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Thailand Energy Scenarios: Pathways towards Carbon Neutrality 2050

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ABSTRACT

"Carbon neutrality" has become a challenging target for the energy sector, which may lead to a major structural redesign of the sector. This may inevitably have an impact on the country's economic structure. Future policies should be carefully formulated, taking into consideration both the positives and negatives, as well as the short-and long-term effects on the nation's energy and economy in the future. This will ensure that the nation receives the maximum benefit in terms of energy security, carbon targets, environmental and social care, and sustainable economic growth. The various driving factors to achieve carbon neutrality by 2050 were analyzed based on the STEEP analysis, with an emphasis on the energy sector, which is found to make the largest contribution to greenhouse gas emissions. It found that political will, green technology, and financial incentives are the most influential factors in achieving the carbon neutrality target. These factors are considered as critical uncertainties when building two future scenarios for the energy sector. The Classic scenario reflects the attempt to achieve carbon neutrality with an emphasis on clean technologies, such as renewable energy, green hydrogen, and carbon capture, utilization, and storage (CCUS). Meanwhile, the target will become even more challenging when energy efficiency is to be increased, such as electric vehicle. The Orchestra scenario shows how energy management, a decentralized energy system and promoting the prosumer market, especially in the residential sector, are used to try to reach carbon neutrality. In conclusion, both scenarios may result in the achievement of the 2050 carbon neutrality target. The Orchestra scenario may need planning, a holistic management approach, and active cooperation from various sectors. On the contrary, in the Classic scenario, most activities are restricted to the energy sector, which may entail some risks, particularly the rising demand for carbon offsets from other countries.

Keywords: Carbon Neutrality, Low-Carbon Pathway, Low-Carbon Scenario, BCG Model, Climate Change
JEL Classifications: Q47, Q48, Q54, Q58

1. INTRODUCTION

"Carbon neutrality" has become a challenging target for the energy sector, which may lead to a major structural redesign of the sector. This may inevitably have an impact on the country's economic structure. Future policies should be wisely formulated, taking into consideration both the positives and negatives, as well as the short-and long-term effects on the nation's energy and economy in the future. This will ensure that the nation receives the maximum benefit in terms of energy security, carbon targets, environmental and social care, and sustainable economic growth.

The target to achieve carbon neutrality by 2050 has challenged to the energy sector, which is the highest greenhouse gas (GHG) emissions emitter. The sector will have to arrange not only for sufficient supply to meet increasing demand, but also will have to emit fewer greenhouse gases so that the world will achieve its climate goal. Reducing GHG emissions across the entire energy sector will require transformations, such as a substantial reduction in fossil fuel use, the use of low-emission energy sources, the switch to alternative energy carriers, and energy efficiency and conservation (Intergovernmental Panel on Climate Change, 2022). Energy technology development from now on will be

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directed towards clean and high-efficiency energy. A roadmap for the global energy sector also shows different options and energy technologies that will support the energy sector reach its goal of carbon neutrality by 2050. These include solar energy, wind energy, hydrogen, electric vehicles, advanced batteries, and carbon capture, utilization and storage (CCUS) technology, as well as energy efficiency enhancement (International Energy Agency, 2021).

At the 2021 United Nations Climate Change Conference or the 26th Conference of the Parties (COP 26), Thailand announced its carbon neutrality goal by 2050 and net-zero emissions goal by 2065 (Thailand Greenhouse Gas Management Organization, 2021). Pursuing these goals is a huge challenge for Thailand. This is because Thailand's energy system, which is the most greenhouse gas emitting sector, still relies heavily on an inefficient fossil-based energy system and high energy intensity economic development. Achieving this ambitious goal requires the government to significantly strengthen and then productively implement energy and climate policies and technology development (Nakapreecha et al., 2021).

Therefore, this study aims to analyze the possible Thailand's scenarios and pathways to achieve carbon neutrality in the energy sector by 2050. Key mitigation technologies and policy support are also needed to be identified and prioritized.

2. METHODOLOGY FOR ENERGY MODELLING

2.1. Scenario Building

Scenario building was employed to analyze the possible pathways to achieve carbon neutrality in the energy sector. Scenario building is a method used to determine the feasibility of the future on issues of interest, suitable for policy and strategic planning. Initially, it starts with a look at the relevant qualitative future. This methodology is based on the brainstorming of experts from all sectors, e.g., public, private, and academic. The steps of scenario building are presented as a diagram in Figure 1 (Pongthanaisawan et al., 2018).

First, the focal issues were identified. Relevant driving forces or drivers to the focal issue, such as social drivers, technological drivers, economic drivers, environmental drivers, and political drivers, were analyzed using STEEP analysis. Then, the critical uncertainties were identified and ranked regarding their importance and uncertainty. Then the most important and highest uncertainty drivers would be selected to examine their interactions with each other using scenario logic. At the end, the scenarios would be named, and all driving forces in each scenario would be characterized to reflect the characteristics of the scenarios.

2.2. Energy Account Model

In an energy accounting model, as shown in Figure 2 (Wangjiraniran et al., 2022), calculation begins with an analysis of the 'final energy demand' in the demand analysis module. Energy demand in each economic sector could be taken into account, depending on data readiness and driving factors, for example, economic growth, changes in demographics, and the energy price, which could affect energy consumption in that sector. The demand for each type of energy in the demand analysis module will be used as the starting point for energy transformation analysis, which includes many variables about the manufacturing sector, such as energy transformation efficiency, production capacity, fuel consumption and production ratios, production sequencing, import and export demand, etc. The resource analysis, which looks at Thailand's primary energy demand, will then be able to calculate resource demand based on these factors. The resource analysis shows changes in the relationship between demand and supply in the entire energy system.

The macroeconomic approach models for subsector were composed to estimate energy demand for each economic sector, i.e., industry, transport, residential, commercial, and agriculture. The parameters of gross domestic product (GDP) and population were used as explanatory variables in the models. In addition, the end-use energy demand model will be applied for stock turnover analysis in the road transport sector, as shown in Figure 3 (Wangjiraniran, et al., 2017).

In this study, the energy accounting model was constructed using the "Low Emissions Analysis Platform" (LEAP) program as a tool (Heaps, 2022). LEAP is a software designed to assist quantitative analysis to project a comprehensive picture of energy demand and supply. Moreover, LEAP can modify mathematical equations and be used at different levels of energy data, from data by sector to more detailed data at the end-user level. With its ability to facilitate the collection of technological and numerical data relating to greenhouse gas emissions and environmental impact, LEAP can assess the impact of greenhouse gas emissions and other environmental impacts caused by the energy sector.

3. FUTURE SCENARIOS AND DRIVING FACTORS TO ACHIEVE CARBON NEUTRALITY

3.1. Driving Factors Analysis

The analysis of driving factors to achieve carbon neutrality by 2050 is based on the STEEP analysis, which investigates how external factors—social, technological, economical environmental, and political factors—affect the energy sector. The analysis was made through a brainstorming workshop with experts from the public, private and academic sectors. The driving factors were assessed for their impact on carbon neutrality, as shown in Figure 4, which can be summarized as follows:

- Political factors and policy continuity are considered the most influential factors on the targets to achieve carbon neutrality
- Next to political factors is the development of green technology, which directly affects financial and tax incentive measures as well as support for investments in green technology, which will have to happen at the same time as the market grows. To develop a market for green technology, public awareness of the environment, energy and environmental literacy, and access to information are needed. Business models that

Figure 1: Scenario building methodology

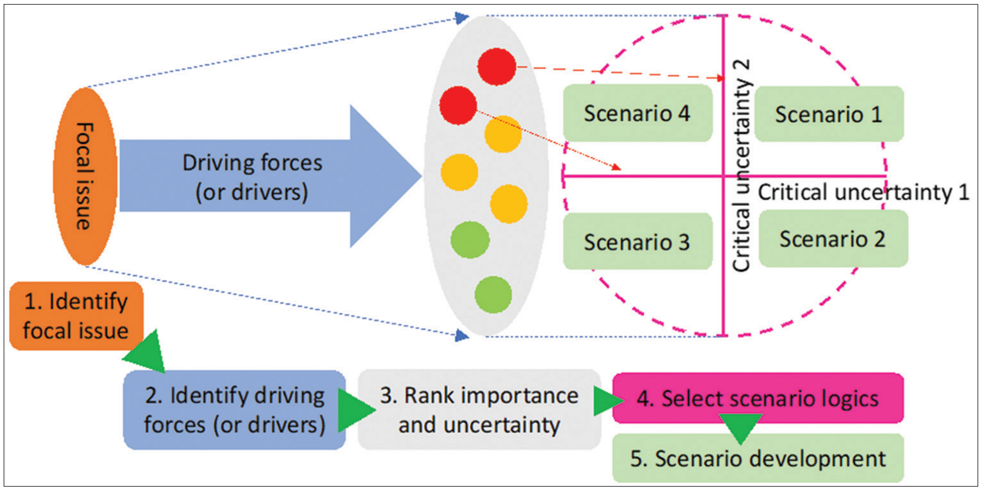


Figure 2: Structure of Thailand's energy system

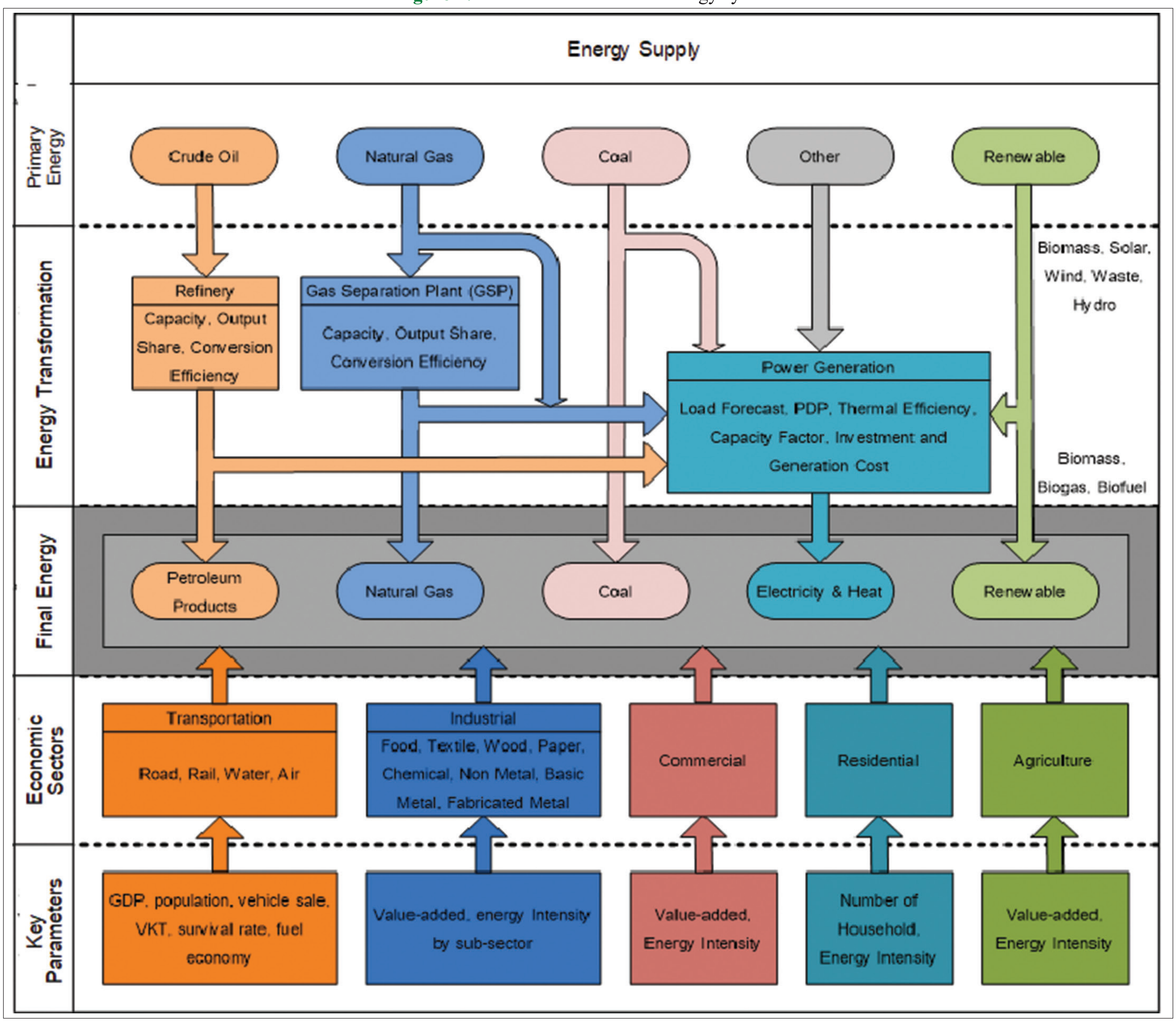


Figure 3: Structure of Thailand's energy system in road transport sector

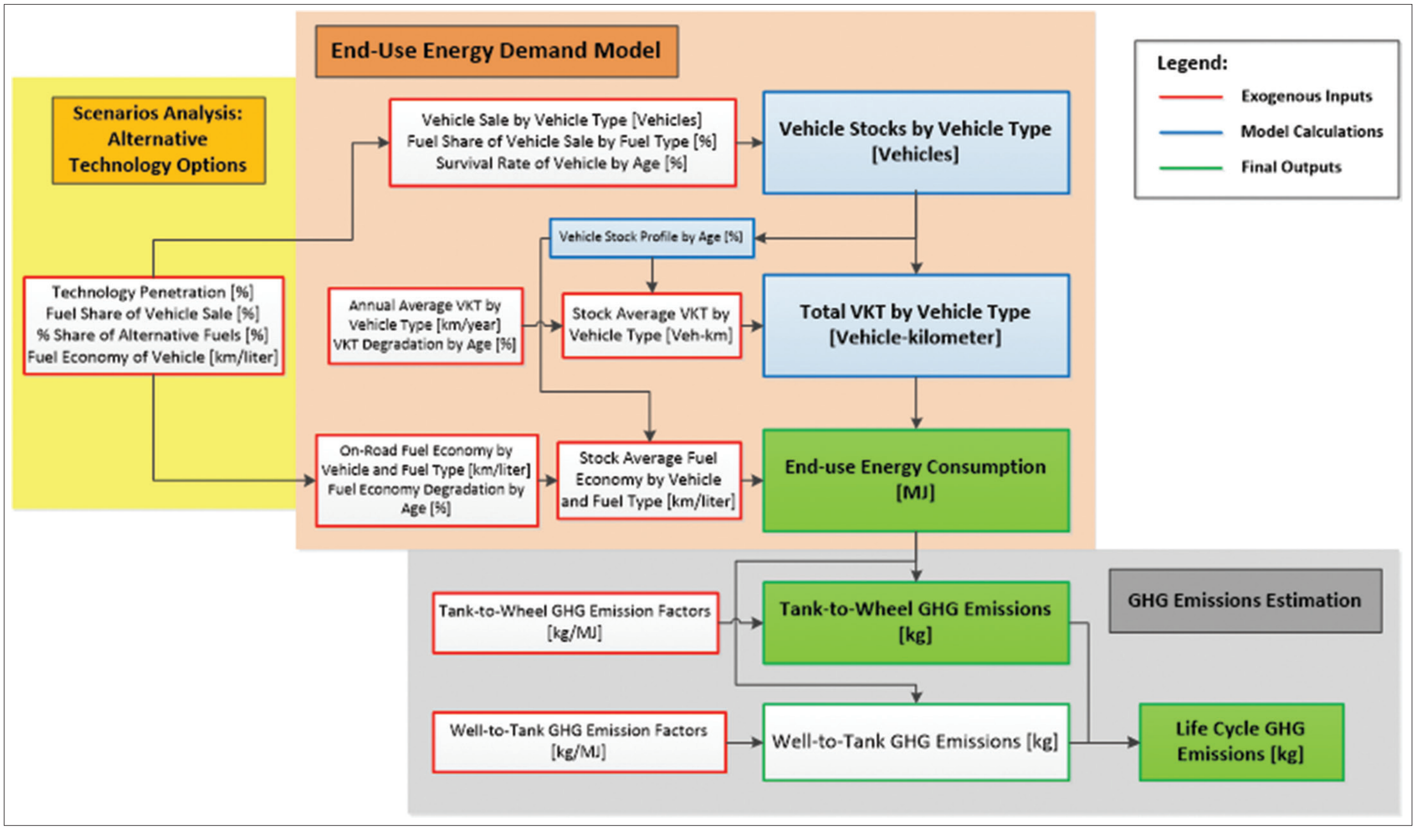
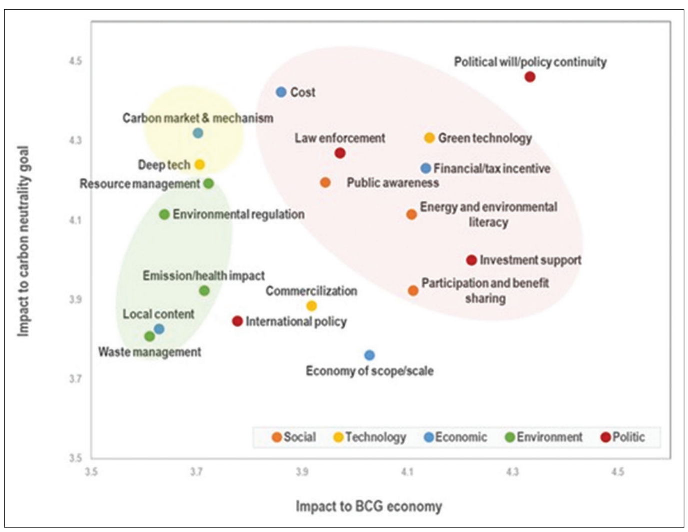


Figure 4: Impacts of driving factors to achieve carbon neutrality goals. (5 = most influencing factor, 1 = least influencing factor)



encourage consumer participation and sharing of benefits are also important

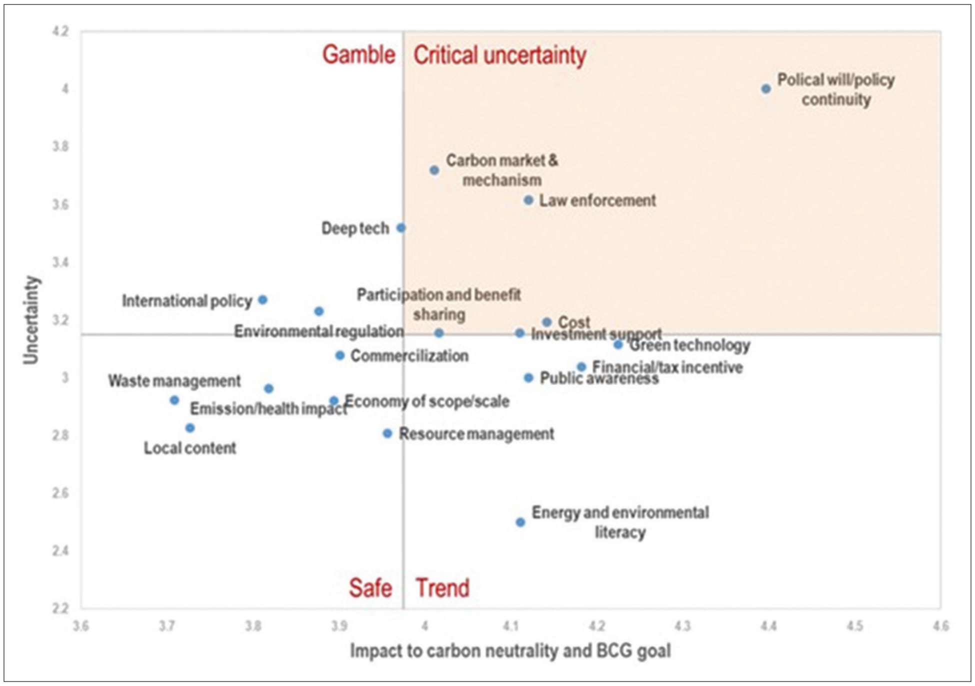
- Environmental factors, as defined by environmental regulations and measures, such as emissions and health impacts, resource management, and waste management, are regarded as having a great influence on the carbon neutrality target
- In the long term, the carbon neutrality goal is considered to heavily depend on the development of clean mechanisms, such as the carbon market, deep technologies like hydrogen, and CCUS, and future technologies like blockchain and big data. This is because clean mechanisms have a lot of potential and are expected to be able to handle the excess greenhouse gas emissions. However, in the short term, risk is expected from an uncertain response from the market due to the high cost.

3.2. Critical Uncertainties

Critical uncertainties considered for the construction of future scenarios were based on two criteria. Such factors must have a critical impact on the goals to achieve carbon neutrality and the BCG model. Importantly, such factors must have the potential to create uncertainty in the future, leading to an unclear picture of the future that could go in many different directions. Based on the brainstorming workshop, the levels of impacts and the critical uncertainties in the Thai contexts, as shown in Figure 5, can be summarized as follows:

- Political will or policy uncertainty – is the most influential factor for achieving carbon neutrality. Law enforcement and the carbon market and mechanism are also considered factors in this category
- The development of green technology, such as solar energy, bioenergy, and waste-to-energy, as well as financial and tax incentives and investment in green businesses are also seen as major trends for the transition to carbon neutrality. Some social factors are also included in this category, for example, awareness and understanding of environmental values, public participation, and the benefit sharing model
- Deep technology factors, such as hydrogen, CCUS, and future technologies like blockchain and big data, are seen as having high influence on target attainment in the long term. However, these factors do not appear clear in the short term, bringing

Figure 5: Critical uncertainties affecting carbon neutrality and BCG model attainment. (5 = most influencing factor, 1 = least influencing factor)



the overall impact to a moderate level. The development of this group of crucial uncertainties, however, must be closely monitored.

3.3. Key Assumptions for Future Scenarios of Carbon Neutrality

Analyzing the above driving factors shows how important "policy making" is for Thailand to achieve its carbon neutrality target. The future scenarios considered possible options for taking the country towards attaining the carbon neutrality goal by the year 2050 can be presented in two scenarios: the Classic scenario and the Orchestra scenario. The energy transition, which is based on the 4D1E framework (digitalization, decarbonization, decentralization, deregulation, and electrification), was taken into account when making these scenarios, as shown in Figure 6.

3.3.1. Classic scenario

This scenario shows the effort to achieve carbon neutrality, with a focus on clean energy sources like bioenergy based on the biobased economy concept, waste-to-energy, waste materials based on the circular economy concept, and other clean technologies, such as solar energy, green hydrogen, and CCUS. Meanwhile, the target will become even more challenging when energy efficiency needs to be increased. The market for electric vehicles is growing by leaps and bounds thanks to public policies and measures that are being enforced and that offer financial incentives for users who wish to use new technologies. These policies and measures also encourage investment in green businesses.

Even though, in the Classic scenario, clean energy will be use up to its maximum potential, carbon offsets are still needed to close the gap found in achieving carbon neutrality by 2050. Figure 7a presents different weights given to different issues in the 4D1E development in the Classic scenario.

3.3.2. Orchestra scenario

The Orchestra scenario reflects the attempt to achieve carbon neutrality by focusing on energy management, a decentralized energy system, promoting the prosumer market, and encouraging power sale and purchase among users, particularly in the residential sector, where the market is huge. In this scenario, strict measures for energy management and information and communication technology (ICT) are also emphasized to maximize energy efficiency, along with restructuring some economic sectors to achieve a lower energy intensity. Like in the Classic scenario, sources of clean energy are to be identified. In addition to the government's push for clean energy, the Orchestra scenario takes into account the active participation of different sectors and the social trends toward environmental awareness, knowledge, and understanding. This will directly lead to the growth of the prosumer market, smart technology, ICT, and decentralized energy systems. Moreover, the Orchestra scenario needs efficient collaborations among relevant organizations to push for economic restructuring, the enforcement of environmental policies, and the transition of the automobile industry.

Through these attempts, the need for carbon offset in the Orchestra scenario will be lower than that in the Classic scenario. The weights given to the various issues in the 4D1E development are also shown in Figure 7b.

4. CARBON NEUTRALITY PATHWAYS OF THAILAND'S ENERGY SECTOR

4.1. The Prosumer Market has a Promising Future

Rooftop solar panels and energy storage systems have more attractive returns on investment thanks to more advanced technology and falling production costs. Moreover, the energy policy that aims to encourage power consumers to earn some

Figure 6: Driving factors and energy products contributing to the carbon neutrality target based on the 4D1E framework

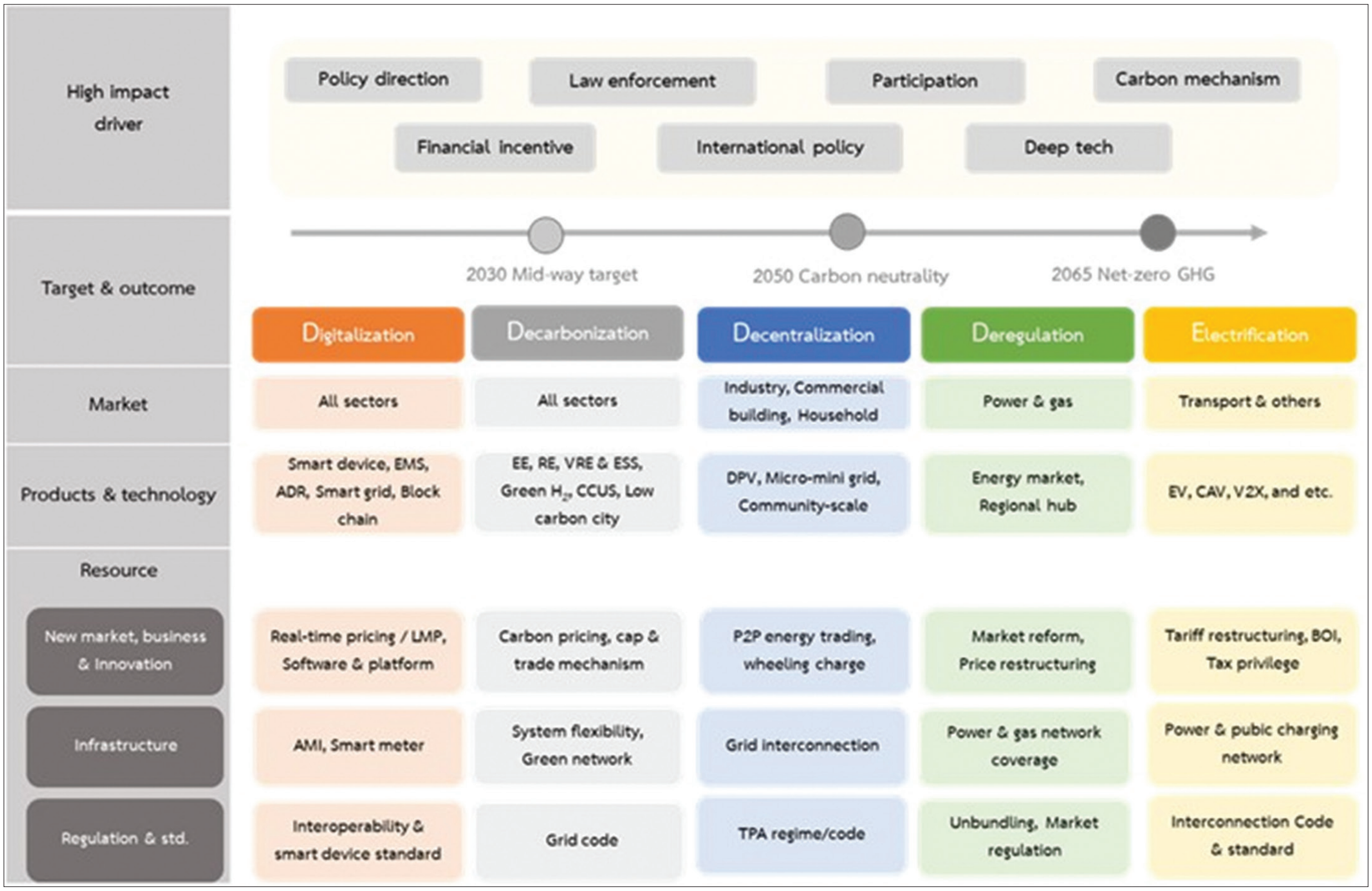
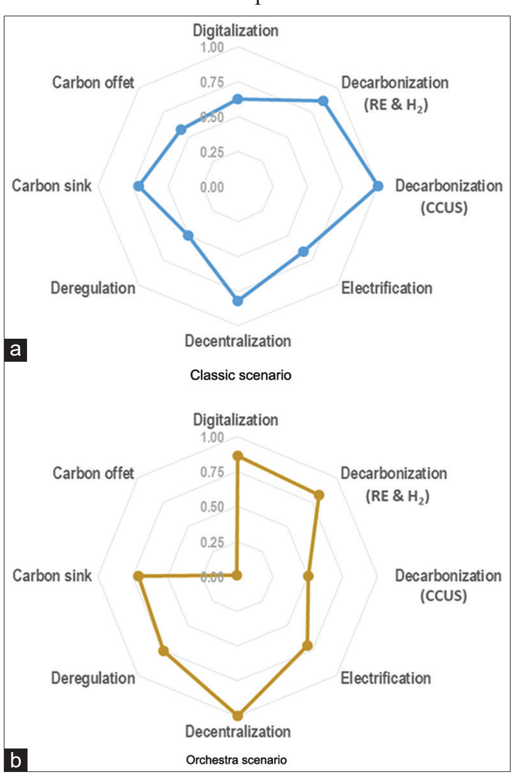


Figure 7: (a and b) Weight of issues to achieve carbon neutrality target based on 4D1E development in each scenario



additional income according to the decentralization approach will give a bright future to the prosumer market in Thailand. The country is now running a pilot project to encourage power sales and purchases among consumers in both the public and private sectors. This is called P2P energy trading. Criteria for the service charge for the power grid are also being set up, along with the technical standards that go with them. When all these relevant factors come together, the prosumer market in Thailand will see dramatic growth, as shown in Figure 8 (Energy Research Institute, 2020).

4.1.1. Classic scenario

At the early stage, most of the growth in prosumers will come from factories and trading businesses that gain their returns on investment through energy cost saving. After 2025, growth will accelerate under the condition that the prosumer market is wide open and attractive grid service rates are offered, especially for the residential sector. This may come in the form of an electricity charge discount for daytime power consumption and DPV installation as an investment in power sale in the case of zero or low electricity load during the day. More applications of electricity storage systems for power management will also be seen. The installation capacity of prosumers is expected to reach 28.5 GW by 2050.

4.1.2. Orchestra scenario

The scenario is similar to the Classic scenario, but there are more incentives provided to support the establishment of the prosumer

Figure 8: (a and b) Prosumer market forecast

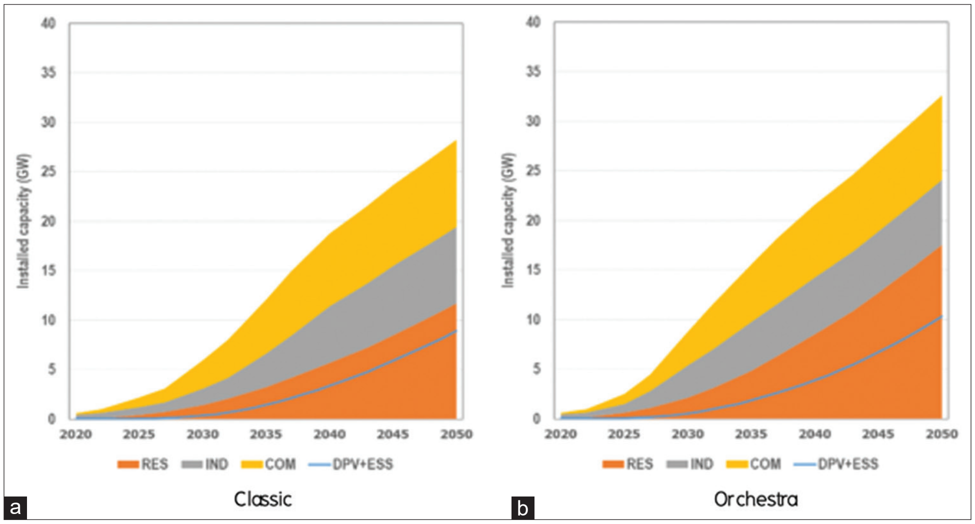
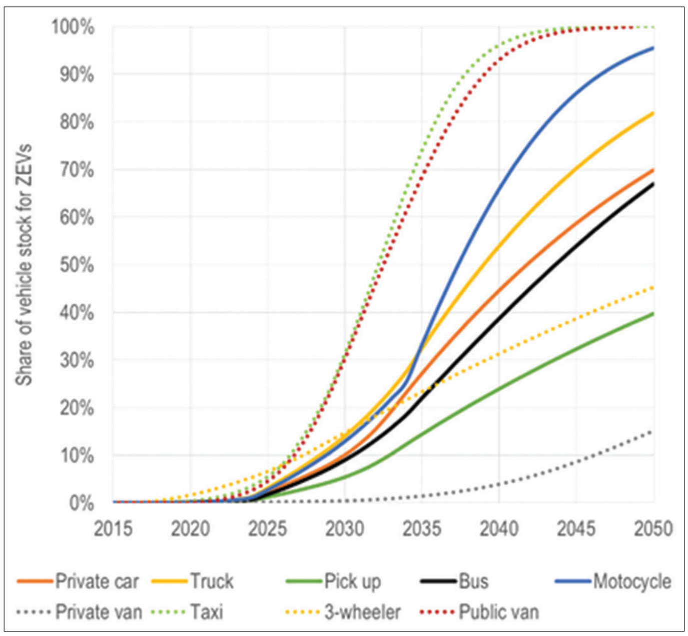


Figure 9: Ratio of EVs to total vehicle stock



market, such as the development of financial mechanisms to facilitate access to sources of funding and credit services, particularly for the residential sector. It is, however, anticipated that there will be a higher number of prosumers in the residential sector in the Orchestra scenario than in the Classic scenario. The installation capacity of prosumers is expected to reach 32.5 GW by 2050.

4.2. Electric Vehicles will Transform Thailand's Transportation Energy Structure

A clear target set by the government to promote electric vehicles (EVs) will be the primary factor supporting the growth of electric vehicles in Thailand. The market for electric vehicles is expected to grow by leaps and bounds in the next 5 years, and all sales will be of electric vehicles from 2035 onward, as shown in Figure 9. Nevertheless, as the vehicles in Thailand generally have a lengthy lifespan, the switch to all electric vehicles may take longer than expected.

An analysis of the ratio of electric vehicles to the entire vehicle stock, as shown in Figure 10, found that taxis and public vans will be the group with the fastest growth of electric vehicles due to the government-regulated service life, followed by motorcycles, of which the lifespan is shorter than other types of vehicles. Private cars, pick-up trucks, and large trucks, which have a big share of energy consumption (over 84% of the combined demand for energy in the road transport sector), may need a long time to phase out of the system.

The change reflects future trends appeared in both the Classic and Orchestra scenarios. But in the Orchestra scenario, there are more factors contributing to the increase in energy efficiency. This makes the trend of energy consumption in the transport sector slightly lower than that in the Classic scenario, as shown in Figure 11 and summarized as follows:

- Future demand for energy in the transport sector in both the Classic and Orchestra scenarios will move in the same direction. As electric power has grown, the consumption of oil products has dropped dramatically. The period between 2041 and 2042 will see demand for electric power outgrow demand for oil products
- As the energy efficiency of electric vehicles is higher than that of combustion engines, particularly in the tank-to-wheel part, the overall energy demand in the land transport sector is predicted to slow down in the long run
- Considering there is a certain amount of biofuel in the blend (20% for bioethanol and 7% for biodiesel), the use of biofuels will decline as the demand for oil products declines. In this regard, there is a thinking to alleviate impact on related businesses by promoting new products that can create value addition for businesses involving biobased economies, some of which are the petrochemical, and food and drug industries. This is to replace the biofuel market, which does not have a very bright future
- The fuel cell electric vehicle (FCEV) is expected to play a limited role in overall energy consumption due to its uncertain value for use. It is, however, expected that the FCEV market will start and grow after 2040, particularly in the large truck and passenger car groups

Figure 10: (a and b) Comparison of energy demand trends in the transport sector between Classic and Orchestra scenarios (a) Classic scenario (b) Orchestra scenario

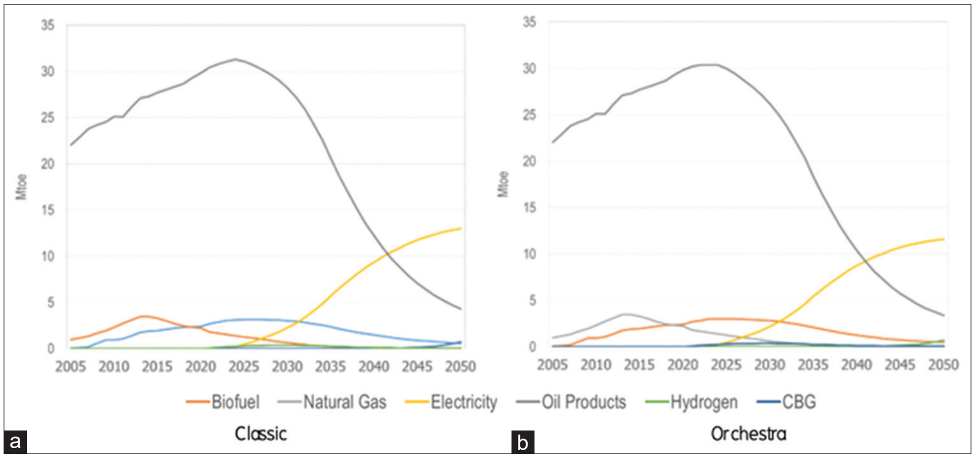
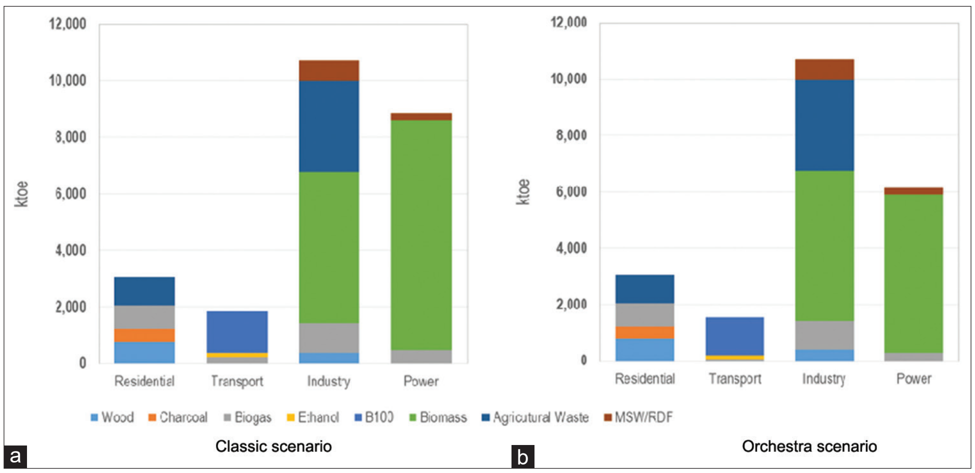


Figure 11: (a and b) Forecast of consumption of bioenergy and refuse-derived fuels in 2050



4.3. Biomass and Waste-to-Energy will Play a Key Role, Depending on the Ability to Take Advantage of them

Thailand has 25 million people working in the agricultural sector, which accounts for 40% of the total population. Farmland takes up around 149 million rai or 23.84 million hectares, or 46.5% of the country area. Thailand is, therefore, considered a high-potential site for bioenergy. There are various materials in this sector that can be used to produce bioenergy. For example, husk and sugarcane pulp can be used to produce biomass, and molasse, sugarcane, tapioca, and palm oil can be used to produce biofuel. The combined energy production from these materials is around 16.3 million tons of crude oil equivalent (Mtoe). Municipal waste, on the other hand, can be used in various forms of energy, e.g., by being burned as fuel in incinerators. Regarding to the assessment, energy potential from waste is expected to about 683.07 kilotonnes of crude oil equivalent (ktoe), which was based on the amount of waste collected and disposed of minus the amount of waste already converted into energy in each locality.

In addition, waste from livestock farming can be used to make biogas as well as refuse-derived fuel (RDF). Key factors that can help bioenergy and energy-from-waste replace fossil fuels are raw material price, fuel quality, transport cost, technology, new types of raw materials, and particularly supportive policy and good collaboration between related parties.

The future market for bioenergy and waste-to-energy will mainly lie in the power production and industrial sectors. The use of conventional biomass in the residential sector, meanwhile, will slow down. So will the use of biofuels in the transport sector, resulting from the growth of electric vehicles. A forecast of bioenergy and refuse-derived fuel (RDF) consumption in 2050 is presented in Figure 11.

4.3.1. Classic scenario

The consumption of bioenergy and RDF is primarily based on the potential of currently available technology and raw materials. Power generation and industrial sectors are regarded as the main targets for the use of biomass (power: industry = 60:40). In 2050, the use of biomass and agricultural waste will account for 17.7 Mtoe, or 77% of total potential.

4.3.2. Orchestra scenario

Similar to the Classic scenario, biomass for power generation and industrial sectors will still be the main targets (power: industry = 50:50). But as the Orchestra scenario puts an emphasis on energy efficiency, the consumption of biomass will be slightly lower than in the Classic scenario. Therefore, it is predicted that consumption for biomass and agricultural waste will be 15.2 Mtoe, or 66% of total potential, in 2050.

4.4. Hydrogen is an Essential Alternative in the Long Term, Possibly Taking Over Natural Gas

Hydrogen will become an important energy source for many countries to reach their carbon neutrality goal, and Thailand is no exception. With properties and usage comparable to those of natural gas, hydrogen is considered a stable source of clean energy. It may replace natural gas and become the energy of the future. So far, hydrogen has not yet been used as an energy source in Thailand due to its high cost, particularly green hydrogen. However, technology and the growing global market may bring down the cost of hydrogen to a competitive level.

Figure 12 shows Thailand's hydrogen roadmap (Energy Policy and Planning Office, 2021) It shows the initial feasibility of using hydrogen in the power sector (to generate power), the industrial sector (to produce heat), the transport sector (to power FCEVs), and the energy storage systems. Hydrogen may be used in the form of direct combustion as part of the fuel blend in the natural gas piping network or in the form of a fuel cell, etc. Hydrogen demand in each scenario is presented in Figure 13.

4.4.1. Classic scenario

Commercial use of hydrogen to replace fossil fuels in the power, industrial, and transport sectors will start in 2030, with an expectation for consumption as fuel of around 9.5 MTOE, or 5.9% of primary energy demand in 2050.[1]

4.4.2. Orchestra scenario

Similar to the Classic scenario, commercial use of hydrogen will start in 2030. But as the Orchestra scenario puts an emphasis on energy efficiency, hydrogen consumption will be slightly less than in the Classic scenario. Therefore, consumption as fuel is expected at around 6.2 MTOE, or 5.0% of primary energy demand in 2050.

4.5. Carbon Capture, Utilization, and Storage (CCUS), is an Essential Alternative to Achieve Carbon Neutrality Goal

The need for CCUS technology has increased following the announcement on carbon neutrality, similar to hydrogen. However, the potential of CCUS in Thailand is considered uncertain due to limited available geological data about carbon reserves,

1 Hydrogen potential in Thailand, as analyzed by METI, is estimated at around 0.5-1.6 MTOE in 2040.

Figure 12: The goal of promoting the use of hydrogen in the energy sector

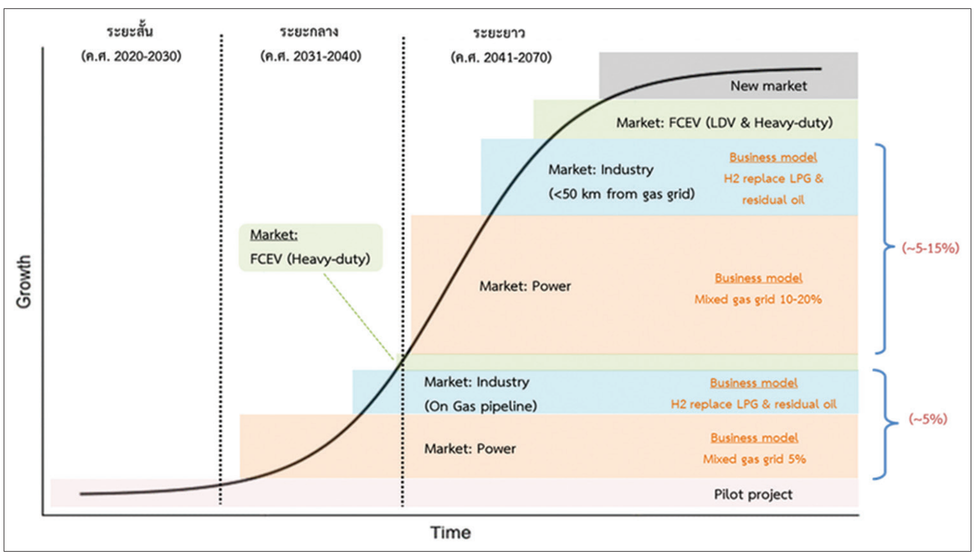
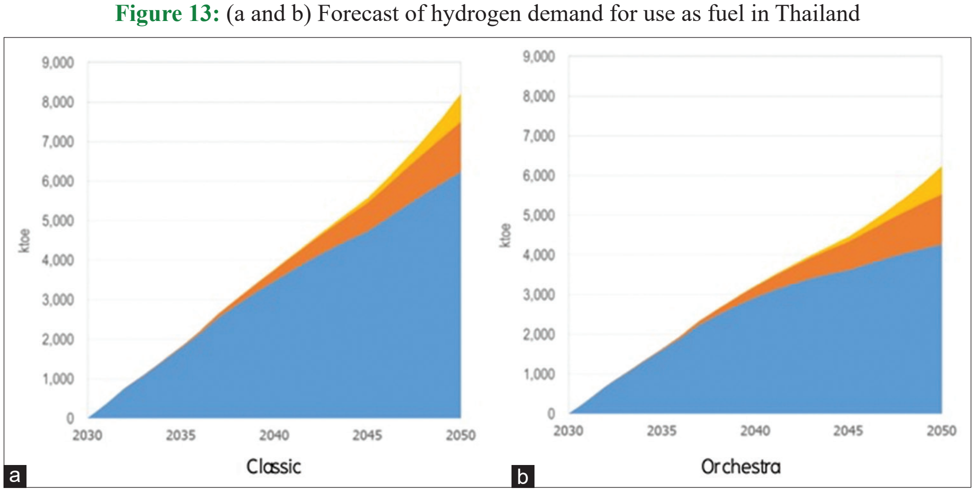


Figure 13: (a and b) Forecast of hydrogen demand for use as fuel in Thailand



carbon emissions, and usage experiments, as well as limited studies on transport and investment feasibility. However, based on preliminary assessment of Economic Research Institute for ASEAN and East Asia (ERIA), Thailand has a potential carbon storage capacity of around 10.3 $GtCO_2eq$ in saline aquifers in the Greater Thai Basin and Pattani Basin as well as in some natural gas and oil producing areas. The major CCUS markets will be power plants and industrial plants with high carbon emissions from the use of fossil fuels. The business model considered most viable for investment is the reuse of captured carbon in the enhanced oil recovery (EOR) process. The CCUS market value, assessed from carbon emission volumes in the power generation and industrial sectors, is shown in Figure 14.

4.5.1. Classic scenario

Carbon emissions in the power generation and industrial sectors will reach their peak in 2030, then slow down due to the rise in clean energy and amount to 140.7 $MtCO_2eq$. The CCUS market value will continue to increase based on the assumption that the carbon price remains between US$100 and US$200 in 2050.

4.5.2. Orchestra scenario

After the COVID-19 pandemic, carbon emissions in the power generation and industrial sectors will start to level off until 2030, and then they will decline continuously. This is because strict measures on energy efficiency and clean energy will cause emissions in these two sectors to drop to 72.8 $MtCO_2eq$. This will give a short-term rise to the future CCUS market value. However, in the long term, the CCUS market does not show a bright future, particularly when the carbon price is around US$100 as of 2050. But if the carbon price shoots up to US$200 by 2050, the CCUS market value could possibly almost double from its current value.

4.6. Pathways of Greenhouse Gas Emissions Reduction to Carbon Neutrality

Power generation, industry, and transport are the three target sectors for greenhouse gas reduction in Thailand's energy sector. Meanwhile, excess carbon also has management options through a carbon sink allocated to the energy sector (around 86 $MtCO_2eq$ out of 120 $MtCO_2eq$) and carbon offsets (Thailand Greenhouse Gas Management Organization, 2022).

Results of the assessment of the amount of greenhouse gas emissions in the energy sector in both the Classic and Orchestra scenarios are shown in Figure 15. These scenarios can be summarized as follows:

- Power generation is the target sector considered to be able to achieve the highest volume of greenhouse gas reduction. Around 146 $MtCO_2eq$ and 165 $MtCO_2eq$ can be reduced in the Classic and Orchestra scenarios, respectively. The most influential factor in greenhouse gas reduction in the sector is technological change toward electrification, particularly electric vehicles. Other factors, including the improvement of energy efficiency and the growth of prosumers, will lower the demand for electricity and consequently lower power production. Notably, the technologies for generating power from renewable energy are another influential factor that will facilitate the sector's efforts to reduce greenhouse gas emissions.
- Factors that will significantly reduce greenhouse gas emissions in the transport sector are the rise of electric vehicles and the switch from finished oil products to electricity as the main source of energy. Therefore, the calculation of greenhouse gas volumes, which was earlier done at emission sources, will be moved to the power generation sector. Still, there are other factors that contribute to a greater reduction in greenhouse gas emissions. There are the expected improvements of the efficiency of future vehicles, the improvements of energy efficiency, and the changes in travel and transport modes.
- The industrial sector plays an important role in reducing greenhouse gas emissions. In the Classic scenario, it is expected that around 96 $MtCO_2eq$ of greenhouse gases will be reduced, while over 147 $MtCO_2eq$ of greenhouse gases could be reduced in the Orchestra. This is because the Orchestra scenario focus on energy management and greater energy efficiency.
- In the long run, hydrogen is predicted to considerably influence the attainment of carbon neutrality. Still, the future of hydrogen in Thailand appears to be very uncertain, similar to that of carbon capture, utilization, and storage (CCUS). The demand for fossil fuels in the Classic scenario, which will fall at a slower pace than that in the Orchestra scenario, will give a brighter future to the CCUS market.
- To achieve carbon neutrality by 2050 in the Classic scenario, additional carbon offsets of around 30 MtCO2eq will be required. The carbon neutrality goal seems more achievable in the Orchestra scenario even without carbon offset.

Figure 14: Forecast of CCUS market value and carbon emission volumes in Thailand's power generation and industrial sectors

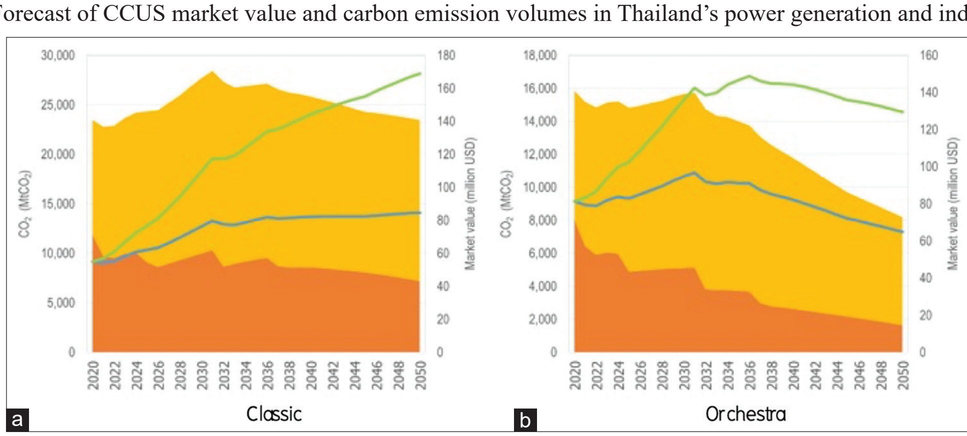


Figure 15: Total greenhouse gas emissions in the energy sector in 2050

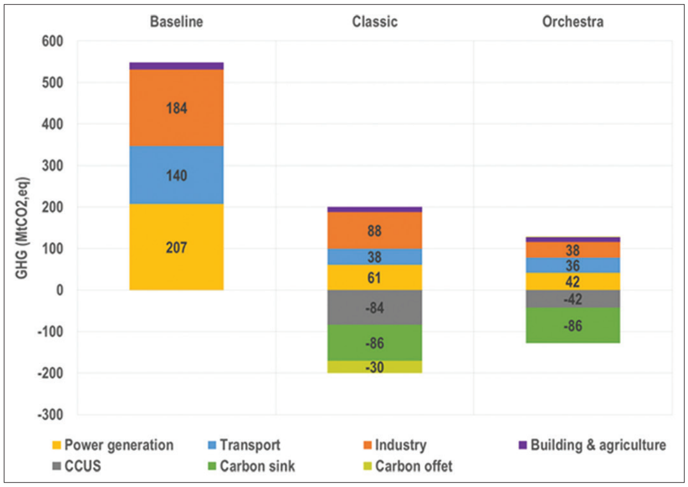


Figure 16: Marginal abatement cost in the classic scenario

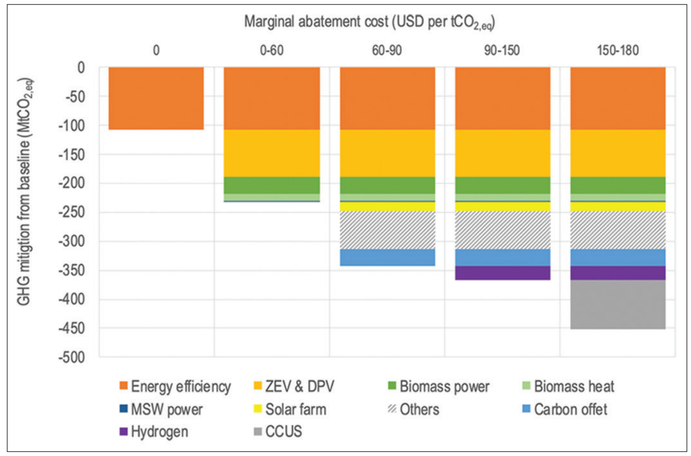
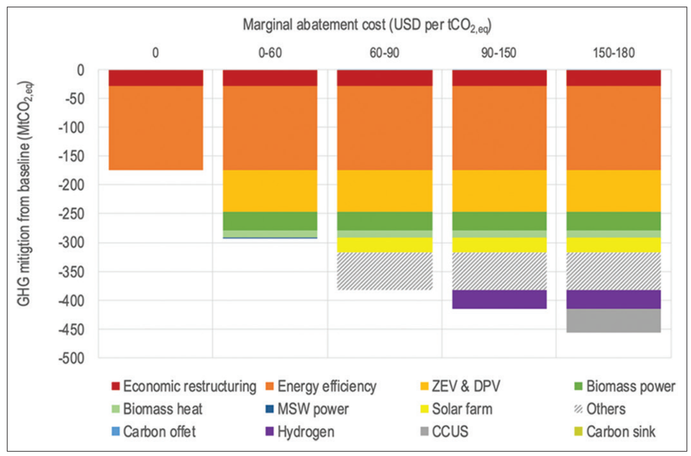


Figure 17: Marginal abatement cost in the Orchestra scenario



4.7. Growing Demand for Reductions in Greenhouse Gas Emissions May Entail Higher Costs More Analysis of the Benefit for the Economic Sector is thus Required

The different weights given to the various measures for greenhouse gas reduction between the Classic and Orchestra scenarios will affect cost and benefit for the economic sector in different ways. The marginal abatement cost of some of the technologies for greenhouse gas reduction for the Classic and Orchestra scenarios is shown in Figures 16 and 17, respectively.

- Energy efficiency could be improved through structural changes in economic sectors that lead to less resource consumption and higher value addition. Modern technology, changes in consumer behavior, the rise of prosumer and electric vehicles can also contribute to energy efficiency improvement. Even though increasing energy efficiency is considered the least expensive option, it may make it difficult to achieve the goal because it highly depends on collaboration from several sectors. If the goal can be achieved, an increase in energy efficiency will be highly influential.
- In the Classic scenario, energy efficiency improvements will result in a greenhouse gas reduction of over 35% of the total volumes of greenhouse gases required for reduction to attain the carbon neutrality goal. As high as 45% can be achieved in the Orchestra scenario.
- Technologies for clean energy that are already on the market include those that use biomass to produce electricity and heat, waste-to-energy technologies, solar technologies, etc. The average marginal abatement cost of these technologies is higher than that of energy efficiency improvement. But the technologies do have practical application, as can be seen from operations that have already been done with some supporting mechanisms, such as improvement, measures for buying electricity produced from renewable energy and measures for promoting investment. However, there may be some problems with alternatives in this group of technologies, such as a shortage and price of raw materials in the case of biomass, problems with plant management in the case of waste-to-energy, problems connecting solar farms to the grid, and the high cost of energy storage systems. In this respect, the ability to reduce greenhouse gas emissions between the Classic and Orchestra scenarios is comparable, at around 10%-13% of the greenhouse gases required for elimination to achieve the carbon neutrality target.
- Future technologies, including hydrogen and CCUS, are expected to play a prominent role in achieving the long-term goal of reducing greenhouse gases. However, this group of technologies requires high investment costs while its commercialization is still uncertain. The Classic scenario shows that this group of technologies will be able to reduce around 20% of the total greenhouse gases needed for elimination to achieve the carbon neutrality target. The Orchestra scenario, meanwhile, gives a 14% possibility.
- The cost of a carbon offset still looks uncertain because it depends on future demand and supply for greenhouse gas reduction. The unit cost of carbon, for which assessment is based on a carbon tax and emission trading scheme (ETS), is currently at around US$ 40-80/tCO2eq (Figure 17). It is lower than the marginal abatement cost of future technologies, but it is still higher than the cost of developing energy-efficient and clean technologies, which are already being commercialized.

5. CONCLUSION

This study uses the 4D1E framework to outline actions that may be taken in the energy sector to move toward the goal of carbon neutrality in Thailand. The Classic and Orchestra scenarios show different weights to be put on different activities involving economic restructuring, energy demand management, promotion of clean energy, new technologies, and carbon offsets. Overall, each option has its own cost and its own effect on subsequent economic sectors.

The Classic scenario reflects the attempt to achieve carbon neutrality with an emphasis on clean technologies, such as renewable energy, green hydrogen, and CCUS. The target will become even more challenging when energy efficiency needs to be increased, such as with electric vehicles. The Orchestra scenario reflects the attempt to achieve carbon neutrality through energy management, a decentralized energy system, and promotion of the prosumer market, particularly in the residential sector.

With the lowest relative cost, energy efficiency technologies are considered promising mitigation technologies for the early stages. Since the average marginal cost of clean energy technologies need is higher, they need more supporting mechanisms to promote their adoption, such as developing technologies, investing in infrastructure, and building up market. Future energy technologies, such as hydrogen and CCUS, are expected to play their role in the long run, as their commercialization is currently uncertain.

In conclusion, both scenarios could lead to the carbon neutrality goal by 2050. The Orchestra scenario may need planning, a holistic management approach, and active cooperation from various sectors. On the contrary, in the Classic scenario, most activities are restricted to the energy sector, which may entail some risks, particularly the rising demand for carbon offsets from other countries. Taking advantage of their competitive costs, energy efficiency technologies would play an important role in the short- to medium-term. While renewable energy and future energy technologies need more supporting mechanisms to develop both technologies and markets, they are expected to play a crucial role in the long term to achieve the carbon neutrality target.

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