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VIETNAM ENERGY OUTLOOK REPORT 2021

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Executive Summary

Since November 2021, Viet Nam has embarked on a path to net zero emissions in 2050

At the United Nations Climate Change Conference (COP26) in Glasgow in November 2021, Prime Minister, Mr. Pham Minh Chinh, pledged for Viet Nam to reach a net zero CO_2 emissions target by 2050. Over the last few years, Viet Nam has already taken a series of important steps to reduce CO_2 emissions from the energy sector. The new pledge, however, marks a major shift in the development of the economy, including the energy sector.

The Viet Nam Energy Outlook Report 2021 (EOR21) examines possible pathways for the development of the energy sector including a trajectory reaching the net zero target. Other scenarios explored in the EOR21 address specific topics including the transport sector and air pollution.

The main findings of EOR21 are summarised below.

Pathway to net zero carbon emissions 2050

To reach net zero emissions by 2050 at least cost, renewable electricity should be the main substitute for fossil fuels, either directly or indirectly through production of electro-fuels

According to the analysis, electricity consumption will more than double in 2050 compared to the Baseline (BSL) scenario. The power system must supply more than 70% of the total final energy demand with renewable energy (RE)-based electricity in 2050 to reach the net zero target.

Most of the fossil fuel substitution will be by direct electrification. Around 8% of final energy demand including aviation and shipping may need to be indirectly electrified by using liquid or gaseous fuels produced from renewable electricity (e-fuels).

Power generation capacity including storage could reach at least 2,200 GW by 2050, which is more than four times higher than in the BSL scenario in 2050 and around 30 times the current installed capacity.

Electricity generation and storage capacity in 2050 Net Zero scenario (NZ) are mainly composed of: Storage: (47%); Solar (43%) and Wind (7%). The primary sources of RE-based power production are solar (75%) and wind (21%).

Early reinforcement of transmission capacity is needed; Storage is not needed until after 2030 to ensure cost efficiency

The high RE share requires large investments in balancing technologies including transmission and storage.

Today, transmission capacity is a bottleneck, especially to the north. By 2030, it is estimated that an additional 12 GW of interregional transmission capacity should be commissioned i.e., around 40% increase compared to present capacity. By 2050 in the NZ scenario the total capacity should reach around 160 GW equal to 5-6 times the current transmission capacity and 3 times the capacity in the BSL scenario. To accomplish this, early action is required.

Storage capacity should grow from almost none in 2030 to around 460 GW in 2050. The needed storage capacity is mainly batteries with 2-4 hours of storage but also up to 9 GW of pumped hydro storage (PHS) with around 10 hours of storage.

Achieving net zero emissions is possible, green energy system comes at a 10% additional cost in the period 2020-2050

The power system costs in the baseline and the net zero scenario are similar until 2030. The power system investments in 2050 are 5 - 6 time greater in the NZ scenario compared to the BSL scenario, while the entire cost of the power system is 3.2 times greater due to the absence of fuel costs. But the energy system is more than the power system. The analysis shows that the energy system costs are very similar in all scenarios until 2040, while it increases to a 45% difference in 2050. With the assumed socio-economic discount rate of 10%, the net present value of the whole energy system costs for the period 2020-2050 is only 10% higher in the NZ scenario compared to the BSL scenario.

Emissions should peak no later than in 2035 to meet the net zero target, to stay within carbon emission budget and to avoid excessive costs

To contribute to the goal of keeping the global temperature rise well below 2 degrees (Paris Agreement), the remaining CO_2 emissions should stay within a CO_2 budget of 11 bn tons and emissions should peak no later than 2035. If emissions peak later, the costs of reaching net zero could rise sharply.

For this to happen no new coal power plants beyond the already committed plants should be commissioned and no new gas plants after 2035. In addition, a strong focus should be on new industrial long-lived process equipment to be low-carbon emissions and investments in fossil fuel-based technologies should end in due time to avoid the stranded assets by 2050.

Nuclear power is only cost-efficient if the implementation of renewable energy, particularly solar energy is severely constrained

The analysis shows that current nuclear power technologies are not cost-competitive with the combination of solar, wind, storage, and transmission. Only when these technologies are prevented from being fully utilised, for example because of constraints on access to land, nuclear power can be competitive towards net zero in 2050. For example, if only half of the land area of 11,000 km^2 solar energy potential is available in the NZ, there will be a need for 35 GW of nuclear power.

Current socio-economic discount rate of 10% should be lowered

For investment planning, a socio-economic discount rate is used to compare costs today with future costs. A high socio-economic discount rate favours projects with relatively low upfront (investment) costs and relatively higher running costs, such as fossil fuel, versus RE technologies.

A reduction of the currently applied socio-economic discount rate of 10% to 6.3% would shift the optimal energy mix to increase investment in solar by 60%, in wind by 23% and in storage by 30%, replacing mainly gas-fired power plants.

Energy supply security can be strongly improved.

Fuel Import share could increase from 36% in 2020 to 60% in 2030 and 70% in 2050

Viet Nam's import dependency is expected to increase significantly in the next decade (BSL scenario). The share of imported fuels reaches 53% - 60% in 2030 in the analysed scenarios. Coal and oil products imported to Viet Nam will almost triple compared to current imports by 2030, and liquified natural gas (LNG) will become a major new imported commodity in Viet Nam. By 2050, the share of imported fuels can reach 70% in the BSL scenario with imported fuel costs corresponding to 53 bn USD.

Import dependency leads to vulnerability to international fuel price variations

By lowering fuel imports, the energy system will also reduce risks related to fuel price variations. Especially, a cost-optimal use of LNG is highly sensitive to fuel price variations. A price increase of 20% leads to a 50% reduction in the use of LNG in the power sector in the BSL scenario. An even higher LNG price will lead to even lower need for LNG.

Reaching net zero will make Viet Nam independent of fuel import

By reaching net zero emissions in 2050, the long-term energy security can be substantially enhanced by greatly reduced reliance on fuel imports in the next decades and lower import costs. The NZ scenario reaches an almost self-sufficient energy supply in 2050. This can be achieved by electrification of end-use sectors supplied by a power system which is fully based on domestic RE, and to a lesser degree by additional use of domestic biomass. The costs of imported fuels are reduced by 42 bn USD in 2050 compared to the BSL scenario.

Power Generation

The power sector could fuel the green transition of the entire energy system with more than double the electricity generation compared to the baseline scenario

Since renewables are soon or already the least-cost sources of energy, and since the costs are steadily decreasing with time, a high degree of electrification is the most cost-efficient pathway towards net zero in 2050.

Therefore, electricity generation should double by 2030 compared to 2020 and increase to more than 8 times the current annual generation in 2050, more than double the generation of the BSL scenario. This extra electricity will be used to electrify and decarbonize the rest of the energy system. Especially the transport sector and the industrial sector have great potential for electrification.

According to the present analysis, a cost-optimised scenario, where Viet Nam reaches its net zero emission target in 2050, includes a total capacity of 38 GW solar power and 21 GW wind power already in 2030. In 2050, the capacity of wind power reaches around 150 GW, and the capacity of solar power reaches around 950 GW.

Even in a scenario without climate targets (BSL scenario), an installed capacity of a minimum of 22 GW of solar power by 2030 is cost-optimal from the whole Vietnamese energy system. Therefore, new policies to encourage investments in new solar PV (photovoltaic) should be implemented as soon as possible to stay on track towards net zero emissions in 2050.

Onshore wind and utility-scale PV are already or soon the cheapest sources of electricity, but utility-scale PV is highly dependent on land availability. The area needed for the 840 GW utility-scale PV is 3.3% of the total area of Viet Nam with current technology, however technology development towards higher efficiency could reduce the need for land area. If only half the land area is available for solar power, 420 GW solar power may be replaced by 77 GW onshore wind, 56 GW offshore wind and 35 GW nuclear power at an extra cost of 27 Bn USD/year in 2050 equivalent to 13% of the total power system cost.

Stop planning new coal-fired power plants and refurbish existing plants to become more flexible to better integrate renewables

Around 24 GW of coal-fired power plants are in operation today. A further 6 GW are already under construction or expected to be constructed by 2030. A further 7 GW coal plants have already signed contracts but due to challenges in financing, they are not considered as committed here.

The analysis shows that no new coal-fired power plants are needed until 2030. Furthermore, no new coal-fired power plants should be built after 2030 to stay on the pathway to net zero emissions in 2050. Finally, existing coal-fired power plants should be phased out sooner than by the end of their technical lifetime and they should transition from the role of baseload to operate with decreasing capacity factor towards 2050.

Limit the expansion of domestic natural gas and LNG-fired power plants

Around 7 GW of domestic natural gas-fired power plants are in operation today while no LNG-fired power plants are yet in operation. A further 3 GW of domestic natural gas-fired power plants and 15 GW of new LNG-fired power plants are expected to be constructed by 2030.

From 2035 to 2050 3 GW of additional domestic gas-fired power plants and 20-45 GW of new LNG-fired power plants are installed in all scenarios except for the NZ scenario where the total installed capacity of natural gas-fired power plants does not exceed the already committed 25 GW and decreases towards 2050. Therefore, it is recommended to not invest in new domestic gas-fired power plants and keep the new LNG-power plants to a minimum. However, gas-fired generation could still be the technology of choice for backup/peak capacity due to its significantly lower CO_2 emission intensity, and flexible operation advantages.

The green transition of the power system will be very capital-intensive and could require annual investments of up to 167 bn USD in 2050 in the NZ scenario, corresponding to around 11% of the projected national GDP in 2050 and, 5-6 times more than in the BSL scenario.

Power system costs will shift towards less fuel costs and much more capital investment costs. In the NZ scenario in 2050, it is estimated that the power system needs 167 bn USD of investments, of which 106 bn USD in RE, 54 bn USD in storage and 7 bn USD in interregional transmission. This is equivalent to around 11% of the projected GDP in 2050. Capital investment costs are around 50% of total power system costs in 2030 in all scenarios while towards net zero in 2050 it increases to 90% of the total power system costs.

The capital-intensive nature of RE means that it will be key for Viet Nam to introduce risk-lowering measures for investors which, in turn, should lower the electricity prices for end users.

To kick-start installation of offshore wind, the regulatory framework must be developed

Viet Nam has a large potential for offshore wind but so far no offshore wind power plant has been built and operated partly due to obstacles in project approval process including: i) complicated and unclear permitting and licensing procedures that involve many authorities; ii) lack of policies and guidelines related to finance and investment support mechanism; iii) lack of stable policy and pricing scheme for offshore wind power.

These are just some of the barriers which must be overcome by Vietnamese authorities to bring confidence to investors, promote investment in the offshore wind energy sector to ensure energy security, bring socio-economic efficiency as well as realize Vietnam's climate commitment.

Power System Balancing

Reinforce the transmission system as soon as possible

According to available data, the best resource for RE is in the southern regions whereas the demand centers are around Ha Noi and Ho Chi Minh City. Therefore, to fulfil the emissions reduction commitments, a comprehensive expansion and enhancement of the transmission system is needed. An additional interregional transmission capacity of 12 GW already in 2030 is needed in all scenarios corresponding to around 40% of the transmission capacity in 2020. Furthermore, to reach net zero in 2050 a total interregional transmission capacity of around 160 GW is needed equivalent to 5-6 times the capacity in 2020. The transmission lines needed include HVDC (High Voltage Direct Current) lines from Centre Central and South Central to North of 39 GW and 18 GW respectively.

Prepare for storage to play a central role after 2030

To reach net zero in 2050 around 450 GW of storage is needed, but the analysis suggests that only after 2030 is large-scale battery storage needed and cost-efficient. Future battery costs are uncertain and if they turn out 150% higher than expected, the needed battery storage would "only" be 270 GW and the optimal power mix could shift towards around 150 GW solar power being replaced by 50 GW wind power and 23 GW of nuclear power.

Ensure new and existing thermal power plants to be flexible

Thermal power plants will play a different role in the transition to a net zero power system converting from providers of baseload to integrators of renewables and having much lower capacity factors. Therefore, new and retrofitted existing thermal power plants must become more flexible in terms of ramp rates, minimum load, and startup time.

Optimal hourly merit order dispatch is assumed in the analyses. This is normally achieved with wholesale power markets. Therefore, it is recommended to avoid new fixed price contracts with minimum generation agreements. Instead, the power plants should sell their electricity and services in the power markets.

Ensure demand-side flexibility

An efficient integration of variable renewables should also include demand-side flexibility, especially from electric vehicles (EVs) in the short term and electrolysis in the longer term. EVs can charge flexibly with little or no loss of comfort and could have a total charge/discharge capacity of 500-600 GW thus exceeding that of large-scale batteries.

If flexible charging is not achieved, there is a risk of local grid overloads and an increased need for other measures of balancing. Furthermore, communication and control infrastructure and standards are prerequisites and must be in place at the beginning of the transition of the transport sector.

Ancillary services markets

To ensure cost-efficient balancing of the power system, markets for ancillary services must be implemented as soon as possible. The ancillary services markets should be technology neutral and allow for participation from all types of electricity generating technologies as well as storage and demand facilities. The remuneration should be attractive e.g., based on a component of capacity payment and a component of activation payment both based on merit order selection.

The Transport Sector

Early action is needed to decarbonise the transport sector by 2050. Co-benefits are less air pollution and less import dependency

Significant increase in transport demand is expected. The demand increases 3.5 times for passenger and 7 times for freight between 2020 and 2050. Direct electrification is key – around 80% and 50% of passenger and freight demand respectively will be electrified in the NZ scenario in 2050. Road transport should be almost fully electrified.

As an early action, a swift transition of the transport sector requires a rapid expansion and upgrade of charging and power distribution infrastructure. Electric cars, trucks and vans are first to become part of the fleet (from 2025), motorbikes, buses, and metro from 2030. All new vans should be electric from 2030, all new buses and trucks from 2040 to reach net zero.

The number of cars is projected to increase 3.0 and 8.5 times in 2030 and 2050 compared to 2020, respectively. Therefore, a shift from private to collective passenger transport will be needed to avoid congestion, pollution, and additional fuel consumption.

The combined effect of electrification and switch towards biofuels in the transport sector in the NZ scenario will result in 100 Mt less CO_2 emissions in 2050 compared to the BSL scenario.

1/3 of the transport demand needs to be supplied by more expensive options than direct electrification

Biofuels and e-fuels are used at the end of the analysed period in the net zero pathway in cases where an electrical alternative is not viable. Direct electrification supplies almost 2/3 of the transport demand in 2050 in NZ scenario. The rest should be covered by e-fuels and biofuels.

For shipping and aviation, since a viable electrification alternative does not currently exist, bio- and e-fuels are currently the best option to supply more than 1,000 bn ton-kms of freight demand in 2050 in NZ scenario.

Modal shift of over 700 bn ton-km of freight transport demand from trucks to railway (which is easy to electrify) helps reaching the net zero target.

Start phasing out fossil-fuel internal combustion engines from 2025 and switch to collective transport from 2030

A roadmap for the future transport sector in Viet Nam should include incentives for phasing out internal combustion engines (ICEs), switching to collective transport modes, developing charging and distribution infrastructure and switching towards railway in the freight transport.

Energy Demand

Low energy efficiency compliance is costly

In a scenario where compliance with energy-efficiency measures is low, the total system costs increase by around 5% throughout the analysed period. Energy efficiency (EE) is thus a low-hanging fruit to pick if a policy with solid incentives for compliance is implemented.

Improved data for modelling of energy demand and energy efficiency

A functional EE policy requires a detailed understanding of the actual energy use as well as the viable options for improved efficiency. Currently, such information is sparse. This is particularly the case in certain sectors such as industry and buildings. This creates difficulties in modelling these sectors, which in turn translates to difficulties quantifying the potential for EE improvement and designing effective policy measures.

Therefore, it is recommended to swiftly implement the Viet Nam Energy Efficiency and Conservation Program (VNEEP) action on energy data collection and allow this to form the analytical basis for policies on EE. Reliable data is needed at both sector and end-use levels, including efficiency potentials and costs. For the very energy-intensive technologies, there is a need for detailed cost-benefit analyses of technology alternatives. It is further recommended to develop demand-side models as a tool to assess the impacts of specific energy demand-side policies.

Strengthening supervision and enforcement of law and legislation in the field of energy efficiency

A first step towards a solid data foundation and implementation of EE of large consumers could be to enforce Circular 25 stipulating reporting and auditing of large energy users (more than 100,000 kWh annually), which would directly provide improvements to EE as well as benefit long-term energy planning studies.

Air Pollution

The impact of air pollution from the energy sector on human health could triple by 2050 in the baseline scenario

The total costs of air pollution of the energy system associated to human health impacts, covering the pollutants nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter 2.5 ($PM_{2.5}$), in 2050 is projected to increase from 4.6 bn USD in 2020 to 13.3 bn USD in the BSL scenario. Further, a shift in the sectorial contribution to air pollution is observed. In 2020, road transport contributes the most to air pollution with 1.9 bn USD. Already by 2030, the industrial sector will contribute the most to air pollution (47%), followed by the power sector (24%) and the transport sector (19%) in the BSL scenario.

The most cost-efficient measures to reduce air pollution are found in the transport and power sector

In the transport sector, substituting high-polluting diesel-combustion engines, especially heavy-duty vehicles such as buses and trucks, with electric equivalents by 2030 can reduce the cost associated with air pollution by around 0.35 bn USD annually. Electrification of cars and motorbikes will further add to a reduction in air pollution costs.

In the power sector, investments in coal power are not cost-competitive with LNG and RE when air pollution and health costs are considered. The analysis shows that if no new coal power plants are commissioned after 2030, air pollution costs can be reduced by at least 0.7 bn USD annually compared to the BSL scenario.

In both sectors, these air pollution reductions can be realised without additional total cost because the additional costs required for the energy system are compensated by reduced health costs.

Air pollution abatement and CO_2 emission reduction go together

CO_2 emission reduction measures such as reduced coal power and increased electrification of demand sectors lead to a direct improvement of air pollution. In a scenario where Viet Nam reaches net zero emissions in 2050, costs related to air pollution can be reduced by at least 87% compared to the BSL scenario.

Refine representation of air pollution in governmental planning

To improve the existing methodology, it is crucial to 1) Develop a detailed emission inventory for Viet Nam and build an air quality monitoring network / MRV system (measurement, reporting, verification), 2) Apply and support the research of valuation of health impacts from air pollution, and 3) Determine the national emission factors for all energy-consuming technologies. This can further serve to feed into general city planning, including for collective transport etc.

Contents

Figures

Tables

Abbreviations and Acronyms

AP	Air pollution scenario
BaU	Business as usual
BC	Sensitivity scenario: High battery costs
BSL	Baseline scenario
CCGT	combined cycle gas turbine
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
COP26	26th UN Climate Change Conference of the Parties
DAC	Direct air capture
DEA	Danish Energy Agency
DR	Sensitivity scenario: low socio-economic discount rate
DSM	Demand side management
EE	Energy efficiency
e-fuel	Electro-fuel produced by hydrogen from electrolysis
EMP	National Energy Master Plan for the period 2021-2030, vision to 2050
EOR19	Viet Nam Energy Outlook Report 2019
EOR21	Viet Nam Energy Outlook Report 2021 (this report)
EREA	Electricity and Renewable Energy Authority
EV	Electric vehicle
EVN	Viet Nam Electricity
FEC	Final energy consumption
FIT	Feed-in-Tariff
FLH	Full load hours per year. Equivalent to capacity factor multiplied with hours per year, typically 8760
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic information system
GoV	Government of Viet Nam
GP	Green Power scenario
GT	Green Transport scenario
HD	Sensitivity scenario: high demand
HLNG	Sensitivity scenario: High LNG price
HVDC	High-voltage direct current
ICE	Internal combustion engine
LCOE	Levelised cost of electricity
LNG	Liquefied natural gas
LowEE	Sensitivity scenario: low energy efficiency compliance
LowPV	Sensitivity scenario: low solar PV potential
MB	Motorbikes
MOIT	Ministry of Industry and Trade
MRV	Measurement, reporting, verification
MSW	Municipal solid waste
NLDC	National Load Dispatch Centre Viet Nam

NO_X	Nitrogen Oxides
NZ	Net zero scenario
O&M	Operation and maintenance
OECD	Organisation for Economic Cooperation and Development
PDP8	National Power Development Plan 8 for the period 2021-2030, vision to 2045
PHS	Pumped hydro storage
PM_{10}	Particulate matter 10
$PM_{2.5}$	Particulate matter 2.5
PPA	Power purchase agreement
PV	Photovoltaic
RE	Renewable energy (not including nuclear)
RoR	Run-of-river hydro power
SO_2	Sulphur dioxide
TPES	Total primary energy supply
V2G	Vehicle-to-grid
VND	Vietnamese Dong. The Vietnamese currency
VNEEP	Viet Nam Energy Efficiency and Conservation Program
VWEM	Vietnam Wholesale Energy Market
WHO	World Health Organization

1

Introduction

1. Introduction

1.1 Purpose of the Report

The Viet Nam Energy Outlook Report 2021 provides mid- to long-term perspectives on possible development paths of the Vietnamese energy system to provide input for policy makers and energy planners in Viet Nam.

The EOR21 presents and discusses the newest insights on the possible mid- to long-term development pathways of the Vietnamese energy system, illustrated through a set of explorative and normative scenarios. The objective is to foster a wider consensus and understanding among the Vietnamese energy community on the opportunities and challenges of the sector, and to support and inspire the debate about alternative pathways. This is done by quantitatively evaluating the consequences of different pathways with specific focus on economy, fuel import dependency, GHG (greenhouse gas) emissions and health impacts from air pollution. Finally, we reflect on the potential policy implications.

The EOR is published jointly by EREA and DEA biennially. The first edition was published in 2017, the second in 2019 and this is the third edition. The report thus builds on the modelling framework and analyses in the EOR19, which analysed five different scenarios: A RE target scenario, a scenario with no new coal power generation beyond 2025, a combined EE and RE target scenario, and finally, a scenario combining the EE, RE and no new coal scenarios. A key finding was that when combining the three low-carbon pathways (RE target, no new coal investments after 2025 and energy efficiency), GHG emissions would be reduced by 40% in 2050 as compared to a scenario with no efforts to reduce GHG emissions.

The main additions of the EOR21 to the EOR19 are:

1. A scenario compatible with the target of net zero emissions in 2050
2. An in-depth study on reduction of GHG emissions and air pollution of the transport sector
3. A refined representation of air pollution costs: The report includes sector-specific air pollution costs and one scenario where air pollution costs are included in the optimisation

The scenarios are described in detail in Chapter 3. Scenarios

Further additions and updates since the EOR19 are updated Viet Nam Technology Catalogue for power generation and storage (EREA & DEA, 2021a), updated fuel price projections, updated resource potentials all providing updated data as inputs to the models. Finally, a feature of demand-side flexibility is now included in the Balmorel model.

1.2 Structure of the Report

The report is structured around seven themes, which reflect the key challenges for the development of the energy system in Viet Nam. These are:

- **Pathway to net zero**: Examines future pathways for Viet Nam to reach the net zero emissions target by 2050.
- **Energy security:** Assesses the degree to which Viet Nam will be dependent on fuel imports in the future, to what extent the dependency can be decreased by domestic deployment of renewables, and how the dependency is affected by alternative demand projections.
- **Power system investments:** Evaluates future potential development in the power mix and costs related to various energy technologies in the Vietnamese power system in a range of scenarios.
- **Power system balancing:** Assesses the changes needed to the power system to allow for net zero emissions in 2050.
- **Energy transition in the transport sector:** Investigates the possibilities for reducing emissions from transport by switching transport modes from fossil fuel based to electric transport, e-fuels, and biofuels as well as from individual to public transport.

- **Energy demand**: Assesses the future energy demand in Viet Nam and how to supply it.
- **Air Pollution**: Assesses the cost associated with air pollution impacts to human health and investigates the consequence of internalising these costs in the optimisation.

Each of the themes are covered in separate chapters organised in three sections:

- Status and Trends, describing the current context of Viet Nam.
- Energy Outlook, presenting results of the analysis.
- Policy Outlook and Recommendations, reflecting on how the challenges can be addressed

2

Scenarios

2. Scenarios

2.1 Scenarios Analysed

In the same manner as in EOR19, energy system modelling and analysis constitutes the basis for the results, conclusions and recommendations presented in this report. Five main scenarios are designed to explore different futures for the Vietnamese energy system until 2050. As such, the scenarios are not designed as the "recommended" energy system pathways, but rather meant as indicative "what-if"-scenarios from which insights have been drawn on the relevant themes for the Vietnamese context. The themes correspond to the chapters of this report.

2.2 Analysis Preconditions

The report is based on long-term energy system analyses, derived from least-cost optimisation of investments in and operation of energy technologies, covering all sectors of the Vietnamese energy system (supply, transformation, demand) with a time horizon until 2050. These basic conditions apply:

- The energy system of Viet Nam has been modelled in the period from 2020 to 2050. Two modelling frameworks have been employed: the TIMES model, which covers all sectors of the energy system to provide a high-level perspective; and the Balmorel model, which analyses the power system in higher level of detail. The TIMES model includes every year of the analysis period in the simulation, while Balmorel model has been run for every fifth year of the 2020-2050 period.
- The Vietnamese power system is divided into seven regions dynamically linked by transmission lines. Technical potentials rather than economic potentials of RE are used since the cost optimisation in the model evaluates the economy.
- As a starting point, an update of the planned power capacity in the draft Power Development Plan 8 (PDP8) is included in the models, while the calibration with energy consumption is done according to the draft Energy Master Plan (EMP) (Institute of Energy, 2021).
- This is a long-term energy planning document and does not have a short-term energy system development in focus.
- Being a multiple scenario study, conclusions are drawn by comparing scenarios, not by pointing out a recommended scenario.
- The scenarios have technology in focus and are built by defining targets, i.e., the scenarios present the optimal socio-economic least-cost pathways, under certain conditions, with no direct accounting of taxes and subsidies. The simultaneous least-cost optimisation is performed across all sectors of the Vietnamese energy system, namely power, transport, industry, residential, agriculture and commercial sectors.
- A 10% socio-economic discount rate is applied across all technologies in the least-cost optimisation, which in the longer term may be interpreted as a conservative assumption unfavourable for capital-intensive technologies such as wind and solar.
- Data for long-term studies will always be uncertain. However, for the EOR21, considerable effort has been made to develop and use sound input data, especially on power generation and fuel prices. Viet Nam Technology Catalogue for power generation and storage is published as a separate publication while "Fuel Price Projections for Vietnam" is published as a background report to EOR21 (EREA & DEA, 2021).

For more details on the modelling framework and the key input assumptions and data, the reader is referred to the EOR21 Technical Report and the EOR21 background reports.

2.3 Main Scenarios

Five main scenarios analysed in EOR21 are named and described in Table 2.1.

Table 2.1 The five main scenarios in the EOR21

Scenarios	Description
Baseline (BSL)	The Baseline scenario can be understood as the reference scenario. It includes the existing policies and contracted commissioning of new plants. The CO_2-emission pathway follows the assumptions to reduce emissions from the energy system in 2030 by 15% and in 2045 by 20% compared to a business-as-usual scenario, while reaching minimum RE share in primary energy of 15% and 25% in 2030 and 2045, respectively. The committed capacity in the power sector follows PDP8 until 2026 and includes no new coal from 2035.
Green Power (GP)	The Green Power scenario analyses a more ambitious green power sector with higher shares of RE (38% by 2030 and 75% by 2050), while the RE share in primary energy, CO_2-emissions pathway, committed power capacities and investment restriction on new coal from 2035 follow BSL scenario.
Green Transport (GT)	The Green Transport scenario analyses a future with higher shares of electrification in the transport sector (75%, 90%, and 90% of cars, busses and trucks by 2050, respectively; 30% electric motor bikes by 2030; 57% electric passenger train demand by 2050), combined with more RE in the power sector, modal shift towards collective means of transport (70% of motorbikes to metro in Ha Noi and Ho Chi Minh City: by 2050) and no new gasoline motorbikes from 2030.
Air Pollution (AP)	The Air Pollution scenario analyses the future Vietnamese energy system after including the air pollution costs in the optimisation. We include different costs per sector, depending on where the sectors are emitting. The pollution unit costs used in the analysis have been projected to future costs by assuming a direct relationship with population growth. The air pollutants considered in the energy systems models are NO_X, SO_2, $PM_{2.5}$, and their resulting pollution costs.
Pathway to Net zero (NZ)	The Pathway to Net zero scenario assumes with 66% confidence that the development of Viet Nam's energy system will be constrained by a carbon budget corresponding to a global temperature rise of 2°C set out in the Paris Agreement. The global carbon budget is allocated to individual countries (including Viet Nam) using their respective population ('equity') and historical emission ('inertia') coefficients. "Equity" suggests a sharing based on country population and leads to the same per capita emissions (i.e. more population translates into larger carbon budget share). "Inertia" splits the carbon budget according to how fast individual countries are currently consuming it (i.e. higher prior emissions increase future emission entitlement to ensure feasible/less drastic transition). NZ scenario shows the importance of achieving emission reductions sooner rather than later, i.e., while still achieving Viet Nam's net zero target in 2050. The carbon budget for the period 2020 to 2050 amount to 11.2 bn t CO_2 and it is assumed to peak in 2035.

All five scenarios have been computed in the interlinked model setup comprising three energy models:

- The TIMES model covering the whole energy system, from import and extraction of fuels, through transformation sectors to demand sectors
- The Balmorel model, covering a detailed representation of the power sector
- The PSS/E model, representing the detailed transmission grid

2.4 Sensitivity Scenarios

The results of the main scenarios show the cost-optimal investment and operation of the Vietnamese energy system until 2050. Some of the assumptions in the main scenarios are uncertain due to uncertain nature of projecting the future (fuel and technology prices and energy demands), some due to neglecting non-economic barriers to investing (implementation rates of energy efficient devices), while some uncertainties stem from a consensus of today which could change in the future (such as socio-economic discount rate, solar PV's economic potential). Therefore, we have adopted seven sensitivity scenarios (based on BSL scenario if not mentioned otherwise) characterised by different input parameters from the main scenarios:

- Low socio-economic discount rate scenario (DR): This sensitivity scenario sets the socio-economic discount rate to 6.3%[1] compared to 10% in main scenarios.
- Low EE Compliance scenario (LowEE): This sensitivity scenario analyses the consequence of not achieving compliance with the VNEEP3 targets as compliance with targets and current regulations is a main challenge in the implementation of EE. Only 50% penetration of EE devices compared to BSL scenario is assumed, so that energy demand will be higher than in the BSL scenario.
- High demand scenario (HD): High forecasted gross domestic product (GDP) growth rate from the High Demand scenario in the draft PDP8 (The Ministry of Industry and Trade, March 2022) is used to calculate energy demand in the TIMES model. The energy demand in this sensitivity will be higher than in the BSL scenario.
- High LNG price scenarios (HLNG): Fuel prices are notoriously difficult to predict and therefore and especially variations in the LNG price could have a large impact on the total system costs and the least-cost solution. Therefore, a sensitivity scenario with a higher LNG price is included. In the high LNG price scenario, the price of imported LNG is 20% higher than the BSL scenario.
- High battery cost scenario (BC): This sensitivity analysis will assume the high investment costs from Viet Nam Technology Catalogue for power generation and storage (EREA, MOIT, and DEA, 2021) to investigate its impact on the power system. This sensitivity analysis is based on the NZ scenario.
- Low solar technical potential scenario (LowPV): Technical potential of utility-scale solar PV in the NZ scenario at approximately 800 GW heavily affects the land-use, i.e., only half of the technical potential for utility-scale solar PV. This sensitivity analysis is based on the NZ scenario.

[1] A study by OECD estimates the correct socio-economic discount rate for Viet Nam to be 6.3% (Coleman, B., 2021)

3

Pathway Towards Net Zero Emissions

3. Pathway Towards Net Zero Emissions

3.1 Status and Trends

This chapter analyses the development trends of the energy sector in the BSL scenario and the four alternative scenarios, with specific emphasis on the net zero emissions target scenario.

3.2 Energy Sector Outlook

In the BSL scenario, total primary energy supply (TPES) increases by a factor of 3.9 from 2020 to 2050, primarily driven by the high economic growth rate (Figure 3.1).

The distribution of demand across sectors is quite consistent over time in the BSL scenario. The industry's share is by far the largest, varying from 55% in 2020 to 63% in 2040. In 2050, the share drops to 58%. The transport sector comes in second with shares ranging from 21% in 2020 to 14% in 2040. In 2050, it increases to 16%.

Across scenarios, the main driver of change in final energy consumption (FEC) is the rate of electrification. In the NZ scenario where electricity demand share is much higher than in the BSL scenario (71% vs 30%) the final energy demand is reduced by 19%. This is primarily because energy losses in electric processes is usually much lower than in thermal processes while EVs are more efficient than ICE vehicles.

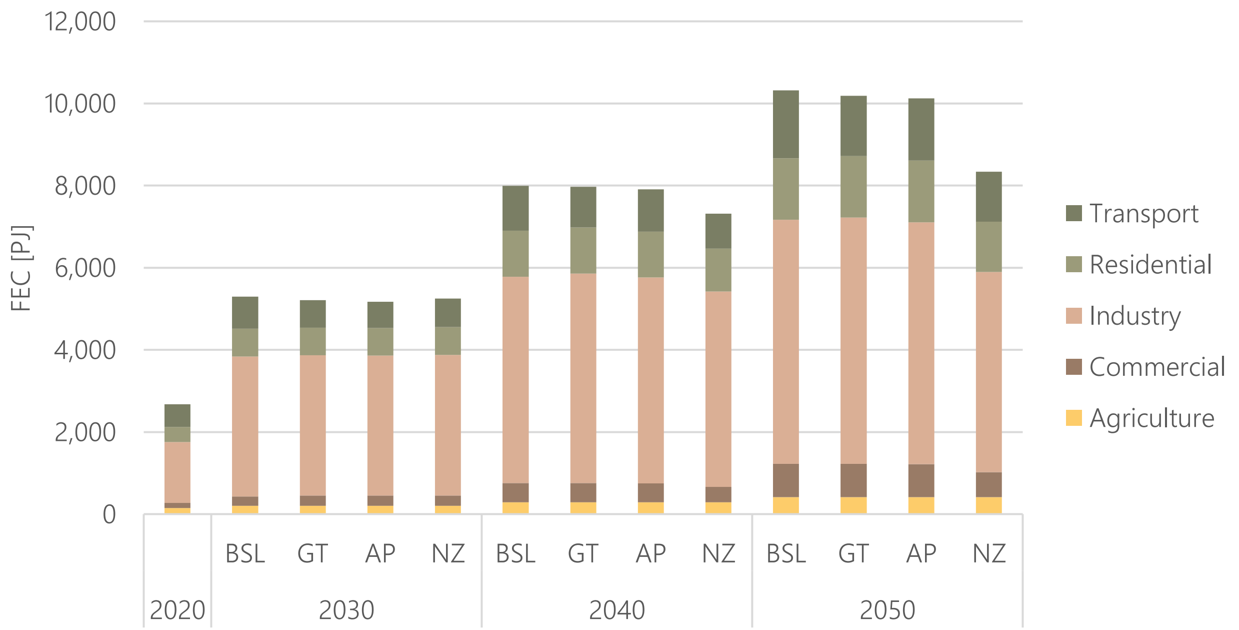

Figure 3.1 Final energy consumption by sector and scenario 2020-2050

The TPES is set to increase rapidly over the analysed period, as presented in Figure 3.2. By 2030, total TPES increases by a factor of 1.7 compared to 2020 in the BSL scenario. From 2020 to 2050, the total growth factor in the BSL scenario is 3.5.

In the BSL scenario, coal is set to maintain its role as the dominant fuel. In 2020, the coal share is 44%, increasing to 51% by 2035, and then it declines to 40% in 2050.

In general, the differences in policies reflected in the scenarios have limited effect up to 2030. This is due to several factors, including that most power generation development is already committed up until 2030. In addition, energy supply to the other sectors is linked to already installed technology (buildings, vehicles etc.) sometimes with decades of lifetime left. Even in the NZ scenario, the TPES changes only marginally by 2030, where the RE share increases from 21% in the BSL scenario to 25%. By 2040, the NZ scenario's RE share is 55%. From then onwards, the RE share shoots up to reach 90% in 2050 (Figure 3.2).

By 2040, the GP scenario with its increased RE targets in the power sector (38% by 2030, 75% by 2050) take effect on the TPES, when parts of the coal and gas consumption is substituted by RE.

From 2040 to 2050, differences between scenarios become more pronounced. The GT scenario substitutes parts of the oil products by electricity in the transport sector, raising the RE share by 4% points. The GP scenario substitutes coal by RE, leading to an increased RE share from 31% to 34%. Most significantly, the NZ scenario increases RE share to 90%.

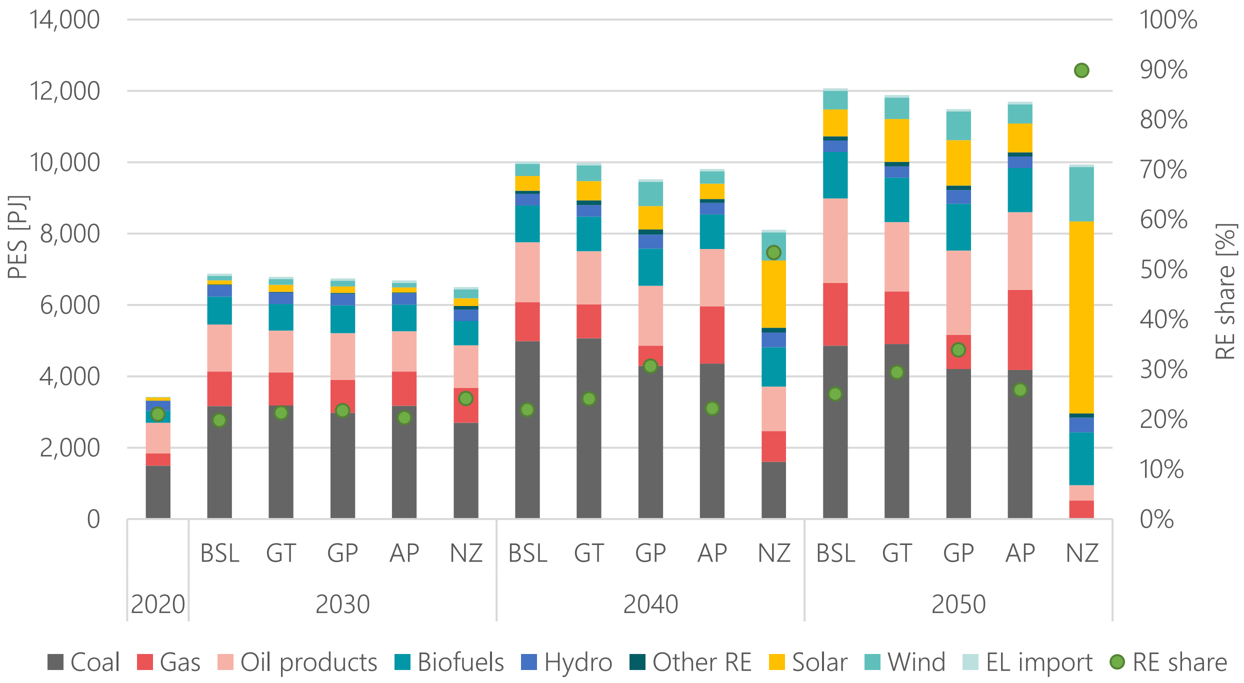

Figure 3.2 Primary energy supply and RE share by scenario and year, 2020-2050

The tendency to accelerate the effect of the policies proposed in the scenarios over time is caused by several factors. Firstly, a shift from high carbon-intensive to low carbon intensive technologies, such as EVs, often takes place in connection with decommissioning of old technology. Secondly, minimum constraints on low-carbon intensive capacity additions, such as new power generation capacity, only take effect over time. Finally, the costs of key RE technologies are projected to drop continually over time, which tends to delay investments in the more expensive technologies such as storage. Therefore, it may be more cost-optimal to delay certain investments until costs are competitive.

The AP scenario in which pollution costs are included in the cost optimisation, a considerable substitution of imported coal by natural gas, which has emission costs only half that of coal, can be observed.

The effects on fuel import across scenarios is substantial. In 2020, fuel import – coal and oil – was 37% of total FEC. In each decade, import increases both in total numbers and in share of the total consumption. This is particularly true for the BSL scenario, where import share reaches as much as 71% in 2050.

Most notably, the NZ scenario has a high impact on the import dependency, which is reduced to only 10% in 2050 (More on this in Chapter 5. Energy Security).

CO_2 emissions

CO_2 emissions increase fast in tandem with FEC in BSL scenario. From 2020 to 2030, emissions increase by a factor of 1.9 in the BSL scenario. By 2050, emissions increase by a factor of 3.1 as compared to 2020.

The two main emitting sectors in 2020 are the power sector (41%) and the industrial sector (28%) according to the analysis. From 2030 to 2050, the industry's emission share increases in all scenarios. In 2050 in BSL scenario, the industrial sector dominates with 43% of emissions and the power sector comes in second with 30% of total emissions.

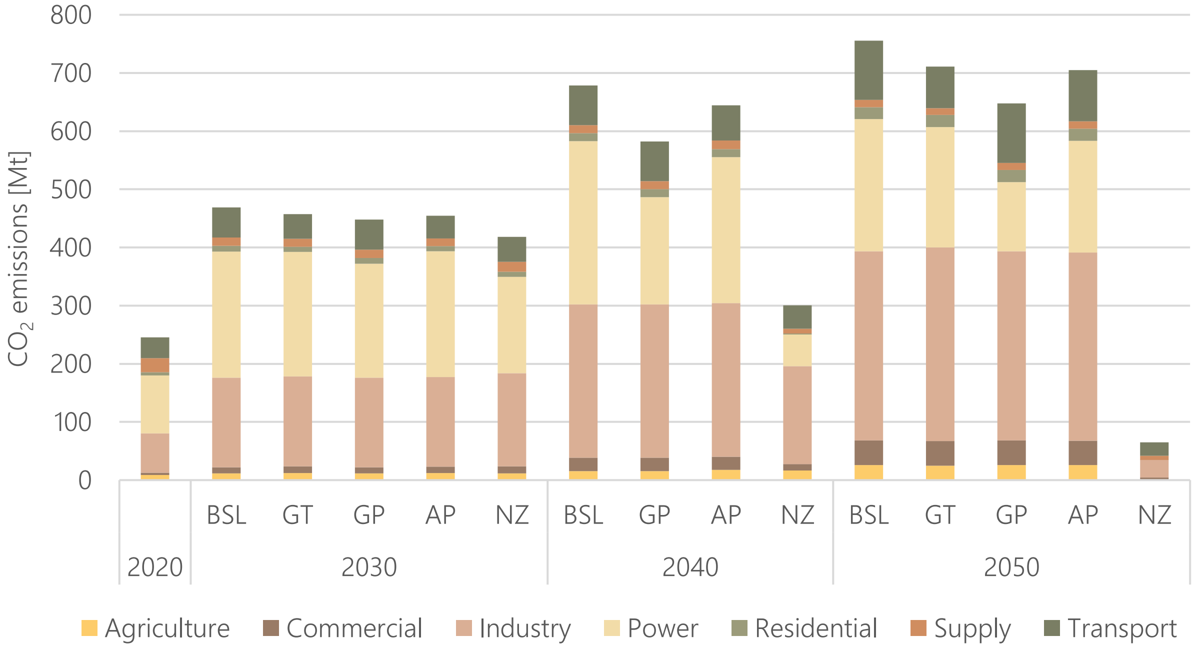

Figure 3.3 CO_2 emissions by sector for each scenario, 2020-2050

In the GT scenario, which assumes an accelerated electrification of the transport sector supplied with RE, CO_2 emissions from transport sector are reduced by 19% in 2030 increasing to 30% by 2050. The remaining emissions from this sector relates to shipping, which in the model is assumed to continue to use oil as fuel.

Internalisation of air pollution costs (AP scenario) reduces total energy sector emissions by 3% in 2030, 5% in 2040 and 7% in 2050.

When raising the minimum RE targets in the power sector (GP scenario), the power sector emissions are reduced by 10% in 2030, 34% in 2040, and 48% in 2050 compared to the BSL scenario.

In the NZ scenario, the total CO_2 emissions are reduced by 11% in 2030, 56% in 2040 and 91% in 2050 compared to the BSL scenario. The main impact is in the power sector, where emissions are reduced by 24% in 2030, 81% in 2040 and 100% in 2050 compared to the BSL scenario.

The transport sector emissions are reduced by 16% in 2030, by 41% in 2040 and by 77% in 2050 compared to BSL due to the inability of the model to substitute shipping fuels. E-jet fuel is implemented only in 2050. The industry sector is also only partly decarbonised in 2050, since sufficient decarbonisation technologies are not yet implemented in the model. The remaining interventions to reach net zero for each sector is described in the following section.

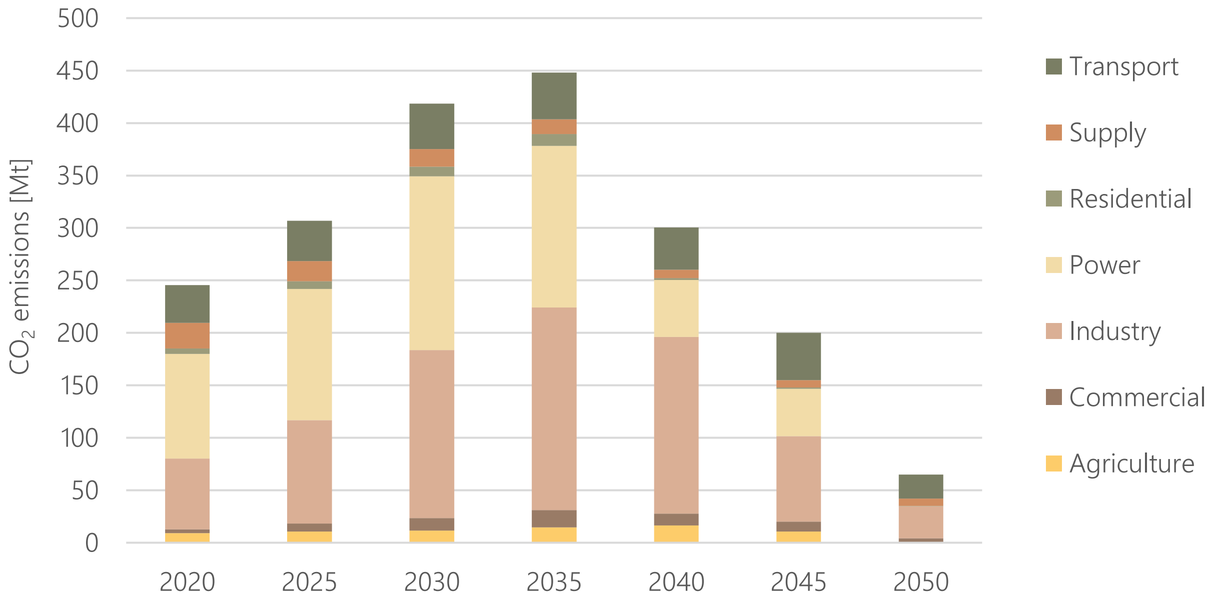

Figure 3.4 Emissions in the NZ scenario by sector and year

Main interventions to reach net zero emissions

Except for the already committed power plants, the least-cost model results include the following main interventions:

Power sector interventions

CO_2 emissions from the power sector can be eliminated by transitioning to 100% RE by 2050. For the total energy system, the model shows a 90% transition to RE. However, the remaining 10% can be substituted using technologies not implemented in the model at this time. More on this below.

The main renewables are solar power, wind power and hydropower balanced with batteries, pumped hydro storage, and reinforced transmission lines and demand response. The power sector will also contribute to decarbonising the other sectors due to the electrification of transport and industrial processes. These interventions are explained in detail in Chapter 5. Energy Security.

Industry sector interventions

The main intervention in the industrial sector is substitution of coal by electricity and biomass (Figure 3.5). In the BSL scenario, coal accounts for 53% of total FEC in 2050, mainly being used for process heat. In the NZ scenario, coal is phased out and mostly substituted by electricity, which increases the share from 23% in BSL to 73% in NZ. Also, some coal is substituted by natural gas.

The remaining fossil fuels in the industrial sector could be substituted by e-fuels or biofuels and carbon capture and storage (CCS) (More on this below).

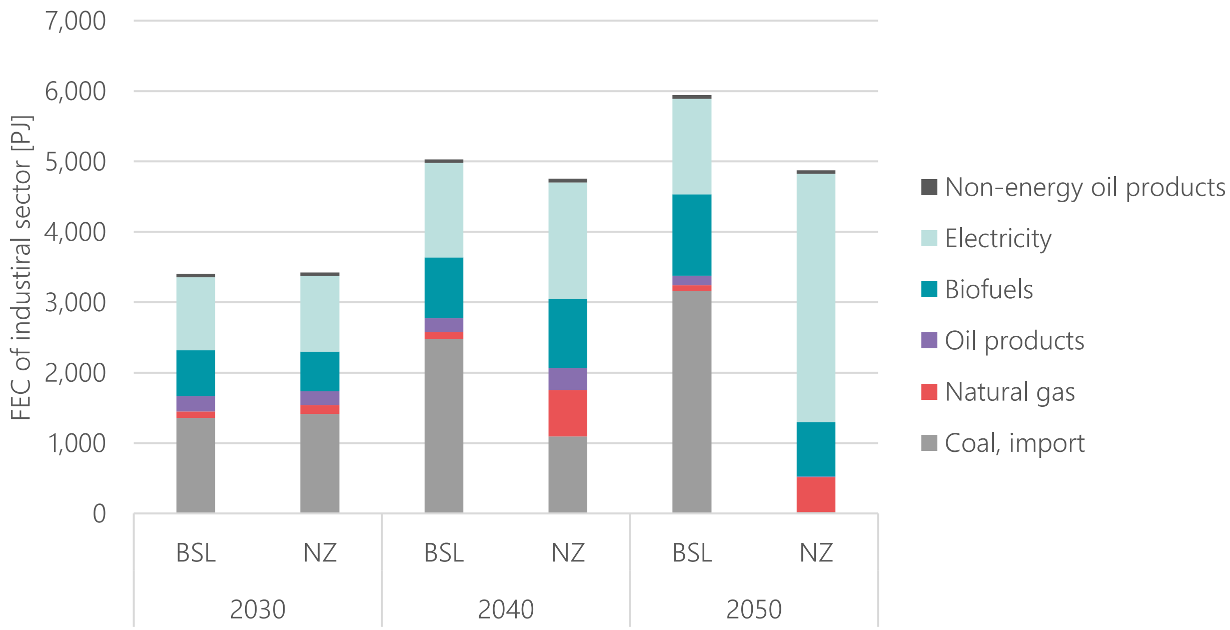

Figure 3.5 Final energy consumption in the industrial sector in BSL and NZ scenarios.

Transport sector interventions

The main transport sector interventions are substitution of fossil fuels by direct or indirect electrification.

Motorbikes, cars, trucks, and buses can be directly electrified using batteries and electric motors. This measure is increasingly cost-efficient over the years, as costs of electrical vehicles will go down. By 2050 in the NZ scenario, direct electricity demand accounts for 61%. 7% of road transport remains fuelled by diesel and gasoline. This would eventually be substituted by electricity as the remaining vehicles are retiring.

Jet fuel is substituted fully by e-fuel (see below). The carbon required to produce this fuel is obtained from direct air capture (DAC).

The remaining 21% of emissions appearing in the NZ scenario for 2050 comes from fuel oil and a bit of diesel used in coastal and waterways freight transport. This is expected to be substituted by emission neutral e-fuels such as ammonia or e-methanol-based hydrogen produced from RE-based electrolysis. These technologies were not included in the analysis, but the solution is briefly described below.

Agriculture, commercial and residential sector interventions

For these three sectors, the main intervention is the electrification of a wide range of technologies incl. heating. While in 2020 56% of the final demand was electricity, this share increases to 91% in 2050. The total fossil fuel share drops from 39% in 2020 to 6% in 2050.

Additional measures needed to reach net zero

The NZ scenario does not completely reach the zero-emission target in 2050. The model includes a wide range of commercially available technologies, but for some subsectors, the currently available options are not sufficient for full decarbonisation. Additional measures are required, which have not been included in the model yet. An outline of such possible additional measures is presented below. The remaining CO_2 emissions derive from the fuels and sectors shown in Figure 3.6.

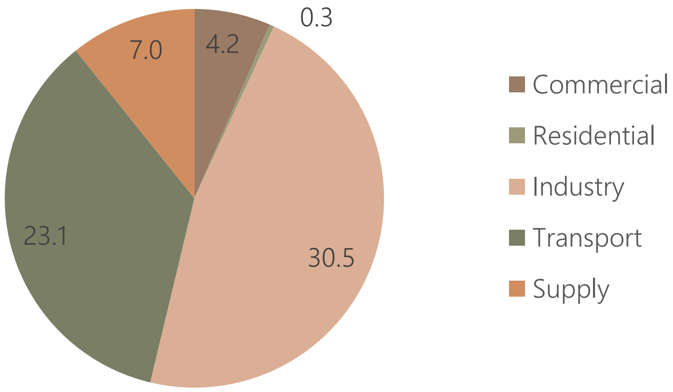

Figure 3.6 Remaining CO_2 emissions [Mt] in 2050 in the model by sector.

Table 3.1 Remaining CO_2 emissions in NZ scenario 2050 by fuel type and sector ($MtCO_2eq$).

Sector	Coal	Natural gas	Refined oil products	Fuel production	Total
Industrial	1.7	27.9	0.9		30.5
Commercial			4.3		4.3
Residential			0.3		0.3
Transport			23.0		23.0
Supply				7.0	7.0
Total	1.7	27.9	28.5	7.0	65.1

Available additional technologies and resources to reach zero emissions by 2050

E-fuels

E-fuels is a group of gaseous or liquid fuels, which are based on hydrogen produced by electrolysis. Hydrogen can further be converted to a range of fuels such as ammonia by adding nitrogen in a chemical process, or to a wide range of hydrocarbons with addition of CO_2. E-fuels can substitute both natural gas and liquid fossil fuels. Furthermore, since e-fuels are cheaper to store than electricity, electrolysis can help balance the power system.

The resource availability for production of e-hydrogen in Viet Nam is very large. Even in the NZ scenario, Viet Nam will still have a large unspent RE resource by 2050, particularly offshore wind resources. Besides, nitrogen is freely available to extract from the atmosphere.

To produce hydrocarbons from hydrogen, a carbon source is needed. One source could be CCU (carbon capture and utilisation) from large sources of emission from industrial thermal processes such as cement production and others. As fossil fuels are phased out, CO_2 from CCU will be limited to large plants combusting biomass or other non-fossil carbon-rich fuels, coupled with process-related CO_2 emissions such as from cement plants, where the calcination process itself produces CO_2. Another source could be DAC, which is still an emerging technology extracting CO_2 from the atmosphere. This resource is for practical purposes unlimited, but the technology still only emerging and thus quite expensive.

Long-term forecasts of costs of various e- fuels suggest that hydrogen will be cost competitive with most fossil fuels. Ammonia and methanol could become competitive with 1. Generation biofuels, while aviation fuel would be more expensive than 1. Generation biofuel, but less so than 2. Generation biofuel.

The three main types of first-generation biofuels used commercially are biodiesel (bio-esters), bioethanol, and biogas. At present, they are produced from commodities that are also used for food. Therefore, the 'first-generation' biofuels appear unsustainable because of the potential stress that their production places on food commodities. Second generation biofuels are produced from biomass in a more sustainable fashion, which is truly carbon neutral or even carbon negative in terms of its impact on CO_2 concentrations. In the context of biofuel production, the term "plant biomass" refers largely to lignocellulosic material as this makes up the majority of the cheap and abundant non-food materials available from plants (S.N. Naik, 2010).

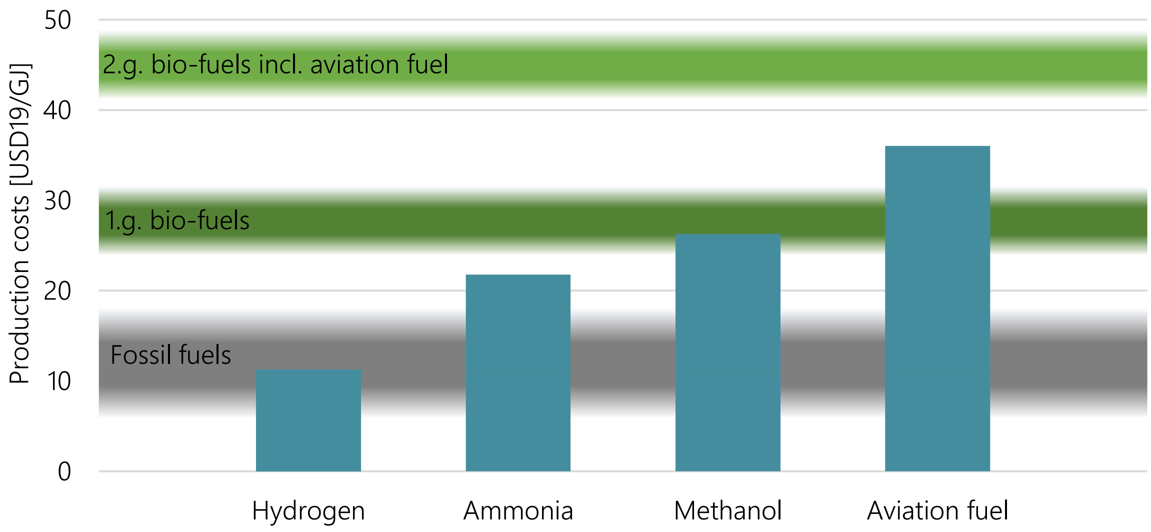

Figure 3.7 Long-term forecast of costs of e-fuels (Danish Ministry of Climate, Energy and Utilities, 2021)

The potential for substitution by e-fuels is illustrated in Figure 3.8. It shows that for shipping and aviation, e-fuels could have a robust potential to substitute almost all of fossil fuel, while the remainder could be electrified.

All road transport could be supplied by direct electrification combined with e-fuels. For direct firing processes in industries and other sectors, other renewable fuels such as biogas and biomass could be more appropriate due to lower costs.

The main transport sector fuels are diesel oil for shipping and fuel for aviation. CO_2 emissions from shipping are expected to be avoided through substitution with e-fuels such as ammonia or methanol. This option is, however, not available in the model. Below the impacts of such a fuel shift is outlined.

Biomass

The remaining biomass resource, which for model-technical reasons is not fully used in the NZ scenario, amounts to 370 PJ. Depending on the specific sources, a range of technologies could be applied to convert to energy, including direct combustion, bio-digestion (wet biomass resources) or pyrolysis, which transforms the biomass into a gaseous fraction of CO_2 and hydrocarbons and a solid fraction of biochar. The latter can be stored in the soil to improve the soil quality for agriculture while removing the carbon kept in the biochar long-term from the atmosphere. If the transformation processes are centralised into large plants, it could be feasible to extract CO_2.

If the 370 PJ of biomass not used for energy production is used for electricity production with capture of CO_2, there is a potential for approximately 34 $MtCO_2$ reduction of emissions. Capturing of CO_2 has a cost of around

70-180 USD2020/t CO_2[2]. This includes both the CO_2-capture, transport, and storage. The total cost of the capture and storage of CO_2 would then be 2.4-6.1 bn USD2020.

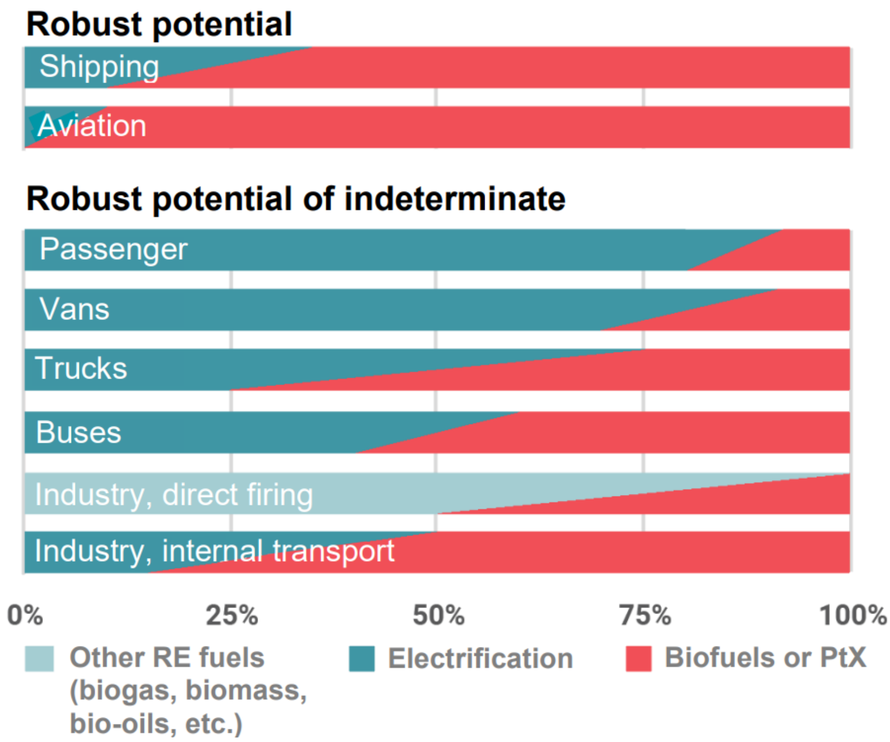

Figure 3.8 Estimated long-term potential for RE-sources in transport and Industry (Danish Ministry of Climate, Energy and Utilities, 2021)

Sketch of strategy to abate the remaining 65 Mt CO_2 by 2050

Abating the remaining 30.5 $MtCO_2eq$ (CO_2 equivalent) from fossil fuels in industry would need a variety of different alternative fuels depending on the specific process. At least some of the remaining coal is a feedstock for steel manufacturing and might not easily be substituted. Natural gas is used as fuel for combined heat and power generation and for process heat. It is likely that the latter two could be substituted by e-fuels or biofuels.

The 23 $MtCO_2eq$ from remaining fossil fuels in the transport sector stems from fuel oil and diesel for shipping, except for 5% used in trains and cars. Fuel for shipping could be completely substituted by ammonia (provided that new ships are designed for this fuel), which is expected to be the most cost-effective renewable alternative to oil products. The amount of electricity required to produce this amount would be around 100 PJ or 28 TWh, corresponding to around 6 GW of offshore wind capacity.

For the remaining sectors, the main use of fossil fuels comes from the use of transport fuels and refined oil products, corresponding to 5.6 $MtCO_2eq$. How to replace these fossil fuels depends on the sector. For the agricultural, commercial, and residential sectors, the total emissions come from 60 PJ of diesel and kerosene (6 PJ). Most of this could be replaced by imported or locally produced biofuels, a larger electrification rate or, hydrogen or other e-fuels.

Costs

Like the parameters analysed above, energy system costs are mostly driven by the overall economic development of the economy.

[2] Technology readiness and costs of CCS. Global CCS Institute

The costs analysis presented in Figure 3.9 assumes that the whole energy system in the base year (2015) is paid off. The BSL scenario's annual costs increase by a factor of 2.8 from 2020 to 2030, especially driven by capital costs. The share of capital costs to total costs in the BSL scenario increases from 33% in 2020 to 48% in 2030. In 2050, the share of capital costs increases to 58%.

Conversely, annual fuel costs are reduced from 37% in 2020 to 30% in 2030 in the BSL scenario. In 2050, fuel costs in that scenario account for only 22%.

The GT and GP scenario costs differ only marginally from the BSL scenario, namely around 0.5%. However, the NZ scenario stands out with higher annual capital costs and lower fuel costs in all years, resulting in higher total costs from 2040 and particularly in 2050. In 2040, NZ total annual energy system costs are 12% above BSL, while in 2050 total costs of the NZ scenario is 52% higher measured in USD 2019 value.

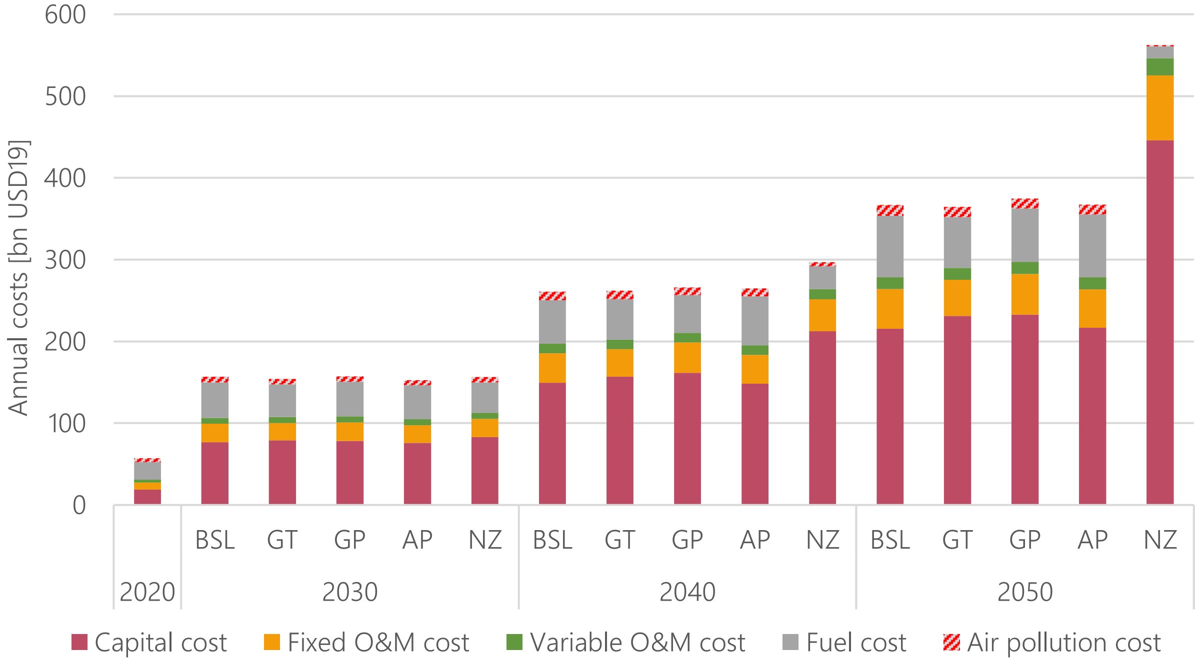

Figure 3.9 Annual total energy sector costs by cost type, scenario, and year, 2020-2050

However, according to the Vietnamese government and international practice, resources spent this year are valued higher than resources spent in the future. One reason for this practice is that resources spent this year for some given purpose could alternatively have been spent on another investment with a certain rate of return, for example considered as an average rate of return of public investment. This means that investing this year in the energy sector incurs an opportunity cost that could have been realised through another investment.

To take account of this difference in the value of money spent now compared to money spent later, future costs are discounted back to 2015 using an annual socio-economic discount rate of 10% as is the practice in Viet Nam. The sum of annual discounted costs of a given scenario is called the net present value or the total system costs of that scenario. The choice of socio-economic discount rate has as considerable impact on the optimisation of a given scenario. A socio-economic discount rate for Viet Nam has been estimated using the Social Rate of Time Preference method. It was found that the rate should be in the range from 6 to 8% with a preference for the lower bound in line with best practice employed by the Intergovernmental Panel on Climate Change (Coleman, 2021).

Figure 3.10 shows the implications of optimisation of the BSL scenario with a 10% socio-economic discount rate and the same scenario using 6.3% as the socio-economic discount rate. Already in 2030, it is optimal to invest in 25% more solar energy and 39% more storage capacity using 6.3% as socio-economic discount rate, while wind capacity investment capacity drops by 7%. In 2040, solar and storage capacity increases by 34% and 32% respectively compared to same year with 10% socio-economic discount rate, while wind power investment increases by 47%. In 2050, solar and storage capacity increases by 59 and 30% respectively compared with high socio-economic discount rate optimisation, while wind increases by 23%. Natural gas is reduced by 35%.

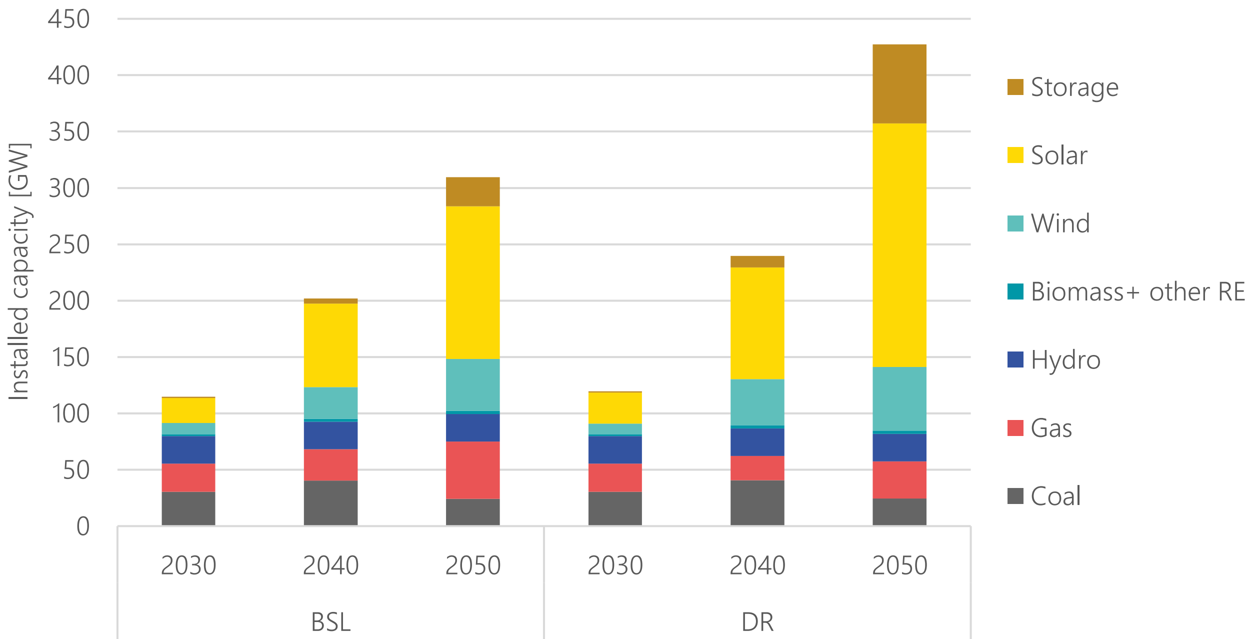

Figure 3.10 Investment in power sector generation and storage capacity in BSL scenario with 10% socio-economic discount rate and the same scenario with 6.3% socio-economic discount rate.

Financing the green transition

RE technologies are capital intensive, while once they are deployed; operation is cheap since they do not require fuels.

The government of Viet Nam (GoV) has made important steps to improve conditions for investments in RE technology, and financing of renewables has proved to be increasingly easy. Still several conditions are perceived by investors to increase uncertainty and risks. When a developer assesses potential risks before engaging in a project, particular focus would be on issues such as transparency around permitting, risk of losses due to curtailment, contract termination conditions etc.

However, some aspects of regulation fall short of requirements for bankability of OECD (Organisation for Economic Cooperation and Development) based investors, such as provision of termination compensation, lack of curtailment protection and lack of international arbitration. Continued work on investment risk reduction could help bring down the costs of capital for RE projects and thus up the feasibility for investors.

RE power project permitting, and approval procedures are still a source of project delay. This could be alleviated through the establishment of a one-stop-shop for engagement with the authorities. Additionally, more transparent regulation on criteria for obtaining permits could help assess chances of obtaining a permit for a given project.

Currently transmission infrastructure is fully financed through Viet Nam Electricity (EVN). A possible opening for private investors in the transmission system could ease the access to finance.

The implementation of the EE program is hampered by perceived high investment risks. Part of the solution could be to improve the regulatory framework for energy performance contracting. Unlike several neighbouring countries, this concept did not really take off in Viet Nam. This is partly due to regulatory barriers, including the absence of a dedicated framework providing clear guidance on accounting and taxation treatment, third party monitoring & verification, and specialised arbitration procedures.

3.3 Key Messages and Recommendations

To reach net zero emissions by 2050 at least cost, renewable electricity should be the main substitute for fossil fuels, either directly or indirectly through production of e-fuels

According to the analysis, electricity consumption will more than double in 2050 compared to the BSL scenario. The power system must supply more than 70% of the total final energy demand with RE-based electricity in 2050 to reach the net zero target.

Most of the fossil fuel substitution will be by direct electrification. Around 8% of final energy demand including aviation and shipping may need to be indirectly electrified by using electro-fuels (e-fuels).

Power generation capacity including storage could reach at least 2,200 GW by 2050, which is more than four times higher than in the BSL scenario in 2050.

Electricity generation and storage capacity in 2050 NZ scenario is mainly composed of: Storage: (47%); Solar (43%) and Wind (7%). Main primary sources of RE are solar (75%) and wind (21%).

Early reinforcement of transmission capacity is needed; Storage is not needed until after 2030 to ensure cost efficiency

The high RE share requires large investments in balancing technologies including transmission and storage.

Today, transmission capacity is a bottleneck especially to the north. By 2030, it is estimated that an additional 12 GW of interregional transmission capacity should be commissioned i.e., around 40% increase compared to present capacity. By 2050 in the NZ scenario the total capacity should reach around 160 GW equal to 5-6 times the current transmission capacity and 3 times the capacity in the BSL scenario. To accomplish this, early action is required.

Storage capacity should grow from almost none in 2030 to around 460 GW in 2050. The needed storage capacity is mainly batteries with 2-4 hours of storage but also up to 9 GW of pumped hydro storage (PHS) with around 10 hours of storage.

Achieving net zero emissions is possible, green energy system comes at a 10% additional cost in the period 2020-2050

The power system costs in the baseline and the net zero scenario are similar until 2030. The power system investments in 2050 is 5 - 6 time greater in the NZ scenario compared to the BSL scenario, while the entire cost of the power system is 3.2 times greater due to the absence of fuel costs. But the energy system is more than the power system. The analysis shows that the energy system costs are very similar in all scenarios until 2040, while it increases to a 45% difference in 2050. With the assumed socio-economic discount rate of 10%, the net present value of the whole energy system costs for the period 2020-2050 is only 10% higher in the NZ scenario compared to the BSL scenario.

Emissions should peak no later than in 2035 to meet the net zero target, to stay within carbon emission budget and to avoid excessive costs

To contribute to the goal of keeping the global temperature rise well below 2 degrees (Paris Agreement), the remaining CO_2 emissions should stay within a CO_2 budget of 11 bn tons and emissions should peak no later than 2035. If emissions peak later, the costs of reaching net zero could rise sharply.

For this to happen no new coal power plants beyond the already committed plants should be commissioned and no new gas plants after 2035. In addition, a strong focus should be on new industrial long-lived process equipment to be low-carbon emissions and investments in fossil fuel-based technologies should end in due time to avoid the stranded assets by 2050.

Nuclear power is only cost-efficient if the implementation of renewable energy, particularly solar energy is severely constrained

The analysis shows that current nuclear power technologies are not cost-competitive with the combination of solar, wind, storage, and transmission. Only when these technologies are prevented from being fully utilised, for example because of constraints on access to land, nuclear power can be competitive towards net zero in 2050. For example, if only half of the 11,000 km^2 solar energy potential is available in the NZ, there will be a need for 35 GW of nuclear power.

Current socio-economic discount rate of 10% should be lowered

For investment planning, a socio-economic discount rate is used to compare costs today with future costs. A high socio-economic discount rate favours projects with relatively low upfront (investment) costs and relatively higher running costs, such as fossil fuel projects, versus RE technologies.

A reduction of the currently applied socio-economic discount rate of 10% to 6.3% as recommended by OECD would shift the optimal energy mix to increase investment in solar by 60%, in wind by 23% and in storage by 30%, replacing mainly gas-fired power plants (Coleman, 2021).

4

Energy Security

4. Energy Security

4.1 Status and Trends

Energy security can be defined as uninterrupted availability of energy sources at an affordable price (International Energy Agency, 2019) (The Ministry of Industry and Trade, March 2022).

Energy security is an important parameter in energy planning in Viet Nam as in many other countries as highlighted in the draft EMP (Institute of Energy, 2021). A high level of security of supply is needed to support socio-economic development and therefore a high dependency on imported fuels is undesired. The draft PDP8 includes energy security as one of the scoring parameters to assess the scenarios (The Ministry of Industry and Trade, March 2022).

Many different parameters are relevant in the light of energy security. To ensure short-term energy security/uninterrupted electricity supply, other factors such as strengthening of the transmission and distribution grid are relevant. Similarly, power balancing is a prerequisite for maintaining a reliable and stable power supply in Viet Nam as well as a balanced electricity exchange by further expansion of transmission lines to neighbouring countries can support energy security. Chapter 7. Power System Balancing is dealing with these factors.

In this chapter of the energy outlook report the impact on the energy security by three key parameters relevant for long-term energy planning is examined:

1. The share of imported fuels
2. The costs of imported fuels
3. Diversification of energy sources

This is in line with the factors considered in the draft PDP8 assessment on energy security (The Ministry of Industry and Trade, March 2022). Import of electricity is not considered.

Fuel diversification trend

The increasing energy demand led to changes in fuel mix in the TPES in the last few years, as presented in Figure 4.1. Coal became the main commodity in the Vietnamese energy sector, its share increased significantly, from 28% in 2010 to 35% in 2015 and to 50% in 2019 (GSO, 2020). This decreased fuel diversification.

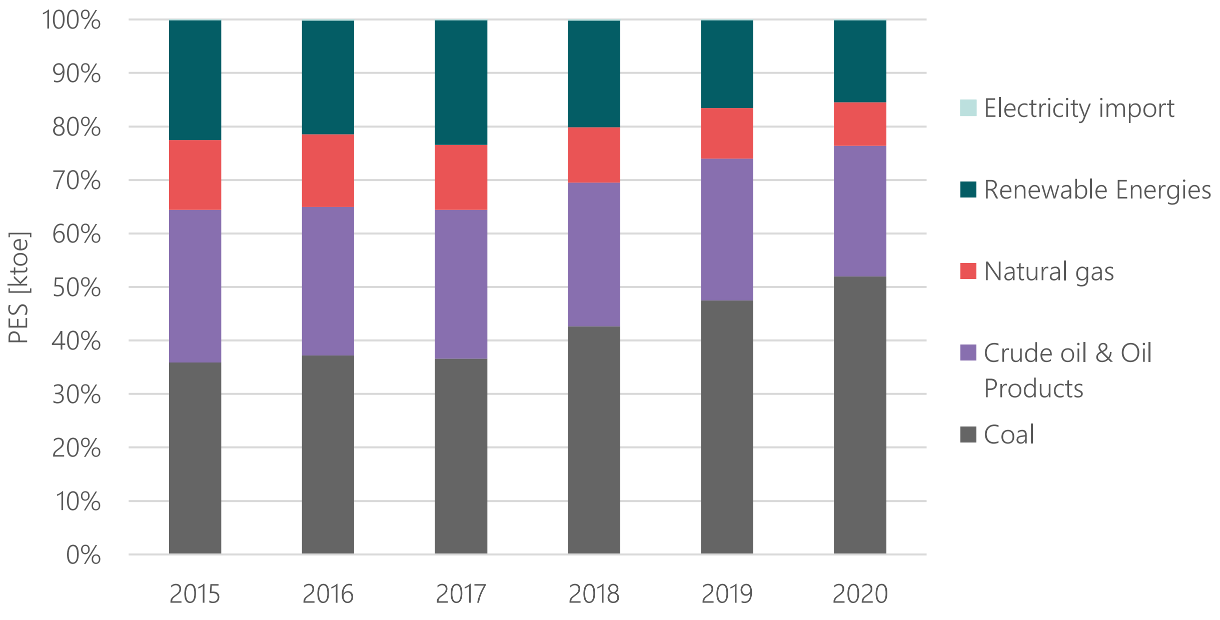

Figure 4.1 Fuel share of primary energy supply, 2015-2020 (VNEEP, 2021)

Import trends

Viet Nam is currently producing coal, natural gas, and crude oil of various qualities for power production and industrial purposes. At the current reserve/extraction rate, the domestic coal, natural gas, and crude oil resources are expected to last 70, 45 and 18 years, respectively (Institute of Energy, 2021). However, the annual extraction rates do not meet the growing demand any longer. Additionally, import of fossil fuels is sometimes cheaper than the costs related to the usage of domestic resources and power plants tend to prioritise the cheapest fuel. The two effects led to an increase in import of fuels during the last decade and Viet Nam has turned from a net-exporter of energy to a net-import country in 2015 as shown in Figure 4.2 (Institute of Energy, 2021). In 2019, the net-import of oil corresponds to 30% of the Vietnamese oil consumption and about 50% of the coal used in Viet Nam originates from abroad (GSO, 2020).

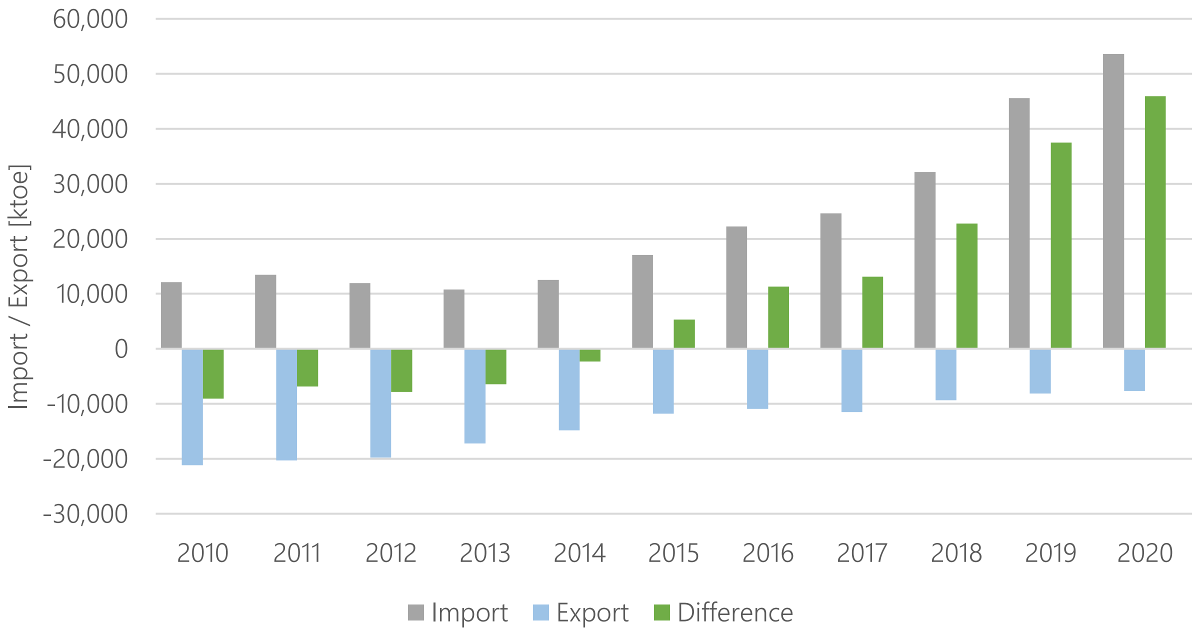

Figure 4.2 Gross and net import / export of fuels, 2010-2020

In 2019, solar and wind power became a significant part of the energy system (Chapter 6. Power System), giving the opportunity to reduce the rising fuel imports of the power sector as well as to support the fuel diversity. Additionally, Viet Nam has domestic biomass resources such as rice husk, bagasse or straw which are not fully utilised today. The residential use of biomass has declined during the last decade but the use of biomass in the industrial and power sector is estimated to increase significantly (Institute of Energy, 2021).

The domestic natural gas resources will soon be unable to meet the increasing demand as well as due to reduced domestic exploration potential in the future. Natural gas power has significant reduced GHG emissions compared to coal power and is therefore often seen as an environmentally benign alternative to coal. In Viet Nam 15 GW of new LNG-fired power plants are expected to be constructed up until 2030.

Viet Nam is planning to strengthen transmission grid connection with Laos to increase electricity imports (bilateral) from renewable sources, mainly hydropower and wind power. Further, domestic coal is prioritised over imported coal in Viet Nam. Aligned with this policy, a prioritization of domestic coal is also included in the analysed scenarios to avoid substitution of domestic coal due to price uncertainty of imported coal.

The impacts on energy security are examined by comparing import volumes, fuel shares and costs measured against system costs for scenarios in focus. The base year of the TIMES model utilised in EOR21 is 2015 and therefore small mismatches between statistical data and model results for 2020 can be expected.

4.2 Energy Security Outlook

Import dependency and fuel costs

In 2020, around 1/3 of the TPES is imported, and this number will increase significantly during the next decade according to this analysis. Throughout all scenarios, the share of fuel imports is reaching values between 53% and 61% by 2030. The BSL scenario shows that the import share could reach up to 70% by 2050.

In the BSL, GT and GP scenario, coal and oil products imported to Viet Nam will almost triple todays import by 2030, and even in the NZ scenario over 2.5 times more coal and 2 times the amount of oil products is imported by 2030.

The import of coal to Viet Nam can reach over 4,500 PJ (107,460 ktoe (kilo tonnes of oil equivalent) by 2050, in the BSL scenario corresponding to over 5 times the domestic coal extraction rate.

Import of oil products could exceed 2,300 PJ in 2050, not only because of increasing demand but also due to almost fully exhausted crude oil resources around 2040. In the BSL scenario 80% of the freight demand and 60% of the passenger demand is covered by oil products in 2050. This creates especially for the transport sector a high import dependency and thereby a high vulnerability to international fuel price fluctuations.

Additionally, LNG will be a new imported commodity for Viet Nam. By 2030, when the natural gas demand increases by more than 2.5 times compared to 2020, imports of around 500 PJ by 2030 can be seen throughout all scenarios. In the long-term, the import of natural gas is varying across scenarios with highest imports in the BSL scenario of 1,500 PJ in 2050.

The import of electricity plays only a minor role due to limited interconnections to neighbouring countries.

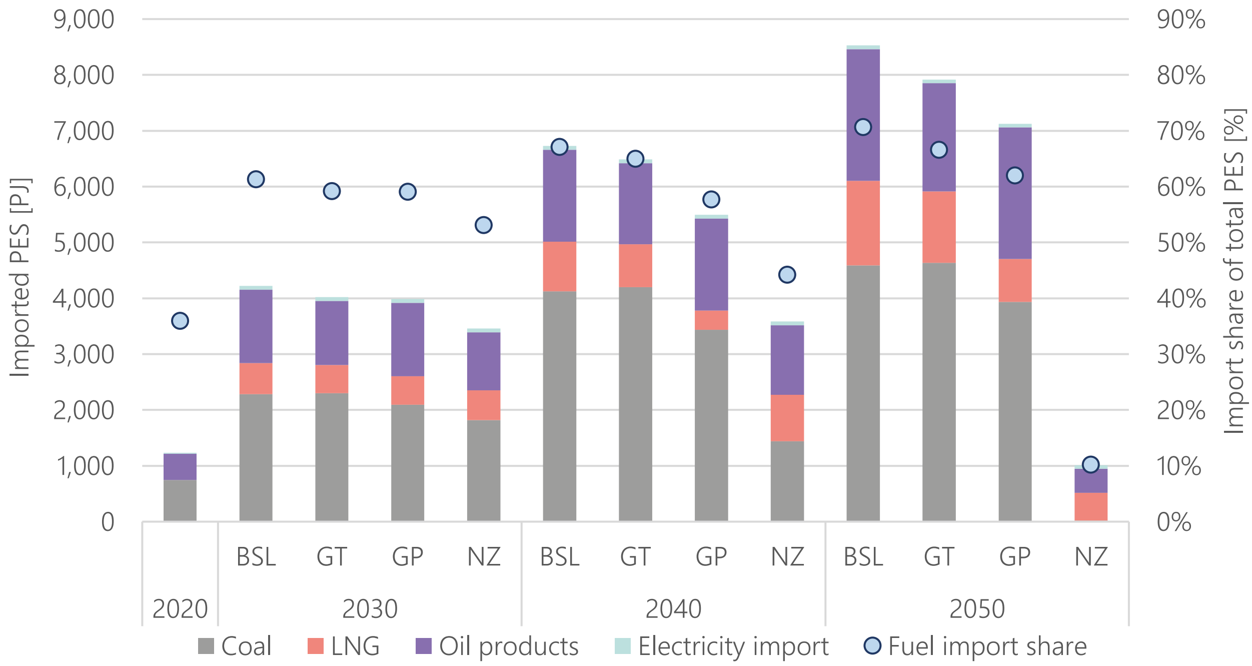

Figure 4.3 Amount of imported primary energy supply and import share of primary energy supply

The substitution of imported fossil fuels in the transport sector can be done by electrification and shift to domestically produced biofuels. However, electrification of the transport fleet doesn't bring reduced import dependence on its own. For example, if electricity production is based on imported coal, electrification of the transport sector won't reduce the import dependency of the whole energy system. In the GT scenario all additional electricity demand from the transport sector is assumed to be supplied by RE, thus making GT scenario suitable for exploring reduced energy import dependency. The electrification targets in the transport sector of the GT scenario provide a reduction of imported oil products of 165 PJ in 2030 and 420 PJ in 2050, however, the total import share of the energy system is still very high at 67%.

The GP scenario shows that a power generation fuel mix with 75% RE reduces the import of coal and gas in the power system by over 50% each compared to the BSL scenario. However, the total import dependency of Viet Nam remains at a high level of 62%. This highlights that many imported fossil fuels are used in other sectors such as industry and transport. To decrease import dependency substantially, the entire energy system needs to be addressed.

The NZ scenario is the only analysed scenario where the import dependency of Viet Nam is reduced significantly. In 2050, at least 90% of primary energy supply comes from domestic resources. This can be achieved by electrification of end-use sectors supplied by a RE-based power system and high utilization of domestic biomass of 85% in 2050. The remaining imported LNG and oil products are used in the model results for industrial purposes and shipping fuel, respectively. The presented substitution options of those fossil fuels, provided in Chapter 4. Pathway to Net zero, can further reduce import dependency.

With the power sector being the foundation for a substantial reduction in import dependency, the following section will provide a more detailed analysis of the imported fuels in the power sector. Figure 4.4 highlights the amount and share of imported fuels in the power sector.

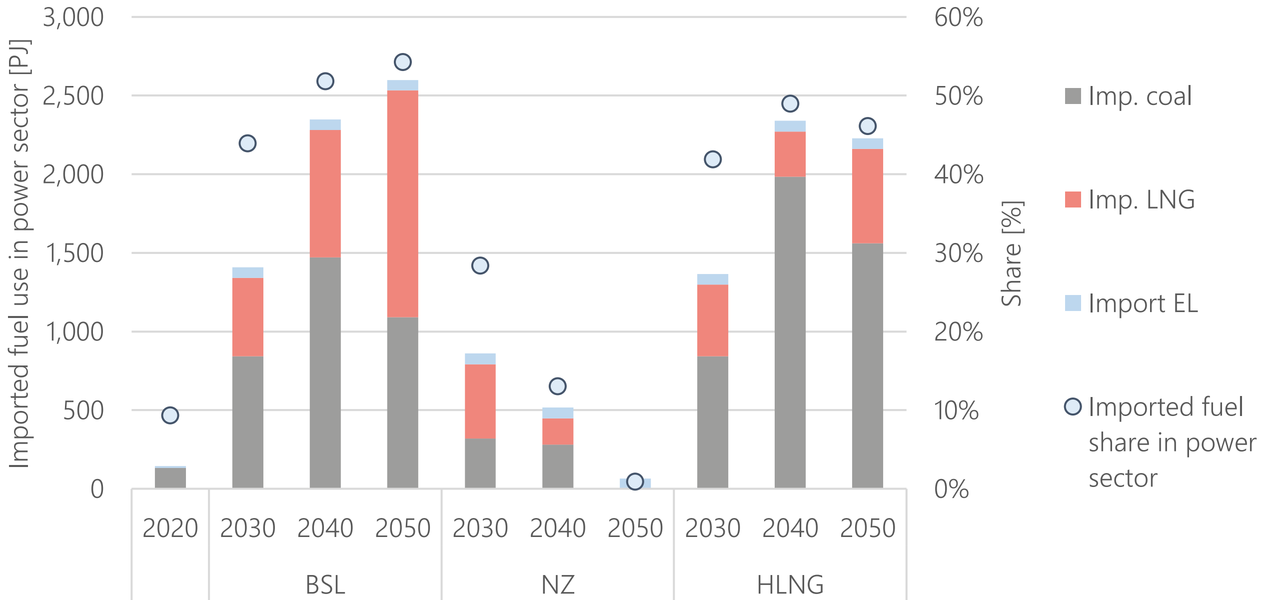

Figure 4.4 Import of coal and gas, and share of imported fuels in the power sector

In the BSL scenario, imported fuels in the power sector can reach 1400 and 2600 PJ in 2030 and 2050, respectively, and by this over 50% of the fuel supply for power generation is imported in 2050. The NZ scenario provides a power mix which is much less reliant on importing fuels in the entire period due to the early investments in RE. This supports a higher security in the power sector which can indirectly affect all demand sectors supplied by electricity. In 2030, only 860 PJ are needed to be imported, corresponding to 28% of the primary energy supply for electricity generation. The import of fuel is continuously decreased in the NZ scenario despite an increasing electricity demand until a fully domestically supplied power sector is reached by 2050, expect for a minor amount of electricity import.

Vulnerability to international fuel price fluctuations

The draft EMP highlights stable prices for energy are crucial to support the growing economy of Viet Nam. Costs of fossil fuels account for 37% of the total system costs in 2020 as shown in Figure 4.5. The fuel cost share of total energy system costs will decrease in all scenarios. However, the fuel costs remain responsible for around 20% of the energy system costs in 2050 in the BSL scenario.

In absolute terms, the fuel costs are expected to increase. Following the BSL scenario, an increase from 21 bn USD in 2020 to 75 bn USD could be reached by 2050 whereof around 71% are spent only on imported fuels. The high

RE share in the GP scenario provides fuel costs reductions of 6-10 bn USD annually from 2035 on, mostly on imported fuels.

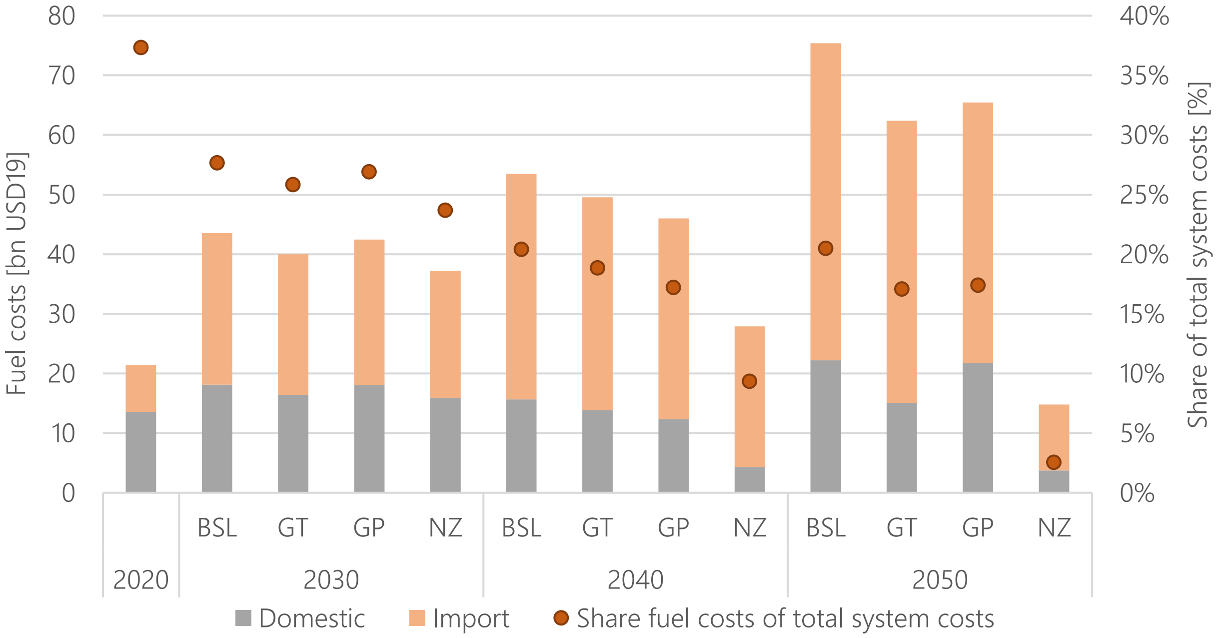

Figure 4.5 Fuel costs and fuel cost share of total costs

The NZ scenario has the lowest fuel costs through the entire period with a peak at 40 bn USD in 2035 and costs below today's values in 2050. By this, the fuel costs are responsible for only 2.5% of the total system costs in NZ scenario and the fuel price risk is significantly reduced.

System vulnerability to fuel price changes to LNG

LNG is expected to play a significant role in the future Vietnamese energy system. Historically the LNG market price has been more volatile than e.g., coal. The potential price volatility creates a risk for an energy system highly relying on LNG. Therefore, the EOR21 features a sensitivity study based on the BSL scenario with an alternative cost projection for LNG to identify the sensitivity of the cost-optimal share of LNG in the Vietnamese energy sector. For the sensitivity analysis called HLNG, a 20% higher LNG price was used.

Figure 4.4 shows the imported fuel use of the power sector in the BSL and HLNG scenario. While the BSL scenario shows a steady growth in LNG with import of up to 1,440 PJ in 2050, the HLNG scenario reduces the annual consumption of LNG to a maximum of 600 PJ in 2050, 58% lower than in the BSL scenario. It shows that the cost-optimal potential of LNG is very volatile. The reduced use is also reflected in reduced investments in LNG power plants. The cost-optimal share of LNG capacity is almost halved down to 22 GW in 2050 in the HLNG scenario.

Energy source diversification

Diversification is a particularly relevant issue when it comes to imported fuels. These fuels may be subject to geopolitical or other events out of control of the Viet Nam.
For RE resources diversification may also be an issue in the sense that the RE sources depend on such factors as wind speed, solar insolation, and rainfall. However, these risks can be mitigated through effective planning of the energy system.

The fuel diversification in the total primary energy supply can be seen in Figure 4.8. The only new energy source introduced to the Vietnamese energy system in the main scenarios is offshore wind. The concentration of the different fuel types differs significantly between the scenarios.

According to the modelling results, Viet Nam's energy mix in 2020 is highly concentrated around coal, covering 44 % of Viet Nam's energy mix, followed by oil products covering 25% of the primary energy supply. The concentration on coal is expected to increase in the BSL and GT scenario until 2040 before it is slightly decreasing to 40%. The introduction of more RE, as in the GP and NZ scenario, allows a generation mix less concentrated around coal. In the GP scenario, the share of coal is reduced to 37% in 2050 through more solar power, onshore and offshore wind power. Further, offshore wind is already introduced by 2035 in these two scenarios, increasing the energy diversification.

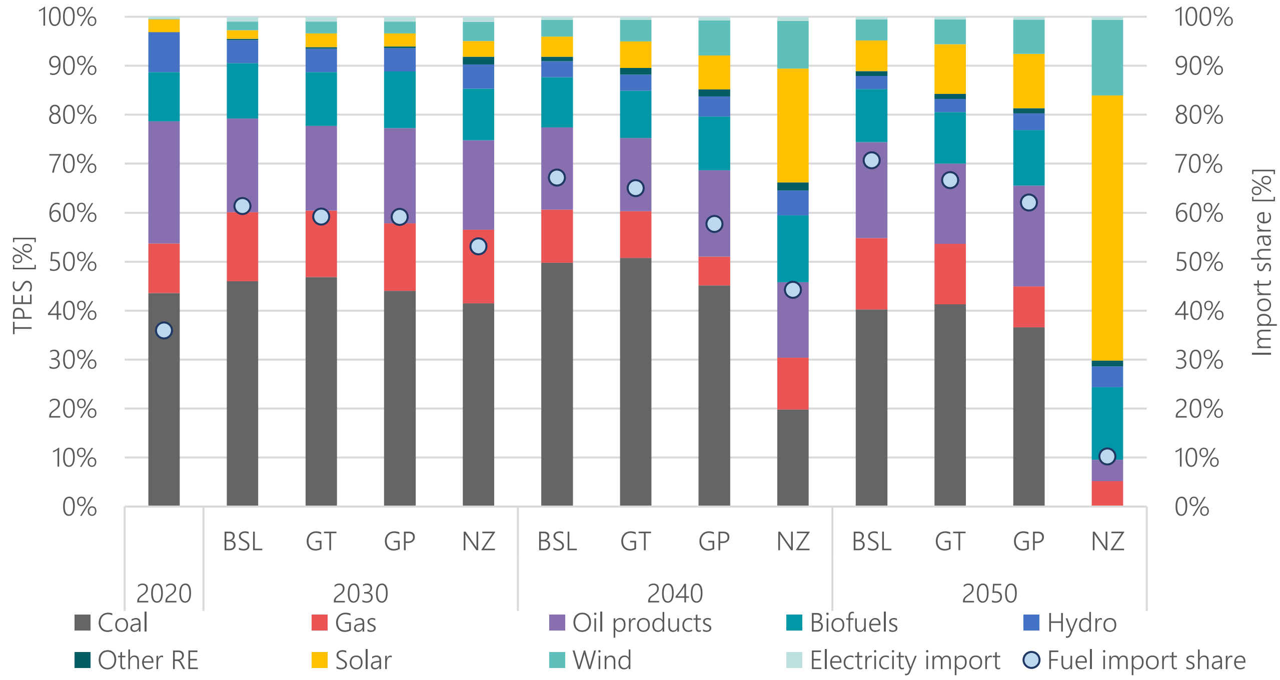

Figure 4.6 Fuel diversification and import share

In the NZ scenario, the share of the different energy commodities is well balanced by 2040 with RE energies covering over 50% of the TPES.

In 2050 in the NZ scenario, the domestic RE share is 90%. Solar energy accounts for 55% of the energy supply, but as mentioned this should not impose a supply risk in a system designed to effectively integrate such large share of solar energy in the system.

If for whatever reason it proves unfeasible to build such large share of solar energy in the system, it will be optimal to substitute with more wind and nuclear energy (Chapter 6. Power System). By the introduction of more wind power as well as nuclear power, the energy diversification is increased.

4.3 Key Messages and Recommendations

Fuel import share could increase from 36% in 2020 to 60% in 2030 and 70% in 2050

Viet Nam's import dependency is expected to increase significantly in the next decade. The share of imported fuels reaches between 53% - 60% in the analysed scenarios. Coal and oil products imported to Viet Nam will almost triple todays import by 2030, and LNG will become a new imported commodity in Viet Nam. By 2050, the share can reach 70% in the BSL scenario with imported fuel costs corresponding to 53 bn USD.

Import dependency leads to vulnerability to international fuel price variations

With lower fuel imports, the energy system will also reduce risks related to fuel price variations. Especially the cost-optimal use of LNG is highly sensitive to fuel price variations. A price increase of LNG of 20% leads to a 50%

reduction of LNG use in the power sector in the BSL scenario. An even higher LNG price will lead to even lower need for LNG.

Reaching net zero will make Viet Nam independent of fuel import

By reaching net zero emissions in 2050, the long-term energy security can be substantially enhanced by reduced fuel imports in the next decades and lower import costs. The NZ scenario reaches an almost self-sufficient energy supply in 2050. This can be achieved by electrification of end-use sectors supplied by a power system which is fully based on domestic RE, and to a lesser degree by additional use of biomass. The cost for imported fuels is reduced by 42 bn USD in 2050 compared to the BSL scenario.

5

Power Generation

5. Power Generation

5.1 Status and Trends

Power sector development in Viet Nam

The Vietnamese power sector is under rapid development. For years expansion of the sector has been based primarily on coal and hydro. The country has been self-sufficient in these resources until recently. Almost all potential for large hydro power plants has already been utilised. Expansion of coal power is challenged by difficulties of financing since an increasing number of financial institutions are refusing to finance coal-fired power plants due to increased climate awareness and increased risks (OECD, 2021). Furthermore, Viet Nam has a strengthened focus on RE over the last few years facilitated by feed-in-tariffs (FIT).

The power sector faces several challenges in the medium and long-term development: the growth of the power demand, need for large investment capital and the environmental and climate concerns. The main challenges can be summarised as follows:

- **Power demand is expected to continue to grow rapidly towards 2030 and beyond.** The draft PDP8 forecasted in the BSL scenario average annual power demand growth of 9.1% between 2021 and 2025, falling to 8% annually between 2026 and 2030. In such a scenario, the share of RE (including hydro) capacity is over 47% and solar and wind power capacity over 26% in 2030. Growth of this magnitude poses major challenges covering many aspects.

- **Viet Nam has become a net importer of fuels.** The domestic sources are becoming exhausted. According to draft PDP8, Viet Nam have exploited most of its economic and technical potential of large and medium-sized hydro plants. The available supply of domestic coal is assumed roughly constant while the available domestic gas supply is slowly decreasing. With a rapidly increasing energy demand Viet Nam will have to import LNG to provide gas for existing combined cycle gas turbines (CCGTs) in the Southeast as well as new gas-fired power plants.

- **Rapid growth in RE deployment requires changes to system regulation, design, and operation.** By the end of 2021, the Vietnamese power system had about 4 GW of wind power and 16.9 GW of solar power and these variable RE sources account for 29% of the total installed capacity and 40% of the peak load. RE sources are expected to develop on a large scale in the South and Central regions, while the power demand centres will grow particularly in the North and the Southern regions. To avoid curtailment and ensure high reliability of the power system with a large share of non-dispatchable RE sources, especially in the future, the Vietnamese power sector needs to reform. Namely, there is a need for a reform of power system operation strategies, power market and financing regulation and investments in transmission in the short term and electricity storage in the long term. To attract investments in flexible power production, the market mechanisms need to be in place.

- **Environmental and climate change issues increasingly put pressure on the electricity sector**. Up to 2030, CO_2 emissions in the power system account for 70% of total emissions from the energy system and 60% of total national CO_2 emissions. At COP26, the Vietnamese Prime Minister announced that the country will be net zero GHG emitter by 2050. This announcement was followed by a decree on climate change mitigation in January 2022. The decree stipulates an integrated governance of all greenhouse gas emissions across the whole economy based on the Paris Agreement commitments. National emission quota will be assigned to all major emitters such as thermal power plants.

- **Affordable and secure supply of electricity remains high priority.** In parallel with environmental targets, the electricity price needs to stay reasonable while maintaining a high level of security of supply to facilitate socioeconomic development. Security of energy supply can be hampered mainly by the lack of generation, transmission, and distribution capacity as well as inefficient power market regulation. In addition, the GoV considers import dependence a major risk factor for security of energy supply. It is possible to maintain low costs and a high level of supply security during a net zero emission transition. However, this calls for careful sector planning as well as a comprehensive sector reform.

- **Difficulties in mobilizing investment capital for the power sector.** In recent time an increasing share of investment banks has chosen to abstain from investment in coal fired power plants. This adds to the urgency to divert investment capital towards RE-based supply. Since the FITs for RE expired there has been a policy gap for RE development. Furthermore, the non-bankable PPAs remains a main barrier for attracting investors. There is an urgent need to address these barriers to attract investment and reduce financing costs.

Viet Nam's electricity system has a total installed capacity of about 76 GW today including rooftop solar power as seen in Figure 5.1. It is more than 3.7 times the installed capacity in 2010. The system has historically been dominated by coal, natural gas, and hydro power but since 2019 almost 16.5 GW of solar power has been installed, of which around 7.8 GW is rooftop PV. Additionally, 4 GW of wind power is in operation.

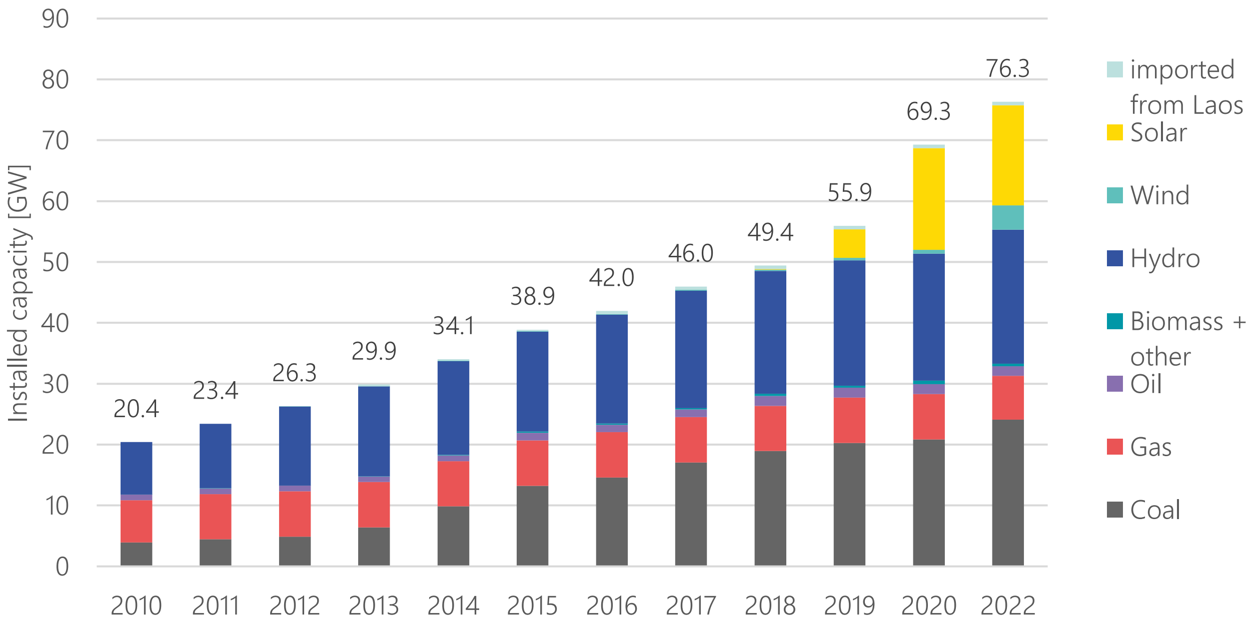

Figure 5.1 Historical installed capacity for electricity generation in Viet Nam. Data for 2022 is extracted from (Vietnam Electricity National Load Dispatch Center, 2022) on April 7th, 2022

Resources

Viet Nam is close to fully utilizing its potential for large-scale and medium-scale hydropower but there is still an untapped potential for small-scale hydro of around 11 GW. While Viet Nam has experienced a substantial increase in solar power plants connected to the grid in 2020, the country still houses a vast remaining potential for deployment of RE technologies.

With a coastline of 3,260 km, Viet Nam has large potential for offshore wind power. On land, the country has already proved to be ready to tap into the potential of solar PV. Rooftop solar is prioritised previously to reduce peak load and grid impact.

Viet Nam has a large onshore wind resource, which requires much less the land use than utility-scale PV. There is currently around 4 GW of onshore wind power installed. The summary of RE (Except biomass) and large pumped hydro storage potentials are presented in Figure 5.2. Small hydro is defined to be no larger than 30 MW and is mostly run-of-river (RoR) where large- and medium-scale hydro is larger than 30 MW and mostly connected to a reservoir.

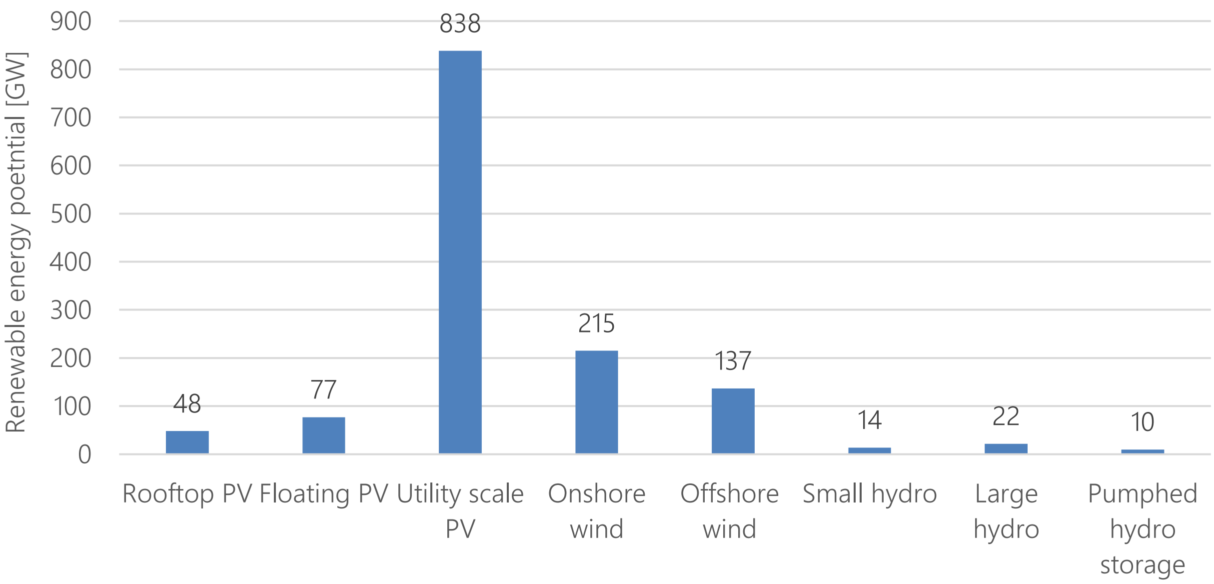

Figure 5.2 Available RE and large pumped hydro storage (PHS) potential

Viet Nam is especially rich in bagasse which can be used for electricity and industrial heat production. Bagasse, municipal solid waste (MSW) and other biomass potentials available for power generation in different scenarios are presented in Figure 5.3. The potential varies since biomass resources are also used in e.g., the industry and transport sector. The optimisation models determine the optimal allocation of the resources in each scenario.

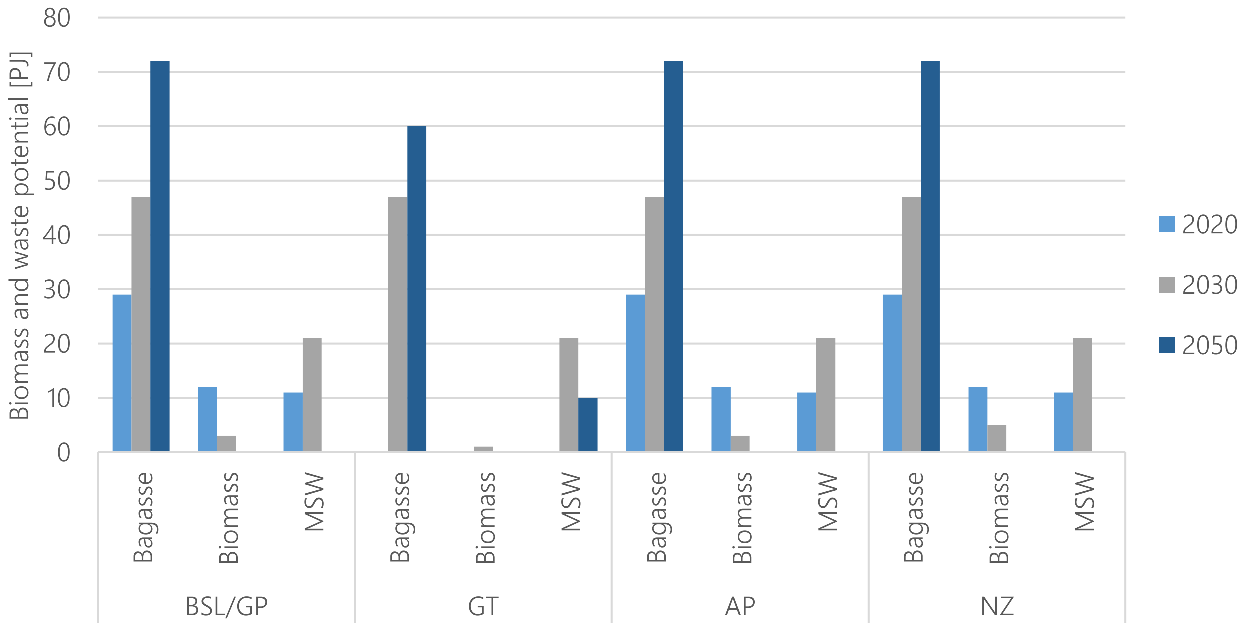

Figure 5.3 Bagasse, municipal solid waste, and other biomass resources allocated for the power sector across analysed scenarios

Finally, Viet Nam also has significant fossil fuel resources with a new reserve of natural gas recently discovered in Ken Bau. Viet Nam has around 24 GW of coal-fired power plants in operation today and further 6 GW are already under construction or expected to be constructed up until and including 2030. These investments are included in all scenarios. 7 additional GW coal plants have already signed contracts but due to challenges in financing, they are not considered as committed in the scenarios.

Generation costs

The costs of the electricity generating technologies are in the Viet Nam Technology Catalogue for power generation and storage (EREA & DEA, 2021a). Evaluating the costs of generated electricity by levelised cost of energy (LCOE), it is seen in Figure 5.4 that coal- and gas-fired power plants were still on average cheapest in 2020 (not considering CO_2 emission costs), but around 2030 the best sites for utility-scale PV and onshore wind becomes cheaper than the coal and gas-fired technologies. In the long term towards 2050, all potentials for solar PV, onshore wind power, and some offshore wind sites become cheaper than thermal technologies.

The advantage of utility-scale PV over rooftop PV is the economy of scale and better solar resources, while the main disadvantage is the land costs. However, as presented in Figure 5.4, even including land cost, LCOE for utility-scale is slightly lower than rooftop PV. The high/low range in Figure 5.4 indicates variation in capacity factor. Assumed full load hours per year (FLH) for coal and gas are 6,000, for nuclear 7,500, for biomass 3,800 and for hydro 2,950 FLH. The span of LCOE for wind and solar power represents the variations in FLHs. A socio-economic discount rate of 10% is used. LCOE is a term describing the electricity generation cost of a technology in net present value. LCOE does not consider the system aspect and is thus a simplistic method for comparison.

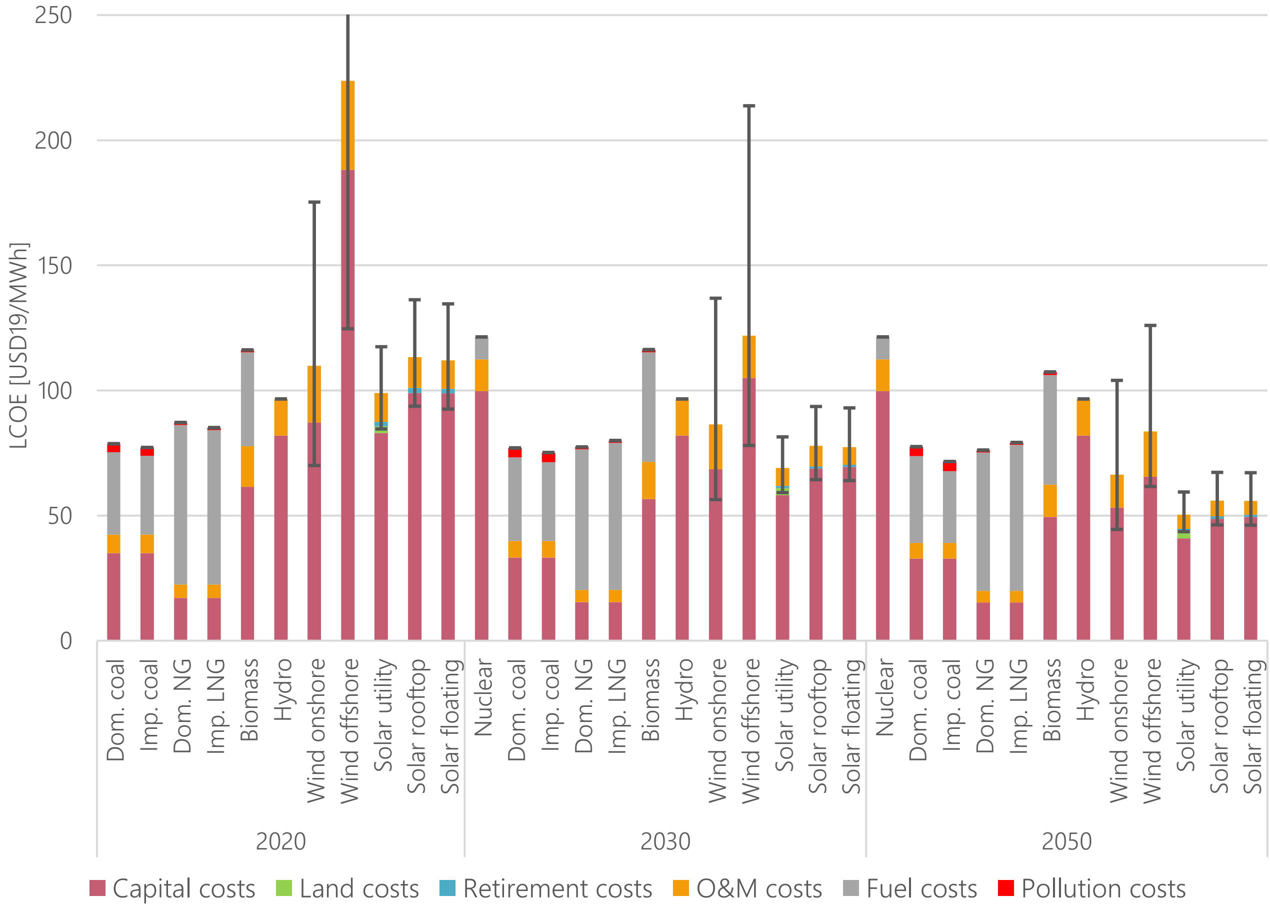

Figure 5.4 LCOE for electricity generating technologies

5.2 Power Generation Outlook

Power Generation

The electricity production in all scenarios along with the RE share is presented in Figure 5.5. RE shares are shown with red or green circles (on secondary axis). The RE share is indicated in red when it matches the minimum requirement (see Chapter 2. Scenarios) and in green if it surpasses the minimum requirement.

The electricity generation doubles by 2030 in all scenarios due to continued economic growth and in BSL, GP, and AP it almost doubles again between 2030 and 2050. The electricity generation in 2050 is 10% higher in GT than in BSL due to electrification of the transport sector but the electricity generation in NZ is more than double of BSL in 2050 due to the comprehensive electrification of all other sectors. Thus, the power sector is expected to fuel the green transition of the other sectors towards the net zero society. The main resources are solar PV, wind power and hydro power.

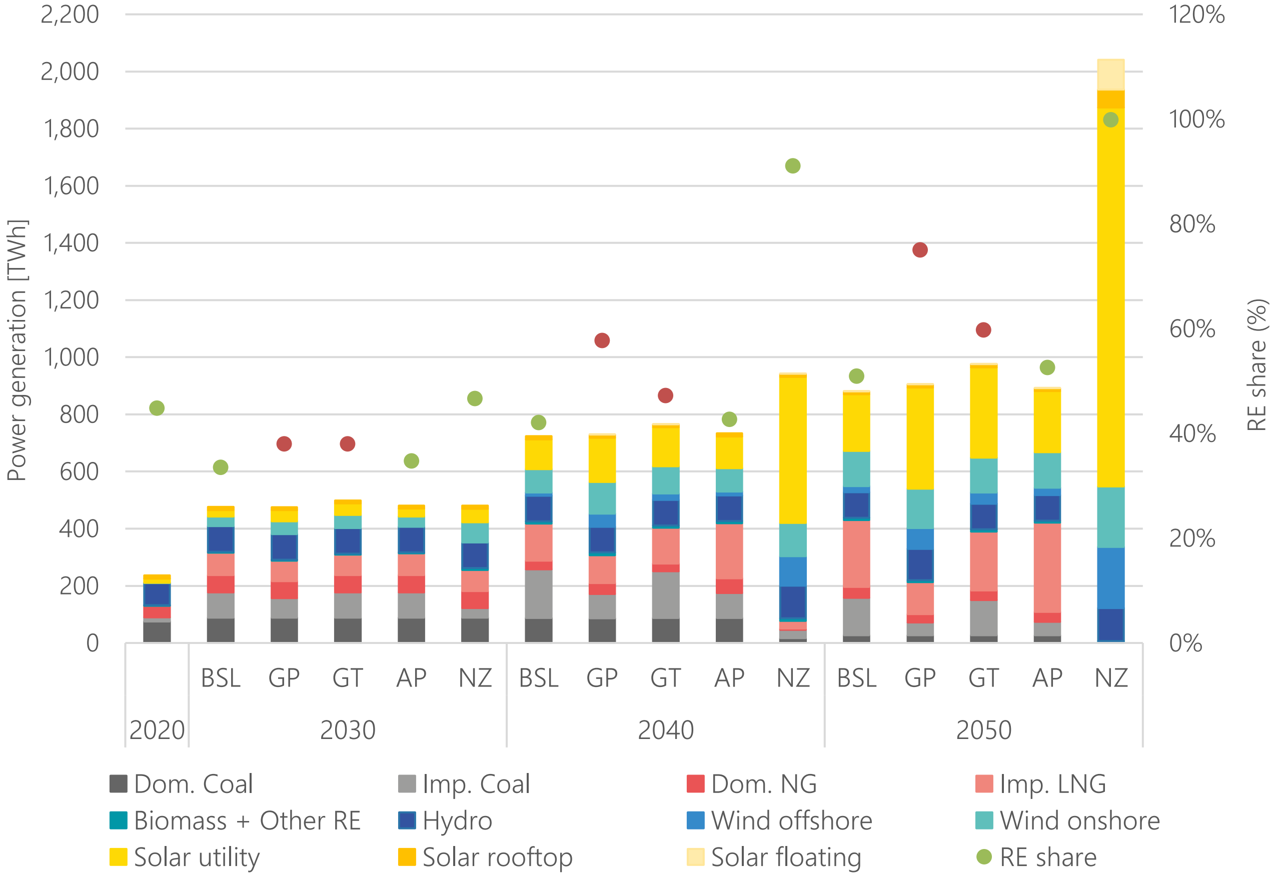

Figure 5.5 Power generation in analysed scenarios

To meet the increasing electricity demand, large investments in generation technologies are needed in the Vietnamese power sector. The installed capacities for the analysed scenarios are presented in Figure 5.6. In the BSL scenario, which results in the lowest electricity consumption, the installed capacity increases by a factor of 4 by 2050 compared to 2020. The NZ scenario requires the highest capacity, with about 450 GW RE installed in 2040 and 1,100 GW RE in 2050. The remaining 27 GW fossil capacity (coal and natural gas) in 2050 are no longer operating as presented in Figure 5.5 but indicate that the power plants have not reached end of their technical lifetimes.

A minimum increase in coal and natural gas power plants by 2030 is included in all scenarios covering already planned projects. Significant investments in solar PV capacity can be observed in all scenarios. Due to lower FLH compared to controllable technologies, the share of solar capacity is much higher compared to its share in the power production. In the following section, the installed capacities of the different technologies in the analysed scenarios are described in detail.

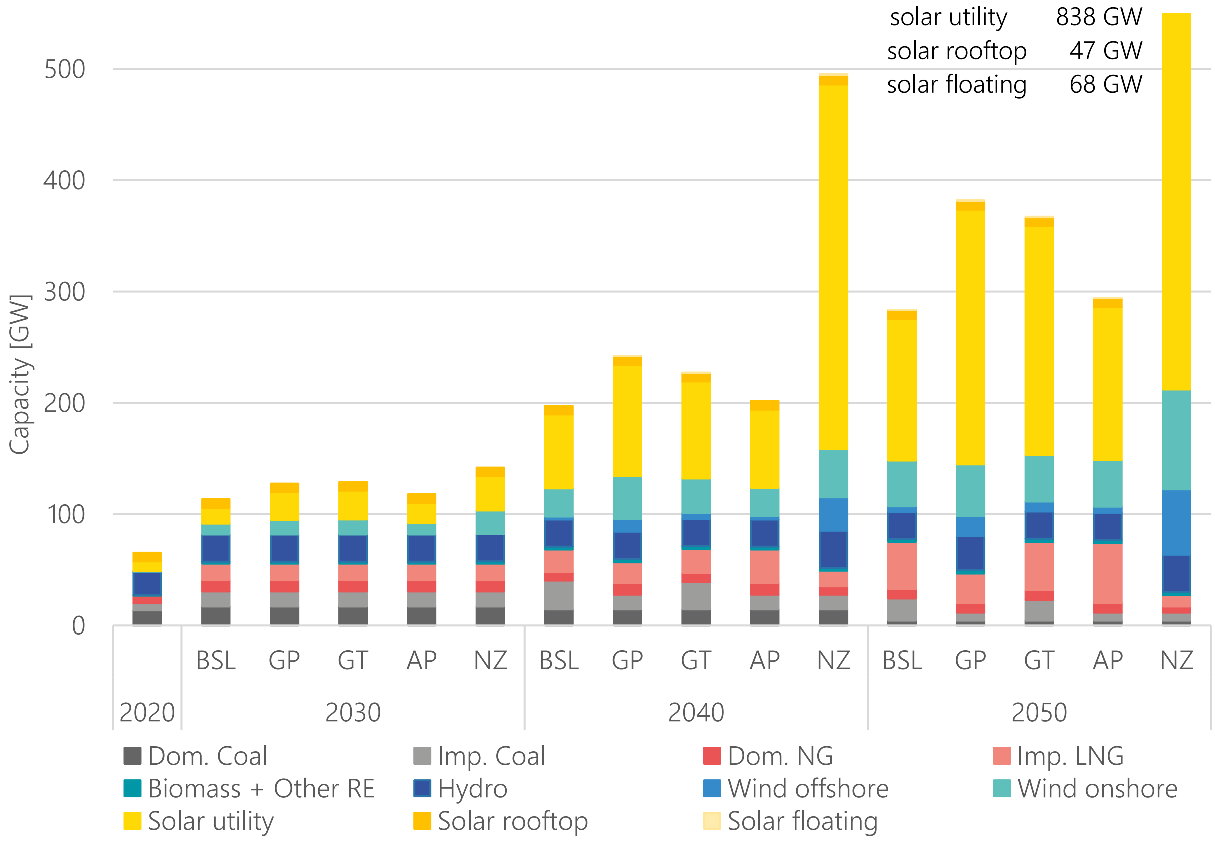

Figure 5.6 Installed capacity in analysed scenarios

Solar power

Solar power should play a key role in the future Vietnamese energy system simply because it is expected to be the cheapest resource. Table 5.1 is presents available and utilised regional potentials (expressed in GW and km^2) in GP and NZ scenarios.

In 2030 a minimum of 14-18 GW of utility-scale PV is expected to be cost-efficient. To be on track towards net zero by 2050, 31 GW of utility-scale PV should be installed by 2030. This can seem overwhelming considering the current situation where Viet Nam is experiencing challenges integrating the existing solar PV capacity and consequently high curtailment rates. But according to the analysis and modelling framework it is possible to balance the power system with this additional capacity of PV with no significant curtailment and without storage. However, additional transmission capacity is needed in all scenarios. Figure 6.7 shows that 24 GW of interregional transmission capacity additional to the existing 51 GW will be needed. Furthermore, additional transmission capacity internally in each of the seven regions will be needed and this will be much more comprehensive than the interregional needs and which is not included in the cost-optimisation (EREA & DEA, 2022a). Finally, the additional PV capacity requires optimal dispatch of thermal power plants, which is difficult today due to long-term contracts. Furthermore, intra-hour balancing is not considered in the modelling framework, but solar PV can cause large variations in generation within minutes especially on cloudy days. Finally, the system operator needs good forecasts, access to sufficient balancing capacity and other ancillary services, adequate real-time monitoring of the grid and experience in operating a power system with a high share of VRE.

In 2050, BSL has 127 GW utility-scale PV and NZ has an overwhelming 838 GW which is also the assumed maximum potential. Thus, there seems to be almost no upper limit to how much solar power can be integrated in the power system if the transmission grid is expanded. Battery storage is expected to be cost-efficient in the long term and therefore play a large role in the integration of PV. The results show that installed capacities of PV and battery storage are closely correlated. This indicates that they supplement each other well since PV has a daily pattern and battery storage is suitable for short term storage of a few hours e.g., from noon/afternoon to evening. For more details see Chapter 6. Power System Balancing.

Rooftop is constrained in system operation. Floating PV is not competitive with utility-scale PV due to higher installation, operation, and maintenance costs, and therefore almost none is installed except in the NZ scenario after the full potential of utility-scale PV is utilised in 2050 where 68 GW of floating and 47 GW of rooftop PV is installed.

The main downside of utility-scale PV is the land area requirements. According to the Viet Nam Technology Catalogue for power generation and storage (EREA & DEA, 2021a), the typical land use value is 1.1 ha/MWp for the existing PV technology.

Table 5.1 Total utility-scale PV potential and total area per region, installed utility-scale PV capacity in 2050 and % of potential per region, area used for installed utility-scale PV capacity in 2050 and % of total area per region for the GP and NZ scenario.

Region	Total potential (GW)	Total area (km^2)	GP PV capacity in 2050 (GW, % of potential)	GP Required area in 2050 (km^2, % of total area)	NZ PV capacity in 2050 (GW, % of potential)	NZ Required area in 2050 (km^2, % of total area)
North	83	116,459	55 (66%)	664 (0.6%)	83 (100%)	1,001 (0.9%)
North Central	104	41,587	28 (27%)	332 (0.8%)	104 (100%)	1,243 (3%)
Centre Central	44	26,536	16 (37%)	195 (0.7%)	44 (100%)	528 (2%)
Highland	229	54,508	21 (11%)	253 (0.5%)	229 (100%)	2,748 (5%)
South Central	130	27,527	19 (12%)	223 (0.8%)	130 (100%)	1,561 (5.7%)
Southeast	164	37,280	70 (43%)	845 (2.3%)	164 (100%)	1,963 (5.3%)
Southwest	84	23,519	20 (23%)	235 (1%)	84 (100%)	1,013 (4.3%)
Total	838	330,952	229 (27%)	2,747 (0.8%)	838 (100%)	10,057 (3%)

In the NZ scenario, the 838 GW will require a land area of around 11,000 km^2 or 3.3% of the total land area in Viet Nam. For comparison, a GIS (geographical information system) based study of ground-mounted solar PV potential in Viet Nam shows, that the technically feasible land area for solar PV is 50,000 km^2 or 14% of the total land area (GIZ, 2018). This is the area remaining when excluding built land, roads and other infrastructure, forests, steep slopes, small plots, high-value land such as rice fields etc. When considering economic constraints including insolation, distance to power grid, land costs and others, the economic potential is found to be between 5,000 and 11,000 km^2. The solar PV costs in this study are based on 2018-prices but the costs have decreased considerably since then and are expected to decrease even further. Therefore, the available land area of 11,000 km^2 seems to be realistic.

The largest solar capacity deployed in the NZ scenario is in the South region (329 GW in 2050), corresponding to 3.9% of the total region area. Only unused land is considered in the scenarios.

Around half of the expansion of solar PV in the EOR21 is concentrated in the South region. Solar PV in this region is attractive from a least-cost perspective, because of the good solar resources and the large power consumption in large cities such as Ho Chi Minh City. Even though it represents a small share of land, the 378 GW of solar capacity in the South region in 2050 implies a huge development in one single region with an average of more than 10 GW every year throughout the period to reach the expected capacity in 2050.

The strong development in the southern regions happens despite 50% above average assumed land costs and 150% above the assumed land costs in the North.

Table 5.2 shows utilised potential for utility-scale PVs by region in different scenarios in 2050. Most notably, the entire potential is utilised in 2050 in NZ scenario, which emphasizes the efforts needed to reach net zero in 2050. Second, the North region is the most utilised in all scenarios due to proximity to the demand centres in the North and cheaper land relative to the South regions, despite having poorer resources than the South. Highland and South Central regions are the least utilised relative to their potential in all scenarios due to low demand in the regions and consequently need to transmit to other regions, and high land costs.

Table 5.2 Share of utility-scale solar potential installed in 2050

Region	BSL	GP	GT	AP	NZ
North	40%	66%	66%	38%	100%
North Central	11%	27%	23%	18%	100%
Centre Central	25%	37%	35%	25%	100%
Highland	5%	9%	6%	6%	100%
South Central	4%	14%	9%	4%	100%
Southeast	25%	43%	38%	26%	100%
Southwest	14%	23%	28%	17%	100%
Total	15%	27%	25%	16%	100%

Where utility-scale solar power is cheaper due to economy of scale, rooftop solar has the advantage of not occupying land when located on roofs of existing buildings, which serves other purposes. Furthermore, if a substantial share of the production is used directly in the building that houses the plant, grid integration costs could be reduced.

Therefore, costs of land are added to the utility-scale solar PV costs in the models. We further differentiate the land costs across seven regions according to the land price frameworks 2020. The future land costs are obtained by scaling today's values with population growth in the respective regions. More details about land costs for utility-scale PV can be found in the Technical Report.

The future land cost is uncertain and could shift the balance towards less utility-scale PV if the cost increases more than assumed in this study. Therefore, a sensitivity study was performed reducing the potential for utility-scale PV to 420 GW equal to 50% of the original potential. The sensitivity study shows that the reduced capacity of solar power would be replaced by wind and nuclear power. More details are described later in this chapter.

Onshore wind power

After utility-scale PV, onshore wind power is expected to play the largest role. The existing 4 GW is almost doubled to 7 GW already in 2025 in the GT scenario to fuel the electrification of the transport sector. In 2030, 10 GW of wind seems cost-optimal while to be on track towards net zero in 2050, 21 GW is needed. In 2050 all scenarios have 40-50 GW of onshore wind except NZ which has 90 GW.

Since onshore wind is cheaper than nearshore and offshore wind, onshore wind is the dominating technology. But some share of offshore wind from 2035 onwards is found to be cost-efficient even though the full potential of onshore wind is not utilised yet. NZ and GP have 8 and 2 GW offshore in 2035 while all scenarios have offshore wind from 2040 onwards. NZ has 54 GW of offshore wind in 2050.

Since solar PV is dominant in most scenarios but highly dependent on land availability and the cost projection of battery storage, two sensitivity studies were performed, namely LowPV, and the BC scenario where battery costs are increased to the upper bound uncertainty described in the Viet Nam Technology Catalogue for power generation and storage (EREA & DEA, 2021a) equal to around 250% the original cost in 2050.

If the potential for utility-scale PV shows to be only 50% of the assumed in the main scenarios or if the battery costs turn out to be higher than expected, wind power will play a larger role after 2030. More specifically, installed capacity in NZ scenario with reduced potential for solar power would be 167 GW, 110 GW and 16 GW for onshore, offshore, and nearshore wind, respectively. Like in NZ scenario with higher battery costs the installed capacity would be 121 GW, 79 GW and 2 GW for onshore, offshore, and nearshore wind respectively.

For each region, three different wind profiles have been used: high, medium, and low wind class. The wind speeds are between 4.5 – 5.5 m/s, 5.5 – 6 m/s and above 6m/s for low medium and high class, respectively. None of the low wind areas are attractive for investments across the main analysed scenarios (only in LowPV), with the only exception being the Southwest region in NZ where all available renewable options must be utilised. Compared to solar PV, onshore wind requires much less land, and international experiences show that onshore wind can easily be combined with agriculture, which makes it easier to integrate in Viet Nam.

Table 5.3 Total potential for onshore and offshore wind per region and installed capacity by 2050 and share of the potential for the GP and NZ scenario

Region	Potential (GW)		GP Installed capacity in 2050 (GW, % of potential)		NZ Installed capacity in 2050 (GW, % of potential)	
	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore
North	13	11	1 (5%)	0 (0%)	1 (5%)	10 (94%)
North Central	11	6	2 (14%)	2 (28%)	2 (14%)	3 (41%)
Centre Central	11		2 (19%)	0 (0%)	2 (19%)	0 (0%)
Highland	74		10 (13%)	0 (0%)	6 (9%)	0 (0%)
South Central	35	81	9 (26%)	16 (19%)	10 (30%)	26 (32%)
Southeast	5	5	0 (2%)	0 (0%)	0 (2%)	0 (0%)
Southwest	69	34	24 (34%)	0 (0%)	69 (100%)	20 (58%)
Total	217	137	47 (21%)	17 (13%)	90 (41%)	59 (43%)

Offshore wind

The long coastline naturally provides Viet Nam with a large potential for offshore wind. A conservative estimated potential of 137 GW is used in this analysis based on a list of specific identified sites (Danish Energy Agency, 2020), further shortlisted due to shipping routes and other concerns. But the potential could be around 600 GW if sites further from shore are also considered, according to the World Bank (World Bank, 2021).

Offshore wind is a complex and large-scale technology which involves very large investments, a comprehensive supply chain and engagement of multiple authorities including maritime, energy, fishery, military authorities and more. Therefore, it takes many years to develop an offshore wind farm in experienced offshore wind countries and even longer in countries with limited or no experience.

The latest auctions in experienced offshore wind countries such as Denmark, Germany and Netherlands have delivered competitive results from economy-of-scale projects. However, to reach this competitiveness requires authorities to develop a systematic and long-term plan, managed and executed according to best practices to create trust and lower perceived regulatory risks. Clear cost reductions are possible if authorities develop the regulatory framework to facilitate and de-risk these large infrastructure projects.

A strategic focus is needed for offshore wind to be efficiently developed in Viet Nam. Regulatory barriers must be handled, and ambitious targets must be set to attract the supply chain, investors, and competition (Danish Energy Agency, 2020) (EREA, DEA & Royal Danish Embassy in Vietnam, 2021).

- Set clear, ambitious, and long-term targets for integration of offshore wind power
- Identify and reserve offshore wind zones through maritime spatial planning; consider undertaking environmental impact assessments and other preparatory site studies
- Define 'real' offshore wind by a distance to shore of at least 6 nautical miles (~11 km), mainly to avoid negative visual impacts, avoid conflicts with near-shore activities and simplify consenting.
- Develop streamlined and transparent permitting procedures
- Develop and publish a strategy for remuneration of offshore wind power (FIT vs. Auctioning) including bankable PPA terms
- Integrate international best practices regarding wind farm design and certification
- Consider possible adverse effects of local content requirements

Hydro power

The hydro power resource in Viet Nam is large but already almost entirely utilised for large-scale hydro which is defined as greater than 30 MW and typically with a connected reservoir. But there is still a large remaining potential for small-scale RoR hydro power of around 10 GW.

Hydro power including small-scale hydro increases in all scenarios from 21 GW in 2020 to 31, 33 and 24 GW in GP, NZ and the remaining three scenarios in 2050, respectively. This makes small-scale hydro power a robust part of the power production mix.

Nuclear

Nuclear power is currently not considered in the planning of the Vietnamese power system although there have been studies of the potential for nuclear in Viet Nam previously. The net zero target announcement in COP26 has restarted the debate about the need for nuclear power in Viet Nam.

None of the main scenarios analysed include nuclear power which indicates that nuclear is not a cost-efficient technology nor needed to reach the net zero target. However, the sensitivity studies indicate that if the potential for utility-scale PV is only 50% of the assumed potential or if the battery cost turns out much higher than assumed, nuclear could play a role from 2040 to reach net zero in 2050.

Costs

Figure 5.7 shows the power system cost per MWh of electricity generated in all scenarios. The division of costs is shifting from fuel costs being the largest share, to capital cost of generation, especially for the NZ scenario where there are no fossil fuels left in 2050. Furthermore, in the NZ scenario the electricity generation more than doubles to fuel the decarbonisation through electrification in the other sectors. Therefore, the need for capital investments in power generation and storage in NZ in 2050 reaches 160 bn USD per year equivalent to 5-6 times the needed investments in BSL. The need for investments in interregional transmission in NZ in 2050 reaches 7 bn USD per year which is more than 10 times the need for investments in the BSL scenario. But investments in interregional transmission are still a relatively low share of the total costs of the power system (4%). The model setup only considers transmission between the seven regions, so upgrade of internal transmission system as well as distribution system is not included. The main cost is the capital investment in generation and storage accounting for around 85% of the total power system costs.

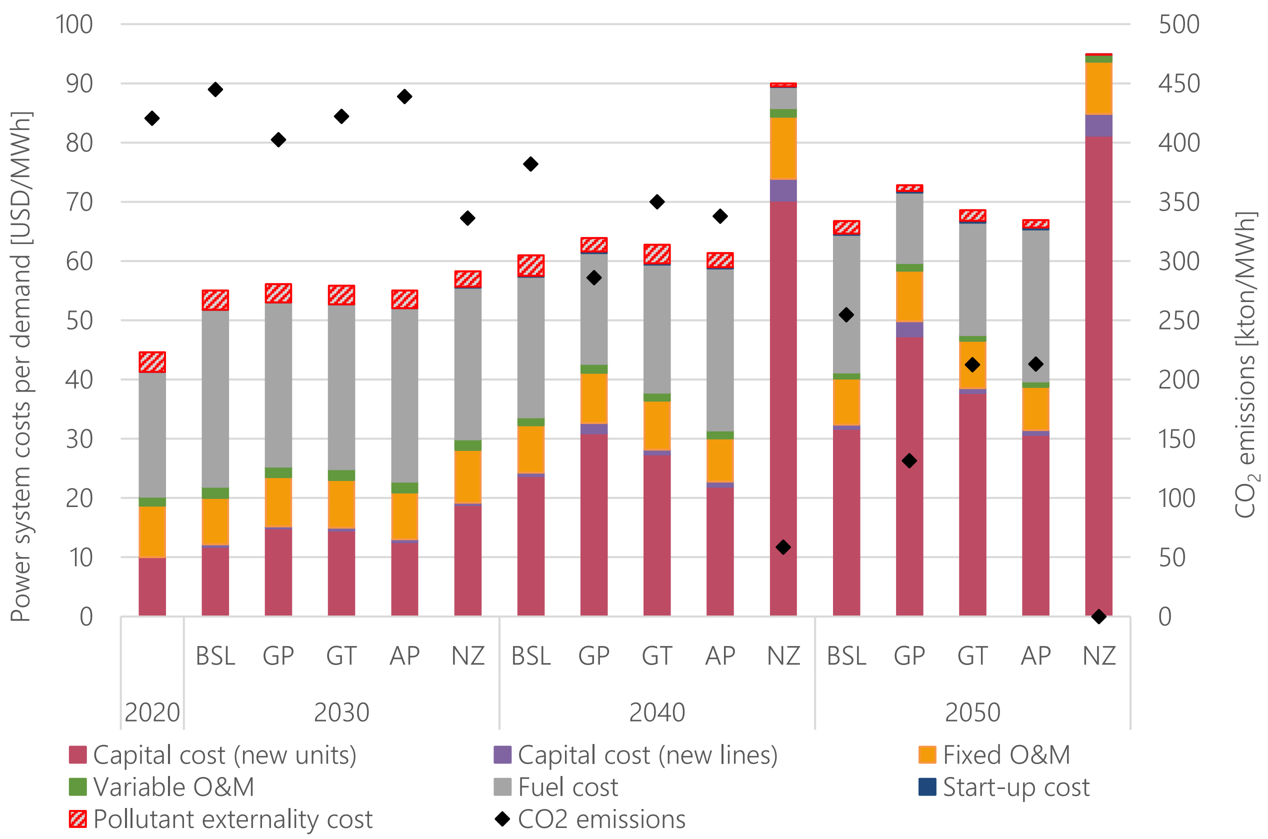

Figure 5.7 Power system costs per MWh of demand

Effects of lower socio-economic discount rate (DR)

The choice of socio-economic discount rate used for the calculation of costs has a large impact on the cost results.

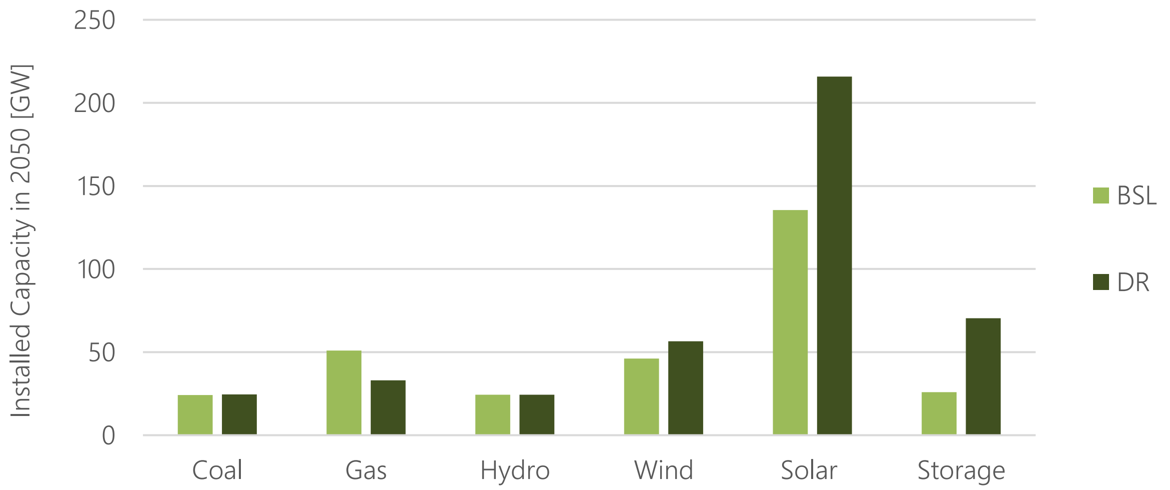

Figure 5.8 Impact of lower socio-economic discount rate on installed power generation and storage capacity in BSL 2050.

Following the practice of the GoV the analysis applies a socio-economic discount rate of 10%. A high socio-economic discount rate leads to undervaluing capital-intensive technologies such as RE technologies against fuel-intensive technologies such as thermal power.

An economic analysis for Viet Nam finds that the socio-economic discount rate should be 6-8%, leaning towards the lower end of the spectrum (Coleman, 2021).

A sensitivity analysis of the BSL scenario using a socio-economic discount rate of 6.3% shows, that for 2050 the total costs of the power sector in 2050 is 12% lower, while cumulative CO_2 emissions for the whole energy system between 2020 and 2050 are reduced by 6% due to increased replacement of coal and gas with renewables. Natural gas capacity decreases by 40% while solar and wind capacity together increase by 50% as seen in Figure 5.8.

Effects of high battery cost in a net zero scenario (BC)

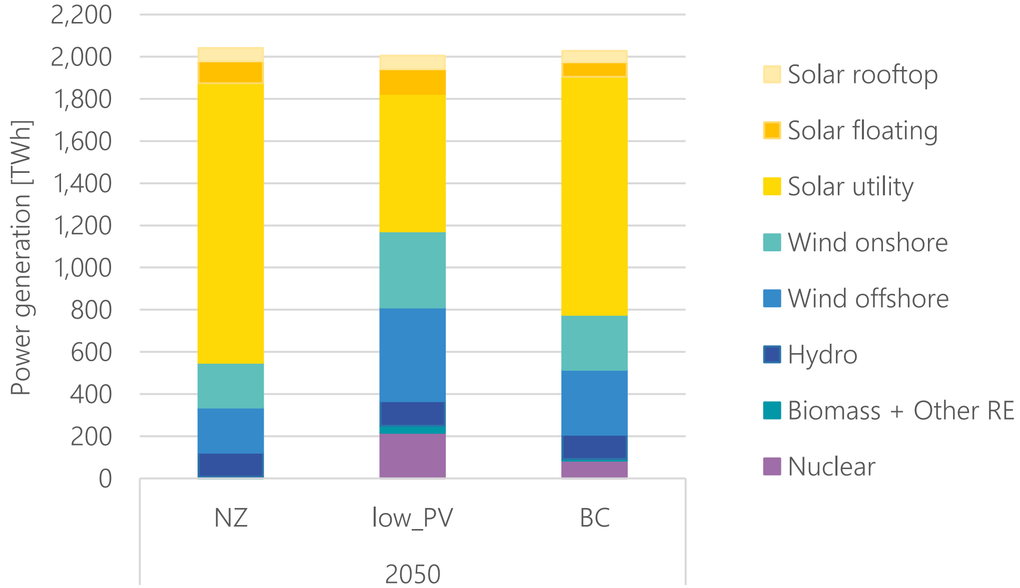

Figure 5.9 Power generation in 2050 in the NZ, LowPV and BC scenarios

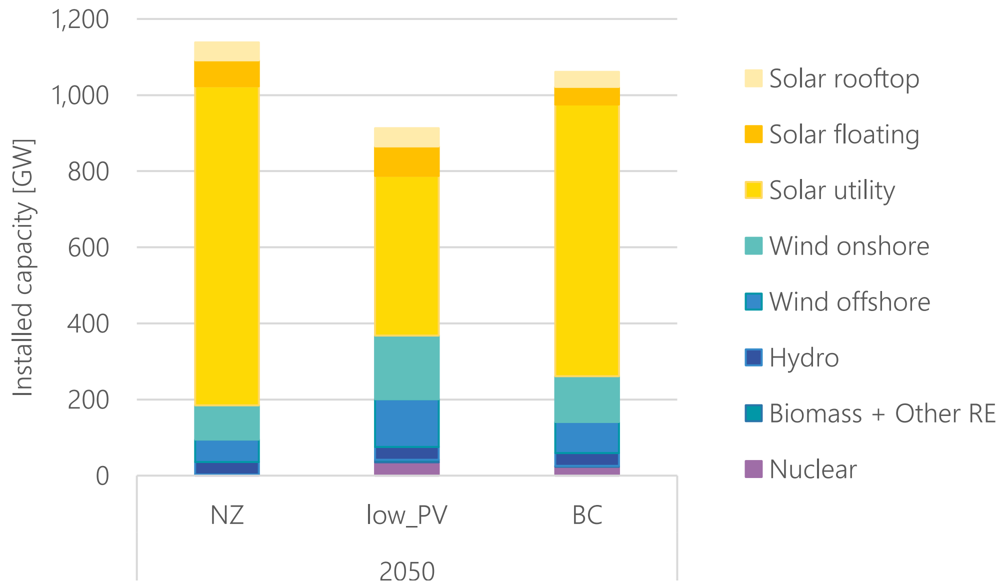

Figure 5.10 Installed capacity in 2050 in the NZ, LowPV and BC scenario

Considering the large uncertainty of battery costs decades ahead, a sensitivity analysis on the NZ scenario was made under the assumption that battery costs in 2050 would be around 2.5 times the assumed cost in the base case (EREA & DEA, 2021a). With increased cost of batteries, the investment in batteries is reduced from around 450 to 275 GW, solar PV is reduced from around 950 to 800 GW. Instead, wind increases from around 150 to 200 GW and 23 GW of nuclear power is introduced. Despite relatively small installed capacity compared to wind and solar, nuclear gets much more operating hours and is therefore visible on Figure 5.9. The installed capacities can be found in Figure 5.10. The remaining unused coal and natural gas capacity of 12 GW and 16 GW respectively, is excluded from Figure 5.10. The total power system cost in 2050 will grow by 21% equivalent to 42 bn USD.

Effects of lower availability of land area for solar utility-scale PV (LowPV)

The NZ scenario assumes availability of 11,000 km^2 for utility-scale PV. Although this was found to be feasible (GIZ, 2018), there might be reasons why less land would in practice be available. Therefore, a sensitivity analysis on the NZ scenario was prepared assuming only 50% of the full land area available equal to 420 GW.

In 2050 in NZ scenario with lower PV potential, 420 GW of PV could be replaced by 35 GW of nuclear and around 140 GW of wind power which almost doubles from around 150 GW, shown in Figure 5.10. Rooftop and floating PV increases only marginally to compensate for the 420 GW of utility-scale PV. Less solar PV also leads to around 170 GW less batteries and around 30 GW less transmission. Power system cost increase in 2050 by 27 bn USD equivalent to 13%.

The role of fossil fuels in the power sector

Coal and natural gas are key commodities in the Vietnamese power sector as of today, covering 55% of the power generation in 2020. The installed capacity of coal and gas will increase in the next decade as there are numerous new coal and LNG plants already planned.

Until 2030, no new coal or natural gas power capacity are installed besides the 30 GW coal and 25 GW gas already in operation or expected to be constructed in any of the scenarios. This indicates that sufficient coal and gas capacity is already planned in the short term. For the NZ scenario, the already planned imported coal power plants operate at 50% less FLHs already in 2030, indicating that more coal capacity is planned than what is needed in the short term to reach the net zero target.

After 2030, additional coal capacity is only added in the BSL and GT scenario, but no new coal capacity is added in the scenarios focusing on air pollution or with increasing share of RE, namely the AP, GP, and NZ scenario. It underlines that to reach the net zero target in 2050, the 30 GW coal power already in operation or considered planned is more than sufficient.

Like coal power, additional natural gas capacity is not needed beyond the already existing or planned ones, covering a total of 10 GW of domestic natural gas-fired power plants and 15 GW of new LNG-fired plants by 2030. After 2030, new gas capacity is added in all scenarios, more specifically 3-11 GW in 2035, and 38-49 GW by 2050 in BSL, AP and GT scenarios, respectively. Neither of these scenarios includes climate targets nor high RE targets. In the GP scenario, only 22 GW gas capacity should be added by 2050. To reach net zero emission the total gas capacity should not exceed the already planned 25 GW.

5.3 Key Messages and Recommendations

The power sector will fuel the green transition of the entire energy system with more than double the electricity generation compared to the BSL scenario

Since renewables are soon or already the least-cost sources of energy, and since the costs are steadily decreasing with time, a high degree of electrification is the most cost-efficient pathway towards net zero in 2050.

Therefore, electricity generation should double by 2030 compared to 2020 and increase to more than 8 times the current annual generation in 2050, more than double the generation of the BSL scenario. This extra electricity will be used to electrify and decarbonize the rest of the energy system. Especially the transport sector and the industrial sector have great potential for electrification.

According to the present analysis, a cost-optimised scenario, where Viet Nam reaches its net zero emission target in 2050 includes a total capacity of 38 GW solar power and 21 GW wind power already in 2030. In 2050, the capacity of wind power reaches around 150 GW, and the capacity of solar power reaches around 950 GW.

Even in a scenario without climate targets (BSL scenario), an installed capacity of a minimum of 22 GW of solar power by 2030 is cost-optimal from the whole Vietnamese energy system. Therefore, new policies to encourage investments in new solar PV (photovoltaic) should be implemented as soon as possible to stay on track towards net zero emissions in 2050.

Onshore wind and utility-scale PV are already or soon the cheapest sources of electricity, but utility-scale PV is highly dependent on land availability. The area needed for the 840 GW utility-scale PV is 3.3% of the total area of Viet Nam with current technology, however technology development towards higher efficiency could reduce the need for land area. If only half the land area is available for solar power, 420 GW solar power may be replaced by 77 GW onshore wind, 56 GW offshore wind and 35 GW nuclear power at an extra cost of 27 Bn USD/year in 2050 equivalent to 13% of the total power system cost.

Stop planning new coal-fired power plants and refurbish existing plants to become more flexible to better integrate renewables

Around 24 GW of coal-fired power plants are in operation today, a further 6 GW are already under construction or expected to be constructed by 2030, and an additional 7 GW coal plants have already signed contracts but due to challenges in financing, they are not considered as committed here.

The analysis shows that no new coal-fired power plants are needed until 2030. Furthermore, no new coal-fired power plants should be built after 2030 to stay on the pathway to net zero emissions in 2050. Finally, existing coal-fired power plants should be phased out sooner than by the end of their technical lifetime and they should transition from the role of baseload to operate with decreasing capacity factor towards 2050.

Limit the expansion of domestic natural gas and LNG-fired power plants

Around 7 GW of domestic natural gas-fired power plants are in operation today while no LNG-fired power plants are yet in operation. A further 3 GW of domestic natural gas-fired power plants and 15 GW of new LNG-fired power plants are expected to be constructed by 2030

From 2035 to 2050 3 GW of additional domestic gas-fired power plants and 20-45 GW of new LNG-fired power plants are installed in all scenarios except for the NZ scenario where the total installed capacity of natural gas-fired power plants does not exceed the already committed 25 GW and decreases towards 2050. Therefore, it is recommended to not invest in new domestic gas-fired power plants and keep the new LNG-power plants to a minimum. However, gas-fired generation could still be the technology of choice for backup/peak capacity due to its significantly lower CO_2 emission intensity, and flexible operation advantages.

The green transition of the power system will be very capital-intensive and could require annual investments of up to 167 bn USD in 2050 in the NZ scenario, corresponding to around 11% of the projected national GDP in 2050 and, 5-6 times more than in the BSL scenario.

Power system costs will shift towards less fuel costs and much more capital investment costs. In the NZ scenario in 2050, it is estimated that the power system needs 167 bn USD of investments, of which 106 bn USD in RE, 54 bn USD in storage and 7 bn USD in interregional transmission. This is equivalent to around 11% of the GDP in 2050. Capital investment costs are around 50% of total power system costs in 2030 in all scenarios while towards net zero in 2050 it increases to 90% of the total power system costs.

The capital-intensive nature of RE means that it will be key for Viet Nam to introduce risk-lowering measures for investors which, in turn, should lower the electricity prices for end users.

To kick-start installation of offshore wind, the regulatory framework must be developed

Viet Nam has a large potential for offshore wind but so far no offshore wind power plant has been built and operated partly due to obstacles in project approval process including: i) complicated and unclear permitting and licensing procedures that involve many authorities; ii) lack of policies and guidelines related to finance and investment support mechanism; iii) lack of stable policy and pricing scheme for offshore wind power.

These are just some of the barriers which must be overcome by Vietnamese authorities to bring confidence to investors, promote investment in the offshore wind energy sector to ensure energy security, bring socio-economic efficiency as well as realize Vietnam's climate commitment.

6 Power System Balancing

6. Power System Balancing

6.1 Status and Trends

A power system must balance second by second and traditionally, the main challenge has been to balance the variation in demand with dispatchable power plants. But with increasing amounts of variable RE connected to the grid, the dynamics of balancing changes and the need for balancing could increase.

Until recently, the three main sources of electricity in Viet Nam are coal, natural gas, and hydro power as seen in Figure 6.1. Coal-fired power plants operate as baseload since they have the lowest marginal cost and are not very flexible. Natural gas-fired power plants have higher marginal costs and are more flexible and therefore they operate with a lower capacity factor and more dynamically depending on the demand. The marginal cost of hydro power is close to zero since the "fuel" (water) is free but unlike for coal and gas, the amount of fuel is constrained by precipitation and environmental considerations. Furthermore, hydropower with reservoirs can be very flexible and therefore they are used for balancing and ancillary services in Viet Nam today.

The recent rapid increase in grid-connected solar and wind capacity is challenging the transmission system. Challenges in balancing the grid along with frequent congestions in some locations on high voltage level are causing extensive curtailment of solar power in some periods to avoid overload of power lines and ensure stable system operation.

Additional flexibility measures are therefore needed towards net zero in 2050. In the latest draft plans for PDP8, in 2045, up to 35 GW hydro power is mentioned; a large increase compared to the current 22 GW. Up to 28.95 GW storage is also mentioned. Furthermore, up to 31.4 GW of new LNG-fired power plants and up to 27.3 GW of flexible sources are considered. Finally, a comprehensive reinforcement of the transmission system is considered to better transport electricity across regions from the areas with high RE resources to the demand centres.

6.2 Power System Balancing Outlook

Variability and power system dynamics

Figure 6.1 shows hourly power production in week 4 of 2025 in BSL scenario which has the lowest demand because of the Tet holidays. Coal and gas are operating as baseload, solar PV has a dominating daily pattern, but hydro power can balance the solar and wind power. The share of variable RE is still small and storage is not yet needed.

Figure 6.2 shows power production and use of storage in week 4 of 2035 in BSL scenario. The size of the whole power system grows significantly from 2025 to 2035, so the peaks in 2025 around 35 GW increases to around 68 GW in 2035. Utility-scale solar power is much more pronounced during the middle of the day (up to 33 GW) which creates a need for balancing. Solar PV peak coincides with minimum wind production this week, but this is not always the case. The response from the system is to utilise the pumped hydro capacity of 1.2 GW and demand flexibility (see details later in this chapter). Coal and gas no longer operate at constant load.

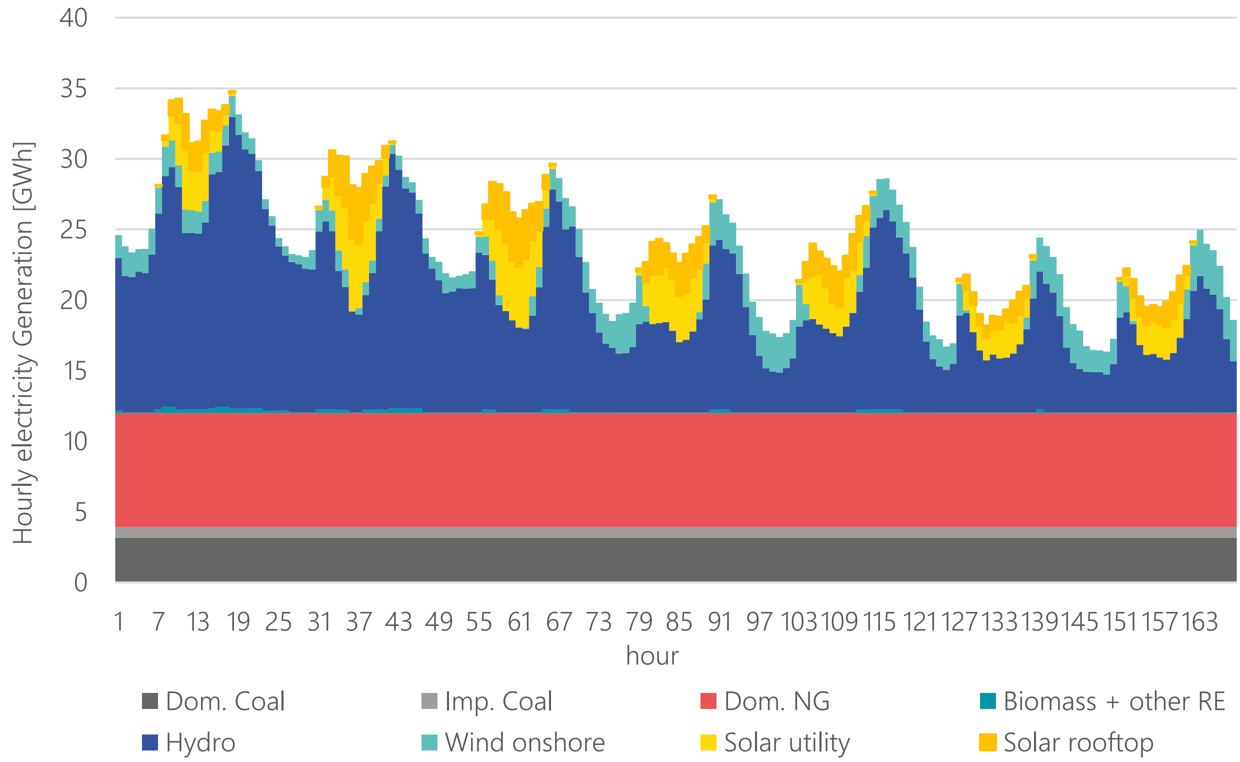

Figure 6.1 Hourly electricity production in week 4 of 2025.

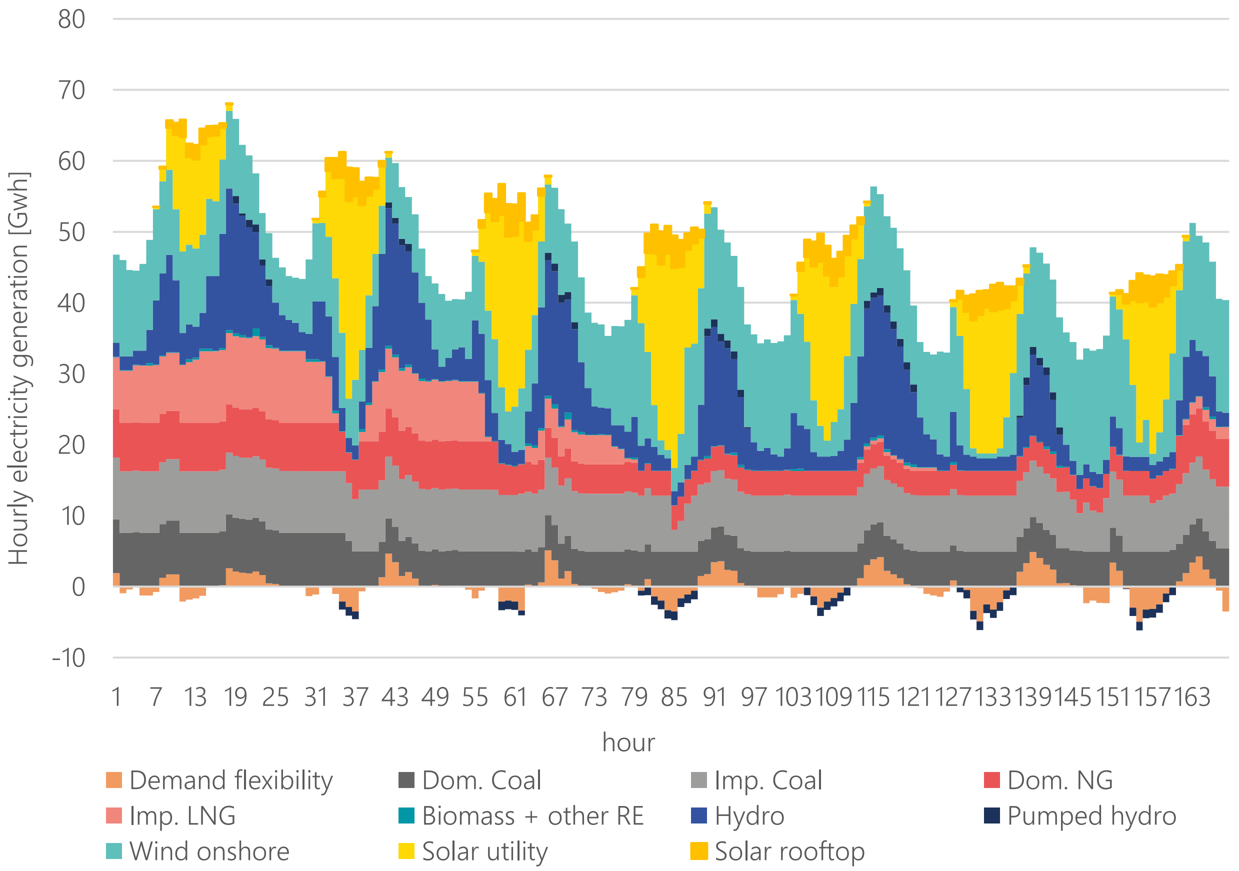

Figure 6.2 Hourly electricity production and storage use in week 4 of 2035

Flexibility of Thermal Power Plants

Coal- and gas-fired power plants are typically constructed based on a long-term fixed price contract with a guaranteed minimum annual generation in Viet Nam. These contracts reduce the financial risk for the power plant owner since they are ensured a fixed income for many years to amortise the investment. Furthermore, they can make long-term fixed price agreements for fuel supply which reduces the financial risk further. But as seen in Figure 6.1 and 6.2, the role of the thermal power plants should change from supplying stable baseload to dynamically integrating renewables as more solar and wind power is connected to the grid. This trend implies less annual generation from thermal power plants and thus interferes with the long-term contracts. The trend will start earlier and be stronger in the NZ scenario compared to the BSL scenario in the figures above.

Figure 6.3 shows the average FLH for coal- and gas-fired power plants. In the BSL scenario, the FLH are stable between 5,000-7,000 annually except for domestic natural gas which decreases in 2040 and 2050. The reason for domestic gas decreasing instead of the more expensive imported LNG is that domestic natural gas is mainly available in the regions with the most wind and solar power. For the NZ scenario the trend towards less FLHs is very clear. In 2030, the imported coal-fired power plants should reduce generation to around 2,500 FLHs. In 2040, all generation from coal- and gas-fired power plants should be reduced to around 1-2,000 FLHs and in 2050 the generation should be completely stopped in line with the net zero target. The results indicate that coal- and gas-fired power plants with long-term, minimum annual generation contracts should not be part of the power system towards net zero in 2050. Thus, they could lead to expensive lock-in effects and jeopardize reaching net zero in 2050.

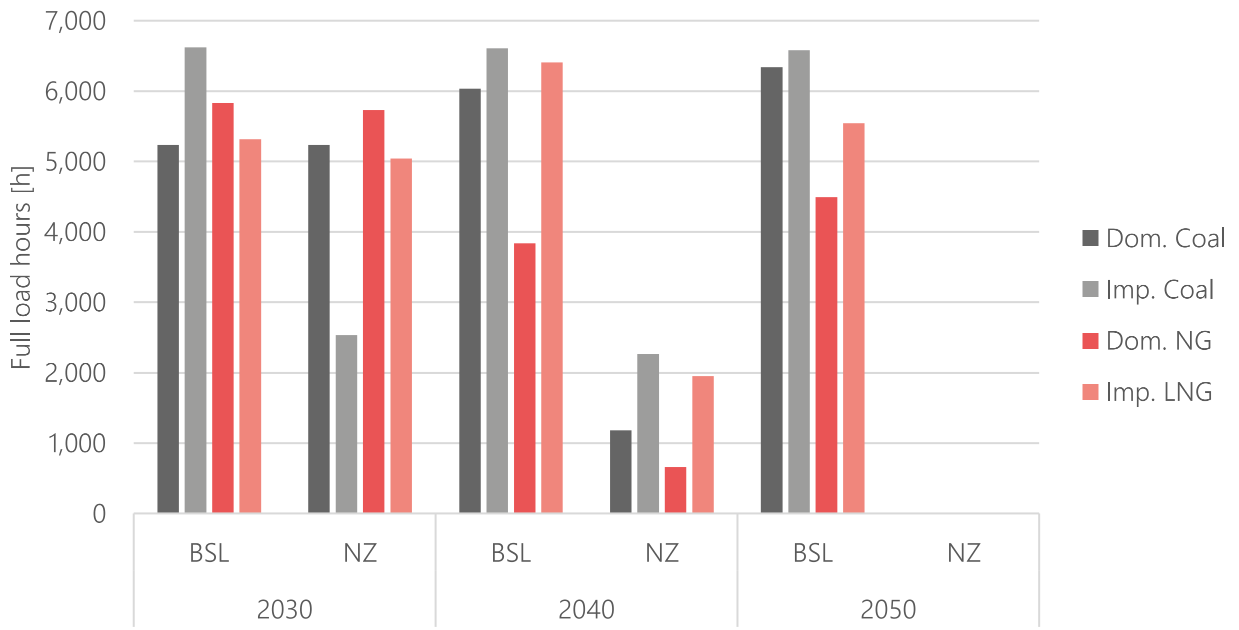

Figure 6.3 Average FLHs for coal- and gas-fired power plants in BSL and NZ.

The transition from fossil-fuel baseload power plants to dynamic integrator of wind and solar power can be implemented on a system-wide level through power markets, incentivising optimal hourly dispatch according to marginal generation costs for each available technology. The Viet Nam Wholesale Energy Market (VWEM) is already in operation today but still lacks the volume to ensure optimal hourly dispatch for the whole power system. Many thermal power plants do not trade through the VWEM since they already hold the long-term fixed price contracts mentioned above. Therefore, today renewables are often curtailed in situations of excess electricity, where thermal power plants could have reduced generation and saved fuel and emissions. The hourly price and generation in VWEM can be found in the National Load Dispatch Center (NLDC) website, and an example is shown in Figure 6.4. A trend is already observed towards lower prices around noon where the solar PV generation is high.

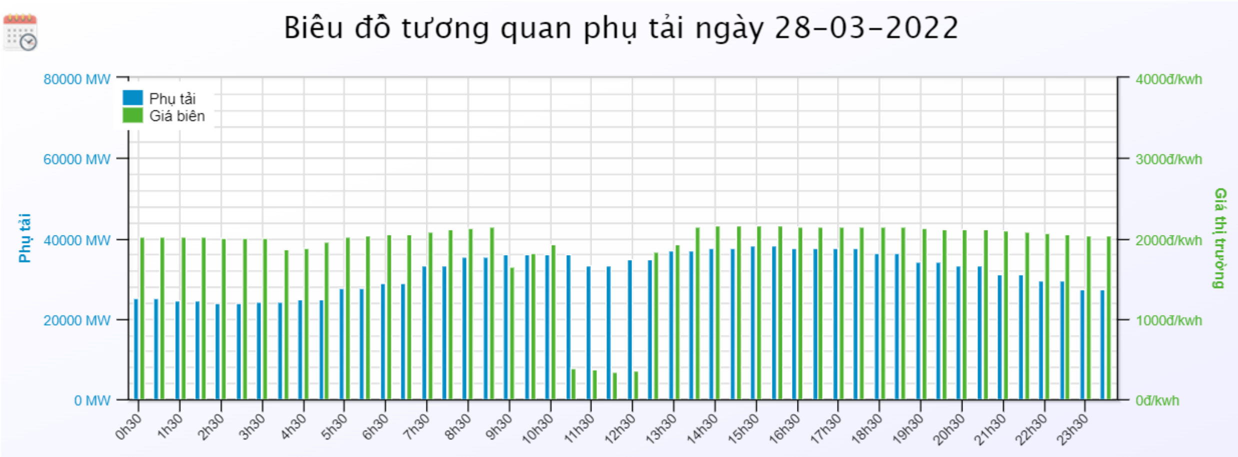

Figure 6.4 Hourly electricity price in the VWEM on March 28th, 2022. The electricity price decreases around noon where the generation from solar PV is highest. Blue is the generation in MW and Green is the price in VND/kWh (Vietnam Electricity National Load Dispatch Center, 2022).

For existing thermal power plants, especially coal-fired plants, it can be challenging to transition from operating as baseload to dynamically adjust generation according to hourly varying prices. But changes can be made to reduce minimum generation capacity and increase ramp rates, some of which do not even require large investments. Therefore, these changes could be profitable in a future market-based power system dominated by RE, allowing the plants to operate at full load when prices are high, and quickly ramp down at low prices. They could even create opportunities for new revenue streams e.g., providing ancillary services such as frequency and voltage services to stabilise the power system (Danish Energy Agency, the Electric Power Planning and Engineering Institute, the China National Renewable Energy Centre, the Danish TSO Energinet and Ea Energy Analyses, 2018).

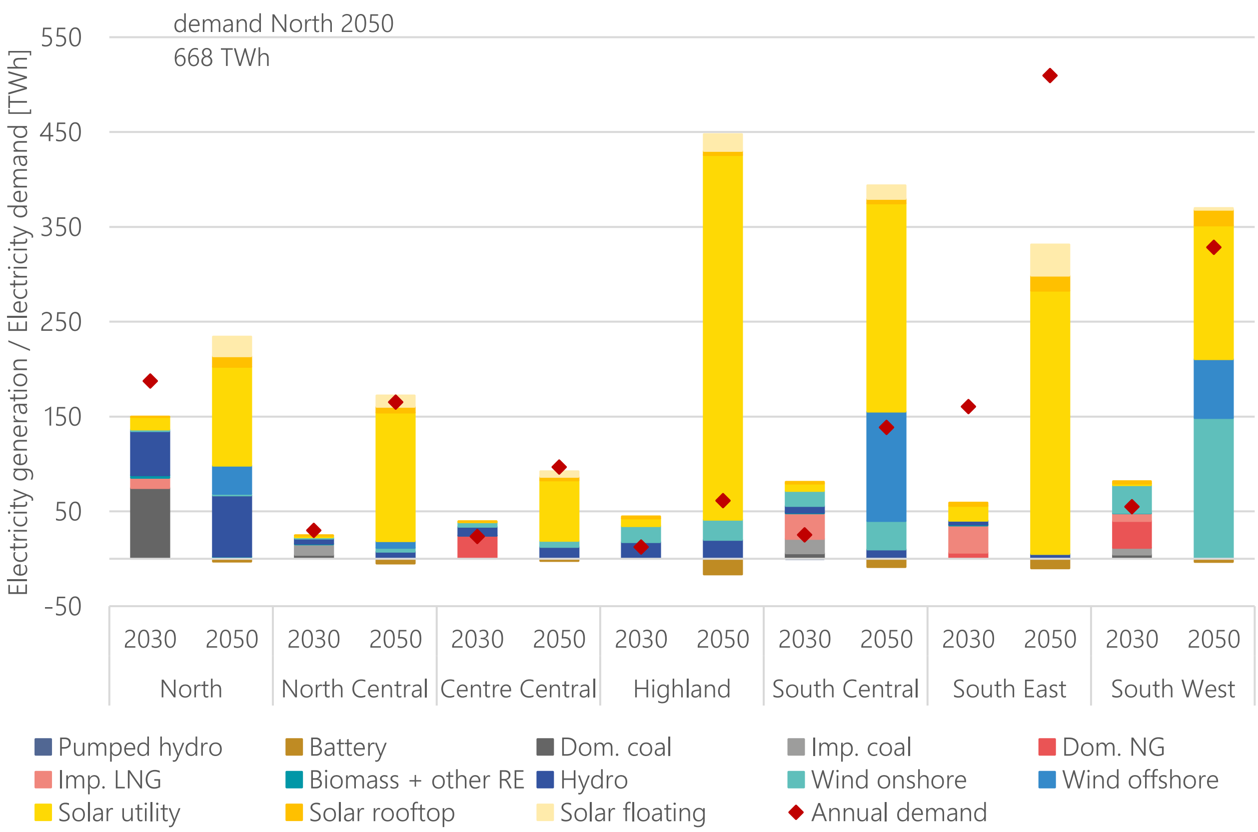

Figure 6.5 Electricity demand and generated electricity per region and per technology for NZ scenario in 2030 and 2050. Some regions have large imbalances and thus electricity must be transmitted between regions.

Transmission

Viet Nam's demand centres are mainly the North region and the Southeast region. The wind resources are mainly in the Southwest and Southcentral, the solar resources are more evenly distributed with the highest levels in the Highlands, followed by Southeast and Southcentral. Figure 6.5 shows the electricity generated and the demand per region per technology in NZ in 2030 and 2050. Due to the imbalance between generation and demand within each region, a lot of electricity is transmitted across regions.

Figure 6.6 shows the transmission capacity in NZ in 2050 and the annual transmitted electricity. It is seen that the transmission capacity between almost all neighbouring regions should be reinforced. Furthermore, a few non-neighbouring regions should be directly connected with HVDC transmission lines (Institute of Energy of Vietnam, 2020).

The total interregional transmission capacity should be reinforced to around 41 GW in 2030 from 29 GW in 2020. North and Southeast are the largest net importers of electricity and Highlands and South Central are the largest exporters of electricity. Centre Central is a large transit region relevant for connecting the northern regions with the Highlands.

In NZ in 2050 (Figure 6.6) the largest increase in transmission capacity is observed between Highlands and Center Central where an additional 43 GW is added compared to the existing 6 GW. Second is the link between the non-neighbouring regions Centre Central and North where 39 GW of HVDC is needed. Third is another HVDC link to the North but from South Central of 18 GW. Furthermore, South Central and Southeast have an additional 12 GW link, Highlands and Southeast additional 10 GW and North Central and North additional 7 GW.

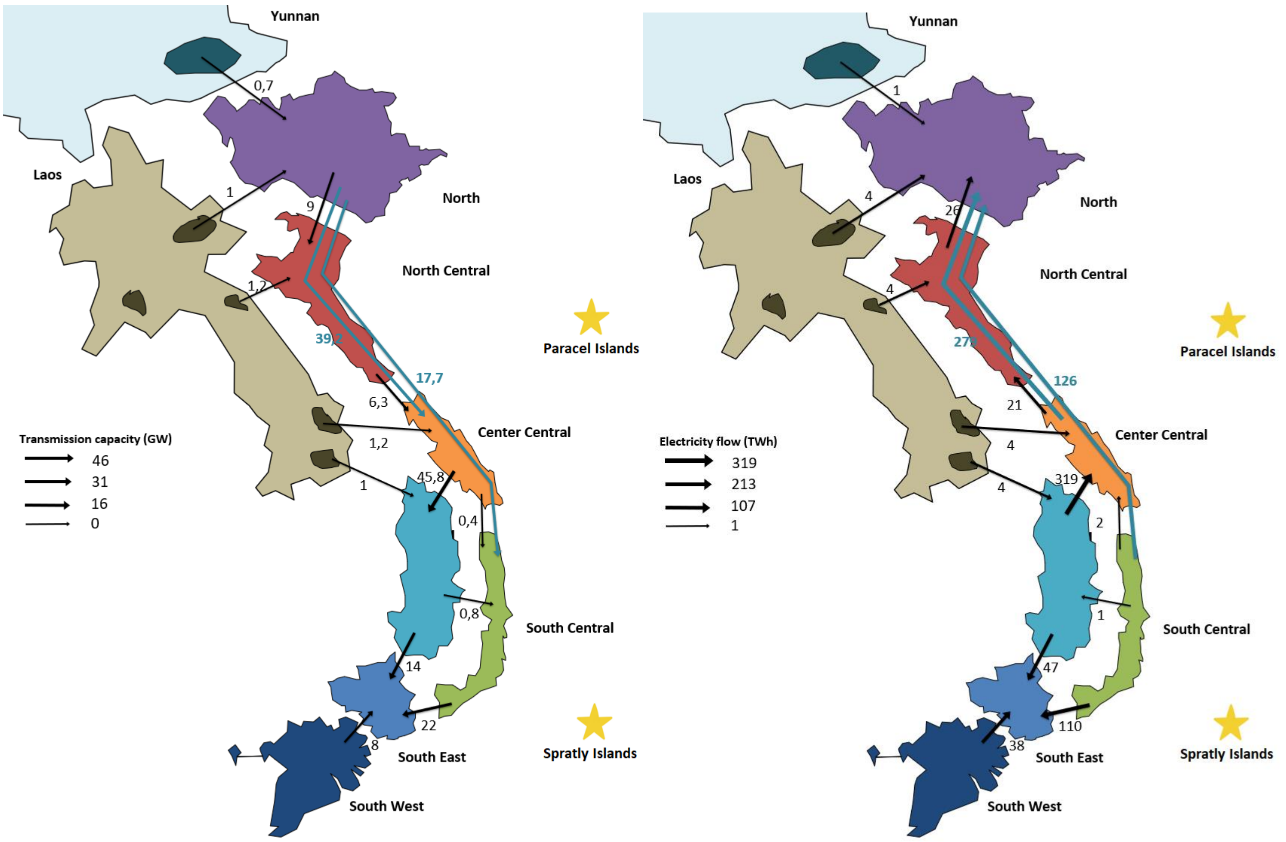

Figure 6.6 Transmission between regions in NZ in 2050. The map on the left shows the capacity of transmission lines between regions and the map on the right shows the annual transmitted electricity. HVDC lines between North and Centre Central and North and South Central are represented with blue lines.

HVDC lines are cost-efficient compared to HVAC over long distances (more than around 500 km). Therefore, HVDC lines between the demand centre in the North region and the RE resources in the Centre Central and South Central region could be a good supplement to the HVAC grid. In the NZ scenario 4 GW HVDC lines are added already in 2035 between North and Centre Central and 3 GW between North and South Central. The capacities increase to 39 GW and 17 GW, respectively, 2050. In the BSL scenario there is little or no need for HVDC lines (Institute of Energy of Vietnam, 2020).

To conclude, to reach the net zero target in 2050 HVDC lines should be in operation by 2035. The HVDC technology has additional benefits since the power flow can be controlled and the converter stations can provide ancillary services. But they are also a new and very different grid component which is more complicated to operate. Therefore, it is recommended to start planning HVDC lines soon, develop capacity in operation of HVDC lines within the system operator and develop the regulatory framework for this new technology.

Figure 6.7 presents the increase in transmission capacity and battery capacity (left) and wind and solar capacity (right) compared to 2020 in BSL, GP and NZ scenarios. All scenarios look very similar until 2030. BSL scenario requires the least investments in batteries and transmission because of the smallest addition of wind and PV capacity. Namely, only 181 GW of wind and solar is installed in 2050 in BSL scenario. To balance the added renewables, 90 GW of interregional transmission lines and 25 GW of batteries is necessary, or 0.12 GW of transmission and 0.15 GW of batteries per GW of wind and solar.

Wind and solar capacities develop faster in GP and NZ. In GP scenario, the growth of wind and solar capacity compared to 2020 is 21, 141 and 284 GW in 2030, 2040 and 2050, respectively. This is followed by 80 GW of batteries and 46 GW of new transmission lines, corresponding to 0.28 GW and 0.16 GW of additional batteries and transmission per GW of added wind and solar. NZ scenario requires 457 GW batteries and 134 GW of new transmission lines to integrate 100% variable RE production. 457 GW of batteries relative to 1,085 GW of new wind and solar capacity results in a ratio of 0.42, while the ratio of new transmission to new wind and solar (0.12) remains within the range of other scenarios.

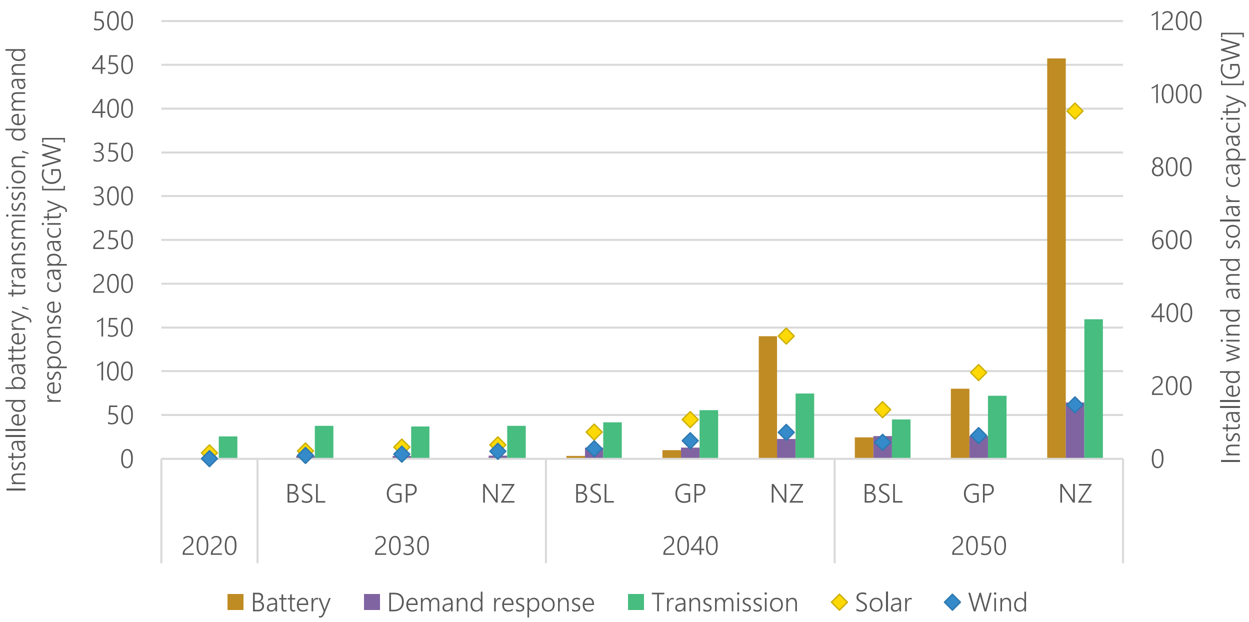

Figure 6.7 Transmission capacity and battery capacity (left), and wind and solar capacity (right) in BSL, GP and NZ scenario

Evaluation of the transmission capacity in the LowPV sensitivity scenario where only 50% of the utility-scale PV potential is available and thus wind and nuclear power replaces solar PV, shows that slightly less transmission capacity is needed (Figure 6.9). The North still has high net import but is importing a major share from the South Central and the neighbouring region North Central. The relevance of the Highlands for electricity generation for the rest of the country is largely decreased and by this much less transmission through Centre Central is required. In 2050, the transmission capacity from Highlands to Centre Central is reduced by 31 GW and the HVDC line connecting Centre Central with North is almost halved as compared to the NZ scenario. The reason for the reduced potential for electricity export from Highlands is that the solar capacity is reduced by 70% in this region.

Furthermore, Centre Central is generating more electricity from nuclear power. Finally, the increased amount of offshore wind and additional nuclear power in South Central allows even more export from this region of the country, leading to an increase in transmission lines to the Centre Central by 6 GW and increase of the HVDC line to North by 9 GW.

A detailed study of the transmission system adequacy was performed to check whether the transmission investments modelled in Balmorel would be sufficient to secure supply in extreme the most extreme hours in BSL scenario. The analysis was performed using the PSS/E model on the BSL scenario in 2025 and 2035. The analysis shows that the resulting inter-regional transmission lines from Balmorel are adequate. Furthermore, that the Balmorel grid loss assumptions could be between 0.6% and 1.4% overestimated compared to PSS/E estimates (EREA & DEA, 2022a).

Storage

Storage could play a large role in balancing the power system but only after 2030 as seen in Figure 6.7. The optimal location of storage facilities is shown in Figure 6.8 for the NZ scenario. The Highlands region needs the largest amount of battery storage which seems reasonable since Highlands has much more wind and solar power generation than the demand in the region. Southeast and Southcentral also have large needs for battery storage. These regions also have a large imbalance between generation and regional demand. Therefore, it seems like battery storage is to some extent replacing transmission lines in the long term.

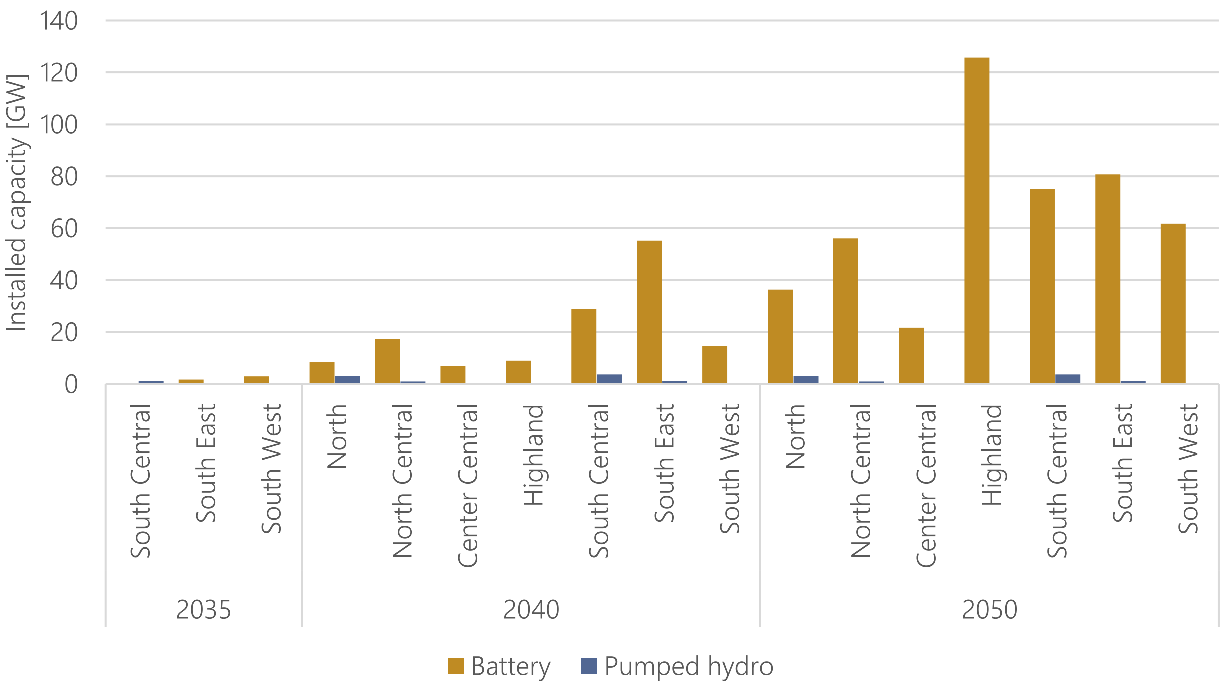

Figure 6.8 Installed storage capacity per region for NZ in 2035, 2040 and 2050

The potential for PHS is only 10 GW while the potential for batteries is not limited. PHS has a c-ratio (ratio between energy stored (MWh) and charge/discharge capacity (MW)) of around 10 and cannot be changed much due to geographical and environmental constraints. But batteries can be more freely designed with the most optimal c-rate and this feature is also represented in the model. Table 6.1 shows the c-ratio for BSL and NZ scenario from 2035 to 2050. It is observed that the optimal c-rate in 2035 is around 2.5 while in the longer term it varies between 2.7 and 5.1 between scenarios. This indicates that a higher c-ratio is optimal as the RE share increases. Table 6.1 also shows that PHS and batteries capacities are gradually increasing together thus supplementing each other well. But the vast majority of storage is batteries.

Table 6.1 C-ratios for batteries and PHS per scenario from 2035 to 2050

Year	Scenario	Batteries			Pumped hydro		
		Inverter capacity (GW)	Storage volume (GWh)	C-ratio	Pump/Turbine Capacity (GW)	Storage volume (GWh)	C-ratio
2035	**BSL**	-	-	-	1	10	8.66
	GP	1	2	2.51	1	10	8.66
	NZ	5	11	2.51	1	10	8.66
2040	**BSL**	3	9	2.73	1	10	8.66
	GP	10	26	2.62	3	23	8.67
	NZ	140	678	4.84	9	83	9.33
2045	**BSL**	6	17	2.73	1	10	8.66
	GP	21	59	2.83	6	59	9.81
	NZ	331	1,619	4.89	9	83	9.33
2050	**BSL**	25	68	2.75	1	10	8.66
	GP	80	281	3.51	6	59	9.81
	NZ	457	2,324	5.08	9	83	9.33

Most scenarios show a large amount of battery storage in the long term, but large-scale battery storage is an emerging technology and not widely used yet. The financial and technical parameters of batteries are updated for 2021 in the Viet Nam Technology Catalogue for power generation and storage (EREA & DEA, 2021a), but the projections are still uncertain. Because of the uncertainty related to projecting prices for battery technologies, EOR21 includes a sensitivity analysis based on the NZ scenario but with higher costs of batteries. Figure 6.9 shows that a higher battery cost leads to a reduced installed battery capacity from around 460 GW to around 270 GW. This also leads to a reduced solar PV capacity from around 950 GW to around 800 GW.

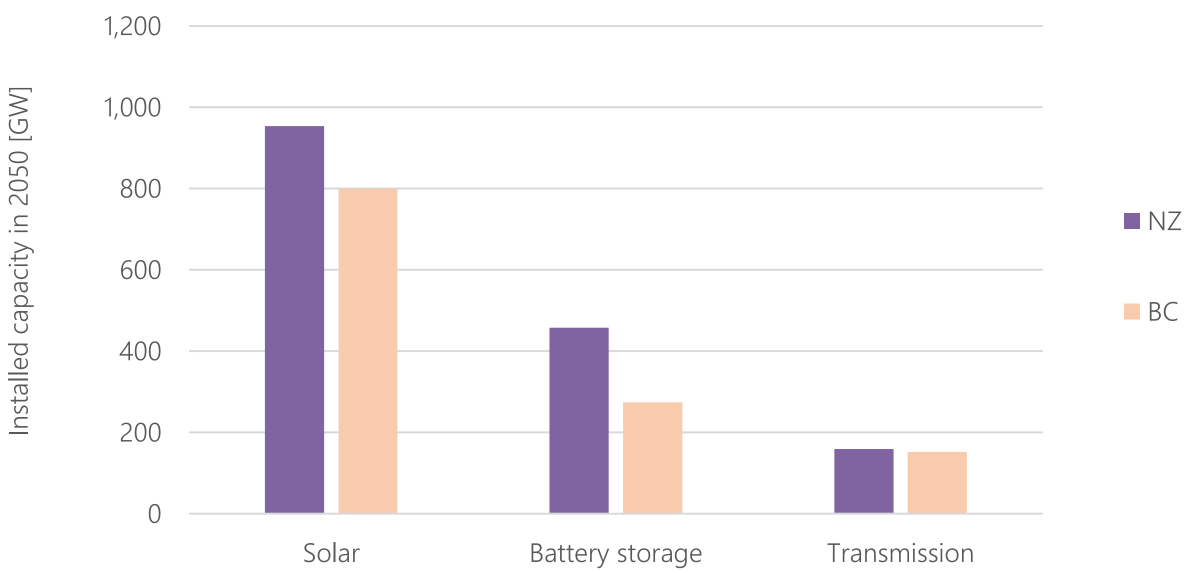

Figure 6.9 Installed solar, battery, and transmission capacity in 2050 in NZ compared to NZ with higher battery cost (BC).

Since disposal of batteries can be associated with extra costs if the appropriate recycling systems are not implemented, an additional cost of 0.02-0.03 M USD/MW is added as disposal cost at the end of life of the batteries.

Demand flexibility

Flexibility of electricity consumption could also play a role in the balancing in a net zero energy system largely based on variable RE. Advances in communication and control technologies, electricity market development along with increased share of wind and solar power make it possible and increasingly profitable to adjust some types of consumption according to RE generation. Furthermore, since RE will fuel the transition of the other sectors including the transport and industry sectors, new opportunities for flexible consumption also arise. Electric vehicles around the world are part of Vehicle-to-Grid (V2G) system in which EVs are providing flexibility to the grid by shifting the time of charging, adjusting the charging rate and some even by discharging to the grid. As the share of EVs increases, the potential for flexibility also increases. In the longer-term, hydrogen production from electrolysis (and ammonia production from hydrogen) might be needed in large scale to transition the heavy transport sector (see Chapter 8. Transport). Since hydrogen is easier to store than electricity, the electrolysers could also provide a high capacity of flexibility. Other industrial electricity consumers could also have potential for flexibility.

In the NZ scenario where the transport sector is largely electrified, there are around 77 million EVs with a total battery capacity of around 2,600 GWh and a maximum charge/discharge rate of around 550 GW in 2050. This is even more than the installed utility-scale battery storage in the NZ scenario. If only a small share of this storage capacity becomes available for balancing the power system, that could reduce the need for utility-scale batteries. The EVs are not always available for balancing services since they are not always connected to the grid and since the owners need them fully charged at certain times. Assuming a conservative 20%,30%,40% of EVs in 2030,2040,2050 respectively that would naturally charge at a given time but be willing to postpone charging within the day results in up to a maximum of 16 GW of down-regulating demand response from EVs being considered in the model, in NZ, in 2050. Upregulating capacity is assumed higher as more people might be inclined to charge their vehicle additionally, leading to a maximum of 51 GW. Similar assumptions are included for the industrial sector though with lower rates of available flexibility amount to around 13 GW of consumption available to shift within the day.

An example of the behaviour of flexible demand is seen in Figure 6.2 for BSL in 2035. Furthermore, the total available potential of demand flexibility in all scenarios is shown in Figure 6.7.

Preconditions for realising demand flexibility include providing incentives and developing communication and control standards. Therefore, the wholesale market must be developed to support demand side flexibility. Furthermore, ancillary services markets should be developed, and they should support participation of the demand side flexibility.

6.3 Key Messages and Recommendations

Reinforce the transmission system as soon as possible

According to available data, the best resource for RE is in the southern regions whereas the demand centres are around Ha Noi and Ho Chi Minh City. Therefore, to fulfil the emissions reduction commitments, a comprehensive expansion and enhancement of the transmission system is needed. An additional interregional transmission capacity of 12 GW already in 2030 is needed in all scenarios corresponding to around 40% of the transmission capacity in 2020. Furthermore, to reach net zero in 2050 a total interregional transmission capacity of around 160 GW is needed equivalent to 5-6 times the capacity in 2020. The transmission lines needed include HVDC (High Voltage Direct Current) lines from Centre Central and South Central to North of 39 GW and 18 GW respectively.

Prepare for storage to play a central role after 2030

To reach net zero in 2050 around 450 GW of storage is needed, but the analysis suggests that only after 2030 is large-scale battery storage needed and cost-efficient. Future battery costs are uncertain and if they turn out 150%

higher than expected, the needed battery storage would "only" be 270 GW and the optimal power mix could shift towards around 150 GW solar power being replaced by 50 GW wind power and 23 GW of nuclear power.

Ensure new and existing thermal power plants to be flexible

Thermal power plants will play a different role in the transition to a net zero power system converting from providers of baseload to integrators of renewables and having much lower capacity factors. Therefore, new and retrofitted existing thermal power plants must become more flexible in terms of ramp rates, minimum load, and startup time.

Optimal hourly merit order dispatch is assumed in the analyses. This is normally achieved with wholesale power markets. Therefore, it is recommended to avoid new fixed price contracts with minimum generation agreements. Instead, the power plants should sell their electricity and services in the power markets.

Ensure demand-side flexibility

An efficient integration of variable renewables should also include demand side flexibility, especially from EVs in the short term and electrolysis in the longer term. EVs can charge flexibly with little or no loss of comfort and could have a total charge/discharge capacity of 500-600 GW thus exceeding that of large-scale batteries.

If flexible charging is not achieved, there is a risk of local grid overloads and an increased need for other measures of balancing. Furthermore, communication and control infrastructure and standards are prerequisites and must be in place at the beginning of the transition of the transport sector.

Ancillary services markets

To ensure cost-efficient balancing of the power system, markets for ancillary services must be implemented as soon as possible. The ancillary services markets should be technology neutral and allow for participation from all types of electricity generating technologies as well as storage and demand facilities. The remuneration should be attractive e.g., based on a component of capacity payment and a component of activation payment both based on merit order selection.

7

Transport

7. Transport

7.1 Status and Trends

Most domestic passenger transport in Viet Nam today is done by road transport and aviation. Railways and ships only play a small role. Passenger transport has been steadily growing in the last ten years though with a sharp decrease in 2020 due to the COVID-19 pandemic as seen in Figure 7.1. The total passenger transport is expected to exceed 800 bn passenger-kilometre[3] by 2030; more than a 5-fold increase in just 10 years.

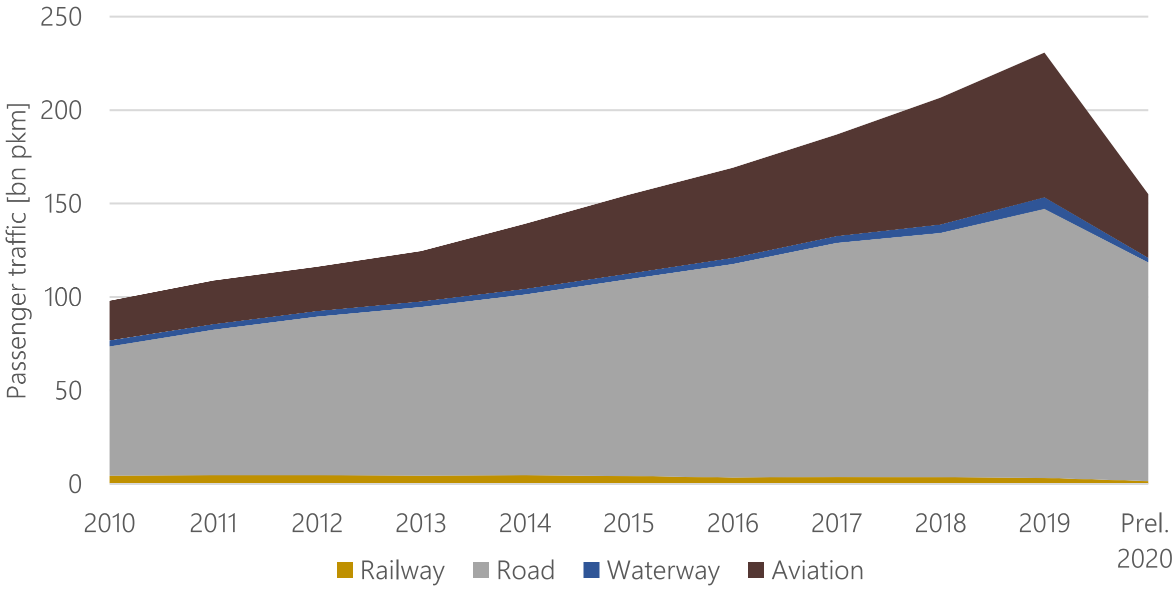

Figure 7.1 Passenger traffic by types of transport (Source: GSO Statistical yearbook)

Domestic freight transport is mainly done by shipping and road as seen in Figure 7.2. Freight transport has also grown steadily except for 2020 due to the pandemic. The growth rates have been lower than for passenger transport.

The energy supply to the transport sector in Viet Nam constitutes 23% of total primary energy supply in 2020. Today, the sector is almost exclusively fuelled by petroleum products and hence, is responsible for around 85% of the total oil use in Viet Nam. The transport sector is responsible for 15% of CO_2 emissions, and a significant share of air pollution affecting public health negatively.

The transport sector is currently facing several challenges, which can be summarised in three categories:

- Congestions in cities. Most road transport in the large cities is done by motorbikes today. As the population becomes wealthier, many people are projected to want to swap the motorbike for a car. This could impose a large burden on the traffic in the cities which are already experiencing frequent congestion. Better public transport options might be able to reduce this development. All major cities have a wide network of busses today and the first metro line of the country opened earlier this year in Ha Noi with more metro lines in the pipeline for the coming 10 years.

- Air pollution. The large cities of Viet Nam are experiencing alarmingly high rates of air pollution with substantial negative impact on public health. The transport sector is a significant contributor to this together with the power sector, the industrial sector, and the residential sector. Potential solutions to this could be higher efficiency standards, particle filters, and electrification, more public transport and more.

[3] From TIMES results (813 bn passenger-kilometers)

- Fuel import dependency and climate impact. The transport demand is rapidly increasing and if it is to be fueled by oil products, it will have a growing climate impact as well as results in a growing fuel import dependency. A potential solution to this could be increased electrification of the transport sector and e-fuels for those parts, which are difficult to electrify, mainly aviation and shipping.

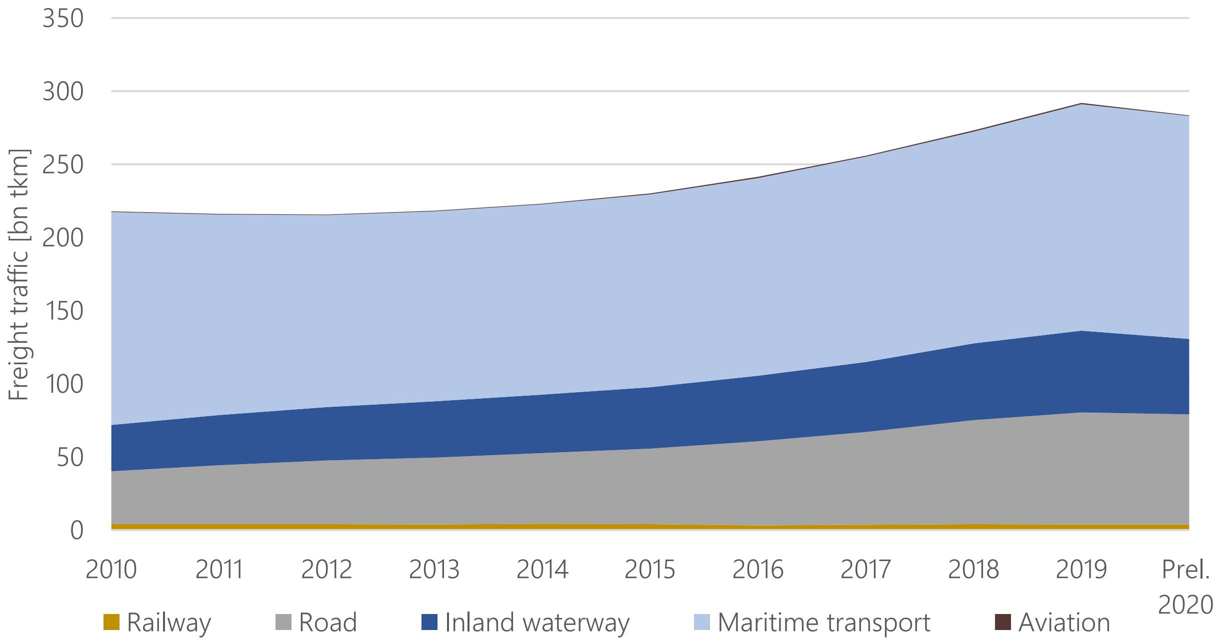

Figure 7.2 Freight traffic by type of transport. (Source: GSO Statistical yearbook)

7.2 Transport Outlook

Final energy demand and CO_2 emissions from the transport sector

As of today, the transport sector is one of the main emitters of CO_2 in Viet Nam, due to its high dependency on fossil fuels for all modes of transport, be it passenger or freight. In line with the overall growth projections for Viet Nam, the transport service demand is expected to increase significantly towards 2050 compared to 2020 levels. If the energy supply remains oil based, CO_2 emissions will increase at similar rates.

The person transport demand is projected to grow almost linearly to multiply by a factor of 3.5 until 2050, whilst freight demand is projected to increase exponentially up to a factor of 7 towards 2050, as presented in Figure 7.3. The service demands in the passenger and freight transport do not grow uniformly. Most notably, the largest service demands are for passenger transport by cars and coastal freight transport. Their respective growth in 2050 relative to 2020 is 8.5 and 6.9 times. The same energy service demand projections for passenger transport are used throughout main scenarios, while exogenous modal shift from coastal and inland freight transport, trucks and light commercial vehicles is introduced towards electrified railway transport in GT and NZ scenarios.

The present chapter describes the development of the transport sector in three scenarios:

- The BSL scenario is based on current policies without exogenous modal shift or interventions in the transport sector. It serves as a BSL scenario for comparison.
- A GT scenario is developed to show the consequence of implementing specific policy targets in the transport sector aiming at a more environmentally friendly transport sector in Viet Nam. The implemented targets comprise among others higher electrification rates of public and freight transport as well as a higher utilization of public transport in Ha Noi and Ho Chi Minh City. Table 7.1 gives the full overview of

the targets related to the transport sector. The transport service demands are exogenously defined for each technology, such as car, motorbike, or rail freight transport; the model does not optimise on the modal choice and any modal shifts are external inputs. The electrification rates of transport technologies are given as minimum shares.

- The NZ scenario includes the same assumptions as GT and moreover the target to reach net zero GHG emissions by 2050.

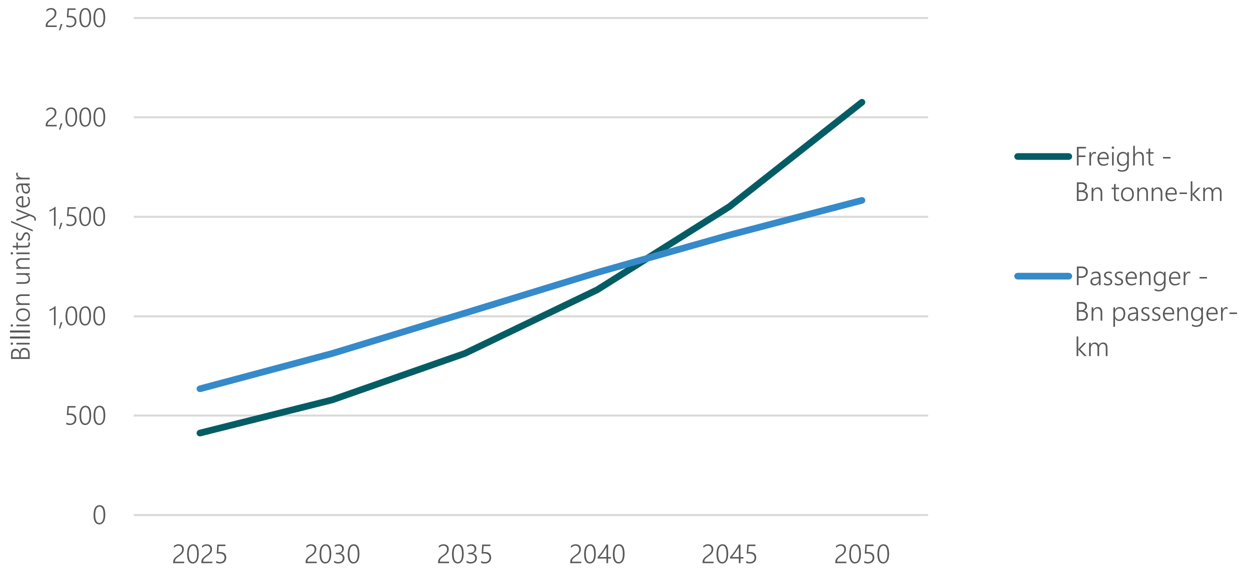

Figure 7.3 Projected demand for person transport and freight transport in BSL scenario

Table 7.1 Exogenous assumptions in GT scenario

Passenger transport			
	Motorbikes	no new gasoline motorbikes[4] min 30% electric motorbikes	from 2030 from 2030
	Cars	min 75% of new cars are EV	by 2050
	Bus	min 90% of new busses are electrified	by 2050
	Train	min 57% of train transport is electrified	by 2050
	Modal shift	70% of motorbike transport is shifted to metro	by 2050
Freight transport			
	Train	min 35% of train transport is electrified	by 2050
	Trucks	min 90% of new trucks are electrified	by 2050
	Modal shift	35% of freight transport by electric trains	by 2050
Electricity demand of the transport sector			
	additional electricity demand of transport sector to be supplied by RE		all years

Figure 7.4 shows the FEC divided into fuels and the CO_2 emissions from the transport sector for the three target scenarios. In 2020, the transport sector is dominated by diesel and gasoline, which constitute 81% of FEC. In 2030, the increase of transportation demands in BSL scenario is covered mostly by gasoline, but due to growth of aviation demand and larger penetration of kerosene, shares of gasoline and diesel and decreasing. NZ and GT scenarios look alike in 2030, they use less gasoline and diesel and more electricity and result in around 18% less

[4] This constraint is shared with other scenarios

CO_2 emissions compared to BSL scenario. Despite the growth of kerosene and electricity use and decrease of gasoline use in all three presented scenarios, the differences between the scenarios are more pronounced in 2040 - diesel consumption grows by over 65% in BSL scenario, while it remains stable in NZ scenario. Furthermore, the electricity consumption grows the strongest in NZ scenario, more than 4 times between 2030 and 2040. Finally, FEC looks fully different in the analysed scenarios in 2050 – 62% of FEC in BSL is still supplied by gasoline and diesel, 31% of FEC In GT scenario is supplied by electricity while the rest is based on fossil fuels. NZ scenario in 2050 is dominated by electricity (45% of FEC) and biofuels and e-fuels (30% of FEC) resulting in 23 Mt CO_2, the remaining emissions are due to fuel oil in the shipping sector. This means that the NZ scenario is not fully compliant with the net zero emission target of the Vietnamese Government. Further abatement measures to reach net zero emissions for the shipping industry are outlined in Chapter 4. Pathway to Net zero.

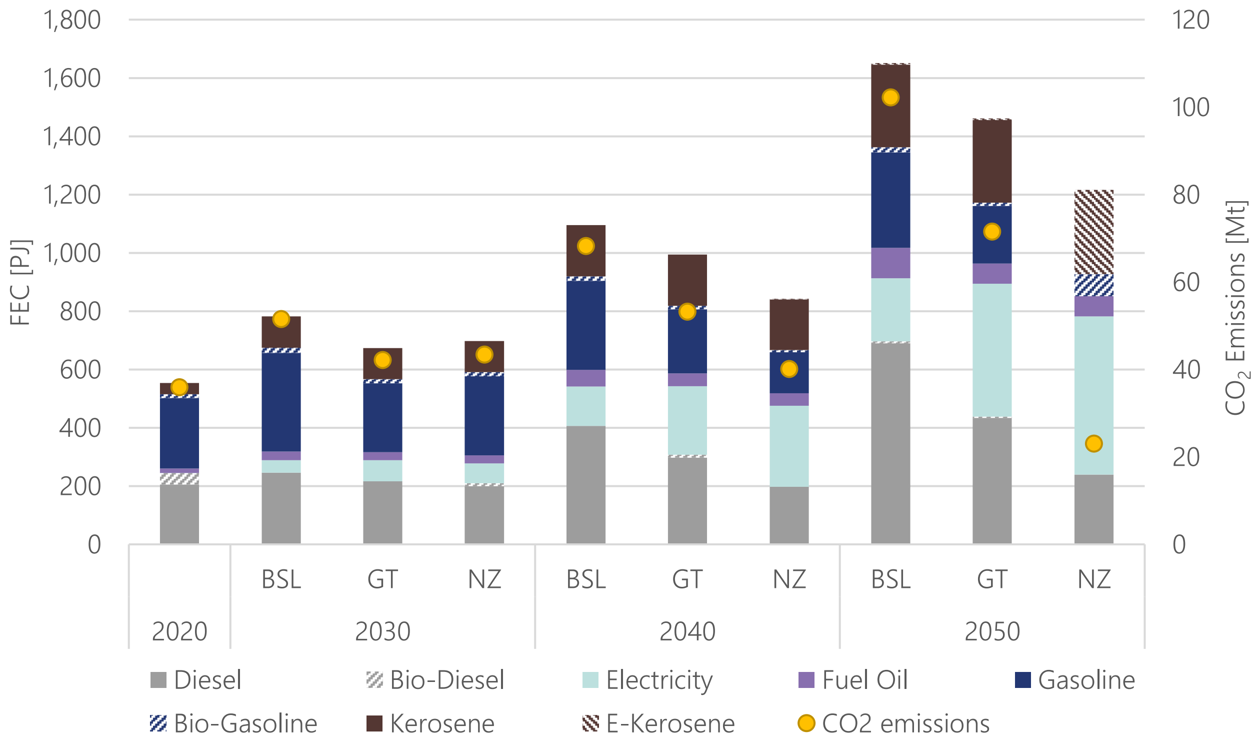

Figure 7.4 Final energy consumption and CO_2 emissions (secondary axis) from the transport sector

The main takeaway from Figure 7.4 is that if the right actions are taken, FEC can grow much less, than the passenger and freight service demand of 3.5 and 6.9 times between 2020 and 2050, respectively. This is due to more efficient transport means and electrification. Biofuels seems not to be cost-efficient and are used mainly where electrification is not possible, but emission reduction targets must be met. Direct use of electricity increased from close to zero in 2020 to between 13% in BSL and 45% of FEC in NZ scenario in 2050.

Passenger transport

Figure 7.5 shows the passenger transport demand aggregated into fuels. The figure covers private and public transport means, namely cars, motorbikes, buses, trains, ships, and aviation. The amount of gasoline decreases in all scenarios, electrification, and use of kerosene in the aviation sector grow in all scenarios. Biofuels seem to be an expensive fuel switching option and are used only in 2050 in NZ scenario to replace kerosene in aviation (e-kerosene) and gasoline for scooters and motorbikes (bio-gasoline). Metro is responsible for a negligible part of electrification in BSL scenario but delivers more than 150 M passenger-km in NZ and GT scenario in 2050.

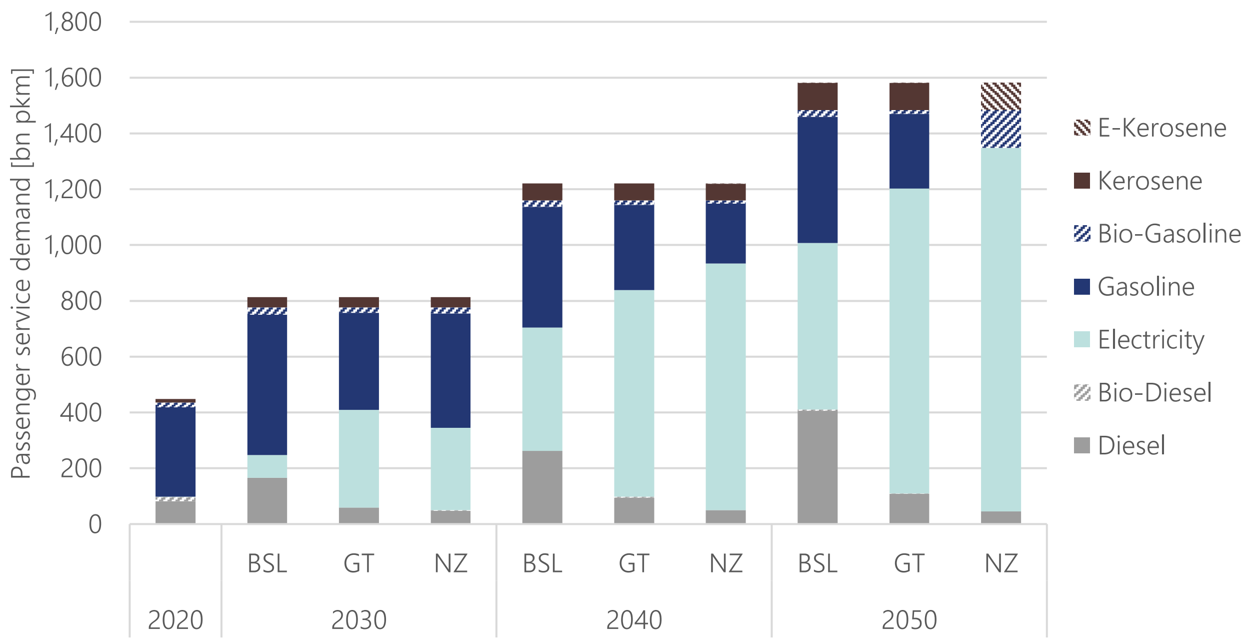

Figure 7.5 Passenger transport demand by fuel type

Figure 7.6 presents difference in passenger demand between BSL and GT, and between BSL and NZ scenario aggregated by fuel and transport mode. Railway is excluded from Figure 7.5 because there was no visible difference from BSL, while cars and vans are grouped into cars to improve visibility. The modal shift is exogenous, i.e., it is not optimised by the modelling suite. The optimised dimension in the transport sector is the choice of transport device based on the fuel use, such as for example electrical, fossil fuel or biofuel-fuelled cars.

Private passenger transport demand is served by cars and MBs. There is currently around 50 million MBs in Viet Nam but still the amount is expected to increase by around 56% in 2050 in BSL scenario. The expected increase in transport demand served by MBs in GT and NZ scenarios is only 28% due to exogenous modal shift towards metro in Ho Chi Minh City and Ha Noi. Electric MBs will be competitive from 2030 in BSL scenario but not to the extent that a 30% share of new MBs can be expected by that year, as is the target for the GT scenario. NZ scenario in 2050 is characterized by 60% electric MBs and 40% supplied by bio-gasoline.

The amount of car transport is expected to increase more than 8-fold by 2050 and electric cars will be competitive from 2030. To reach the 2050 net zero target almost all cars must be electric by 2050. Use of biofuels is negligible in BSL and GT scenarios, while biofuels are not used for fuelling cars in NZ scenario throughout the analysed period.

Share of electricity use in cars and MBs combined reaches 31%, 65% and 84% in 2050 in BSL, GT and NZ scenario, respectively. This shows that electrification of the private passenger fleet should be more aggressive than in the GT scenario to meet net zero emissions by 2050 in the most cost-effective way. The modal shift towards public transport in all scenarios, such as busses and coaches, play an important role in keeping the fuel consumption under control.

Passenger transport demand within cities is projected to increase around 5 times between 2020 and 2050. Today most public transport is diesel busses. Diesel busses will continue to be dominant fuel for busses in BSL scenario. The share of electric busses in GT scenario will reach 66% in 2050, but to reach the 2050 net zero target almost all busses must be electric from 2040. The large cities in Viet Nam are planning metro networks and the first metro line in Viet Nam opened in Ha Noi in the fall of 2021. In GT and NZ scenario, the shift towards metro increases electrification.

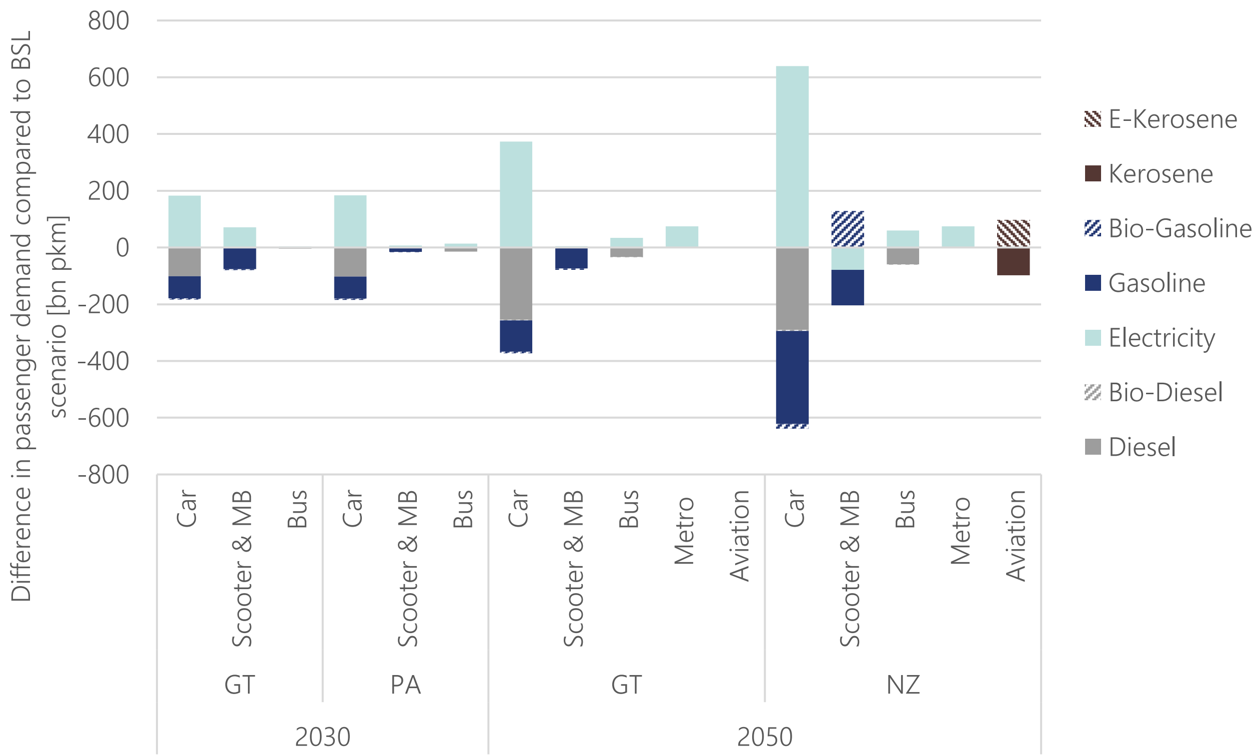

Figure 7.6 Difference in passenger transport demand compared to the BSL scenario by transport mode and fuel type

The demand for domestic aviation is expected to grow more than 7-fold by 2050 while ferry transport is expected to grow almost 4-fold. Airplanes are fuelled by kerosene in all scenarios throughout the analysed period, with the only exception being NZ scenario in 2050 in which kerosene is replaced by bio-kerosene. Ferries are fuelled by diesel in all scenarios, which does not correspond to net zero target. Short-distance electric ferries are already in operation in many countries today and are expected to increase in the future. Ammonia is a supply option for both short- and long-distance ferries. More details on potential net zero pathway for ferries can be found in Chapter 4. Pathway to Net zero.

Freight transport

Figure 7.7 shows the freight transport demand aggregated into fuels. The figure covers all modes of freight transport, namely trains, trucks, and ships. Seven-fold increase in freight transport demand results in growth of diesel, electricity, and fuel oil use in all scenarios between 2020 and 2050. The share of diesel decreases, while the electricity share increases in all scenarios reaching 48% in NZ scenario. In NZ scenario, trucks and trains are fully electrified in 2050 while ships run on fuel oil. This result is not in line with net zero target; details on how to reach bet-zero emissions in the shipping sector, such as ammonia use, are outlined in Chapter 4. Pathway to Net zero. Biofuels and e-fuels are not part of the cost-optimal solution for the shipping sector.

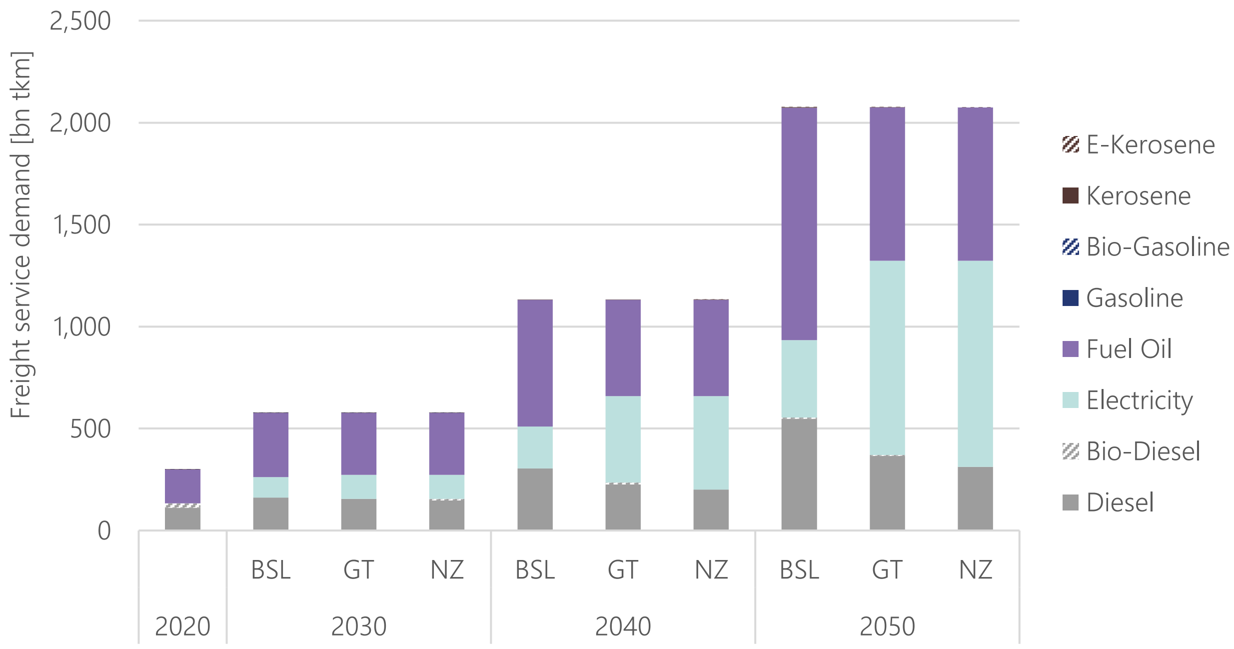

Figure 7.7 Freight service demand by fuel type

Figure 7.8 presents difference in freight transport demand between BSL and GT and between BSL and NZ scenario aggregated by fuel and transport mode. Today, domestic freight transport is covered by roughly 78% shipping and 22% trucking. Electric trains have a large potential to take over parts of the increasing freight transport demand. Aviation is not used for domestic freight transport today and is not considered a suitable solution in the future either.

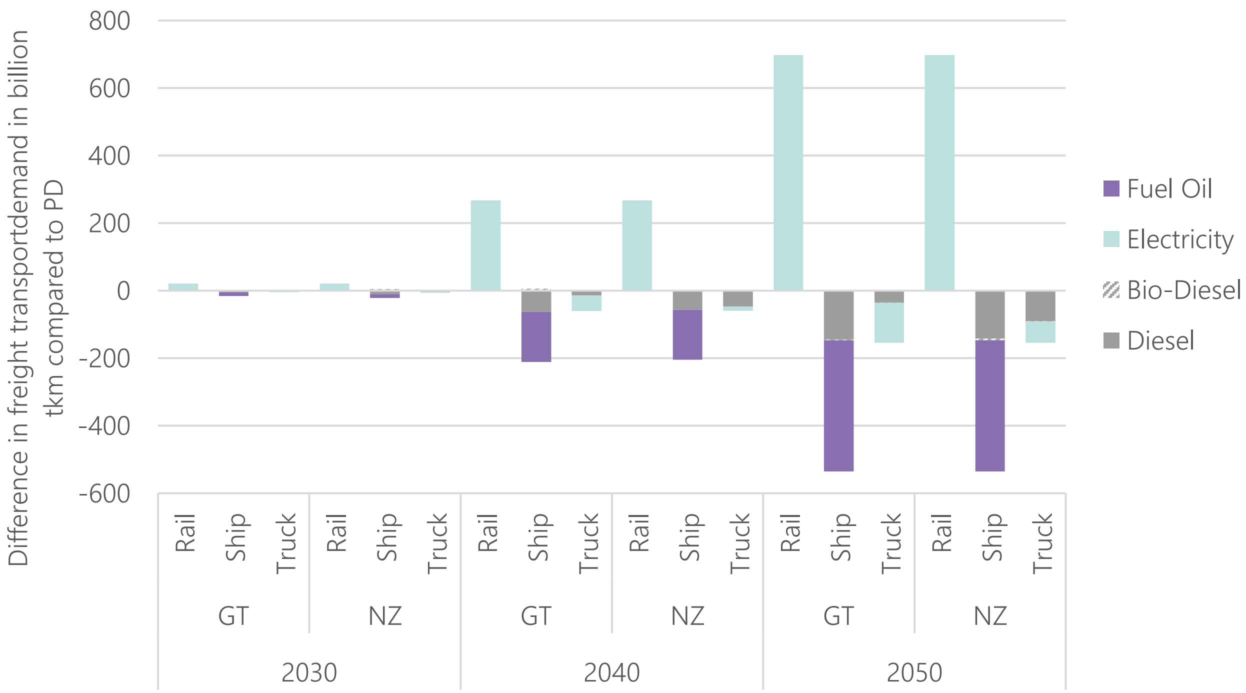

Figure 7.8 Difference in freight transport demand compared to the BSL scenario by transport mode and fuel type

Results from all scenarios are very similar in 2030, the main differences happen after. As for the passenger transport, the freight modal shift is exogenous, i.e., it is not optimised by the modelling suite. The optimised dimension in the transport sector is the choice of transport device based on the fuel use. The results are influenced by exogenous modal shift from trucks and ships to railway from 2035 to 2050. The main fuel supply option for trains is electricity, supplying over 94% and 96% of the train freight demand in 2040 and 2050, respectively in both NZ and GT scenarios. Shipping is a cost-efficient means of freight transport and will grow in all scenarios but more in BSL than in GT and NZ scenarios due to fewer freight trains in BSL. As mentioned above, the models employed in EOR21 do not offer renewable alternative for shipping, which are supplied by diesel and fuel oil in all scenarios. Trucks are currently fuelled by diesel but already from 2025, electric trucks are competitive, and the share of electric trucks grows substantially. Diesel-fuelled trucks will also grow slowly from 2025 in BSL scenario but in GT and NZ scenario the share of electric trucks will be over 94% from 2040.

Cost of the transport sector

The costs of BSL, GT and NZ scenarios are presented in Figure 7.9. The marginal (unit) fuel costs in NZ scenario close to the end of the analysed period become unrealistically large due to approaching resource limitations. Therefore, instead of presenting the unit costs from NZ scenario, Figure 7.9 is presented with (unit) fuel costs from GT scenario.

The costs of the transport sector grow in all scenarios due to increased transport demand. In 2030, the costs are similar in all three scenarios; however, they are the lowest in BSL scenario and the highest in GT scenario. The costs are the highest in GT scenario due to the strongest switch from gasoline to electric motorbikes. In 2050, the largest cost is in NZ scenario due to the net zero target in 2050 and intensive switching of trucks and busses to electricity. This continues into 2050, where all buses, almost all cars and all metro convert to electricity. High fuel costs in GT and NZ scenario reflect increase of transport demand, large electrification of the passenger transport and high electricity prices. The investment costs are reflecting the cost of transport devices, thus the difference in investment costs is due to new vehicles and charging infrastructure.

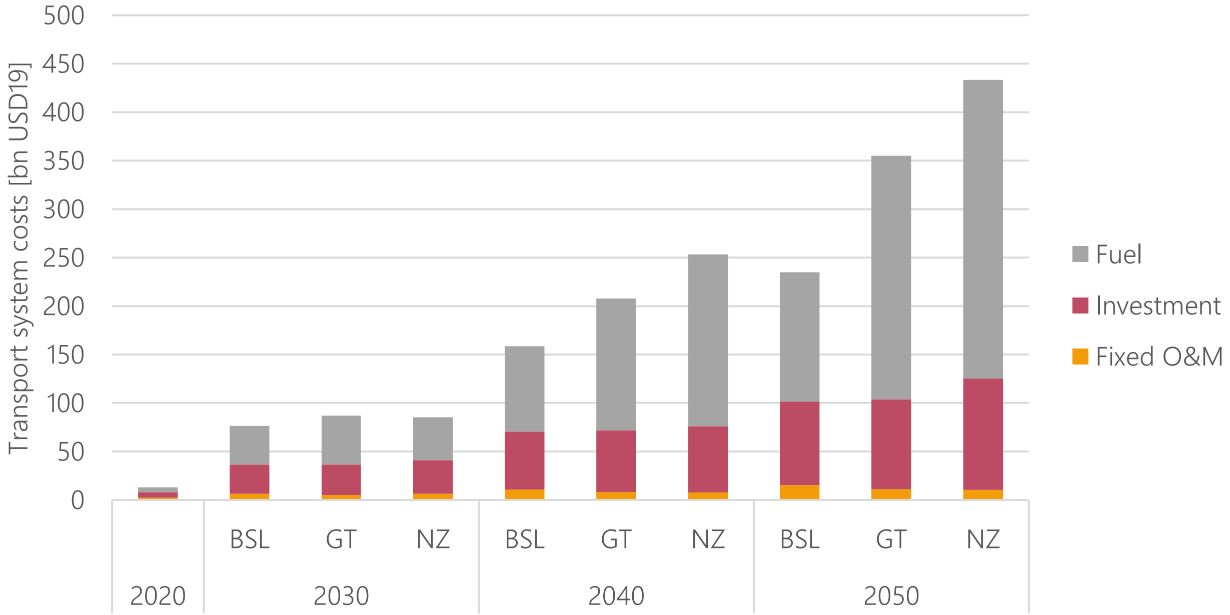

Figure 7.9 Annual costs of the transport system

7.3 Key Messages and Recommendations

Early action is needed for fuels shift and electrification of the transport sector to reach net zero emissions by 2050. Co-benefits are less air pollution and less import dependency

Significant increase in transport demand is expected: 3.5 and 7 times for passenger and freight between 2020 and 2050, respectively. Direct electrification is key – around 80% and 50% of passenger and freight demand respectively will be electrified in the NZ scenario in 2050. Road transport should be almost fully electrified.

As an early action, a swift transition of the transport sector requires a rapid expansion and upgrade of charging and power distribution infrastructure. Electric cars, trucks and vans are first to become part of the fleet (from 2025), motorbikes, buses, and metro from 2030. All new vans should be electric from 2030, all new buses and trucks from 2040 to reach net zero.

The number of cars is projected to increase 3.0 times in 2030 and 8.5 times in 2050 compared to 2020, respectively. Therefore, a shift from private to collective passenger transport will be needed to avoid congestion, pollution, and additional fuel consumption.

The combined effect of electrification and switch towards biofuels in the transport sector in the NZ scenario will result in 100 Mt less CO_2 emissions in 2050 compared to the BSL scenario.

1/3 of the transport demand needs to be supplied by more expensive options than direct electrification

Biofuels and e-fuels are used at the end of the analysed period in the net zero pathway in cases where an electrical alternative is not viable. Direct electrification supplies almost 2/3 of the transport demand in 2050 in NZ scenario. The rest should be covered by e-fuels and biofuels.

For shipping and aviation, since a viable electrification alternative does not currently exist, bio- and e-fuels are currently the best option to supply more than 1,000 bn ton-km of freight demand in 2050 in NZ scenario.

Modal shift of over 700 bn ton-km of freight transport demand from trucks to railway (which is easy to electrify) helps reaching the net zero target.

Start phasing out ICEs from 2025 and switch to collective transport from 2030

A roadmap for the future transport sector in Viet Nam should include strong reform policies, effective measures, and incentives for phasing out ICEs, switch to collective transport modes, developing charging and distribution infrastructure and switching towards electric railway in the freight transport.

8

Energy Demand

8. Energy Demand

8.1 Status and Trends

The energy consumption in Viet Nam has increased rapidly for decades. During the period 2010 to 2019, energy demand grew by an average of 4.3% p.a. (Institute of Energy, 2021). Moreover, since 2010, the Vietnamese GDP has increased faster than the energy demand. As a result, the energy intensity of the economy has dropped by 14% between 2010 and 2019. The energy intensity is, however, still considerably higher than in the neighbouring countries. Another significant trend in Viet Nam is the fast electrification of the economy. From 2010 to 2019, electricity intensity (electricity demand per unit of GDP) has increased by 43%.

It is a continuing challenge to expand the electricity generation capacity with the rapid pace of the energy demand growth, and particularly the rapid growth in electricity demand specifically. For this reason, Viet Nam has promoted the efficient use of energy since 2006 through a range of different programs. The main program is VNEEP, which is currently in its third phase. The program created energy savings of 3.4% from 2006 to 2010 compared to a Business-as-usual (BaU) scenario and the 2011-2015 target of 5.7% reduction was reportedly met and even surpassed in certain industries (The Ministry of Industry and Trade, March 2022).

The current program phase, VNEEP3, is scheduled for 2019-2030, split into two periods from 2019-2025 and 2026-2030. The 2025 targets include an overall energy demand reduction of 5-7%. In addition, several targets are set related to the EE of specific sub-sectors as well as power losses, policy development targets, targets for compliance with regulation and more. The 2030 targets include an overall energy demand saving of 8-10% during the period 2019-2030 compared to a BaU scenario.

The implementation of VNEEP3 has been somewhat slowed down by several factors, including the loss of momentum interim phase between VNEEP2 and VNEEP3, and the COVID-19 pandemic. The government has launched several new initiatives to further strengthen EE.

Decree No. 06/2022/ND-CP of 7 January 2022 stipulates the issuance of carbon emission quota, based on which the entities must make carbon reduction plans. A carbon market is planned for full operation by 2028, with the pilot starting in 2025.

MOIT, with the assistance of the Danish Energy Agency, is working on the development of a voluntary agreement scheme with technical guidelines for EE in industrial sectors. This should support the implementation of Decree No. 06 to support and stimulate adoption of best available technologies.

When fully implemented, Decree No. 06 could considerably increase the financial incentive for energy intensive sectors, such as heavy industries, to invest more in EE.

The same goes for a potential enforcement of Circular 25/2020/TT-BCT, which would provide a solid data foundation and implementation of EE of large consumers. Circular 25/2020/TT-BCT stipulates the reporting and auditing of large energy users (more than 100,000 kWh annually) and would directly provide improvements to EE as well as benefit long-term energy planning studies.

Other international cooperation initiatives are ongoing to strengthen the VNEEP3 program implementation, addressing particularly VNEEP3 compliance issues; easing financing of EE investments and strengthening MOIT program implementation capacity.

In addition to the VNEEP3 program, a demand side management program (DSM) has been running for several years with a particular focus on efficient use of electricity, including installation of time-of-use electricity meters, efficient lighting programs, promotion of solar water heaters and solar rooftop systems to save on grid electricity, and demand response programs to reduce peak electricity demand. The DSM program is planned to continue until 2030.

8.2 Energy Demand Outlook

The EOR21 assumes the same development of energy service demands for five main scenarios and all sensitivity scenarios except for the HD scenario, which assumes a higher demand. All main, and all sensitivity scenarios besides the HD scenario are presented in Figure 8.1 below.

The growth in energy service demands is steep across sectors but it is most pronounced in the transport sector, in which the demand grows around seven-fold between 2020 and 2050. The energy service demands increase around 6 times in the residential, commercial, and industrial sectors, and 3.4 times in the agricultural sector. The transport sector is not uniform – the increase in energy service demands ranges from 4.2 times for light commercial vehicles to 11.5 times for transport of goods via railway. Such strong demand growths put substantial pressure on the whole energy system, including import, transmission, transformation, and end-use sectors.

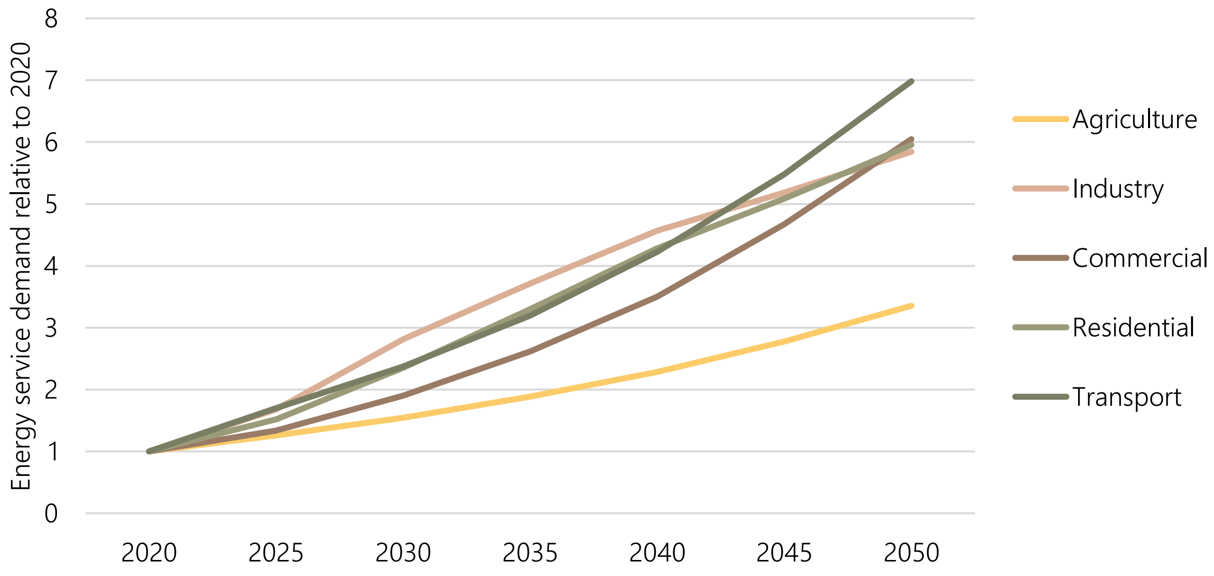

Figure 8.1 Growth of energy demand services relative to 2020

The energy service demands must be served, but that can be done efficient. For example, energy service demand in passenger transport (expressed in passenger-km) can be delivered by vehicles characterized by different EE standards, resulting in different fuel demands. Equivalent reasoning can be used to explain how the energy service demands presented in Figure 8.1 can result in different final energy demands.

The strength of the methodology applied in EOR21 is that it finds the cost-optimal development for the entire Vietnamese energy system until 2050. This means that development of one sector could appear as sub-optimal, but the benefits are happening in another sector of the energy system. The cost-optimisation methodology applied in TIMES and Balmorel models is described in detail in the Technical Report.

In the following figures, four scenarios are presented each with different purposes: The BSL-scenario serves as a basis for comparison, the NZ scenario shows the role of EE in a very ambitious climate scenario, while the LowEE scenario and HD scenario aim to show the effects of a low EE penetration relative to the demand on costs, emissions, and final energy consumption.

Low EE penetration rates relative to demands in the LowEE and HD scenarios are caused by different reasons: The maximum EE implementation rates are lower in the LowEE scenario than in all other scenarios, while in the HD scenario, the demands are higher than in the other scenarios.

The maximum EE implementation rates relative to the potentials presented in the VNEEP study is presented in Table 8.1 below. The remaining devices are either existing devices or 'standard' devices. 'Standard'-level devices are still better than the existing ones, but subpar to the efficient ones. Since the existing devices are dying out, the sum of efficient and 'standard' devices is reaching 100% in 2050. Thus, the VNEEP targets are fulfilled in all scenarios. In the transport sector, EE is reflected as investment opportunities in more efficient vehicles as well as (exogenous) change from one form of transportation to another (I.e., modal shift).

Table 8.1 Maximum EE implementation in LowEE and other scenarios

Scenario	2025		2030		2050	
	Agricultural, Industrial	Residential, Commercial	Agricultural, Industrial	Residential, Commercial	Agricultural, Industrial	Residential, Commercial
All other scenarios	50%	60%	70%	80%	100%	100%
LowEE sensitivity	25%	30%	35%	40%	50%	50%

The implementation rates of energy-efficient technologies throughout the analysed period are presented in Figure 8.2. The energy efficient technologies are covering the increasing demand after the decommissioning of existing technologies, but also before the end of lifetime of existing technologies. The energy efficient devices correspond to different levels of EE; they are aggregated in Figure 8.2.

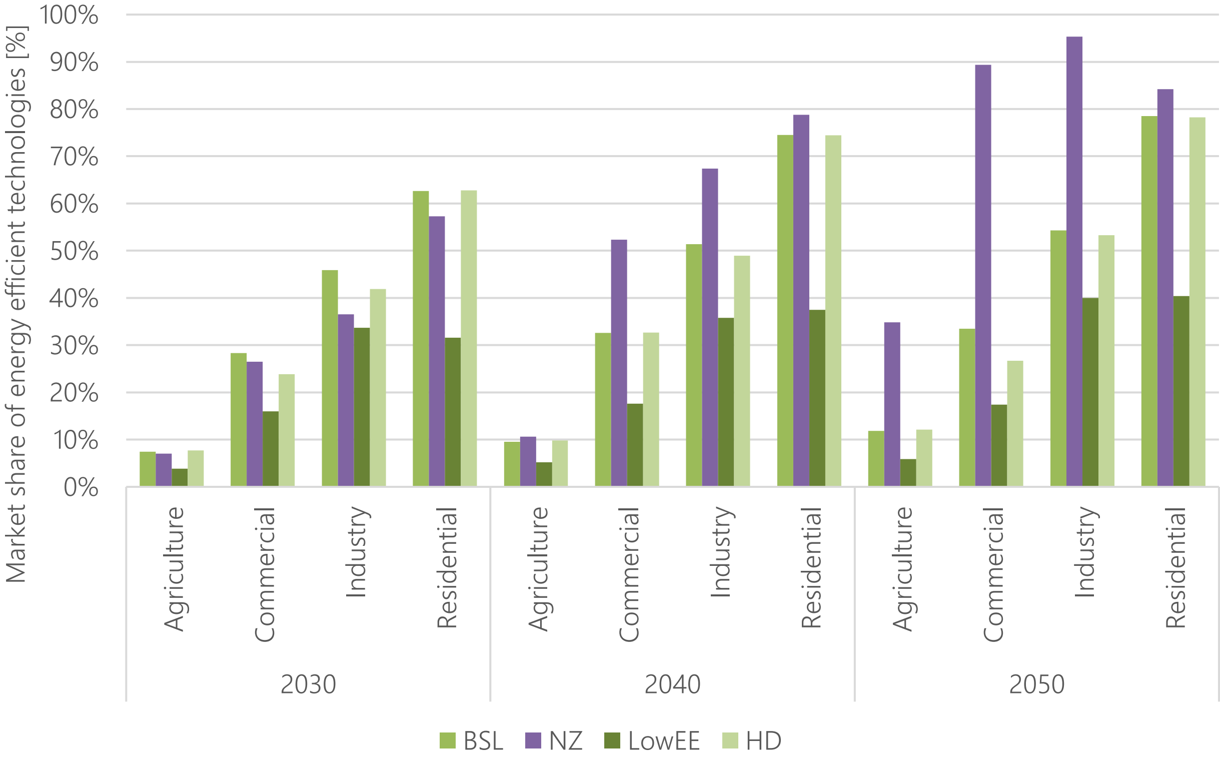

Figure 8.2 Implementation rates of energy efficient technologies

From Figure 8.2, it is evident that the implementation rates are the lowest in the agricultural sector and the highest in the residential sector. The reason for this lies in the costs:

Firstly, the least expensive savings are in the residential sector and the most expensive are in agriculture. The cost-optimisation is done for the whole energy system, rather than for individual sectors.

Secondly, the extensive implementation of EE measures starts early in the analysed period, already in 2030, even in the BSL scenario. For example, more than 60% of the EE potential in the residential sector in 2030 is utilised in the BSL scenario.

Thirdly, the implementation rates in the BSL and HD scenario are very similar before 2050, which means that the level of energy-efficient demand technologies in the BSL scenario constitutes a tipping point after which investments in production technologies become more cost-efficient.

Finally, to achieve the NZ scenario, the whole energy system needs to be pushed to the limits, including production, transformation, and the end-use sectors. The same is true for energy-efficient devices; however, the analysis results show that the scenarios are quite similar in 2030 due to the lifetime of devices incl. vehicles. The rapid implementation here starts in 2040, and a large difference across scenarios is only apparent from 2045 onward. As a result, the share of energy-efficient devices in industrial sector reaches 95%, which is the largest difference between the NZ scenario and the other analysed scenarios.

Figure 8.3 and Figure 8.4 show FEC by end-use sector and fuel, respectively. Overall, the FEC between 2020 and 2050 increases by a factor of 3.9, 3.1, 4.0 and 4.6 across scenarios. The small growth of FEC in the NZ scenario is due to this scenario experiencing the greatest implementation of energy-efficient measures, while the largest growth of FEC happens in the HD scenario where an assumed higher economic growth leads to a higher energy demand.

The commercial sector has the highest growth of FEC throughout the analysed period out of all the sectors, namely between 4.9 times and 8 times in the NZ and HD scenarios, respectively. This can be explained by a 6x growth in energy service demands and expensive EE measures compared to the residential and industrial sectors. On the other hand, despite the six-fold increase in energy service demands, FEC in the industrial and the residential sector increases by a factor of 3.3 and 4.8 in the NZ and HD scenario, respectively.

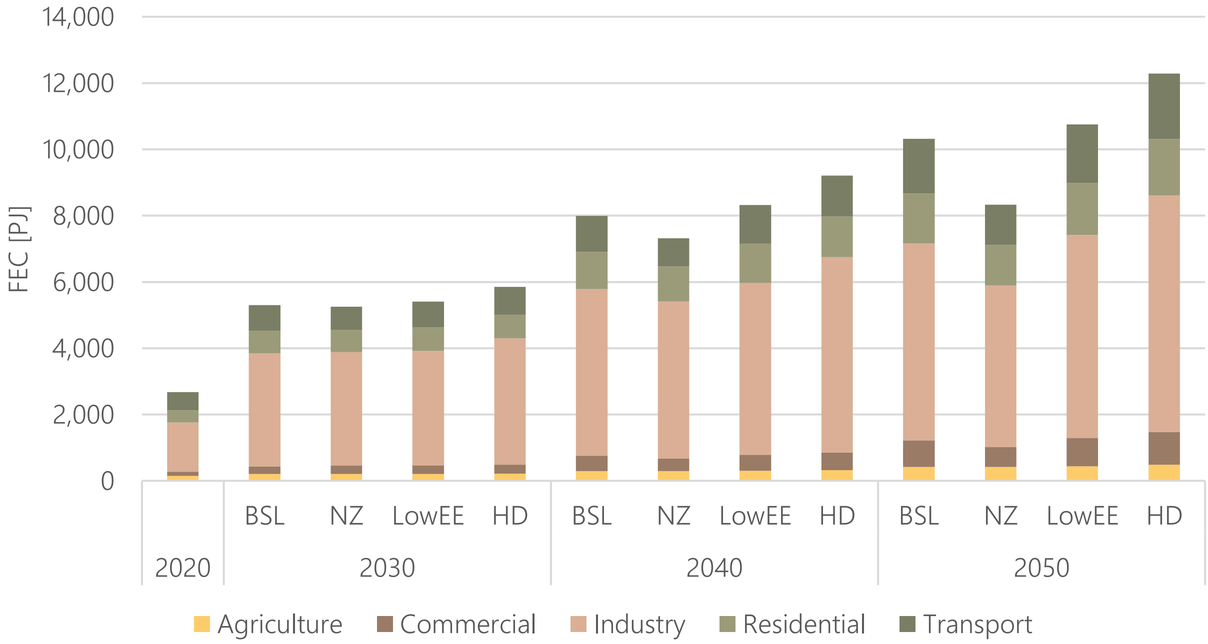

Figure 8.3 Final energy consumption by end-use sector

In all analysed scenarios, the implementation of EE measures in the residential and industrial sectors is quite similar, but the difference is in the pathway to 2050. Namely, the EE measures in the residential sector start out stronger in 2030 and 2040, while the EE measures in the industrial sector finish stronger. The reason for the relatively high penetration of EE measures in the residential sector is that there is a lot of potential at low cost.

The FEC increases from 2,600 PJ in 2020 to between 8,300 PJ in the NZ scenario and 12,200 PJ in the HD scenario in 2050, amounting to an increase of between 3.2 and 3.7 times the FEC. Different cost-optimal strategies are employed in the NZ compared to the other analysed scenarios. The NZ scenario focuses on electrification to complement more energy-efficient processes, the use of biofuels instead of oil and products, and natural gas as a replacement for coal. As a result, the electricity share in the FEC increases from 31% in 2020 to 73% in 2050.

The other scenarios employ different strategies – the share of coal in the FEC increases from 23% in 2020 to over 34% in 2050, while shares of electricity, oil products and biofuels remain constant or slightly drop. In all presented scenarios, coal and electricity take the highest share in the FEC in 2050. However, in the NZ scenario, electricity is the main fuel, while in the other scenarios it is coal, and it is mostly utilised in the industrial sector.

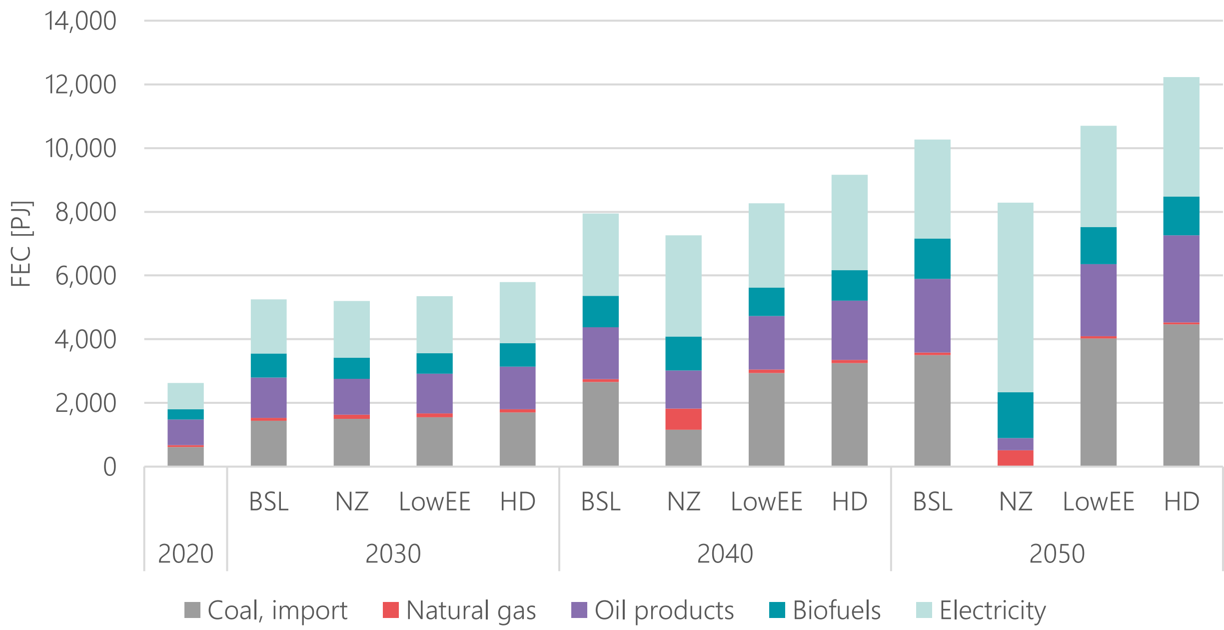

Figure 8.4 Final energy consumption by fuel

Figure 8.5 shows the annual energy system cost and total CO_2 emissions for the BSL, LowEE, HD and NZ scenarios between 2020 and 2050. When the costs of the BSL scenario are compared to the LowEE scenario, LowEE has 7% higher costs in 2030 (11 bn USD), 2% higher costs in 2040 (6 bn USD) and 1% lower energy system costs in 2050 (3 bn USD). Therefore, it is cost-optimal to utilise more than 50% of the VNEEP targets with energy-efficient devices (the rest are 'standard' devices), otherwise the energy system becomes more expensive.

The HD scenario shows the effects of higher demand on the future Vietnamese energy system. Even though the implementation of EE measures is higher than in the BSL and LowEE scenarios, the system becomes more expensive than in those scenarios. Most notably, the energy system becomes 18% more expensive than in the BSL scenario, which is based on the same assumptions except for the demand. Even though high demand might come from a higher level of economic activity in the country, the energy system needs to be prepared for that.

The cost-optimal solution points in the direction of increased EE, increased consumption of imported coal and oil products, and increased import dependence and higher CO_2 emissions. Therefore, to avoid an increased import dependence and higher CO_2 emissions, ambitious EE policies should be put in place not only to promote cost-effective measures but also as a contingency measure for an unexpected demand growth.

To reach as low as 65 Mt CO_2 emissions in 2050 in the NZ scenario, the whole energy system needs to be pushed to the limits of EE applications. The cost of the NZ scenario in 2030 are almost the same as in the BSL scenario: 12% higher in 2040 and 52% higher in 2050. The dominant part of the costs in 2050, namely around 78%, is due to capital costs, of which EE measures are a part. The EE measures in 2050 are mostly in the industrial and commercial sectors, while the significant investments in the residential sector start already from 2030.

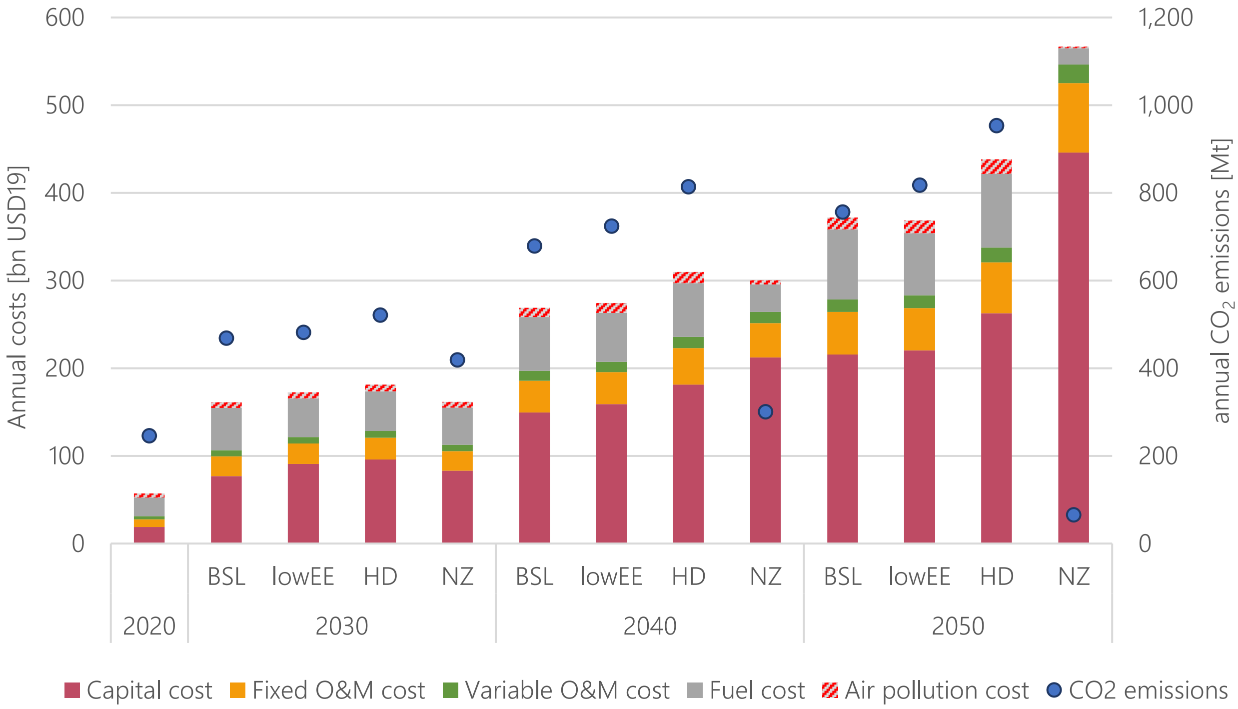

Figure 8.5 Annual total system costs and CO_2 emissions

Summary

The results of the analysed scenarios show that EE measures are an important part of the future Vietnamese energy system. A substantial part of the EE measures is cost-efficient already in 2030 and should be implemented from a system point of view. This message is valid for all scenarios, from the BSL to the NZ scenarios.

The energy service demand increases by around six times in the residential, commercial, and industrial sectors and 3.4 times in the agricultural sector between 2020 and 2050. Due to the EE measures, which cushions the increased demand, the FEC increases by a factor of 3.9 and 3.1 in BSL and NZ scenarios, respectively. The EE measures are mostly represented in the residential and the industrial sector, and the least in the agricultural sector. Even in the BSL scenario, the extensive implementation of EE measures starts already in 2030.

In the most ambitious scenario, the NZ scenario, the implementation accelerates from 2040 and reaches very high levels by 2050. E.g., the share of energy-efficient devices in the industrial sector reaches 95% in 2050. Therefore, it is recommended to implement EE measures as soon as possible and put more focus on the residential sector until 2030 as well as increase the focus on the commercial and industrial sectors later.

To reach the net zero target as per the NZ scenario, a substantial degree of electrification is needed to complement energy-efficient processes, the use of biofuels instead of oil and natural gas as a replacement for coal. As a result, the electricity share in the FEC increases from 31% in 2020 to 73% in 2050. In the other scenarios, the share of coal in FEC increases, while shares of electricity, oil products and biofuels remain constant or slightly drop compared to 2020.

When the costs of the BSL scenario are compared to LowEE, LowEE has 7% higher costs in 2030 (11 bn USD), 2% higher costs in 2040 (6 bn USD) and 1% lower energy system costs in 2050 (3 bn USD). Therefore, it is cost-optimal to utilise more than 50% of the VNEEP potential with devices more efficient than standard devices. The VNEEP targets are fully exploited by default in all scenarios.

In the HD scenario, implementation of EE measures remains at the level of the BSL scenario, but the consumption of imported coal and oil products increases, which translates into increased import dependence and higher CO_2 emissions. Therefore, to avoid increased import dependence and higher CO_2 emissions, ambitious EE policies should be put in place beyond promotion of cost-effective measures, but also as a contingency measure for unexpected demand growth.

8.3 Key Messages and Recommendations

Low EE-compliance is costly

In a scenario where compliance with energy-efficiency measures is low, the total system costs increase by around 5% throughout the analysed period. EE is thus a long-hanging fruit to pick if a policy with solid incentives for compliance is implemented.

Improved data for modelling of energy demand and energy efficiency

A functional EE policy requires a detailed understanding of the actual energy use as well as the viable options for improved efficiency. Currently, such information is sparse. This is particularly the case in certain sectors such as industry and buildings. This creates difficulties in modelling these sectors, which in turn translates to difficulties quantifying the potential for EE improvement and designing effective policy measures.

Therefore, it is recommended to swiftly implement the Viet Nam Energy Efficiency and Conservation Program (VNEEP) action on energy data collection and allow this to form the analytical basis for policies on EE. Reliable data is needed at both sector and end-use levels, including efficiency potentials and costs. For the very energy-intensive technologies, there is a need for detailed cost-benefit analyses of technology alternatives. It is further recommended to develop demand-side models as a tool to assess the impacts of specific energy demand-side policies.

Strengthening supervision and enforcement of law and legislation in the field of energy efficiency

A first step towards a solid data foundation and implementation of EE of large consumers could be to enforce Circular 25 stipulating reporting and auditing of large energy users (more than 100,000 kWh annually), which would directly provide improvements to EE as well as benefit long-term energy planning studies.

9
Air Pollution

9 Air Pollution

9.1 Status and Trends

Air pollution has proved to have a considerable implication on human health. This implication has a direct economic consequence in terms of higher healthcare costs and less efficient labour as well as an indirect economic consequence in terms of impact on quality of life and environmental impacts. The energy sector is the predominant source of air pollution from human activities. Nearly all SO_2 and NO_x emissions and about 85% emissions of PM origin from the energy sector, mainly from the combustion of coal and oil, as well as from natural gas and biomass (International Energy Agency, 2016).

Air pollution is a growing challenge in Viet Nam, especially in the major cities. For example, in Ha Noi in 2016 the annual mean values of PM_{10} and $PM_{2.5}$ were 5 times higher than WHO (World Health Organization) recommendations. A recent study of public health impacts of $PM_{2.5}$ exposure in Ha Noi finds that life expectancy of people is Ha Noi is reduced by 2.5 years on average (Live & Learn for Environment and Community, Hanoi University of Public Health, University of Engineering and Technology - Vietnam National University in Hanoi and United States Agency for International Development, 2019)

Health implication from air pollution is a focus topic in Viet Nam. The draft PDP8 and draft EMP have included health cost of air pollution in all investigated scenarios[5].

Aligned with this, the Viet Nam EOR21 analyses both energy consumption, air pollution and human health. This is done by combining state-of-the-art atmospheric modelling with energy system optimisation.

9.2 Air Pollution Outlook

Improved Methodology to Evaluate the Health Costs of Air Pollution

The EOR21 air pollution cost analysis covers the costs of air pollution from the three main pollutants NO_X, SO_2 and $PM_{2.5}$ with differentiated costs for each sector: power, industry, residential, commercial, agriculture and transport. Further, the EOR21 features a dedicated pollution cost scenario, called air pollution (AP) scenario, in which the costs of air pollution are included in the cost-optimisation – could be in the form of taxes – to show how the energy system would be optimised under such conditions. Thus, the AP scenario allows for evaluation of the optimal power generation mix, development of the different energy sectors and fuel usage of the entire energy system considering the socio-economic costs of air pollution. The other scenarios include air pollution costs added to the total costs after optimisation.

The applied sector specific air pollution costs account for the different exposure to pollutants from the sectors leading to varying effects on human health. This approach allows a differentiated analysis and could be integrated in the given sectorial analysis of the model framework.

Health impacts are analysed by a three-step approach (Figure 9.1).

- *Step 1: Determine emission concentration and dispersion (DEHM)*. The first step tracks the long-range dispersion of pollutants on a sectoral level based on historical emissions, weather patterns, and chemical reactions in the atmosphere. This is done by the Danish Eulerian Hemispheric Model (DEHM), a model originally developed for air quality monitoring in Denmark and Europe. The DEHM is an atmospheric 3D model nested in different domains down to 17x17 km resolution with a detailed meteorological and surface representation.

[5] The applied health unit cost of air pollution is approximately 7 USD/kg for $PM_{2.5}$ and 5 USD/kg for NO_X and SO_2 in 2020, which increases towards 2030 and 2045 with the same rate of expected population growth

- *Step 2: Calculate health cost pr. unit of pollutants in USD2019 (EVA)*. The concentration of pollutants is combined with population data (density and age) to determine the exposure of pollutants to humans. By using exposure-response functions, it is possible to estimate the health effects, which are then valuated to determine the unit costs.
- *Step 3: Include cost of air pollution in energy system models (TIMES & Balmorel)*. In the third step, the unit costs are linked to emissions of the air pollutants in the energy system modelling setup of TIMES and Balmorel.

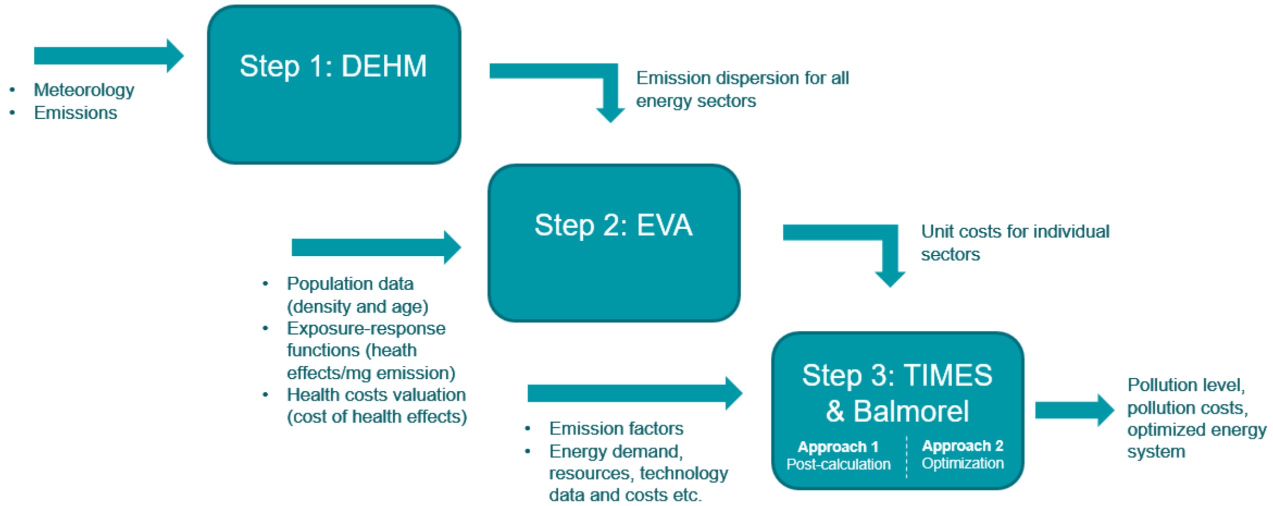

Figure 9.1 Methodology to analyse the relationship between energy consumption, air pollution and human health.

The sector specific unit costs which are output from Step 2 is shown in Table 9.1. These unit costs are developed for 2016 and projected with population growth to the target years 2020 to 2050. This is the same approach to projection of unit costs as is used in draft PDP8 and draft EMP.

Table 9.1 Unit costs for 2020 per sector and per pollutant as calculated in Step 2. (EREA & DEA, 2022b).

[USD19/kg]			
2020	SO_2	NO_X	$PM_{2.5}$
Agricultural	3	6	17
Commercial	6	11	31
Industry	2	5	6
Power	2	4	5
Residential	6	11	31
Supply	2	4	5
Transport-Road	3	6	17
Transport-Water	2	2	3

Results

The development of air pollution from the energy sector and associated costs are shown, followed by an analysis on sectorial level identifying least-cost measures to reduce air pollution. The focus in this section will be on the BSL, NZ and AP scenario. The BSL scenario serves as baseline scenario, while the NZ scenario illustrates the effect of an ambitious climate scenario on air quality, and the AP scenario shows the effects when including air pollution into energy system planning.

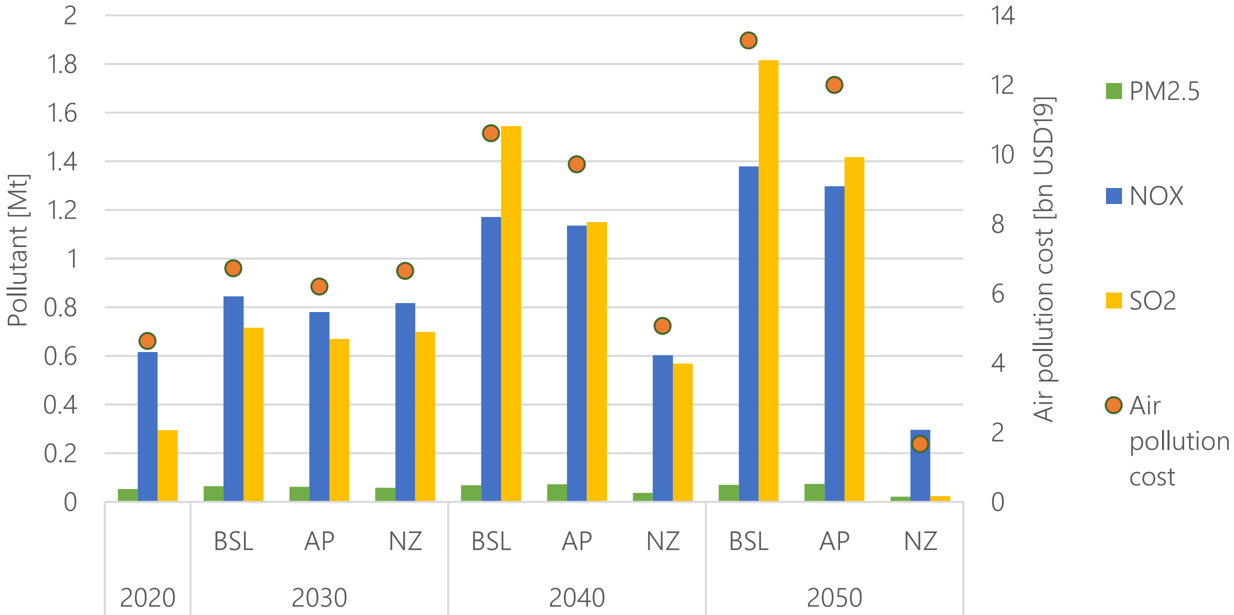

Figure 9.2 $PM_{2.5}$, NO_X and SO_2 emissions and air pollution costs

Figure 9.2 shows that the costs of air pollution are about 4.6 bn USD in 2020. This corresponds to 8% of the total energy system costs. The BSL scenario shows that the air pollution costs can increase to 6.7 bn USD in 2030 and triple today's value by 2050, reaching up to 13.3 bn USD. This corresponds to 3.6% of the total power system costs in 2050.

When fossil fuel technologies are substituted by renewables, the amount of pollution can be reduced significantly and thereby reduce the related costs as shown in the NZ scenario. The ambitious emission reductions lead to a decrease in air pollution costs by 90% (11.6 bn USD) in 2050.

The AP scenario shows that accounting for air pollution costs in the energy system model will lead to a reduction of air pollution costs compared to the BSL scenario by 0.5 bn and 1.3 bn USD compared to the BSL scenario, in 2030 and 2050, respectively.

The reduction of negative health effects in the AP scenario does not come with an extra cost as seen in Figure 9.3. The reduction in air pollution costs will roughly compensate other increased costs. Additionally, a reduction in CO_2 emissions is also achieved: Up to 50 Mt annually in 2050 and 740 Mt over the analysed period compared to BSL because fossil fuels with high CO_2 emissions are also related to high pollutants and thus become less competitive.

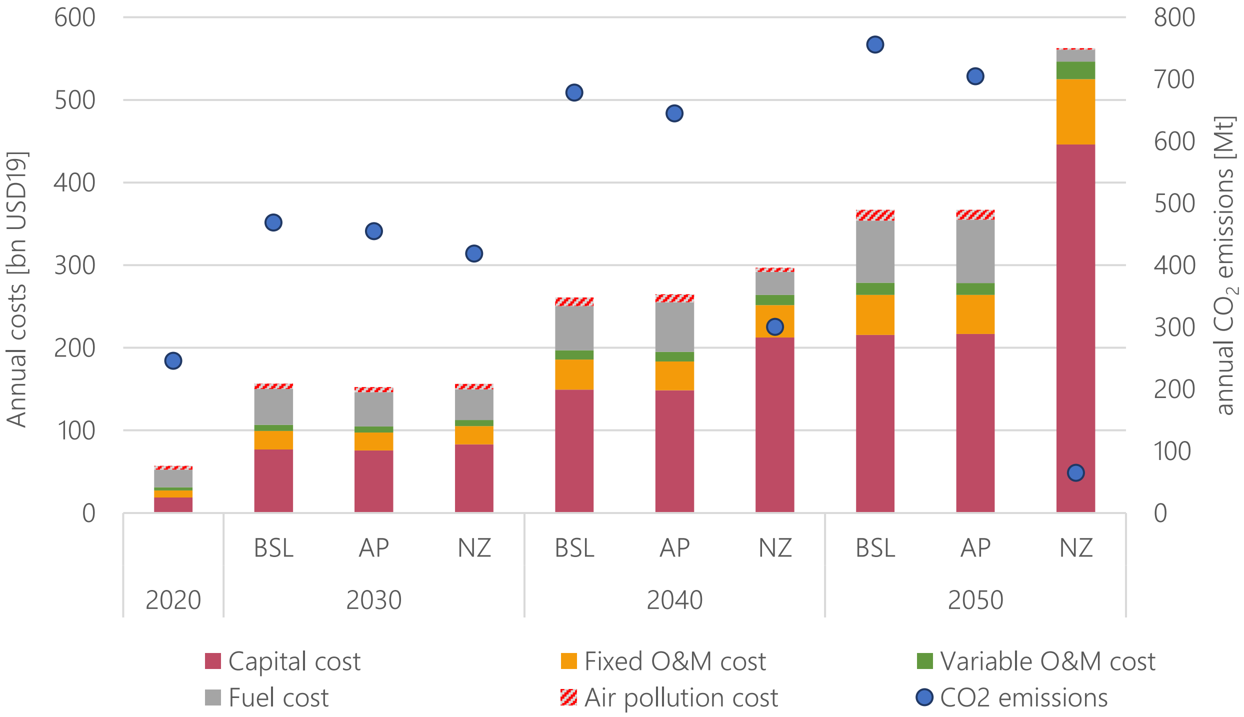

Figure 9.3 Total annual system costs and annual CO_2 emissions

The negative health effects vary significantly across sectors due to various fuel use and different exposure to pollutants (Figure 9.4). In 2020, road transport had the highest impact on air pollution responsible for 42% of all air pollution costs. With the predicted economic growth of Viet Nam, industry will become the sector with the highest health impact, despite lower unit costs for the industrial sector. The power and transport sector will follow as second and third sectors with highest pollution costs. The air pollution costs from the residential sector amounts to 0.5 bn USD today (11 % of the energy related air pollution costs) and is expected to double towards 2025 and then drastically reduce to 0.3 bn USD.

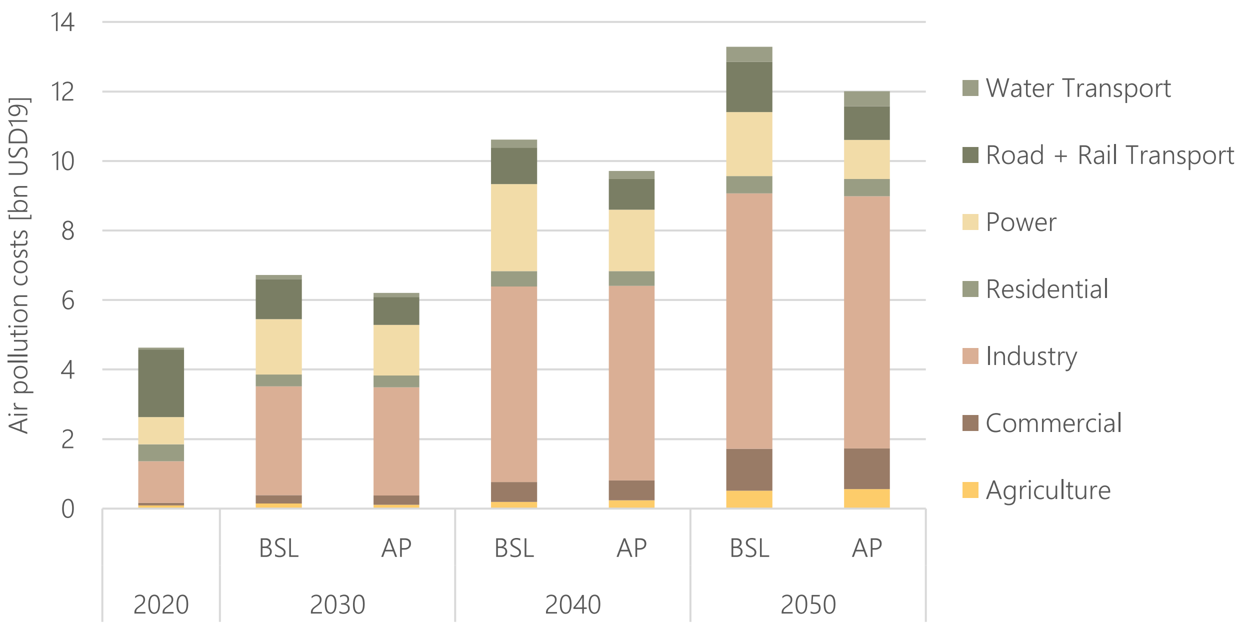

Figure 9.4 Air pollution costs by sector

The sectorial comparison of the BSL and AP scenario allows to identify the sectors in which the most cost-efficient air pollution reductions can be made. In 2030, the main reduction can be achieved from the road transport sector. The power sector also has great potential for reducing pollution, especially from 2040. These two sectors cover over 90 % of the annual cost reduction from pollutions in the AP scenario compared to BSL. The industrial sector contributes only 7.5% to the air pollution costs reduction in 2050, despite being responsible for 60% of the air pollution costs in BSL in 2050.

The most cost-effective short-term measure to reduce air pollution are achieved in the transport sector and in the power sector. A detailed sectorial analysis is given in the following.

Pollution reduction in the transport sector

The transport sector is a main source for NO_X and $PM_{2.5}$ emissions and the high exposure of people to pollutants from road transport leads to high air pollution costs. Especially diesel combustion engines, which are significant more polluting compared to gasoline-fuelled vehicles (International Energy Agency, 2016) contribute largely to road transport pollution.

The analysis shows that today's high amount of pollution from the transport sector will substantially decrease in Viet Nam, despite increased transport demands and fuel consumption. Due to higher emission standards of new vehicles as well as an absolute reduction of diesel engines, a reduction in NO_X by over 50% and $PM_{2.5}$ by 20% is expected in this decade while the transport service demand increases by 80% and 93% for passengers and freights, respectively.

Figure 9.5 presents the fuel usage in the road and railway transportation sector and the corresponding sectorial pollutant costs for the BSL, GT and AP scenarios. With the integration of health costs in the analysis, transport sector shows further reduction of harmful pollutants by 1/3 compared to the BSL scenario in 2030. The air pollution costs in the AP scenario are decreased by 0.35 bn USD compared to the BSL scenario in 2030 and down about 0.5 bn USD in 2050 mainly driven by the reduction of NO_X throughout the entire period.

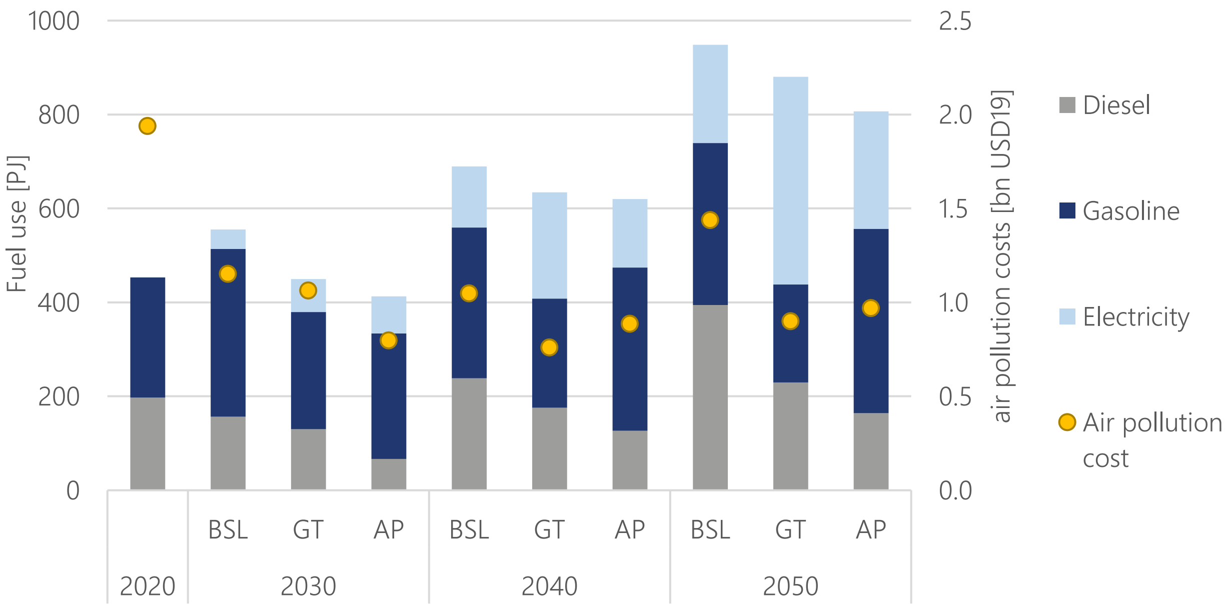

Figure 9.5 Fuel use and air pollution costs in road and railway transport

The most cost-efficient reduction measure provides the substitution of high-polluting diesel combustion engines by electrification. Compared to the BSL scenario, the consumption of diesel is reduced between 50 - 60% annually in the years after 2030, in the AP scenario. Over 92% of this diesel substitution can be traced back to electrification of buses and trucks. The electrification rate in 2050 is 31% in the AP scenario compared to 22% in the BSL scenario. An additional benefit of the increased electrification is the reduction of CO_2 emissions from road transport of over 12.5 Mt annually from 2030 on compared to the BSL scenario.

The air pollution reduction from the transport sector in the AP scenario outperforms the GT scenario by 30% in 2030 and reaches comparable cost reductions 2050 despite very different measures. This result shows that high electrification of the car and motorbike fleet and mode shift towards more public transport as done in the GT scenario, provides also significant improvement of air pollution.

Pollution reduction in the power sector

The power sector is also affected by internalizing air pollution in the energy system (Figure 9.6).

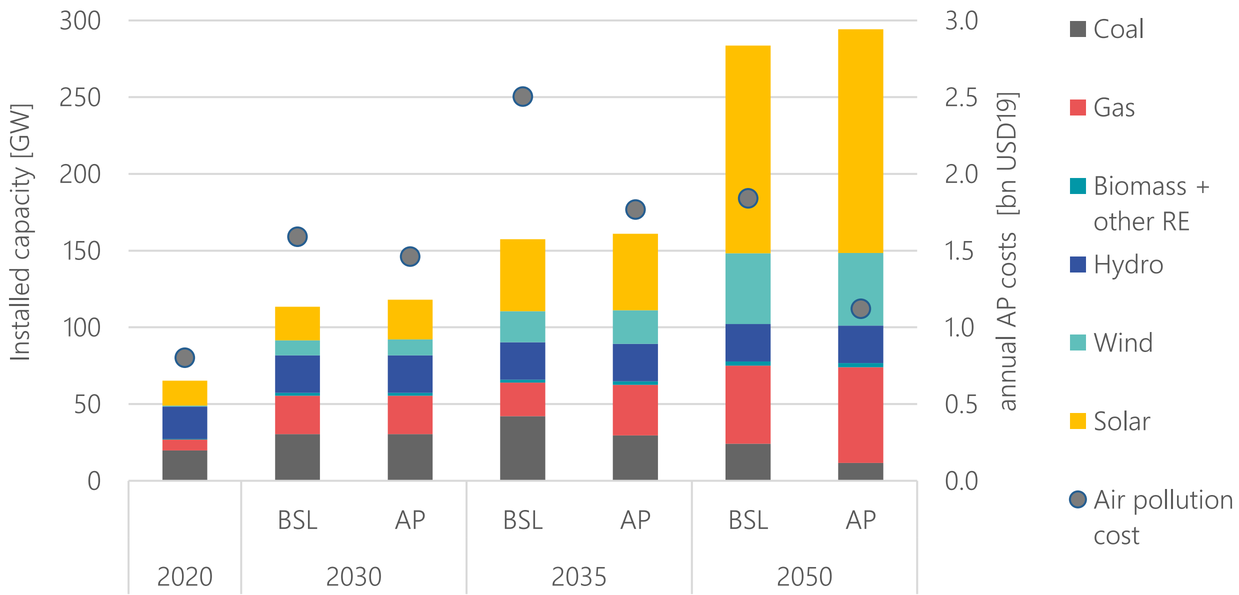

Figure 9.6 Installed capacity by fuel type in the power sector and annual air pollution costs

The greatest difference between the scenarios is the amount of coal and gas power plants after 2030. In all scenarios, minimum 30 GW coal power plants will be available by 2030 because of the already planned and commissioned ones today. In the BSL scenario, additional 13 GW coal is installed in 2035 while in the AP scenario, there will be no additional investment in coal power plants beyond the ones already planned. Thus, when considering the costs of air pollution, new investments in coal power is no longer cost-competitive. Instead, more natural gas capacity is installed and thereby it is the scenario with the highest natural gas investments. Furthermore, small amounts of additional wind and solar capacity is installed compared to the BSL scenario.

The AP scenario uses annually about 630 PJ less coal compared to the BSL scenario from 2035 onwards. With coal being the main source of SO_2 (International Energy Agency, 2016), the SO_2 emissions are reduced by around 70% in the power sector corresponding to a reduction in air pollution cost of over 0.7 bn USD annually after 2035. Additionally, the low coal consumption reduces the CO_2 emissions 30-35 Mt annually in the power sector alone compared to the BSL scenario.

9.3 Key Messages and Recommendations

The impact of air pollution from the energy sector to human health could triple by 2050 in the BSL scenario

The total costs of air pollution of the energy system associated to human health impacts, covering the pollutants nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter 2.5 ($PM_{2.5}$), in 2050 is projected to increase from 4.6 bn USD in 2020 to 13.3 bn USD in the BSL scenario. Further, a shift in the sectorial contribution to air pollution is observed. In 2020, road transport contributes the most to air pollution with 1.9 bn USD. Already by

2030, the industrial sector will contribute the most to air pollution (47%), followed by the power sector (24%) and the transport sector (19%) in the BSL scenario.

The most cost-efficient measures to reduce air pollution are found in the transport and power sector

In the transport sector, substituting high-polluting diesel-combustion engines, especially heavy-duty vehicles such as buses and trucks, with electric equivalents by 2030 can reduce the cost associated with air pollution by around 0.35 bn USD annually. Electrification of cars and motorbikes will further add to a reduction in air pollution costs.

In the power sector, investments in coal power are not cost-competitive with LNG and RE when air pollution and health costs are considered. The analysis shows that if no new coal power plants are commissioned after 2030, air pollution costs can be reduced by at least 0.7 bn USD annually compared to the BSL scenario.

In both sectors, these air pollution reductions can be realised without additional total cost because the additional costs required for the energy system are compensated by reduced health costs.

Air pollution abatement and CO_2 emission reduction go together

CO_2 emission reduction measures such as reduced coal power and increased electrification of demand sectors lead to a direct improvement of air pollution. In a scenario where Viet Nam reaches net zero emissions in 2050, costs related to air pollution can be reduced by at least 87% compared to the BSL scenario.

Refine representation of air pollution in governmental planning

To improve the existing methodology, it is crucial to 1) Develop a detailed emission inventory for Viet Nam and build an air quality monitoring network / MRV system, 2) Apply and support the research of valuation of health impacts from air pollution, and 3) Determine the national emission factors for all energy-consuming technologies. This can further serve to feed into general city planning, including for collective transport etc.

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