ENERGY TRANSITION IN THE THAI INDUSTRIAL SECTOR

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Abstract

Thailand declared its target to achieve carbon neutrality by 2050 and net-zero emissions by 2065. The success of the energy transition, shifting away from the use of fossil fuels towards more renewables and low-carbon sources of energy, of the industrial sector will contribute significantly to Thailand's pathways to achieve climate goals and national priorities. This paper examines the current landscape and drivers for the energy transition of the industrial sector, including pathways for industrial decarbonization from global and international experiences. The findings suggest that availability of clean electricity is the backbone of the energy transition in the industrial sector, supporting the industrial sector in reducing emissions, alleviating risks of high energy costs from vulnerable fossil fuel prices, ensuring the industry competitiveness and enabling deeper decarbonization in the industrial sector. Carbon capture technologies and green hydrogen should be needed in the medium and long term, rather than in the short term. Thailand needs a supportive net-zero regulatory and policy framework as well as a just transition plan for the industrial sector.

About this publication

This publication presents analysis of current landscape and drivers for energy transition in the Thai industrial sector, including suggestions on pathways and key measures based on global and international experience. The industrial sector is the largest sector consuming final energy consumption in Thailand and consumes the highest electricity compared to other sectors. The energy transition in the industrial sector is therefore crucial for Thailand's pathways to achieve carbon neutrality and net-zero emissions goals. Furthermore, the energy transition in the Thai industrial sector will have significant impacts on the economies, employment, and competitiveness of the country, including social and sustainable development objectives. This publication also aims to advocate the cost-effective and efficient pathways for the energy transition as well as fostering dialogues on this topic.

About the authors

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Previously, Supawan has worked for USAID Clean Power Asia program for three and a half years, managing projects to advise the Government of Southeast Asian countries on renewable energy policies with studies on the economic and technical impacts of distributed PV, disruptive technologies in the power sector and renewable energy auctions. She also worked as a researcher for the study on a peer-to-peer electricity trading project funded by Thailand's Office of the Energy Regulatory Commission. Prior to joining USAID Clean Power Asia, she gained research experience with international organizations on energy and climate mitigation policies, and has several years' experience at PwC Thailand assisting the public and private sector on feasibility studies, valuation, and high-level market analysis.

She holds a PhD in Economics from the National Institute of Development Administration, Thailand and a MSc in Project Analysis, Finance and Investment from the University of York, United Kingdom.under the National Environmental Board. Sujitra holds a doctorate and master's degree in environmental economics from Hiroshima University, Japan. She completed her Bachelor in Political Science (International Relations) from Chulalongkorn University.

1 I INTRODUCTION

Thailand declared its target to achieve carbon neutrality by 2050 and net-zero emissions by 2065 to the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Climate Change Conference (COP26) in November 2021. Aligning with these international commitments on climate goals, Thailand has also put several policy goals and measures related to the energy transition as national priorities in its National Economic and Social Development Plan (the 13th NESDP) and Thailand's Development Action Plan using the bio-circular-green (BCG) model 2021-2027.

Following climate commitments, the coming New Energy Plan (NEP), expected to be officially enforced in 2024, will shape the energy transition with policy directions and targets set for the energy sector. Key targets include the power sector generation mix in the Power Development Plan (PDP), the shares of renewable energy in the electricity and heat sectors in Alternative Energy and Development Plan (AEDP), and the energy intensity target in the Energy Efficiency plan (EEP). These targets will shape policy incentives and regulations for the energy sector, including the energy consumption in the industrial sector, from the year 2024 to 2037.

In addition to policies, the following international trade, business practice and finance directions could put pressures on domestic industries:

- Impacts of the Europe's Carbon Border Adjustment Mechanism (EU-CBAM) and similarly the US-CBAM under the U.S. Clean Competition Act on several industrial sectors such as steel, aluminum, and cement.
- The increasing adoption of Environment, Social and Governance (ESG) principles in business practice.
- The influence of remarkable growth of the RE100 network (the global corporate renewable energy initiative gathering corporate businesses that committed to a 100% clean electricity) on domestic firms in the supply chain to align with the parent companies' goals such as a target to use 100% clean electricity

These market forces will incentivize the industrial players to change their energy consumption towards more renewables, clean electricity, and low-carbon technologies to remain competitiveness and gain access to a large pool of green finance.

International and national drivers will lead to another evolution[1] of the industrial sector towards a green industrialization era and shape the directions and incentives for the energy transition in the industrial sector in the next 30 years.

Energy transition in the industrial sector will play a key role for Thailand to achieve the carbon neutrality and net-zero emissions goals. Currently, the industrial sector is the largest sector contributing to about 39% of final energy consumption and accounts for 45% of electricity consumption in Thailand in 2022.

The success of the energy transition (e.g., shifting away from the use of fossil fuels towards more renewables and low-carbon sources of energy) of the industrial sector will contribute significantly to Thailand's pathways to achieve climate goals and national priorities. Furthermore, the energy transition in the Thai industrial sector will have significant impacts on the economies, employment, and competitiveness of the country, including social and sustainable development objectives.

In addition to providing an overview of the current energy consumption in Thailand, this paper aims to identify drivers for the energy transition in the Thai industrial sector, including suggestions on pathways and key measures for the energy transition.

1. The first industrial revolution, began in the 18th century, started with the use of stream power and mechanical production. Currently, we has been in the Industry 4.0 era since the 20th century and now is entering the Industry 5.0 with the new focus on human-centric approach co-work with robots and sustainability, including bio-economy and renewable resources.

The findings of this paper aim to answer the following key questions to support energy transition in the Thai industrial sector:

- What is the current landscape of energy consumption in the industrial sector?
- What drives energy transition in the Thai industrial sector?
- What could be pathways for energy transition in the industrial sector from global and international perspectives?
- What could be pathways and key measures for the energy transition in the Thai industrial sector?

Section 2 provides the landscape of energy consumption in the Thai industrial sector by fuel sources and sub sectors. Section 3 identifies drivers for the energy transition in the Thai industrial sector.

Based on a range of recently published international scenarios and reports, Section 4 presents pathways for the industrial sector from global and international perspectives.

Section 5 summarizes the framework of key measures for energy transition in the Thai industrial sector and the conclusion and policy suggestions are provided in Section 6.

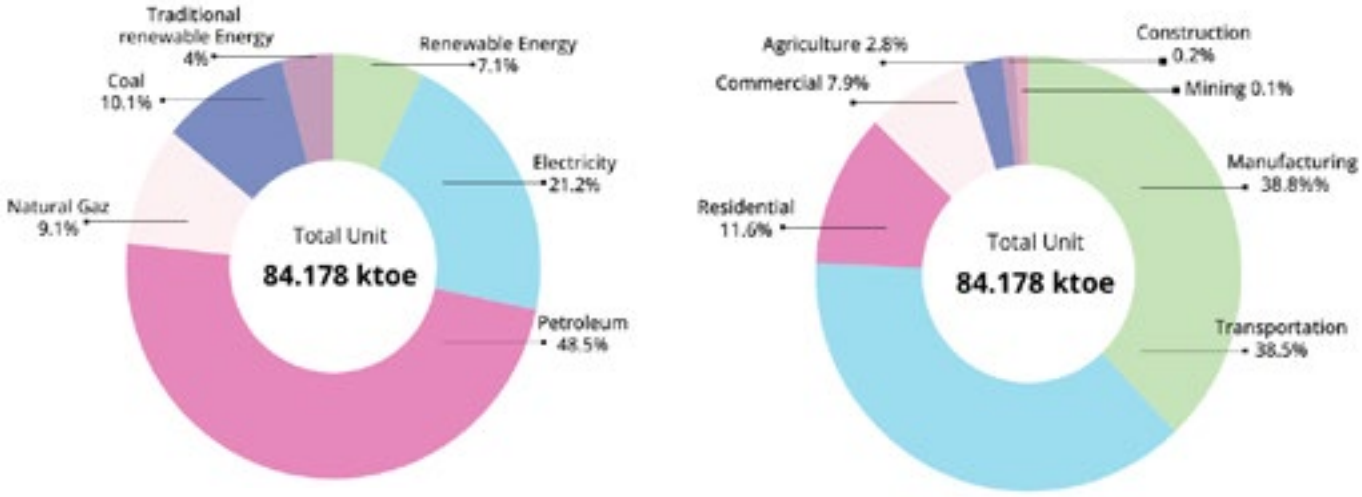
2 I CURRENT LANDSCAPE OF ENERGY CONSUMPTION IN THE THAI INDUSTRIAL SECTOR

The industrial sector is the largest sector consuming final energy consumption in Thailand and use almost all final coal, natural gas and renewable energy consumption.

Figure 2.1 shows the share of final energy consumption by sector and by fuel type. In 2022, the industry or manufacturing sector consumed 32,703 kilotons of oil equivalent (ktoe) or a 39% share, followed by transportation (38%) and residential (12%). Industry consumes all final energy consumption of coal (14,206 thousand tons), solid biomass (23,234 thousand tons) and biogas (1,289 million cubic meters). About 86% share or 279,974 million standard cubic feet (mmscf) of natural gas final consumption was used for the industrial sector.

Furthermore, the industrial sector consumes the largest share of electricity consumption in gigawatt hours (GWh) in Thailand, accounting for 45% of all electricity consumption, followed by the residential (27%) and business (24%) sectors in 2022 (EPPO, 2023).

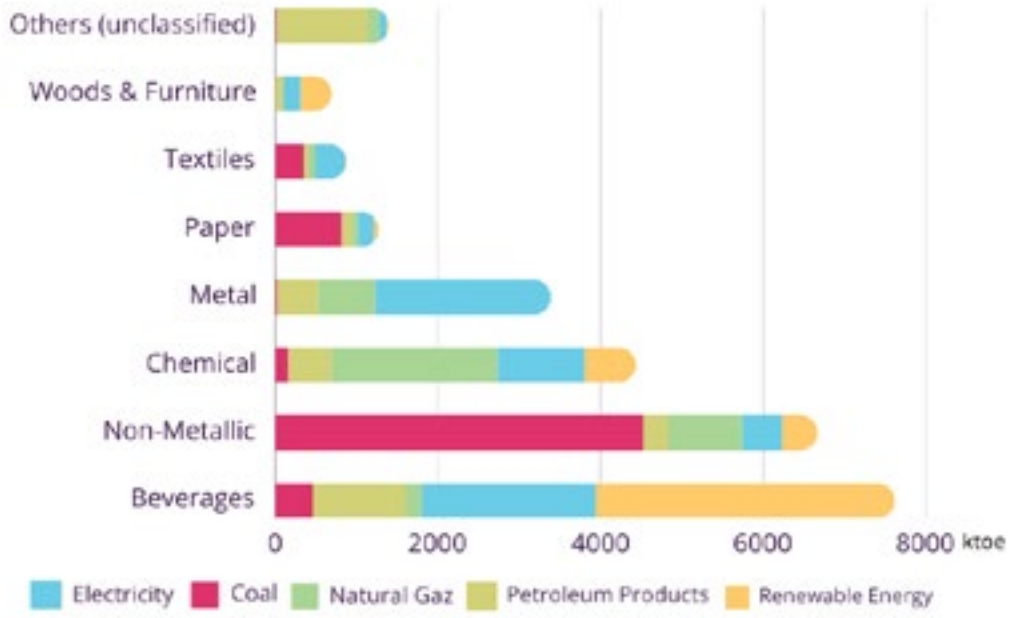
Figure 2.1 Share of final energy consumption in Thailand by sector and fuel type in 2022



Source: (DEDE, 2023)

Note: 1) Data were taken from Department of Alternative Energy Development and Efficiency (DEDE) 2) Renewable energy includes wind, solar, biomass and biogas while traditional renewable energy includes fuel wood, charcoal, paddy husk and agricultural waste.

Figure 2.2 Final energy consumption in key manufacturing sectors in 2021



Source: Author illustration (DEDE, 2022)

Figure 2.3 Share of final energy consumption by type in key manufacturing sectors in 2021

Source: Author illustration (DEDE, 2022)

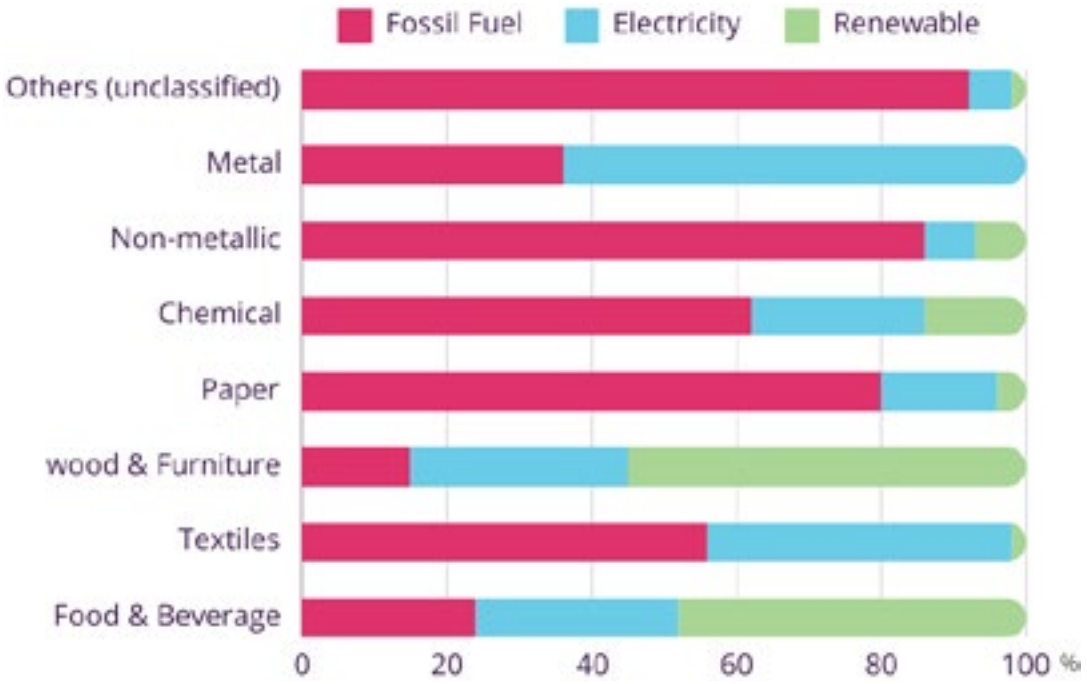


Table 2.1 Renewable energy share by key energy consumption type in 2022

Consumption type	Total Consumption	Renewable Energy Consumption	Renewable Energy Share
Final energy consumption (ktoe)	84,178	6,018	7.1%
Electricity installed capacity (MW)	57,380	12,659	22.1%
Electricity consumption (GWh)	215,838	21,876	10.1%
Heat consumption in manufacturing (ktoe)	32,704	6,018	18.4%

Source: Author illustration (DEDE, 2022)

Note: Data were taken from DEDE and Energy Planning and Policy Office (EPPO)

Final energy consumption in key manufacturing sectors

Non-metallic (e.g., cement, glass, ceramic, etc.), chemical, food and beverage sectors consume the largest amount of fossil fuels (i.e., coal, petroleum products and natural gas) in the industrial sector, totalled 70% of fossil fuels consumed in the industrial sector, followed by metal and paper sectors (see Figure 2.2). The electricity consumption is the highest among metal, food and beverage and chemical sectors, while renewable energy is used mostly in the food and beverage sector.

Looking at the current share of final energy consumption by type in each sector (see Figure 2.3), the share of fossil fuels consumed in non-metallic and paper sectors is more than 80%. Interestingly, the share of fossil fuel consumption in other unclassified sectors exceeds 90%, indicating the need to support cross-sectoral energy transition efforts. Metal industry uses electricity as the largest share of final consumption (64%). Food and beverage and wood and furniture sectors have high share of renewable energy consumption, 48% and 55%, respectively. Meanwhile, most industrial sectors have lower than 5% renewable energy share in their final consumption. The energy transition towards higher renewable energy in most industrial sectors is therefore challenging and requires transformational changes in their production processes and the use of energy sources.

Current renewable energy contribution

Overall, renewable energy currently contributes to about 7.1% of final energy consumption (in ktoe) in Thailand. Table 2.1 summarizes renewable energy's contribution to final energy consumption.

Electricity generation from renewable sources accounts for only about 10%. About 70% of electricity in Thailand was generated from natural gas and coal (EPPO, 2023). This indicates that the use of electricity from the grid is still highly fossil-fuel intensive and could not be claimed as clean electricity in Thailand. The transformation of the electricity sector is therefore the key for energy transition in the industrial sector.

Almost all heat consumption in Thailand is consumed by the industrial sector and only about 18% of heat produced from renewable energy sources.

3 I DRIVERS FOR THE ENERGY TRANSITION IN THE THAI INDUSTRIAL SECTOR

Energy transition refers to the shift from using fossil fuels (i.e., coal oil and gas) to renewable or low-carbon fuels (e.g., wind, solar, hydropower, bioenergy, hydrogen, etc.). This includes the shift from burning fossil fuels to using renewable resources such as solar and wind to generate electricity.

The context of energy transition refers to both the direct use of renewables and the indirect use of renewables through electrification (e.g., using clean electricity to replace oil in transport sector or produce heat in the industrial sector).

This section summarizes several incentives and risks that are driving the energy transition in the Thai industrial sector.

3.1 Policy incentives

The government's commitment to achieve carbon neutrality by 2050 and net-zero emissions by 2065 at COP26 in November 2021 marked significant policy movements in Thailand towards the energy transition.

In particular, the Ministry of Energy is developing a National Energy Plan (NEP) 2024 for the period 2024-2037, that will align with carbon neutrality in 2050. The NEP is the new masterplan for the Thai energy sector that consists of five energy action plans: Power Development Plan (PDP), Alternative Energy Development Plan (AEDP), Energy Efficiency Plan (EEP), Oil Plan, and Gas Plan.

The Ministry of Energy is still in the process of preparing the NEP to align the energy plan with Thailand's carbon neutrality target. It is expected that the NEP will be finalized and officially announced in 2024.

However, the National Energy Policy Council (NEPC)[2] has already announced in 2022 the following policy directions under the NEP:

- Increase the use of renewable energy to at least 50% in 2050
- Promote the use of electric vehicles with the target to achieve a 30% share of the total new car production by 2030.
- Increase energy efficiency by 30% using technology and innovation to optimize energy efficiency management.
- Modify energy business structure to facilitate energy transition with 4D1E framework (Decarbonization, Digitalization, Decentralization, Deregulation, and Electrification)

The energy sector aims to reduce greenhouse gas (GHG) emissions by at least 82 million tCO2 by 2030 compared to a business-as-usual (BAU) case under Thailand's Nationally Determined Contribution (NDC) Sectoral Action Plan 2021-2030 (ONEP, 2023). The draft action plan on GHG emissions in the energy sector consists of three energy action plans:

- **AEDP** for the year 2015-2037 aims to increase the share of renewable energy sources to 30% of final energy consumption by 2037. The AEDP will set targets for renewable energy in the form of electricity, heat, and biofuels.
- **EEP** for the year 2018-2037 aims to reduce energy intensity by 30% by 2037 compared to 2010. The EE plan will set energy conservation targets for industry, business, residence, agriculture, and transport sectors.
- **PDP** for the year 2018-2037 set the plan for constructing new power plants with renewable energy sources and

2. NEPC, established under the National Energy Policy Council Act, B.E. 1992, is responsible for the cabinet approval of national energy policies, including recommendations, evaluations and setting the rules for the energy sector. Members of the NEPC include the Prime Minister and Ministers of various ministries. (NEPO, 1997)

phasing out fossil-fuel power plants. The PDP has four main guidelines: i) promote renewable power generation ii) allocate main power plants for regional energy security iii) purchase renewable energy annually under the renewable energy generation policy and at a price not exceeding Grid Parity iv) ensure quality and prices of energy conservation policy.

The NEP, including EE, AEDP and PDP, will provide directions for supporting policies and regulations in the energy sector towards the energy transition with increasing share of renewables in economic sectors.

In addition to the NEP, the **13th National Economic and Social Development Plan** (NESDP) for the year 2023-2027, a second-level plan that translates the National Strategy into implementation, will be used as a framework for a 5-year plan under the third-level action plans by ministries. The related targets set under the NESDP (NESDC, 2023) include:

- Ensuring the transition of production and consumption towards sustainability: No less than 20% of overall GHG emission reductions (i.e., from energy, transport, industry, and waste management) by 2027 from BAU level
- Enhancing Thailand's ability to cope with changes and risks under the new global context: no less than 24% of renewable energy share in the final energy consumption by 2027
- Transforming the automobile industry into an electric vehicle industry throughout the supply chain along with the targets of achieving new registration of 282,240 zero-emission vehicles (ZEVs), including battery-powered EVs (BEVs) and fuel-cell EVs (FCEVs), accounting for 26% of all vehicles by 2027

Furthermore, related strategies under the NESDP milestone on Thailand's circular economy and low-carbon society that may drive government support to the energy transition in the industrial sector are summarized in Table 3.1

Strategies	Details
a. Develop industries and services based on the circular economy and a low-carbon society	Increase efficiency in product manufacturing and services, develop mechanisms to increase efficiency in the circular use of materials, promote green financial measures and investments as well as sustainability reporting standards and investments in eco-friendly economic activities
b. Research and develop databases for carbon trade	Include data on measurements of carbon emissions from manufacturing and services. Facilitate carbon trade for both emitters and capturers
c. Promote business transition to the circular economy and a low-carbon society	Include advanced technologies, innovations, mechanisms, and platform to support business and local knowledge to increase resource efficiency
d. Promote carbon capture, utilization, and storage technology	Include capturing carbon dioxide from the energy and industrial sectors and promoting infrastructure for carbon storage and transport.
e. Revising laws to facilitate the circular economy and reduction of GHG emissions in all sectors	Implement financial and fiscal measures to raise the standards of manufacturing processes to reduce pollution and increase resource efficiency.
f. Advocate for alternative energy and energy-saving innovation for households	Promote affordable energy-saving innovations, raising awareness on efficient energy consumption and long-term cost reductions.
g. Promote eco-friendly transportation	Include the use of mass transit systems, the development of eco-friendly public transport networks with low carbon emissions and the use of efficient clean-energy vehicles.

Source: (NESDC, 2023)

These strategies will be implemented through various ministries' action plans that direct policy incentives and government budget to support the energy transition activities in economic sectors, including the industrial sector.

Bio-Circular-Green Economy Model (BCG) is one of the four principles adopted in providing the directions of the 13th NESDP. As endorsed by the cabinet in February 2022, the **BCG Action Plan for the year 2021-2027** (NSTDA, 2022) set four main goals related to sustainable economic growth, social equity, sustainability of resources and the environment and self-reliance, including the target to cut back 2005 GHG emissions by at least 20-25%. Related actions that may drive the energy transition for the industrial sector include:

- Increase market competitiveness of biobased products by removing legal barriers and introducing instruments such as carbon pricing and carbon credit
- Adopt green and sustainable manufacturing that minimizes waste and upgrade manufacturing process with advanced technologies.
- Support small and medium enterprises (SMEs) to employ biotechnology to add value to products and services, build innovation business and participate in the global value chain.
- Promote investment opportunity and market in the circular economy, including establishing platforms and infrastructure and supporting research, technology and innovation to create new goods and services from recycling and upcycling.
- Build a critical mass of experts and raise awareness of sustainable production and consumption.

The BCG action plan focuses on five strategic sectors, including energy, material and biochemicals sector. This sector has the target to achieve a 30% share of renewable energy consumption in final consumption by 2037, aligned with the target set in AEDP. Under the BCG agenda, Thailand aims to improve the competitiveness of key industries (including electric vehicle, digital economy, and clean energy) and to reduce resources use by 25% and 15 million tons of CO2 under circular economy policy (NXPO, 2022).

For the industrial sector's specific policies, there are two existing industrial plans, however; none of them have yet been updated to reflect the recent climate goals. In addition, new industries, and technologies for the energy transition such as electric vehicles and CCUS have not yet been included in these plans.

Existing industrial plans include a 20-year National industrial Development Master Plan (2012-2031) and Industrial Development Strategy 4.0 (2017-2037). The Ministry of Industry also initiated Thailand Green Industry Promotion and Development in 2011 to provide incentives such as annual fee waiving, green logo and green productivity loan to green organizations certified under the 5-level development of green industry criteria. However, this green industry certification has not yet proved to be effective in driving the energy transition.

Office of National Higher Education Science Research and Innovation Policy Council (NXPO), a national designated entity of the Climate Technology Centre and Network (CTCN) under the UNFCCC, has partnered with the Siam Cement Group to jointly develop Innovation Roadmap for Industrial Decarbonization for Thailand to serve as a blueprint for Thai industries to achieve carbon neutrality and net-zero emissions (NXPO, 2022). This will be the first industrial decarbonization roadmap for Thailand[3] that potentially drive the energy transition in the industrial sector.

In addition, Thailand is drafting its first Climate Change Act to regulate emissions and enhance climate resilience, expected to be launched in 2024.

These policies play significant roles in driving the industrial sector with policy incentives provided by the government to shift from using fossil fuels towards renewable and low-carbon fuel sources.

3 . The timeline for the official launch of the roadmap is unknown

3.2 Risks of higher energy prices from fossil fuel sources

Rising costs of fossil fuels and electricity price are pushing private sector towards the energy transition due to economic and cost incentives. In 2022, recent liquified natural gas (LNG) price crisis triggered by the Russian-Ukraine war has led to high electricity prices in Thailand (Praiwan, 2022). This was due to high reliance on imported LNG for power generation. In addition, the ongoing impacts of global geopolitics and wars are expected to lead to volatile LNG prices and put pressure on LNG supply, potentially leading to insecure supply of natural gas in Thailand that could also be further threatened by expected declining imports of gas resources from Myanmar.

In 2022, the deployment of solar rooftop for self-consumption by commercial and industrial end users was expected to grow by more than 50% driven by higher electricity price and lower investment cost (Kasikorn Research Center, 2022). In addition, the use of carbon pricing mechanisms to achieve climate goals internationally and locally are likely to further raise the prices of fossil fuels. Meanwhile, the prices of green and low-carbon fuel sources are likely to decline due to advanced technologies and policy support. These economic incentives will drive the private sector towards the shift to more renewable and low-carbon fuels.

3.3 Risks of higher costs from the impacts of CBAM

The Europe Carbon Border Adjustment Mechanism (EU-CBAM), effective since May 2023, aims to put a price on the carbon emitted during the production of carbon-intensive goods that are imported to the EU, initially covering imports of products from six sectors: cement, iron and steel, aluminum, fertilizers, electricity and hydrogen (European Commission, 2023). During the transition period (from 1 October 2023 to 31 December 2025), exporters in targeted sectors must report the volume of products imported to the EU, the amount of CO2 emitted, and carbon fees paid for emissions generated in the country of origin of imported goods).

The overall impact of EU-CBAM on Thai industries may not be high initially as the share of Thai exported goods to the EU is not as high as in the U.S., China or Japan, however, the impacts on Thai industries could be higher if EU-CBAM extends to cover other goods in the future such as petroleum, ceramics, glass, pulp and paper (Baker&Mckenzie, 2023). It is estimated that the impact of CBAM in Thailand could result in 0.2% reductions in GDP (NewClimate, 2023). EU-CBAM will put three industries at risk, plastics, steel and aluminum with export values of 676 million USD, 201 million USD, 111 million USD, respectively, in 2022 (OIE, 2023).

In addition, the U.S. has introduced the Clean Competition Act that also comprises a carbon border adjustment mechanism (US-CBAM) for imported products, expected to start in 2026 on targeted industries such as petrochemicals, fertilizer, cement, iron and steel, glass, pulp and paper, and ethanol. The iron and steel, petrochemical and aluminium industries as well as machinery and electronic equipment will be mostly affected due to the high share of exports to the U.S. (KResearchCenter, 2022).

CBAM will drive targeted industries towards the energy transition to reduce the costs of CBAM certificates. Also, industry players would call for government support to implement carbon pricing mechanisms in Thailand to avoid paying higher costs to buy CBAM certificates.

3.4 Private sector initiatives

Several private sector initiatives drive both international and Thai companies to set emission reduction targets that aligned with climate goals. Notable initiatives include RE100 (requires members to set a target for achieving 100% renewable electricity by 2050), **Science-based Targets Initiatives** (with more than 7,879 companies[4] taking actions in 2024 with science-based targets and net-zero commitments to achieve the 1.50C pathway, including Thai

4. Science based targets website

companies such as Electricity Generating Public Company Limited and Central Pattana Public Company Limited) and **Climate Action 100+** (a global investor coalition that aims to improve the climate performance of large emitters with strong corporate emissions reduction strategies) (ESCAP, 2023).

Large corporates in various industries that committed emission reduction targets or 100% renewable electricity targets under these initiatives have also put pressure on their subsidiaries and suppliers in various countries to move towards the energy transition. For example, the remarkable growth of the RE100 network in many countries indirectly affect Thai companies in the supply chain to align with the parent companies' goals such as a target to use 100% clean electricity.

Similarly, Thailand established several initiatives and network among the private sector, including the Thai RE100 Association and the Thailand Carbon Neutral Network. These networks will serve as key platforms for private sector to support each other and push for support from the government in implementing activities to reduce emissions.

Parent companies and subsidiaries participating in the RE100 network are demanding more renewable energy certificates to make reliable claims when they cannot solely rely on their own efforts to achieve 100% clean electricity. This drives the market growth of International Renewable Energy Certification ("I-REC"), issued by the Electricity Generating Authority of Thailand, which provides a reliable proof of renewable energy generation (Nagashima Ohno & Tsunematsu, 2023). The growth of demand for I-REC also drives the demand for renewable energy projects in Thailand.

3.5 Social incentives

The impacts on green job creations could provide social and economic incentives for the country to move towards the energy transition; however, concerns on the impacts of job losses (e.g., in fossil fuel extraction, existing fossil fuel power plants and the manufacturing of internal combustion engine vehicles) may slow the transition.

Analysis indicates a strong demand for green jobs with high skills in Thailand from job-seeking websites in 2022, especially the energy sector such as designing solar energy systems, carbon footprint management and energy modelling jobs, but Thailand lacks qualified workers for well-paying green job (Rattanakhamfu, 2023). So, the government needs to play roles to equip the Thai workforce with the necessary skills required for the growing green job market to drive the social benefit of the energy transition.

3.6 Financial incentives

The Environment, Social and Governance (ESG) practices have remarkedly emerged in Thailand, adopted by leading companies in the Thai capital market. Since 2022, the Stock Exchange of Thailand (SEC) has mandated listed companies in Thailand to disclose information about their ESG performance across their value chain in the so-called 'Form 56-1 One Report', including carbon emissions (Black, Sullivan, & Priovashini, 2022). The disclosure of ESG performances provide information for investors who are looking to invest in companies with sustainable business practices. In addition, the SEC promotes several sustainable financing instruments such as sustainable bonds and Sustainable and Responsible Investing Fund (SRI) fund (e.g., offering the application fee exemption incentives). Companies with ESG practices will obtain advantages in accessing these sustainable financing instruments.

In addition, the Bank of Thailand (BOT) issued a policy statement to internalize environmental and climate change aspects into financial institution business in February 2023, not on a mandatory basis but with the aim to support financial institutions in providing green financial products and services to support the transition towards more sustainable business environment (Nagashima Ohno & Tsunematsu, 2023).

In June 2023, the BOT published Thailand Taxonomy Phase I to provide guidelines for economic activities relating to the energy and transportation sectors (i.e., highest emission contribution sectors) that are climate-aligned (BOT, 2023). This

taxonomy is aimed to serve as a reference tool for policymakers and financial institutions to plan policies and strategies as well as green funding towards the climate mitigation measures and a sustainable environment.

Furthermore, there are several new fiscal incentives provided by the Government to promote the expansion of the EV industry in 2024, including government subsidies to increase the demand of EVs (e.g., subsidies range between 50,000 to 100,000 Baht per electric car with the price less than 2 million Baht or equipped with a battery of at least 50 kilowatt-hours) and support Thailand to be an EV manufacturing hub (e.g., a reduction in import duties of up to 40% for completely built up electric cars in 2024 and 2025 with the price not more than 2 million Baht) (Arunmas & Apisitniran, 2023)

4 I PATHWAYS FOR THE ENERGY TRANSITION IN THE INDUSTRIAL SECTOR FROM GLOBAL AND INTERNATIONAL PERSPECTIVES

4.1 Pathways in the IEA's world energy outlook 2023

Globally, the industrial sector is the largest energy consumer (38% of total final consumption) and emits the largest CO2 (47% of CO2 emissions including those from electricity and heat) in the end-use sector (IEA, 2023).
Energy-intensive industries (i.e., iron and steel, chemicals, non-metallic minerals, non-ferrous metals and paper) heavily use fossil fuels, contributing significant shares of coal (90%), oil (>70%) and natural gas (55%) demand in industry (IEA, 2023).

Meanwhile other non-energy-intensive or light industries (e.g., food and textiles) accounts for about 30% of demand in the industrial sector. These light industries need lower temperature in the production process and mainly use electricity (37%), natural gas (20%), oil (15%) and bioenergy (14%) in their energy mix.

According to International Energy Agency (IEA)'s Announced Pledges Scenario (IEA, 2023), the decarbonization pathways for energy used in the industrial sector include:

- **Coal:** The rise of secondary steel production mainly will reduce coal demand. In addition, electrification of light industries, hydrogen-based iron production and higher use of bioenergy will lower coal demand in the industrial sector, and about 20% of coal use will be equipped with CCUS in 2050.
- **Oil:** The oil demand in the industrial sector mostly comes from petrochemical industry. The demand measures such as the bans of single-use plastics will reduce oil demand by 2050.
- **Electricity:** Increased electrification becomes the key for decarbonizing the industrial sector, non-energy-intensive industries, particularly the electrification of process heat (e.g., heat pumps for lower temperature applications such as in food and machinery sectors and electric arc furnaces for high temperature such as in steel industry)

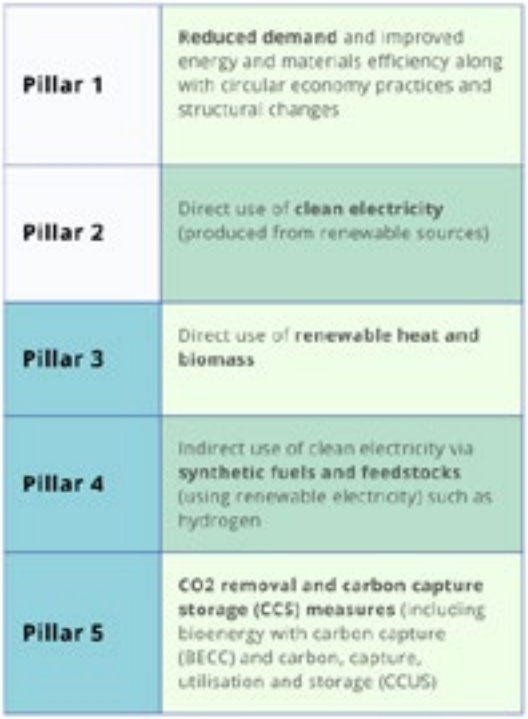
Key decarbonization pathways for the industrial sector include promoting material efficiency, increased electrification, increased sustainable bioenergy and the use of green hydrogen (produced using electrolyzes).

4.2 Pathways in the IRENA's World Energy Transitions outlook 2023

To meet the International Renewable Energy Agency (IRENA)'s 1.5oC scenario, estimated annual emissions need to decline from 34 one billion tonnes of CO2 (GtCO2) under the reference case to net-zero CO2 emissions by 2050 (IRENA, 2023). Aligning with the decarbonization pathways, CO2 emissions from the industrial sector is estimated to reduce the greatest by 12.7 GtCO2 from the reference case to meet the net-zero target. Figure 4.1 summarizes five pillars for decarbonation of the industrial sector.

The need for the energy transition from the use of fossil fuels towards renewables and low-carbon technologies to reduce emissions across industrial sectors will require both cross-cutting measures and sector-specific policies and actions. Such industrial transformation would require investments in new technologies and machines enabling radical changes in the production processes and how materials are produced, consumed, and disposed of.

Figure 4.1 IRENA's decarbonization pillars for the industrial sector



Source: (IRENA, 2023)

IRENA (2023) highlights the need for strategies and roadmaps as key enablers for industry sector transformation, including carbon pricing policies, green public procurement, standards for low-carbon materials and products as well as a circularity-based framework. Strategies and roadmaps should include targets and timelines for green hydrogen, sustainable biomass, and electrification targets across relevant sectors.

4.3 The U.S. industrial decarbonization roadmap

The U.S. was the second largest CO2 emitter in 2022 and one of a few countries that published an industrial decarbonization roadmap by the Department of Energy. Similar to Thailand's industrial sector contribution to CO2 emissions, the U.S. industrial sector accounted for about one-third of the country's primary energy use and contributed to 30% of energy-related CO2 emissions. The U.S. Department of Energy (U.S. DOE) has published an industrial decarbonization roadmap (U.S. DOE, 2022) to be aligned with the climate goals to achieve 100% carbon pollution-free electricity by 2035 and net-zero GHG emissions by 2050.

Considering key technology needs as well as industrial competitiveness, the U.S. industrial decarbonization roadmap focuses on four key pillars of industrial decarbonization:

- **Pillar 1 - Energy efficiency (EE)** focuses on the direct reduction of energy consumption through technologies and management processes such as smart manufacturing strategies. While EE provides the most cost-effective and near-term solutions, EE strategies should also be aligned with long-term pathways (e.g., transition to process-heat technologies and low carbon sources) to avoid lock-in to hard-to-decarbonize technologies.
- **Pillar 2 - Industrial Electrification (IE)** enables a shift from combustion fuels to low-carbon electricity, for example, through electrification of process heat using heat pumps and waste heat to power (WHP) electric technologies. IE are now viable for low-to-medium temperature heat industries, however; alternatives such as the use of hydrogen may be more feasible for higher temperature heat industries towards low-carbon process heating.
- **Pillar 3 - Low-carbon fuels, feedstocks, and energy sources (LCFFES**) substitute fossil fuel sources with renewable sourced electricity, biofuels, clean hydrogen and solar thermal power. The deployment of LCFFES will be critical for deeper decarbonization in fossil fuel-reliant industries. However, some technologies such as clean hydrogen still requires long-term research and development.
- **Pillar 4 - Carbon capture, utilization, and storage (CCUS)** will be critical for capturing the remaining emissions from hard-to-abate industrial sectors as the other three pillars will not be sufficient to meet the net-zero target.

In addition to these four pillars, the U.S. industrial roadmap also highlights the roadmap of five key subsectors: iron and steel, chemicals, food and beverage, petroleum refining, and cement.

The U.S. industrial decarbonization roadmap will also directs 40% of the overall benefits of federal investments, including investments in clean energy and energy efficiency, to be flowed to disadvantaged communities under the Justice40 Initiative. Advancing industrial decarbonization by developing new technologies to reduce GHG emissions will address both environmental and inequality issues.

4.4 China industrial decarbonization action plans

China is the global largest CO2 emitter in 2022. In China, the industrial sector largely consumes about 70% of final energy consumption in the country in 2020 (IEA, 2021). The industrial sector is the second-largest source of CO2 emissions, or about 35% of total energy sector emissions. Chemicals, steel, and cement sectors are the largest sectors contributing to CO2 emissions in the industrial sector.

China has pledged to peak CO2 emissions by 2030 and to be carbon neutral by 2060. Accordingly, the Chinese government subsequently published the following national action plans and legislations that foster industrial decarbonization (WEF, 2022a):

- **the 14th Five-Year Plan and 2035 Strategic Vision Goals** set targets for key industrial clusters, including circularity transformation pilot, eco-industrial, low-carbon industrial, green and near-zero carbon emission pilot clusters. This Consequently, China successfully developed about 400 industrial clusters in 2021. In addition, this legislation also allocates funds to support hydrogen stations in all clusters and biomass projects.
- **Action Plan for Peak CO2 Emission 2030** set targets and action plans for key industries (i.e., steel, non-ferrous metal, building materials and petrochemical industries), plans to promote green and low-carbon development in the industrial sector as well as plans to reduce expansion of energy-intensive and high-emission projects to reach the goal of peaking CO2 before 2030 (NDRC, 2021).
- **Others** include i) Guides on the Establishment of a Low-carbon Circular Economy System ii) Opinions on the New Development to Realize Carbon Peak and Neutrality and iii) Trading Guidelines of Carbon Emission Rights

In addition, the Chinese government provide financial incentives (e.g., grants, public funds, subsidies, tax exemptions, low-interest loans, etc.) to support key technologies such as efficiency and circularity, direct electrification, and renewable heat, CCUS and hydrogen (WEF, 2022a).
The government's action plans, legislations and financial incentives provide key enabling environment to support industrial decarbonization in China.

4.5 Other international experience for fostering industrial transition to net zero

In the **United States**, Inflation Reduction Act (IRA) was put into law in 2022, providing several tax provisions and significant grant and loan programs to support deployment of commercially available and innovative clean energy technologies as well as to build a cleaner industrial sector (The Whitehouse, 2023).

The Act provides financial support to i) new advanced industrial facilities deployment program ii) advanced energy project credit to include industrial emissions reduction (e.g., installing low-carbon heat systems, carbon capture systems, energy efficiency measure, etc.) iii) CCUS iv) reduction of methane from oil and gas industry operation v) implement the American Innovation and Manufacturing (AIM) Act to phase down the production and consumption of hydrofluorocarbons (HFCs) and facilitate the transition to next-generation technologies through sector-based restriction.

The U.S. put a lot of financial incentives to support industrial players to lead the transition and enhance the competitiveness of the U.S. in the clean technologies.

In Europe, Green Deal Industrial Plan has been implemented to accelerate the transition to climate neutrality and create supportive environment for scaling up Europe's manufacturing capacity for a net-zero industry (European Commission, 2023). Four pillars of the Green Deal Industrial Plan include:

- **Pillar 1 Predictable and simplified regulatory environment:** This pillar initiates Net-Zero Industry Act (which identifies goals and provides regulatory framework for net-zero industrial capacity), Critical Raw Materials Act (which ensures sufficient raw materials for manufacturing key technologies) and Reform of Electricity Market Design (which ensures consumers benefit from the lower costs of renewable)
- **Pillar 2 Faster access to funding:** This pillar will speed up investment and financing for clean-tech production in Europe. The pillar objectives include guaranteeing necessary aid grants to fast-track the green transition, facilitating the use of existing EU funds, and setting up the European Sovereignty Fund for investment needs.
- **Pillar 3 Enhancing the necessary skills:** This pillar aims to develop skills needed for the green transition. The plan proposes the establishment of Net-Zero Industry Academies, facilitating access of third-country nationals to EU labour markets in priority sectors and fostering public and private funding for skill development.
- **Pillar 4 Facilitating open and fair trade:** This pillar will develop the EU's network of Free Trade Agreements and other forms of cooperation with partners to support green transition, under the principles of fair competition and open trade.

To build a net-zero industry, Europe needs an industrial plan that covers not only establishing a predictable and simplified regulatory environment but also ensuring the industry have access to funding, the necessary skilled workforce for new technologies and an open and fair trade with global partners.

5 I PATHWAYS AND KEY MEASURES FOR ENERGY TRANSITION IN THE THAI INDUSTRIAL SECTOR

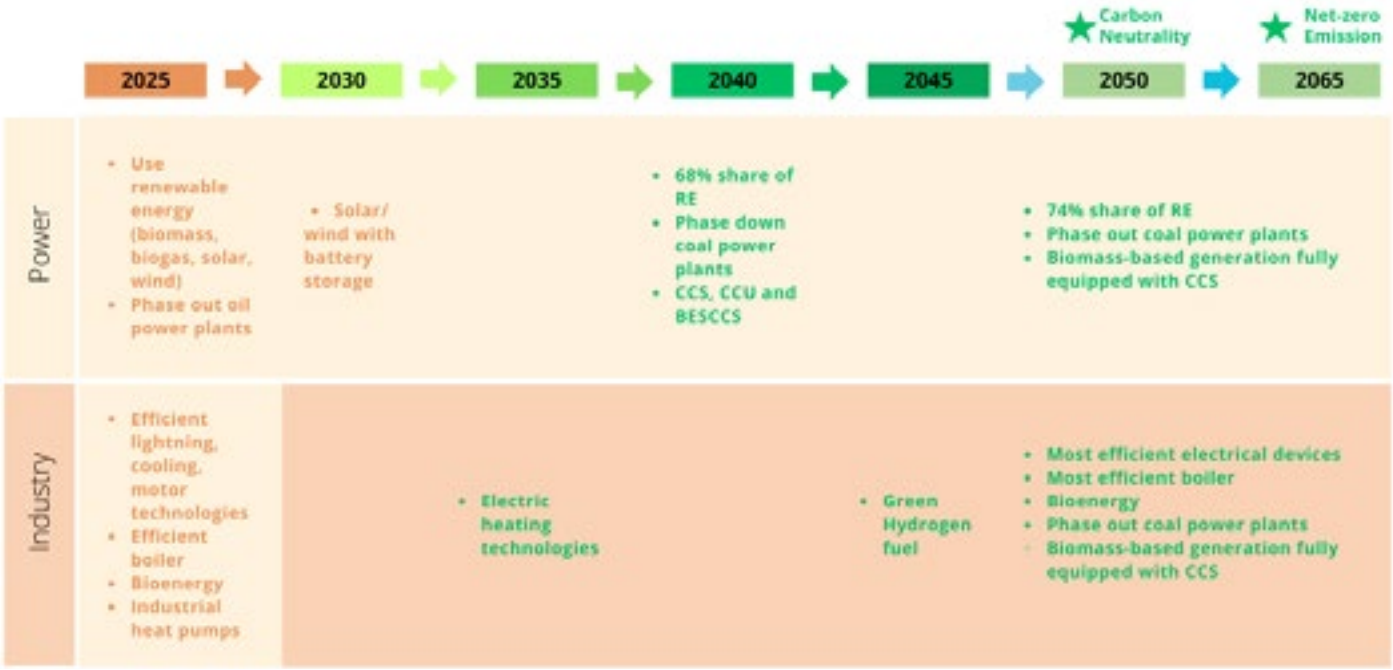
At the COP28 in November 2023, Thailand reaffirmed the targets to achieve carbon neutrality by 2050 and net-zero emissions by 2065 (The Nation, 2023). In addition, Thailand announced the aims towards the following directions:

- Peak its emissions by 2025
- Increase renewable energy share in electricity to 68% by 2040 and 74% by 2050
- Move towards phasing down fossil fuel in line with carbon neutrality

These directions align with the revised Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS), submitted to the UNFCCC in 2022, that set goals and measures for Thailand to meet carbon neutrality by 2050.

The LT-LEDS identifies key measures for emissions reduction in each sector, including power generation and manufacturing industries as outlined in Figure 5.1. Along with these measures, the LT-LEDS also identifies support needs (e.g., technical assistance, technological transfer and development, capacity building, seed funding, pilot implementation, etc.) in the energy and industry sectors as summarized in Table 5.1.

Figure 5.1 Key milestones for pathways of power and industrial sectors towards carbon neutrality in Thailand



Source: (ONEP, 2022)

Table 5.1 Thailand's support needs for pathways in energy and industry sector

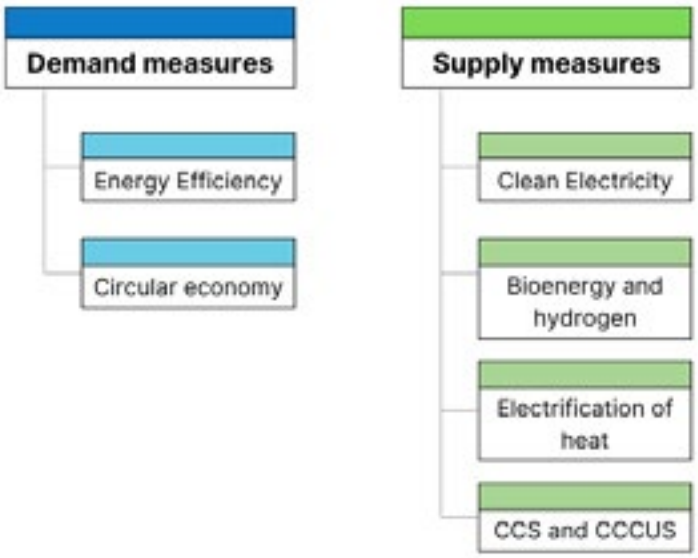
Energy Sector	Industry Sector
Short-term • Renewable energy technologies (e.g., solar and wind) and approaches in advanced energy storage systems (EES) and Demand-side management • Grid modernization and micro-grid development • Smart energy management and digitalization of renewable energy control centre platform • Electricity market reform and incentive schemes to promote RE investments and markets **Medium-term** • CCS and CCUS technologies in power plants • Bioenergy with CCS (BECCS) **Long-term** • Green hydrogen	• Energy efficiency improvement and low-carbon transition in iron and steel, aluminium, cement, chemical and other industries • Enhanced uses of renewables in industrial value chain • Smart energy management • CCS and CCUS in industries • Scaling up of cooling and refrigeration substitution and HFC phaseout • Scaling up and mainstreaming of climate objectives in the Extended Producer Responsibility (EPR) framework • Policy framework for nitrous oxide phaseout from nitric acid and caprolactam industries

The LT-LEDS has set guidelines for long-term targets and measures for emissions reduction toward carbon neutrality and net-zero emissions goals in Thailand; however, ministries responsible for the implementation of policies and action plans in each sector have their plans and strategies for implementation in practice that will align with each ministry's visions and objectives.

Based on international pathways described in Section 4 and key measures identified in Thailand's LT-LEDS, the framework for demand and supply measures identified to support the energy transition in the Thai industrial sector is illustrated in Figure 5.2.

To achieve climate goals, both measures in reducing demand for energy consumption through improved efficiency and material circularity as well as measures in greening the energy supply through increased renewable and low-carbon energy sources are crucial for the energy transition in the industrial sector.

Figure 5.2 Framework for demand and supply measures for energy transition in the Thai industrial sector



Demand measures for the energy transition

Energy efficiency (EE) is a low-hanging fruit and cost-effective measure that should be prioritized in the near term to reduce energy consumption in the industrial sector. EE measures include the adoption of more efficient lighting, cooling, motor technologies as well as efficient boilers and smart energy management in production. Thailand has set EE targets as well as policy and financial support for EE projects under the EEP.

Circular economy (CE) principles help reduce the industry's demand for energy and GHG emissions in energy-intensive industries such as steel, cement, and plastics. More efficient and circular use of materials could reduce the demand for fossil fuels, energy and CO2 consumption (Agora, 2022). Thailand has set key targets, including policy and financial incentives, to support circular economy under the 13th NESDP and the BCG Action Plans for 2021-2027.

Supply measures for the energy transition

Clean electricity is the backbone of energy transition in the industrial sector; however, it could also be the bottleneck of the green transition. As the industrial sector currently consumes significant electricity consumption, the use of clean electricity sourced from renewable energy helps the industry sector reduce emissions from their electricity consumption and enable deeper decarbonization through possible electrification processes such as heat. Without the radical transformation of the electricity grid and electricity market reform and incentives for renewable energy investments, unavailable access to clean electricity from the grid will become a bottleneck for the industrial transition. Thailand has set targets on renewable energy share in the electricity generation under the PDP. In addition, the directions towards the electricity market reform and grid modernization will be provided in the coming NEP.

Bioenergy and hydrogen can be used to replace fossil fuels as fuels and feedstocks for the industrial production. Bioenergy has promising potential as a source of industrial heat, while hydrogen could be used as feedstocks in hard-to-abate industrial sectors. As bioenergy and hydrogen could be applicable in various sectors from renewable sources for power generation, to direct use for industrial heat and biofuels in the transport sector, there should be a central planning towards the bioenergy and hydrogen roadmap in Thailand that integrates demand and supply strategies across sectors. Thailand has set targets and strategies for bioenergy and hydrogen in the AEDP, the 13th NESDP and the BCG Action Plan.

Electrification of heat enables a shift from fossil fuels to low-carbon electricity to generate heat through switching to heat pumps, electronic boilers, furnace. Currently, Thailand has not yet set the targets and action plans that directly support the electrification of heat in the industrial sector, however; electrification of heat is identified as a main decarbonization option for the industrial sector (IEA, 2023) (Mckinsey, 2018) (U.S. DOE, 2022). The success of this measure will also depend on the availability of clean electricity grid or own clean electricity generated for self-consumption.

CCS and CCUS are required to accomplish climate targets for hard-to-abate or energy-intensive sectors such as cement, chemicals and steel. The remaining CO2 emissions generated from the production will be captured and stored using carbon, capture, and storage (CCS) technologies or used as a feedstock in other processes through carbon, capture and utilization (CCU) technologies. Thailand's Department of Mineral Fuel (DMF) is preparing Thailand's carbon, capture, utilization and storage (CCUS) roadmap and potentially develops a CCUS hub, integrating all stakeholders including public and private sectors (power plants, cement industry, exploration and production and other industries) (Suwannathong, 2023). Thailand has set policies to support the development of CCUS under the 13th NESDP and the National Energy Plan.

Sectoral industrial roadmaps

In addition to national policies and plans that provide directions and support for the energy transition in the industrial sector. Industry associations and companies in some energy-intensive industries also developed their own industrial roadmap to achieve climate goals.

Thai Cement Manufacturer Associations (TCMA) developed 'Thailand Chapter: Net Zero Cement & Concrete Roadmap 2050' to set targets and pathways for the cement and concrete industry to achieve net-zero target in 2050 in line with the Global Cement Concrete Association (GCCA). According to the Net Zero pathway for cement and concrete industry, CCUS will contribute the largest share to net zero (45%), followed by efficiency in design and construction (15%), savings in clinker production (12%), savings in cement and binders (10%), CO2 sink: recarbonation (8%) and efficiency in concrete production (5%) and decarbonization of electricity (5%). (Intarode, 2022).

PTTGC, a leading chemical and petrochemical company in Thailand, announced the targets and plans to reduce GHG emissions by 20% by 2030 and achieve a net-zero target by 2050 through three pillars of the transition. The compensation-driven pillar such as or capture and offset carbon projects such as CCS, reforestation, and direct air capture projects contributes to the largest share of the contribution (55%) to net-zero pathway, while efficiency-driven and portfolio-driven pillars contribute about 20% and 25%, respectively, to the net-zero pathway (PTTGC Group, 2021).

The Iron and Steel Institute of Thailand (ISIT) is developing the roadmap for the iron and steel industry in 2023 and conducted a study of the EU-CBAM's impact on the Thai steel industry in 2022, analyzing some potential technologies that reduce energy consumption or lead to energy savings in the steel production process.

While energy-intensive sectors have clear incentives to establish their industrial roadmap to achieve the net-zero target and provide guidelines for prioritized technologies and pillars for the transition, other industries may not yet be aware of the benefits from the industrial roadmap that would guide their future pathways. The roadmap for a cross-cutting pillar such as electrification of heat could potentially be applicable at an industry-wide level, for example, for low-temperature heat industries such as food and beverage, paper, and textile (which together contributed to about 37% of final energy consumption in the Thai industrial sector).

6 I CONCLUSION AND POLICY SUGGESTIONS

The industrial sector is the largest sector consuming final energy consumption in Thailand and consumes the highest electricity compared to other sectors. The energy transition in the industrial sector is therefore crucial for Thailand's pathways to achieve carbon neutrality and net-zero emissions goals.

In addition to policy regulations and incentives from the government, private sector initiatives, risks of high energy cost and the impacts of CBAM have put pressure on the industrial sector to shift from fossil fuels towards renewable and low-carbon energy sources. Consequently, energy-intensive sectors such as cement, chemicals and steel have been urged to unveil net-zero targets and pathways, while other industrial sectors in Thailand still lack awareness and industrial roadmaps toward the energy transition or decarbonization pathways.

The global energy outlook and transition scenarios as well as international practices suggest key common measures for industrial transition, including energy efficiency, industrial electrification, the direct use of bioenergy and low-carbon sources as fuels and feedstock and the use of carbon capture technologies.

In addition, the movement of advanced economies like the U.S., Europe and China stressed the importance of having a national industrial decarbonization roadmap, legislation, and action plans as well as policy and financial incentives provided by the government in pushing for the success of the energy transition in the industrial sector and ensure the industry competitiveness.

Policy suggestions to foster the energy transition in the Thai industrial sector are summarized as follows.

The availability of clean electricity is the backbone of the energy transition in the industrial sector.

As the industrial sector currently consumes a significant share of electricity in their energy consumption, the use of clean electricity sourced from renewable energy helps the industrial sector reduce emissions from their electricity consumption and alleviate risks of high electricity costs from vulnerable prices of fossil fuels.

In addition, the availability of clean electricity from the grid helps ensure industry competitiveness amid the global movements toward increased carbon pricing and a stricter trade restriction environment as well as increased roles of ESG principles and the RE100 network.

In addition, clean electricity will further enable deeper decarbonization in the industrial sector through the electrification of industrial heat. To achieve a 64% share of renewable energy in electricity generation by 2040 and a 78% share by 2050, the LT-LEDS urged the need to support renewable energy technologies such as solar and wind, EES and demand-side management, grid modernization, digitalization of renewable energy control centre platform and electricity market reform and incentives in the short term.

Reform of electricity market design is a key initiative under Europe's Green Deal Industry Plan to ensure consumers benefit from the lower costs of renewables.

Grid electricity with high reliance on fossil fuels will become a bottleneck for the industrial transition in Thailand and may threaten energy security and industry competitiveness in the future. Therefore, a radical transformation of the electricity grid and electricity market reform and incentives will be crucial for unlocking energy transition in the industrial sector in Thailand.

Carbon capture technologies and green hydrogen should be needed in the medium and long term, rather than in the short term.

The New Energy Plan expected in 2024 should set a clear target for the share of renewables for electricity generation that align with climate goals and include monitoring and evaluation mechanisms to track the progress towards the targets.

Thailand needs a supportive net-zero regulatory and policy framework for the industrial sector.

Several existing industrial plans in Thailand include some related policy goals and measures for a net-zero pathway; however, there is no existing direct regulatory framework and national roadmap for the industrial sector in Thailand to achieve carbon neutrality or net-zero targets.

The U.S. DOE published a decarbonization industrial roadmap and Europe put the Net-Zero Industry Act under the Green Deal Industrial Plan as an initiative to identify goals and suitable regulatory framework for accelerating the transition to climate neutrality and enhancing the competitiveness of the net-zero industry.A new Industry Act

or national industrial roadmap to support the industrial transition to net zero is necessary to provide mandates, clear directions, and incentives for the industrial sector to invest in necessary technologies and access to financial instruments for the transition.

The government should support a just transition and provide a comprehensive plan for the energy transition in the industrial sector.

A just transition consideration could be put into an industrial roadmap like in the U.S. Industrial decarbonization roadmap that directs 40% of the overall benefits to be flowed to disadvantaged communities. Also, Europe provides a comprehensive industrial plan that does not only establish a predictable and simplified regulatory environment but also ensures the industry has access to funding, the necessary skilled workforce for new technologies and an open and fair trade with global partners.

In Thailand, SMEs usually lack sufficient knowledge, capacity, and funding for investments in clean technologies or transformation of the production process. In addition, the development of the necessary workforce for the green transition and financial incentives are considered separately by various ministries, lacking a cooperation and integration plan to support the net-zero transition for the industrial sector.

The government could consider a comprehensive industrial plan that also provides an enabling environment and incentives to support SMEs, alleviate the negative impacts on affected groups, develop a necessary workforce for the transition and provide financial incentives for the transition. A comprehensive plan will not only foster industrial transition to meet climate goals but also address economic and equality problems. The process for planning and implementing such comprehensive industrial plan could involve multi-stakeholder collaboration and open for public dialogues that bring together not only government officials under the Ministry of Energy or the Ministry of Industry, but also experts from various aspects of the transition (e.g., political economy, trade unions, labor unions, climate finance, corporate ESG reporting, gender and social inclusion).

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