019). Comprehensive review on the techno-economics of sustainable large-scale clean hydrogen production. *Journal of Cleaner Production, 220*, 593-609. https://doi.org/10.1016/j.jclepro.2019.01.309

Fang, X., Ravishankara, A. R., Velders, G. J. M., Molina, M. J., Su, S., Zhang, J., Hu, J., & Prinn, R. G. (2018). Changes in Emissions of Ozone-Depleting Substances from China Due to Implementation of the Montreal Protocol. *Environmental science & technology, 52*(19), 11359-11366. https://doi.org/10.1021/acs.est.8b01280 https://doi.org/10.13169/polipers.19.1.0035

International Energy Agency. (2023). Thailand's Clean Electricity Transition. https://www.iea.org/reports/thailands-clean-electricity-transition

IRENA. (2017). Renewable energy outlook: Thailand. In. International Renewable Energy Agency. https://www.irena.org/-/media/files/irena/agency/publication/2017/nov/irena_outlook_thailand_2017.pdf

Jusakulvijit, P., Bezama, A., & Thrän, D. (2021). The Availability and Assessment of Potential Agricultural Residues for the Regional Development of Second-Generation Bioethanol in Thailand. *Waste and Biomass Valorization, 12*(11), 6091-6118. https://doi.org/10.1007/s12649-021-01424-y

Kokchang, P., Junlakarn, S., & Audomvongseree, K. (2020). Business model and market designs for solar prosumer on peer to peer energy trading in Thailand. *IOP conference series. Earth and environmental science, 463*(1), 12127. https://doi.org/10.1088/1755-1315/463/1/012127

KPMG. (2020). Shifting to alternative energy. In *The energy transformation*. https://assets.kpmg.com/content/dam/kpmg/th/pdf/2020/01/th-shifting-to-alternative-energy.pdf

Kumar, S. (2016). Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand. *Applied energy*, *163*, 63-70. https://doi.org/10.1016/j.apenergy.2015.11.019

Limmeechokchai, B., Lorm, R., & Thampanishvong, K. (2023). Thailand Power Sector Modelling. *Thailand Development Research Institute* https://files.unsdsn.org/Final%20AGF-TH%202.1%20report%20(2023).pdf

Ministry of Energy. (2018). Energy conservation plan 2015–2036 (Energy Efficiency Plan; EEP 2015). In. Department of Alternative Energy Development and Efficiency, Ministry of Energy (TH). https://policy.asiapacificenergy.org/sites/default/files/Energy%20Efficiency%20Plan%202015-2036%20%28EEP%202015%29%28TH%29.pdf

Ministry of Energy. (2020a). Renewable and alternative energy development plan 2018-2037. In. Department of Alternative Energy Development and Energy Efficiency https://climate-laws.org/documents/alternative-energy-development-plan-2018-2037_0167?id=alternative-energy-development-plan-2018-2037_c79f

Ministry of Energy. (2020b). Thailand's electric power development plan 2018-2037. In. Energy Policy and Planning Office. https://policy.asiapacificenergy.org/sites/default/files/Thailand%E2%80%99s%20Power%20Development%20Plan%20%28PDP%29%20%282018%E2%80%932037%29%20%28TH%29.pdf

Ministry of Natural Resources and Environment. (2021). Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy. *Submitted under the Paris Agreement*. https://unfccc.int/sites/default/files/resource/Thailand_LTS1.pdf

Misila, P., Winyuchakrit, P., & Limmeechokchai, B. (2020). Thailand's long-term GHG emission reduction in 2050: the achievement of renewable energy and energy efficiency beyond the NDC. *Heliyon*, *6*(12). https://doi.org/10.1016/j.heliyon.2020.e05720

ONEP. (2015). Climate Change Master Plan 2015-2050. In National Committee on Climate Change (Ed.). https://faolex.fao.org/docs/pdf/tha203759.pdf

ONEP. (2017). Second Biennial Update Report of Thailand. In UNFCC (Ed.). Office of Natural Resources and Environmental Policy and Planning Bangkok. https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/347251_Thailand-BUR2-1-SBUR%20THAILAND.pdf

ONEP. (2020a). *Thailand's Updated Nationally Determined Contributions (NDCs)*. United Nations Framework Convention on Climate Change. https://unfccc.int/documents/497980

ONEP. (2020b). Thailand third biennial update report. In. Office of Natural Resources and Environmental Policy and Planning Bangkok. https://unfccc.int/sites/default/files/resource/BUR3_Thailand_251220%20.pdf

ONEP. (2022a). Thailand fourth biennial update report. In. Office of Natural Resources and Environmental Policy and Planning Bangkok. https://unfccc.int/sites/default/files/resource/Thailand_BUR4_final_28122022.pdf

ONEP. (2022b). *Thailand's 2nd Updated Nationally determined contributions (NDCs)*. United Nations Framework Convention on Climate Change.

https://unfccc.int/sites/default/files/NDC/2022-11/Thailand%202nd%20Updated%20NDC.pdf

Peerapong, P., & Limmeechokchai, B. (2016). Waste to electricity generation in Thailand: Technology, policy, generation cost, and incentives of investment. *Engineering Journal*, *20*(4), 171-177. https://doi.org/10.4186/ej.2016.20.4.171

Pita, P., Winyuchakrit, P., & Limmeechokchai, B. (2020). Analysis of factors affecting energy consumption and CO2 emissions in Thailand's road passenger transport. *Heliyon*, *6*(10), e05112-e05112. https://doi.org/10.1016/j.heliyon.2020.e05112

Pongthanaisawan, J., Wangjiraniran, W., & Nakapreecha, N. (2023). Thailand Energy Scenarios: Pathways towards Carbon Neutrality 2050. *International Journal of Energy Economics and Policy*, *13*(1), 489-500. https://doi.org/10.32479/ijeep.13884

Porter, K. M. P., Rutkow, L., & McGinty, E. E. (2018). The Importance of Policy Change for Addressing Public Health Problems. *Public Health Reports (1974)*, *133*(1S), 9S-14S. https://doi.org/10.1177/0033354918788880

Puree, S., & Praiphol, K. (2017). *Energy transition in Thailand: Challenges and opportunities*. Friedrich-Ebert-Stiftung Thailand Office. https://library.fes.de/pdf-files/bueros/thailand/13888.pdf

Reda, B., Elzamar, A. A., AlFazzani, S., & Ezzat, S. M. (2024). Green hydrogen as a source of renewable energy: a step towards sustainability, an overview. *Environment, development and sustainability*. https://doi.org/10.1007/s10668-024-04892-z

Srithiam, W., Asadamonkol, S., & Sumranwanich, T. (2015). Smart Grid National Pilot Project in Mae Hong Son Province, Thailand. *Energy & environment (Essex, England)*, *26*(1-2), 23-34. https://doi.org/10.1260/0958-305X.26.1-2.23

Tongsopit, S. (2015). Thailand's feed-in tariff for residential rooftop solar PV systems: Progress so far. *Energy for sustainable development*, *29*, 127-134. https://doi.org/10.1016/j.esd.2015.10.012

Tongsopit, S., Junlakarn, S., Chaianong, A., Overland, I., & Vakulchuk, R. (2024). Prosumer solar power and energy storage forecasting in countries with limited data: The case of Thailand. *Heliyon*, *10*(2), e23997-e23997. https://doi.org/10.1016/j.heliyon.2024.e23997

Tongsopit, S., Junlakarn, S., Wibulpolprasert, W., Chaianong, A., Kokchang, P., & Hoang, N. V. (2019). The economics of solar PV self-consumption in Thailand. *Renewable energy*, *138*, 395-408. https://doi.org/10.1016/j.renene.2019.01.087

UNEP. (2012). Montreal Protocol on substances that deplete the ozone layer 2012: a success in the making In *25 years Montreal Protocol* https://ozone.unep.org/sites/default/files/Success_in_the_making_2012.pdf

UNFCC. (2021). The United States of America Nationally Determined Contribution. https://unfccc.int/sites/default/files/NDC/2022-06/United%20States%20NDC%20April%2021%202021%20Final.pdf

Vivatpinyo, A., & Pharino, C. (2019). Challenges of Energy Efficiency Promoting Policy in Thailand. *IOP conference series. Earth and environmental science*, *268*(1), 12070. https://doi.org/10.1088/1755-1315/268/1/012070

World Health Organization (WHO). (2023). Climate change. In *Factsheet*. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

Zhang, K., Bokka, H. K., & Lau, H. C. (2022). Decarbonizing the energy and industry sectors in Thailand by carbon capture and storage. *Journal of Petroleum Science and Engineering, 209*. https://doi.org/10.1016/j.petrol.2021.109979