

100%RE
multi-actor
partnerships

Viet Nam's Energy Sector Vision: **TOWARDS 100% RENEWABLE ENERGY BY 2050**

SUMMARY REPORT | MARCH 2023

A background image showing several wind turbines silhouetted against a vibrant sunset sky with orange and yellow hues. The sun is low on the horizon, creating a strong glow.

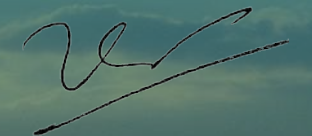
FOREWORD BY WWF-VIET NAM

Vietnam has the fastest increase in greenhouse gas (GHG) emissions in the Greater Mekong Sub-region. According to the emission scenario, the GHG emissions of Viet Nam are forecasted to reach up to 1,495.4 million tons of CO₂eq by 2050, in which the energy sector accounts for 81% of the total GHG emissions. In this context, Viet Nam has made great efforts to reduce GHG emissions which are highly praised by the international community such as the commitment to reaching net-zero carbon emissions by 2050 at the COP26 and the Updated National Determined Contributions (NDC 2022) at the COP27, in which the country's 2030 unconditional and conditional GHG emissions reduction targets have been increased from 9% and 27% to 15.8% and 43.5% compared to BAU, respectively. To achieve this goal, it is critical for Viet Nam to accelerate the energy transition towards Renewable Energy (RE) in all sectors.

The report **“Energy Sector Vision: Towards 100% Renewable Energy for Viet Nam by 2050”** was implemented under the **“Multi-Actor Partnership (MAP) for Implementing Nationally Determined Contributions with 100% Renewable Energy (RE) for All in the Global South” project (100% RE MAP)**. The study has developed 03 scenarios for the Energy Sector of Viet Nam: BAU Scenario, 80% RE Scenario (80RE), and 100% RE Scenario (100RE) by 2050, based on the current power generation mix and energy plans and master plan of the Government, in order to build a feasible energy transition roadmap.

We hope this study will provide policymakers and stakeholders with useful and science-based information for promoting renewable energy development, contributing to delivering on emissions reduction commitments in the national NDC as well as achieving the Net Zero target.

This report is a product of 100% RE MAP project prepared by WWF-Viet Nam and our partners. We sincerely thank the MAP members, individual experts and project partners who helped shape this report.

A handwritten signature in black ink, appearing to be 'VNT', located above the name of the CEO.

Dr. Van Ngoc Thinh
CEO, WWF-Viet Nam

ABOUT THE 100% RE MAP PROJECT

The scale of the transformation ahead calls for collaboration and collective action. Inclusive alliances must be built that include people from all sectors, regions, and walks of life. We need a positive vision for our future, one that empowers change-makers and builds capacities across all sectors. By focusing on the opportunities related to 100% RE, rather than focusing on the fear related to the looming climate crisis, we can unlock the transformative power of renewables.

The Multi-Actor Partnership for Implementing Nationally Determined Contributions with 100% Renewable Energy for All in the Global South (100% RE MAP) is a project to facilitate positive changes and advance the transformation necessary to ensure economic and social development in line with the Paris Agreement's climate target of 1.5 °C. By strengthening MAPs, we enable inclusive decision-making and unlock disruptive innovations for scalability. The project ensures strategic buy-in from opinion leaders, academia, civil society, government and think tanks, and is being implemented simultaneously in Nepal, Uganda and Vietnam. The 100% RE scenario covers state-of-the-art modelling technologies that highlight possible transition pathways towards 100% RE and enable comparisons to business-as-usual pathways.

About the Authors

Intelligent Energy Systems (IES) is an Australian consulting firm established in 1983 to provide advisory services and software solutions to organizations working in the energy industry. IES specializes in taking a systematic approach to solving problems in energy markets that require consideration of energy policy, legislation, economics, finance, and engineering. IES has a proven track record in advising government departments, regulators, system and market operators, transmission companies, generators, and retailers in the Asia Pacific region, including Australia, the Greater Mekong Sub-region, Philippines, Singapore, and elsewhere.

IES Project Team:

Stuart Thorncraft, Sami Aoude, Patrick Wang, Johnathan Cheung, Ho Dinh Tham, Pranav Deshpande and Anthony Kubursy.

Project's Consortium



WWF-Viet Nam is recognised as the leading conservation organisation in the country, with a mission to stop the degradation of the country's natural environment and build a future in which humans live in harmony with nature. Its objective is to reduce environmental footprint and secure a sustainable future for the next generations. Ecological integrity and biodiversity conservation and restoration are cornerstones for WWF-Viet Nam's strategy.

WWF Germany is an independent, non-profit, non-partisan foundation, and part of the WWF network, which operates in over 100 countries and consists of national organizations and program offices.



The **Green Innovation and Development Centre** (GreenID) works to achieve fundamental change in the approach to sustainable development by promoting the transition to a sustainable energy system, good environmental governance and inclusive decision processes.



The **Vietnam Business Council for Sustainable Development** (VBCSD) is a business-led organization with the mandate to promote the business community's active role and strong advocate on the implementation of the Strategic Orientations for Sustainable Development in Viet Nam, to facilitate the dialogue among business

community, the Government and civil organizations for sustainable development.



Brot für die Welt is the globally active development and relief agency of the Protestant Churches in Germany. In more than 90 countries all across the globe, we empower the poor and marginalized and closely and continuously cooperate with local, often church-related partner organizations. Through lobbying, public relations and education we seek to influence political decisions in favor of the poor and to raise awareness for the necessity of a sustainable way of life.



The **World Future Council** is a foundation based in Hamburg, Germany. Against the background of ever-increasing global problems that affect all areas of human life, a global group of experts have set up the World Future Council as a politically neutral and independent body. It brings the interests of future generations to the centre of policy making and addresses challenges to our common future and provides decision makers with effective policy solutions.



The project is supported by the **German Federal Ministry for Economic Cooperation and Development (BMZ)**.

Disclaimer

This report has been prepared by Intelligent Energy Systems (IES) for World Wide Fund for Nature – Vietnam (WWF-Vietnam) and is supplied in good faith and reflects the knowledge, expertise and experience of the Consultant. In conducting the analysis for this report the Consultant has endeavoured to use what it considers is the best information available at the date of publication. The Consultant makes no representations or warranties as to the accuracy of the assumptions or estimates on which the forecasts and calculations are based.

The degree of reliance placed upon the projections in this report is a matter for that reader's own commercial judgement and the Consultant accepts no responsibility whatsoever for any loss occasioned by any person acting or refraining from action as a result of reliance on the report.

Contributor

Editor in Chief & Technical Editor: Stuart Thorncraft

Editorial team primarily contributes to the Report:

Pham Cam Nhung, Nguyen Thanh Trung, Nguyen Thai Binh, Pham Huong Mai, Nguyen Thi Ha, Nguyen Quoc Khanh, Nguyen Duc Tuyen

With special thanks for the review and contributions from:

Ma Khai Hien, Rafael Guevara Senga, Richard Scotney, Tran Dinh Sinh, Ta Hung, Nghiem Thi Ngoan, Nguyen Huu Nam, Nguyen Duc Binh, Nguyen Hong Quan, Pham Thanh, Tran Thien Khanh, Du Van Toan, Hoang Minh Thu, Truong Thi Ai Nhi, Truong Nhu Tung, Le Thu Thao, Nguyen Thanh Trung

The work would not have been possible without the tremendous help and engagement of Anna Skowron, Lena Dente, Dr. Joachim Fünfgelt, Jaime Medina Fernandez, Fentje Jacobsen, Corinne Kowalski, Sebastian Akermann.

TABLE OF CONTENTS

Abbreviations	1
Summary	2
1 Three Scenarios	4
2 Demand and supply development - BAU	8
2.1 The Industrial Sector	10
2.2 The Transport Sector	11
2.3 The Household Sector	13
2.4 The Commercial Sector	14
2.5 The Agricultural Sector	15
2.6 The Power System	16
2.7 Emissions	18
3 Scenario comparison	20
3.1 The Industrial Sector	22
3.2 The Transport Sector	23
3.3 The Household Sector	24
3.4 The Commercial Sector	25
3.5 The Agricultural Sector	26
3.6 The Power System	27
3.7 Emissions	30
3.8 Costs	31
4 Policy Recommendations	34
4.1 Policies in Energy and Energy infrastructure planning	36
4.2 Investment planning	36
4.3 Improving system operations for electricity	36
4.4 Institutional arrangements	36
4.5 Energy pricing and contracts	37
4.6 Transport sector	37
4.7 Climate, health and environment	37
Appx. A Just Energy Transition Partnership (JETP)	38



ABBREVIATIONS

Abbreviation	Definition
100RE	Scenario targeting 100% RE by 2050
80RE	Scenario targeting 80% RE by 2050
BAU	Business As Usual Scenario
Capex	Capital expenditure
DSP	Demand side participation
EMP	Energy Master Plan
EV	Electric vehicle
ICE	Internal combustion engine(s)
JETP	Just Energy Transition Partnership
LCOE	Levelised Cost of Electricity
MMTOE	million tonnes oil equivalent
NPV	Net present value
O&M	Operations and maintenance
RE	Renewable electricity
TFEC	Total final energy consumption



SUMMARY

Vietnam's economy has grown at high rates and energy consumption has grown with it. The three largest energy consuming sectors in the economy; Industrial, Transport and Household; account for more than 90% of the national energy consumption in Vietnam. The Commercial and Agriculture sectors account for the remaining small share. Three scenarios were modelled:

The BAU scenario assumes development of energy consumption and production in line with the targets in the Energy Master Plan (EMP) preferred scenario (A1), the November 2022 version of the Draft Power Development Plan (PDP8) and current related policy targets.

The more ambitious 80 RE scenario targets 80% of final energy, consumed in the economy by 2050, to be derived from renewable energy sources. Twenty percent of final energy consumed is still sourced from fossil sources.

Finally, the 100RE scenario envisages an even more rapid adoption of RE across the economy to achieve the goal of 100% renewable energy by 2050. RE displaces all fossil energy carriers.



The establishment of the Just Energy Transition Partnership (JETP) was announced on 14 December 2022. The publicly available information is not sufficiently detailed to allow a precise estimate of its cost impacts to be made. We make broad assumptions and comment on its implication to the results of this study in Appendix A.

Energy consumption is expected to grow over the horizon from 65 to 244 million tonnes oil equivalent (MMTOE) over the horizon in the BAU. All sectors of the economy remain dependent on fossil fuels (74%). Transport grows to between 6 to 7 times current levels but remains, like all the other sectors heavily reliant on fossil fuels. The power system sees a reduction in thermal generation from 60% to 42% while renewables expand to supply the balance. Within thermal generation gas takes over the leading position from coal as no new coal enters the system from 2037 and 15 GW of coal capacity retires.

In the 100RE scenario energy consumption grows to 223 MMTOE in 2050, over 8% lower than the BAU, due to higher energy efficiency across the sectors. All sectors are transformed to renewable energy through a combination

of electrification and conversion to renewable fuels. The power system is supplied by 100% renewable sources replacing coal and gas. Solar and wind capacities expand backed by long duration batteries. Demand side participation plays a role in managing peak electricity demand. Transmission capacity is up to eight times higher than in the BAU. The higher transmission capacity is needed to flow energy from the Central region to the North region.

The 80RE scenario sees the same trends of the 100RE except that around 20% of energy consumption is allowed to remain fossil-based by 2050. With slightly lower improvement in energy efficiency, energy consumption in 2050 grows to 229 MMTOE, 6% lower than the BAU. 52 GW of gas capacity remains in the power system along with 9 GW of coal. Renewables share of generated electricity expands to 86%. Transmission capacity in this scenario is six times higher than in the BAU.

The levelized cost of electricity (LCOE) increases from the current level of USD 59/MWh with higher renewables in the power system. In 2050 the LCOE is USD 61/MWh for the BAU, USD 70/MWh for the

80RE and USD 78/MWh for the 100RE.

The net present value of economy-wide costs including the cost of externalities is highest for the BAU at 1,943 billion USD, followed by 80RE at 1,767 billion USD (9% lower than the BAU), and lowest for the 100RE at 1,747 billion USD (10% lower than BAU). Emissions fall with increased renewable energy share in the economy.

Total economy-wide investment requirements are highest for the BAU at 5,133 billion USD, lowest for 80RE at 3,817 billion USD (26% lower than BAU), with 100RE being second lowest at 4,089 billion USD (20% lower than BAU). 80RE has the lowest investment as it avoids transforming some high-cost areas required to achieve transformation to 100% renewable energy in the 100RE scenario.

Based on the findings policy recommendations are proposed to encourage and integrate renewables into the power system, reward renewables and flexible operation of power resources, expand energy efficiency, and encourage the adoption of EV and renewable fuel powered modes of transport.



Industrial, Transport and Household sectors account for more than

90%
of the national
energy consumption

All sectors of the economy remain dependent on fossil fuels

74%

Renewables share of generated electricity expands to

86%

1 THREE SCENARIOS

Three scenarios were modelled for the energy sector in Vietnam:



Business As Usual (BAU)



80% RE by 2050 (80RE)



100% RE by 2050 (100RE)

The BAU scenario assumes development of energy consumption and production in line with the targets in the Energy Master Plan (EMP) preferred scenario (A1), the November 2022 version of the Draft Power Development Plan (PDP8) and current related policy targets.

The more ambitious 80 RE scenario targets 80% of final energy, consumed in the economy by 2050, to be derived from renewable energy sources. Twenty percent of final energy consumed is still sourced from fossil sources.

Finally, the 100RE scenario envisages an even more rapid adoption of RE across the economy to achieve the goal of 100% renewable energy by 2050. RE displaces all fossil energy carriers.

In the two high renewable energy scenarios, the power system is supplied primarily by renewable electricity (RE) sources. The higher rate of electrification in these scenarios is correlated with a higher share of consumption from renewables. Other forms of RE carriers, such as renewable fuels, feature in these scenarios in applications where electrification is challenging to implement, such as in aviation and some water transport.



TABLE 1. General description of main features of each scenario

ASPECT	BUSINESS AS USUAL	80% RE BY 2050	100% RE BY 2050
Description	Continuation of consumption in line with the preferred EMP scenario, Scenario A1	Accelerated adoption of renewable energy options to reach 80% renewable energy by 2050 and allows for 20% of economy still based on fossil fuels. Economy growth per projections in EMP Scenario A1	Higher acceleration of adoption of renewable energy options to reach 100% renewable energy (including conversion to renewable fuels) by 2050. Economy growth per projections in EMP Scenario A1
Industry	Continuation of current trends in energy usage and sources. Includes achievement of VNEEP targets incorporated in EMP Scenario A1	Accelerated adoption of electrification for heat. Higher share of renewable energy generation in the power system. Renewable fuels used for heat energy that is not electrified	Higher acceleration of adoption of electrification for heat. Higher share of renewable energy generation in the power system. Renewable fuels used for heat energy that is not electrified
Transport	Modest EV penetration	Very high conversion to EVs or renewable fuels by 2050. EVs are powered by an increasing RE share in the power system. Fossil fuels remain in the sector	100% conversion to renewables through EVs or renewable fuels by 2050. EVs are powered by an increasing RE share in the power system

Residential	Continuation of current trends in energy usage and sources in line with EMP Scenario A1	Accelerated adoption of solar heating, electrification for heating, efficient electrified cooking and efficient lighting. Phasing out of LPG and biomass in cooking. Higher share of renewable energy generation in the power system	Higher acceleration of adoption of solar heating, electrification for heating, efficient electrified cooking and efficient lighting. Phasing out of LPG and biomass in cooking. Higher share of renewable energy generation in the power system
Commercial	Continuation of current trends in energy usage and sources in line with EMP Scenario A1	Accelerated adoption of solar heating, electrification for heating and efficient lighting. Higher share of renewable energy generation in the power system	Higher acceleration of adoption of solar heating, electrification for heating and efficient lighting. Higher share of renewable energy generation in the power system
Agriculture, Forestry and Fishery	Continuation of current trends in energy usage and sources in line with EMP Scenario A1	Accelerated adoption of renewable fuels. Higher share of renewable energy generation in the power system	Higher acceleration of adoption of renewable fuels. Higher share of renewable energy generation in the power system
Power sector	No new entrant coal from 2037. RE generation share in line with PDP8 base case outlook	80% RE generation share by 2050. No new entrant coal from 2030. Additional transmission allowed to be built above the BAU transmission plan	100% RE generation share by 2050. No new entrant coal or gas from 2026. Additional transmission allowed to be built above the BAU transmission plan



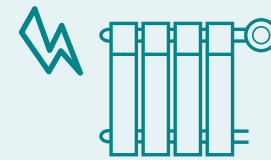
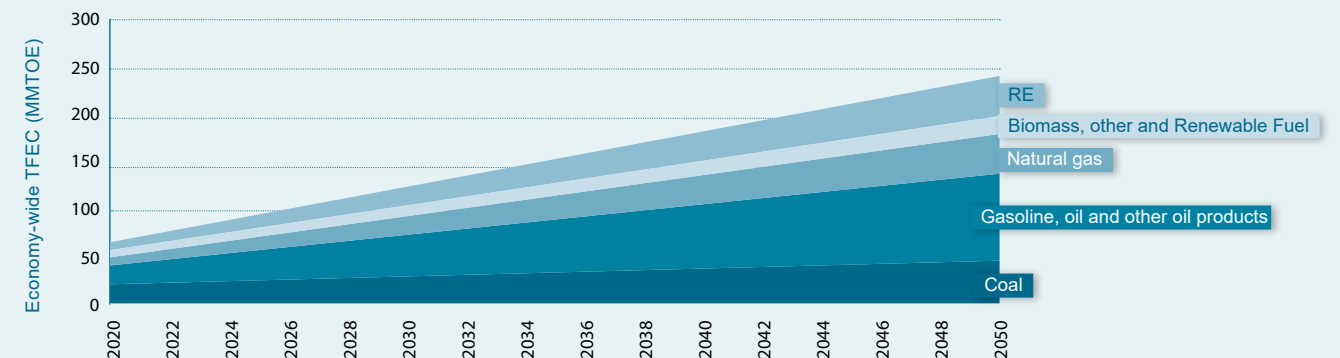
2 DEMAND & SUPPLY DEVELOPMENT - BAU



Demand for energy is projected to grow over the study horizon from 65 to 244 million tonnes oil equivalent (MMTOE). Referring to Figure 1 which shows the development of Total Final Energy Consumption (TFEC) in the BAU including energy used in the generation of electricity in the power

sector, consumption of coal-based energy, dark brown in the chart, grows before levelling off then experiencing a small decline to 45 MMTOE by 2050. The share of oil-based energy, black colour in the chart, is projected to have the largest share by 2050, growing to 92 MMTOE. Gas and renewables grow to occupy 18% and 26% respectively.

FIGURE 1. Economy-wide TFEC- BAU

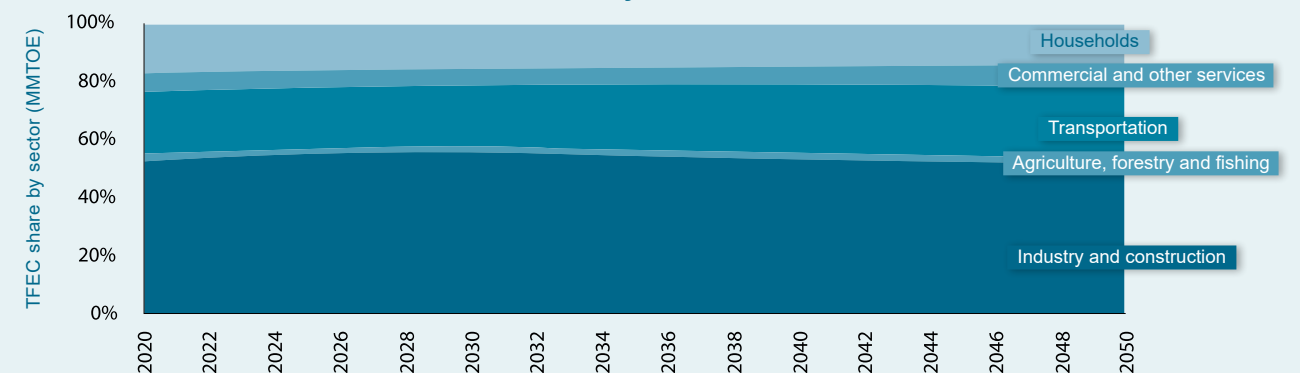


The three largest consuming sectors; Industrial, Transportation and Household; remain responsible for the lion share of consumption and maintain their relative ranking. Figure 2 shows the development of share by sector. The energy consumption in each sector includes electricity consumed by that sector from the power system.

Total Final Energy Consumption (TFEC) in a sector shows the consumption in the sector by energy carrier including electricity. The

consumption of electricity is typically presented as the aggregate of electricity consumption from renewable and non-renewable sources. Given the focus of this project on renewable energy we have intentionally presented electricity consumption from renewable sources under the category 'RE' in the charts, and the remaining portion of electricity consumption from the power system is then added back to the sector's consumption of each energy carrier. The charts readily provide a comprehensive view of consumption of renewable and non-renewable energy in a sector.

FIGURE 2. TFEC share by sector - BAU

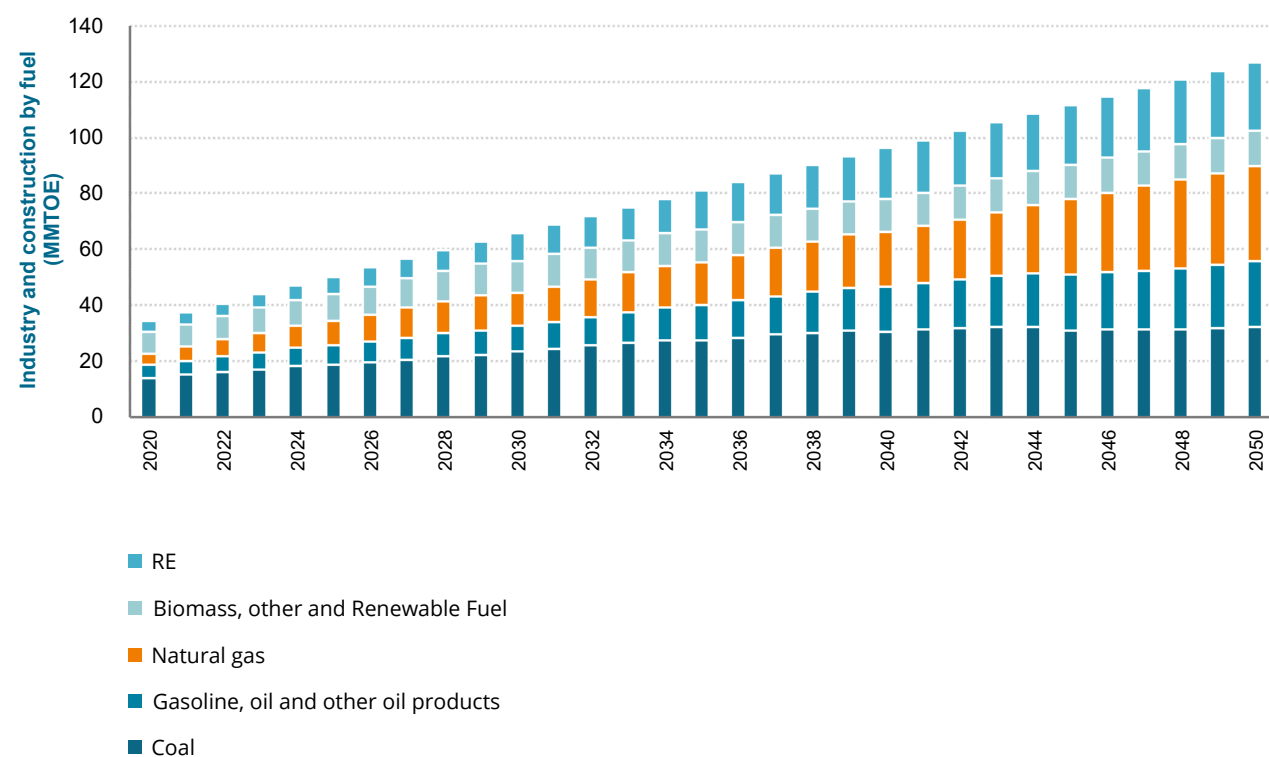




2.1. The Industrial Sector

Turning to energy consumption in the individual sectors, coal consumption of the Industrial sector, refer to Figure 3, increases in absolute terms, but the rate of increase slows down gradually and consumption levels out in the latter years within the 30 to 32 MMTOE range. The consumption of Gasoline, oil and other oil products increases throughout the study period from 5 to 23 MMTOE. Natural gas consumption increases at a faster rate than the other fossil fuels starting at 4 and ending at 34 MMTOE. Biomass increases at a modest rate while RE consumption (through the power sector) increases at a higher rate than that of biomass.

FIGURE 3. TFEC by Type - Industrial Sector - BAU



2.2. The Transport Sector

Transport requirements are modelled to grow in line with GDP growth. Passenger and freight traffic is projected to increase by 6 to 7 times current levels by 2050. Figure 4 and Figure 5 show respectively the growth, by mode of transport, in passenger traffic (in billion person-kilometres) and freight traffic (in billion ton-kilometres). Road transport has the highest share of passenger traffic with a significant share for aviation. In freight, maritime transport continues to command the largest share followed by Road and inland waterway modes. The BAU assumes little to no electrification or conversion to renewable fuels. The Transport sector therefore remains heavily reliant on gasoline, diesel and oil products, refer to Figure 6.

FIGURE 4. Passenger Requirements by Category

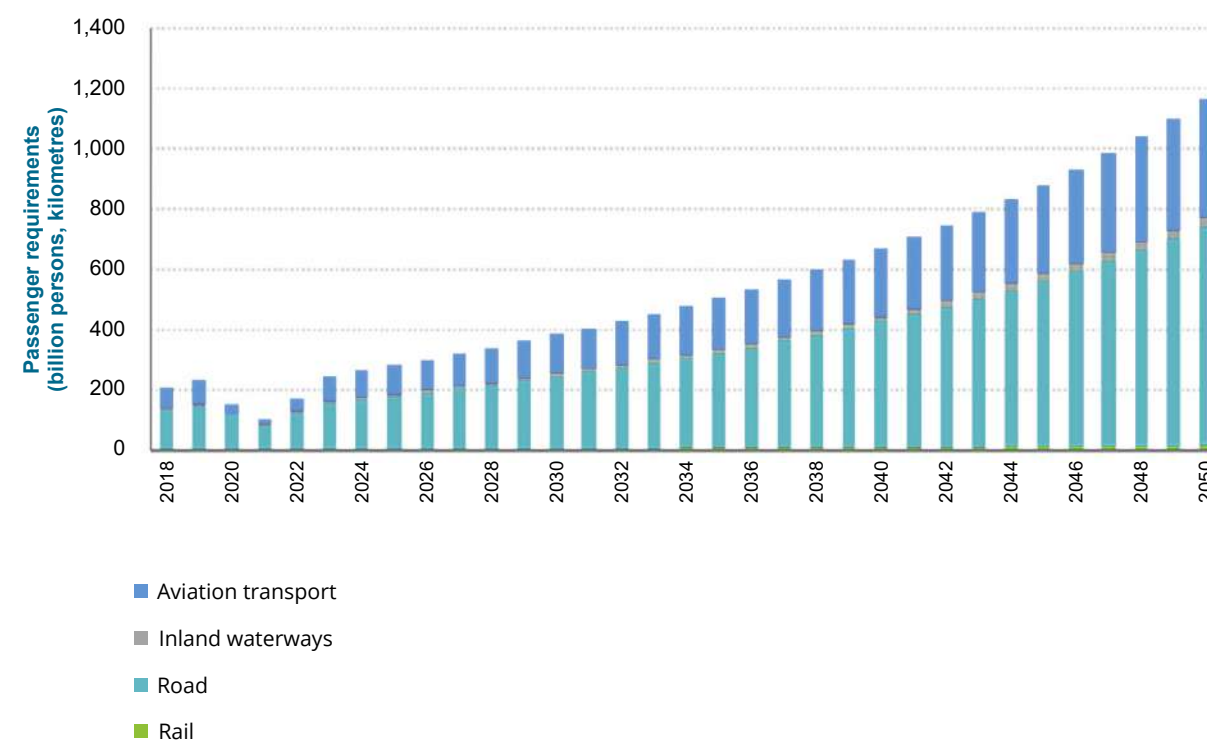


FIGURE 5. Freight Requirements by Category

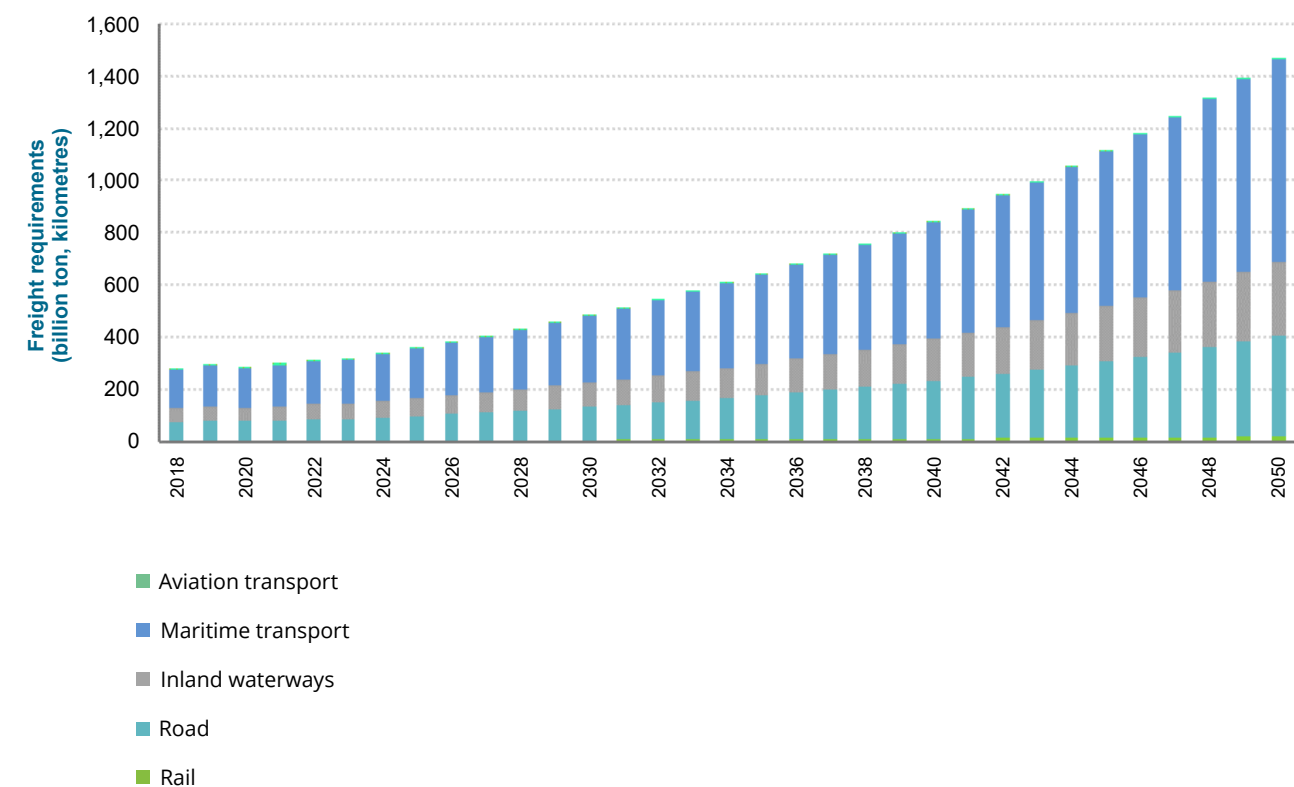
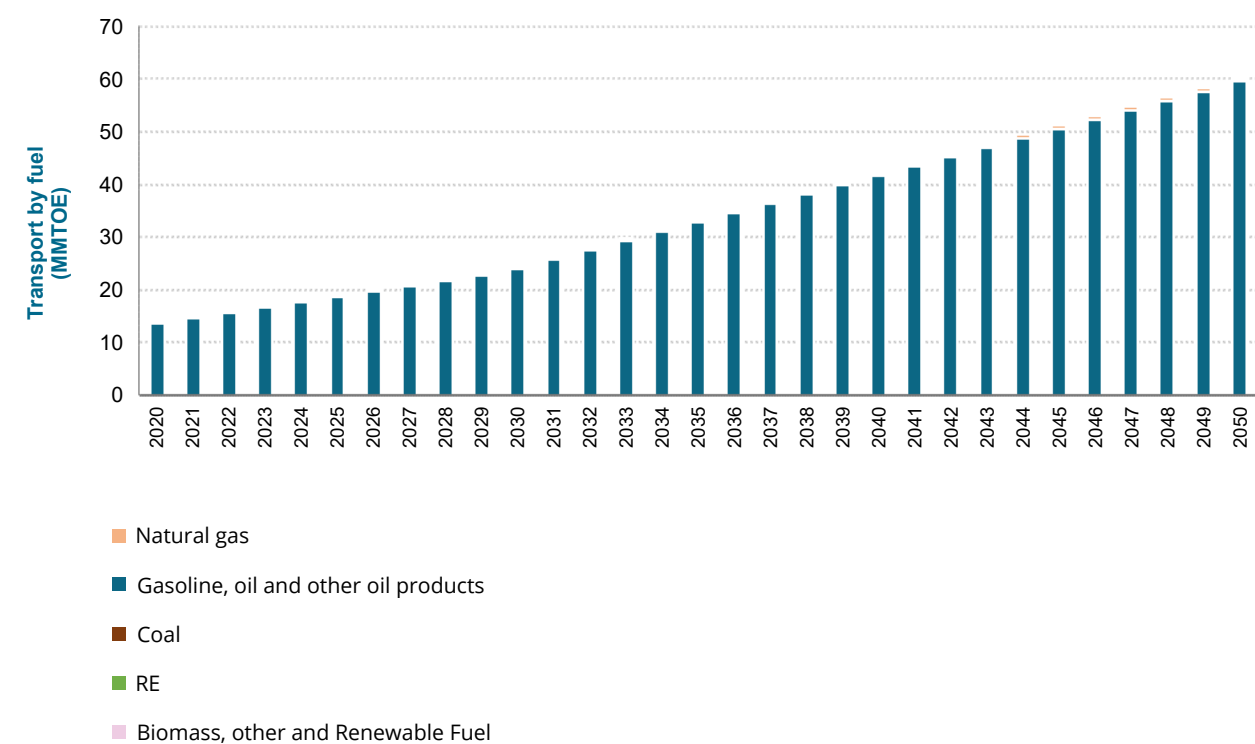


FIGURE 6. Transport TPEC (MMTOE)

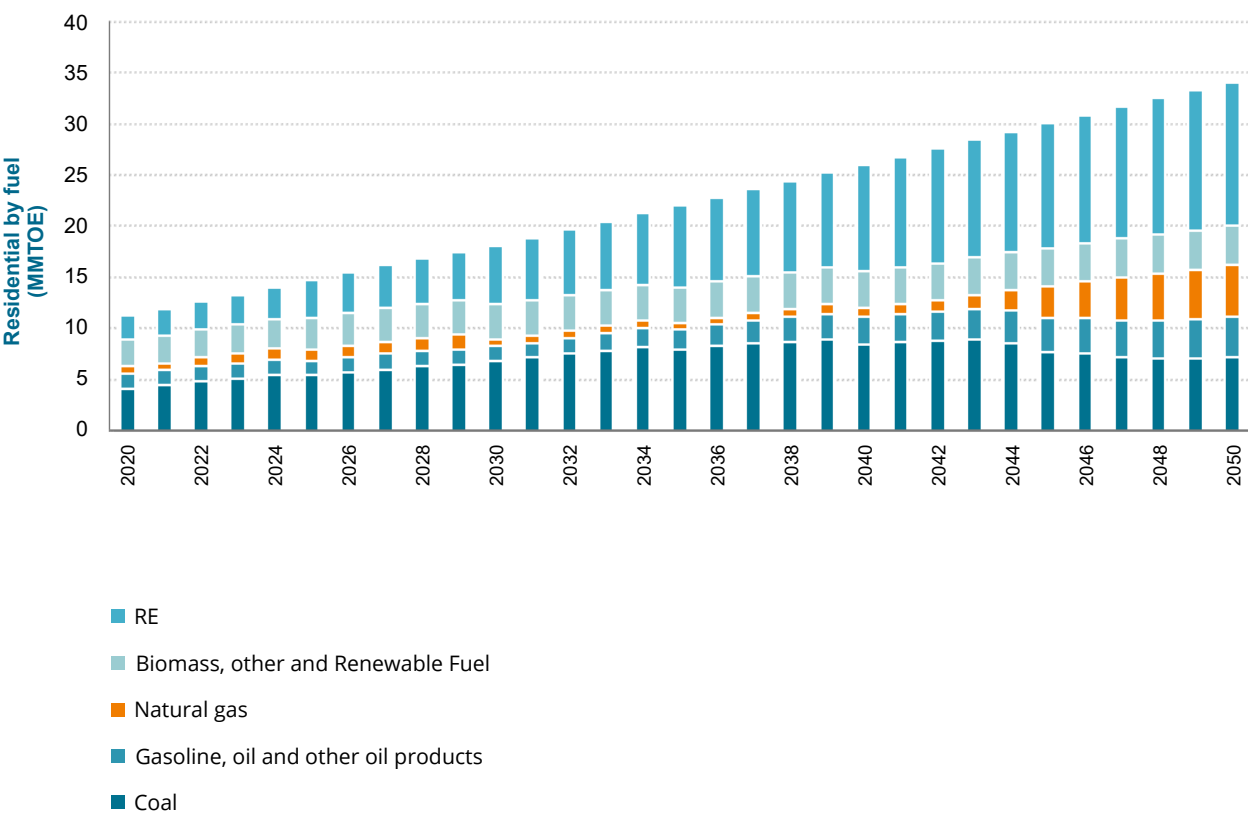


2.3. The Household Sector

The Household sector is the third largest consumer of energy in Vietnam. Energy consumption grows from 11 to 34 MMTOE driven by population growth, improvement in the standard of living and the trend of increasing urbanisation. The share of coal declines to a 21% share while that of renewable energy grows to 52%, refer to Figure 7. With near complete electrification of households, electricity is the dominant energy carrier consumed in this sector. Cooking and water heating represent about a quarter of the energy used in this sector. The main energy carrier for cooking in urban areas is LPG and biomass in rural areas. Water heating accounts for between 16% and 21% of electric consumption for a family of four.¹

¹ Vietnam - National Energy Efficiency Program 2019 – 2030, Appendix 3, p 74

FIGURE 7. Household Sector Energy Demand by Fuel Type

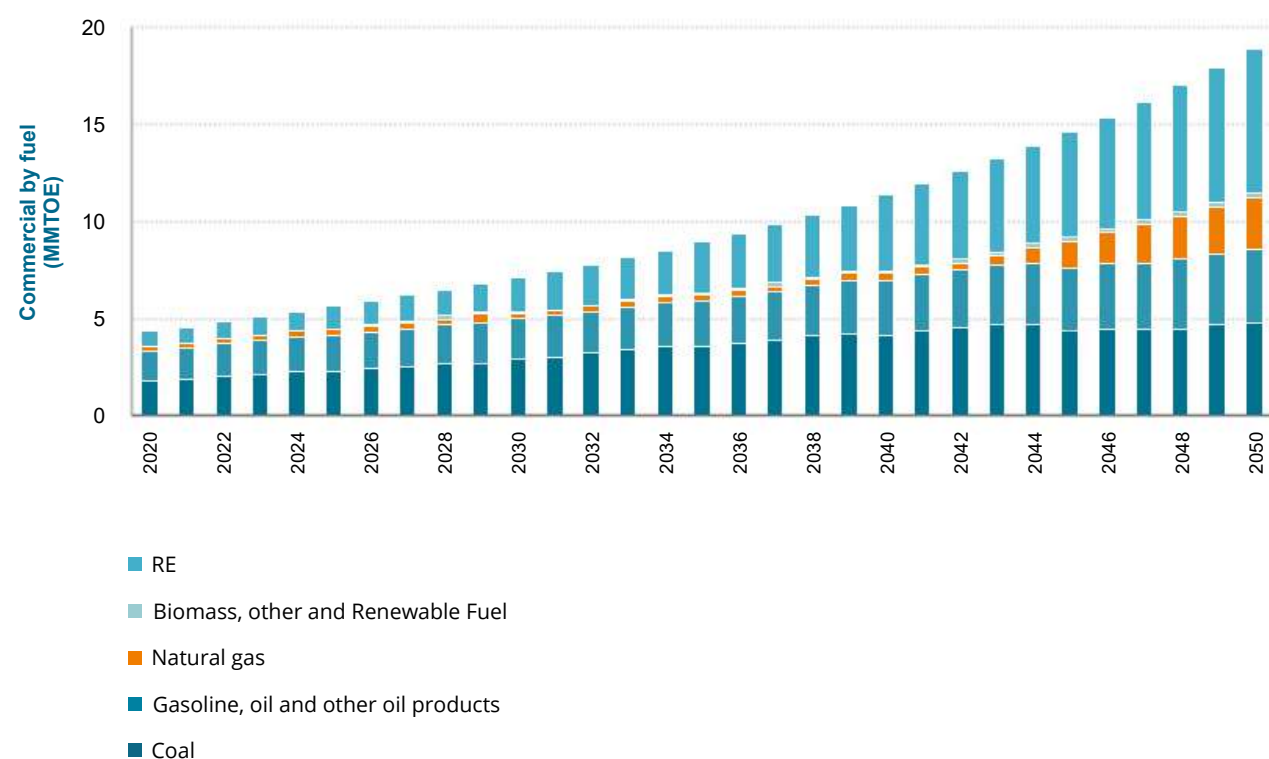




2.4. The Commercial Sector

The Commercial sector and the agriculture sectors are the two smallest consumers of energy in Vietnam. The Commercial sector accounted for approximately 5% of the national final energy consumption in 2020. Coal and oil-based energy consumption continues to grow, to reach in 2050 approximately 4 and 5 MMTOE respectively, but the consumption of RE grows at a faster rate over the study horizon to reach over 7 MMTOE. Energy consumption more than triples in the sector to 19 MMTOE, see Figure 8.

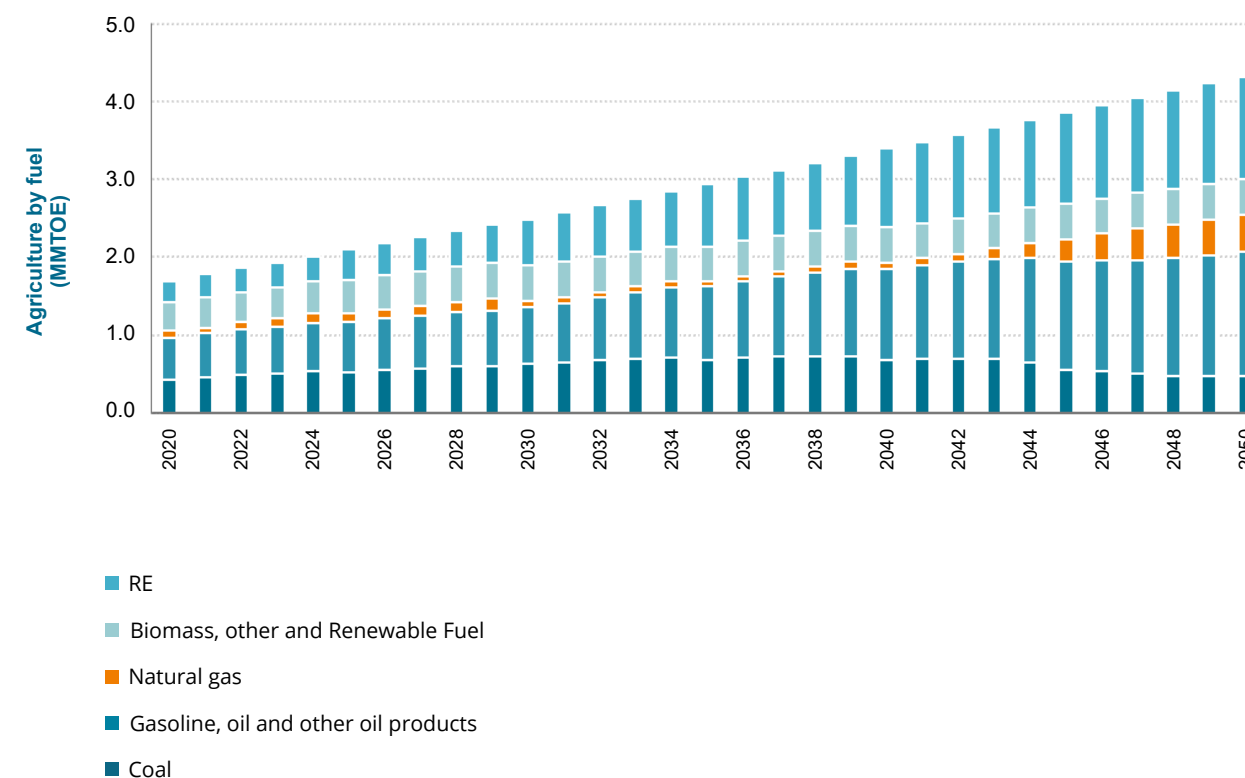
FIGURE 8. Commercial Sector Energy Demand by Fuel Type



2.5. The Agricultural Sector

The Agricultural sector also includes forestry and fishery/aquaculture activities. The sector accounts for about 3% of the national final energy consumption. As Figure 9 shows, all energy carriers, with the exception of coal are projected to grow in the sector. Energy consumption more than doubles over the study horizon to 4 MMTOE. The largest growth in absolute terms is in oil-based energy and RE that grow respectively to 1.6 and 1.3 MMTOE in 2050.

FIGURE 9. Agricultural Sector Energy Demand by Fuel Type

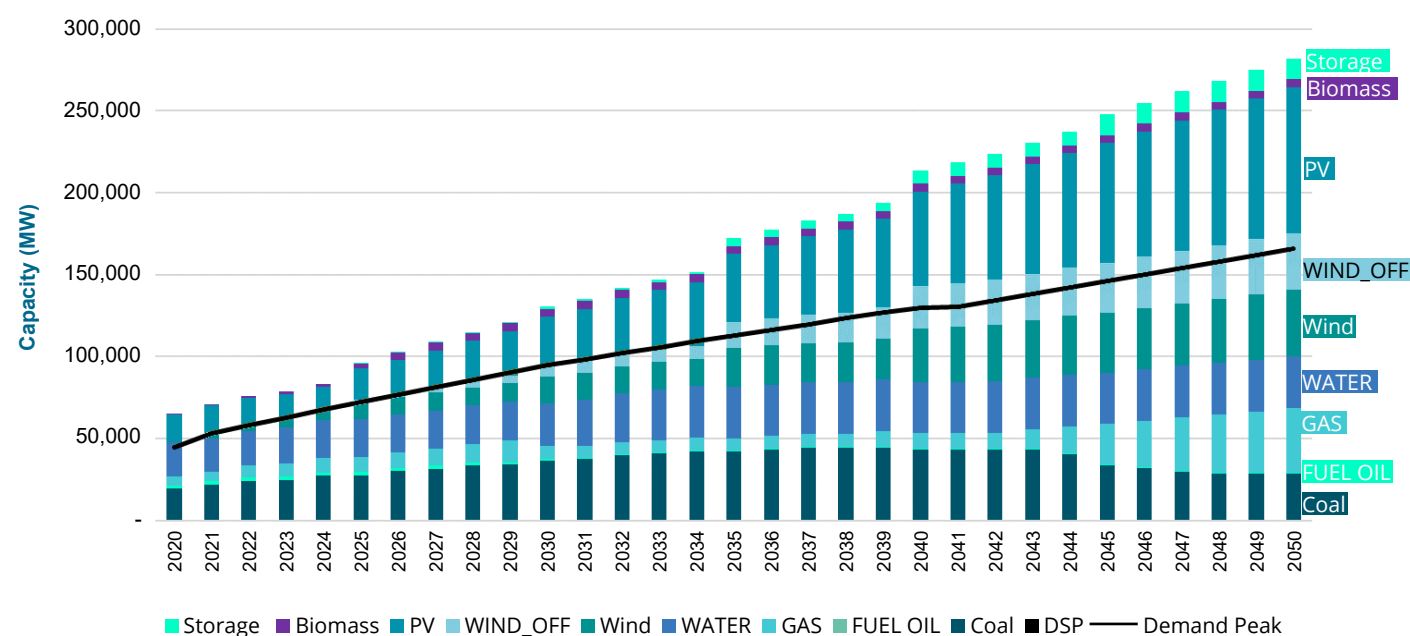




2.6. The Power System

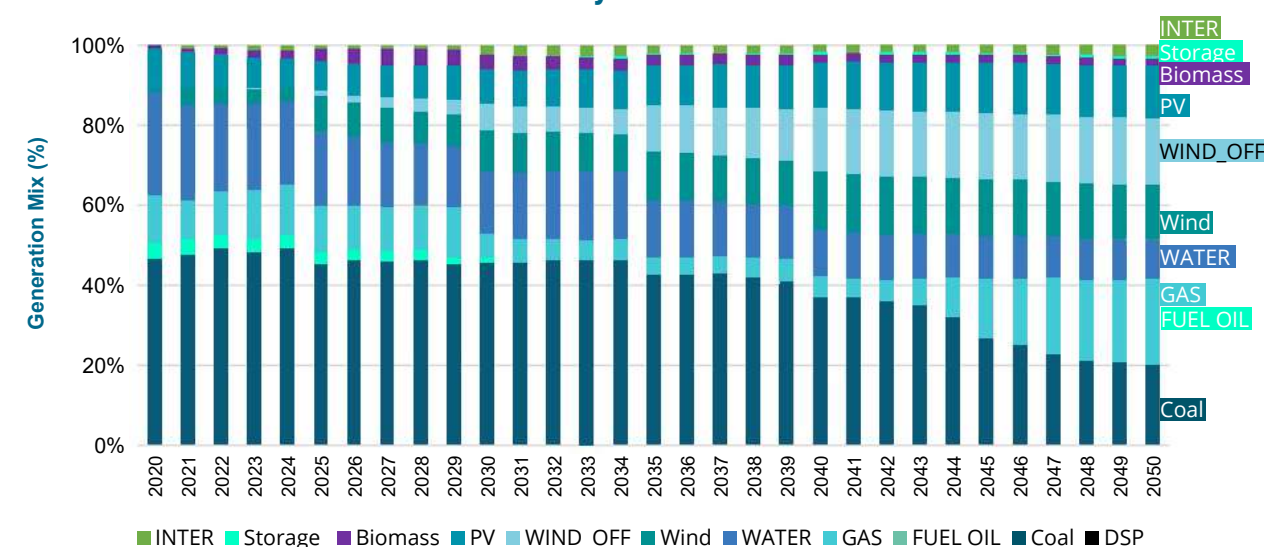
The power system installed capacity and peak demand (black straight line in Figure 10) are projected to grow. Coal's share declines driven by no new coal entrants from 2037 and retirement of 15 GW from 2040 to 2050. Committed gas generators enter the system in 2028 and further gas is introduced post 2040 eventually replacing coal as the major fuel for power. The power system also sees 30 GW of solar, 17 GW of wind and offshore wind, and 13 GW storage to support the RE capacity.

FIGURE 10. System Installed Capacity and Peak Demand



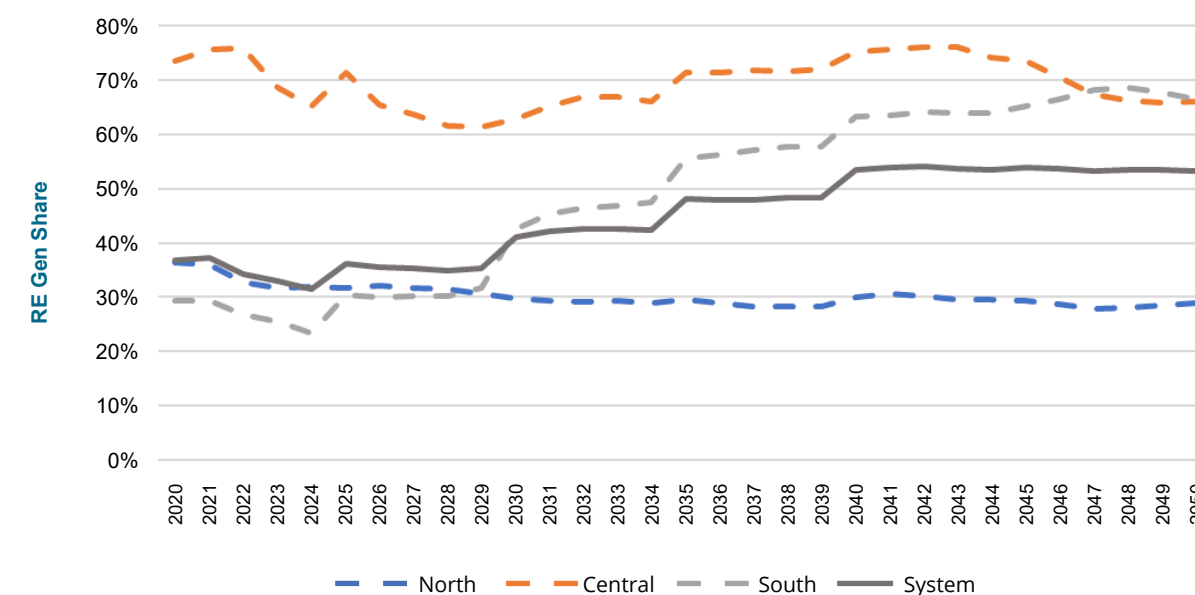
The generation mix picture is consistent with the capacity picture. Figure 11 shows coal's share declining, gas taking over the lead late in the horizon and an increasing share of renewables. The share of thermal generation falls from 60% to 42% and the balance is supplied by renewables and about 3% from imports.

FIGURE 11. System Generation Mix



The share of generation coming from RE, shown in Figure 12, is highest in the Central region, the South region catches up to it while the North region continues to have a low share.

FIGURE 12. RE Generation Share

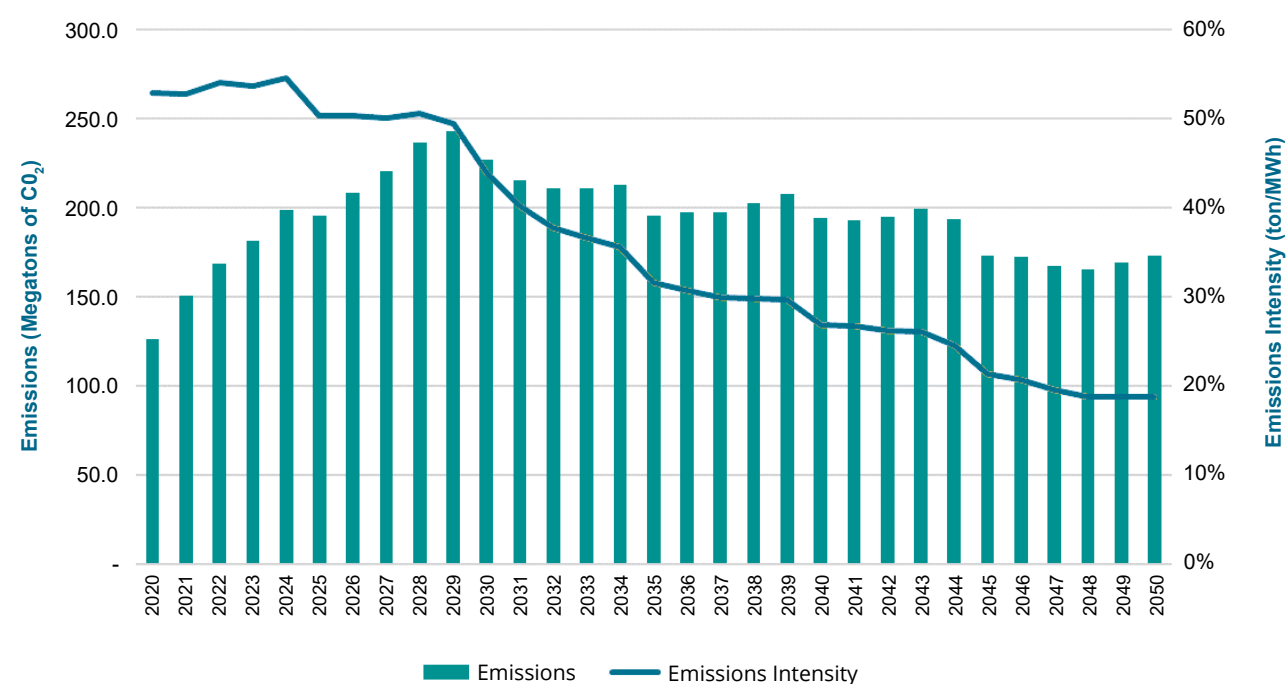




2.7. Emissions

Emissions increase steadily from 2020 to 2030 at the same rate as demand because the demand is met by new thermal developments, as reflected by the flat profile in emissions intensity during this period, refer to Figure 13. After 2030, the total emissions are relatively stable but the emissions intensity halves from 0.5 to 0.25 tons per MWh as retiring coal generators are replaced by RE and lower emitting gas generators.

FIGURE 13. System Emissions and Emissions Intensity



The next section compares the three scenarios including on cost parameters.

3 SCENARIO COMPARISON



Table 2 . Summary metrics

Metrics	BAU	80RE	100RE
TFEC (2050)	244	229 (-6%)	223 (-8%)
TFEC (fossil fuel, 2050 share)	74%	21%	0%
TFEC (RE, 2050 share)	19%	65%	78%
TFEC (Biomass, other and Renewable Fuel, 2050 share)	7%	14%	22%
NPV of costs (incl externalities, billions USD)	1,943	1,767 (-9%)	1,747 (-10%)
Total investment requirements (billions USD)	5,133	3,817 (-26%)	4,089 (-20%)

* Percentage difference from the BAU is shown between parentheses.



We next compare each sector across the three scenarios BAU, 80RE and 100RE, using snapshot years 2020, 2030, 2040 and 2050. The energy consumption in each sector includes electricity consumed by that sector from the power system.

Annual costs in the 80RE and 100RE are lower by about 9% to 10% respectively compared to the BAU after including externalities. Table 2 shows summary metrics of the scenarios. The high RE scenarios require significant electrification and supplying the powers system from RE sources. By 2050, in the 100RE scenario Vietnam relies on renewable electricity generation for 78% of its energy consumption and the balance from renewable fuels. In comparison, the 80RE scenario generates 65% of its energy needs through renewable electricity, with approximately 14% from renewable fuels, but still relies on fossil fuel consumption (20%) for processes that are costly to electrify or convert to renewable fuel. The BAU remains largely fossil-fuel based (74%). The significant reduction in costs to achieve these objectives is largely driven by increased energy efficiency (mainly in the transport sector) and declining costs over time (from projected declining electric vehicles, solar, wind and battery energy storage system costs).

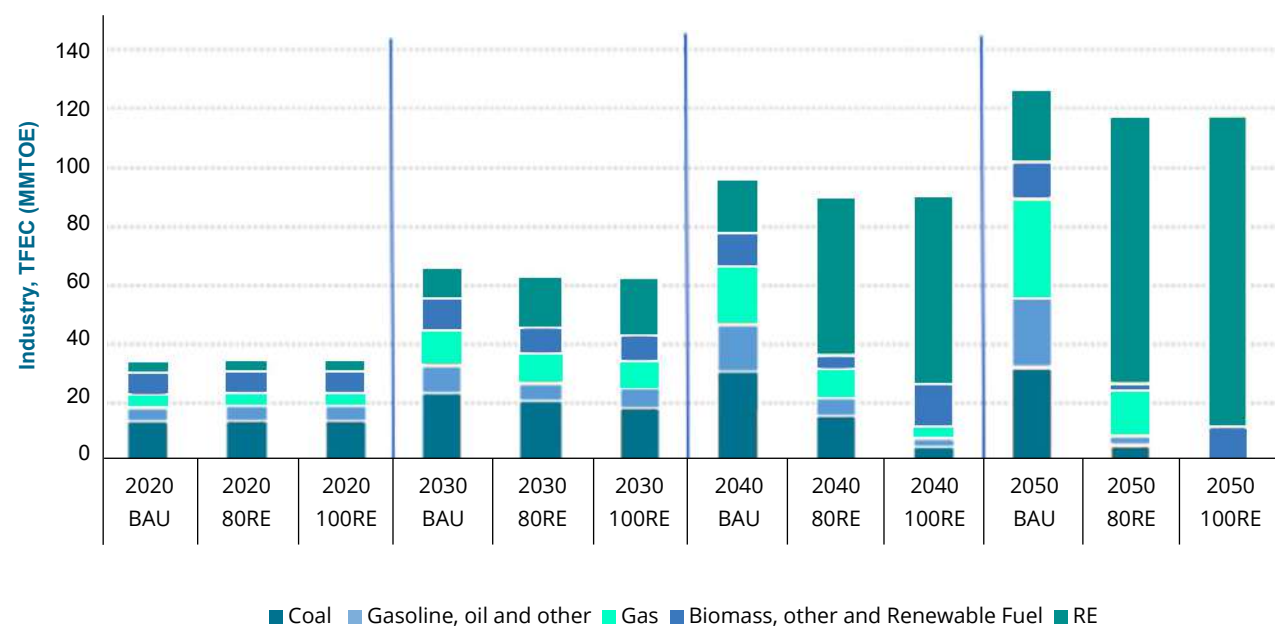




3.1. The Industrial Sector

The Industrial sector continues to be the largest energy consumer in the economy in all scenarios. Figure 14 shows that fossil fuel carriers dominate the sector in the BAU (71%). In the 100RE scenario RE has the indisputable dominant share as shown in 2040 (70%) and 2050 (90%). Fossil energy carriers are completely displaced by renewables by 2050 as RE expands further and the balance of demand is furnished by biomass and renewable fuels. In the 80RE scenario 20% fossil fuels remain in the sector to minimise high cost conversions to renewable fuels (found in the 100RE). The consumption of gas in the sector (13% of TFEC) comes from the sector's consumption of electricity through the power system; gas generators are allowed to remain in the power system in the 80RE scenario. Higher energy efficiency in the 80RE and 100RE scenarios compared to the BAU results in lower total final energy consumed. The TFEC in 100RE is slightly higher than in 80RE by 2050 because the energy required to produce renewable fuels offsets higher energy efficiency in the 100RE.

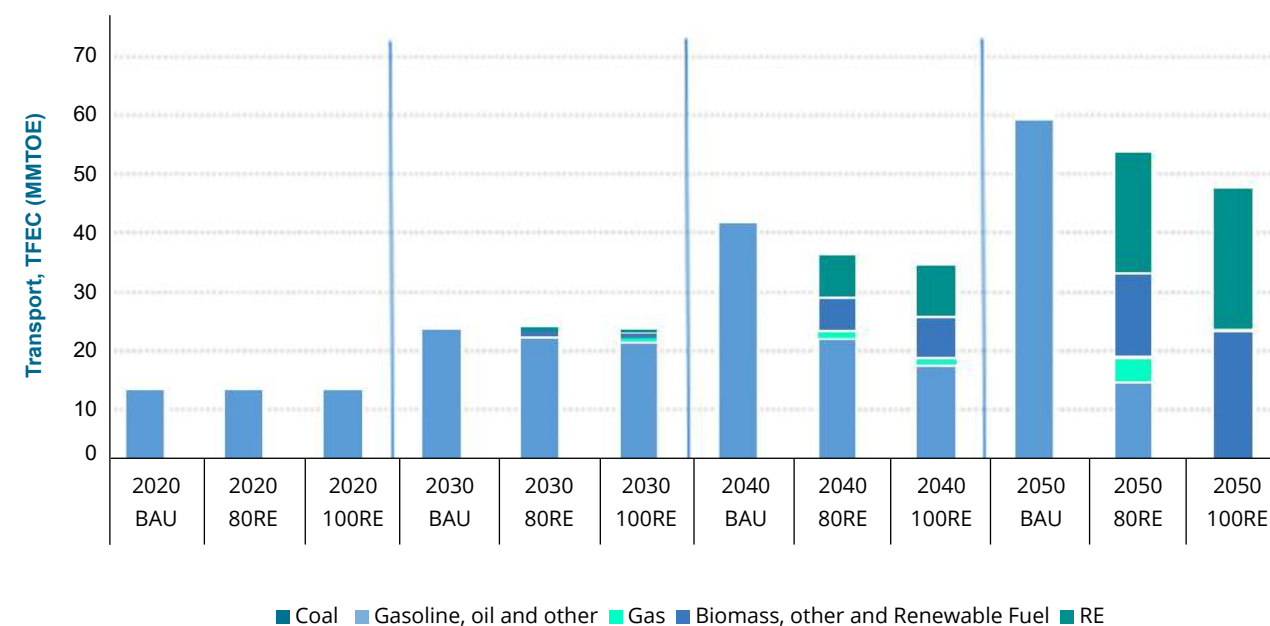
FIGURE 14. TFEC by Fuel Type - Industrial Sector - Scenario Comparison



3.2. The Transport Sector

The Transport sector is transformed from being highly fossil fuel dependent, in the BAU, to being supplied by electricity and renewable fuels, in the high RE scenarios. Figure 15 shows that electrification accounts for a high share of energy use by 2050, 38% and 50% in 80RE and 100RE respectively, and is easiest in road transport. A higher EV share results in lower TFEC in the sector. Renewable fuels are used in areas where electrification is technically or financially challenging, such as in aviation and maritime transport applications. In the 80RE scenario fossil fuels are used in the transport sector directly primarily replacing renewable fuels. Similar to the Industrial sector we see gas in the transport sector coming from the gas generators that are allowed to remain in the power system in 80RE. Fossil-based energy in 80RE, including the sector's share of fossil-based energy from the power system, accounts for 19 MMTOE.

FIGURE 15. TFEC by Fuel Type - Transport Sector - Scenario Comparison





3.3. The Household Sector

The Household sector is the third largest energy consumer in Vietnam with 34 to 35 MMTOE TFEC in 2050. Households in Vietnam are virtually entirely electrified. In the high RE scenarios cooking is converted to electricity from LPG, mainly used in urban areas, and from coal, mainly used in rural areas. The power system is entirely, in 100RE, or primarily, in 80RE, supplied by renewable sources. Increased electrification of this sector supports the transition to renewable energy. Refer to Figure 16. Renewable energy accounts for 89% of the sector's consumption in 2050 in the 80RE scenario and 100% in the 100RE scenario.



3.4. The Commercial Sector

The Commercial sector is the second smallest energy consumer nationally. Higher electrification, 78% by 2050, and conversion to biomass and renewable fuels, 22% by 2050, drives the transition to renewable energy in this sector. In the 100RE scenario the power system is entirely supplied by renewable sources, refer to Figure 17. Renewable energy accounts for 89% of the sector in 2050 under the 80RE scenario and 100% in the 100RE.

FIGURE 16. TFEC share by Fuel Type - Household Sector - Scenario Comparison

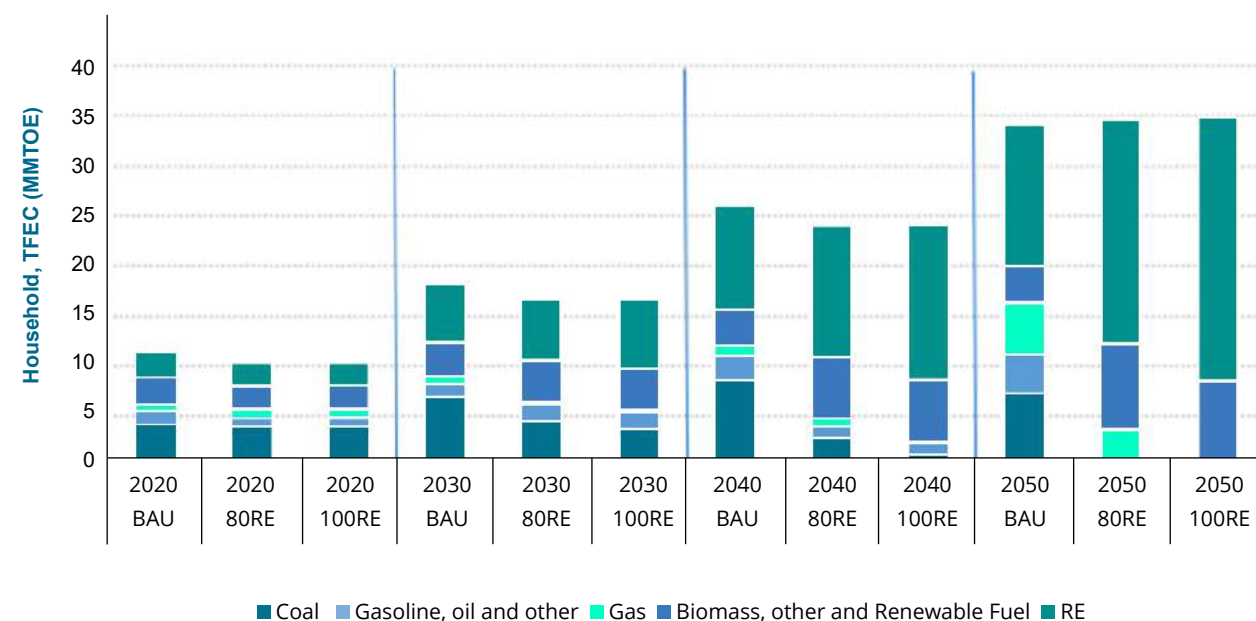
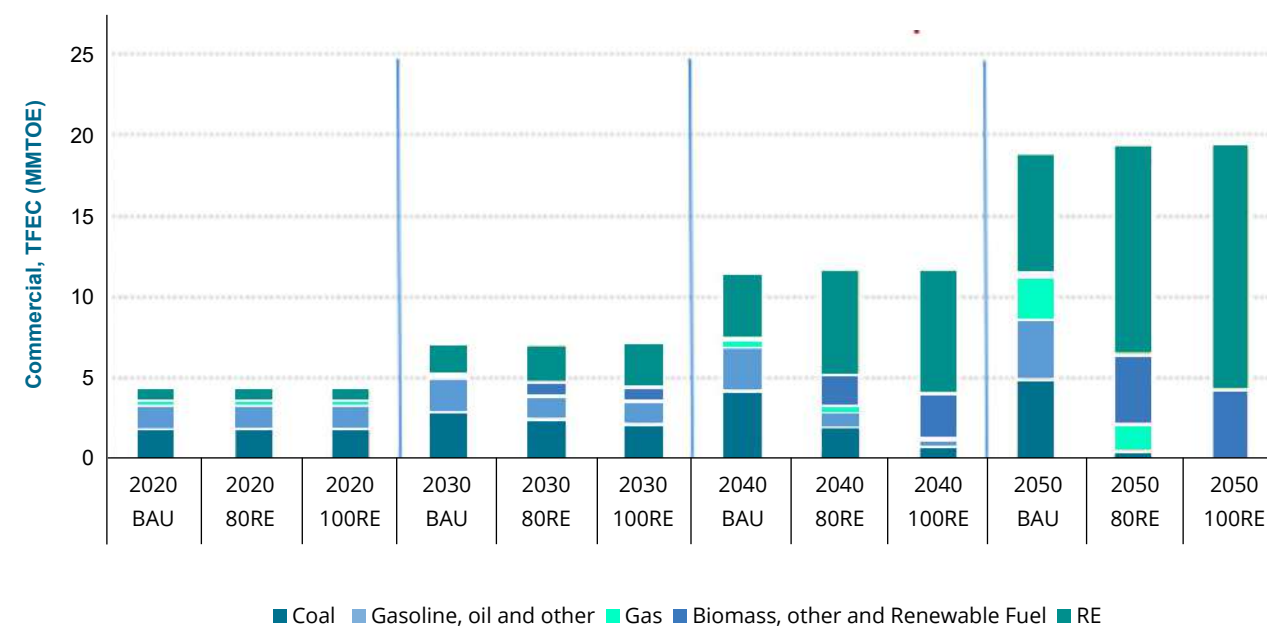


FIGURE 17. TFEC share by Fuel Type - Commercial Sector - Scenario Comparison

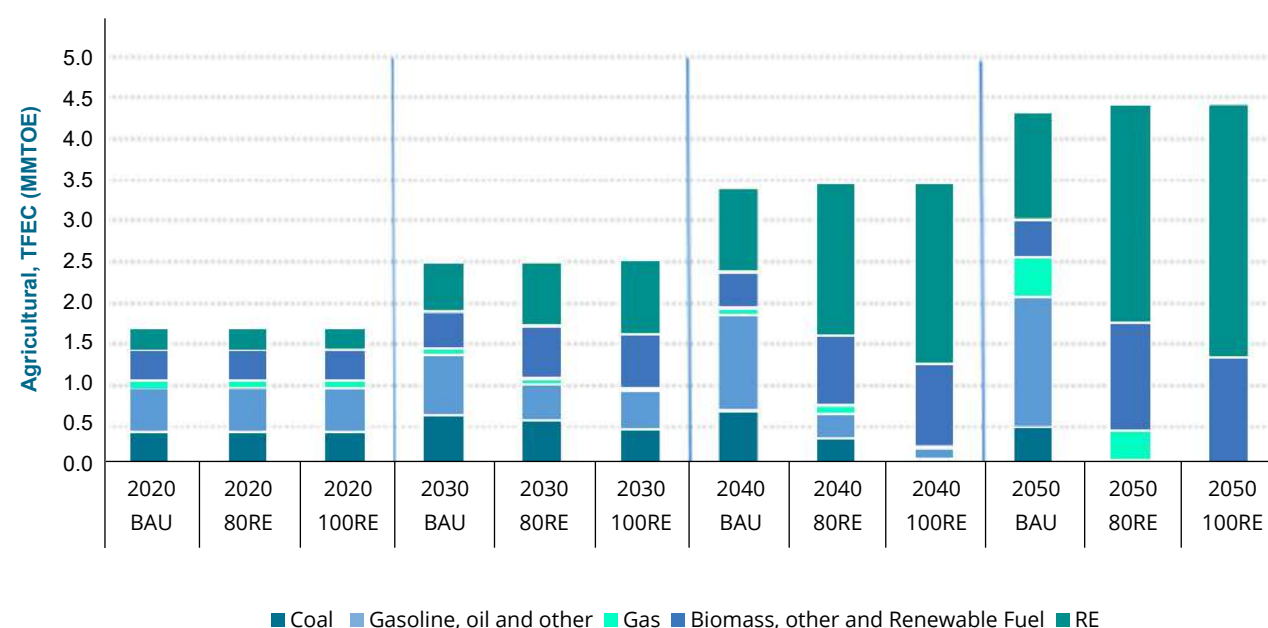




3.5. The Agricultural Sector

The smallest energy consumer is the Agricultural sector. Electrification in 2050 increases from 53% in the BAU to 60% and 70% in the 80RE and 100RE scenarios respectively. The remaining share in both high RE scenarios comes from biomass and renewable fuels, refer to Figure 18. Renewable energy accounts for 90% of the sector in 2050 under the 80RE scenario and 100% in the 100RE scenario.

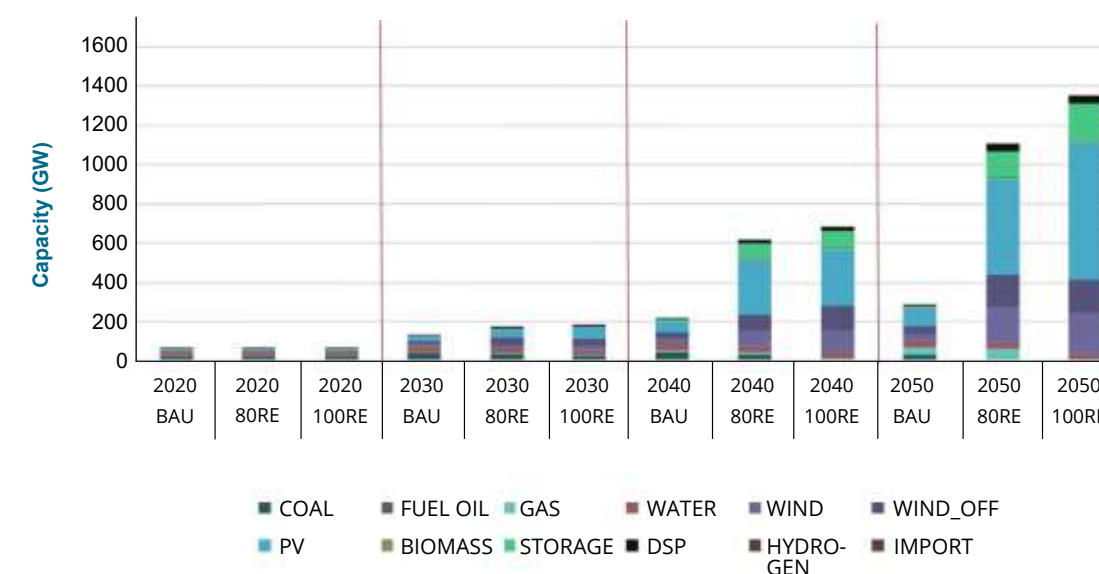
FIGURE 18. TFEC share by Fuel Type - Agricultural Sector - Scenario Comparison



3.6. The Power System

The BAU has a growing proportion of installed gas generators, to replace retiring coal assets and met increasing demand. While renewables expand in the BAU they expand much faster in the high RE scenarios to almost five times the capacity in the BAU. Figure 19 compares installed capacity across the scenarios. By 2050, higher solar capacity in the 100RE compared to the 80RE is required to replace the gas and little remaining coal in the 80RE scenario. The high levels of installed capacity of solar in 2050 (450 GW in 80RE, 730 GW in 100RE) require large areas of land. The high solar capacity it is within the more than 1500 GW of solar technical potential, estimated based on GIS mapping, in the PDP8. It is also less than what was considered feasible by other studies, that based the land requirement on the typical land use value of 1.1 ha/MWp solar technology in the Vietnam technology catalogue.²

FIGURE 19. Comparison of System Installed Capacity



² EREA & DEA. (2021a). Vietnamese technology catalogue. Hanoi: Electricity and Renewable Energy Authority & Danish Energy Agency

The share of coal in generation declines in all scenarios. Referring to Figure 20, by 2030 thermal generation decreases to 40% in 80RE and to 30% in 100RE compared to BAU. By 2050, the share of thermal generation decreases to just 12% in the 80RE scenario and 0% in the 100RE scenario. The remaining share of generation in the high RE scenarios comes from renewables, dominated by wind and solar. To help meet demand in peak periods in the 80RE and 100RE scenarios, battery capacity of 77 GW and 88 GW by 2040, and 135 GW and 198 GW is needed by 2050 in the respective scenarios. Battery assets in the high RE scenarios have between five to six hours storage capacity. The BAU has a higher share of firm generation capacity and a much lower battery capacity, 13 GW of one-hour battery, by 2050. Demand Side Participation (DSP) provides up to 2% of generation share in 2050 in the high RE scenarios. Hydrogen does not feature significantly in the transition to RE due to low roundtrip efficiency of 23% and the assumed availability of solar and wind. This does not preclude the utilisation of hydrogen in specific instances where, for certain local conditions, it may prove to be more cost effective than other options or if it is desired to gain experience on research and production of hydrogen to keep it alive as an option for future.

By 2030 thermal
generation decreases to
40%
in 80RE and to
30%
in 100RE compared to BAU

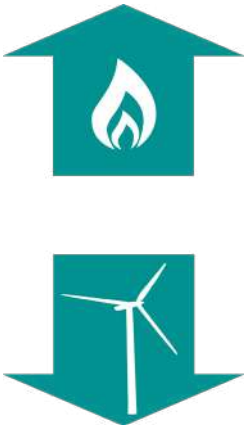
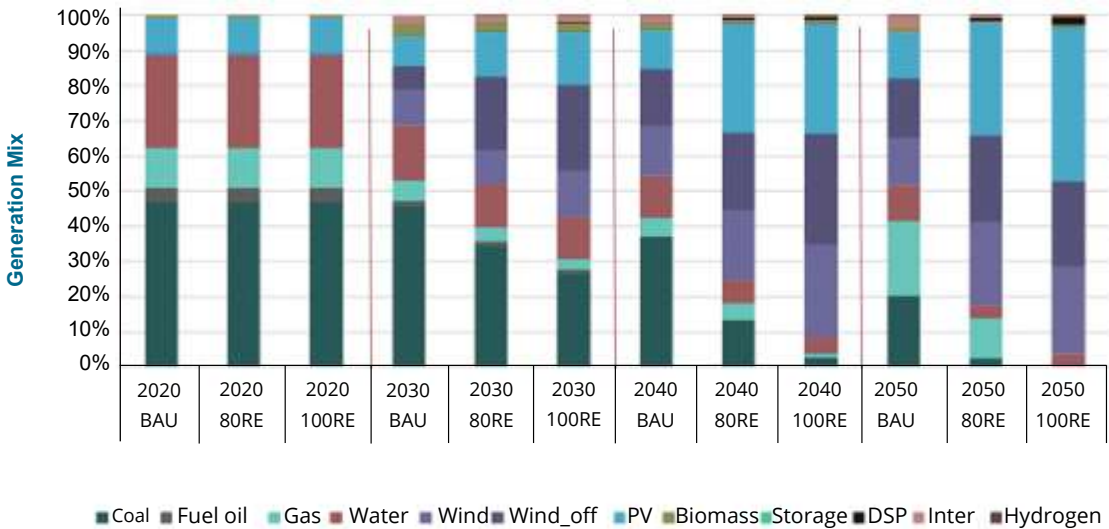


FIGURE 20. Comparison of Generation Mix



Transmission capacity in the high RE scenarios is up to eight times of that required in the BAU. It mainly transmits energy from the Central region to the North region. The dispatch profile in the BAU is similar between 2030 and 2050 except that gas overtakes coal as the leading technology. In 2050, 100RE has a higher PV peak at 360 GW compared to 252 for 80RE. Battery is dispatched in intervals of low solar generation and provides a total of 600 GWh in 100RE compared to 480 GWh in 80RE. DSP contributes to reducing the peak demand outside the intervals with high solar generation.

Considering costs of the power system in isolation of the rest of the economy, the 100RE scenario has lower fuel costs (yellow bar in Figure 21) than the BAU, but higher capex and O&M costs. Fuel costs in the 80RE scenario represent the gas and little coal fossil fuels allowed under that scenario. The LCOE of the power system is higher for the high RE scenarios when the RE penetration levels reach high levels in latter part of the analysis horizon, refer to Figure 22.

FIGURE 21. Comparison of Total Power System Cost by Component

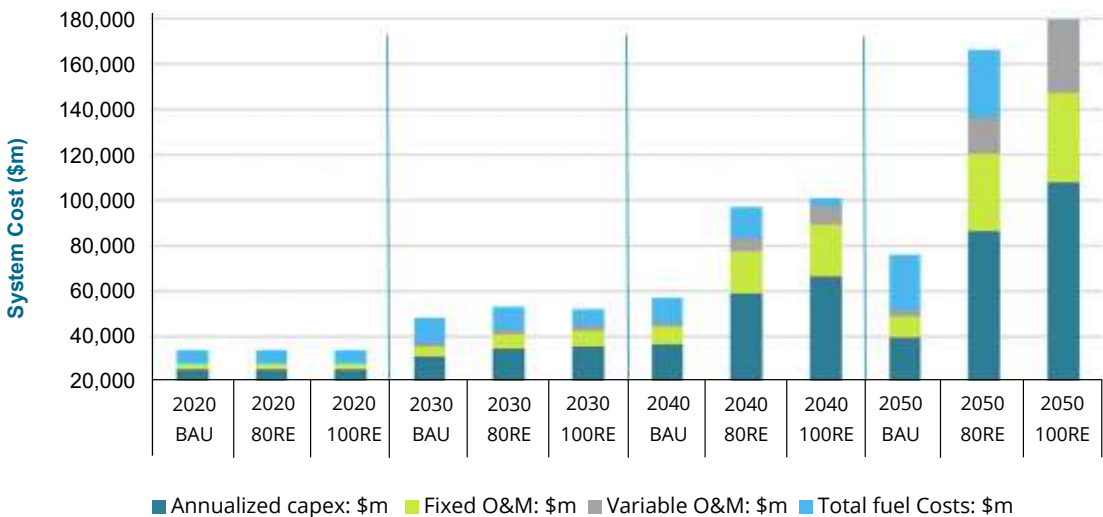
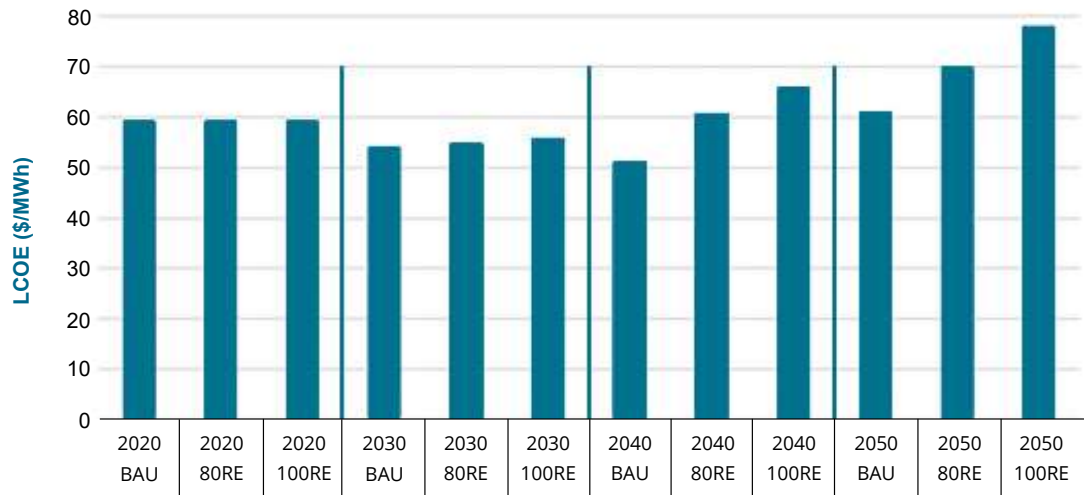


FIGURE 22. Comparison of LCOE

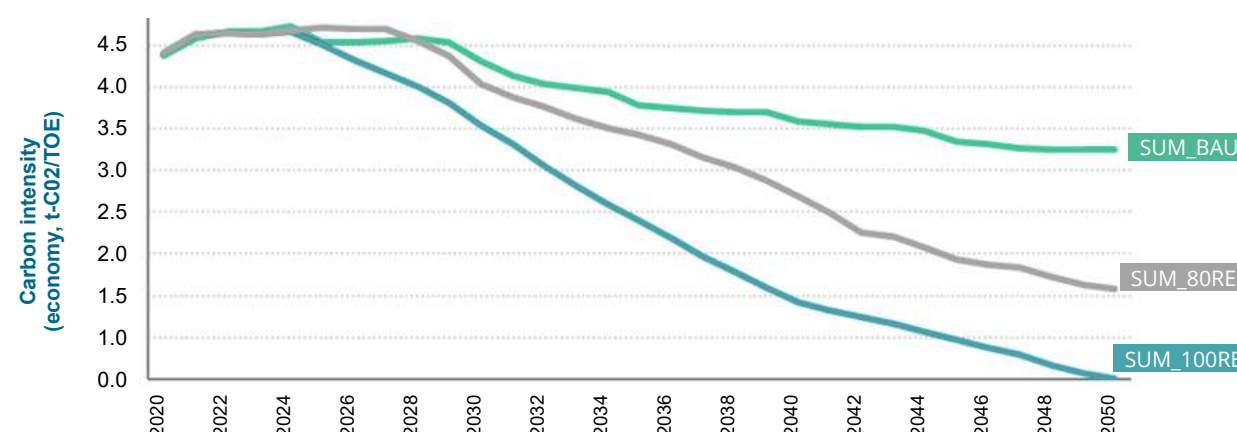




3.7. Emissions

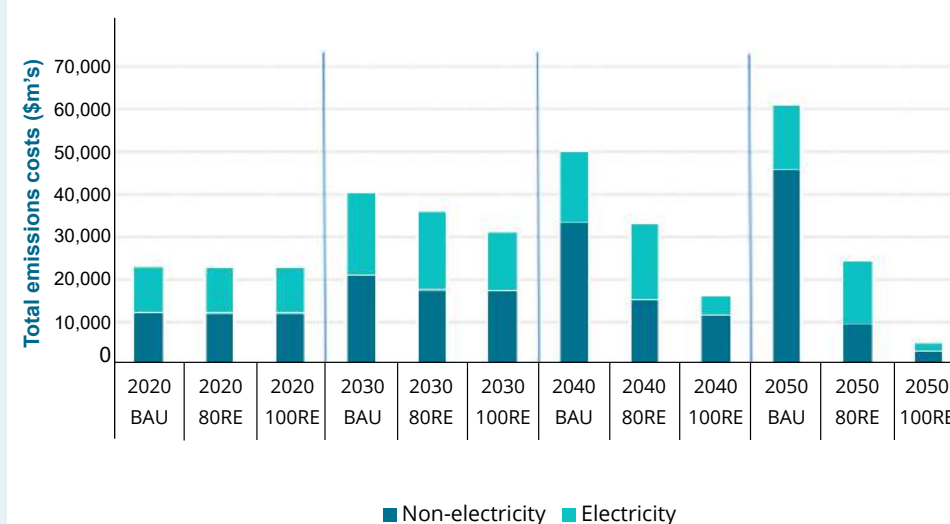
Figure 23 plots the carbon intensity which is seen to decline in all scenarios from 2030. The 100RE scenario has the lowest carbon intensity followed by 80RE and BAU, in that order.

FIGURE 23. Economy-wide Carbon Intensity - Scenario Comparison



The cost of emission is shown in Figure 24 divided into costs attributed to the power system (the 'Electricity' category) and costs from the rest of the economy (the 'Non-electricity' category). Cost of externalities increases in the BAU as energy demands grow. In the high RE scenarios externalities costs fall as RE share increases and are lowest for 100RE.

FIGURE 24. Total Emissions Cost - Scenario Comparison



3.8. Costs

When we consider investment and technology costs over the entire economy the picture is different than when considering the power system in isolation. Annual costs for snapshot years by component for the power system and the rest of the economy are plotted in Figure 25. Total economy-wide investment requirements are highest for the BAU at 5,133 billion USD, lowest for 80RE at 3,817 billion USD (26% lower than BAU), with 100RE being second lowest at 4,089 billion USD (20% lower than BAU). 80RE has the lowest investment as it avoids transforming some high-cost areas required to achieve transformation to 100% renewable energy in the 100RE scenario. Over time, technology costs increase more than fuel costs. By 2050, technology costs comprise more than 75% of the total annual cost. High RE scenarios benefit from falling new technology costs compared to stagnant costs of traditional technologies in the BAU case. Although the 100RE case benefits from lower fuel consumption due the electrification of more than 75% of total energy consumption, it requires high technology costs to convert traditional fossil-fuel based generation and energy processes to renewable alternatives.

FIGURE 25. Economy-wide Costs by Component - Scenario Comparison

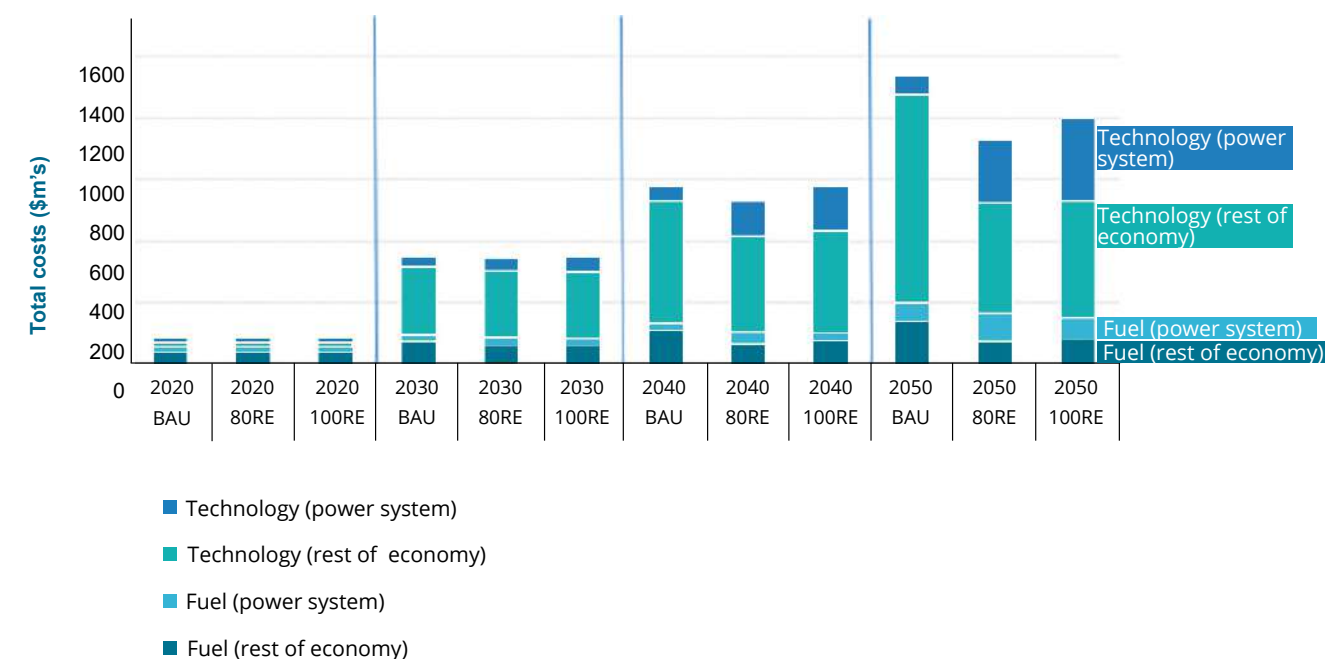
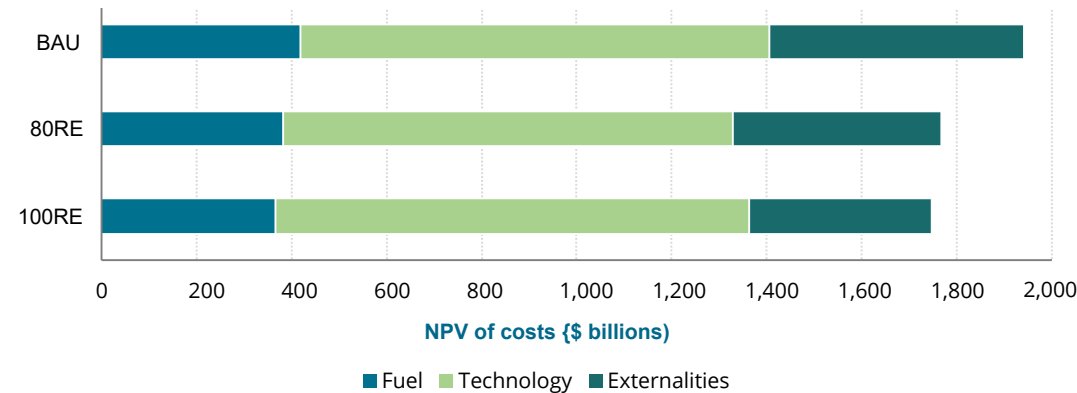


Figure 26 compares the NPV of economy-wide costs across the three scenarios. The BAU has the highest cost because of continued and growing fossil fuel consumption. The net present value of economy-wide costs including the cost of externalities is highest for the BAU at 1,943 billion USD, followed by 80RE at 1,767 billion USD (9% lower than the BAU), and lowest for the 100RE at 1,747 billion USD (10% lower than BAU). Investments in the 100RE scenario occur later in the horizon which mainly accounts for 100RE having a lower NPV than 80RE.

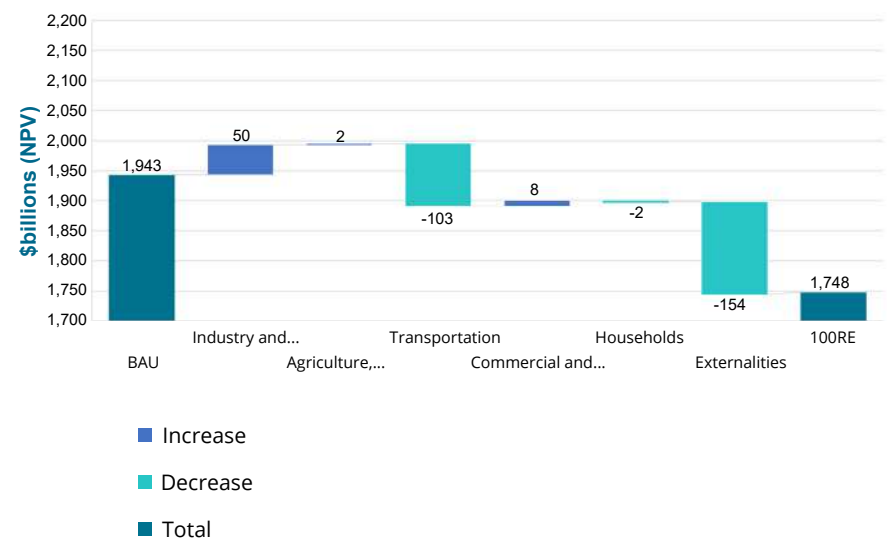
FIGURE 26. NPV of Costs by Scenario

Note: Assumes discount rate of 10%



The waterfall chart in Figure 27 shows the difference in the 100RE scenario and BAU costs broken down by sector. Externalities cost is shown as a separate category and is not double counted in sector costs. The main cost reductions come from the Transport sector and reduction in the cost of Externalities due to lower emissions. EVs are more fuel efficient and are projected to enjoy falling technology costs compared to traditional technologies. Transforming the Industrial sector to renewables results in higher costs in the 100RE scenario compared to the BAU.

FIGURE 27. Cost Comparison by Sector - BAU and 100RE Scenarios



Comparisons of annualised costs by scenario for the Industrial and Transport sectors, the largest cost movements by sector in the waterfall chart, are shown by major cost category in Figure 28 and Figure 29. Annualised cost to electrify or convert process equipment to renewable fuels in the Industrial sector increase from BAU to 80RE to 100RE but fuel costs follow the opposite trend. EVs benefit from falling technology prices compared to ICE technologies. The differences are most stark in the 2050 year.

FIGURE 28. Annualised Costs by Component - Industrial Sector - Scenario Comparison

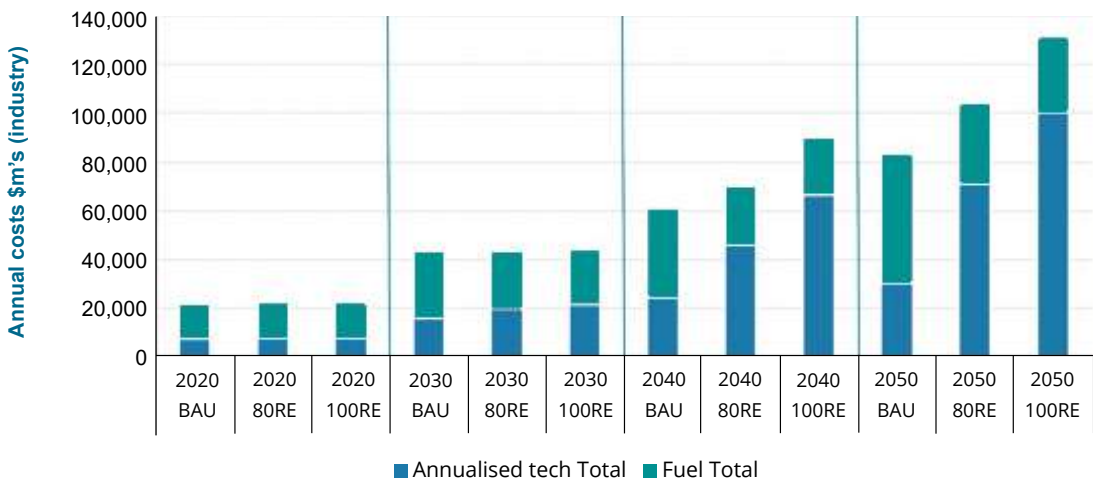
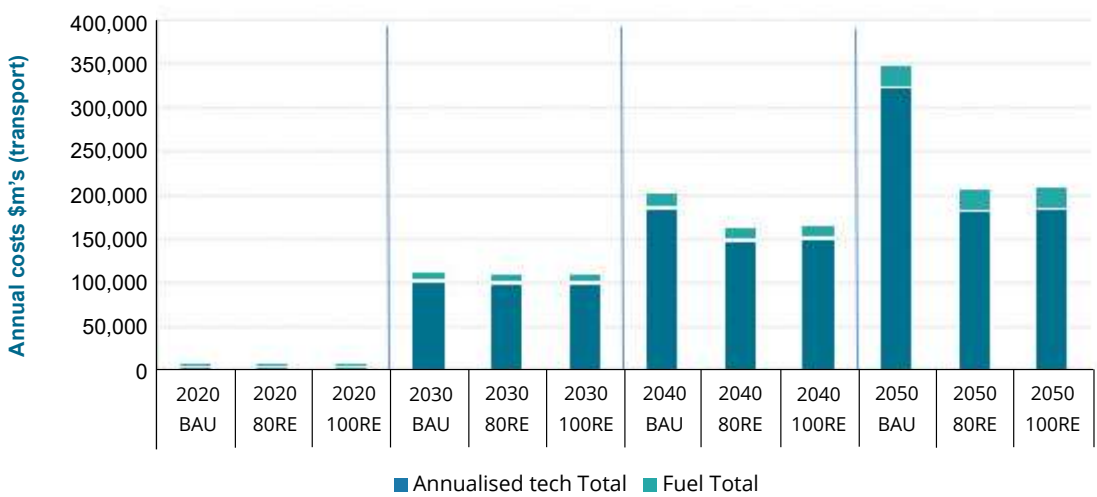


FIGURE 29. Annualised Costs by Component - Transport Sector - Scenario Comparison

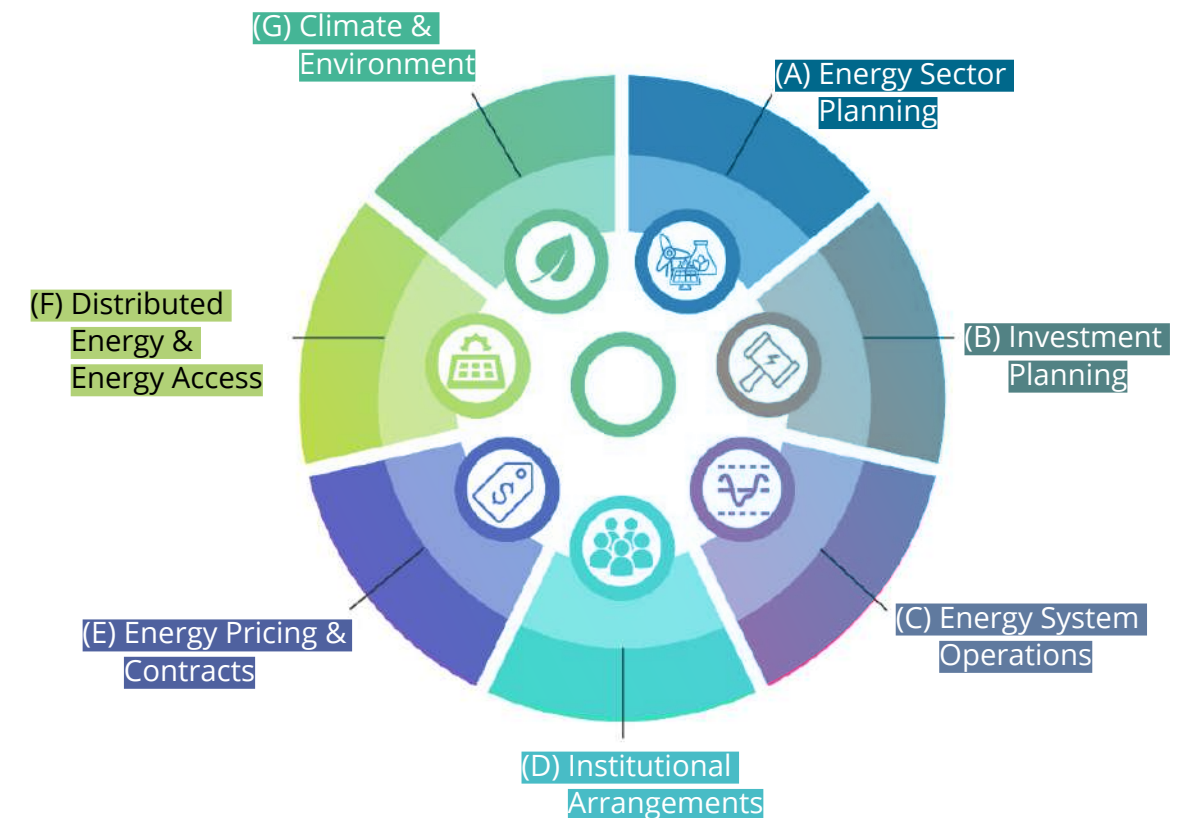


4 POLICY RECOMMENDATIONS

The modelling and analysis of the results suggest that 100% RE is achievable by 2050. Vietnam has in place several policies dealing with the energy sector that can be built upon. The policy recommendations follow the policy framework illustrated in Figure 101 which sets out key areas of policy focused on encouraging the uptake of renewable energy.



FIGURE 30. Renewable Energy Policy Framework for the Energy Sector



4.1. Energy sector planning

Electrification of the sectors based on expanding renewables is key to achieving high RE levels and the vision of 100% RE by 2050. In the high RE scenarios, electricity satisfies more than 50% of the energy consumed by 2040. By 2050 this rises to three quarters of energy consumed in the 100RE scenario and nearly two thirds in the 80RE scenario. This requires policies to integrate RE sources into the planning and operation of the power system including the grid which needs to develop to allow power from resource rich areas to reach high demand areas.

Policies to encourage flexibility needed by the power system. This includes encouraging demand-side flexibility, response to system needs (such as primary frequency response) and developing ancillary services markets.

Targeting higher levels of Energy Efficiency (EE) through a mix of incentives, regulation, standardisation of methods, better data collection, strengthening regulation, monitoring and enforcement, and capability building.

4.2. Investment planning

Improve resource mapping and integrating planning requirements across networks, power system requirement, environmental, and health. Offshore wind requires additional attention including in the areas of surveying, evaluation and permitting.

Use auctions, an approach that has already been used successfully in other jurisdictions.

4.3. Improving system operations for electricity

Upgrade the grid code, system operation and forecasting to enable the integration of RE in an orderly and robust power dispatch system without unduly constraining RE from being dispatched.

Improve the underlying IT technologies to better integrate BESS and VRE into the power system. Modelling shows the growing share (and importance) of storage. Storage can play an important role in providing energy as well as system services to maintain system security and reliability.

4.4. Institutional arrangements

Strengthen governance including in the areas of monitoring and reporting.

Develop standards, methods and reporting systems for carbon accounting.

Develop the workforce to support achievement of the goals set in the policies.



4.5. Energy pricing and contracts

Reward flexibility, integrate distributed resources, collect accurate information in a timely manner and reward RE adoption through green certificates in addition to the announced system for carbon credits. The growing importance of EVs is seen by the growing electricity consumption in the transport sector in the high RE scenarios.



4.6. Transport sector

Encourage electrification and adoption of EV through financial support for early adopters and providing the necessary infrastructure. Modelling shows that the majority of passenger transport and freight will shift to EV and policies to encourage this shift are needed.

Develop regulation to encourage EV owners to participate in the bidirectional network that will develop.

Enforce the targets in the recently announced policy to phase out ICE.



4.7. Climate, health and environment

Develop an overarching planning framework that integrates climate policies, decarbonisation strategies and achievement of NDC targets. These policies will improve health outcomes by reducing pollution, reduce dependence on imported energy and accrue economic benefits to the economy.

Appendix A

JUST ENERGY TRANSITION PARTNERSHIP (JETP)

The establishment of the Just Energy Transition Partnership (JETP) was announced on 14 December 2022. The JETP is an agreement between Vietnam and the International Partners Group consisting of the European Union, USA, Italy, Canada, Japan, Norway and Denmark. The JETP will mobilise \$15.5 billion of public and private finance over the next three to five years. The amount is made up of \$7.75 billion in pledges, from the IPG in addition to the Asian Development Bank and the International Finance Corporation, and a commitment to facilitate a further \$7.75

billion in private investment from private financial institutions coordinated by the Glasgow Financial Alliance for Net Zero (GFANZ) which includes an initial set of 11 major financial institutions.³ The structure (grant versus debt) and terms of the funding is not known. The press release on the GFANZ website states it will work with the Vietnam Government to ensure continued improvement in the policy and enabling environment, availability of public finance to de-risk private finance, and securing a robust pipeline of competitive tenders for projects.⁴

The JETP targets published on the European Commission's site are:

- Bring forward the peaking date of GHG emissions in Vietnam by five years from 2035 to 2030.
- Reduce peak annual power sector GHG emissions by up to 30 percent (from 240 megatons to 170 megatons) and bring forward the peaking date of GHG emissions in Vietnam by five years from 2035 to 2030.
- Limit Vietnam's peak coal capacity to 30.2 GW (down from a current planning figure of 37 GW).

- Accelerate the adoption of renewables so that it accounts for a minimum of 47 percent of electricity generation by 2030 (up from the current planned generation share of 36 per cent).

It is estimated that the JETP will result in a cumulative reduction of around 200 megatons of greenhouse gas emissions by 2030, and a further 300 megatons by 2035, making a total of around 500 megatons.

Vietnam is the third country to launch a JETP following South Africa (at COP 26) and Indonesia (at the 2022 G20 Leaders' Summit).

The JETP announcement and publicly available information is not sufficiently detailed to allow a precise estimate of its cost

impacts to be made. We make some broad assumptions about the trajectory of change to arrive at high-level cost impacts in relation to the modelling output of our study.

The BAU scenario in this study estimates 45% of electricity to be generated from Hydro, Solar, Wind, and Biomass in 2030. This share is close to the November 2022 version of the draft PDP8 and the JETP target of 47%. Therefore, we do not expect the expansion of power generation from RE to significantly impact the power system related capex or power cost (\$/MWh) estimated in our modelling of the BAU scenario. We note that the JETP uses a different base of 36% of electricity generated from renewables in 2030, which

appears to be based on an earlier version of the draft PDP8.

The JETP estimates that limiting the maximum capacity of coal to 30.2 GW (from 37 GW) will achieve a cumulative reduction of 500 megatonnes of carbon emissions by 2035. At \$40 per tonne of carbon the estimated cumulative cost of emissions in the JETP would be lower than the BAU by 20 billion dollars, around 5% of the BAU emissions costs.

Emissions peak at 243 megatonnes in 2029. Coal capacity in the BAU is 36.4 GW in 2030. It peaks in the period 2037 to 2039 before starting to decline from 2040.

³ Available on the European Commission website https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7671
The full English text of the political declaration can be found on the UK Government website <https://www.gov.uk/government/publications/vietnams-just-energy-transition-partnership-political-declaration/political-declaration-on-establishing-the-just-energy-transition-partnership-with-viet-nam>
⁴ Refer to the GFANZ website on <https://www.gfanzero.com/press/gfanz-establishes-working-group-to-support-capital-mobilization-for-the-vietnam-just-energy-transition-partnership/>



Working to sustain the natural world for the benefit of people and wildlife.

together possible™

vietnam.panda.org

© 2023

© 1986 Panda symbol WWF – World Wide Fund for Nature (Formerly World Wildlife Fund)
® “WWF” is a WWF Registered Trademark. WWF, Avenue du Mont-Bland,
1196 Gland, Switzerland. Tel. +41 22 364 9111. Fax. +41 22 364 0332.

For contact details and further information, please visit vietnam.panda.org