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Fiscal Policy to Support the Green and Just Energy Transition

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Fiscal Policy to Support the Green and Just Energy Transition

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Foreword

As the President of the Economic Research Institute for ASEAN and East Asia (ERIA), it is my distinct honour to present this comprehensive study on the economic impact of the green and just transition in selected East Asian economies and the European Union. Climate change remains one of the most pressing challenges of our time, and addressing it requires a concerted effort from all sectors of society. At ERIA, we are committed to advancing economic research that not only highlights the challenges but also identifies viable solutions for a sustainable future.

This study provides an in-depth analysis of green transition efforts in select economies. The country authors examine various relevant aspects, such as governance systems, development agendas, economic structures, and fiscal policies. The impacts of green policies on economies and people have been estimated and projected. It also underscores the critical role of both public and private sectors in mobilising the necessary financial resources to support climate action. In addition to sectoral case studies, the report presents a detailed examination of strategies employed by Indonesia, Malaysia, Thailand, Japan, and the European Union in their transition towards a low-carbon economy.

Our findings highlight the importance of strategic planning, robust fiscal policies, and innovative financial mechanisms in implementing a successful green transition. It is vital to incorporate the principles of a just transition, ensuring that the shift to renewable energy and sustainable practices is both inclusive and equitable, particularly for those most vulnerable to the impacts of climate change.

I extend my deepest gratitude to the dedicated team of researchers and contributors who have worked tirelessly to produce this report. Their expertise and unwavering commitment have been instrumental in completing this study. I also wish to thank our partners and stakeholders for their invaluable support and collaboration.

As we move forward, it is imperative that we continue to foster both international and regional cooperation, particularly in the East Asia context. We must also strengthen our collective efforts to leverage innovative financial instruments and complement them with effective fiscal policies to finance the transition and mitigate the adverse effects of climate change. I believe the insights and recommendations in this study will serve as a valuable resource for policymakers, researchers, and practitioners as we work towards a sustainable and resilient future for East Asia and beyond.

Tetsuya Watanabe
President of ERIA (Economic Research Institute for ASEAN and East Asia)

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ACEA	European Automobile Manufacturers Association
AEDP 2018	Alternative and Renewable Energy Development Plan 2018–2041
APG	Association of Southeast Asian Nations (ASEAN) power grid
ASEAN	Association of Southeast Asian Nation
BCC	Banker–Charnes–Cooper
BOI	Board of Investment
CBAM	carbon border adjustment mechanism
CCR	Charnes–Cooper–Rhodes
CCS	carbon capture and storage
CCUS	carbon capture, utilisation, and storage
CDR	carbon dioxide removal
CFPP	coal-fired power plants
CGE	computable general equilibrium
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
COP	Conference of the Parties
CPI	consumer price index
DEA	data envelopment analysis
DID	difference-in-differences
DMU	decision-making unit
DTN	National Energy Policy
EEA	European Environment Agency
EEP 2018	Energy Efficiency Plan 2018–2041
EFTA	European Free Trade Association
EPBD	EU Energy Performance of Buildings Directive
ERIA	Economic Research Institute for ASEAN and East Asia
ESG	environmental, social, and governance

ESR	Effort Sharing Regulation
ETM	Energy Transition Mechanism
ETS2	Emissions Trading System 2
EU	European Union
EU ETS	EU Emission Trading System
EV	electric vehicle
FiT	feed-in-tariff
G7	Group of Seven
Gas Plan 2018	Natural Gas Management Plan 2018–2041
GBS	Green Bond Standard
GDP	gross domestic product
GHG	greenhouse gas
ggCO2	gigagrams of carbon dioxide
ggCO2eq	gigagrams of carbon dioxide equivalent.
GHG	greenhouse gas
GoI	Government of Indonesia
GPI	government policy indicator
GRDP	gross regional domestic product
GW	gigawatt
GWh	gigawatt hours
GX	Green Transformation Policy
GX Policy	Basic Policy for the Realisation of Green Transformation
HDV	heavy-duty vehicle
HETR	The Hydrogen Economy and Technology Roadmap
IA	impact assessment
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
ILUC	indirect land use change
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use

ISIC	International Standard Industrial Classification
JETP	Just Energy Transition Partnership
kg H2	kilogramme of hydrogen
kW	kilowatt
LULUCF	land use, land-use change and forestry
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MEMR	Ministry of Energy and Mineral Resources
METI	Ministry of Economy, Trade, and Industry
MSR	Market Stability Reserve
MtCO2	metric tonnes of carbon dioxide
MtCO2e	metric tonnes of carbon dioxide equivalent
Mtoe	million tonnes of oil equivalent
MyRER	Malaysia Renewable Energy Roadmap
MW	megawatt
NDC	nationally determined contributions
NETR	National Energy Transition Roadmap
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
Oil Plan 2018	Fuel Management Plan 2018–2041
PDP 2018 Rev.1	Power Development Plan 2018–2041
PHEV	plug-in hybrid electric vehicle
PLN	State Electricity Company - Perusahaan Listrik Negara
PMK	Peraturan Menteri Keuangan
PLTU	coal-based power plant
ppm	part per million
PV	photovoltaic
Q	Quarter
R&D	research and development
RED II	Renewable Energy Directive II
RISE	Regulatory Indicators for Sustainable Energy

RM	Malaysian ringgit
ROI	return on investment
SOEC	soil oxide electrolyser cell
Solar PV	solar photovoltaic technology
SR15	Special Report on Global Warming of 1.5°C
SAF	sustainable aviation fuels
SAM	social accounting matrix
SE4ALL	Sustainable Energy for All
SEDA	Sustainable Energy Development Authority
SDG	Sustainable Development Goals
SIBS	Large and Medium Manufacturing Industry Survey
SME	small and medium enterprise
SUSENAS	National Socioeconomic Survey
tCO2	ton carbon dioxide
TFEC	total final energy consumption
TPES	total primary energy supply
TWh	terawatt-hours
UK	United Kingdom
US	United States
UNFCC	United Nations Framework on Climate Change Conference
WLTP	World Harmonised Light Vehicle Test Procedure
ZEV	zero-emission vehicle
ZLEV	zero- and low-emission vehicle

Chapter 1

Achieving Climate Goals: The Intersection of Policy, Finance, and Innovation

Fukunari Kimura, Fauziah Zen, Alloysius Joko Purwanto, and Denisa Athallia

1. Introduction

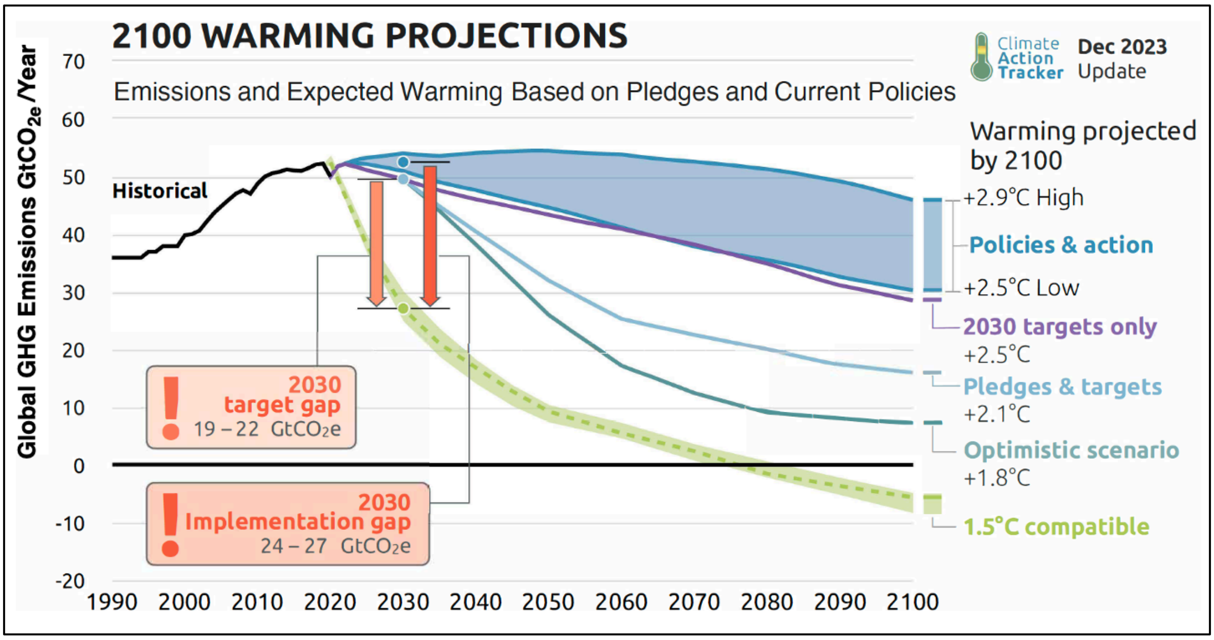
The increasing threats from climate change have become a major global concern. Nations have sought to mitigate these threats through international agreements such as the Paris Agreement, Conference of the Parties (COP) meetings, and nationally determined contributions (NDCs). There is a widespread consensus that addressing climate change requires a collective effort, however, there are two main reasons why market mechanisms alone are insufficient to solve climate change issues. First, everyone is affected by the climate. It is not limited by territorial boundaries and it generates both positive and negative externalities. Second, the adverse impacts of climate change are delayed and widespread, and there are no clear economic incentives for private individuals or entities to take responsibility for them.

In the public sector, fiscal policy and budgeting are crucial tools to enable governments to lead, influence, and shape the green transition. Budgetary policies are essential to demonstrate the consistency of government action on climate change by linking revenue and expenditure strategies to climate objectives. Fiscal policy also plays a key role in shaping and influencing private sector behaviour towards more sustainable practices. Common policy instruments include command-and-control measures, taxation, incentives and disincentives, market creation, and regulatory frameworks.

Recognising the pivotal role of the public sector in promoting a green economy, this study examines examples from three developing Association of Southeast Asian Nation (ASEAN) Member States – Indonesia, Malaysia, and Thailand – and two advanced economies – the European Union (EU) and Japan. The analysis focuses on their respective green policies in selected sectors. The need for decarbonisation is urgent, as there is a significant gap between climate pledges and actual progress, exacerbated by ongoing global conflicts and crises, such as wars and the impact of the coronavirus disease (COVID-19) pandemic, which have distracted from efforts to combat global warming (Figure 1.1).

The study highlights the critical importance of strategic planning, robust fiscal policies, and innovative solutions to drive the green transition. The experiences of the countries and economies studied provide valuable lessons for developing tailored approaches to effectively address climate change and promote sustainable development on a global scale.

Figure 1.1. Paths of the Pledges for Several Scenarios and the Gaps with Current Policies



°C = degrees Celsius, GHG = greenhouse gas, GtCO2e = gigatons of carbon dioxide warming equivalent.
Source: Climate Analytics (2024).

While economies have differing capacities to decarbonise, all actions and efforts are counted if they produce net benefits. There are also arguments over which policies and actions are more efficient and effective; and it has been suggested that we must focus on high impact policies. Focusing only on high impact policies, however, is not the only path to take, because limited capacity in many countries may make these policies undeliverable. This is one of the benefits of allowing countries to define their own NDCs.

Private financing for the transition is crucial, since public capacity is limited. Decarbonisation requires strong complementarity between public and private partnerships not only for financing but also for setting and implementing standards, actions, mitigation, and adaptation efforts.

The fiscal role in promoting decarbonisation includes the use of taxes and subsidies to influence behaviour. Implementation of carbon taxes for fossil fuels and providing subsidies for renewable energy projects can incentivise reductions in greenhouse gas (GHG) emissions and encourage the adoption of cleaner technologies. Direct and indirect green public investment and fiscal policy can play a significant role in funding essential green infrastructure projects, such as the development of electric vehicle (EV) ecosystems and renewable energy installations. Such investments would not only reduce emissions but should also stimulate green job creation and economic growth.

Support for green facilitations, including infrastructure for the EV ecosystem, tax allowances, and subsidies for renewable energy projects, is essential for accelerating the green transition. Governments can provide tax incentives and allowances to reduce the financial burden on companies and individuals investing in green technologies. These measures can drive innovation, lower costs, and increase the adoption of environmentally friendly practices across various sectors.

Green bonds have emerged as a powerful tool for financing sustainable projects in Asia. These bonds provide a way for governments and corporations to raise capital specifically earmarked for green initiatives, such as renewable energy, energy efficiency, and sustainable infrastructure projects. The growing market for green bonds in Asia reflects the region's commitment to integrating sustainability into financial practices and attracting investment for climate action.

Other innovative green finance mechanisms, such as climate funds, carbon markets, green credit lines, and sustainability-linked loans, offer additional avenues for mobilising resources for environmental projects. These innovative financial instruments can attract private sector participation and create new opportunities for collaboration between public and private entities. By leveraging these tools, countries can enhance their capacity to fund and implement effective climate change mitigation and adaptation strategies.

2. Financing for a Green and Just Transition

The concept of a just energy transition emphasises the importance of ensuring that the shift to a low-carbon economy is both equitable and inclusive. This involves considering the rights and needs of all stakeholders, particularly those most vulnerable to the impacts of climate change and the transition itself.

In developing and emerging economies, affordable energy prices are especially critical. A significant portion of the population remains vulnerable and relies on low energy costs not only for essential needs such as cooking and household lighting but also for everyday activities such as powering small fishing boats, preparing and selling food, and commuting to work or school.

In countries with heavily subsidised fuel prices, reducing subsidies with each price adjustment often leads to higher-than-expected rises in inflation. This creates a stronger link between energy and other sectors than previously observed. To mitigate the impact, governments typically provide additional welfare support through cash transfers or in-kind benefits. There is also price discrimination (subsidised prices) for energy consumed by specific groups in many developing economies, including low-income households, farmers and fishermen, public transportation operators, small businesses, religious organisations, and charitable groups. While this policy aims to protect these vulnerable groups from high inflationary commodity prices, it often results in misallocation due to errors in inclusion and exclusion. This challenge is particularly significant in nations with outdated socio-economic databases, numerous remote regions, and limited implementation capacities.

The massive shift from fossil fuels to renewable energy sources will significantly disrupt industries such as coal, oil, and gas, destabilising regional economies heavily dependent on these sectors. This challenge is particularly serious in countries with unequal resource distribution, such as Indonesia, where a substantial portion of subnational revenue comes from natural resources shared with the national government.

While the renewable energy sector has the potential to create millions of new jobs, it also poses a significant risk of job losses in traditional fossil fuel industries. The new jobs often require retraining and relocation, as they demand different skills and may not be available in the same locations as the displaced jobs. Hence, a framework for a just transition is vital, to maximise the potential gains while reducing the negative impacts or compensating for them.

International climate funds are primarily allocated to developed markets at the implementation level, leading to a lack of funding for emerging and developing markets, which face the most severe impacts. The implementation of COP targets generally depends on aggregate funding data, creating significant barriers for developing economies to access these funds. During the application stage, the standards and mandated obligations necessary to access funds can result in the exclusion of developing economies.

It is also crucial to manage the phase-out of fossil fuels responsibly to avoid simply shifting emissions to alternative fossil-based sources. For example, promoting EVs in countries reliant on fossil fuels for electricity generation requires complementary policies to reduce dependence on fossil fuels for electricity. Although EVs can potentially reduce overall net carbon emissions compared to combustion engine vehicles, these efforts must be paired with initiatives to increase the share of renewable energy in the electricity mix.

Achieving net zero emissions will require substantial growth in renewable energy capacity, necessitating increased funding and international cooperation. It is essential to ensure that decarbonisation efforts do not exacerbate existing inequalities or create new forms of climate or environmental injustice. By integrating equity into the transition process, we can foster a more inclusive and sustainable future for all.

Green finance is a crucial component of sustainable finance, encompassing instruments aimed at achieving social, economic, and other Sustainable Development Goals (SDGs). Specifically, green finance targets climate change mitigation and adaptation, and addresses various environmental issues. The transition towards a green economy is heavily influenced by government policies, which are crucial in shaping and driving the development of green finance systems.

To achieve the ambitious targets set by the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development, substantial investments are necessary. The Intergovernmental Panel on Climate Change (IPCC) estimates that global annual investment needs to range from $1.6 trillion[1] to $3.8 trillion from 2020 to 2050 to maintain global warming within a 1.5°C scenario (Masson-Delmotte et. al, 2018). Public finance alone is insufficient; thus, leveraging private sector investments is crucial. Blended finance that combines concessional funds from public sources with private capital can help reduce investment risks and attract private investors (Climate Policy Initiative, 2018).

Green bonds have emerged as a vital tool for raising capital for environmentally friendly projects. The development of green bond markets, supported by clear standards and taxonomies, can channel investments into renewable energy, energy efficiency, and sustainable infrastructure. For instance, the EU's Green Bond Standard (GBS) aims to enhance transparency and credibility in the green bond market, ensuring that funds are used for genuinely sustainable projects (European Commission, 2019b).

The size of the green bond market has seen significant growth in recent years (Table 1.1). The global sustainable bond market has expanded by more than 20% annually, with the ASEAN region experiencing even more rapid growth – almost 50% in 2022 and 28% in 2023. Green bonds now constitute nearly half of the total outstanding sustainable bonds in ASEAN. Notably, both the public and private sectors contributed almost equally to the issuance of sustainable bonds in 2023.

Table 1.1. Market Size of Sustainable Bond Markets

Region	2021	2022	2023	2024 Q1
Global				
Outstanding stock ($ mn)	2,594,000	3,306,000	4,000,000	4,264,000
% YoY growth		27.2%	21.0%	17.7%
EU-20				
Outstanding stock ($ mn)	1,157,000	1,246,000	1,508,000	1,603,000
% YoY growth		7.7%	21.0%	20.4%
Japan				
Outstanding stock ($ mn)	79,069	115,982	163,337	
% YoY growth	64.9%	46.7%	40.8%	

[1] In this chapter, $ refers to United States dollars.

Region	2021	2022	2023	2024 Q1
% issued by public sector	29.6%	28.3%	31.6%	
% green bonds	46.7%	45.8%	43.9%	
ASEAN				
Outstanding stock ($ mn)	37,929	56,725	72,687	73,000
% YoY growth	92.9%	49.6%	28.1%	16.6%
% issued by public sector	32.3%	43.9%	49.1%	
% green bonds	48.4%	47.0%	46.8%	
Indonesia				
Outstanding stock ($ mn)	7,079	9,871	11,959	11,800
% YoY growth	39.6%	39.4%	21.2%	26.0%
% issued by public sector	57.5%	63.0%	63.7%	66.0%
% green bonds	73.6%	79.2%	78.4%	81.7%
Malaysia				
Outstanding stock ($ mn)	6,276	10,353	13,198	13,100
% YoY growth	118.9%	65.0%	27.5%	5.3%
% issued by public sector	20.7%	22.4%	26.3%	26.1%
% green bonds	30.5%	19.6%	19.3%	18.8%
Thailand				
Outstanding stock ($ mn)	10,719	14,803	19,774	19,400
% YoY growth	134.2%	38.1%	33.6%	17.07%
% issued by public sector	64.2%	62.2%	68.3%	68.9%
% green bonds	28.7%	26.1%	22.7%	21.7%

% = percent, $ = United States dollar, ASEAN = Association of Southeast Asian Nations, mn = million, YoY = year on year,

Source: Asian Bonds Online (2024).

Quarter 1 (Q1) of 2024 was particularly prolific, with a total of $276 billion (54.6% Q on Q) in global issuance of sustainable bonds. The share of the global sustainable bond market in the general bond market increased to 15% in 2023, up from 14% in 2022 and 12% in 2021. The market for sustainable bonds, especially green bonds, is set to continue growing. According to Environmental Finance's forecast, green bond issuance is expected to reach $600 billion in 2024, $700 billion in 2025, and $850 billion in 2026.

In Q1 of 2024, the total issuance of green finance instruments amounted to $4,264 million, representing 17.7% of the total issuance of sustainable finance instruments. Of this, green bonds accounted for a significant portion, with $1,603 million issued, making up 20.4% of the green finance market.

However, the distribution of green bonds between public and private sectors varies across countries. In Indonesia and Thailand, the public sector dominates by issuing more than 60% of the sustainable bonds. Conversely, Malaysia's market is largely driven by the private sector, with only 26% of the bonds issued by the government.

Table 1. also highlights the regional differences in green finance adoption. ASEAN's robust growth in green bonds is notable, reflecting the region's commitment to transitioning towards a greener economy. The data also shows that within ASEAN, public sector involvement is substantial in countries such as Indonesia and Thailand, which contrasts with Malaysia's private sector-led market.

Several key market drivers are fuelling this growth. Lower interest rates are creating more favourable market conditions for green projects such as EVs and renewable energy to expand and for bonds to be issued. Additionally, there is a push for more diverse energy stacks, including renewables, hydrogen, ammonia, sustainable bioenergy, synthetic fuels, nuclear, and oil and gas with both carbon capture, utilisation, and storage (CCUS) and carbon capture and storage. The use of proceeds structure, defined by new standards and regulations such as the EU GBS, helps 'ring-fence' capital specifically for green projects.

Europe continues to lead the sustainable bond market, accounting for 37.6% of global sustainable bond stock and 55% of global issuance. Major issuances in 2023 included Italy's sovereign green bonds, as well as bonds from Germany and the UK.. Europe's regulatory framework has seen significant developments, such as the EU GBS, which aims to improve transparency and credibility in the green bond market.

Japan has introduced the Green Transformation (GX) Policy, aiming for ¥150 trillion (~$1 trillion) in private-public investment over 10 years. This includes the world's first sovereign climate transition bonds and the implementation of carbon taxes and emissions trading systems.

The ASEAN+3 region[2] has shown significant growth in sustainable bond issuance, with a 21.4% year on year increase in Q1 2024, outpacing both the EU and global averages.

[2] ASEAN+3 consists of ten ASEAN Member States plus China, Japan, and the Republic of Korea, henceforth Korea.

Efforts include the development of regional taxonomies and frameworks, such as the ASEAN Taxonomy for Sustainable Finance v3, and initiatives such as the Energy Transition Mechanism and Just Energy Transition Partnership to finance early coal retirement and decarbonise energy sectors.

While the green bond market is experiencing significant growth, the green loan market lags by $30 billion per year globally. To address this gap, recent initiatives have been introduced, such as the establishment of discounted lending facilities for green projects by central banks, including the Bank of China and the Bank of Japan.

These trends underscore the importance of tailored government policies and incentives to stimulate both public and private sector participation in green finance. The rapid growth of green bonds in ASEAN, driven by strategic policies and strong market demand, illustrates the potential for significant environmental and economic benefits through well-coordinated green finance initiatives.

Overall, the development of green finance is pivotal to achieve global sustainability targets. The varying levels of public and private sector involvement across regions highlight the need for adaptive policy frameworks that can effectively harness the strengths of both sectors to drive the green transition.

One of the efforts to achieve both emission reduction and mobilisation of funds is implementing carbon markets and pricing mechanisms, such as carbon taxes and cap-and-trade systems. This will incentivise the reduction of GHG emissions by putting a price on carbon. These mechanisms encourage businesses to invest in low-carbon technologies and practices. Revenue generated from carbon pricing can be reinvested in green projects and used to support communities affected by the transition (UNFCCC, 2015).

Globally, developed countries committed to mobilising $100 billion annually by 2020 to support climate action in developing countries. This finance is crucial for enabling developing nations to invest in green technologies and build resilience to climate impacts. However, the actual disbursement has been far lower than the pledge. Initiatives such as the Green Climate Fund and the Adaptation Fund play a significant role in channelling these resources to where they are most needed (UNFCCC, 2018).

Strong institutional frameworks and supportive policies are essential for scaling up green finance. Governments can create enabling environments through regulatory measures, such as mandatory environmental, social, and governance disclosures, green finance taxonomies, and incentives for sustainable investments. Central banks and financial regulators can also play a pivotal role by integrating climate risks into financial supervision and promoting green lending practices (Schumacher, Chenet, and Voltz, 2020).

All these financing mobilisation efforts should work under the principle of just transition. The shift to a low-carbon economy is fair and inclusive, particularly for workers and communities dependent on fossil fuel industries. Just Transition Funds can provide financial support for retraining and reskilling workers, developing new economic opportunities, and ensuring social protection for vulnerable groups. The EU's Just Transition Mechanism, for example, includes a dedicated fund to support regions most affected by the transition (European Commission, 2018).

Engaging local communities and stakeholders in the planning and implementation of green projects is vital to ensure that the benefits of the transition are widely shared. Transparent and inclusive decision-making processes can help build trust and support for green initiatives, while also addressing potential social and economic impacts (UNEP, 2019).

Financing a green and just transition requires a concerted effort from both public and private sectors, supported by robust policies and regulatory frameworks. By mobilising the necessary financial resources and ensuring that the transition is equitable, we can achieve SDGs and mitigate the adverse effects of climate change. The integration of environmental, social, and governance considerations into financial decision-making will be key to driving this transformation and building a resilient, low-carbon future. The following section of this chapter summarises key messages from the scoping countries and offers suggestions for moving forward.

3. Countries' Experiences

3.1. Indonesia

Indonesia has taken a remarkable step in implementing a strategic plan to combat climate change. With the signing of the Global Coal to Clean Power Transition Statement at COP26, the country is exploring the early retirement of coal-fired power plants (CFPPs), known as the 'coal phase-out' plan, with estimated funding of up to $48 billion. The plan aims to close CFPPs by 2050 while promoting the development of renewable energy. In addition, the national government in Indonesia is developing an energy transition strategy that aims to reduce dependence on fossil fuels, increase renewable energy capacity, and maximise energy efficiency, making renewable energy the primary option.

The Economic Research Institute for ASEAN and East Asia (ERIA)'s Energy Outlook and Energy Saving Potential in East Asia 2023 (Kimura, Phoumin, and Purwanto, 2023) shows that even with Indonesia's carbon neutrality target year of 2060, by 2050 power generated by coal must be reduced to only 178 terawatt-hours (TWh) compared to the estimated 650 TWh in the business-as-usual scenario. The 179 TWh of electricity should be delivered with the most advanced clean coal technology and around 42% of it must be combined with carbon capture and storage.

The coal phase-out plan is, however, economically costly as it may require Indonesia to sacrifice an opportunity to achieve the Golden Indonesia 2045 Vision. Implementation of the coal phase-out plan means that Indonesia cannot make optimal use of all available resources, including abundant and comparatively low-cost fossil energy sources. The plan is also financially costly, requiring significant funding from various parties. The government has predicted that by 2030, early retirement of CFPPs will have cost $25–$30 billion. Investing in renewable energy will cost $20–$25 billion per year, increasing the cost burden for coal phase-out and renewable energy development.

The empirical findings of this study show that the presence of CFPPs significantly influenced Indonesia's well-being at both macro and micro levels. At the macro level, the presence of CFPPs significantly and adversely affects Indonesia's economic development as measured by gross domestic product (GDP) and its growth rate. The results of the analysis indicate that the total annual economic cost of CFPPs is an estimated $92.88 billion. At the micro level, the presence of CFPPs is associated with an increase in monthly electricity spending by an average of about $48.24 per household per year, an increase of about 6.1%, or a total annual value of $15.5 billion at the national level. Regarding the manufacturing business sector, the presence of CFPP operations has a positive impact on the return on capital of companies, with the effect quantified as an increase of 0.16 percentage points, or equal to a change of 3.1%. The results also suggest that, on average, the positive impact on return on investment is estimated at $7.87 million per company per year, equating to a total annual value of $43.6 billion nationally.

Summarising the overall effects of CFPPs at the macro and micro levels, it appears that the presence of CFPPs results in a potential annual net economic loss. The simulation model shows how important it is to consider the financial impact of implementing the coal phase-out plan. CCUS is the most practical option amongst scenarios to help Indonesia achieve its net carbon emissions target by 2060.

3.2. Malaysia

Malaysia has abundant resources capable of producing renewable energy for electricity generation. The introduction of renewable energy as the fifth fuel in 2001 is one of Malaysia's initiatives to ensure sustainable energy supplies and to meet the country's energy demand growth. Since then, the legal, regulatory, and financial framework was set up to realise the planned renewable electricity generation targets.

At present, the share of renewable energy in the national energy mix is about 2%, and the Government of Malaysia plans to raise it to 20% by 2025. ERIA's Energy Outlook and Energy Saving Potential in East Asia 2023 (Kimura, Phoumin, and Purwanto, 2023) suggests increasing this share target to at least 28% by 2030 and to maintain that share level to reach carbon neutrality by 2050. The main goal is to turn the current national energy mix into more renewable energy sources, not just for the sake of continuity of supply but also for the pressing environmental issues that arise from the use of fossil fuels. In this regard, the government has developed the energy policy over the years to ensure the electricity supply supports the rapid growth of the country's energy demand and efficiently utilises domestic natural resources. The energy transition in Malaysia became more environmentally friendly when, from 2000, there was a need to diversify energy supplies. The energy policy and strategies evolved gradually to solve climate change issues through the development of renewable energy. The mid-term review of the 11th Malaysian Plan 2016–2020 stated that the current priority of the energy policy was to match its strategic priorities outlined in the SDGs of the United Nations Development Programme.

Various policy instruments have been developed and used to promote the adoption of renewable energy technology in the power generation sector. Researchers in Malaysia have undertaken studies to analyse the effectiveness of green policy implementation to achieve the country's objectives and to meet the target of increasing the adoption of renewable energy. However, there has been insufficient research into the environmental factors that impact the effectiveness of implementing these policies. When formulating the current policy portfolio, it is, therefore, important to identify these environmental factors and study how they may contribute to the effectiveness of the policy implementation. This can also offer guidance on what needs to be done. With various renewable energy policies already adopted and others still under discussion, this publication offers information and feedback about the environmental factors that affect policy effectiveness. Decision makers can use it to implement, or possibly redesign policies.

In this study, the environmental factors affecting the technical efficiency scores of renewable energy development in Malaysia are determined by using a two-stage analysis. In the first stage, Malaysian renewable energy development efficiency scores are calculated using the data envelopment analysis method with three inputs: the number of employments, electricity consumption, and licensed renewable energy capacity, and two outputs: renewable energy generation and GDP. The second stage uses the Tobit regression analysis to investigate the relationship between the efficiency scores and environmental variables beyond renewable energy development control.

3.3. Thailand

The study on Thailand's EV policy in this report focused on its economic and GHG emission impacts. The authors employed a computable general equilibrium model to simulate the impact of the domestic expansion of EV production, reaching the proportion of 30% in the year 2030 and continuously growing in the later years. This scheme is a replication of the national EV promotion policy (the '30@30 plan'). The model includes 47 production sectors and 53 commodities. It also incorporates the representative of aggregate household, government, and the rest of the world. The details of fiscal structure comprise the main sources of fiscal income, which are direct tax, tariff, value-added tax, excise tax, and other indirect taxes. The fiscal revenue includes dividends earned from state-owned enterprises and other capital incomes. The mechanism of the recursive dynamic of this model is based on the capital accumulation process, enabling the inter-temporal relationship between investment and capital stock. The production and utilisation of EVs have been included in the constructed computable general equilibrium model.

The simulation results indicate that the 30@30 plan will boost real GDP and investment, while slightly increasing inflation and inducing a trade deficit. In particular, the substitution between internal combustion engine cars and EVs will initiate a change in household consumption patterns, allowing more consumption due to less expenditure on transportation. This change will subsequently create economy-wide impacts and will eventually lead to higher household income. This simulation outcome also indicates that GHG emissions will be reduced by approximately 8% during the period 2035–2040. However, the 30@30 plan will continuously incur a budget deficit because the lowered demand for internal combustion engine vehicles will decrease government revenue from excise tax, tariffs, and other indirect taxes. Notably, the simulation result identifies that the reduction of GHG emissions created by this EV policy is equivalent to the fiscal burden of \$55.2–\$82.6 per tonne of CO2. This cost-benefit ratio would be the criterion for comparing with other GHG reduction policies.

3.4. European Union

According to the EU Climate Law, Europe needs to achieve climate neutrality by 2050. For transport the EU's Sustainable and Smart Mobility Strategy aims to deliver a 90 % reduction in emissions from the transport sector by 2050. In recent years, with the Fit for 55 package and other policy initiatives, the EU has made substantial efforts to improve its existing legislation as well as to introduce new legislation for the decarbonisation of transport.

The chapter on the EU first presents a general overview of EU policies for the decarbonisation of transport. It then takes a deeper dive into the following pieces of legislation, discussing the main changes they entail for the future: (i) The EU Emission Trading System and its future extension to road transport, buildings, and additional industrial sectors, (ii) the related Social Climate Fund, (iii) the CO2 emission performance standards for cars, vans, and heavy duty vehicles and finally (iii) the Renewable Energy Directive and the new regulation for sustainable fuels in aviation. Based on the impact assessments they are expected to have a profound effect on the future environmental performance of the transport sector in the EU. In the future it will be important to regularly assess the progress and the economic and social impacts of the policies, to see whether they remain in line with the objectives.

3.5. Japan

Japan's energy transition, based on the latest GX policy, is analysed from an economic perspective taking as a case study, the carbon capture, CCUS technology for methanol production in Japan. The study for the Basic Guidelines on Climate Transition Finance was launched in 2021 to finance the GX Transition in Japan (METI, 2023).

The economic analysis reveals Japan's challenges with sustainable energy and regulations. In comparison to its Group of Seven (G7) counterparts, Japan faces hurdles to boost renewable energy adoption, improve energy efficiency, and reduce fossil fuel subsidies and this is hindering its transition to a sustainable, green economy. While all G7 countries ensure universal access to modern energy services, Japan exhibits higher energy intensity in its economy, pointing to potential inefficiencies in consumption and lower use of energy-saving technology. Japan's lag in renewable energy is striking. Despite supply growth, its total energy supply and consumption share remains below 10%, contrasting with its 2030 target of 36%–38%. Regulatory indicators show that Japan's renewable energy and energy efficiency policies are weaker than other G7 members, especially in network connections, incentives, and financing mechanisms. In addition, fiscal trends are worrisome. Government subsidies for fossil fuels, initially affected by the coronavirus disease (COVID-19), surged after 2021, reaching about 3.5% of GDP, the highest amongst G7 nations. This rise may hinder the shift to renewables and the green economy, potentially causing inefficient use of resources and environmental issues. Moreover, Japan's low government spending on research and development for environmental protection and taxes signals challenges in adopting renewable energy technologies and transitioning to a greener economy. These trends align with Japan's relatively lower share of renewable energy in its primary energy supply.

4. Lessons Learned: Insights from Global Climate Action with a Focus on the Association of Southeast Asian Nations

Global efforts to fulfil the commitment to the Paris Agreement have provided invaluable lessons in the fight against climate change. These lessons highlight the importance of international collaboration, flexibility, regular reviews, economic transformation, climate finance, and the science–policy interface. Here, we delve into these key areas, emphasising their relevance to the ASEAN region.

- **The importance of strategic planning and policy frameworks.** The experiences of ASEAN countries such as Indonesia, Malaysia, and Thailand underscore the critical role of strategic planning and robust policy frameworks to drive the green transition. Indonesia's coal phase-out plan and Malaysia's renewable energy policies exemplify the need for comprehensive energy transition strategies to set clear targets and pathways for decarbonisation (Kutani, Namba, and Phoumin, 2024).
- **Economic transformation is possible:** The growth of renewable energy and the implementation of carbon pricing in many countries demonstrate that economic systems can adapt to align with climate goals. These changes show that economic transformation towards sustainability is achievable, and that climate action can be integrated into economic development strategies. In ASEAN, countries such as Indonesia and Malaysia are already making strides in renewable energy adoption and sustainable finance.

- Economic and social impacts of energy transition and the need for inclusive and just transition. The transition to renewable energy and the phase-out of fossil fuels have significant economic and social implications. Indonesia's early retirement of CFPPs presents both economic costs and opportunities for economic restructuring. Similarly, Thailand's EV policy demonstrates the potential for economic growth and GHG emission reductions, while also highlighting the fiscal challenges associated with reduced government revenue from traditional energy sources. Indonesia's approach to providing welfare support during the coal phase-out and Thailand's focus on household consumption patterns in its EV policy are examples of efforts to achieve a just transition (Kutani, Namba, and Phoumin, 2024).
- Global cooperation is essential: The Paris Agreement has underscored the critical importance of international collaboration to tackle climate change. The near-universal participation of countries highlights a collective recognition of the global nature of this challenge. This cooperation is vital for sharing knowledge, resources, and technologies that can drive global climate action. For ASEAN, regional cooperation through initiatives such as the ASEAN Alliance on Carbon Market is crucial to leverage collective strengths and address shared challenges.
- Role of public and private sector collaboration: Effective collaboration between the public and private sectors is crucial to mobilise the necessary financial resources and expertise for the green transition. The growth of green bonds in ASEAN, driven by both public and private sector participation, underscores the importance of leveraging private investments to complement public funding. Malaysia's private sector-led green bond market exemplifies how private investments can drive sustainable finance (Kutani, Namba, and Phoumin, 2024).
- Flexibility enhances participation: The Paris Agreement has encouraged widespread participation by allowing countries to set their own targets through NDCs. This flexible approach accommodates countries' diverse national circumstances and capabilities, making it possible for all nations to contribute to global climate goals in a manner that aligns with their unique contexts. ASEAN countries, with their varying levels of development and economic structures, benefit from this flexibility, enabling tailored climate strategies.
- Climate finance is a key enabler: The emphasis on climate finance within the Paris Agreement has highlighted its crucial role in supporting developing countries' transitions to low-carbon economies. Adequate financial resources are essential for these countries to implement effective climate actions, and the mobilisation of climate finance has been a significant driver of progress. ASEAN countries, with their significant financing gaps, can benefit from innovative financial mechanisms and international support.
- Challenges of implementing carbon pricing and market mechanisms: There are challenges to implementing carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems in ASEAN due to varying levels of economic development and

institutional capacity. However, these mechanisms are essential for incentivising low-carbon investments and generating revenue for green projects. The experiences of developed markets, such as the EU's Emission Trading System, provide valuable insights for ASEAN countries in designing effective carbon pricing policies (European Commission, 2019a).

- Science–policy interface is crucial: The Paris Agreement's reliance on scientific assessments, particularly from the IPCC, underscores the importance of basing climate action on the best available science. This science–policy interface ensures that climate strategies are informed by robust and up-to-date scientific knowledge, enhancing their effectiveness and credibility. ASEAN countries can leverage regional scientific collaborations to inform their policies.

These lessons from the Paris Agreement provide a roadmap for future climate action, particularly for the ASEAN region. By embracing these insights, ASEAN countries can enhance their climate strategies, foster regional cooperation, and make significant strides towards a sustainable and resilient future.

5. Future Strategic Priorities in Climate Action for the Association of Southeast Asian Nations: Strengthening Policy and Regulatory Frameworks and Implementing Effective Climate Policies

ASEAN Member States must continue to bolster their policy and regulatory frameworks to support the green transition. While setting targets is important, the emphasis must now shift towards the concrete implementation of climate policies and measures at both national and local levels. Effective action on the ground is essential to achieve the desired climate outcomes. This includes developing robust implementation plans, building institutional capacities, and ensuring that policies are effectively enforced across ASEAN. Research from ERIA shows that setting clear and ambitious renewable energy targets, developing comprehensive energy transition plans, and implementing supportive policies such as subsidies for renewable energy projects and tax incentives for green investments is crucial (Kutani, Namba, and Phoumin, 2024).

- Promoting regional cooperation and knowledge sharing: Regional cooperation and knowledge sharing amongst ASEAN countries can accelerate the green transition by facilitating the exchange of best practices and lessons learned. Initiatives such as the ASEAN Plan of Action for Energy Cooperation and regional taxonomies for sustainable finance can help harmonise policies and standards, creating a more conducive environment for green investments (ASEAN, 2020).
- Enhancing public–private partnerships: Building on the success of green bonds and other sustainable finance instruments, ASEAN Member States should enhance public–private partnerships to mobilise additional financial resources for green projects. Governments can play a key role in de-risking investments through

blended finance mechanisms and by providing guarantees for private sector investments in renewable energy and other green technologies (Climate Policy Initiative, 2018).

- Fostering innovation and technology development: Investing in research and development for green technologies is essential for driving innovation and reducing the costs of renewable energy and other low-carbon solutions. ASEAN countries should prioritise funding for clean energy research and support the development of local green technology industries to enhance their competitiveness in the global market (Kutani, Namba, and Phoumin, 2024).
- Ensuring a just and inclusive transition: Policies and programmes aimed at ensuring a just and inclusive transition should be integral to the green transition strategies of ASEAN countries. This includes providing support for retraining and reskilling workers affected by the shift away from fossil fuels, developing social protection measures for vulnerable populations, and engaging local communities in the planning and implementation of green projects (UNEP, 2019).
- Leveraging international support and climate finance: ASEAN countries should actively seek international support and climate finance to complement domestic efforts to achieve their green transition goals. Engaging with multilateral development banks, international climate funds, and bilateral partners can provide access to additional financial resources and technical assistance for implementing ambitious climate policies (UNFCCC, 2018). The current programme of the Just Energy Transition Partnership in Indonesia, for example, is important to open wider international support for developing economies.

  Developed countries must fulfil and exceed their commitment to mobilise $100 billion annually for developing nations. Exploring innovative financing mechanisms will be essential to support the global transition to a low-carbon economy. Enhanced climate finance will enable ASEAN countries to implement ambitious climate actions and build resilience to climate impacts.
- Strengthening adaptation efforts: As climate impacts intensify, there needs to be a greater focus on adaptation strategies, particularly for vulnerable communities and ecosystems. Enhancing resilience to climate change is as important as mitigating its causes. Strengthening adaptation efforts will help ASEAN communities cope with the impacts of climate change and protect livelihoods and ecosystems.
- Investing in clean energy technologies: Continued investment in clean energy technologies, energy storage, and negative emissions technologies will be vital for meeting long-term climate goals. Innovation in these areas can drive significant progress in reducing emissions and enhancing energy efficiency. ASEAN countries can benefit from regional technology transfer and innovation hubs.
- Integrating climate goals with sustainable development: Future efforts should align climate goals with broader sustainable development objectives. This integration can create co-benefits for health, equity, and economic growth, ensuring

that climate action contributes to overall societal well-being. Integrating climate action with sustainable development will help ASEAN achieve multiple global goals simultaneously.

- Improving monitoring, reporting, and verification mechanisms: Improving mechanisms for monitoring, reporting, and verifying emissions reductions and climate finance will build trust and drive progress. Transparency and accountability are key to ensuring that commitments are met, and that progress is accurately tracked. Enhancing these mechanisms will strengthen the credibility and effectiveness of climate actions in ASEAN.
- Engaging non-state actors: Encouraging and recognising the contributions of cities, businesses, and civil society organisations can complement national efforts and drive bottom-up change. Non-state actors play a crucial role in advancing climate action at various levels. Engaging these actors will enhance the overall impact of climate initiatives and foster a more inclusive approach to climate action in ASEAN.
- Addressing loss and damage: As climate impacts worsen, increased attention and resources need to be devoted to addressing loss and damage in vulnerable countries. Providing support for these countries is essential for equitable climate action. Addressing loss and damage will help ensure that the most affected communities in ASEAN receive the assistance they need to recover and rebuild.

By learning from past experiences and adopting a forward-looking approach, ASEAN countries can effectively navigate the challenges of the green transition and build a sustainable, low-carbon future that benefits all segments of society.

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Chapter 2

Financing The Green and Just Energy Transition: Green Fiscal Policy for Just and Fair Transition to a Green Economy

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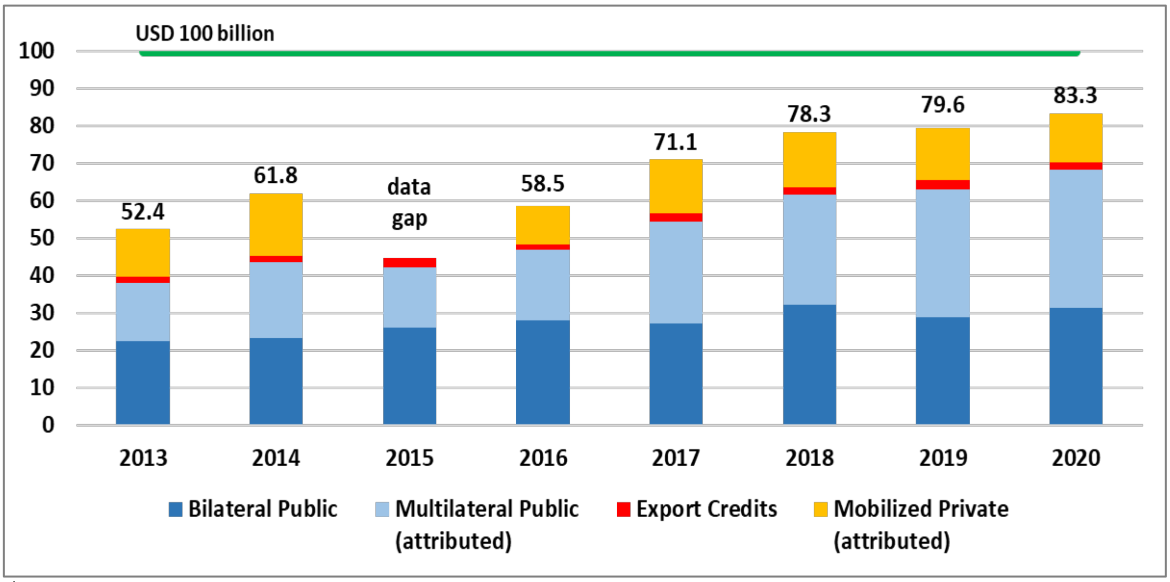
1. Introduction

1.1. Background

Green practices are essential to reduce environmental effects, adapt to climate resilience, save the planet, and improve quality of life. The amount of effort and sacrifice required from all nations worldwide to achieve this is challenging. Leaders of emerging economies demand that rich countries provide real financial contributions to reduce carbon emissions, reasoning that it is easier for advanced economies to adopt green transitions than emerging economies. These leaders are also critical of the demands of rich countries that emerging economies should contain their carbon emission rates. In parallel, development finance patterns are shifting from general funds to earmarked funds, and bilateral official development assistance is more common than multilateral assistance.

At the 15th Conference of the Parties of the United Nations Framework on Climate Change Conference (UNFCCC) in Copenhagen in 2009, developed countries committed to a collective goal of mobilising $100 billion a year for less wealthy nations by 2020 to help them adapt to climate change and mitigate further temperature increases. Regrettably, the funding promise was violated. The mobilisation of private climate finance was lower than anticipated (Figure 2.1) and mostly took place in middle-income countries with relatively conducive enabling environments and relatively low-risk profiles. The Organisation for Economic Co-operation and Development (OECD) reported that the amount was only $7.6 billion in 2019, including $14 billion from the private sector. Also, the multilateral development banks only committed $66 billion in 2020 with $38 billion to low-income and middle-income economies to support climate finance (OECD, 2022). Therefore, in anticipation that this trend will persist, emerging economies should investigate alternative sources of financing.

Figure 2.1. Aggregate Trends of Climate Finance Provided and Mobilised by Developed Countries
($ billion)



$ refers to US dollars.
Source: OECD (2022).

With the increasing concern about the threat of climate change amongst all nations, Indonesia continues to design a strategic plan to contribute substantially to addressing climate change issues. At COP26 in Glasgow in 2021, Indonesia signed the Global Coal to Clean Power Transition Statement agreeing to accelerate the net zero carbon emissions target by 2060. The Indonesian Ministry of Energy and Mineral Resources (MEMR) is examining opportunities for the early retirement of coal-fired power plants (CFPPs) (later known as the 'Coal Phase-Out' plan) with a total capacity of 9.3 gigawatts (GW) before 2030[1], which can be accomplished with a total of up to $48 billion in funding support. Specifically, the coal phase-out plan will be split into two schemes: 5.5 GW without a replacement for a renewable energy facility and 3.7 GW with a renewable energy replacement facility. The plan is referred to in Presidential Regulation Number 112 of 2022, on Accelerated Development of Renewable Energy for Electrical Supply (PR 112/2022). It states that the coal-based power plants (CFPP) will operate no later than 2050 while simultaneously fostering the development of renewable energy.

Although deciding not to be bound to stop issuing new licences, subject to special conditions, or to stop constructing CFPPs that do not use carbon capture and storage technology (i.e. unabated coal-fired power plant), Indonesia has shown determination to

[1] The Institute for Essential Services Reform estimates in IESR, Agora Energiewende, and LUT University (2021) that Indonesia must shut down CFPPs with a total capacity of 10.5 GW before 2030 (1.2 GW higher than the government's initial plan), to meet the Paris Agreement's 1.5°C global average temperature target.

take progressive steps toward decarbonising the energy sector and to promoting an equitable energy transition by expanding the use of renewable energy to offset the phasing out of CFPPs, thereby reducing the nation's vulnerability to future worldwide environmental crises, both in terms of risk and severity.

With cooperation from the Government of Indonesia's (GoI) Ministry of Finance and Ministry of State-Owned Enterprise, the National Energy Council and the MEMR are preparing a comprehensive road map and energy transition strategy in Indonesia. The primary objective is to progressively reduce reliance on fossil fuels (especially coal) while simultaneously expanding the capacity of renewable energy sources and maximising energy efficiency. The focus of the policy is to make renewable energy the primary option, thereby reducing the dependency on coal over time.

It is noteworthy that the implementation of the coal phase-out plan is complex to execute as it forces the GoI to decide between pursuing higher growth opportunities or prioritising environmental protection. In its latest update to the 2025–2045 National Long-Term Development Plan, the GoI has restated its ambition to achieve the targets set out in the Golden Indonesia 2045 Vision. Indonesia aims to escape the middle-income trap by 2041 through achieving an average national economic growth rate of 6%–7% per year from 2025, reaching a gross national income level of $23,000–$30,300 in 2045. This would be on a par with developed countries, reducing the poverty rate to less than 1%, and decreasing income inequality. To realise that vision, Indonesia needs to optimise all available resources, including abundant and comparatively low-cost fossil energy sources. According to the MEMR, coal contributed the most to the provision of primary energy in Indonesia in 2020 (38.46%), followed by oil and liquefied petroleum gas (32.82%), natural gas (17.44%), liquefied natural gas (11.28%), biofuel (3.8%), hydropower (3.16%), other renewable energy (2.11%), geothermal (2.01%), wind power (0.08%), solar power (0.05%), and biogas (0.01%). In short, the coal phase-out plan may require Indonesia to sacrifice a once-in-a-lifetime opportunity to achieve the country's 2045 vision. This is economically costly.

On top of that, the coal phase-out is financially costly to put into practice. The decision to implement the CFPP early retirement programme will necessitate significant funding from numerous parties. The GoI indicated that if completed before 2030, the early retirement of 5.5 GW CFPP and its replacement with a renewable energy facility will cost $25–$30 billion. In addition, the cost of investing in renewable energy and other forms of sustainable energy is estimated to be between $20–$25 billion per year until 2030 and will continue to rise thereafter. This increases the cost burden required to implement the coal phase-out plan and to develop renewable energy to achieve the goals stated in PR 112/2022 by 2050.

Indeed, the sooner the coal phase-out plan is implemented, the greater the GoI's opportunity to avoid the risk of financial losses from stranded assets in the CFPP sector, which is estimated to reach $26 billion after 2040. However, bringing forward the closure of CFPP was conditional on receiving sufficient financial help from multilateral institutions, the private sector, and developed countries to build new capacity into the renewable energy sector while ensuring electricity remains affordable when it switches to renewable sources. Only development partners, governments, and private sector operators from countries with a good reputation for addressing climate change will be considered for the blended green finance funding required for the coal phase-out plan.

Given this situation, it is necessary to assess the impact of implementing the coal phase-out plan in Indonesia in terms of economic cost. Few studies in recent years have estimated the costs required to implement the plan to phase out coal in Indonesia, and those studies that have been conducted have restricted the scope of the estimation to financial cost calculations. Assessing the economic impact is important because the cost burden of the coal phase-out plan is certainly greater than the aggregated calculations of the financial costs associated with closure, replacement, or investment in renewable energy. From a microeconomic standpoint, the coal phase-out plan could significantly affect the welfare of economic agents (i.e. households and firms). Filling in the cost calculation gap can provide a solid basis for formulating appropriate compensation policies (i.e. fiscal policies) in response to the implementation of the coal phase-out plan.

This study will assess the potential economic costs or losses that may result from the implementation of the coal phase-out plan and will produce long-term economic projections based on alternative scenarios to keep Indonesia's commitment to decarbonising the energy sector as realistic as possible. An empirical approach will be used to investigate how the coal phase-out plan may affect consumers (households) and producers (manufacturing firms), as well as the regulator of the public sector (government) using the following key measures: (i) changes in households' welfare, (ii) changes in firms' investment return, and (iii) changes in government tax revenues.

Recognising the need for large amounts of funding to implement the coal phase-out plan, as well as the fact that climate financing cannot be solely reliant on funds provided by international development partners that are less than what was promised, the GoI needs to take immediate action to anticipate the economic costs or losses associated with the coal phase-out plan. Designing an adequate fiscal policy framework that eases the just energy transition and accelerates the stages of the coal phase-out plan could be an essential first step. Hence, the analysis results of the economic losses calculation should be followed by proposed recommendations for fiscal policy options, adjusted to the most realistic scenario, with the objective to compensate for the negative effects of the coal phase-out plan on people and businesses.

In terms of fiscal policy discussion, this study will focus on how to innovate government spending and revenues with an emphasis on creating incentives for transitioning to a greener economy (e.g. lowering taxes on capital goods expenditures). Because of the broad range of green-oriented fiscal policies, the study will limit the scope of fiscal policy options discussed to those that intersect with areas of manufacturing firms' business investment, government taxes and subsidies, and households' income and consumption in relation to the coal phase-out plan. Finally, this study will analyse challenges and barriers to adoption of those proposed green fiscal policy options in Indonesia.

1.2. Research Objectives

The study has two research objectives. The first objective is to assess the economic impact of the operation of CFPPs and the economic losses caused by the coal phase-out plan's implementation. The second objective is to design feasible green-towards fiscal policies to compensate for, and finance, a rapid coal phase-out and just energy transition.

1.3. Research Contributions

This study provides two contributions. First, a well-documented policy framework for supporting the implementation of green and just energy transition in Indonesia is established. Second, we provide empirical evidence to advocate for a more pragmatic approach to implementing a coal phase-out strategy.

2. Policy Context

2.1. Coal Phase-Out Worldwide

Coal transition began in 2015, when the United Kingdom (UK) became the first government to implement a coal phase-out strategy, putting out the plan ahead of the 2015 Paris climate summit.

However, the concept of coal phase-out has garnered significant traction amongst nations worldwide in the last few years, due to growing concern about climate change and its adverse environmental impact. All the scenarios prescribed by the Paris Agreement to achieve the 1.5 degrees Celsius temperature rise limit necessitate a swift reduction in coal consumption (International Energy Agency, 2021a). According to estimations from the International Energy Agency, unabated coal usage in the global energy sector must decline by 55% by the year 2030 and be completely phased out by 2040 to achieve carbon neutrality by 2050 (International Energy Agency, 2021b).

There is a notable upsurge in the global impetus toward coal phase-out. During COP26, a resolute commitment was made to relegate coal power to the annals of history. This commitment was exemplified by 47 nations signing the Global Coal to Clean Power Transition Statement, accompanied by 11 countries, including Indonesia, announcing fresh phase-out pledges. These Glasgow Breakthroughs have been embraced to ensure that clean power emerges as the most cost-effective and dependable alternative for all countries to meet their power requirements efficiently by 2030.

The consequences of coal phase-out are something that many countries need to consider. It impacts the economy in several ways, including triggering a decline in economic activities (Trencher, et al., 2022), jobs losses (Burke, Best, and Jotzo, 2019; ILO, 2022; Vogt-Schilb and Feng, 2019), and damaging social-cultural identity (McDowall, 2022). The impact will be more severe in those areas which are dependent on coal for their economic activities. Unstable coal prices could create severe economic problems for those areas that are reliant on coal, and it could create problems of stranded assets for the power sector (Gray et al, 2018). Thus, every country needs to prepare an enabling environment before deciding to implement a coal phase-out policy.

Several countries, such as Canada, Germany, and the UK, have successfully implemented a coal phase-out policy that includes policy measures to mitigate the cost of phasing out coal from the economy. In addition to strategies that all of the countries implemented, fiscal policy was one of the enablers for success, ensuring the transition was smooth. The fiscal policies of Canada, Germany, and the UK are shown in Table 2.1.

Table 2.1. Fiscal Policy for Coal Transition from Benchmarking Countries

Countries	Fiscal Policy Measures
United Kingdom	▪ Carbon tax ▪ Compensation for ex-miners and community (training and jobs opportunity outside mining) ▪ Reclamation ▪ Infrastructure investment
Germany	▪ Compensation payment for power plant ▪ Social security for employee ▪ Subsidy for grid charge after 2023
Canada	▪ Carbon tax ▪ Compensation for coal power companies to develop gas and renewable energy power plant ▪ Support for workers (pension bridge, training, counselling, etc.)

Source: Compiled from Brauers, Oei, and Walk. (2020), Macintyre (2014), Fothergill (2017), Littlecott, Uise Burrows and Skillings. (2018), Oei et al., (2020), Agora Energiewende and Aurora Energy Research (2019), Keles and Yilmaz (2020), and Krawchenko and Gordon (2021).

The coal phase outs in Canada, Germany, and the UK yield insightful lessons that demonstrate the intricate nature of such endeavours, highlighting the range of forces at work, including environmental imperatives, economic realignments, and regulatory initiatives. A salient lesson is the indispensability of a holistic approach that embraces robust stakeholder engagement, well-structured policy frameworks, nuanced mitigation strategies for adversely affected communities, and judiciously adjustable temporal frameworks. Effective communication strategies that explain the rationale and growing benefits of the policy, alongside international collaboration and cross-learning, also increase efficacy. The importance of significant investment in innovative solutions, research, and steadfast long-term planning is pivotal, and reinforces the complex and interwoven fabric that characterises coal phase outs and their intricate socioeconomic ramifications.

The Russia–Ukraine conflict has become one of the major hurdles to implement the coal phase-out agenda. The conflict creates additional concerns about energy security for countries in the European Union while opening opportunities for fossil fuel producing countries. The conflict has meant that Russia, previously the leading supplier of natural gas, coal, and oil to the European Union countries, has disturbed the energy market, leading to energy security issues for many European countries. Germany, for instance, who had a clear commitment to phase out coal by 2038 has sought alternative sources of energy than Russia's natural gas by reviving two coal power plants, while the Czech Republic has revived their coal mining activities for energy security[2]. The situation has also opened opportunities for coal producing countries to continue their activities as there are potential buyers for the coal. Thus, the coal phase-out plans of several coal producing countries may be in jeopardy if they are not supported by ambitious renewable energy.

2.2. Coal Phase-Out in Indonesia

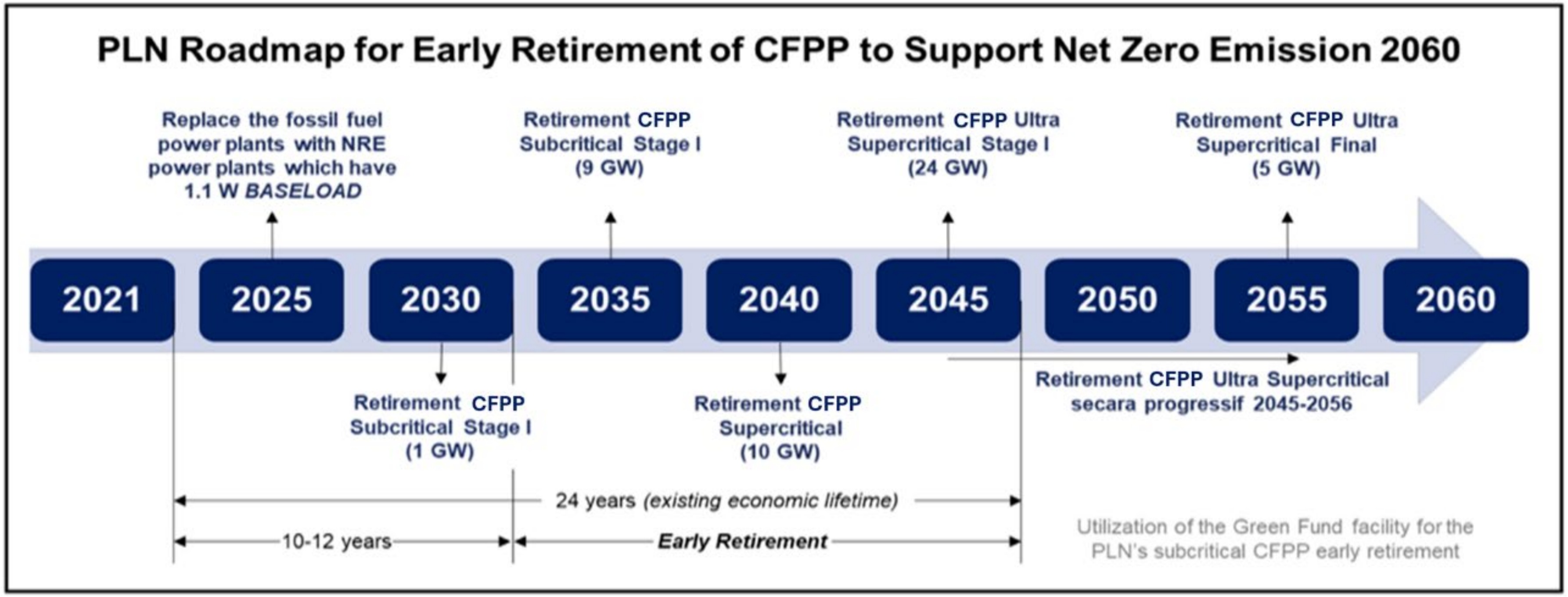
In 2021, President Joko Widodo announced a net zero emission target of 2060 and ordered the state electricity company, *Perusahaan Listrik Negara* (PLN), to stop building new coal plants outside of the projects agreed in the 2021–2030 *Rencana Usaha Penyediaan Tenaga Listrik* (Electricity Supply Business Plan). At COP26, Indonesia also agreed to the Global Coal to Clean Power Transition Statement, which contains a pledge to move away from sustainable coal power generation by the 2040s or sooner. Later in 2022, the government announced the Indonesia Energy Transition Mechanism (ETM) Country Platform, and the Just Energy Transition Partnership (JETP) — a commitment to mobilise $20 billion in public and private capital to reach peak electricity sector emissions in 2030 and reach net zero in 2050. In the same year, the government also released PR 112/2022. Its provisions for the acceleration of the delivery of renewable energy to produce electricity has become the legal basis for the government's support for the coal phase-out initiatives.

Indonesia is the 7th largest nation in terms of the number of CFPPs deployed (Cui et al.,

[2] Euronews.green (2022).

2022), boasting a current operational count of approximately 86 CFPPs, collectively yielding an installed capacity of 40.2 GW as of 2022 (MEMR, 2023). Predominantly concentrated within the Java, Bali, and Sumatra regions, these operating CFPPs produce a substantial surplus capacity in relation to historical benchmarks and precedent standards. Given this, careful consideration should be given to curtailing or deferring new generation capacity until there has been a resumption of load growth to pre-pandemic levels. This is anticipated to materialise around 2029–2030 (Fiscal Policy Agency, 2023). In response, there has been a collaborative effort between the MEMR and PLN, culminating in the development of a comprehensive retirement strategy for these power plants. Characterised by a phased approach, PLN's preliminary scheme envisions the phased retirement of an initial 1 GW of power plants before 2030, followed by a series of subsequent retirements extending until 2055, culminating in the decommissioning of the final unabated CFPP. This intricate trajectory aligns with Indonesia's aspirations to achieve its net zero emission 2060 targets (Figure 2.2).

Figure 2.2. State Electricity Company Pathway for Coal Fired Power Plant Early Retirement



CFPP = coal-fired power plant; GW = gigawatt; NRE = New and Renewable Energy; PLN = State Electricity Company - *Perusahaan Listrik Negara*.

Source: Fiscal Policy Agency (2023).

2.3. Fiscal Policy Instruments

Coinciding with COP26 in 2021, President Joko Widodo took a significant step by signing Presidential Regulation No. 98/2021 on The Implementation of Carbon Pricing to Achieve the Nationally Determined Contribution Target and Control over Greenhouse Gas Emissions in the National Development (PR 98/2021). This regulation focuses on the carbon economic value for achieving nationally determined contribution targets and for controlling greenhouse gas (GHG) emissions. It is widely recognised that this regulation will play a pivotal role in helping Indonesia reach its GHG emission reduction targets, as outlined in the Nationally Determined Contribution (NDC) for climate control. Moreover, the regulation, known as the Carbon Economic Value Presidential Regulation, is expected to serve as a catalyst for increased funding and investment in initiatives that promote environmentally friendly practices, ultimately leading to a reduction in GHG emissions.

PR 98/2021 lays out the government's strategies for deploying economic tools to both mitigate climate change and adapt to it. A notable instrument is the Tax Regulation Harmonization Law, known as Law No. 7 of 2021. The introduction of the carbon tax is designed to incentivise economic entities to shift towards low-carbon green economic activities or to decrease their emission outputs. The carbon tax is set to be implemented from 2025, initially targeting the CFPP sector through a cap-and-tax emission-based taxation mechanism. The stipulated tax rate stands at a minimum of Rp30 or around $2 per kilogram of carbon dioxide (CO_2), in accordance with the provisions outlined in Law No. 7 of 2021 concerning Tax Regulation Harmonization.

3. Empirical Results

3.1. Impact of Coal-Fired Power Plants on Economic Development

This section presents the results of the empirical estimation of the impact of operating CFPPs on economic development from a macro-level perspective and discusses the implications of the findings. The results will serve as a benchmark before predicting the impact of CFPPs at micro level, i.e. on households and manufacturing firms.

Tables 2.2 and 2.3 show compact estimation results of the impact of operating CFPPs on gross domestic product (GDP) at the provincial level in Indonesia in the period 1976–2022, examining four specifications and using level and log transformations of GDP as a measurement indicator, respectively. As the numbers of the provincial GDP have been proportionally weighted to be comparable with the national GDP, it is argued that the estimated coefficient can also be indicative of the national level to some extent.

Table 2.2. Impact of Operating Coal-Fired Power Plants on Growth Rate

Independent Variables	Dependent Variable: Provincial GDP (log)			
	(1)	(2)	(3)	(4)
Presence of CFPP	1.336***	1.029***	-0.009**	-0.014**
(1 if implemented, 0 otherwise)	(0.076)	(0.088)	(0.005)	(0.005)
Control variables	No	Yes	Yes	Yes
Fixed effects for regions	No	No	Yes	Yes
Fixed effects*linear trends	No	No	No	Yes
Adj. R-square	0.166	0.190	0.999	0.999
Observations	1536	1536	1536	1536

CFPP = coal-fired power plant; GDP = gross domestic product.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses.
Source: Authors' calculation (2023).

Column 1 in Tables 2.2 and 2.3 records results from the unconditional staggered difference-in-differences (DID). Column 2 considers control variables for the number of active CFPPs in operation and their characteristics, for example: the accumulated capacity of electricity generated by CFPPs, the combustion technology used by CFPP, heat rates, capacity factors, emission factors, annual CO_2 production, and the CFPP's lifespan. Other relevant variables are included such as the population level, the GDP ratio of the agricultural sector to the manufacturing sector, the classification of eastern–western zones, the number of provinces that rely on coal extraction, and the year of economic decentralisation and regional proliferation. All variables are measured at the provincial level. Several dummies that historically caused economic disturbances (e.g. the Asian Financial Crisis 1997–1998, the Global Financial Crisis 2007–2008, and the coronavirus disease (COVID-19) pandemic, are also incorporated into the model. Column 3 presents the results of the regression accounting for fixed effects for years and provinces. Column 4 includes region-specific linear trends to account for possible systematic differences in trends across regional–distribution service offices pairs defined by PLN. In particular, when the dependent variable is in logarithmic form as presented in Table 2.3, the effect of the CFPPs is represented as a percentage change by $100(e^{\beta}-1)$.

The estimation results in Table 2.2 provide an interesting finding. The unconditional staggered DID estimates a positive effect of approximately $14.5 billion on GDP level which statistically differs from zero. In terms of log GDP, the effect is quantified as a point estimate of 1.34.

Table 2.3. Impact of Operating Coal-Fired Power Plants on Gross Domestic Product

Independent Variables	Dependent Variable: Provincial GDP ($ billion) (1)	(2)	(3)	(4)
Presence of CFPP	14.470***	4.952**	-9.460***	-3.440***
(1 if implemented, 0 otherwise)	(1.791)	(2.031)	(1.676)	(1.212)
Control variables	No	Yes	Yes	Yes
Fixed effects for year and province	No	No	Yes	Yes
Fixed effects for regional*linear trends	No	No	No	Yes
Adj. R-square	0.040	0.089	0.693	0.914
Observations	1536	1536	1536	1536

$ refers to US dollars; CFPP = coal-fired power plant.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses.
Source: Authors' calculation (2023).

Nevertheless, both estimates are overestimated since adding more controls and fixed effects provides lower estimates. Column 2 controls for time-variant covariates, providing lower estimates by one-third (i.e. seven-tenths in logarithmic form). One possible explanation is that the time-variant provincial characteristics correspond to the likelihood of being part of the CFPPs but tend to increase the economic output. Column 3 adds year and province to capture time-specific shocks and time-invariant differences, respectively. Surprisingly, the inclusions alter the previous estimates in Columns 1 and 2, with the estimated effect indicating the opposite direction and resulting in a relatively smaller effect. It suggests that the presence of active CFPPs is likely to have a negative relationship with GDP level. The point estimate is statistically significant at the 5% level.

At this point, interpretation should be taken with caution because the DID regression model provides a quasi-experimental setting that employs longitudinal data from treatment and control groups to produce an appropriate counterfactual condition in estimating the causal effect. Instead of asserting that the presence of CFPPs would lead to a decrease in the GDP level, it is more acceptable to explain that GDP will grow further but will result in higher reported figures in the absence of CFPPs operation.

Finally, the last column adds regional–distribution service specific linear time trends, resulting in an adjustment to a reduced point estimate. The active CFPPs operation is now associated with a lower GDP level by an average of 1.4% or roughly equivalent to a $3.44 billion reduction per year at 2010 constant prices, *ceteris paribus*, serving as our baseline estimate. In comparison to the realised GDP level of Indonesia (2022) in a constant local currency price unit, the estimated impact contributed by CFPPs operation in a specific province will result in a proportionate number of 0.26% of national GDP.

Further, presuming that the CFPP locations are currently expanding to 27 out of 34 provinces, the total annual impact on average would be predicted to reach $92.88 billion per year. The figures are proportional to 7.13% of Indonesia's real GDP in 2022.

There are several explanations for the empirical results. First, in the long run, operating CFPPs will significantly increase GHG emissions (e.g. CO_2 and methane) and will contribute to global warming and climate change through more frequent and severe natural disasters that damage ecosystems and infrastructure, disrupt economic activities, and increase human suffering. All of these, in turn, can reduce economic growth. Various economic sectors (e.g. agriculture, fisheries, tourism, health, and infrastructure) may be negatively impacted by climate change. More large-scale carbon emissions emitted by the CFPPs also trigger rising temperatures, which can increase the risk of drought since at higher temperatures, water dissipates more rapidly resulting in dryer soil. Dryer soil will lower crop yield output and livestock productivity, and these effects can reduce income, exacerbate poverty, reduce growth in the agriculture sector, as well as other specific economic sectors with stronger backward and forward linkages to this sector, and ultimately will have a negative impact on national welfare and economic development.

Second, CFPPs can reduce GDP growth by harming the environment and human health. Producing pollutants such as particulate matter, sulphur dioxide, nitrogen oxides, and mercury can cause respiratory diseases, cardiovascular problems, neurological disorders, and premature deaths. The health and environmental costs of coal pollution can reduce GDP by lowering human productivity, increasing health expenditure, and degrading social welfare (Rokhmawati et al, 2023).

Finally, the CFPPs influence GDP because they can impede investments in cleaner and more efficient energy sources, including renewable ones. CFPPs rely on a limited, non-renewable resource that is susceptible to coal price fluctuations due to changes in demand and supply, geopolitical factors, and environmental regulations. These variables can increase the price of coal-based electricity generation and create uncertainty for investors and consumers. On top of that, CFPPs have high capital costs and long lifetimes, which lock in carbon-intensive infrastructure for decades. CFPPs can reduce the flexibility and resilience of the power system to cope with changing demand patterns and limit the potential for economic diversification and technological innovation in low-carbon sectors.

The rationale for the results of the estimation is consistent with prior research. CFPPs will have a positive impact on the ratio of GDP-to-investment cost (Hartono et al., 2020) but it will still be less than renewable power plants such as geothermal, wind, and hydro energy. Moreover, the results are consistent with previous research on the effects of carbon dioxide emissions on economic growth. For instance, Dong, Xu, and Fan (2020) demonstrated a long-term equilibrium relationship between industrial structure upgrading, economic growth, and carbon emissions – in which an increase in carbon emissions will restrict the promotion of industrial structure upgrading and have a detrimental impact on economic growth. The results are also supported by Narayan and Narayan (2010) who found that the country's long run income elasticity is smaller than the elasticity in the short run and found that the long-term impact of CO_2 emissions reduces developing countries' economic growth as their income elasticity in the long-term is less than in the short-term.

However, this study acknowledges a limitation caused by the presence of spatial spillover effect which may cause a potential bias in estimation. Emissions produced by CFPPs can exceed inter-regions because they are not confined by provincial boundaries. The pollutants can travel across the atmosphere and affect the climate of other provinces or the larger region. Hence, the estimated coefficient could be underestimated at the province level. However, as the provincial GDP is weighted to the national average, the potential bias of aggregate impact can be minimised and is still within acceptable ranges.

3.1.1. Heterogeneity Analysis

To gain a deeper understanding of the estimation results, the benchmark specification (last column in Tables 2.2 and 2.3) is employed on different subsamples based on the setting of emission standards for CFPP in the Association of Southeast Asian Nations (ASEAN) region (Nian, Kresnawan, and Suryadi, 2021). The purpose is to observe the different effects of the CFPPs on economic levels and growth in each subsample which are categorised into two divisions: (i) subcritical CFPPs, and (ii) non-subcritical CFPPs which includes supercritical and ultra-supercritical types.

Table 2.4 reports the estimates, revealing consistent estimates of coefficients but differing size of magnitudes between subsamples. The characteristics are twofold. First, both in terms of GDP level and log GDP, the subcritical CFPPs have a larger estimated impact compared to the non-subcritical CFPPs. The results align with the fact that subcritical CFPPs are less efficient and generate more emissions than their supercritical and ultra-supercritical counterparts. Second, the effects statistically differ from zero, except for the non-subcritical CFPPs subsample. This finding emphasises the disadvantages of using subcritical CFPPs that are associated with less advanced technology.

Table 2.4. Estimated Impact on Economic Level and Growth (Subsamples) of Operating Coal-Fired Power Plants

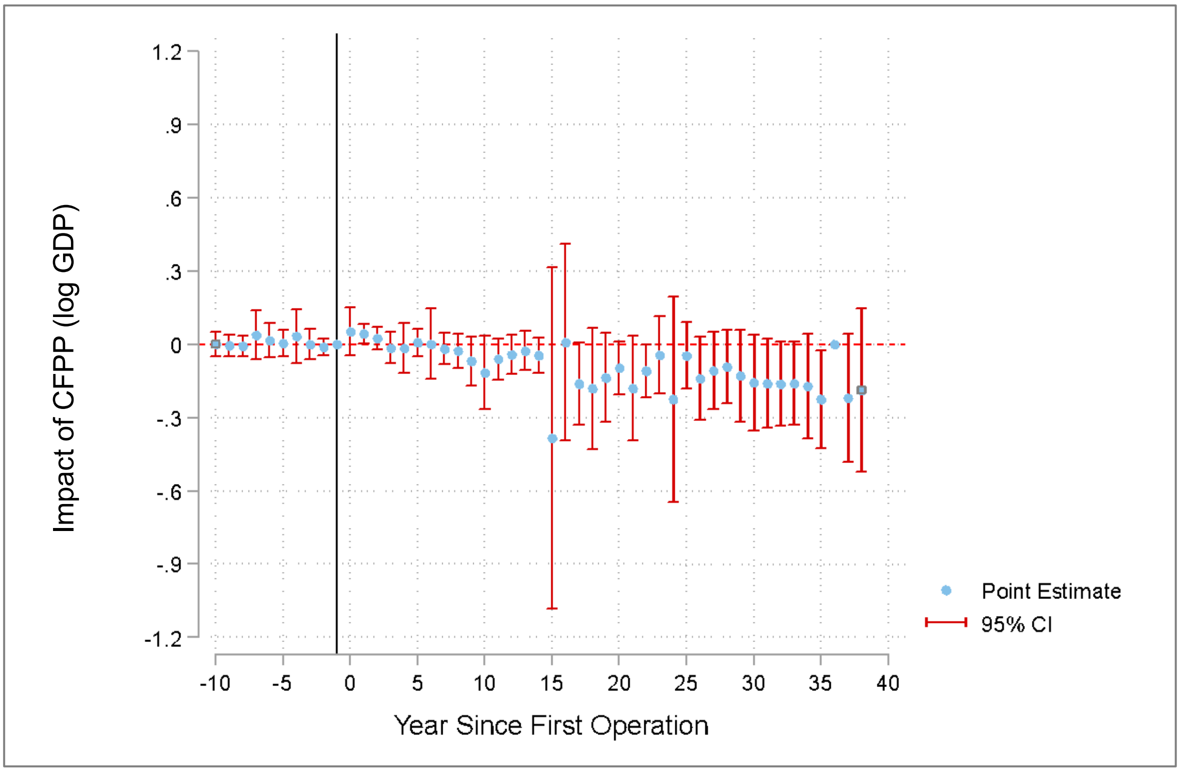
Independent Variables	Dependent Variable: Provincial GDP			
	GDP Level ($ billion)		Log GDP	
	Only Subcritical	Excluding Subcritical	Only Subcritical	Excluding Subcritical
	(1)	(2)	(3)	(4)
Presence of CFPP	-4.125***	-2.835	-0.023***	-0.012
(1 if implemented, 0 otherwise)	(1.284)	(1.909)	(0.005)	(0.008)
Control variables	Yes	Yes	Yes	Yes
Fixed effects for regions	Yes	Yes	Yes	Yes
Fixed effects*linear trends	Yes	Yes	Yes	Yes
Adj. R-square	0.914	0.914	0.999	0.999
Observations	1520	1588	1520	1588

$ refers to US dollar; CFPP = coal-fired power plant; GDP = gross domestic product.; US = United States.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses.
Source: Authors' calculation (2023).

3.1.2. Dynamic Treatment Effects

The structure of the dataset used in this study allows for an examination of the dynamic treatment effects of the presence of CFPPs activities. Figure 2.3 presents these effects over time. The results indicate that the effects on GDP were positive in the short run but tended to be negative in the long run with the magnitude of the effects growing over time.

Figure 2.3. Event Study Analysis: The Dynamic Effect of Coal-Fired Power Plants on Economic Development



CFPP = Coal-fired power plant; CI = Confidence interval; GDP = Gross domestic product.
Source: Authors' calculation (2023).

The full sample estimate shows that the effect ranges from 2.4% to 5.2%, which is statistically significant at the 5% level for the first three years since the CFPPs have been fully operational. After the third year of operation, point estimates are toward negative values but statistically not different from zero. On average, the effect becomes statistically significant at the 10% level when the CFPPs have been in operation for 17 years. A plausible explanation for why the impact is likely to revert to an upward trend in some periods of observation could be the establishment of new additional CFPPs in the respective locations which can balance the diminishing benefits of existing units. However, the overall trend of the dynamic effect of CFPPs on economic development is decreasing. This result suggests that the economic benefits of CFPPs as an alternative energy source for electricity generation cannot be maintained for a prolonged period unless technological advancements can improve efficiency and manage the negative externalities (Raihan et al., 2023). The figure also reveals that the parallel trend, an important assumption for the DID regression model, is likely to hold. An anticipatory effect is undetected since the point estimates for the lead term are statistically insignificant (i.e. *p*-value is 0.4222).

The result also suggests that the dynamic effect is heterogeneous across CFPPs and more evident for subcritical CFPPs subsample. Figure 2.4 suggests that the downward trend of dynamic estimate for subcritical CFPPs declines faster than the non-subcritical group. This finding raises concerns regarding the issuance of a CFPPs establishment and operation licence permit, in which the public policy stakeholder should take the minimum technological aspect of CFPPs into account. Last, the dynamic effect results broadly validate our baseline findings that the negative effect of CFPPs on economic development continues to grow over time.

Figure 2.4. Event Study Analysis: The Dynamic Effect of Coal-Fired Power Plants on Economic Development

(a) Subcritical Coal Fired Power Plant Subsample

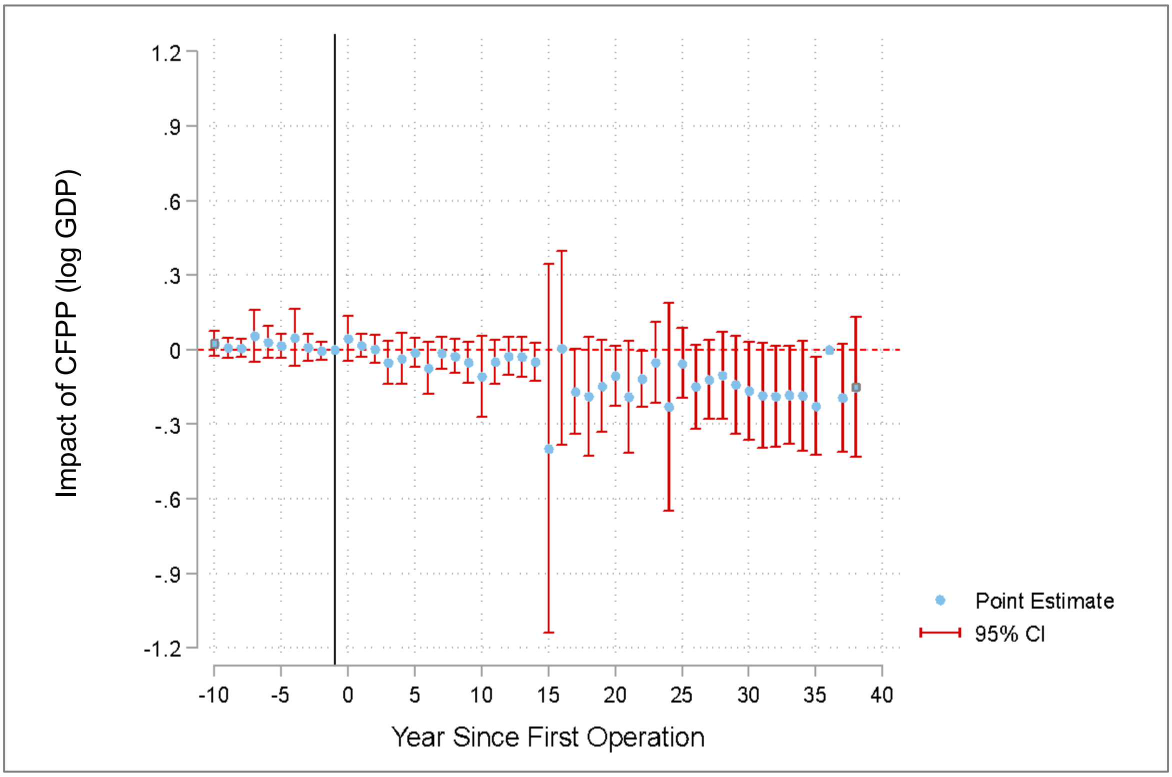
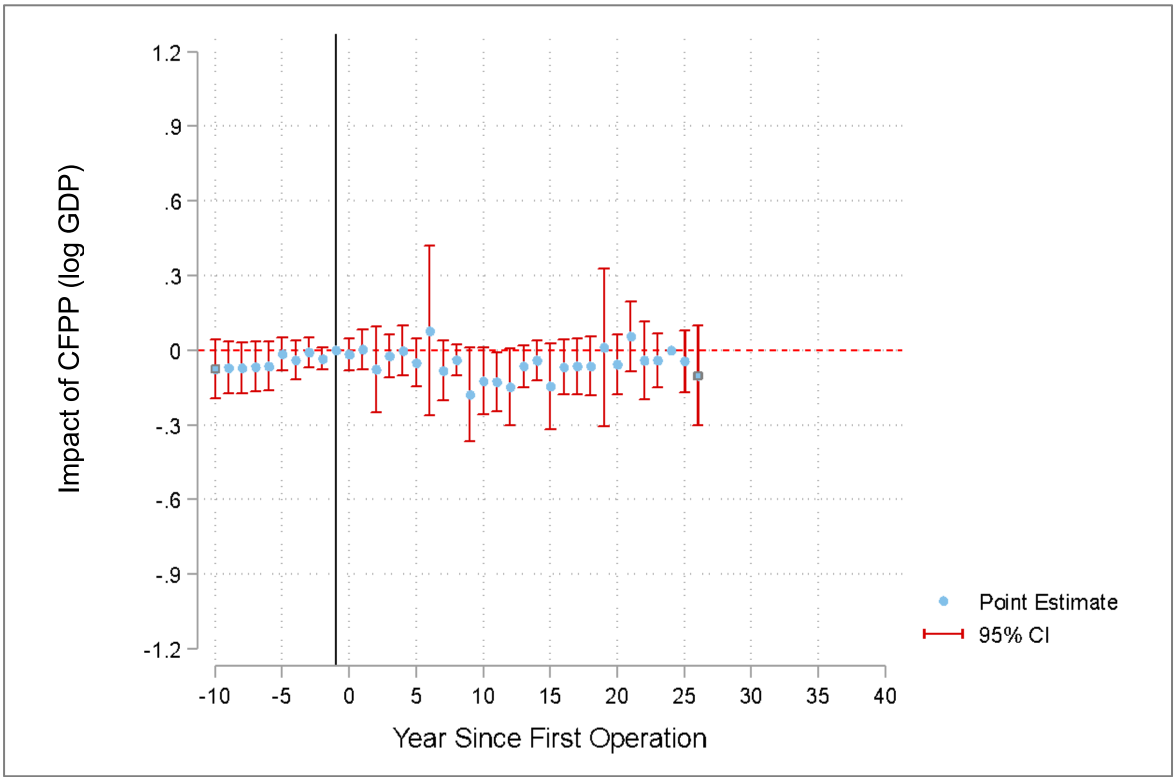


Figure 2.4. *Continued*

(b) Supercritical and Ultra-Critical Coal Fired Power Plant Subsample



CFPP = Coal-fired power plant; CI = Confidence Interval; GDP = Gross domestic product.
Source: Authors' calculation (2023).

3.2. Impact of Coal-Fired Power Plants on Households

This section discusses the estimation results of the presence of CFPP on household expenditure. Table 2.5 shows the results of estimating household expenditure indicators, based on the presence of CFPPs, at household level for the period 2011–2022, examining four different specifications. It also considers average monthly household expenditure and its logarithmic forms as outcome variables, respectively. Column 1 presents the unconditional staggered DID. Column 2 adds control variables including average household size, percentage of household heads with high school diplomas or higher, percentage of household heads working in the formal sector, and percentage of gross regional domestic product (GRDP) from the mining sector. Column 3 adds district and year fixed effects. Column 4 includes district-specific linear trends. In Panel B, as the dependent variable is in logarithmic scale, we can interpret the resulting coefficients as the percentage change in the monthly household expenditure.

Table 2.5. Impact of Coal-Fired Power Plants on Household Monthly Expenditure

	Dependent Variable: Monthly Household Expenditure			
	(1)	(2)	(3)	(4)
Panel A: Dependent Variable at Level				
Presence of CFPP	17.499***	13.999***	50.989***	48.244***
(1 if implemented, 0 otherwise)	(0.414)	(0.398)	(2.689)	(2.693)
Adj. R-square	0.000	0.077	0.155	0.156
Observations	3640146	3640146	3640146	3640146
Panel B: Dependent Variable at Log				
Presence of CFPP	0.075***	0.063***	0.174***	0.168***
(1 if implemented, 0 otherwise)	(0.001)	(0.001)	(0.006)	(0.006)
Adj. R-square	0.001	0.109	0.260	0.261
Observations	3640146	3640146	3640146	3640146
Control Variables	No	Yes	Yes	Yes
FE for year and district	No	No	Yes	Yes
FE for regional*linear trends	No	No	No	Yes

CFPP = coal-fired power plant; FE = fixed effects; GDP = gross domestic product.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses. Control variables include average household size, percentage of household heads with a high school degree or higher, percentage of household heads working in the formal sector, and percentage of GDP from the mining sector.
Source: Authors' calculation (2023).

Table 2.5 Panel A shows the impact of CFPP operation on the average monthly household expenditure for the period 2011–2022. The unconditional model shows positive and significant effects (Column 1); however, this figure is likely to suffer from bias. Subsequent regressions using various sets of control variables reduce the magnitude of the effect. Column 2 shows the results after controlling for district characteristics which were likely to affect both treatment and outcome variables. Column 3 adds district and year fixed effects to control for time-invariant heterogeneity within each district as well as common linear trend across districts. Adding further adjustment in the form of interaction terms between region and year fixed effects refines our point estimates of the CFPP impact on household expenditure in Column 4. Using the full specification in Column 4, the average monthly expenditure of households in CFPP districts is around $48.24 higher than that of households in non-CFPP districts.

The positive and statistically significant effects hold when the same model is estimated with the logarithmic form of monthly household expenditure, as shown in Table 2.5 Panel B. Results from all four different specifications follow the same general patterns seen in Panel A. As the dependent variable is in logarithmic scale, the resulting coefficients can be interpreted as the percentage change in total household expenditure. Column 4 presents the model with a full set of controls, showing that households in CFPP districts spend about 0.168% more each month on average than those in non-CFPP districts.

To put these estimated effects into context, we calculate the monetary benefit received by households in CFPP districts per year and compare the resulting figure with the 2022 GDP for comparison. We consider only the coefficient from the fully specified level model (Panel A Column 4). Multiplying the estimated coefficient by the total number of households in CFPP districts, the positive effect on household expenditure is estimated to reach approximately $7.95 billion per year at the national level. This figure is proportional to 0.84% of the 2022 real GDP.

Table 2.6 presents the estimation results of the impact of CFPPs in the district on the average monthly household electricity expenditure. The model specification mirrors that of Table 2.5. Looking at the full specification, we find that the presence of CFPPs is associated with higher average monthly household electricity expenditure by around $1.77 (Panel A Column 4). Upon estimating the same model using the logarithmic form of monthly household electricity expenditure, we observe that the average monthly electricity expenditure of households in CFPP districts is approximately 0.257% higher compared to households in non-CFPP districts (Panel B Column 4). These effects are statistically significant at 1% level.

Table 2.6. Impact of Coal-Fired Power Plants on Average Monthly Electricity Expenditure

	Dependent Variable: Monthly Household Electricity Expenditure			
	(1)	(2)	(3)	(4)
Panel A: Dependent Variable at Level				
Presence of CFPP	1.147***	1.054***	1.902***	1.771***
(1 if implemented, 0 otherwise)	(0.018)	(0.018)	(0.118)	(0.118)
Adj. R-square	0.001	0.053	0.157	0.157
Observations	3640146	3640146	3640146	3640146
Panel B: Dependent Variable at Log				
Presence of CFPP	0.151***	0.141***	0.252***	0.257***
(1 if implemented, 0 otherwise)	(0.002)	(0.001)	(0.009)	(0.009)
Adj. R-square	0.003	0.106	0.313	0.314
Observations	3373979	3373979	3373979	3373979
Control variables	No	Yes	Yes	Yes
FE for Year and District	No	No	Yes	Yes
FE for Regional*Linear Trends	No	No	No	Yes

CFPP = coal-fired power plant; FE = fixed effects; GDP = gross domestic product.

Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses. Control variables include average household size, percentage of household heads with a high school degree or higher, percentage of household heads working in the formal sector, and percentage of GDP from the mining sector.

Source: Authors' calculation (2023).

3.3. Impact of Coal-Fired Power Plants on Manufacturing Firms

This section presents the results of the empirical estimation of the impact of operating CFPPs on manufacturing firms' performance at the micro-level and discusses the implications of the findings. The results serve as a basis to measure the economic impact of developing baselines and alternatives to a coal phase-out scenario.

Table 2.7 shows a compact estimation result of the impact of operating CFPPs on manufacturing firm's return on investment (ROI) in Indonesia during the period 2000–2020, using level and log transformations of ROI as a measurement indicator and examining four specifications of each. The observation of analysis is at firm level, categorised based on the UN Statistics Division 2-digits codes of the International Standard Industrial Classification (ISIC) of all economic activities.

Table 2.7. Impact of Operating Coal-Fired Power Plants on Manufacturing Firms' Return on Investment

Independent Variables	Dependent Variable: ROI (level)			
	(1)	(2)	(3)	(4)
Presence of CFPP	0.249***	0.274***	0.231***	0.160**
(1 if implemented, 0 otherwise)	(0.027)	(0.037)	(0.046)	(0.066)
Control variables	No	Yes	Yes	Yes
Fixed effects for year and firms	No	No	Yes	Yes
Fixed effects for regional*linear trends	No	No	No	Yes
Adj. R-square	0.001	0.001	0.090	0.135
Observations	109284	109284	109284	109284

Independent Variables	Dependent Variable: ROI (log)			
	(1)	(2)	(3)	(4)
Presence of CFPP	0.038***	0.056***	0.045***	0.031***
(1 if implemented, 0 otherwise)	(0.004)	(0.006)	(0.006)	(0.009)
Control variables	No	Yes	Yes	Yes
Fixed effects for year and firms	No	No	Yes	Yes
Fixed effects for regional*linear trends	No	No	No	Yes
Adj. R-square	0.001	0.001	0.213	0.301
Observations	109284	109284	109284	109284

CFPP = coal-fired power plant; ROI = return on investment.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses.
Source: Authors' calculation (2023).

Column 1 depicts the results from the unconditional staggered DID. Column 2 considers control factors for company size in terms of number of employees, total quantity of kilowatt hours of electricity used to conduct production operations, and the total units and characteristics of active CFPPs within the regions where the firms are located (for example, accumulated capacity of electricity generated as well as combustion technology used by those CFPPs). Several dummies that historically caused economic disturbances (e.g. the Asian Financial Crisis 1997–1998, the Global Financial Crisis 2007–2008, and the COVID-19 pandemic), are also incorporated into the model.

Column 3 presents the results of the regression accounting for fixed effects for years and province. Column 4 includes region-specific linear trends to account for three possible systematic differences in trends, namely: ISIC–province pairs, ISIC-province pairs, and firm-province pairs. When the dependent variable is in logarithmic form, the effect of the CFPPs is represented as a percentage change by $100(e^{\beta}-1)$.

The estimate results in Table 2.7 are as anticipated. The unconditional staggered DID estimates that the presence of CFPP operations has a 0.249-point positive impact on firms' return investment on average, which statistically differs from zero. As the ROI has already been expressed as a percentage unit, the coefficient can be directly interpreted as percentage point changes. In terms of log ROI, the effect is quantified as a 3.8% increase.

The estimates in Column 1 seem to be overestimated since adding more controls provides lower estimates, except in Column 2 when no fixed effects are included. The effect of time-varying firm characteristics on ROI is stronger when covariates are controlled for, which leads to a higher estimate. Column 3 adds year and firm fixed effects to capture time-specific shocks and time-invariant differences, respectively, which provides lower estimates.

Finally, the last column adds ISIC–province pairs, ISIC-province pairs, and firm-province specific linear time trends, thereby correcting for an upward bias and resulting in lower estimates. The active CFPPs operation is now associated with an increase in ROI level by an average of 0.16 percentage point – *ceteris paribus*, serving as our baseline estimate. In the absence of CFPPs operation, under the counterfactual setting, the manufacturing firms would have a lower ROI rate.

Although literature suggests that the impact of CFPPs on manufacturing firms' ROI is complex and depends on various factors (e.g. Abeberese, 2017; Dong, Xu, and Fan, 2020). The presence of CFPPs can benefit Indonesia's manufacturing sector in several ways. Possible explanations for the empirical results are set out below.

Due to its characteristics, CFPPs have advantages over other power resources in terms of cost-effectiveness, constant energy, and reliability factors to meet energy consumption needs and to supply electricity during peak power demand as either base power or off-peak power to help the grid system avoid outages. This is especially advantageous for manufacturing firms whose machinery and equipment require a stable and consistent electricity supply (e.g. iron, steel, textiles, cement, fertiliser, and paper factories). With a lower risk of power outage, the firm spends less money on repairs and maintenance of machinery and equipment, making them more durable for long-term use. This enables the firm to streamline costs and create a larger net profit, resulting in a higher ROI. The research of Xu, et al. (2022) supports this explanation, indicating that electricity supply is crucial for the profitability and productivity of businesses. Grainger and Zhang (2019) suggest that more reliable electricity supply within a region would substantially boost local manufacturing firms' outputs, thereby contributing to an increase in the ROI.

To obtain a more intuitive explanation, we attempted to calculate the monetary value of a ROI experienced by manufacturing firms that gain a positive impact from the presence of CFPPs. Multiplying the estimated coefficient by the total realised investment of each firm within their respective treatment periods, the positive impact on ROI is estimated on average at $7.87 million per firm per year or annually equivalent to a total of $43.6 billion at the national level. In comparison to the realised GDP level of Indonesia (2022) in a constant local currency price unit, the figures are proportional to 3.34% of Indonesia's real GDP in 2022.

To provide a broader insight into the impact of CFPPs on manufacturing firms, the benchmark specification (last column in Tables 2.7) is used to analyse whether there is an impact on the firm's electricity consumption. In addition, a heterogeneity analysis is performed to fully understand the estimation results by employing the benchmark specification (last column in Tables 2.7) on different subsamples on varying sizes of manufacturing firms in terms of total workers (e.g. medium-size firms and larger-size firms) according to the Central Bureau of Statistics of Indonesia criteria.

Table 2.8 reveals consistent estimates of coefficients but differing sizes of magnitude between subsamples. The presence of CFPPs have influenced the manufacturing firms to increase their electricity consumption by an average of 14.3%, *ceteris paribus*. Interestingly, the effect is statistically significant and more pronounced for large-sized firms than for medium-sized firms. This finding demonstrates that large manufacturing firms can benefit more from the presence of CFPPs. As the CFPPs provide a cost-effective, reliable, and sufficient electricity supply, manufacturing firms can utilise their machinery and equipment at higher rates.

Table 2.8. Estimated Impact of Operating Coal-Fired Power Plants on Manufacturing Firms' Electricity Consumption (Subsamples)

Independent Variables	Dependent Variable: ROI (log)		
	All Sample	Medium-size Firms	Large-size Firms
	(1)	(2)	(3)
Presence of CFPP	0.143***	0.070	0.194***
(1 if implemented, 0 otherwise)	(0.038)	(0.044)	(0.052)
Control variables	Yes	Yes	Yes
Fixed effects for firms	Yes	Yes	Yes
Fixed effects*linear trends	Yes	Yes	Yes
Adj. R-square	0.371	0.428	0.282
Observations	109284	53626	55108

CFPP = coal-fired power plant; ROI = return on investment.
Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. Standard errors are reported in parentheses.
Source: Authors' calculation (2023).

3.4. Estimating the Economic Cost of Accelerating the Coal Phase-Out Plan in Indonesia

In this subsection, we develop three different scenarios to evaluate the economic cost consequences of implementing the coal phase-out plan or not, and also take into account various implementation schedules when deciding to implement it. Scenarios one and two will be explored first.

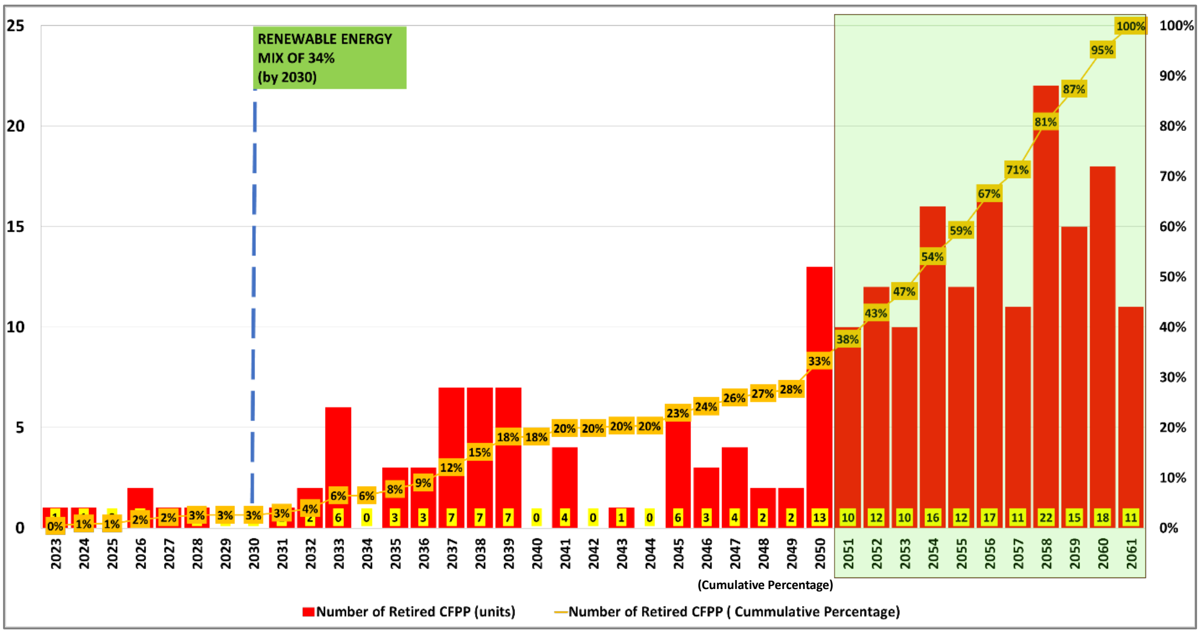
The first scenario is to abandon the coal phase-out plan option. In this model, the coal phase-out plan will not be accelerated at any cost and thus can be viewed as business-as-usual. No new permits or licences will be issued by the government for the additional establishment of CFPPs. The transition to renewable energy sources will occur when the CFPPs reach the end of their lifespan and need to be replaced.

The second scenario involves taking action towards the coal phase-out plan. In that model, the coal phase-out plan will be accelerated. However, the timing of implementation can vary. For example, accelerating the execution of a plan by a few years depends on the economic life usage of CFPPs. As a consequence, the economic costs associated with accelerating the planned execution timeline will vary depending on how early the plan is started. Another consideration is that the switch to renewable energy sources will happen in proportion to the amount of electricity capacity supply that needs to be replaced on time for every gigawatt of electricity lost when an extra CFPP unit shuts down early.

The economic cost of accelerating the coal phase-out plan will include: (i) the retirement cost of CFPPs; (ii) the investment cost of electricity power capacity replacement generated by renewable energy sources; and (iii) the losses of economic benefits for the impacted economic agents due to the presence of CFPPs, – i.e. households and manufacturing firms. The sum of these costs will be considered the total economic costs that should be compensated if the government decides to move forward with the coal phase-out plan to meet its emission reduction commitment.

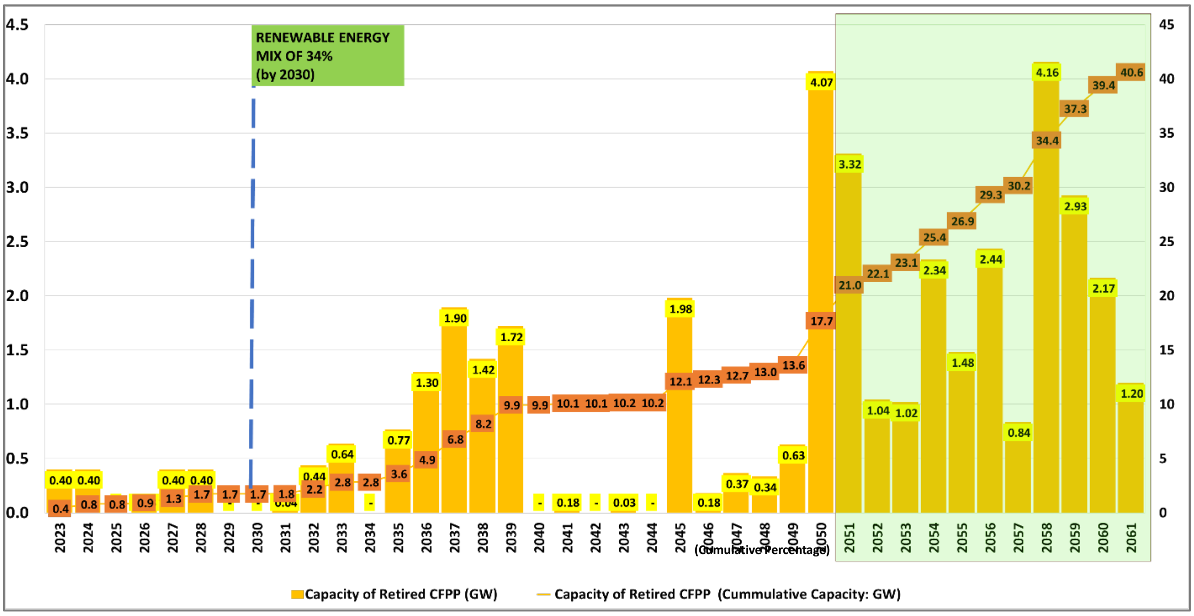
The first scenario, i.e. no implementation of a coal phase-out has a timeline for the natural path of the CFPP's operation period. The natural path sets out conditions where all CFPP units are permitted to operate until they reach the maximum limit for year of operation or economic lifetime usage. For this stage, we utilise the Global Coal Plant Tracker data collected by the Global Energy Monitor, which contains a list of existing active CFPPs in Indonesia that are currently operational. Figure 2.5 depicts the pattern of the natural path of these CFPPs' retirement since 2023, assuming they are permitted to operate at their maximum economic lifetime utilisation. Meanwhile, Figure 2.6 shows the pattern of the natural path in terms of CFPPs' GW capacity.

Figure 2.5. The Natural Path of Retirement for Current Active Coal-Fired Power Plants in Indonesia



CFPP = Coal-fired power plant.
Source: Authors' calculation (2023), based on Global Energy Monitor (2022).

Figure 2.6. Power Capacity Loss Due to the Natural Path of Retirement for Coal-Fired Power Plants in Indonesia



CFPP = Coal-fired power plant; GW = gigawatt
Source: Authors' calculation (2023), based on Global Energy Monitor (2022).

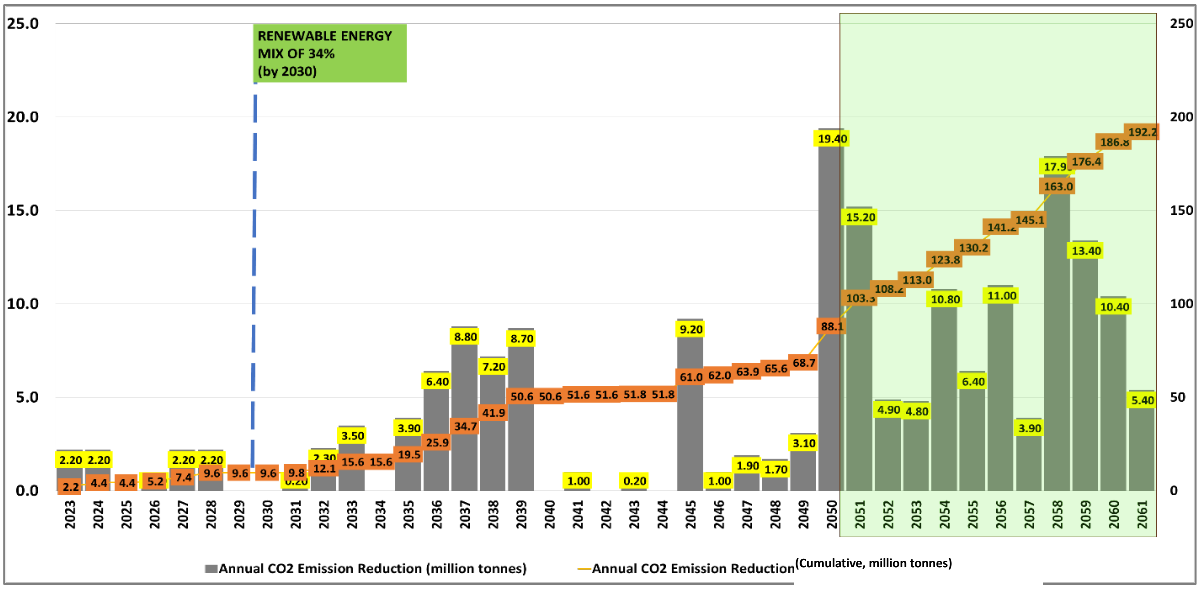
According to the natural path of CFPPs economic lifetime, 77 units (about 33% of the total number of active CFPPs) are expected to retire by late 2050. Because there are no active CFPPs currently being retired early, the only costs that arise are those of providing new renewable energy-based power plants to substitute those CFPPs due to retire at a specific point in the future. According to the GoI's plan to enable a high share of renewable energy into its national power system based on the projected load and demand growth (Ordonez, Fritz, and Eckstein, 2022), this might be effectively implemented by 2030. Consequently, during this period, there will be compensation costs involved for households and manufacturing firms as they will not be able to swiftly obtain access to new, alternative power supplies, at least not until the establishment of renewable energy-based power plants that are available to all and commercially operated.

As shown in Figure 5, the GoI will confront the dilemma of coal phase-out in the post-2050 period, when approximately 154 units, or 67% of the total number of CFPPs, are in line to normally discontinue their operation. However, the PR 112/2022 has already regulated that the CFPPs will operate no later than 2050, meaning that the 'do nothing' policy cannot be an option. The longer the CFPPs operate, the longer their negative effects on the environment will persist (i.e. the air will become dirtier due to pollutant emissions while the public's awareness of the importance of a clean environment will increase).

This, then, will be the starting point to construct the second scenario, which simulates the acceleration of the coal phase-out plan by up to eleven years from the normal time of CFPP retirement. In that way, the aim of the coal phase-out plan is to shut down all CFPPs that will be still in operation after 2050.

The third scenario is to allow those CFPPs to retire beyond 2050 and thus continue operating them until they reach their maximum economic lifetime. Eliminating the negative externalities of CFPP (i.e. reducing CO_2 emissions) should be addressed by investing in carbon capture, utilisation, and storage (CCUS) technology so their impact is less harmful to health and the environment. Figure 2.7 presents the level of annual CO_2 emission reduction when the CFPPs are normally shut down in specific years. The numbers will be a basis to calculate the necessary investment in CCUS technology. Forecasting simulations will estimate the costs to be borne under each scenario and the information will be used to seek and develop funding strategies.

Figure 2.7. The Annual Carbon Dioxide Emission Reduction Due to the Natural Path of Retirement for Coal-Fired Power Plants in Indonesia



CO_2 = carbon dioxide.
Source: Authors' calculation (2023), based on Global Energy Monitor (2022).

Table 2.9 provides a summary of the outcomes for all three scenarios. The estimated costs can be categorised into three components – investment costs associated with renewable energy establishment, costs to shut down CFPPs, and compensation costs for those households and manufacturing firms negatively impacted by the early removal of CFPPs. In contrast, the implementation of the coal phase-out policy in Indonesia will require substantial financial support, amounting to an annual average of more than $100 million.

Table 2.9. Simulation Results for All Scenarios
(in $billion)

Aspect	Scenario 1 (BAU)	Scenario 2 (Coal Phase-Out)	Scenario 3 (CCUS)
Investment cost on renewable energy	56.74	56.74	56.74
Early retirement cost of CFPP	-	27.79	-
Compensation cost for households and manufacturing firms	397.53	5,667.67	397.53
Investment cost on CCUS	-	-	21.91
Total cost (2023-2061)	**454.27**	**5,752.21**	**476.18**
Total cost per year	**11.95**	**151.37**	**12.53**

$ refers to US dollars.
BAU = business-as-usual; CCUS = carbon capture, utilisation, and storage; CFPP = coal-fired power plant.
Source: Authors' calculation (2023).

Considering the commitment made by developed economies towards assisting developing countries to pursue climate funding, it becomes apparent that scenario three (the use of CCUSs) will be the most viable option due to its comparatively lower financial requirements. The discussion of the economic costs of the coal phase-out plan, along with its fiscal consequences, and other related financing policies will be described in the next section. It is, however, important to acknowledge that the simulation results are based on the replacement conditions for the currently active CFPPs and have not yet incorporated the annual growth rate of electricity demand.

4. Discussion on Financing Framework and Policy Recommendations

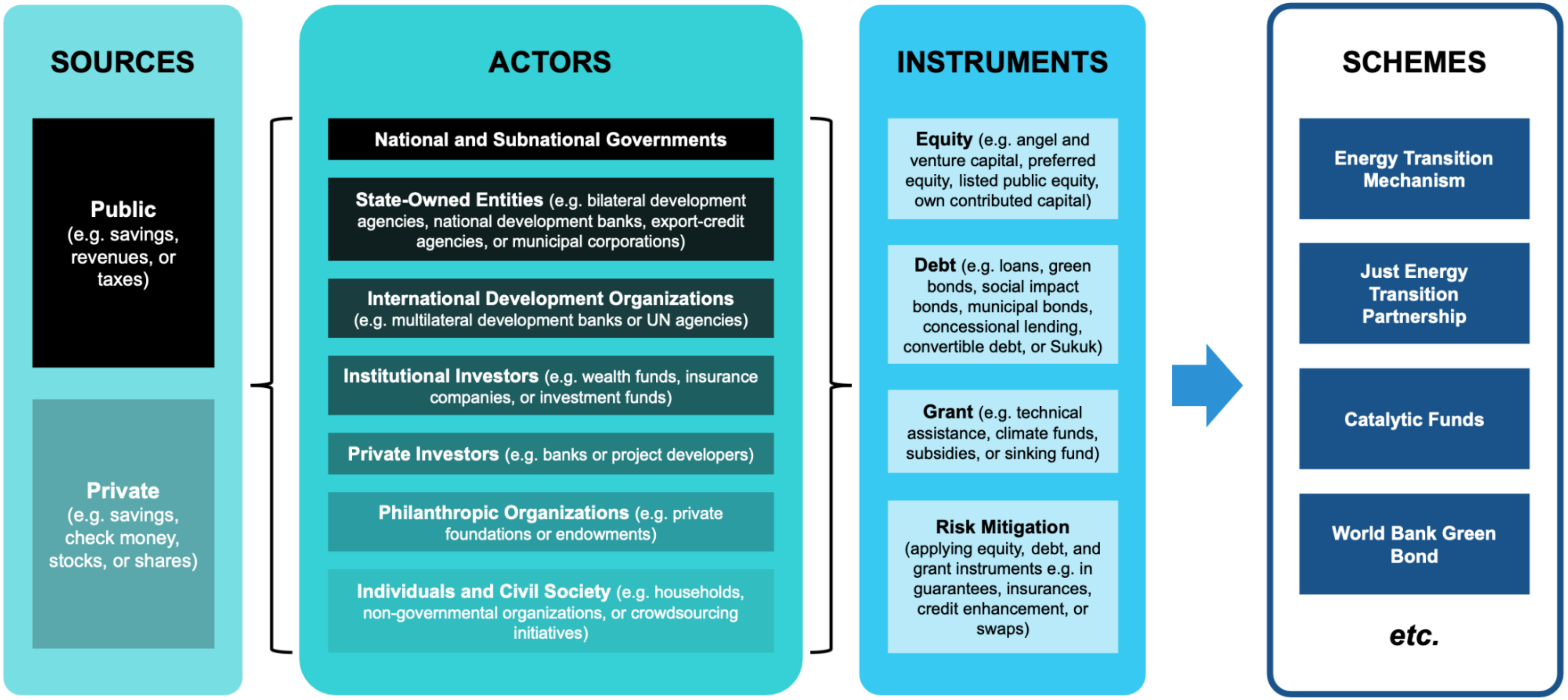
4.1. Global Initiatives to Finance Indonesia's Coal Phase-Out

Indonesia has committed to reduce its emissions in accordance with the Paris Agreement goal. This commitment is stated in the Indonesia Enhanced NDC which was submitted in September 2022. In this newest document, Indonesia has increased its unconditional emission reduction target from 29% in the First NDC to 31.98% in the Updated NDC, and its conditional target from 41% in the Updated NDC to 43.20% in the Indonesia Enhanced NDC (GoI 2022).

The implementation of the NDC requires large investments from public and private sources. The Enhanced NDC document refers to the 3rd Biennial Update Report which states the estimated finances needed to achieve the unconditional target from 2018–2030 as about $281 billion and the conditional target as about $281 billion. Of that, state funds can only contribute around 34% and the rest should be provided from non-state funding sources (Luthfyana and Mafira, 2023).

Considering this massive investment gap, it is imperative that Indonesia seeks funding from other sources. Figure 2.8 shows the financing framework for climate change projects that Indonesia could leverage. While funding could be found from either public or private funds, the financing schemes need not perfectly align with this dichotomy. At present, there are various schemes that blend public and private funds, especially for climate-related programmes (e.g. blended finance). One of the main challenges in climate change finance, however, is the coordination between public and private funds so that green projects can be delivered in an effective and efficient way.

Figure 2.8. Green Financing Framework



Source: Adapted from New Climate Economy (2016).

Various global financing initiatives are available for Indonesia to tap into to finance its energy transition (Table 2.10). For instance, the country has secured a global commitment under JETP financing of approximately $20 billion. Financing mechanisms under the JETP scheme blend equity investments, grants, concessional and commercial loans, and guarantees. However, challenges remain in terms of the type of financing instruments offered under the scheme. At present, only a small percentage of financing under the JETP programme comes in the form of grants.

Table 2.10. Available Financing Schemes to Combat of Climate Change

No	Schemes	Committed Amount	Instrument Types	Channelling Institutions	Funding Sources
1	Energy Transition Mechanism	1a. ADB's Energy Transition Mechanism and the World Bank Group			
		$500 million from CIF-ACT; $2.2 billion from ADB & WBG; $2 billion from GoI & private sector	• grants • concessional loans • market-rate loans • RBL • FIL through PT SMI, & project loans	• ADB • WBG	• GoI • Climate Investment Fund: CIF-ACT • Multilateral development banks: ADB & WBG • Private sector: International Finance Corporation, ADB, & private sector
		1b. Indonesia's Energy Transition Mechanism Country Platform			
		Contribution from GoI to be confirmed	GoI contribution • state budget • concessional loans • market-rate loans • carbon credit revenues	• PT SMI	GoI; • Ministry of Finance • Ministry of Energy and Mineral Resources • Ministry of State-Owned Enterprise • Ministry of Environment and Forests
		1c. State Electricity Company Energy Transition Mechanism			
		PLN has indicated a need for $726 billion	• equity • debt • grants	-	• PLN & partners

No	Schemes	Committed Amount	Instrument Types	Channelling Institutions	Funding Sources
		until 2060			
		1d. Indonesian Investment Authority's Energy Transition Mechanism			
		Undisclosed for CFPP retirement: $2 billion for the Green Fund	• equity & • debt	• Indonesia Investment Authority	• Indonesia Investment Authority
2	Just Energy Transition Partnership	$20 billion committed to Indonesia ($10 billion public funds & $10 billion private capital)	• grants • concessional loans • market-rate loans • guarantees • private investments	• International Partners Group (Public) • Glasgow Financial Alliance for Net Zero (Private)	• Governments of IPG countries: Canada, Denmark, France, Germany, Italy, Japan, Norway, UK, US. • Private financial institutions: Bank of America, Citi, Deutsche Bank, HSBC, Macquarie, MUFG, Standard Chartered
3	ASEAN Catalytic Green Finance Facility	$1.8 billion	• loans • technical assistance	• ADB	• ADB • Agence Française de Développement • CDP • Economic Development Cooperation Fund • European Investment Bank • EU • Foreign, Commonwealt

No	Schemes	Committed Amount	Instrument Types	Channelling Institutions	Funding Sources
					h & Development Office ● Green Climate Fund ● KfW
4	Clean Energy Financing Partnership Facility	Realisation: $284.4 million to 235 projects (as of 2022)	● debt & ● grants	● ADB	● Governments of Australia, Canada, Japan, Norway, Spain, Sweden, & UK ● Global Carbon Capture and Storage Institute
5	Global Green Growth Institute	$1 billion in 2021	● grants	● Global Green Growth Institute	● Governments of Australia, Denmark, Germany, Indonesia, the Republic of Korea, Mexico, Norway, Switzerland, UAE, & UK
6	Green Climate Fund	$9.3 billion between 2024–2027	● grants ● debt ● equity ● guarante e	● World Bank interim trustee & ● UNFCCC	● Established by 194 countries party to the UNFCCC
7	World Bank Green Bond	Realisation: $16.5 billion (as of 2022)	● debt bonds	● World Bank	● Fixed income investors

ADB = Asian Development Bank; ASEAN = Association of Southeast Asian Nations; CDP = Carbon Disclosure Project; CIF-ACT – Climate Investment Fund: Accelerating Coal Transition Investment Programme; CFPP = coal-fired power plant; EU = European Union; FIL = Financing Intermediary Loan; GoI = Government of Indonesia; HSBC = Hong Kong & Shanghai Banking Corporation; IPG = International Partners Group; KfW = Kreditanstalt für Wiederaufbau; MUFG = Mitsubishi UFJ Financial Group, Inc; PLN = State Electricity Company - Perusahaan Listrik Negara; PT SMI = PT Sarana Multi Infrastruktur (Persero); RBL = Result-Based Lending; UAE = United Arab Emirates; UK = United Kingdom; UNFCC = United Nations Framework Convention on Climate Change; US = United States; WBG = World Bank Group.
Source: Authors' collection from various documents (2023).

Another financing initiative is the ETM. The GoI has just launched the ETM Country Platform in November 2022 aimed at providing finance to accelerate the national energy transition by mobilising private and public funds sustainably. The GoI has chosen the state-owned *PT Sarana Multi Infrastruktur* as the Country Platform Manager and tasked them with developing a co-operative financing and investing framework for ETM programmes in Indonesia. Programmes under the ETM will mainly be funded with blended financing schemes with fundings from various parties.

4.2. Fiscal Support for Just Energy Transition

The GoI could only provide limited funding resources for phasing out coal. However, they could play a critical role in accelerating coal phase-out by providing various fiscal supports. The Minister of Finance has issued several regulations, for example *Peraturan Menteri Keuangan (*PMK*)* pertaining to fiscal incentives for coal phase-out, particularly for the advancement of renewable energy, in alignment with the provisions outlined in Law No. 30 of 2007 on Energy. The law grants the GoI the authority to offer resources and incentives to both corporations and individuals to promote the provision of renewable energy. This adheres to a range of tax and duty regulations, which provide tax incentives for strategic endeavours relating to income tax, value-added tax, and import taxes and duties. The fiscal instruments and their corresponding implementing regulations are presented in Table 2.11.

Table 2.11. Summary of Regulations on Fiscal Incentives for Renewable Energy Development

Fiscal Incentives	Detailed Instruments	Regulations
Tax and duty allowances	▪ Investment tax deduction equivalent to 30% of fixed capital investment, applied as 5% over 6 years; ▪ Accelerated depreciation and amortisation; ▪ Exemption from Article 22 import tax on machines and equipment, excluding spare parts; depending on the imported goods, this can be as much as 7.5% of the declared	✓ Government Regulation No. 78 of 2019 on Income Tax Facilities for Investment in Certain Industries and/or Regions; ✓ PMK No. 89 of 2015 as amended by PMK No. 11 of 2020 on Procedures for Provision of Income Tax Facilities for Investment in Certain Industries and/or Regions as well as Transfer of Assets and Sanctions for

Fiscal Incentives	Detailed Instruments	Regulations
	value; ▪ VAT exemption on imported goods, excluding spare parts; ▪ Import duty exemption; ▪ Reduction of tax on dividends remitted to non-residents to 10% or less depending on the prevailing tax treaty; ▪ Extension of tax loss carry forward from 5 years up to 10 years, subject to certain criteria.	Domestic Taxpayers; ✓ PMK No. 21 of 2010 on Provision of Tax and Duty Facilities for Renewable Energy Activities; ✓ PMK No. 176 of 2009 as amended by PMK No. 188 of 2015 and PMK No. 76 of 2012 on Import Duty Exemption for Investment in Equipment, Goods and Materials for Industrial Development.
Tax holiday	▪ Corporate income tax holidays for investment in 'pioneer industries' including 'economic infrastructure,' which includes renewable energy power plants.	✓ PMK No. 130 of 2020 on Provision of Corporate Income Tax Reduction Facilities; ✓ Investment Coordinating Board Regulation No. 7 of 2020.

$ refers to US dollars.
PMK = *Peraturan Menteri Keuangan.* VAT = value-added tax.
Sources: Authors' summary from Government Regulation No. 78 of 2019 on Income Tax Facilities for Investment in Certain Industries and/or Regions; PMK No. 89 of 2015 as amended by PMK No. 11 of 2020 on Procedures for Provision of Income Tax Facilities for Investment in Certain Industries and/or Regions as well as Transfer of Assets and Sanctions for Domestic Taxpayers; PMK No. 21 of 2010 on Provision of Tax and Duty Facilities for Renewable Energy Activities; PMK No. 176 of 2009 as amended by PMK No. 188 of 2015 and PMK No. 76 of 2012 on Import Duty Exemption for Investment in Equipment, Goods and Materials for Industrial Development; PMK No. 130 of 2020 on Provision of Corporate Income Tax Reduction Facilities; Investment Coordinating Board Regulation No. 7 of 2020.

Aside from tax-related fiscal incentives, the GoI could provide incentives in other forms. It could, for example, conduct budget tagging to help private stakeholders to identify relevant projects. Budget tagging allows the government to earmark specific funds or budgets for coal phase-out projects. By clearly identifying these allocations, private stakeholders can readily identify and access relevant projects, thereby encouraging their active involvement and investment in the transition away from coal. This approach has been recognised as instrumental in channelling funds toward sustainable initiatives and projects (World Bank, 2019).

Another way the GoI could contribute to the rapid phase-out of coal would be to introduce a carbon tax and carbon credit. A carbon tax places a financial burden on carbon emissions, providing a direct economic incentive for industry to reduce its carbon footprint. Carbon credits allow companies that have reduced their emissions below a certain level to sell the excess reduction as credits to other companies, thereby promoting emissions reductions in a market-driven manner. Revenue from such a carbon tax system can be reinvested in renewable energy projects or used to provide subsidies for clean energy technologies, thereby encouraging the adoption of sustainable alternatives and accelerating the phase-out of coal. This approach is consistent with the principles of environmental economics and promotes the internalisation of external environmental costs (Tietenberg and Lewis, 2018). Furthermore, this method is also in line with global best practices, as evidenced by countries such as Denmark and Sweden, which have effectively used carbon pricing mechanisms to incentivise the transition to cleaner energy sources (World Bank, 2019).

4.3. Managing the Socioeconomic Impact of Coal Phase-Out

Although it may have unfavourable effects, Indonesia must phase out coal if it is to meet its carbon commitment. In terms of energy sources used to generate electricity nationally, coal continues to be the most common choice. Accordingly, it is imperative to guarantee that electricity can meet present and future demand by decreasing the significant role that coal plays. Phase-out of coal also implies the possibility of primary economic sector loss for coal-dependent regions at the regional level. The coal industry in these areas may support a sizeable number of direct and indirect jobs, as well as local government revenue, by taxes, royalties, and dividends from state-owned businesses. For this reason, moving away from coal may have a negative economic effect on areas that rely heavily on it.

Considering the possible negative effects of the transition from coal to renewable energy, JETP is being pushed to make sure that no population segment is sacrificed in the process of expanding renewable energy sources. In the context of JETP, there are several policy suggestions that can be made.

- To address the challenges associated with transitioning away from coal in regions heavily dependent on this fossil fuel, the GoI can support regional and local governments. This assistance can facilitate the transition of these areas from coal-based economies to more sustainable alternatives. A viable approach is to implement a variety of incentive programmes. For example, the GoI could establish incentive schemes that encourage investments aimed at replacing coal-related activities in these coal-dependent regions. In this way, the government can help promote economic diversification, job creation, and infrastructure development, ultimately mitigating the impact of the coal phase-out on these communities.

- With the implementation of coal phase-out initiatives, central and local governments have the chance to provide households with important support. Reskilling training programmes for employees who might suffer due to the shift away from coal-based industries are one crucial kind of support. Through the development of new skills and competencies, these employment opportunities enable workers to consider different industries and career paths. In addition to helping the workforce avoid the negative effects of the phase-out of coal, governments can support a more diverse and sustainable economy that supports larger environmental and economic objectives by funding reskilling initiatives.

5. Conclusion

The results of empirical analysis in this study are summarised as follows. From the macro-level perspective, the presence of CFPPs have a significantly unfavourable influence on the economic development of Indonesia, measured by GDP and its growth rate. This is because the operation of CFPPs entails negative externalities that can potentially impact the productivity of specific economic sectors through the mechanism of environmental risks. The outcomes become evident when comparing the effect of subcritical and non-subcritical CFPPs. Subcritical CFPPs exhibit lower efficiency levels and emit greater quantities of pollutants compared to their supercritical and ultra-supercritical counterparts. This underlines the drawbacks associated with the utilisation of subcritical CFPPs, which results in increased economic costs. The findings of the analysis indicate that the total annual economic costs of CFPPs are estimated to amount to $92.88 billion, equivalent to roughly 7.13% of Indonesia's actual GDP in 2022.

From the micro-level perspective related to the household sector, the estimation results showed that CFPPs have a positive impact on the average monthly expenditure per household at the city level, with the effect quantified as $18.83 or equivalent to a 0.8% increase. Additionally, the presence of CFPPs is associated with increased monthly electricity spending by an average of approximately $48.24 per household per year, an increase of approximately 6.1%, which corresponds to a national total of $15.5 billion annually. Compared to Indonesia's realised GDP level (2022) in a constant local currency price unit, the figures are proportional to 0.61% of Indonesia's real GDP in 2022.

From the micro-level perspective regarding the manufacturing business sector, the estimation results showed that the presence of CFPPs operations has a positive impact on the return on assets of companies, with the effect quantified as an increase of 0.16 percentage points or equal to 3.1%. The use of CFPPs can lead to a reduction in the risk of power outages and thus increases the lifespan of companies' machines and systems. This, in turn, improves cost optimisation, resulting in higher net profits and ultimately a higher ROI. Another consideration is that a more reliable electricity supply within a region would significantly increase the output of local manufacturing companies, thereby helping to increase ROI.

The results also show that large manufacturing companies can benefit more from the presence of CFPPs as they can utilise their machines and equipment more quickly. The findings of the analysis indicate that, on average, the positive impact on ROI is estimated at $7.87 million per company per year, for a total annual value of $43.6 billion nationally. Compared to Indonesia's realised GDP level (2022) in a constant price unit in local currency, the figures are proportional to 3.34% of Indonesia's real GDP in 2022. From a summary of the aggregate impact of CFPPs on both the macro and micro-level perspective, it can be concluded that the presence of CFPPs results in a potential annual net economic loss.

The simulation model shows that the economic cost consequences of implementing the coal phase-out plan are of great importance. Amongst the various scenarios, the use of CCUS is the most viable option to help Indonesia achieve its goal of net zero carbon emissions by 2060.

The investments required to implement the coal phase-out require the GoI to develop various sources of financing, both public and private. The ETM and theJETP are two of the most significant global financing initiatives that the GoI could use to accelerate its energy transition. Due to their limited availability, public funds should be directed towards efforts to incentivise private sector participation in the energy transition. Beyond financial support, the GoI could play a critical role in ensuring that the coal phase-out is implemented in an equitable manner by considering the potential economic impact on coal-dependent regions.

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Appendix

Datasets and Methods for Empirical Analysis Data

The study employs multiple datasets, which are mostly obtained from Indonesia's Statistics Central Agency (BPS). Table A.1 lists the variables utilised in each dataset, along with their disaggregation levels. The brief description of each dataset is as follows.

1. National Socioeconomic Survey (SUSENAS).
   We utilise SUSENAS to collect socioeconomic data at the individual and household levels from the core and consumption modules. The variables include per capita spending, energy consumption, household characteristics such as size and proportion of urban population, and head of household characteristics such as age, gender, and level of education. We aggregate them at the district and provincial levels.
2. National Labour Force Survey (SAKERNAS).
   We use SAKERNAS to gather labour market statistics such as the fraction of informal labour, labour force participation rates, unemployment rates, and the number of working-age people. We aggregate them at the district and provincial level.
3. Large and Medium Manufacturing Industry Survey (SIBS).
   SIBS allows us to acquire firm-level data such as sales, earnings, and ROI, as well as industry statistics such as average worker count, foreign and domestic ownership, and so on. We aggregate them at the provincial level.
4. Village Potential Statistics (PODES).
   We utilise PODES to collect village-level topographical data such as topography and natural catastrophes. We aggregated them to the district level.
5. GRDP and other socioeconomic data from the Statistics of Indonesia at district and province levels, published by BPS regional-level offices.
6. Database of 253 existing CFPPs in Indonesia, including location, capacity, and year of operation. The database was released by Indonesian Ministry of Energy and Mineral Resources (MEMR).

Table A1. Variables and Data Sources

Datasets	Variables	Disaggregation
SUSENAS (Core and Consumption Modules)	▪ Per capita household expenditure ▪ Household characteristics	▪ Individual ▪ Household ▪ District
SAKERNAS	▪ Per capita household expenditure	▪ Individual ▪ Household ▪ District
SIBS	▪ Firms characteristic ▪ Energy consumption ▪ ROI	▪ Firm ▪ Province
PODES	▪ District-level geographical characteristics	▪ Village ▪ District
BPS Daerah	▪ GDP ▪ GDP per capita ▪ Government revenues and expenditures	▪ District
Directorate General of Mineral and Coal, Indonesian Ministry of Energy and Mineral Resources (MEMR)	▪ Location, capacity, and commercial operation date of 253 existing coal-based power plants ▪ Historical coal prices	▪ District

BPS = Statistics Indonesia (Central Bureau of Statistics - *Badan Pusat Statistik*); GDP = gross domestic product, PODES = Village Potential Statistics; ROI = return on investment; SAKERNAS = National Labour Force Survey; SIBS = Large and Medium Manufacturing Industry Survey; SUSENAS = National Socioeconomic Survey.

Source: SUSENAS, SAKERNAS, SIBS, PODES, Local BPS Offices, and Directorate General of Mineral and Coal Ministry of Energy and Mineral Resources.

Methods

To estimate the potential impact of coal phase-out in Indonesia, we developed four econometric models: (i) Economic impact model; (ii) Household welfare impact model; (ii) Firm performance impact model; and (iv) Forecasting model.

Models 1–3 aim to estimate the effect of treatment on outcomes and are estimated using the DID approach. In this approach, we compare the difference between treatment and control groups (the first difference) for the period before and after the treatment (the second difference) has occurred. In our case, the treatment refers to the presence of CFPP in a region (district or province). Model 4 aims to forecast outcome variables in the future based on parameters obtained from Models 1–3.

Model 1: Economic Impact

Coal phase-out could bring an adverse impact to regions that rely heavily on coal-related industries. To account for the non-random location of CFPP, we use the DID approach and modify the baseline equation into the following model:

$$Y_{it} = \alpha + \beta CFPP_{it} + \gamma X_{it} + \delta_i + v_t + \varepsilon_{it} \#(1)$$

where Y_{it} is the GRDP of district i at period t; $CFPP_{it}$ is a dummy variable equal to 1 if there is a CFPP in district i at period t and 0 otherwise; X_{it} is a vector of controls; δ_i is the district fixed effect; v_t is the year fixed effect; and ε_{it} is the error term. Our coefficient of interest, β, indicates the effect of the presence of CFPPs on GRDP and essentially measures how coal phase-out potentially affects the local economy in districts that have a CFPPs compared with those that do not.

The X vector includes district-level covariates as well as district and time-specific factors that may affect GRDP in each district. These include population size, provincial capital dummy, district fixed effects, and year fixed effects. The district fixed effects are included to control for unobserved factors that may cause persistent differences in regional GRDP, which may be correlated with the likelihood of having a CFPP. The year fixed effects are included to control any shocks to GRDP that are common across districts in each period.

As the year of operation of each CFPP varies across districts, Equation (1) is estimated using the staggered DID approach following (Goodman-Bacon, 2021).

Model 2: Household Welfare Impact

At the micro level, CFPP closure could potentially induce welfare changes of residents in coal-reliant regions. To investigate this, we develop a household-level model as follows:

$$W_{hit} = \alpha + \beta CFPP_{it} + \gamma X_{hit} + \delta_i + v_t + \varepsilon_{it} \#(2)$$

where W_{hit} is per capita expenditure of household h in district i at year t; $CFPP_{it}$ is a dummy variable equal to 1 if there is a CFPP in district i at period t and 0 otherwise; X_{hit} is a vector of household-level controls; δ_i is the district fixed effect; v_t is the year fixed effect; and ε_{it} is the error term.

Equation (2) is estimated using the staggered DID approach following (Goodman-Bacon, 2021).

Model 3: Firm Performance Impact

The second micro-level evaluation concerns the potential impact of coal phase-out on firms' performances. We employ a similar approach to estimate the magnitude of potential CFPP closure on businesses' ROI using the following specification:

$$R_{fjt} = \alpha + \beta CFPP_{jt} + \gamma X_{fjt} + \delta_j + v_t + \varepsilon_{jt} \#(3)$$

where R_{fjt} is the ROI of firm f located in province j at year t; $CFPP_{jt}$ is a dummy variable equal to 1 if there is a CFPP in province j at period t and 0 otherwise; X_{fjt} is a vector of firm-level controls; δ_j is the province fixed effect; v_t is the year fixed effect; and ε_{jt} is the error term.

Equation (3) cannot be estimated at district level due to the limitation of SIBS as our source of firm-level data. Thus, we aggregated our control variables to province level.

Model 4: GDP Forecasting

After obtaining estimates of the economic impact due to the operation of CFPPs at the macro and micro levels (i.e. at the company and household levels), the next step is to project how the national economy will develop in the long-term when the coal phase-out plan is gradually implemented. To do this, we build assumptions and develop model simulations of different scenarios based on whether or not the coal phase-out plan is implemented in the future, and on the speed of the phase-out timeline.

Chapter 3

The Green Economy Transition: The Effect of Environmental Factors on Renewable Energy Development in Malaysia

Norasikin Ahmad Ludin, Fairuz Suzana Mohd Chachuli, and Nurfarhana Alyssa Ahmad Affandi

1. Introduction

1.1. The Energy Landscape in Malaysia

The energy sector, which is the main driver of growth in the Malaysian economy and energy-intensive industries contributes 28% of gross domestic product (GDP) and employ 25% of the total workforce. Furthermore, the energy sector is a significant source of national income, with petroleum-related income accounting for 31% of fiscal income and energy exports accounting for 13% of total export value (Energy Commission, 2020). The energy sector has made significant contributions to national socioeconomic impacts, providing daily access to electricity to over 10 million customers and serving as a foundational enabler for people mobility through the reliable supply of various transport fuels. Jobs and business opportunities created in the energy sector, as well as economic multipliers in energy-related supply chains, have all contributed significantly to the country's quality of life and have had positive socioeconomic effects.

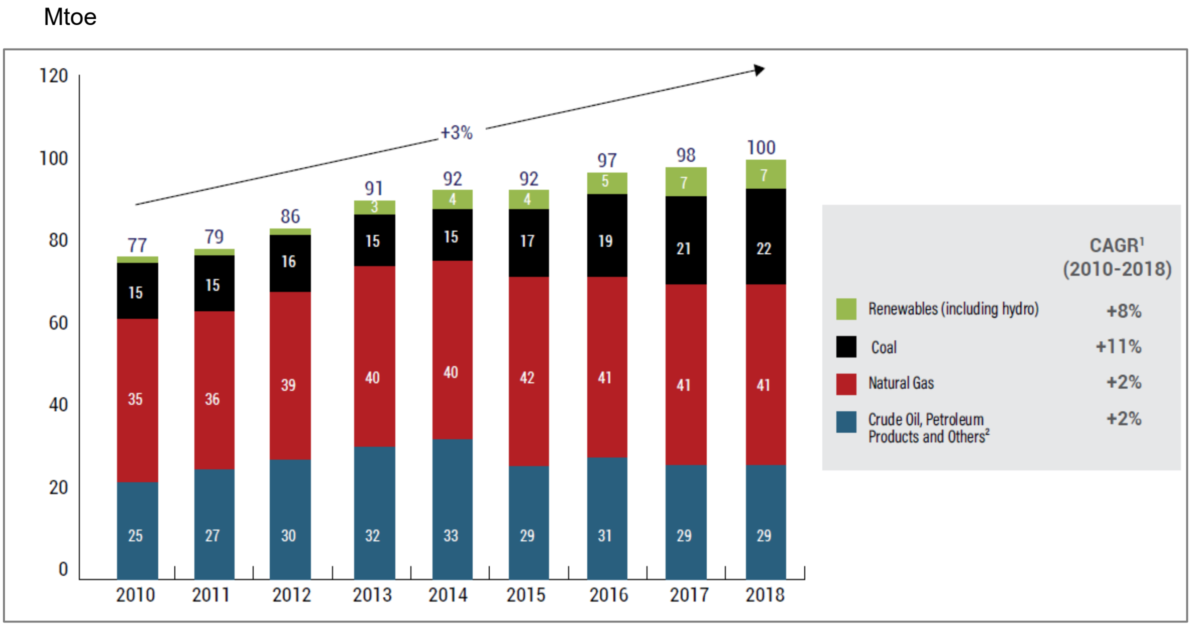
The energy sector has always been a critical driver of national growth. It has contributed significantly to Malaysia's GDP over the years, creating skilled jobs, playing an important role in international trade, and serving as a major source of fiscal income for the country's coffers. The energy sector will continue to play an important role in Malaysia's future economy, as it is a high-value sector based on innovation, technology, and human capital. Considered a key enabler and driving factor of production for numerous major sectors of the national economy, a future-proof and competitive energy sector has far-reaching positive spillover effects for the nation's entire economy.

In addition to driving economic development, the energy sector plays a critical role in contributing to Malaysia's social outcomes. Energy resources can be used to grow high-value downstream industries in Sabah and Sarawak, as well as rural states in Peninsular Malaysia. Increasing access to reliable energy can help rural communities achieve socioeconomic empowerment. Also, if used in the right way, the energy sector can help make the environment more sustainable, which can lead to a better quality of life for people and new business opportunities in the green economy.

On the supply side, the national total primary energy supply (TPES) mix is mostly made up of four energy sources as shown in Figure 3.1. At 41% of TPES, natural gas makes up most of the primary energy supply. This is followed by crude oil and petroleum products at 29% and coal at 22%. Renewable sources make up 7% of TPES, most of which are hydroelectric, solar, and bioenergy. At 11% per year, coal has the highest rate of growth. This is mostly because of demand from Peninsular Malaysia's power sector. Energy security and cost are the main reasons why coal is becoming a bigger part of the primary energy mix.

According to projections, the primary energy supply will evolve to enable greater environmental sustainability. In line with the Five-Fuel Diversification Policy, measures to promote and increase the share of renewable energy were developed in 2000 (Mekhilef, 2014). As imported non-renewable energy sources are replaced with indigenous sources of renewable energy in the primary energy mix, these measures will collectively reduce overall energy sector emissions intensity and increase domestic energy self-sufficiency.

Figure 3.1. Total Primary Energy Supply Based on Energy Source



CAGR = compound annual growth rate; Mtoe = million tonnes of oil equivalent.
Notes: The data are rounded to the nearest decimal point.
*Others refer to non-crude energy forms which consist of imported light diesel, slop reprocess, crude residuum, and residue used as refinery intake.
Source: Energy Commission (2020).

1.2. Existing Energy-Related Acts and Policies

A variety of existing energy-related acts and policies establish the direction and guiding principles for Malaysia's energy sector. Through these acts and policies, the country has been able to make balanced progress on all aspects of the energy trilemma focusing on security, affordability, and sustainability, to strategically navigate the nation's energy transition towards increasing the share of renewable energy. The acts, which are supported by a set of policies, give specific stakeholders in the energy landscape the authority to carry out responsibilities in accordance with energy-related acts and policies, as shown in Figures 3.2 and 3.3.

Figure 3.2. Energy-Related Acts

1974 — 1990 — 1993 — 2001 — 2011

Petroleum Development Act (1974)

- To vest the **entire ownership in and the exclusive rights** for the exploration and exploitation of petroleum resource in PETRONAS.
- PETRONAS shall be subject to the control and **direction of the Prime Minister.**
- The **National Petroleum Advisory Council** is set up to advise the Prime Minister on national policy, interests and matters pertaining to petroleum, petroleum industries, energy resources and their utilisation.

Electricity Supply Act (1990)

- To provide for the **regulation of the electricity supply industry.**
- Supply of electricity at **reasonable prices and licensing of electrical installation** and to promote safe and efficient systems for electricity-related operations.

Gas Supply Act (1993)

- To provide for the **licensing of natural gas** supply to consumers at reasonable prices, with continuous supply and good quality.
- Ensure the **safe and efficient operation** of natural gas pipelines, installations and appliances.

Energy Commission Act (2001)

- **Establishment of the Energy Commission.**
- Authorise the Energy Commission to **regulate energy supply activities** including the enforcement of energy supply laws.

Renewable Energy Act (2011)

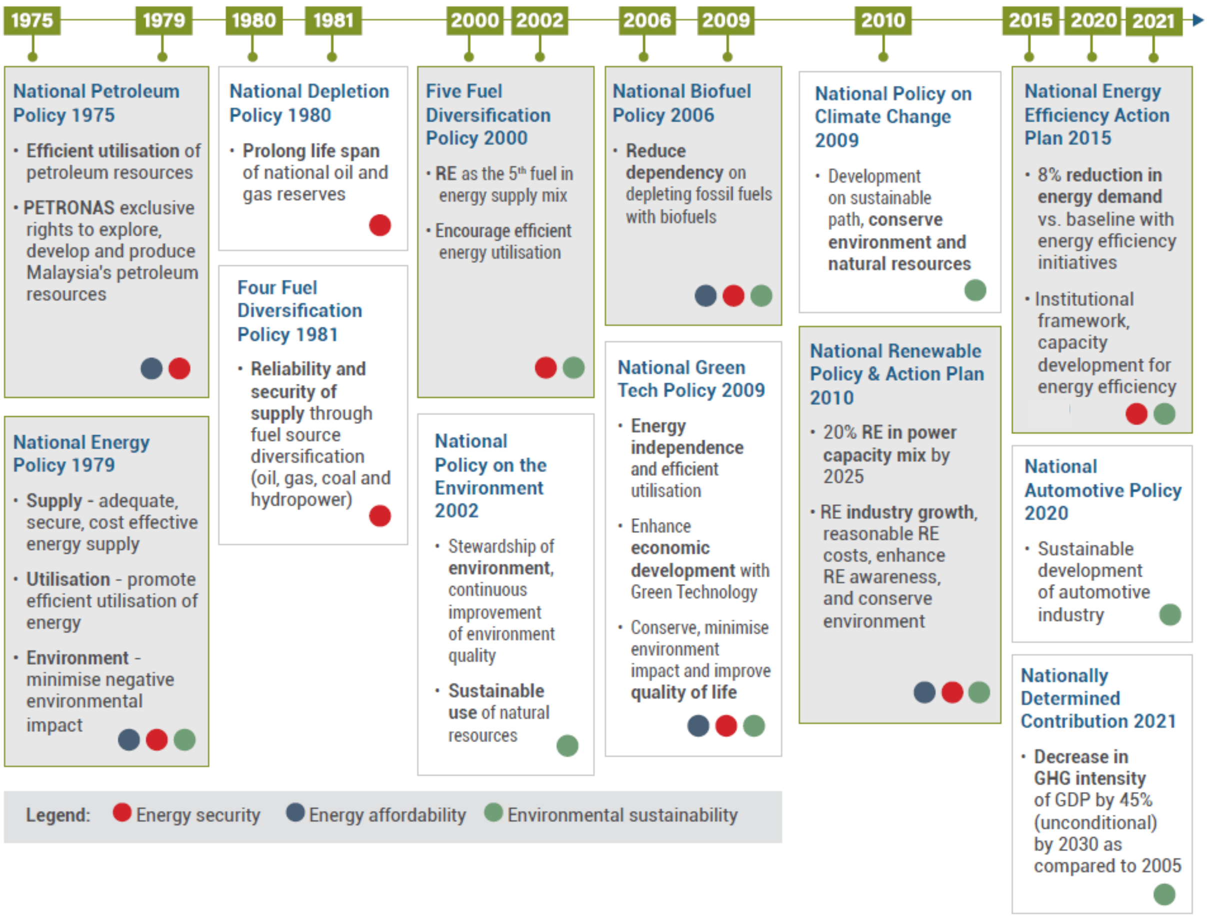
- To provide for the **establishment and implementation of a feed-in tariff (FiT) system** to increase electricity generation from renewable sources.

Sustainable Energy Development Authority Act (2011)

- To provide for the **establishment of the Sustainable Energy Development Authority (SEDA).**
- SEDA is responsible for **sustainable energy laws and to promote the use of sustainable energy.**

Source: EPU (2023).

Figure 3.3. Energy-Related Policies



GDP = gross domestic product; GHG = greenhouse gas; RE = renewable energy
Source: EPU (2023).

In addition to the core energy-related policies listed above, other related policies, such as housing, transportation, and industrial policies, have significant implications for the energy sector. Thus, the sector needs a new energy strategy to strengthen and unify the policies that are already in place so that the future direction and goals of the energy sector are clear. A new energy policy will ensure coordinated energy sector responses that are in line with national aspirations and agendas, as well as being future-proof and consistent with global energy transition trends. This will create a coordinated long-term vision and action plans amongst various stakeholders, economic sectors, and energy-related industries to address challenges and reap benefits from the global energy transition megatrend. The new policy will provide the most up to date and visionary direction for the energy sector to facilitate long-term investment decisions by investors and industries, thereby stimulating GDP growth and job opportunities. Strengthening the energy sector's enablers and governance will help plan, develop, and implement a comprehensive and integrated energy policy. This will also help refine the aggregate effects of different policies and development plans in other economic sectors, such as the transport sector's public transportation plan, fuel economy, and next-generation vehicles.

1.3. The National Energy Policy, 2022–2040

The National Energy Policy (DTN) 2022-2040 was launched in September 2022 to demonstrate the federal government's commitment to energy transition as shown in Figure 3.4 (Gov of Malaysia, 2023). The DTN aims to improve economic resilience and ensure energy recovery while achieving equality and universal access and ensuring environmental sustainability using energy-based hydrocarbons and renewable energy sources. The DTN is leading the way in a practical transition to a cleaner energy mix by encouraging improved demand-side management; the development, commercialisation, and adoption of green technologies; as well as the upskilling of the energy sector workforce to meet future industry needs. Furthermore, the DTN will foster an appealing investment climate, including increased compliance with environmental, social, and governance (ESG) commitments for key energy sub-sectors such as the upstream oil and gas sector.

Figure 3.4. National Energy Policy Vision and Objectives

Source: EPU (2022).

The DTN charts a path forward and outlines key priorities for the energy sector in the coming years. The DTN will position the energy sector as a driver of socioeconomic development. Aspiration will ensure that the energy sector is future-proof and strategically positioned to meet new challenges, as well as that the sector fully exploits the opportunities brought about by the energy transition. The energy sector needs to increase productivity, enable high-value-added growth, such as in downstream industries, and stimulate new future economic sectors to promote economic development and move the nation toward high-income nation status. Sustainable mobility, renewable energy, and the green economy are three of the five Key Economic Growth Activities that are directly related to the energy sector. Promoting new energy-related sectors will also help the country's fiscal and economic resilience by reducing reliance on petroleum-based revenue and commodity trade.

The DTN will also open economic opportunities that support a robust economic recovery and speed the nation's recovery from the coronavirus disease (COVID-19) pandemic. The DTN will serve as a catalyst for new investments to be directed toward the green economy and areas of the emerging energy sector to promote long-term GDP growth and job creation. To escape the middle-income trap and move closer to becoming a prosperous high-income country, Malaysia will need to grow its high-value downstream industries and find new sources of economic growth in the energy sector.

1.4. Low Carbon Nation Aspiration 2040

The Low Carbon Nation Aspiration 2040 is based on energy plans that are already in place. The government will take a more proactive approach by identifying and developing selective leadership in low-carbon economy areas where the country has high potential and a competitive advantage. Appropriate government incentives will be provided to attract investments in low-carbon technology development. This will position the country as a leader in high-growth areas such as renewable energy, energy storage, low-carbon mobility, the hydrogen economy, and others.

The government will take on a more proactive role by identifying and cultivating selective leadership in the low-carbon economy sectors that are in line with the regions where the nation has high potential and a competitive advantage. It aims to increase the modal share of urban public transportation; the penetration of electric vehicles; the use of alternative, lower-carbon fuels in heavy vehicles and marine transport; and energy efficiency improvements in the industrial, commercial, and residential sectors. The Low Carbon Nation Aspiration 2040 also calls for no new coal power plants and a higher level of renewable energy penetration in installed capacity and TPES. The Low Carbon Nation Aspiration 2040 aims to reach nine specific goals as shown in Figure 3.5.

The aspiration is anticipated to have a significant positive impact on economic development, increasing GDP and creating jobs. It will also help bring in the next wave of green growth foreign direct investment. Furthermore, improvements in each dimension of the energy trilemma are expected, including a reduction in emissions intensity. Private and public investments should be made in a timely manner to facilitate the transition to support the aspiration. The government must also create catalytic incentives and supportive regulatory frameworks to encourage low-carbon economy growth ecosystem investments and transition. Additionally, policy and technological trends should be monitored to update targets.

Figure 3.5. Selected Targets on Low Carbon Nation Aspiration 2040

Selected Targets		2018	Low Carbon Nation Aspiration 2040
1. Percentage of urban public transport modal share	Energy affordability; Environmental sustainability	20%	50%
2. Percentage of electric vehicle (EV) share	Environmental sustainability	<1%	38%
3. Alternative fuel standard for heavy transport	Environmental sustainability	B5	B30
4. Percentage of Liquefied Natural Gas (LNG) as alternative fuel for marine transport	Environmental sustainability	0%	25%
5. Percentage of industrial and commercial energy efficiency savings	Energy affordability; Energy security; Environmental sustainability	<1%	11%
6. Percentage of residential energy efficiency savings	Energy affordability; Energy security; Environmental sustainability	<1%	10%
7. Total installed capacity of RE	Energy affordability; Energy security; Environmental sustainability	7,597 MW	18,431 MW
8. Percentage of coal in installed capacity	Energy affordability; Energy security; Environmental sustainability	31.4%	18.6%
9. Percentage of RE in TPES	Energy affordability; Energy security; Environmental sustainability	7.2%	17%

Legend: Energy security, Energy affordability, Environmental sustainability

< = less than; MW = megawatt; RE = renewable energy; TPES = total primary energy supply.
Source: EPU (2023).

1.5. Energy Sector Governance

Energy sector governance and planning are complex due to the scope and cross-sectoral nature of energy-related decision-making. Energy demand planning cuts across key sectors of the economy, involving stakeholders from the transportation, industrial, residential, and commercial sectors. Energy supply planning, which includes multiple energy sources such as oil, natural gas, coal, and renewable energy, necessitates extensive cross-sector collaboration with relevant stakeholders. The energy sector is governed by ministries, agencies, and regulators whose mandates are outlined in key legislative acts as shown in Figures 3.6 and 3.7.

Energy sector governance will be strengthened to improve efficiency and enable more holistic planning to address domestic and global developments. It includes improving energy sector governance through ministry-agency collaboration and streamlining energy-related topics amongst multiple stakeholders for improved accountability and implementation. Regulatory coverage, oversight clarity, and capability building should be improved to keep pace with technological developments across sectors.

Figure 3.6. Key Energy-Related Ministries

Ministries with direct energy-related responsibilities			
Economic Planning Unit, Prime Minister's Department (EPU)	Ministry of Energy and Natural Resources (KeTSA)	Ministry of Plantation Industry and Commodities (MPIC)	Ministry of Domestic Trade and Consumer Affairs (KPDNHEP)
Ministries related to key final energy demand sectors		***Cross-cutting influence***	***State-specific entities***
Ministry of Transport (MOT)	Ministry of Housing and Local Government (KPKT)	Ministry of Finance (MOF)	State Economic Planning Unit (UPEN) Sabah
Ministry of International Trade and Industry (MITI)	Ministry of Rural Development (KPLB)	Ministry of Environment and Water (KASA)	State Economic Planning Unit (UPEN) Sarawak
Ministry of Federal Territories (KWP)	Ministry of Agriculture and Food Industry (MAFI)	Ministry of Science, Technology, and Innovaton (MOSTI)	Ministry of Utility and Telecommunication (Sarawak)

Source: EPU (2023).

Figure 3.7. Key Energy-Related Organisations

Key Energy-Related Organisations			**Key Energy-Regulators**
Power-related	***Oil and gas-related***	***Cross-cutting influence***	***Electricity and piped gas***
Single Buyer (SB)	Malaysia Petroleum Resources Corporation (MPRC)	Malaysian Green Technology and Climate Change Corporation (MGTC)	Suruhanjaya Tenaga Energy Commission Energy Commission (ST)
Grid System Operator (GSO)	**Renewable Energy related**	Malaysian Investment Development Authority (MIDA)	**Upstream Oil and Gas**
MyPower	Sustainable Energy Development Authority (SEDA)	Malaysia Automotive, Robotics and IoT Institute (MARii)	Petroliam Nasional Berhad (PETRONAS)

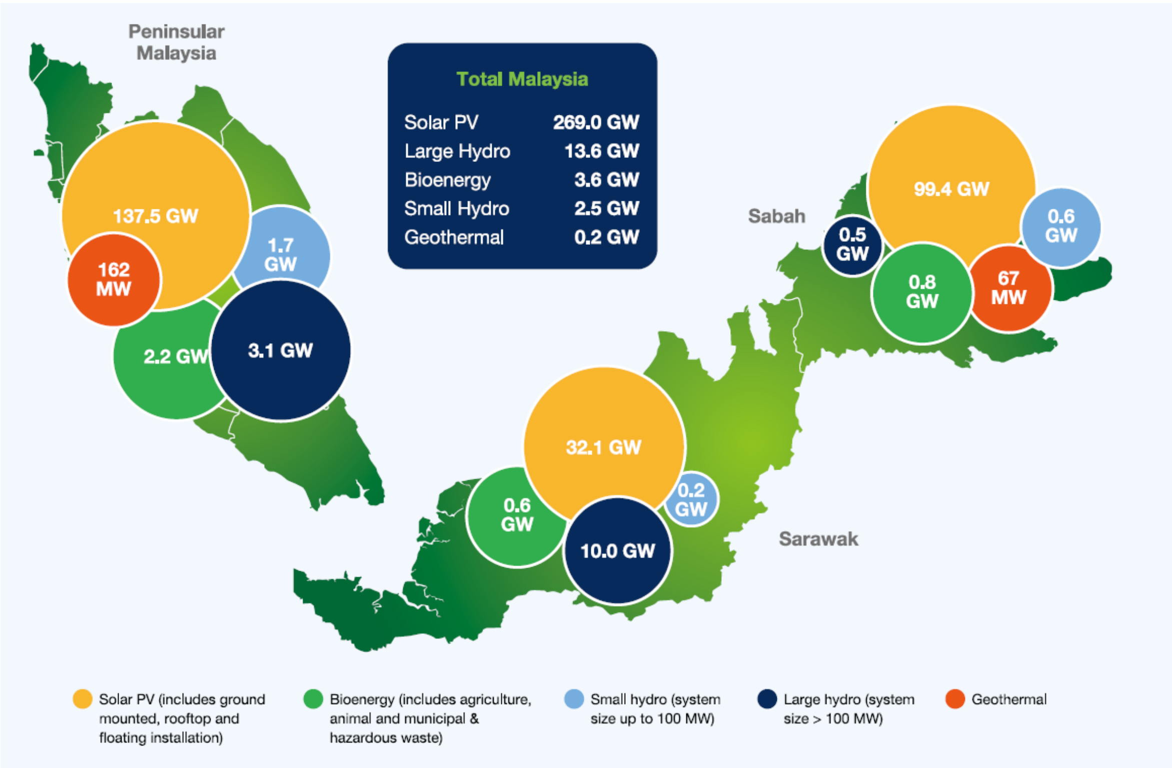
Source: EPU (2023).

2. Renewable Energy Development in Malaysia

2.1. Malaysia's Potential Renewable

According to the Malaysia Renewable Energy Roadmap (MyRER), a review of Malaysian renewable energy resource potential has been conducted to identify of the following resource potential. Solar photovoltaics (PV) has the highest potential of 269 gigawatts (GW) dominated by ground-mounted configurations (210 GW), including considerable potential from rooftop (42 GW) and floating configurations (17 GW) (SEDA 2021). Large hydro above 100 megawatts (MW) accounted resource potential close to 13.6 GW (13,619 MW) whereby 3.1 GW is identified in Peninsular Malaysia, 493 MW in Sabah, and 10 GW in Sarawak. 2.5 GW resource potential for small hydro up to 100 MW capacity. Total resource potential for bioenergy is expected up to 3.6 GW, including biomass (2.3 GW), biogas (736 MW), and municipal solid waste (516 MW). Malaysia also has expected geothermal resource potential of 229 MW. The summary of renewable energy resource potential in Malaysia by states is shown in Figure 3.8.

Figure 3.8. Summary of Renewable Energy Resource Potential in Malaysia



GW = gigawatt; MW = megawatt; PV = photovoltaic.
Source: SEDA (2021).

Malaysia's advantageous geographical location provides an abundance of indigenous natural resources that are readily available for use in renewable energy power generation. Malaysia's proximity to the equator provides year-round solar irradiance in the range of 1,575 to 1,812 kilowatt hours per square metre, comparable to countries with more mature and developed solar PV markets. About 450 palm oil mills in Malaysia have the potential to process an average of 95.5 million tonnes of fresh fruit bunches each year. The waste from palm oil processing can be used as feedstock for bioenergy power generation, either by burning biomass or capturing biogas. Malaysia also has agricultural and livestock waste from rice production, wood processing, and animal waste, that can be used to make electricity. Malaysia's growing population and increase in urbanisation have led to a rise in the amount of municipal solid waste. Each year, an estimated 9.5 million tonnes of solid waste are made. Waste-to-energy technologies could be used to make electricity from bioenergy. Malaysia also has 189 river basins that could be used to create small amounts of hydroelectric power (SEDA,2021).

2.2. Regulatory Analysis of Renewable Energy in Malaysia

Renewable energy was first introduced as the country's "fifth fuel" and alternative source of power generation in 1999 and was part of the government's plan to diversify the nation's energy mix. Between 2001 and 2020, several initiatives, programmes, and strategies have been created and put into action to support the development of renewable energy technologies. The Small Renewable Energy Power Programme, as well as the Biomass Power Generation and Cogeneration Full Scale Model Demonstration Project, were introduced under the Eighth Malaysia Plan (2001–2005), leveraging readily available oil palm-based by-products for small-scale electricity generation. The Malaysia Building Integrated Photovoltaic Project, which was implemented as part of the Ninth Malaysia Plan (2006–2010), saw an increase in rooftop solar development. The project focused on developing policies for PV systems that connect to the grid, as well as on market and incentive measures, and a programme to build people's skills for rooftop solar.

The programmes and projects of the 8th and 9th plans led to the creation of the National Renewable Energy Policy and Action Plan in 2010. The goal of this plan was to set up a policy guide for the development of renewable energy in Malaysia. In the Tenth Malaysia Plan (2011–2015), of the National Renewable Energy Policy and Action Plan paved the way for renewable energy development as one of the key new areas of growth for the energy sector. During this time, the Renewable Energy Act 2011 (Act 725) and the Sustainable Energy Development Authority (SEDA) Act 2011 (Act 726) was passed, resulting in the establishment of SEDA as the designated authority for renewable energy development in Malaysia. The Feed-in-Tariff (FiT) scheme was also introduced and implemented in 2011 to accelerate the growth of grid-connected renewable energy in Peninsular Malaysia, Labuan, and Sabah.

The initiative to promote renewable energy growth advanced further under the Eleventh

Malaysia Plan (2016–2020). For the first time, solar auctioning and rooftop solar quotas were made available through the Large Scale Solar, Net Energy Metering, and Self-Consumption Programmes. Malaysia's renewable energy capacity had grown significantly by the end of the 11th Plan, from a base of 53 MW of renewable energy connected to the grid (without large hydro) between 2001 and 2009 to a total installed capacity of 1.6GW between 2011 and 2015. The total renewable energy capacity had grown to 2.8 GW by December 2020, or 8.45 GW when all renewable energy resources were considered (SEDA, 2021).

Malaysia aims to increase its renewable energy growth from the current 23% or 8.45 GW renewable energy in its power installed capacity in the future. According to the MyRER, the share of renewable energy will increase to 31% or 12.9 GW in 2025, and 40% or 18.0 GW in 2035. The renewable energy initiatives outlined in this roadmap are intended to support Malaysia's commitment to reducing greenhouse gas emissions under the Paris Agreement, which is led by the United Nations Framework Convention on Climate Change. Malaysia has agreed to reduce its carbon intensity (as a percentage of GDP) by 45% by 2030 compared to the figure in 2005. The realisation of the government's vision is critical in assisting the country to meet its Nationally Determined Contributions targets.

Malaysia offered 1,000 MW of large scale solar projects, 500 MW of solar rooftop quotas, and 188 MW of non-solar quotas to encourage investment and growth after the COVID-19 pandemic. The pandemic has also created more social and economic opportunities for businesses and policymakers in Malaysia to take on more ESG commitments. Malaysian businesses are becoming more interested in changing their strategies to focus on sustainability, as more people realise how important it is to their financial health. The need to get the economy back on track after the pandemic and the need to keep up with the current energy megatrend are two reasons why the government should look at its medium- and long-term goals and strategies for developing renewable energy in the country. For this reason, MyRER was created to help the government reach its goals for the future of renewable energy, which includes a total investment of RM53 billion and the creation of 46,336 jobs.

2.3. Main Renewable Energy Authorities and Regulators

Malaysia's renewable energy policies are primarily implemented, monitored, and enforced by the bodies listed below. The Ministry of Natural Resources, Environment, and Climate Change is a ministry of the Government of Malaysia with responsibility for energy, natural resources, environment, climate change, land, mines, minerals, geoscience, biodiversity, wildlife, national parks, forestry, surveying, mapping, and geospatial data. The Energy Commission is the primary regulator of the energy sector in Peninsular Malaysia and Sabah. It is charged with balancing the needs of consumers and energy suppliers while encouraging economic development and creating positive market competition in the electricity and piped gas supply industries. SEDA's primary function is to administer and manage the implementation of the FiT mechanism as outlined in the Renewable Energy Act. SEDA monitors and ensures that existing sustainable energy policies are carried out efficiently, in addition to advocating for the deployment of sustainable energy initiatives for the development of the nation's economy.

Renewable energy is primarily governed by three types of legislation. The Electricity Supply Act of 2001 governs the electricity supply industry, reasonable pricing of electricity supply, electrical installation licencing, and other issues concerning the safe and efficient use of electricity. The SEDA Act 2011 created the statutory body, the Sustainable Energy Development Authority, and empowered it to carry out its duties related to the development of sustainable energy sources. These powers include giving advice to the government on issues related to sustainable energy, promoting the national policy goals for renewable energy, and getting people to invest in renewable energy sectors. The Renewable Energy Act 2011, along with other subsidiary legislation, went into effect as one of the initiatives prompted by the National Renewable Energy Policy and Action Plan. The Renewable Energy Act was enacted with the goal of focusing on renewable energy development in relation to the FiT mechanism.

SEDA manages the Renewable Energy Fund, which is another important part of the Renewable Energy Act. The fund, which is made up of sums allocated by parliament, sums collected by SEDA under the Renewable Energy Act, and income from investments made from the fund, aims to provide funding and financial support to the FiT mechanism as well as to enforce the Renewable Energy Act.

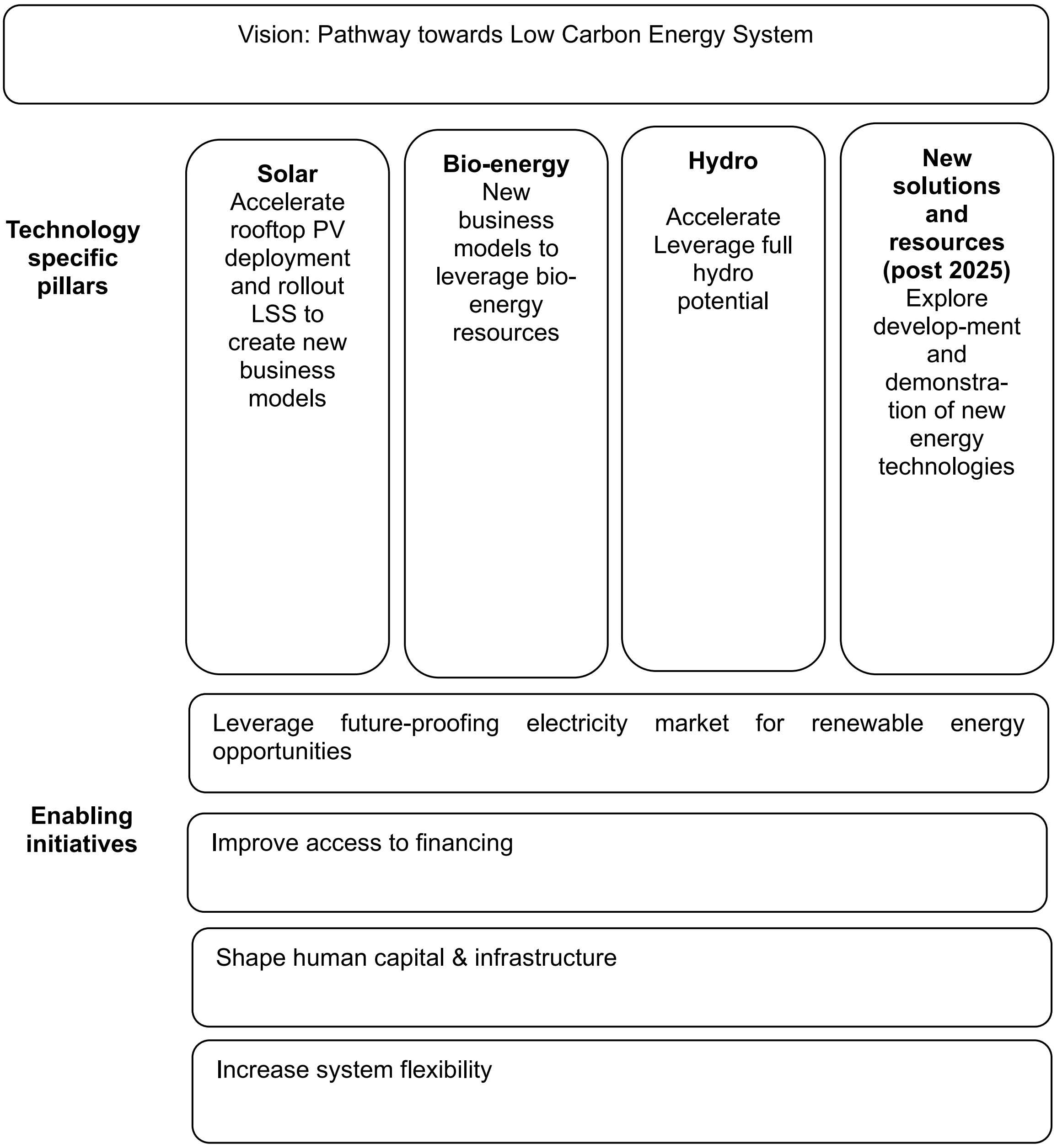
2.4. Malaysia Renewable Energy Roadmap

MyRER is a strategic framework aimed at achieving a 31% renewable energy share in the national capacity mix by 2025 and decarbonisation of the electricity sector by 2035. Figure 3.9 shows the four technology-specific pillars and four enabling initiatives that support the MyRER vision. The strategic framework calls for different groups to work together in a coordinated way to help Malaysia take advantage of the huge potential that renewable energy projects offer to improve economic, environmental, and social outcomes.

MyRER covers both grid-connected and off-grid renewable energy sources in Malaysia. In the MyRER, bioenergy, hydropower, solar PV, and other technologies such as geothermal power generation and wind energy are all considered as renewable energy resources. Bioenergy includes municipal solid waste, landfill gas, and agricultural waste. Palm oil waste and palm oil mill effluent, wood residues, and other agricultural waste (e.g. rice husks, straw, and animal waste) are also considered bioenergy sources.

Hydropower of all capacities is included, but small hydropower of up to 100 MW is evaluated separately. The MyRER also considers solar PV assessment based on ground-mounted, rooftop, and floating applications.

Figure 3.9. Malaysia Renewable Energy Roadmap Strategic Framework



LSS = large scale solar; PV = photovoltaic.
Source: SEDA (2021).

The use of fossil fuels continues to dominate the national installed capacity mix in Malaysia. Malaysia's share of renewable energy remains lower than the global and regional averages. By the end of 2020, renewable energy made up 23% of the installed power capacity in the country. This compares to a global average of 37% and a regional average of 30% in Southeast Asia (SEDA, 2021). There is an urgent need to speed-up the deployment of renewable energy in Malaysia to meet the renewable energy and climate goals that have been set. This can be done by strengthening existing programmes and introducing new ones, as well as by the government making sure that current electricity market regulations and power sector industry practises will continue to work in the future. This roadmap will be the forward-looking document that explains how to speed-up the use of renewable energy in Malaysia. More importantly, the roadmap aims to find a balance between environmental goals, keeping prices low and maintaining economic benefits, and keeping system security by reducing the effects of variable renewable energy sources. This will allow the Malaysian power sector to provide reliable and affordable green power to everyone.

3. Methodology

3.1. Data Envelopment Analysis Model

The data envelopment analysis (DEA) model is a non-parametric technique that can be used to evaluate the efficiency of a set of decision-making units (DMUs) using multiple inputs and outputs (Suzuki and Nijkamp, 2016; Cooper, Selford, and Tone, 1999; Cooper, Selford, and Tone, 2007). Two basic models of DEA are used, namely, the Charnes–Cooper–Rhodes (CCR) model and the Banker–Charnes–Cooper (BCC) model (Zhou, et al., 2018; Galán-Martín, et al., 2016; Woo, et al., 2015). The CCR-DEA model evaluates the gross efficiency of a DMU that comprises technical efficiency and scale efficiency and aggregates it into a single value (Ramanathan, 2003). Technical efficiency is defined as the efficiency in converting inputs to outputs, whereas scale efficiency recognises that the economy of scale cannot be attained at all scales of production (Alrashidi, 2015). The scale efficiency is at its maximum, 100%, and is referred to as the most productive scale size (Galán-Martín, et al., 2016). The constant return to scale assumes that inputs and outputs are proportional to each other. In the CCR model, the format of the efficient frontier is a straight line with an angle of 45 degrees (Sabli, et al., 2019).

The current study chooses the BCC-DEA output-oriented model, which assumes variable return to scale to calculate the technical efficiency scores of renewable energy development in Malaysia from 2010–2017. The BCC-DEA output-oriented paradigm is depicted in Equation (1) (Cadoret, et al., 2016).

$Min\ \Phi$, subject to

$$\sum_{j=1}^{n} z_i x_{ij} + s_j^- = x_0, (i = 1, \ldots, m) \quad \ldots(1)$$

$$\sum_{j=1}^{n} z_j y_{rj} - s_j^+ = \theta_0 y_0, (r = 1, \ldots, s)$$

$z_0 \geq 0, j = 1, \ldots, n$

if variable return to scale, add $\sum_{j=1}^{n} z_j = 1$,

where n is the number of existing DMUs, m denotes the input, and s denotes the output for each DMUj (j=1, 2,..., n). xij is the ith input of DMUj, and yrj is the rth output of DMUj. Slack variables measure the excess inputs and outputs, s_i^- and s_j^+. The efficiency value, which is in the range of (0,1), is denoted by θ0.

The DEA method is used to measure efficiency, and typically for second-stage analysis, a regression model is used to correlate the DEA efficiency score with environmental factors that affect the efficiency and inefficiency of a DMU (Sağlam, 2017; Sarra, Mazzocchitti, and Raposelli, 2017; Niu, et al., 2018). Environmental factors are those that can affect the efficiency of a DMU and are beyond control. The value of the DEA efficiency score is between the interval of 0 and 1 (0 ≤ & ≤ 1), which will make the dependent variable a finite dependent variable (Prinz and Pageis, 2018; Sirin, 2011). The Tobit model is well known for its advantages in controlling the character distribution of inefficiency measures. Therefore, the DEA efficiency score obtained in the first stage will be used as the second stage's dependent variable and analyse the DMU's characteristics and environmental variables.

3.2. Tobit Regression Analysis

This study used a Tobit regression model to conduct a second-stage DEA analysis. The Tobit regression model was introduced through the early work of Tobin in 1958 (del Río, 2017). According to Tobin (1958), most variables have specific characteristics, such as having a lower limit or higher and taking a limit value for many respondents or units of analysis. The Tobit regression model can be used to describe the relationship between latent variables or non-negative dependent variables, with environmental variables when data is censored or truncated (Sağlam, 2017; Niu et al., 2018). The relative efficiency scores obtained from the DEA analysis ranged from 0.000 to 1.000. Therefore, the Tobit model is an appropriate method for conducting the second-stage DEA analysis because the data obtained from the first stage DEA analysis are censored from the lower and upper limits (Can Şener, Sharp, and Anctil, 2018). The Tobit regression model can be formulated as shown in Equation (2) for an output-oriented BCC-DEA model (Sağlam, 2017):

$$y_i^* = \beta' x_i + \varepsilon_i \qquad \ldots(2)$$

$$y_i = \begin{cases} y_i^*, if\ y_i^* > 0 \\ 0, if\ y_i^* x = 0 \end{cases}$$

$$\varepsilon_i \sim N(0, \sigma^2)$$

where, x_i is a vector of an independent variable; $\boldsymbol{\beta}$ is the parameter vector to be estimated; y_i^* is a latent variable; y_i is the DEA efficiency score; and $\boldsymbol{\varepsilon}_i$ error terms that are normally distributed, equal and independent.

3.3. Conceptual Framework

Various policy instruments have been developed and used to promote the adoption of renewable energy technology in the power generation sector. Previous researchers have undertaken various analytical studies to analyse the effectiveness of the green policy implementation towards achieving their objectives and meeting the target in increasing the adoption of renewable energy in the country. However, the environmental factors that influenced the effectiveness of implementing these policies are lacking in the literature. Therefore, identifying the environmental factors that may contribute to the effectiveness of the policy implementation can be very useful in the current policy portfolio formulation and can act as guidance on what needs to be done. With various renewable energy policies adopted and still under discussion, the literature stressed the need to evaluate the environmental factors that may influence these policy instruments' ability to achieve their targets. This evaluation can serve as feedback and give decision-makers information about the environmental factors that may affect the policy effectiveness, which might lead to redesigning the policy or its implementation process.

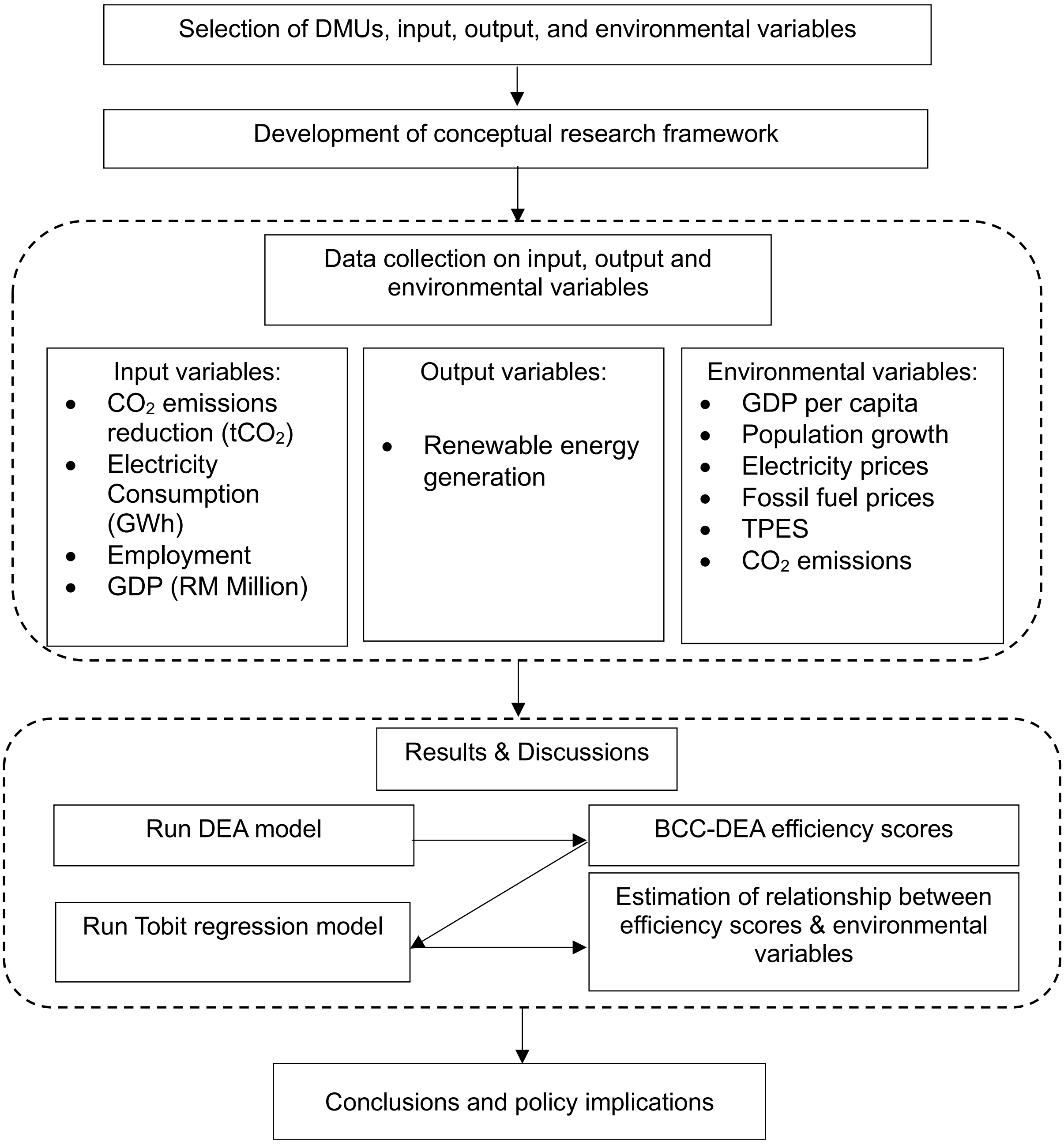
This study aims to determine the environmental factors affecting the technical efficiency scores of renewable energy development in Malaysia using a two-stage analysis. In the first stage, Malaysian renewable energy development efficiency scores are calculated using the DEA method with four inputs: the number of employments, electricity consumption, GDP, and licensed renewable energy capacity, and one output which is renewable energy generation. The second stage uses the Tobit regression analysis to investigate the relationship between the efficiency scores and environmental variables beyond renewable energy development control. Six environmental variables which are GDP per capita, population growth, electricity prices, fossil fuel prices, TPES, and carbon dioxide (CO_2) emissions will be assessed to evaluate the significant impact toward the technical efficiency scores obtained from the DEA results. The conceptual framework of this study is illustrated in Figure 3.10.

The objective of this study is to:

1. develop a comprehensive overview of Malaysia's renewable energy development in energy transition;
2. study the effects of the four input and one output variables that have been predetermined in this study by using the developed output-oriented BCC-DEA model;
3. apply the Tobit regression model for further investigations of the DEA results using six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions; and
4. evaluate the present efficiency of renewable energy development and the future of

the renewable energy sector for both energy practitioners and policy makers planning future investments and propose some insight from the findings.

Figure 3.10. Conceptual Research Framework



BCC = Banker–Charnes–Cooper; CO_2 = carbon dioxide; DEA = data envelopment analysis; DMU = decision-making unit; GDP = gross domestic product; GWh = gigawatt hour; RM = Malaysian ringgit; tCO_2 = total carbon dioxide; TPES = total primary energy supply.
Source: Author.

Considering this conceptual framework, the evaluation in this study will be led by the following key questions:

1. To what extent has the introduction and implementation of operational policy related to the renewable energy sector affected renewable energy development in Malaysia? Does the operational policy help speed-up the energy transition in Malaysia?
2. To what extent has the impact of environmental or other significant factors affected renewable energy development in Malaysia? Based on this finding, the significant factors that contribute to the performance of renewable energy development in Malaysia will be determined.
3. To what extent has the introduction and implementation of new operational policy related to renewable energy sector in Malaysia been affected by environmental factors such as population growth, electricity prices, TPES, CO_2 emissions, GDP per capita, and fossil fuel prices? Based on this finding, it is possible to propose a feasible attractive scheme or programme to attract more business investment in clean energy transition in Malaysia?
4. What action should the Government of Malaysia undertake to improve the effectiveness of operational policy implementation to ensure it can achieve the desired target in the future? This is important because empirical research recommends that the impact of renewable energy and just transition policies should be enhanced to achieve best results (Fairuz, et al., 2021).

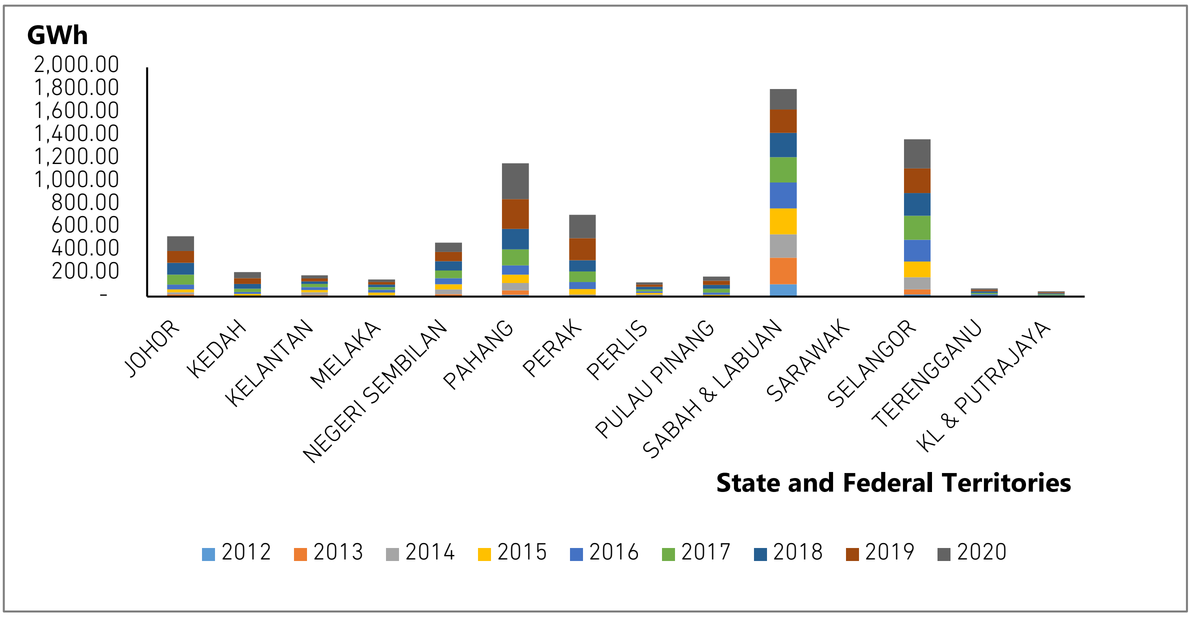
3.4. Selection of Variables

In the first-stage analysis, the employment numbers, electricity consumption, and renewable energy licensed capacity were selected as inputs, and renewable energy generation and GDP were selected as outputs in the DEA analysis. The technical efficiency scores obtained from the DEA results will be used as a dependent variable in the Tobit regression analysis to determine the relationship with six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions. The data collection process for all variables selected in this study is collected from the respective government agencies.

DMU used in this study covers both samples from the public sectors and private sectors, categorised according to the 13 states and federal territories in Malaysia. The study will consider 9 years of data during 2012–2020 since the year 2020 is the latest annual report published by the respected authorities.

Renewable energy generation by state and federal territory is shown in Figure 3.11. Malaysia has generated 7,025.32 GWh of electricity from renewable energy such as hydro, solar, biomass, and biogas resources during 2012–2020. Sabah and Labuan are the states and the federal territories that generated the highest amount of renewable energy at 2,076.10 GWh, followed by Selangor at 1,373.35 GWh and Pahang at 1,162.39 GWh. Of all of Malaysia's renewable energy resources, solar PV accounts for almost 40% of the country's total cumulative renewable energy generation with the highest installed capacity during 2012–2020.

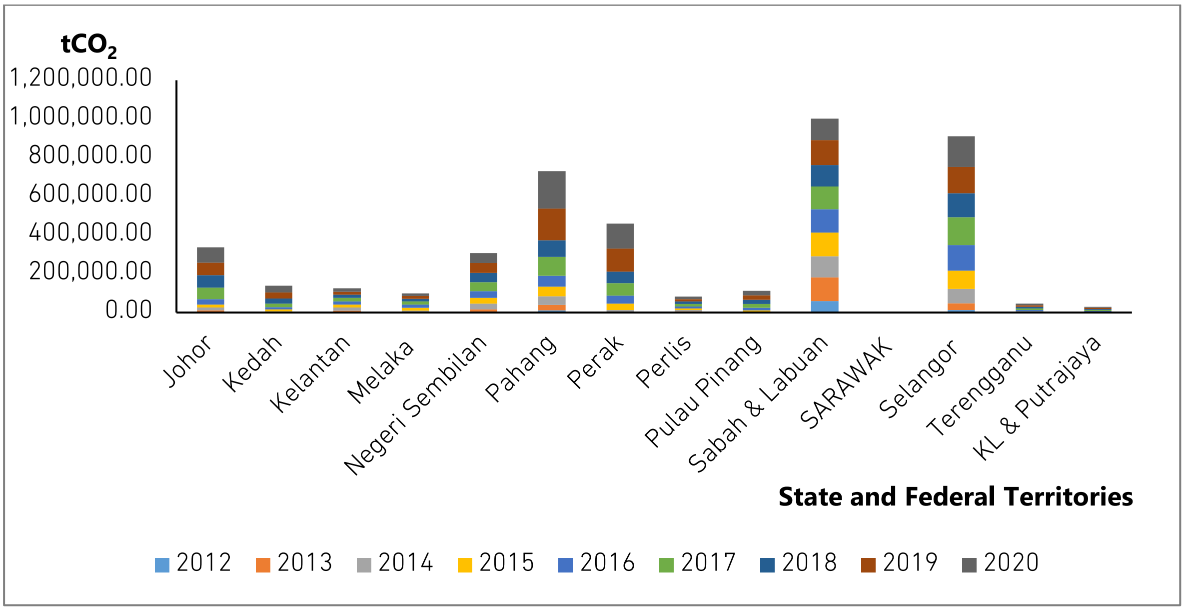
Figure 3.11. Renewable Energy Generation by State and Federal Territory in Malaysia



GWh = gigawatt hour; KL = Kuala Lumpur.
Source: Author.

Figure 3.12 shows the cumulative CO_2 emissions reduction according to state and federal territory in Malaysia. Based on the total renewable energy generated in the country, 4,249,451 tonnes of CO_2 emissions were displaced from the conventional fossil fuels plants in the period 2012–2020. Solar PV has displaced most of the CO_2 emissions at 40%, followed by biomass, biogas and small hydro renewable energy resources at 25%, 21% and 14% respectively.

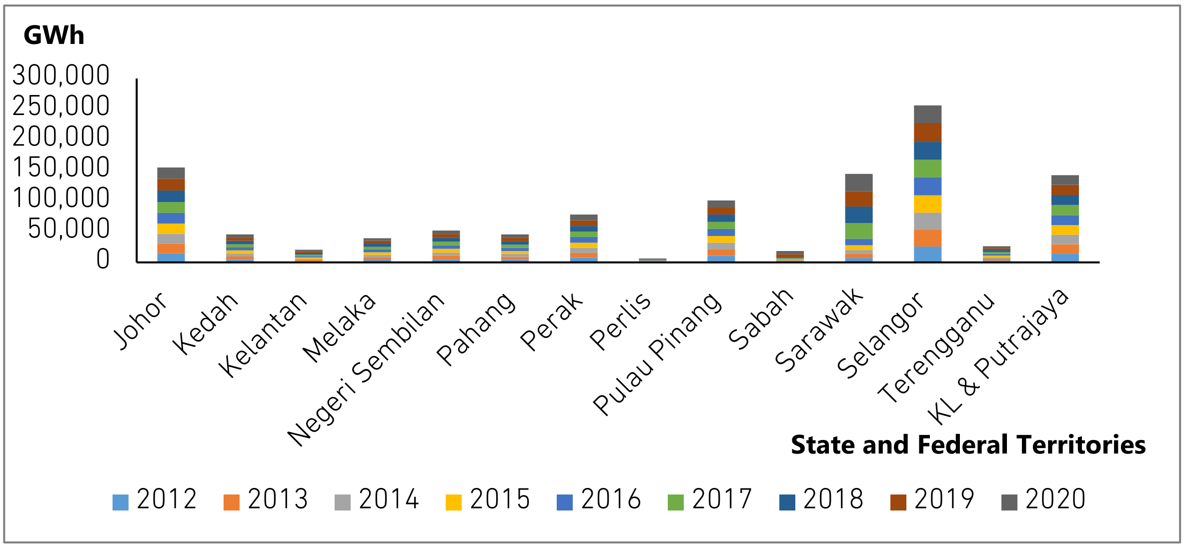
Figure 3.12. Cumulative CO_2 Emissions Reduction According to State and Federal Territory



CO_2 = carbon dioxide; tCO_2 = total carbon dioxide; KL = Kuala Lumpur.
Source: Author.

Figure 3.13 shows the electricity consumption (GWh) by state and federal territory in Malaysia during 2012–2020. In the period 2012–2020, the total or electricity consumption in Malaysia was 1,131,846 GWh, which includes all main power generating stations connected to the National Grid system and by off-grid. In terms of mix energy sources overall, 37.3% of the generation capacity in Malaysia was based on natural gas, 37.9% on coal, 23.2% on renewable energy, 1.5% on diesel and other sources accounted for 0.1%. Hydroelectric supplied 76% of the renewable energy, followed by 17% from solar and 7% from biomass/biogas. When comparing all the states and federal territories in Malaysia during 2012–2020, Selangor has the highest electricity consumption at 256,014 GWh, followed by Johor at 154,837 GWh, and Sarawak at 144,176 GWh.

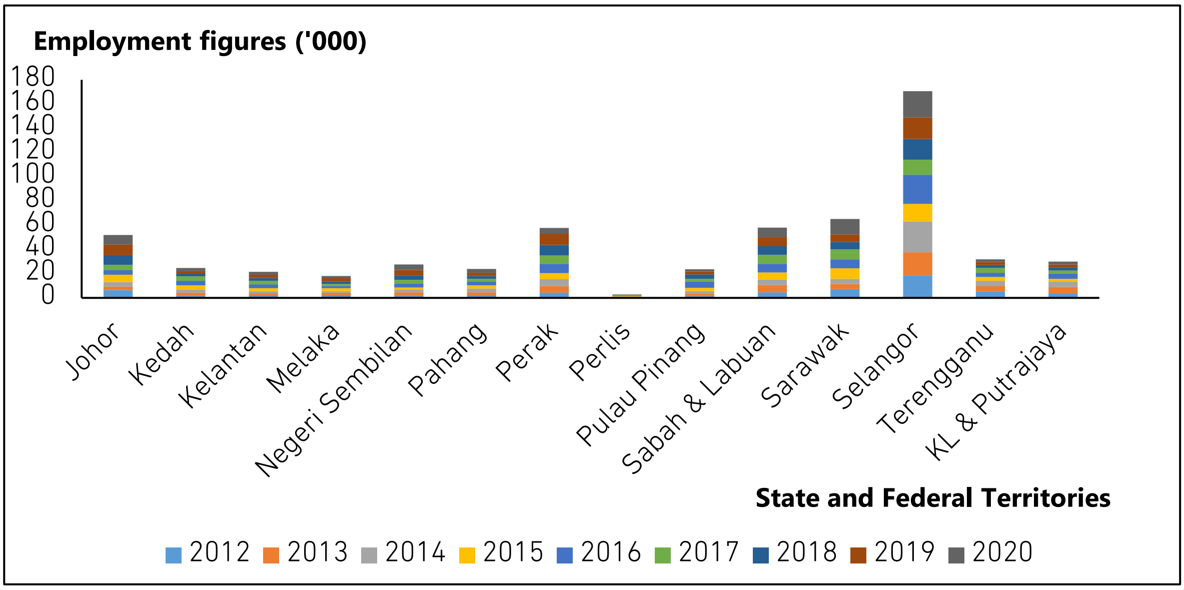
Figure 3.13. Electricity Consumption by State and Federal Territory in Malaysia



GWh = gigawatt hour; KL = Kuala Lumpur.
Source: Author.

Figure 3.14 shows the number of people employed in the electricity, gas, and water supply sector in Malaysia during 2012–2020. Around 76,400 people were employed in these industries in Malaysia in 2020. The greatest number were employed in Selangor (21,600), followed by Sarawak(12,800), Johor (7,900), and Sabah (7,800).

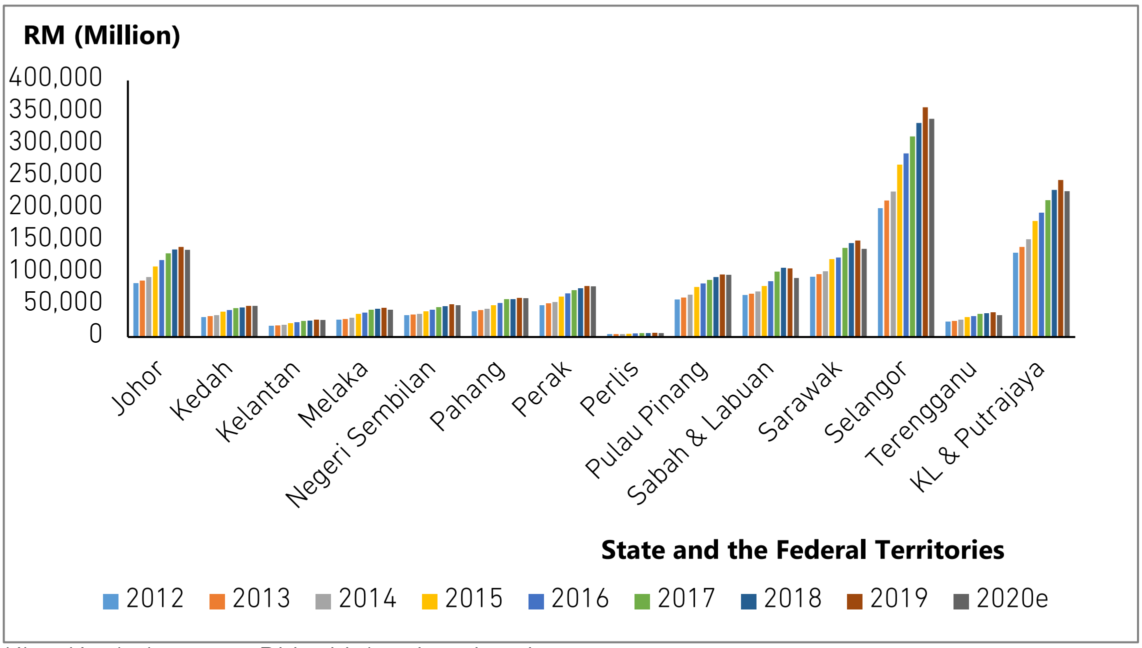
Figure 3.14. Employment Figures in the Electricity, Gas and Water Supply Sector in Malaysia, 2020–2020



KL = Kuala Lumpur.
Source: Author.

Figure 3.15 shows the GDP by state and federal territory in Malaysia during 2012–2020 at the amount of RM11,057,236 million. Six states and federal territories – Johor, Kuala Lumpur, Labuan, Penang, Putrajaya, Sabah, Sarawak, and Selangor – have remained the largest contributors to the national GDP with a total contribution of 74.64%. Selangor made a higher contribution to Malaysia's GDP during this period due to the vibrant economic activity in the state supported by the manufacturing and services sectors. In 2018 its contribution was 23.7%, in 2019 it was 24.1% and in 2020 it was 24.3.

Figure 3.15. Gross Domestic Product by State and Federal Territory at Constant Prices (2010 = 100), Malaysia



KL = Kuala Lumpur; RM = Malaysian ringgit.
Source: Author.

4. Results and Discussion

4.1. Data Envelopment Analysis Result

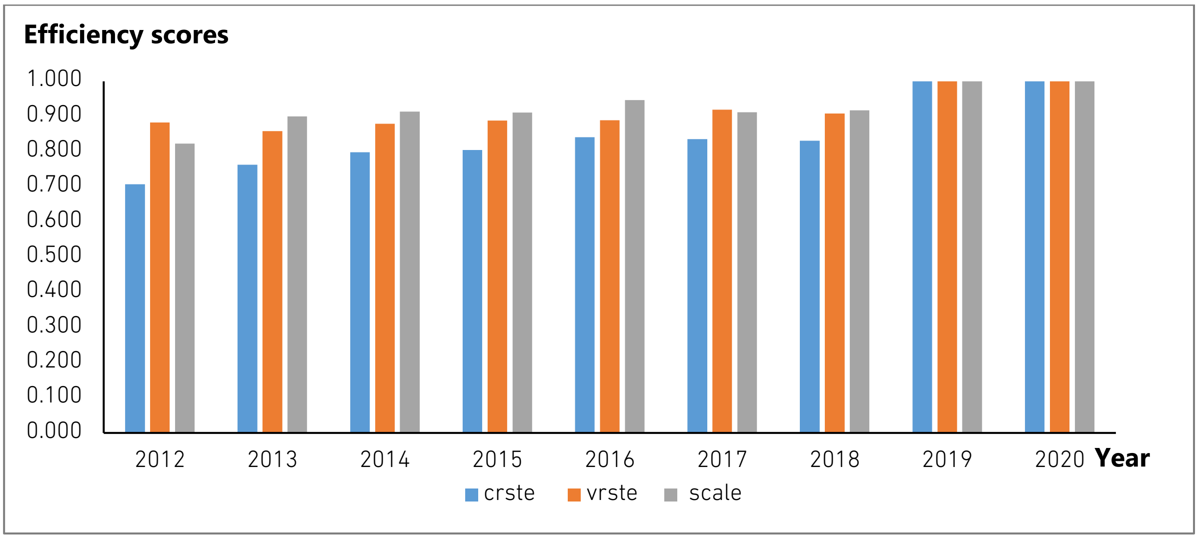
Table 3.1 and Figure 3.16 show the efficiency score of renewable energy development in Malaysia during 2012–2020. Years with efficiency ratings equal to the 1.000 are deemed relatively efficient because they are positioned within the period's boundaries of achievable production. Meanwhile, those years whose efficiency scores are below the units are considered below the boundary and relatively inefficient. The mean technical efficiency score is 0.842, mean pure technical efficiency score is 0.914, and mean scale efficiency score is 0.925. The results show that the performance of renewable energy development in Malaysia increased during 2012–2020 with the mean overall performance at 91.40%. Only years 2019 and 2020 achieved the pure technical efficiency of 1.000 with a performance of 100% and reflect the successful implementation of renewable energy, including FiT, Net Energy Metering, and Large Scale Solar.

Table 3.1. Efficiency Score of Renewable Energy Development in Malaysia

Year	Technical Efficiency (crste)	Pure Technical Efficiency (vrste)	Scale Efficiency (scale)
2012	0.707	0.883	0.823
2013	0.763	0.858	0.900
2014	0.798	0.879	0.914
2015	0.805	0.888	0.911
2016	0.841	0.889	0.947
2017	0.836	0.919	0.912
2018	0.831	0.908	0.918
2019	1.000	1.000	1.000
2020	1.000	1.000	1.000
Mean	**0.842**	**0.914**	**0.925**

crste = constant return to scale technical efficiency; vrste = variable return to scale technical efficiency
Source: Author.

Figure 3.16. Efficiency Score of Renewable Energy Development in Malaysia



crste = constant return to scale technical efficiency; vrste = variable return to scale technical efficiency
Source: Author.

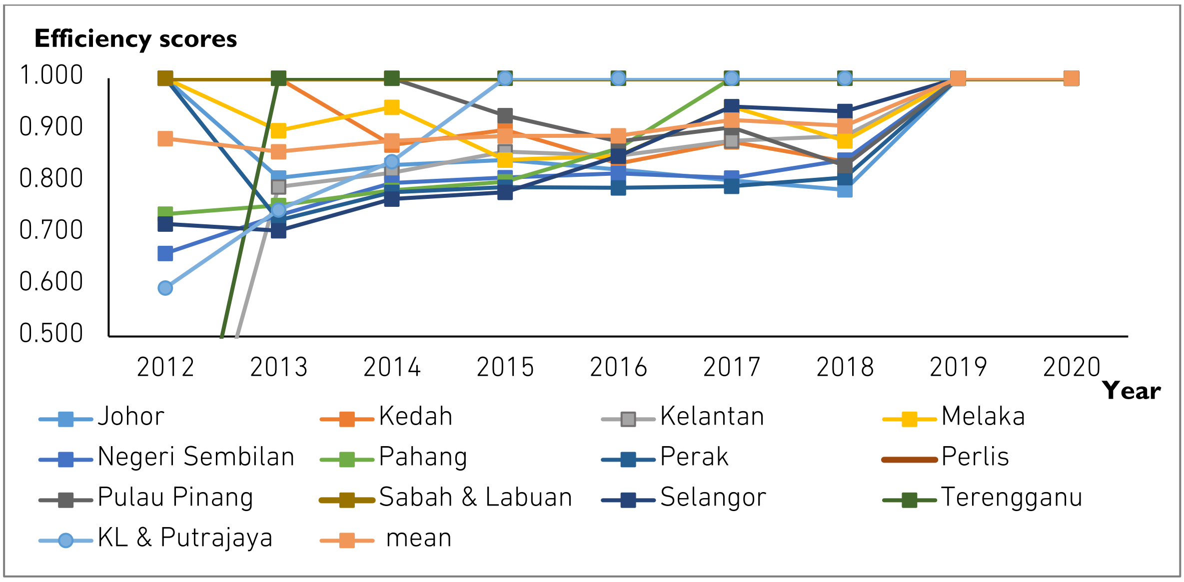
Table 3.2 and Figure 3.17 show the results of pure technical efficiency of renewable energy development by state and federal territory in Malaysia during 2012–2020. The performance of all states and federal territories varies according to year. However, all performed well at 100% during 2019 and 2020 and the mean performance of all states and federal territories increased gradually during 2012–2020. Only three states (Perlis, Sabah, and Terengganu) and one federal territory (Labua), obtained a mean efficiency of 1.000 during the study period of 2012–2020.

Table 3.2. Technical Efficiency of Renewable Energy Development by State and Federal Territory in Malaysia

State/Federal Territory	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Johor	1.000	0.807	0.832	0.842	0.823	0.802	0.784	1.000	1.000	**0.877**
Kedah	1.000	1.000	0.871	0.900	0.835	0.877	0.839	1.000	1.000	**0.925**
Kelantan		0.790	0.817	0.858	0.850	0.879	0.888	1.000	1.000	**0.885**
Melaka	1.000	0.899	0.944	0.842	0.850	0.945	0.879	1.000	1.000	**0.929**
Negeri Sembilan	0.661	0.735	0.797	0.808	0.816	0.807	0.842	1.000	1.000	**0.830**
Pahang	0.737	0.754	0.783	0.800	0.864	1.000	1.000	1.000	1.000	**0.882**
Perak	1.000	0.725	0.779	0.789	0.788	0.791	0.808	1.000	1.000	**0.853**
Perlis	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Pulau Pinang	1.000	1.000	1.000	0.928	0.878	0.905	0.831	1.000	1.000	**0.949**
Sabah & Labuan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Selangor	0.718	0.705	0.766	0.779	0.849	0.945	0.936	1.000	1.000	**0.855**
Terengganu		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
KL & Putrajaya	0.594	0.745	0.839	1.000	1.000	1.000	1.000	1.000	1.000	**0.909**
Mean	**0.883**	**0.858**	**0.879**	**0.888**	**0.889**	**0.919**	**0.908**	**1.000**	**1.000**	0.914

KL = Kuala Lumpur.
Source: Author.

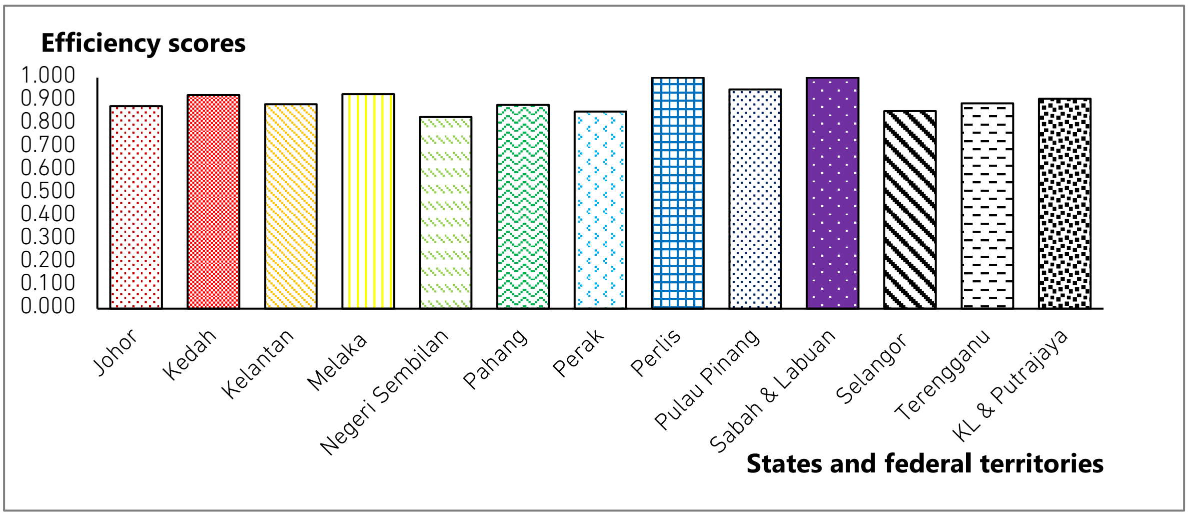
Figure 3.17. Technical Efficiency of Renewable Energy Development in Malaysia



KL = Kuala Lumpur.
Source: Author.

Figure 3.18 shows that three states – Perlis, Sabah, and Terengganu – and one federal territory – Labuan – are the most effective in developing renewable energy in Malaysia with a score of 1.000. This means that all these states fully and effectively used their resources at 100% to produce renewable energy for electricity generation. Negeri Sembilan is the most inefficient state in Malaysia in terms of renewable energy growth with a renewable energy development performance of 83.0%.

Figure 3.18. Mean Technical Efficiency by State and Federal Territory in Malaysia



KL = Kuala Lumpur.
Source: Author.

4.2. Tobit Regression Result

The second-stage DEA analysis used a Tobit regression model to evaluate the effects of environmental variables on the technical efficiency scores from the DEA results. The technical efficiency scores which represent the renewable energy growth obtained from the DEA results will be used as a dependent variable in the Tobit regression analysis to determine the relationship with the six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions. The results of the Tobit regression analysis are shown in Table 3.3. In this study, four environmental variables (population, GDP per capita, annual CO_2 emissions, and TPES) have a significant impact towards renewable energy growth in Malaysia, while electricity selling prices has no significant impact on renewable energy growth.

The GDP per capita and TPES has a positive impact on renewable energy growth in Malaysia, while population and annual CO_2 emissions have a negative impact. The renewable energy growth would increase by 6.43 points if GDP per capita increased by one point while holding all other variables in the model constant. Thus, the higher the GDP per capita, the higher the renewable energy growth. If TPES increases by one point, renewable energy growth would increase by 11.3 points while holding all other variables in the model constant. Thus, the higher the TPES, the higher the renewable energy growth. The renewable energy growth will decrease by 8.28 points if population increases by one point while holding all other variables in the model constant. Thus, the higher the population, the lower the renewable energy growth. If annual CO_2 emissions increase by one point, renewable energy growth would decrease by 6.01 points while holding all other variables in the model constant. Thus, the higher the annual CO_2 emissions, the lower the renewable energy growth.

Table 3.3. Tobit Regression Results

Technical Efficiency	t	P>t	[95% conf. interval]	
Electricity selling prices (cent/kwh)	0.54	0.620	-0.008	0.012
Population (million)	-8.28	0.001	-0.124	-0.062
GDP per capita at current prices (RM)	6.43	0.003	0.000	0.000
Annual CO_2 emissions (Mtonnes)	-6.01	0.004	0.000	0.000
TPES (ktoe)	11.3	0.000	0.000	0.000

> = greater than; CO_2 = carbon dioxide; cent/kwh = US dollar cent per kilowatt hour; conf. interval = confidence interval; GDP = gross domestic product; ktoe = kilotonne of oil equivalent; Mtonnes = million tonnes; RM = Malaysian ringgit; TPES = total primary energy supply.
Source: Author.

4.3. Issues and Challenges in Renewable Energy Development in Malaysia

There is no one answer to accelerate renewable energy transition in Malaysia. However, liberalising the energy sector would play an important role. Allowing third-party access to the grid would better enable the nation to face the challenges in the renewable energy transition journey. Collaboration with third parties would assist in the development of required technology and infrastructure, enable fair access to the renewable energy market, as well as promote healthy competition in the supply chain and industries. On the consumers' end, this would mean that they would benefit from competitive prices. For the nation, it simply means sustainability and securitisation of energy supply in the long run.

Though a critical part in speeding up the renewable energy transition, Malaysia does not have existing carbon tax or carbon trading mechanisms in place. The government is, however, conducting a feasibility study on the impacts of such mechanisms on market players including small medium enterprises (SMEs). It is encouraging to note that the Ministry of Finance has signalled that the carbon tax mechanism is a government priority although it will likely not be implemented soon (MGTC, 2023).

The challenge of implementing this scheme is that it requires a delicate balance between economic development and market equity. Moreover, the efficacy of the mechanism is highly dependent on the quality of carbon emission data by corporates. Most companies in Malaysia have just embarked on their climate accounting journey with only a few players tracking their Scope 3 emissions i.e. indirect carbon emissions emitted through their upstream and downstream supply chain. Having a foundation of good data is an important prerequisite to ensure that players pay their fair share. This also prevents inequity in taxation.

Moving from the initial cross-border bilateral power grid, to a sub-regional, and later to an integrated Southeast Asia grid, would make the Association of Southeast Nations (ASEAN) Power Grid (APG) an enabler for the region's decarbonisation efforts. Such region-wide transmission of electricity generated through renewable energy would not only maximise the use of renewable energy, but also help to meet the rising demand and improve energy access at a lower cost over the long run. A report by the International Energy Agency has shown how the line transmitted cheaper electricity generated from hydropower resources in Sarawak to Indonesia, replacing fuel-oil based generators in that country (SEDA, 2021).

Given the magnitude of this initiative, the APG must be reliable and capable of dealing with significant amounts of energy with minimum interruptions. As much as the APG can be part of the solution, it is challenging, as it depends greatly on the varying contributions of the member states. Therefore, there should be strategies to strengthen the grid via grid infrastructure investment and capacity investment to accommodate renewable resource-rich locations. Development of policies and financial mechanisms to promote smart grid technologies and interconnectedness amongst the member states via the grid would greatly accelerate the process. All of these would be better enabled with policies to develop and implement standardised, measurable, and stricter emission targets and action plans, followed by a monitoring mechanism. Hence, the political and regulatory landscape of member states is key here.

4.4. The Future of Green Economy Transition in Malaysia

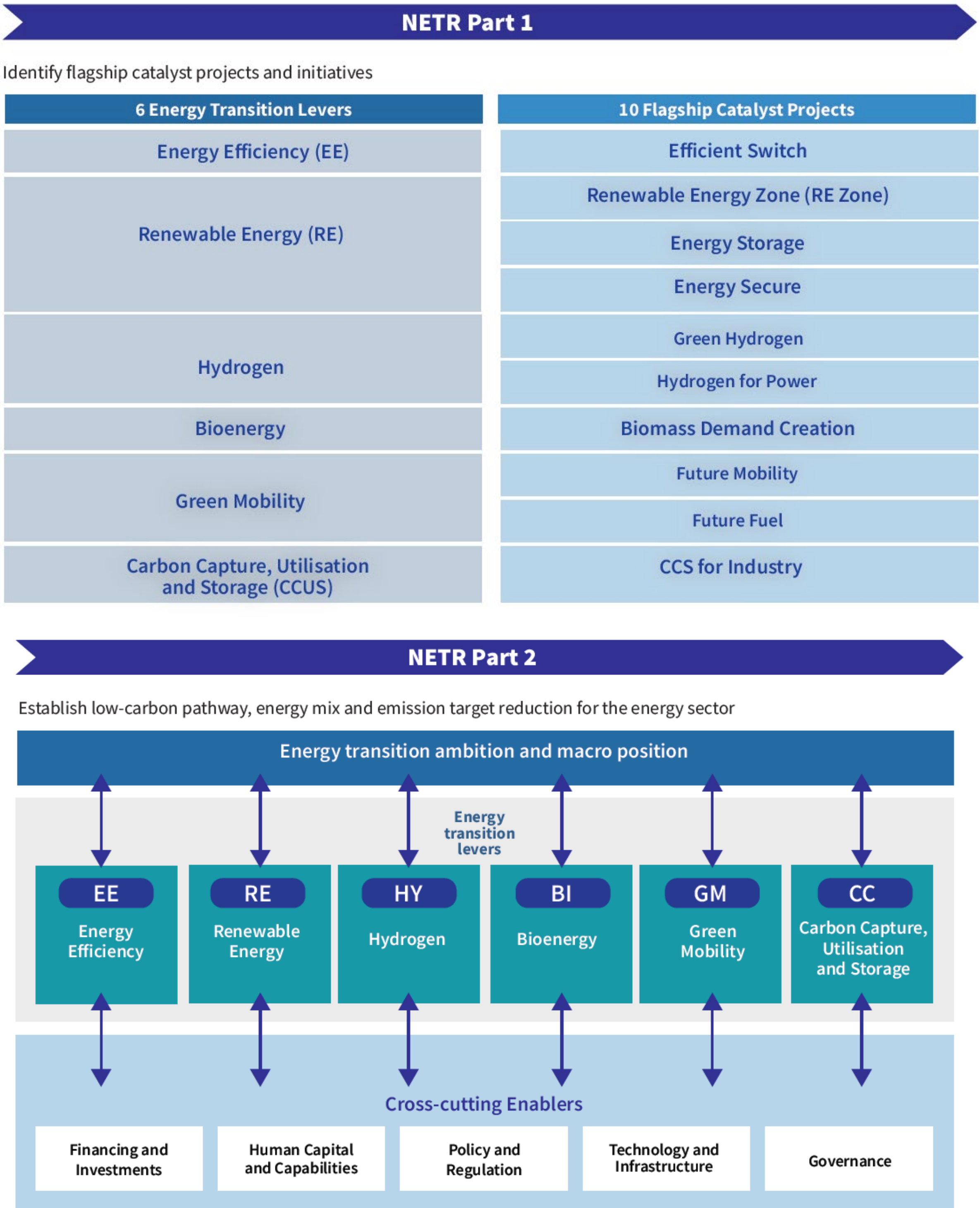
4.4.1. National Energy Transition Roadmap

Malaysia is committed to low-carbon development aimed at restructuring the economic landscape to a more sustainable one. In this context, NETR sets the goal to accelerate energy transition and change the way energy is generated to improve climate resilience. NETR has developed the Responsible Transition Pathway 2050 to shift Malaysia's energy systems from fossil fuel-based to greener and low-carbon systems. The TPES modelling indicated that our energy demand will increase marginally at 0.2% annually from 95 million tonnes of oil equivalent (Mtoe) in 2023 to 102 Mtoe in 2050. The Responsible Transition Pathway 2050 has also shown promising decarbonisation results as evidenced by the phasing out of coal and the reduction of fossil fuel reliance from 96% in 2023 to 77% in 2050. Natural gas is set to be not only a transitional fuel, but also the primary contributor of TPES at 57 Mtoe (56%) followed by renewables that include solar, hydro, and bioenergy, which collectively contribute 23% of TPES in 2050 from a mere 4% in 2023 (MoE, 2023).

NETR outlines 50 initiatives under the six energy transition levers and five enablers, in addition to the 10 flagship projects and initiatives announced in July 2023. The energy transition financing will be undertaken through a combination of grants, loans, rebates, incentives, and other investments to support the whole-of-nation approach. NETR aims to power Malaysia's future by unlocking potential in new growth areas and delivering progress and prosperity to Malaysian households and businesses. The successful implementation of NETR will uplift GDP value from RM25 billion in 2023 to RM220 billion and generate 310,000 jobs in 2050 (MoE 2023).

The development of the NETR is divided into two parts as shown in Figure 3.19. Part 1 outlines the 10 flagship catalyst projects and impact initiatives based on six energy transition levers, namely EE; RE; hydrogen; bioenergy; green mobility; and carbon capture, utilisation and storage. The six levers are further supported by five enablers: financing and investment; policy and regulation; human capital and just transition; technology and infrastructure; and governance and implementation. Part 2 focuses on establishing the energy mix, greenhouse gas emissions reduction pathway, selected targets and initiatives. Targeted investments, people strategies and international cooperation planning, as well as policy and regulatory frameworks, will be strengthened to develop the talent, technology and infrastructure needed to scale-up and sustain decarbonisation efforts.

Figure 3.19. Energy Transition Levers and Project Prioritisation Criteria



NETR = National Energy Transition Roadmap.
Source: MoE (2023).

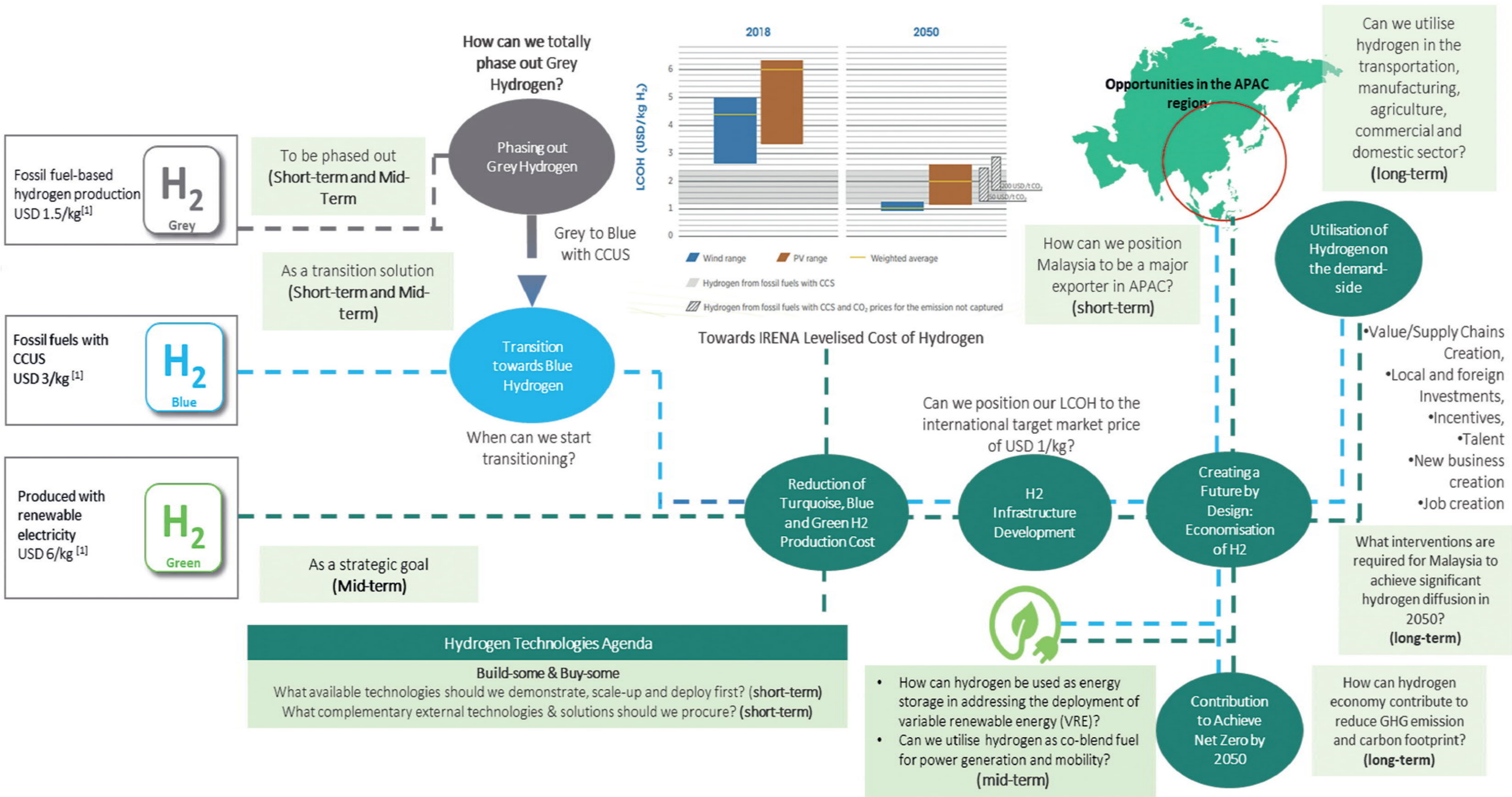
The urgency for Malaysia's shift to sustainable energy is fuelled by global commitments, particularly the Paris Agreement and the need to fortify economic diversification and energy security. In addition, industry related to the energy transition has the potential to be a new source of growth that can benefit from the global market. The International Energy Agency reports that investment in the development of the clean energy industry is expected to reach USD1.7 trillion in 2023 (MoE, 2023). The focus of global investment is on the development of renewable energy, energy efficiency, and strengthening the grid and energy storage. Moreover, corporations and enterprises confront a rapidly changing market landscape where carbon costs will reshape business dynamics and potentially strain competitiveness. Meanwhile, the imminent realities of climate change, exemplified by rising sea levels, extreme weather events, and escalating heatwaves highlight the direct and tangible impacts on the public's daily lives. Beyond mitigating risks, the energy transition presents Malaysia with the opportunity to restructure its economy and maximise the potential for green growth that balances sustainability, enhances GDP, creates jobs, and meets the needs of its people and businesses.

4.4.2. The Hydrogen Economy and Technology Roadmap

Hydrogen has long been regarded as the fuel of the future. The Ministry of Science, Technology, and Innovation, believes that hydrogen could become a fuel of the present before the next decade, delivered by technological innovation and driven by systematic planning (MOSTI, 2023). The Hydrogen Economy and Technology Roadmap (HETR) is the ministry's answer to addressing the three energy challenges namely reliability, affordability, and sustainability, while achieving decarbonisation targets.

As a supporting document to the DTN 2022–2040, HETR is also not merely a roadmap for decarbonisation through energy transition but also a living document for new industrial development propelled by technologies and innovation. Many countries have strategic interests in being innovators and technology producers, rather than just technology users, especially in critical areas such as transition to clean energy. Malaysia is no exception, and the Ministry of Science, Technology, and Innovation has ambitions to be more than a mere spectator in the globally developing hydrogen economy. Via the HETR, it aims for Malaysia to be a leading hydrogen economy country by the year 2050 while achieving the world's decarbonisation targets. The adoption of hydrogen into more domestic sectors and progressively into export operations will benefit revenue generation significantly in the short-, medium- and long-term and will position Malaysia to be a major exporter in the Asia and the Pacific region with projected revenue of more than RM400 billion by the year 2050 (MOSTI, 2023). These revenues reflect the benefit of the developing an infrastructure for export, utilising domestic sectors and opening new avenues for job creation.

Figure 3.20. An Overview of the Roadmap Presenting the Current, Short-Term, Mid-Term and Long-Term Target



APAC = the Asia Pacific region; CCS = carbon capture and storage; CO_2 = carbon dioxide; CCUS = carbon capture, utilisation, and storage; H2 = hydrogen; IRENA =The International Renewable Energy Agency; LCOH = levelised cost of hydrogen; USD/kg = United States dollar per kilo.

Source: MOSTI (2023).

Figure 3.20 presents an overview of the targets in the HETR. It shows the different colours for hydrogen classification that relate to Malaysia, represented as grey, blue, and green hydrogen respectively. These colours represent the source and route of hydrogen production

4.4.3. The Future of Green Incentives under Malaysia's Budget 2024

The National Budget 2024, tabled by the Prime Minister Datuk Seri Anwar Ibrahim at the Dewan Rakyat on 13 October 2023, included allocations to support energy transition and biodiversity initiatives, and to spur the voluntary carbon market in the country. Electric vehicles are a huge focus under the energy transition category. For instance, the government welcomed investments of more than RM170 million by companies such as Tenaga Nasional Bhd, Gentari Sdn Bhd and Tesla Malaysia to install 180 electric vehicle charging stations. Additionally, to foster the use of electric motorcycles, the government will introduce the Electric Motorcycle Usage Incentive Scheme to those with an annual income of below RM120,000. This scheme will provide up to RM2,400 rebate to buyers.

As for the adoption of renewable energy sources, the government will extend the Net Energy Metering programme offer period until 31 December 2024 to encourage the installation of solar panels in residential premises. It is also developing a roof solar buyback programme with minimal cost implications. At the same time, the government is encouraging companies to offer a zero-capital expenditure subscription model for solar power systems, as offered by Gentari, for residential properties. Other than that, the government reiterated its aspirations to realise the NETR through the allocation of RM2 billion as seed funding for the National Energy Transition Facility.

To achieve the target of 70% renewable energy capacity by 2050, efforts to improve the implementation of the Corporate Green Power Programme will be continued as one of the implementation methods of the Third-Party Access model. The government will continue to explore the model and develop appropriate implementation methods to drive investment in renewable energy capacity (MoE, 2023).

The government also seeks to repair and maintain public infrastructure, with RM100 million given to maintain streetlights and to replacing them with light emitting diodes that can save up to 60% of electricity used. To encourage more companies to participate in the voluntary carbon market, the government proposed an additional tax deduction up to RM300,000 for companies that spend on measurement, reporting, and verification related to the development of carbon projects. These expenses can be deducted from the income from carbon credit sales traded at the Bursa Carbon Exchange.

The federal government will lead the way in issuing biodiversity *sukuk or Islamic bond* up to RM1 billion, which will be used in reforestation and replanting degraded forests that will in turn, generate carbon credits. The replanting initiative to be undertaken in collaboration with interested state governments and will potentially benefit from some of the carbon credit generated. Companies purchase carbon credits from the voluntary carbon market that are generated from projects that remove, reduce, or avoid, carbon emissions, to offset their own emissions. The Bursa Carbon Exchange launched its first auction in March, using carbon credits generated from projects in China and Cambodia.

4.4.4. The Future of Environmental, Social, and Governance in Malaysia

Budget 2024 is a promising one, especially within the ESG space, as sustainability is integrated into economic policies. Measures were presented to drive sustainable growth to protect as well as empower the welfare of Malaysians. That includes focusing on strategies to prioritise sectors and initiatives that are investment intensive. This reflects the government's recognition of ESG as a "need" today, and the whole-of-nation approach to make Malaysia an investment destination that can also achieve carbon neutrality by 2050.

Budget 2024 lays the foundation not only for the NETR with a RM2 billion allocation, but also a RM200 million start-up fund for the New Industrial Master Plan 2030. This is in addition to the RM200bil financing funds by financial institutions to encourage industries to transition towards a low-carbon economy. A RM900mil loan fund has been allocated for SME to increase business productivity through automation and digitalisation. Leveraging on this could lead to higher sustainability performance through the optimisation of resources used, waste reduction, streamlining of supply chain, and promoting workplace safety. Guaranteed funds of up to RM20bil will be made available for SME entrepreneurs, particularly for those involved in green economy, technology, and halal fields.

Putrajaya will be modelled as Malaysia's low-carbon city through the installation of solar panels on the roofs of government buildings and the use of electric vehicles as official vehicles, as the government leads by example in sustainability – further boosting investor confidence as ESG shifts from being just an investment category to a mainstream strategy.

5. Conclusion

Malaysia has made an ambitious pledge to achieve "net-zero" carbon emissions by 2050. To achieve net-zero emissions, a country must absorb as much carbon as it produces. Thus, the strategy would be to increase efforts to transition from carbon-emitting energy sources, such as coal and natural gas, to renewable green energy while also promoting carbon sequestration. As a result, the transition from "brown energy" (polluting sources) to "green energy" (renewable sources) must be accelerated.

Malaysia must improve its system flexibility to achieve "net-zero" carbon emissions by 2050. Ambitious and long-term planning must emphasise solutions to overcome the current grid integration challenges and create grid flexibility. Renewable energy investment, on the other hand, remains a major impediment to Malaysia's energy transition. There is a need to strengthen national financing institutions, overcome regulatory and market barriers, and reduce government spending on fossil fuel subsidies. Malaysia urgently needs to create a more favourable investment environment for renewables. It can achieve its renewed ambition of reaching net-zero emissions by 2050 by implementing a strategy and policies that prioritise clean energy investments and are consistent at all levels of government.

The renewable energy industry in Malaysia has a strong value chain that runs from the point of production to the point of service provision. To attract high-value but environmentally friendly investment, the country must make the most of its competitive advantage. Power generation and supply planning policies that are comprehensive, competitive, and aspirational must also support this strategic intent. In turn, these policies must be based on sustainable energy and consider current social and economic needs. Malaysia has a variety of renewable power systems, which gives it the chance to supply to neighbouring countries and be flexible, by using energy storage and by connecting more of the region. Achieving energy transition in the most cost-effective manner will necessitate a greater integration of renewables within Malaysia's national power systems and with its neighbours.

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Chapter 4

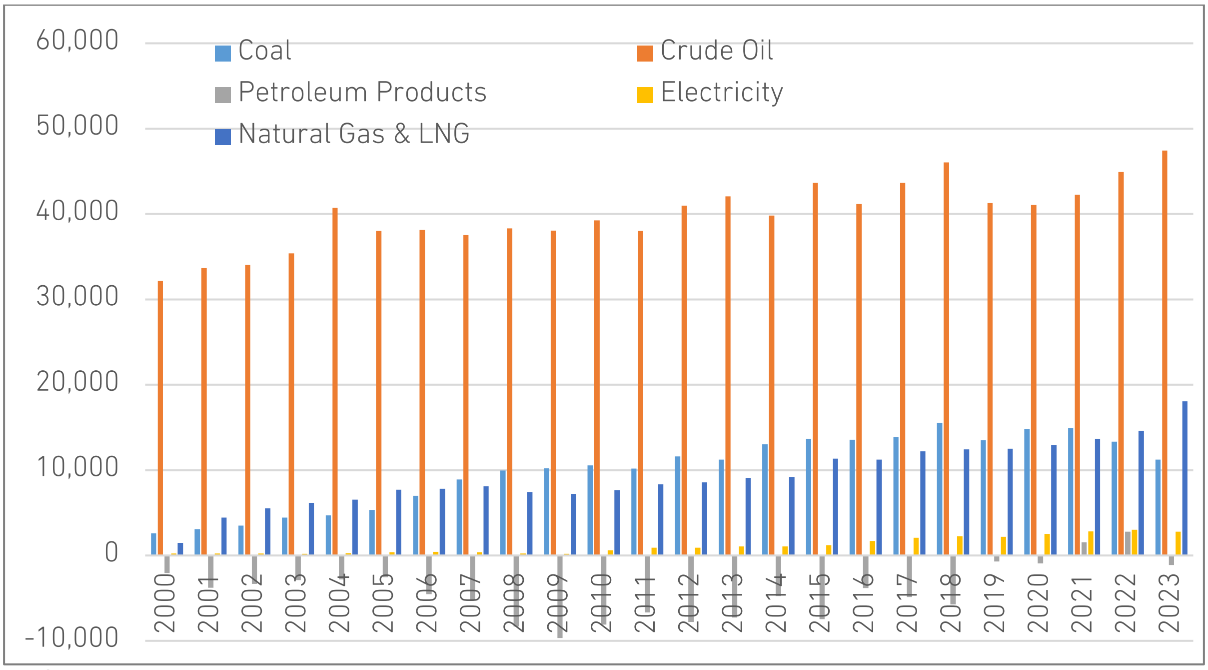
The Economic and Greenhouse Gas Emission Impacts of Electric Vehicles

Nattapong Puttanapong and Thongchart Bowonthumrongchai

1. Introduction

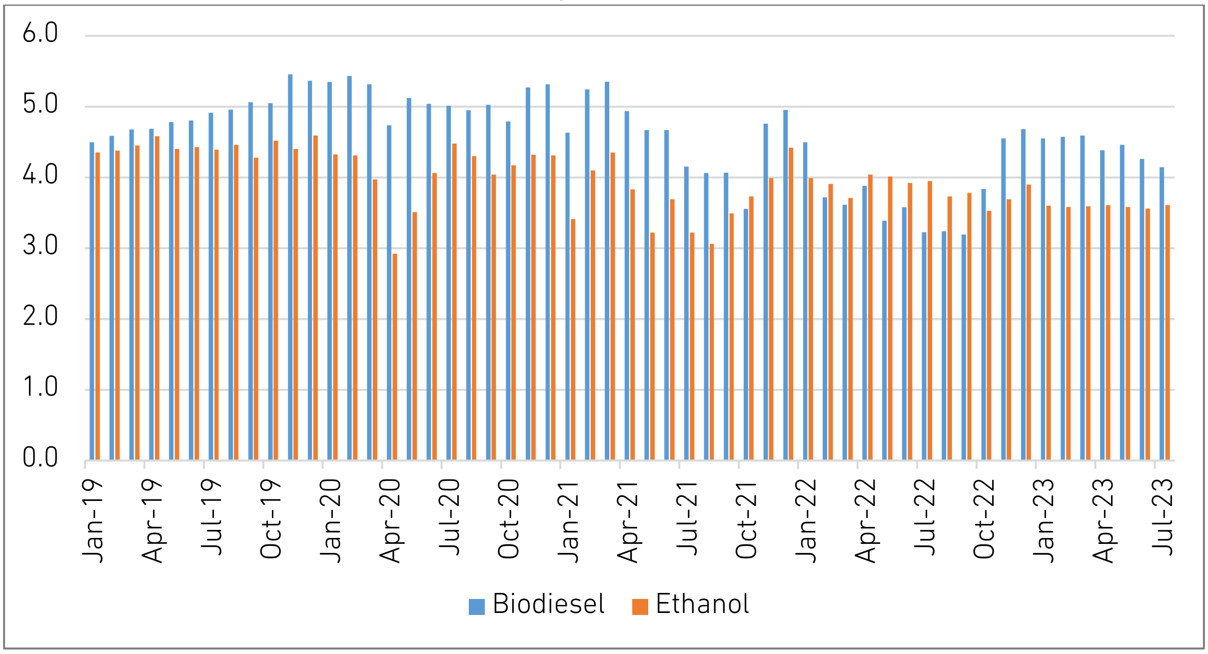
The economy in Thailand has long been intertwined with the fossil fuel and automotive sectors. Despite a constrained domestic petroleum supply necessitating substantial crude oil imports to sustain transport sector growth, fossil fuels remain pivotal energy sources, as depicted in Figure 4.1. Since 2001, Thailand has enacted policies to bolster domestic biofuel production and consumption, initially through tax incentives and price subsidies for bioethanol and biodiesel producers. This approach, subject to periodic updates, has consistently augmented production and demand, as illustrated in Figure 4.2, positioning Thailand as the world's 7th largest biofuel producer in 2021.

Figure 4.1. Net Imports of Commercial Primary Energy
(Unit: KTOE, Kilo Tonnes of Oil Equivalent)



LNG = liquefied natural gas
Source: Energy Statistics of Thailand (2024), Energy Policy and Planning Office (EPPO), Thailand's Ministry of Energy

Figure 4.2. Thailand's Biofuel Consumption, 2019–2023
(Daily Average in Million Litres)



Source: Department of Energy Business, Thailand's Ministry of Energy

Simultaneously, the automotive industry, which has seen growth since the 1990s, has been strategically nurtured by the Government of Thailand through tax and investment incentives, focusing on specific vehicle categories such as fuel-efficient and biofuel cars and light pick-up trucks. Consequently, Thailand achieved a global rank of 18th in car exports in 2020, exporting a total of $8.28 billion.[1]

Amidst evolving challenges, energy and industrial policies have undergone revisions. Globally, the surge in awareness and initiatives to reduce greenhouse gas (GHG) emissions is notable. Domestically, the advent of electric vehicles (EVs) poses a potential disruption to the existing industrial policy strategy. Additionally, alterations in biofuel targets and fiscal conditions have prompted adjustments in fuel cross-subsidy rates. Given these factors, this study employs a general equilibrium approach to explore the comprehensive impacts on the economy and proposes forward-looking policies, considering the intricate interplay amongst energy sources, GHG emissions, industrial output, and fiscal health.

The study sets out to achieve the following objectives:

(1) Perform a comprehensive review of pertinent national strategies and policies, including:

- Alternative Energy Development Plan 2018–2037 (Ministry of Energy)
- Thailand's Mid-Century, Long-Term Low Greenhouse Gas Emission Development

[1] In this report, $ refers to US dollar.

Strategy (Ministry of Natural Resources and Environment)
- National Development Plan for the Electric Vehicle (Ministry of Energy and Ministry of Industry)
- Fiscal Sustainability Framework (Ministry of Finance)

(2) Develop the social accounting matrix (SAM) and dynamic computable general equilibrium (CGE) model

(3) Examine the comprehensive impacts on the economy

2. Review of Related Policies

2.1. National Policy on Electric Vehicles

The National Electric Vehicle Policy Committee has approved the "30@30" policy plan, aiming for zero-emission vehicles (ZEVs) to account for at least 30% of total vehicle production by 2030. This plan comprises potential reductions in import duties and excise taxes, as well as conditional subsidies for imported electric vehicles (EVs). It is structured in a three-phase development:

- Phase 1 (2021–2022): The focus is on encouraging electric motorcycle use and developing supportive infrastructure nationwide.
- Phase 2 (2023–2025): The aim is to foster the EV industry, including EVs and battery production, targeting cost benefits via economies of scale.
- Phase 3 (2026–2030): Aspiration is to drive the 30@30 policy by making production of cars, pick-up trucks, and motorcycles 30% of total automotive production in 2030, in conjunction with domestic battery production.

The National Electric Vehicle Policy Committee established specific targets for production and promotion of ZEVs during a meeting on May 12, 2023. This coordinated effort of multiple sectors that all aimed to reach the target by 2030 resulted in the following goals:

(1) Production of 725,000 cars and pick-up trucks, 675,000 motorcycles, and 34,000 buses/trucks, as well as a plan for three-wheeled vehicles, passenger boats, and rail system production.

(2) Promotion of 440,000 cars and pick-up trucks, 650,000 motorcycles, 33,000 buses/trucks, as well as a target to promote 12,000 public fast-charge stations and 1,450 battery-swapping stations for electric motorcycles.

The following measures have been designed to boost ZEVs:

- Manufacturing promotion: The EV and parts industry will be encouraged to establish Thailand as a production hub for EVs and their components, including defining essential vehicle and parts standards, thus supporting business transitions to EVs, and developing workforce strategies.
- Demand stimulus: This will include tax and non-tax measures, with rapid

implementation actions such as promoting electric motorcycles for commercial transport and governmental use.

- Infrastructure development: There will be a move to: encourage the creation of electric charging stations; enact relevant laws and regulations; promote smart grid technology, domestic production, and utilisation of electric vehicle batteries; manage used batteries; and focus on workforce development.
- Financial and tax incentives: These are one of the main policy instruments. Table 4.1 shows the new excise tax rates, aimed at promoting the production of EVs.

Table 4.1. Excise Tax Rates

Vehicle Category	Effective Date	Former Rates	New Rates	Eligibility and Conditions
Battery EV	June 2022	8%	2%	Eligible car manufacturers must satisfy specific criteria as stated in the Excise Announcements.
PHEV*	January 2026	8%–26%	5%–10%	The new tax rates are structured to encourage the production of PHEVs with smaller fuel tanks and a longer driving range per charge.
ICE passenger cars**	January 2026	30%–35%	29%–38%	Tax rates will incrementally rise based on variables such as vehicle classification, fuel type, engine capacity, and levels of carbon and particulate matter emissions.
Fuel cell EV	January 2026	2%	1%	

cc = cubic centimetres; EV = electric vehicle; g/km = grammes per kilometre; ICE = internal combustion engine; PHEV = plug-in hybrid electric vehicle.
* with cylinder up to 3,000 cc
** with cylinder up to 3,000 cc, and carbon emission above 150 g/km
Source: National Electric Vehicle Policy Committee and Baker & McKenzie. https://insightplus.bakermckenzie.com/bm/industrials-manufacturing-transportation/thailand-ev-landscape-how-it-looks-now-and-whats-on-the-horizon

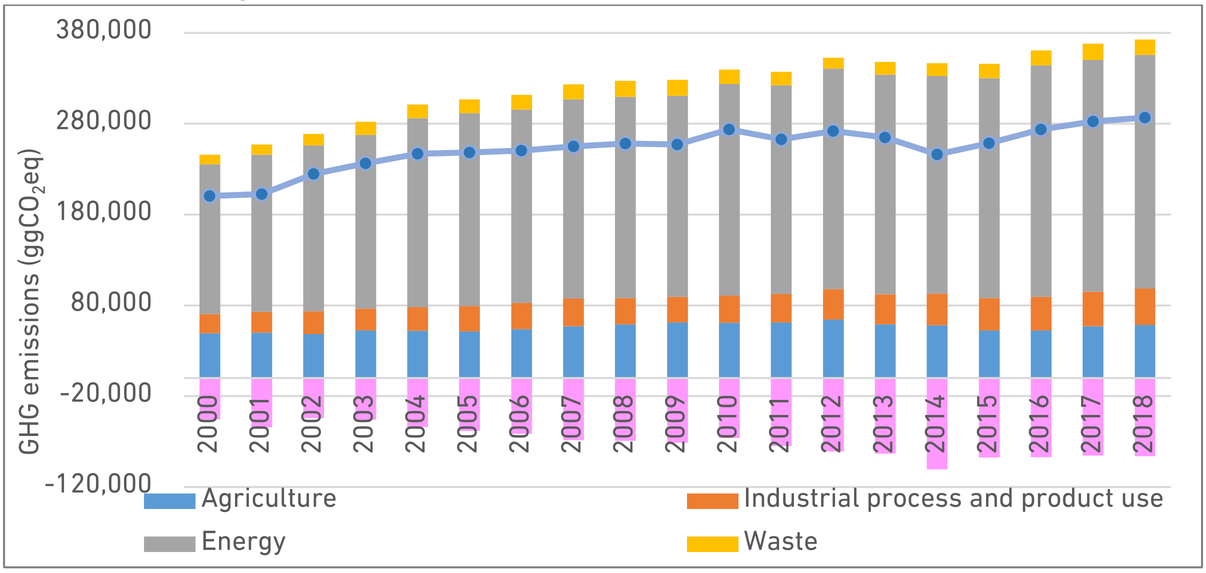
2.2. Thailand's Greenhouse Gas Emission Mitigation Plan

2.2.1. Thailand's Emission Profile

Figure 4.3 illustrates the upward trend in Thailand's GHG emissions from 2000 to 2018. The total GHG emissions (excluding land use, land-use change, and forestry (LULUCF)) during this period increased from 245,899.56 gigagrams of carbon dioxide equivalent.

(ggCO$_2$eq) to 372,648.77 ggCO$_2$eq, at an average annual growth rate of 2.34%. Concurrently, carbon dioxide (CO_2) removal efforts expanded, rising from 45,443.60 ggCO$_2$eq in 2000 to 85,968.30 ggCO$_2$eq in 2018. The net GHG emissions consequently increased from 200,455.96 ggCO$_2$eq in 2000 to 286,680.47 ggCO$_2$eq in 2018, with an average yearly growth rate of 2.01%.

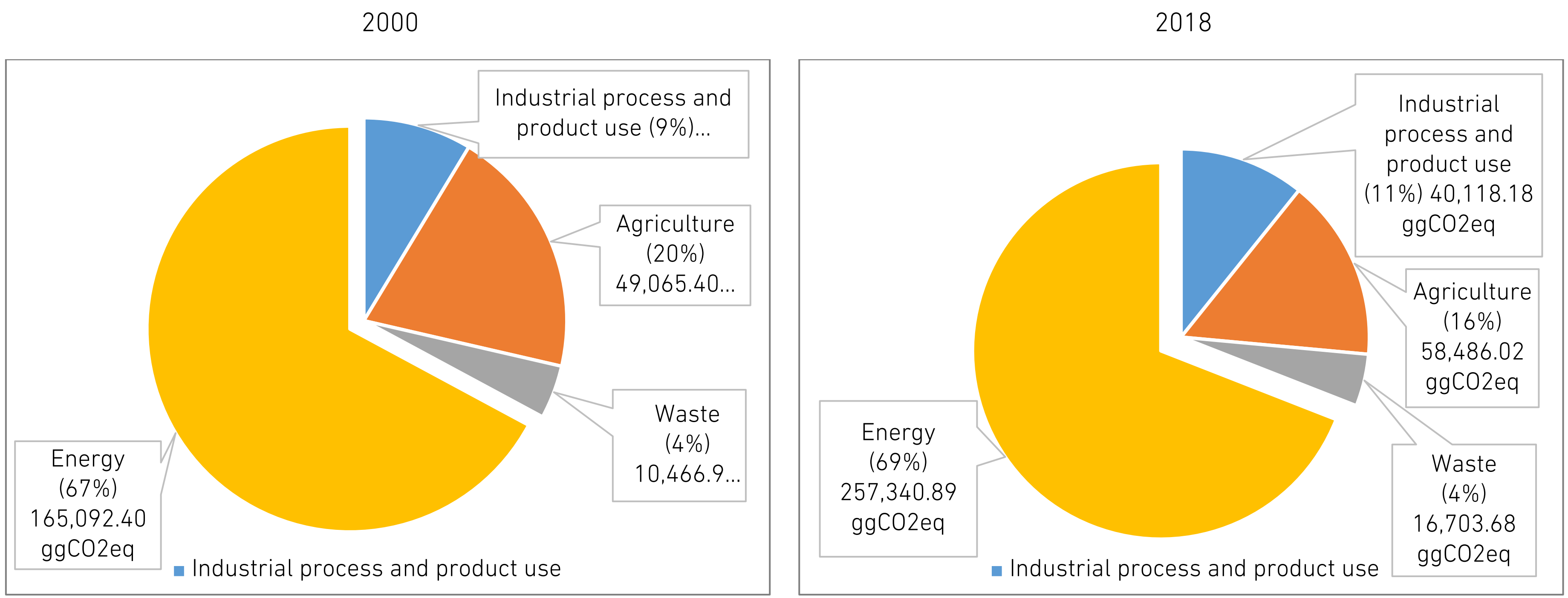
Figure 4.3. Thailand's Greenhouse Gas Emission Trends



ggCO$_2$eq = gigagrams of carbon dioxide equivalent; GHG = greenhouse gas; LULUCF = land use, land-use change, and forestry.
Source: UNFCCC (2022).

Figure 4.4 illustrates the changes in GHG emissions in Thailand from 2000 to 2018, with the energy sector emerging as the primary contributor. During this period, emissions from the energy sector surged by 55.88%, growing from 165,092.40 ggCO$_2$ to 257,340.89 ggCO$_2$. This sector's share of total emissions increased from 67.14% in 2000 to 69.06% in 2018. Meanwhile, the agricultural sector's emission contribution decreased from 19.95% to 15.69%. The industrial processes and product use (IPPU) and waste sectors conversely experienced a slight uptick in their emission shares, rising from 4.26% to 4.48%.

Figure 4.4. Total Greenhouse Gas Emissions by Sector, 2000 and 2018
(Excluding Land Use, Land-Use Change, and Forestry)



$ggCO_2eq$ = gigagrams of carbon dioxide equivalent
Source: UNFCCC (2022).

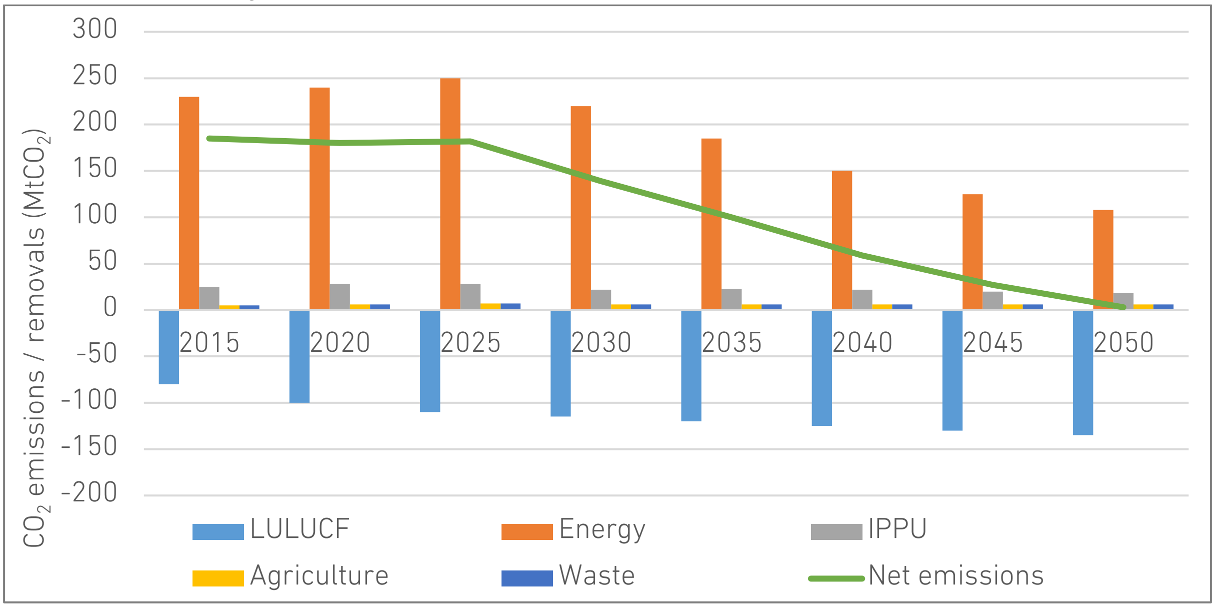
2.2.2. Thailand's Roadmap to Achieving Carbon Neutrality

Thailand has committed to achieving carbon neutrality by 2050, with a primary focus on reducing CO_2 emissions from the energy sector, which is the main contributor to GHG emissions. The country's preliminary National Energy Plan 2022 outlined strategic guidance to relevant entities to transition toward cleaner energy systems and align with the 2050 carbon neutrality goal. In this framework:

- at least 50% of the new power generation capacity is expected to be derived from renewable sources by 2050.
- the market is projected to be dominated by EVs, specifically battery electric vehicles and plug-in hybrid electric vehicles (PHEV), targeting a 69% share by 2035.
- emissions from the IPPU, waste, and agriculture sectors are forecasted to conform to the 1.5-degree pathway, with the IPPU sector, particularly the cement industry, being a major source of CO_2 emissions. The implementation of carbon capture (usage) and storage technologies is foreseen to mitigate carbon in this sector further.
- an enhanced contribution to carbon removal is anticipated from the LULUCF sector, projected to reach 120 metric tonnes of CO_2 ($MtCO_2$) in nationwide CO_2 removal by 2037.

Figure 4.5 illustrates Thailand's pathway to 2050 carbon neutrality, with net emissions expected to reach 137.3 $MtCO_2$ in 2030, declining to 63.1 $MtCO_2$ in 2040. This comprehensive plan highlights the multi-faceted approach required to realise the ambitious goal of carbon neutrality in Thailand.

Figure 4.5. Thailand's 2050 Carbon Neutrality Pathway



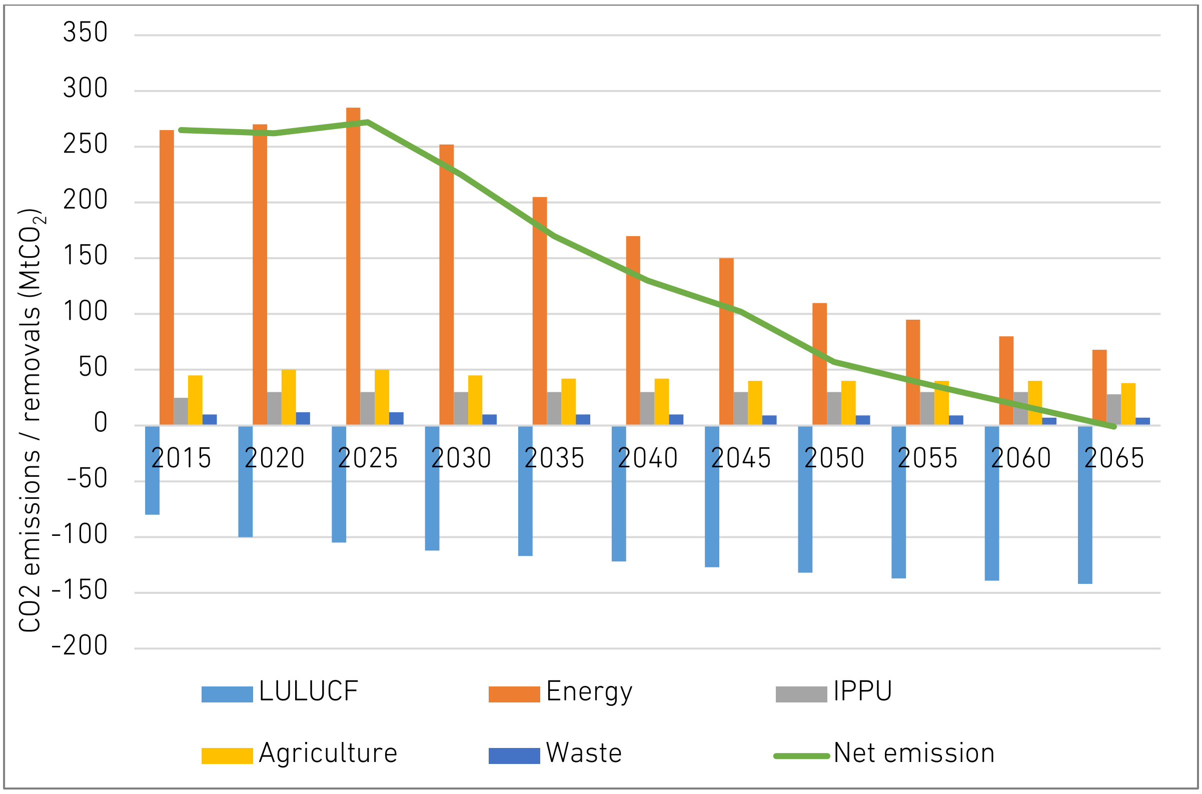
IPPU = industrial processes and product use; LULUCF = land use, land-use change, and forestry; $MtCO_2$ = metric tonnes of carbon dioxide.
Source: UNFCCC (2022).

2.2.3 Thailand's Roadmap to Achieving Net-Zero Greenhouse Gas Emissions

Figure 4.6 outlines Thailand's plan to achieve net-zero GHG emissions by 2065, with the LULUCF sector's contribution of 120 $MtCO_2$ projected to remain constant from 2037 until the end of the 21st century. This projection aligns with the National Strategy (2018–2037) objectives to increase forest and green areas to 55% of Thailand's total land area.

Thailand is expected to reach a net emission level of 64.1metric tonnes of CO_2 equivalent (MtCO2e) by 2050 under the 2065 net-zero GHG emission. GHG emissions are anticipated to peak at 388 $MtCO_2e$ in 2025, after which the energy sector will become key to reducing emissions. Following 2050, emissions are projected to align with the Intergovernmental Panel on Climate Change 1.5-degree pathway, reflecting Thailand's ambition to balance GHG emissions and carbon sequestration by 2065.

Figure 4.6. Thailand's 2065 Net-Zero Greenhouse Gas Emission Pathway



GHG = greenhouse gas; IPPU = industrial processes and product use; LULUCF = land use, land-use change, and forestry; $MtCO_2e$ = metric tonnes of carbon dioxide equivalent.
Source: UNFCCC (2022).

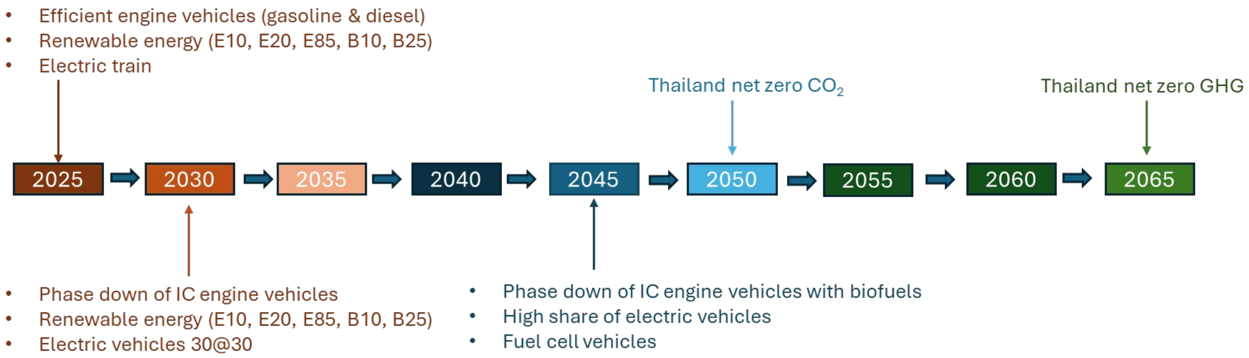
Thailand's net-zero GHG emission strategy will depend on the phase-out of coal and the incorporation of negative emission technologies in the energy sector. Essential components of this approach include the utilisation of bioenergy with carbon capture and storage and direct air capture and storage.

2.2.4 Roadmap for Greenhouse Gas Mitigation in Transportation

Thailand's transport sector primarily utilises fossil fuels, which comprise gasoline, diesel, compressed natural gas, fuel oil, and liquefied petroleum gas (LPG), complemented by mandatory biofuel blends. Figure 4.7 shows that the potential for decarbonisation in this sector depends on the adoption of cleaner and more efficient technologies, such as hybrid, PHEV, electric, and fuel cell EVs. Fuel cell technology appears especially promising for long-haul truck segments.

It is crucial to emphasise that the transport sector's shift towards electrification must be preceded by the decarbonisation of the power sector. Unlike the well-to-wheel GHG emissions of internal combustion engine (ICE) vehicles, EV's emissions are directly tied to the GHG emissions of the power sector. Therefore, without an increased emphasis on cleaner and renewable technologies within the power sector, electrification in the transport sector may yield negligible GHG reductions or potentially even exacerbate emissions.

Figure 4.7. Net-Zero Greenhouse Gas Emissions Timeline for the Transport Sector



B = biodiesel; CO_2 = carbon dioxide; E = ethanol; GHG = greenhouse gas; IC = internal combustion.
Source: UNFCCC (2022).

The transition to cleaner technologies in the transport sector, such as EVs, presents challenges but is facilitated by the anticipated decline in battery costs. The prices of EVs and hydrogen-powered fuel cell electric vehicles are expected to decrease significantly by 2030. The market share for new battery EVs and PHEV is projected to reach at least 30% by that time, while the phasing out of ICE vehicles is set to commence post–2035 (as detailed in Figure 4.5). Strategies to enhance the efficiency of ICE vehicles comprise the adoption of EURO 5 and EURO 6 standards, the promotion of liquid biofuels, and the elimination of petroleum subsidies.

Energy efficiency improvements in the transport sector can be realised through behavioural changes, road surface enhancements, and engine performance upgrades.

2.3. Fiscal Sustainability Framework

The preservation of fiscal sustainability along with the adherence to fiscal discipline holds profound significance for the Thai economy. Not only do these factors ensure that the government, the private sector, and the public have confidence in the country's fiscal stability, but they also help build trust amongst domestic and foreign investors. Fiscal stability also enhances the country's fiscal credibility on the global stage, such as with international financial institutions and credit rating agencies.

To achieve the goal of fiscal sustainability in the medium- and long-term, the Ministry of Finance, through the Office of Fiscal Policy, has developed a framework for fiscal sustainability, which comprises revenue estimates, expenditure, fiscal balance, and public debt for a medium-term period of five years. This framework serves as a guideline for fiscal management and is considered along with the government's policy plans and measures. The indicators and targets of the fiscal sustainability framework have been established and adjusted several times. The current indicators are as follows:

- Indicator 1: The public debt should not exceed 60% of GDP.
- Indicator 2: The debt burden should not exceed 15% of the budget.
- Indicator 3: The budget should be balanced.
- Indicator 4: Investment expenditure should not be less than 25% of the budget.

In establishing this fiscal sustainability framework, the Fiscal Policy Office has utilised a crucial tool, namely, the Fiscal Sustainability Model. This model is utilised for estimating the revenue, expenditure, fiscal balance, and public debt of the government. The estimation incorporates various assumptions regarding revenue and expenditure within the budgetary framework, derived from plans and measures that relate to government policy, such as debt repayment expenditure and investment outlays from the government's large-scale investment projects.

The Fiscal Policy Office has continually revised the indicators and targets of the fiscal sustainability framework to ensure they remain appropriate for the country's economic and fiscal conditions, and to foster fiscal sustainability. The Fiscal Policy Office consistently disseminates the fiscal sustainability framework to the public via the office's monthly fiscal situation report. Table 4.2 exemplarily shows the statistics during 2018–2022. Essentially, indicators 1 and 2 have been consistently satisfied. However, indicators 3 and 4 are constantly violating the thresholds.

Table 4.2. Main Indicators of Fiscal Sustainability Framework

Fiscal year	2018E	2019E	2020E	2021E	2022E
Fiscal sustainability framework targets and indicators					
Public debt outstanding /GDP	≤ 60	≤ 60	≤ 60	≤ 60	≤ 60
Debt/budget (%)	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15
Budget balance (million baht)					
Capital expenditure/budget (%)	≥ 25	≥ 25	≥ 25	≥ 25	≥ 25
Performance within the framework of fiscal sustainability					
1. Public debt outstanding /GDP (1.2/1.1)	**43.3**	**44.4**	**45.7**	**47.4**	**47.9**
1.1 Nominal GDP (million baht)	17,091,700	18,117,200	19,204,200	20,433,300	21,659,300
1.2 Outstanding public debt (million baht)	7,402,143	8,036,764	8,775,918	9,691,581	10,381,773
2. Debt/budget (2.1/3.2)	**8.7**	**9.3**	**9.8**	**10.4**	**10.9**
2.1 Debt obligation (million baht) (2.1.1 + 2.1.2)	259,610	297,971	324,767	359,364	392,644
2.1.1 Pay the principal of the loan (million baht)	78,206	96,000	99,000	104,100	108,300
2.1.2 Interest and fees (million baht)	181,404	201,971	225,767	255,264	284,344
3. Budget balance (million Baht) (3.1–3.2)	**(450,000)**	**(450,000)**	**(527,000)**	**(584,000)**	**(578,000)**
3.1 Net government revenue (million baht)	2,550,000	2,750,000	2,773,000	2,886,000	3,032,000

Fiscal year	2018E	2019E	2020E	2021E	2022E
3.2 Expenditure budget (million baht)	3,000,000	3,200,000	3,300,000	3,470,000	3,610,000
4. Capital expenditure/budget (4.1/3.2)	**21.6**	**21.8**	**22.0**	**21.9**	**21.5**
4.1 Capital expenditures (million baht)	649,138	698,848	725,003	758,927	776,098

GDP = gross domestic product.

Note: All data are still estimates. The finalised statistics will be officially announced by the Fiscal Policy Office of the Ministry of Finance.

Source: Government of Thailand, Ministry of Finance. https://www.fpo.go.th/main/Statistic-Database.aspx and https://www.fpo.go.th/main/Economic-report/

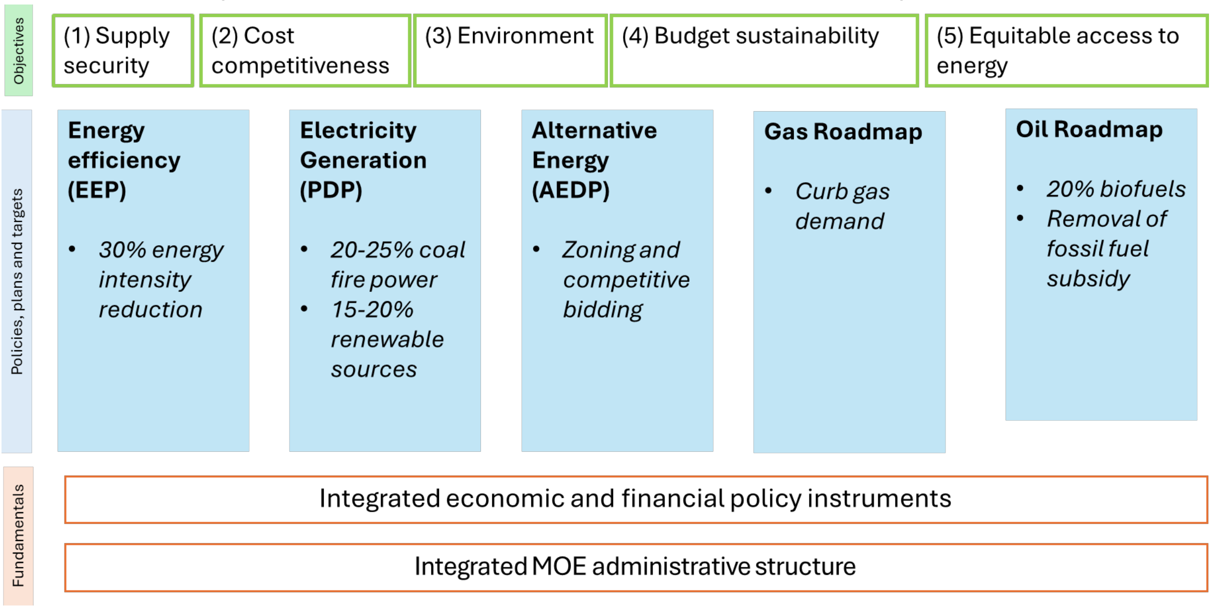
2.4. Energy Plans

Thailand's energy policies have been governed by five major plans, which are:

- The Power Development Plan 2018–2037 (PDP 2018 Rev.1)
- The Alternative and Renewable Energy Development Plan 2018–2037 (AEDP 2018)
- The Energy Efficiency Plan 2018–2037 (EEP 2018)
- The Natural Gas Management Plan 2018–2037 (Gas Plan 2018)
- The Fuel Management Plan (Oil Plan 2015–2037).

As shown in Figure 4.8, these strategies are anticipated to guide the nation's energy policy and advancement towards enhanced efficiency and sustainability. The main contexts of each plan are summarised in the next sections.

Figure 4.8. The Structural Relationship of all Energy Plans



AEDP = Alternative and Renewable Energy Development Plan; EEP = Energy Efficiency Plan; LNG = liquefied natural gas; MOE = Ministry of Energy; PDP = Power Development Plan.
Source: Government of Thailand. Ministry of Energy.

2.4.1. Power Development Plan 2018–2037

The PDP 2018 Rev.1 is a comprehensive strategy formulated by the Energy Regulatory Commission of Thailand. Its primary aim is to ensure a sufficient electricity supply that supports the country's socio-economic development. This plan is a blueprint for enhancing the nation's electricity generation and transmission infrastructure over the next 15 to 20 years. Periodic updates to the PDP align with revised electricity demand forecasts to adapt to changing economic conditions.

The PDP provides forecasts for electricity demand, which is essential for strategic planning. Reliable predictions guarantee that investments in expanding power generation will adequately meet growing electricity needs. On the technical side, the PDP specifies the future construction of large-scale power projects as well as smaller-scale power plants, including renewable energy sources. The PDP also identifies the following to provide sufficient details for research and planning:

- the proportion of types of fuels used in electricity generation;
- the expansion of electricity transmission systems;
- estimates of financial investment in the expansion of power generation and transmission systems;
- the impact on electricity prices;
- the amount of GHG emissions.

2.4.2. Alternative and Renewable Energy Development Plan 2018–2037

Thailand imports various energy sources, such as crude oil, refined oil, natural gas, coal, lignite, and electricity. Official statistics show that the country heavily depends on imported crude oil and coal/lignite, with import rates at 85% and 78%, respectively. To reduce this dependency and diversify risk more evenly, boosting domestic energy production through alternative energy sources is crucial. This strategy also supports eco-friendly and sustainable energy solutions.

The nation possesses an abundance of agricultural resources that can be converted into energy, such as biomass, biogas from energy crops, biodiesel, and ethanol. Additionally, industrial waste and wastewater can be harnessed for energy production. Thailand is also rich in natural energy potential, particularly solar energy, receiving an average of 18.2 megajoules of solar radiation per square metre daily. Some areas also show significant promise for wind energy, with capacities estimated between 600 and 2,000 watts per square metre. These alternative energy sources hold great promise for enhancing Thailand's energy security in the future. Concurrently, the AEDP 2018 initiative plays a crucial role in reducing greenhouse gas emissions, aiding the country's pursuit of a zero-emission target.

2.4.3. Energy Efficiency Plan 2018–2037

Energy efficiency and conservation are essential components of Thailand's energy strategy. The manufacturing and industrial sectors, which are pivotal to the economy, have the potential to significantly reduce emissions by implementing energy-efficient processes.

The promotion of energy conservation is driven not only by environmental concerns but also by significant financial incentives. Economic factors have gained significance because of the price volatility and energy supply. Consequently, the public sector has taken the lead in encouraging investments in the energy sector. The EEP 2018 was established and enforced as a government-led initiative to promote energy efficiency and conservation.

Thailand's EEP 2018 targets a 30% reduction in energy consumption by 2037, based on 2010 levels. The Board of Investment (BOI), the government agency supervising and promoting private investment, proactively supports energy conservation, efficiency, and savings. Financially, to promote corporate investment in energy improvements, the BOI has introduced incentives. Investments in six specific areas can benefit from a 50% reduction in corporate income tax for three years. The investments that align with the BOI's criteria are:

- utilisation of alternative energy;
- energy enhancement through machinery adoption and improvement;
- efficiency augmentation in research, development, or engineering design;
- efficiency improvements in production processes conforming to international sustainability certification; and
- implementation of digital technology.

2.4.4. Natural Gas Management Plan 2018–2037

The Gas Plan 2018, spanning from 2018 to 2037, aims to secure a stable natural gas supply at reasonable prices and efficiently manage infrastructure to bolster Thailand's economic and social progress while reducing environmental harm. This strategy aligns with the nation's long-term strategic goals and energy reform initiatives. The plan's four main objectives are:

- increasing natural gas use across economic sectors to minimise air pollution;
- expediting natural gas exploration and production domestically, including in joint and overlapping areas;
- developing sufficient and efficient natural gas infrastructure to meet regional needs; and
- fostering competition in the natural gas sector to ensure energy sector stability and sustainability.

The Gas Plan 2018, revised from the Gas Plan 2015, reflects updates in Thailand's PDP 2018 Rev.1 and lower-than-expected natural gas consumption. This revised plan responds to the current production levels in the Gulf of Thailand, which have reduced the need for additional natural gas from existing contracts. It forecasts a modest annual increase in natural gas demand of 0.7%, growing from 4,676 million cubic feet per day in 2018 to 5,348 million cubic feet per day by 2040. While demand is expected to rise in power generation and industrial sectors, it is projected to decline in gas separation plants and transportation.

Natural gas supply sources will include domestic production, imports from Myanmar, and liquefied natural gas (LNG) imports. By 2040, new natural gas or LNG contracts are expected to account for about 68% of the total supply, a decrease from earlier projections. Thailand's LNG terminal capacity is projected to reach 34.8 million tonnes annually by 2030, with potential expansion to 47.5 million tonnes per year, indicating the possibility of underutilized capacity. The plan also emphasizes promoting the use of natural gas across various economic sectors and enhancing Thailand's position in the energy market.

2.4.5. Fuel Management Plan 2018–2037

The Oil Plan 2018, covering the period from 2018 to 2037, aims to provide a steady fuel supply to support economic growth by balancing fossil fuels and biofuels. The plan focuses on improving the quality of eco-friendly fuels and developing efficient infrastructure, aligning with the nation's long-term strategy for competitive and sustainable growth. This plan integrates with the EEP 2018 and AEDP 2018, which set targets for using biodiesel and ethanol in transportation. It also complements the Gas Plan 2018 by promoting the use of natural gas in transportation, especially for large trucks.

The Oil Plan 2018 is in line with Thailand's 20-year energy reform strategy, which aims to overhaul the energy structure in the transportation sector. Measures include promoting electric vehicles (EVs), supporting ethanol usage, and reducing LPG usage. By 2037, overall fuel consumption is expected to increase by 43%, with the transport sector being the main consumer. Based on current demands and projections, the Oil Plan 2018 forecasts 2037 fuel consumption across six categories: gasoline, diesel (including high-speed diesel), jet fuel, kerosene, heating oil, LPG for transport, and natural gas for vehicles.

The Oil Plan 2018 sets forth four key goals for fuel management:

- Fuel security: Maintain a minimum of 50 days' fuel reserve and diversify crude oil sources.
- Eco-friendly domestic fuel: Prioritise biofuels, with high-speed diesel B10 for diesel vehicles and ethanol E20 for gasoline vehicles and achieve Euro 5 standards by 2024.
- Efficient fuel infrastructure: Support economic growth using northern and northeastern oil pipeline systems and the expansion of LPG storage facilities.
- Regulatory framework: Foster competitive fuel markets by revising and implementing policies, laws, and regulations, including updating the Fuel Trade Act B.E. 2543 (2000), for which a new draft is in progress.

3. Research Methodology

3.1. Social Accounting Matrix

Table 4.3 provides a comprehensive account of all the sectors, institutions, and other elements incorporated in the SAM created in this research. This SAM is based on the official 2015 Input-Output table released by the Office of the National Economic and Social Development Council. It aims to accurately represent the main transactions within the Thai economy and has several features.

- It incorporates 47 production sectors and 53 commodities. The aggregated official Input-Output table published by the Office of the National Economic and Social Development Council is the main source of data along with the authors' augmentation to include production activities related to EVs.
- The labour and capital are factors of production. Capital is the aggregate of land, buildings, machinery, and other capital-intensive inputs.
- It uses an aggregate household with the aggregate pattern of expenditure and saving.
- It encapsulates the government's role, especially in revenue collection and budget expenditure and covers three categories of taxes — direct tax, indirect tax, and import tariffs.
- The accounts of savings and investment are derived from information listed in the official Input-Output table. This study augments the details of household-specific savings amounts by using data from the Household Socio-Economic Survey. The values of gross fixed capital formation are directly sourced from the official Input-Output table.
- The last entity is 'the rest of the world', representing the aggregate activities of other nations. In particular, 'the rest of the world' engages in transactions of international trade and transfers.

Figure 4.9 depicts the main structure of SAM. Tables 4.3–4.5 list all sectors, institutions, and other items on the constructed SAM table.

Figure 4.9. The Main Structure of the Social Accounting Matrix

	Primary factors	Households	Firms	Government	Tax	Rest of the world	Activities	Commodities	Saving-investment
Primary factors									
Households	Primary factors ownership								
Firms	Primary factors ownership		Institutional Transfer			Transfer from rest of the world			
Government					Tax income				
Tax			Direct tax					Indirect tax	
Rest of the world								Import	
Activities								Domestic commodities supply	
Commodities		Private consumption		Public consumption		Export	Intermediate demand		Investment and change in inventories
Saving-investment			Private saving		Public saving	Borrowing from abroad			

Source: Author's calculations.

Table 4.3. Production Activities on the Social Accounting Matrix Table

Number	Abbreviation	Description
1	AGR_A	Agriculture forestry and fisheries
2	SGC_A	Sugarcane planting
3	CAS_A	Cassava planting
4	OPM_A	Oil palm plantation
5	COA_A	Coal production
6	CRD_A	Petroleum exploration and production
7	MIN_A	Mining
8	FOD_A	Food and beverage manufacturing
9	CPO_A	Crude palm oil production
10	SUG_A	Sugar production
11	CHM_A	Chemicals paper and textiles
12	PTR_A	Oil refinery
13	PDP_A	Pure biodiesel production
14	ETH-C_A	Ethanol production from cassava
15	ETH-M_A	Ethanol production from molasses
16	OPR_A	Lubricants and other petroleum
17	MNM_A	Metals and non-metals manufacturing
18	MHE_A	Machinery and electrical equipment
19	PVM_A	Solar panel manufacturing
20	BAT_A	Manufacturing of battery for internal combustion vehicle
21	BAT-E_A V	Battery manufacturing for electric vehicle
22	TRI_A	Machinery manufacturing for transportation
23	TRM_A	Maintenance of internal combustion vehicles
24	EV-MAIN_A	Electric vehicle maintenance
25	ICE-PROD_A	Internal combustion vehicle manufacturing
26	EV-PROD_A	Electric vehicle manufacturing
27	OMF_A	Other industries
28	ISVP_A	Independent private power plants
29	EGAT_A	Electricity Generating Authority of Thailand (EGAT)

Number	Abbreviation	Description
30	EGAT-TRAN_A	Power transmission and distribution
31	MEA-PEA_A	Metropolitan Electricity Authority and Provincial Electricity Authority
32	PRO_A	Solar rooftop electricity generation
33	GSP_A	Natural gas separation plant
34	WSP_A	Construction and waterworks
35	TRD_A	Trade and services
36	RAI_A	Rail transport
37	RDP_A	Transport (passenger) by road
38	RDF_A	Transport (cargo) by road
39	LDS_A	Land service
40	OCW_A	Water transportation coastal and sea
41	POR_A	Port services
42	AIR_A	Air freight
43	LGS_A	Logistics services
44	COM_A	Telecommunications
45	BUS_A	Business and financial services
46	PUB_A	Public administration
47	UNC_A	Other unspecified service activities

Source: Author's calculations.

Table 4.4. Commodities on the Social Accounting Matrix Table

Number	Abbreviation	Description
1	AGR_C	Agriculture forestry and fisheries
2	SGC_C	Sugarcane planting
3	CAS_C	Cassava planting
4	OPM_C	Oil palm plantation
5	COA_C	Coal production
6	CRD_C	Petroleum exploration and production
7	NGR_C	Natural gas production
8	MIN_C	Mining
9	FOD_C	Food and beverage manufacturing
10	SUG_C	Sugar production
11	MOL_C	Molasses production
12	CPO_C	Crude palm oil
13	CHM_C	Chemical product
14	LPG_C	Liquefied petroleum gas
15	GSH_C	Kerosene
16	JET_C	Jet fuel
17	DIE_C	Diesel
18	FUO_C	Fuel oil
19	ATB_C	Other petroleum products
20	B100_C	Biodiesel
21	ETH_C	Ethanol
22	OPR_C	Other products
23	MNM_C	Metals and non-metals manufacturing
24	MHE_C	Machinery and electrical equipment
25	PVM_C	Solar panel manufacturing
26	BAT_C	Battery manufacturing for internal combustion vehicle
27	BAT-EV_C	Battery manufacturing for electric vehicles
28	TRI_C	Machinery manufacturing for transportation
29	TRM_C	Maintenance of internal combustion vehicles

Number	Abbreviation	Description
30	EV-MAIN_C	Electric vehicle maintenance
31	ICE-PROD_C	Internal combustion vehicle manufacturing
32	EV-PROD_C	Electric vehicle manufacturing
33	OMF_C	Other industries
34	ELE-ISVP_C	Independent private power plants
35	ELE-EGAT_C	Electricity Generating Authority of Thailand
36	EGAT-TRAN_C	Power transmission and distribution
37	ELE_C	Metropolitan Electricity Authority and Provincial Electricity Authority
38	PRO_C	Solar rooftop electricity generation
39	PNG_C	Natural gas
40	WSP_C	Construction and waterworks
41	TRD_C	Trade and services
42	RAI_C	Rail transport
43	RDP_C	Transport (passenger) by road
44	RDF_C	Transport (cargo) by road
45	LDS_C	Land service
46	OCW_C	Water transportation coastal and sea
47	POR_C	Port services
48	AIR_C	Air freight
49	LGS_C	Logistics services
50	COM_C	Telecommunications
51	BUS_C	Business and financial services
52	PUB_C	Public administration
53	UNC_C	Other unspecified service activities

Source: Author's calculations.

Table 4.5. Factors of Production and Institutions on the Social Accounting Matrix Table

Abbreviation	Description
Lab	Labour
Capital	Capital
HH	Aggregate household
Govt	Government
TD	Direct tax
TM	Import tax
TI	Indirect tax
RoW	Rest of the world
SAV_INV	Saving and investment
VSTK	Change in stock

Source: Author's calculations.

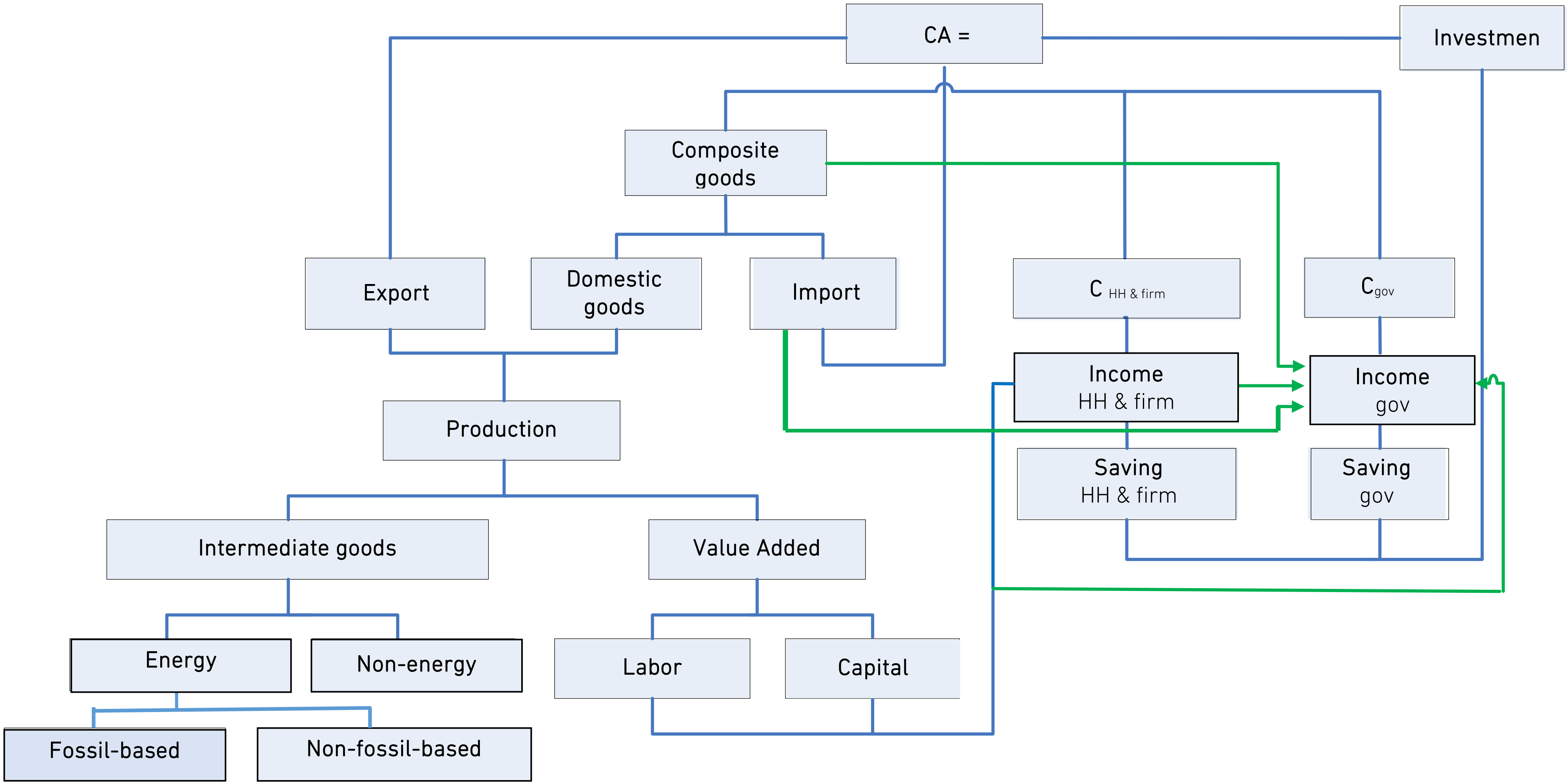
3.2. The Main Structure of Computable General Equilibrium Model

The CGE model is a structural model that replicates the main nationwide relationships amongst various economic entities. In general, it represents annual economic activities and transactions. Constructed based on general equilibrium theory, the model maintains the economy-wide equilibrium, in which price adjustment is the main mechanism of equilibrating the balance of all markets. The impact simulations can be conducted by incorporating exogenous shocks, causing a ripple effect throughout the economy, and achieving a new equilibrium. Due to its ability to analyse the impact on the entire economic system, the CGE model is widely applied in policy-oriented studies.

In the CGE model, all relationships are based on microeconomic theory. Each economic entity is represented as mathematical equations governing its behaviour in achieving optimal objectives under resource and technological constraints. In practice, the model represents the simultaneous adjustments of production behaviours of various industries, consumptions of many household classifications, the interventions of government, and the influences of international trade. Hence, many equations are incorporated into a system, causing the mode to be large and complex. To determine the impact on the economic system, various endogenous and exogenous variables must be defined. Endogenous variables are values computed by the model, while exogenous variables, such as policy-oriented variables, are set by the users (or the modeller).

The production sector utilises production factors to create goods and services, including primary factors such as labour and capital, and intermediate factors, which include all goods and services in the market. As shown in Figure 4.10, each production sector combines the intermediate goods and primary factors (e.g., labour and captivating) to produce the goods and services, subsequently distributed for domestic consumption and export. For domestic consumption, the domestically produced products are combined with imported goods and become final goods consumed by households, the government, the investment sector, and exported abroad. Households use income from labour and capital returns to purchase goods and services, with the remainder used for savings and investment. The government generates income from taxes on households and the production sector to spend on fiscal budget and public investment. Following the macroeconomic concept of saving and investment balance, savings from private and public sectors finance the purchase of capital for production in the next annual cycle (i.e., the investment). It is notable that this saving and investment relationship institutes capital accumulation, which is the main dynamic process of economic growth.

Figure 4.10. The Main Structure of the Computable General Equilibrium Model



CA = current account; Cgov = government consumption; gov = government; KA = capital account; CHH & firm = private consumption (household and firm); HH = aggregate household.
Source: Author's calculations.

As defined by microeconomic theory, production and consumption activities, concurrently influenced by the market system, are the crucial structures of the economy. Based on this foundation, the CGE model comprises all markets, including goods, services, and production factor markets. All prices and quantities simultaneously adjust until reaching the economy-wide equilibria. When changes from external factors affect prices and/or quantities of goods and services in a particular market, the producers and consumers alter their production and consumption until reaching the new equilibrium levels of goods and services in all markets are achieved. Based on a foundation of general equilibrium theory, the economy-wide market equilibria are the main mechanism of the model. Hence, Walras's law is conventionally applied as a crucial criterion for determining the validity of the developed CGE model.

The main analytical framework for this study is the standard structure of the dynamic CGE model introduced by Decaluwé et al. (2013). It comprises the production behaviour of all sectors governed by a multi-level nested structure with the mathematical specifications of constant elasticity substitution technology. The CGE model has been constructed using the 2015 SAM table, with details previously described in Section 3.1, as the baseline.

3.3. Inclusion of Electric Vehicles in the Standard Computable General Equilibrium Model

The dynamic computable CGE model used for evaluating the impact of electricity primarily draws from the mathematical framework and parameters established by Haputta et al. (2022), Phomsoda, Puttanapong, and Piantanakulchai (2021a and 2021b), Haputta et al. (2020), and Kaenchan et al. (2019). This model incorporates the production and use of EVs based on methodologies developed by Guo et al. (2022), Guo et al. (2022), Lin and Wu (2021), Chen et al. (2021), Shibusawa and Miyata (2017), and Miyata, Shibusawa, and Fujii (2018). The cost structure for EV production in this model is informed by research from Suehiro and Purwanto (2020) and Lutsey and Nicholas (2019). Additionally, the model's assumptions about future battery costs are aligned with projections made by Mauler et al. (2021).

3.4. Simulation Strategy

The critical aspects of this study include the specifics and prospective developments in EV production and usage. As outlined in Table 4.6, the cost structure, focusing on major EV components and their associated expenses follows the studies by Suehiro and Purwanto (2020) and Lutsey and Nicholas (2019).

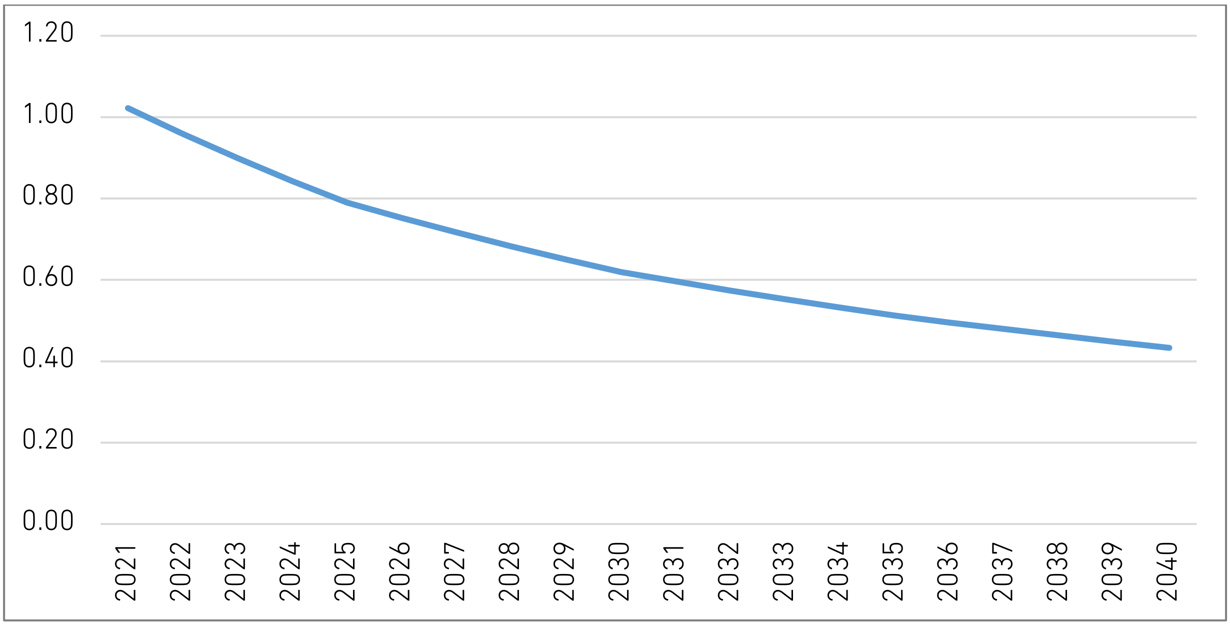
Table 4.6. Cost Structure of Electric Vehicle Production

Parts	2021 (%)	2025 (%)
Battery pack	30.16	30.62
Thermal management	0.66	0.86
Power distribution	0.66	1.13
Inverter	1.83	2.00
Electric drive module	3.15	4.13
DC converter	0.39	0.51
Controller	0.13	0.18
Control module	0.24	0.32
High voltage cables	0.88	1.16
On-board charger	0.72	0.78
Charging cord	0.39	0.52
Vehicle assembly	33.04	45.54
Indirect cost	27.76	12.25
Total	100.00	100.00

% = percent; DC = direct current.
Note: Numbers may not sum precisely due to rounding.
Source: Lutsey and Nicholas (2019) and author's estimation.

Figure 4.11 illustrates that the battery price is projected to decrease exponentially over time, in line with the findings of Mauler et al. (2021). Assuming a rise in domestic production and an increasing market demand for EVs, the share of EV production will align with the 30@30 strategy, with this trend expected to continue expanding through to 2040, the terminal year of our simulation. Technically speaking, in the simulated model, the escalation in EV production was primarily a consequence of a sustained increase in investments directed towards EV manufacturing, a factor that was externally preset in the model's parameters. Additionally, the surge in demand for EVs was influenced by modifications in the parameters that depict the marginal propensity to consume both ICE and EV cars. The underlying assumption here was a gradual but steady shift in consumer preference, favouring the substitution of ICE vehicles with EVs as shown in Figure 4.12.

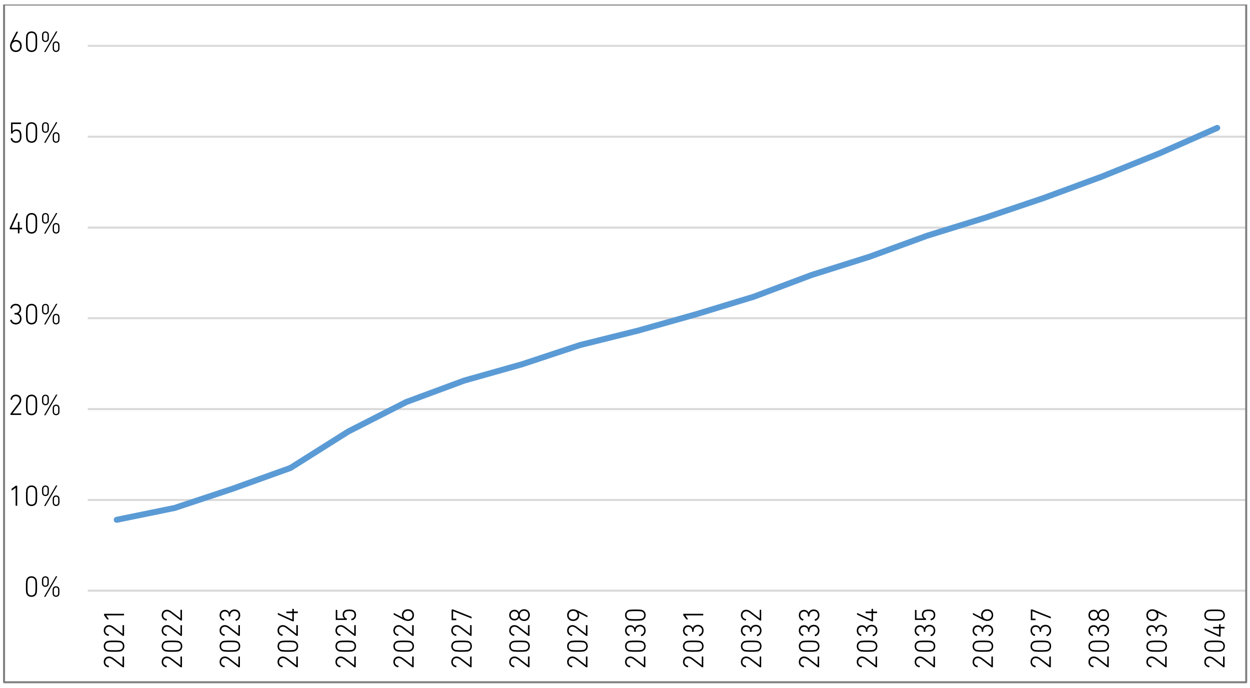
Figure 4.11. The Price Index of Electric Vehicle Batteries over the Projected Period (2021–2040)



Source: Authors' calculation.

Figure 4.12. The Proportion of Electric Vehicles to the Total Domestic Production of Vehicles

(%)



Source: Author's calculation.

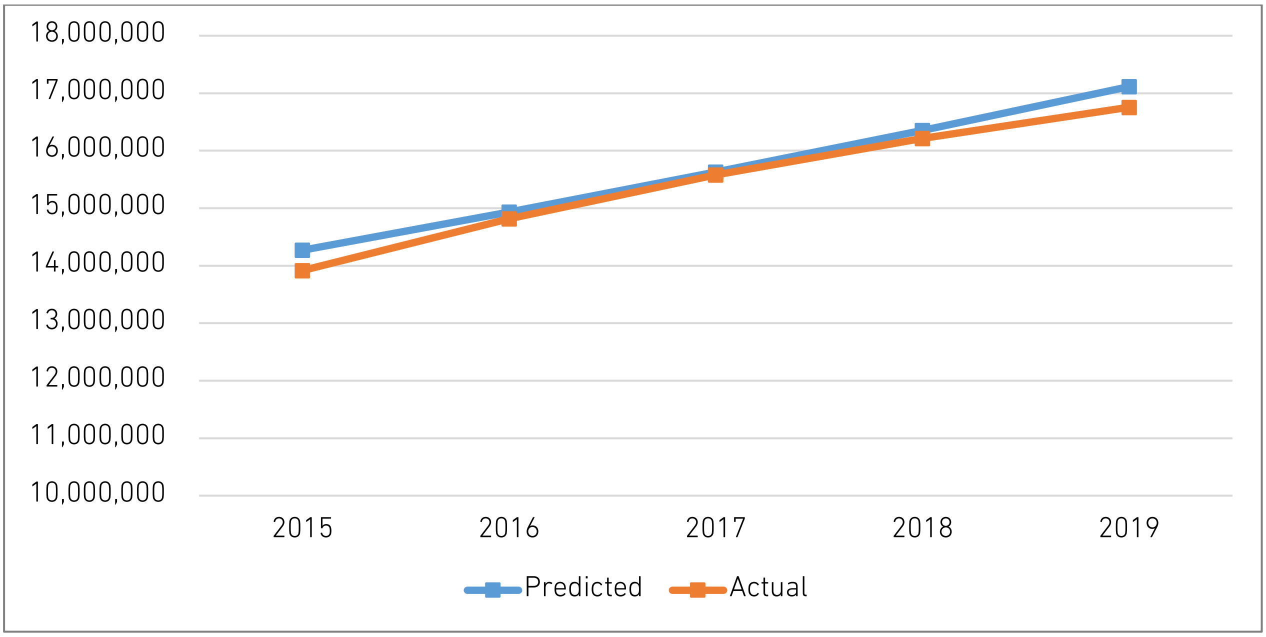
4. Research Methodology

4.1. Social Accounting Matrix

To verify the compatibility of the developed model to replicate the main characteristics of the Thai economy, the simulation results were generated with the aim of ascertaining the model's accuracy.

Figure 4.13 depicts the predictive performance of the developed dynamic CGE model, closely replicating the value of real GDP during 2015–2019. Furthermore, Table 4.7 shows the comparison between the actual and simulated values of the main macroeconomic indices for the period 2015–2019. Using the -mean-square error values as the criterion, these in-sample simulation results indicate that this model can replicate the dynamic adjustment of the Thai economy, giving confidence that it can be used to accurately study future policies.

Figure 4.13. A Comparison of Real Gross Domestic Product



Source: Author's calculation.

Table 4.7. A Comparison between Actual and Simulated Values of Macro Indication during 2015–2019

Macroeconomic Indicators	Sources	2015	2016	2017	2018	2019	RMSE (%)
Real GDP	Predicted	14,283,653.18	14,938,992.79	15,638,025.90	16,362,934.42	17,127,257.15	1.62
	Actual	13,916,250.00	14,816,268.00	15,581,153.00	16,214,622.00	16,756,074.00	
Private consumption	Predicted	7,205,527.24	7,540,744.92	7,897,377.99	8,260,140.78	8,644,883.39	3.12
	Actual	7,056,809.00	7,296,683.00	7,579,744.00	8,002,725.00	8,448,321.00	
Gross fixed capital formation	Predicted	3,334,347.04	3,567,452.74	3,814,944.99	4,076,455.16	4,352,289.75	8.63
	Actual	3,371,068.00	3,459,899.00	3,579,845.00	3,726,894.00	3,814,370.00	
Import	Predicted	6,728,685.48	7,801,051.11	8,399,835.43	7,788,875.42	8,565,105.25	12.05s
	Actual	7,861,679.00	7,806,464.00	8,397,736.00	9,771,154.45	8,543,405.00	
Export	Predicted	8,091,690.73	8,456,061.44	8,837,577.22	9,235,348.50	9,651,870.77	12.25
	Actual	9,295,635.00	9,785,868.00	10,326,731.00	10,616,164.00	10,086,594.00	
CPI	Predicted	1.000	1.007	1.015	1.020	1.028	0.35
	Actual	1.000	1.002	1.009	1.019	1.027	

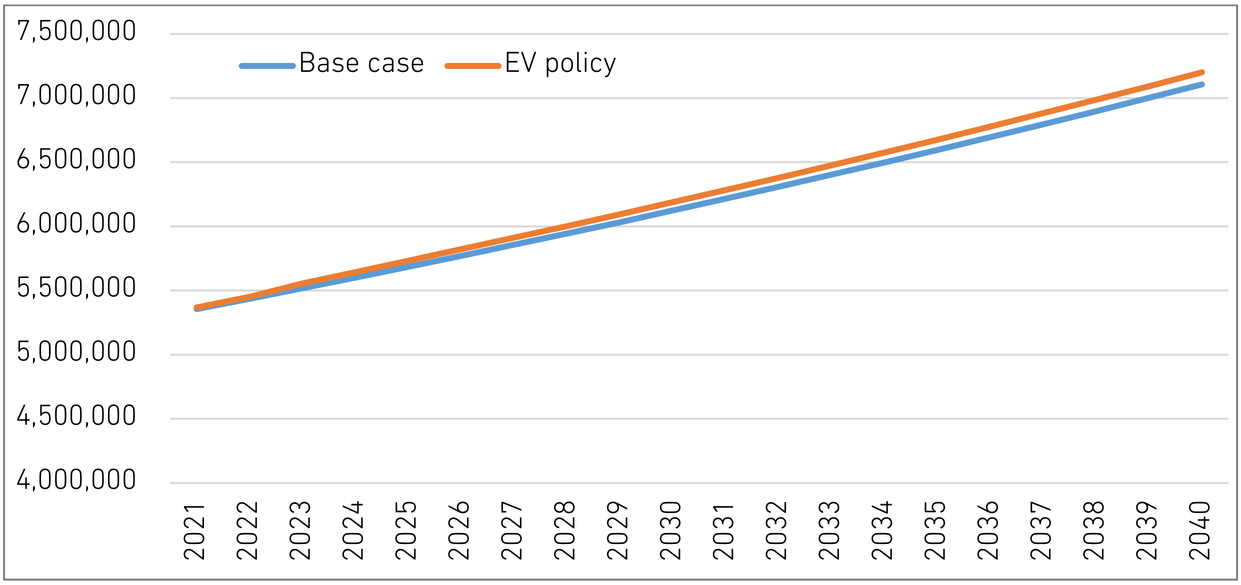
CPI = consumer price index; GDP = gross domestic product; RMSE = root-mean square error
Source: Author's calculation.

4.2. Impacts of the Electric Vehicle Policy

4.2.1. Impacts on Macroeconomic Indicators

The developed general equilibrium model in this research demonstrates the changes in every sector within Thailand's economic system across various dimensions. In terms of the macroeconomic perspective, the primary consideration is the impact on gross domestic product (GDP), which reveals a net positive influence on the total economic measure. As shown in Figure 4.14, the simulation outcome indicated the continuous growth of GDP throughout the forecast period, both in terms of current and real GDP values. This estimation result reveals that increasing the proportion of EVs has a positive effect, leading to economic expansion.

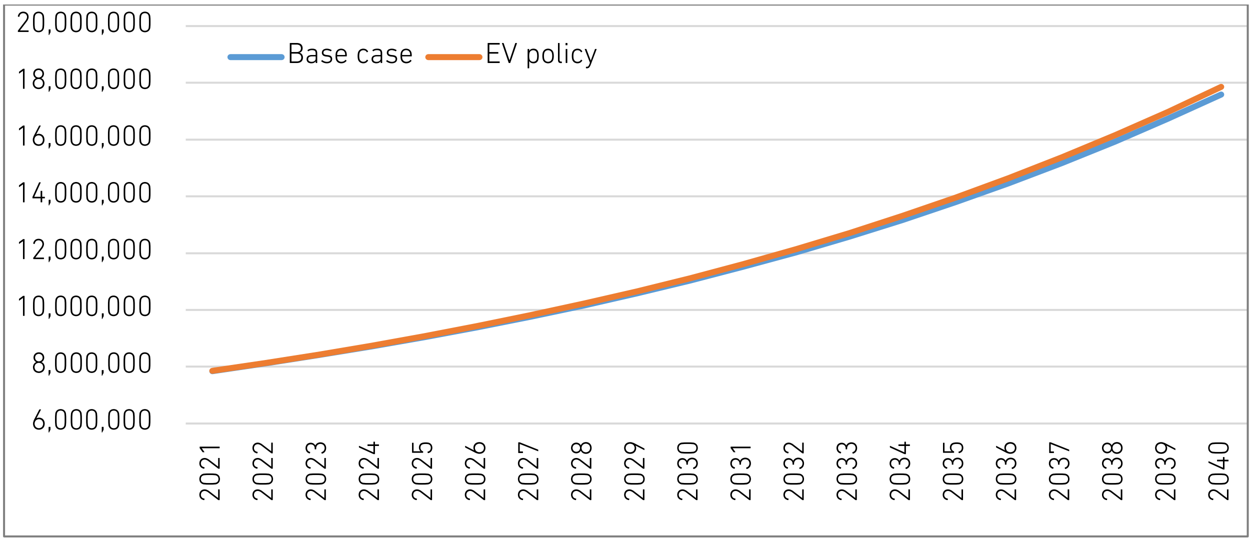
Figure 4.14. The Impact of the Electric Vehicle Policy on Real Gross Domestic Product (million baht at 2021 prices)



EV = electric vehicle
Note: Numerical results are shown in Table A.1.
Source: Author's calculation.

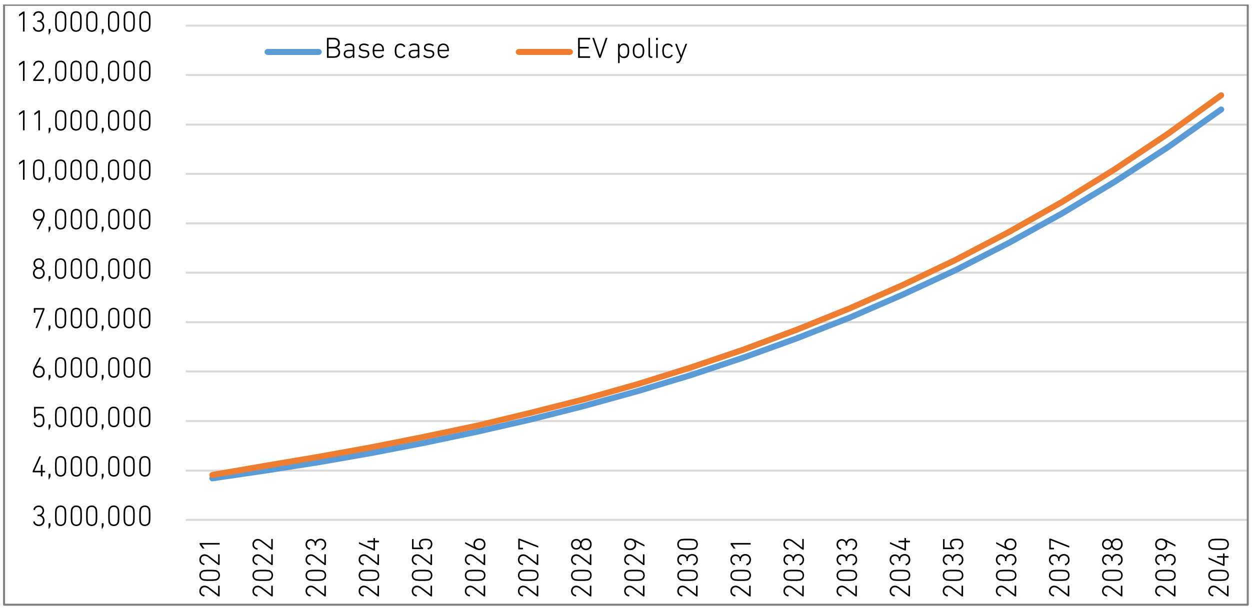
When considering the main components of GDP, it is evident that total private consumption continuously increases, as shown Figure 4.15. Furthermore, overall investment (i.e., gross fixed capital formation) also continuously expands, as indicated by Figure 4.16. Both values are components that reflect changes in economic activity values resulting from domestic sectors and arise from households and the private sector. They benefit from an expansion of the proportion of vehicle usage in the country, reflecting the transmission of government policy impacts to the private sector and households, leading to macroeconomic expansion in the long-term.

Figure 4.15. The Impact of the Electric Vehicle Policy on Total Private Consumption
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.2.
Source: Author's calculation.

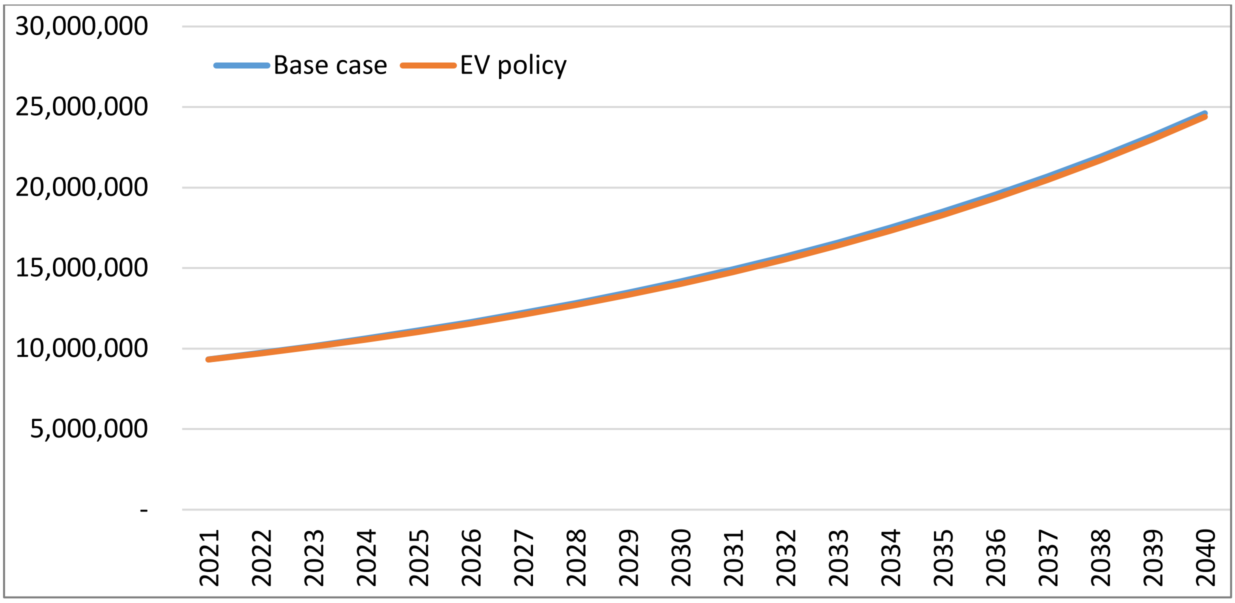
Figure 4.16. The Impact of the Electric Vehicle Policy on Gross Fixed Capital Formation
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.3.
Source: Author's calculation.

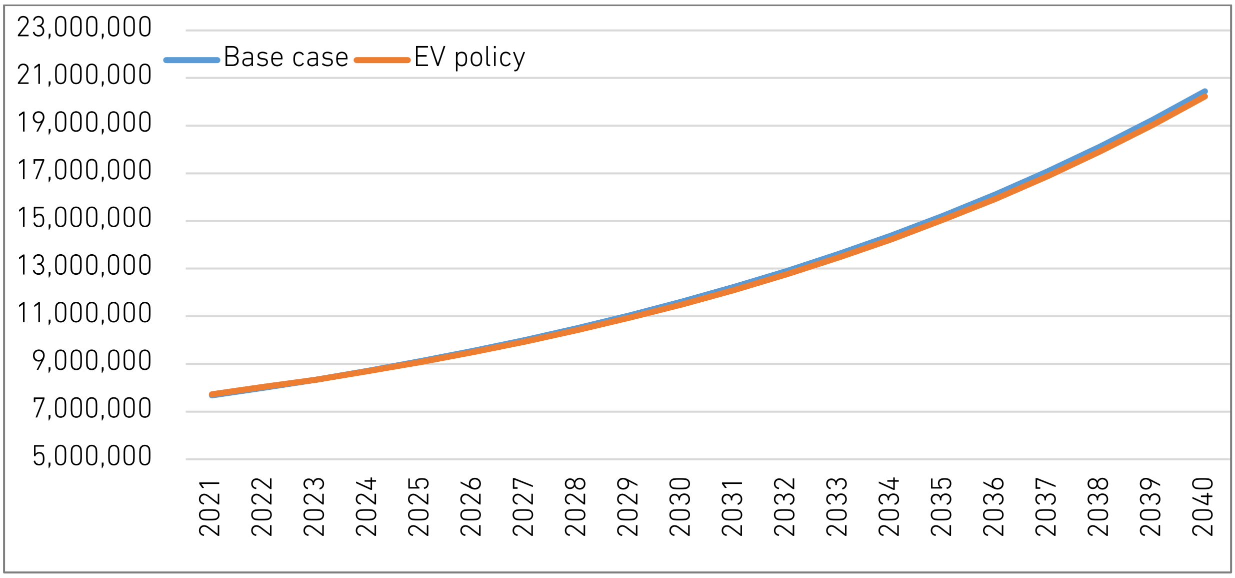
The impacts of EV policy on international trade are shown in Figures 4.17–4.19. The simulated result indicates that the expansion of EV production and utilisation will lead to a slight decline in export and import. Thus, the net current account will also marginally decrease.

Figure 4.17. The Impact of the Electric Vehicle Policy on Total Export
(million baht at 2021 prices)



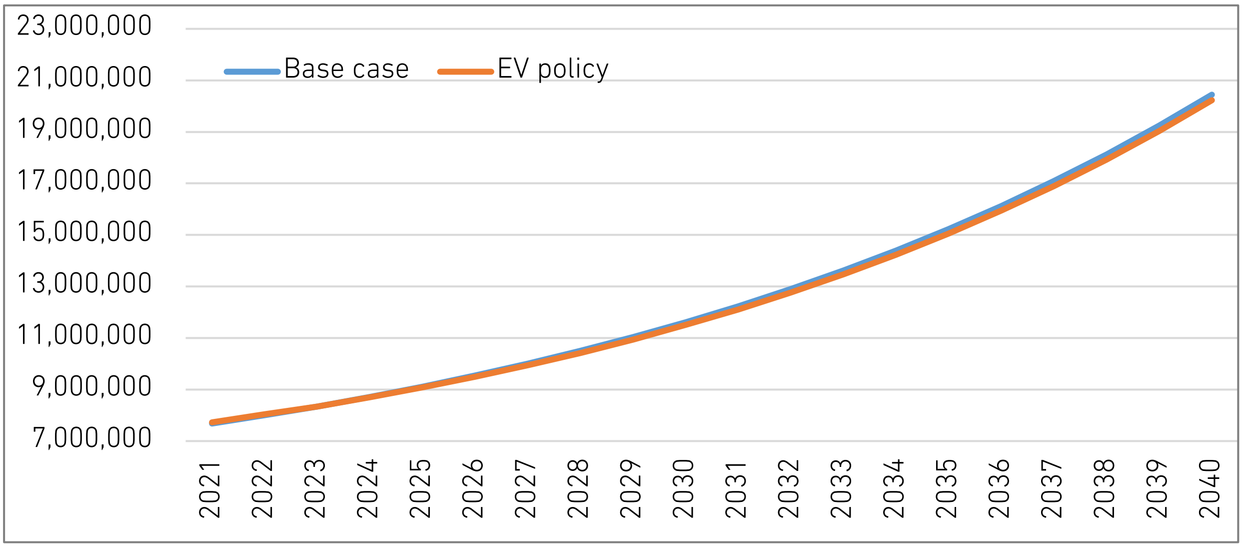
EV = electric vehicle.
Note: Numerical results are shown in Table A.4.
Source: Author's calculation.

Figure 4.18. The Impact of the Electric Vehicle Policy on Total Import
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.5.
Source: Author's calculation.

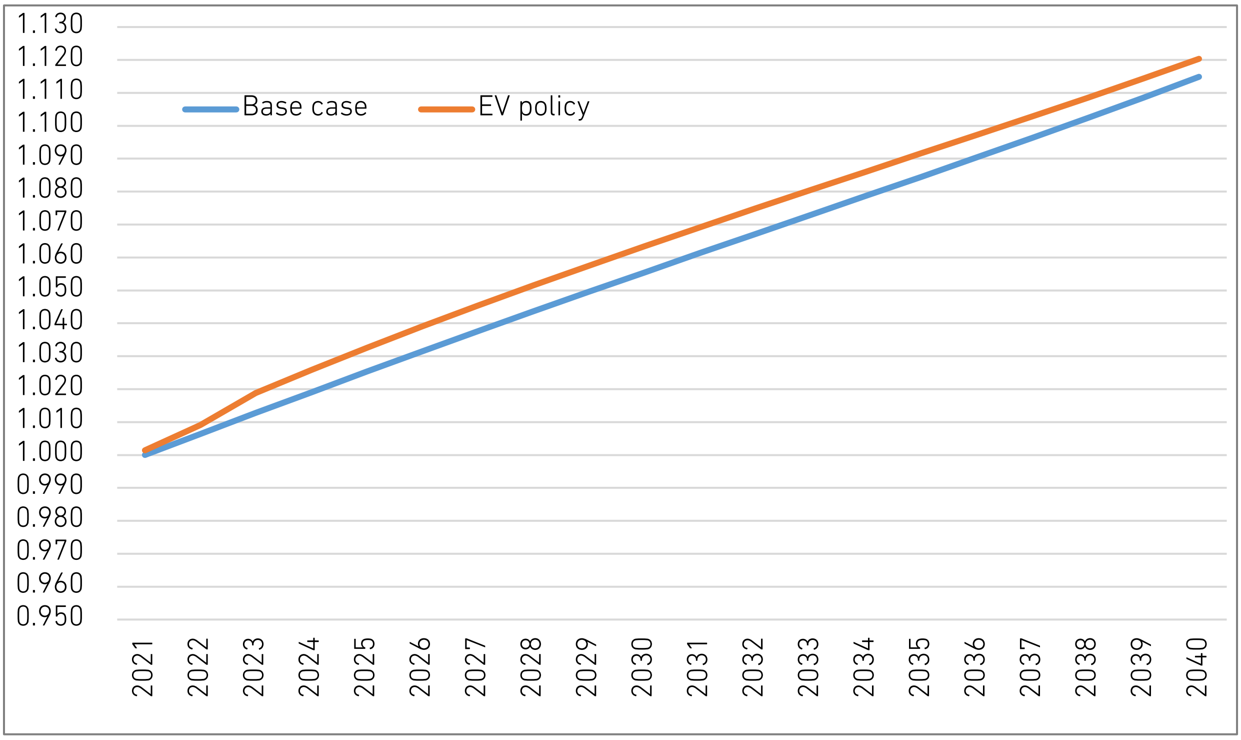
Figure 4.19. The Impact of the Electric Vehicle Policy on Net Current Account Balance
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.6.
Source: Author's calculation.

Considering the impact on the consumer price index (CPI), the economic expansion results in higher inflation than the base case due to an increase in overall demand (aggregate demand), both from overall consumption and overall investment, affecting product price levels. However, as shown in Figure 4.20, it was found that the CPI increased only slightly from the base case in all future scenarios because there was also an expansion of overall supply. Therefore, the change in the product price level does not significantly affect the overall economy.

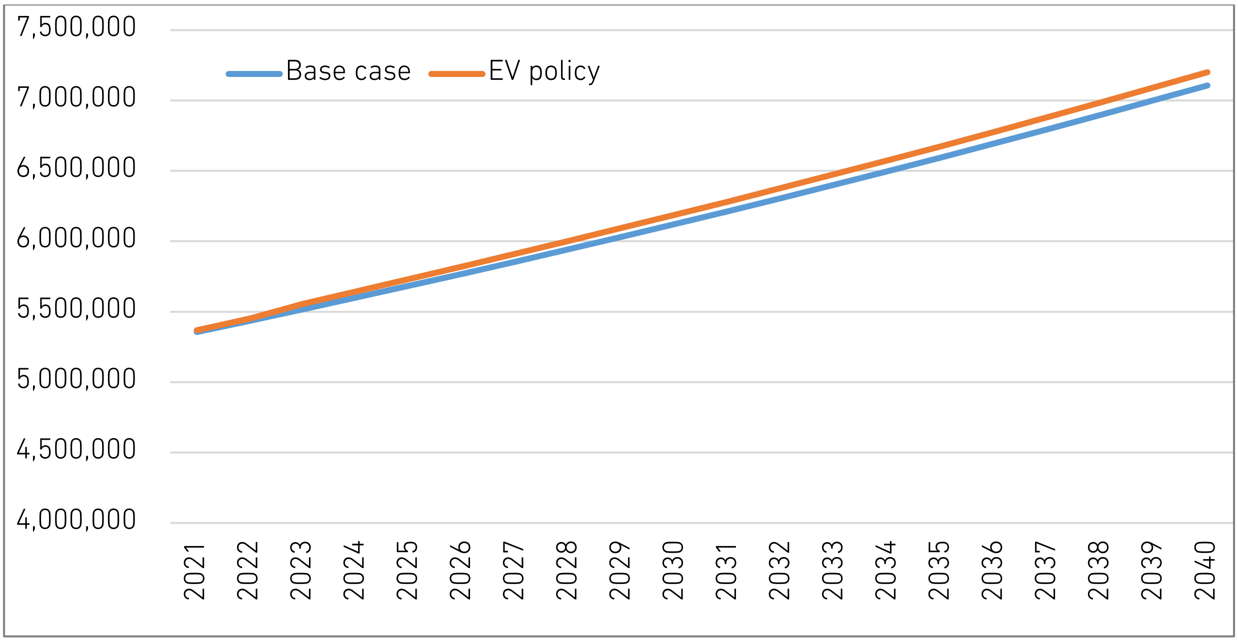
Figure 4.20. The Impact of the Electric Vehicle Policy on The Consumer Price Index
(Year 2021 = 1.00)



EV = electric vehicle.
Note: Numerical results are shown in Table A.7.
Source: Author's calculation.

Figure 4.21 illustrates the impact on the total value of wage income. This simulation outcome indicates a positive impact as the total monetary value of employment will rise until 2040. This macro indicator represents the other aspect of economy-wide benefit, which subsequently improve household's consumption.

Figure 4.21. The Impact of the Electric Vehicle Policy on The Total Value of Employment
(million baht at 2021 prices)



EV = electric vehicle.
Source: Author's calculation.

4.2.2. Impacts on Production by Sector

The simulation results identify the details of the interconnections amongst various sectors within the economic system, enabling an analysis of sectoral impacts. The details of the impacts of changes in production by sector are shown in Table 4.8.

Table 4.8. The Sectoral Impacts of the Electric Vehicle Policy
(Average Change in Total Output)

Abbreviation	Description	Average (%)	Max (%)	Min (%)
AGR	Agriculture, forestry, and fisheries	0.54	1.20	-0.02
AIR	Air freight	-2.04	0.01	-3.33
BAT	Manufacturing of batteries for internal combustion vehicles	8.10	27.38	-0.05
BAT-EV	Batteries for EV	-5.07	9.31	-11.62
BUS	Business and financial services	0.58	0.92	0.07
CAS	Cassava planting	-2.92	0.06	-4.58
CHM	Chemicals paper and textiles	-0.69	0.00	-1.05
COA	Coal production	0.43	1.56	-0.01
COM	Telecommunications	0.46	1.08	0.00
CPO	Crude palm oil production	-5.70	0.12	-8.34
CRD	Petroleum exploration and production	-11.51	0.05	-18.56
EGAT	Electricity Generating Authority of Thailand	-0.68	0.82	-3.58
EGAT-TRAN	Power transmission and distribution	2.27	5.28	0.10
ETH-C	Ethanol production from cassava	-26.09	0.33	-45.48
ETH-M	Ethanol production from molasses	-6.62	0.20	-8.21
EV-MAIN	EV maintenance	31.32	57.22	1.03
EV-PROD	EV manufacturing	108.90	245.40	0.98
FOD	Food and beverage manufacturing	0.60	1.31	-0.05
GSP	Natural gas separation plant	-18.37	0.07	-26.10
ICE-PROD	Internal combustion vehicle manufacturing	-7.51	0.19	-18.36
ISVP	Independent private power plants	3.82	10.14	0.10
LDS	Land service	0.63	1.10	0.09
LGS	Logistics services	0.09	0.60	-0.08
MEA-PEA	Metropolitan Electricity Authority and Provincial Electricity Authority	2.25	5.23	0.10
MHE	Machinery and electrical equipment	-1.01	0.06	-1.44
MIN	Mining	-0.16	0.28	-0.44
MNM	Metals and non-metals manufacturing	-0.66	0.05	-1.08

Abbreviation	Description	Average (%)	Max (%)	Min (%)
OCW	Water transportation coastal and sea	-0.17	0.46	-0.80
OMF	Other industries	-0.96	0.02	-1.29
OPM	Oil palm plantation	-5.06	0.11	-7.46
OPR	Lubricants and other petroleum	-0.92	0.05	-1.49
POR	Port services	-0.16	0.12	-0.35
PRO	Solar rooftop electricity generation	71.56	164.67	0.12
PTR	Oil refinery	-13.71	0.25	-19.91
PUB	Public administration	0.11	0.32	-0.04
PVM	Solar panel manufacturing	12.35	45.23	-0.13
RAI	Rail transport	1.30	1.88	0.07
RDF	Transport (cargo) by road	0.39	0.76	0.18
RDP	Transport (passenger) by road	1.87	2.51	-0.01
SGC	Sugarcane planting	-0.31	0.04	-0.54
SUG	Sugar production	-0.43	0.05	-0.68
TRD	Trade and services	5.05	8.80	0.08
TRI	Machinery manufacturing for transportation	0.01	0.48	-0.26
TRM	Maintenance of internal combustion vehicles	0.94	1.28	0.24
UNC	Other unspecified service activities	2.71	3.82	0.03
WSP	Construction and waterworks	1.25	1.46	1.01

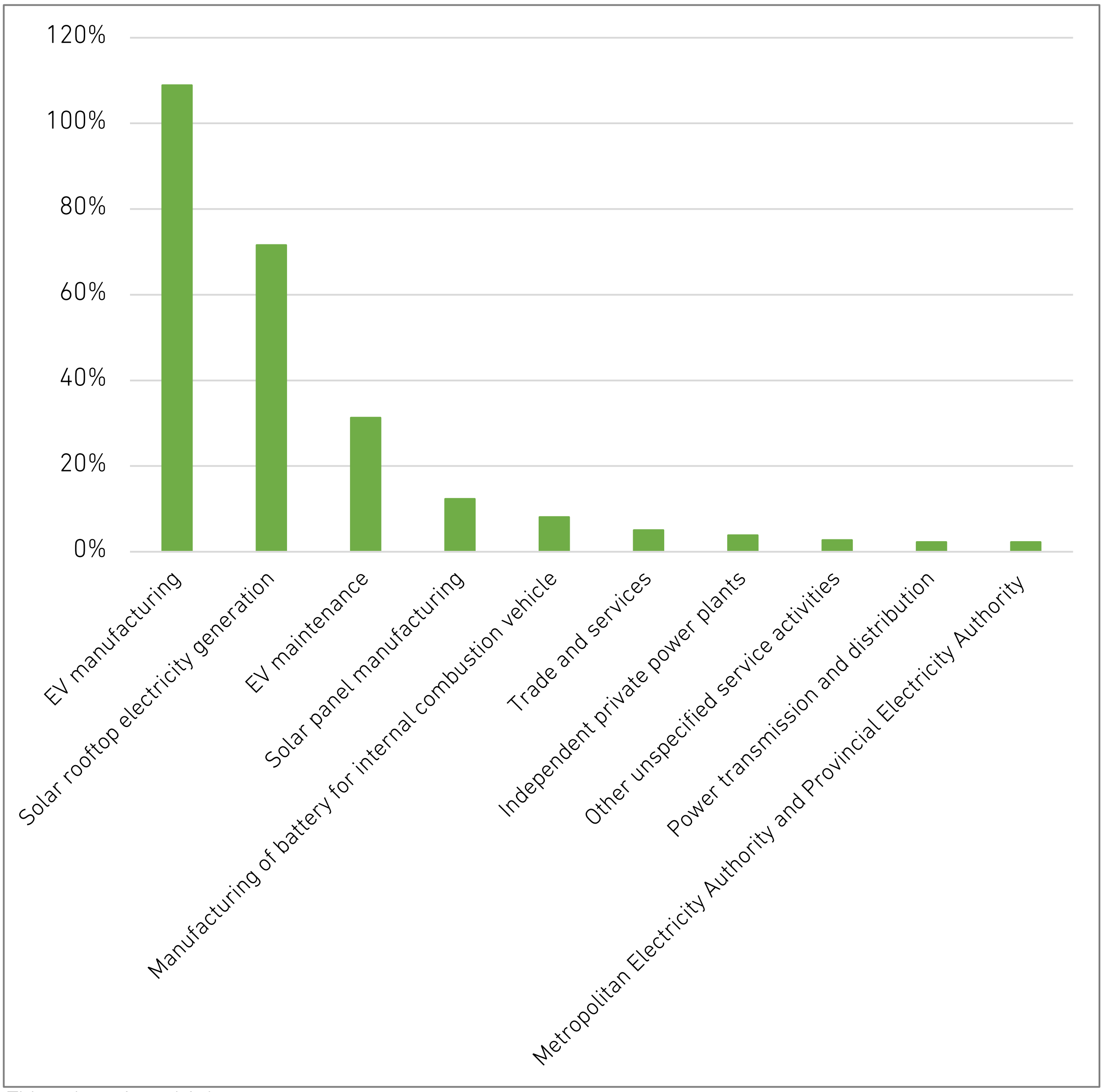
EV = electric vehicle
Note: Numerical results are shown in Table A.7.
Source: Author's calculation.

According to Figure 4.22 and Table 4.8, the impact of transformative technology will positively affect 24 production activities, while the rest will be negatively impacted. The greatest increase in production is in sectors related to the production and use of EVs as listed below.

(1) EV manufacturing (increasing by 0.978% to 245.399%)
(2) Solar rooftop electricity generation (increasing by 0.11% to 164.670%)
(3) EV maintenance (increasing by 1.032% to 57.219%)
(4) Solar panel manufacturing (increasing by -0.132% to 45.229%)
(5) Manufacturing of batteries for internal combustion vehicles (increasing by -0.047% to 27.377%)

(6) Trade and services (increasing by 0.080% to 8.800%)
(7) Independent private power plants (increasing by 0.102% to 10.144%)
(8) Other unspecified service activities (increasing by 0.02% to 3.820%)
(9) Power transmission and distribution (increasing by 0.102% to 5.277%)
(10) Metropolitan Electricity Authority and Provincial Electricity Authority (increasing by 0.101% to 5.230%)

Figure 4.22. The Sectors with the Highest Positive Impacts Due to the Electric Vehicle Policy
(%)



EV = electric vehicle.
Source: Author's calculation.

However, the simulation result also indicates a negative impact on some production sectors. This is due to the implications of the new policy promoting the production and use of EVs, and the energy scheme allowing electricity production from household rooftops (solar rooftops). As illustrated in Figure 23, the most negatively impacted sectors include:

(1) Ethanol production from cassava (changing between -45.489% and 0.327%)

(2) Natural gas separation plant (changing between -26.096% and 0.067%)

(3) Oil refinery (changing between -19.908% and 0.250%)

(4) Petroleum exploration and production (changing between -18.562% and 0.052%)

(5) Internal combustion vehicle manufacturing (changing between -18.361% and 0.189%)

(6) Ethanol production from molasses (changing between -8.209% and 0.203%)

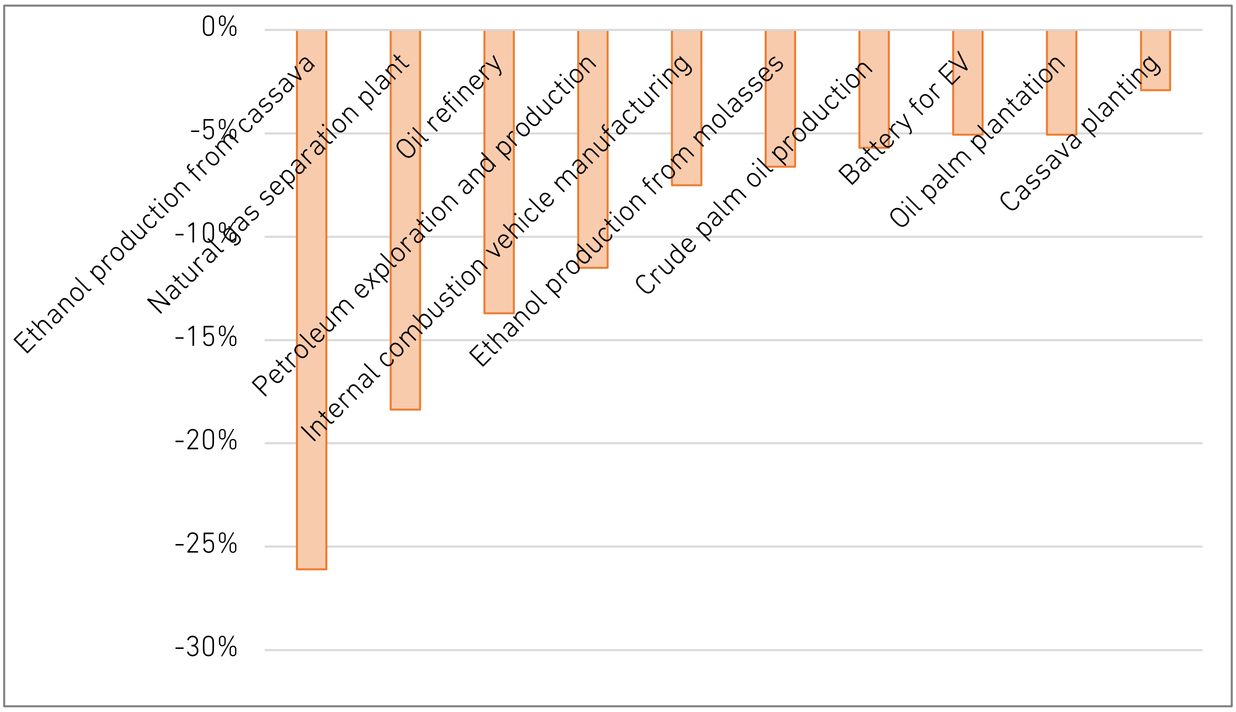
(7) Crude palm oil production (changing between -8.341% and 0.115%)

(8) Batteries for EV (changing between -11.620% and 9.310%)

(9) Oil palm plantation (changing between -7.462% and 0.106%)

(10) Cassava planting (changing between -4.579% and 0.060%)

Figure 4.23. The Sectors with the Highest Negative Impacts Due to the Electric Vehicle Policy
(%)

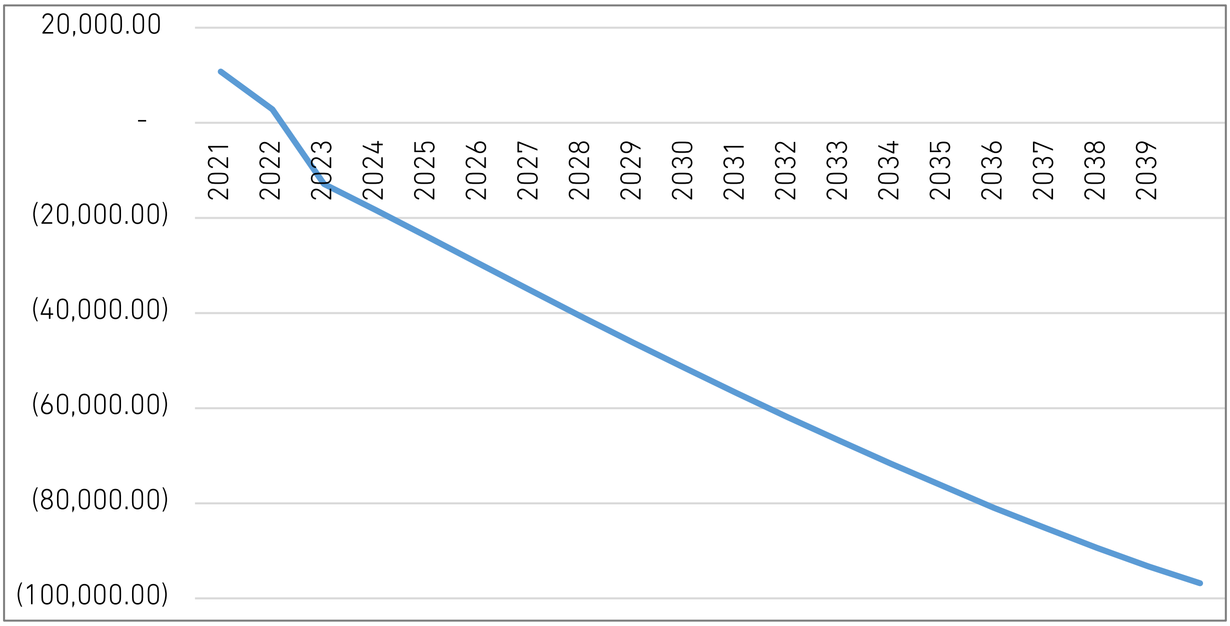


EV = electric vehicle.
Note: Numerical results are shown in Table A.8.
Source: Author's calculation.

4.2.3. Impacts on Fiscal Status

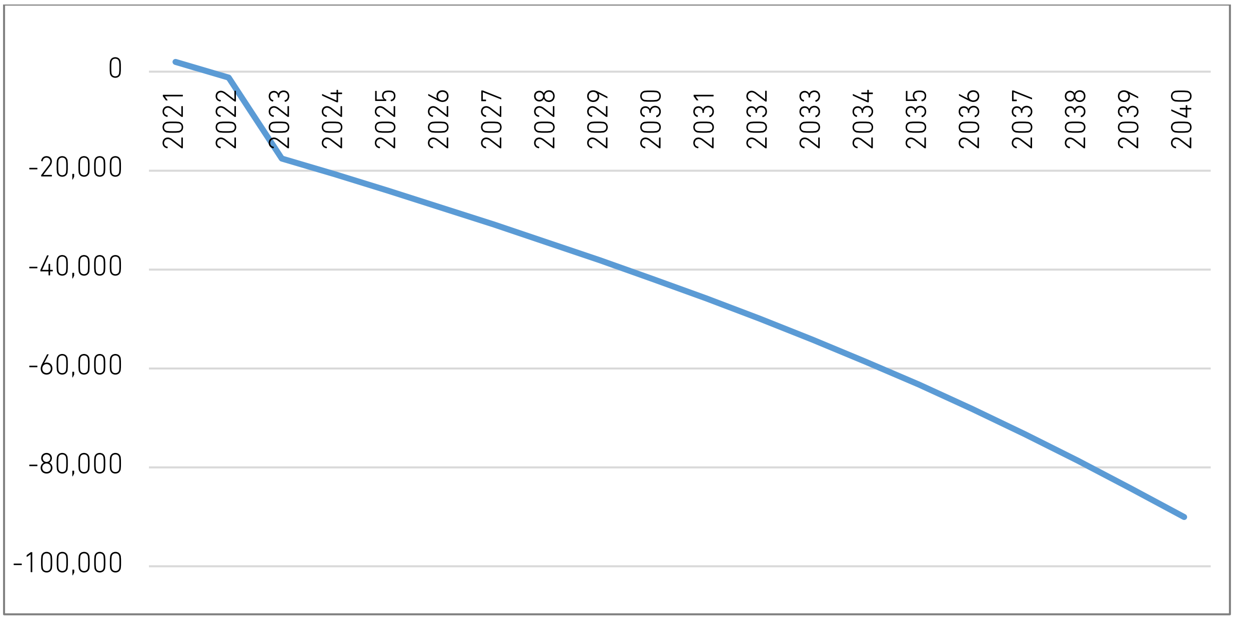
One of the main focuses of this study is the fiscal stability of the Government of Thailand. The simulation result generated by the developed CGE model indicates the declining total government revenue. As shown in Figure 4.24, the total income of the Government of Thailand will decline during 2021–2040. Figures 4.25–4.27 show the structure of revenue sources, which is a combination of direct tax, indirect tax, and tariffs. The implementation of EV policy can lead to the decline of indirect tax and tariffs, substantially contributing to the long-term trend of declining total revenue.

Figure 4.24. Changes in Total Government Revenue Due to The Electric Vehicle Policy (million baht)



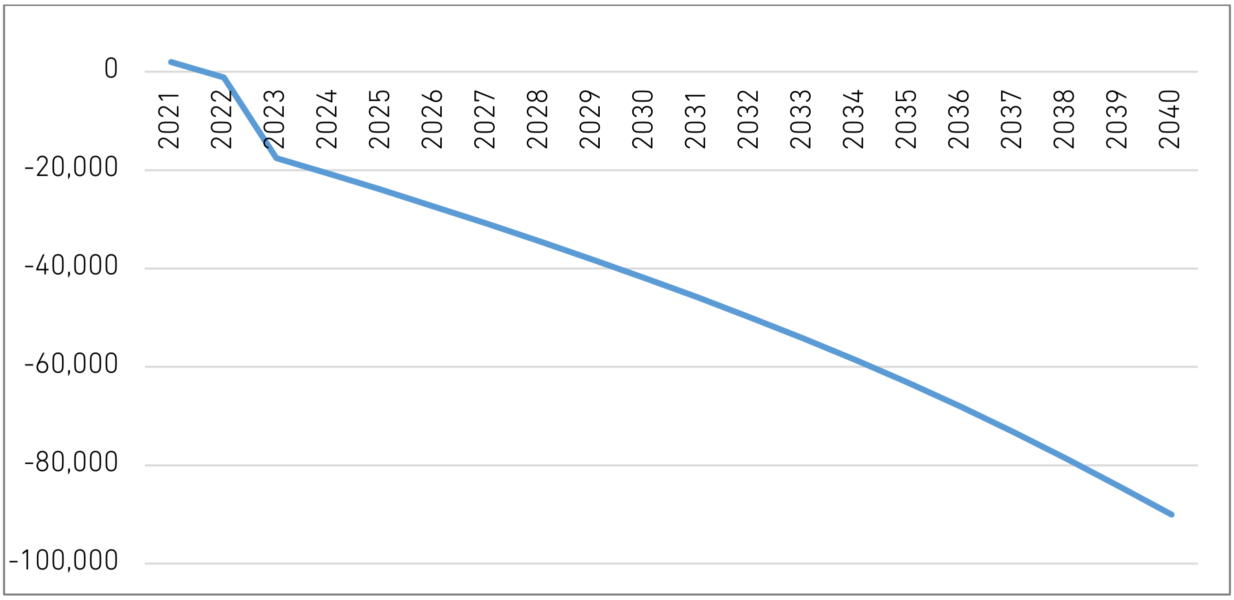
Note: Numerical results are shown in Table A.8.
Source: Author’s calculation.

Figure 4.25. Changes in Total Direct Tax Due to the Electric Vehicle Policy
(million baht)



Note: Numerical results are shown in Table A.9.
Source: Author's calculation.

Figure 4.26. Changes in Total Indirect Tax due to the Electric Vehicle Policy
(million baht)



Note: Numerical results are shown in Table A.10.
Source: Author's calculation.

Following the conventional specification of the CGE model, the real value of current government consumption was set as the exogenous variable. Hence, its market price value can be varied due to inflation. Thus, as indicated in Table 4.9, the annual market price values of current government consumption were slightly inflated due to the low level of inflation.

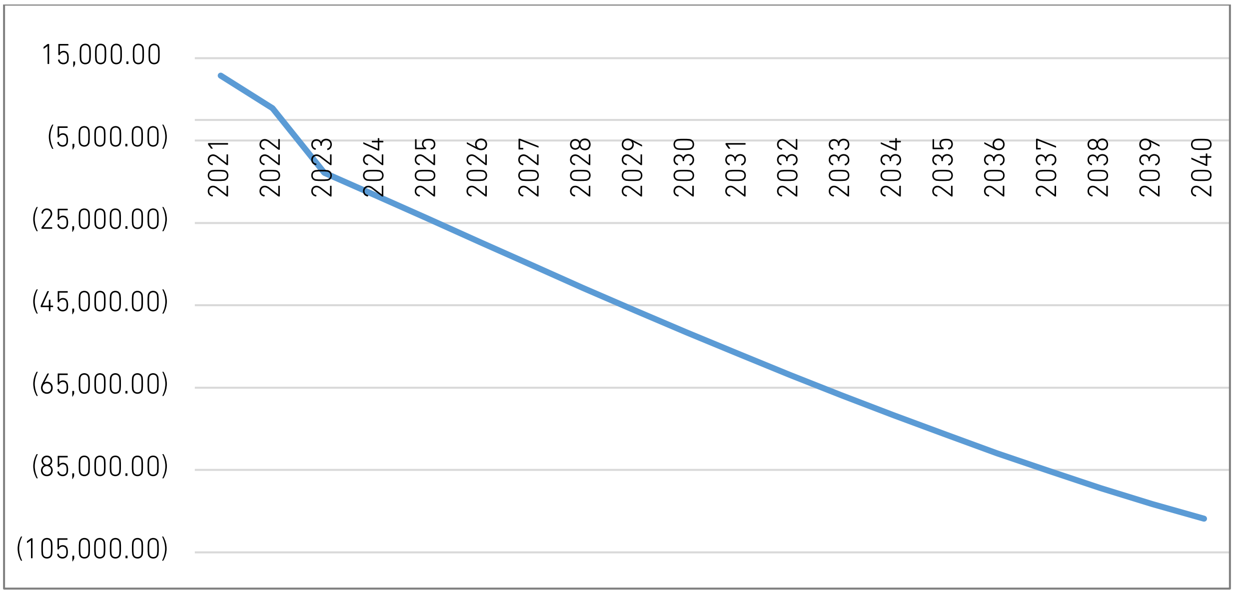
Table 4.9. Current Government Consumption
(million baht)

Year	Base case	EV policy	Change (%)
2021	2,501,024.40	2,503,455.15	0.10
2022	2,575,176.45	2,579,756.43	0.18
2023	2,650,179.52	2,660,591.27	0.39
2024	2,725,913.68	2,737,979.36	0.44
2025	2,802,231.50	2,815,638.22	0.48
2026	2,878,995.44	2,893,442.84	0.50
2027	2,956,073.12	2,971,359.76	0.52
2028	3,033,342.81	3,049,372.33	0.53
2029	3,110,694.67	3,127,383.37	0.54
2030	3,188,033.16	3,205,307.94	0.54
2031	3,265,279.13	3,283,064.42	0.54
2032	3,342,372.04	3,360,650.28	0.55
2033	3,419,272.21	3,438,033.72	0.55
2034	3,495,962.86	3,515,200.18	0.55
2035	3,572,451.89	3,592,171.78	0.55
2036	3,648,773.21	3,668,966.78	0.55
2037	3,724,987.53	3,745,621.52	0.55
2038	3,801,182.55	3,822,258.70	0.55
2039	3,877,472.50	3,899,012.01	0.56
2040	3,953,997.03	3,976,198.66	0.56

EV = electric vehicle.
Source: Author's calculation.

Figure 4.27 show the impacts on fiscal balance. With continuously declining revenue, the fiscal balance is predicted to be negative during 2023–2040. This result highlights a serious concern about future fiscal sustainability. As previously discussed in Section 2.3, to avoid fiscal insolvency, the public debt per GDP ratio and the government budget have been targeted. However, the EV policy will incur the future fiscal burden. Therefore, the cost and benefit of this policy should be thoroughly examined and discussed.

Figure 4.27. Fiscal Balance Due to The Electric Vehicle Policy
(million baht)

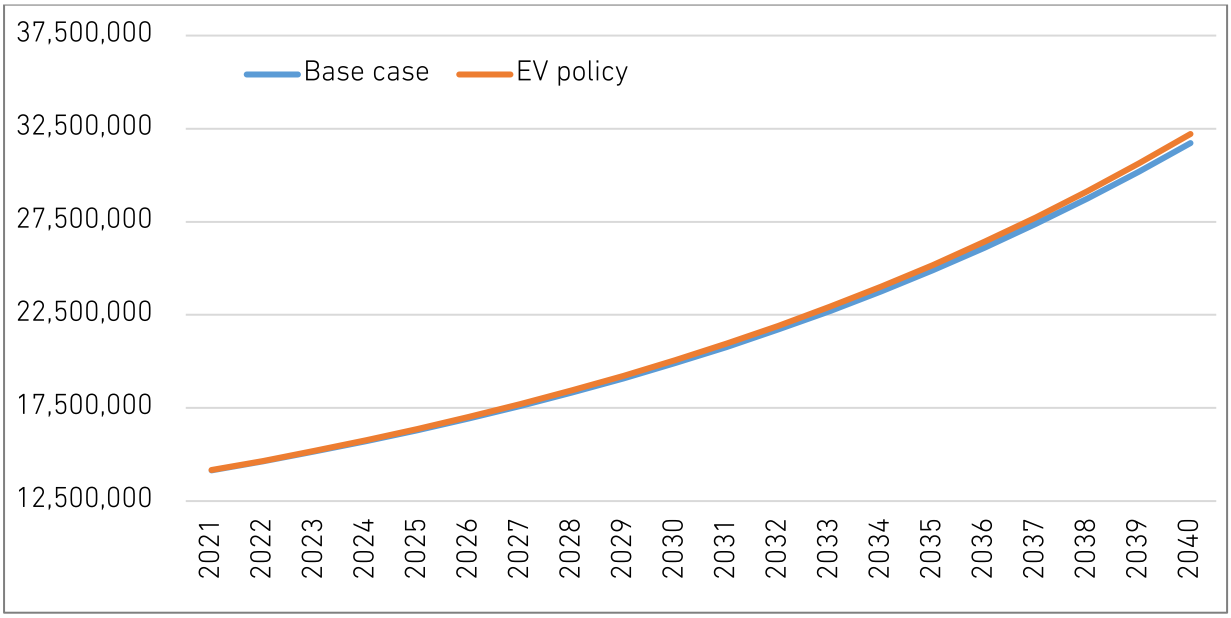


Note: Numerical results are shown in Table A.11.
Source: Author's calculation.

4.2.4. Impacts on Aggregate Household

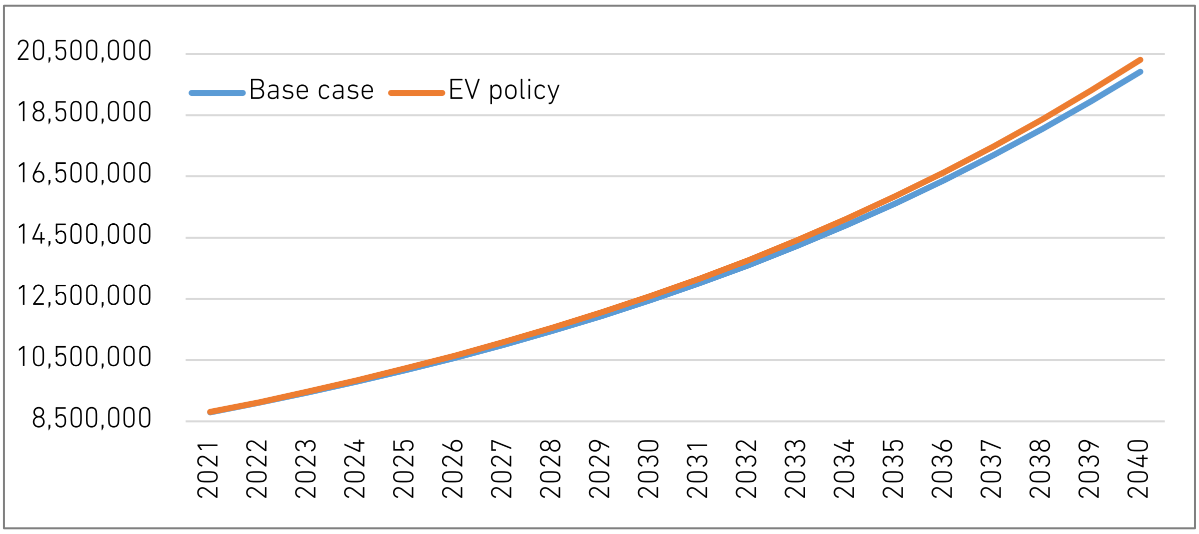
As shown and discussed in Section 4.2.1, the CGE model forecasted that the economy of Thailand would benefit from the EV policy. Main macro indicators identify the expansion of GDP and employment. Based on these results, this section further examines the details of impacts of the aggregate household. As displayed in Figure 4.28, the income of the aggregate household will continuously increase. In particular, as shown in Figures 4.29 and 4.30, the income from both capital and wages will rise. This change is the outcome of the expanding economy. Notably, the percentage change on capital is greater than that of wage. This disparity creates concerns, and its impact on income inequality should be investigated.

Figure 4.28. Impact of the Electric Vehicle Policy on Aggregate Household Income
(million baht at 2021 prices)



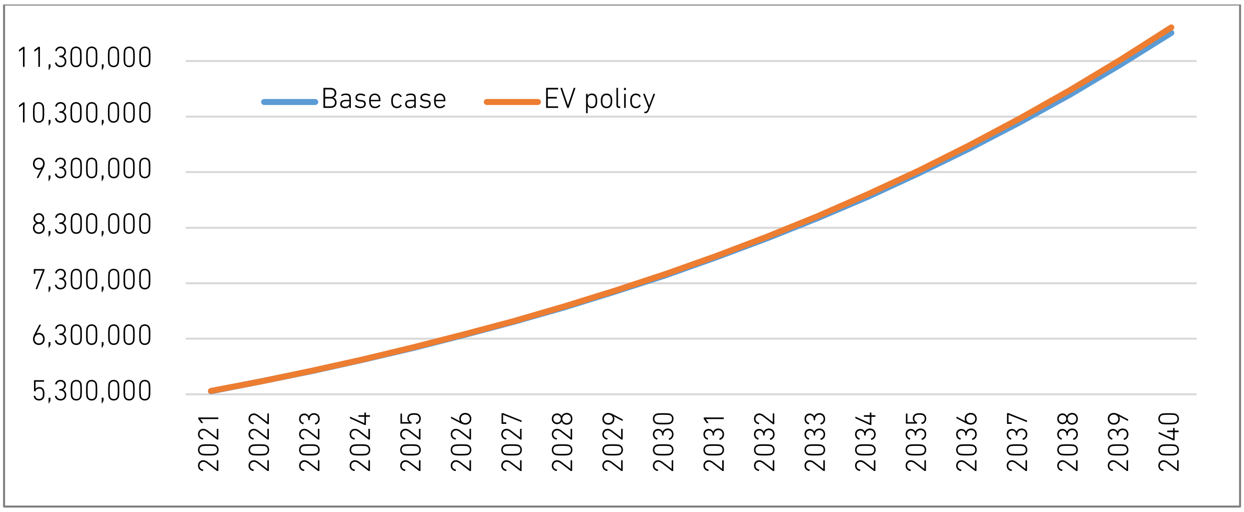
EV = electric vehicle.
Note: Numerical results are shown in Table A.12.
Source: Author's calculation.

Figure 4.29. Impact of the Electric Vehicle Policy on Aggregate Household Income from Capital
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.13.
Source: Author's calculation.

Figure 4.30. Impact of the Electric Vehicle Policy on Aggregate Household Income from Wages
(million baht at 2021 prices)



EV = electric vehicle.
Note: Numerical results are shown in Table A.14.
Source: Author's calculation.

In addition to the increment of income, the structure of production is shaped by the varied characteristics of the changes in consumption patterns. Table 4.10 lists the changes in consumption share. Goods and services with the highest and lowest changes in consumption are shown in Figures 4.31 and 4.32. Influenced by the EV policy, the changes in purchases of EV cars and related services are amongst the highest increment, while fossil fuels and related activities are ranked the lowest. Since this model allows for the implementation of solar rooftops as the alternative energy source, the aggregate household also increases the share of this new electricity supply.

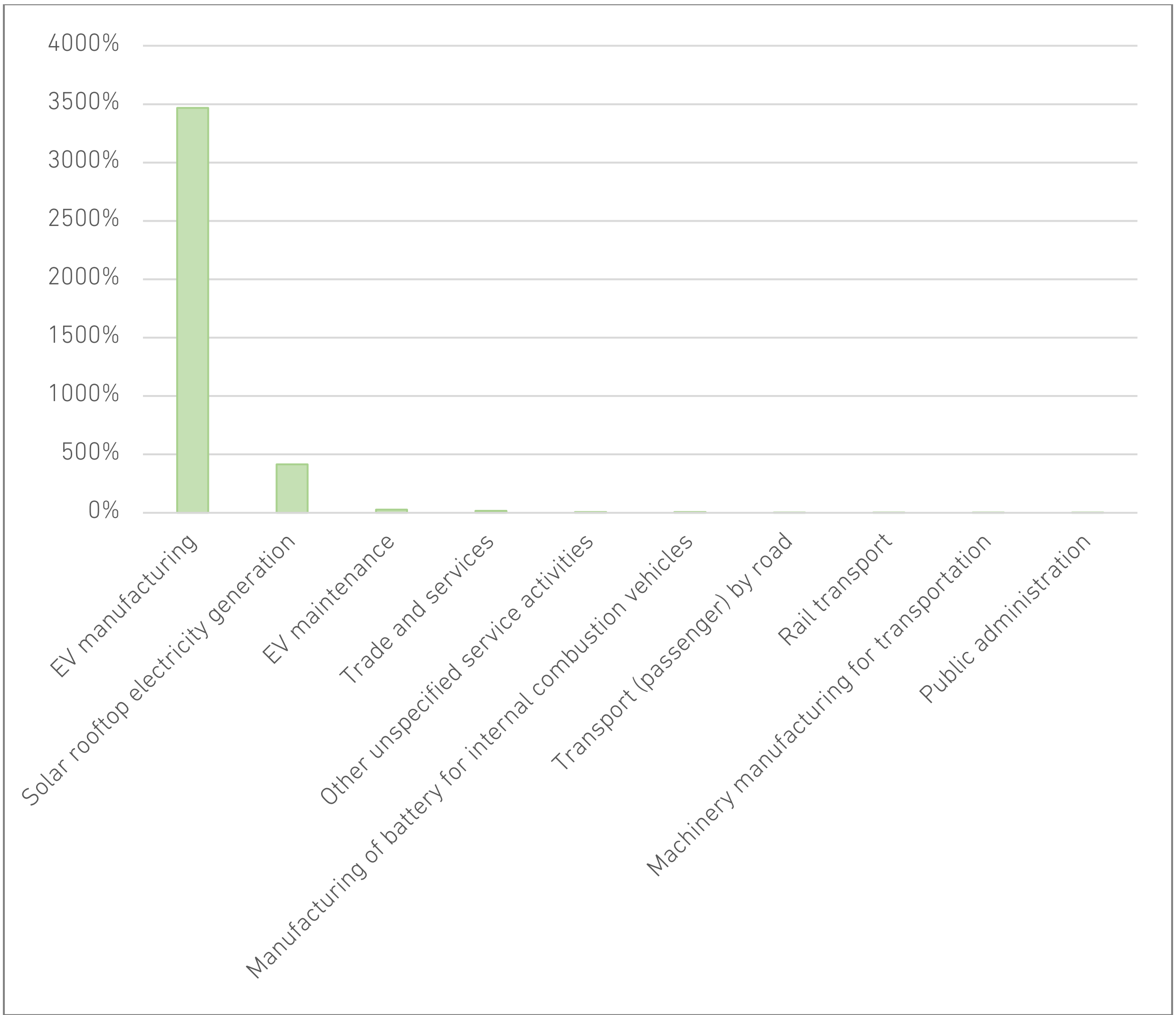
The new consumption pattern corresponds to the change in the sectoral production shown in Section 4.2.2. Hence, the simulation result from CGE model indicates that the EV policy can generate impacts on the structure of both supply and demand. This simulation outcome also suggests the related policies which should support the economy-wide adjustment.

Table 4.10. Change in Household Consumption
(% from base case)

Abbreviation	Description	Average
AGR	Agriculture, forestry, and fisheries	1.0
AIR	Air freight	0.9
BAT	Manufacturing of batteries for internal combustion vehicles	5.4
BUS	Business and financial services	1.5
CAS	Cassava planting	1.3
CHM	Chemicals paper and textiles	1.8
COM	Telecommunications	1.5
DIE	Diesel	-62.2
ELE	Electricity	0.3
EV-MAIN	EV maintenance	26.4
EV-PROD	EV manufacturing	3466.5
FOD	Food and beverage manufacturing	1.4
ICE-PROD	Internal combustion vehicle manufacturing	-22.7
LDS	Land service	1.3
LGS	Logistics services	1.6
MHE	Machinery and electrical equipment	1.9
MNM	Metals and non-metals manufacturing	2.0
OCW	Water transportation coastal and sea	1.3
OMF	Other industries	1.8
OPM	Oil palm plantation	1.6
OPR	Lubricants and other petroleum	1.4
PNG	Petroleum and natural gas	-72.6
PRO	Solar rooftop electricity generation	414.8
PUB	Public administration	2.0
RAI	Rail transport	2.2
RDF	Transport (cargo) by road	1.8
RDP	Transport (passenger) by road	2.3
SGC	Sugarcane planting	1.1
SUG	Sugar production	1.3
TRD	Trade and services	16.6
TRI	Machinery manufacturing for transportation	2.0
TRM	Maintenance of internal combustion vehicles	1.6
UNC	Other unspecified service activities	5.7
WSP	Construction and waterworks	1.6

EV = electric vehicle.
Source: Author's calculation.

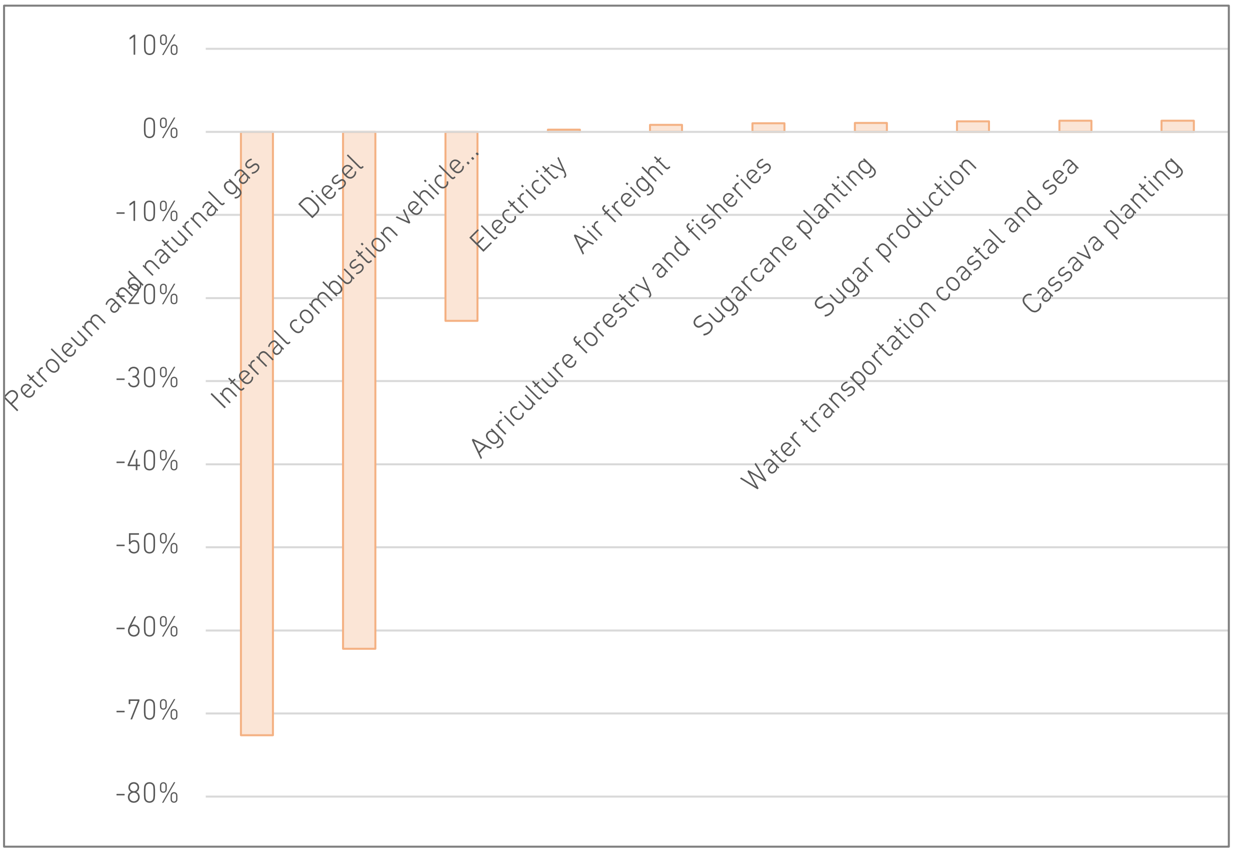
Figure 4.31. Top Ten Goods and Services with the Highest Increment in the Consumption Basket
(%)



EV = electric vehicle.
Source: Author's calculation.

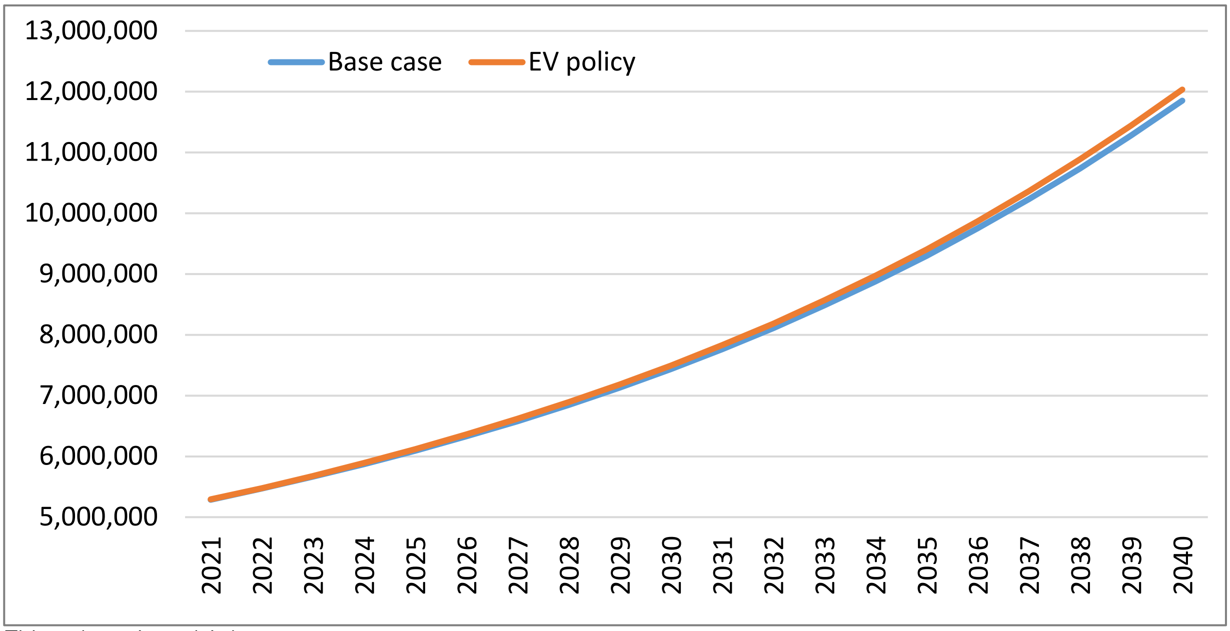
Figure 4.32. Top Ten Goods and Services with the Lowest Increment in the Consumption Basket

(%)



Source: Author's calculation.

Figure 4.33. Impact of the Electric Vehicle Policy on Aggregate Household Saving
(million baht at 2021 price)



EV = electric vehicle.
Note: Numerical results are shown in Table A.15.
Source: Author's calculation.

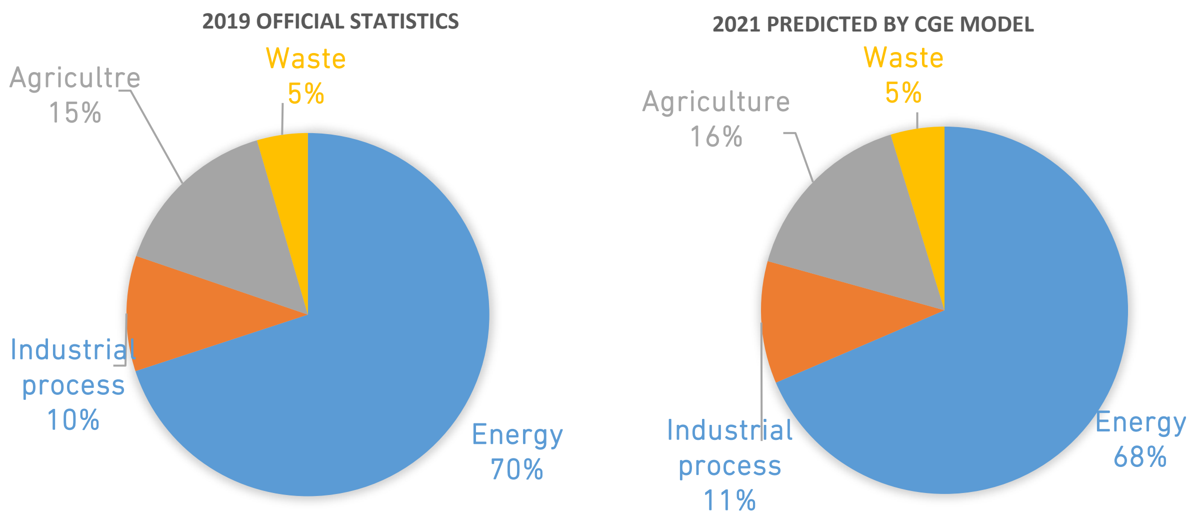
The changes in income and consumption patterns of aggregate household will ultimately affect saving. As indicated by Figure 4.33, the EV policy will consistently increase the saving of aggregate household. This outcome is a combination of increasing income and altered consumption basket.

4.2.5. Impacts of Greenhouse Gas Emissions

The developed CGE model includes the ability to estimate GHGs emissions. With details of fossil-based intermediate goods and sources of energy for each production activity, the simulation results can quantify the amount of GHGs emissions categorised by specific fuel or activity.

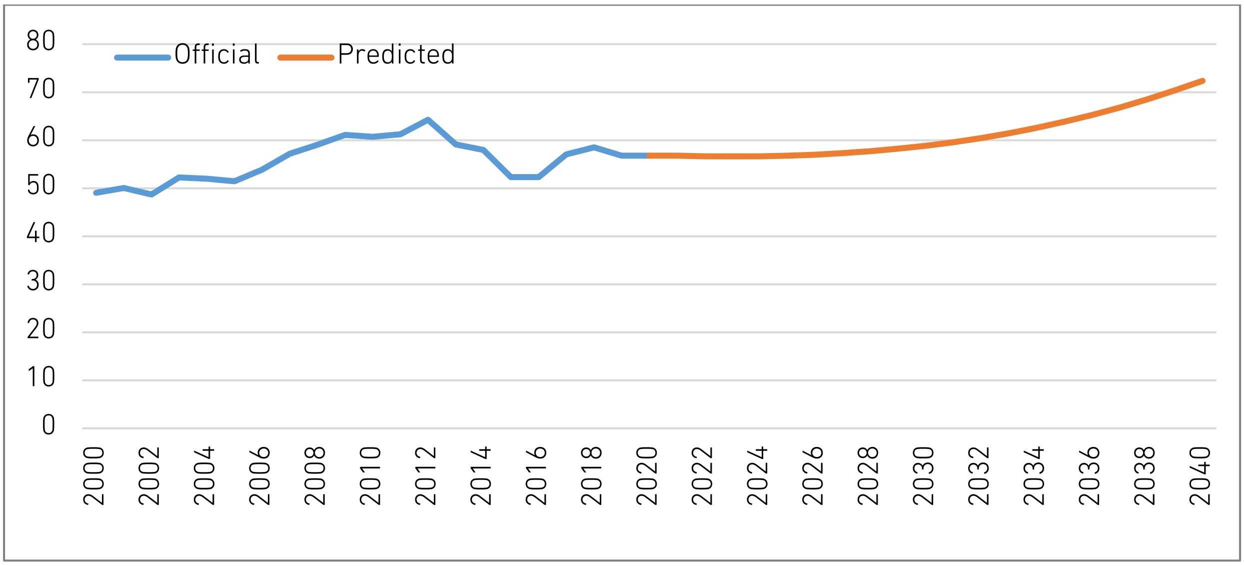
Figure 4.34 compares the GHG emission classified by activity between the simulation results and the official statistics. This comparison shows that the CGE model can closely replicate the structure of GHG emissions in Thailand. Additionally, Figures 4.35–4.38 illustrate the predicted paths of GHG emissions for each activity. This forecast of base case scenario indicates that without an emission reduction policy, emissions will grow continuously.

Figure 4.34. Greenhouse Gas Emissions Classified by Activity



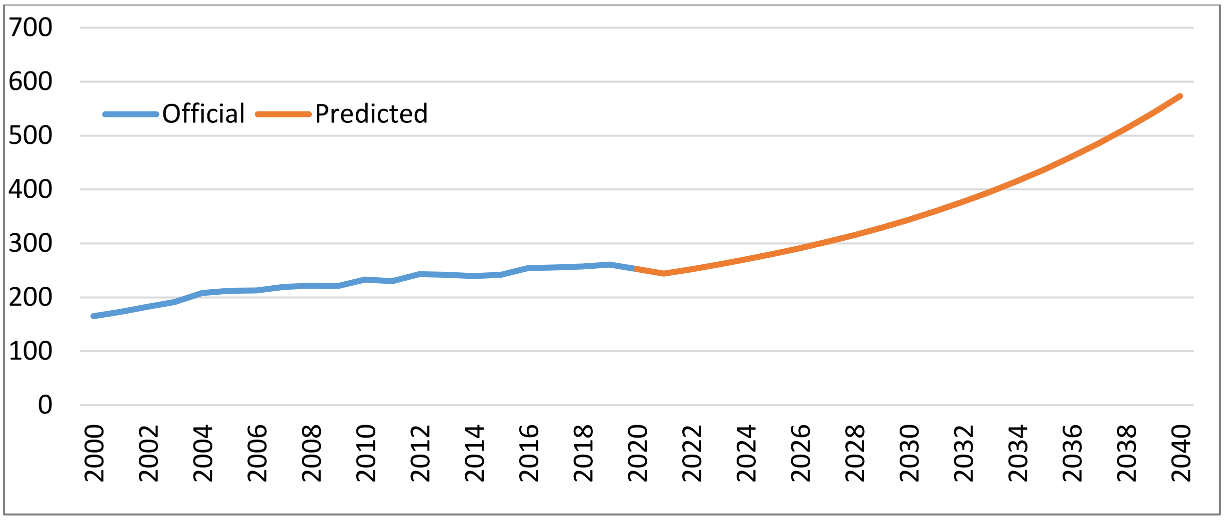
CGE = computable general equilibrium.
Source: Thailand Greenhouse Gas Management Organization and model's prediction.

Figure 4.35. Greenhouse Gas Emissions from Agriculture (Base Case)
(million tonnes CO_2 equivalent)



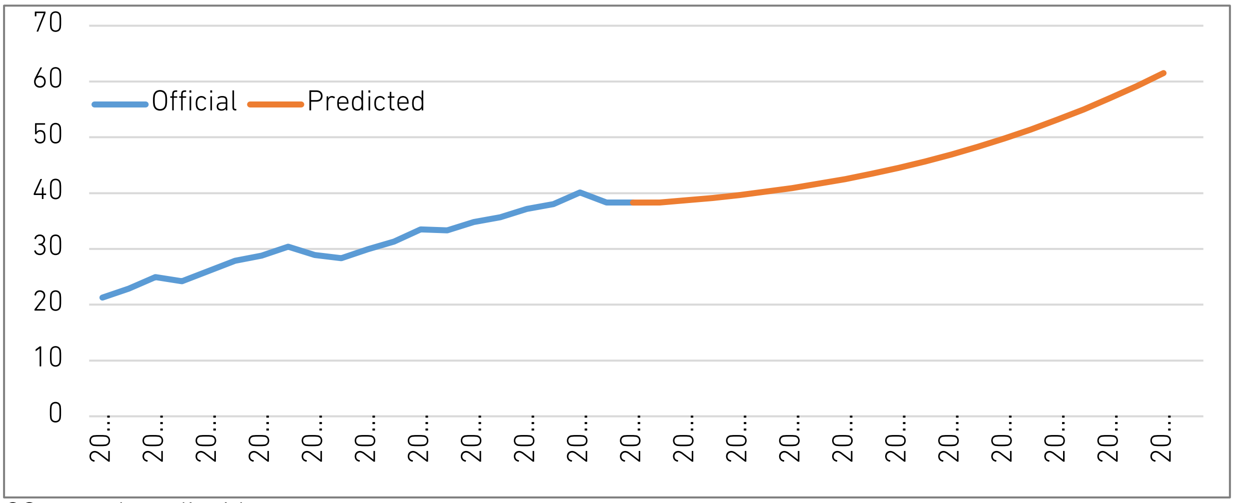
CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

Figure 4.36. Greenhouse Gas Emissions from Energy (Base Case)
(million tonnes CO_2 equivalent)



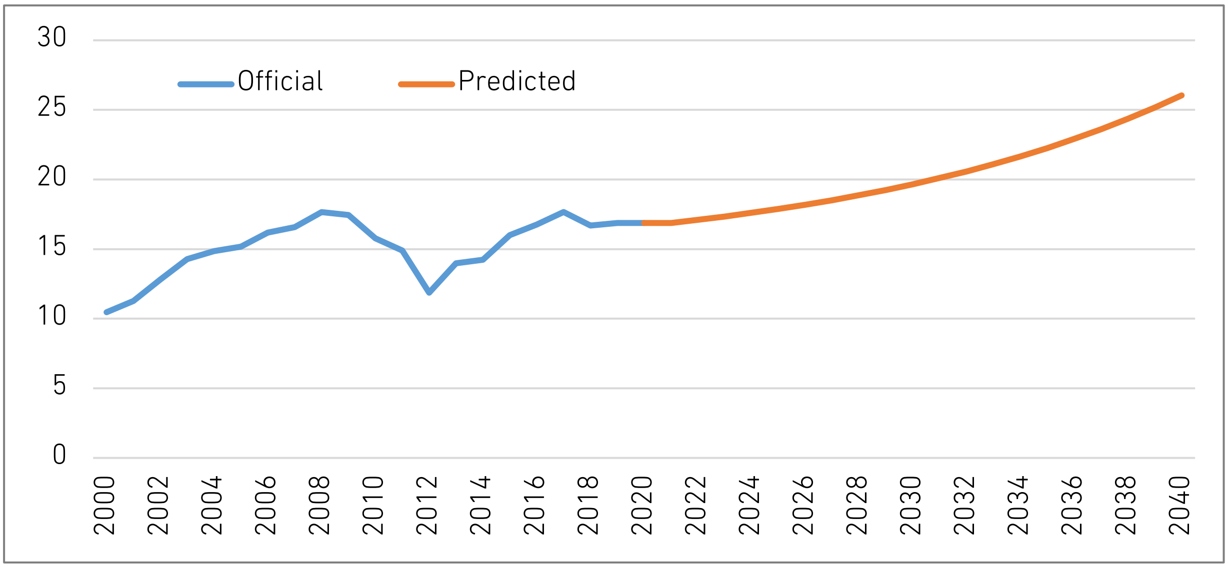
CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

Figure 4.37. Greenhouse Gas Emissions from Industrial Processes (Base Case)
(million tonnes CO_2 equivalent)



CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

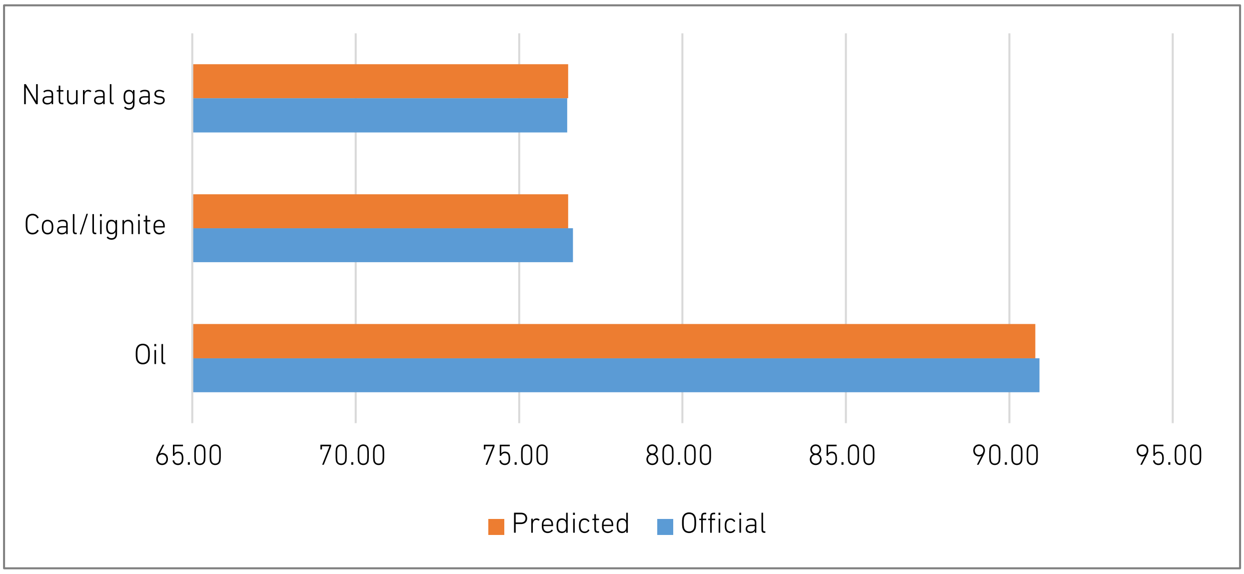
Figure 4.38. Greenhouse Gas Emissions from Waste (Base Case)
(million tonnes CO_2 equivalent)



CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

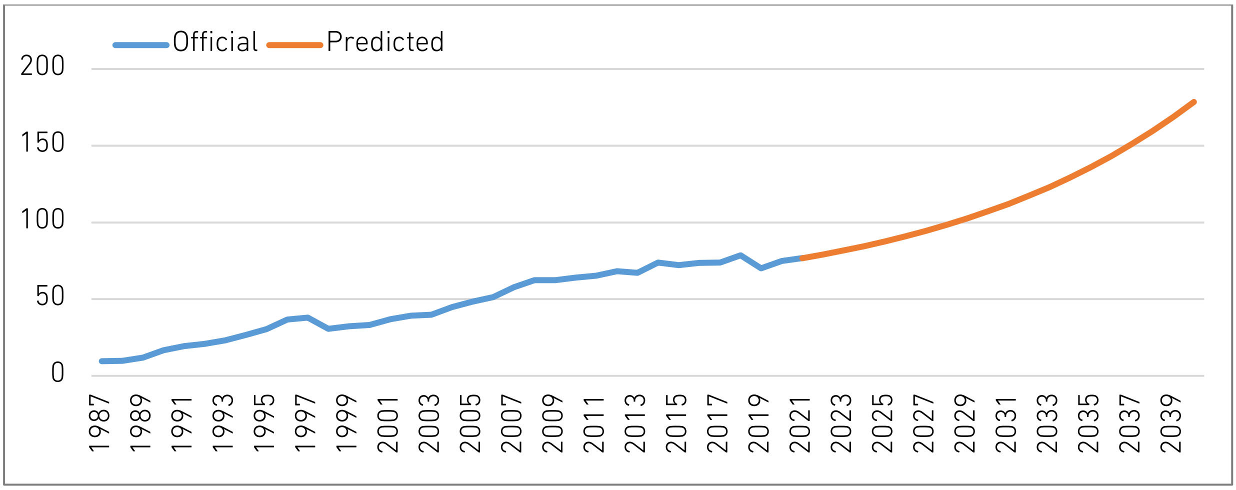
Figures 4.39–4.42 show the specific emission paths in the energy sector. Figure 4.39 shows the predictive performance of the CGE model, which can replicate the emission close to the official statistics for each fuel. Figures 4.40–4.42 illustrate the paths of each fossil fuel, driven by the economic growth of the base case scenario.

Figure 4.39. Greenhouse Gas Emissions from Main Energy Sources in 2021
(million tonnes CO_2 equivalent)



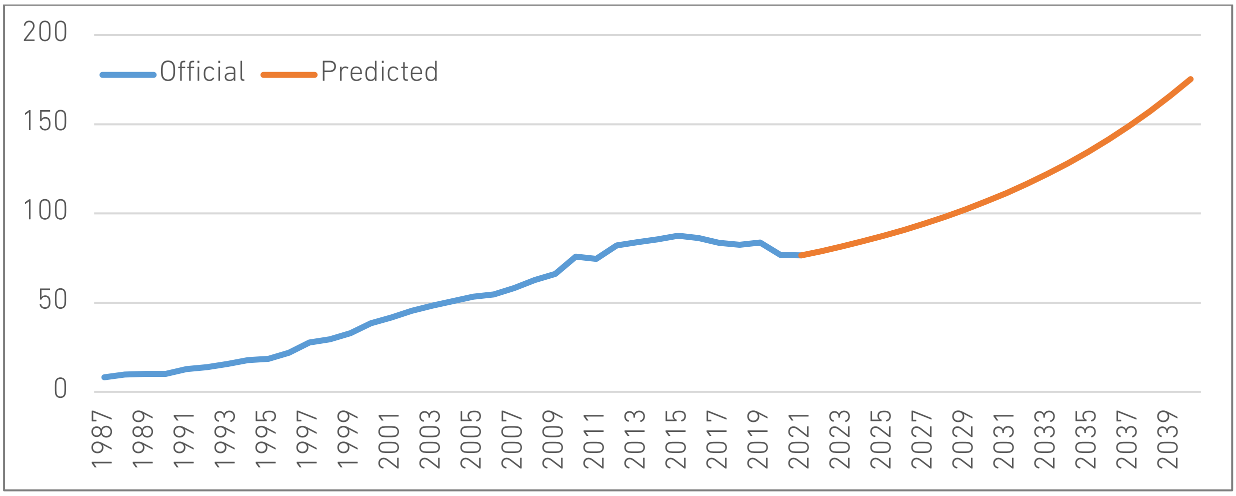
CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

Figure 4.40. Greenhouse Gas Emission from Coal (Base Case)
(million tonnes CO_2 equivalent)



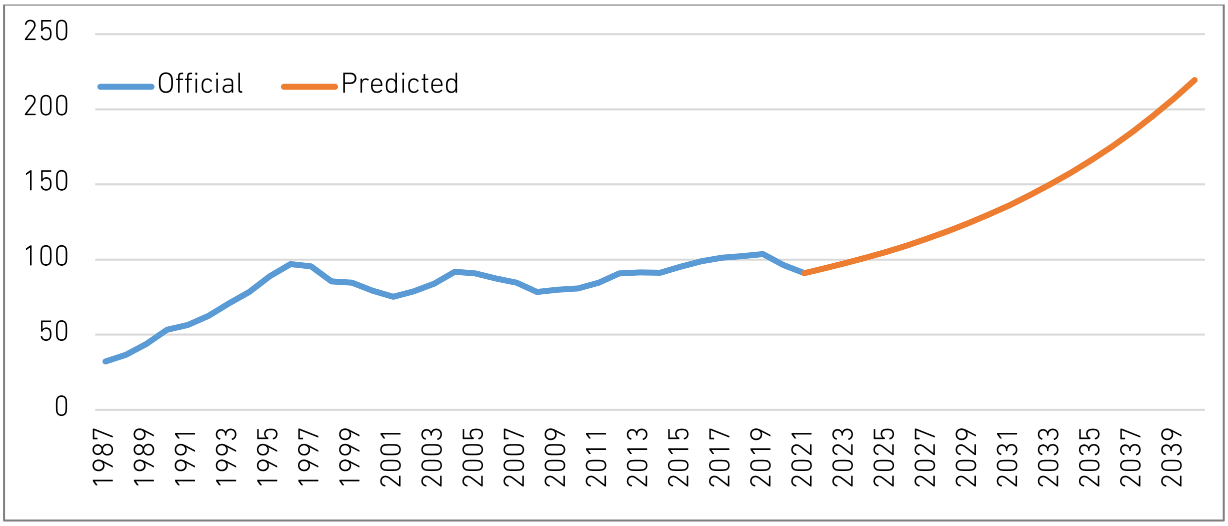
CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

Figure 4.41. Greenhouse Gas Emissions from Natural Gas (Base Case)
(million tonnes CO_2 equivalent)



CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

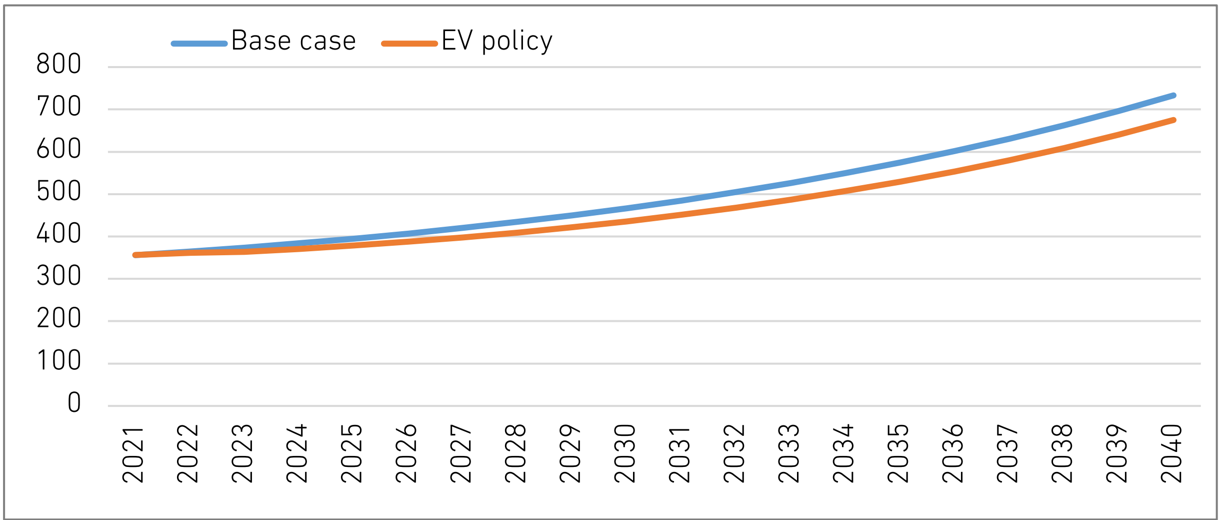
Figure 4.42. Greenhouse Gas Emissions from Oil (Base Case)
(million tonnes CO_2 equivalent)



CO_2 = carbon dioxide.
Source: Thailand Greenhouse Gas Management Organisation (for official statistics) and the model's prediction.

With the EV policy, the simulation outcome produced by the CGE model indicates the alternative path, which generates a lower amount of GHG emission. As shown in Figure 4.43 and Table 4.11, the expansion of EV production and utilisation can continuously reduce the GHG emission. Specifically, the reduction will reach approximately 8% during the period 2035–2040. This simulation result suggests that EV policy will lower GHG emissions through both direct and indirect effects. This prediction is in line with international experience, as documented by Wu, Zhou, and Gohlke (2024), Xu et al. (2021), Plötz et al. (2021), Bahamonde-Birke (2020), Fritz, Plötz and Funke (2019), Bellocchi et al. (2018), Teixeira and Sodré (2018), Falcão, Teixeira, and Sondré (2017), Mishina and Muromachi (2017) and McLaren et al. (2016).

Figure 4.43. The Impacts of The Electric Vehicle Policy on Greenhouse Gas Emissions
(million tonnes CO_2 equivalent)



CO_2 = carbon dioxide; EV = electric vehicle.
Source: Author's calculation.

Table 4.11. The Impact of The Electric Vehicle Policy on Total Greenhouse Gas Emissions
(million tonnes CO_2 equivalent)

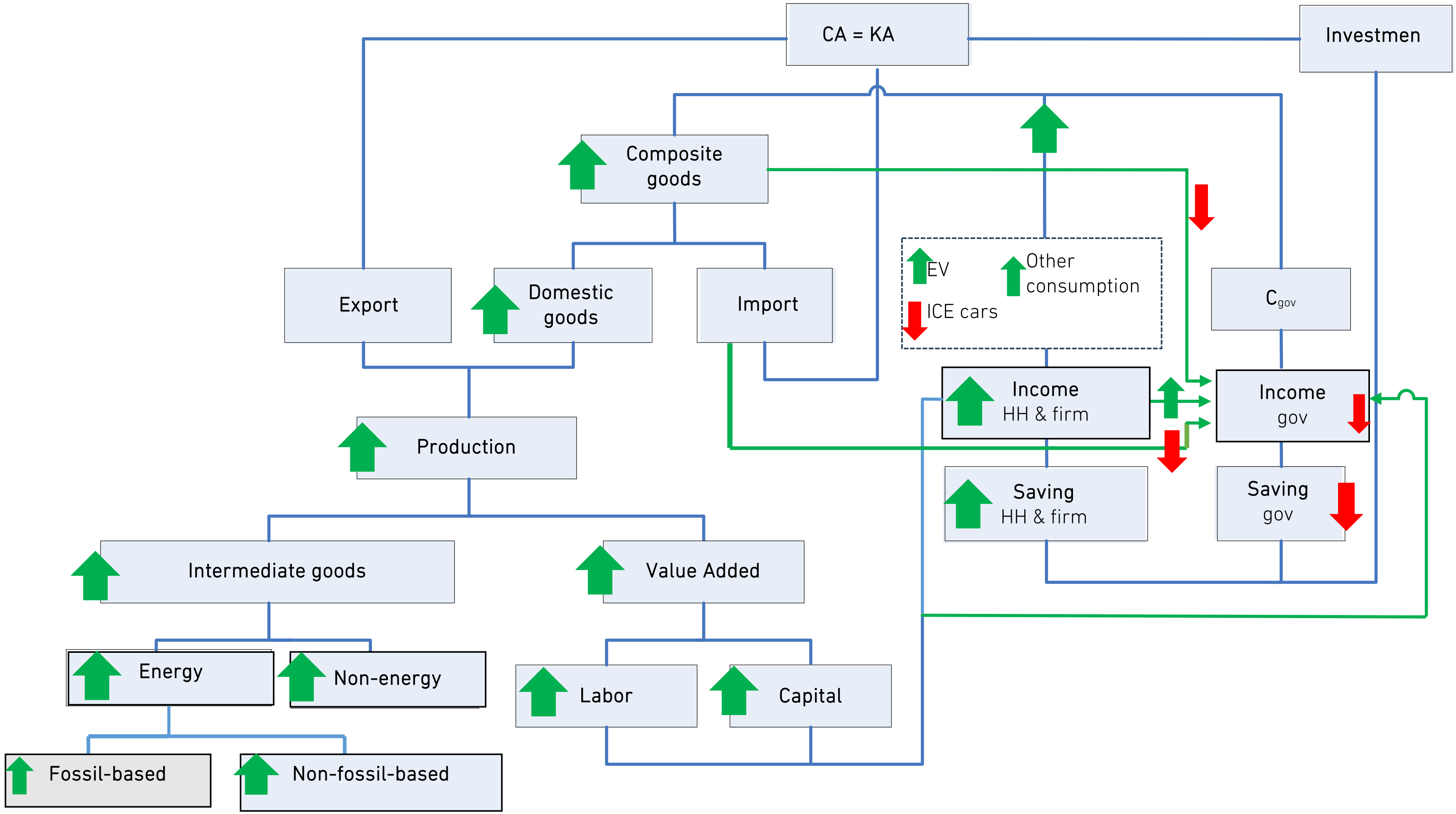
Year	Base case	EV policy	Change (%)
2021	355.98	356.42	0.12
2022	364.53	361.13	-0.93
2023	373.85	363.73	-2.71
2024	384.00	370.78	-3.44
2025	395.06	378.82	-4.11
2026	407.10	387.89	-4.72
2027	420.20	398.08	-5.26
2028	434.45	409.40	-5.77
2029	449.93	421.96	-6.22
2030	466.75	435.90	-6.61
2031	485.00	451.30	-6.95
2032	504.79	468.24	-7.24
2033	526.24	486.85	-7.48
2034	549.45	507.19	-7.69
2035	574.56	529.45	-7.85
2036	601.69	553.70	-7.98
2037	630.97	580.13	-8.06
2038	662.55	608.96	-8.09
2039	696.56	640.36	-8.07
2040	733.16	675.08	-7.92

CO_2 = carbon dioxide; EV = electric vehicle.
Source: Author's calculation.

4.3. Discussion and Policy Recommendations

This study applied the CGE model to explore the economy-wide impacts of implementing the EV policy. The simulation results indicated that the targeted production of EV (i.e., 30@30 scheme), along with switching consumption patterns of household toward more utilisation of EV, can lead to positive impacts on GDP, household income, household saving, total employment, and the reduction of GHG emissions. Also, the production sectors related to EV production and solar rooftops can produce the highest expansion. Figure 4.44 illustrates this economy-wide transmission mechanism.

Figure 4.44. The Propagation of The Electric Vehicle Policy in the Economy



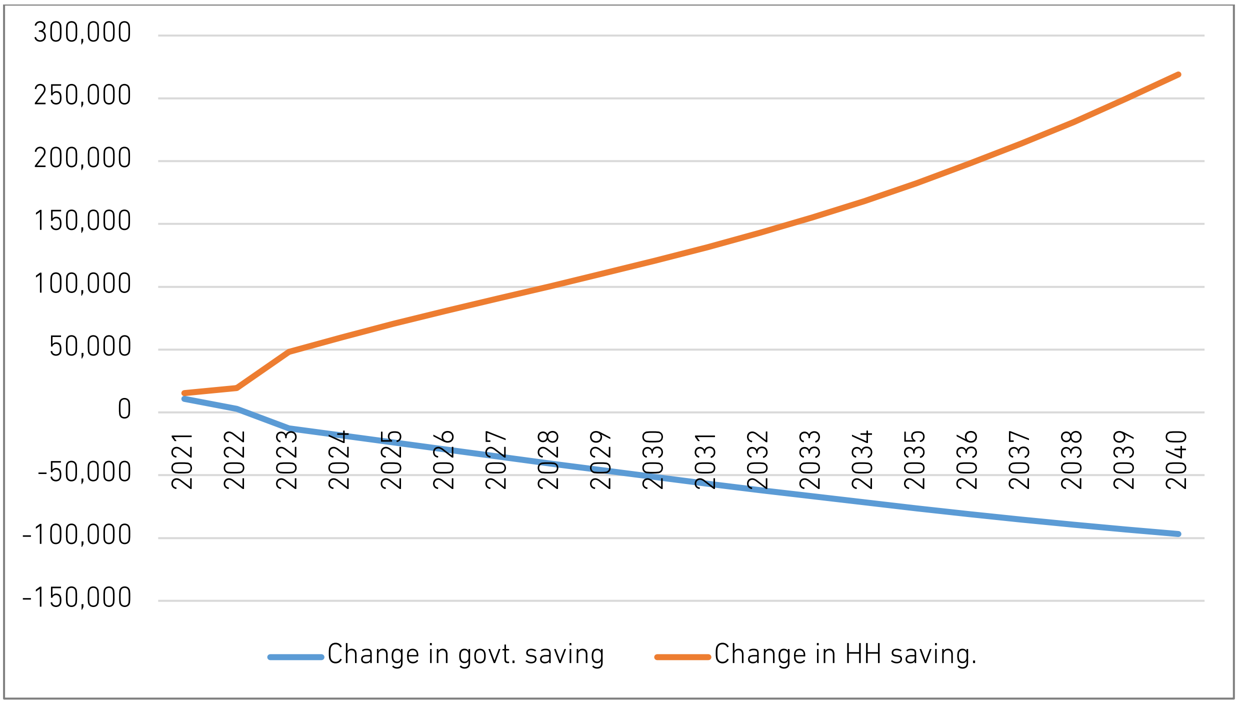
CA = current account; KA = capital account; Cgov = government consumption; EV = electric vehicle; Gov = government; HH = aggregate household; ICE = internal combustion engine.

Source: Author's calculation.

However, even though the simulation outcome indicated the net positive impacts on GDP, this policy can yield a negative impact on the current account, inflation, fiscal balance, and production activities related to ICE vehicles, biofuels, and fossil fuels.

Notably, as previously discussed in Sections 4.2.3 and 4.2.4, the impacts on household and fiscal status are opposite. Figure 4.45 reflects this serious concern, showing that the aggregate household can continuously create more savings, while the fiscal status (i.e., government saving) will be incrementally worsening. This result clearly identifies the future violation of some fiscal indicators as listed in Section 2.3.

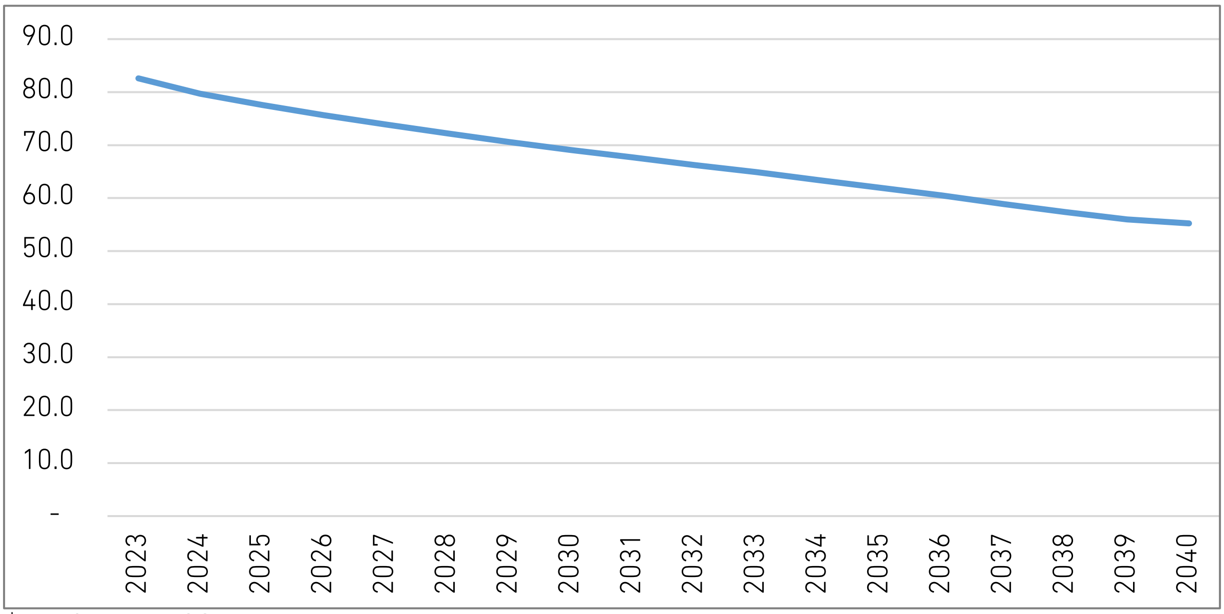
Figure 4.45. Impacts on The Savings of Government and Aggregate Household (million baht)



Govt = government; HH = aggregate household.
Source: Author's calculation.

The implication of EV policy can lead to the reduction of GHG. By computing the ratio of additional fiscal deficit per additional GHG reduction, Figure 4.46 illustrates the equivalent cost of GHG reduction (adjusted by CPI). It shows that this deflated cost will be $82.60 in 2023 and will steadily decline to $55.20 in 2040. This value will be a very useful criterion for policy evaluation. This result suggests that the reduction in GHG emissions will place a substantial financial burden on the government, leading to a consistent increase in the budget deficit as shown in Figure 4.46.

Figure 4.46. The Ratio of Greenhouse Gas Reduction to Budget Deficit Change
($ per tonne CO_2 equivalent)



$ = US dollar; CO_2 = carbon dioxide.
Source: Author's calculation.

These key findings lead to the following policy recommendations.

1) With the future adjustment of production structure, the government should formulate policies supporting the restructure and reallocation of producers and labour working in the supply chains of ICE vehicles, biofuels, and fossil fuels. This impact mitigation scheme would reduce the negative impacts that might incur future economic and social consequences caused by production contraction and unemployment in the affected sectors.
2) Notably, the simulation result indicated the increasing import of EV batteries. This trend identified the insufficient capability of domestic production. Thus, the development and expansion of EV battery production should be supported.
3) New fiscal policies are required to manage fiscal sustainability. Additional revenues such as carbon tax and an annual EV ownership tax might be the new sources. These proposed taxes would reallocate some portion of the aggregate household savings to finance the budget deficit.
4) The equivalent cost of GHG reduction due to EV policy, as shown in Table 4, should be consistently updated and verified. It will be the crucial benchmark for evaluating the fiscal cost and environmental benefit of EV policy. It should also be compared internationally and domestically with alternative policy instruments (such as the carbon tax or the market price of carbon price).

4.4. Limitations

The limitations of this study are fourfold.

1) The sensitivity analysis of the elasticity of substitution between ICE and EV cars should be undertaken.
2) The changing behaviour of household triggered by EV policy should be additionally explored. Specifically, a sensitivity analysis of the elasticity parameters of the consumption basket should be conducted.
3) The production of ICE cars is an aggregate sector. The impact of EV policy on the supply chain of ICE car production can be enriched if this sector is disaggregated into detailed activities.
4) For future study, the other costs (such as the life cycle assessment of EV cars and batteries) should be incorporated to extend the coverage of the analysis.

5. Conclusion

This study developed a dynamic CGE model for examining the economy-wide impacts of implementing EV policy in Thailand. The constructed CGE model is based on a SAM table extended from the 2015 official Input-Output table. The model was calibrated to replicate the production and utilisation induced by the national EC promotion plan (30@30 policy). Following the national target for EV manufacturing to account for 30% of total car production by 2030, the simulation results showed that this policy will yield a net positive impact on the Thai economy.

Real GDP, total employment, total income, total household consumption, and the production of goods and services related to EV cars will all increase.

On the other hand, this policy will lead to an increasing fiscal deficit, influenced by the declining indirect tax and tariffs. In addition, production sectors related to ICE cars, biofuels, and fossil fuels will contract. To maintain fiscal sustainability, the government should restructure its revenues related to fossil fuels and seek new sources of income such as carbon tax or annual EV ownership tax.

The constructed CGE model incorporated the details of GHG emissions, showing that the EV policy will reduce the total emissions. However, this change is multidimensional. The fiscal deficit burdens the GHG reduction. This study showed that the cost of reducing one tonne of CO_2 is equivalent to a fiscal deficit of \$55.20–\$82.60. This key finding can be used as the criterion for policy evaluation.

Future studies should include a sensitivity analysis of elasticity parameters, especially the selection between ICE and EV cars. A similar test should also be undertaken to examine the sensitivity of a household's consumption basket after purchasing an EV car. Finally, the details of sectors related to ICE production should be enriched, allowing the investigation of impacts on the supply chain of automotive parts.

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Appendix

Table A.1. Impact of the Electric Vehicle Policy on Gross Domestic Product

	GDP at Market Price (million baht)			Real GDP (million baht at 2021 prices)		
Year	Base Case	EV Policy	Diff (%)	Base Case	EV Policy	Diff (%)
2021	15,411,517.31	15,455,787.09	0.29	15,411,517.31	15,425,282.21	0.09
2022	16,048,405.73	16,104,320.45	0.35	15,879,133.79	15,906,153.02	0.17
2023	16,724,121.36	16,859,414.90	0.81	16,380,783.80	16,434,762.40	0.33
2024	17,442,496.62	17,607,994.42	0.95	16,919,242.39	16,983,500.43	0.38
2025	18,207,389.45	18,401,810.86	1.07	17,497,485.28	17,571,587.67	0.42
2026	19,022,841.94	19,244,200.39	1.16	18,118,701.13	18,202,194.35	0.46
2027	19,893,096.37	20,140,198.33	1.24	18,786,303.91	18,879,310.45	0.50
2028	20,822,635.06	21,095,582.53	1.31	19,503,938.50	19,607,377.95	0.53
2029	21,816,197.61	22,115,385.70	1.37	20,275,482.96	20,390,838.22	0.57
2030	22,878,794.66	23,205,360.29	1.43	21,105,046.78	21,234,401.90	0.61
2031	24,015,713.61	24,370,619.25	1.48	21,996,965.24	22,142,746.42	0.66
2032	25,232,519.38	25,617,852.43	1.53	22,955,789.54	23,120,930.66	0.72
2033	26,535,049.84	26,953,212.95	1.58	23,986,272.70	24,174,803.42	0.79
2034	27,929,406.68	28,383,381.65	1.63	25,093,351.23	25,308,374.71	0.86
2035	29,421,942.06	29,914,822.34	1.68	26,282,122.42	26,528,379.23	0.94
2036	31,019,241.44	31,554,122.39	1.72	27,557,817.89	27,839,073.78	1.02
2037	32,728,103.23	33,306,997.66	1.77	28,925,773.50	29,246,725.06	1.11
2038	34,555,515.87	35,182,130.86	1.81	30,391,396.47	30,758,107.95	1.21
2039	36,508,633.13	37,186,743.11	1.86	31,960,130.48	32,379,165.40	1.31
2040	38,594,748.34	39,326,950.55	1.90	33,637,419.69	34,115,306.34	1.42

EV = electric vehicle; GDP = gross domestic product.
Note: Figure 4.14 shows the graphical representation of these results.
Source: Author's calculation.

Table A.2. Impact of the Electric Vehicle Policy on Total Private Consumption

	Private Consumption at Market Price (million baht)			Real Private Consumption (million baht at 2021 prices)		
Year	Base Case	EV policy	Diff (%)	Base Case	EV Policy	Diff (%)
2021	7,843,620.74	7,866,404.48	0.29	7,843,620.74	7,855,296.60	0.15
2022	8,169,162.87	8,198,063.93	0.35	8,117,056.25	8,124,468.39	0.09
2023	8,514,224.66	8,585,740.47	0.84	8,406,840.68	8,427,449.31	0.25
2024	8,880,761.95	8,969,095.60	0.99	8,714,580.81	8,743,490.87	0.33
2025	9,270,740.49	9,375,323.36	1.13	9,041,960.38	9,079,728.99	0.42
2026	9,686,210.44	9,806,049.66	1.24	9,390,705.63	9,437,497.06	0.50
2027	10,129,317.49	10,263,792.70	1.33	9,762,596.90	9,818,548.53	0.57
2028	10,602,323.00	10,751,481.05	1.41	10,159,467.54	10,225,023.29	0.65
2029	11,107,613.22	11,271,620.73	1.48	10,583,205.05	10,658,858.35	0.71
2030	11,647,706.15	11,827,111.49	1.54	11,035,748.14	11,122,253.67	0.78
2031	12,225,254.33	12,420,481.89	1.60	11,519,081.03	11,617,190.10	0.85
2032	12,843,044.88	13,055,141.09	1.65	12,035,224.35	12,146,107.71	0.92
2033	13,503,996.76	13,734,100.76	1.70	12,586,222.97	12,711,072.67	0.99
2034	14,211,155.60	14,460,877.34	1.76	13,174,131.02	13,314,811.85	1.07
2035	14,967,686.32	15,238,550.70	1.81	13,800,994.74	13,959,074.81	1.15
2036	15,776,863.77	16,070,540.56	1.86	14,468,833.45	14,646,299.17	1.23
2037	16,642,061.73	16,959,516.42	1.91	15,179,619.59	15,377,821.27	1.31
2038	17,566,740.60	17,909,811.60	1.95	15,935,258.41	16,156,168.24	1.39
2039	18,554,434.15	18,924,975.93	2.00	16,737,568.15	16,983,057.87	1.47
2040	19,608,735.83	20,007,927.39	2.04	17,588,261.66	17,858,767.14	1.54

EV = electric vehicle.
Note: Figure 4.15 shows the graphical representation of these results.
Source: Author's calculation.

Table A.3. Impact of the Electric Vehicle Policy on Gross Fixed Capital Formation

	Gross Fixed Capital Formation at Market Price (million baht)			Real Gross Fixed Capital Formation (million baht at 2021 prices)		
Year	Base Case	EV Policy	Diff (%)	Base Case	EV Policy	Diff (%)
2021	3,840,172.65	3,923,257.03	2.16	3,840,172.65	3,909,145.50	1.80%
2022	4,018,472.66	4,104,001.99	2.13	3,996,468.40	4,094,657.25	2.46%
2023	4,211,536.75	4,299,725.03	2.09	4,167,867.02	4,273,735.29	2.54%
2024	4,421,187.85	4,512,684.08	2.07	4,355,823.85	4,467,507.73	2.56%
2025	4,649,224.19	4,744,343.07	2.05	4,561,872.96	4,679,599.98	2.58
2026	4,897,534.72	4,996,564.34	2.02	4,787,680.76	4,911,175.00	2.58
2027	5,168,103.53	5,271,304.67	2.00	5,035,051.41	5,164,914.12	2.58
2028	5,463,034.76	5,570,591.04	1.97	5,305,937.22	5,442,810.83	2.58
2029	5,784,561.64	5,896,663.95	1.94	5,602,441.92	5,747,137.00	2.58
2030	6,135,054.25	6,251,888.79	1.90	5,926,822.73	6,080,172.22	2.59
2031	6,517,022.54	6,638,764.92	1.87	6,281,490.12	6,443,852.37	2.58
2032	6,933,116.73	7,059,940.50	1.83	6,669,005.98	6,841,238.09	2.58
2033	7,386,124.82	7,518,209.99	1.79	7,092,079.88	7,275,400.40	2.58
2034	7,878,967.77	8,016,503.77	1.75	7,553,563.53	7,748,460.29	2.58
2035	8,414,692.33	8,557,878.68	1.70	8,056,443.35	8,264,135.79	2.58
2036	8,996,461.89	9,145,508.52	1.66	8,603,831.15	8,824,690.43	2.57
2037	9,627,545.66	9,782,726.69	1.61	9,198,953.10	9,434,317.18	2.56
2038	10,311,306.38	10,472,822.52	1.57	9,845,137.19	10,096,362.24	2.55
2039	11,051,187.01	11,219,267.21	1.52	10,545,799.37	10,814,396.50	2.55
2040	11,850,696.89	12,025,601.84	1.48	11,304,428.80	11,592,252.99	2.55

EV = electric vehicle.
Note: Figure 4.16 shows the graphical representation of these results.
Source: Author's calculation.

Table A.4. Impact of the Electric Vehicle Policy on Total Exports
(million baht)

	Total Exports		
Year	Base Case	EV Policy	Diff (%)
2021	9,329,456.26	9,318,533.46	-0.12
2022	9,731,741.71	9,704,856.97	-0.28
2023	10,162,906.37	10,107,793.09	-0.54
2024	10,624,776.99	10,554,188.55	-0.66
2025	11,119,437.08	11,033,059.14	-0.78
2026	11,649,185.10	11,547,167.30	-0.88
2027	12,216,554.02	12,099,125.31	-0.96
2028	12,824,311.46	12,691,816.69	-1.03
2029	13,475,465.36	13,328,618.34	-1.09
2030	14,173,267.14	14,012,912.84	-1.13
2031	14,921,215.05	14,748,496.92	-1.16
2032	15,723,056.92	15,539,065.98	-1.17
2033	16,582,792.35	16,389,019.56	-1.17
2034	17,504,674.40	17,302,166.81	-1.16
2035	18,493,210.69	18,283,586.13	-1.13
2036	19,553,163.95	19,337,613.82	-1.10
2037	20,689,552.23	20,469,957.61	-1.06
2038	21,907,648.75	21,685,796.35	-1.01
2039	23,212,981.89	22,990,846.35	-0.96
2040	24,611,335.26	24,391,498.20	-0.89

EV = electric vehicle.
Note: Figure 4.17 shows the graphical representation of these results.
Source: Author's calculation.

Table A.5. Impact of the Electric Vehicle Policy on Total Imports
(million baht)

	Total Imports (million baht)		
Year	Base Case	EV Policy	Diff (%)
2021	7,680,707.86	7,727,040.12	0.60
2022	8,000,555.88	8,038,089.73	0.47
2023	8,345,161.26	8,344,873.52	0.00
2024	8,716,144.63	8,698,143.91	-0.21
2025	9,115,373.09	9,079,992.43	-0.39
2026	9,544,917.92	9,493,184.02	-0.54
2027	10,007,073.48	9,939,705.07	-0.67
2028	10,504,356.89	10,421,822.10	-0.79
2029	11,039,513.06	10,942,476.88	-0.88
2030	11,615,517.22	11,504,488.49	-0.96
2031	12,235,577.64	12,111,501.96	-1.01
2032	12,903,137.64	12,766,464.81	-1.06
2033	13,621,877.10	13,473,374.13	-1.09
2034	14,395,713.39	14,235,420.84	-1.11
2035	15,228,801.63	15,057,371.29	-1.13
2036	16,125,534.44	15,943,196.82	-1.13
2037	17,090,541.24	16,898,415.18	-1.12
2038	18,128,687.22	17,927,409.75	-1.11
2039	19,245,072.28	19,035,444.33	-1.09
2040	20,445,030.17	20,228,659.56	-1.06

EV = electric vehicle.
Note: Figure 4.18 shows the graphical representation of these results.
Source: Author’s calculation.

Table A.6. Impact of the Electric Vehicle Policy on Net Current Account Balance

	Net Current Account (million baht)		
Year	Base Case	EV Policy	Diff (%)
2021	7,680,707.86	7,727,040.12	0.60
2022	8,000,555.88	8,038,089.73	0.47
2023	8,345,161.26	8,344,873.52	0.00
2024	8,716,144.63	8,698,143.91	-0.21
2025	9,115,373.09	9,079,992.43	-0.39
2026	9,544,917.92	9,493,184.02	-0.54
2027	10,007,073.48	9,939,705.07	-0.67
2028	10,504,356.89	10,421,822.10	-0.79
2029	11,039,513.06	10,942,476.88	-0.88
2030	11,615,517.22	11,504,488.49	-0.96
2031	12,235,577.64	12,111,501.96	-1.01
2032	12,903,137.64	12,766,464.81	-1.06
2033	13,621,877.10	13,473,374.13	-1.09
2034	14,395,713.39	14,235,420.84	-1.11
2035	15,228,801.63	15,057,371.29	-1.13
2036	16,125,534.44	15,943,196.82	-1.13
2037	17,090,541.24	16,898,415.18	-1.12
2038	18,128,687.22	17,927,409.75	-1.11
2039	19,245,072.28	19,035,444.33	-1.09
2040	20,445,030.17	20,228,659.56	-1.06

EV = electric vehicle.
Note: Figure 4.19 shows the graphical representation of these results.
Source: Author’s calculation.

Table A.7. Impact of the Electric Vehicle Policy on the Consumer Price Index

	Consumer Price Index		
Year	Base Case	EV Policy	Diff (%)
2021	1.000	1.001	0.141
2022	1.006	1.009	0.262
2023	1.013	1.019	0.593
2024	1.019	1.026	0.661
2025	1.025	1.033	0.707
2026	1.031	1.039	0.735
2027	1.038	1.045	0.750
2028	1.044	1.051	0.757
2029	1.050	1.057	0.756
2030	1.055	1.063	0.751
2031	1.061	1.069	0.739
2032	1.067	1.075	0.723
2033	1.073	1.080	0.705
2034	1.079	1.086	0.682
2035	1.085	1.092	0.657
2036	1.090	1.097	0.627
2037	1.096	1.103	0.594
2038	1.102	1.109	0.559
2039	1.109	1.114	0.523
2040	1.115	1.120	0.490

EV = electric vehicle.
Note: Figure 4.20 shows the graphical representation of these results.
Source: Author’s calculation.

Table A.8. Total Government Revenue
(million baht)

Year	Base Case	EV Policy	Change	Change (%)
2021	2,905,988.74	2,916,755.76	10,767.02	0.37
2022	3,023,277.48	3,026,093.56	2,816.08	0.09
2023	3,148,603.49	3,135,762.94	-12,840.55	-0.41
2024	3,282,692.86	3,264,363.75	-18,329.11	-0.56
2025	3,426,270.11	3,402,332.56	-23,937.55	-0.70
2026	3,580,117.47	3,550,513.55	-29,603.92	-0.83
2027	3,745,068.97	3,709,883.04	-35,185.93	-0.94
2028	3,922,020.04	3,881,259.55	-40,760.48	-1.04
2029	4,111,929.58	4,065,699.86	-46,229.73	-1.12
2030	4,315,822.87	4,264,266.05	-51,556.82	-1.19
2031	4,534,792.71	4,478,003.20	-56,789.50	-1.25
2032	4,770,000.19	4,708,103.90	-61,896.28	-1.30
2033	5,022,674.57	4,955,825.26	-66,849.31	-1.33
2034	5,294,112.48	5,222,437.05	-71,675.43	-1.35
2035	5,585,676.53	5,509,326.98	-76,349.55	-1.37
2036	5,898,793.22	5,817,827.28	-80,965.93	-1.37
2037	6,234,950.37	6,149,710.67	-85,239.69	-1.37
2038	6,595,694.08	6,506,331.62	-89,362.46	-1.35
2039	6,982,625.28	6,889,313.92	-93,311.36	-1.34
2040	7,397,396.12	7,300,574.98	-96,821.14	-1.31

EV = electric vehicle.
Note: Figure 4.24 shows the graphical representation of these results.
Source: Author's calculation.

Table A.9. Total Government Revenue from Direct Tax
(million baht)

Year	Base Case	EV Policy	Change	Change (%)
2021	1,019,017.02	1,021,977.01	2,959.99	0.29
2022	1,061,310.37	1,065,065.10	3,754.73	0.35
2023	1,106,139.65	1,115,430.74	9,291.10	0.84
2024	1,153,758.95	1,165,234.96	11,476.01	0.99
2025	1,204,423.66	1,218,010.72	13,587.06	1.13
2026	1,258,400.13	1,273,969.24	15,569.11	1.24
2027	1,315,967.12	1,333,437.69	17,470.57	1.33
2028	1,377,418.41	1,396,796.53	19,378.12	1.41
2029	1,443,064.03	1,464,371.34	21,307.31	1.48
2030	1,513,231.10	1,536,538.85	23,307.74	1.54
2031	1,588,264.23	1,613,627.55	25,363.31	1.60
2032	1,668,525.52	1,696,080.35	27,554.83	1.65
2033	1,754,394.18	1,784,288.53	29,894.34	1.70
2034	1,846,265.90	1,878,708.91	32,443.01	1.76
2035	1,944,551.85	1,979,741.64	35,189.80	1.81
2036	2,049,677.48	2,087,830.99	38,153.51	1.86
2037	2,162,081.11	2,203,323.76	41,242.65	1.91
2038	2,282,212.30	2,326,782.94	44,570.64	1.95
2039	2,410,530.15	2,458,669.70	48,139.55	2.00
2040	2,547,501.51	2,599,363.14	51,861.63	2.04

EV = electric vehicle.
Note: Figure 4.25 shows the graphical representation of these results.
Source: Author's calculation.

Table A.10. Total Government Revenue from Indirect Tax
(million baht)

Year	Base Case	EV Policy	Change	Change (%)
2021	171,482.40	173,454.61	1,972.21	1.15
2022	177,892.77	176,717.93	-1,174.84	-0.66
2023	184,725.42	167,165.32	-17,560.09	-9.51
2024	192,053.38	171,310.39	-20,742.99	-10.80
2025	199,923.36	175,890.50	-24,032.87	-12.02
2026	208,386.00	180,951.39	-27,434.61	-13.17
2027	217,491.27	186,571.34	-30,919.94	-14.22
2028	227,292.25	192,800.40	-34,491.85	-15.18
2029	237,845.05	199,690.41	-38,154.64	-16.04
2030	249,209.47	207,267.39	-41,942.07	-16.83
2031	261,449.02	215,580.72	-45,868.30	-17.54
2032	274,631.06	224,683.51	-49,947.55	-18.19
2033	288,826.71	234,635.23	-54,191.48	-18.76
2034	304,110.82	245,479.95	-58,630.87	-19.28
2035	320,561.78	257,289.60	-63,272.17	-19.74
2036	338,261.39	270,114.91	-68,146.48	-20.15
2037	357,294.65	284,031.72	-73,262.94	-20.50
2038	377,749.48	299,114.89	-78,634.59	-20.82
2039	399,716.48	315,438.14	-84,278.33	-21.08
2040	423,288.63	333,247.99	-90,040.63	-21.27

EV = electric vehicle.
Note: Figure 4.26 shows the graphical representation of these results.
Source: Author's calculation.

Table A.11. Fiscal Balance
(million baht at market price)

Year	Base Case	EV Policy	Change	Change (%)
2021	404,964.34	415,731.36	10,767.02	2.66
2022	447,222.34	450,038.42	2,816.08	0.63
2023	495,266.70	482,426.15	-12,840.55	-2.59
2024	549,755.96	531,426.86	-18,329.11	-3.33
2025	611,345.11	587,407.56	-23,937.55	-3.92
2026	680,744.72	651,140.80	-29,603.92	-4.35
2027	758,715.04	723,529.11	-35,185.93	-4.64
2028	846,075.49	805,315.00	-40,760.48	-4.82
2029	943,706.70	897,476.97	-46,229.73	-4.90
2030	1,052,553.30	1,000,996.48	-51,556.82	-4.90
2031	1,173,625.05	1,116,835.54	-56,789.50	-4.84
2032	1,307,997.50	1,246,101.22	-61,896.28	-4.73
2033	1,456,811.79	1,389,962.49	-66,849.31	-4.59
2034	1,621,273.83	1,549,598.40	-71,675.43	-4.42
2035	1,802,652.72	1,726,303.16	-76,349.55	-4.24
2036	2,002,278.69	1,921,312.76	-80,965.93	-4.04
2037	2,221,540.41	2,136,300.71	-85,239.69	-3.84
2038	2,461,881.81	2,372,519.36	-89,362.46	-3.63
2039	2,724,798.65	2,631,487.29	-93,311.36	-3.42
2040	3,011,834.69	2,915,013.55	-96,821.14	-3.21

EV = electric vehicle.
Note: Figure 4.27 shows the graphical representation of these results.
Source: Author's calculation.

Table A.12. Aggregate Household Income
(million baht)

	Aggregate Household Income at Market Price (million baht)			Real Aggregate Household Income (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2021	14,148,459.48	14,189,557.20	0.29%	14,148,459.48	14,169,520.60	0.15
2022	14,735,678.04	14,787,810.27	0.35%	14,641,687.21	14,655,057.36	0.09
2023	15,358,106.49	15,487,107.96	0.84%	15,164,405.41	15,201,579.61	0.25
2024	16,019,272.83	16,178,610.60	0.99%	15,719,512.40	15,771,660.86	0.33
2025	16,722,722.91	16,911,371.31	1.13%	16,310,045.37	16,378,173.03	0.42
2026	17,472,154.82	17,688,322.89	1.24%	16,939,118.11	17,023,521.30	0.50
2027	18,271,439.02	18,514,007.75	1.33%	17,609,942.05	17,710,868.58	0.57
2028	19,124,654.59	19,393,708.47	1.41%	18,325,824.22	18,444,074.82	0.65
2029	20,036,105.87	20,331,945.47	1.48%	19,090,169.30	19,226,634.03	0.71
2030	21,010,334.89	21,333,949.36	1.54%	19,906,474.39	20,062,514.57	0.78
2031	22,052,126.33	22,404,281.21	1.60%	20,778,318.66	20,955,289.51	0.85
2032	23,166,507.68	23,549,090.52	1.65%	21,709,346.97	21,909,360.30	0.92
2033	24,358,744.17	24,773,809.77	1.70%	22,703,247.85	22,928,453.91	0.99
2034	25,634,329.59	26,084,782.00	1.76%	23,763,726.62	24,017,489.14	1.07
2035	26,998,972.85	27,487,562.74	1.81%	24,894,474.29	25,179,621.87	1.15
2036	28,458,581.21	28,988,320.52	1.86%	26,099,133.37	26,419,249.13	1.23

	Aggregate Household Income at Market Price (million baht)			Real Aggregate Household Income (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2037	30,019,240.34	30,591,870.62	1.91%	27,381,261.77	27,738,781.42	1.31
2038	31,687,192.16	32,306,029.59	1.95%	28,744,296.21	29,142,777.21	1.39
2039	33,468,810.95	34,137,200.66	2.00%	30,191,516.47	30,634,335.10	1.47
2040	35,370,578.66	36,090,647.33	2.04%	31,726,012.22	32,213,954.72	1.54

EV = electric vehicle.

Note: Figure 4.28 shows the graphical representation of these results.

Source: Author’s calculation.

Table A.13. Aggregate Household Income from Capital
(million baht)

	Aggregate Household Income from Capital at Market Price (million baht)			Real Aggregate Household from Capital (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base case	EV policy	Change (%)
2021	8,792,721.52	8,821,231.55	0.32	8,792,721.52	8,808,775.39	0.18
2022	9,166,894.52	9,203,532.86	0.40	9,108,423.92	9,120,911.05	0.14
2023	9,563,161.24	9,653,114.70	0.94	9,442,547.76	9,475,144.88	0.35
2024	9,983,817.21	10,096,809.03	1.13	9,796,995.16	9,842,838.28	0.47
2025	10,431,094.05	10,566,470.98	1.30	10,173,679.14	10,233,320.93	0.59
2026	10,907,322.21	11,063,882.74	1.44	10,574,563.99	10,648,055.47	0.69
2027	11,414,925.82	11,591,955.17	1.55	11,001,661.23	11,089,095.21	0.79
2028	11,956,452.69	12,154,053.67	1.65	11,457,035.70	11,558,917.44	0.89
2029	12,534,581.74	12,752,977.55	1.74	11,942,804.11	12,059,683.74	0.98
2030	13,152,130.14	13,392,014.31	1.82	12,461,131.30	12,593,893.32	1.07
2031	13,812,054.30	14,073,989.69	1.90	13,014,221.90	13,163,757.67	1.15
2032	14,517,447.86	14,802,842.15	1.97	13,604,308.30	13,772,115.82	1.23
2033	15,271,536.22	15,581,839.99	2.03	14,233,634.93	14,421,177.18	1.32
2034	16,077,668.15	16,415,211.61	2.10	14,904,439.35	15,114,259.60	1.41

	Aggregate Household Income from Capital at Market Price (million baht)			Real Aggregate Household from Capital (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base case	EV policy	Change (%)
2035	16,939,304.79	17,306,114.84	2.17	15,618,930.76	15,853,039.86	1.50
2036	17,860,006.35	18,258,533.94	2.23	16,379,266.57	16,640,383.03	1.59
2037	18,843,416.91	19,275,202.92	2.29	17,187,527.91	17,477,539.94	1.69
2038	19,893,247.76	20,360,748.57	2.35	18,045,695.03	18,367,121.15	1.78
2039	21,013,259.86	21,518,973.11	2.41	18,955,623.56	19,310,881.40	1.87
2040	22,207,246.00	22,752,842.53	2.46	19,919,022.66	20,308,836.04	1.96

EV = electric vehicle.
Note: Figure 4.29 shows the graphical representation of these results.
Source: Author's calculation.

Table A.14. Aggregate Household Income from Wages
(million baht)

Year	Aggregate Household Income from Wage at Market Price (million baht)			Real Aggregate Household Income from Wage (million baht at 2021 prices)		
	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2021	5,355,737.96	5,368,325.65	0.24	5,355,737.96	5,360,745.22	0.09
2022	5,568,783.52	5,584,277.40	0.28	5,533,263.29	5,534,146.31	0.02
2023	5,794,945.25	5,833,993.25	0.67	5,721,857.65	5,726,434.73	0.08
2024	6,035,455.62	6,081,801.57	0.77	5,922,517.24	5,928,822.58	0.11
2025	6,291,628.86	6,344,900.34	0.85	6,136,366.23	6,144,852.10	0.14
2026	6,564,832.61	6,624,440.16	0.91	6,364,554.12	6,375,465.82	0.17
2027	6,856,513.19	6,922,052.58	0.96	6,608,280.82	6,621,773.37	0.20
2028	7,168,201.89	7,239,654.81	1.00	6,868,788.52	6,885,157.38	0.24
2029	7,501,524.13	7,578,967.92	1.03	7,147,365.19	7,166,950.29	0.27
2030	7,858,204.75	7,941,935.04	1.07	7,445,343.08	7,468,621.25	0.31
2031	8,240,072.04	8,330,291.52	1.09	7,764,096.76	7,791,531.85	0.35
2032	8,649,059.81	8,746,248.37	1.12	8,105,038.66	8,137,244.48	0.40
2033	9,087,207.95	9,191,969.78	1.15	8,469,612.92	8,507,276.74	0.44
2034	9,556,661.44	9,669,570.39	1.18	8,859,287.27	8,903,229.55	0.50
2035	10,059,668.07	10,181,447.89	1.21	9,275,543.53	9,326,582.01	0.55

	Aggregate Household Income from Wage at Market Price (million baht)			Real Aggregate Household Income from Wage (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2036	10,598,574.86	10,729,786.58	1.24	9,719,866.80	9,778,866.10	0.61
2037	11,175,823.43	11,316,667.70	1.26	10,193,733.86	10,261,241.48	0.66
2038	11,793,944.40	11,945,281.02	1.28	10,698,601.18	10,775,656.05	0.72
2039	12,455,551.09	12,618,227.55	1.31	11,235,892.92	11,323,453.70	0.78
2040	13,163,332.66	13,337,804.80	1.33	11,806,989.55	11,905,118.68	0.83

EV = electric vehicle.

Note: Figure 4.30 shows the graphical representation of these results.

Source: Author's calculation.

Table A.15. Impact of the Electric Vehicle Policy on Aggregate Household Saving

	Aggregate Household Saving at Market Price (million baht)			Real Aggregate Household Saving (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2021	5,285,821.72	5,301,175.70	0.29	5,285,821.72	5,293,690.09	0.15
2022	5,505,204.80	5,524,681.24	0.35	5,470,090.11	5,475,085.16	0.09
2023	5,737,742.18	5,785,936.74	0.84	5,665,376.05	5,679,264.21	0.25
2024	5,984,751.93	6,044,280.04	0.99	5,872,762.34	5,892,244.85	0.33
2025	6,247,558.76	6,318,037.23	1.13	6,093,383.67	6,118,835.96	0.42
2026	6,527,544.25	6,608,303.99	1.24	6,328,403.35	6,359,936.12	0.50
2027	6,826,154.41	6,916,777.36	1.33	6,579,021.15	6,616,726.99	0.57
2028	7,144,913.17	7,245,430.89	1.41	6,846,472.56	6,890,650.63	0.65
2029	7,485,428.62	7,595,953.40	1.48	7,132,029.58	7,183,012.39	0.71
2030	7,849,397.64	7,970,299.03	1.54	7,436,998.69	7,495,294.83	0.78
2031	8,238,607.77	8,370,171.77	1.60	7,762,717.08	7,828,832.85	0.85
2032	8,654,937.28	8,797,869.07	1.65	8,110,546.44	8,185,270.81	0.92
2033	9,100,353.23	9,255,420.48	1.70	8,481,864.80	8,566,001.11	0.99
2034	9,576,908.09	9,745,195.75	1.76	8,878,056.47	8,972,861.38	1.07
2035	10,086,734.69	10,269,270.39	1.81	9,300,500.38	9,407,030.66	1.15
2036	10,632,039.96	10,829,948.97	1.86	9,750,557.38	9,870,151.66	1.23

	Aggregate Household Saving at Market Price (million baht)			Real Aggregate Household Saving (million baht at 2021 prices)		
Year	Base Case	EV Policy	Change (%)	Base Case	EV Policy	Change (%)
2037	11,215,097.50	11,429,030.44	1.91	10,229,556.67	10,363,124.93	1.31
2038	11,838,239.26	12,069,435.05	1.95	10,738,782.22	10,887,653.52	1.39
2039	12,503,846.66	12,753,555.03	2.00	11,279,459.34	11,444,895.04	1.47
2040	13,214,341.33	13,483,356.81	2.04	11,852,742.31	12,035,036.16	1.54

EV = electric vehicle.
Note: Figure 4.33 shows the graphical representation of these results.
Source: Author's calculation.

Chapter 5

European Union Transition to Green Energy in the Transport Sector

Inge Mayeres

1. Introduction

During President Ursula von der Leyen's first term, the European Commission, reoriented its strategic focus, with decarbonisation as one of the major priorities. The decarbonisation strategy is set out in the Communication on the European Green Deal (EC, 2019a). This aims to make Europe the first climate-neutral continent by 2050. The European Union (EU) Climate Law (EU, 2021c) binds Europe to achieving climate neutrality by 2050 and sets an intermediate target of a 55% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990. This report was written in December 2023, therefore it relates to the relevant legislation and status of the legislative process at the time.

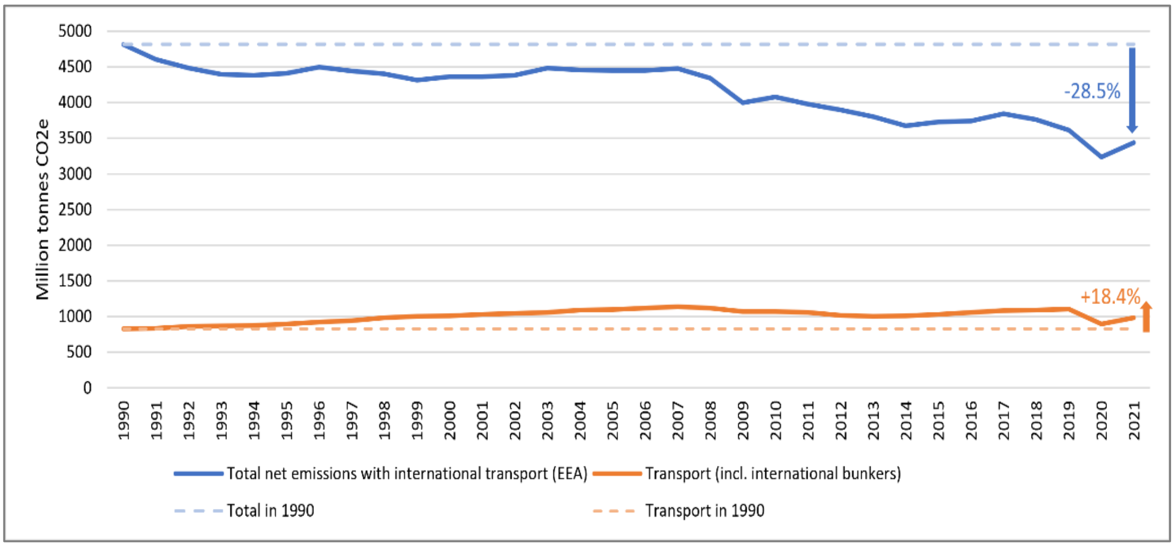
1.1. The Greenhouse Gas Emissions of Transport in the EU

Between 1990 and 2021 overall net GHG emissions in the EU-27[1] have fallen by 28.5%.[2] In most sectors, the GHG emissions decreased. However, those of transport (including international bunkers) have risen by 18.4%. Consequently, transport's share of GHG emissions has grown. The exhaust emissions of transport (including international bunkers) were responsible for 28.5% of total GHG emissions in the EU-27 in 2021, compared to 17.2% in 1990. The transport sector is a major contributor to GHG emissions in the EU-27 because of its strong dependence on fossil fuels (Figure 5.1).

[1] EU-27 refers to the EU with its 27 Member States, as of 1 February 2020.
[2] This includes GHG emissions from land use, land use change, and forestry; indirect CO_2 emissions; and international bunkers.

Figure 5.1. Total Net Greenhouse Gas Emissions and Greenhouse Gas Emissions from Transport in the EU-27 – Million Tonnes of Carbon Dioxide Equivalent and Change between 1990 and 2021

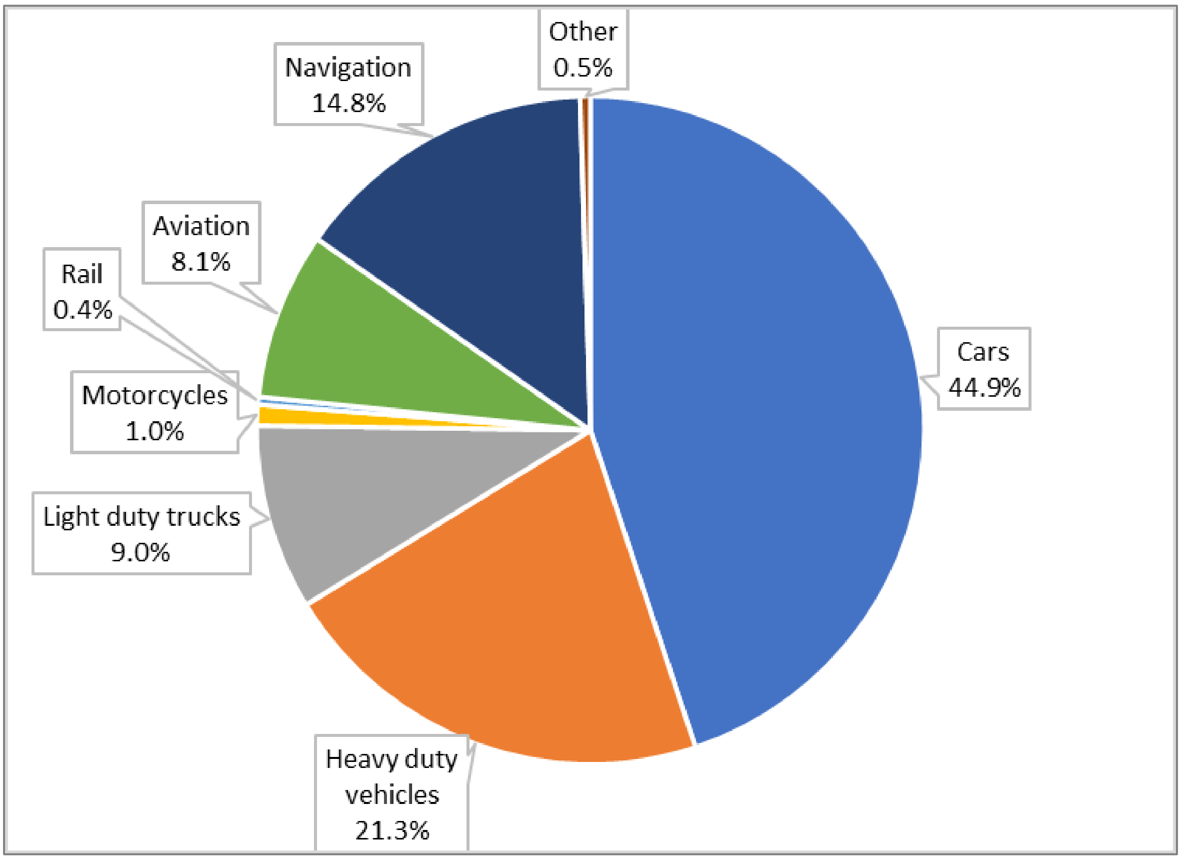
(%)



CO_2e = carbon dioxide equivalent; EEA = European Environment Agency;
Source: EEA (2023c).

Within the whole transport sector (including international aviation and navigation), car transport accounted for 44.9% of GHG emissions in 2021 (Figure 5.2). Other important modes were heavy-duty vehicles (HDVs) (21.3%), navigation (14.8%), light-duty trucks (9.0%) and civil aviation (8.1%) (EEA, 2023c).

Figure 5.2. Share of Transport Subsectors in Greenhouse Gas Emissions by Transport (Including International Bunkers) in the EU-27 during 2021



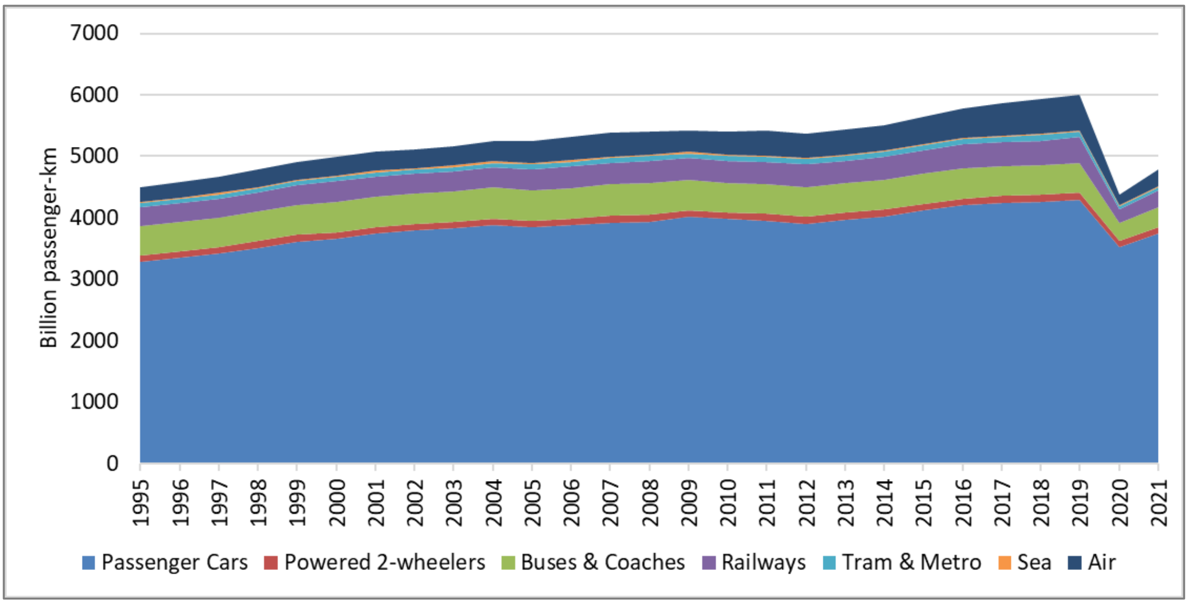
Source: EEA (2023c).

A decomposition analysis by the European Environment Agency (EEA) of the GHG emissions of passenger cars and heavy-duty trucks in 2000–2019, showed that the main driver of the increase in emissions for these two vehicle types between 2000 and 2019 was the growth in transport activity, strengthened by their growing dominance in passenger and freight transport, respectively (see Section 1.2). This outdid the positive effects on GHG emissions achieved by a higher energy efficiency and larger uptake of biofuels and led to a net increase in emissions (EEA, 2022).

1.2. The Transport Sector in the EU-27

In 2021 the demand for motorised passenger transport was estimated to be 4,780 billion passenger-km (Figure 5.3). Passenger cars were the dominant mode with a share of 78.3% (compared to 73.3% in 2000). The motorisation rate in 2021 was 597 cars per 1,000 inhabitants. Buses and coaches had a share of 6.8% and the share of heavy rail was 5.6%. Domestic and intra-EU air transport had a share of 5.7%. The share of light rail and sea transport was 1.2% and 0.3% respectively.

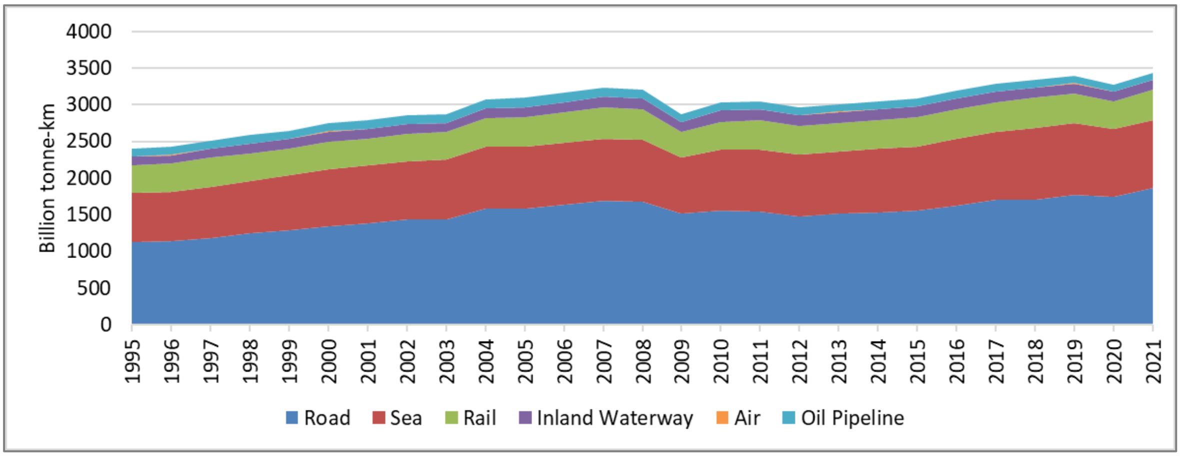
Figure 5.3. Passenger Transport Volumes by Mode in the European Union-27, 1995–2020
(billion passenger-km)



km = kilometre.
Note: Sea and air: only domestic and international intra-EU-27 transport.
Source: EC (2023b).

In 2021 3,432 billion tonne-km were transported by freight transport in the EU-27 (Figure 5.4). Road transport accounted for more than half of this (54.3%, compared to 48.8% in 2000), domestic intra-EU maritime transport had a share of 27.2%. The shares of the other modes were: 11.9% for rail, 4.0% for inland waterways, 2.6 % for oil pipelines and 0.1% for air transport.

Figure 5.4. Freight Transport Volumes by Mode in the European Union-27, 1995–2020



km = kilometre.
Note: Sea and air: only domestic and international intra-EU-27 transport.
Source: EC (2023b).

Table 5.1 presents additional information for aviation, for the flights at EU-27+European Free Trade Association (EFTA) airports.[3] In 2019 passenger and freight transport by air was considerably higher than in 2005. Passenger-km grew by 90% and tonne-km by 60%. In 2020 and 2021 the sector was affected considerably by the coronavirus disease (COVID-19) pandemic, with the largest impact for passenger transport.

[3] The EFTA consists of four countries: Iceland, Liechtenstein, Norway and Switzerland.

Table 5.1. Evolution of Air Traffic, Fuel Burn, and Net Carbon Dioxide Emissions at European Union-27 And European Free Trade Association Airports

(millions and (% change to 2005))

	2019	2020	2021
Flights	9.3 (+15%)	4.1 (-49%)	5.1 (-37%)
Passengers	818 (+71%)	229 (-52%)	304 (-36%)
Passenger-km	1484 (+90%)	389 (-50%)	509 (-35%)
Cargo (tonne-km)	8.4 (+60%)	7.3 (+39%)	n/a
Fuel burn [(i)] (tonnes)	46.5 (+34%)	20.1 (-42%)	20.4 (-41%)
CO2 emissions [(i)] (tonnes)	147 (+34%)	64 (-42%)	65 (-41%)
Net CO2 emissions [(i, ii)] (tonnes)	114 (+4%)	64 (-42%)	65 (-41%)

CO_2 = carbon dioxide; EFTA= European Free Trade Association; ETS = Emission Trading System; EU = European Union; km = kilometre.
Notes:
[(i)] The figures are for all flights departing from EU-27 or EFTA airports (flights coming from outside EU-27 or EFTA are not included);
[(ii)] The net CO2 emissions indicator takes into account emission reductions from the EU ETS.
Source: EASA, EEA, and Eurocontrol (2023).

The Climate Law does not set a separate reduction target for transport. As indicated in Section 1.1 the sector is an important source of emissions. Moreover, the EU Reference Scenario 2020 projected that without additional actions the GHG emissions of the transport sector would fall by only 22% by 2050 compared to 1990 (EC, 2021a). The European Green Deal points out that "to achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050" (EC, 2019b).[4] The Sustainable and Smart Mobility Strategy (EC, 2020) sets out a roadmap for a sustainable and smart future for European transport, with an action plan towards an objective to deliver this. The following milestones are set:

- By 2030:
  - at least 30 million cars with zero emissions will drive on European roads. To put this in perspective, in 2022 the number of battery electric cars in the EU-27 numbered 3.1 million or 1.19% of the total car fleet (EAFO, 2023);

[4] Based on the EU Reference Scenario 2020 (EC, 2021a), without additional policies, the transport emissions would exceed this target by approximately 485 million tonnes of CO_2. Emissions include international aviation but exclude international maritime transport.

    - 100 European cities will be climate neutral;
    - high-speed rail travel will double;
    - scheduled collective travel for trajectories of less than 500 km should be carbon neutral;
    - automated mobility will be available at large scale; and
    - zero-emission maritime vessels will be market ready.
- By 2035:
    - zero-emission large aircraft will be market ready.
- By 2050:
    - almost all cars, light commercial vehicles, buses, and new HDVs, will be zero-emission;
    - freight transport by rail will double; and
    - a fully operational, multimodal Trans-European Transport Network will exist for sustainable and smart travel with high-speed connectivity.

The strategy indicates that to reach the climate targets "all policy levers must be pulled: (i) measures to significantly reduce the current dependence on fossil fuels (by replacing existing fleets with low- and zero-emission vehicles and boosting the use of renewable and low-carbon fuels); (ii) decisive action to shift more activity towards more sustainable transport modes (notably increasing the number of passengers travelling by rail and commuting by public transport and active modes, as well as shifting a substantial amount of freight onto rail, inland waterways, and short sea shipping); and (iii) internalisation of external costs (by implementing the 'polluter pays' and 'user pays' principles, in particular through carbon pricing and infrastructure charging mechanisms)."

The first policy lever is discussed in Sections 3.2 and 3.3. Some of the milestones defined above relate to the second policy lever – modal shift. Concerning the internalisation of external costs, the strategy states that rail and waterborne-based intermodal transport will be able to compete on an equal footing with road-only transport in the EU by 2030 (in terms of the share of external costs internalised). In addition, it specifies that all external costs of transport within the EU should be covered by transport users by 2050 at the latest.

In July 2021, the European Commission published a set of detailed legislative proposals, called the Fit for 55 or Delivering the European Green Deal package, to achieve the targets agreed in the European Climate Law. It contained new legislative proposals as well as proposals for the revision of existing EU legislation. Since the transport sector is responsible for a considerable share of GHG emissions, greening that sector is crucial. Therefore, the Fit for 55 package also contained proposals that were aimed specifically at the transport sector. After the Russian invasion of Ukraine, the European Commission took further initiatives, including the REPowerEU proposal, with even more ambitious targets for the share of renewable energy.

This report aims to give an overview of the EU policies for the transition to green energy in the transport sector. Section 2 will present a general overview of the main EU policies for the decarbonisation of the transport sector. Section 3 will then discuss four policies in more detail, namely the EU Emission Trading System (EU ETS) and its future extension to road transport and buildings; the EU CO2 emission performance standards for cars, light commercial vehicles, and HDVs; the EU's renewable energy policy (with a focus on aviation); and the Social Climate Fund.

2. A General Overview of European Union Policies for the Decarbonisation of the Transport Sector

This section gives a general overview of EU policies for the decarbonisation of the transport sector. Table 5.2 summarises a selection of EU legislation that is currently in place or which has been adopted for the future and the strategies used to reduce GHG emissions. The first section lists regulations and directives that have a broader scope than transport but that form the general framework for decarbonisation, including that of passenger and freight transport. The second section lists selected legislation that is more specific to transport.

Table 5.2. Overview of Selected European Union Directives and Regulations for the Decarbonisation of Transport

	Type of Policy Instrument	Avoid/Shift/Improve
General directives and regulations		
Effort Sharing Regulation	General: Target setting for emission reductions	n.a.
Energy Efficiency Directive	General: Target setting for energy efficiency	n.a.
Energy Taxation Directive	Rules for taxation (market-based policy)	A/S/I: via impact of taxation on energy and electricity prices

EU Emission Trading System (current scope)	Cap-and-trade (tradeable emission permits) – market-based policy	A/S/I: via impact of price of emission permits on energy and electricity prices
Renewable Energy Directive	Blending mandate / GHG intensity reduction target	I
Social Climate Fund	Funding	n.a.
Directives and regulations with specific provisions for transport		
General		
Toll Directive	Rules for pricing road transport per km (market-based policy)	A/S/I: via toll
Vehicles		
CO2 emission performance standards	Emission standards for vehicles	I
Energy used by transport		
Future EU Emission Trading System for road transport, buildings and other sectors	Cap-and-trade (tradeable emission permits) – market-based policy	A/S/I: via impact of price of emission permits on road transport fuels
Alternative Fuel Infrastructure Directive and Regulation	Target setting for alternative fuel infrastructure provision	I

A = avoid; I = improve; n.a. = not applicable; S = shift.
Source: Author's summary.

In the case of the Effort Sharing Regulation (ESR), the Energy Efficiency Directive and the legislation regarding the alternative fuel infrastructure targets that are set must be met at EU or Member State level. In the other cases the type of policy instruments covered by the legislation is diverse. The CO_2 emission performance standards define the reduction in the CO_2 emissions per km that should be reached at fleet level for the new vehicles that are sold in the EU. The Renewable Energy Directive imposes blending mandates, or alternatively puts forward a GHG intensity reduction target. In addition, there are market-based instruments, i.e., policy instruments that use markets, prices, or other economic variables to provide incentives to reduce the GHG emissions. The Energy Taxation Directive and the Toll Directive set rules for the taxation of energy and the charging of road use, respectively. The EU Emission Trading System and its future extension to road transport and buildings are an example of a so-called cap-and-trade scheme, with tradeable emission permits. Finally, the Social Climate Fund provides funding with the aim of ensuring that the transition is fair.

The last column of the table categorises the legislation according to the Avoid-Shift-Improve framework. This framework is based on Dalkmann and Brannigan (2007) and is frequently applied by the EEA in its classification of policy strategies. In the case of transport,

- 'avoid' strategies are directed towards reducing the number or length of trips;
- 'shift' strategies aim for a modal shift towards more environmentally friendly transport modes. Together with the avoid strategies, they address transport demand as a determinant of GHG emissions; and
- 'improve' strategies are concerned with improving vehicle and fuel technologies to be more environmentally friendly.

The market-based policy instruments have the potential to act both on transport demand, modal choice (avoid and shift), and vehicle/fuel choice (improve). The CO2 emission performance standard and the blending mandate for renewable fuels are improve strategies aimed at a better environmental performance of vehicles and transport energy.

In addition to the legislation in table 5.2, a broad range of other policies is also in place at EU level as well as Member State level to optimise transport volumes and modal choice (avoid/shift strategies). These include, financial support to sustainable modes, the removal of administrative and technical barriers for sustainable modes, the support for digital solutions and initiatives, and programmes to stimulate sustainable urban mobility (EEA, 2022).

Section 3 will discuss in more detail four policies for the decarbonisation of transport. Before turning to that discussion, Table 3 summarises the main elements of the other legislation that was presented in Table 2. This covers the policy framework before Fit for 55, and the initiatives included in the Fit for-55 package and afterwards, some of which have already been transposed in legal acts and some are still in the legislative process.

Table 5.3. Summary of the Main Elements of the Effort Sharing Regulation, the Energy Efficiency Directive, the Energy Taxation Directive, and the Toll Directive

Current Legislation or Legislation Before Fit for 55			Fit for 55 or Afterwards
Regulation/Directive	Objectives for 2030 and Main Elements	Relevance for Transport	Status Of Legislative Process (1/12/2023) And Changes Relevant for Transport
Effort Sharing Regulation Regulation (EU) 2018/842	The Regulation covers all GHG emissions that are not covered by the EU ETS or the LULUCF Regulation. The objective at EU level is as follows: GHG emission reduction in non-ETS sectors by 30% compared to 2005. Apart from the objective at EU level the regulation also sets binding emission reduction objectives per Member State.	Transport is one of the sectors covered by the regulation. There is no separate objective for transport.	Proposal for amendment (EC, 2021e) Result: Regulation (EU) 2023/857 (19/4/2023) The objective has been made more ambitious compared to the objective of Regulation 2018/842. - a reduction in GHG emissions, by 2030, of 40% compared to 2005 (EU level); and - stricter targets than in the previous regulation for the Member States. Transport continues to be covered by the amended regulation.
Energy Efficiency Directive Directive 2012/27/EU, amended by	It sets as a target an improvement in energy efficiency by at least 32.5% (compared to the energy outlook	The energy consumption by transport is part of total energy consumption.	Proposal for recast: COM(2021) 558 final After the Russian invasion of Ukraine the proposed targets were

Current Legislation or Legislation Before Fit for 55			Fit for 55 or Afterwards
Regulation/Directive	**Objectives for 2030 and Main Elements**	**Relevance for Transport**	**Status Of Legislative Process (1/12/2023) And Changes Relevant for Transport**
Directive (EU) 2018/2002	for 2020), at EU level. The final energy consumption(*) should be reduced by 0.8% per year in the period 2021–2030.	There is no separate target for transport. For the provisions about the energy efficiency in final energy consumption, each Member State can decide to include transport or not.	made more ambitious in the REPowerEU Plan. Result: Directive (EU) 2023/1791 (13/9/2023) - Reduction of energy consumption by at least 11.7% by 2030 (compared to the 2020 EU Reference Scenario); - Maximum final energy consumption in 2030: 763 Mtoe. - Indicative maximum primary energy consumption in 2030: 992.5 Mtoe
Energy Taxation Directive Directive 2003/96/EC	The directive determines the EU rules and minimum excises that Member States should apply to energy products and electricity.	Transport uses energy products and electricity that are covered by this directive. Most Member States apply tariffs that are well above the current minimum levels.	Proposal for recast: COM(2021) 563 final The proposal includes amongst other things: - a new structure of taxation tariffs, based on the energy content and the environmental characteristics of the fuels and electricity (highest tariffs for the most polluting fuels); - a broader tax base that includes more products in the scope of the directive and abolishes

Current Legislation or Legislation Before Fit for 55			Fit for 55 or Afterwards
Regulation/Directive	Objectives for 2030 and Main Elements	Relevance for Transport	Status Of Legislative Process (1/12/2023) And Changes Relevant for Transport
			some exemptions and rebates. Status: The legislative process is ongoing.
Toll Directive Directive (EU) 2022/362 amending Directives 1999/62/EC, 1999/37/EC and (EU) 2019/520		The directive sets the general conditions for the European toll and user charges imposed on road vehicles. It covers both light- and heavy-duty vehicles. The 2022 Directive expresses a preference for distance-based charges rather than time-based charges. The latter should be phased out. The 2022 Directive introduces the differentiation according to the CO2 emissions of the vehicles and allows for a favourable	n.a.

Current Legislation or Legislation Before Fit for 55			Fit for 55 or Afterwards
Regulation/Directive	Objectives for 2030 and Main Elements	Relevance for Transport	Status Of Legislative Process (1/12/2023) And Changes Relevant for Transport
		treatment of zero-emission vehicles.	

CO_2 = carbon dioxide; EC = European Commission; EU = European Union; GHG = greenhouse gas; LULUCF =land use, land-use change, and forestry; Mtoe = million tonnes of oil equivalent; n.a. = not applicable.
Notes:
(*) Primary energy consumption measures total domestic energy demand, while final energy consumption refers to what end users actually consume. The difference relates mainly to what the energy sector needs itself and to transformation and distribution losses (Eurostat, no date).
Source: Author's summary.

3. A Deeper Dive into Four European Union Policies

In this section the following decarbonisation policies are discussed in more detail:

- The EU ETS and its future extension to road transport and buildings;
- The CO_2 emission performance standards for cars, light commercial vehicles and heavy-duty trucks; and
- Renewable energy in transport, with a focus on aviation.

In addition, the expected role of the Social Climate Fund is discussed.

3.1. The European Union ETS and its Future Extension to Road Transport and Buildings

3.1.1. General Discussion

The EU ETS is a cornerstone of the EU's climate policy. It was introduced in 2005 with Directive 2003/87/EC. Over time, it has undergone several revisions to ensure its alignment with the EU climate policy objectives. The Fit for 55 package contained a proposal for the amendment of the EU ETS (COM(2021) 551 final) which resulted in the adoption of Directive (EU) 2023/959 on the EU ETS and Regulation (EU) 2023/957 on the inclusion of maritime transport activities in the EU ETS. The former also introduces a separate system for road transport, buildings, and other sectors – the Emissions Trading System 2 (ETS2). Table 5.4 summarises some main elements of the two systems.

Table 5.4. The European Union Emission Trading Scheme

	EU Emissions Trading Scheme	EU Emissions Trading Scheme 2 (separate system)
Sectors covered and geographical scope	1,000 heavy energy-using installations, including power stations and industrial plants in the European Economic Area (EU-27 & Iceland, Liechtenstein and Norway) Aviation (since 2012), currently only flights within European Economic Area and flights to the UK Gradual phase-in of emissions from maritime transport between 2024–2026 (certain vessels); 100% of emissions between European ports and while at berth in European ports; 50% of emissions for voyages to/from European ports Link with the Swiss ETS	Fuel distributors for road transport, buildings and additional industrial sectors
Period	From 2005 onwards, with several revisions and extension of sectors covered Provisions of Directive (EU) 2023/959 on the EU ETS and Regulation (EU) 2023/957 will apply as from 2024	From 2027 onwards (possibly 2028 in case of high energy prices)
Target reduction for 2030	-62% compared to 2005 Linear reduction factor: - 2024–2027: 4.3% - 2028–2030: 4.4%	-42% compared to 2005 Linear reduction factor: - To 2027: 5.1% - 2028–2030: 5.38%
Other aspects	Gradual phasing out of free allowances, complemented by	No free allowances Social Climate Fund

	EU Emissions Trading Scheme	EU Emissions Trading Scheme 2 (separate system)
	introduction of Carbon Border Adjustment Mechanism Strengthening of Market Stability Reserve to absorb any price shocks from the upcoming changes to the ETS	

EU = European Union, ETS = Emissions Trading Scheme.
Source: EC (no date: a); EU (2023a); and EU (2023c).

The EU ETS operates in the European Economic Area (EU-27 + Iceland, Liechtenstein, and Norway). The United Kingdom stopped participating with the end of EU membership and established its own system.[5] Since 2020 Switzerland's ETS is linked to the EU ETS (EC: no date. b).

The EU ETS currently regulates the emissions of approximately 10,000 companies and covers the electricity and heat generation plants, energy-intensive industry and commercial flights within the European Economic Area.[6] With the recent reform the system will be extended to maritime transport, for which it will be introduced gradually between 2024 and 2026. This will cover all emissions from certain vessels docking in EU harbours from intra-EU voyages and 50% of non-EU voyages.

Both the EU ETS and the ETS2 are cap-and-trade systems where a cap limits the total amount of certain GHGs that can be emitted by the actors covered by the schemes. The cap represents the total emission allowances and is reduced over time. Under the new directive the emissions should be reduced by 62% by 2030 (instead of 43% before) compared to 2005. To achieve this reduction, the number of allowances will be reduced following a linear path, with an annual reduction factor of 2.2% until 2023, 4.3% from 2024 and 4.4% from 2028. The reform also provides increased funding for decarbonising the ETS sectors.

Currently, the allowances are partly auctioned and partly distributed for free depending on the industries' risk of carbon leakage. In the future the free allowances will be

[5] This implies that the price of emission allowances can be different in the two systems. Such differences are indeed observed, as shown in Ember (2023). For example, in large part due to the different economic context in the EU-27 and the UK, on 21 September 2023, the cost per tonne of CO2 was approximately €84/tonne in the EU ETS and €39/tonne (£34/tonne) in the UK ETS.

[6] The UK ETS covers UK domestic flights, flights from the UK to the European Economic Area, and flights between the UK and Gibraltar.

gradually phased out, together with the introduction of the carbon border adjustment mechanism (CBAM). The CBAM aims to avoid carbon leakage. It is a pricing system that will apply to energy-intensive products imported into the EU.

At the end of each year, the industries must surrender enough allowances to cover their emissions, or heavy fines apply. If an installation reduces its emission and has spare allowances, it can keep them to cover future emissions or sell them to another installation. The number of allowances is limited through the Market Stability Reserve (MSR), which allows for a better matching between the supply of allowances to be auctioned and demand. The recent reform prolongs the MSR's doubled intake rate that applied until 2023 and included further refinements to it.

The future ETS2 will be a separate self-standing scheme for fuel distribution for road transport, buildings, and additional sectors. By adding ETS2 to transport, the Commission aims to contribute to the internalisation of climate externalities in transport and level the playing field between fossil fuelled vehicles and electric ones.

To minimise the transaction costs, the ETS2 will regulate fuel distributors rather than the end consumers (households, vehicle drivers, and companies in the additional sectors). The sectors covered by the ETS2 will have to reduce their emissions by 42% by 2030 compared to 2005. The linear reduction factor of the emissions cap will be set at 5.1% from 2024 and 5.38% from 2028. All allowances will be auctioned. The fuel distributors will need to obtain enough allowances and surrender them to cover the GHG emissions from the combustion of the fuel they supply to the market (EPRS, 2023). This will apply from 2027 (or at the latest in 2028 in the case of high energy prices). The financial incentive to the end users will be given by the CO2 ETS2 price which would be reflected in the fuel price depending on its carbon intensity. The intention is to provide additional financial incentives to use energy-efficient vehicles, low-carbon fuels, and to make more sustainable mobility choices. As the ETS2 is a separate system, the price of the emission allowances is likely to be different from, and higher than, that of the EU ETS. Economic theory indicates that the cost-effectiveness of two separate systems is lower than of an integrated system (Ochelen, Mayeres and Proost, 2021). However, the decision to have a separate system was taken to reduce the risk to the existing system.

3.1.2. Complementarity with Other European Union Legislation for the Decarbonisation of Transport

While currently, the EU ETS only covers part of the transport sector, namely commercial flights within the European Economic Area, it also indirectly covers part of the well-to-tank emissions of other transport modes. As the EU ETS includes power generation in its scope, it is an essential way to control the well-to-tank GHG emissions of electric trains and electric road vehicles. Driving an electric car instead of a gasoline or diesel car, avoids the CO_2 emissions of the gasoline and diesel car. This benefit is not undone by the extra CO_2 emissions of the electricity production for the electric car, as the power generation sector falls under the EU ETS cap, and therefore these emissions will be compensated for by a reduction of CO2 emissions elsewhere in the EU ETS. With the higher uptake of EVs that is expected for the future, given the stricter CO2 emission performance standards (see Section 3.2), a larger part of transport will therefore indirectly fall under the current EU ETS, even without an extension of its scope. The EU ETS also regulates the well-to-tank emissions associated with fuel production by regulated refineries.

For aviation within the European Economic Area and, in the future, the maritime sector, the EU ETS is the main EU decarbonising policy. In the future this will be complemented by the blending mandate on renewable fuels (see Section 3.3).

The future ETS2 for road transport and buildings gives a further incentive for the decarbonisation of road transport, which will strengthen the renewable energy policy and the CO_2 emission performance standards. It will coexist with the ESR and aims to contribute to the cost-effective achievement of the targets set by that regulation.

Whereas the main instrument tackling emissions from road transport is the CO_2 emission performance standard regulation, the ETS2 should be considered as a complementary measure. Ochelen, Mayeres, and Proost (2021) discuss a number of reasons for this. Emission performance standards are expected to secure long-term emission reductions, which will come at the cost of the required investments and will, in turn, put downward pressure on ETS2 allowances prices. The standards, however, do not address all CO_2 emissions from road transport. Indeed, with the standards:

- the focus is only on the new car fleet, but they provide no incentive for drivers of the existing car fleet to change their driving behaviour;
- a rebound effect can be expected: *ceteris paribus*, drivers of new, fuel-efficient internal combustion vehicles are incentivised to use their car for more, and longer trips, as driving becomes relatively cheaper, reducing the expected environmental benefit of the fuel efficiency improvement. As the share of electric cars increases, this rebound effect on emissions will become smaller;[7]
- there is also some empirical evidence that car manufacturers have adapted to the standard as it is currently designed by making their car models heavier, which counteracts part of the CO_2 gains; and
- drivers of plug-in hybrid electric vehicles (PHEV) can still decide how much to drive in electric charge-depleting mode (given the electric range of their vehicle).

[7] It will still exist, however, for other transport externalities such as congestion, accidents, or non-exhaust emissions of air pollutants.

A carbon price via the ETS2 (or via fuel taxation[8]) contributes to curbing these problems: it gives an incentive to all vehicle users to lower their CO_2 emissions via all possible abatement options. These include reducing the number of vehicle kilometres they drive and choosing to drive more efficient vehicles, (also to scrap older unregulated vehicles) and/or to use less carbon intensive fuels. However, a similar incentive is also given by the implicit or explicit carbon pricing via fuel taxation and the CO_2 differentiation of road charges that the Toll Directive allows for. Therefore, there is an overlap between the instruments, which decreases the possible efficiency gains of the ETS2. In the case of fuel taxation this might be tackled by reducing fuel taxes when the ETS2 starts. This is, however, not foreseen currently.

3.1.3. Performance up to Now

The EEA publishes the EU ETS data viewer on its website (EEA, 2024). Each year the trends and projections in the EU ETS are also reported for the EEA. According to the edition for 2022, the emissions from stationary installations covered by the EU ETS have fallen by 36% between 2005 and 2021. This is mainly because of emission reductions in power generation, where the share of renewables has increased over time. Emissions in the largest industrial sectors (iron and steel, cement and lime, and refineries) have also fallen but at a smaller rate. There has been a reduction in the number of allowances that are allocated for free to the stationary sectors. The largest reduction took place between 2012 and 2013, with the transition from the second to the third trading period, when free allocation was no longer possible for power generation. The share of auctioned allowances has increased over time, as have the revenues from auctioning, also due to the increase in the price of the carbon permits (Nissen et al., 2022).

For aviation within the European Economic Area, the verified emissions increased between 2013 and 2019. In 2020 they decreased substantially, as the sector was hit hard by the COVID-19 pandemic. In 2021 air travel had not fully recovered, leading to emissions that were higher than in 2020 but lower than in 2019. In 2013–2019 the verified emissions were higher than the allowances for aviation, so that emission allowances needed to be bought from the non-aviation ETS sectors. In 2020 the verified emissions were below the aviation allowances, and in 2021 they were almost equal (Nissen et al., 2022).

The price of EU carbon permits has increased considerably over the past years, going from below €10/tonne in 2018 to between €80–€100/tonne in 2023 (Ember, 2023). This evolution is related to the introduction of the MSR, reforms in the ETS in the fourth

[8] The existing fuel taxes take up this role already (even if they do not perfectly reflect the carbon content of the different fuels, and they are not the same in all Member States) as in many Member States they imply relatively high carbon prices for road transport.

trading period and the adoption of the EU Climate Law, followed by the Fit for 55 package, which showed the commitment of the EU to achieve its climate goals.

3.1.4. Expected Economic and Social Impacts from the Emission Trading System 2 and the Extension to Maritime Transport

As the focus of this report lies in transport, the expected economic and social impacts are discussed for the future extension of the ETS to road transport and buildings and the extension to the emissions from the maritime sector. The discussion is based on the results of the Impact Assessment (IA) that was prepared by the European Commission for the draft reform of the ETS (EC, 2021d).

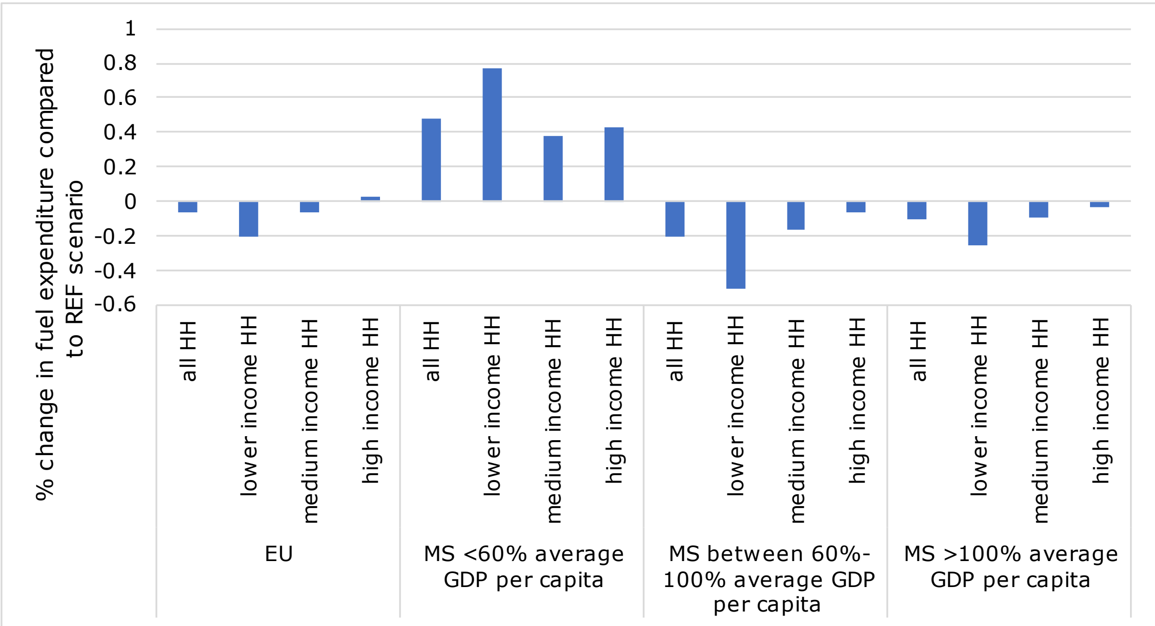
For the extension of the maritime sector, emission reduction in 2030 is expected to be 45 metric tonnes of CO_2 equivalent compared to the total emissions from the sector of 138 metric tonnes in the baseline. About one quarter is expected to be realised in the sector itself, and the rest via the buying of allowances from non-maritime ETS sectors which will consequently reduce their emissions. Within the sector itself, the IA predicts that the emission reductions will be realised mainly by improvements in energy efficiency, and not from the uptake of sustainable fuels, as the EU ETS price is not sufficiently high in 2030 to cover the price gap between conventional and sustainable fuels.

The IA projects that the net social benefit of the extension to maritime transport is positive, with a value of €1.01 billion. Shipping activities would go down by 0.9%, and costs would increase by 7.0%. The extension would generate an additional €2.4 billion in auction revenues (assuming an allowance price of €45/tonne). The impact on the different household income groups is negative but expected to be very small.

Given the emission reduction targets that are set by the Climate Law and the ESR, the ETS2 is considered to be a way to contribute to the cost-effective realisation of these targets, complementary to other policies (see also Section 3.1.2), though the incentives given will be different across Member Stares, given the range of fuel taxes across the EU. The IA points out that the ETS2 will affect individual spending on transport (and heating) fuels in the short or medium term, until the emission abating technologies fully realise their potential, and that this will have implications for social acceptability.

Figure 5.5 presents the projected change in fuel spending compared to the reference scenario per income group, for the EU as a whole and three groups of Member States: those with a gross domestic product (GDP) per capita less than 60% of the EU average, those whose GDP per capita is between 60% and 100% of the EU average, and those with an above-average GDP per capita. This is the case in the MIX scenario, that combines the ETS reform with other elements of the Fit for 55 package. Spending on fuel as a percentage of income is estimated to decrease by 0.12 percentage points on average. This is because the other measures in the MIX scenario help to reduce the consumption of fossil fuels. The changes are unevenly distributed amongst income groups and Member States. However, in all cases they are estimated to be below one percentage point. According to the IA, the revenues raised should be sufficient to tackle the social and distributional concerns, together with other funds. Auction revenues could be used for the Innovation Fund but also to address social and distributional concerns. With the aim to shield vulnerable households, microbusinesses, and transport users from the costs of ETS2, the Fit for 55 package also includes a new Social Climate Fund (see Section 3.1.5).

Figure 5.5. Estimated Change in Fuel Expenditure as a Percentage of Household Consumption Expenditures due to Emission Trading System 2 for Transport and Buildings per Income Group, and Member State Level of Gross Domestic Product per Capita – MIX Scenario Compared to the Reference Scenario



> = greater than; < = less than; EU = European Union; GDP = gross domestic product; HH = household; MS = Member State; REF = reference.
Source: EC (2021d).

The EU ETS2 is expected to have a small impact on total employment, but to lead to changes in the sectoral composition of employment and in the skills that are needed. With a carbon price of €48/tonne, the diesel price at the pump is expected to increase by 10% to 14% based on the price in 2021, depending on the fuel tax level in the Member States, and that of gasoline would rise by 7% to 12%. According to the IA the proportion of spending on transport is typically the highest for the lower-middle- and middle-income groups, which means they would be hit the hardest on average (people in the lowest income group have less access to a private vehicle). Still, this is only indicative, as the variability in car use within the income groups is large, and even in the poorest income group there are households who drive frequently, and who would therefore have a large increase in costs (Heyndrickx, Vanheukelom and Proost, 2021). The IA points out that 'the social impacts could be mitigated with a multi-faceted policy approach at EU and national levels.' (EC, 2021d: 129). For this purpose, the Fit for 55 package also contains a proposal for a Social Climate Fund, which will be discussed in the next section.

3.1.5. The Social Climate Fund

The Social Climate Fund was recently adopted by means of Regulation (EU) 2023/955. The fund is established for the period from 2026 to 2032. It will be mainly funded by revenue from the EU ETS2 up to a maximum amount of €65 billion, to be supplemented by national contributions. The Member States must cover at least 25% of the estimated total costs of their plans themselves. The Social Climate Fund aims to give financial support to the EU Member States for the measures and investments included in their Social Climate Plans. The regulation specifies, amongst other things, the allocation rules to divide the budget amongst the Member States, the elements that should be included in the Member States' Social Climate Plans, the principles governing the fund, the eligible measures, and the assessment of the plans by the European Commission. The Social Climate Fund is additional to other EU funds, such as the Modernisation Fund, Just Transition Fund, European Structural and Investment Funds, Recovery and Resilience Facility, and InvestEU, as well as national or regional funding. In its opinion on the Social Climate Fund, the European Court of Auditors pointed out the importance of coordination and complementarity of the various funding sources, as well as the risk of double funding (ECA, 2020).

The purpose of the Social Climate Fund measures and investments is to help vulnerable households, microenterprises, and transport users to cope with the consequences of the EU ETS2 and other climate measures in energy and transport. It focuses particularly on households in energy and/or transport poverty. The support can take the form of temporary direct income support and measures and investments to improve the energy efficiency of buildings, decarbonisation of heating and cooling of buildings, and to improve access to zero- and low-emission mobility. The purpose is not to compensate vulnerable households and microenterprises for additional costs, but to support investments to reduce emissions and relieve the CO_2-related burden. In this way, the financial consequences of the climate policies will be reduced and households will be more resilient to any future price increases.

The regulation specifies the maximum budget allocation to each Member State and considers the following variables:

- the population at risk of poverty living in rural areas;
- the CO_2 emissions from fuel combustion by households;

- the percentage of households at risk of poverty with arrears on their utility bills;
- the total population;
- the Member State's gross national income per capita, measured in purchasing power standard; and
- the share of reference emissions from road transportation, commercial and public services and the residential sector.

This mix is chosen to reduce the negative distributional consequences of the EU climate policy.

3.2. The Carbon Dioxide Emission Performance Standards for Cars, Light Commercial Vehicles, and Heavy-Duty Vehicles

3.2.1. General Discussion

CO2 emissions standards have been applied in Europe since 2008, with a voluntary agreement between the European Commission and the European Automobile Manufacturers Association (ACEA) on emissions from new cars. In 2009, this was replaced by mandatory targets for cars, which were tightened over time, and in 2011 a similar approach was introduced for new light commercial vehicles. From January 2020, Regulation (EU) 2019/631 came into force. It covered new passenger cars and new light commercial vehicles. It defined EU fleet-wide targets for 2025 and 2030 as a percentage reduction from the 2021 baseline. These are:

- for new passenger cars: a 15% reduction from 2025 and a 37.5% reduction from 2030; and
- for new light commercial vehicles: a 15% reduction from 2025 and a 31% reduction from 2030.

The binding CO_2 targets apply to the average emissions of each manufacturer's new registered vehicles across the EU, rather than to each individual new vehicle or country. The regulation also includes sales benchmarks for zero- and low-emission vehicles (ZLEVs). From 2025, a manufacturer's specific CO_2 emissions target is relaxed if its share of registered ZLEVs exceeds the benchmarks.

The system provides flexibility for manufacturers to decide how to comply and thus aims to increase the cost-effectiveness of achieving the standards. They can invest in research and development (R&D) to increase the fuel efficiency of cars with an internal combustion engine, or to make ZLEV cheaper and/or better performing; they can increase the share of smaller and more fuel-efficient cars; or they can pool with other manufacturers.[9]

Laboratory tests are used to assess whether CO_2 emissions comply with the targets. In the past, it was found that manufacturers partially met their targets by optimising their vehicle emissions during the test cycle, rather than reducing emissions on the road. Therefore, a new test procedure, the World Harmonised Light Vehicle Test Procedure (WLTP), has been developed instead of the earlier New European Driving Cycle (UNECE, 2014). Since 2021, the assessment is based entirely on the WLTP data. To prevent the gap between tested and real emissions from evolving unfavourably, the European Commission is now also collecting data on actual CO_2 emissions and energy consumption. Implementing Regulation (EU) 2021/392 (EU, 2021a) sets out the rules for data collection by manufacturers and national authorities.

In the Fit for 55 package, the European Commission proposed a revision of CO_2 standards for cars and vans (EC, 2021e). The legislative process around this resulted in Regulation (EU) 2023/851 (19/4/2023)[10]. Under this new regulation, the 2030 CO_2 target for the entire EU car fleet is as follows: -55% for new cars and -50% for new vans, instead of -37.5% and -31% respectively in the earlier regulation. From 2035, the target for both new cars and vans is 0g/km. The credits for ZLEVs will disappear. The European Commission is required to conduct a review of the effectiveness and impact of the regulation in 2026.

Under this regulation, the Commission will also take legislative initiatives so that vehicles with internal combustion engines may still be sold new after 2035, provided they run solely and permanently on renewable fuels of non-biological origin (i.e. e-fuels or synthetic fuels produced from CO_2 and hydrogen and produced from renewable energy). These fuels are still under development and there is great uncertainty about their future availability, environmental impact, and cost (Grahn et al., 2022).

In 2019, Regulation (EU) 2019/1242a, setting the first EU CO_2 emission standards for HDVs was adopted (EU, 2019). It covers large trucks, which account for 65%–70% of all

[9] Regarding pooling, individual manufacturers in a pool are viewed as a single manufacturer for the purposes of the CO2 emission regulation. This allows those with low fleet emissions to offset the high fleet emissions of other manufacturers.

[10] After Brexit, the transitional arrangements specified that the UK remained part of the EU car CO2 regulation until 2020. Hence, cars sold in the UK in 2020 counted towards the EU target, but not after that date. Subsequently the UK legislation has been updated (UK Vehicle Certification Agency, 2021). Recently the Government of the UK announced the introduction of a zero-emission vehicle mandate. It sets minimum annual targets for the share of zero-emission vehicles in the sales of new cars and vans. For cars, these rise from 22% in 2024 to 80% in 2030 and for vans, from 10% in 2024 to 70% in 2030. This increases to 100% in 2035 (UK Department for Transport, 2023).

CO2 emissions from HDVs. The regulation sets EU fleet-wide targets for reducing the average CO2 emissions from such new trucks. The targets are:

- from 2025, a reduction of 15% compared with the reference period (1 July 2019 to 30 June 2020); and
- from 2030 onwards, a 30% reduction compared with the same reference period.

The regulation for HDVs sets targets following the same principles as the legislation for cars and light commercial vehicles. The targets concern the fleet-wide average of manufacturers' new trucks. The regulation also includes an incentive mechanism for ZLEVs.

In 2023, the Commission proposed a revision of the regulation on CO2 emission standards for HDVs. The IA for this revision points out that unless further action is taken the CO2 emissions from the HDV sector will fall by only around 14% and 70% in 2030 and 2050, respectively, compared to 2015, which is not enough to realise the climate ambitions in a cost-effective way. Therefore, the proposal introduces new, stronger CO2 emission standards for HDVs from 2030 onwards and extends the scope of the regulation to cover smaller trucks, city buses, long-distance buses, and trailers. The legislative process for this revision is still ongoing.

3.2.2. Complementarity with Other European Union Legislation for the Decarbonisation of Transport

As the new vehicles with lower emission factors penetrate the vehicle stock, the exhaust CO_2 emissions of road transport will fall. The CO_2 emissions associated with electricity production for the electric vehicles (EVs) currently fall under the scope of the EU ETS. CO_2 emissions from vehicles with an internal combustion engine will fall under the ETS2. In addition, the mix of fuels must conform with the blending mandate or GHG intensity reduction target of the Renewable Energy Directive. To support the uptake of EVs the recently adopted Alternative Fuel Infrastructure Regulation (which will apply instead of the previous Alternative Fuel Infrastructure Directive) includes specific targets for the charging capacity for EVs according to the EV fleet evolution (EU, 2023e). It also requires the installation of charging and refuelling points at regular intervals on main roads, sets targets for liquefied/compressed natural gas infrastructure, and strengthens governance for progress monitoring.

The availability of charging infrastructure is also affected by a revision of the EU Energy Performance of Buildings Directive (EPBD) (Directive (EU) 2018/844). The directive contains measures to ensure that building car parks are gradually equipped with EV charging points. The EPBD includes provisions to equip new or renovated buildings with specific infrastructure (power lines) suitable for the subsequent installation of charging points. It also requires Member States to set requirements for the installation of a minimum number of charging points for all non-residential buildings with more than 20 parking spaces by 1 January 2025, and to simplify the installation of charging points in buildings, for example through authorisation and approval procedures. The ongoing revision of the EPBD (COM(2021) 802 final) also aims to make buildings more suitable for EVs, including smart charging requirements.

In addition to these policies at EU level, all EU Member States give additional incentives in one way or another to decarbonise road vehicles by means of tax benefits or incentives. The measures that are taken and their exact definition differ across the countries. Table 5.5 gives a general overview for the EU-27 and EFTA Member States and the UK, based on ACEA (2023)[11].

Table 5.5. Tax Benefits and Purchase Incentives for Electric Cars and Charging Infrastructure in the European Union-27 and the European Free Trade Association Member States and the UK

(Situation in 2023 as assessed by the European Automobile Manufacturers Association)

Type of Measure	Countries
Tax Benefits	
Acquisition	21 EU Member States: Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain & Iceland, Switzerland.
Ownership	22 EU Member States: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden & Switzerland
Company cars	16 EU Member States: Austria, Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania*, Luxembourg, Netherlands, Portugal, Spain, Sweden & Switzerland, UK
Incentives	
Purchase	21 EU Member States: Austria, Belgium (2024 onwards), Croatia, Cyprus*, Czech Republic, Estonia, France*, Germany, Greece*, Hungary, Ireland, Italy*, Lithuania*, Luxembourg,

[11] The report by ACEA gives some more detail about these measures. Each year ACEA also publishes a more complete overview of taxation in Europe.

Type of Measure	Countries
	Malta*, Netherlands, Poland, Portugal, Romania, Slovenia, Spain* & Iceland, UK**
Charging infrastructure	8 EU Member States: Austria, Belgium, Czech Republic, Denmark, Italy, Poland, Spain, Sweden & Iceland, Switzerland, UK

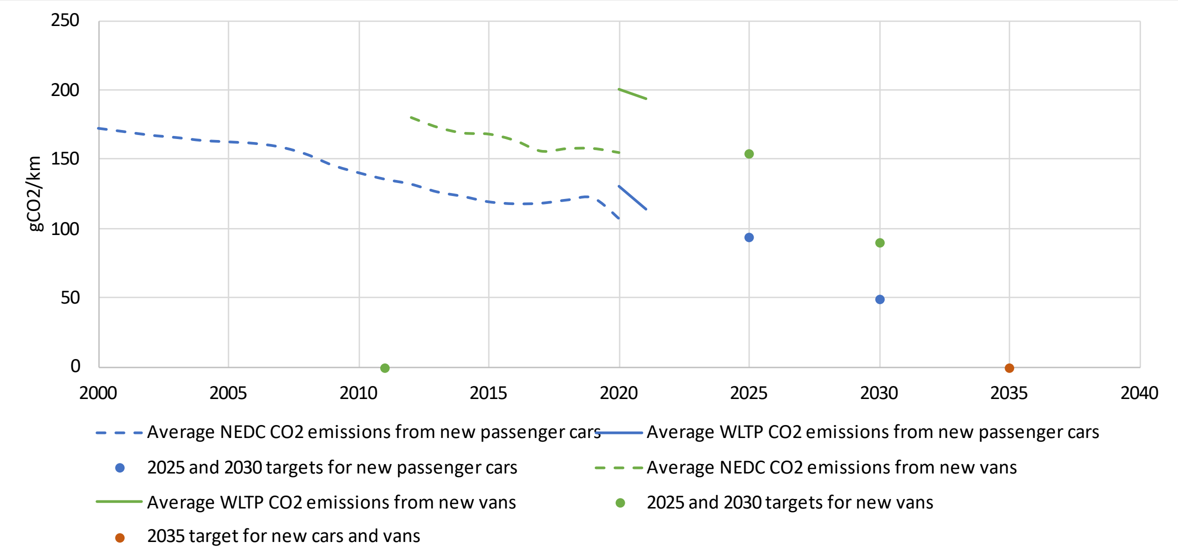
EU = European Union; UK = United Kingdom.
Notes: * including scrapping incentives; ** for conversion to wheelchair accessible vehicles
Source: ACEA (2023).

3.2.3. Performance up to Now

Figure 5.6 shows average CO_2 emission factors from new cars and vans up to 2021, as well as the targets for future years. In addition to the emission factors according to the New European Driving Cycle, the figure presents the performance based on the WLTP test cycle for 2020 and 2021. This test cycle will be used in future years. The average emission factors have fallen over time for both cars and vans. In 2021 the emission factor for cars and vans were respectively 12.5% and 3.5% lower than in 2020. This is mainly due to the larger share of EVs in new registrations, especially in the car registrations (Figure 5.7). In 2021, most car and van manufacturers and all pools of manufacturers met their binding CO_2 emission targets (EEA, 2023a, and EEA, 2023b).

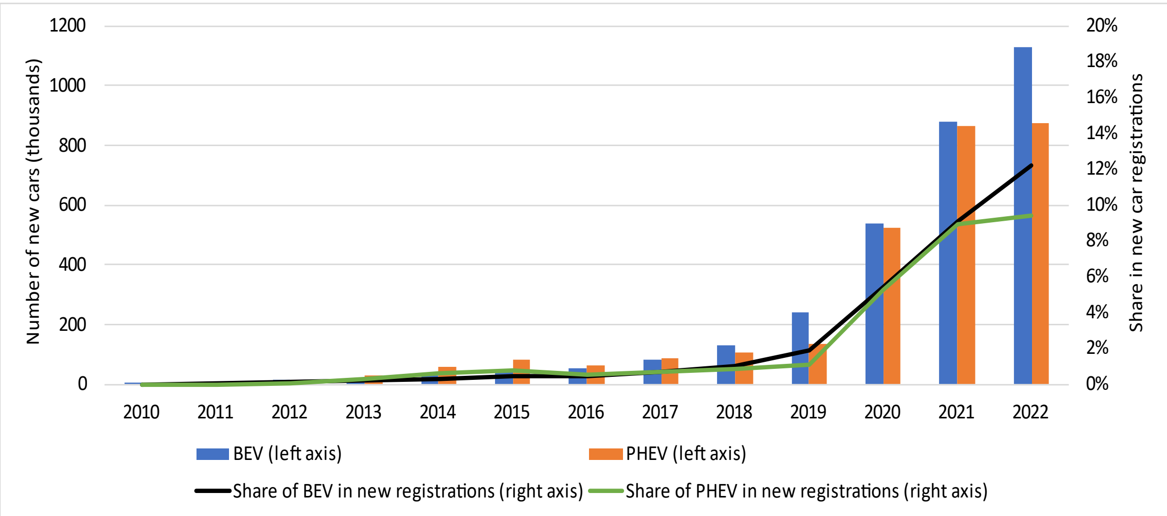
In 2022 the share of electric cars in new registrations increased compared to 2021, from 9.1% to 12.2% for battery electric cars and a smaller increase from 9.2% to 9.4% for PHEVs. As the new registrations only gradually penetrate the total car stock, the share of the electric cars in the total car stock in 2022 was still modest: about 1.2% for battery electric cars and 1.1% for PHEVs (compared to respectively 0.7% and 0.7% in 2021) (EEA, 2023d). The share of electric vans in the van stock was 0.77% in 2022, mostly consisting of battery electric vans. In that same year electric vans had a share of about 4.9% in registrations of new vans. (EAFO, 2023).

Figure 5.6. Average Carbon Dioxide Emissions from New Passenger Cars and Vans and Future Targets



CO_2 = carbon dioxide; gCO_2/km = grammes of carbon dioxide per kilometre; NEDC = New European Driving Cycle; WLTP = World Harmonised Light Vehicle Test Procedure.
Note: Country coverage: EU-27, Iceland, Norway,and the UK
Source: based on EEA (2023a and 2023b).

Figure 5.7. New Registrations of Electric Cars in the European Union-27, 2010–2022



BEV: Battery electric vehicle; PHEV: Plug-in hybrid electric vehicle
Source: EEA (2023d).

An evaluation for HDVs is not yet available. The EEA has determined that in the reference period (2019–2020), the average specific CO_2 emissions of all new HDVs registered in the EU was 52.75g/tonne-km (reflecting total lifetime emissions) (EC and EEA, no date).

3.2.4. Expected Economic and Social Impacts

The IA for the newly accepted CO_2 emission standards for cars and light commercial vehicles put forward the significant strengthening the CO_2 targets for cars and vans as of 2030 as the preferred option (EC, 2021c). The baseline scenario for the assessment is the EU Reference Scenario 2020 which represents the legislation in place at the time. The IA considers that the strengthening of the emission standards is implemented within a scenario consistent with the other policies in the Fit for 55 package (MIX scenario).

According to the IA the strengthening of the CO2 standards, together with other policies in the MIX scenario, would allow a reduction in exhaust CO2 emissions from cars and vans of 32%–33% in 2030, 56%–66% in 2035 and 83%–89% in 2040 in comparison to 2005 levels. This is higher than the reductions in the baseline scenario (Table 5.6). The trends for the well-to-wheel CO_2 emissions are similar to those for the exhaust CO_2 emissions, taking into account the other policies in the MIX scenario, and specifically the strengthening of the current EU ETS, the introduction of a separate EU ETS for road transport and buildings, and the revision of the Renewable Energy Directive. The MIX policy scenario also includes more stringent air pollution standards for cars and vans.

Table 5.6 also presents the estimated net savings in the total cost of ownership (TCO) from the perspective of the first user (first 5 years) and second user (next 5 years), considering the residual value of the vehicles. In addition, societal savings are presented which also include the benefits from the lower well-to-wheel CO_2 emissions and are estimated over the vehicle lifetime (15 years). There are net savings for the end user in all years and for all levels of stringency of the standards considered in the IA. While the stricter emission standards imply higher upfront capital costs, this extra cost is more than compensated for by lower energy costs. There are also net savings from a societal point of view.

Table 5.6. Estimated Net Economic Savings from a Societal and End-User Perspective of Stricter Carbon Dioxide Emission Performance Standards for New Cars and Vans in the European Union, as Calculated in the Impact Assessment

	2030	2035	2040
CO_2 emissions			
Decrease in exhaust CO2 emissions from cars and vans compared to 2005 (%)	32%–33% (in baseline: 28%)	56%–66% (in baseline: 39%)	83%–89% (in baseline: 48%)
Net economic savings from societal perspective (Impact of CO2 emission performance standards only, in MIX policy scenario context)			
€/car	€860–€1,600	€1,500–€3,400	€4,600–€5,100
€/van	€1000–€1,200	€4,000–€5,100	€5,600–€6,400
TCO for first and second users of new cars and vans (Impact of CO2 emission performance standards only, in MIX policy scenario context)			
€/car	First user: €330–€600 Second user: €450–€800	First user: €970–€2200 Second user: €1,300–€2,700	First user: €2800–€3100 Second user: €2800–€3000
€/van	First user: €340–€600 Second user: €460–€880	First user: €3,400–€4,000 Second user: €2,800–€4,400	First user: €5,200–€5,500 Second user: €3,700–€3,900

€ = euro; CO_2 = carbon dioxide; TCO = total cost of ownership.
Source: based on EC (2021c).

The CO_2 emission performance standards interact with other policies in the MIX policy scenario, which leads to higher energy prices and additional capital costs for vehicles with an internal combustion engine due to stricter air pollutant emissions standards. In that case there are net costs rather than net savings in the case of CO2 emission standards with low stringency. However, with medium to high stringency of the new standards, there is a net saving, which increases with the level of stringency.

In terms of affordability (the variety of vehicle choice available per consumer group) the CO_2 emission standards are expected to mainly affect the affordability for households in the second and third quintile. For households in the lowest quintile, the set of vehicles that are affordable to them as first and second user is already relatively limited in the baseline, and it does not change because of more stringent emission standards. For the households in the two highest quintiles there are no affordability issues, as well as for households in the third quintile as second user and for all households as third users. For the other cases, affordability issues are found for some vehicle sizes and drivetrains.

For the subjective TCO, which includes purchase price or loan payments and other group-specific parameters in the TCO, the IA shows that more stringent emission standards translate, for the lower-income groups, into higher savings relative to their annual income than for higher income groups. This is because they are more likely to be second or third users. Therefore, they can benefit from the savings in energy costs while not having to pay a high upfront capital cost. It is also the consequence of expressing the savings in terms of income, which is lower for these households. In this regard the International Council on Clean Transportation (ICCT) warns that there are still relatively few EVs on the market and many are marketed as luxury vehicles that are typically purchased by affluent households (Bauer, Hsu, and Lutsey, 2021). Goetzel and Hasnazzaman (2022), referring to the German market, also show that price parity for small cars will not be achieved before 2030 whereas luxury and midsized EVs are already close to price parity. These studies show the importance of reducing the purchase cost of used and small EVs to enable lower-income households access to the cost savings and substantial equity benefits associated with EVs.

The IA of the strengthened CO_2 emission standards also evaluates the broader economic effects. The impact on GDP is assessed to be positive and small, with the largest percentage change in 2040, of 0.28% to 0.65%. The CO_2 targets are projected to lead to more consumer expenditure, and higher investment in vehicle technology and infrastructure. The automotive and petroleum refining sector are projected to be affected negatively, while the sectors in the EV supply chain (such as electronics, metals, and electrical equipment) and the power sector are affected positively. The IA also projects a small increase in employment. The increase is largest for the most stringent standards and increases over time. The largest change is projected in 2040 with the most stringent standard – 0.3% compared to the baseline. The IA stresses the need to reskill the workforce and teach the skills required for the future to young people to facilitate the transition.

The Joint Research Centre (JRC) recently published an update of an earlier report on supply chain dependency, which also projects the demand for raw materials up to 2050 in the EU (Carrara et al., 2023). This has been done for five strategic sectors, including electric mobility. The JRC expects a huge increase in demand for raw materials for electric mobility, and this not only at European level but also in the rest of the world. It points to high dependence on regions outside the EU, and especially China. According to the JRC the supply risk is high, and for electric mobility this applies to all stages of supply. The role of recycling depends on the volume of end-of-life products and is expected to be rather limited. In the case of batteries, the JRC estimates that – considering the known and planned mining projects for lithium, cobalt, manganese, and nickel – the demand for raw materials after 2030 will exceed the known potential supply unless investments are stepped up in time. It also highlights the importance of investing in R&D to reduce supply-side risks through the development of advanced materials, alternative technologies, or more efficient use of materials. The JRC's conclusions for e-mobility feedstocks are generally in line with those of the International Energy Agency's Global EV Outlook 2022 (IEA, 2022).

The European Commission has recently taken initiatives to reduce risks by proposing a regulation on critical raw materials (the Critical Raw Materials Act) (COM, 2023: 160). With this, it aims to be 'a comprehensive response to the risks of critical raw materials supply disruption and the structural vulnerabilities of EU critical raw materials supply chains.' (EC, 2023a). Alongside this proposal, the Commission has also prepared an outline for a Net-Zero Industry Act (COM, 2023: 161) to ensure the scale-up of production of key carbon-neutral technologies for clean energy chains.

3.3. Renewable Energy in Transport with a Focus on Sustainable Aviation Fuels

3.3.1. General Discussion

According to the current Renewable Energy Directive II (RED II) (Directive 2018/2001/EU) (EU, 2021b), in each Member State, energy from renewable sources in road and rail is at least 14% of the final consumption of energy in transport. In addition, there is a specific target for advanced biofuels, gradually increasing to 3.5% by 2030. The RED II also sets several requirements on the sustainability and GHG emissions of biofuels in transport which they must meet in order to count towards the overall 14% target and qualify for possible government financial support. The RED II sets limits for biofuels with a high risk of indirect land use change (ILUC), namely liquid biomass and fuels from biomass that significantly expand cultivation on land with high carbon storage. A phase out of these fuels is imposed between 2023 and 2030. Moreover, the share of fuels based on several feedstocks that can be processed with mature technologies (including used cooking oils and animal fats) should not exceed 1.7%.

There is no specific target for aviation, but SAFs can be taken into account when assessing the target.

The RED II is complemented by Delegated Regulation (EU) 2019/807. The regulation includes criteria for identifying feedstocks with high ILUC risk and general criteria for certifying biofuels with low ILUC risk. Criteria are proposed for improvements in agricultural practices (additionality measures) that allow for an increase in the yield of food and feed crops on land already used for this dpurpose or growing such crops on unused or abandoned land.

In the July 2021 Fit for 55 package, the European Commission included a proposal to revise the current directive (COM(2021) 557 final). Following the Russian invasion of Ukraine, the European Commission proposed the REPowerEU plan (COM(2022) 230 final), which includes a series of integrated actions to save energy, diversify and secure energy supply, boost the adoption of renewable energy, and smartly combine investment and reforms.

The resulting new directive that was signed in October 2023 (EU, 2023b) sets a target for the share of energy from renewable sources in gross final consumption of energy in the European Community of at least 45% instead of 32%. For transport, Member States must either ensure that the share of renewable energy in transport is at least 29% by 2030 or that the GHG emission intensity is reduced by at least 14.5% by 2030, compared to a baseline.

While the RED II target applied to energy consumed by road and rail transport, the new targets apply to all energy consumption by transport. Another new feature is that renewable fuels and renewable electricity count towards the emission intensity reduction target based on their GHG emission reductions.

The new directive requires that the combined share of advanced biofuels and biogas and of renewable fuels of non-biological origin in the energy supplied to the transport sector is at least 1% in 2025 and 5.5% in 2030, of which a share of at least one percentage point is from renewable fuels of non-biological origin in 2030. It also includes a credit system for the supply of renewable electricity to the transport sector through public charging stations. Private charging stations may also be taken into account here on condition that it can be proved that the renewable electricity is only supplied to EVs.

Regarding the issue of ILUC, the new directive sets limits on high ILUC risk biofuels, bioliquids, and biomass fuels with a significant expansion in land with high carbon stock. The Member States will still be able to use (and import) fuels covered by these limits, but they will not be able to include these volumes when calculating the extent to which they have fulfilled their overall renewable targets and the target share of renewables in transport. The limits impose a freeze equivalent to 2019 levels for the period 2021–2023, which will gradually decrease from the end of 2023 to zero by 2030. The new Directive also introduces an exemption to these limits for biofuels, bioliquids, and biomass fuels certified as low ILUC risk.

For aviation and the maritime sector, two separate proposals were included in the Fit for 55 package. For aviation the REFuelEU Aviation Regulation was adopted in October 2023 (EU, 2023d). It states that :

- Aviation fuel suppliers will have to ensure that all fuel made available to aircraft operators at EU airports contains a minimum share of sustainable aviation fuels (SAFs) from 2025 and from 2030, a minimum share of synthetic fuels, with both shares increasing progressively until 2050. Table 5.7 summarises the evolution of the targets over time.

- Aircraft operators will have to ensure that the annual quantity of aviation fuel uplifted at a given EU airport is at least 90% of the annual aviation fuel required, to avoid emissions related to extra weight caused by tankering practices.

Table 5.7. REFuelEU Aviation: Minimum Share of Sustainable Aviation Fuels and Synthetic Fuels

	2025–2029	2030–2031	2032–2034	2035–2039	2040–2044	2045–2049	2050 onwards
SAF	2%	6%	6%	20%	24%	42%	70%
Subtarget synthetic fuels		On average 1.2% (min. 0.7% per year)	On average 2% (min. share of 1.2% in 2032–2033 and 2% in 2034)	5%	10%	15%	35%

SAF = sustainable aviation fuel.
Source: EU (2023d).

3.3.2. Complementarity of REFuelEU Aviation with Other European Union Legislation for the Decarbonisation of Transport

The EU aims to reduce the climate impact of aviation by means of a basket of measures. These include support for R&D on carbon-neutral aircraft, improvements in air traffic management and the inclusion of flights within the European Economic Area in the EU ETS (see Section 3.1). The proposal to revise the Energy Taxation Directive could lead to a tax on conventional jet fuel. The REFuelEU Aviation Regulation is an additional element in this basket of measures and imposes a blending mandate for SAF, with a sub target for synthetic fuels. The targets of the regulation apply to all fuel supplied at EU airports, so not only for flights within the European Economic Area. Therefore, the range of flights covered is broader than that of the EU ETS for aviation.

The regulation specifies that the following fuels are eligible:

- aviation biofuels that meet the sustainability and lifecycle emissions criteria laid down in the RED II and that are certified in accordance with the RED II. According to Article 4(5) SAF produced from the following feedstocks shall be excluded from the calculation of the minimum shares of SAF for sustainability reasons: 'food and feed crops'[12], intermediate crops, palm fatty acid distillate and palm and soy-derived materials, and soap stock and its derivatives. However, that exclusion shall not apply to any feedstock that is included in Annex IX to Directive (EU) 2018/2001(EU, 2021b), under the conditions set out in that Annex.

- synthetic aviation fuels (also called renewable fuels of non-biological origin) and recycled carbon aviation fuels that comply with the lifecycle emissions savings threshold of the RED II.

Renewable hydrogen for aviation and low-carbon aviation fuels achieving at least the same level of lifecycle emissions savings as synthetic aviation fuels are also included within the scope of the regulation.

SAF typically have lower aromatics and sulphur content than conventional jet fuel. Therefore, the uptake of SAF also contributes to the reduction of the non-CO_2 climate impact of aviation. According to Lee et al. (2021) these non-CO_2 climate impacts are responsible globally for two thirds of the total climate impact of aviation.

3.3.3. Performance up to Now

In 2021, the share of renewable sources in transport reached 9.1% at EU level. In 2004 it was 1.6%. The share in 2021 was 1.2 percentage points lower than in 2020. In absolute terms the use of renewable energy in transport increased compared to 2020, but the share was lower than in that year because transport activities increased in 2021 with the relaxation of COVID-19 restrictions, and there was a change in methodology. The RED II sets a target of 14% in 2030, but the compromise text on its revision is more ambitious.

The share of renewable energy in transport varies substantially between EU Member States. With a share of respectively 30.4% and 20.5%, Sweden and Finland are well above the 14%. In 20 Member States the rate is below 10%.

For aviation, the share of SAFs is currently very low. In 2020 EU SAF supply was less than 0.05% of total EU aviation fuel use (EASA, EEA, and Eurocontrol, 2023).

3.3.4. Expected Economic and Social Impacts of REFuelEU Aviation

The IA of the REFuelEU Aviation Regulation considered different policy options to promote the uptake of SAF (EC, 2021b). For the policy option that was closest to the approach adopted in the final act (Option C1) the net present value (NPV) of the benefits

[12] In Article 2 of the RED II, these are defined as follows: 'starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land.'

over the whole period to 2050 were found to be €67.5 billion higher than the costs. The IA indicated that the required feedstock and renewable electricity for SAF production will be available and that sufficient SAF can be supplied to the market. It also indicated that the mandate means that SAF can be introduced more quickly to the market than in the baseline scenario. This means that the use of conventional jet fuel can be reduced in line with the EU's climate ambitions. The improvement of air quality is another environmental benefit. Because of the fuel uplift obligation, the risk of tankering is estimated to be low. It indicates, however, that there is a moderate risk of competitive disadvantage with non-EU airlines on some routes.

As SAF is more costly than conventional jet fuel, the blending mandate will lead to higher fuel costs. The IA estimates that with policy option C1 in 2030 the cost of the fuel blend will be 1.4% higher than in the baseline, and almost 44% higher in 2050. As a result, ticket prices are estimated to be 0.8% higher in 2030 and 8.1% higher in 2050 than in the reference scenario. This results in less air travel (a reduction by 2% in 2030 to 5.9% in 2050), which is partly compensated by a switch to rail. The total costs for the aviation sector increase by 0.3% over the entire time horizon up to 2050. Fuel costs increase (NPV equal to €104 billion) but the capital and operational costs fall due to a lower travel demand (NPV equal to -€84 billion). The NPV of the capital investments in SAF production is estimated to be €10.5 billion. The blending mandate is expected to lead to a net job creation. This is limited in 2030 but larger in the long term. For policy option C1, the net increase in employment would be 202,000 in 2050. This is the net outcome of a loss of 46,000 jobs directly and indirectly related to the aviation sector due to lower air travel, which is expected to be more than compensated for by an increase of 248,000 jobs directly and indirectly related to SAF production.

4. Concluding Remarks

According to the EU Climate Law, Europe needs to achieve climate neutrality by 2050. For transport, the EU's Sustainable and Smart Mobility Strategy aims to deliver a 90% reduction in emissions from the transport sector by 2050. The overview in this chapter shows that in recent years, with the Fit for 55 package and other policy initiatives, the EU has made substantial efforts to improve its existing legislation as well as to introduce new legislation for the decarbonisation of transport. At the time of writing, many of the proposals have led to adopted legislation, with modifications, and others are still to follow. The IAs indicated that they would have a profound effect on the future environmental performance of the transport sector in the EU. In the future it will be important to regularly assess the progress and the economic and social impacts, to see whether they remain in line with the objectives.

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Chapter 6

Energy Transition in Japan from the Perspective of Economics and Technology

Joni Jupesta, Upalat Korwatanasakul, and Keigo Akimoto

1. Introduction

The Paris Agreement, which is the framework and target for reducing greenhouse gas (GHG) emissions after 2020, was decided at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCC) held in Paris in December 2015 and it came into effect on 4 November, 2016. Japan signed on 8 November, 2016 and joined the Contracting Parties on 8 December of that year. The Paris Agreement is epoch-making in that it has created a legally binding international framework for almost all countries to work on reducing GHG emissions, regardless of whether they are developed or developing countries. In November 2021, COP26, which was delayed by one year due to the Coronavirus disease (COVID-19) pandemic, was held in Glasgow, United Kingdom. The agreements reached there related to the market mechanisms regarding Article 6 of the Paris Agreement, efforts to limit the rise in global average temperature to 1.5°C and accelerating the reduction of coal-fired power generation which was not taken by any emission reduction measures. The Special Report on Global Warming of 1.5°C (SR15) of the International Panel on Climate Change (IPCC) also indicates that it is necessary to achieve net-zero emissions by around 2050 to maintain a global temperature rise below 1.5°C (IPCC, 2018). The world is seeking large reductions in emissions, including net-zero emissions.

Within this international setting, the Government of Japan has strengthened its climate change measures. It formulated a long-term growth strategy based on the Paris Agreement and in compliance with the resolution of COP21 that required each country to formulate and submit such a proposal. The Government has submitted its target to the UNFCCC. The long-term goals include (1) pursuing a level of carbon dioxide (CO_2) emissions that are well below 2°C, (2) pursuing a level of CO_2 emissions that are below 1.5°C, and (3) achieving virtually zero CO_2 emissions in the latter half of the twenty-first century. This corresponds to the Paris Agreement's long-term goals to hold the average increase in global temperature to well below 2°C above pre-industrial levels; limit increases to 1.5°C above pre-industrial levels, and achieve net-zero emissions in the second half of the twenty-first century.

According to the SR15 and the IPCC 5th Assessment Report, however, achieving the target of 2°C or 1.5°C will come at a significant financial cost. For example, according to the Assessment Report (IPCC 2014), even in the world's lowest-cost cases, the marginal CO2 abatement costs for the 2°C consistent scenarios (430–530 parts per million (ppm) equivalent in 2100) are about \$100–\$300/total CO_2 (tCO_2) [1] and \$1,000–\$3,000/tCO2 (25–75 percentile range) in 2050 and 2100, respectively. The SR15 also reports a marginal abatement cost of \$245–\$14,300/tCO_2 (median: about \$2,800/tCO_2) in 2050, for the target of 1.5°C. While the targets of 2°C or 1.5°C are technologically feasible, their economic and political feasibility is unclear, considering such high emission reduction costs. Gambhir et al. (2019) argue that the marginal CO_2 abatement costs for the 2°C consistent scenarios are about \$100–\$300/tCO_2 and \$1,000–\$3,000/tCO2 (25–75 percentile range) in 2050 and 2100, respectively, and those for the 1.5°C scenario are about \$220–\$430/tCO_2 and \$2,500–\$5,000/tCO_2 (25–75 percentile range) in 2050 and 2100, respectively, according to 240 scenarios by five different integrated assessment models. They indicate the median marginal cost in 2100 for the below 1.5°C scenarios are about three times higher than those for the 2°C scenarios (Akimoto et al., 2021).

The SR15 (IPCC, 2018) mentioned an interesting scenario for the 1.5°C target: the Low Energy Demand scenario. It assumes the demand for a decent living and rapid technological and social innovations and estimates the low final energy demands. Due to the estimated low energy demands, the marginal abatement cost for the 1.5°C target in 2050 is about \$150/tCO_2, significantly smaller than the categorised scenarios with a cost of about \$400/tCO_2 (IPCC, 2018). Van Vuuren et al. (2020) show that based on the meta-analyses of the results of integrated assessment models, the abatement costs increase exponentially and have larger uncertainties due to deep emission reductions. Thus, the existing empirical studies, with few exceptions, estimate high costs for deep emission reductions, including net-zero emissions.

Human activities, principally through GHG emissions, have unequivocally caused global warming, with the global surface temperature reaching 1.1°C above 1850–1900 levels during 2011–2020 (IPCC, 2022). Global GHG emissions have continued to increase, with unprecedented activity arising from unsustainable energy use, land use and land-use changes, lifestyle changes, and changes in patterns of consumption and production across regions, between and within countries, and amongst individuals (IPCC, 2023). COP28 in Dubai, United Arab Emirates, will focus on the Paris Agreement implementation, including the Global Stock Take targets on nationally determined contributions (NDC) in 2030, financing mitigation/adaptation, decarbonisation for clean energy, and carbon trading to accelerate the mitigation.

[1] In this report, \$ refers to US dollar.

The study for the Basic Guidelines on Climate Transition Finance was launched in 2021 to finance the Green Transition in Japan (Gov. of Japan: METI, 2023a). The study set out in this chapter analyses Japan's energy transition from an economic perspective, based on the latest green transformation policy. The case study on the carbon capture, utilisation, and storage (CCUS) of methanol production in Japan will also be elaborated upon.

2. Literature Review on the Just Energy Transition in Japan

The first section of the literature review outlines the carbon-neutral policy in Japan, including CCUS technology. The second section covers the fiscal aspect of the carbon-neutral policy.

2.1. Carbon-Neutral Policy in Japan

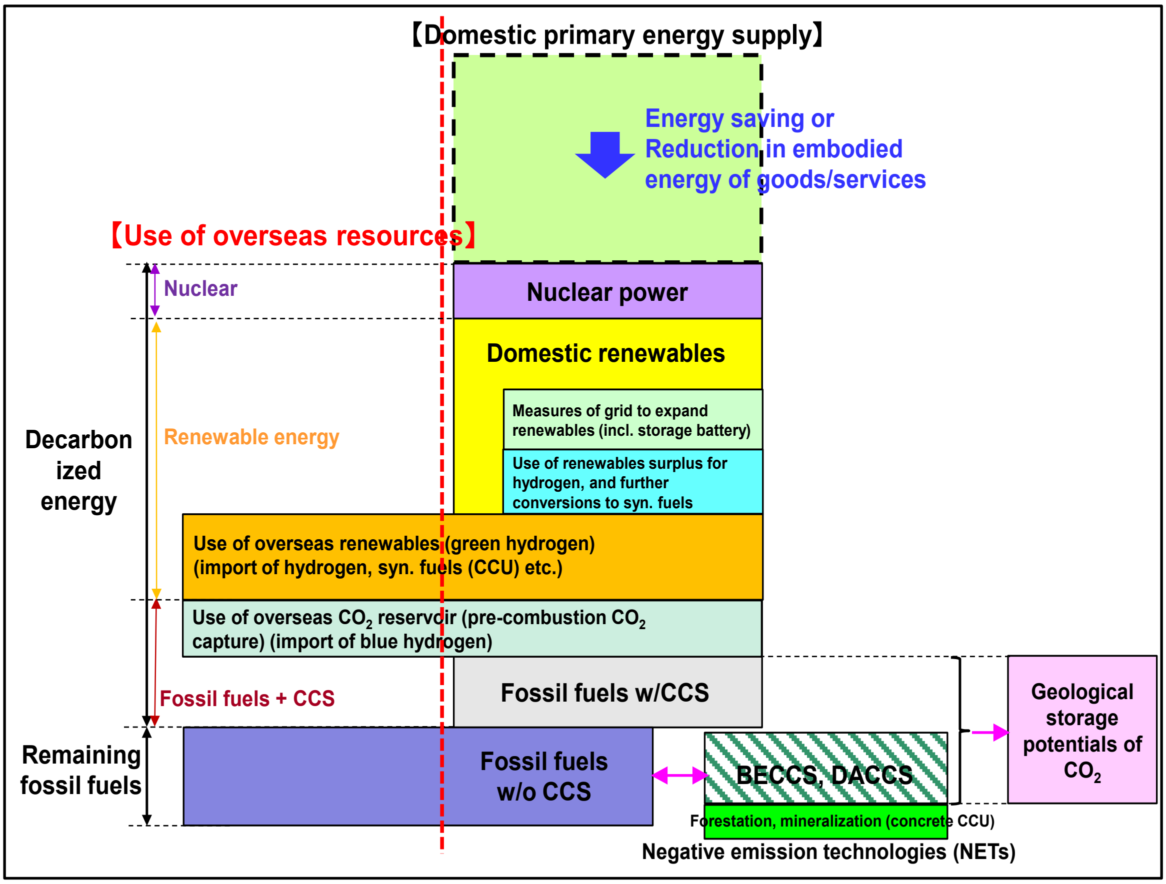
2.1.1. Green Growth Strategy

As one of the Group of Seven (G7) countries, Japan has been actively promoting decarbonisation to increase its competitiveness. Many other countries have also done this, announcing their GHG mitigation policy through carbon neutrality targets. During Yoshihide Suga's administration in 2020, Japan announced a carbon neutrality target to be reached by 2050. The Green Growth Strategy was announced in 2021 to break down the carbon neutrality target into greater detail. This was followed with a Basic Policy for Realising the Green Transformation (GX) Policy in 2022 (Gov. of Japan: METI, 2023b).

The 2021 Green Growth Strategy mentioned that carbon neutrality in 2050 would be achieved by increasing electrification in the building, industry, and transport sectors. Heat demand that cannot be electrified will rely on carbon-free fuel, hydrogen, and CO2 – carbon recycling from fossil fuels. Innovations in industrial process and technologies with negative emissions will be the next priority after electrification. The Research Institute of Innovative Technology for the Earth has been conducting scenario analysis for Japan towards carbon neutrality in 2050 (Akimoto et al., 2021). Figure 6.1 gives an overview of energy supply systems to achieve net-zero emissions, including the role of CCUS and carbon dioxide removals (CDR). The primary energy sources for carbon neutrality are renewable, nuclear, and fossil fuels, with carbon capture and storage (CCS). The CDR will be used to offset the fossil fuels without CCUS.

Since Japan is an island country, the power grid system is not connected to that of the rest of the world. Hence, pursuing other countries' hydrogen and hydrogen-based energy sources is more important. As a reference, renewable energy such as solar photovoltaic technology (solar PV), wind power, hydropower, geothermal, and biomass will contribute 50%-60% of power generation in 2050, 10% will come from hydrogen and ammonia fuel for power generation, and 30%-40% will come from nuclear power and thermal power plants with CO2 capture (Akimoto et al., 2021). It is necessary to introduce as much renewable energy as possible as a major power source and implement policy measures to drive innovation and societal implementation of all possible options: hydrogen, ammonia, and CCUS/carbon recycling, amongst others. To achieve carbon neutrality at a minimum cost, all the energy supply prices are expected to be reduced through technological innovation, cost reduction, and easing introduction restrictions.

Figure 6.1. Carbon Neutrality in Energy towards 2050 for Japan.



BECCS = bioenergy carbon capture and storage; CCS = carbon capture and storage; CCU = carbon capture and utilisation; CO_2 = carbon dioxide; DACCS = direct air carbon capture and storage; syn. = synthetic; w/o = without.
Source: Akimoto et al. (2021).

2.1.2. Green Transformation Policy

GX refers to transforming the entire economic and social system from an economy, society, and industrial structure dependent on fossil fuels to 'structures driven by clean energy' (Gov. of Japan: METI, 2023d). In 2022, the Government of Japan published the GX Policy with a detailed plan in the subsequent Basic Policy for GX Realisation (GX Basic Policy) in 2023. Its primary objective is to support a broader energy transition in Asia as both a lender and technology exporter. In short, this policy aims to drive economic growth and development by GHG mitigation. Five key initiatives are discussed to achieve ¥150 billion ($1 trillion)[2] of private and public investment for GX:

1. Growth-oriented carbon pricing (including GX Transition Bonds);
2. Integrated regulatory and assistance promotion measures;
3. New financing methods;
4. International development strategy, including the formation of the Asia Zero Emissions Community; and
5. Development of GX League (a forum for cooperation between companies, government, and academia).

GX Basic Policy outlines an ambitious plan for Japan's commitment to achieve 46% GHG emissions reduction by 2030 and carbon neutrality by 2050. It serves a dual purpose – climate change measures and economic sustainability – by ensuring the competitiveness of both industries and the nation. There are two important pillars of the GX Basic Policy: domestic renewable energy enhancement and leveraging global renewable energy, including hydrogen and fuel ammonia as energy storage. Hydrogen-based and biogenic fuels can play a role in reducing emissions. Apart from fuel usage, it is also feed stock for chemical products (e.g., methanol and ethanol). Carbon recycling (i.e., CCUS) is one of the key technologies for carbon neutrality.

2.1.3. Carbon Capture, Utilisation, and Storage

CCUS consists of two elements: CCU and CCS. CCU is the technology to utilise CO_2 to produce synthetic fuels, chemicals, cement, and agriculture products. Because CO_2 is part of fuel gas from industrial processes, capturing and recycling CO_2 is considered a circular economy. Some private actors, such as Mitsubishi Chemicals, have been on the front line of CCU. CCS can capture and store CO_2 not to be released into the atmosphere. Methods for the CO_2 capture include chemical and physical absorption and membrane separation.

In principle, Japan maximises renewable (domestic or imported) usage to reduce CO2 emissions. However, there are three key reasons for CCUS adoption:

1. Infrastructure constraints: CCUS can be easily adapted to the existing industry but adopting the new hydrogen-based renewable energy-based infrastructure, such as port or electrification infrastructure, is not simple.
2. Technology availability: The required technologies for emissions reduction vary

[2] Exchange rate in 2023: $1=¥150

depending on the industry and processes involved, and when multiple options are available, their maturity level also varies.

3. Level of funding: CCUS can be added relatively simply compared to new power generation, which requires 30–40 years of capital investment to implement renewable energy/hydrogen-based facilities.

An example of CCU is methanol production from hydrogen and CO2 conducted by Mitsubishi Chemical Group. In terms of CO2 storage, the government aims to achieve a target of 120–240 million tonnes of CO2 by 2050 by securing CO2 storage of 5 to 12 million tonnes of CO2 by 2030. The storage cost is expected to be reduced from ¥4,000/tonnes CO2 to ¥2,000/tonnes CO2 in 2030 and ¥1,000/tonnes CO2 in 2050 (MUFG, 2023). The private sector has already engaged in the CCU project and Mitsubishi Heavy Industry has a 70% share of the global market for CO2 capture facilities.

2.2. Fiscal Policy

2.2.1. The Green Innovation Fund

In 2021, the Green Growth Strategy established ¥2 trillion as the Green Innovation Fund. The New Energy and Industrial Technology Development Organisation operates the fund. To maximise the results of each project amidst intensifying competition for business leadership in the sector, the evaluation criteria for funding are:

1. potential for CO_2 reduction contribution and economic ripple effects;
2. the degree of technical difficulty and the possibility of practical application.(Policy support is based on this criterion); and
3. potential market growth and international competitiveness.

The Green Innovation Fund encourages the participation of small and medium enterprises and start-ups that support the base of the supply chain and play a role in creating new industries. This ¥2 trillion budget will encourage private investment of around ¥15 trillion in research and development (R&D) and equipment. It will also draw approximately $30.7 trillion (approximately ¥3,000 trillion) in global environmental, social, and governance (ESG) funds, and generate future income and employment for the Japanese economy.

The R&D tax expansion was also implemented due to the 2050 carbon neutrality policy. Enterprises can request tax deductions in corporate tax of up to 30% compared to 25% in the previous measure. This stimulates the desire for private companies to invest in carbon neutrality. Regarding green finance, the green bond market is expanding domestically and internationally, with annual domestic issuance exceeding ¥1 trillion in 2020. Transition finance funds GHG reduction efforts based on a long-term strategy to realise a decarbonised society. The government will promote initiatives to encourage private enterprises to actively invest in advanced equipment that contributes to low-carbon development by utilising a leasing method that is expected to encourage significant capital investment and aims to encourage investment of ¥150 billion or more.

In addition, the government will also provide risk money support to green ventures, including renewable energy businesses (e.g., offshore wind power), those that utilise low fuel consumption technology, and next-generation battery storage businesses. Government-owned banks such as the Development Bank of Japan have established the Green Investment Promotion Fund with a project scale of ¥80 billion. Japan Bank for International Cooperation also established the Post-COVID-19 Growth Facility with a project size of ¥1.5 trillion to support overseas development of quality infrastructure and other overseas business activities by Japanese companies working towards a decarbonised society.

To develop the International Financial Centre[3], the Financial Service Agency of Japan encouraged private industry to establish a certification mechanism for evaluating the eligibility of green bonds. An external organisation provides objective certification of the eligibility of green bonds. The Financial Services Agency and other independent organisations will examine the nature of ESG evaluation organisations (e.g., transparency and governance) in light of some comments that external evaluation methods for ESG are not always clear.

2.2.2. The Green Transformation Fund

The budget for the green transformation is ¥150 trillion for ten years (2023–2033) (GR, 2023) (Table 6.1). There are five targets in the energy sectors: 1) reach 38% renewable energy in power by 2030, 2) install 10 gigawatts (GW) of wind power and 118 GW of solar power by 2030, 3) increase nuclear power to 22% of by 2030, 4) lower the cost of hydrogen by ¥30 by 2030, and 5) build CCUS facilities to capture 140 million tonnes of CO2 by 2050.

[3] Further information about this centre can be found at: https://www.fsa.go.jp/internationalfinancialcenter/

Table 6.1. Green Transformation Budget Commitment

Focus	Approx. 17 Trillion JPY (Annual)	150 Trillion JPY investment in 10 years Examples of planned investments	Investment Cost
Decarbonisation of power supplies	5 Trillion JPY (Annual)	• Renewable energy (Implementation through FIT/FIP framework) • Hydrogen, Ammonia (Investment in infrastructure development) • Battery production (For vehicles and fixed-ground use)	2 Trillion JPY 0.3 Trillion JPY 0.6 Trillion JPY
Decarbonisation of manufacturing processes	2 Trillion JPY (Annual)	• Decarbonisation of manufacturing processes (e.g., Next-generation manufacturing process technology, carbon neutral power generation facilities) • Installation of industrial heat pumps and cogeneration facilities	1.4 Trillion JPY 0.5 Trillion JPY
End-use sector	4 Trillion JPY (Annual)	• Introduction of energy-efficient homes and buildings • Introduction of next-generation vehicles	1.8 Trillion JPY 1.8 Trillion JPY
Infrastructure development	4 Trillion JPY (Annual)	• Grid reinforcement cost (Masterplan) • Automobile infrastructure development (Charging station, Hydrogen station) • Digital society infrastructure developments (Semiconductor manufacturing facilities, data centers)	0.5 Trillion JPY 0.2 Trillion JPY 3.5 Trillion JPY
R&D	2 Trillion JPY (Annual)	• Carbon recycling (e.g., CCS, methanation, synthetic fuel, SAF) • Development of carbon-neutral manufacturing processes (e.g., hydrogen reduction steelmaking). • Nuclear (R&D on next-generation nuclear plants) • Implementation of advanced CCS projects	0.5 Trillion JPY 0.1 Trillion JPY 0.1 Trillion JPY 0.6 Trillion JPY

¥ = Japanese yen; CCS = carbon capture and storage; FIT/FIP =feed in tariff/feed in premium; R&D = research and development.
Source: GR Japan (2023).

The CCUS value chain will require ¥4 trillion between 2023 and 2033. To achieve the CCS target of 120–240 million tonnes of CO2/year, however, (approximately 10%–20% of Japan's emissions target), tens of trillions more will be required. There is a supply-side challenge with synthetic fuels, such as establishing manufacturing capacity and developing CO2 counting rules. The GX budget also indicates that funding of ¥3 trillion will be needed over the next 10 years in addition to the CCUS supply chain.

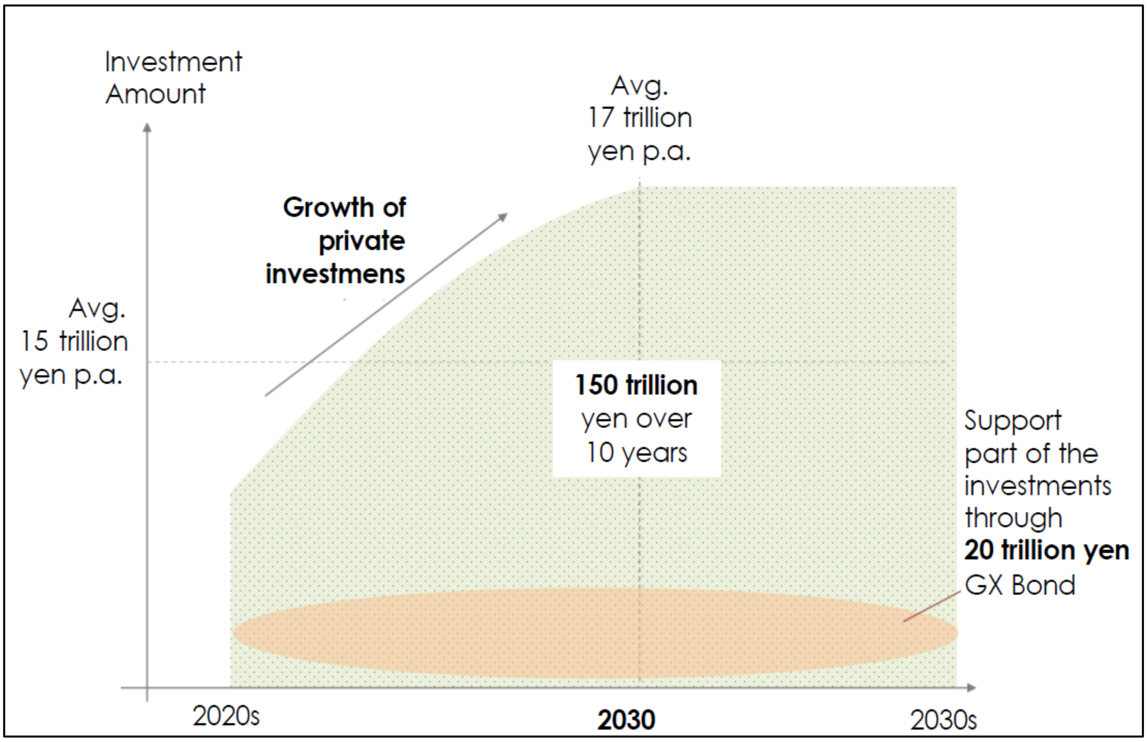
There are two aims within the Basic Policy for GX: ensuring a stable energy supply and realising and implementing the 'Pro-Growth Carbon Pricing Concept' and other initiatives. The first aim requires the expansion of renewable energy domestically and globally. The second aim relates to carbon pricing. There are four pillars to carbon pricing:

1. Upfront investment support by utilising the GX Economic Transition Bond (GX Bond): The initial investment of ¥20 trillion (about $144 billion) will be implemented to form long-term support measures and increase predictability for the private sector. Figure 6.2 shows the relationship between the GX Transition Bond and the GX Fund.
2. GX Investment incentives through carbon price to incentivise businesses to undertake GX: For example, the emissions trading scheme will be implemented in phases for high GHG emissions sectors through voluntary carbon trading

amongst the GX League. Carbon levies targeting fossil fuel importers such as power, oil, and gas companies will also be implemented. These have been introduced at an affordable rate initially. The price will be reviewed annually with a gradual increase to incentivise GX investments to reduce reliance on fossil fuels.

3. Utilisation of new financial instruments: The GX promotion organisation will consider and implement supplementary measures to address risks during the gradual social implementation of GX technologies to accelerate investment into GX. An environment will be created to promote sustainable finance, including disclosures of climate change-related information, and to strengthen efforts towards an international understanding of transition finance.
4. International strategy, Just Transitions, and GX of small and medium enterprises and others: The global market expansion will focus on green products such as steel, plastic, carbon-neutral fuel, industrial heat pumps, etc. This has also led to discussion about Japan's technological advantages, such as CDR technologies and next-generation reactors through the United States (US), Japan, and other partnerships. In Asia, Japan will focus on the Asia Zero Emissions Community as a regional platform; the Joint Crediting Mechanism to reach partnerships with 25 countries by 2025 and expand the CCS project; and the Asia Energy Transition Initiative with $10 billion for technology development and deployment, such as renewable energy, liquified natural gas, CCUS, ammonia, and hydrogen.

Figure 6.2. Green Transformation Transition Bond



¥ = Japanese yen, Avg. = average; GX = Green Transformation; p.a = per annum.
Source: GR Japan (2023).

3. Methodology

3.1. Green Economy Transition Outlook in the Group of Seven

To understand the current progress of green economy transition, this section assesses sustainable energy for all and energy and fiscal policies in Japan and its G7 peers through various indicators, namely the World Bank's Sustainable Energy for All (SE4ALL), Regulatory Indicators for Sustainable Energy (RISE), and Government Policy Indicators (GPI) of the International Monetary Fund (IMF) (Table 2). SE4ALL indicators illustrate the current energy situation, particularly renewable energy, from the demand and supply sides, whereas RISE and GPI show governments' commitments and efforts to achieve SE4ALL. Comparing the trends of the selected indicators to the benchmark countries provides insights into areas of policy that Japan should focus on and invest in more, to catch up with other G7 countries.

3.1.1. Sustainable Energy for All

In response to the SE4ALL initiative by the United Nations Secretary-General, the World Bank created a SE4ALL database with a set of country-level indicators on electricity, non-solid fuel, renewable energy, and overall energy to monitor SE4ALL's global objectives. The objectives include 1) to ensure universal access to modern energy services, 2) to double the global rate of improvement in global energy efficiency, and 3) to double the share of renewable energy in the global energy mix (World Bank, 2023a) (Table 2). Despite its usefulness, the SE4ALL database was discontinued in 2016. This study follows the proposed set of indicators and compiles SE4ALL data from the World Bank's Open Data (Energy & Mining) and the Organisation for Economic Co-operation and Development's (OECD) renewable energy data to generate up to date SE4ALL data. Some original indicators, such as energy intensity and renewable energy output, have been adjusted depending on data availability.

According to the World Bank (2023a), the definition of each indicator is as follows:

- Access to electricity (% of rural population with access): Percentage of rural population with access to electricity.
- Access to electricity (% of total population): Percentage of total population with access to electricity.
- Access to electricity (% of urban population with access): Percentage of urban population with access to electricity.
- Energy intensity level of primary energy (MJ/2011 $PPP): A ratio between energy supply and GDP measured at purchasing power parity. Energy intensity indicates how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one output unit.

- **Renewable electricity output (GWh)**: Electric output (GWh) of power plants using renewable resources, including wind, solar PV, solar thermal, hydro, marine, geothermal, solid biofuels, renewable municipal waste, liquid biofuels, and biogas. Electricity production from hydro-pumped storage is excluded.
- **Renewable electricity share of total electricity output (%)**: Electricity generated by power plants using renewable resources as a share of total electricity output.
- **Renewable energy consumption (Terajoule)**: This indicator includes energy consumption from all renewable resources: hydro, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine, and waste.
- **Renewable energy share of total fine energy consumption (%)**: Share of renewable energy in total final energy consumption.
- **Total electricity output (GWh)**: Total GWh generated by all power plants.
- **Total final energy consumption** : This indicator is derived from energy balance statistics and is equivalent to total final consumption, excluding non-energy use.

Table 6.2. Selected Indicators for Analysis

Sustainable Energy for All – Sustainable Energy Situation	
Original Set of Indicators	Adjusted Indicators (Authors' Compilation)
1. Access to clean fuels and technologies for cooking (% of total population)	Unchanged
2. Access to electricity (% of rural population with access)	Unchanged
3. Access to electricity (% of total population)	Unchanged
4. Access to electricity (% of urban population with access)	Unchanged
5. Energy intensity level of primary energy (MJ per 2011 USD PPP)	Energy intensity level of primary energy (MJ per 2017 $PPP)
6. Renewable electricity output (GWh)	Total renewable energy (KTOE)
7. Renewable electricity share of total electricity output (%)	Renewable energy share of primary energy supply
8. Renewable energy consumption (TJ)	Unavailable
9. Renewable energy consumption share of TFEC	Renewable energy consumption share of TFEC

10.Total electricity output (GWh) 11.TFEC (TJ)	Unavailable Unavailable
Regulatory indicators for sustainable energy – energy policies	
1. Electricity access 2. Clean cooking 3. Renewable energy a. Legal framework for renewable energy b. Planning for renewable energy expansion c. Incentives and regulatory support for renewable energy d. Attributes of financial and regulatory incentives e. Network connection and use f. Counterparty risk g. Carbon pricing and monitoring 4. Energy efficiency a. National energy efficiency planning b. Energy efficiency entities c. Incentives & mandates: industrial and commercial end users d. Incentives & mandates: public sector e. Incentives & mandates: energy utility programmes f. Financing mechanisms for energy efficiency g. Minimum energy efficiency performance standards h. Energy labelling systems i. Building energy codes j. Transport sector k. Carbon pricing and monitoring mechanism	
Government policy indicators – fiscal policies	
1. Fossil fuel subsidies (% of GDP) 2. Fossil fuel subsidies ($ at constant 2021 prices) 3. R&D environmental protection expenditure (% of GDP) 4. Environmental taxes (% of GDP)	

$ = US dollar; GDP = gross domestic product; GWh = gigawatt hours; KTOE = kilotonnes of oil equivalent; MJ = megajoules; PPP = purchasing power parity; R&D = research and development; TFEC = total final energy consumption; TJ = terajoule.
Source: Authors compilation.

3.1.2. Regulatory Indicators for Sustainable Energy

RISE is designed to facilitate cross-country comparisons of policy frameworks supporting universal access to clean energy as outlined in Sustainable Development Goal (SDG) 7. It analyses national legislation, policies, and strategies over 140 economies as of 31 December, 2021. It assesses their progress through 30 key indicators categorised under four pillars—electricity access, clean cooking, renewable energy, and energy efficiency. The score of each indicator and pillar ranges from 0 to 100 and can be segmented into three categories—green (67–100), indicating mature policies with room for improvement; yellow (33–67), representing developing frameworks; and red (0–33), signifying early-stage adoption (ESMAP, 2022).

3.1.3. Fiscal Policies

Governments rely on tax and expenditure policies as key instruments to combat environmental issues, particularly climate change. Environmental taxes disincentivise environmentally harmful practices while generating government revenues to invest in and subsidise economic and technological choices that positively affect the environment, e.g. public investments in eco-friendly infrastructure, subsidies to encourage renewable energy adoption, and adaptation spending for climate resilience (IMF, 2022).

As RISE documents the existence of legislation, policies, and strategies regardless of their enforcement, it is important to recognise that it may not fully capture the nuanced quality of policy content and is not an indicator of progress toward SDG 7 (World Bank, 2023a). The information regarding fiscal policies that address environmental issues such as renewable energies record actual policy implementation and the government's commitment to, and priorities for, the transition to a green economy. They thus, supplement the RISE analysis. From 2005 to 2025 the IMF created a climate change dashboard that provided international statistical data on key GPIs, including fossil fuel subsidies, environmental taxes, and government expenditure on R&D environmental protection, depending on each indicator's data availability and forecasts.

According to the IMF (2022), the definition of each indicator is as follows:

- An environmental tax represents a fee imposed on a specific product unit with an adverse environmental impact.
- Government expenditure on environmental protection illustrates each government's monetary allocation to environmental preservation activities, presented as a percentage of the country's GDP. These activities are part of a predefined range of actions outlined within the Classification of Functions of Government Framework. They encompass pollution reduction, biodiversity conservation, and waste management.

- **Fossil fuel subsidies** demonstrate the approximate worth of explicit and implicit government subsidies linked to fossil fuels (such as coal, natural gas, petroleum, and electricity). Explicit subsidies denote the under-pricing resulting from supply costs surpassing the prices paid by consumers. Implicit subsidies signify the variance between supply costs and socially optimal prices (considering the negative impacts of fossil fuel usage and the revenue loss from consumption taxes), excluding explicit subsidies. The total subsidies comprise both implicit and explicit subsidies. It is crucial to distinguish this economic concept and the estimates based on models from subsidies defined in government financial statistics.

3.2. Techno-Economic Analysis of Carbon Capture, Utilisation and Storage

The learning curve phenomenon has been commonly used for emerging hydrogen or solar PV technologies (Jupesta et al., 2022). This curve was first observed and documented in the 19th century by German psychologist Hermann Ebbinghaus. He described learning as an exponential process, meaning that the fastest learning occurs in the beginning and that exponentially more effort is required for subsequent increases in learning. Ebbinghaus was the first researcher to mathematically document the learning process in an experiment he conducted (Junginger and Louwen, 2020). The most widely used model in energy literature to forecast changes in technology costs is the 'one-factor learning curve.' This formulation is derived from empirical observations across various energy technologies that frequently indicate a log-linear relationship between the unit cost of the technology and its cumulative output (production) or installed capacity (Rubin, Davison, and Herzog, 2015). The future costs are estimated using the concept of learning-by-doing, discussed by (Ferioli, Schoots, and van der Zwaan, 2009). This can be quantitatively expressed as:

$$C_{x_t} = C_{x_0} \left(\frac{x_t}{x_0}\right)^b \quad (1)$$

Where x_0 represents carbon capture in t CO2 in year 2020 (year 1)

x_t represents carbon capture in t CO2 in year t

C_{x_0} is a unit cost of a product, process or technology in year 1

C_{x_t} is a unit cost of a product, process or technology in year t

b is a positive learning parameter.

Moreover, the fractional reduction in cost associated with a doubling of installed capacity is referred to as the learning rate and is given by:

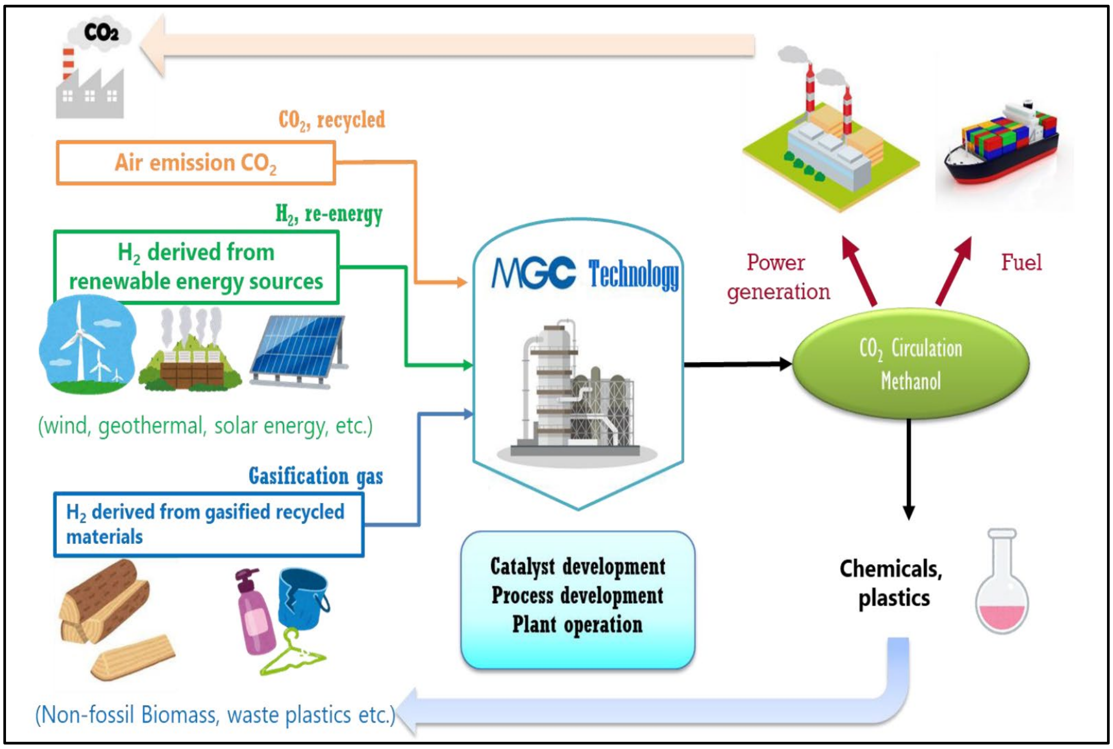
$LR = 1 - 2^b$ (2)

The case study is from the methanol production from Mitsubishi Chemical Group (2023), as depicted in Figure 6.3. For this study, there are three scenarios based on the learning rate for the methanol plant: Scenario 1 is learning rate 11.95% (50% of the LR of solar PV) (Junginger & Louwen, 2020), Scenario 2 is learning rate 23.9% (100% of the LR of solar PV), and Scenario 3 is learning rate 35.85%. (150% of the LR of solar PV).

Figure 6.3 has three elements: recycling CO_2, hydrogen from gasification gas, and hydrogen from renewable energy. All these elements will become feed stock for the methanol plant. The CO_2 source was obtained from industrial processes, including the hard-to-abate industries (chemical, iron/steel, and cement). The fuel gas from this industry has a high CO_2 concentration of 20%–30% compared with the air (440 ppm); hence, the absorption of CO_2 will need less energy compared with direct air capture. Hydrogen is obtained from renewable energy sources or water photolysis. Table 6.3 shows the input data on CO_2, hydrogen, and methanol production costs.

To reduce the CO_2 emissions from industry, they will be recycled and reused to produce fuel such as methanol. Methanol is useful for various products, chemicals, plastics, fertilisers, and fuel. This study specialises in maritime fuel demand since this sector is a hard-to-abate industry and is getting more attention nowadays. While all supply chains need long freight maritime ships, the GHG emissions from the shipping sector will influence global trade. The techno-economic analysis is an analysis of the costs during the production process. There are four production processes of the elements for the methanol in this study: recycled CO_2, hydrogen from renewable energy, hydrogen from gasification gas, and plant operation by a mixture of all three elements.

Figure 6.3. Carbon Capture and Utilisation in Methanol Production



CO_2 = carbon dioxide; H_2 = hydrogen; MGC = Mitsubishi Gas Chemical.
Source: MGC (2023).

Table 6.3. Cost of Methanol Production

Inflow/Outflow	Mass Balance (t/t methanol)	Cost (US$/t methanol)	References
Inlet CO_2	1.46	10.88	Morimoto et al. (2022)
Inlet H_2	0.199	228.83	Galimova et al. (2023)
Inlet air to the furnace	0.813		
Outlet methanol	1	357	Statista (2023)
Outlet H_2O	0.569		
Flue gas from the furnace	0.905		
Production	Energy Balance (MWh/t methanol)	Cost ($/t methanol)	
Electricity consumption	0.169		
Heating needs	0.169		
Cooling needs	0.169		
Total energy	0.507	70.64	Global Petrol Prices, (2023)

$ = US dollar; CO2 = carbon dioxide; H2 = hydrogen; H2O = water; MWh = megawatt hours; t =tonne '
Source: Perez-Fortez et al. (2016).

4. Results and Discussions

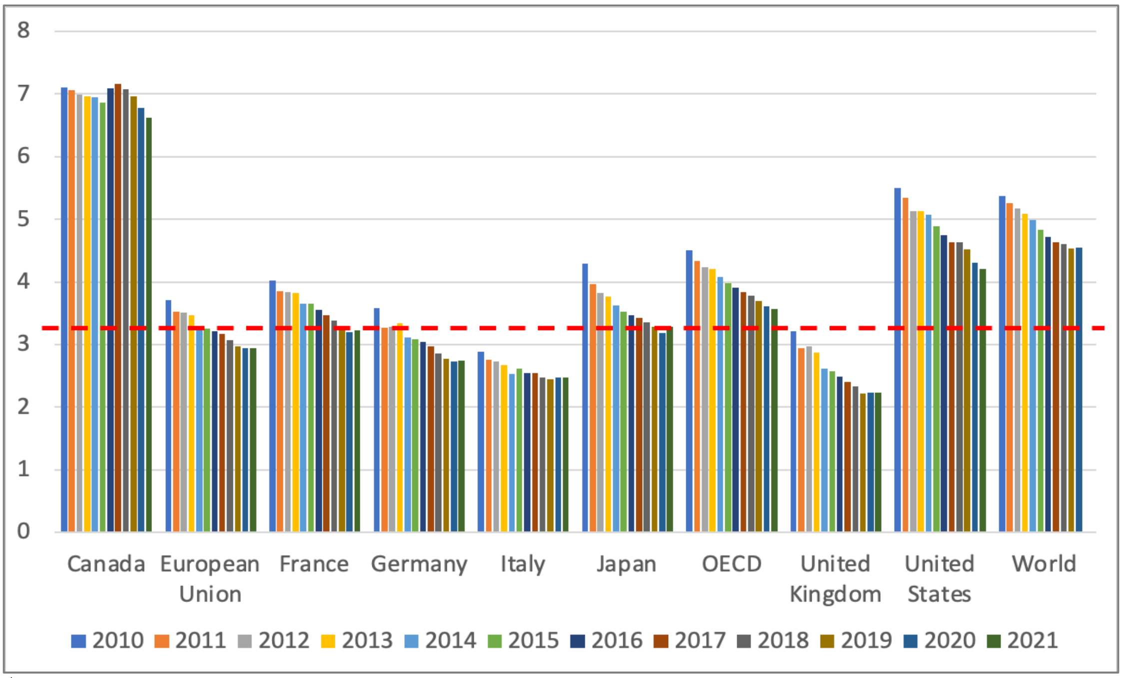
4.1. Economic Analysis of the Group of Seven Countries

4.1.1. Sustainable Energy for All

Access to modern energy services is not an issue for the G7. The G7 economies provide universal access to electricity (100% of the population), clean fuels, and cooking technologies in urban and rural areas. The world average for this provision is 51% in rural areas and 87% in urban areas (World Bank, 2023a).

For the past decade, the decline in the energy intensity level of primary energy has been observable amongst the G7 (Figure 6.4). However, Japan has been ranked as the third- or fourth-largest country amongst the G7 that utilises more energy to produce a unit of economic output, i.e., a higher energy intensity level. As energy intensity level is the ratio between energy supply and GDP measured at purchasing power parity, Japan's relatively high energy intensity level possibly indicates 1) the country's lower energy efficiency technologies for consumption and production, 2) lower commitment to promoting energy-saving behaviours, technologies, and systems, e.g. energy, transport, industry, food, and land use (UN DESA and UNFCCC, 2022), or 3) more energy consumption for non-economic activities that do not contribute to GDP.

Figure 6.4. The Energy Intensity Level of Primary Energy
(Megajoules per Gross Domestic Product (Measured at 2017 $ Purchasing Power Parity))

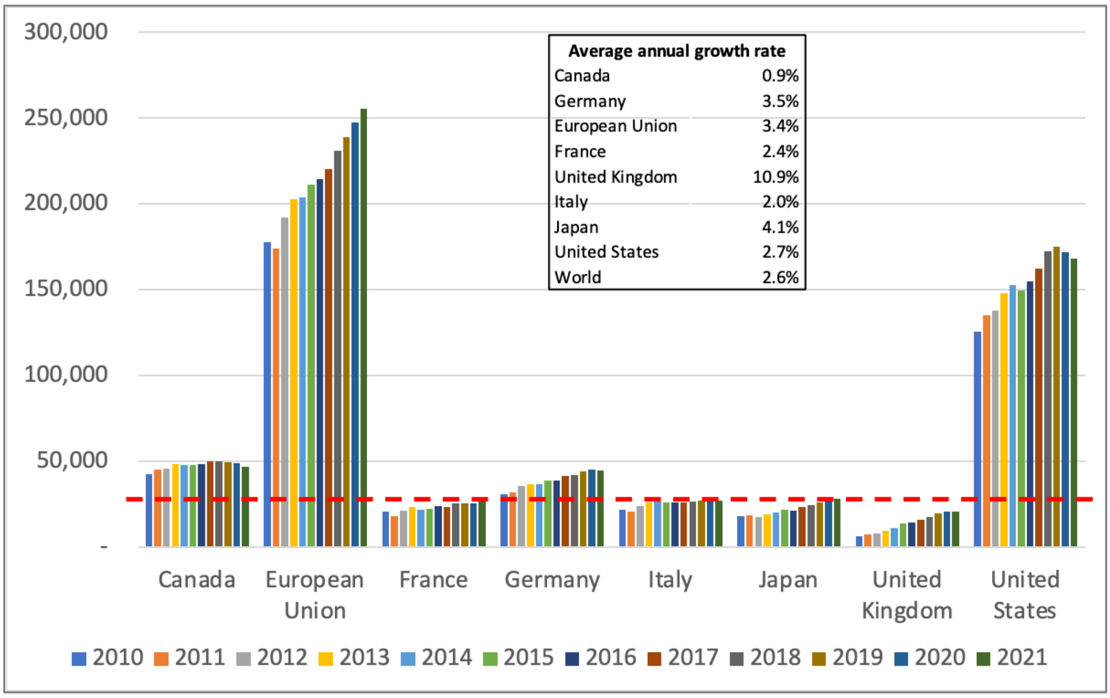


$ = US dollar; GDP = gross domestic product; MJ = megajoule; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.
Source: Author's calculations, based on World Bank (2023b).

In terms of the production and consumption of renewable energy, Japan performs the worst amongst the G7. This leads to questions over its commitment to sustainable energy for all and its ability to meet the SDG targets, particularly SDG 7.2: 'By 2030, increase substantially the share of renewable energy in the global energy mix.' In response to SDG 7.2, Japan's Sixth Strategic Energy Plan states that 36%–38% of the country's power generation mix should come from renewable energy by 2030 (Gov. of Japan: METI, 2021).

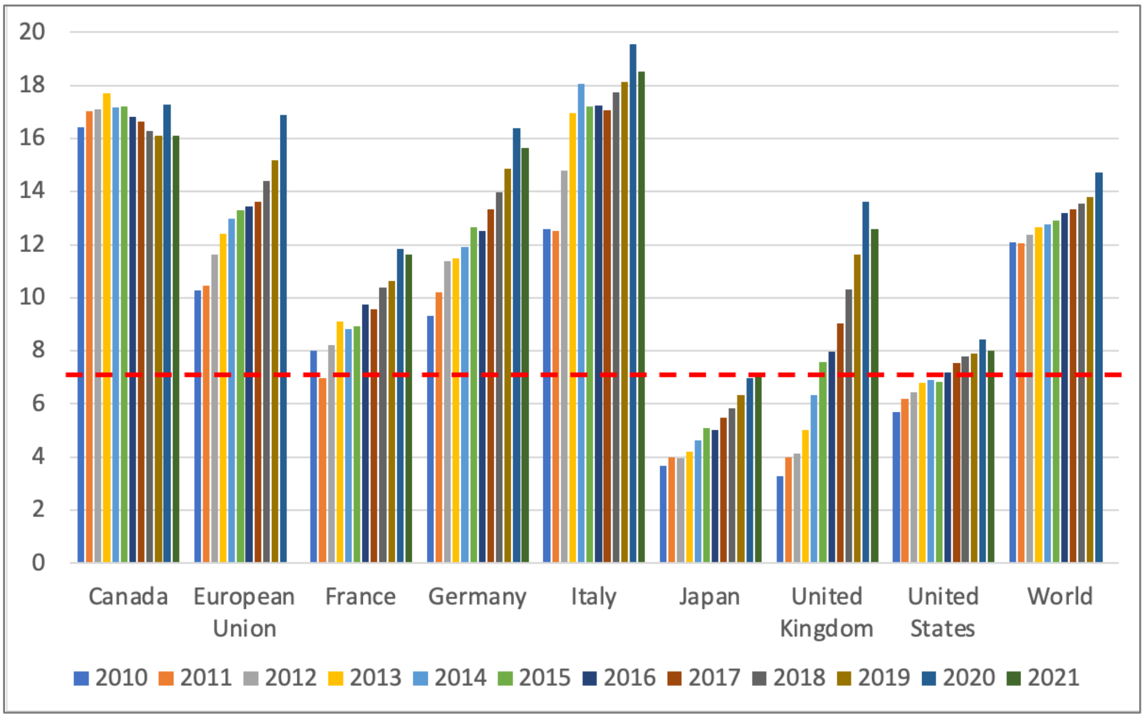
Despite the high growth of Japan's renewable energy supply, the shares of renewable energy in total energy supply and consumption are the lowest amongst the G7. Japan's renewable energy supply grows 4.1% annually, from 18,368 kilotonnes of oil equivalent in 2010 to 28,457 kilotonnes of oil equivalent in 2021. The growth is faster than in most G7 countries, behind only the United Kingdom (10.9%) (Figure 6.5). Even though Japan's renewable energy supply has been lower than that of France and Italy for the last decade, it outweighed the supplies of both countries in 2021. The rising shares of renewable energy production and consumption have also been observable during the same period due to the growth in renewable energy supply (Figures 6.4 and 6.5). Nevertheless, the share of renewable energy in the Japanese energy mix is less than 10% in production and consumption, lower than the rest of the G7. While Figure 6.5 shows the increase in renewable energy supply with high growth, the increase cannot catch up with the faster growth of energy demand illustrated by the small shares of the national energy mix in Figures 6.6 and 6.7.

Figure 6.5. Renewable Energy Supply
(Kilotonnes of oil equivalent)



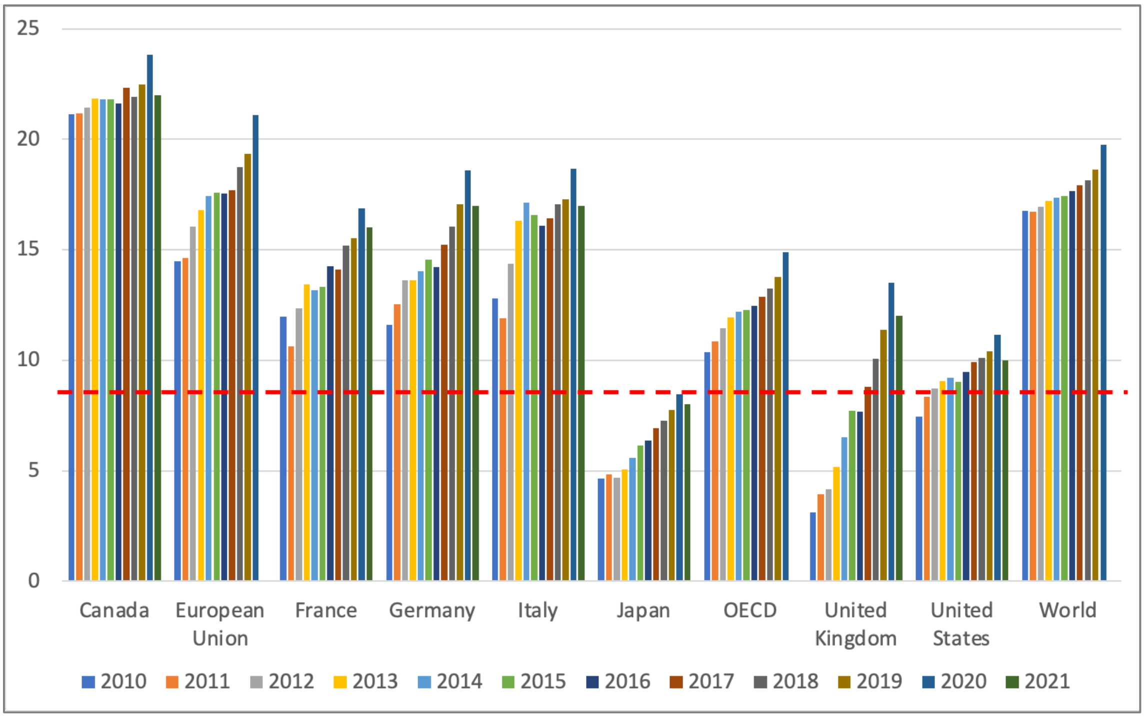
Source: Author's calculations, based on OECD (2023).

Figure 6.6. Renewable Energy Supply
(% of primary energy supply)



Source: Author's calculations, based on OECD (2023).

Figure 6.7. Renewable Energy Consumption
(% of total final energy consumption)



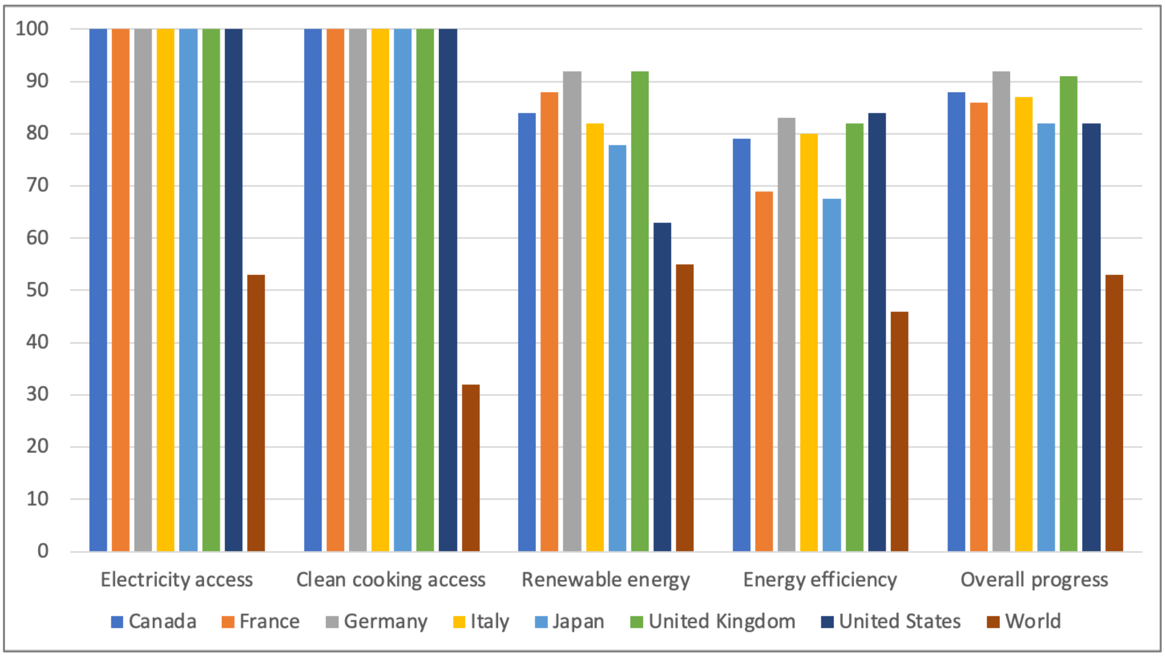
Source: Author's calculations, based on World Bank (2023b).

4.1.2. Regulatory Indicators for Sustainable Energy

Japan's overall progress on sustainable energy regulation lags behind the rest of the G7. Its overall score is 82, the same as the US (Figure 6.6). Consistent with the SE4ALL indicators, Japan and the other G7 economies' scores relating to regulations regarding access to modern energy services, i.e., electricity and clean cooking, reach the maximum score, ensuring universal access to the services. In contrast, the global average for these scores is 53 for electricity access and 32 for clean cooking (Figure 6.8).

In terms of renewable energy policy and regulation, Japan (78) scores 4, which is 14 points lower than the other G7 members, except the US (63), making it the second-worst performing country amongst the G7 (Table 6.4). Japan's lower than average score for renewable energy is primarily due to low scores achieved on Indicator 5: Network Connection and Pricing (57). This is particularly noticeable in the areas of connection, where, for example, there is no grid code that specifies connection procedures, and cost allocation and there is a lack of real-time dispatch operation.

Figure 6.8. Progress on Sustainable Energy Regulation by Pillar



Source: Authors calculations, based on ESMAP (2022).

Table 6.4. Renewable Energy Policy and Regulation Pillar

Country	Indicator 1: Legal framework for renewable energy	Indicator 2: Planning for renewable energy expansion	Indicator 3: Incentives and regulatory support for renewable energy	Indicator 4: Attributes of financial and regulatory incentives	Indicator 5: Network connection and pricing	Indicator 6: Counterparty risk	indicator 7: Carbon pricing and monitoring mechanism
Canada	80	79	89	82	81	75	100
France	100	92	74	100	66	82	100
Germany	100	96	94	82	87	85	100
Italy	80	96	85	55	94	67	100
Japan	80	75	79	82	57	77	100
United Kingdom	80	100	94	100	94	75	100
United States	56	59	56	31	77	63	100

Source: Authors, based on ESMAP (2022).

Similarly, Japan's average score for energy efficiency (68) trails behind the G7's average score by ten points, sitting at the bottom of the league table (Figure 6.6). Relatively low scores on incentives and mandates (Indicators 4 and 5), financing mechanisms (Indicator 6), and building energy codes (Indicator 9) contribute to Japan's weak performance in this pillar (Table 6.4). Japan's incentive and mandate regulations regarding energy utility programmes and the public sector are at an early stage. Several mechanisms and measures are missing, such as regulations for transmission and distribution networks, demand-side management and demand-response, cost recovery, and utility consumer pricing and information. Like the other G7 economies, insufficient financing mechanisms for energy efficiency are evident in Japan. The country has not adopted on-bill financing and repayment; green or energy efficiency bonds; credit lines and revolving funds for energy efficiency activities; and partial risk guarantees in residential, commercial, and industrial sectors.

In contrast to the other G7 countries, Japan's residential sector adopts more mechanisms that are less available to the commercial and industrial sectors, such as discounted green mortgages. In addition, building energy codes is another area in which Japan does not perform well (Table 6.5). The building energy standards are not regularly updated, and building energy information is not disclosed in the residential and commercial sectors.

Table 6.5. Energy Efficiency Policy and Regulation Pillar

Country	Indicator 1: National energy efficiency planning	Indicator 2: Energy efficiency entities	Indicator 3: Incentives & mandates: industrial and commercial end users	Indicator 4: Incentives & mandates: public sector	Indicator 5: Incentives & mandates: energy utility programs	Indicator 6: Financing mechanisms for energy efficiency	Indicator 7: Minimum energy efficiency performance standards	Indicator 8: Energy labeling systems	Indicator 9: Building energy codes	Indicator 10: Transport sector	indicator 11: Carbon pricing and monitoring mechanism
Canada	100	75	67	100	35	52	90	92	75	83	100
France	93	92	75	75	39	25	83	50	81	50	100
Germany	89	100	100	63	30	60	92	100	77	100	100
Italy	82	100	63	100	73	43	90	50	79	100	100
Japan	78	67	75	38	31	35	92	96	58	83	100
United Kingdom	89	100	100	88	72	43	78	88	84	67	100
United States	78	87	100	80	51	58	88	87	90	100	100

Source: Authors, based on ESMAP, (2022).

Figure 6.9 shows a positive relationship between renewable utilisation and the G7 economies' scores on the renewable energy regulation pillar. On average, the renewable energy share of the primary energy supply and the renewable energy consumption share of total fine energy consumption tend to rise with the progress in renewable energy regulation. It is possible that regulatory efforts to plan for renewable energy expansion in Canada, Germany, and Italy provide incentives and regulatory support for renewable energy. The efforts, in turn, develop better network connections and pricing mechanisms, positively affecting renewable utilisation (Table 4). However, Japan and the US perform poorly in these areas, resulting in the lowest renewable energy shares in production and consumption.

Figure 6.9. Correlation between Renewable Utilisation and Progress on Renewable Energy Regulation amongst the Group of Seven Economies, 2021

a. Renewable Energy Share of Primary Energy Supply

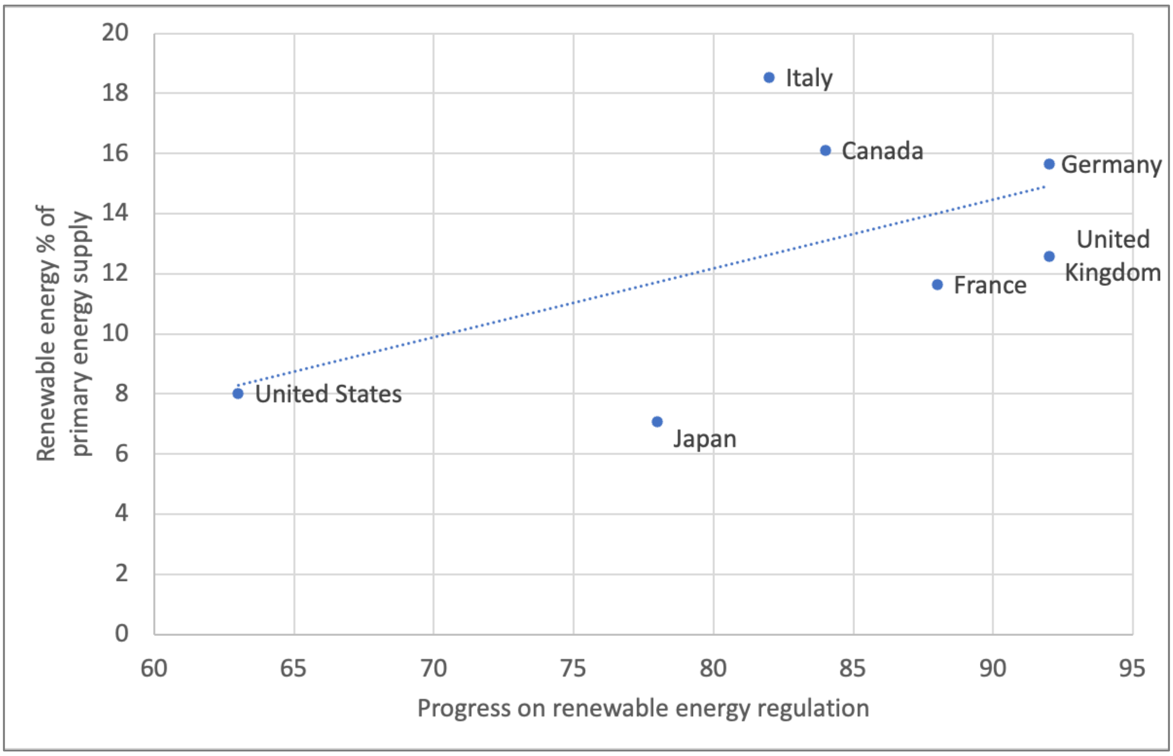
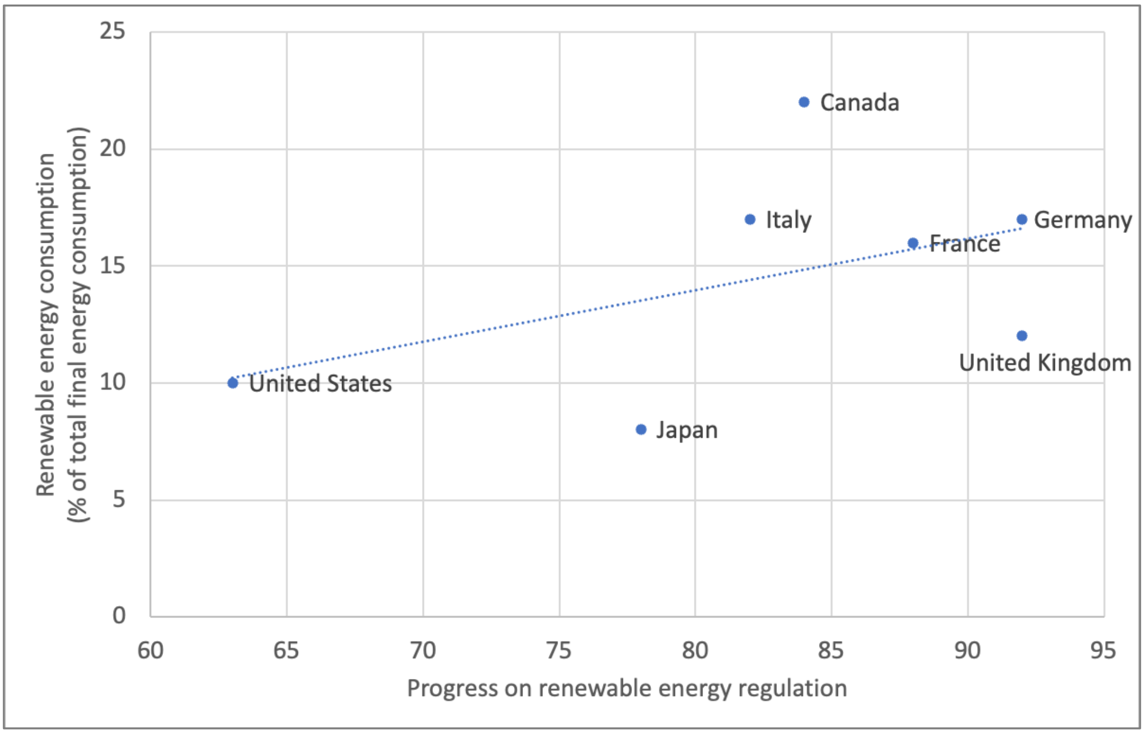


Figure 6.9. *Continued*

b. Renewable Energy Consumption

(% of total final energy consumption)



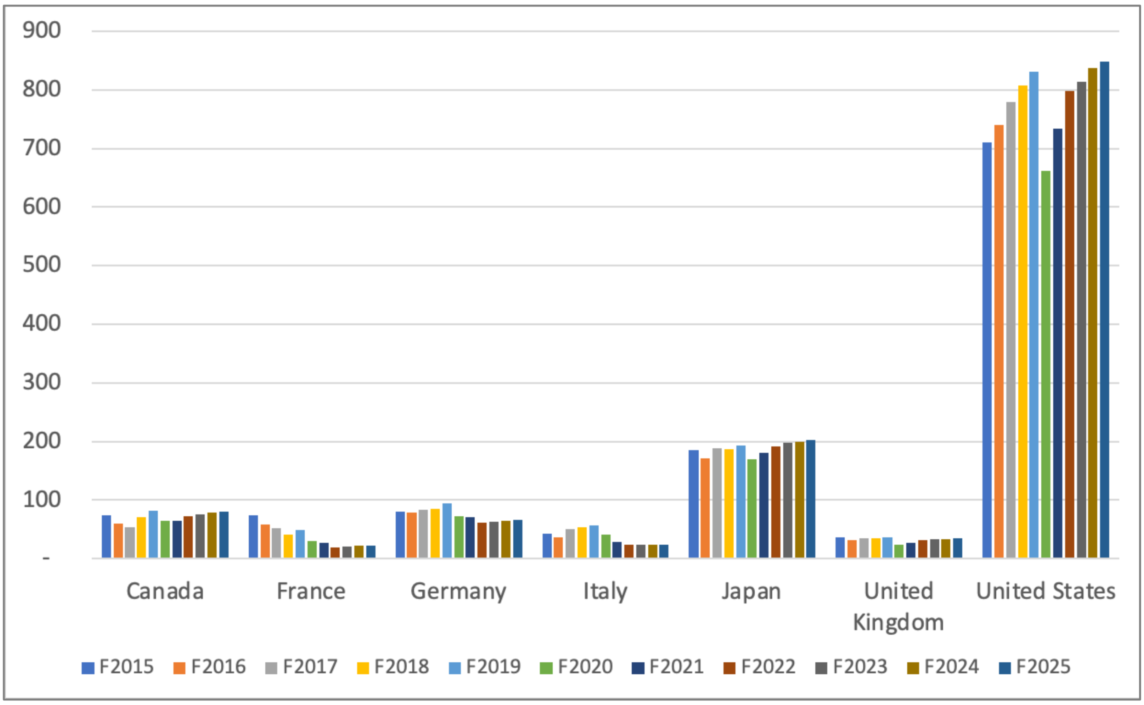
Source: Authors calculations, based on OECD, (2023) and ESMAP, (2022).

4.1.3. Fiscal Policies

Figures 6.10 and 6.11 show the estimated value of explicit and implicit government subsidies related to fossil fuels, including coal; natural gas; petroleum; and electricity; and their share of GDP. There was a sharp drop in the subsidies due to the COVID-19 pandemic amongst G7 economies. However, the subsidies constantly grow after 2021 in most countries, especially Canada, Japan, and the US, representing the top three within the G7. Figure 6.11 illustrates a similar trend, showing the rising subsidies one or two years after the COVID-19 pandemic, accounting for approximately 3.5% of GDP in Canada, Japan, and the US, the highest share amongst the G7.

Subsidies aim to ensure that all consumers have access to, or can afford, a particular product or service, in this case, fossil fuel, through market distortions, resulting in inefficient resource allocation and fiscal burdens. Greater fiscal burdens may force the government to raise taxes, increase borrowing (to continue subsidising fossil fuels), or cut spending (on renewable energy-related policies). Literature reveals that fossil fuel subsidies cause fossil fuel overconsumption with environmental externalities (Burniaux and Chateau, 2014; Schwanitz et al., 2014) and hinder the development of low-carbon technological substitutes, e.g. renewable energy and the overall green economy transition (Bridle and Kitson, 2014; Merrill et al., 2015; Schmidt, Born, and Schneider, 2012). Figure 6.14a indicates a negative relationship between renewable utilisation and fossil fuel subsidies amongst the G7, supporting the existing literature.

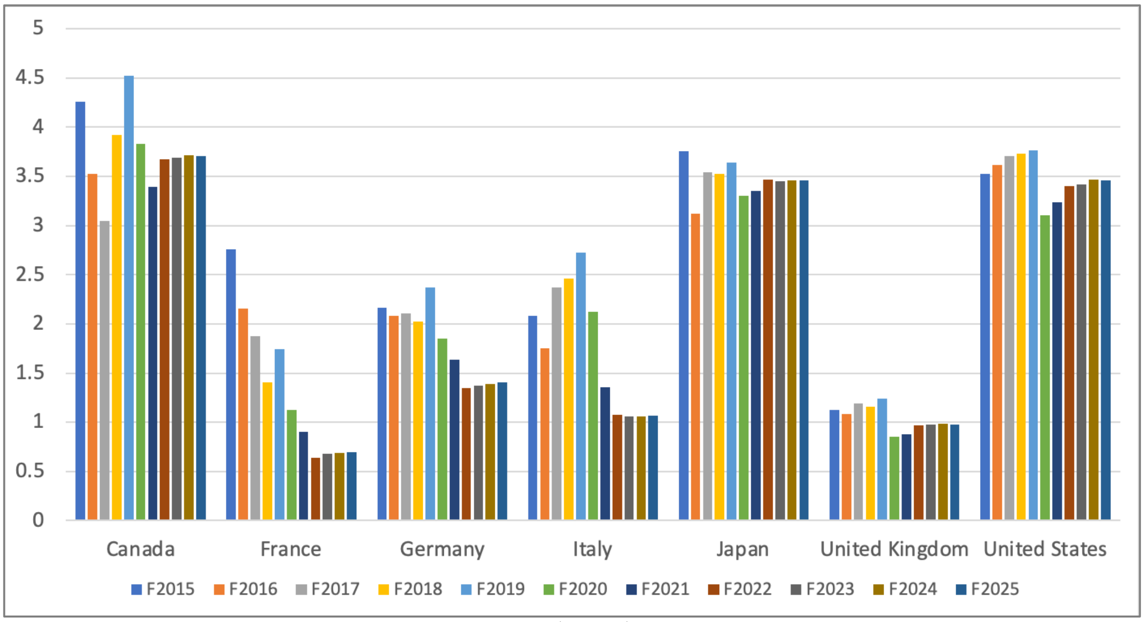
Figure 6.10. Fossil Fuel Subsidies
($ billion at constant 2021 prices)



$ = US dollars.
Source: Author's calculations, based on IMF, (2022).

Figure 6.11. Fossil Fuel Subsidies

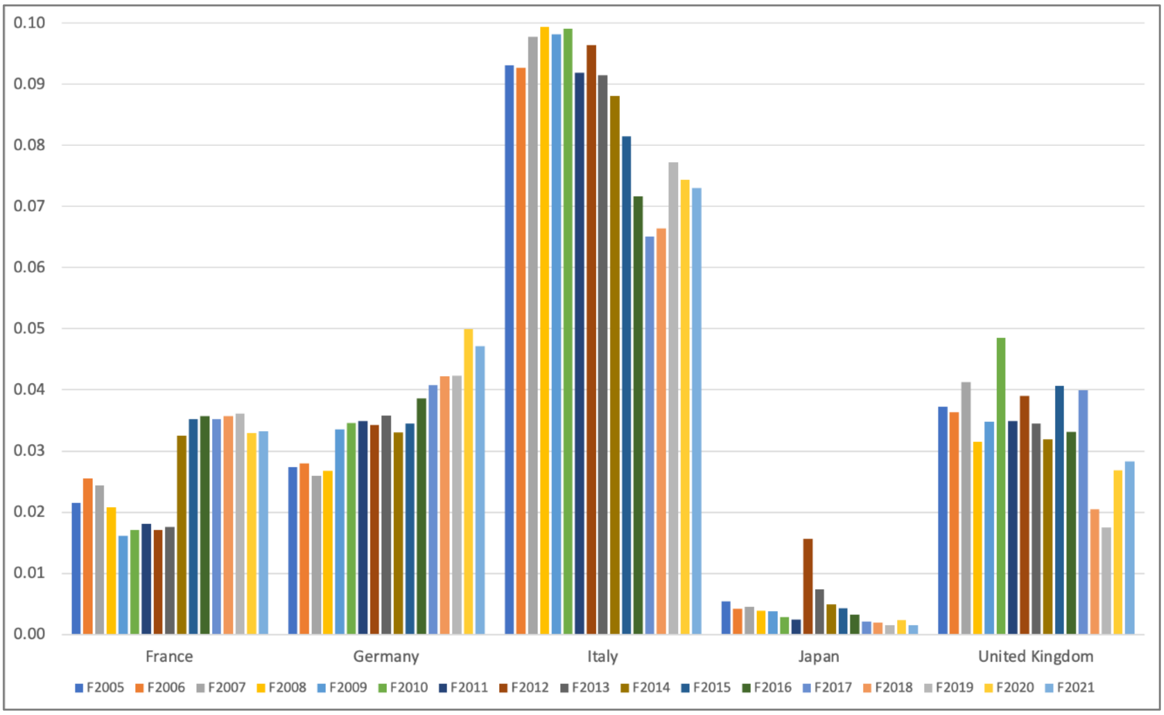
(Percentage of gross domestic product)



Source: Author's calculations, based on IMF, (2022).

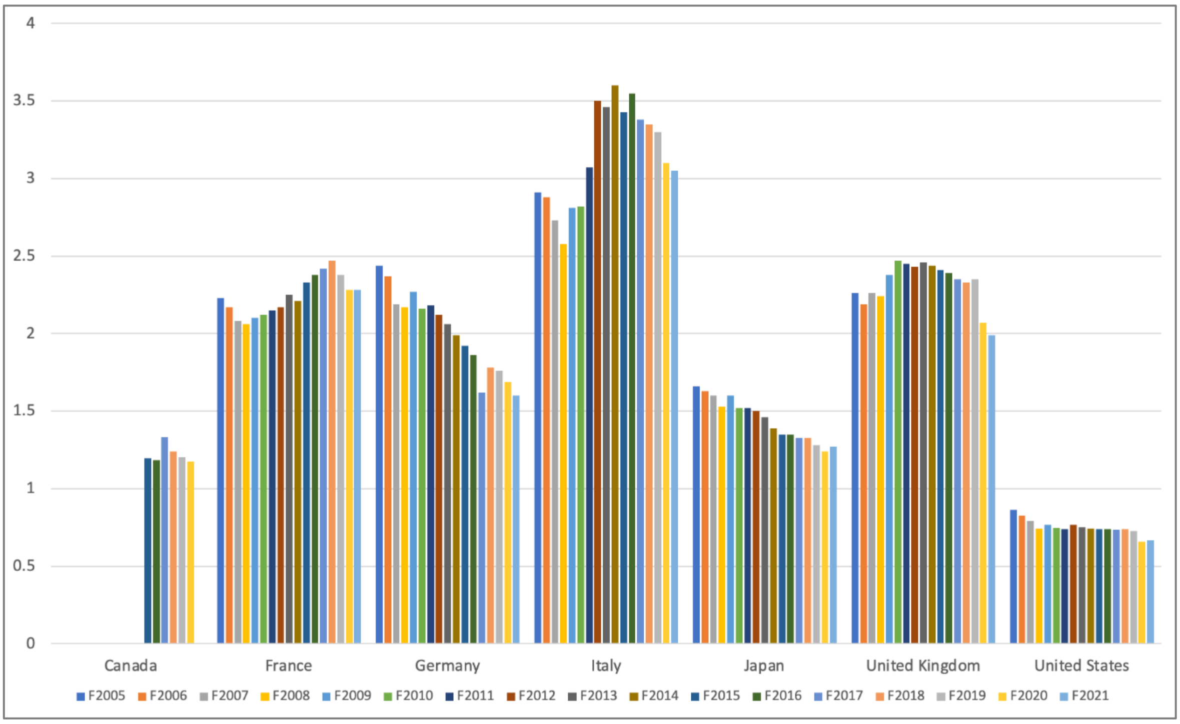
Japan performs poorly in government expenditure on R&D for environmental protection and environmental taxes. Amongst the G7, it ranks the worst in R&D for environmental protection spending (Figure 6.12) while being third from the bottom regarding environmental taxes (Figure 6.13). The two indicators are important as they point to the government's commitment and financial resources to develop measures to engage with environmental issues, including renewable energy technologies. Countries with low government expenditure on R&D for environmental protection share of GDP and environmental tax share of GDP, i.e. Japan and the US, tend to have low renewable energy share of primary energy supply (Figures 6.14b and 6.14c), signalling a slower transition towards a green economy.

Figure 6.12. Government Expenditure on Research and Development Environmental Protection
(Percentage of gross domestic product)



Source: Author's caculations, based on IMF, (2022).

Figure 6.13. Environmental Taxes
(percentage of gross domestic product)

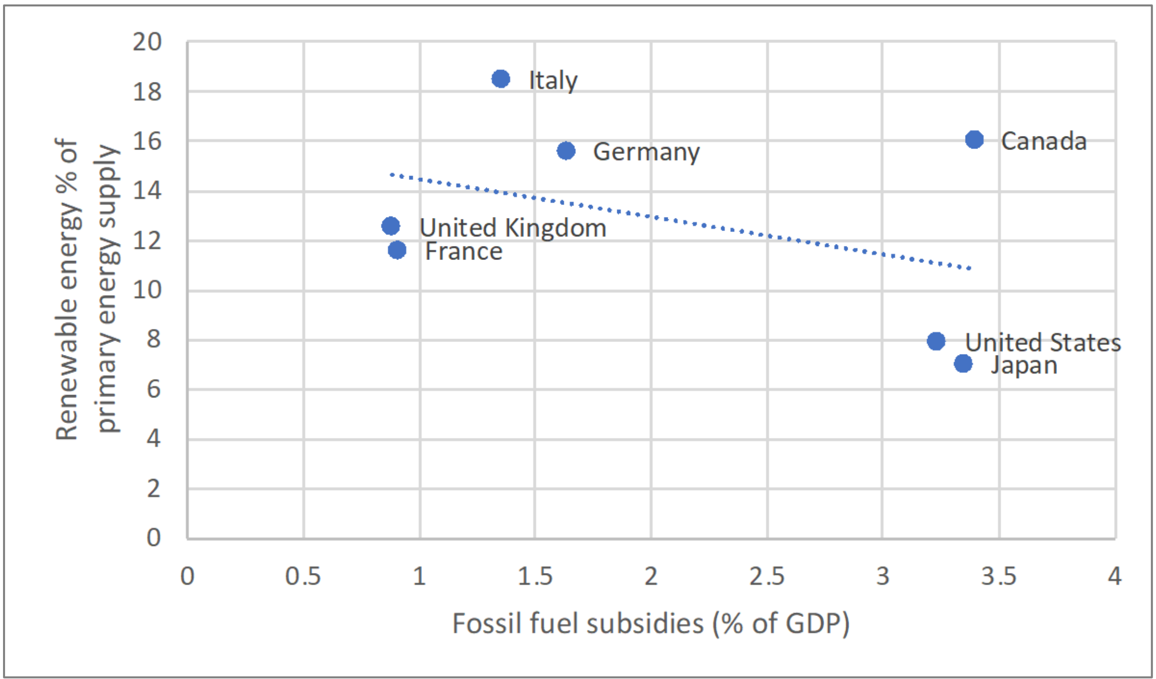


Source: Author's calcuations, based on IMF (2022).

Figure 6.14. Correlation between Renewable Utilisation and Fiscal Policies amongst the Group of Seven Economies, 2021

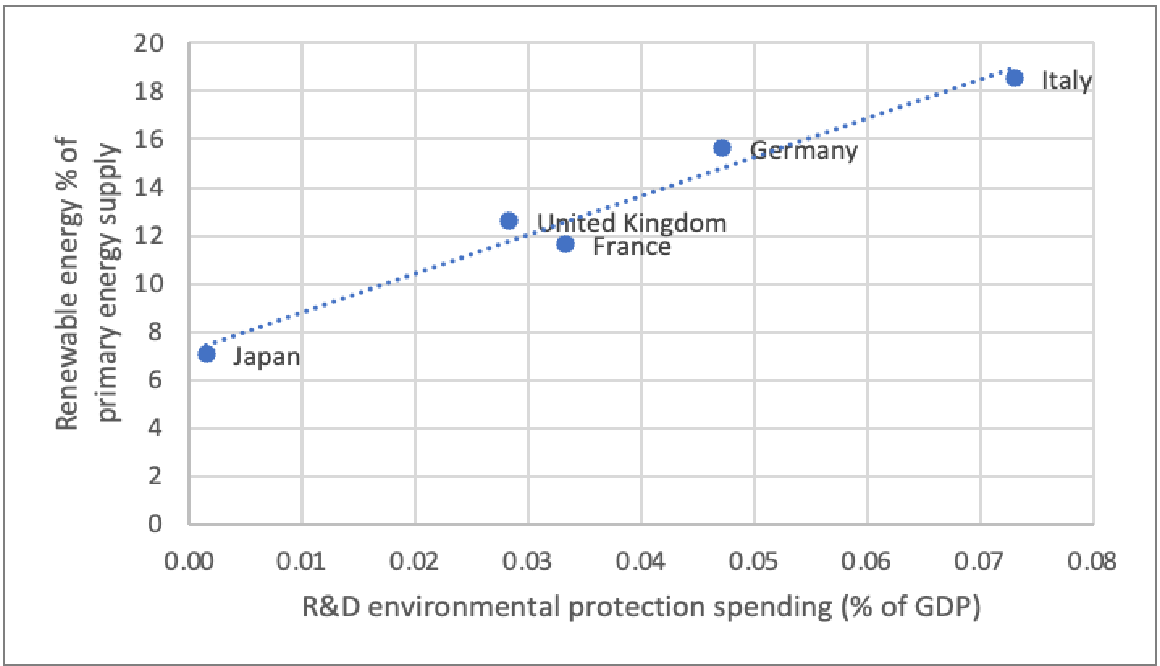
a. Fossil Fuel Subsidies

(percentage of gross domestic product)

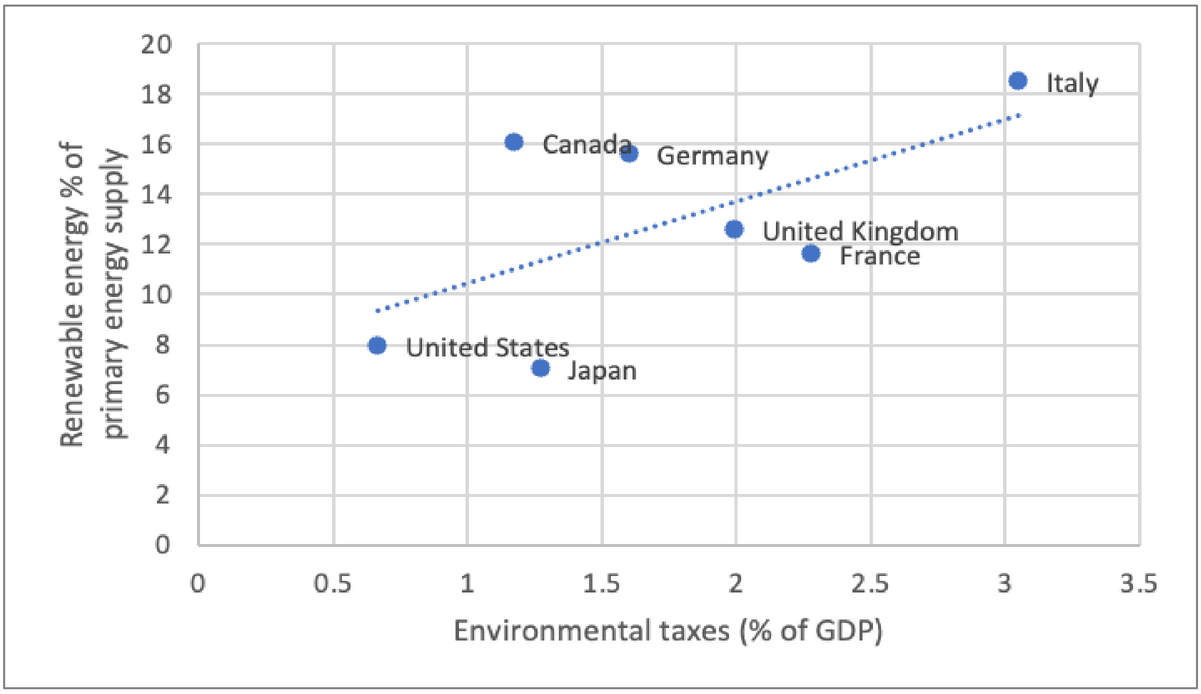


b. Government Expenditure on Research and Development Environmental Protection

(percentage of gross domestic product)



c. Environmental Taxes
(percentage of gross domestic product)



Source: Author's calculations, based on IMF, (2022) and OECD, (2023).

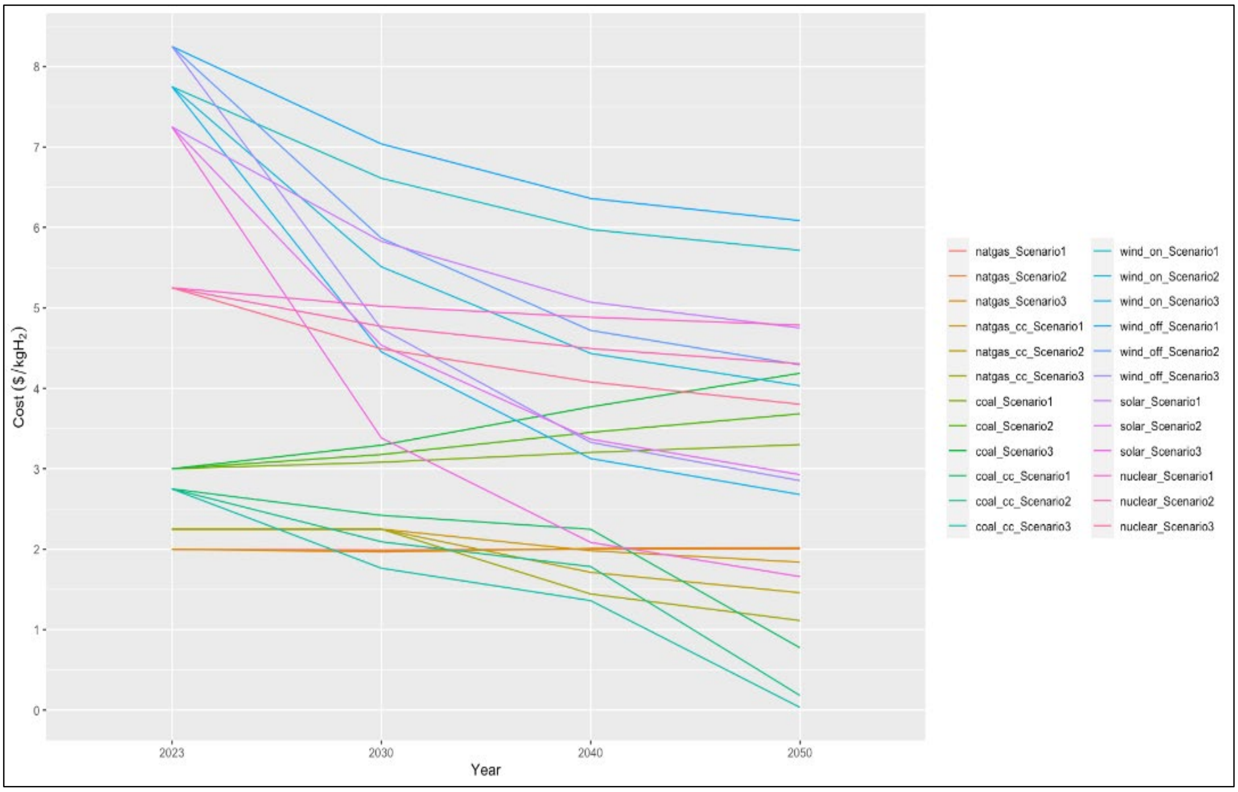
4.2. Carbon Capture, Utilisation, and Storage Case Study in Methanol Production in Japan

While the methanol was obtained from hydrogen and CO2, the focus of the study is the hydrogen cost since the CO2 cost almost free; it isobtained from the flue gas from the power plant/industries as mentioned in 3.2. It also discussed on the electrolyser technology cost which is critical for the hydrogen production. The transport cost for the hydrogen will be outlined as well assumed the hydrogen partly imported from abroad.

4.2.1. The Hydrogen Production Cost

The cost of hydrogen production has declined from 2023 to 2050 thanks to the learning curve, as shown in Figure 15. Due to technological learning/R&D, hydrogen production costs have declined from various energy sources (natural gas only and with CCS, coal only and CCS, wind onshore and offshore, solar PV, and nuclear). The lowest cost of hydrogen production will be from coal with CCS $0.03/kilogramme of hydrogen (kg H2) followed by natural gas with CCS $1.18/kg H2 and solar PV $1.66/kg H2. This all comes from Scenario 3 with a learning rate of 35.9%; 150% of the current learning rate of solar PV. In the case of Scenario 2, whereas the learning rate is similar to the current learning rate of solar PV at 23.9%, the lowest cost for hydrogen production will be from coal: $0.18/kg H2, natural gas with CCS $1.46 US/kg H2; and solar PV $2.93 US/kg H2. In the case of Scenario 1, with a learning rate of 11.59%, 50% of the current learning rate of solar PV, only coal with CCS could reach the cost of hydrogen production below $1/kg H2 ($0.77/kg H2). The Ministry of Economy, Trade, and Industry (METI) of the Government of Japan aims to achieve a hydrogen cost of ¥222/kg H2 (Gov. of Japan: METI, 2023c: 15) or $1.59/kg H2 with an exchange rate of ¥140/$ (World Currency Shop, 2023). Hence, only coal with CCS and natural gas with CCS is eligible to deliver the target of METI hydrogen cost ¥222 in 2050 in Scenarios 2 and 3 and only coal with CCS meets the target for Scenario 1. While domestically produced and internationally imported renewable energy such as solar PV can deliver the cost target for hydrogen production in Japan, hydrogen production from carbon-neutral fuels such as coal and natural gas with CCS is still the best available option and the one that seems most feasible from Southeast Asia producer countries such as Indonesia (coal), Malaysia, and Brunei Darussalam (natural gas).

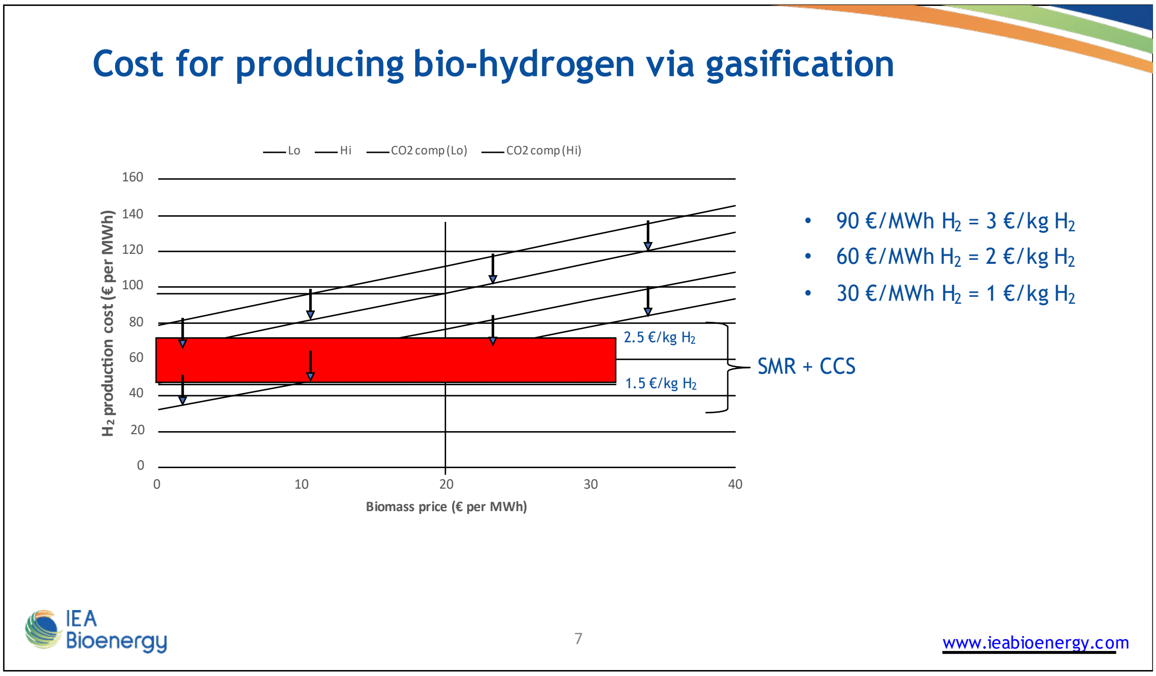
Figure 6.15. Cost of Hydrogen Production



$ = US dollar; kgH2 = kilogramme of hydrogen; natgas = natural gas.
Source: Authors calculations based on cost data in 2023 from IEA (2023a) and energy supply data from IEA (2023b).

While the hydrogen from Figure 6.15 doesn't consider biomass, to add the biomass, we elaborate on the study from International Energy Agency Bioenergy (Lundgren, 2023) on the biomass-based hydrogen production cost. That study showed that biomass could be carbon emissions negative/carbon removal since biomass absorbs CO_2 from the atmosphere during its lifetime. For every tonne of biomass gasified, 0.15 tonnes of hydrogen can be produced together with 1.5 tonnes of CO_2. While the cost of producing biomass-based hydrogen through gasification/steam methane reforming is €1–€2/kg H_2, adding CCS will cost €0.5/kg H2 as depicted in Figure 6.16. With the exchange rate of €1 = ¥155 (World Currency Shop, 2023), the cost for hydrogen production with a biomass price of €20/MWh still exceeds the METI target cost in 2050: ¥232–¥387.5/kg H_2 However, since biomass has other co-benefits in terms of carbon-negative emissions, there is a possibility of lowering the cost from the carbon market as CDR, which is under discussion at COP28 in Dubai, United Arab Emirates Arab (UNFCCC, 2023).

Figure 6.16. Biohydrogen from Gasification

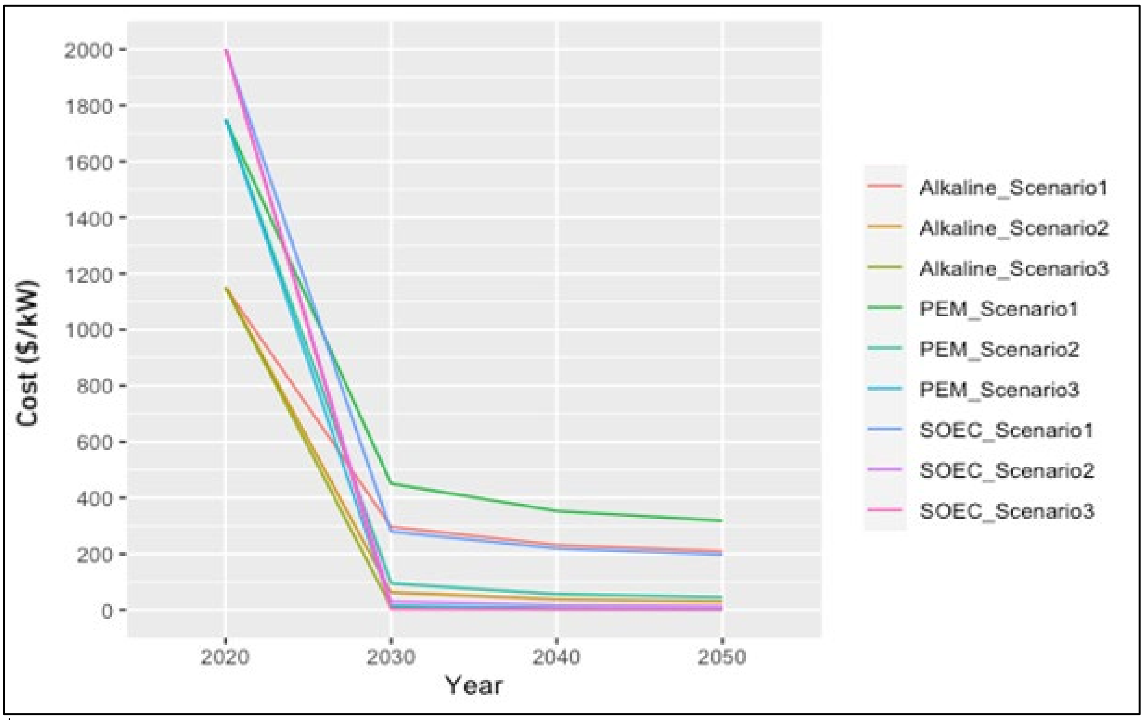


€= euro; CCS = carbon capture and storage; H2 = hydrogen; kg = kilogram; MWh = megawatt hour; SMR =.steam methane reforming.
Source: Lundgren, (2023).

4.2.2. The Electrolysis Cost

The highest component cost when producing green hydrogen from renewable energy sources (solar PV, offshore and onshore wind, geothermal, biomass) is the electrolysis cost, followed by the electricity cost relative to the location where it is produced (Galimova et al., 2023). Electrolyser technology, which can use electricity to split water into hydrogen and oxygen, is critical for producing low-emission hydrogen from renewable or nuclear electricity. This technology has grown rapidly in the past few years (IEA, 2023a). Amongst all three existing technologies, the solid oxide electrolyser cell delivers the lowest cost ($0.62/kilowatts (kW) in 2050) followed by alkaline technology ($3.02/kW) and polymer electrolyte membrane technology ($4.58/kW) in Scenario 3. In Scenario 2, the electrolyser costs in 2050 will be $13.95/kW, $29.72/kW and $45.14/kW, respectively. In Scenario 1 the electrolyser costs will be $197.76/kW, $209.35/kW and $318.32/kW (Figure 6.17 and Table 6.6).

Figure 6.17. The Technological Learning from Electrolysis Technology



$ = US dollar; PEM = polymer electrolyte membrane; SOEC = solid oxide electrolyser cell.
Source: Author's calculations, based on cost data from IEA (2020).

Table 6.6. The Technological Learning from Electrolyser Technology

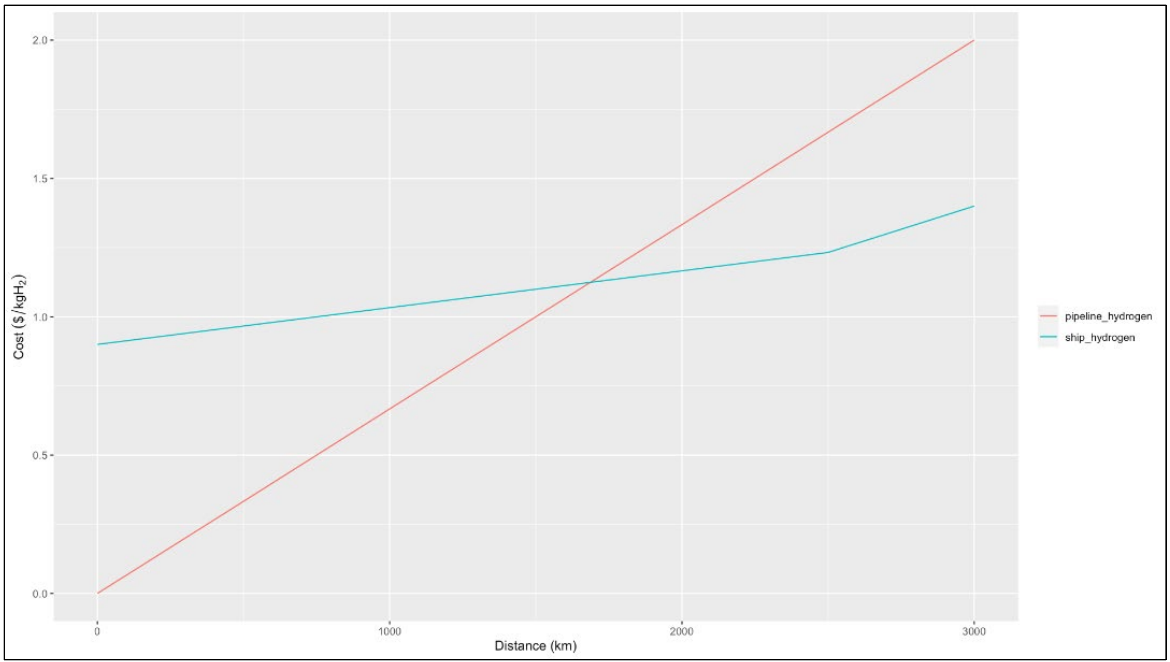
	Cost (USD/kW)	2020	2030	2040	2050
Alkaline	Scenario 1	1150	296	232	209
	Scenario 2	1150	63	37	29
	Scenario 3	1150	10	4	3
PEM	Scenario 1	1750	450	353	318
	Scenario 2	1750	95	56	45
	Scenario 3	1750	15	7	5
SOEC	Scenario 1	2000	280	219	198
	Scenario 2	2000	29	17	14
	Scenario 3	2000	2	1	1

$ = US dollar; kW = kilowatt; PEM = polymer electrolyte membrane; SOEC = solid oxide electrolyser cell.
Source: Authors calculations based on electrolyser technology cost data from IEA (2020).

4.2.3. Transport Cost

While hydrogen production in Japan is not sufficient to fulfil the targeted demand, there is a possibility that additional costs, such as transportation, would be incurred due to imported hydrogen from overseas. Figure 6.18. shows the cost of storage and long-distance transportation of hydrogen by ship and pipeline. For every kilometre in transport distance, the hydrogen transported by pipeline tends to have a higher cost than hydrogen transported by ship. The shipping cost will be from $0.90, $1.00, $1.10, $1.10, $1.20, and $1.40 /kg H2 for 500km, 1,000km, 1,500km, 2,000km, 2,500km, and 3,000 km respectively, while the transport cost through a pipeline is $0.30, $0.70, $1.00, $1.30, $1.70, and $2.00 for the same distances. Pipeline costs will be lower than shipping costs for distances up to 1,700 km. After that, shipping costs are the less expensive option. The maritime shipping industry is one of the most conservative industries with small margins and it is hard to decarbonise (IMO, 2023). By implementing net-zero GHG emissions in the shipping industry, the cost will decline further in the long run.

Figure 6.18. Costs of Storage and Long-Distance Hydrogen Transport



$ = US dollar; kgH_2 = kilogramme of hydrogen; km = kilometre;
Source: Author's calculations, based on the transport cost data from IEA (2019).

5. Conclusion and Outlook

It is possible that Japan's relatively high energy intensity level implies lower energy efficiency technologies for consumption and production; lower commitment to promoting energy-saving behaviours, technologies, and systems; and more energy consumption for non-economic activities. Despite Japan's high renewable energy supply growth, the increase cannot match the faster growth of energy demand illustrated by the small shares of the national energy mix. The newly enacted GX Policy in December 2022 will enhance Japan's commitment to sustainable energy for all and its ability to meet the SDG targets. Regarding sustainable energy regulation, Japan must improve its renewable energy, i.e., network connection, pricing, connection and cost allocation; renewable grid integration; energy efficiency (incentives and mandates); financing mechanisms; and building energy codes. Japan has already committed to raising its government budget towards the transition to a green economy and sustainable development while prompting a just transition through a reduction in fossil fuel subsidies; improvement in spending on R&D environmental protection, particularly those promoting renewable energy; and enhancement of environmental taxes.

CCUS is one of the key policies in GX that combines CO2 from industry with hydrogen. Achieving clean hydrogen is important through fossil fuel with CCS or renewable energy sources. This study highlights the significant advances in hydrogen production technology and the economic feasibility of several methods in the run-up to 2050. The learning curve has significantly reduced the cost of hydrogen production, with coal combined with CCS emerging as the most cost-effective option at \$0.03/kg H2, followed by natural gas with CCS at \$1.18/kg H2, and solar PV at \$1.66/kg H2 under Scenario 3. METI's target hydrogen cost of ¥222/kg H2 (\$1.59/kg H2) is achievable mainly through coal and natural gas with CCS, showing the crucial role these technologies will play in Japan's energy strategy. The electrolyser technologies that are critical for low-emission hydrogen production from renewable or nuclear electricity show promising cost reductions, particularly the solid oxide electrolyser cell that is projected at \$0.62/kW by 2050 in Scenario 3.

A study of transportation costs shows that while pipeline transport is initially cheaper, shipping becomes more cost-effective for distances beyond 1,700 km. The transition to net-zero GHG emissions in the shipping industry is likely to further decrease these costs. Japan's green transformation, supported by the newly enacted GX policy, promises significant economic benefits. By fostering partnerships with Southeast Asian countries for hydrogen production, Japan can secure a sustainable and economically viable energy future. Robust capacity-building, including the development of digital skills, will be essential to reach these goals.

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