Diagnostic Study on Net-Zero for The Energy Sector in Vietnam

Deliverable 4 (Final Report): Net-Zero for the Energy Sector in Vietnam

By E4SMA

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ABOUT THE CONSORTIUM

E4SMA (Italy) is the project leader, specializing in energy and climate modelling and support to decision makers. Energy Modelling Lab (Denmark) supported the model development. VietStar Training & Consulting (Vietnam) is responsible for stakeholder engagement and communication.

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DISCLAIMER

This "*Net-Zero for the Energy Sector in Vietnam*" Report is prepared under the project "*Diagnostic Study on Net-Zero for The Energy Sector in Vietnam*" and exclusively for the Southeast Asia Energy Transition Partnership (ETP). The findings and opinions expressed in the report are those of the authors and do not necessarily reflect the views of any associated government or organisation. Without prior written permission from ETP, no part of it may be reproduced, quoted, or distributed to any third party.

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Acronyms

BECCS	Bioenergy with carbon capture and storage
BESS	Battery energy storage system
BEV	Battery electric vehicles
CBAM	Carbon border adjustment mechanism
CCS	Carbon capture and storage
CCUS	Carbon capture, utilization and storage
CO_2	Carbon dioxide
CO_{2eq}	Carbon dioxide equivalent
COP	Coefficient of performance
COP26	UN Climate Change Conference of the Parties
DEU	Designated energy users
DPPA	Direct power purchase agreement
DR	Demand response
DSM	Demand side management
ESCO	Energy service company
EMP	Vietnam's national energy master plan
EOR23	Vietnam energy outlook report 2023 (in preparation)
ETP	Southeast Asia Energy Transition Partnership
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
EVs	Electric vehicles
FEC	Final energy consumption
FIT	Feed-in tariff
GA	Green ammonia
GDP	Gross domestic product
GH	Green hydrogen
GHG	Greenhouse gases
GW	Gigawatt
H_2	Hydrogen
HVDC	High-voltage direct current
IEA	International Energy Agency
JETP	Just Energy Transition Partnership
LNG	Liquified natural gas
LPG	Liquified petroleum gas
LULUCF	Land use, land use change and forestry
MOIT	Ministry of Industry and Trade (Vietnam)

MONRE	Ministry of Natural Resources and Environment (Vietnam)
Mt	Million metric tonnes
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NDC	Nationally determined contribution
NZE	Net-zero emissions
PDP8	Vietnam's eight National power development plan
PES	Primary energy supply
PHEV	Plug-in hybrid vehicles
PV	Solar photovoltaic
R&D	Research and development
RES	Renewable energy sources
TFEC	Total final energy consumption
TIMES	The Integrated MARKAL-EFOM System
UNOPS	United Nations Office for Project Services
USD	United States dollar
WB	World Bank
WWF	World Wide Fund

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1 Introduction

1.1 Objective of the study

In November 2021, during the COP26 summit, Prime Minister Pham Minh Chinh announced that with its own resources, along with the cooperation and support from the international community, Vietnam would develop and implement strong emissions reduction measures to achieve net-zero emissions (NZE) by 2050.

Large investments and deep transformation of all sectors of the economy will be needed to achieve the net-zero emission target. Finding the optimal investments and combinations of resources to decarbonize the economy of Vietnam while ensuring energy security and a fair and just energy transition requires a dedicated analytical process.

> The "***Diagnostic Study on Net-Zero for The Energy Sector in Vietnam***" aims to start developing such a process. The study is funded by the Southeast Asia Energy Transition Partnership (ETP) and is designed to evaluate the transition of Vietnam's energy sector towards the net-zero emissions target by 2050. An important feature of this study is the active involvement of various stakeholders to ensure this is not a closed but participatory approach.

The project aims to provide substantial support for the implementation of the Prime Minister's Decision 888/QD-TTg, which outlines the specific tasks and solutions required to fulfil the commitments made during COP26. The project also aims to support the implementation of the National Energy Master Plan (Decision Number 893/ QD-TTg) and the Just Energy Transition Partnership (JETP) program.

Finally, the study aims to serve as the basis for fostering ongoing collaboration between ETP and the Department of Oil, Gas and Coal of the Ministry of Industry and Trade (MOIT), to help facilitate a just transition for the oil, gas, and coal industries in Vietnam as they strive to meet net-zero emission targets and mitigate adverse impacts on communities affected by this transition.

1.1 Objective of the report

> The objective of the Final Report "***Net-Zero for the Energy Sector in Vietnam***" is to formulate key recommendations for the technological transformation of the energy sector and the policies to achieve the net-zero emission in Vietnam's energy sector by 2050.

It is based on the outcomes of the modelling exercise presented in the Mid-Term Report "*Assessment Report of the Energy Sector in Vietnam*". These outcomes are included in Annex 1. The data and assumptions used in the modelling exercise were described in the "*Data and Assumption Book*", available upon request to ETP, in Vietnamese and English.

The pathway and recommendations proposed by the study towards the net-zero emission target must be understood as reflecting a possible future of the energy system of Vietnam. The study aims to explore possible outlooks and to suggest milestones, to bring knowledge into the decision-making process. It does not aim to prescribe a specific pathway nor make mandatory proposals.

2 The fundamentals of the analysis: energy system modelling, public data and stakeholder consultations

2.1 The modelling exercise behind the NZE

The NZE study is based on a modelling exercise employing a techno-economic model of the Vietnamese energy system, the **TIMES-Vietnam (TIMES-VN)**. TIMES-VN is built using the TIMES modelling framework (Box 1), extensively adopted across many countries for informing the policymakers about the feasible options for decarbonizing their energy systems.

TIMES-Vietnam portrays the **full energy system**, from fuel extraction and trading to fuel processing and transport, electricity generation, and all final energy demands on a sectoral basis, with a high level of technical detail. The technology explicit nature of the model is relevant for policymakers who want to better understand the role of specific technologies and energy commodities and develop appropriate policies to accelerate the deployment of these technologies and commodities. The comprehensive sector coverage allows the assessment of the interactions between energy sectors, such as the impacts on the electricity generation system from further electrification of end-use sectors, and the competition between fuels and technical solutions across sectors.

The model generates scenarios for the evolution of the energy system based on different assumptions around the evolution of demands, future technology costs and unique circumstances of the country.

Box 1. TIMES-Vietnam, a well-suited model to inform decisions about climate strategies

TIMES (an acronym for The Integrated MARKAL-EFOM System) is a partial equilibrium model generator for local, national, or multi-regional energy systems, which provides a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon. This tool is developed and maintained by the Energy Technology Systems Analysis Programme (ETSAP), one of the Collaboration Programmes of the International Energy Agency. It is used in over 70 countries.

TIMES-Vietnam models the energy system with a Reference Energy System. It is a network description of energy flows with a description of all technologies that are involved, or potentially involved, in the production, transformation, and use of various energy forms to satisfy energy demand services required by economic activities. Those energy services are, for example, passenger kilometres in passenger transportation, tonnes of cement produced by the industrial sectors, useful energy requirements for air conditioning in buildings, etc. Demand devices and technologies (cars, trains, air-conditioners, industrial processes, etc.) transform various energy carriers into useful demands. Energy carriers are generated from the transformation of primary energy forms obtained from energy resources technologies or imports.

The model aims to supply energy services at minimum cost, maximising the total surplus defined as the sum of surplus of the suppliers and consumers, by simultaneously making decisions on equipment investment and operation; primary energy supply; and energy trade. It essentially provides the optimal mix and competitive set of technologies (capacity and activity) and fuels at each period under various policy scenarios.

TIMES-Vietnam includes all the sectors of the economy, from the supply and transformation side (domestic resources, fuel trading, refineries, other key transformations including biofuel and hydrogen production and delivery, power sector, transmission, and distribution grids) to the end-use sides (residential, services, industry, transport, agriculture).

The model used for the study is an improved version of previous applications of TIMES-Vietnam, in part reshaped and improved to better capture key critical elements regarding energy transition towards net-zero, with updated data, and increased specificity of the Vietnamese energy system, including more detailed transportation and industry sector representation.

2.2 Data, assumptions and scenarios

2.2.1 Publicly available data

The TIMES-Vietnam, as other energy system models, is **data-driven** and requires multiple inputs, such as energy balances, socio-economic drivers, techno-economic characterization of key technologies, policy decisions, etc. Transparency of the data used in the analysis is key for modelling studies.

> All data assumptions, including population and economic growth, prices, domestic resources potentials, technologies, are transparently reported in the project Deliverable "***Data and Assumption Book***", available in Vietnamese and English. The relevance and the credibility of the assumptions were confirmed through consultation with a range of stakeholders (see next section).

Key assumptions on energy resource potentials, socio-economic conditions, international and domestic fuel prices have been retrieved from **publicly available data and expert knowledge** (Table 1), including the Power Development Plan (PDP8) for the period 2021-2030, with a vision to 2050, as stipulated in Decision 500/QD-TTg and approved in May 2023, the Energy Master Plan (EMP) (Decision Number 893/ QD-TTg), approved in July 2023, which play a pivotal role in shaping the NZE strategy. Energy balances are based on estimates from the Institute of Energy. The characteristics of the existing and new technologies are sourced from publicly available national and international sources, such as the Vietnamese technology catalogue, which is published by Electricity and Renewable Energy Authority (EREA) and the Danish Energy Agency (DEA), the DEA technology catalogues, and reports published by the International Energy Agency and the European Commission.

Table 1. Main sources of information

GDP AND POPULATION	ENERGY POTENTIALS
Energy Master Plan 2023	Energy Master Plan 2023 Power Development Plan (PDP8)
ENERGY PRICES	**TECHNOLOGY DATABASE**
World bank (Commodity Markets Prices), Power Development Plan (PDP8) Energy Master Plan 2023	Institute of Energy Vietnamese technology database DEA technology database IEA-ETSAP technology database EU Reference scenario Scientific articles

2.2.2 Policy assumptions and sensitivity analysis

The proposed NZE analysis takes into careful consideration the **most recent plans and policies** of Vietnam as well as stakeholders views. These are either fully included in the NZE, used as a benchmark, or explored in sensitivity scenarios (Table 2).

Table 2. Main policy assumptions of the NZE scenario

TOPIC	POLICY OR PLAN	2030	2050
Greenhouse Gas Trajectory	*National Strategy for Climate Change to 2050 (2022)* [1]	Energy: 457 Mt CO_{2eq} Non-Energy: 168 Mt CO_{2eq} – of which 86 Mt CO_{2eq} from industrial processes	Energy: 101 Mt CO_{2eq} Non-Energy: 84 Mt CO_{2eq} – of which 20 Mt CO_{2eq} from industrial processes
	EMP (2023)	LULUCF: -95 Mt CO_{2eq}	LULUCF: -185 Mt CO_{2eq}
	PDP8 (2023)	Energy sector: 399-499 Mt CO_{2eq} [2]	-
	JETP (2022) and PDP8 (2023)	Power sector: 204-254 Mt CO_{2eq}. 170 Mt CO_{2eq} if JETP is implemented [3]. Peak of power sector emissions: 2030	-
Coal Phase Out	*PDP8 (2023) and JETP (2022)*	30.1 GW max	Coal phase-out for power production
Renewable for Electricity Generation	*PDP8 (2023)*	Share 30.9 - 39.2% [2]	Share 67.5 - 71.5% [2]
Green Fuels and Electrification of Transport	*Action Program for Transition to green energy and mitigation of carbon dioxide and methane emissions from transportation (2022)* [3]	At least 25% of cars and motorbikes and 15% of buses and taxis with electricity and green energy [3]	100% of taxis, 75% of buses, 50% of cars and motorbikes, 50% of heavy-duty vehicles, 40% of domestic navigation, 70% of domestic rail with electricity and green energy [3]
Energy Efficiency	*Vietnam Energy Efficiency Program 2019–2030 (VNEEP 3)*	Reduce Total Final Energy Consumption by 8-10% compared to reference case [2]	-
Other	*Nuclear*	No nuclear	No nuclear
	Bioenergy with Carbon Capture and Storage (BECCS)	No BECCS	No BECCS
	Power plant capacities	Aligned with PDP8 [3]	-

[1] The 2030 targets of the National Strategy for Climate Change to 2050 correspond to the conditional emission reductions proposed by the Nationally Determined Contribution (NDC). The unconditional emission reductions of the NDC are much smaller, resulting in higher emissions in 2030 (782 Mt CO_{2eq}).

[2] Used as a benchmark.

[3] Sensitivity variants are proposed to analyse the JETP commitments, the full application of the Transportation Program, and lower liquefied natural gas penetration.

Seven sensitivity cases, or scenario variants, are carried out to help understand the impacts of uncertain key parameters on the pathway to reach the NZE target in 2050 (Table 3). They focus on economic growth, the Just Energy Transition Partnership (JETP) commitments, the magnitude of deployment of carbon capture and storage, the implementation of transportation policies, the availability of onshore wind and the role of liquified natural gas (LNG).

The sensitivity analyses were defined in collaboration with stakeholders and the ETP. Each sensitivity case focuses on one specific assumption in order to capture clearly the effect on the NZE strategy of each specific uncertainty. In order to ensure that the sensitivity cases reflect well the unique circumstances of Vietnam, they were defined based on the feedback received from stakeholders during the consultation workshops.

Table 3. Sensitivity analyses

NAME	SENSITIVITY PARAMETERS	RATIONALE
HIGH GDP Accelerated economic growth.	Higher economic growth (7.5% per year after 2030 instead of 6.5% per year), following official projections reflected in EMP.	Economic projections of Vietnam envision a more rapid development of the economy, implying higher energy service demands.
JETP Accelerated mitigation.	JETP mitigation objective: limit of 170 Mt CO_{2eq} by power plants in 2030. Renewable energy power plant capacities can exceed PDP8.	JETP proposes a more ambitious emission target by 2030, associated with a higher penetration of renewable energy.
HIGH CCS Accelerated innovation in carbon capture.	No limit on the emissions captured from CCS plants (power and industry).	CCS plays a critical role in emission-intensive industrial sectors like Iron and steel and Cement. However, the availability and costs of CCS are highly uncertain. Sensitivity analyses are essential to better understand the dependence of the decarbonization pathway on CCS under different conditions. They will help decision-makers to define relevant policies and R&D strategies.
LOW CCS Conservative deployment of carbon capture.	Single aggregated target (121 Mt total) on energy-related and process-related emissions. The model is free to reduce emissions from energy or processes to reach the NZE target.	
TRANSPORT Deeper decarbonization of the transportation sector.	100% of road transport, rail, and inland navigation by 2050 with electricity and green energy.	Transforming the transport sector is challenging in any country. This scenario explores the feasibility and impacts of the full implementation of the Transportation Strategy.
LOW ONSHORE Limited onshore wind deployment.	50% reduction of onshore wind potential, reflecting land and acceptability issues.	Onshore wind raises challenges in terms of required land and social acceptability. At the opposite, offshore wind attracts more and more investors and policymakers.
LOW LNG-P Reduced LNG in power.	Committed LNG power plants (PDP8) are not considered.	Limiting the commissioning of new fossil assets, more particularly LNG plants, may accelerate the penetration of renewable sources.

2.3 A collaborative approach with stakeholders

The formulation of the NZE scenario, the definition of the sensitivity cases and the overall findings are the result of close collaboration and coordination with ETP and local stakeholders. This collaborative approach aimed at ensuring the high quality of data and assumptions used in the analyses, and the relevance of the transformation of the energy sector proposed to reach the NZE target.

The **stakeholders** who actively participated in these consultations included the Ministry of Industry and Trade (MOIT), Ministry of Natural Resources and Environment (MONRE), Vietnam Oil and Gas Group (PVN), Vietnam Electricity (EVN), Power Generation Corporation 2 (GENCO2),

> Vinacomin Power (TKV), Danish-Vietnamese Energy Partnership Program (DEPPIII), Danish Energy Agency (DEA), French Development Agency (AFD), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), World Wide Fund for Nature (WWF), and the World Bank (WB).

Several consultations were held. They have been instrumental in fine-tuning data and assumptions underpinning the NZE scenario and its associated sensitivity analysis.

- **The inception workshop** was held in February 2023. Its objective was to inform key stakeholders of the energy sector of Vietnam about the study, to guarantee that the study was well-aligned with the realities and priorities of stakeholders, and to establish a collaborative working framework with stakeholders.
- **A technical workshop** was held in May 2023, supported by the publication of a "Data and Assumption Book", available in Vietnamese and English. The workshop allowed for an exchange of perspectives, created a shared understanding of the key data and assumptions used in the analysis, and collated views on the sensitivity analysis to be conducted. During this consultation, stakeholders expressed a strong interest in better understanding how end-use sectors and energy supply sectors could be transformed in an integrated way. They also emphasized the need for a deeper understanding of the role of hydrogen, ammonia, and carbon capture and storage in industry. Notably, they acknowledged the energy technology catalogue under preparation by the Danish Energy Agency as a reliable source of information regarding technology costs, performance, and emission characteristics.
- **Another technical workshop** was held in August 2023 to disseminate the main findings of the NZE scenario assessment, including the sensitivity analysis. This event served as an opportunity to gather feedback from stakeholders concerning the technological transformation of the energy sector and to gather their views on policy recommendations for the NZE implementation. Stakeholders highlighted their interest in understanding the respective contribution of the different sectors to the decarbonization pathways, as well as the role of carbon capture, utilization and storage (CCS/CCUS). There were questions raised about the feasibility of a rapid penetration of LNG infrastructure within a relatively short period, questioning the justification for such investments. This led to refinements in the representation of the LNG value chain within the model to better align with the realities of investments in this sector. Stakeholders also suggested the need to identify key milestones every 5 years, to facilitate monitoring and evaluation; a feature that has been integrated into this Final Report.

Kick Off Workshop – Hanoi, February 2023

Consultation Workshop, Hanoi, May 2023

Consultation Workshop, Hanoi, August 2023

2.4 Complementarity with other studies

Several studies, prior to this one, have provided useful insights about the energy transition of Vietnam, such as VIET SE & RMI (2022)[1], World Bank Group (2022)[2], USAID (2021)[3], EREA&DEA (2021)[4], and WWF (2023)[5]. Each of them provides insights on specific elements of the energy transition of Vietnam

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[1] VIET SE & RMI. (2022). *Review and Gap Analysis of the Existing Abatement Scenarios for Vietnam.* ETP & UNOPS.

[2] World Bank Group. (2022). *Vietnam Country Climate and Development Report*. Washington DC.

[3] USAID. (2021). *Technical Report: Analysis of Peak Coal in Vietnam Long-term Power Development Planning Scenarios.* Prepared by Deloitte for USAID/Vietnam, Environment and Social Development Office.

[4] EREA & DEA. (2022). *Vietnam Energy Outlook Report 2021.* Prepared by the Electricity and Renewable Energy Authority in Viet Nam (EREA) under the Ministry of Industry and Trade (MOIT) together with the Danish Energy Agency (DEA).

[5] WWF. (2023). *Energy Sector Vision: Towards 100% Renewable Energy for Viet Nam by 2050.* Prepared by Intelligent Energy Systems for World Wide Fund for Nature in Vietnam.

towards low carbon targets[6]. However, none considered the more recent net zero emission target applied to the entire economy by 2050, which was the specific focus of this study.

> The **added value of this study** is its capacity to propose short-term and long-term energy sector transformations to reach the 2050 NZE target, and to provide a strategic view on the required investments across all sectors of the energy system, from energy supply to end-use sectors, and their interactions, rigorously represented within the techno-economic modelling framework. Moreover, a distinctive feature of this study is the active involvement of various stakeholders.

Other modelling exercises are ongoing in Vietnam, such as the analysis of socio-economic impacts of climate change and adaptation strategies in Vietnam, carried out by the French Development Agency (AFD), and the preparation of the Energy Outlook Report 2023 (EOR23) by DEA.

The AFD study employs the GEMMES Vietnam macro-economic model, which provides insights on the macro-economic implications of climate change and of a transition to NZE. By focussing on macro-economic impacts, the AFD modelling analysis directly complements this study.

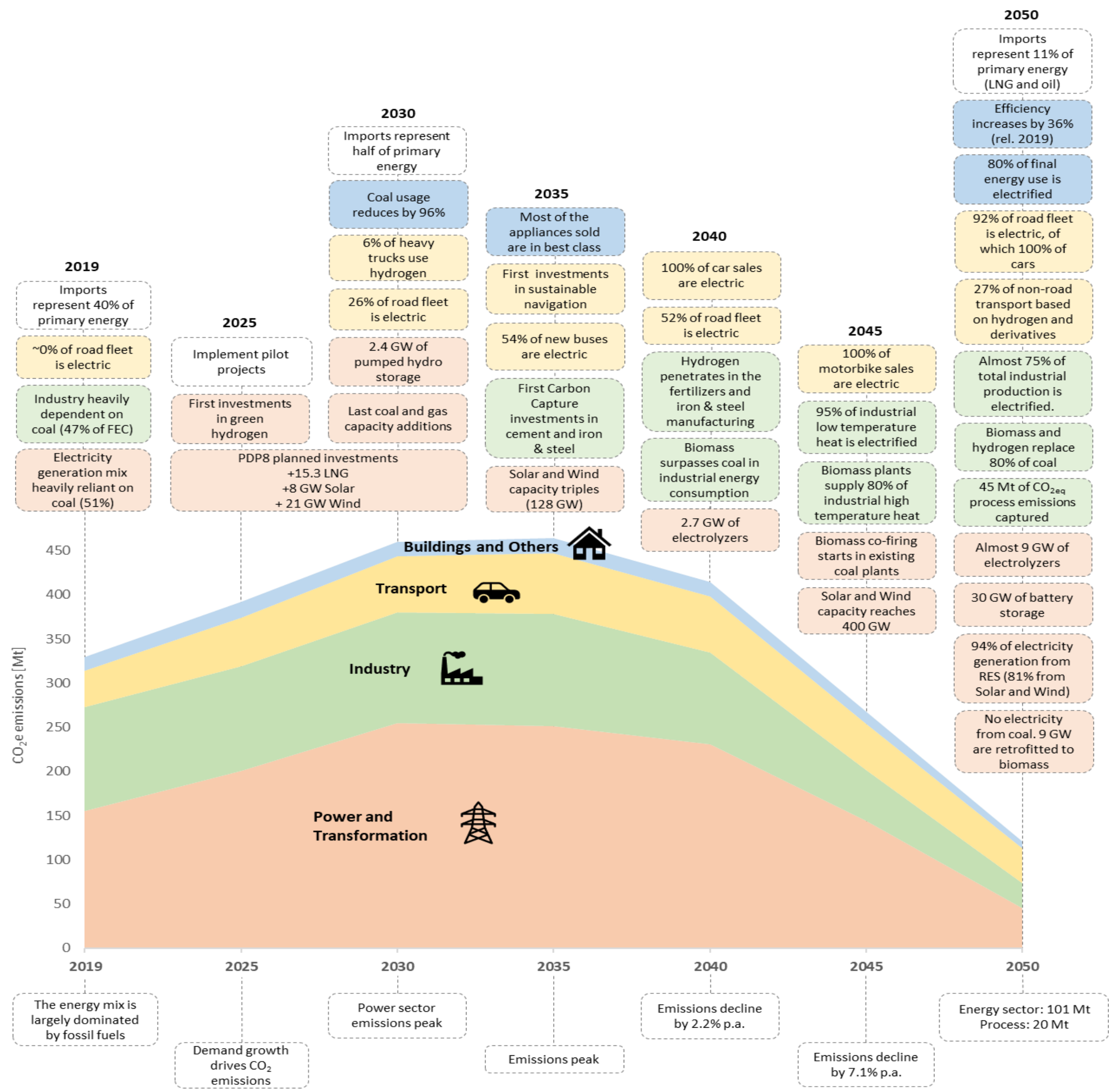
EOR23 employs a suite of techno-economic models (TIMES, as well as Balmorel and PSS/E, focused on power). This study shares some common assumptions with the EOR23, such as the techno-economic characterization of technologies. There are also substantial differences related to demand projections, renewable potentials, and specific mitigation options, such as the Direct Air Capture (DAC), available as a possible mitigation option in the EOR23 outlook but not in the ETP scenarios, due to its low acceptance and high uncertainties. The details of the scenarios analysed under EOR23 were not available at the time of finalizing this study. However, the Consultants regularly communicated with the team in charge of EOR23 to ensure the complementarity between the scenarios defined in EOR23 and those proposed in this study.

> In conclusion, the **diversity of the studies** focused on the energy transition of Vietnam in the recent years is very positive and must be encouraged. It adds value to the government's decision-making process on the roadmaps needed to reach the NZE targets.

3 The transformation of the energy sector towards Net-Zero Emissions : Key Findings

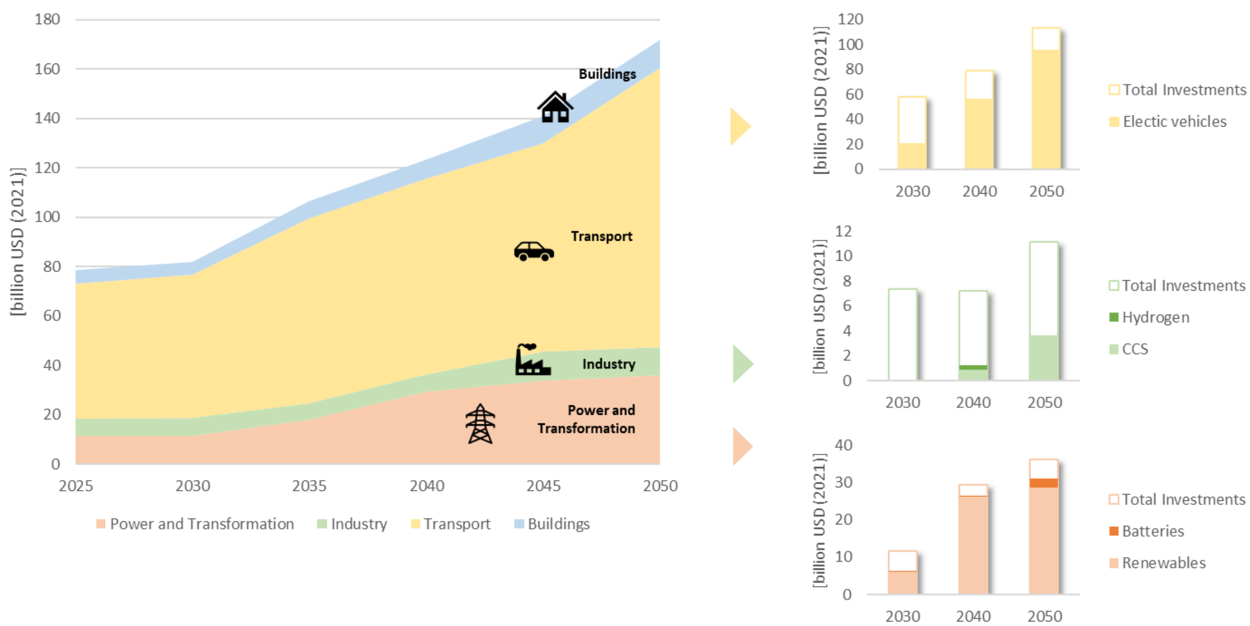
The analysis of the NZE scenario and its variants contributed to identifying the transformation of the energy sector towards a new configuration based on large electrification, renewable energy sources and efficient uses of energy. **Key milestones** contributing to achieving the NZE are illustrated in Figure 1. The **investment trajectory** needed to reach these milestones is provided in Figure 2. **The main findings**, based on the detailed and quantitative outcomes provided in the Mid-Term Report and included in the Annex, are as follows.

[6] More details are available in the *Inception Report* of this study.



Source: Analyses based on the outcomes of TIMES-VN

Figure 1. Milestones towards the Net-Zero Emission target



Source: Analyses based on the outcomes of TIMES-VN

Figure 2. Investment trajectory in key sectors

Finding 1. Renewables and energy efficiency are key to reaching the NZE objectives, driving fossil fuel demand down while satisfying the growth of the Vietnamese economy.

Renewable energy sources, dominated by wind, solar and bioenergy, represent 82% of the primary energy supply in 2050. The primary energy intensity of the economy is reduced by four times between 2019 and 2050, driven by the electrification of the energy system, moving away from inefficient energy sources, like coal, and the use of more efficient conversion technologies and appliances.

Finding 2. The electrification of end-uses accelerates over the next two decades, completed by the deployment of green fuels for hard-to-electrify uses.

The electricity share in the final energy consumption reaches 40% in 2030 and 66% in 2050. Most of the energy services for buildings, road light vehicles and industrial energy services are progressively electrified. Bioenergy, green hydrogen and, to a lesser extent, green ammonia, have a notable role to play in some specific industrial sectors (high-temperature heat production, cement production, iron and steel production) and transportation modes (heavy-trucks and non-road transport).

Finding 3. The adoption of best-in-class efficient appliances is essential.

More efficient appliances need to be gradually adopted in all sectors of the economy, contributing to important reductions in final energy intensity. This means improving the technical efficiency of equipment such as electric motors and air conditioners and promoting more efficient energy sources. For example, according to the proposed NZE, in the transport sector, the energy intensity (fuel consumption per km travelled) reaches reductions of 80% for private vehicles like cars, motorbikes, and vans, and 65% for buses, between today and 2050. The estimated energy intensity of cement and steel reduces by 40% and 23% by 2050 respectively. In the buildings sector, the reduction in energy intensity reaches 40% in air conditioning, 35% in electric appliances, and 20% in lighting and cooking.

Finding 4. The decarbonization of the power sector should start now and accelerate after 2030.
A high demand for green electricity is needed to sustain the electrification of end-uses, essential to the NZE pathway. The installed wind and solar capacity reaches 41 GW in 2030, triples between 2030 and 2035 (128 GW) and reaches 550 GW in 2050. In parallel, the installed capacities of LNG, gas and coal power plants increase until 2030, following the PDP8 plans. Pumped hydropower and batteries are installed as electricity storage.

Finding 5. Coal power plants are converted to co-firing with biomass and used as dispatchable power plants, alongside gas and LNG power plants.
A significant capacity (around 45 GW) of dispatchable power plants (coal, gas, LNG plants) remain in the power system as a reserve. However, only a fraction of this capacity is utilised for power generation. Gas and LNG plants operate with an average capacity factor of less than 50% in 2050. Coal power plants operate in co-firing mode from 2045, with a full replacement of coal by biomass in 2050. They are used with an average capacity factor of less than 30%. Other co-firing options (e.g., ammonia and hydrogen) are not deployed because of the high costs of the supply chain.

Finding 6. Carbon capture and storage (CCS) is not needed in the power sector, but is essential in industry.
Achieving the NZE target is feasible without CCS in the power sector. However, the mitigation target of 20 Mt CO_{2eq}, proposed in the National Strategy on Climate Change for process-related emissions in 2050, is feasible only if at least 45 Mt of CO_{2eq} is captured in the industry sector, more particularly in the cement sector and, to a lesser extent, in the iron and steel and ammonia sectors.

A lower deployment of CCS is possible with less ambitious reductions of process-related emissions, but which would need to be compensated by higher reductions in energy-related emissions, through additional investments in the power sector (balanced against lower investments in the industry sector).

Finding 7. Light electric vehicle deployment will accelerate and dominate, but other transportation modes may not need to fully decarbonise by 2050.
In the proposed NZE, the transportation sector is responsible for around half the remaining emissions in 2050. Light vehicles (cars, motorbikes, and light-duty vehicles) are fully electrified in 2050. Plug-in hybrid vehicles are adopted as soon as 2025 and play a bridging role while battery electric vehicles progressively penetrate the market. Buses are almost fully electrified too (the non-electrified share consume blends of fossil and renewable oil). However, other modes are only partially decarbonized. Alternative fuels are used to partially decarbonize trucks (biodiesel, biomethanol, hydrogen to a lesser extent), aviation (biojetfuel), navigation (biomethanol, e-ammonia to a lesser extent) and rail (electricity, hydrogen to a lesser extent).

The application of the *Action Program for Transition to Green Energy and Mitigation of Carbon Dioxide and Methane Emissions from Transportation* would succeed in decarbonizing almost 100% of the transport sector by 2050 by boosting the penetration of biofuel, hydrogen, and e-fuel. No additional electrification would occur.

Finding 8. Earlier penetration of renewable energy would occur if less LNG power plants were commissioned or JETP commitments were implemented.

Limiting the commissioning of new fossil assets, particularly LNG plants, in the short term, would contribute to advance the penetration of renewable power plants, without changing the longer-term trends. The higher investments required in the power sector are compensated, from the total system cost perspective, by lower operating costs, compared to the use of LNG power plants.

Implementing the more ambitious JETP engagement requires additional installed solar and wind capacity of 83 GW by 2030 compared to the NZE scenario, which is challenging, but reduced investments in the longer term. The investment in the power sector in 2030 (USD25 billion) would be more than doubled compared to the NZE (USD11 billion). The earlier investments contribute to reduced longer term investments (2040-2050) in the power sector.

Finding 9. Annual Investments of up to USD170 billion per year are needed in 2050.

Investments of USD85 billion per year in 2025, increasing to USD170 billion per year in 2050 are needed to satisfy the energy demand services associated with the economic activities and at the same time to meet the NZE target (Figure 2). Transportation (including private vehicles) mobilizes the biggest share of these investments, followed by the power sector and industry.

As the transition towards cleaner transportation gains momentum, electric vehicles are anticipated to mobilize the highest share of transport-related investments (up to 85% by 2050). This underscores a clear commitment to electrify the transport sector as a key driver of emissions reduction.

Similar patterns emerge in the electricity generation sector, particularly regarding investments in renewable energy sources. Investments in wind, solar, and other renewable technologies collectively drive around 80% of investments in the power sector. This highlights the growing significance of renewable energy in reshaping the power generation landscape, as the nation increasingly turns to cleaner sources of electricity.

In the industrial sector, the investment landscape reflects the diversified approach to emissions reduction across different manufacturing sectors. This underscores that there is no one-size-fits-all solution to the complex challenge of industrial emissions reduction.

Finding 10. The drop in fossil fuel consumption is favourable to energy independence goals but new energy security concerns may emerge.

In the proposed NZE, the dependency of Vietnam on energy imports increases until 2030 due to increased imports of fossil fuels, including gas. The decarbonization targets positively contribute to the energy independence of Vietnam in the longer term by promoting the use of local resources (biomass, solar and wind). The remaining small industrial demand for coal in 2050 is supplied by domestic resources. However, the supply chain of clean energy technologies, like batteries, solar PV, electrolysers, heat pumps, wind turbines, may emerge as a new security risk in a context of high demand at the global level. Taking action to promote the domestic supply of key clean energy technologies deserves attention.

Finding 11. The NZE paves the way for almost 1 million direct jobs (net) by 2050 in the power sector, but measures are needed to ensure a just transition for workers.

According to the Co-benefit study[7], solar and wind will create 3.5 jobs and 2.8 jobs respectively per average installed MW capacity, whereas coal creates only 1.4 jobs. The proposed NZE will require almost 1 million direct jobs by 2050 in the power sector, with a strong acceleration in new employment from 2030. These will counterbalance jobs lost in the fossil fuel sector, but appropriate measures will be needed to ensure a just transition for workers.

Finding 12. Achieving the NZE is the opportunity to reach universal clean energy access, particularly for cooking.

In the NZE, biomass and LPG are still consumed for cooking. Decision-makers should ensure that cooking solutions are available to all households, notably as biomass remains the primary fuel for cooking, because inefficient biomass combustion has dramatic impacts on climate, health, gender inequalities, and deforestation.

4 Policy recommendations

4.1 The suggested policy portfolio

4.1.1 Renewable energy

The proposed NZE pathways suggest that the share of renewable energy sources (RES) increases rapidly, particularly in the power sector.

Specific pricing mechanisms, more particularly ceiling tariff, auction-based price discovery (some of which are already in-place) are essential to support the penetration of RES in the power system. Feed-in-tariffs (FITs) are now less relevant, at least for wind and solar, which should rather move to auction scheme, because the potential capacity to be installed is very high. In this context, a competitive scheme for selecting the best projects is more appropriate.

Increasing the share of RES in the power system requires ensuring the **stable and reliable operation of the national electricity grid** through appropriate grid operating standards. Moreover, battery

[7] https://www.cobenefits.info/country-studies-infographics/studies/vietnam/

energy storage system (BESS), pumped storage, hydropower extensions, smart grid, demand response (peaking tariff, curtailable rates, time-of-use tariffs etc.), power market ancillary services are relevant options to reinforce the stability of the grid.

Development of small-scale, distributed energy resources deployed in behind-the-meter contexts, such as **rooftop solar PV with zero export mode** (no injection to the grid), as targeted in the PDP8, is applicable in the residential and commercial/industrial sectors, especially in the areas at risk of electricity shortage such as the North.[8] Strong development of RES needs also to go hand in hand with building electricity storage systems. Policies to support the development of energy storage technologies, such as **Battery Energy Storage System (BESS**), would include the regulation of the selling price of electricity from BESS to levels equivalent to the electricity price during peak-hours of the system, or allow the selling price of electricity from RES projects with BESS to be higher than in the case of RES without BESS.

Out of the RES currently available for Vietnam's power generation, **offshore wind** has been recognized to play an important role for Vietnam power sector. Incentives and mechanisms need to be formulated for its development, include:

- Early formulation of legal documents for offshore wind power development, such as decrees, circulars, technical regulations, national standards on offshore wind power development.
- Appointing a national focal agency to implement the national master plan on offshore wind power development.
- Developing a bidding mechanism in the field of offshore wind power to select projects with reasonable and effective electricity prices and avoiding major impacts on the average cost of the entire power system in the context of a strong development trend of this power source in the future.
- Developing short- and long-term cooperation plans with international organizations in developing local human resources for this type of RES.

Production of new energy products such as **Green Hydrogen (GH)** and **Green Ammonia (GA)** under conditions of surplus renewable electricity also need to be encouraged. The establishment of direct power purchase agreement (DPPA) mechanisms may positively impact such implementation, allowing RES producers to sell surplus electricity directly to GH and GA producers.

The feasibility of a **one-stop shop authority** for wind and solar projects would deserve further exploration, since wind energy, for example, is now managed by several authorities in Vietnam. It could be inspired from experiences of the Danish Energy Agency[9], ensuring a smooth and administratively lean process in consenting the development of wind and solar farms including their decommissioning.

[8] Decision no. 500/QD-TTg dated 15th May 2023

[9] https://ens.dk/sites/ens.dk/files/Globalcooperation/one-stop_shop_oct2020.pdf

4.1.2 Carbon capture and storage (CCS) and carbon capture, utilization, and storage (CCUS)

In the proposed NZE, CCS is a critical option to reduce the process related GHG emissions from the industry sector. Some suggestions for **implementing and developing CCS/CCUS projects** in Vietnam are as follows:

- Formulate a strategy for research, development and deployment of CO_2 recovery, its treatment, and its reuse technology.
- Create incentives/mechanisms for businesses implementing CCUS projects, such as preferential tax rates. These businesses may include:
    - those that apply recovery technologies to reduce CO_2 emissions (steel, cement, petrochemical refineries, oil and gas, etc.).
    - those that invest capital and technology to provide CO_2 recovery, transportation, and storage services;
    - those that recover CO_2 and reuse it.
- Develop legal regulations on CCS/CCUS that are relevant to each target group mentioned above.
- Plan the areas and geological layers that can store CO_2 gas.

4.1.3 Electrification of end-uses

The proposed NZE shows the important role of electrification in the end-use sector in meeting the NZE target.

Electricity is expected to assume a crucial role as an energy vector for decarbonizing **thermal (heating and cooling) needs** in industry, commercial services, and residential sectors. Heat pumps, characterized by their high coefficient of performance (COP), are especially instrumental in providing efficient heating and cooling solutions and can be deployed at varying scales. This ranges from large heat pumps servicing district heating networks to smaller heat pumps catering to individual buildings or even single rooms.

To facilitate the widespread adoption of heat pump technology and promote sustainable heating solutions, several key policy recommendations are outlined:

1. Financial Incentives: The formulation and implementation of financial incentives in the form of subsidies, loans, or tax incentives can stimulate greater adoption of heat pump technology. These incentives provide tangible benefits to individuals and organizations, encouraging the transition to cleaner heating methods.
2. Building Regulations: The establishment of stringent building regulations can serve as a pivotal lever in driving the adoption of heat pump technology. These regulations can mandate or incentivize the integration of heat pump systems in new construction or renovations, thus promoting more energy-efficient and environmentally friendly heating solutions.

3. Stable Regulatory Environment: Creating a stable regulatory environment with long-term policies is essential for promoting investments in heat pump technology. Consistency in policy signals provides confidence to investors and industry stakeholders, fostering the necessary conditions for the growth of heat pump technology.

By implementing these recommendations, Vietnam can significantly advance the adoption of heat pump technology, thereby contributing to the reduction of carbon emissions and the transition to more sustainable heating solutions.

The proposed Net Zero Emission (NZE) plan also underscores the significant potential of electrification in decarbonizing the **transport sector**. Enhanced support policies are needed to boost the EV ecosystem. This includes the evaluation and implementation of tax reductions to make EVs more cost-competitive and attractive to consumers; for example, through a reduction in the special consumption tax levied on EVs, with a priority given to locally produced EVs. To support local production, tax exemptions on imports of raw materials, supplies, and components essential to produce EVs could help encourage their local manufacturing. Supporting the establishment of battery factories to lower the cost of EVs and enhance supply security is also important. A robust and competitive battery manufacturing sector is pivotal in promoting the widespread adoption of EVs (Box 3). The expansion of the availability of charging station systems, and support for their operation (to ensure the convenience and reliability of charging infrastructure) must also be considered.

By implementing these recommendations, Vietnam can facilitate the growth of the Electric Vehicle market, encouraging a shift towards cleaner and more sustainable transportation options, which align with the objectives of the NZE plan.

4.1.4 Alternative fuels

In the proposed NZE, **biomass and biodiesel** play a pivotal role in reducing emissions by substituting fossil fuels in hard-to-electrify end-uses and in power generation. To foster the development and utilization of biomass and biofuels for energy services, the following key recommendations are highlighted:

- Clear Biofuel Roadmap: Formulate a clear roadmap for reasonable use of biofuel in order to promote effective use of biofuels for energy services. It should include the valorisation of biomass waste, such as sugar industry’s bagasse.
- Incentives and Support: Create incentives and provide support for businesses/agencies engaged in the production, blending, and distribution of biofuels. This support can encompass financial assistance, technological assistance, tax benefits, and land use policies that encourage and facilitate the biofuel industry's growth.
- Research and Development (R&D): Promote research and development efforts aimed at improving the yield of raw materials used for biofuel production. Additionally, emphasize the

development of second and third-generation biofuels, and advanced high-performance production technologies.

- Tax Adjustment: Adjust (decrease) the environmental protection tax imposed on biofuels. This adjustment is justified by biofuels' ability to reduce emissions when compared to mineral gasoline. A reduced tax burden can make biofuels more cost-competitive and attractive.
- Retail: Encourage and facilitate retail stores to become distribution points for biofuels. This step can expand the availability and accessibility of biofuels to consumers, promoting their use in everyday applications.

4.1.5 Energy efficiency

Energy efficiency has a central role to the transformation of the energy system towards NZE. The following actions would contribute to transition towards a more energy efficient economy:

- **Revision of the legal framework for energy efficiency activities** (EEC Law, Decree 21): In Vietnam, the EEC Law[10], approved in 2010, has set a milestone legal framework for facilitating energy efficiency activities. The Law has two under law decrees such as Decree No. 21/2011/NĐ-CP[11] and Decree No. 17/2022/NĐ-CP[12] detailing the Law implementation. After more than a decade of implementation, the law needs to be reviewed and amended to enhance market instruments, policies, and mechanisms that accelerate investments in energy efficiency activities. Key aspects for improvement include incentive mechanisms, the establishment of energy efficiency funds, support for energy service companies (ESCOs), green building standards, and the promotion of Net-Zero building construction.

- **Obligatory regulations and incentive mechanisms for energy efficiency investments**: Under the EEC Law, Decree No. 21/2011/NĐ-CP, the MOIT issued Circular No. 25/2020/TT-BCT[13] for responsibilities of designated energy users (DEUs)[14]. Responsibilities of DEUs need to be clarified and aligned with current organizational structures, reinforcing coordination among relevant Ministries and local authorities in managing energy efficiency compliance. Furthermore, energy efficiency benchmark circulars should be developed for various products and subsectors.

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[10] Law No. 50/2010/QH12

[11] Decree No. 21/2011/NĐ-CP on Detailing the Law on Economical and Efficient use of Energy and Measures for its implementation.

[12] Decree No. 17/2022/NĐ-CP Regulations on penalties for administrative violations in the field of electricity, safety of hydropower stations, economical and efficient use of energy

[13] Circular No. 25/2020/TT-BCT on preparing plans for economical and efficient use of energy and reports on implementation thereof; implementation of energy accounting.

[14] Designated energy user refers to an industrial, agricultural or transportation facility having annual energy consumption of at least 1,000 tonnes of oil equivalent (TOE); a construction building used as head office, working office or house; education institution, medical establishment, recreational facility, or sport facility; hotel, supermarket, restaurant, or shop having annual energy consumption of at least 500 tonnes of oil equivalent (TOE)

- **Legal bases for new fields**: The establishment of a supportive framework for the Energy Service Company (ESCO) system (Box 2) is needed. This mechanism could include accreditation systems for energy audit service providers, the creation of energy efficiency funds (equity funds, energy efficiency revolving funds, etc.), and the introduction of other financial instruments such as technical assistance, credit lines, carbon finance, and green bonds. To promote demand side management (DSM) and demand response (DR) activities, encompassing technologies like smart meters and other technology to remotely control load coupled with dynamic pricing of electricity, a comprehensive legal framework should be developed. This includes technical accreditation systems and financial regulations that facilitate DSM and DR activities in Vietnam.

- **Sectoral policies (major industrial subsectors like iron and steel, cement):** Under the EEC Law, via a series of circulars, MOIT has formulated energy efficiency norms for several industrial subsectors which include beverage, iron & steel, plastic, pulp & paper, aquatic products, and sugar[15]. These norms need to be reviewed, updated, and expanded. New energy efficiency norms should be issued for other critical industrial subsectors and products, including cement, fertilizer, chemicals, food processing, textile and garment manufacturing. Similarly, the development of energy efficiency norms or benchmarks for the buildings sector should be explored, recognizing the significance of electrification in this sector as a key component of achieving Net-Zero emissions.

Box 2. The potential role of the Energy Service Companies (ESCOs)

Energy service companies (ESCOs) deliver energy efficiency projects that are financed based on energy savings. They design, install, and in some cases, finance energy efficiency projects through a contractual agreement with the energy-using customer, usually using an energy performance contract (EPC). The EPC commits the ESCO to installing the necessary equipment, provides a performance guarantee and establishes the terms of any upfront or ongoing payments, which are intended to be less than the financial savings realised by the project. Different types of EPCs are available. Depending on the customer's preference and access to capital, the customer, the ESCO, or a combination of the two can be responsible for securing the finance for the project.

On average, ESCO projects are delivering energy savings upwards of 25%. While ESCOs can implement projects in buildings, industry, and transport in both the private and public sectors, the majority of ESCO projects takes place in the non-residential buildings sector, followed by industry, with virtually no projects in the transport sector. Lack of technical and financial capacity, inappropriate policies, and the usual consideration of energy efficiency as too risky are barriers to the development of ESCOs.

Source: IEA website[16]

[15] Circular No. 19/2016/TT-BCT; Circular No. 20/2016/TT-BCT; Circular No. 38/2016/TT-BCT; Circular No. 24/2017/TT-BCT; Circular No. 52/2018/TT-BCT; Circular No. 39/2019/TT-BCT.

[16] https://www.iea.org/reports/energy-service-companies-escos-2

4.1.6 Carbon market

The introduction of carbon instruments to put a **price on carbon** emissions is a crucial step in influencing energy production and consumption decisions while generating revenues to expedite the transition to a Net-Zero Emission (NZE) economy. In the proposed NZE, the overall carbon price is projected to reach USD50 per metric ton of CO_{2eq} in 2030, further rising to USD80 per ton of CO_{2eq} by 2050.

The development and implementation of carbon markets in Vietnam should be closely linked to the energy transition and NZE agenda. An effectively functioning carbon market plays a pivotal role in avoiding stranded assets in energy investment. Furthermore, carbon instruments enhance the competitiveness of domestically produced goods for exporting to the global markets. More particularly, the European Carbon Border Adjustment Mechanism (CBAM) serves as a mechanism to assign a fair price to carbon emissions generated during the production of carbon-intensive goods imported into Europe, and to encourage cleaner industrial production in non-EU countries. The CBAM will initially apply to imports of specific goods such as cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen[17]. Mandatory carbon pricing in exporting countries, like Vietnam, can be credited under CBAM, reducing the differential to be paid.

Vietnam is currently devising a project to develop a domestic carbon market, focusing on the mandatory trading of greenhouse gases (GHG) emissions quotas for industries and businesses within the domestic market, while also considering international market integration. Decree 06/2022/ND-CP[18], issued on 7 January 2022, lays down clear regulations for the development of Vietnam's carbon market. In the years 2023-2027, the emphasis will be on developing regulations on carbon credit management, quotas trading, carbon credit exchange with piloting implementation of carbon credit exchange from 2025. From 2028, the carbon credit exchange will be fully operational, connecting with the global carbon market.

4.1.7 Socio-economic transformation

In the pathway for achieving NZE, many new and emerging technologies are required for the transition. These cutting-edge technologies encompass a wide range of sectors and applications, including batteries, electrolysers, electrical vehicles (bikes, cars, etc.), solar PV panels, wind turbines, advanced biofuel production, synthetic fuels, carbon capture, utilization and storage, etc. Focused policy measures for **development of new industrial sectors** corresponding to these technologies are also very important for avoiding supply disruptions and reinforcing security. This would help increase domestic competitiveness and reduce the development costs of new and cutting-edge technologies as well of costs of producing clean energy. To drive the successful adoption of these

[17] https://www.energytransitionpartnership.org/uploads/2023/08/Final-CBAM-Assessment-Report_20230503.pdf

[18] Decree 06/2022/ND-CP dated January 7, 2022 on mitigation of GHG emissions and protection of ozone layer

emerging technologies, specific strategies for research and development (R&D), capacity building, technology transfer and industrial development are needed. Several countries are engaging in the development and expansion of their capacity to manufacture clean technologies through supporting policies (Box 3).

Box 3. Examples of policies and measures to expand domestic manufacturing in other countries

- Battery production facilities in the United States, driven in large part by the incentives provided by the Inflation Reduction Act (IRA).
- Domestic manufacturing of solar PV and batteries in India, driven by the Production Linked Incentive (PLI) programme. It includes the provision of nearly USD2.4 billion under the second phase of the High Efficiency Solar PV Modules PLI that began in October 2022 and USD2.5 billion under the Advanced Chemistry Cell Battery Storage PLI announced in late 2021.
- Strengthening clean technology manufacturing in the European Union through the Net-Zero Industry Act (NZIA), announced in March 2023.
- Battery manufacturing in Japan through USD1.8 billion in subsidies, part of the Japan's Green Transformation (GX) initiative.
- Support to new manufacturing equipment for key clean technologies by refundable tax credit for 30% of investment cost, in Canada's 2023 Budget;
- Support domestic battery manufacturing thanks to USD5 billion in loans and guarantees from the Export-Import Bank of Korea and state-owned Korea Trade Insurance.
- Support to clean technology manufacturing in Australia with USD2 billion for the sector via the National Reconstruction Fund.

Source: IEA (2023)[19]

The journey to achieve the NZE implies a **rapid transformation in energy sector employment**, with a strong demand for workers in the clean energy sector, particularly in the power sector, while employment in carbon-intensive sectors is expected to decline. The availability of qualified workers is too low in Vietnam. To manage this workforce transition effectively and mitigate negative political and social impacts, several measures might be considered[20]:

- Labour Market Program: Establish labour market programs that support workers transitioning across sectors. These programs should enhance labour market flexibility and include measures such as compensation and reskilling. International experience underscores the value of early, short, and intensive retraining programs, which are more effective in helping workers transition to new occupations.
- Accelerating Workforce Qualification: Develop a comprehensive strategy for vocational training and university programs that places a strong emphasis on renewable energy and

[19] IEA. (2023). Net Zero Roadmap. A Global Pathway to Keep the 1.5 °C Goal in Reach. 2023 Update. International Energy Agency.

[20] Based on: Cobenefit Study (2019). Future skills and job creation through renewable energy in Vietnam; and World Bank Group. (2022). Vietnam Country Climate and Development Report. Washington DC.

clean technologies. Collaborative efforts between the government and the private sector are essential to ensure the relevance of training programs and their rapid implementation.
- Broadening Job Visibility: Increase awareness and visibility of job opportunities in the renewable energy sector.

It's also important to consider the workforce needs in the central government to ensure the implementation of a relevant institutional and regulatory framework. For example, in Denmark, about 2,000 of the 100,000 jobs in the energy sector are in the central government dealing with energy and climate, the equivalent of the MOIT and MONRE workforce.

Furthermore, policies encouraging **behavioural changes and greener lifestyle** should complete the portfolio of interventions aimed at achieving NZE. Vietnam has issued the National Green Growth Strategy[21] with important objectives for green lifestyle and promoting sustainable consumption. Beside the necessary changes in legal frameworks for energy efficiency activities, behavioural changes in energy consumption are also needed. Possible behavioural changes for reducing or eliminating unnecessary or wasteful energy consumption include walking, cycling or taking public transportation instead of driving; moderating the use of air conditioning and heating; replacing air travel with train journeys where possible; or choosing a more fuel-efficient vehicle. These changes can improve wellbeing and public health and positively contribute to decarbonisation.

4.2 Where to start

The process of facilitating the energy transition in Vietnam can begin by addressing several key areas and implementing pilot projects that seize the opportunities presented by this transition. Here are some actionable steps to initiate the transition.

Enhance the regulatory framework:

1. Revise the legal bases, regulations, and tariff framework necessary for upscaling renewable development with focus on onshore wind, offshore wind parks and large onshore floating PV plants.
2. Create a one-stop shop authority responsible for planning, tendering, and approving new renewable energy projects.
3. Implement incentive mechanisms for phasing out coal in new and existing coal-fired projects. This may include enhancing energy efficiency and smart control in coal-fired power plants, co-firing with biomass and ammonia, and ancillary services (frequency control, reactive power and voltage control, black start, operative reserve, load following etc.) with capacity charges for reserve capacity.

[21] Prime minister's Decision No. 1658/QD-TTg dated on 1st October 2021 on the National green growth strategy for the 2021 - 2030 period, with a vision by 2050.

Define innovative financing mechanisms:

1. Define and promote credit line and energy service company (ESCO) scheme to accelerate investments in energy efficiency, particularly in industry and buildings. This may require revising and amending existing legislation such as the EEC Law and its under law documents.
2. Define and promulgate a clear roadmap and milestones for avoiding new investment in fossil fuel boilers and furnaces in industry.
3. Enhance tariffs for alternative fuels like natural gas and biomass and explore the implementation of carbon markets to support fuel switching in industry.

Speed-up market development with pilot projects:

1. Implement pilot projects for battery energy storage systems (BESS) in areas potentially facing electricity shortages. These projects should be strategically located near renewable sources and available transmission infrastructure to enhance system flexibility.
2. Implement pilot projects to investigate the technical and economic viability of green hydrogen production technology. The initial pilot project may start with a capacity of 10-20 MW and should be located near potential green hydrogen users, such as oil refineries, fertilizer producers, and fuel cell manufacturers. The proximity to a seaport should also considered, as it may enable export opportunities, in particular to Japan and Korea.
3. Implement a small-scale pilot for carbon dioxide capture, either in existing thermal power plants or industrial facilities. The project should be located near existing oil extraction areas in the south to utilize the captured CO_2 for enhanced oil recovery.

Prepare for the future:

1. Ensure relevant capacity building in critical fields, including renewable power, battery technology, H_2 electrolysis, electrical vehicles, energy efficiency, and high-voltage direct current (HVDC) transmission.

Prepare large investments in each coming decade:

1. In 2023-2030, large investments are foreseen for renewable power technologies such as onshore wind, offshore wind, and solar. The primary objective is to slowdown the increasing trends of fossil fuel use and imported fuels.
2. In the period 2031-2030, along with renewable power technologies, co-firing technology, battery storage, building electrification, charging infrastructure for electrical vehicles, hydrogen electrolysis, and green building may attract large investments. Large investments in this period would come with a primary objective for maintaining the increasing trends of renewable power and upscaling the emerging technology.
3. In 2041-2050, the target should focus on cutting-edge technologies such as advanced biofuels, H_2-based fuels, synthetic fuels, carbon capture and storage, net-zero buildings, etc. These technologies are essential for achieving Net-Zero emission targets, particularly in hard-to-decarbonize sectors like iron & steel, cement, and long-distance transport (heavy trucks, maritime navigation, airplane).

5 Annex 1. Results-Based Monitoring Framework

The results of the project are monitored through the following framework: E4SMA- Diagnostic Study on Net-Zero for The Energy Sector in Vietnam. All reports update the achievement of the indicators.

6 Annex 2. Outcomes of the assessment (Mid-Term Report)

This Annex includes the main outcomes of the assessment, extracted from the Mid-Term Report "Assessment Report of the Energy Sector in Vietnam".

6.1 Towards the decarbonization of the economy

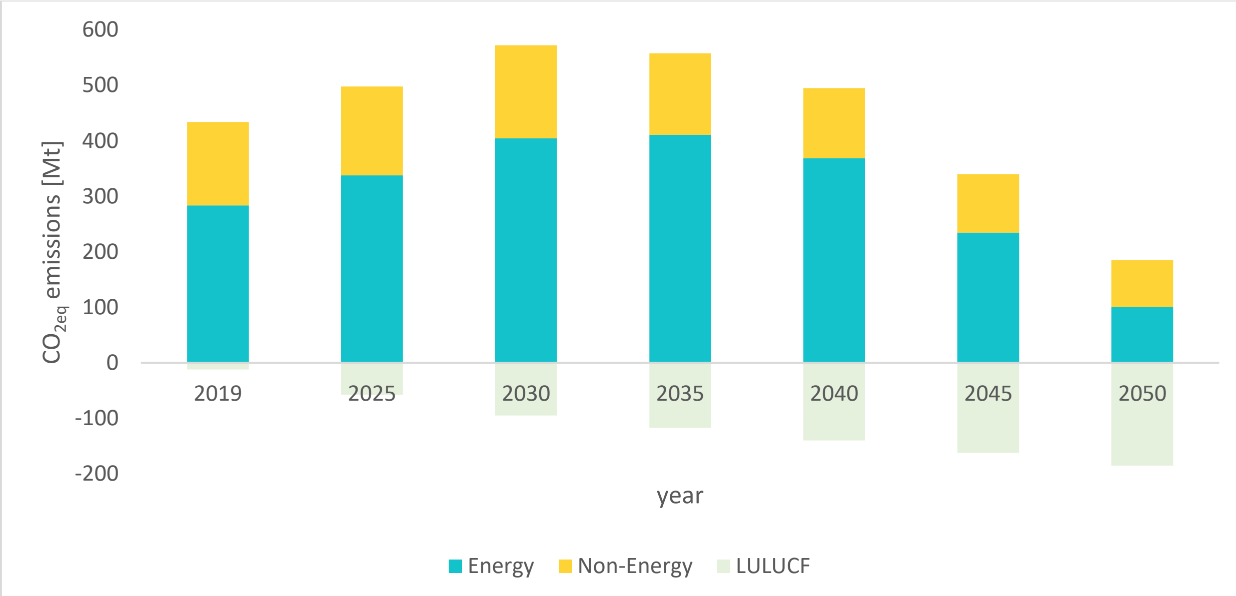
6.1.1 Emission reductions

An overall emission trajectory aligning with the national projections

As described in Table 1, specific targets apply separately to energy-related emissions and non-energy emissions. Non-energy emissions include process-related emissions, such as non-combustion process emissions from cement production or chemical industries. Land Use, Land Use Change and Forestry (LULUCF) emissions are exogenous to the scenario, and are fixed to the levels estimated by national references.

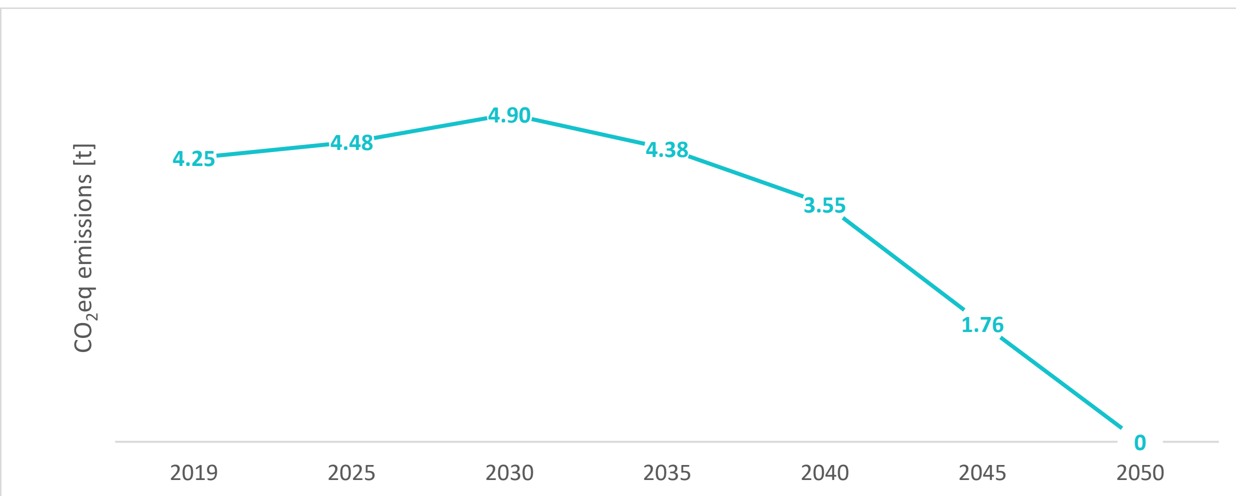
The overall emission trajectory of the NZE is well-aligned to the national projections estimated by the National Strategy for Climate Change to 2050 and the Energy Master Plan, with a peak of 411 Mt CO_{2eq} of energy-related emission in 2035, decreasing rapidly after 2035 to reach the target of 101 Mt CO_{2eq} in 2050 (Figure 2).

The corresponding emissions per capita (Figure 3) slightly increase until 2030 before decreasing rapidly. It always remains below the unstainable levels of industrial countries.



Source: Non-energy and LULUCF emissions are based on the National Strategy for Climate Change to 2050 (2022) and the Energy Master Plan (2023). Energy emissions are an outcome of TIMES-VN.

Figure 2. GHG emissions (energy, non-energy and LULUCF), 2019-2050



Source: Calculation based on outcome of TIMES-VN

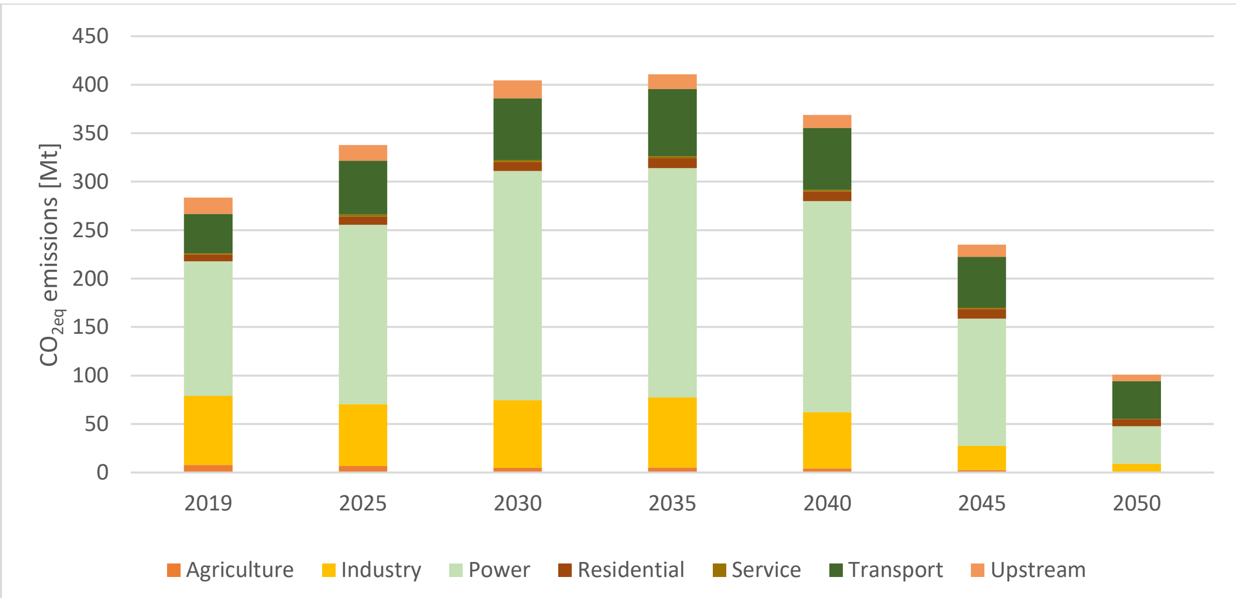
Figure 3. GHG emissions per capita, 2019-2050

A rapid decarbonization of the power sector and slower decarbonisation of the transportation and industry sectors

The power sector dominates GHG emissions during the next two decades (Figure 4). It represents 52% in 2019 and more than 60% of energy-related emissions in 2040. However, despite the increase in electricity production resulting from the electrification of the economy, emissions in the power sector stabilize and reduce rapidly after 2035, representing 42% of emissions in 2050.

The emission reductions in transport[22] are more challenging and its share of emissions increases from 15% in 2019 to 38% in 2050.

The reduction in energy-related emissions from the industry sector is rapid after 2035. However, emissions observed up to this point hide major changes in the sector, mostly electrification, which if absent would lead to even higher emissions due to Vietnam's rapid economic growth.



Source: Outcome of TIMES-VN.

Figure 4. Energy-related greenhouse gas emissions by sector, 2019-2050

6.1.2 Decarbonization strategies

The primary energy supply perspective: the expected penetration of renewable sources[23]

Modelling results show how primary energy supply (PES) changes in the NZE scenario pathways (Figure 5). While the current energy system largely relies on fossil fuels, the energy system will primarily rely on renewable energy sources (RES) in the NZE scenario. The share of RES in primary energy supply increases, from a low value of 17% in 2019 to 22% by 2030; it then accelerates rapidly, achieving approximately 82% of PES in 2050. Growth is primarily driven by increased bioenergy usage

[22] More details on the transformation of the sector are provided in the next section. Moreover, a sensitivity analysis (TRANSPORT) explores deeper mitigation opportunities in the transportation sector.

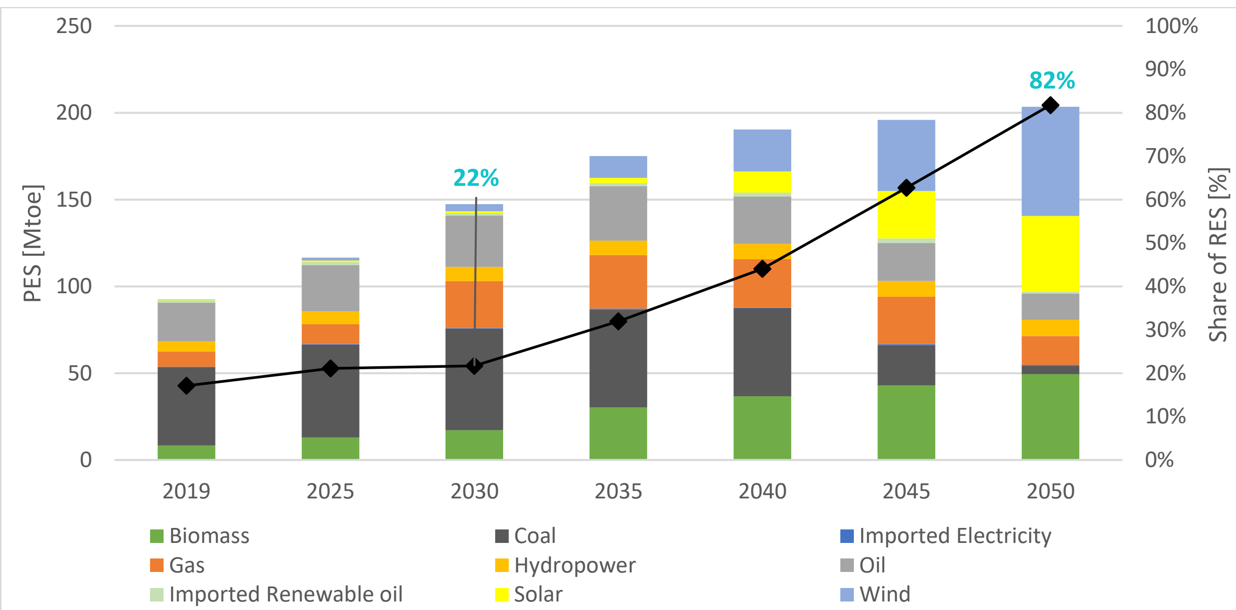
[23] A sensitivity analysis (JETP) explores the consequences on renewable energy of lower emissions targets in 2030.

in end-use sectors (transportation and industry) and a rapid growth of wind and solar for electricity generation.

Natural gas plays a transition role, contributing to reducing the reliance on coal in the mid-term period (15-20 years) before declining at the end of the horizon.

Coal remains quite stable until 2040, used for electricity generation and in industry. It declines rapidly from 2040 due to its high carbon intensity. It is worth noting that coal does not fully disappear from the energy system by 2050, being used in the cement, iron and steel sectors. These are associated with carbon capture (more details in section 4.2.2).

Fossil oil supply slightly increases until 2035, driven by the increased energy demand mostly in the transportation and buildings sectors. Oil is then substituted by biofuels and electricity in transportation, while LPG continues to be used in the residential sector. More details about the end-use sectors are provided later in the report.



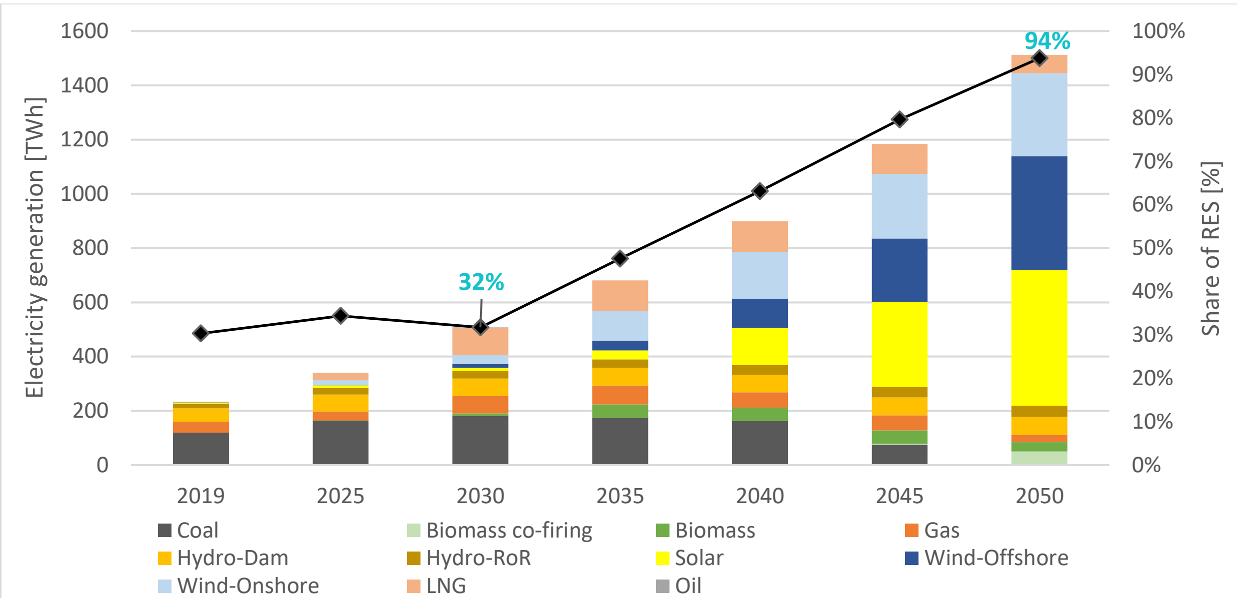
Source: Outcome of TIMES-VN.

Figure 5. Primary energy supply by fuel and renewable energy share, 2019-2050

In the power sector, the RES share remains relatively stable between 2019 and 2030, reflecting the parallel growth of LNG and gas power plants on one hand, and solar and wind power plants on the other hand. Post-2030 results show a steeper growth of renewable electricity generation, primarily from solar and wind. Dispatchable generation using biomass also grows over time, accounting for about 6% of electricity generation by 2050, including the conversion of existing coal power plants into co-firing plants.

Other co-firing options (e.g. ammonia and hydrogen) are not deploying, primarily due to cost reasons. Investing to produce and supply ammonia and hydrogen for the power sector is not the most cost-effective decarbonization option given ammonia and hydrogen production costs and their own consumption of electricity. The use of ammonia and hydrogen as clean energy sources is more economic in end-use sectors which are difficult to electrify. More cost-effective is investing in wind and solar complemented by a baseload provided by gas, LNG and biomass, is more cost-efficient.

Additional investments (not shown in the graph) are foreseen on electricity storage, including investments in pumped storage hydropower for 2.4 GW from 2030, and batteries for 11 GW and 30 GW by 2045 and 2050 respectively.



Source: Outcome of TIMES-VN.

Figure 6. Electricity generation by fuel and renewable energy share, 2019-2050

The unavoidable role of CCS in the cement sector[24]

Carbon capture and storage (CCS) is commonly considered a necessary mitigation option to reach zero emission in 2050, due to emissions from hard-to-abate sectors. However, its global deployment is not as fast as expected (IEA, 2023)[25]. It requires specific enabling conditions, including policy and regulatory framework, public support, and technology innovation. During stakeholder consultation, it

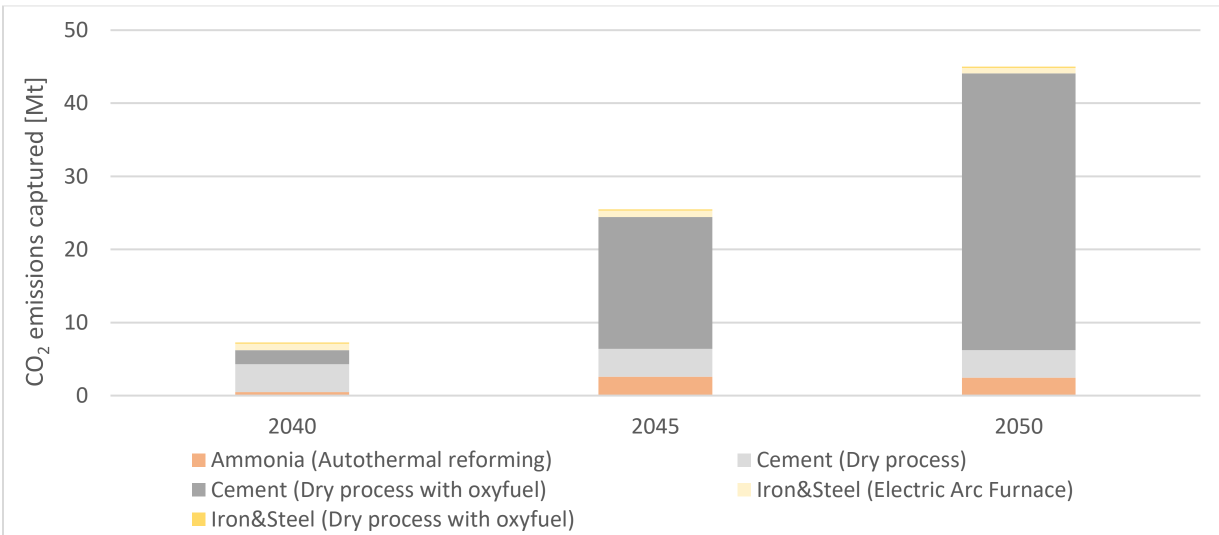
[24] Sensitivity analyses (LOW-CCS and HIGH-CCS) explore the consequences of a larger and of a lower deployment of CCS in Vietnam.

[25] IEA (2023), Tracking Clean Energy Progress 2023, IEA, Paris https://www.iea.org/reports/tracking-clean-energy-progress-2023, License: CC BY 4.0

emerged that CCS was currently not a first-choice mitigation option in Vietnam due to technical uncertainties and low public acceptance.

Results show that achieving NZE is feasible without CCS in the power sector. However, CCS remains a critical option for hard-to-abate industrial sectors, more particularly to reduce process-related emissions. The total amount of captured CO_2 in the industry sector will reach 45 Mt in 2050 (Figure 7). In other words, the mitigation target of 20 Mt CO_2, imposed on process-related emissions, is not feasible with a lower amount of captured CO_2.

The capture occurs mostly in the cement sector (up to 84% of all captured emissions), and, to a lower extent, in the iron and steel and ammonia sectors (Figure 7).

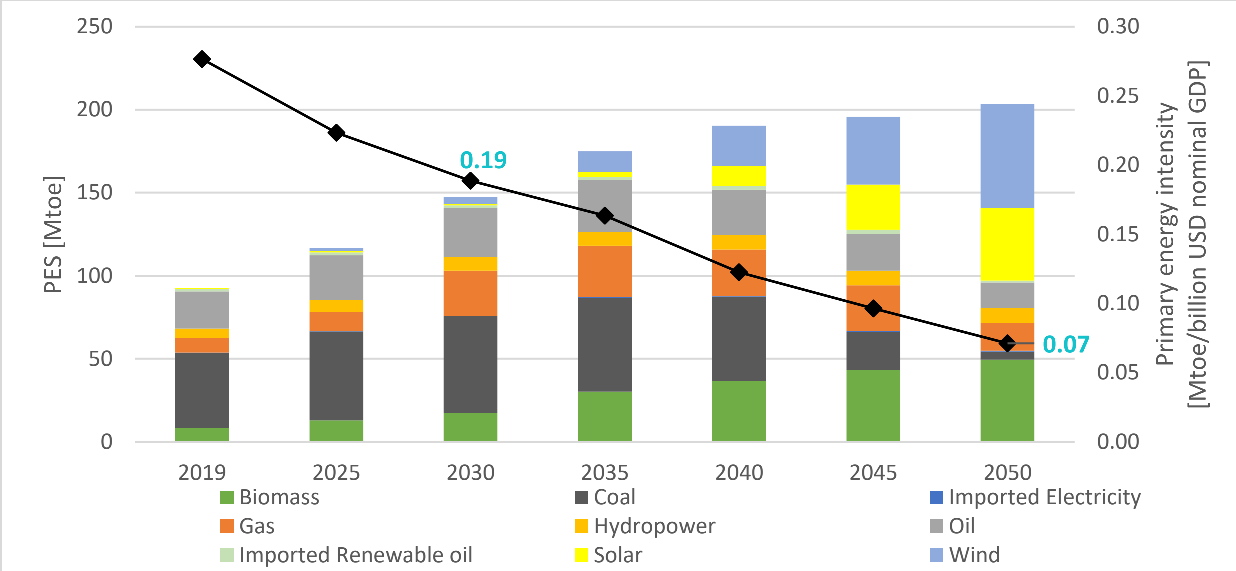


Source: Outcome of TIMES-VN.

Figure 7. Captured CO_2 by sector and process type, 2019-2050

The notable reduction in the energy intensity of the economy

The primary energy intensity is considerably reduced throughout the period, by 4 times between 2019 and 2050 (Figure 8). The energy efficiency of technologies and the substitution of coal for natural gas drive the initial reduction in the energy intensity of the economy. The strong penetration of renewable energy sources (notably wind and solar) and the electrification of all sectors drive the gain in energy efficiency of the economy observed during the period 2035-50.



Source: Outcome of TIMES-VN.

Figure 8. Primary energy supply by fuel and energy intensity, 2019-2050

Electrification, bioenergy and energy efficiency to decarbonize the end-use sectors[26]

Concerning the decarbonization of end-use sectors, three main strategies have been identified.

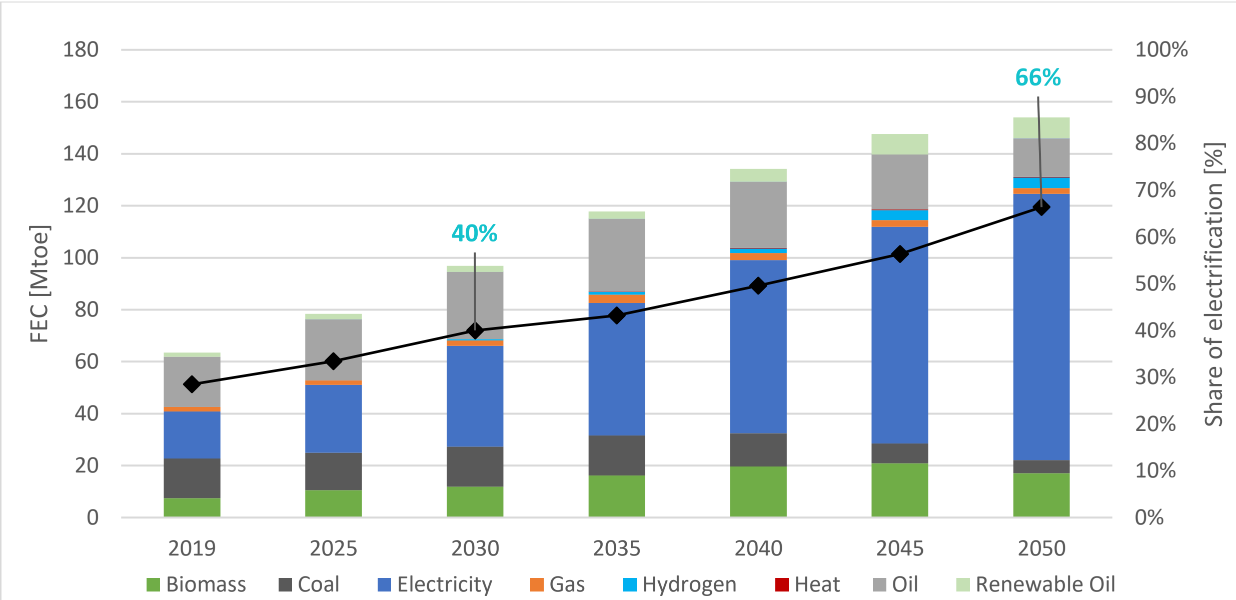
Not surprisingly, electrification of end-use sectors is the dominating decarbonization strategy. The electricity share in the final energy consumption (FEC) reaches 40% in 2030 and 66% in 2050 (Figure 9).

Secondly, bioenergy plays a notable mitigation role, particularly in industry and transport. Biomass replaces coal as the primary fuel for high-temperature heat production in all industrial subsectors. Liquid biofuels (7.4 Mtoe in 2050) and synthetic fuels (0.7 Mtoe in 2050, of mostly ammonia) contribute to decarbonization in the transport sector.

Last, but not least, energy efficiency plays a fundamental role. In the transport sector, energy intensity, expressed in terms of fuel consumption per km travelled, reduces steeply over the entire horizon, reaching reductions, compared to today's levels, of around 80% for private vehicles like cars, motorbikes, and vans, and 65% for buses. This progress is driven by the introduction of more efficient engines and the electrification of transportation modes. Plug-in hybrid vehicles (PHEV) are adopted as soon as 2025 (they represent 100% of electric cars on the road in 2025) and play a bridging role, between 2025 and 2040, while battery electric vehicles (BEV) progressively penetrate the market. BEVs represent more than 50% of electric cars in 2050 and 100% of them in 2050. Similar patterns occur in industry. For example, the estimated energy intensity of cement and steel reduces by 40% and 23%

[26] Specific insights for each end-use sector are provided in other sections.

by 2050 respectively. In the buildings sector, efficient appliances are gradually adopted in all areas of energy demand, contributing to a reduction in energy intensity by 2050 of 40% in air conditioning, 35% in electric appliances, and 20% in lighting and cooking.



Source: Outcome of TIMES-VN.

Figure 9. Final energy consumption (FEC) and share of electricity in end-use sectors, 2019-2050

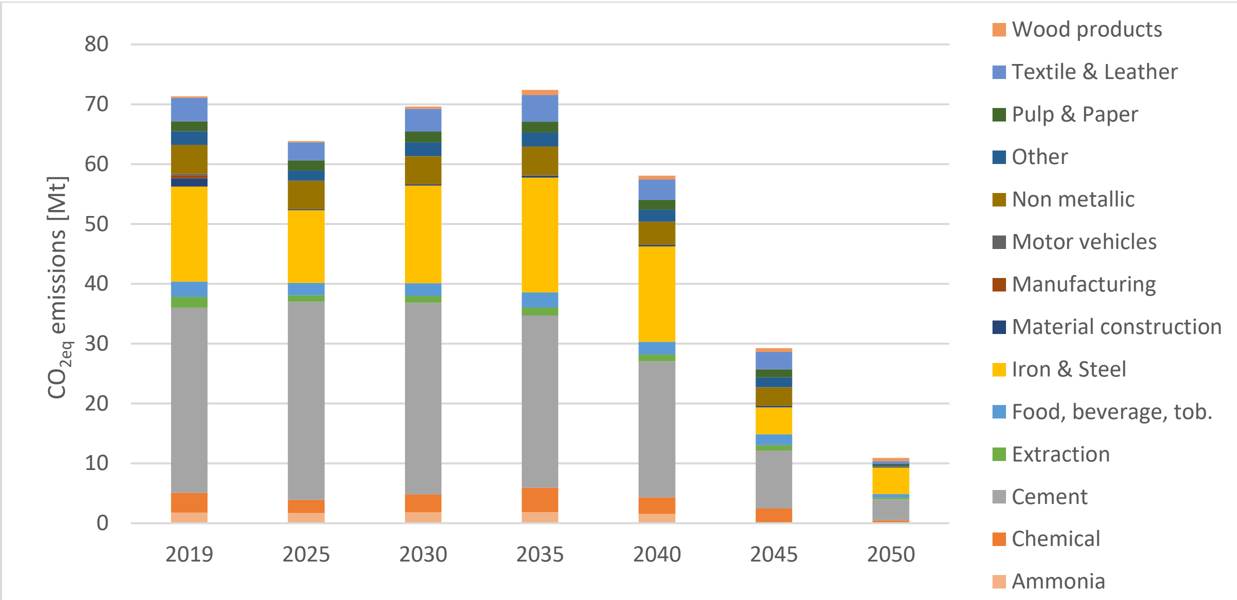
6.1.3 Zooming in end-use sectors

The dominant industrial emissions from cement and iron and steel production

Focusing only on energy-related emissions, cement and iron and steel are the major greenhouse contributors from the industry sector (Figure 10). Although the two sectors engage in rapid decarbonisation after 2035, they do not become carbon neutral by 2050; their remaining emissions represent 8 Mt CO_2eq, or 73% of total industrial emissions.

At the international level, the emissions of these two subsectors are strategic in the context of the European Carbon Border Adjustment Mechanism (CBAM). The application of a carbon tax to engage these sectors in the reduction of their emission intensity and encourage the adoption of cleaner technologies could reduce the negative impacts of CBAM on producers and exporters of these products to Europe, in addition to contributing to reaching the NZE target[27].

[27] A detailed analysis of the impact of CBAM for Vietnam was commissioned by ETP: Chu, H.L., Do, T.N. et al. (2023). *Carbon Border Adjustment Mechanism Impact Assessment Report for Vietnam*, prepared for the Energy Transition Partnership for Southeast Asia (ETP), Hanoi-Vietnam. It can be retrieved from: https://www.energytransitionpartnership.org/uploads/2023/08/Final-CBAM-Assessment-Report_20230503.pdf.



Source: Outcome of TIMES-VN.

Figure 10. Energy-related GHG emissions by industrial sub-sector, 2019-2050

The deep electrification of the rapidly growing industry sector

The growth of industrial energy consumption (Figure 11) is driven by rapid economic development.

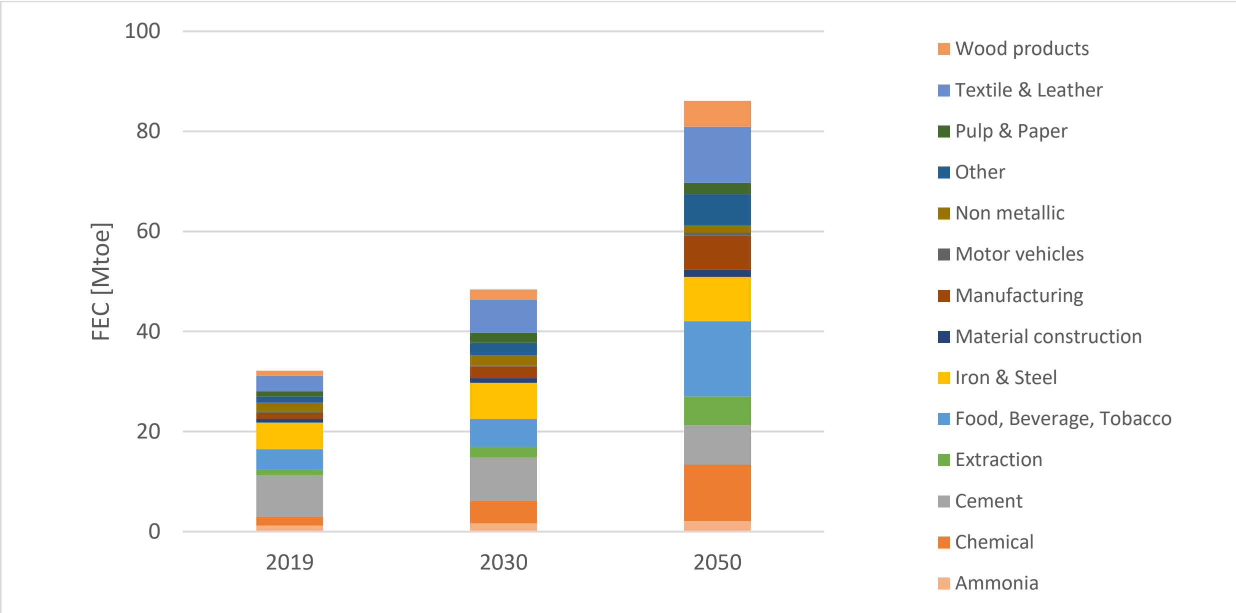
The electrification of the sector is the primary decarbonization strategy (Figure 12), reaching 50% in 2030 and 74% in 2050. Electricity is used mainly in low-temperature heat and machine drive processes across all industrial subsectors.

Biomass also plays an important role, replacing coal for high-temperature heat production in most industries, and partially replacing coal in cement production processes.

Hydrogen penetrates the industrial final energy mix after 2040, and is mainly consumed in the iron and steel industry (H_2 direct reduction process) and, to a lesser extent, in ammonia synthesis plants (Haber-Bosch process).

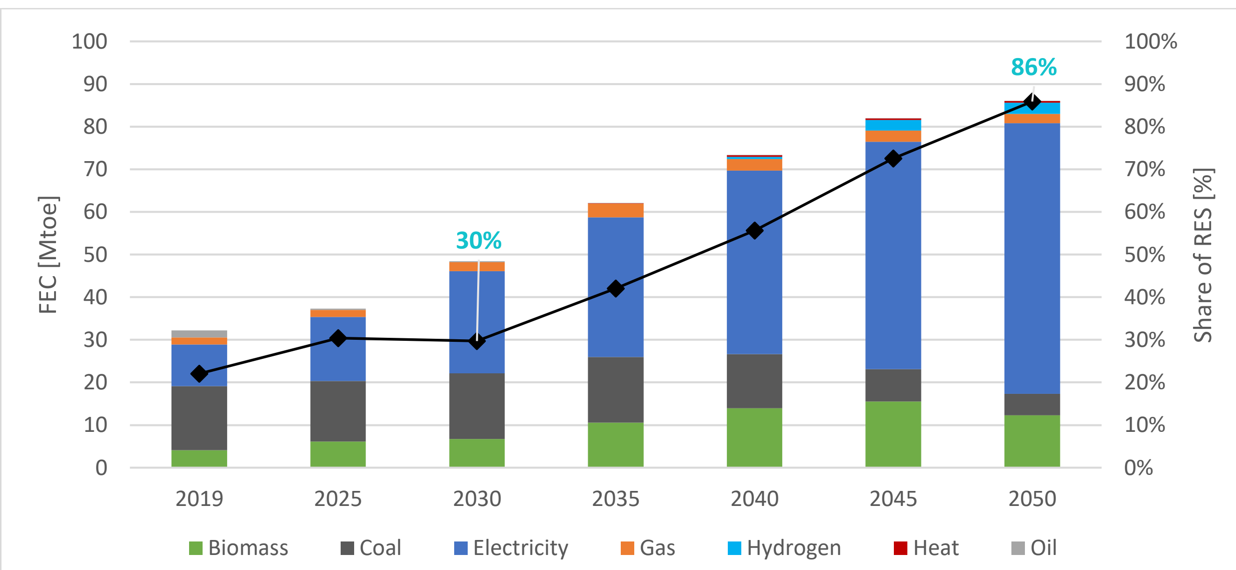
Although decreasing, fossil fuels (coal and natural gas) remain in the energy mix of the sector until 2050. Coal is mainly used in the cement sector for clinker production and secondarily, in steelmaking processes. Natural gas is almost entirely used in the ammonia industry as feedstock and for heat generation.

The overall share of RES (including renewable-based electricity) in industry reaches 30% in 2030 and 86% in 2050.



Source: Outcome of TIMES-VN.

Figure 11. Final energy consumption by industry sub-sectors, 2019, 2030, and 2050



Source: Outcome of TIMES-VN.

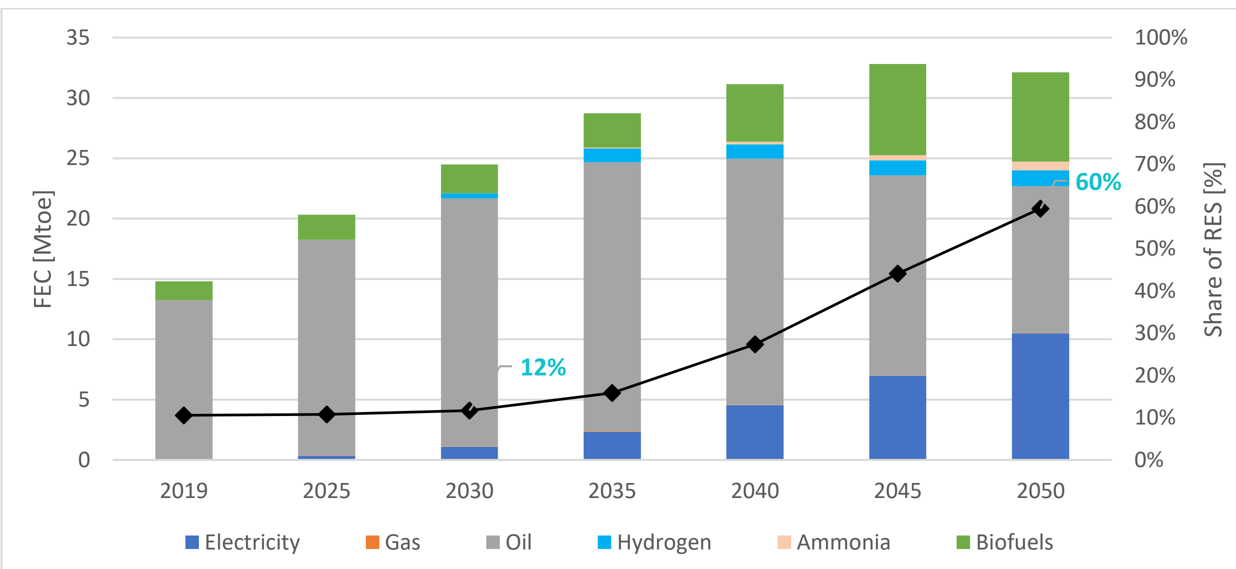
Figure 12. Energy mix of industry sector by fuel and renewable energy share, 2019-2050

The balanced use of electricity and biofuels to decarbonize transportation[28]

Electrification and biofuels contribute in a balanced manner to the decarbonization of the transportation sector (Figure 13). As a result, the share of RES (including renewable-based electricity) in transport grows from 12% in 2030 to 64% in 2050.

According to the modelling results, electricity accounts for 5% and 32% of sector consumption in 2030 and 2050 respectively, while biofuels account for 10% and 29% respectively. Hydrogen see limited penetration from 2030, reaching 6% of the sector's consumption in 2050.

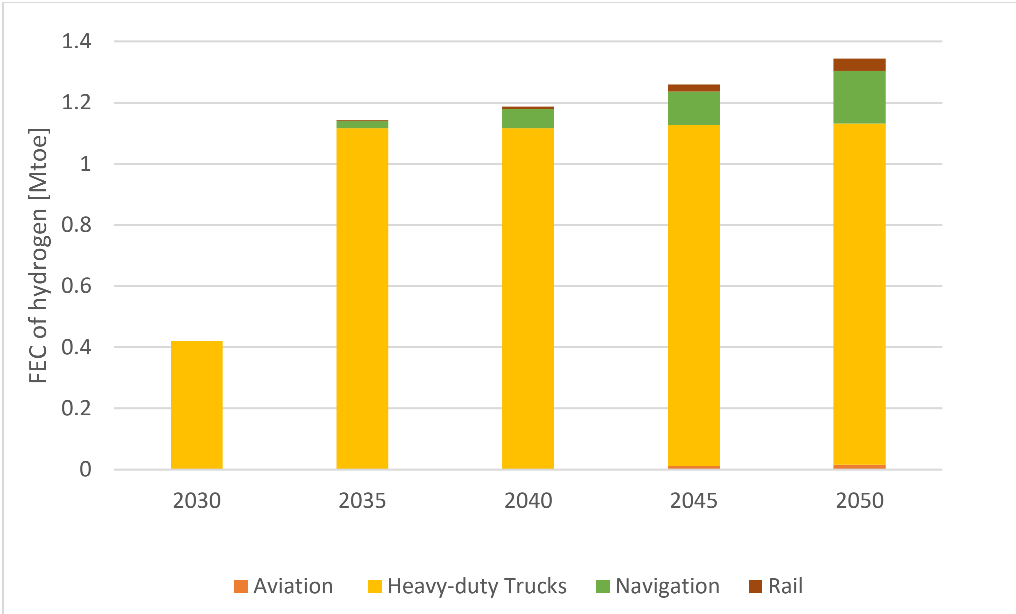
Biofuels, hydrogen, and e-fuels are used to decarbonize the hard-to-electrify transportation end-uses. They are mostly consumed by trucks (biodiesel and biomethanol), aviation (biojetfuel) and, to a lesser extent, by navigation (biomethanol) (Figures 14, 15, 16). To a limited extent, synthetic ammonia (e-ammonia) contributes to the decarbonization of the navigation sector and hydrogen contributes to the decarbonization of trucks. More information on the production and consumption of methanol, hydrogen and ammonia is provided in section 3.4.



Source: Outcome of TIMES-VN.

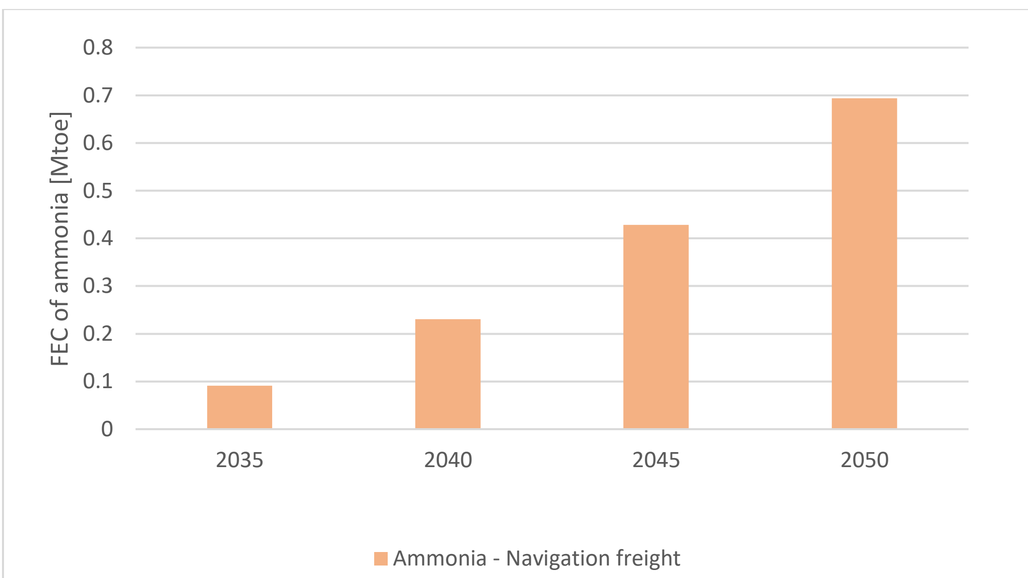
Figure 13. Energy mix of the transport sector by fuels and RES share, 2019-2050

[28] Reminder: In the main NZE scenario, more decarbonization flexibility is left to the transportation sector compared to the Transportation Action Program. The sensitivity analysis "TRANSPORT" includes the full Transportation Action Program. The reader is referred to Table 1 for more details.



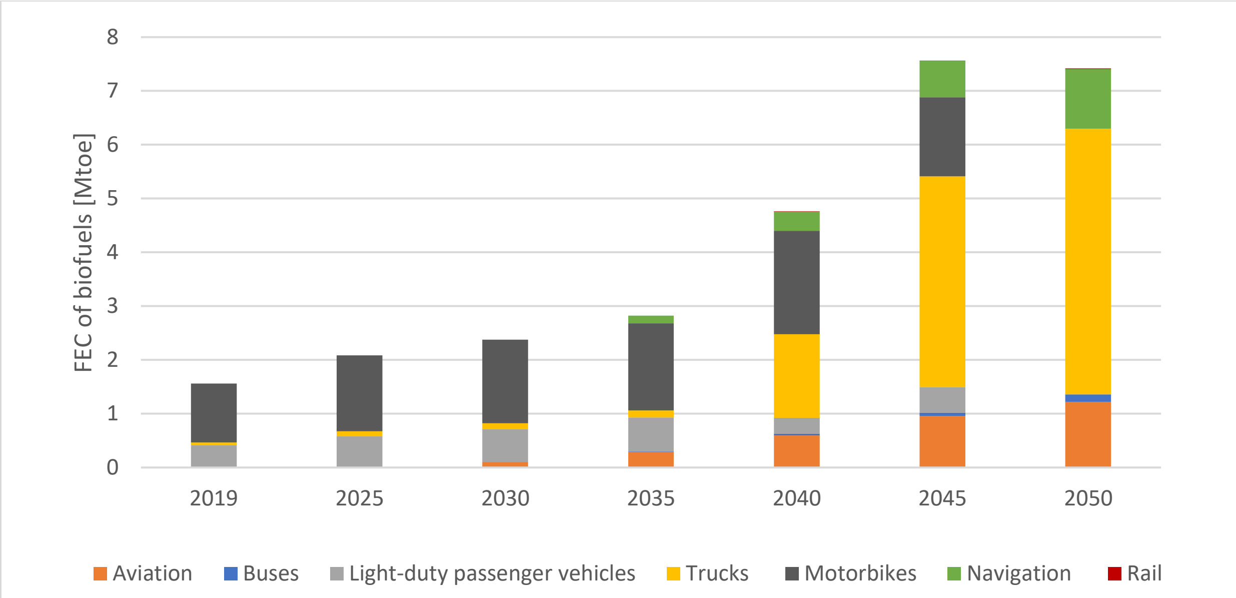
Source: Outcome of TIMES-VN.

Figure 14. Use of hydrogen in the transport sector, 2030-2050



Source: Outcome of TIMES-VN.

Figure 15. Use of ammonia in the transport sector, 2035-2050



Source: Outcome of TIMES-VN.

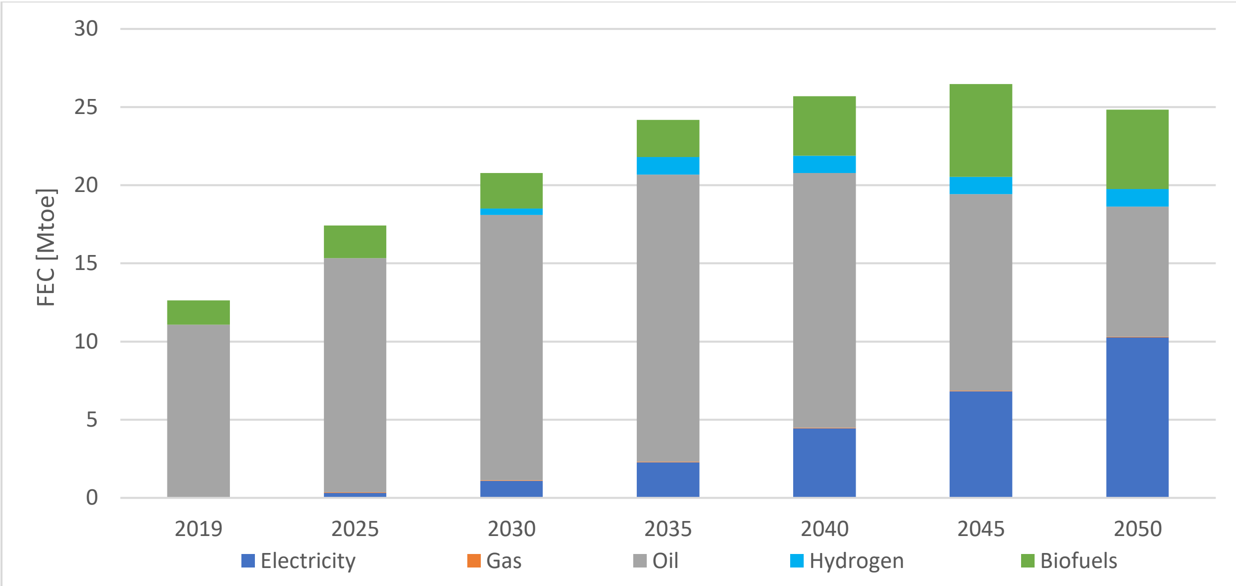
Figure 16. Use of biofuels in the transport sector, 2019-2050

The progressive electrification of light road vehicles and harder-to-decarbonize heavy-duty trucks

Electrification is progressive, reaching 40% of final energy consumption (FEC) of road transport in 2050 (Figure 17). This is dominated by light vehicles: cars, motorbikes, and light-duty vehicles, which are 100% electrified in 2050, indicating the high potential of electric vehicles for these transport modes.

Buses constitute another road transportation mode that is substantially electrified, with electricity representing 75% of the energy mix of buses in 2050, and the remaining 25% using blends of fossil and renewable oil.

According to the results obtained with TIMES-VN, the decarbonization of heavy-duty trucks is more difficult. Trucks represent a substantial and growing share of final energy consumption of the road transport subsector (35% in 2030, 50% in 2040 and almost 60% in 2050) due to two complementary factors: the rapid growth of the service demand for heavy-duty trucks, driven by the strong economic growth of the economy; and the transition of the other road subsectors to efficient electric vehicles, reducing their contribution to the final energy mix. In contrast to other road transport vehicles, the electrification of heavy-duty trucks is limited (electricity represents only 12% of the FEC of heavy-duty trucks in 2050). Renewable liquid fuels, especially biomethanol, constitute the preferred decarbonization option (33.5% of the FEC in 2050), while hydrogen plays a smaller role (7.5%). Fossil oil remains the main fuel (47%).

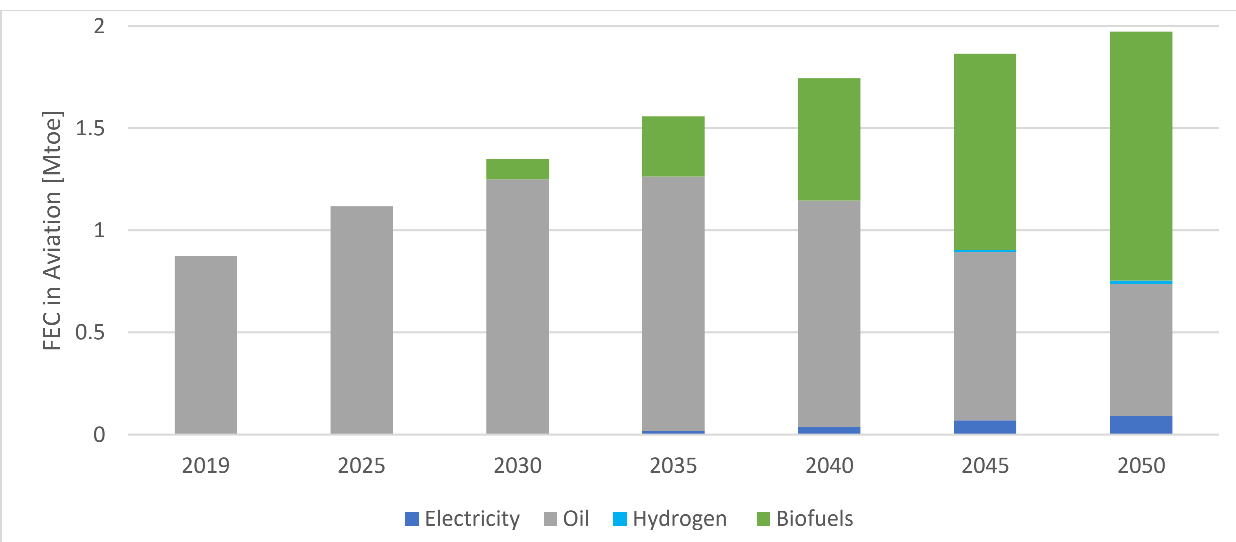


Source: Outcome of TIMES-VN.

Figure 17. Energy mix of the road transport subsector, 2019-2050

The slow transformation of the energy mix for aviation, navigation and rail transportation modes

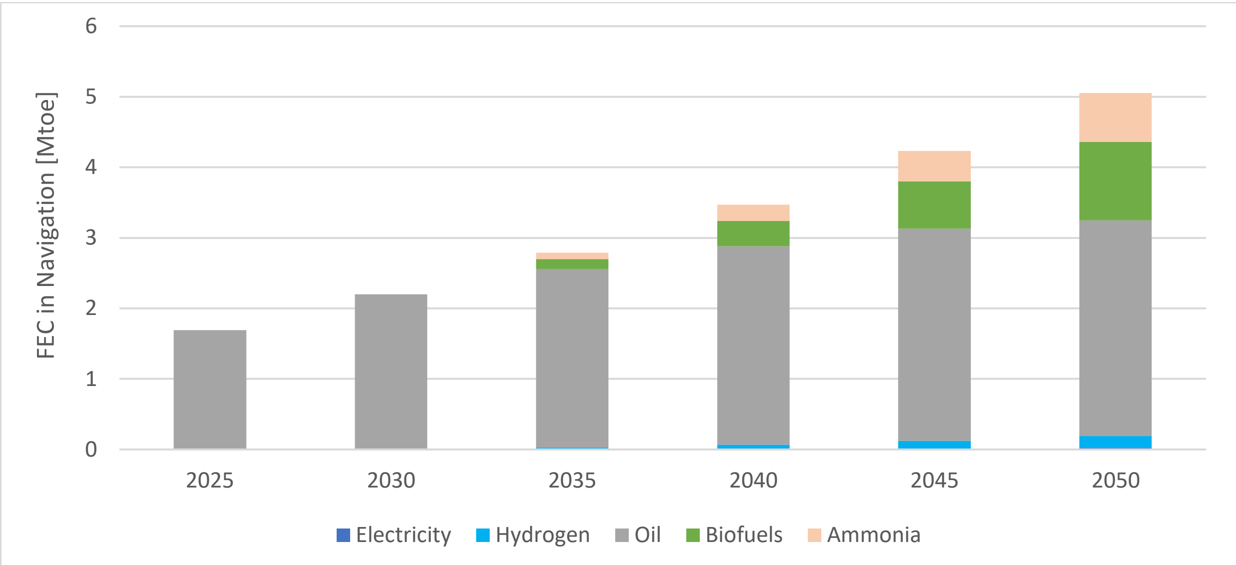
More than half (62%) of aviation energy consumption in 2050 relies on sustainable aviation fuels (SAF), mainly biojet fuel (Figure 18). Conventional oil still accounts for 32.5% of the energy mix. Electricity, mostly used in hybrid planes, accounts for 4.5% and hydrogen for only 1%.



Source: Outcome of TIMES-VN.

Figure 18. Energy mix of the aviation subsector, 2019-2050

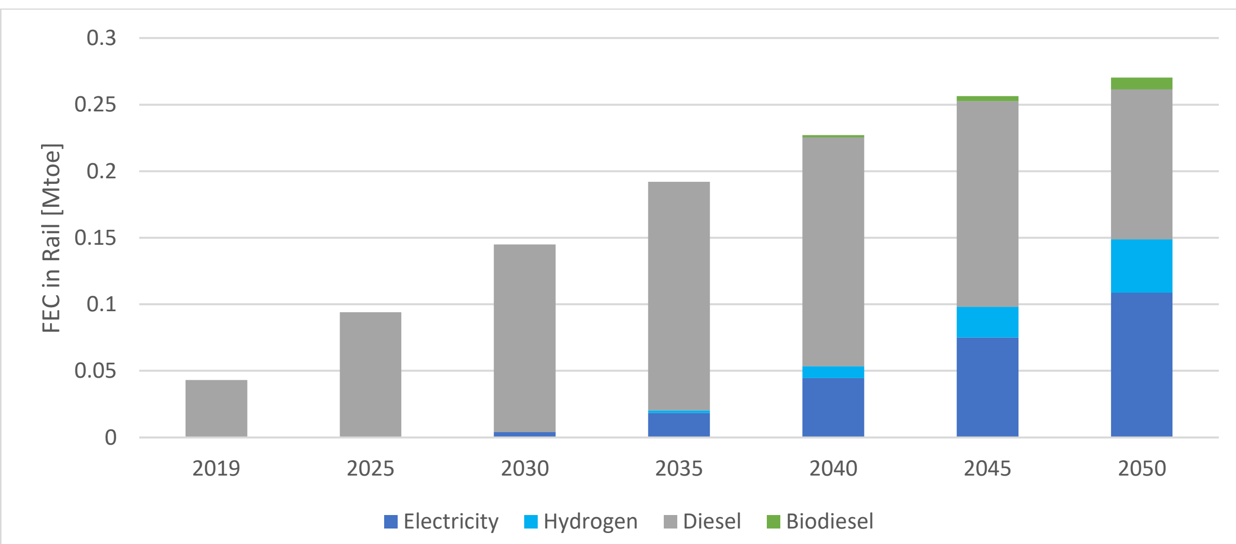
In navigation (Figure 19), oil also remains the dominating fuel in 2050 (60% of total consumption). A mix of alternative fuels starts replacing conventional oil from 2035, primarily biomethanol (21% of the energy mix in 2050) and e-ammonia (14% in 2050). Hydrogen reaches 3.5% of FEC, while biodiesel and electricity remain marginal.



Source: Outcome of TIMES-VN.

Figure 19. Energy mix of the navigation subsector, 2019-2050

Lastly, rail transport (Figure 20), currently dominated by diesel, relies in 2050 equally on diesel (42%) and electricity (40%), with hydrogen (15%) and biodiesel (3%) completing the mix.

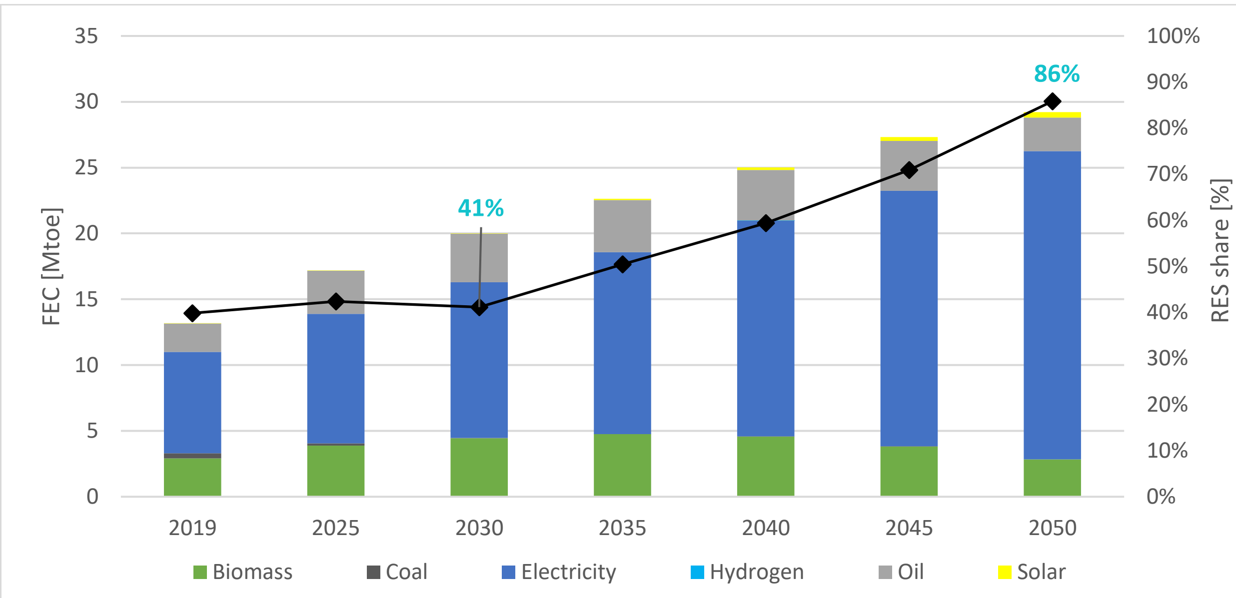


Source: Outcome of TIMES-VN.

Figure 20. Energy mix of the rail subsector, 2019-2050

The rapid electrification of buildings

Most of the energy services of buildings can be easily electrified, as observed in the NZE scenario (Figure 21). However, scenario results indicate that biomass and LPG are still consumed for cooking throughout the period. The cooking sector deserves special attention from decision-makers in energy policy development in Vietnam, to ensure that if biomass remains a cooking fuel, it is used in advanced cookstoves limiting the negative impacts of inefficient biomass combustion on climate, health, gender inequalities, and deforestation.



Source: Outcome of TIMES-VN.

Figure 21. Final energy use in buildings and renewable energy share, 2019-2050

6.1.4 Changes in the technological structure of the energy supply sector

The critical decarbonization of the power sector

Given the role of electrification in decarbonizing the economy, the transformation of the power sector towards renewable energy is critical to the success of the NZE (Figure 22).

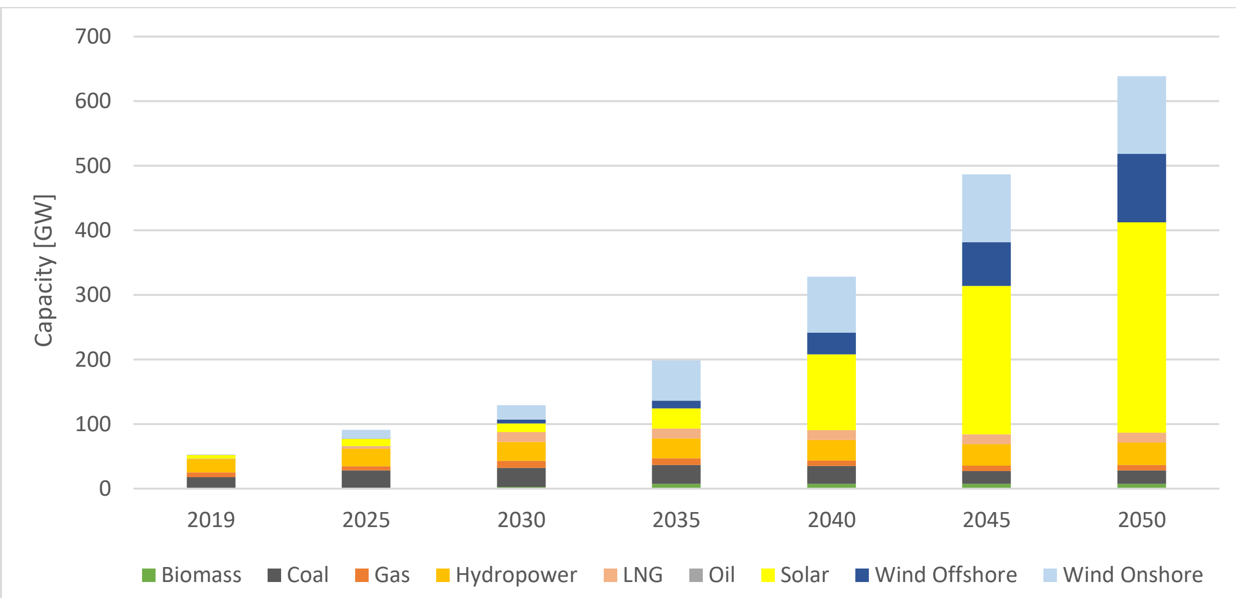
Installed solar capacity reaches 13 GW in 2030 and 325 GW in 2050; onshore[29] and offshore wind reach 22 GW and 6 GW respectively in 2030, and 120 and 106 GW in 2050. Dam-based hydropower reaches the planned capacity (around 20 GW) by 2030.

[29] A sensitivity analysis (LOW ONSHORE) explores the consequences of a lower penetration of onshore wind.

Coal power plant capacity increases steadily up to 2030, when it reaches the maximum level of 30 GW, reflecting the limit in PDP8 and decision 1009/QD-TTg on JETP implementation. It then gradually decreases to 12 GW by 2050, as coal plants are decommissioned. New coal/biomass co-firing power plants penetrate the market in 2045; their capacity reaches 8.2 GW in 2050. As mentioned in section 3.2.1, other co-firing options (e.g. ammonia and hydrogen) are not used because of economic reasons.

The capacities of LNG and domestic gas-fired power plants increase until 2030, following the PDP8 projections. Their respective installed capacity of 10 GW and 15 GW remains stable until the end of the period.

A significant capacity (around 45 GW) of dispatchable power plants (coal, gas, LNG plants) remain in the power system as a reserve. Only a fraction of this capacity is utilized for power generation: domestic gas and LNG plants operate with an average capacity factor of 45% in 2050; coal power plants remain in operation with average capacity factors of 45% in 2045 and 28% in 2050. However, coal power plants operate in co-firing mode from 2045, replacing full coal utilization with biomass by 2050. In other words, two types of transformation are observed with coal power plants: the conversion to co-firing, and lower utilization.



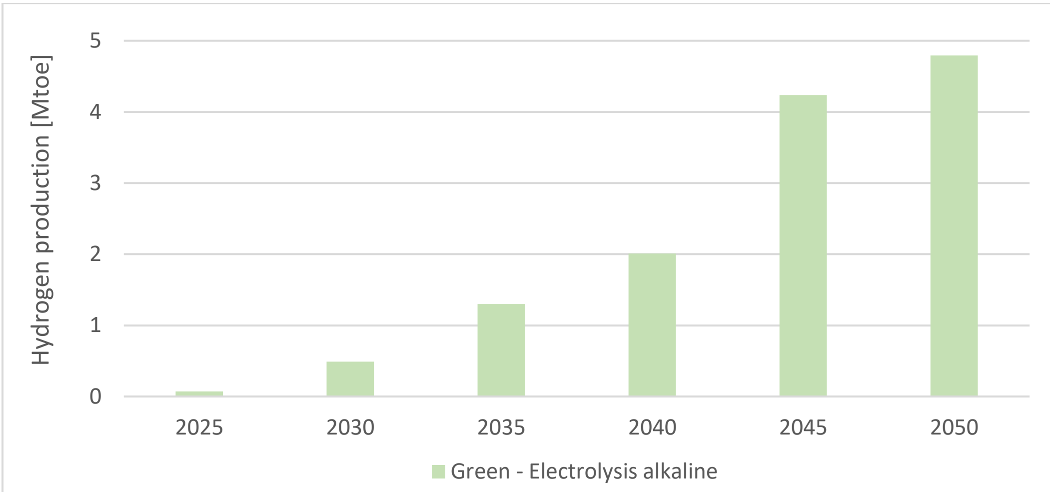
Source: Outcome of TIMES-VN.

Figure 22. Installed capacities* of power plants, 2019-2050

* The category "Coal" includes coal-fired power plants and Coal/Biomass co-firing power plants

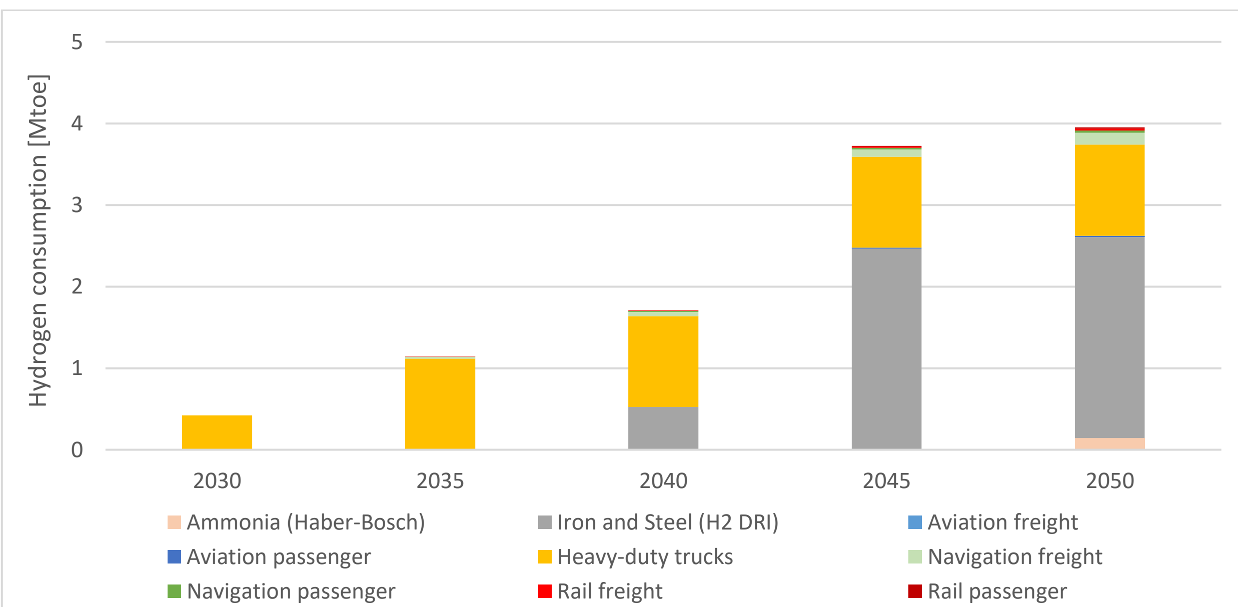
The case of alternative fuels: green hydrogen, methanol and ammonia

All hydrogen produced in the NZE is green hydrogen from electrolysis (Figure 23). As a reminder, blue hydrogen is not considered a mitigation option, based on stakeholders' preferences. Hydrogen is consumed mostly in the iron and steel industry and by heavy-duty trucks (Figure 24).



Source: Outcome of TIMES-VN.

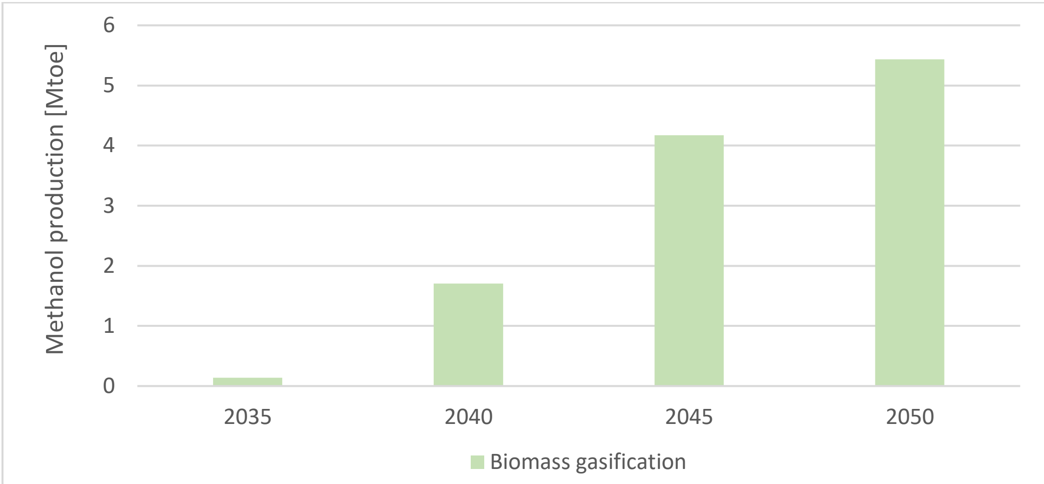
Figure 23. Hydrogen production, 2019-2050



Source: Outcome of TIMES-VN.

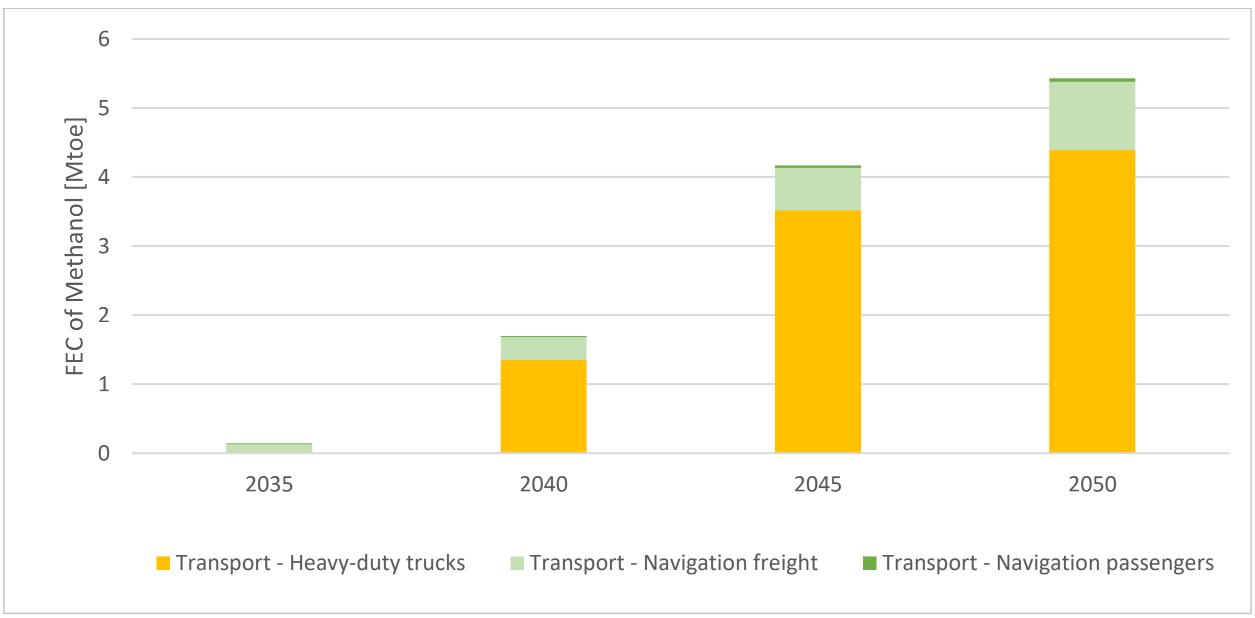
Figure 24. Hydrogen consumption in end-use sectors, 2019-2050

Methanol is entirely produced by biomass gasification (Figure 25) and consumed exclusively by the transportation sector, predominantly in trucks (Figure 26).



Source: Outcome of TIMES-VN.

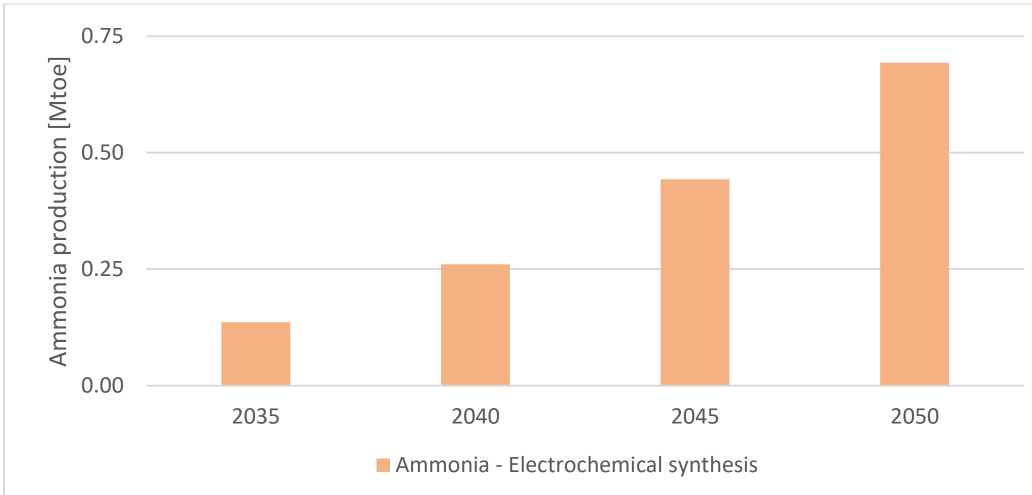
Figure 25. Methanol production, 2019-2050



Source: Outcome of TIMES-VN.

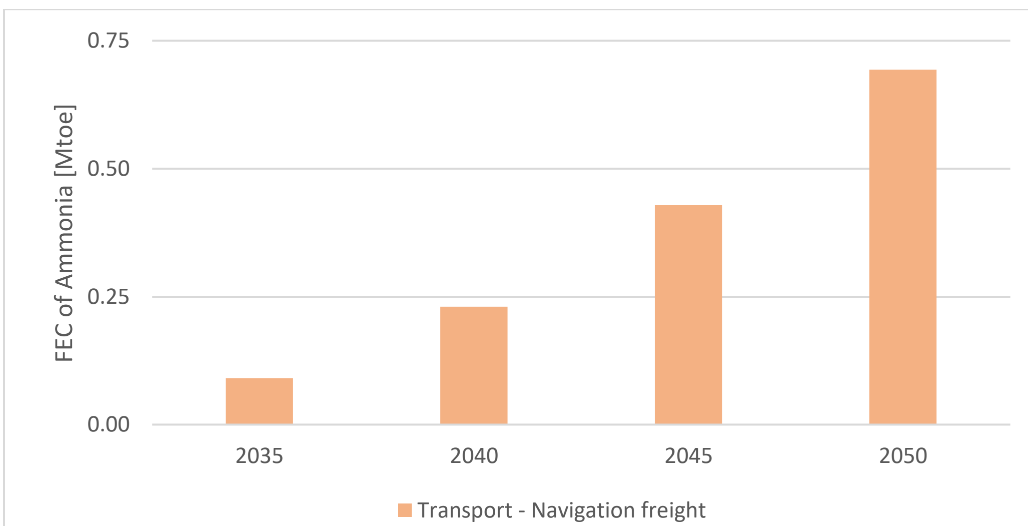
Figure 26. Methanol consumption in end-use sectors, 2019-2050

Ammonia, produced in very small quantities, is fully generated from green hydrogen (Figure 27) and entirely used for navigation transport (Figure 28).



Source: Outcome of TIMES-VN.

Figure 27. Ammonia production, 2019-2050



Source: Outcome of TIMES-VN.

Figure 28. Ammonia consumption in end-use sectors, 2019-2050

6.2 Energy security and socio-economic feasibility

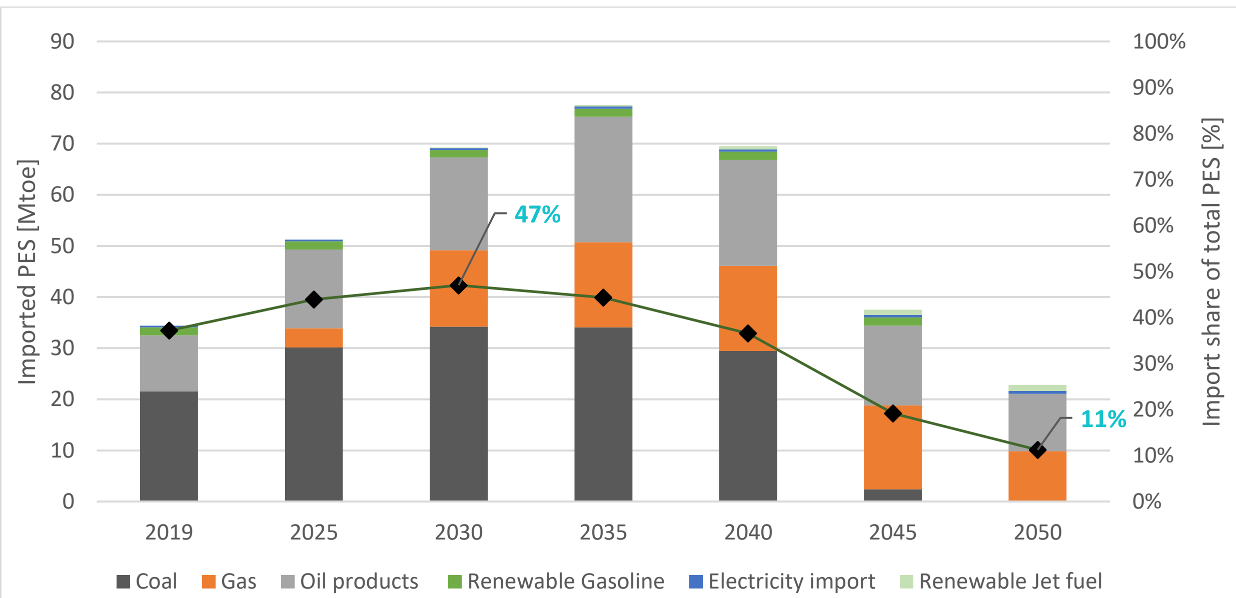
6.2.1 Energy security

Towards the energy independence of Vietnam

Decarbonization positively contributes to the energy independence of Vietnam in the longer term by promoting the use of local resources (biomass, solar and wind). Overall, the dependency on energy imports increases until 2030 (share of imports of 53% of primary energy) due to increased imports of fossil fuels, including gas, which plays a role as a mid-term transition fuel. The dependency on energy imports decreases after 2030 to reach 11% in 2050, due to remaining oil and LNG imports.

Coal imports increase from 20 Mtoe to 34 Mtoe by 2030, due to overall demand growth. They rapidly decline after 2040, as the energy sector is decarbonized, with zero imports by the end of the period. The remaining small industrial demand for coal in 2050 is supplied by domestic resources.

Small volumes of renewable gasoline and jet fuels are imported from 2030.



Source: Outcome of TIMES-VN.

Figure 29. Amount of imported primary energy supply, and import share of primary energy supply, 2019-2050

The diversity of the energy mix

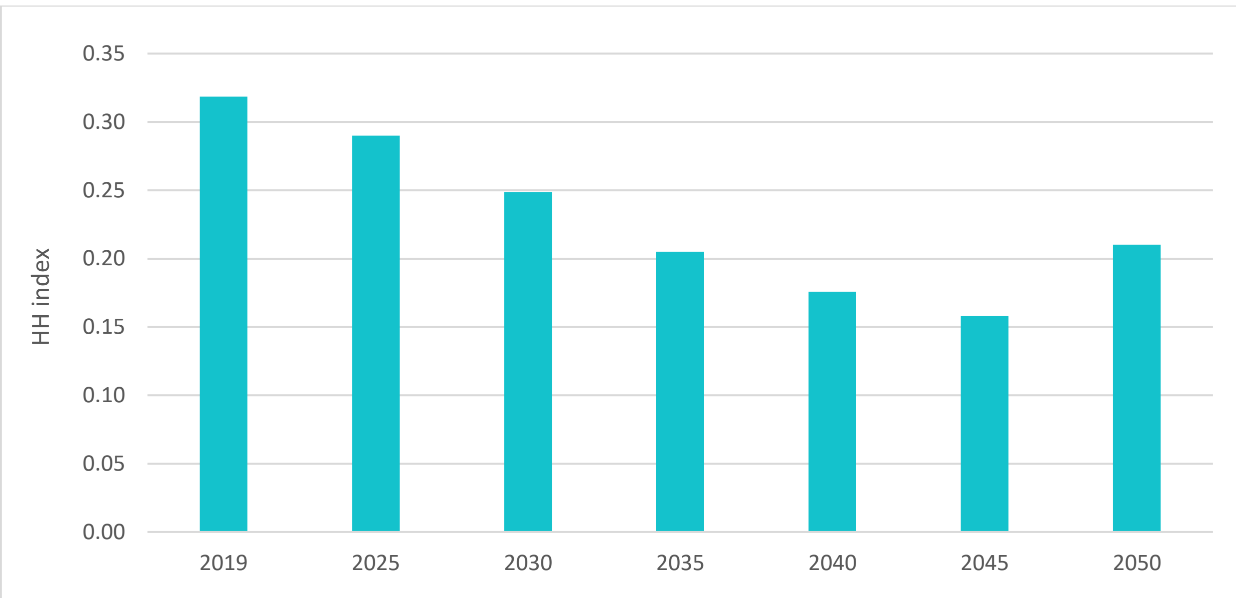
Energy diversity is another facet of energy security, with higher diversity usually considered to be associated with a higher resilience of the energy sector to external shocks. It is expressed using the

Herfindahl-Hirschman Index (HHI). Lower values of HHI indicate a more diverse energy mix (see Formula below). This index is also used in other studies like WWF (2023)[30].

$$HHI = s_1^2 + s_2^2 + s_3^2 + \cdots + s_n^2$$

Where:
s_n = the market share percentage of fuel n

The decarbonisation of the economy of Vietnam contributes to a higher resilience of the energy system thanks to the increased diversity of the energy mix until 2045. The increase of the index value in 2050 reflects the dominating role of solar, wind and biomass, reducing diversity in the primary energy mix, and therefore highlighting the trade-off between diversity and decarbonization requirements.



Source: Calculated based on the outcomes of TIMES-VN.

Figure 30. Herfindahl-Hirschman Index, 2019-2050

6.2.2 The socio-economic feasibility

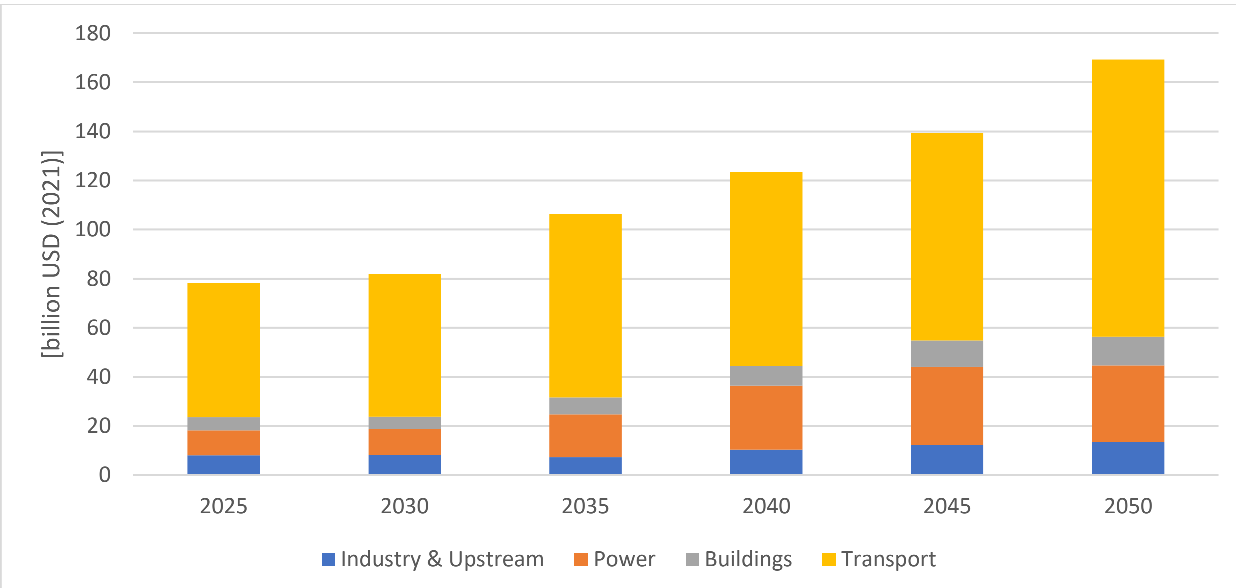
USD170 billion per year needed in 2050, mostly for transport sector investment

This section analyses the required investment in the NZE scenario. The investments reported here involve all technologies needed to meet energy demand associated with economic activities, and not only the additional investments to reach the NZE target. These investments include public investments (e.g. new power plants) and private expenditures (e.g. expenditures to buy a new car or replace an air

[30] WWF. (2023). *Energy Sector Vision: Towards 100% Renewable Energy for Viet Nam by 2050.* Prepared by Intelligent Energy Systems for the World Wide Fund for Nature in Vietnam.

conditioning system). The comparison between the NZE scenario and the Sensitivity scenarios contributes to understanding the additional investments, if any, required in the specific context of each sensitivity scenario.

The required annual investments related to the energy system are doubled between 2025 (USD80 billion) and 2050 (USD170 billion), increasing across all sectors. Transportation mobilizes the biggest share of these investments, representing around 70% of the total annual investments throughout the period, against 13 to 22% for the power sector and 7 to 9% for industry (Figure 31).



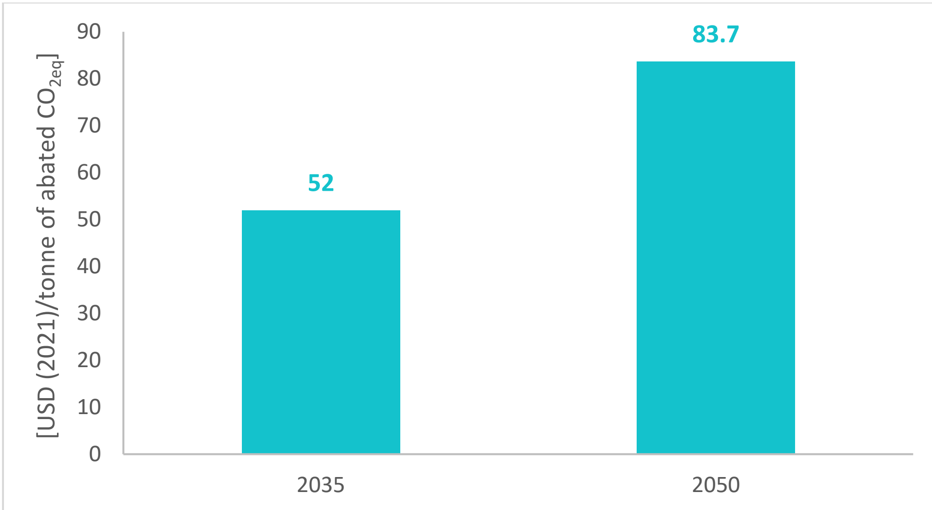
Source: Outcome of TIMES-VN.

Figure 31. Average annual investment expenditures by sector*, 2025-2050

* Note: Investments under "Upstream" cover investments related to hydrogen and e-fuels production. Investments related to fossil fuel mining are not fully captured by the model, by construction.

Carbon prices of up to USD80/t $CO_{2,eq}$ required by 2050

GHG marginal costs provide a useful indication of the costs of abating the last tonne of CO_{2eq}. Scenario results show abatement costs rising from USD50/tonne in 2035 to over USD80/tonne in 2050 (Figure 32). Increasing abatement costs indicate the increasing challenge of reducing emissions.

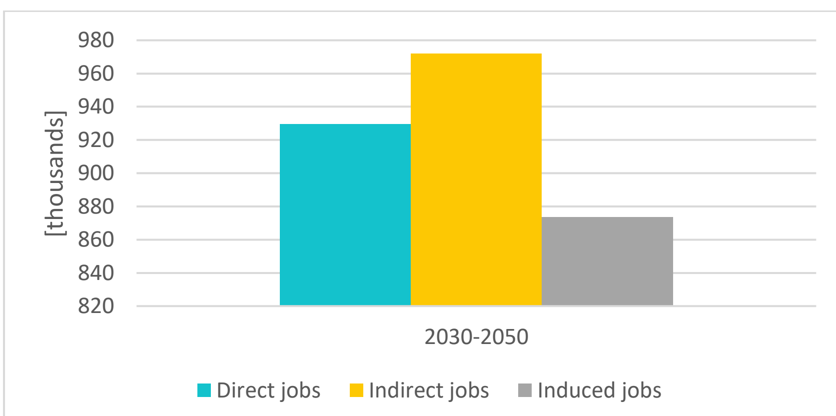


Source: Outcome of TIMES-VN.

Figure 32. Greenhouse abatement costs, 2035-2050

Almost 1 million direct jobs created (net) by 2050 in the power sector

The assumptions used to calculate the job implications of the NZE are based on the Cobenefit project[31]. The growth in overall power generation is associated with a strong increase in jobs, including direct, indirect, and induced employment effects[32] (Figures 33 to 35). The losses in fossil fuels in 2030-2050 (Figure 35) are more than counterbalanced by the jobs created by the deployment of renewable power plants. This will require new training capacities at universities and technical schools.

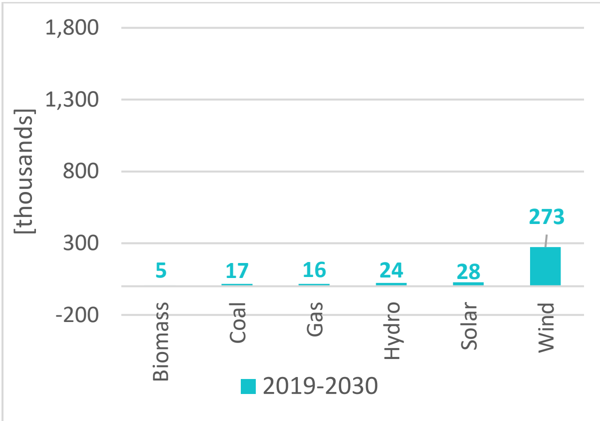


Source: Calculated based on the outcome of TIMES-VN, using the assumption provided by the Cobenefit Project.

Figure 33. Job positions created by job type, 2019-2050

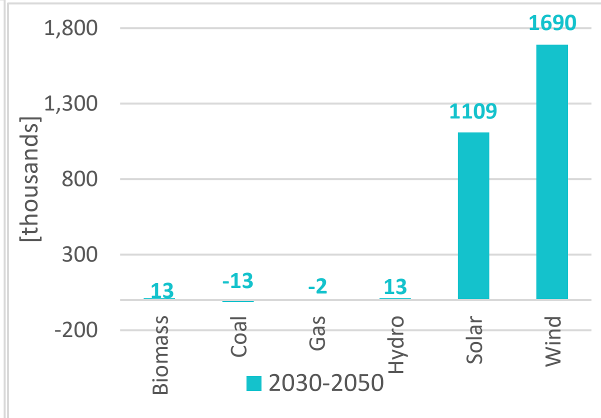
[31] https://www.cobenefits.info/wp-content/uploads/2020/08/COBENEFITS-Vietnam_Employment_Exec-Report.pdf

[32] As defined in the Cobenefit Project: a) Direct employment effect (direct jobs) is employment created due to changes in production of a given sector, which adjusts to meet the change in demand for a good or service. b) Indirect employment effect (indirect jobs) is the change in employment in sectors linked to a given sector through its intermediate consumption of goods and services. c) Induced employment effect (induced jobs) is the change in employment resulting from changes in demand due to direct and indirect employment effects.



Source: Calculated based on the outcome of TIMES-VN, using the assumption provided by the Cobenefit Project

Figure 34. Job positions created by fuel type, 2019-2030



Source: Calculated based on the outcome of TIMES-VN, using the assumption provided by the Cobenefit Project

Figure 35. Job positions created by fuel type, 2030-2050

6.3 An uncertain future: sensitivity analysis

6.3.1 The rationale behind the proposed sensitivity analysis

Seven (7) scenario variants are carried out to help understand the impacts of uncertain key parameters on the pathway to reach the NZE target in 2050. Each sensitivity case focuses on one specific assumption to capture the effect of the represented uncertainty on the NZE strategy.

To ensure that the sensitivity analysis reflect well the unique circumstances of Vietnam, the cases were defined based on the feedback received from stakeholders during the consultation workshops. This included the interest to explore: more optimistic mitigation targets as proposed by the JETP, the possible resistance to the penetration of onshore wind due to land constraints and acceptability challenges, the consequences of the uncertainties related to CCS, the risks of lock-in associated with the penetration of liquified natural gas. The sensitivity about transportation was defined due to the critical role of this sector in Vietnam's mitigation strategies, given the population and economic growth of the country.

SCENARIO	SENSITIVITY PARAMETERS AND INPUTS	RATIONALE AND KEY QUESTIONS
HIGH GDP Accelerated economic growth.	Higher economic growth (EMP projects an increase of economic growth from 6.5% to 7.5% per year after 2030).	Economic projections of Vietnam envision a more rapid development of the economy, implying higher energy service demands. An economic growth of 7.5% per year after 2030 is very high and may or may not be realized, depending on global and local macroeconomic trends. A sensitivity analysis based on high economic growth remains of high relevance to

		explore the strategies to reach the NZE objective under harder conditions of high energy demands. *Which additional efforts and investments are needed to reach the NZE objective in the context of higher energy service demands?*
JETP Accelerated mitigation.	JETP mitigation objective: limit of 170 Mt CO_2eq by power plants in 2030. Renewable energy power plant capacities can exceed PDP8.	This scenario is particularly relevant since JETP proposes a more ambitious emission target by 2030, associated with a higher penetration of renewable energy. *What is the additional cost for Vietnam of advanced mitigation? What is the expected additional role of renewable energy power plants? Which sectors can reduce even more their emissions?*
HIGH CCS Accelerated innovation in carbon capture.	No limit on the emissions captured from CCS plants (power and industry)	The NZE analysis demonstrates that CCS plays a critical role in emission-intensive industrial sectors like Iron and steel and Cement. However, the availability and costs of CCS are highly uncertain. The HIGH CCS and LOW CCS sensitivity cases are very relevant to better understand the dependence of the decarbonization pathway on CCS under different conditions. They will help decision-makers to define relevant policies and R&D strategies. This scenario explores an outlook where innovation allows a larger deployment of CCS. Reminder: BECCS is excluded from the available mitigation solutions. *What is the possible contribution of CCS to reach NZE? Is CCS limited to industry sectors or is it needed in the power sector? Would CCS deserve a higher role in NZE roadmaps than usually expected?*
LOW CCS Conservative deployment of carbon capture.	Single aggregated target (121 Mt total) on energy-related and process-related emissions. The model is free to reduce emissions from energy or processes to reach the NZE target.	As explained above, the availability and costs of CCS are highly uncertain. This scenario explores an outlook where the deployment of CCS is limited. The feasibility of this scenario requires the aggregation of energy-related and industrial process-related emissions under a common scope and target. Reminder: BECCS is excluded from the available mitigation solutions. *What are the additional mitigation opportunities to reduce energy-related emissions? Is it realistic to limit the process-related emissions to 20 MtCO2 in 2050? How does the energy system adapt to lower penetration of CCS in the industry sector?*
TRANSPORT	100% of road transport, rail, and inland navigation by	Better understanding the decarbonization potential of the transportation sector is particularly relevant

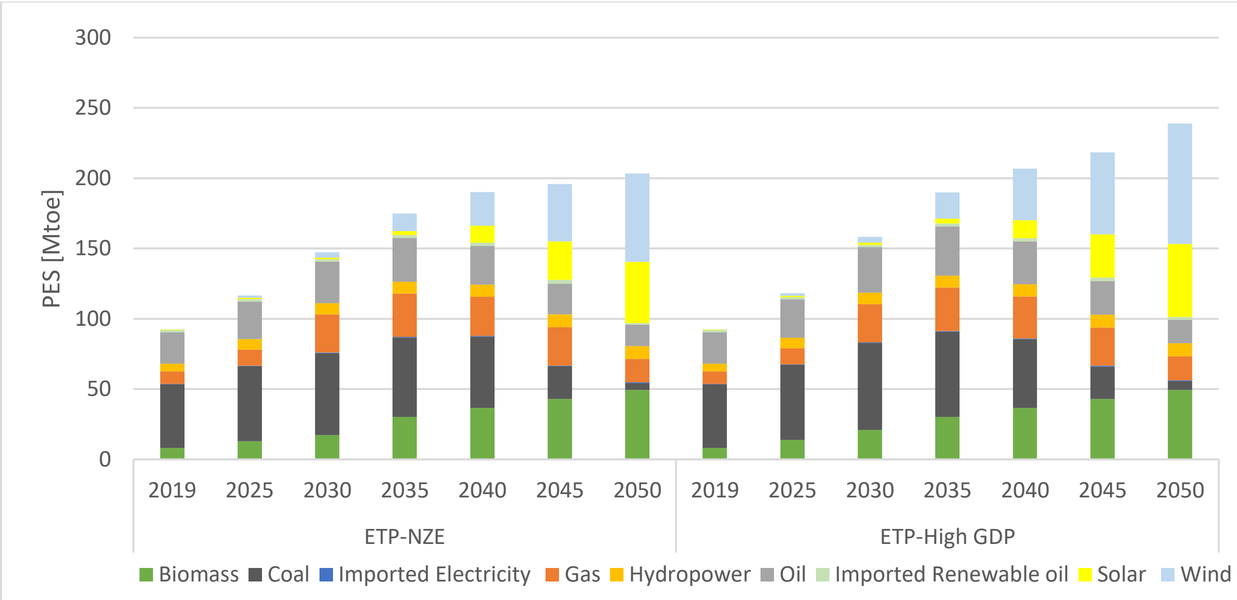
Deeper decarbonization of the transportation sector.	2050 with electricity and green energy	because the full transformation of the transportation sector to electricity and green energy is challenging in any country. This scenario explores the feasibility and impacts of the full implementation of the Transportation Strategy. *Which fuels and technologies contribute to the transportation strategy? What are the impacts on the other sectors of the energy system? Which are the investments required to fully transform the sector?*
LOW ONSHORE Limited onshore wind deployment.	50% reduction of onshore wind potential, reflecting land and acceptability issues	The relevance of this analysis is driven by the challenges raised by the penetration of onshore wind power in terms of required land and social acceptability. On the other hand, offshore wind power is more and more attractive from the perspective of investors and policymakers. *How to compensate for low acceptability and therefore low penetration of onshore wind? Can offshore wind become a preferred mitigation option?*
LOW LNG-P Reduced LNG in power.	Committed LNG power plants (PDP8) are not considered.	A lower penetration of liquified natural gas power may prevent the power system from being locked into a gas future and therefore support a faster penetration of renewable. It is therefore relevant to explore how the energy system is transformed if the LNG power plants proposed in PDP8 and EMP were not committed. *Is it feasible to use less fossil fuels than the expected amounts of PDP8 and EMP?*

6.3.2 Accelerated economic growth (HIGH GDP)

This sensitivity variant shows that accelerated economic growth would likely translate into a higher energy demand (+7% in 2030 and +17% by 2050 relative to the NZE scenario) (Figure 36).

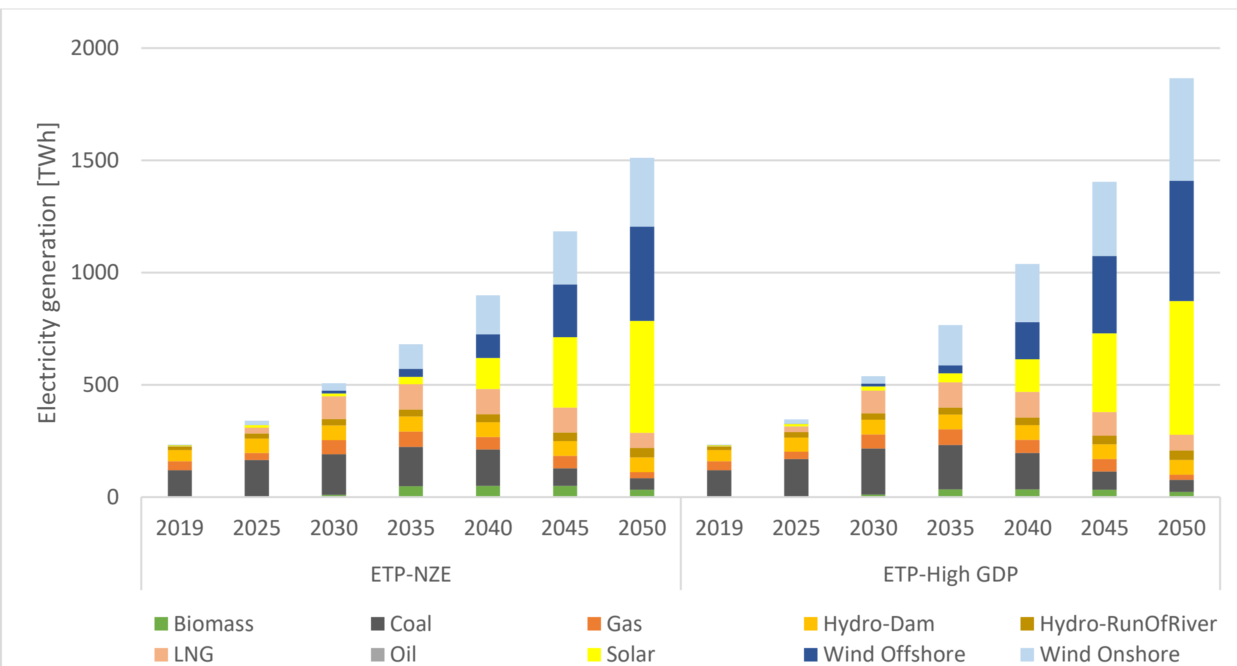
Consequently, several mitigation strategies need to be reinforced, more particularly the electrification of the energy system sectors (+7% and +23% in 2030 and 2050 – Figure 37), and the penetration of carbon capture in energy-intensive industry sectors (reaching 52 Mt CO_2 captured in 2050 – Figure 38),

The resulting additional investments reach USD12 billion in 2030 and USD40 billion in 2050 in comparison to the NZE scenario, with increased investments particularly in power and transportation (Figure 39).



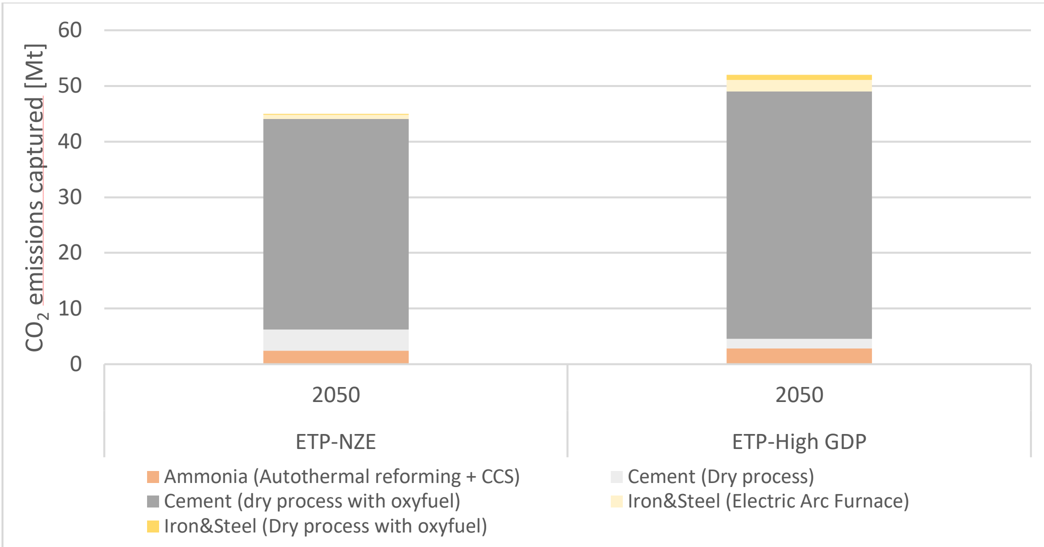
Source: Outcome of TIMES-VN.

Figure 36. Primary energy supply NZE vs High GDP, 2019-2050



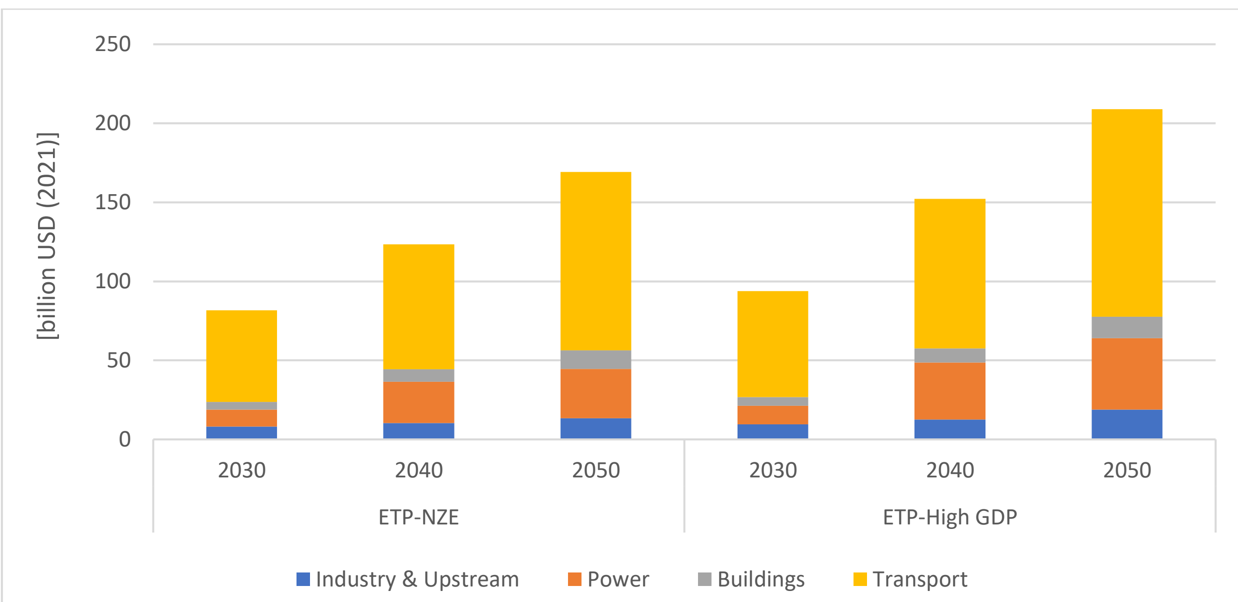
Source: Outcome of TIMES-VN.

Figure 37. Electricity generation NZE vs High GDP, 2019-2050



Source: Outcome of TIMES-VN.

Figure 38. Captured CO_2 emissions NZE vs High GDP, 2050



Source: Outcome of TIMES-VN.

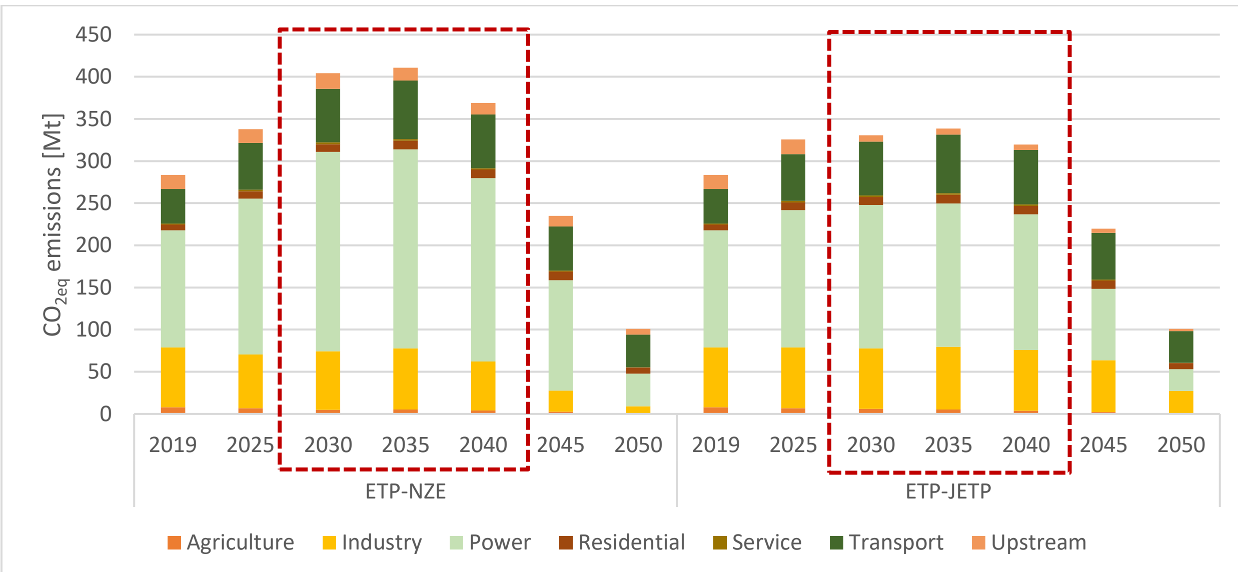
Figure 39. Average investment expenditure by sector* NZE vs High GDP, 2030-2050

* Note: Investments under "Upstream" cover investments related to hydrogen and e-fuels production. Investments related to fossil fuel mining are not fully captured by the model, by construction.

6.3.3 Accelerated mitigation: the JETP commitments (JETP)

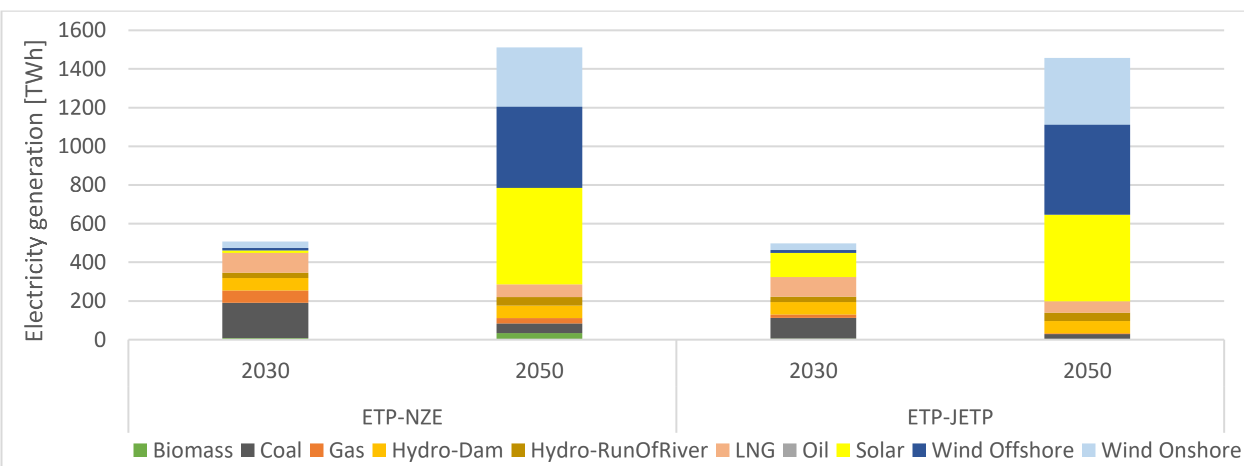
The JETP commitments drive additional emission reductions of around 55 Mt CO_2eq from the electricity generation sector in the mid-term 2030-2040 (Figure 40).

Reaching this additional emission reduction requires additional installed solar and wind capacity of 83 GW by 2030 compared to the NZE scenario, which will be challenging over such a short time period (Figure 41). These accelerated investments in 2030 contribute to reduced investments in the longer term (Figure 42).



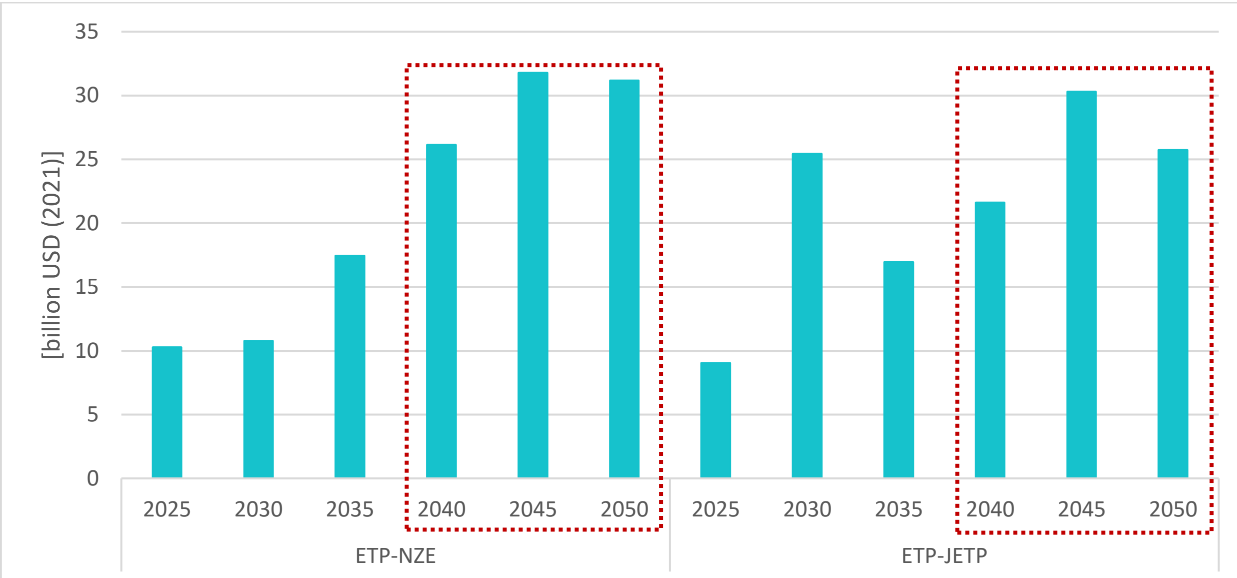
Source: Outcome of TIMES-VN.

Figure 40. $CO_{2,eq}$ emissions by sector NZE vs JETP, 2019-2050



Source: Outcome of TIMES-VN.

Figure 41. Electricity generation NZE vs JETP, 2030 and 2050

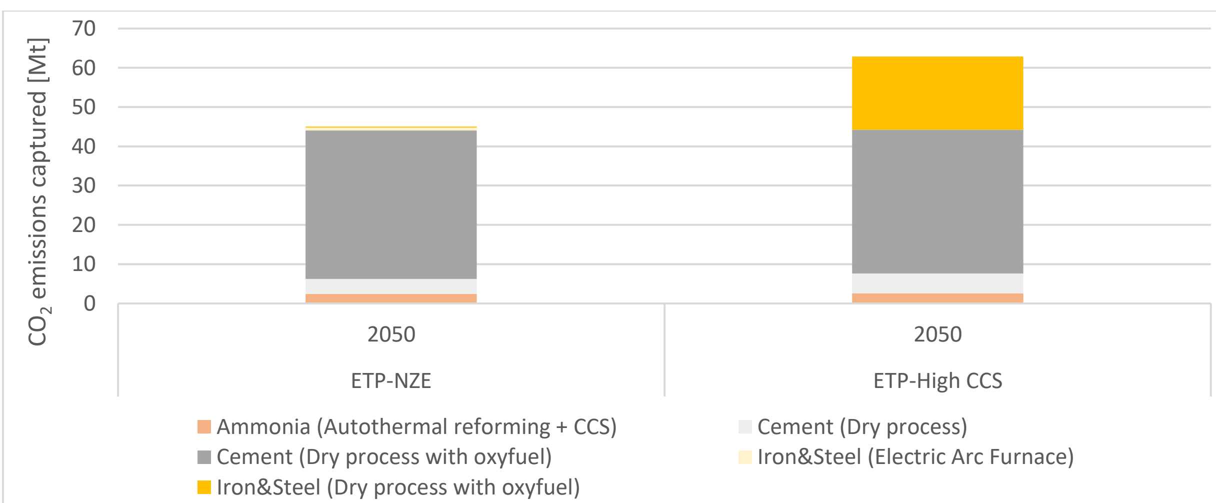


Source: Outcome of TIMES-VN.

Figure 42. Power sector average annual investment expenditure NZE vs JETP, 2025-2050

6.3.4 Accelerated innovation in favour of higher deployment of carbon capture (HIGH CCS)

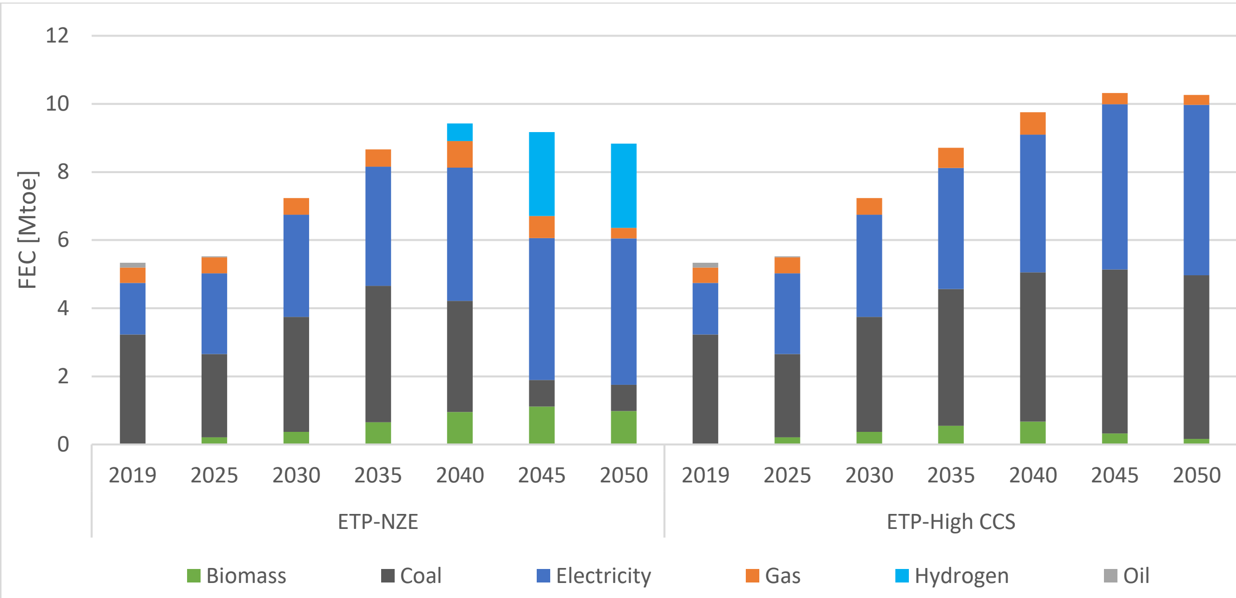
Increased deployment of CCS enables the implementation of additional mitigation opportunities in hard-to-decarbonize industrial sectors, more particularly in the iron and steel sector (Figure 43). While captured emissions in cement and ammonia sectors remain similar to the NZE scenario, the captured CO_2 emissions from iron and steel plants grow from less than 1 Mt CO_2 to 20 Mt CO_2 in 2050.



Source: Outcome of TIMES-VN.

Figure 43. Captured CO_2 emissions NZE vs High CCS, 2050

The key CCS technology in the iron and steel sector is the dry process with oxyfuel which consumes mainly coal and captures both energy-related and process-related emissions. This results in additional coal consumption in the sector, and therefore, an overall higher energy consumption by the sector (Figure 44). The introduction of the dry process oxyfuel technology is preferred to hydrogen-based steelmaking, mainly due to the high costs of the green hydrogen supply chain.



Source: Outcome of TIMES-VN.

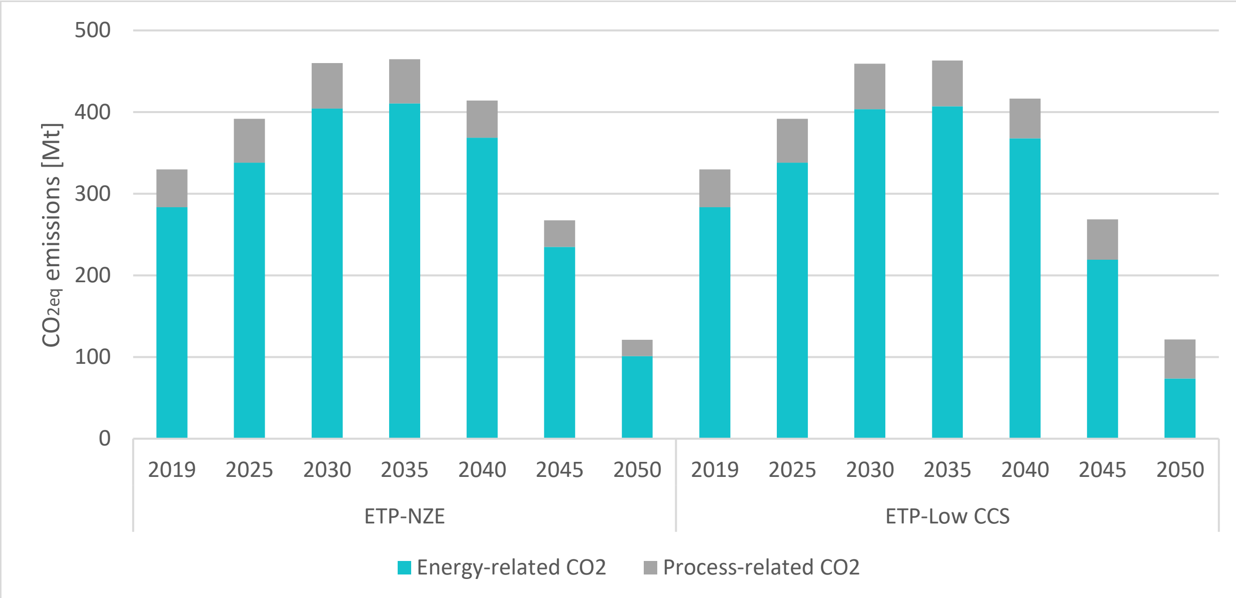
Figure 44. Energy mix of the Iron and steel sector, NZE vs High CCS, 2019-2050

6.3.5 Conservative deployment of carbon capture in industry (LOW CCS)

Almost 45 Mt of process-related emissions are abated through CCS deployment in the NZE scenario, 42 Mt of which are captured in the cement sector, where no cement production alternative is available with lower process-related emissions. In other words, a limited deployment of carbon capture in industry would imply that the explicit target of 20 Mt CO_2 proposed in the National Strategy on Climate Change for process-related emissions in 2050 would not be feasible.

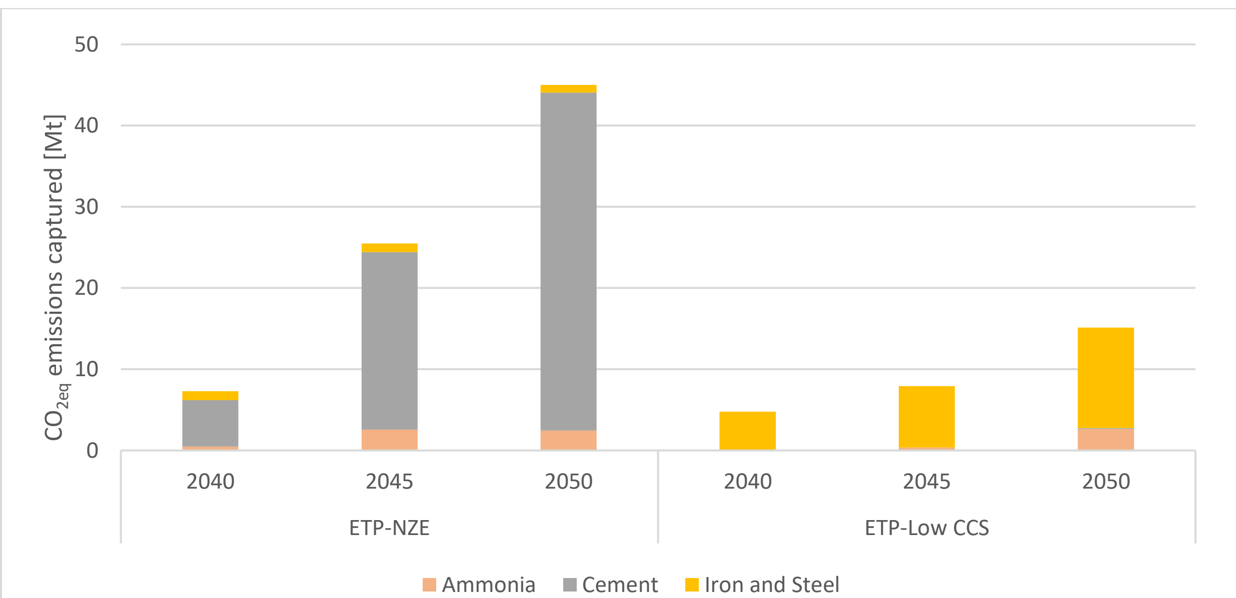
An alternative approach for achieving the NZE target without a large deployment of CCS technologies is to require a less ambitious reduction from the process-related emissions and compensate for the smaller reduction with higher reductions of energy-related emissions. In the Low CCS scenario, the additional reduction of energy-related emission reaches 27 Mt $CO_{2,eq}$ in 2050 (total of 101 Mt in ETP-NZE against 74 Mt in ETP-Low CCS, Figure 45). The captured CO_2 is reduced to a total amount of 15 Mt $CO_{2,eq}$ per year in 2050.

CCS shifts from cement and ammonia plants to iron and steel plants, particularly oxyfuel plants. Indeed, these plants are more cost-efficient than CCS in cement and ammonia, and also contribute to the abatement of energy-related emissions. This option is not used in the NZE scenario due to the severity of the target imposed on process-related emissions. In this case, cement plants with CCS are preferred despite, their high costs, because this industry is the most intensive in terms of process-related emissions.



Source: Outcome of TIMES-VN.

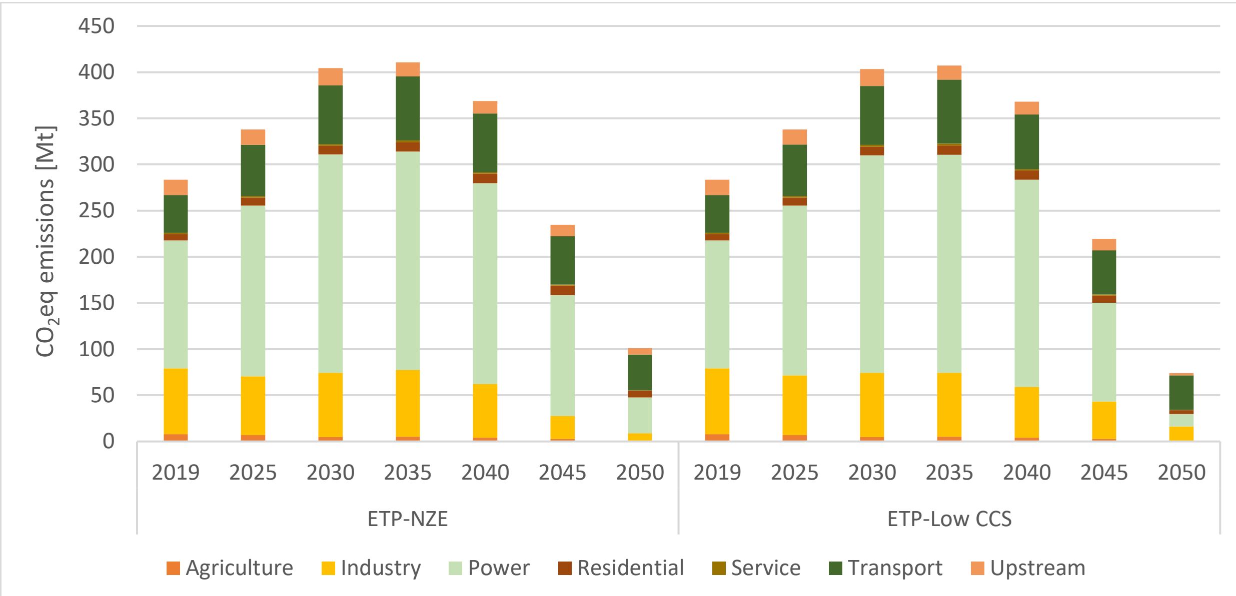
Figure 45. Total energy and process-related $CO_{2,eq}$ emissions, NZE vs Low CCS, 2019-2050



Source: Outcome of TIMES-VN.

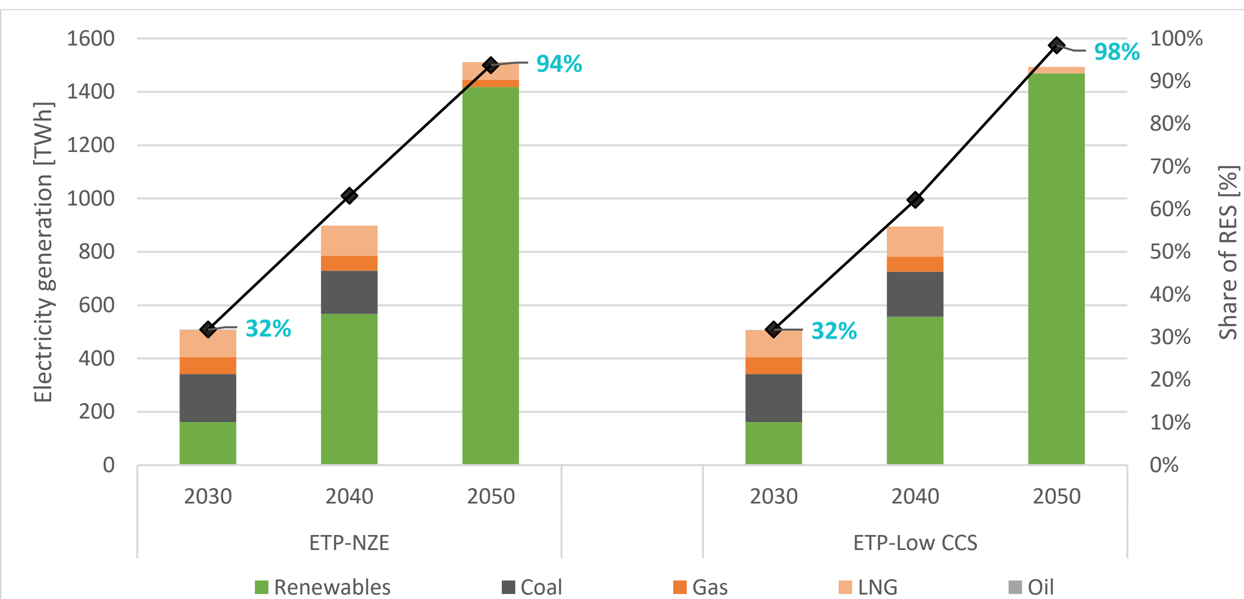
Figure 46. Captured CO_2 emissions by sector NZE vs Low CCS, 2030-2050

As expected, the deeper decarbonization of the energy sector is achieved through increased efforts in the power sector, which, in the Low CCS scenario, ends up emitting 70% less $CO_{2,eq}$ than in the NZE scenario (Figure 47). Power generation by fossil-fuelled power plants – coal, domestic gas, and LNG plants - are substituted by renewable power plants (Figure 48), leading to a slight increase in the renewable share of electricity generation. A small decrease in total electricity generation is observed, attributable to the lower role played by CCS units in the industrial sector.



Source: Outcome of TIMES-VN.

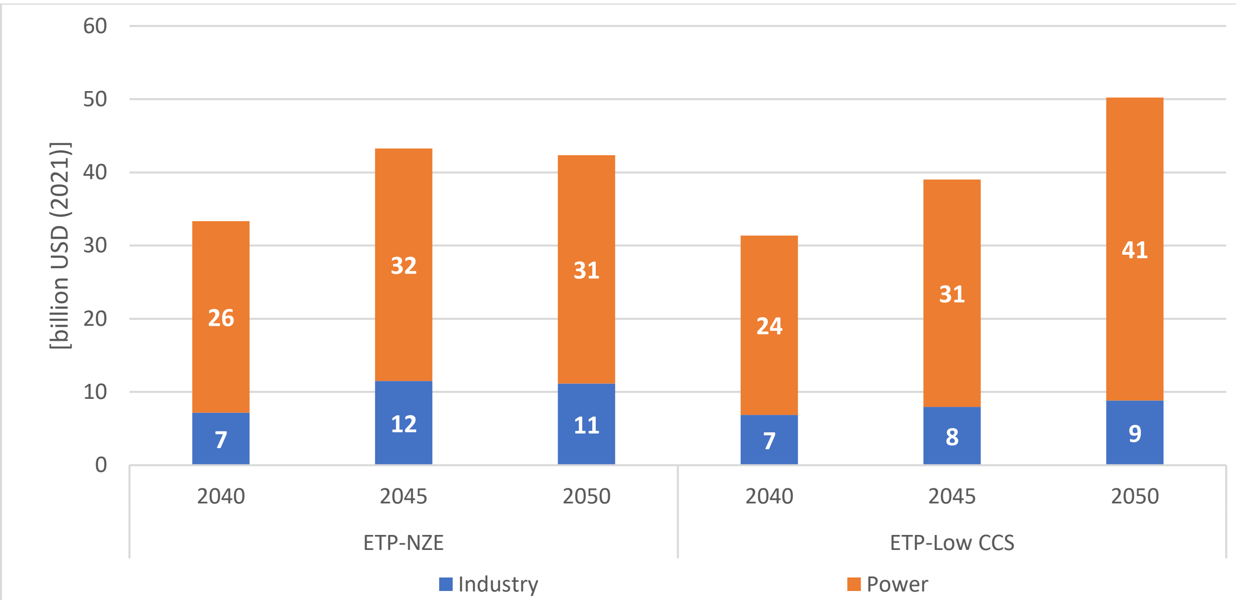
Figure 47. $CO_{2,eq}$ emissions by sector NZE vs Low CCS, 2019-2050



Source: Outcome of TIMES-VN.

Figure 48. Electricity generation by source and renewable energy share NZE vs Low CCS, 2030-2050

In terms of overall investment expenditure, the Low CCS scenario would require higher investments in the power sector (+USD8 billion overall in the period 2040-2050) but lower investments in the industrial sector (-USD6 billion during the same period). The overall expenditure in the Low CCS scenario is higher by almost USD2 billion.



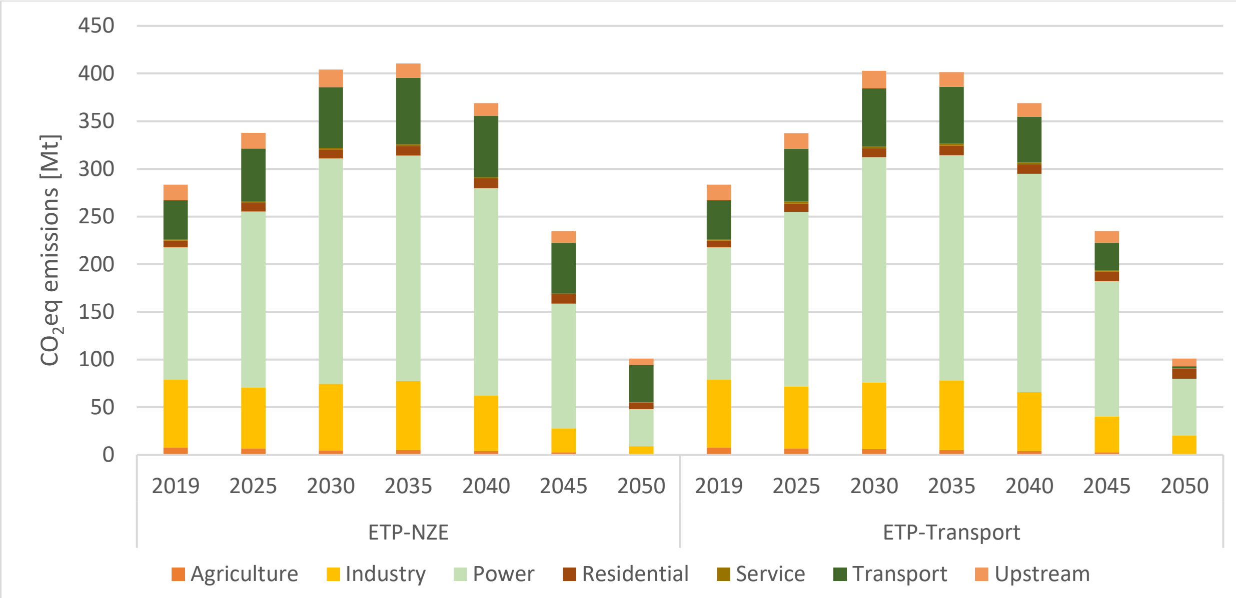
Source: Outcome of TIMES-VN.

Figure 49. Power and Industry average annual investment expenditure NZE vs Low CCS, 2040-2050

6.3.6 Deeper decarbonization of the transportation sector (TRANSPORT)

The full implementation of the policies of the Action Program for Transition to Green Energy and Mitigation of Carbon Dioxide and Methane Emissions from Transportation would decarbonize almost 100% of the transport sector by 2050 since it includes provisions for the full decarbonization of most transport modes. Overall emissions of the transport sector would drop down to less than 2 Mt $CO_{2,eq}$ in 2050, allowing other sectors, particularly power and industry, to emit slightly more CO_2 (Figure 50).

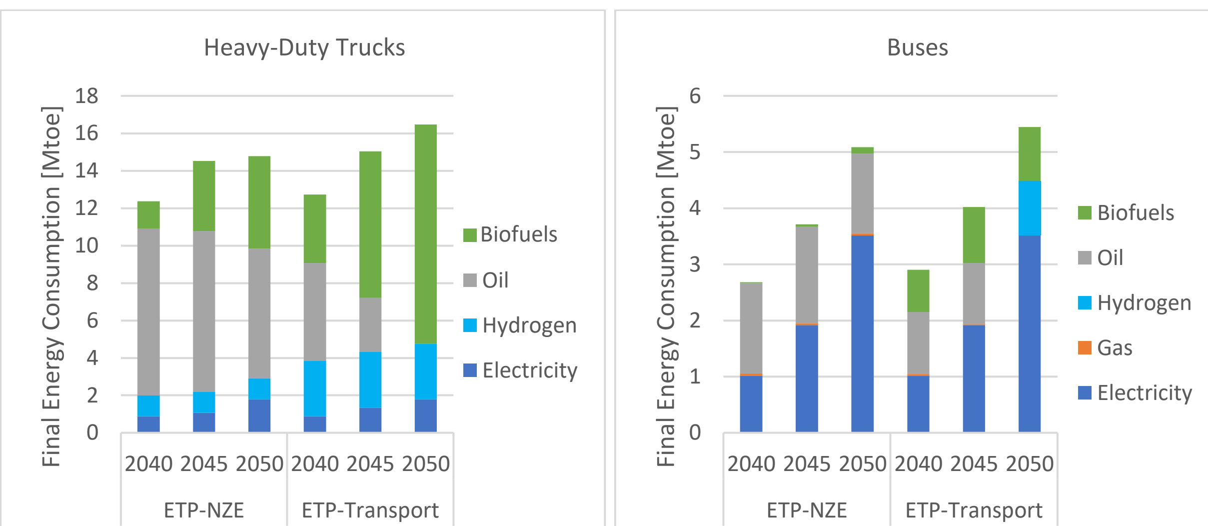
It is noteworthy that the electrification levels do not change substantially, indicating that the feasible electrification levels are already achieved in the NZE scenario. This implies that electrification of transport can be an economically attractive option for many transport end-uses, even if no specific policies are introduced.



Source: Outcome of TIMES-VN.

Figure 50. $CO_{2,eq}$ emissions by sector NZE vs Transport, 2019-2050

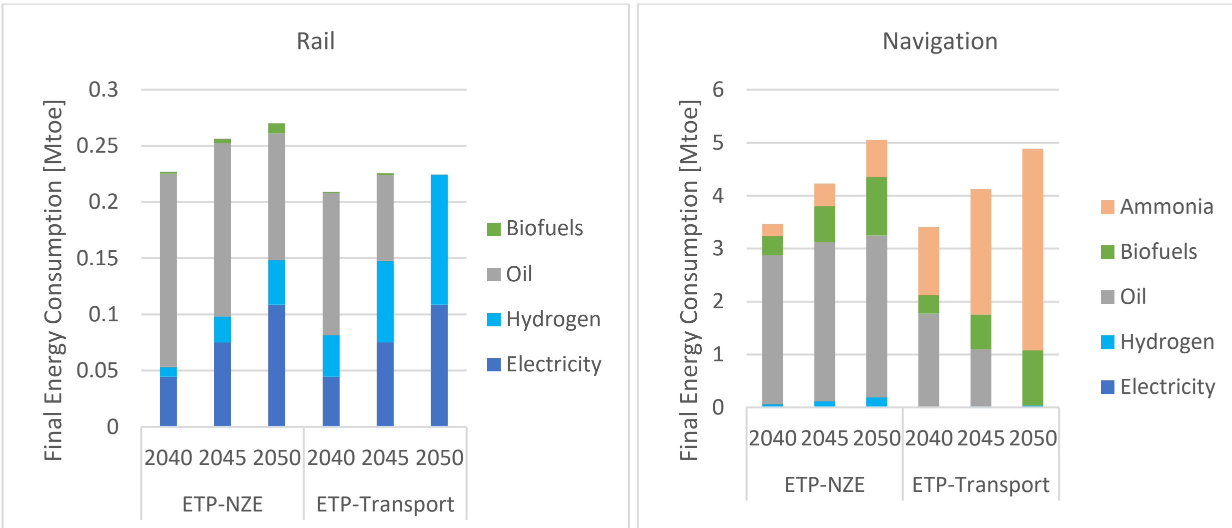
The abatement of the residual transport emissions obviously occurs in the sectors which are not fully decarbonized in the ETP-NZE scenario, namely heavy-duty trucks, buses, and non-road transport modes, with additional biofuels, hydrogen and e-fuels (in the form of e-ammonia used in navigation). Heavy-duty trucks rely mostly on biofuels and secondarily on hydrogen, while biofuels and hydrogen play an equally important role in substituting oil in buses in 2050 (Figure 51).



Source: Outcome of TIMES-VN.

Figure 51. Heavy-duty trucks (left) and buses (right) final energy consumption by energy carrier, NZE vs Transport, 2040-2050

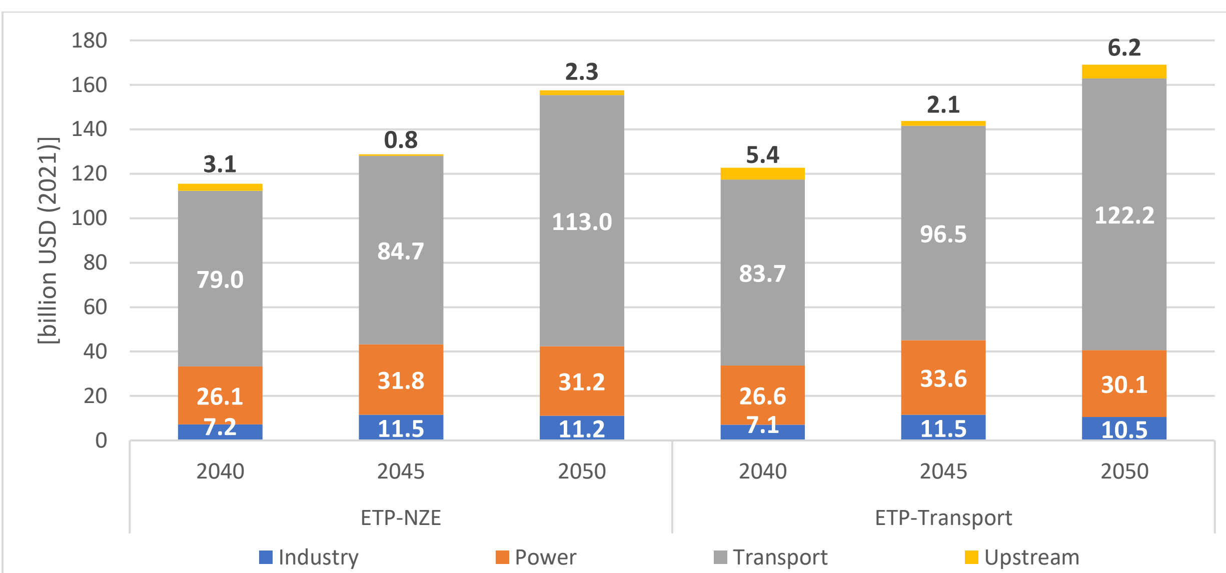
As for non-road transportation, the decarbonization of navigation is achieved through the deployment of e-ammonia and biomethanol, while the residual diesel used in rail transport in 2050 is replaced by green hydrogen (Figure 52).



Source: Outcome of TIMES-VN.

Figure 52. Rail (left) and Navigation (right) transport final energy consumption by energy carrier, NZE vs Transport, 2040-2050

The high decarbonization of transport requires additional investments in the transport sector (+USD26 billion in the period 2040-2050) as well as in the upstream (+USD7.5 billion) and power (+USD1 billion) sectors, given the additional infrastructure for biofuel and hydrogen/e-fuel production (Figure 53). Deferred investments in the industrial sectors (only USD0.7 billion) do not compensate for the additional investments in transport decarbonisation.

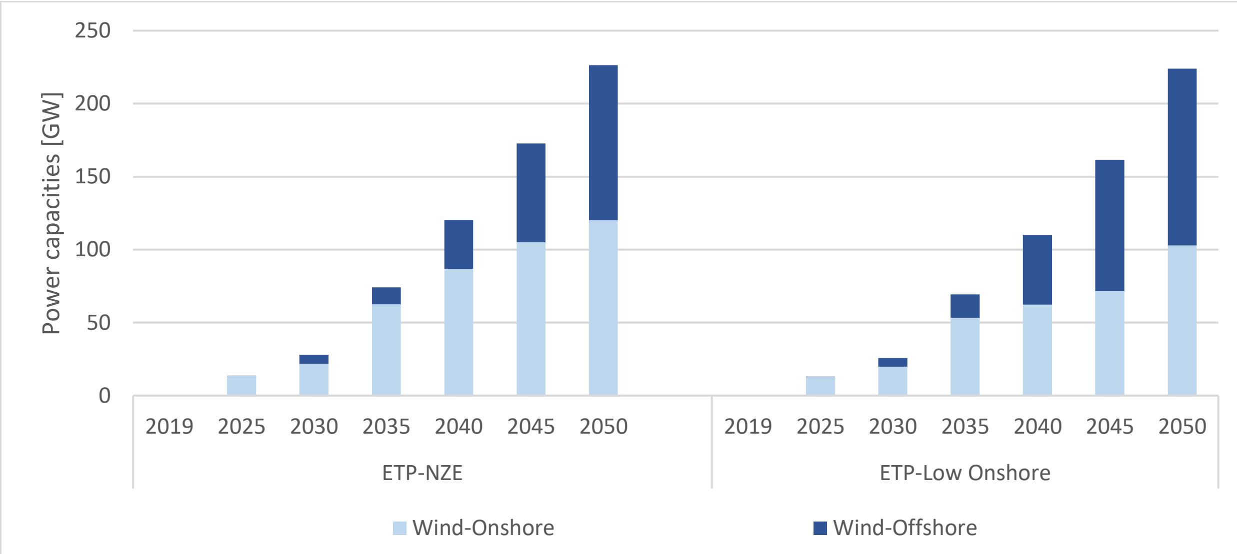


Source: Outcome of TIMES-VN.

Figure 53. Average annual investment expenditure by sector NZE vs Transport, 2040-2050

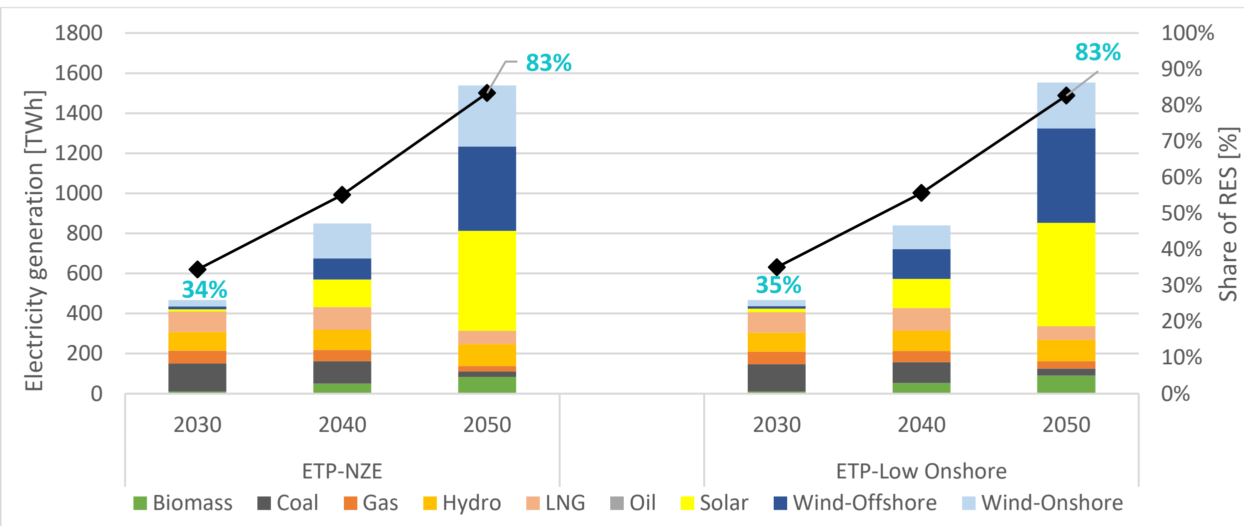
6.3.7 Limited onshore wind deployment (LOW ONSHORE)

An investment limit in onshore wind farms due to limited land availability or low local acceptance would lead to a shift to offshore wind and, to a lesser extent, solar power. A reduction of onshore capacity by 18 GW would trigger additional investments in offshore wind up to 15 GW, the rest being compensated by solar power plants (Figure 54). The total electricity produced remains unaffected (Figure 55).



Source: Outcome of TIMES-VN.

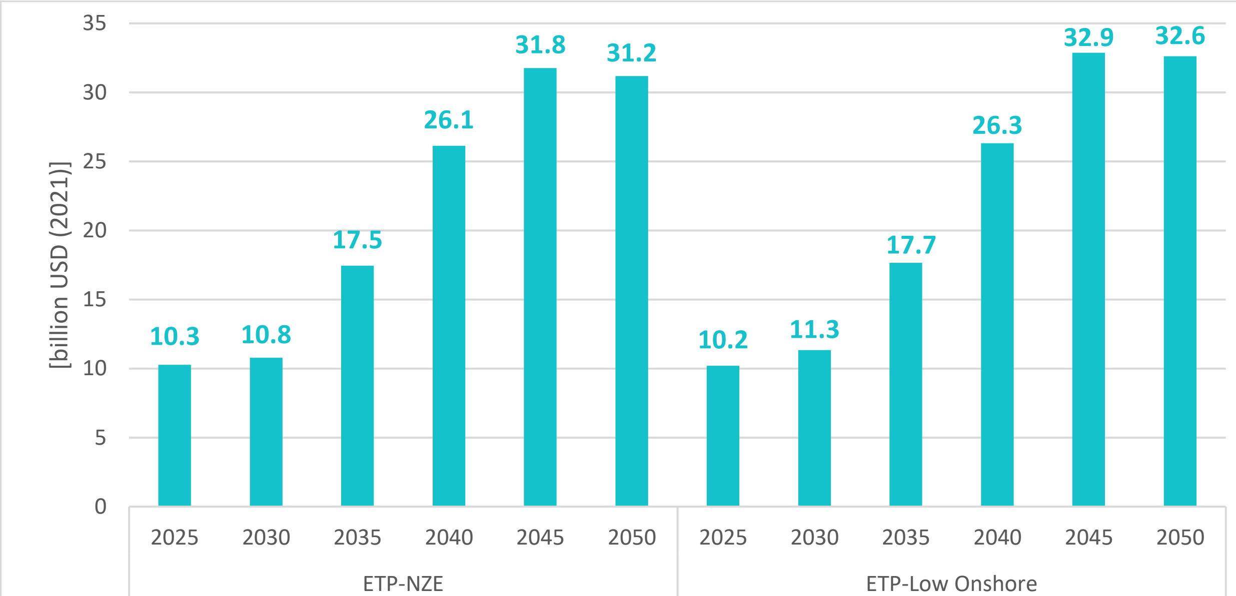
Figure 54. Onshore and offshore wind power plant capacities NZE vs Low Onshore, 2019-2050



Source: Outcome of TIMES-VN.

Figure 55. Electricity generation by source and renewable energy share NZE vs Low Onshore, 2030-2050

The shift from onshore to offshore wind and solar power requires an increased expenditure of around USD3 billion in the period 2040-2050 (Figure 56).



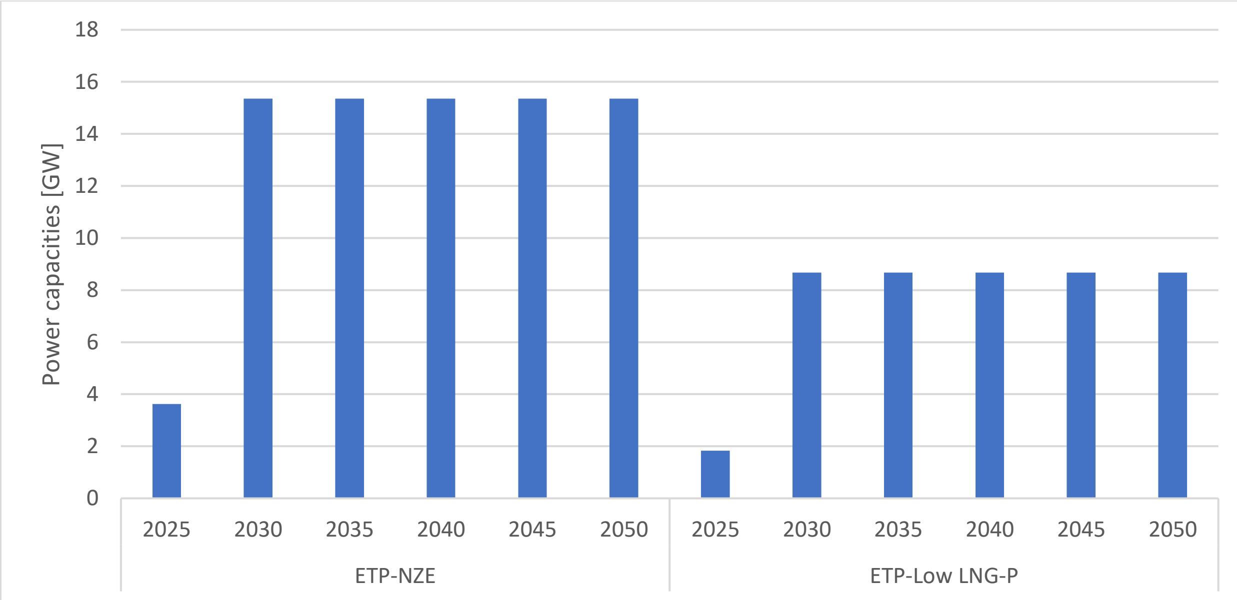
Source: Outcome of TIMES-VN.

Figure 56. Power sector average investment expenditure NZE vs Low Onshore, 2025-2050

6.3.8 Reduced LNG penetration in the power sector (LOW LNG-P)

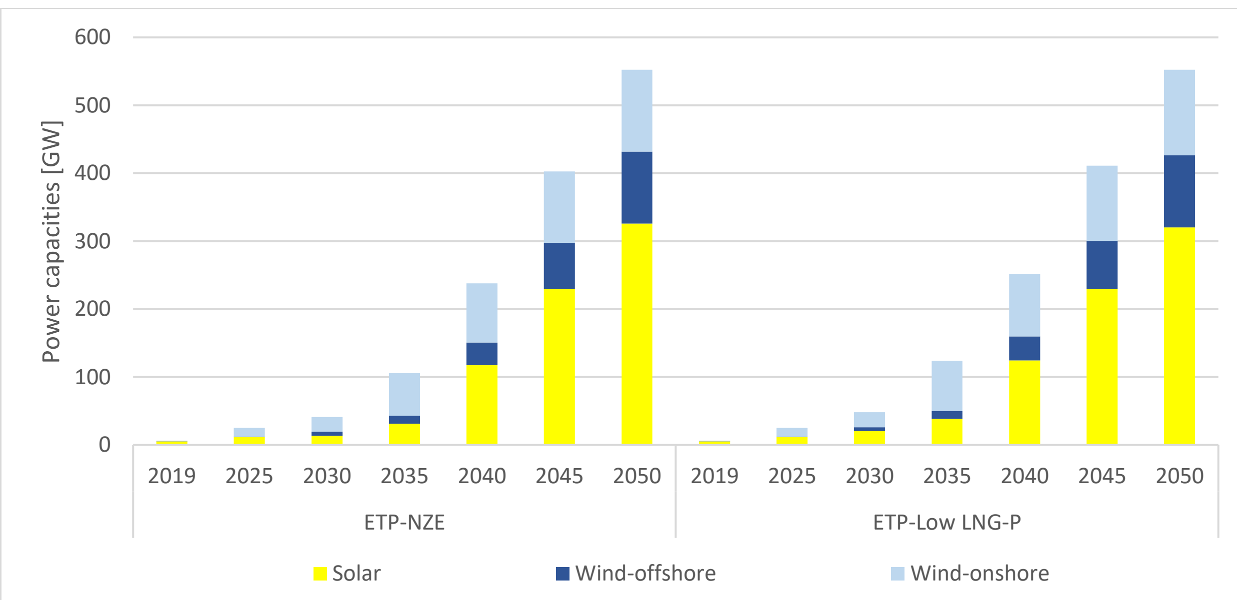
Limiting the commissioning of new fossil assets, particularly LNG plants, in the short to medium terms, deserves attention in the context of decarbonization. Such a roadmap would enhance investments in renewable plants over the same period. Indeed, investments in renewable energy are brought forward by a few years (Figure 58). Wind and solar capacities are higher in the Low LNG scenario in 2035 but at the same levels in 2050.

The higher investments required in the power sector (Figure 59) are compensated, from the total system cost perspective, by lower operating costs, compared to the use of LNG power plants.



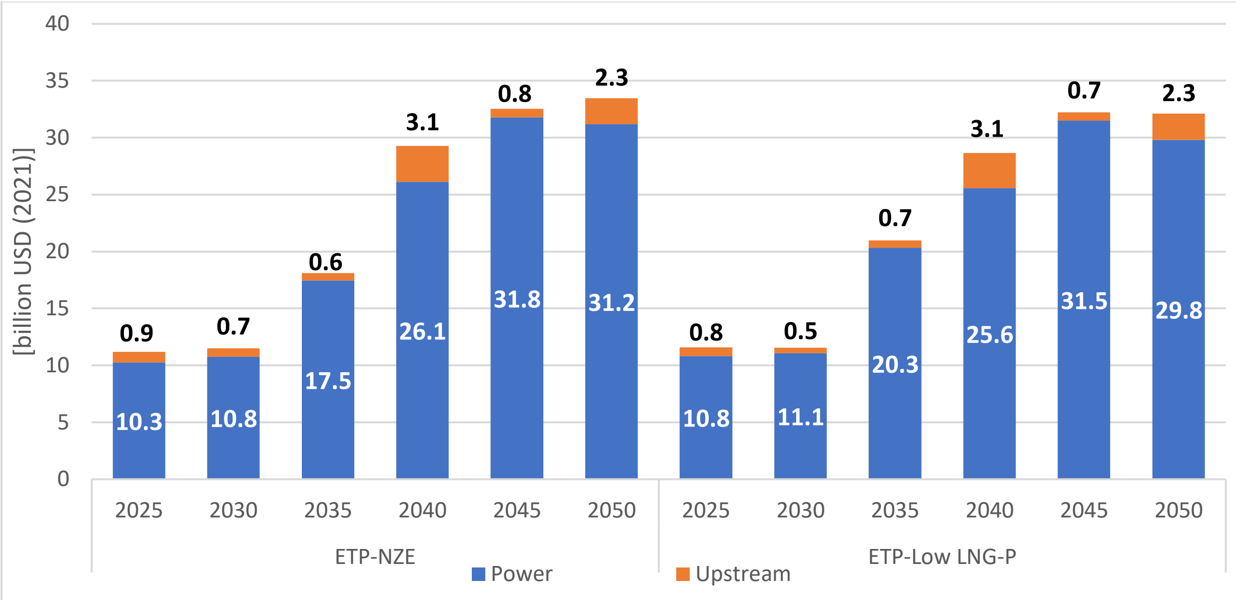
Source: Outcome of TIMES-VN.

Figure 57. LNG power plant capacities NZE vs Low LNG-P, 2025-2050



Source: Outcome of TIMES-VN.

Figure 58. Renewable power plant capacities NZE vs Low LNG-P, 2019-2050



Source: Outcome of TIMES-VN.

Figure 59. Average annual investment expenditure by power and upstream sector NZE vs Low LNG-P, 2025-2050

6.4 From outcomes to policy recommendations

This Mid-Term Report presented the direct outcomes of the assessment of the NZE scenario and its sensitivities, modelled by TIMES-VN. It described the required transformations of the energy system towards decarbonization, including the energy supply and end-use sectors, the socio-economic feasibility of these transformations and the impacts on energy security.

The assessment of the energy sector of Vietnam proposed in this report establishes the basis for key messages and policy recommendations, included in the Final Project Report "Net-Zero for the Energy Sector in Vietnam".