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

Data and Assumption book

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Contents

1 Introduction

1.1 Objectives of the study

In November 2021, at COP26, Prime Minister Pham Minh Chinh announced that with its own resources, along with the cooperation and support from the international community, Vietnam will 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 reach the NZE target. Finding the optimal investments and combinations of resources to ensure decarbonization, energy security, and improved economic outcomes while ensuring a fair and just energy transition requires a dedicated and diverse analytical process.

The "Diagnostic Study on Net-Zero for The Energy Sector in Vietnam", funded by the Southeast Asia Energy Transition Partnership (ETP), assesses the transition of Vietnam's energy sector to net-zero scenarios by 2050. It aims to support the implementation of the Prime Minister's Decision 888/QD-TTg on tasks and solutions for COP26 commitment implementation. It is also expected to be relevant for the implementation of the National Energy Master Plan and for the Just Energy Transition Platform (JETP) program. In this context, the Department of Oil, Gas and Coal requested (letter of 07/12/2022) support to ETP/UNOPS for (i) implementation of National Energy Master Plan; (ii) Just Energy Transition with focus on restructuring oil, gas and coal sector toward less dependence on fossil fuels, social impacts resilience, capacity building and job creation; and (iii) consultation on the ETP's Net-zero study for the Energy Sector of Vietnam.

1.2 Overview of the report

The objective of the Data and Assumption Book is to ensure a shared understanding of the key data and assumptions to be used in the analysis of the NZE scenario.

The report describes the key socio-economic drivers that characterize the outlook of Vietnam. It also provides the prices of the energy commodities traded in international markets and the energy resources available in Vietnam. These data are used as a basis to build the NZE scenario.

It also synthetizes the key targets of the policies in place in Vietnam to promote green growth, reduce greenhouse gas emissions, and ensure energy security. Amongst them, the Energy Master Plan, central to the on-going study, is under approval, The Power Development Plan (PDP8) was approved on 15 May 2023 and the approved targets are included in this report.

It gives an overview of the technologies available in each sector, supported by the sources of the data, as well as the benefits and limits of the different technological options available for decarbonizing the economy.

Finally, it introduces the levers and the influencing factors that affect the required transformation and investments to achieve the Net Zero target in Vietnam and which are used to define the core NZE scenario and several sensitivity scenarios carried out to enrich the understanding of the portfolio of technology choices and policy decisions.

The Data and Assumption Book takes into consideration the conclusions of a consultation of stakeholders held in May 2023 to gather additional inputs on data and assumptions and to collect views on sensitivity analyses to be carried out in the study. Representatives from the Ministry of Industry and Trade (MOIT), the Ministry of Natural Resources and Environment (MONRE), international cooperation agencies, and key energy sector stakeholders, such as Vietnam Oil and Gas Group (PVN), Vietnam Electricity (EVN), and Vietnam National Coal and Mineral Industries Group (Vinacomin), attended the workshop.

2 Socio-economic drivers and energy resources

This section describes the socio-economic drivers that characterize the outlook of Vietnam. It also provides the prices of the energy commodities traded in international markets and the energy resources available in Vietnam. These data are used as a basis to build the NZE scenario.

2.1 Most recent socio-economic projections in Vietnam

The consumed energy and the required investments in the NZE are driven by the demands in energy services in all the sectors of the economy of Vietnam. Energy services are, for example, tonnes of cement produced by the industrial sector, passenger-kilometres driven by motorcycles, demand for air conditioning in buildings, etc. (Table 2-1).

Table 2-1. Energy services represented in the NZE scenario

Sector	Service demand	Unit
Agriculture	Agriculture (aggregated service)	PJ
Industry	Iron and Steel Cement Ammonia	Million Tonnes
	Pulp and Paper Textile and Leather Wood Products Food, Beverage, Tobacco Processing Manufacturing of Machinery and Equipment Material Construction Motor Vehicles Manufacturing Extractive Industries Other Chemicals Other Non-Metallic Other Industries	PJ
Residential	Air Conditioning Cooking Electric Appliances Lighting Thermal Uses Other Uses	PJ
Commercial	Air Conditioning Cooking Electric Appliances Lighting Street Lighting Thermal Uses Other Uses	PJ

Transportation	*Road Passenger Transport* Cars Motorbikes Light commercial passenger Buses	Billion Passengers Km
	Road Freight Transport Heavy-Duty Trucks Light Commercial Freight Vehicles	Billion Tonnes Km
	Non-Road Passenger Transport Rail Navigation Aviation	Billion Passengers Km
	Non-Road Freight Rail Navigation Aviation	Billion Tonnes Km

Source: TIMES-EVN

The future energy services are calculated using socio-economic drivers such as GDP, population, GDP per capita. The socio-economic drivers from today to 2050, used in the assessment of the NZE, are the most recent official data available in Vietnam (Resolution No.81/2023QH15[1] and National Masterplan[2]).

In 2023, the National Assembly issued Resolution No.81/2023QH15 with the following targets on socio-economic development in 2021-2030 with the vision to 2050:

- GDP growth rate: about 7% per year in 2021-2025; 6.5%-7.5% per year in 2031-2050.
- GDP per capita: 7,500 USD by 2030, 27,000-32,000 USD by 2050.
- The economic structure of GDP: by 2030, the service sector accounts for more than 50%, the industrial sector over 40%, and the agricultural sector below 10%.

The Government's report on the National Masterplan submitted to the National Assembly includes two scenarios for socio-economic development as below:

- Low scenario: average GDP growth rate of 6.26% per year in 2021-2025, 6.34% per year in 2026-2030, and 6.49% in 2031-2050; GDP per capita of 7,000 USD by 2030, 13,000 USD by 2040, and 25,000 USD by 2050.
- High scenario: average GDP growth rate of 6.63% per year in 2021-2025, 7.48% per year in 2026-2030, and 7.16% in 2031-2050; GDP per capita of 7,500 USD by 2030, 16,500 USD by 2040 (high-income level by WB standard) and 32,000 USD by 2050.

The two scenarios are summarized in table 2-2.

Table 2-2. Main characteristics of the two scenarios in the National Master Plan

[1] Resolution No. 81/2023/QH15 on National master plan in 2021-2030 with vision to 2050 (January 2023)

[2] Government's Summary report on National master plan in 2021-2030 with vision to 2050 (2023)

	Year	2025	2030	2035	2045	2050
	Exchange rate (VND/USD)	24604	26569	30503	40205	46158
	Population (thousand persons)	101704	105689	108121	113152	115755
Low scenario	**Real GDP (trillion VND 2010)**	6797	9260	12568	23429	32612
	Nominal GDP (trillion VND)	12858	20754	32657	81814	132000
	Nominal GDP (billion USD)	522	781	1070	2034	2860
	GDP per capita (USD/person)	5138	7391	9902	17984	24708
High scenario	**Real GDP (trillion VND 2010)**	6902	9897	14298	28283	39464
	Nominal GDP (trillion VND)	13082	22279	37386	99772	161700
	Nominal GDP (billion USD)	532	842	1234	2510	3552
	GDP per capita (USD/person)	5238	7969	11413	22481	31509

Source: Government's Summary report on National master plan in 2021-2030 with vision to 2050

2.2 Energy prices and trade

2.2.1 International fuel prices

As a net energy importer, Viet Nam is directly exposed to international fuel prices.

The fuel prices assumptions provided by the World bank (Commodity Markets Prices[3]), the Power development plan (PDP8[4]) and the Energy master plan (EMP[5]) are used to project the fuel prices in Vietnam (Table 2-3).

Alternative prices, such as the price projections by the International Energy Agency, and not flat projections for commodities like biomass, should be explored in the analysis of the NZE.

[3] World Bank, Commodity Markets Prices, available online https://www.worldbank.org/en/research/commodity-markets
[4] PM's Decision No. 500/QD-TTg.
[5] Draft EMP submitted by MOIT to GOV for approval in December 2022.

Table 2-3. Energy commodity price projection in Vietnam

Fuel	2025	2030	2035	2040	2045	2050
WORLD PRICES						
Average crude oil (USD/barrel)	55.4	76.0	81.0	85.0	85.0	85.0
Steam coal FOB Australia (USD/ton)	71.0	73.9	72.9	71.9	71.9	71.9
LNG CIF Japan (USD/million BTU)	6.67	8.90	8.90	9.00	9.00	9.00
Imported coal (USD/ton)	100	100	100	101	104	104
Imported green hydrogen (USD/kg)	4	3	2.8	2.6	2.5	2.4
Imported green amoniac (USD/kg)	0.8	0.5	0.45	0.4	0.38	0.35
Uranium (USD/GJ)	4.86	4.86	4.86	4.86	4.86	4.86
DOMESTIC PRICES						
Domestic coal (USD/ton)	70	71	72	73	74	74
Natural gas Block B (USD/million BTU)	11.98	11.98	11.98	11.98	11.98	11.98
Natural gas Blue Whale (USD/million BTU)	9.71	9.71	9.71	9.71	9.71	9.71
Diesel oil (USD/GJ)	11.27	11.90	12.04	12.14	12.14	12.14
Kerosene (USD/GJ)	12.59	13.31	13.46	13.57	13.57	13.57
Jet fuel (USD/GJ)	11.60	12.33	12.48	12.60	12.60	12.60
Gasoline (USD/GJ)	15.93	16.85	17.04	17.19	17.19	17.19
Fuel oil (USD/GJ)	6.43	6.78	6.85	6.91	6.91	6.91
Biomass (USD/tấn)	45	50	60	60	60	60
Straw - 3000 Kcal/kg (USD/GJ)	2.37	2.37	2.37	2.37	2.37	2.37
Bagasse - 1850 Kcal/kg (USD/GJ)	0.16	0.19	0.19	0.19	0.19	0.19
Husk rice - 2800 Kcal/kg (USD/GJ)	0.63	0.74	0.74	0.74	0.74	0.74
Wood - 3500 Kcal/kg (USD/GJ)	3.06	3.06	3.06	3.06	3.06	3.06

Source: World bank (Commodity Markets Prices), Power development plan (PDP8) and Energy master plan (EMP)

2.2.2 Trade infrastructures

Electricity imports [6]

North Vietnam imports electricity from China, while the regions North Central, Centre Central and Highland import from Laos. Potentials for electricity import are as below:

- Laos: Laos can export to Vietnam 1000 MW by 2020, 3000 MW by 2025, 5000 MW by 2030, and 10000 MW as maximum potential.
- Cambodia: under negotiation
- China: China can export 800 MW to Vietnam by 2020, 3000 MW or higher by 2030.

[6] Based on Draft EMP and PDP8

Fossil fuels imports[7]

In the short and medium term, Vietnam can import coal from Indonesia, Australia and South Africa; in the long term, Vietnam can import from Russia and Australia. For period 2030 – 2050, it is feasible for Vietnam to import about 100-200 million tons/year of thermal coal for power production.

In the short and medium term, Vietnam can import LNG from countries such as Australia, Qatar and the US, which are the largest LNG exporters, and which have plans to increase export volumes. In the long term, Vietnam can consider the possibility of importing more LNG from Russia, Turkmenistan, Iran. It is expected that Vietnam may import LNG of 10-20 billion cubic metres for future power plants annually. The requested investments in LNG infrastructures are well represented in the analysis of the NZE under this study.

2.3 National energy resources[8]

2.3.1 Fossil resources

Vietnam is endowed with domestic coal, crude oil and natural gas potentials. Coal deposits are mainly located in the North , oil in the South and natural gas in the South and the Central.

Supply capabilities for domestic coal, crude oil and natural gas to 2050 and used in the NZE scenario of this study, are presented in Table 2-4.

Table 2-4. Supply capabilities for domestic coal, crude oil and natural gas (unit: PJ)

Fuel	2020	2025	2030	2035	2040	2045	2050
Coal	975.8	966.8	985.7	890.6	937.3	932.3	935.0
Oil	651.9	354.2	177.9	83.3	41.6	20.8	10.4
Gas	554.6	436.3	640.8	637.9	598.9	578.9	231.6

Source: : Energy master plan

2.3.2 Renewable resources

Vietnam has significant potential for renewable resources with diversity and larger allocation. The potential of renewable energy use for the NZE scenario is mentioned below in Table 2-5.

[7] Based on PDP8

[8] Based on Draft EMP

Table 2-5. Renewable resources potential for power generation (unit: MW)

Region Source	North	North of central	Central of central	Highland	South of central	South	Total
Offshore wind	13000	6711	1000	0	136000	50200	**206911**
Onshore wind - near offshore wind (> 4,5m/s)	13445	10717	11235	68386	35388	81962	**221133**
Solar Commercial	184042	112495	47082	208618	170191	267982	**990410**
Rooftop solar	10724	5542	3521	2448	4165	22091	**48491**
Biomass	1611	548	336	663	521	1638	**5316**
Small Hydropower	1474	242	410	384	278	70	**2860**
Waste	359	65	33	14	46	999	**1517**
Biogas	5.37	1.5	0.2	0.18	0.51	2.3	**10**
Geothermal	255	51	77	0	60	18	**461**
Tide and wave	530		5		15		**550**

Source: Energy master plan

The potentials of **biomass and waste** are summarized in Table 2-6.

Table 2-6 Potential of biomass and waste

Biomass	Potential (ton)	Potential (mtoe)
Wood	27534158	9.6
Wood waste	2692671	0.9
Agriculture Waste	69320258	19.3
Husk rice	*8069196*	*2.4*
Straw	*28479516*	*8*
Baggass	*7543773*	*1.4*
Other waste	*25227772*	*7.6*
Other waste	601 PJ	14.3
Total		**44.1**

Sources: Energy Master Plan

3 Energy and climate policies

3.1 Synthesis of climate and energy policies to consider in the NZE

In Vietnam, several policies have been put in place to promote green growth, reduce greenhouse gas emissions, and ensure energy security. The main targets of the different policies are presented in table 3-1. More details are provided in Annex A.

Amongst them, the Energy Master Plan is under approval; all other policies were approved. The Power Development Plan (PDP8) was approved on 15 May 2023.

These targets will be used as benchmarks or targets of the NZE scenario.

Table 3-1. Overview of the energy and climate policies considered in the NZE analysis

Document	Key emission and energy targets
Orientation of Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045 (2020) *Politburo's Resolution 55-NQ/TW*	Greenhouse gas emissions reduction by energy sector compared to Business as Usual (BAU): • 15% (2030) • 20% (2045) Renewable energy share in total primary energy supply: • 15 - 20% (2030) • 25 - 30% (2045) Energy saving ratio of total final energy consumption: • 7% (2030) • 14% (2045)
National Strategy for Climate Change to 2050 (2022) *PM's Decision No. 896/QĐ-TTg*	GHG emissions reduction compared to projected BAU: • 32.6% (2030) • 91.6% (2050) Emission: do not exceed • 457 Mt CO2eq (2030) • 101 Mt CO2eq (2050) (land-use, land-use change and forestry LULUCF -185 Mt, energy 101 Mt, agriculture 56 Mt, Industrial Processes and Product IPPU 20 Mt, wastes 8 Mt) Electricity production from renewable energy: increase the share to at least: • 33% (2030) • 55% (2050)
National Green Growth Strategy for 2021-2030 with a vision by 2050 (2021) *PM's Decision No. 1658/QĐ-TTg*	Reducing GHG emission intensity (GHG emissions per GDP) by: • at least 15% compared to 2014 (2030) • at least 30% compared to 2014 (2050) Reducing primary energy consumption per GDP by: • 1.0% - 1.5% annually in the period of 2021 – 2030

	• 1.0% annually by 2050 Share of renewable energy in the total primary energy supply reaches: • 15 – 20% (2030) • 25 - 30% (2050)
Nationally determined contribution	Reduction compared to projected BAU: • 7% in unconditional contribution (2030) • 24.4% in conditional contribution (2030)
Power Development Plan 8 *PM's Decision No. 500/QD-TTg.*	Emissions (BASE scenario, power sector): • 254 Mt CO_2eq (2030) • 31 Mt CO_2eq (2050) Renewable energy share in total electricity generation (base scenario): • 31% (2030) • 68% (2050)
Draft Energy Master Plan	Emissions: • 439-455 Mt CO_2eq (2030) • 98-101 Mt CO_2eq (2050) Renewable energy share in total primary energy supply (base scenario): • 17.4% (2030) • 78.8% (2045)
Vietnam's JETP agreement	Emission peak of no more than 170 Mt CO_2eq by 2030 from electricity generation. Peak of 30.2 GW for coal-fired generation.
Development strategy of Renewable Energy of Vietnam by 2030 with a vision to 2050 *PM's Decision No. 2068/QD-TTg*	Reduction of emissions in the energy sector compared to BAU: • 5% (2020) • 25% (2030) • 45% (2050) Renewable energy share in the total primary energy consumption: • 31% (2020) • 32.3% (2030) • up to around 44% (2050)
Vietnam Energy Efficiency Program 2019 – 2030 period (VNEEP 3) (2019) *PM's Decision No 280/QD-TTg*	2019 – 2025: • reduce TFEC by 5% -7% • electricity losses: under 6.5% • reduce energy consumption compared to 2015 -2018 period: iron and steel by 5-16.5%; chemical by at least 10%; plastic by 21.55 – 24.81%; cement by at least 10.89%; textile by at least 6.8%; beverage by 3 – 6.88%; paper by 8 – 15.8% 2025 – 2030: • reduce TFEC 8-10% • electricity losses: under 6.0% • reduce energy consumption compared to 2015 -2018 period: iron and steel by 5-16.5%; chemical by at least 10%; plastic by 21.55 – 24.81%; cement by at least 10.89%; textile by at least 6.8%; beverage by 4 – 8.44%; paper by 9.9 – 18.48% • reduce petroleum consumption in transportation by 5% compared to sectoral energy forecast to 2030
Action Program for Transition to green energy and mitigation of	12 targets. 1. By 2050, electricity and green energy for 100% of buses and taxis

carbon dioxide and methane emissions from transportation (2022) *PM's Decision No. 876/QD-TT*	2. From 2030, at least 50% of vehicles with electricity and green energy; electricity and green energy for 100% of new taxis 3. From 2025, electricity and green energy for 100% of new buses 4. From 2040, electricity and green energy for all vehicles operating in airfields 5. From 2035, electricity and green energy for 100% of new passenger vehicles and other vehicles in airports 6. By 2050, electricity and green energy for all vehicles and equipment in ports and aids to navigation 7. From 2035, electricity and green energy for ships that are built, converted, and imported; by 2050, electricity and green energy for 100% of ships operating inland 8. By 2050, electricity and green energy for 100% inland railway vehicles and 100% of the equipment used in inland ports and wharves 9. By 2040, electricity and green energy for 100% new inland waterway vehicles. 10. By 2050, electricity and green energy for 100% rolling stocks. 11. By 2050: electricity and green energy for 100% heavy equipment involved in traffic, 12. Develop a green transportation system toward the goal of net-zero greenhouse gas (GHG) emissions by 2050

3.2 Carbon markets

Vietnam has issued a legal framework and policies to establish a **carbon market**. The Environmental Protection Law No. 72/2020/QH14 (Nov. 17, 2020) regulates GHG emission reduction in article 91, which includes the establishment of a domestic carbon market.

Decree No. 06/2022/ND-CP on Regulation on GHG emission reduction and ozone layer protection, issued on January 7, 2022, guides the development of the domestic carbon market, defining GHG inventory requirements in Article 5, Section 1. Emission quotas are allocated based on the GHG inventory, and the decree outlines a roadmap to establish a pilot market by 2025 and an official market by 2028. During the pilot phase, regulations will be developed, capacity-building activities will be implemented, and pilot markets will be established in high-potential areas.

4 Technologies

The analysis of the NZE scenario will provide information about the preferred technological options under different conditions. This section presents an overview of all future technology options for each sector, supported by the sources of the data. Appendix B provides a description of the benefits and limits of the different technological options available for decarbonizing the economy.

4.1 Overview

The most important data points for representing a technology are investment costs, fixed and variable operation and maintenance costs, efficiencies.

These assumptions are based on different reports and studies, presented in the following sections. For existing technologies, the efficiencies have been calibrated to fit with the energy balance.

The sources of data are the same as for the upcoming Energy Outlook Report 2023 to be published by the Electricity and Renewable Energy Agency and the Danish Energy Agency in 2023.

The following sources are used:

- The updated Vietnamese technology catalogues, which will be published by Electricity and Renewable Energy Authority (EREA) and the Danish Energy Agency (DEA) in July 2023. The data in the catalogues are based on expert judgments and have been validated with local stakeholders. The catalogues include technological data on production of power and green fuels and storage options.
- The Danish Energy Agency's technology catalogues[9] have been used in some cases where data was missing. These technology catalogues undergo the same process as the Vietnamese catalogues. In the cases where the Danish catalogues have been used, data have been scaled to reflect the Vietnamese conditions.
- The EU reference scenario 2020[10] has been used mainly for representing technologies in the demand sectors. Based on local experts, the data has been adapted to the Vietnamese context.
- Other reports have been used for specific technologies and sectors:
    - Reports from the International Energy Agency (IEA) for hydrogen related technologies[11], ammonia production[12].

[9] Danish Energy Agency (DEA). *Technology Data*. Retrieved from https://ens.dk/en/our-services/projections-and-models/technology-data

[10] European Commission. (2021). *EU Reference Scenario 2020*. Retrieved from https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

[11] IEA. (2019). *The Future of Hydrogen: Seizing today's opportunities*. Retrieved from https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf

[12] IEA. (2018a). *The Future of Petrochemicals Towards more sustainable plastics and fertilisers*. Retrieved from https://iea.blob.core.windows.net/assets/bee4ef3a-8876-4566-98cf-7a130c013805/The_Future_of_Petrochemicals.pdf

- TNO Technical datasheet for H_2 boiler[13].
- European Commission technical report for Ulcolysis and Ulcowin processes[14].
- Scientific article on steel and cement industries[15] and IEA Reports[16,17] for clinker production data, specifically for the clinker dry process using different technologies.
- IEA-ETSAP Technology Database[18] for various end-use technologies applied in the building sector.
- Scientific article on CO_2 capture from distributed energy systems [19].

4.2 Industry

The industrial sector includes technologies for heating, electric appliances and machine drive and industrial production technologies. An overview can be seen in Table 4-1. The sources in this sector are based on different reports.

[13] TNO. (2020). *Technology Factsheet: H2 Industrial Boiler*. Retrieved from https://energy.nl/wp-content/uploads/h2industrialboiler_28092020_upd-7.pdf

[14] European Commission. (2016). *Iron production by electrochemical reduction of its oxide for high CO2 mitigation (IERO)*. Retrieved from https://op.europa.eu/portal2012-portlet/html/downloadHandler.jsp?identifier=4255cd56-9a96-11e6-9bca-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=

[15] van Ruijven et al.. (2016). *Long-term model-based projections of energy use and CO_2 emissions from the global steel and cement industries*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0921344916301008

[16] IEA. (2018b). *Technology Roadmap Low-Carbon Transition in the Cement Industry*. Retrieved from https://iea.blob.core.windows.net/assets/cbaa3da1-fd61-4c2a-8719-31538f59b54f/TechnologyRoadmapLowCarbonTransitionintheCementIndustry.pdf

[17] IEA. (2013). *Deployment of CCS in the cement industry*. Retrieved from https://ieaghg.org/docs/General_Docs/Reports/2013-19.pdf

[18] IEA-ETSAP. *Energy Supply Technologies Data*. Retreived from https://iea-etsap.org/index.php/energy-technology-data/energy-supply-technologies-data

[19] Takeshi Kuramochi, Andrea Ramírez, Wim Turkenburg, André Faaij, *Techno-economic prospects for CO2 capture from distributed energy systems,* Renewable and Sustainable Energy Reviews, Volume 19, 2013, Pages 328-347, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2012.10.051

Table 4-1. An overview of the technologies in industry

Use	Technology type	Source
Heating	Gas boiler	DEA technology catalogue
	Gas boiler with CCS	Expert's knowledge
	Coal boiler	DEA technology catalogue
	Coal boiler with CCS	Expert's knowledge
	Biomass boiler	DEA technology catalogue
	Oil boiler	DEA technology catalogue
	LPG boiler	DEA technology catalogue
	Hydrogen boiler	TNO (2020)
	Heat pump (air-to-water)	DEA technology catalogue
	Heat pump (brine-to-water)	DEA technology catalogue
Other end uses	Electric appliances	EU Reference scenario
	Electric machine drive	EU Reference scenario
Industrial production technologies	Steel production: Blast Furnace with Basic Oxygen Furnace	IEA (2019)
	Steel production: Blast Furnace with Basic Oxygen Furnace with CCS	IEA (2019), Kuramochi et al. (2013)
	Steel production: Natural Gas based Direct Reduction with Electric Arc Furnace	IEA (2019)
	Steel production: Natural Gas based Direct Reduction with Electric Arc Furnace with CCS	IEA (2019)
	Steel production: Hydrogen based Direct Reduction with Electric Arc Furnace	IEA (2019)
	Steel production: Oxygen-rich smelt reduction with CCUS	IEA (2019)
	Steel production: Scrap to Electric Arc Furnace	
	Steel production: Ulcolysis	European Commission (2016)
	Steel production: Ulcowin	European Commission (2016)
	Clinker production: Dry process -BAT	IEA (2018b), van Ruijven et al. (2016), IEA (2013)
	Clinker production: Dry process with post-combustion CCS	IEA (2018b), van Ruijven et al. (2016), IEA (2013)
	Clinker production: Dry process with oxy fuel CCS	IEA (2018b), van Ruijven et al. (2016), IEA (2013)
	Clinker production: Dry process Hydrogen	van Ruijven et al. (2016), IEA (2013)van Ruijven et al., IEAGHG2013
	Clinker production: Grinding	Calculation
	Ammonia production: Steam Methane Reforming BAT	IEA (2019), IEA (2018a)
	Ammonia production: Autothermal Reforming	IEA (2019), IEA (2018a)
	Ammonia production: Coal Gasification BAT	IEA (2019)
	Ammonia production: Steam Methane Reforming withCCS	IEA (2019)
	Ammonia production: Autothermal Reforming with CCS	IEA (2019)
	Ammonia production: Coal Gasification with CCS	IEA (2019)
	Ammonia production: Electrolysis	IEA (2019)
	Ammonia production: Biomass Gasification	IEA (2019)
	Ammonia production: Naphtha Partial Oxidation	IEA (2018a)
	Ammonia production: Ammonia synthesis unit (Haber-Bosch)	IEA (2019), IEA (2018a)

4.3 Buildings

In the building sector, there are technologies for heating, air conditioning, cooking, lighting, and appliances. All but lighting and appliances (purely electrical) have more options for fuel and type of technology. An overview is shown in Table 4-2.

Table 4-2. Technology options for buildings

Subsector	Technology type	Source
Heating	Gas boiler	EU reference scenario, IEA ETSAP technology database
	Biomass boiler	EU reference scenario, IEA ETSAP technology database
	Oil boiler	EU reference scenario, IEA ETSAP technology database
	LPG boiler	EU reference scenario, IEA ETSAP technology database
	Hydrogen boiler	EU reference scenario, IEA ETSAP technology database
	Wood stove	EU reference scenario, IEA ETSAP technology database
	Coal stove	EU reference scenario, IEA ETSAP technology database
	Heat pump (air-to-air)	EU reference scenario, IEA ETSAP technology database
	Heat pump (air-to-water)	EU reference scenario, IEA ETSAP technology database
	Heat pump (brine-to-water)	EU reference scenario, IEA ETSAP technology database
	Solar heating	EU reference scenario, IEA ETSAP technology database
Other end uses	Air conditioning (electric)	EU reference scenario, IEA ETSAP technology database
	Air conditioning (gas)	EU reference scenario, IEA ETSAP technology database
	Air conditioning (air)	EU reference scenario, IEA ETSAP technology database
	Electric cooking	EU reference scenario, IEA ETSAP technology database
	Gas cooking	EU reference scenario, IEA ETSAP technology database
	LPG cooking	EU reference scenario, IEA ETSAP technology database
	Coal cooking	EU reference scenario, IEA ETSAP technology database
	Oil cooking	EU reference scenario, IEA ETSAP technology database
	Biomass cooking	EU reference scenario, IEA ETSAP technology database
	Electric lighting	EU reference scenario, IEA ETSAP technology database
	Electric appliances	EU reference scenario, IEA ETSAP technology database

4.4 Transport

The transport sector is modelled with different modes of transport and then split into type of technology. Table 4.3 show the options for the transport sector. The data from the EU reference scenario has been adapted to the Vietnamese context by using Vietnamese data on passenger or tonnes-km.

Table 4-3. The technology options in the transport sector

Subsector	Technology type	Source
Cars, light commercial vehicles & medium-duty trucks	Gasoline Internal Combustion Engine (ICE)	EU reference scenario, Institute of Energy (Vietnam)
	Gasoline hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Plug-in gasoline hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Diesel ICE	EU reference scenario, Institute of Energy (Vietnam)
	Diesel hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Diesel plug-in hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Battery electric vehicle	EU reference scenario, Institute of Energy (Vietnam)
	Fuel cell (hydrogen)	EU reference scenario, Institute of Energy (Vietnam)
	Gas ICE	EU reference scenario, Institute of Energy (Vietnam)
	LPG ICE	EU reference scenario, Institute of Energy (Vietnam)
Busses & heavy-duty trucks	Gasoline ICE	EU reference scenario, Institute of Energy (Vietnam)
	Gasoline hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Diesel ICE	EU reference scenario, Institute of Energy (Vietnam)
	Diesel hybrid	EU reference scenario, Institute of Energy (Vietnam)
	Battery electric vehicle	EU reference scenario, Institute of Energy (Vietnam)
	Fuel cell (hydrogen)	EU reference scenario, Institute of Energy (Vietnam)
	Gas ICE	EU reference scenario, Institute of Energy (Vietnam)
	LPG ICE	EU reference scenario, Institute of Energy (Vietnam)
Mopeds & motorbikes	Gasoline ICE	EU reference scenario, Institute of Energy (Vietnam)
	Electric	EU reference scenario, Institute of Energy (Vietnam)
Rail	Diesel	EU reference scenario, Institute of Energy (Vietnam)
	Electricity	EU reference scenario, Institute of Energy (Vietnam)
	Hydrogen	EU reference scenario, Institute of Energy (Vietnam)
Aviation	Jet fuel	EU reference scenario, Institute of Energy (Vietnam)
	Hybrid jet fuel	EU reference scenario, Institute of Energy (Vietnam)
	Electricity	EU reference scenario, Institute of Energy (Vietnam)
	Hydrogen	EU reference scenario, Institute of Energy (Vietnam)
Navigation	Heavy fuel oil	EU reference scenario, Institute of Energy (Vietnam)
	Diesel	EU reference scenario, Institute of Energy (Vietnam)
	Electricity	EU reference scenario, Institute of Energy (Vietnam)
	Gas	EU reference scenario, Institute of Energy (Vietnam)
	Hydrogen	EU reference scenario, Institute of Energy (Vietnam)
	Methanol	EU reference scenario, Institute of Energy (Vietnam)
	Ammonia	EU reference scenario, Institute of Energy (Vietnam)

4.5 Agriculture

The agricultural sector is represented by the shares of fuel use. Table 4-4 presents the possible fuels that can be used in agriculture.

Table 4-4. Fuel types in agriculture

Fuel types	
Biogas	Kerosene
Coal	Renewable Natural Gas
Electricity	Renewable Diesel
Geothermal	Renewable Gasoline
Heat	Renewable LPG
Hydrogen	Renewable Methanol
LPG	Renewable Ammonia
Natural gas	Solar
Diesel	Solid biofuels
Gasoline	Waste
Heavy fuel oil	

4.6 Upstream

The technologies for the upstream sector can be seen in Table 4-5. The sources are a mix of reports and technology catalogues.

Table 4-5. Technologies in the upstream sector

Technology type	Source
H2 production - Steam reforming centralized	EU reference scenario, IEA the future of hydrogen
H2 production - Steam reforming CCS centralized	EU reference scenario, IEA the future of hydrogen
H2 Production - Coal Gasification CCS centralized	EU reference scenario, IEA the future of hydrogen
H2 Production - Coal Gasification centralized	EU reference scenario, IEA the future of hydrogen
H2 production - Electrolysis PEM centralized	Vietnamese technology catalogue
H2 production - Electrolysis Alkaline centralized	Vietnamese technology catalogue
H2 production - Electrolysis PEM captive	Vietnamese technology catalogue
H2 production - Electrolysis Alkaline captive	Vietnamese technology catalogue
Biogas from Biomass	Vietnamese technology catalogue
Synthetic Natural Gas from Biogas upgrading using amine scrubber	Vietnamese technology catalogue
Synthetic Natural Gas from Biomass Gasifications	DEA technology catalogue scaled to fit amine scrubber data from the Vietnamese technology catalogue

Synthetic Natural Gas from Methanisation of Biogas	DEA technology catalogue scaled to fit amine scrubber data from the Vietnamese technology catalogue
Fisher-Tropsch from power to jet	Vietnamese technology catalogue
Fisher-Tropsch from Biomass Gasification	DEA technology catalogue
Bio Diesel from Biomass (catalytic pyrolysis)	DEA technology catalogue
Fisher-Tropsch from Hydrogen to Jet	DEA technology catalogue
Bio Methanol from Biomass Gasification	Vietnamese technology catalogue
Methanol from Power	Vietnamese technology catalogue
Green ammonia synthesis	Vietnamese technology catalogue

4.7 Power

The technology data for the power sector is based on the Vietnamese technology catalogue as shown in table Table 4-6.

Table 4-6. The technologies included in the power sector

Technology type	Source
Steam Turbine Coal Supercritical	Vietnamese technology catalogue
Steam Turbine Coal Ultra-supercritical	Vietnamese technology catalogue
Fluidized Bed Combustion Coal	Vietnamese technology catalogue
Gas Turbine Combined Cycle Gas Conventional	Vietnamese technology catalogue
Very small-scale Gas Plant	Vietnamese technology catalogue
Very small-scale Oil Plant	Vietnamese technology catalogue
Steam Turbine Biomass Solid Conventional	Vietnamese technology catalogue
Small Waste burning plant	Vietnamese technology catalogue
Landfill Gas Power Plant - Municipal Solid Waste	Vietnamese technology catalogue
Nuclear III gen.	Vietnamese technology catalogue
Nuclear - Small Modular Reactor (SMR - Generation IV)	Vietnamese technology catalogue
Gas combined cycle CCS post combustion	Vietnamese technology catalogue
Steam Turbine Coal Supercritical CCS post-combustion	Vietnamese technology catalogue
Steam Turbine Ammonia Supercritical	Vietnamese technology catalogue
Steam Turbine Ammonia Ultra-supercritical	Vietnamese technology catalogue
Steam Turbine Biomass Supercritical	Vietnamese technology catalogue
Steam Turbine Biomass Ultra-supercritical	Vietnamese technology catalogue
Fluidized Bed Combustion Biomass	Vietnamese technology catalogue
Simple cycle gas turbine - large system	Vietnamese technology catalogue
Biogas power plant - small	Vietnamese technology catalogue
Steam Turbine Coal Supercritical with Ammonia co-firing	Vietnamese technology catalogue
Steam Turbine Coal Ultra-supercritical with Ammonia co-firing	Vietnamese technology catalogue
Steam Turbine Coal Supercritical with Biomass co-firing	Vietnamese technology catalogue
Steam Turbine Coal Ultra-supercritical with Biomass co-firing	Vietnamese technology catalogue
Fluidized Bed Combustion Coal + Biomass co-firing	Vietnamese technology catalogue
Hydrogen Turbine Combined Cycle	Vietnamese technology catalogue
Combined cycle gas turbine with hydrogen co-firing	Vietnamese technology catalogue

Wind onshore	Vietnamese technology catalogue
Wind nearshore	Vietnamese technology catalogue
Wind offshore fixed	Vietnamese technology catalogue
Wind offshore floating	Vietnamese technology catalogue
Solar PV - utility-scale	Vietnamese technology catalogue
Tidal power - Impoundment Type	Vietnamese technology catalogue
Tidal power - Stream Type	Vietnamese technology catalogue
Wave power	Vietnamese technology catalogue
Hydro power plant - large system	Vietnamese technology catalogue
Hydro power plant - small system	Vietnamese technology catalogue
Geothermal Low Enthalpy - small	Vietnamese technology catalogue
Geothermal Low Enthalpy - large	Vietnamese technology catalogue
Solar PV - residential	Vietnamese technology catalogue scaled to fit cost difference between residential and industrial PV in the EU reference scenario
Solar PV - rooftop	Vietnamese technology catalogue

4.8 Decarbonization options

Decarbonizing options can be classified in main categories in each sector, as presented below. Appendix B presents the benefits and drawbacks of these different categories of decarbonization options.

4.8.1 End-use sectors

Decarbonizing the demand sectors: agriculture, industry, buildings, and transportation, is crucial for achieving the global goals of reducing greenhouse gas emissions and mitigating climate change. A range of technologies is available to help decarbonize these sectors, from well-established solutions such as energy-efficient lighting and electric vehicles to emerging technologies such as carbon capture and synthetic fuels.

Decarbonization can be based on direct electrification, synthetic fuels, carbon capture, and energy efficiency (Table 4-7) . These options are described in Appendix B.

Table 4-7. Overview of the relevant technologies for each demand sector

	Agriculture	Industry	Buildings	Transport
Direct electrification	X	X	X	X
Synthetic fuels	X	X		X
Carbon capture		X		
Energy efficiency	X	X	X	X

4.8.2 Upstream sector

The upstream sector, which encompasses oil, gas, and coal extraction and production, is responsible for a significant share of greenhouse gas emissions. As the Vietnam transitions to a low-carbon economy, it is essential to decarbonize this sector to achieve the ambitious goals of mitigating climate change. The sector will also be producing the electro- and biofuels needed in the demand sectors in electrolyzers and renewable refineries. Production of electro- and biofuels and direct air capture are decarbonizing options (Table 4-8). They are described in Appendix B.

Table 4-8. Overview of relevant technologies in the upstream sector

	Upstream
Production of electrofuels	X
Production of biofuels	X
Direct air capture	X

4.8.3 Power sector

The power sector is a critical component of an energy system, responsible for generating and delivering electricity to meet the needs of homes, businesses, and industry. It is characterized by a diverse range of technologies, including conventional thermal power plants (such as coal and natural gas), nuclear power plants, hydropower plants, and variable renewable energy sources (such as wind, solar, geothermal and hydro). An overview of options for the power sector is shown in Table 4-9 and described in Appendix B.

Table 4-9. Overview of relevant mitigation options in the power sector

	Power
Wind power	X
Solar power	X
Geothermal power	X
Hydro power	X
Nuclear	X
Biomass fired plants	X
Waste fired plants	X
Hydrogen co-firing	X
Ammonia co-firing	X
Carbon capture	X
Battery storage	X

5 Scenario design

The NZE scenario aims at assessing Vietnam's energy sector transition towards net-zero emissions by 2050, considering the interrelations with major energy-consuming sectors such as transportation, manufacturing, and buildings. The model-based scenario will contribute to inform i) likely technological developments, ii) impacts of policies to implement the identified cost-effective low-carbon mitigation options, iii) total costs and financing needs to achieve the low carbon targets.

5.1 Overview of levers and influencing factors

Several levers and influencing factors affect the required transformation and investments to achieve the Net Zero target in Vietnam. They are useful to define the core NZE scenario and several sensitivity scenarios to enrich the understanding of the portfolio of technology choices and policy decisions.

Key levers considered are as follows:

- The GHG trajectory to reach NZE by 2050, more particularly the expected year of emission peak and the limits possibly imposed to specific sectors, directly influence the nature and the timing of the required transformation of the energy sector; the contribution of the emissions from the non-energy sectors, such as agriculture, land use and land use changes, also influences the required mitigation by the energy sector.
- Specific policies and measures, such as technology subsidies, energy efficiency, penetration of renewable, coal phaseout, guide the transformation of the energy sector to the net–zero target; if not well-defined, these policies and measures can also be the cause of non-optimal costs to the energy transition.
- The availability and costs of key technology options, with a high mitigation potential, influences the overall transformation of the sector. For example, carbon capture and storage offers a high potential of CO_2 mitigation in the industrial and power sectors; although its costs, scalability and social acceptance are still uncertain. Appendix B describes the benefits and limitations of key technologies as well as the associated uncertainties.

Other influencing factors are as follows:

- International price outlooks impact the competition between mitigation options.
- GDP growth directly influences the demand for energy services.
- Behaviours are given an increasing importance in mitigation strategies given their potential to reduce energy demands or even change the nature of the demands (for example, modal shift in transportation).

5.2 Key levers based on existing targets and policies of Vietnam

Besides the targets related to the emissive trajectory of Vietnam, the energy and climate policies include four overarching target categories which are critical in the analysis of the NZE: coal phase-out, renewable energy sources, green fuels/electrification (transportation), and energy efficiency (Table 5-1).

Table 5-1. Scenario levers for the years 2030 and 2050 based on existing policies

Topic	2030	2050
GHG trajectory	*National Strategy for Climate Change to 2050 (2022)* Energy: 457 Mt CO_2eq Non-Energy: 210.7 Mt CO_2eq LULUCF: -95 Mt CO_2eq *PDP8 (2023):* Power sector: 204-254 Mt CO_2eq (170 Mt CO2eq is JETP investments are implemented)	*National Strategy for Climate Change to 2050 (2022)* Energy: 101 Mt CO_2eq Non-Energy: 84 Mt CO_2eq LULUCF: -185 Mt CO_2eq
Emission peaking date	*JETP (2022) / PDP8 (2023):* Peak of power sector emissions: 2030	
Coal phase out	*PDP8 (2023) / JETP (2022):* 30.1 GW max	*PDP8 (2023)* Coal phase-out for power production[(2)]
Share of Renewable Energy Sources[(1)] (Electricity Generation)	*PDP8 (2023):* 30.9 - 39.2%	*PDP8 (2023):* 67.5 - 71.5%
Transport (Green fuels and Electrification)	*Action Program for Transition to green energy and mitigation of carbon dioxide and methane emissions from transportation (2022):* From 2030, at least 50% of vehicles with electricity and green energy; electricity and green energy for 100% of new taxis	*Action Program for Transition to green energy and mitigation of carbon dioxide and methane emissions from transportation (2022):* By 2050, electricity and green energy for 100% of buses, taxis, vehicles and equipment in inland ports and aids to navigation, inland railway vehicles, rolling stocks, and heavy equipment involved in traffic
Energy Efficiency	*Vietnam Energy Efficiency Program 2019 – 2030 period (VNEEP 3)* Reduce Total Final Energy Consumption (TFEC) by 8-10%	

(1) As outlined in the Prime Minister's Decision 896/QD-TTg 2022, proposed renewable energy technologies solutions to reach such targets are: small hydro power plants, expanding current large hydro power plants, increasing renewable energy power plants such as wind, concentrated solar power plants, biomass, green hydrogen, green ammoniac, wave energy, and tidal energy.

(2) Coal power plants within the country are supposed to be decommissioned or converted to utilize biomass energy or ammonia.

5.3 Uncertainties subject to sensitivity analyses

Most of the dimensions characterizing the NZE are subject to uncertainties. Sensitivity analyses will help understanding the impacts of these uncertainties on the transformation of the energy sector to reach the NZE target in 2050. These analyses are also helpful to guide decision-makers in the adoption of appropriate measures to build a resilient transition pathway.

Possible sensitivity parameters are presented in Table 5-2. Several of them emerged from the discussions with stakeholders. The sensitivity analyses will be consolidated in the light of the first outcomes of the NZE scenario and further exchanges with stakeholders, taking into consideration the complementarity with other recent and on-going studies, including the coming Energy Outlook Report 2023.

Table 5-2: Possible focus of the sensitivity analyses

Topic	Possible sensitivity parameters
Emissions trajectory and peaking date	• Uncertain contribution of the non-energy and land- use, land-use change and forestry to total emissions • Delayed/earlier emission peak
Renewable (including green fuels)	• Penetration level of RES in electricity generation • Penetration level of green fuels end-use sectors • Technological discount rates
Energy efficiency	• Energy efficiency gains in end-use sectors, more particularly in the industry sector
Electrification	• Electrification level of end-use sectors, more particularly transportation and industry sectors
Innovative technologies	• Costs and readiness of innovative and uncertain technologies such as carbon capture and storage, direct air capture, green fuels.
International energy markets	• Variations in international energy prices • Limited imports (energy dependence)
Socio-economic drivers and behaviours	• Economic and demographic projections, affecting the demands for energy services. • Behavioural changes, such as lower future energy demand in the residential sector, modal shift in transportation
Other	• Sectoral emission targets or carbon price • Post 2030 Least Cost Power Planning

Appendix A. Reminder of energy and climate policies

Politburo's Resolution 55-NQ/TW, issued on 11/02/2020, outlines Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045. The objective of the policy is to meet domestic energy demands for the targets of the 10-year socio-economic development strategy, with a focus on increasing the share of renewable energy sources in the total primary energy supply. The policy also aims to build a smart and efficient grid system and ensure energy security by meeting the level of strategic petroleum reserve and importing liquefied natural gas. Additionally, the policy sets targets for reducing greenhouse gas emissions and increasing energy savings.

More details in the Inception Report.

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The Prime Minister's Decision 896/QD-TTg 2022 on National Climate Change Strategy through 2050 issued on 26/07/2022. The purpose is to adapt to climate change, reduce greenhouse gas emissions, and to deal with vulnerabilities and risks caused by climate change. The GHG emission reduction target of the energy sector is 32.6% compared to the Business as Usual (BAU) scenario, total GHG emission will not exceed 457 million tons CO2eq in 2030; 91.6% and 101 million tons CO2eq in 2050. Proposed solutions include promoting energy efficiency and clean energy technologies, with a focus on developing small and large hydro power plants, expanding renewable energy production, and increasing the share of electricity production from renewable energy to at least 33% in 2030 and 55% in 2050.

More details in the Inception Report.

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The Prime Minister's Decision 1658/QD-TTg outlines the National Green Growth Strategy for the period of 2021-2030 with a vision towards 2050. The strategy aims to achieve economic prosperity, environmental sustainability, and social equality by accomplishing green growth and restructuring the growth model through innovation. The objectives include reducing primary energy consumption per GDP annually, increasing the share of renewable energy in the total primary energy supply, and reducing GHG emission intensity by at least 15% by 2030 and 30% by 2050 compared to 2014.

More details in the Inception Report.

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The Draft Energy Master Plan for 2021-2030 with visions to 2050 (EMP) focuses on establishing an energy management plan in Vietnam, with the aim of ensuring adequate energy supply for socio-economic development, efficient use of energy resources, and the development of renewable energy sources. The plan has several specific objectives, including analyzing and assessing the current development status of energy sub-sectors, forecasting energy demand, and selecting options for developing energy sub-sectors and infrastructure. Additionally, the plan aims to assess environmental impacts and propose solutions to major development mechanisms and policies, to ensure sustainable development of the national energy sector.

More details in the Inception Report.

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The **Power Development Plan for 2021-2030 with visions to 2050 (PDP8)** aims to build an overall plan for the power sector in Vietnam covering power sources and transmission grid. It was approved on 15 May 2023.

An overview of the approved PDP8 is as follows:

Table A-1. Overview of the approved PDP8

	BASE SCENARIO	HIGH SCENARIO	HIGH ADMINISTRATION SCENARIO
Overall description of the scenario	Electricity demand forecast for base GDP growth rate	Electricity demand forecast for high GDP growth rate	Electricity demand forecast for high GDP growth rate and considering the risks in deployment of several large power plants
Total installed capacity (MW)	140799 MW (2030)	146644 MW (2030)	158244 MW (2030)
	490529 MW (2050)	573129 MW (2050)	573129 MW (2050)
Renewable energy share in total electricity generation (%)	31% (2030)	36% (2030)	39% (2030)
	68% (2050)	72% (2050)	72% (2050)
CO2 emission (Mt CO_2eq)	254 Mt CO_2eq (2035)	266 Mt CO_2eq (2035)	226 Mt CO_2eq (2035)
	31 Mt CO_2eq (2050)	27 Mt CO_2eq (2050)	27 Mt CO_2eq (2050)

Source: Power development plan (PDP8)

The expected installed power capacity by 2030 and 2050 is as follows:

Table A-2. Expected installed power capacity in the PDP8

	By 2030		By 2050	
	MW	%	MW	%
Onshore wind power	21880	14.5	60050 – 77050	12.2 – 13.4
Offshore wind power	6000	4	70000 – 91500	14.3 – 16
Solar power	12836	8.5	168594 – 189294	33.0 – 34.4
Biomass	2270	1.5	6015	1.0 – 1.2
Hydropower	29346	19.5	36016	6.3 – 7.3
Stored power	2700	1.8	30650 – 45550	6.2 – 7.9

Cogeneration	2700	1.8	4500	0.8 – 0.9
Coal	30127	20	0	0
Converted coal*	0	0	25632 – 32432	4.5 – 6.6
Gas	37630	25	14930	2.6 – 3
Hydrogen	0	0	20900 – 29900	4.1 – 5.4
Imports	5000	3.4	11042	1.9 – 2.3
Flexible power sources	0	0	30900 – 46200	6.3 – 8.1
Total	250489	100	490529 – 573129	–

** By 2050 all coal power plants will be converted to run on either ammonia or biomass*

Source: Power development plan (PDP8)

The corresponding investment is estimated to US$135 billion by 2030 (US$120 billion for power generation and US$15 billion for grid infrastructure), and US$399 billion to US$523 billion from 2031 to 2050 (US$364 billion to US$511 billion for power generation and US$35 billion to US$39 billion for grid infrastructure).

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The Political Declaration on establishing the Just Energy Transition Partnership with Vietnam (JETP) aims to reduce emissions from the electricity sector in Vietnam. JETP will support Vietnam to decarbonize in electricity sector and reduce emissions from electricity generation to a peak of no more than 170 MtCO2e by 2030. JETP will also work to reduce Vietnam's projects for coal-fired generation and increase the share of renewable energy in electricity generation from 36% to at least 47%.

More details in the Inception Report.

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Decision No. 2068/QD-TTg (25/22/2015), The Development strategy of Renewable Energy of Vietnam by 2030 with a vision to 2050 aims to increase access to modern, sustainable, and reliable energy sources at reasonable prices for all people. It promotes the use of renewable energy sources to reduce the dependence on fossil fuels, mitigate climate change, and ensure energy security. The strategic objectives include gradually increasing the rate of access to clean energy and electricity for people in rural, mountainous, remote, border, and island areas, reducing greenhouse gas emissions in energy activities, reducing imported fuels for energy purposes, increasing the total amount of renewable energy sources produced and used, and increasing the absorption area of solar water heaters and biofuel production. The policy also focuses on promoting the development of renewable energy technology and industries and building a renewable energy industrial system.

The emission targets for all sectors are descripted clearly in each policy. In order to assess the effectiveness and feasibility of these policies, it is important to create different scenarios and conduct rigorous analysis for energy sector itself. These scenarios will help policymakers to identify potential challenges, opportunities, and necessary actions for energy sector towards to the sustainable development of Vietnam's economy and society.

More details in the Inception Report.

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Under the Law on Energy Efficiency, MOIT has issued several circulars on minimum energy performance standards (benchmarks) for main sub-sectors (iron and steel, beverage, .etc.). These circulars define standards in terms of energy use per unit of production for various materials and products.

In 2019, the **Vietnam Energy Efficiency Program 2019 – 2030 period (VNEEP 3)** was approved by the Government under the **Decision No 280/QD-TTg** with targets for reducing the total final energy consumption (TFEC) by 5-7% in 2025 and 8-10% in 2030 compared to the baseline development. Besides these main targets, the program also has different detailed targets for reducing electricity losses, energy savings for different industrial subsectors, scale of EE and green buildings, share of industrial units with energy management system, fuel economy for vehicles, etc.

By 2025:

- Achieve energy savings ranging from 5.0 to 7.0% of total national energy consumption in the 2019 – 2025 period;
- Reduce energy loss to less than 6.5%;
- Reduce the average energy consumption for industrial branches/sub-branches in comparison with that in the 2015 – 2018 period by: (i) for steel industry: 3.00 – 10.00%, depending on type of products and production technology; (ii) for chemical industry: at least 7.00%; (iii) for plastic production industry: 18.00 - 22.46%; (iv) for cement industry: at least 7.50%; (vi) for textile and garment industry: at least 5.00%; (vii) for alcohol, beer and soft drink industry: 3.00 – 6.88%, depending on type of products and production scale; (viii) for paper industry: 8.00 – 15.80%, depending on type of products and production scale;
- Ensure that at least 70% of industrial parks and 50% of industrial clusters can access and apply energy efficiency and saving solutions;
- Have at least 80 buildings certified as green buildings that use energy thriftily and efficiently;

By 2030:

- Achieve energy savings ranging from 8% to 10% of total national energy consumption in the 2019 – 2030 period;
- Reduce energy loss to less than 6.0%;
- Reduce the average energy consumption for industrial branches/sub-branches in comparison with that in the 2015 – 2018 period by: (i) for steel industry: 5.00 – 16.50%, depending on type of products and production technology; (ii) for chemical industry: at least

10.00%; (iii) for plastic production industry: 21.55 – 24.81%; (iv) for cement industry: at least 10.89%; (vi) for textile and garment industry: at least 6.80%; (vii) for alcohol, beer and soft drink industry: 4.6 – 8.44%, depending on type of products and production scale; (viii) for paper industry: 9.90 –18.48%, depending on type of products and production scale;
- Reduce the fuel consumption in transportation sector by at least 5% of total estimated fuel consumption in transportation sector by 2030; formulate regulations on amounts of fuel consumed by new two-wheeled motorcycles and cars with up to 09 seats, manufactured, assembled or imported;
- Ensure that at least 90% of industrial parks and 70% of industrial clusters can access and apply energy efficiency and saving solutions;
- Carry out energy labelling for at least 50% of building materials subject to insulation requirements;
- Have at least 150 buildings certified as green buildings that use energy thriftily and efficiently;

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In 2022, The Government issued **Action Program for Transition to to green energy and mitigation of carbon dioxide and methane emissions from transportation** (hereinafter referred to as "the Action Program for Transition to Green Energy"). The overall objective is to develop a green transportation system towards the goal of net-zero greenhouse gas (GHG) emissions by 2050. More specifically, the objectives are:

- By 2030, improve the energy efficiency, speed up transition to electricity and green energy in transportation which are available in terms of technology, institutions, and sources in order to fulfil the commitment in the Nationally Determined Contributions (NDC) and the goal of mitigating methane emissions in Vietnam.
- By 2050, rationally develop transport methods, vigorously carry out the transition to electricity and green energy of all equipment, vehicles and infrastructures of transport, aiming at achieving net-zero GHG emissions by 2050.

The roadmap for transition to green energy for different sectors are as below:

a) Roadways

<u>The 2022 - 2030 period</u>

+ Improve manufacture, assembly, import and transition to electricity-powered road vehicles; promote blending and use of E5 gas for 100% of road motor vehicles.
+ Develop charging infrastructures meeting demand of individuals and enterprises.
+ Encourage the transition to green energy for new and existing bus stations and rest stops.

<u>The 2031 - 2050 period</u>

+ By 2040, phase out manufacture, assembly and import of automobiles, motorcycles and mopeds with fossil fuels for domestic use.
+ By 2050: use electricity and green energy for 100% heavy equipment involved in traffic, meet green criteria for bus stations and rest stops; transition to use electricity and green energy for all material handling equipment using fossil fuels.

+ Improve charging infrastructures, provide green energy nationwide in order to meet demand of individuals and enterprises.

b) Railways

The 2022 - 2030 period

+ Organize pilot researches on using railway vehicles with electricity and green energy on existing railway lines in Vietnam. Invest in construction of new railway lines towards a roadmap for electrification.
+ Formulate plans and invest according to a roadmap to replace old railway vehicles with vehicles that may use electricity and green energy.
+ Encourage transition to electricity and green energy for material handling equipment at gas stations.

The 2031 - 2050 period

+ By 2040, partly stop manufacture, assembly and import of railway vehicles and equipment using fossil fuels. Bit by bit, make investment in new railway vehicles using electricity and green energy and transition from railway vehicles using fossil fuels to vehicles using electricity and green energy.
+ By 2050: use electricity and green energy for 100% rolling stocks; transition to electricity and green energy for 100% equipment using fossil fuels at stations.
+ Improve and upgrade existing railway infrastructures to meet the complete transition to equipment using electricity and green energy. Continue to invest in constructing new railway lines towards electrification and using green energy.

c) Inland waterways

The 2022 - 2030 period

+ Encourage the investment in building and importing inland waterway vehicles using electricity and green energy and transition to electricity and green energy for inland waterway vehicles using fossil fuels.
+ Research and develop criteria for green ports and green transport routes as a basis for formulating mechanisms and policies to encourage investment in new and green inland waterway ports. Make pilot application in some inland waterway ports; research and convert some waterway transport routes to green transport routes.

The 2031 - 2050 period

+ Continue to encourage the investment in building and importing inland waterway vehicles using electricity and green energy and converting to use electricity and green energy for inland waterway vehicles using fossil fuels. Encourage the investment in new inland waterway ports towards green development.
+ By 2040, use electricity and green energy for 100% new inland waterway vehicles. Apply criteria for green ports for 100% inland waterway ports; encourage inland ports and wharves that are operating in applying criteria for green ports.
+ By 2050, transition to electricity and green energy for 100% inland railway vehicles using fossil fuels. Transition to electricity and green energy for 100% equipment used in inland ports and wharves.

d) Shipping

The 2022 - 2030 period

+ Encourage Vietnamese ships which are operating inland to fully comply with the regulations of Annex VI of the MARPOL Convention aimed at effectively using energy and the Strategy to mitigate GHG emissions from ships of the International Maritime Organization (IMO) from 2025.

+ Encourage transition to vehicles and equipment using electricity and green energy or have equivalent measures for transition in existing ports, new and additionally invested ports.

The 2031 - 2050 period

+ Encourage Vietnamese ships which are operating inland to fully comply with the regulations of Annex VI of the MARPOL Convention aimed at effectively using energy and the Strategy to mitigate GHG emissions from ships of IMO.

+ Use electricity and green energy for ships which are built, converted and imported after 2035; convert to use electricity and green energy for 100% ships which are operating inland from 2050.

+ Invest in vehicles and equipment using electricity and green energy or have equivalent measures for transition in new and additionally invested ports from 2031.

+ Make transition to electricity and green energy for vehicles and equipment in existing ports and aids to navigation or have equivalent measures for transition from 2040.

+ Use electricity and green energy for all vehicles and equipment in ports and aids to navigation or have equivalent measures for transition from 2050.

d) Aviation

The 2022 - 2030 period

+ Implement all potential measures of aviation sector at the same time to reduce CO2 emissions; research the use of alternative fuels to partly supplement aviation fuels from 2027.

+ By 2030, complete the database system of energy use and fuel consumption of aviation enterprises.

The 2031 - 2050 period

+ From 2035, use at least 10% sustainable fuel for some short-distance flights; use electricity and green energy for 100% of new passenger vehicles and other vehicles in airports.

+ From 2040, use electricity and green energy for all vehicles operating in airfields (excluding special vehicles to which electricity have not yet used).

+ From 2050, transition to 100% green energy and sustainable aviation fuels for aircrafts to minimize GHG emissions. Net zero shall be achieved by carbon offset depending on available technology and remaining emissions.

e) Urban traffic

The 2022 - 2030 period

+ From 2025, use electricity and green energy for 100% new buses.

+ Public transport coverage is expected to reach 45% - 50% in Hanoi; 25% in Ho Chi Minh City; 25% - 35% in Da Nang; 20% in Can Tho; 10% - 15% in Hai Phong; at least 5% in class-I urban areas.

The 2031 - 2050 period

+ From 2030, achieve at least 50% vehicles using electricity and green energy; use electricity and green energy for 100% new taxis.

+ By 2050, use electricity and green energy for 100% buses and taxis.

+ Public transport coverage is expected to reach at least 40% and 10% in special urban areas and class-I urban areas, in turn.

Appendix B. Overview, benefits and limits of decarbonizing options

B.1. The demand sectors

Table B-1. Overview of the relevant technologies for each demand sector

	Agriculture	Industry	Buildings	Transport
Direct electrification	X	X	X	X
Synthetic fuels	X	X		X
Carbon capture		X		
Energy efficiency	X	X	X	X

Direct electrification

OVERVIEW: Direct electrification refers to the use of electricity as the primary source of energy for various applications such as transportation, heating, and industrial processes. For the demand sectors in Vietnam, the use could be electric vehicles or busses, electrical stoves, or heat pumps for process heat generation. The transition to direct electrification means that instead of using fossil fuels to generate electricity, renewable energy sources such as solar, wind, or hydropower are used to produce the electricity directly.

BENEFITS: One of the biggest advantages of direct electrification is that it can significantly reduce greenhouse gas emissions. By using renewable sources of electricity, the carbon footprint of the energy system is minimized. Renewable electricity sources are becoming increasingly cost-competitive, which means that direct electrification can be more cost-effective in the long run.

Direct electrification can lead to increased energy efficiency since electricity can be generated more efficiently than fossil fuels. This means that less energy is wasted during the conversion process. Direct electrification reduces the reliance on fossil fuels and specifically on imported fossil fuels, which can be subject to price volatility and supply disruptions. Direct electrification can lead to improved air quality since it reduces the emissions of harmful pollutants that are associated with fossil fuel use.

LIMITS: The upfront costs of installing the infrastructure for direct electrification can be significant, especially in the case of transportation where it may require significant investment in charging infrastructure. Direct electrification can place significant demands on the electrical grid, which may require upgrades to ensure stability and reliability of the system.

Renewable energy sources like solar and wind can be intermittent, meaning that electricity generation may be variable, which can make it difficult to rely solely on these sources for direct electrification. This can, however, be resolved by installing storage, e.g., batteries, in the system. The production of batteries and other components of direct electrification requires rare earth metals and other materials that may be in limited supply, leading to potential supply chain issues.

Many of these challenges can be addressed with proper planning and investment, and the benefits of direct electrification often outweigh the disadvantages in terms of long-term sustainability and energy security.

Electro- and biofuels

OVERVIEW: Electrofuels and biofuels are both alternative fuels that can be used as substitutes for fossil fuels. Biofuels are fuels made from organic matter, such as plants, crops, and waste. Electrofuels, on the other hand, are a type of synthetic fuel produced using renewable electricity and carbon dioxide (CO_2) captured from the atmosphere or industrial processes. These fuels can be used as a drop-in replacement for fossil fuels in existing combustion engines.

BENEFITS: Alternative fuels can be produced using renewable energy sources, which makes them a low-carbon alternative to fossil fuels. They can reduce dependence on imported fossil fuels, which can improve energy security. They can be produced on demand and in large quantities, which makes them a flexible energy source that can be used to balance the intermittent renewable electricity sources. This goes especially for the electrofuels where a large quantity of electricity is used. Last, alternative fuels can be used directly in existing internal combustion engine vehicles without the need for significant modifications to the engine or refueling infrastructure, making them an attractive option for especially the parts of the transport sector that are too expensive to electrify, e.g., ships and airplanes.

LIMITS: Currently, the cost of producing these fuels is higher than that of traditional fossil fuels, which can make them less economically viable. Production involves several energy-intensive processes, which can result in significant energy losses, and it is limited by the availability of biomass, renewable energy sources and carbon capture technology.

As technology improves and production costs decrease, the advantages of alternative fuels are likely to become more compelling.

Carbon capture

OVERVIEW: Carbon capture is a technological option that captures carbon dioxide (CO_2) emissions from industrial processes and power plants. In the demand sectors, the technology is relevant for the industrial sector only.

BENEFITS: Carbon capture can significantly reduce CO_2 emissions from industrial processes and power plants, which can help mitigate the impact of climate change. Carbon capture can also reduce other pollutants that are often emitted along with CO_2, such as sulfur dioxide and nitrogen oxides, which can improve air quality. Captured CO_2 can either be stored or repurposed for enhanced oil recovery, the production of chemicals and fuels, and other industrial processes, which can provide additional economic benefits and reduce the need for imported fossil fuels.

LIMITS: The installation and maintenance of carbon capture systems can be expensive, which can make it economically challenging for some industries to adopt the technology. Carbon capture systems require energy to operate, which can result in some energy loss and reduce the efficiency of industrial processes. The availability of suitable storage sites for captured CO_2 is limited, which can limit the scalability of carbon capture technology. The transportation and storage of CO2 can present safety risks if not managed properly.

Ongoing research and development are improving its cost-effectiveness and scalability.

Energy efficiency

OVERVIEW: Energy efficiency refers to the practice of using less energy to perform the same tasks, which can result in reduced energy consumption and costs. This can be achieved through various methods such as upgrading equipment and appliances, improving building insulation, using more efficient lighting, and reducing waste.

BENEFITS: The benefits of energy efficiency are many. By reducing energy consumption, energy bills can be significantly lowered, resulting in cost savings for households and businesses. Energy-efficient buildings and appliances can provide better thermal comfort, lighting, and indoor air quality, which can result in improved health and well-being. Energy efficiency can reduce greenhouse gas emissions and other pollutants associated with energy production, helping to mitigate climate change and improve air quality. And last, energy efficiency can reduce dependence on fossil fuels and improve energy security.

LIMITS: Some energy-efficient equipment and appliances may have higher upfront costs, which can be a barrier for some households and businesses. Energy efficiency measures may not have a significant impact on reducing overall energy consumption if energy demand continues to grow. And further, some studies have suggested that energy efficiency improvements may result in rebound effects, where the cost savings and improved energy efficiency can lead to increased energy consumption and undermine the potential benefits.

Overall, energy efficiency is an important strategy for reducing energy consumption and costs, improving environmental and health outcomes, and enhancing energy security. While there are some challenges to implementing energy efficiency measures, ongoing innovation and education can help to overcome these barriers and promote more widespread adoption of energy-efficient practices.

B.2. Upstream sector

Table B-2. Overview of relevant technologies in the upstream sector

	Upstream
Production of electrofuels	X
Production of biofuels	X
Direct air capture	X

Production of electro- and biofuels

Electro- and biofuels offer the potential for reduced greenhouse gas emissions and increased energy security, but their production can lead to competition for land, energy and resource intensity, limited scalability, and potential negative environmental impacts.

Biofuel production

OVERVIEW: Biofuels are fuels made from organic matter, such as plants, crops, and waste. The most common biofuels are ethanol and biodiesel, which are used as substitutes for gasoline and diesel fuel, respectively.

BENEFITS: Biofuels are made from renewable resources, such as agricultural waste and crops, which can be replenished over time. Biofuels can help reduce greenhouse gas emissions compared to fossil fuels, as plants absorb carbon dioxide from the atmosphere while they grow, offsetting the carbon dioxide that is emitted when the biofuels are burned. Biofuel production can create jobs and stimulate rural economies, as the production of biofuels typically occurs in rural areas. Biofuels can help to reduce a country's dependence on foreign oil by providing a domestic source of fuel.

LIMITS: The production of biofuels can compete with food production and result in increased food prices. Additionally, the use of land for biofuel production can lead to deforestation and habitat loss. The production of biofuels requires significant amounts of energy and resources, such as water and fertilizer, which can be costly and have negative environmental impacts. The production of biofuels is limited by the availability of biomass, which means that it may not be a viable solution for meeting all energy needs. The production of biofuels can result in negative environmental impacts, such as soil erosion and increased use of pesticides and fertilizers, which can harm ecosystems and wildlife.

Electrofuel production

OVERVIEW: Electrofuels are a type of synthetic fuel produced using renewable electricity and carbon dioxide captured from the atmosphere or industrial processes. The process involves using renewable electricity to power an electrolyzer, which splits water molecules into hydrogen and oxygen. The produced hydrogen is then used directly for, e.g., industrial processes or in the power sector, or it can be combined with carbon dioxide to produce a liquid fuel, e.g., ammonia or methanol.

BENEFITS: Electrofuels are made from renewable resources, such as renewable electricity and carbon dioxide. Electrofuels can help reduce greenhouse gas emissions compared to fossil fuels, as the production process captures carbon dioxide from the atmosphere or industrial processes and uses renewable electricity. Electrofuels can help to reduce a country's dependence on foreign oil by providing a domestic source of fuel. Electrofuels can be used in existing transportation infrastructure and engines, which means that they can be used as a substitute for fossil fuels without requiring significant changes to the existing infrastructure.

LIMITS: The production of electrofuels requires significant amounts of energy and resources, such as renewable electricity, water, and carbon dioxide capture technologies, which can be costly and have negative environmental impacts. The production of electrofuels is limited by the availability of renewable electricity and carbon dioxide, which means that it may not be a viable solution for meeting energy needs. The cost of producing electrofuels is currently higher than the cost of producing fossil fuels, which can make them less competitive in the marketplace. The production of electrofuels requires the use of renewable electricity and carbon dioxide capture technologies, which can have negative environmental impacts if not properly managed.

Direct air capture

OVERVIEW: Direct air capture (DAC) is a technology that removes carbon dioxide (CO_2) directly from the atmosphere. The process involves capturing CO_2 from the air, typically through a chemical reaction, and then storing or utilizing the captured CO_2.

BENEFITS: DAC can help reduce the amount of CO_2 in the atmosphere, which can mitigate climate change. It can be used in various applications, such as industrial processes, transportation, and electricity generation. DAC can provide a domestic source of carbon dioxide, reducing dependence on imported CO_2 in cases where a lot of CO_2 is needed. DAC has the potential to generate negative emissions, where more CO_2 is removed from the atmosphere than is emitted.

LIMITS: DAC requires significant amounts of energy, which can come from fossil fuels or renewable sources, but either way, it requires a substantial amount of energy to operate. The cost of DAC is currently high, making it difficult to compete with other mitigation measures. Some DAC technologies require large amounts of land, which can have negative environmental impacts. The current DAC technology has limited capacity, and it may not be able to capture a significant amount of CO_2 from the atmosphere. DAC does not address other environmental problems, such as air pollution, and does not provide other benefits associated with renewable energy production, such as job creation or energy security.

In summary, direct air capture offers the potential for significant carbon mitigation, energy security, and flexibility. However, the technology is still in its early stages, and its current limitations include energy intensity, high cost, land use, limited capacity, and a lack of co-benefits.

B.3. Power sector

Table B-3. Overview of relevant mitigation options in the power sector

	Power
Wind power	X
Solar power	X
Geothermal power	X
Hydro power	X
Nuclear	X
Biomass fired plants	X
Waste fired plants	X

Hydrogen co-firing	X
Ammonia co-firing	X
Carbon capture	X
Battery storage	X

Renewable energy

Variable renewable energy technologies refer to the types of renewable energy sources that depend on natural and intermittent factors such as wind, solar radiation, tides, and waves. These energy sources are variable in nature and their availability may vary depending on different factors like location, weather patterns, time of day, and season. Some examples of variable renewable energy technologies of interest for the Vietnam energy system include the following. Overall, variable renewable energy technologies have great potential to play a key role in the transition to a more sustainable energy system. However, their variability also presents technical and operational challenges that must be addressed to ensure a reliable and resilient energy system.

Wind power

Wind turbines convert the kinetic energy of the wind into electricity. Wind power is highly dependent on wind patterns, which can vary greatly from day to day. Usually, three types of wind turbine technologies are distinguished with regards to the location: Onshore, Nearshore, and Offshore. Onshore wind power refers to wind turbines that are installed on land, typically in locations such as open plains, hills, forest or mountains, and in some cases, in urban areas. Nearshore wind power refers to wind turbines that are installed in water bodies that are relatively close to the shore. These turbines can be installed in lakes or other shallow water bodies near the coast, or in the coastal waters themselves. Offshore wind power refers to wind turbines that are installed in bodies of water that are relatively far from the shore, typically in shallow or deep-sea. They can range in size from small turbines used for remote islands to large-scale wind farms with hundreds of turbines and are either fixed to the seabed or build on floating platforms. Where traditional fixed-foundation offshore wind turbines are not feasible floating offshore wind turbines are an alternative option. It allows for the deployment of wind turbines in deeper waters, where traditional fixed-foundation offshore wind turbines are not feasible.

Solar power

Solar panels convert the energy from the sun into electricity. Solar power is highly dependent on sunlight availability. They are commonly used for both residential and commercial applications and can be mounted on rooftops or ground-mounted arrays. There are two types of solar power technologies available. The most well-known is the solar PV technology, where solar cells are made by semiconductor materials to absorb the sunlight and release electrons to generate the electricity. Solar PV has become increasingly cost-competitive with traditional fossil fuels in recent years, making it an attractive option for reducing carbon emissions and meeting the growing demand for clean energy. They can be installed both on rooftops and be ground mounted.

Another type is the solar thermal power technologies. This technology uses large mirrors or lenses, which focus sunlight onto a small area to generate high temperatures. The concentrated solar energy is then used to heat a fluid, which can be water, oil, or another substance, to produce steam. The steam is then used to drive a turbine and generate electricity. This type can only be installed on ground.

Geothermal power

Geothermal energy technologies involve harnessing the Earth's natural heat to generate electricity or to provide heating and cooling. The heat is obtained from the Earth's core, which is constantly generating heat due to radioactive decay. The TIMES model for Vietnam considers only geothermal power plants, which generate electricity by using geothermal energy. Geothermal power plants are often located near geothermal reservoirs, which are typically found near tectonic plate boundaries or areas with high volcanic activity. The advantages of geothermal power plants include their ability to provide reliable, continuous power, and their low greenhouse gas emissions. However, their availability is limited to certain regions, and their construction can be expensive due to the need for specialized equipment and geological expertise.

Hydro power

Hydroelectric power plants generate electricity by harnessing the energy of moving water. There are different types of hydroelectric power plants, including pumped-storage plants and run-of-river plants. The main difference between pumped-storage plants and run-of-river plants is in how they store and release energy. Pumped-storage plants are designed for energy storage and peak power generation, while run-of-river plants generate electricity based on the natural flow of a river. Hydro power is highly dependent on the availability of water, which can vary greatly depending on weather patterns and season.

Thermal energy

Thermal power plants use fuels, such as coal, natural gas, oil, biomass, waste, or uranium/plutonium to generate electricity and often heat as a side product, if it can be utilized. These power plants typically burn the fuels to heat water and produce steam, which drives a turbine to generate electricity. The steam is then cooled and condensed back into water, which is reused in the power generation process. However, in gas turbines the gas-air-mixture drives the turbine directly. They are commonly used for large-scale electricity generation, providing a relatively reliable source of energy. Though, the fossil thermal power plants generate significant greenhouse gas emissions, contributing to climate change.

In recent years, there has been a shift towards cleaner energy sources, such as biomass or carbon capture and storage technologies (CCS), to reduce the environmental impact of conventional thermal power plants. Waste can also be used as a fuel in power plants, which will reduce the amount of waste going to dump sites and landfills and thereby reducing emissions from the more potent methane being emitted there. Partial substitution of fossil fuels by co-firing with renewable hydrogen or ammonia is another option the reduce emissions from these plants. More details on the selected technologies suitable for reducing greenhouse gas emissions from existing thermal power plants in Vietnam are described in the following sections.

Nuclear

A nuclear power plant generates electricity by using heat from nuclear reactions to produce steam, which drives a turbine to generate electricity. Nuclear reactions occur in the reactor, which contains fuel rods made of uranium or plutonium. They are a reliable and efficient source of electricity if sufficient cooling water is available, with the potential for large-scale energy production and low greenhouse gas emissions. However, they also carry risks associated with nuclear accidents and the disposal of radioactive waste, which requires careful management and entails potentially high costs. The permanent storage of radioactive waste remains a major issue.

Hydrogen co-firing

Co-firing of hydrogen in conventional power plants involves adding hydrogen to the fuel mix of a conventional thermal power plant, such as a coal-fired power plant, to reduce greenhouse gas emissions. Hydrogen is a carbon-free fuel that can be produced using renewable energy sources. This process can be done by blending hydrogen with natural gas, coal, or other fuels, and using it as a fuel source for power generation. Co-firing of hydrogen offers a potential pathway for reducing greenhouse gas emissions from existing thermal power plants, while leveraging existing infrastructure.

Ammonia co-firing

Co-firing with ammonia involves using ammonia as a fuel source in thermal power plants, either alone or in combination with other fuels, to reduce greenhouse gas emissions. Ammonia is a carbon-free fuel that can be produced using renewable energy sources and can be used as a direct replacement for fossil fuels in thermal power generation. Co-firing with ammonia can be done by blending it with coal, natural gas, or other fuels, and using it as a fuel source for power generation.
It is still in the experimental stage, and further research and development are needed to improve its use in thermal power plants. However, it has the potential to be a promising pathway for reducing greenhouse gas emissions from power generation.

Carbon capture

As for the industrial sector, carbon capture and storage is also an option for thermal plants. The benefits and limits are the same as in the industrial sector.

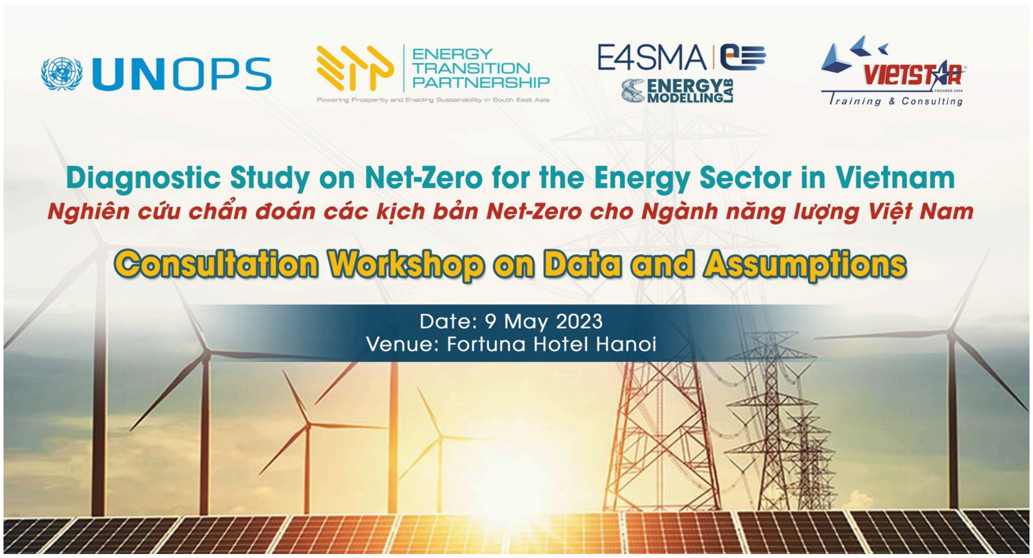
Battery storage

Battery storage for grid balancing refers to the use of large-scale batteries to help balance supply and demand on the electrical grid. These batteries can store excess electricity during periods of low demand and release it back into the grid during periods of high demand, helping to maintain a stable and reliable electricity supply.

Battery storage for grid balancing is becoming increasingly important as more renewable energy sources, such as wind and solar power, are integrated into the grid. These sources of energy are intermittent, meaning that their output can fluctuate based on weather conditions and other factors. Battery storage provides a way to store excess energy generated by renewable sources and release it back into the grid when needed, helping to smooth out these fluctuations and maintain a stable electricity supply.

Battery storage for grid balancing can also provide other benefits, such as reducing the need for expensive peak power plants, which are used to meet short-term spikes in demand on the grid. By providing a reliable and flexible source of energy storage, battery storage can help to improve the overall efficiency and reliability of the electrical grid, while also reducing greenhouse gas emissions and promoting a more sustainable energy system.

Appendix C. Minutes of the Consultation Workshop on Data and Assumptions



AGENDA

DATE 9 May 2023

LANGUAGE Vietnamese and English (simultaneous interpretation)

VENUE Marina room, Level 3, Fortuna Hotel Hanoi**,** 6B Lang Ha, Ba Đinh, Ha Noi, Viet Nam

OBJECTIVES To develop a shared understanding of the key data and assumptions to be used in the analysis of the NZE scenario (co-construction approach).
To gather additional inputs on data and assumptions from stakeholders.
To collect views on sensitivity analyses to be carried out in the study.

Time	Topic	Speakers
9:00-9:30	Welcome and introduction Opening remarks from ETP Brief of the study objectives and Objectives of the mini-workshop Short presentation of the participants (roundtable).	Ms. Mary Pham Thu Hang, consultant Mr. John Cotton, Senior Programme Manager, ETP Mr. Pham Hoang Luong, Local Project Leader, consultant All participants
9:30-9:45	Key socio-economic drivers and technologies available in the Net Zero Emission scenario	International / National Expert

9:45-10:30	Q&A. Discussion *Amongst others:* *1) Data/assumptions which could be at the heart of sensitivity analyses.* *2) Results which are of higher interest to stakeholders.* *3) Additionality from the study over other existing studies and scenarios*	Moderated by Mr. Pham Hoang Luong, Local Project Leader
10:30-10:45	Coffee/Tea break	
10:45-11:00	Policies to be included in the Net Zero Emission scenario	International / National Expert
11:00-11:30	Q&A. Discussion *Amongst others:* *1) Policies already well-engaged and that must be in the NZE.* *2) Less certain policies which could be part of sensitivity analyses.* *3) Policies which are of higher interest to stakeholders.* *4) Additionality from the study over other existing studies and scenarios*	Moderated by Mr. Pham Hoang Luong, local project leader.
11:30-11:45	Closing and next steps	Mr. Pham Hoang Luong, local project leader.

LIST OF ATTENDEES

No	Organisation	Title	Name	Position
1	**Ministry of Industry and Trade (MOIT)**	Mr.	Vũ Xuân Hoàn	Officer of Oil, Gas and Coal Department
2		Ms.	Thanh	Electricity Regulatory Authority of Vietnam (ERAV)
3	**Ministry of Natural Resources and Environment (MONRE)**	Mr.	Phạm Văn Tấn	Deputy Director of Climate Change Department
4	**Danish-Vietnamese Energy Partnership Program**	Mr.	Rasmus Munch Sørensen	

5	**French Development Agency**	Ms.	Nguyễn Thị Thanh An	Head of Climate and Energy Team
6	**UNDP**	Mr	Koos Neefjes	Climate change expert and director
7	**World Wide Fund for Nature (WWF)**	Mr	Nguyễn Thành Trung	Project Manager
8	**Vietnam Oil and Gas Group (PVN**	Ms	Nguyễn Thị Phương Thảo	Electricity and Renewable Energy Division
9		Mr.	Huy	Environment Protetcion Division, Technology, Safety and Environment Depart
10	**Vietnam Electricity (EVN)**	Mr.	Phan Minh Tuấn	Head of International Relations Department
11		Dr.	Đào Thị Hiền	Officer of Science, Technology and Environment Department
12		Mr.	Trần Tuấn Anh	Officer of Science, Technology and Environment Department
13	**Vinacomin Power (TKV)**	Mr.	Nguyễn Mạnh Cường	Technique Department
14	**Energy Transition Partnership (ETP)**	Mr.	John Cotton	Senior Program Manager
15		Mr.	Đỗ Mạnh Toàn	Country Programme Coordinator
16		Ms.	Nguyễn Ngọc Thuỷ	Country Coordinator
17		Ms.	Masako Nemoto	Intern
18	**E4SMA**	Mr.	Maurizio Gargiulo (online)	E4SMA CEO/ Project Team leader
19		Mr.	Phạm Hoàng Lương	Local Project Leader
20	**Vietstar Training and Consulting JSC**	Ms.	Mary Phạm Thu Hằng	VietStar CEO / Local Expert
21		Ms.	Nguyễn Thị Hiền	Project Assistant
22		Ms.	Phạm Thị Hoa Phượng	Project Assistant
23	**-**	Mr.	Nguyễn Ngọc Hưng	Local Expert

24	**Electric Power University**	Ms.	Nguyễn Thị Như Vân	Local Expert

PRESENTATIONS BY EXPERTS

MR. PHẠM HOÀNG LƯƠNG, LOCAL PROJECT LEADER

- Brief of the study objectives and Objectives of the mini-workshop
- Short presentation of the participants

MR. MAURIZIO GARGIULO, E4SMA CEO/ PROJECT TEAM LEADER

Key socio-economic drivers and technologies available in the Net Zero Emission scenario

-
- Key socio-economic drivers: GDP and Population projections, Fuel prices
- Technological mitigation options: Demand sectors, Upstream sector, Power sector
- Key sources for the technology data
- Slides available upon request.

MR. NGUYỄN NGỌC HƯNG, LOCAL EXPERT

Current and Potential Policies for Net-Zero Emission

- Current energy/climate policies
- Ongoing measures for NZE
- International context on NZE
- Slides available upon request.

KEY POINTS SHARED BY PARTICIPANTS

MR. KOOS NEEFJES, CLIMATE CHANGE EXPERT AND DIRECTOR, UNDP (1st comments)

For the presentation by Mr Maurizio

- The good things of the study: to take energy master plan as a source of reference; good objectives; good team of experts. However, not very clear from the presentation about how the study is different from energy master plan, and other studies. How it is going to be different. All are about future scenarios, so what are different perspectives?
- For the question from the presenter: "Which technology should we look at?"
  Firstly, we should look at the technologies that are already looked at in the energy master plan; then the technologies in Vietnam, NDC technical reports on transport, construction, energy sector and other policies with which Vietnam identify domestic means, domestic support as well as international support.
- Should refer to the net-zero study by WWF, just published, which focuses on roughly the same idea of this study. Compare whatever you are doing.

MR. PHẠM VĂN TẤN, DEPUTY DIRECTOR OF CLIMATE CHANGE DEPARTMENT, MONRE

- Mr Tấn joined INDC 2015, updated NDC 2020, NDC2022, Climate change strategy 2022.
- Asked the question: What is the goal of the project? We already have hundreds of Vietnamese and international scientists, including 3 leading Japanese institutes who had been working for 2 years to help Vietnam to develop the Net-zero roadmap to 2050. We use the Draft National Power Development Plan VIII, April 2022 to calculate Net-zero for Vietnam, and calculate emissions reduction in the Nationally Determined Contribution to the United Nations. Now that there is a newer version on May 2, the basic content and net-zero guidelines have been consulted by ministries and agencies and approved by the government. When calculating net-zero 2050, we use at least 5 models: TIMES, LEAD, AIM, NU...so, when adding one more Net-zero Scenario, what is the project's added value for the overall government effort?
- Critical questions are: Are the proposed measures feasible, how much emissions will be reduced, and how much will it cost? Are the technologies available? How can we mobilize the resources of the whole society to achieve that goal?
- The measures in the NDC are not measures that must be followed, but only suggested measures for businesses/agencies to refer to and consider for implementation. If the research has better suggestions, it is also very valuable.
- Are the technologies available? If the study gives better measures, then we can refer to the measures for the NDC 2025 update.

MR. ĐỖ MẠNH TOÀN, COUNTRY PROGRAMME COORDINATOR

This is an ETP project in collaboration with the Oil, Gas and Coal Department, Ministry of Industry and Trade. In this cooperation, there are 3 contents: (i) in this Net-zero study, the Oil, Gas and Coal Department is the main beneficiary of the outcomes of the study; (ii) we provide data to support the Department in the implementation of the National Energy Master Plan after the National Energy Master Plan is approved, (must wait for PDP8 for input). This study will be completed or almost completed when the National Energy Master Plan is approved, serving to support and provide information for the implementation of the National Energy Master Plan; (iii) We also have 2 other studies in progress related to the transition for the Coal industry and the transition for the Oil and Gas industry. This net-zero study also provides important inputs for further studies and further projects between us and the Oil, Gas and Coal Department.

MR. RASMUS MUNCH SØRENSEN, DANISH-VIETNAMESE ENERGY PARTNERSHIP PROGRAM (1st comments)

- Try to minimize the overlap
- Should specify the assumptions on agriculture emissions.
- Expect the world transition to renewable energy will increase the demand of biomass globally. Will biomass price remain the same until 2050? => Need analysis for biomass issues
- Be interested in energy price from IEA, the added value, availability of technologies, discount rate to be used in the investment analysis
- Should increase focus on the supply of different fuels in the future.
- Do some recommendations on infrastructure in different scenarios, infrastructure for coal and gas, hydrogen, ammonia.

MR. VŨ XUÂN HOÀN, OIL, GAS AND COAL DEPARTMENT

- Currently, the Ministry of Industry and Trade is finalizing the PDP 8. The PDP 8 does not mention Nuclear Power, but the Emission Reduction Technology section of this Net-zero Study does mention it, so the study needs further consideration.
- In the most recent appraisal meeting with the Government, the Deputy Prime Minister requested to develop and clarify the scenario of net emission reduction to zero, clearly defining for energy consuming industries, not only the energy supply side but the demand side, so it is relatively extensive. The solution of afforestation to consume carbon is mentioned, the Study can consider whether it can be applied to reduce emissions.
- The Ministry of Industry and Trade is continuing to finalize the Energy Master Plan and PDP 8 under the direction of the Government. It is recommended that this Study refer to the latest version to include updated information in the report.
- The Ministry of Industry and Trade is interested in the role of hydrogen, synthetic fuels from Hydrogen such as ammonia, emethanol..., the role of carbon storage technology in reducing emissions of the energy industry.
- Denmark is completing an energy technology catalogue. The study can refer to the Danish energy technology catalogue. The Study should consult key stakeholders from enterprises for up-to-date and close information

MR PHẠM HOÀNG LƯƠNG RESPONSED TO MR HOÀN

- The draft (4.2023 version) of PDP 8 stated that it is necessary to study, implement, research and propose solutions to allow us to develop nuclear power in case of conditions. In our study, we might cover all the necessary technologies available.
- Regarding net emission 2050 for the whole system, the emission for the power sector is still positive. According to the NDC report (2022 version), emission from the power sector is not beyond 101 $MtCO_2$ eq. by 2050. It is rather challenging for each sector to reach zero. We must activate absorb technologies, develop carbon sinks, specifically LULUCF, and CCUS. This study must analyze the sensitivity to achieve net zero in the power sector, what are the technological solutions?
- This study covers ~~on~~ ammonia, which is very suitable for our development strategy, especially our hydrogen energy strategy in the coming time. Certainly, in the medium and long term, we must produce and use green hydrogen or green fuels, hydrogen products, etc.
- The study will refer to 2-3 reference sources to ensure cross-check: IEA and World Bank...
- Energy catalog is a good reference to actualize costs, and system performance figures to calculate emissions figures.

MR. PHAN MINH TUẤN, HEAD OF INTERNATIONAL RELATIONS DEPARTMENT, EVN

- This study covers many fields. We come from Vietnam Electricity, so we only want to discuss the issue of power sector. Electricity accounts for up to 40% of emissions. EVN has been conducting its own study with the support of EU, AFD, French Electricity Group EDF. When the Study team contacts EVN, we will discuss what we are working on. EVN's development strategy department is assigned the task of net-zero for EVN.
- Need to phase out fossil Fuel, Coal, Gas. What will replace the fossil fuels is a big problem. When it comes to electricity, there should be a transparent analysis of what is the base load

of Vietnam? In the short term, we are still very clear, it is still Coal, Gas, and part of Hydroelectricity. When phasing out fossil Fuel, what will replace the base load. You have to be very clear about the base load, from which net-zero emission can be obtained

- Deputy Prime Minister Tran Hong Ha, during the PDP 8 appraisal meeting, spoke very clearly about new technologies that need to be included. The Deputy Prime Minister is very determined to give up coal, then gas. He mentioned nuclear power, not just limited to SMR - small-scale nuclear reactors, we need to rethink the traditional nuclear power program that we are halfway through.
- Options for clean energy such as Tidal and wave power are not mentioned in the study.

Mr Phạm Hoàng Lương responded to Mr Tuấn

- Establishing an information exchange group: in the upcoming period, there will be a group to work with EVN.
- Phasing out fossil fuels: base load is based on system stability. It is difficult to define what base load is and which singular technology is base load. In the future scenario, the base load is likely to be a combination. It is necessary to consider the stability and security of the system.
- Nuclear power: nuclear power may have to be reconsidered. I think nuclear power will be not feasible in the period from now to 2030; probably the component of nuclear power will be included.
- Clean coal technology: Mr. Tuan's opinion is very reasonable; the consulting team will consider this issue. Burning mixed coal from now to 2030 in thermal power plants in Vinh Tan and Tra Vinh is taken as an example; mixed coal burning will increase combustion and reduce emissions.

MR. NGUYỄN NGỌC HƯNG, LOCAL EXPERT
Responded to Mr Koos

- Difference between the Energy Master Plan and this project: The scope of the Energy Master Plan mainly focuses on Upstream, domestic production of coal, oil and gas, electricity, renewable energy industries.
- Technology options: Should refer to the technologies of Energy master plan and NDP.
- What is particularly important about the study is the Richness of the Technological Database: the technological and financial feasibility for the technology to be applied in the system.
- Reference sources are mentioned in the Data and Assumption book.

Responded to Mr. Tấn

- NDC based on PDP 8 April 2022; so far PDP8 has changed: load forecast based on resolution 81=> reduced electricity demand => reduced coal and LNG in the period 2030-2035 => reduced emission by tens of millions of tons.
- The study provides general solutions: in the model there are many different technologies for Hydro.
- Efficiency: there are many solutions.
- Expected results of this study: feasible time of the study's measure, the size, and the cost?

Responded to Mr. Ramus

- Biomass price: VN has just calculated the domestic price, which tends to increase. The wood pellets flow abroad a lot.
- The discount factor determines the model's investment, especially in renewable energy technologies. Reduced discount rate: investment options will be renewable energy. Consider reducing the discount rate because the traditional I = 10%.
- New energy development infrastructure: (Biofuel, hydrogen...) EV, charging station infrastructure, storage infrastructure, pipeline distribution or power line distribution => need more intensive calculations. Now, Infrastructure costs are integrated in fuel prices. It is difficult to estimate infrastructure costs for new fuels.

Responded to Mr Hoàn

- Regarding nuclear power, PDP8 includes nuclear power, but the investment cost is very high at 5000 - 6000 USD/KWh, the model does not choose as the optimal option.
- When the system switches to a high proportion of renewable energy, the types that are difficult to change in capacity will be more difficult to go with a system with more renewable energy, difficult to increase or decrease capacity or stop the furnace.

MS. NGUYỄN THỊ THANH AN, HEAD OF CLIMATE AND ENERGY TEAM, AFD

- From the perspective of the French Development Agency (AFD) as a development partner, we are very interested in programs to help Vietnam achieve Net-zero, especially in the energy sector. We have been with Vietnam's energy industry, especially Vietnam Electricity (EVN), for more than 20 years, provided many tools and technical support for EVN to develop a strategy for energy transition towards low carbon emissions. AFD provided EVN with direct loans to implement key investment projects of EVN. Currently, we are cooperating in the development of several renewable energy development projects: expanding hydroelectricity, solar power, strengthening transmission and distribution grids to be able to integrate renewable energy especially in the South and Central South regions. The next project under preparation is Bac Ai Pumped-Storage Hydropower Project.
- From the perspective of a development partner, a financial partner, we are interested in financial options. Many domestic policies and mechanisms are needed to create favorable conditions. In the coming time, AFD would like to work with the Government and domestic partners on renewable energy development and connectivity development to promote energy efficiency. AFD can provide direct loans to energy efficiency and renewable energy development partners through credit firms/banks in Vietnam such as Vietcombank, BIDV.
- Quite a lot of international capital resources can be brought into Vietnam. The International Council commits 15.5 billion dollars over the next 3-5 years, provided that the government has policies to implement projects and attract resources. It is important that the research parties present proposals to the government.
- AFD is interested in electricity purchase price or ancillary service price. When it comes to hydroelectricity/storage battery systems, the price mechanism must be clear to promote investment.
- AFD is a financial partner for ETP: AFD continues to accompany ETP in studies.
- In the coming time, AFD will mobilize resources from the European Union, and European co-sponsors to bring preferential financial resources to Vietnam, provided that the government has adequate policies to promote project development.

MR. KOOS (2nd comments)

We discussed almost over 10 years the energy transition, particularly the factors electrify the country. Electricity sector becomes more and more important. We do not talk about the electricity market. The market reform is progressive which is not being discussed as a potential vehicle/ potential opportunity for the energy transition. We have had a lot solar and wind power for 20 years at the fixed price, which is not very helpful in the market. We have a lot of mass run hydro power stations and assets managed by different state-owned enterprises including EVN, not really operating very clearly in the whole sale market. Carbon market will interact with electricity market. Market can kill coal power. The transformation from the base load called coal power to base load on mostly wind is partly enabled by the interconnection of market.
=>The Study should analyse and propose the electricity market as an issue.

MR. RASMUS MUNCH SØRENSEN, DANISH-VIETNAMESE ENERGY PARTNERSHIP PROGRAM (2nd comments)

- Regarding electricity market, should analyse the consequences of the delaying in implimenting the projects in PDP 7.
- Uncertainties such as absorption capacity of renewable energy => need sentitive analysis for uncertainties

Mr LƯƠNG shared about electricity market

- In the draft (4.2023 version) of PDP 8, there ~~are~~ were summaries and lessons learned about the delays in the implementation of projects approved in the PDP 7 and revised PDP 7. This is one of the lagging points for the electricity market problem.
- Regarding issues of uncertainty, in the coming time the government will have appropriate solutions. Currently, we are implementing several wind and solar power projects. These issues will be resolved soon to increase the share of renewable energy in Vietnam's electricity system.

MR NGUYỄN THÀNH TRUNG, WWF VIETNAM

A month ago, WWF Vietnam launched a similar study, developing a 100% renewable energy scenario, which has many similarities with this study. In the WWF study, there are 3 scenarios: BAU, 80% renewable energy and 100% renewable energy. WWF does not study the net-zero scenario but builds the 80%-100% renewable energy scenario. The WWF study also makes the same assumptions as in addition to the power sector, it also builds for 5 sectors: industry, transport, commerce, civil and agriculture. This study recommends technologies for each sector clearly, but there are a few things to keep in mind:
In the study, the proposed technologies are very clear. A few important things to keep in mind:

1. Should focus on the policies for industry and transport (the two most energy consuming industries).
2. When electrification increases, the demand for the electricity increases by 4.6 times => the demand for transmission increases => need policies for distributed solar power.
3. Energy efficiency is very important to achieve net-zero.

4. Cost and investment of proposed scenario are very important. In WWF study, we see that if externality cost is excluded, the cost will increase when the rate of renewable energy increases.
5. WWF wish to combine with this study to make policy recommendations.

MR. NGUYỄN MẠNH CƯỜNG, VINACOMIN POWER

- Vinacomin power is implementing co-firing projects. There is no mechanism and policy to implement co-firing projects.
- It is necessary to review the policy of exporting compressed wood to foreign countries to limit the export of compressed wood.
- Coal-fired thermal power plants will be reduced but not eliminated, wishing to form and develop a carbon credit market so that coal-fired power plants can meet electricity demand because coal-fired power cannot be completely eliminated.
- In order to be carbon neutral, it is better to implement carbon capture measures early.

Mr Lương responded to Mr Cường

- Currently there is no policy for biomass co-firing in the power sector.
- Carbon credit: Deputy Prime Minister Tran Hong Ha discussed that in the medium and long term, the issue of applying carbon credits will take place.
- CCUS: Preliminary experimental studies are underway.

MR. RAMUS (3rd comments)

- Denmark used more than 90% renewable energy.
- They use 2 main strategies to change from coal to biomass: cost consuming and cost efficient. For cost efficient one, power plants are flexible: no longer base load, almost biomas-fired.
- The transition is costly, needs much investment.
- Denmark did the transition to reduce emission.