Review and Gap Analysis of the Existing Abatement Scenarios for Vietnam

D.3. FINAL REPORT

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Hosted By:

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List of Acronyms

ADB	Asian Development Bank
AFD	Agence Française du Développement
CMSC	Commission for the Management of State Capital at Enterprises
DOST	Department of Science and Technology
DP	Development Partner
DPM	Deputy Prime Minister
DSNRE	Department for Science, Education, Natural Resources and Environment (MPI)
EE	Energy Efficiency
ETP	Energy Transition Partnership
ETC	Energy Partnership Council
EREA	Electricity and Renewable Energy Authority
ERAV	Electricity Regulatory Authority of Vietnam
EUD	European Union Delegation
EVN	Electricity of Vietnam
GGGI	Global Green Growth Institute
GIZ	Gesellschaft Fur Internationale Zusammenarbeit
GoV	Government of Vietnam
GSO	General Statistics Office
HLM	High Level Meeting
IEA	International Energy Agency
IFC	International Finance Corporation
IoE	Institute of Energy
IR	Inception Report
ISTEA	Industrial Safety Techniques and Environment Agency

JICA	Japan International Cooperation Agency
KfW	German banking group including KfW Development Bank
KOICA	Korea International Cooperation Agency
MARD	Ministry of Agriculture and Rural Development
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MOF	Ministry of Finance
NLDC	National Load Despatch Centre (EVN)
NPT	National Power Transmission Corporation (EVN)
OECD	Organisation for Economic Cooperation and Development
PM	Prime Minister
PPPs	Public-Private Partnerships
PV	Photovoltaics
RE	Renewable Energy
SOE	State-owned Enterprise
SPRCC	Support Programme to Respond to Climate Change
TA	Technical Assistance
ToRs	Terms of Reference
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

USAID	United States Agency for International Development
VCCI	Vietnam Chamber of Commerce and Industry
VEPG	Vietnam Energy Partnership Group
VM	Vice Minister
WB	World Bank
TWG	Technical Working Group

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1. Executive Summary

The Government of Vietnam can seize the opportunity to address global climate change while prioritizing continued development, job creation, energy security, and improving national balance of payments. The analysis provided below indicates a compelling opportunity in the power sector, that leverages new technologies in a measured and careful manner, to ensure grid reliability and cost considerations.

By 2030, the optimal scenario described below decreases carbon emissions by 59 percent when compared to the business-as-usual scenario described in Vietnam's Nationally Determined Contribution (NDC). This is achieved by investing over time additional power generation from offshore wind, solar, liquefied natural gas (LNG) generation and limiting coal capacity addition to the assets already under consideration, supported by new energy efficiency programs and battery energy storage and optimizing existing hydro power.

Pursuing that path creates two hundred and eighty thousand jobs created versus the current business as usual scenario (an increase of 45 percent). Many of these new roles are in manufacturing, construction, installation, and operations and maintenance, which are stable and valuable positions. The pathway offers powerful economic benefit, with total costs (when considered to 2045) decreasing by 16 percent, producing a total savings of 68 billion USD.

These benefits would support an efficient and low-carbon, low-cost power sector, with greater contribution of renewable energy and with improved grid reliability (the projected loss of load, or chance of a grid outage, would decrease by 68 percent for the grid). Modern manufacturing, technology, and medical services, all require a reliable grid that can seamlessly transition between available generation resources, and our optimized low carbon scenario is also able to deliver this and associated economic benefits.

Despite threats and disruptions from COVID-19 and strained supply chains, the potential for coupling decarbonization and economic growth has never been clearer. Ongoing dependence on imported fossil fuels continue to imperil national finances and create additional financial volatility. Projected investments in long-lived fossil fuel infrastructure options in a timescale where their long-term viability is challenged by cleaner and more economic technologies, raises the potential for disruptions in meeting the growing electricity demand in the country, threatening the ongoing development in Vietnam.

Given the rapid changes in energy technologies in recent years, the importance of power development planning has never been higher. The various pathways presented here, including those that exceed current national climate targets for the power sector, offer significant benefits and should be deeply considered and incorporated.

Looking to the near future, Vietnam can gain by steadily deploying energy efficiency and renewable energy, thereby unlocking further opportunities with the related transportation and heavy industry sectors, including the potential for green hydrogen in the industry, shipping, and power sectors.

2. Introduction of project

As Southeast Asia's continues to benefit from economic growth, the objectives and opportunities of decoupling carbon emissions from continued development have also become clearer. Recent years have brought new challenges, including from the COVID-19 pandemic, and the continued dependence on fossil fuels, much of which are imported, continue to imperil national finances. Projected investments in long-lived fossil fuel infrastructure options further threaten both the financial and the environmental contexts of the region and will influence global climate disruption with prolonged and severe impacts.

The Rapid Response Facility (RRF) was established at the second meeting of the COP26 Energy Ministerial and helps support country partners with a variety of assistance including strategic planning, capacity building, and technical expertise. In Vietnam, the ETP team, with selected sub-consultants VIET-SE and RMI, has engaged broadly with development partners and government leaders to better define scenarios for abatement and carbon reduction. The summary of the conclusions is found herein. This study was conducted from August to November 2021, to provides support for the Vietnamese Government having scientific-based evidence for any commitment and negotiations at the COP26.

These conclusions address the immediate challenges in Vietnam related to power sector decarbonization. Long term planning for the power sector in Vietnam is governed by the Power Development Planning, for which version VIII (hereinafter referred to as 'PDP8') was released in early 2021 and subsequently updated in September and October. This plan envisions a future with a blend of fossil and renewable resources and assesses the required investments (including grid upgrades) over the period 2021 to 2030, with a vision to 2045.

In the past years, Vietnam has advanced rapidly with installations of solar and wind power, reaching almost 35% of total power generation from renewable (when combined with existing hydro power resources) by the end of 2020. From 2017, the country showed impressive leadership with concerted efforts to add renewable – leading to 16.5 GW of solar by the end of 2020 and 600 MW of wind. Vietnam has benefited in the past from the presence and flexibility of hydro capacity in balancing the carbon intensity of its electricity system. The rapidly installed renewable energy, supported financially through the feed-in-tariff (FIT) mechanism, produced financial and operational pressures. The draft PDP8 notes the new renewable energy resources exceed the total determined to be optimal for the grid in the time frame until 2030. Due in part to these concerns, the FIT has been reduced with prices reduced for both wind and solar by more than 30 percent. Recent announcements indicate that the Ministry of Industry and Trade (MoIT) is defining a price mechanism to replace the FIT.

These shifts in support for renewable energy, along with planned further investments in fossil fuel infrastructure, will directly and materially impact the national decarbonization strategy, which has since been bolstered by the announcement by Prime Minister Pham Minh Chinh that Vietnam would achieve net zero by 2050. In this context, and with the critical meeting of the Conference of Parties (COP) in Glasgow in November 2021, the time is right to examine a wide range of scenarios for the power sector in Vietnam and assess the potential for carbon reductions as well as the associated grid performance, economic benefits, and social impacts.

Despite the rapid growth in renewable energy, coal has a high and consistent contribution to the total generation capacity – 34% to 37% (depending on the data source) at the end of 2020. With electricity demand in Vietnam increasing at double-digits average growth rate over the last decade[1], and projected to do so over the next five years, the decisions made now in power sector investments are critical.

Over the course of the last two years, while the renewable energy capacity has increased, so have coal imports to support the operating coal capacity in the country. This creates a risk to national balance of payments (as explored further in this report). Furthermore, the new plants in the pipeline face risks as financial support may be withdrawn by many nations and financiers now avoiding supporting new coal capacity.

To best support Vietnam's NDC targets, the new net zero commitment, and broader needs and opportunities for emissions reductions, the integrated implications of these trends must be thoroughly examined with a variety of scenarios. As part of this initiative, funded by ETC's RRF facility, and on the request of the Vietnamese government, ETP convened the VIET and the RMI teams to examine potential future scenarios for the electricity sector, with an eye on the greenhouse gas emissions measures and its reduction for the electricity sector and also taking into consideration other contemporary scenarios for the electricity sector being used by development institutions. The results here fit within the planning framework as established by MOIT, under the direction of the department of Electricity and Renewable Energy Authority.

[1] Fitch reports the COVID-19 pandemic decreased the growth rate of Vietnamese electricity demand; even still 2020 electricity usage increased 3% and estimated growth for 2021 is 5%.

3. Stakeholders Mapping and Outreach Strategy

The Stakeholder Map is divided into three categories:

- Key stakeholders – with an important role in the energy sector development
- Primary stakeholders – with direct influence on the energy sector development
- Secondary stakeholders – with indirect impact on the energy sector development.

Within these three categories, there are three core areas: the public sector, the private sector, and another group, including civil society, development partners, and embassies.

3.1. Key stakeholders

First Core Area – Public sector

Historically, the coal industry has brought many economic benefits to the country and has been defined as one of the main strengths of the economy. Therefore, a key aspect of any coal abatement planning will have to include changing the role of coal-fired power plants as a necessary pillar for Vietnam's high growth future. Public institutions that have a decision-making role for coal-fired power include:

- **Politburo** is the highest body of the Communist Party of Vietnam plays the role of leading all development orientations of the country in the long term.
- **Centre Economic Commission** (**CEC**) is leading or participating in research, advice, and proposals to develop guidelines, guidelines, and decisions on the socioeconomic field of the Central Committee, Politburo, Secretariat. Leading or coordinating with relevant agencies in researching and proposing major socioeconomic mechanisms and policies, developing production forces and improving of production relations, on social issues. Association associated with the economy as assigned by the Politburo and the Secretariat.
- **National Assembly** (**NA**) makes decisions on objectives, norms, policies, and basic tasks of socioeconomic development and takes policy decisions on finance, foreign exchange, etc. The National Assembly reviews and controls the conformity of decisions on the energy sector to the constitution, laws, and resolutions.

- **Ministry of Industry and Trade** (**MOIT**) plays the most important role in the state level regarding policies, support mechanisms for power plant in terms of development, decommissioning safety and environment, grid planning and investment, quality control.

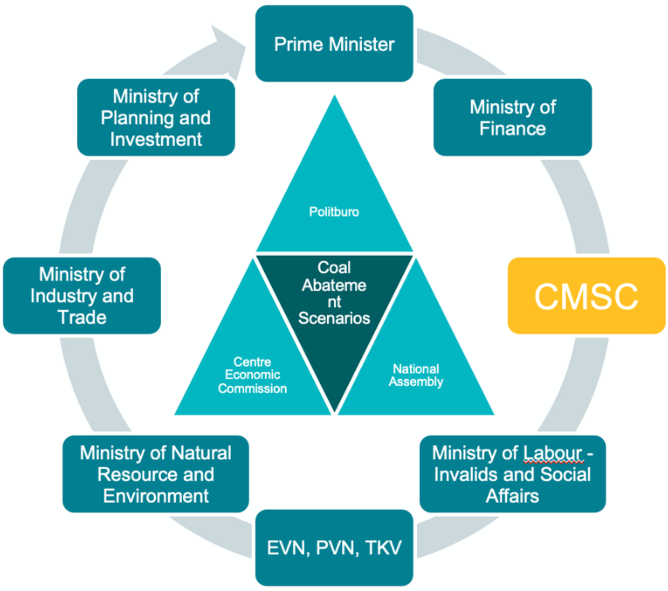
- **Electricity and Renewable Energy Authority (EREA)** is a MOIT-managed agency that performs advisory functions, assists MOIT in the implementation of state management tasks in relation to electricity, new energy, and renewable energy.

- **Electricity Regulatory Authority of Viet Nam (ERAV)** is a MOIT-managed agency (same level as EREA). It monitors the operation of the power sector, ensures power supply security, works out price mechanisms, grants operating licenses for power projects, assists in the development of standards and certifies energy-saving products.

- **Oil, Gas and Coal Department** is responsible to instruct the formulation and give approval for detailed plans for coal mining regions; nationwide peat exploration, exploitation and use plans; schemes for supply of coal to power plants.

- **Industrial Safety Techniques and Environment Agency (ATMT)** is leading responsibility for and coordinating with ministries, branches, and localities to manage environmental issues in coal power plants and implementing activities to respond to climate change within the scope of the ministry's state management.

- **Commission for the Management of State Capital at Enterprises (CMSC)** is designated by the Government to exercise rights and take on duties as the owner's representative to wholly state-owned enterprises such as EVN, PVN, TKV and their subsidiaries. Play the leading role and collaborate with the Ministry of Planning and Investment, the Ministry of Finance, and relevant authorities in requesting the Prime Minister to approve for master plans for the restructuring of enterprises of which CMSC acts as the owner's representative.



- **Ministry of Finance** (**MoF**) is a state management unit, responsible for examining and developing national financial strategies and financial policies, and for producing national economic and financial analysis/ forecasts. MoF does not have any department that specializes in Energy or Industry. According to specific requirements like price valuation as stipulated in documents on Coal abatement scenarios, MOF would establish a working group of various relevant department representatives to provide opinions on MOIT-drafted mechanisms/policies, with a focus on the appraisal of economic-financial efficiency of large projects as prescribed in the legal framework.

- **Ministry of Planning and Investment** (**MPI**) is a government agency performing state management functions regarding planning, investment for development and statistics, including consolidation of national socioeconomic development strategies and plans; development planning and general financial management mechanisms/policies; domestic investment, foreign investment in Vietnam and Vietnam's overseas investment.

- **Vietnam Electricity (EVN)** was formed in 1995 as a vertically integrated, state-owned corporation responsible for Vietnam's power sub-sector. In mid-2006, EVN became a holding group. EVN is still the leading actor in the power sub-sector with wholly-owned subsidiaries: three power generation corporations (GENCOs); the National Power Transmission Corporation (NPT) responsible for power transmission; and the five-power corporation (Hanoi Power Corporation, Northern Power Corporation, Central Power Corporation, Southern Power Corporation, and Ho Chi Minh City Power

Corporation) responsible for power distribution. EVN owns the National Load Dispatch Center, which serves as the system and market operator (SMO). It also owns strategic power plants, including multipurpose hydro power plants (HPPs), the Electric Power Trading Company (EPTC). It is the majority shareholder of partially privatized power plants in the Vietnam Competitive Generation Market (VCGM).

- **Power Generation Corporation (GENCO)'s** essential role in ownership, investment funding in the electricity market; three Power Generation Corporation companies (GENCO 1,2,3). They play an extremely important role in the country's socioeconomic development and national security. EVN owns 100% capital in these big power generation corporation companies. The Power Generation Corporation 3 (GENCO 3) started to equitize in 2017 and GENCO 1 and 2 in 2018. The GENCOs will continue to participate in the competitive wholesale power market after their equalization.
- **Ministry of Natural Resources and Environment** (**MONRE**) is the responsible to guide, examine and organize the implementation of policies, laws, inter-sector, inter-provincial, inter-regional and national strategies, master plans, plans, programs, schemes, projects and tasks on environmental protection and cross-border environmental issues. The Ministry has prime responsibility for organizing the negotiation, signing and implementation of treaties and participating in international environmental organizations; to mobilize international resources; to coordinate and implement international schemes, projects and tasks on environmental cooperation as assigned by the Government.
- **The Vietnam Development Bank** (**VDB**) executes state development investment and export credit policies as regulated by the government. It offers products and services in investment credit, export credit, on-lending official development assistance (ODA) management, TCM and post-investment subsidy, and funding activities. The Bank's duties include mobilizing and receiving capital from domestic and foreign organizations to implement investment and development credit, and export credit of the state, executing the policy of investment and development credit, and export credit of the state, and receiving the trust of ODA capital resource management re-lent by the government.

3.2. Primary stakeholders

Primary stakeholders with direct influence on the coal abatement:

Second Core Area – Private sector stakeholders that shall be involved at different levels in the coal abatement scenarios

Private sector		
Short name	**Full name**	**Main roles in relation to the project**
International Consultants	-	Consulting companies providing energy services across the region and in Vietnam
National Consultants	-	They could be consulting companies or independent consultants providing energy consultancy services in Vietnam

Private sector		
Short name	**Full name**	**Main roles in relation to the project**
National developers	-	Companies developing renewable energy projects in Vietnam
Intl. Banks	International Banks	Foreign banks providing financial support for the Energy projects in Vietnam
EPC Contractors	Engineering, Procurement, and Construction Contractors	Companies are responsible for all the activities from design, procurement, construction to decommissioning power plants.
Equipment Suppliers	-	The companies provide equipment, spare parts for decommissioning power plants and other energy equipment and services.
Com. Banks	Commercial Banks	The banks provide loans to develop RE, EE projects
Intl. EPC	International EPC Contractors	The international companies are responsible for all the activities from design, procurement, construction to commissioning and handover of the project to the End-User or Owner.
Investors	-	Investors (both domestic and international) involved in financing the energy sector in Vietnam, including providing project finance.

3.3. Secondary stakeholders

Secondary stakeholders with indirect influence on the power development and coal abatement:

Third Core Area – Civil Society, Development Partners, Embassies

1. NGOs: implement commune-level energy plants, address commune-level environment problems, conduct surveys on community energy consumption levels and provide technical support to localities.
2. Development Partners (DPs) and Embassies. These partners provide technical assistance and/or funding for the development and implementation of energy plants at the national and local levels.

The following table provides a list of the stakeholders from the civil society, development partners and embassies involved in the topic "Coal abatement scenarios"

Civil social, Development partners		
Short name	**Full name**	**Main roles in relation to the assignment**
WB	The World Bank	WB has done some projects support for renewable energy, energy efficiency, power market reform, energy access, energy data, and statistics; pumped storage and recently peak CO2 emission for Vietnam
ADB	Asian Development Bank	Most of the projects supported by ADB focus on electricity access, human capacity for clean energy strategy and coal retirement mechanism
UK Embassy	Embassy of the United Kingdom in Hanoi	Energy Efficiency, Calculator 2050, Carbon Track
DEA	Denmark Energy Agency	Energy Technology Catalogue….
JICA	Japan International Cooperation Agency	NDC, peak emission

Civil social, Development partners		
Short name	**Full name**	**Main roles in relation to the assignment**
USAID	The United States Agency for International Development	Solar Energy, LNG, DPPA, PDP8
UNDP	United Nations Development Programme	EE & Energy price
UNIDO	United Nations Industrial Development Organization	EE and ISO 5001, Hydrogen
Energy Associations	Vietnam Sustainable Energy Alliance Vietnam Clean Energy Association	These associations carry out policy research activities and support the transfer of energy technologies independently
NGOs	Non-government Organizations	There are some NGOs actively working on renewable energy, energy conservation and green growth, e.g., GreenID, WWF, SNV, etc.

3.4. Outreach Strategy

After direct meetings with development partners and relevant stakeholders, the Consultant team recognized that a research study on emission reduction (from fossil sources coal and gas) has not been deeply conducted for the Vietnamese context. More recently, some development partners have provided technical assistance in different aspects: supporting for Power Development Plan (PDP8), National Energy Master Plan (MPDE), Vietnam Energy Outlook, and other policy research for smart grid, auction mechanism, just transition, etc. From the point of view of government institutions, this assignment appears as new subject and has not been a focus area for the relevant decision-makers from MOIT as well as other State-owned enterprises such as EVN, PVN and Vinacomin.

The Consultants defined as following the outreach strategy to be implemented for five principal stakeholder groups:

High-level policy decision-makers: lack of sufficient and overall information on possibilities to reduce GHG emissions in the power sector. It's important to support their decision on providing information on COP26, and the research outputs supporting the negotiation process on international debates, including technical, economic potential and options for emission reductions in the power sector.

- Policy decision makers in energy sector: should be provided concrete solutions based on evidence-based science proving that Vietnam has a higher potential to reduce its emission than the committed targets as of updated NDC.
- Development partners: Different DPs have actively investigated into this sector by insisting on requesting the Vietnamese Government to consider a higher emission reduction commitment. However, the transfer messages have not been strong enough based on scientific evidence and without any further studies on fossil fuel reserve capacity as well as potential exploitation scenarios of these domestic resources. This research could support to recommend for the Government on the future of fuel depletion and insecure energy risk of the country. Although high-level meetings have been organized and official letters have been addressed to the Government, but still lack of scientific-based evidence for the higher potential of emission reduction in taking into account the realistic development road-map for Vietnam, this creates a negative and inverse reputation of DPs because of their unreasonable demanding, blocking the opportunities for open, straightforward discussion and cooperative actions with MOIT.
- NGOs: Dissemination of information in an informal approach has caused the negative reputation and images of NGOs and the message is transferred in a one-way direction.
- Public community: the Consultant recognizes the hesitation in accessing information of the community. Correct and sufficient information on the energy sector and, more specifically, the power sector could positively impact the transition from fossil fuel resources to renewable energies. Moreover, the communication for energy transition concept plays an essential role in convincing the perception of a broad community. Incorrect messages diffused through social media (Facebook, RE community, etc.) are creating doubts regarding RE development in Vietnam and leading to unnecessary obstacles to the energy transition.

From the above assessment, the Consultant recognizes the importance of providing clear and precise information to relevant and appropriate stakeholder groups on emission reduction potential in the power sector by reducing thermal power plants' share. The development of the energy sector of Vietnam has been linked to the extraction and burning of fuel resources (coal, oil, gas) and hydro power and their contributions to the national socioeconomic development of the country since the last four decades has become inevitable. As a result, policymakers and leaders have focused on traditional thermal technologies. Therefore, it's both important and timeline to strengthen communication strategies in promoting new technology solutions, financial mechanisms suitable to the national context, and raise early alerts regarding risks in planning, investment, management, operating and decommissioning the fossil fuel plants.

The Consultant proposes the outreach strategy as follows:

Key delivered messages

The development of coal-fired power plants increases risks to national energy security

Imports of fossil fuels leads to over-spending

The instability of the imported fossil fuel prices impacts the national long-term economic development

- ***Complementary messages:***
  - The requirement for imported coal for power generation has been increasing.
  - The spent State budget for importing fossil fuel is significantly higher than for Health, Education and Science and Technology;
  - The price of coal and gas depends on the international market, and their unpredictable fluctuation leads to difficulties in stabilizing electricity prices;
  - The depletion of coal reserves for exploitation in Vietnam
  - The energy transition in other sectors such as electrification of industry or transport yields meaningful carbon savings only if renewable energy is the principal factor in the power mix.

- ***Technologies and solutions:***
  - Offshore wind, having a high-capacity factor, (at the range of thermal power plants) could act as a base load power option.
  - The development of green hydrogen for the transport sector and some other industries is an option for reducing GHG emissions.
  - Strengthening the green public transport network and developing a model of sharing public transport vehicles reduces both congestion and emissions
  - Promoting greener aviation and the marine industry sector supports air and water quality
  - Green architecture can reduce energy demands from buildings and improve comfort
  - Carbon capture, storage, and utilization to enable environmental improvement on existing power plants
  - Technology innovation and transfer in managing and operating the power plants.
- ***Finance:***
  - Green financial mechanism for power development, in partnership with international financial institutions and climate finance facilities
  - Mechanism of financing the development of power infrastructure, including required transmission and distribution and smart grid upgrades
  - Financial mechanism to support energy efficiency projects

Strategy of media channels

In order to widely approach the audience and deliver the targeted messages, the Consultant proposes using different media channels for various purposes:

Targeted audience	Communication approach	Delivered messages
High-level policymakers • Vice Prime Minister • Head of the Party Central Committee's Economic Commission • Ministry of Industry and Trade	Closed-door meeting Public high-level dialogue Business forum dialogue	No new coal power plants to be developed to secure national energy with more affordable price.
Development partners	Open discussion on to share research results	Peak CO_2 emission and peak coal used for power. Investment: Power market risk; Access to capital; Regulatory risk.
Policy makers (at working level)	Direct discussion to share research results and seek for their recommendations Direct discussion on fossil industry	Vietnam geopolitics and perception of energy security. The scarcity of supply leads to an unstable coal price market and an increase in electricity prices, which leads to a potential state budget deficit due to electricity price subsidies. Lock-in of fossil fuel infrastructure development. Just transition policy.
Renewable Energy companies	Webinar talk	In the future with less and less fossil reserves, coal

Targeted audience	Communication approach	Delivered messages
	Renewable Energy Community Forum	power will cost higher than renewable energy. Vietnam should develop a road-map to reduce coal electricity production, aiming to double wind and solar generating capacity to 38 GW by 2030.
State companies (PVN, EVN)	Meetings Exchange via emails	Each state company should develop a road-map for investment and human resource development for renewable energy in the long term.
Public communities	Info-graphics (via Facebook, Linkedin and other social media)	In 2020, Vietnam spent ~3.8 Bil.$ to import coal. Allocated state budget 2020: ~ 1.32 Bil.$ for Education ~ 0.95 Bil.$ for Healthcare ~ 0.42 Bil.$ for Science and Technology

The Consultant proposes an outreach strategy based on analyzing the communication habits of each target group. This process is important in helping to make choices by using appropriate communication channels, to communicate the messages or research findings correctly and in cost-effective manner.

4. Gap analysis and Initial finding

Gaps exist throughout the coal abatement effort, driven both by internal limitations (data, available analysis, etc.) and external factors (market dynamics given COVID-19 electricity demand reductions and issues with grid stability and reliability after the rapid increase in renewable energy, particular solar photovoltaics in 2019 and 2020). Initial findings from the VIET and RMI team include an appetite to document and assess existing scenarios for coal abatement, coupled with a practical concern to ensure new scenarios align and augment existing analysis provided under PDP 8.

Internal Gaps (Relevant to the primary stakeholders in the energy sector)		
Gap	**Stakeholders**	**Description**
KfW	Kreditanstalt Für Wiederaufbau	KfW have provided some TA support for renewable energy, energy efficiency
WB	The World Bank	WB have provided some project support for renewable energy, energy efficiency, power market reform, energy access, energy data and statistics; and coal retirement mechanism
ADB	Asian Development Bank	Most of the projects supported by ADB focus on electricity access and coal retirement mechanism
Energy Asso	Vietnam Sustainab	These associations carry out policy research activities and support the

ciati ons	le Energy Alliance Vietnam Clean Energy Association	transfer of energy technologies with an independent approach.
NGOs	Non-government Organizations	There are some NGOs actively working on renewable energy, energy conservation and green growth, e.g., GreenID, WWF, SNV, etc.

Development partners indicated that data covenants and contracts prevent the free sharing of the underlying data, but some partners (Government of Denmark and World Bank) indicated they will share the scenario outputs from their models. These restrictive covenants create a pervasive gap in the joint effort to understand and improve the electricity sector through collaborative analysis and modeling.

Several key technologies that could aid in the integration of renewable energy and better quantify the opportunity for coal abatement remain only partially understood and modeled. These include battery energy storage, the impact of vehicle electrification, and demand flexibility.

External Gaps (Relevant to stakeholders outside the energy sector)		
Gap	**Stakeholders**	**Description**
Equipment suppliers	Siemens Gamesa, GE, others	COVID-19 disruptions caused some delays and re-routing of supply chains, particularly for one important renewable energy sector – offshore wind.
Public health	WHO, Ministry of Health	Ongoing and significant COVID lock-downs in response to the Delta

External Gaps (Relevant to stakeholders outside the energy sector)		
resp onse		variant cause disruptions to meetings and data sharing in the energy sector.
Multinational corporations	Nike, Amazon, Google, etc	These companies have advocated for renewable energy, and the inclusion of wheeling and virtual power purchase agreements (VPPAs). However, the ability to inform coal abatement scenarios remains limited.
NGOs	Non-government Organizations	There are some NGOs working outside the energy sector, but indirectly related to the energy sector (Red Cross, Oxfam, etc.)

Open collaborative working groups to share data and collaborate on scenarios are generally limited (the Technical Working Group chaired by the ADB and World Bank is one exception). Given the importance of the future energy scenarios, the space for both public and private stakeholders to discuss openly should be prioritized.

Initial Findings

In early 2021 (with Letter 1682), and again in September (reviewed results), MOIT released more information about PDP 8. The updated and reviewed results indicate a reduction in overall energy demand (of 5%) and a reduction in the planned new renewable energy capacity (solar reduction of about 6.5% versus previously planned capacity and wind reduction of 20% versus previously planned capacity).

Further details on the rationale behind the reductions are emerging as partners build a deeper understanding of the updates to PDP 8. Coming after the rapid increase in renewable energy, and the usage of the feed-in-tariff (FIT) by the private sector, the government is considering ways to prioritize grid stability.

The VIETSE / RMI team considered using a variety of technical models (between GAMS, Digsilent, Plexos, and LEAP, with the first two the currently prioritized options). These tools will be used to assess the grid and coal abatement and provide outputs for discussion in advance of the November conclusion of this project.

5. International best practices for decarbonizing the power sector

Insights from other economies related to both low carbon transition pathways and mechanisms to implement these plans, including the role of coal transition, help provide context and examples for the transition in Vietnam. The best practices below are a non-exhaustive set and differ widely in circumstances and approach, yet each reveals distinct insights. All the examples indicate that numerous countries are accelerating their efforts to decarbonize and finding ways to benefit constituents and improve their economies while doing so. Each faced distinct challenges, and the approach to overcoming them yield insights for Vietnam.

United States

Driven by pure-economics, the fast-falling cost of clean technologies has made coal an expensive legacy asset for numerous American utilities. More than two-thirds of the operating U.S. coal fleet costs more to run than building a brand new solar or wind plant. Most of these uneconomic plants exist in regulated markets and monopoly utilities which are allowed to pass on the cost and the economic risk of continued operation of these plants on to the consumers.

Over 11 states have now passed or are in the process of passing regulations that allow refinancing of these uneconomic assets at lower cost and using the released capital and financing capacity to replace coal with cheaper cleaner technologies, raise funds for transition support for coal workers, and pass on costs savings thus incurred to the consumers in from of net bill savings.

In Colorado, Wisconsin, Michigan, and New Mexico, the tool of securitization was used to lower electricity rates, compensate existing asset owners, encourage utilities to invest in clean energy, and support communities impacted by the transition. This takes a format similar to refinancing a mortgage. Securitization allows for the replacement of utility-backed capital (often with rates between 8 and 10 percent) with ratepayer backed bonds used for clean energy transition. The experiences of securitization in the United States has demonstrated the need to accompany the financial tool with appropriate legislation that ensures (1) securitization is allowed for the full cost of a plant, (2) high ratings for bonds, and (3) provisions to assist workers and communities impacted by the transition (e.g. specifying portion of bond must be used for job training, severance pay, or worker assistance, as in the case of New Mexico). More information on the tool, and how it's been used in Colorado and other states can be found in the prior links. The following diagram shows the flows of capital implied in a securitization process, including the transition assistance.

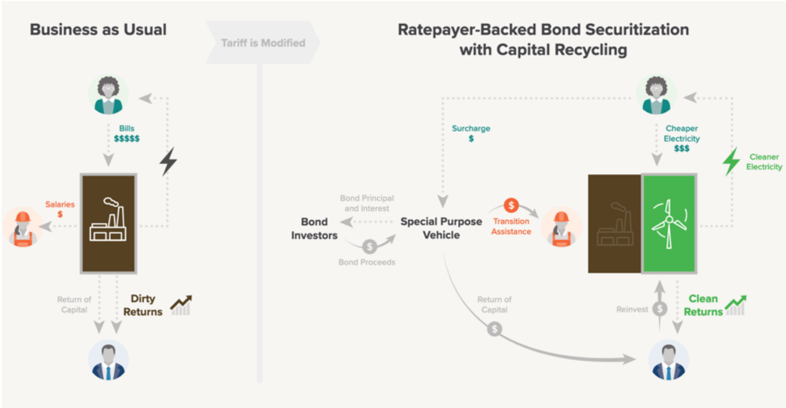


Figure 1: Securitization with Capital Recycling, RMI, 2020

Insight for Vietnam: *Supportive policy measures can facilitate the use of financial engineering tools to reduce cost burdens and share upsides of transition with the most vulnerable segments, workers and their communities and consumers. Financial tools such as securitization allow for the replacement of higher cost existing debt while financing new assets.*

The United Kingdom

Last year coal contributed 1.6% of the country's electricity mix (down from 25% five years ago) and in 2020, the country committed to fully phasing out coal by 2024 (an acceleration from an original target of 2025). In 2019, 83 full days occurred where coal power was not required at all, with further reductions in 2020 (due in part to COVID-19). The approach taken by the United Kingdom for coal transition has been quite rapid, particularly when contrasted with other countries who have a legacy supply chain and business ecosystem for coal.

The United Kingdom achieved its low-carbon transition of the electricity sector through combined efforts of encouraging the growth and wide-scale adoption of wind, both onshore and offshore, and solar (the carbon price floor and the EU ETS; the Contracts for Difference; and the Capacity Market), in parallel to continued focus on reducing the carbon footprint of the energy sector, progressively reducing the allowable emissions from installed capacity, effectively phasing out its coal portfolio. The country uses gas for power grid balancing needs and is adding battery energy storage capacity (1.1GW), which is expected to take on the balancing role in the coming decades. The wholesale market design allows for capacity payments for idle plants (which have assisted lower-utilization coal plants as an effective subsidy). Existing coal plant owners argued and advertised that reducing coal would both increase prices and decrease grid reliability. A concerted response by civil society, research institutes, and experts helped refute this argument.

UNOPS VIET RMI ENERGY TRANSITION PARTNERSHIP

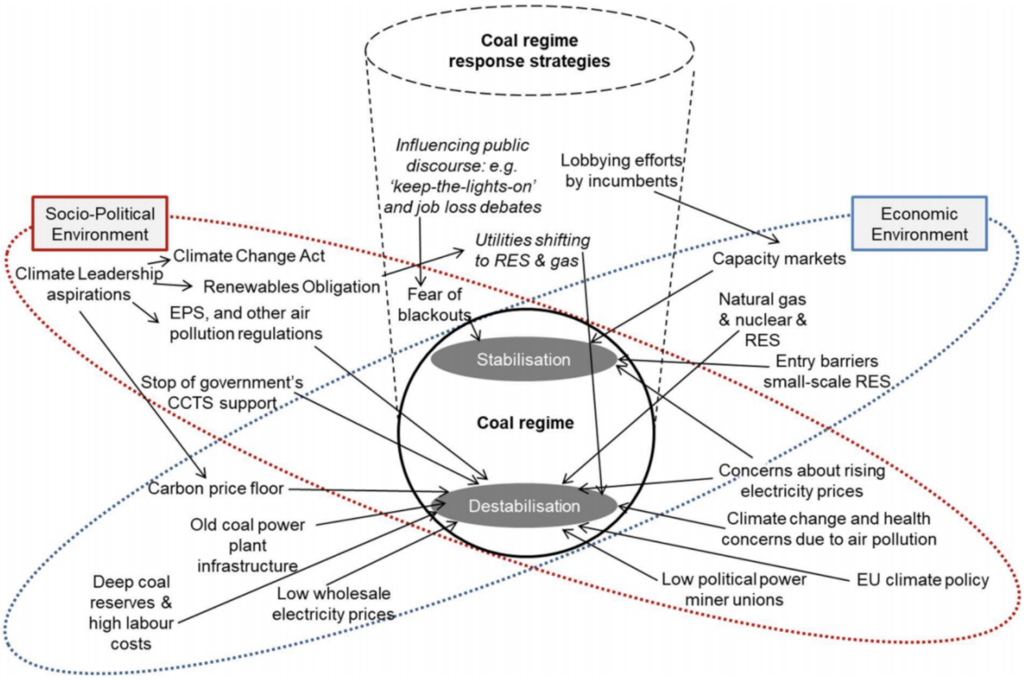


Figure 2: Coal Regime Analysis for the United Kingdom (UNFCCC, 2021)

Insight for Vietnam: *Large-scale adoption of replacement clean generation capacities, supported by available and new ancillary and balancing resources (such as existing hydro power or new battery storage) are a key pillar to support coal abatement. Existing players will use embedded subsidies and public arguments to attempt to derail the clean energy transition, but effective planning and analysis, based in the complex, multi-party energy transition dialogue, can undermine these arguments.*

Germany

Germany's Energiewende launched over a decade ago to transition the country to a low-carbon, environmentally sound, reliable, and affordable energy supply. The effects are clearly visible in increased renewable electricity, reaching a high of over 50 percent of total generation in 2020. The renewable capacity largely replaced a large share of nuclear over this time period, especially as in the aftermath of the Fukushima disaster, Germany mandated all nuclear capacity phase-out by 2022.

Germany is in the middle of a painful and expensive process of quitting coal, with the government approving a plan this year to close the last coal-fired power plant by 2038, setting aside EUR40 billion and inviting plants to participate in auctions to bid a price for closures.

Deep Dive: Auctions

Germany's *Act to Reduce and End Coal-Fired Power Generation* established the country's framework to realize its commitment to phase out coal power by 2038. The policy is intentionally broad and includes support for the structural transformation of German mining regions as well as compensation payments to coal plant owners. While the German government will compensate and close lignite plants in line with contractual agreements negotiated with operators, hard coal plants will close under a reverse auction system. Hard coal plant owners can participate in voluntary auctions, where they submit bids for the compensation price required to retire their plant. The German government then reduces the maximum compensation amount in subsequent auction rounds to create incentives for earlier retirement. Any plants remaining after the last auction in 2027 will be mandated to close without compensation.

Although the concept of compensation is not new, the German model is innovative through the use of competitive tendering. Competitive tendering with a reducing ladder of incentives encourages acceleration of coal plant closures and helps minimize the cost of coal plant closures to the German government and taxpayers. The first two auction rounds were both oversubscribed, contracting the closure of around 4.5 GW of coal capacity for well below the maximum compensation prices. The third round, in July 2021, was under-subscribed, yet still awarded contracts for closing 2.1 GW of capacity and achieved an average price below the maximum.

Source: Adapted from Financing the Coal Transition, RMI, 2021.

The Energiewende has spurred significant increases in renewable energy, but also caused price pressure and at times required greater usage of legacy coal assets. When comparing Germany's transition to the prior example (the United Kingdom), it becomes apparent how Germany's slower and managed transition has yet to yield the same scale of carbon reductions. This is in part due to the larger and more diverse coal extraction industry in Germany.

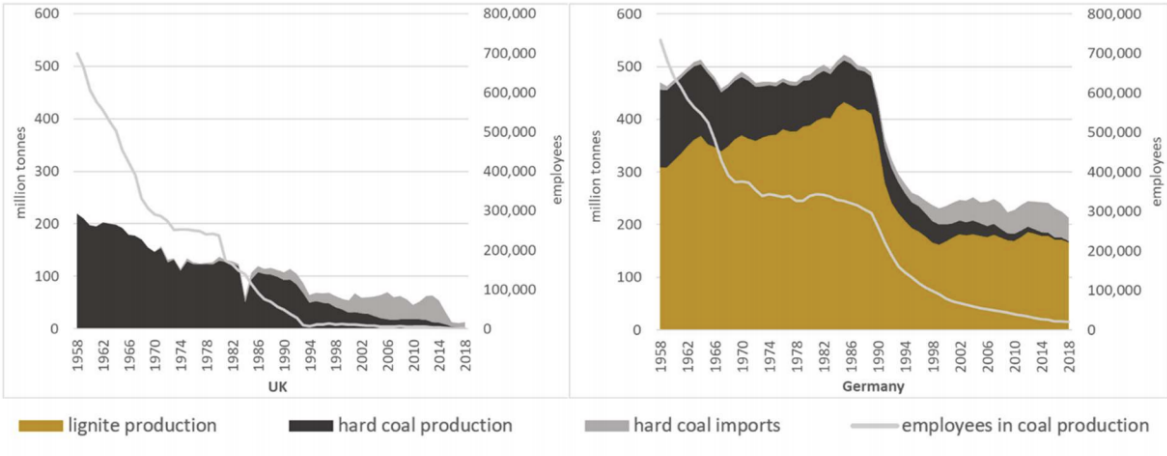


Figure 3: Coal mining, coal imports, and number of direct employees in the UK and Germany from 1958-2018

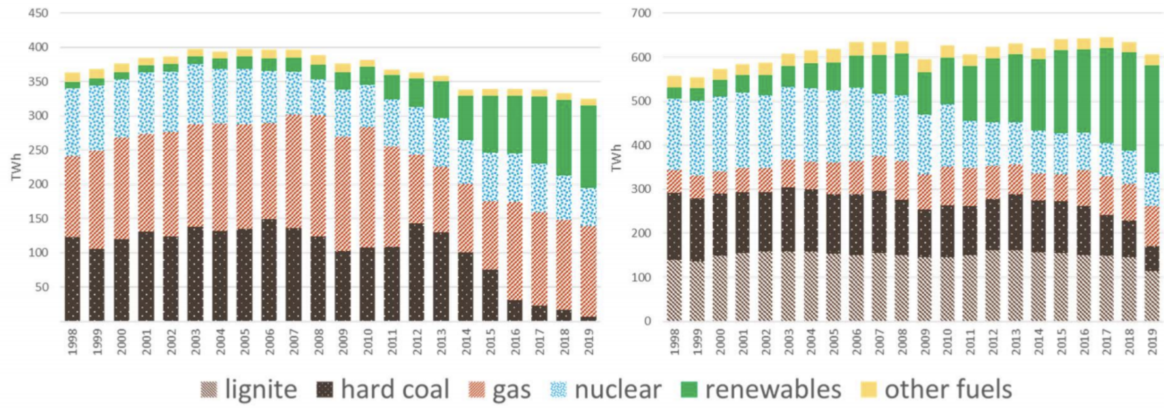


Figure 4: Gross Electricity Generation for the UK (left) and Germany (right) in TWh

Source: Charts from UNFCCC, Hanna Brauers, Pao-Yu Oei, and Paula Walk, 2021

Insight for Vietnam: *While Germany's climate transition journey is far from perfect, there are lessons to be learned from its approach to the phase-out of both nuclear and coal – the country set an exit date and made a plan to support communities and used auctions for price-discovery on plant closures. The Energiewende program effectively used feed-in-tariffs on a schedule (reducing over time) to reduce the total cost and ensure efficient use of financial resources.*

Spain

The coal industry's decline in Spain over the past 30 years has been driven in parts by the EU's commitment to climate-neutrality by 2050, public support for climate action, overcapacity in the electrical grid, and the improving economics of renewable energy. Between 1990 to 2019, the share of coal in Spain fell from 40% to 5%, most of which was imported. In the same period, coal mine employment reduced from 45,000 in 1990 to only 1,700 today.

Since coal is concentrated in a few towns and regions, this transition has disproportionately impacted these areas leading to economic distress. The policies to address the socioeconomic impacts to coal workers in Spain have largely been reactive to the problems created from coal retirement, such as early retirement benefits and compensation for workers. Such uneven impacts occur frequently in the energy transition and should be considered for Vietnam. In response to the efforts to phase out coal, local coalitions (workers, unions, municipal governments, and local businesses) have attempted to prevent mine closures and call for government support of unemployed coal workers. In 2018, under the *Plan Del Carbon,* the coal unions negotiated with the Spanish government to invest 250 million euros (283.6 million USD) in mining regions, early retirement schemes, and local re-employment in environmental restoration work and green industries. This effectively enabled a sustainable development plan for mining regions.

Building on the *Plan Del Carbon,* in 2019, Spain launched it's Just Transition Strategy which will be updated every five years, aims to "ensure that people and regions make the most of the opportunities offered by this transition." A key implementation mechanism for the Just Transition Strategy is 'Just Transition Agreements'. They serve as integrated regional action plans to support economic activity, diversification, and employment in areas at risk from the phase-out of coal, including timelines for implementation. As of November 2020, most of these agreements were still under negotiation. While this measure mitigates some economic impacts to workers, there remains a need to create or expand alternative industries into coal regions to absorb unemployed workers and avoid economic downturn.

Insight for Vietnam: *Unplanned, unmanaged coal transition can concentrate risks on the most vulnerable segments of society, such as workers and entire communities and regions dependent on coal. Including 'Just Transition' as a key ambition of any transition plan will be imperative to reduce this concentration and decades of economic fallout in devastated regions, as well as ensure that impacted workers are appropriately compensated and transitioned into and trained for alternative industries.*

Chile

Chile, as a rapidly growing free-market economy is now ranked as fourth in South America and 33rd in the Global Competitiveness Report. The power sector has been dominated by fossil fuels, with coal, oil and gas contributing more than 70 percent. hydro power provides a significant contribution and development on hydro has continued in this decade. While the mining sector is dominant in the economy, the country does not have significant fossil fuel resources and imports most coal, oil, and gas (the last coal mine closed in 2020). Most coal plants in the country are less than ten years old, but more than 1GW of capacity is older than 30 years.

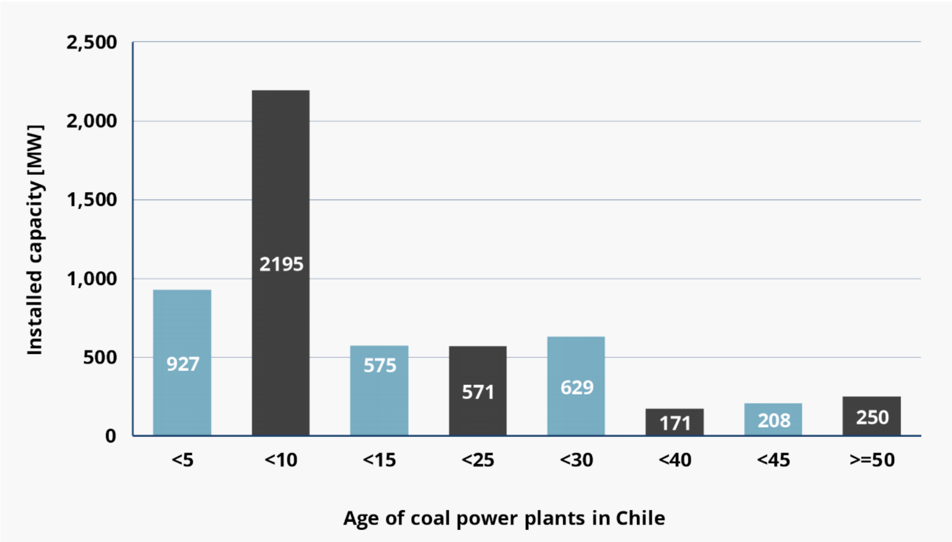


Figure 5: Chilean coal plants by age, before the coal phaseout- commission (Agora Energiewende, 2021)

In the last decade, the country has reduced emissions (19 percent total reduction) primarily through energy efficiency. In 2017, the country initiated a Coal Commission, which ended up engaging private actors to agree to:

1) Cease new development of coal projects,
2) Create a working group to analyse the technical, environmental, social, economic, and energy security aspects of their coal exit strategy, and
3) The Ministry of Energy was nominated to coordinate all actors participating in the working groups

Now the country seeks to bring in additional finance to drive shifts in the power sector. Earlier this year the Inter-American Development Bank (IDB) Invest (the private sector focused arm of IDB) and Engie debuted the first world's first pilot project to monetize the cost of decarbonization. IDB Invest will provide Engie in Chile with US$125 million financial package (comprised of US$74 million senior loan from IDB invest, US$15 million blended financing from Clean Technology Fund (CTF) and $36 million from the Chinese Fund for Co-financing in Latin America and the Caribbean) with a tenor of 12 years, to close coal-fired units and build more than 1,000MW of wind and solar initiatives. These shifts were supported by studies done by the IDB that indicated the shift away from coal would create jobs for the country. In addition, the financial instrument will also monetize the displaced GHG emissions from early closures, by lowering the financing cost in CTF's loan tranche.

Insight for Vietnam: *Creating a central commission on coal transition allowed for public and private actors to work together and reach agreements. Innovative structures can be used to monetize the low-carbon transition fruits, and lower financial burden from transition and associated transactions.*

South Africa

On 3 November 2021, the South African President, Cyril Ramaphosa announced a two-year highly concessional fund of US$8.5 billion, that France, Germany, United Kingdom and United States will provide South Africa to achieve its new NDCs announced at Glasgow. South Africa's state-owned utility, Eskom which is struggling with over US$27 billion in debt largely driven by its coal plant investments. The funds will be mobilised over a period of five years and apart from accelerating investment in renewable energy, electric vehicles and green hydrogen, will provide Eskom the necessary fire power to repurpose coal mines due to retire in the next 15 years and cushion the blow for the workers who might be affected by the shift.

The details of the deal are still being worked out, and as noted by E3G after the announcement, "It's a major test of whether wealthy nations can help developing countries embark on a just transition away from coal."

Insight for Vietnam: *As envisioned with the ADB Energy Transition Mechanism and other approaches, the finance for coal transition is being mobilised and targeted specifically at developing countries. Accessing these funds and ensuring they are well suited to the electricity and finance sectors in Vietnam will be a critical endeavour for all government leaders.*

Take-away messages

Vietnam has the opportunity to benefit from the knowledge gained on these transition journeys, both during implementing and in the planning process, on the pathway to Net Zero by 2050.

- Political will and clarity of ambition, then backed by targeted policy interventions (such as the Energiewende, Chilean Coal Commission, etc.) is key to a successful transition pathway
- Financial tools and solutions (such as auctions and securitization) when supported by policy can be a supportive tool in the furthering of low carbon transition
- Opportunities may exist to monetize the results of low carbon transition and reduce economic burden of transition to impacted regions (including the jobs impacts, as seen in Spain)
- Without a concerted 'Just Transition' plan, the low-carbon transition strategy is only half a plan with serious economic consequences for the future of entire generations and regions, and it needs to be an integral part of any such planning.

Vietnam can take note of these varied examples, while charting a unique course given the individual characteristics of the society and economy.

6. Assessment of the status of the power sector

6.1. Power consumption for the last decade

The commercial power demand in 2020 reached 217 TWh (included the power exported to Laos and Cambodia), an increase of 3% compared to 2019 (209 TWh) due to the impact of COVID19 and has increased 156% compared to 2010 (84.6 TWh). The overall power demand growth rate for the whole period 2011-2020 is 10.3 %/year, in which for the period 2011-2015 increasing of 10.97 %/year and 2016-2020 increasing of 8.2 %/year) (MOIT, Draft Power Development Plan 8, Feb 2021). Average commercial electricity per capita increased 2.2 times, from 982 kWh/person (2010) to 2,180 kWh/person (2019).

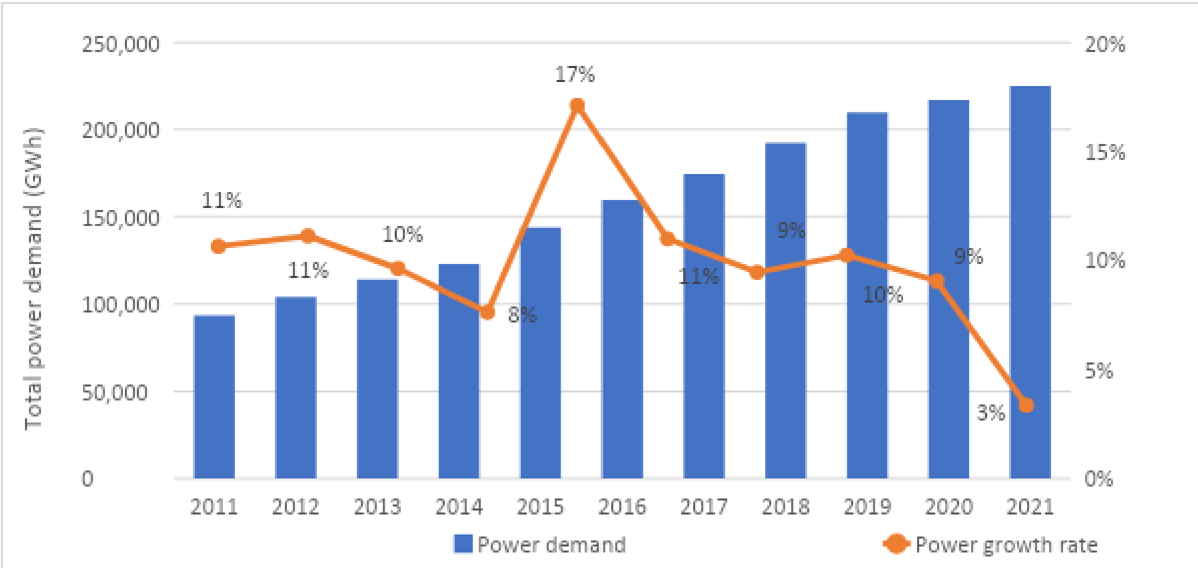


Figure 6: Power demand and growth rate for the period 2010 – 2021

Regarding the power demand per each region Northern – Central – South, the South of Vietnam has been accounting the largest power consumer among three regions, with a growth rate for the 2011 – 2019 period was 9.6 %/year. However, the North has the highest growth rate for power consumption at 11.9 %/year for the same period. The Central region accounted only the most modest part as 10% of the power consumption of the whole country. Meanwhile during the year of 2020, this growth rate decreased in all regions, compared to the annual average. The Central was the most affected region from the COVID 19 due to its large impacts to the trade, tourism, and services activities. The two other regions represented a similar trend in the demand growing, at 5%.

Commercial power per region (GWh)	2010	201 5	201 9	202 0	202 1

Northern	38.499	68.668	106.122	110.937	118.863
Central	9.536	15.372	21.188	21.292	22.56
South	50.073	77.538	109.186	112.491	113.31

(MOIT, Draft Power Development Plan 8, Feb 2021) and (NLDC, 2020 and 2021 Operation Report)

The power has been the most consumed for the Industry and Construction sector for a long period due to its prioritization contributed the socioeconomic development strategy of the country. This sector occupied 52.7% in 2010 of the total power consumption, with a slightly increase to 54% by the end of 2020 and same for 2021. The average growth rate for the whole period 2010 – 2019 was 11.0 %/year, while for the period 2001 – 2010 was 17.5 %/year. The second largest power consumer has been accounted for Residential and Management sector due to the population growth and the improvement of living conditions of end users: more power consumed devices; shifting away from other burning fuels to electricity for cooking and others. However, its share in the final consumption occupied 37.8% in 2010 and 34.3% in 2021.

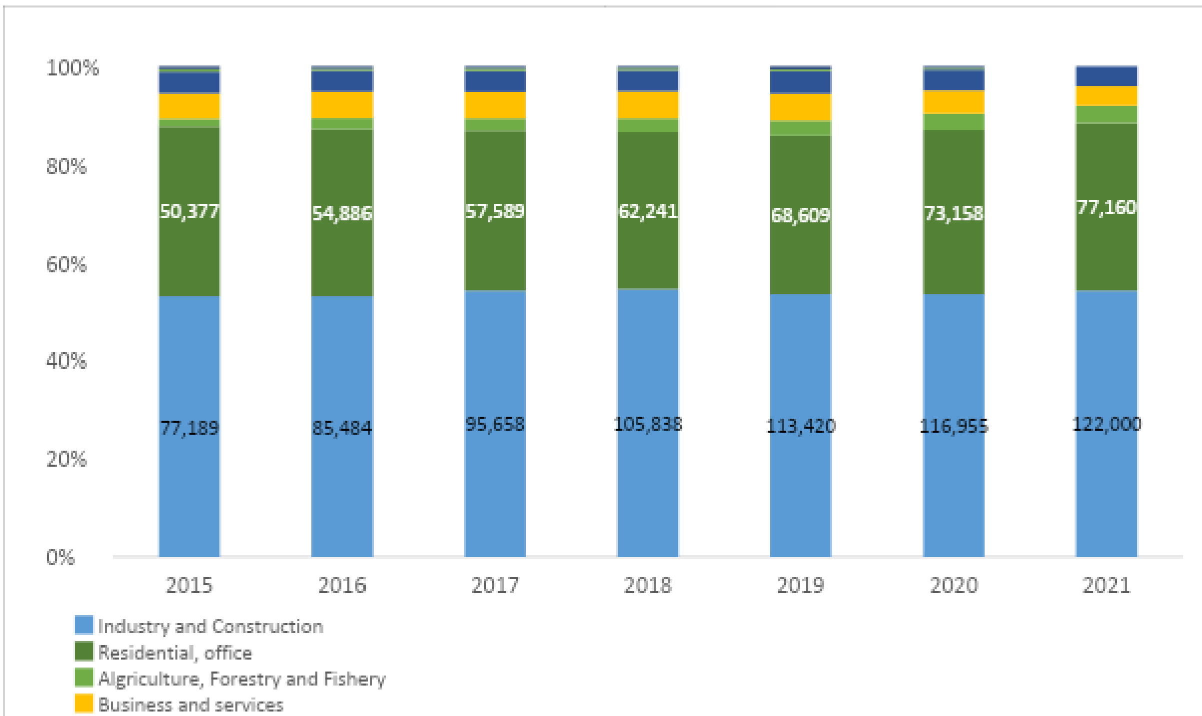


Figure 7: Power demand by sector for 2015 – 2021. The number in the blue and green columns represent the power demand (in TWh) for the two largest power consumption sectors.

The power demand for Agriculture, Forestry and Fishery has increasing significantly with a growth rate of 24.1 %/year for 2011 – 2019 period, leading to an increase from 1.1% (in 2010) to 3.2% in 2019 of the total consumption. The business and services occupied 5.6% in 2019, 4.7% in 2020 and only 4% in 2021 due to impact of COVID19.

6.2. Power sources development

The development of Vietnam's Power system from 2010 to 2018 was primarily based on coal power expansion with 16.2 GW added in the period. However, in the last 3 years, the development trends show a drastic transition toward clean energy resource with RE booming phase started in 2018 with solar energy. The share of solar in the capacity mix growth from negligible level to an astonishing of 25% by the end of 2020. The total installed capacity of solar increases from 84 MW in 2018 to 4439 MW in 2019. After the FIT2 deadline in the end of December 2020, this capacity achieved 8.6 GW of solar farm and 7.9 GW of rooftop solar. The wind to power sector has been observed the similar momentum, with about 4 GW of wind power projects in the pipeline commissioned by the end of October 2021 (deadline of FIT 2 for wind), raising the VRE capacity share to 28.3%.

The total installed capacity of the Vietnam power system reached 77.98 GW at the end of 2021, of which major energy sources for power generation are coal (24.7 GW ~ 31.7%), hydro power (22.1 GW ~ 30%), solar (16.6 GW ~ 21.3%, including RTS), gas (7.4 GW ~ 9.5%), and wind (4.6 GW ~ 6%). The peak load capacity of the overall system (Pmax) in 2021 reached 42.5 GW (on 21/06/2021), increased 10% compared to 2020. The Pmax followed a similar growth rate as the commercial power demand for 2010 – 2020, at rate of 10.8%/year.

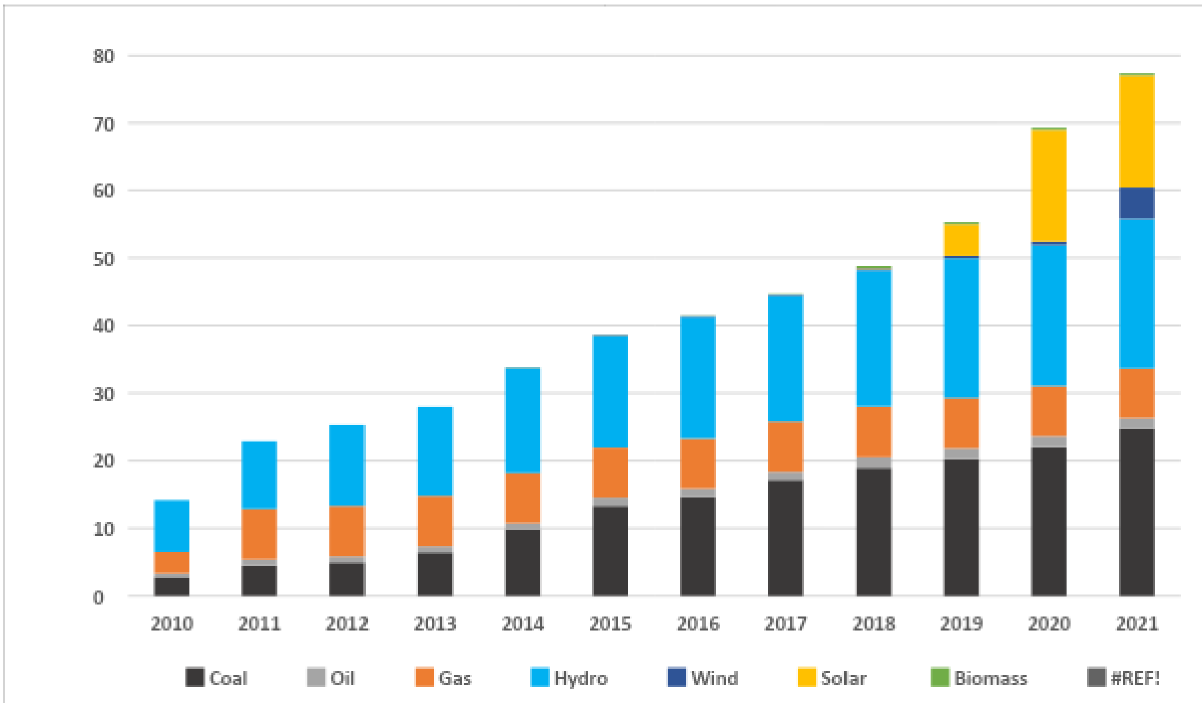


Figure 8: Installed capacity of Vietnam power system for the period 2010 – 2021

For the year of 2021, the total power production of national power system
reached about 255 billion kWh, which increased by 3.34 % as compared to 2020. The highest part of the electricity has been produced from coal thermal power plants (118.3 TWh ~ 46%), followed by hydro power (77.7 TWh ~ 30%). These two power resources have been mobilized to a high capacity factor (ranging 37% - 40% for hydro and 55% - 68% (~ 4800h/year in 2021) for coal power, implicating that the power system is lacking of reserves in the upcoming years. Having a high integrated capacity of VRE into the power system, the generation from 2% in 2019, 4% in 2020 and 12% in 2021, due to its low-capacity factor, plus most of the capacity connected at the end of 2020 for solar and 2021 for wind power capacity (EVN, 2021 Vietnam Power system and Electricity Market Operation).

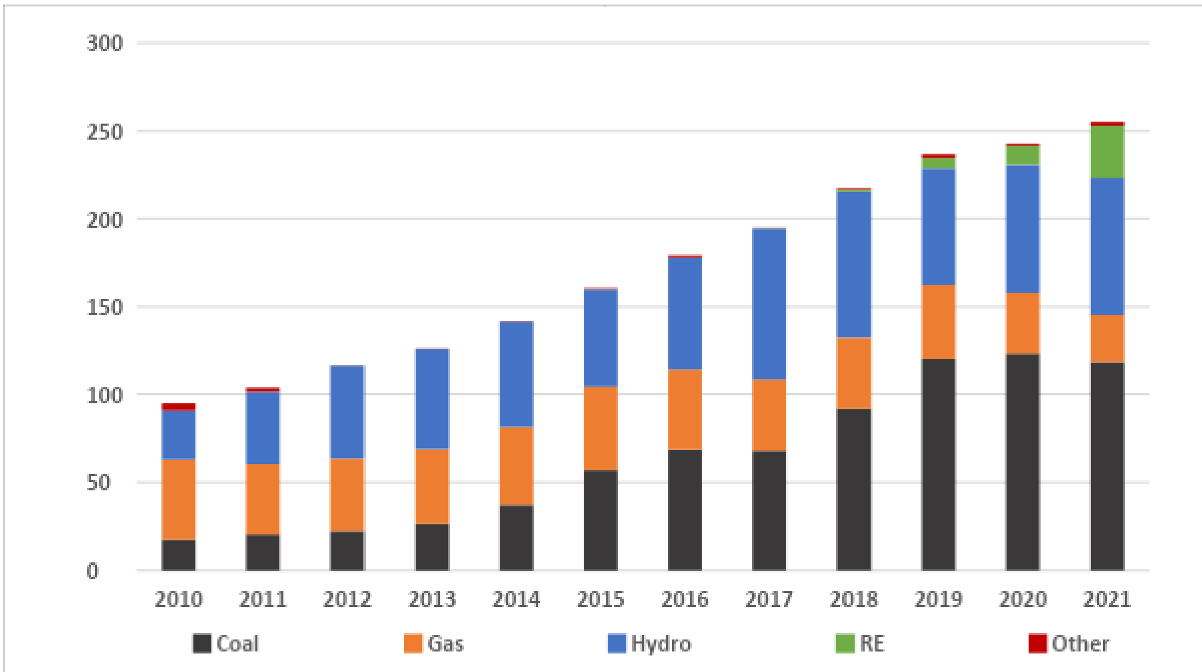


Figure 9: Power generation mix from 2010 – 2021

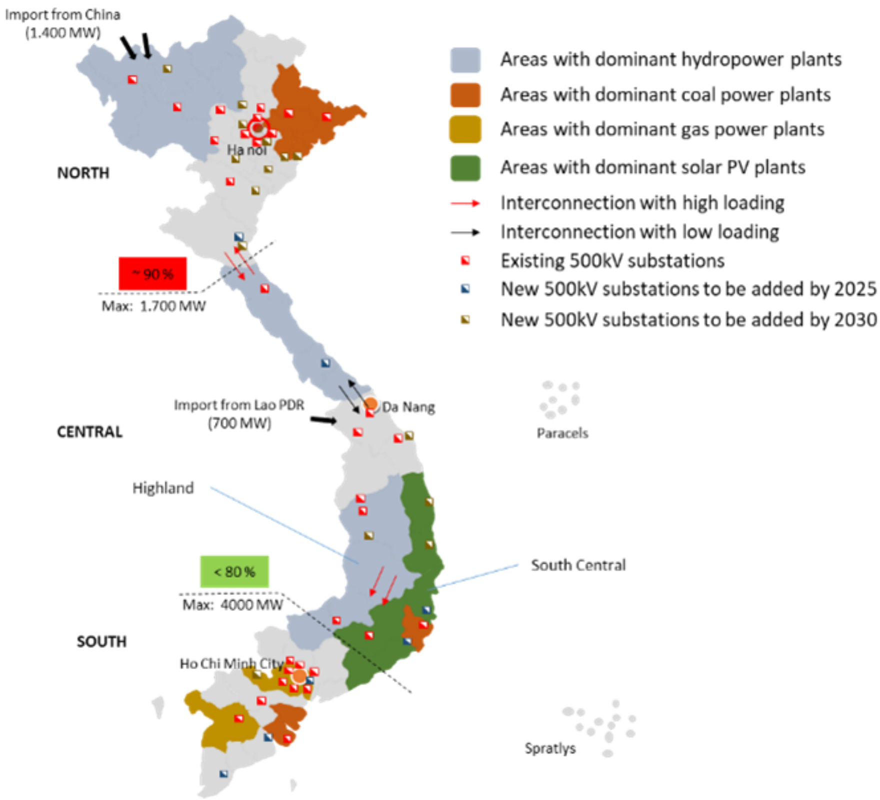
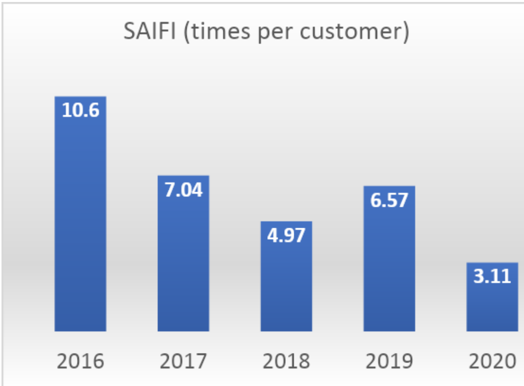
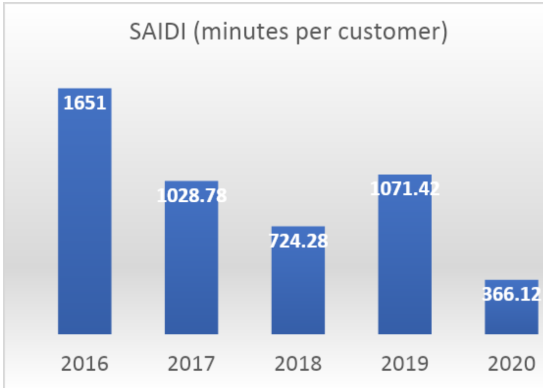


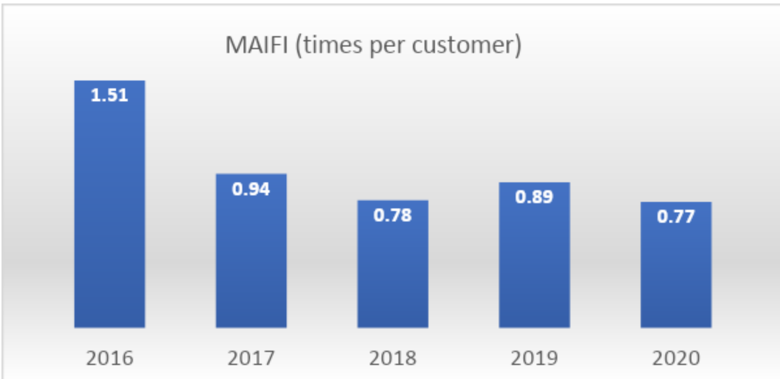
Figure 10: Vietnam Power System

6.3. Power grid operation and management

For the last 5-year period 2016 – 2020, the total power has been transmitted through the national grid achieving 910.5 TWh, with an average growth rate of 7.9%/year. The highest growth was made for 2016 at 11.7% and the lowest was for 2020 at 2% because of COVID19 (EVN NPT, 2020 Operation Report). For 2020, the power sales reached 216,950 million kWh with an increase of 3.42% over the year 2019. The total amount of power transmission was 203,850 million kWh. EVN NPT has managed and operated the national transmission grid in a secure, continuous, and stable manner, contributing to the overall goals of EVN by supplying sufficient power demand for national economic and social development. The reliability of the power supply was enhanced as SAIDI significantly fell by 66.76% from the previous year and the power loss rate declined to 6.42% (EVN, 2021 Annual Report).

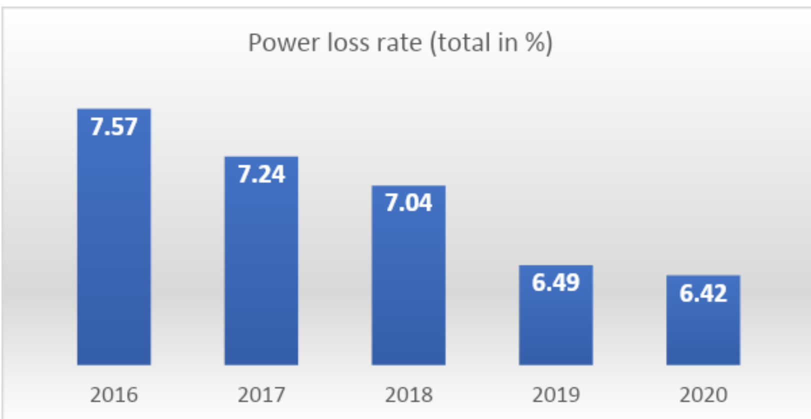






(EVN, 2020 Annual Report)

The power infrastructure has been significantly increasing (under the management of EVN NPT) from 2015 to end of 2020: 500 kV and 220 kV substations: increasing of 39% in term of quantity (with 232 additional substations) and 62% in term of capacity; 500 kV and 220 kV lines: increasing 20% in term of length. The power losses in the transmission grid system have been decreased from 2.39 % to 2.23 % from 2016 to 2020, mostly occurring in the 500 kV transmission lines from the North to the South. During last 5 years, the reliability of operation power grid ensuring the power supply has been significantly improving with a decline in average time for fault clearing indicator from 42.65 minutes in 2016 to 15.68 minutes in 2020. The total non-transmitted power improved from 0.0116% in 2016 to 0.00114% in 2020 (EVN NPT, 2020 Operation Report).



(EVN, 2021 Annual Report)

6.4. Development trends of the power sector of Vietnam

The Ministry of Industry and Trade is responsible for constructing the National Power Development plan. Up to date, the draft Power development plan VIII (PDP8) orienting the sector in the next 10 years with a vision to 2045 has been released several times for open and public consultation (July 2020, February 2021, September 2021). More recently, the Government Office has convened a consultation workshop in the finalization process of the PDP8. The meeting regrouped relevant ministries (MOIT, MPI, MOF, MONRE, MOST); Stated-owned enterprises involving in the power sector (EVN, PVN, TKV), research institutions and others business association. MOIT was revising the previous drafts according to the statement of Prime Minister toward the 2050 net zero racing to achievement at the COP26, with proposition of the power mix as below:

Table 1: Installed capacity by sources for 2025 - 2045 period (Draft PDP8, November 2021)

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	29,679	39,699	43,149	43,149	43,149
Gas	10,907	14,983	17,983	25,883	35,483
LNG	3,500	22,400	36,750	51,150	55,750
Oil	898	138	0	0	0
Hydro (including small power)	25,529	26,113	28,826	29,736	30,936
Wind	12,070	17,338	25,538	31,638	38,838
Offshore wind	0	4,000	10,000	23,000	36,000

Installed capacity (MW)	2025	2030	2035	2040	2045
Solar (including RTS)	18,040	21,390	35,740	50,540	63,640
Biomass and others	1,170	1,520	3,890	4,650	5,250
Storage	0	2,400	3,900	7,500	13,500
Import	4,728	5,742	7,742	10,242	11,042

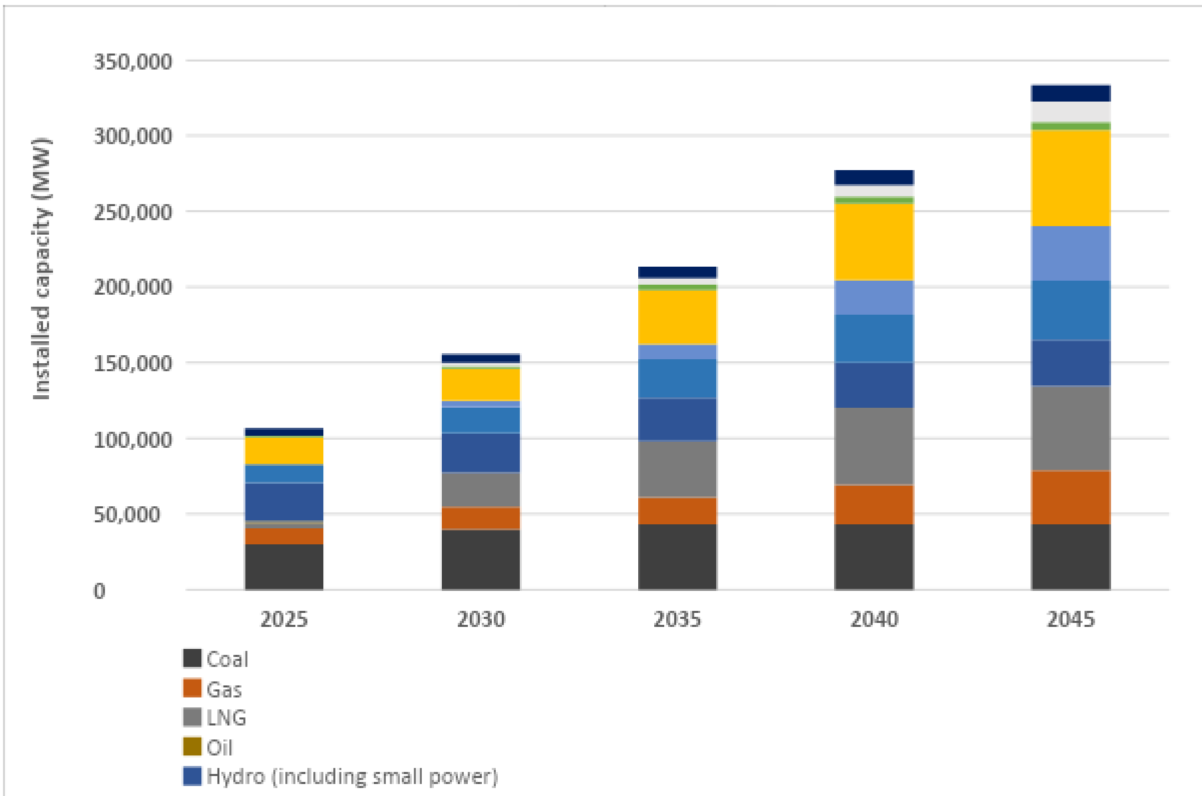


Figure 11: Installed capacity by sources for 2025 - 2045 period (Draft PDP8, November 2021)

The new drafted scenario in November of PDP8 shows that up to 2030,
Vietnam has a total capacity of 155,722 MW compared to 180,027 MW of the drafted scenario in March. There has been a marked change in the power mix planning, in which coal power decreases by 6,694 MW; LNG decreases by 18,550 MW meanwhile there is an increase in power generation of wind power by 1,258 MW and 1,241 MW for hydro.

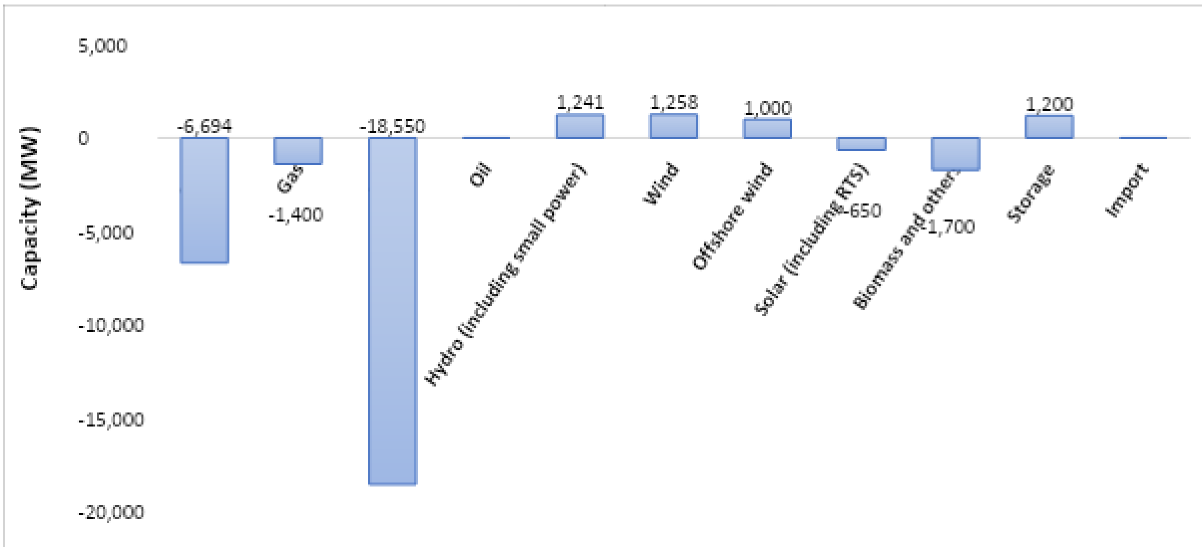


Figure 12: Comparison of the power mix in 2030 before (Mar. 2021) and after COP26 (Nov. 2021)

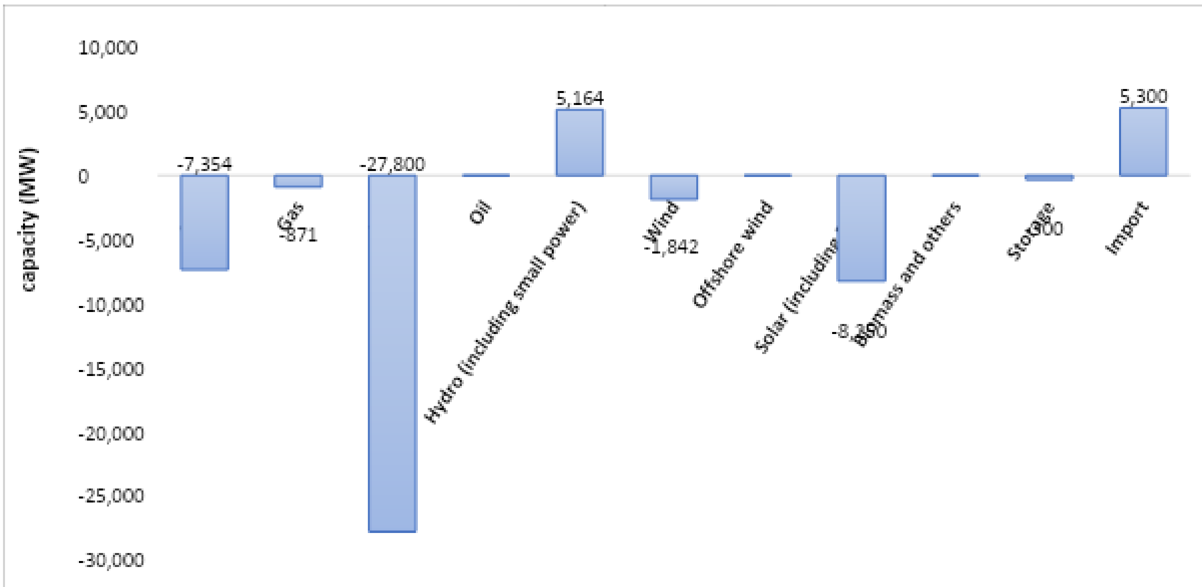


Figure 13: Comparison of the power mix in 2045 before (Mar. 2021) and after COP26 (Nov. 2021)

The key points are summarized as follows:

- Continue to review coal power projects; projects in the pipeline to be implemented before 2030 can continue, but will stop after that. Therefore, the road-map from 2021 to 2030 will remain the same. From 2030 to 2035, MOIT will negotiate with investors to switch from coal to gas.
- Increase offshore wind power projects

- Perform research on power storage and refer to the most updated data on the cost of solar power storage.
- Have a strategy to develop industries within high potential solar power areas to reduce strain on the T&D system.

With this configuration, for the next decade (from 2022 to 2030), the Vietnam power structure will mostly focus on the development of LNG (22.4 GW), coal (15 GW) and onshore wind installation (12.7 GW). For 2031 – 2045 period, LNG is still dominant developed resource and solar to power capacity (42.2 GW). This is followed by other renewable energies, especially wind onshore and offshore. With significant capacity of RE, 11.1 GW of storage is required to be installed during this period to response the reliability and flexibility of the power system.

Table 2: Installed capacity by sources for 2025 - 2045 period (Draft PDP8, November 2021)

Additional capacity (MW)	2021	2022 - 2030	2031 - 2045
Coal	24,697	**15,002**	3,450
Gas	7,398	7,585	**20,500**
LNG	0	**22,400**	**33,350**
Oil	1,579	-1,441	-138
Hydro (including small power)	22,139	3,974	4,823
Onshore wind	4,596	**12,742**	**21,500**
Offshore wind	0	4,000	**32,000**
Solar (including RTS)	16,627	4,763	**42,250**
Biomass and others	325	1,195	3,730
Storage		2,400	**11,100**
Import	620	5,122	5,300

7. Abatement scenarios for emission reduction in the power sector

7.1. Scenario narrative

Scenarios were utilized in this analysis to provide comparisons across different possible futures, and to then assess the impacts of these future choices thoroughly. This section provides an overview of the scenarios and presents the reasoning behind the development of said scenarios. Finally, the characteristics of each scenario are outlined.

There are three scenarios of the development of power sources (Blue, Green and Cyan) and two scenarios of demand (base and EE). The scenarios of power sources aim to promote the reduction of CO_2. This means that the new planned coal-fired power plants must be reduced, and phase out of old and less efficient coal power plants is to be implemented. They are replaced by gas-fired power plants or renewable energy. Meanwhile, the scenario of demand aims to consider the impact of saving energy policies, thereby reducing the total consumption in comparison to the forecasted consumption presented in PDP8.

Table 3: Descriptions of scenarios

Scenario	Description
Business-as-usual (BAU)	This scenario analyzes the currently planned coal developments as outlined in the PDP8 version September 2021. *Supply*: ● Coal capacity increases out to 2035 and stays constant thereafter. ● Domestic gas capacity stays constant after 2030, but LNG steadily increases throughout the study. ● Renewable technologies steadily increase after 2030. *Demand*: ● As based on the demand forecast projected in the drafted PDP8. ● Elasticity per GDP: 1.35 for 2021 – 2025; 1.24 for 2026 – 2030; 0.96 for 2031 – 2035; 0.64 for 2036 – 2040 and 0.46 for 2041 – 2045.
Blue	This scenario analyzes no new coal capacity after 2030, which is compensated by LNG and offshore wind (OSW).

Scenario	Description
	Supply: ● OSW capacity increases 5 GW more than OSW capacity in the BAU case, but other renewable energy technologies follow the BAU case projections. ● Additional LNG is installed to replace the coal capacity in BAU. ● Increase operation efficiency of existing hydro power plants by 10%. *Demand*: ● As based on the demand forecast projected in the drafted PDP8. ● Elasticity per GDP: 1.35 for 2021 – 2025; 1.24 for 2026 – 2030; 0.96 for 2031 – 2035; 0.64 for 2036 – 2040 and 0.46 for 2041 – 2045.
Green	This scenario analyzes no new coal capacity after 2030, which is compensated by renewable energy. *Supply*: ● Coal capacity stays constant after 2030, at a lower level than the coal capacity in the Blue/BAU cases, with the phase out of 3 old coal-fired power plants: Ninh Binh (operated since 1976); Pha Lai 1 (operated since 1986) and Pha Lai 2 (operated since 2001) by 2030. ● Domestic gas stays constant after 2030, and no new LNG capacity is installed. ● Solar, onshore and offshore wind capacity grows rapidly. ● Increase operation efficiency of existing hydro power plants by 10%. *Demand*: ● As based on the demand forecast projected in the drafted PDP8. ● Elasticity per GDP: 1.35 for 2021 – 2025; 1.24 for 2026 – 2030; 0.96 for 2031 – 2035; 0.64 for 2036 – 2040 and 0.46 for 2041 – 2045.
Cyan	This scenario analyzes a mix of the Blue and Green cases. This mix is defined as low carbon development with high renewable additions along with some LNG additions. *Supply*: ● Coal capacity stays constant after 2030, at a lower level than the coal capacity in the Blue/BAU cases, with the phase out of 3 old coal-fired power plants: Ninh Binh (operated since 1976); Pha Lai 1 (operated since 1986) and Pha Lai 2 (operated since 2001) by 2030. ● Domestic gas stays constant after 2030. ● Solar and wind capacity additions dominate the development.

Scenario	Description
	● The growth in wind energy is slightly slower than the Green case, which is compensated by LNG. ● Increase operation efficiency of existing hydro power plants by 10%. *<u>Demand</u>*: ● As based on the demand forecast projected in the drafted PDP8. ● Elasticity per GDP: 1.35 for 2021 – 2025; 1.24 for 2026 – 2030; 0.96 for 2031 – 2035; 0.64 for 2036 – 2040 and 0.46 for 2041 – 2045.
Blue_EE	*<u>Supply</u>*: ● Based on the Blue case. *<u>Demand</u>*: ● Lower demand for electricity due to higher energy efficiency measures (energy efficiency measures projected to save 10% of total energy demand in 2030, starting at 4% in 2025 and increasing up to 16% of total energy demand by 2045). ● Elasticity per GDP: 1.2 for 2021 – 2025; 1.0 for 2026 – 2030; 0.8 for 2031 – 2035; 0.6 for 2036 – 2040 and 0.4 for 2041 – 2045.
Green_EE	*<u>Supply</u>*: ● Based on the Green case. *<u>Demand</u>*: ● Lower demand for electricity due to higher energy efficiency measures (energy efficiency measures projected to save 10% of total energy demand in 2030, starting at 4% in 2025 and increasing up to 16% of total energy demand by 2045). ● Elasticity per GDP: 1.2 for 2021 – 2025; 1.0 for 2026 – 2030; 0.8 for 2031 – 2035; 0.6 for 2036 – 2040 and 0.4 for 2041 – 2045.
Cyan_EE	*<u>Supply</u>*: ● Based on the Cyan case. *<u>Demand</u>*: ● Lower demand for electricity due to higher energy efficiency measures (energy efficiency measures projected to save 10% of total energy demand in 2030, starting at 4% in 2025 and increasing up to 16% of total energy demand by 2045). ● Elasticity per GDP: 1.2 for 2021 – 2025; 1.0 for 2026 – 2030; 0.8 for 2031 – 2035; 0.6 for 2036 – 2040 and 0.4 for 2041 – 2045.

The socioeconomic indicators have been using in this study following the draft PDP8 as follows:

Table 4: socioeconomic assumptions (Draft PDP8)

Assumption	Unit	2021 - 25	2026 - 30	2031 - 35	2036 - 40	2041 - 45
GDP growth rate	%/year	6.8	6.4	6.0	5.6	5.5
Electricity demand growth rate	%/year	9.09	7.95	5.8	3.66	2.61
Elasticity per GDP – BAU scenario		1.35	1.24	0.96	0.64	0.46
Electricity Generation – BAU scenario	TWh	378.3	551.3	727.0	864.9	977.0
Elasticity per GDP – EE scenario		1.2	1.0	0.8	0.6	0.4
Electricity Generation – EE scenario	TWh	364.0	496.4	627.5	740.2	825.3

It's noted that under the framework of this study, the demand projection hasn't been recalculated and was inherited from data forecast of draft PDP8, based on the GDP growth rate at 6.6% for 2021 – 2030 and 5.7 % for 2031- 2045 as presented in the Table 4, as called base demand scenario in this report. However, the assessment of the power demand forecast through different power plans (as shown in the Figure 14) indicated that an overestimation was observed in PDP6, PDP7 and PDP7 revised. Based on that, a second demand scenario called EE has been proposed taking into account higher energy efficiency measures, resulting to a reduction of power consumption by 10% in 2030, starting at 4% in 2025 and increasing up to 16% of total energy demand by 2045.

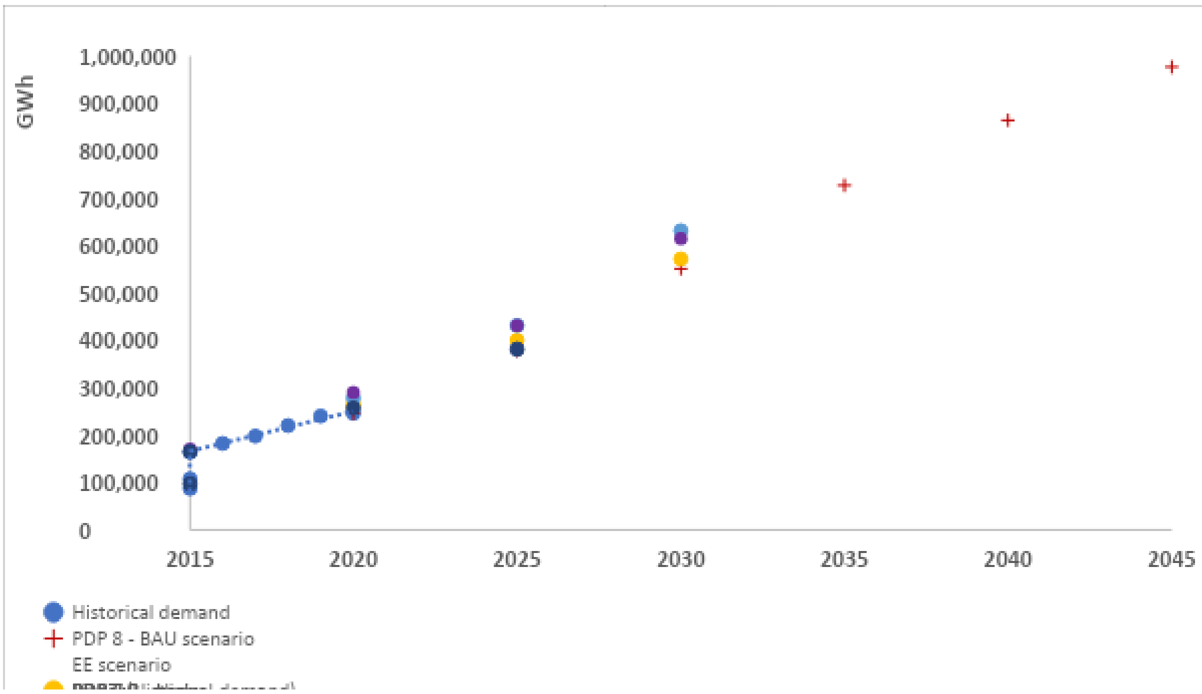


Figure 14: Power demand forecast through different Power Development Plans

The scenarios of the development of power sources are described in more detail below:

BAU: Following the draft PDP8 (September 2021).

Table 5: Power mix in BAU scenario

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	29,429	40,649	50,699	50,699	50,699
Gas	9,857	14,783	14,783	14,783	14,783
LNG	3,500	12,550	23,900	37,900	47,150
Oil	898	138	138	0	0
Hydro	25,389	25,484	27,767	28,567	29,077
Onshore wind	11,320	11,820	17,010	22,110	27,110
Offshore wind	0	0	5,500	13,000	21,000
Solar	17,240	18,640	27,640	38,940	51,540
Biomass and others	1,170	1,170	3,260	4,650	5,250
Storage	0	1,200	3,300	4,800	6,600

BLUE: In 2045: Reduce 20.6 GW of coal-fired and oil-fired power plants, increase 5.4 GW of offshore wind in comparison to the base case. To compensate the lack of electricity, new LNG power plants might need to be built.

Table 6: Power mix in BLUE scenario

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	28,909.32	30,109.32	30,109.32	30,109.32	30,109.32
Gas	9,261.56	14,401.56	14,401.56	14,401.56	14,401.56
LNG	3,500.00	15,700.00	34,656.13	47,012.63	51,750.54
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	26,087.95	26,512.95	28,701.95	29,501.95	30,011.95

Installed capacity (MW)	2025	2030	2035	2040	2045
Onshore wind	11,320.28	11,820.28	17,010.28	22,110.28	27,110.28
Offshore wind	4,200.00	5,400.00	10,900.00	18,400.00	26,400.00
Solar	17,226.90	18,626.90	27,626.90	38,926.90	51,526.90
Biomass and others	345.45	1,055.47	1,055.47	1,055.47	1,055.47
Storage	0.00	2,400.00	3,300.00	6,600.00	11,400.00

GREEN: **In 2045**: Reduce 21.8 GW of coal-fired and oil-fired power plants, only domestic gas-fired power plants are mobilized and not LNG power plants, increase 14.68 GW of solar and 10.2 GW of offshore wind. In case of lack of electricity, new capacity of onshore wind power plants is required to compensate. Due to the increase of renewable energy, the installed capacity of Storage and pumped hydro must be increased.

Table 7: Power mix in GREEN scenario

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	27,769.32	28,969.32	28,969.32	28,969.32	28,969.32
Gas	9,261.56	14,401.56	14,401.56	14,401.56	14,401.56
LNG	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	26,087.95	26,512.95	28,701.95	29,501.95	30,011.95
Onshore wind	11,320.28	21,266.58	60,248.62	84,732.64	97,676.96
Offshore wind	4,200.	10,200.00	15,700.00	23,200.00	31,200.00

Installed capacity (MW)	2025	2030	2035	2040	2045
	00				
Solar	19,727.90	33,308.90	42,308.90	53,608.90	66,208.90
Biomass and others	345.45	1,055.47	1,055.47	1,055.47	1,055.47
Storage	1,800.00	3,459.10	4,379.34	8,242.63	13,658.85

CYAN: **In 2045**: Reduce 21.8 GW of coal-fired and oil-fired power plants, 31.5 GW of gas-fired (including LNG) power plants (only 30% of LNG capacity vs. base case is simulated), increase 14.6 GW of solar and 10.2 GW of offshore wind in comparison to the base case. In case of lack of electricity, onshore wind power plants will be the balance source.

Table 8: Power mix in CYAN scenario

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	27,769	28,969.32	28,969.32	28,969.32	28,969.32

Installed capacity (MW)	2025	2030	2035	2040	2045
	.32				
Gas	9,261.56	14,401.56	14,401.56	14,401.56	14,401.56
LNG	1,500.00	6,000.00	10,700.00	13,700.00	16,050.00
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	26,087.95	26,512.95	28,701.95	29,501.95	30,011.95
Onshore wind	11,320.28	11,839.52	43,442.30	63,224.21	72,494.36
Offshore wind	4,200.	10,200.00	15,700.00	23,200.00	31,200.00

Installed capacity (MW)	2025	2030	2035	2040	2045
	00				
Solar	19,727.90	33,308.90	42,308.90	53,608.90	66,208.90
Biomass and others	345.45	1,055.47	1,055.47	1,055.47	1,055.47
Storage	0.00	2,400.00	3,300.00	6,600.00	11,400.00

To summarize, the BLUE scenario is prioritizing the development of the marine energies (such as importing LNG and increasing the share of offshore wind). GREEN scenario is prioritizing the development of the renewable energies (such as mobilizing the rooftop and floating solar; onshore and offshore wind for power generation) , and CYAN is defined as a mix between Blue and Green as explained above.

Table 9: Summary of power mix in 2030 for 4 considered scenarios

Power mix in 2030

Scenario Power mix	Solar (GW)	Wind (GW)	Biomass & other RE (GW)	Hydro power (GW)	Coal (GW)	Oil & Gas (GW)	Storage (GW)
BAU (PDP8)	18.6	11.8	1.2	25.5	40.6	27.5	1.2
Blue (No new coal)	18.6 (draft PDP8)	11.8 onshore wind + 5.4 offshore wind	1.2	25.5 Increased operation efficiency by 10%	Existing capacity 22.1 + Under construction projects 7.4	14.4 Existing capacity and Domestic gas plants + LNG balanced source at 15.7	2.4
Green (Phase out coal)	18.6 (draft PDP8) + 5 RTS + 9.68 FLS	21.3 onshore wind + 10.2 offshore wind	1.2	25.5 Increased operation efficiency by 10%	22.1 Existing capacity - Old plants to be phased out* 1.14 + Under construction projects 7.4	14.4 Existing capacity + Domestic gas power plants	3.5
Cyan-EE (Real transition)	18.6 (draft PDP8) + 5 RTS + 9.68 FLS	Onshore wind balanced source 11.8 + 10.2 offshore wind	1.2	25.5 Increased operation efficiency by 10%	22.1 Existing capacity - Old plants to be phased out* 1.14 + Under construction projects 7.4	14.4 Existing capacity and Domestic gas plants + 6 LNG	2.15

** 3 Old coal-fired power plants to be phased out: Ninh Binh (operated since 1976); Pha Lai 1 (operated since 1986) and Pha Lai 2 (operated since 2001).*

7.2. Input data

Technical input

There are many types of generators divided into three main catalogues: thermal power plant, hydro power plant, and renewable energy power plant. Here, thermal power plants contain coal-fired power plants, gas-fired power plants (Gas and LNG), and oil-fired power plants, while hydro power plants include small and large hydro power plants. Renewable power plants have biomass, waste incineration, rooftop solar and solar farm, onshore and offshore wind.

In 2025, the total installed capacity is 98.8 GW, then it increases year by year aiming to meet the development of demand with 126.4 GW in 2030, 174 GW in 2035, 215.5 GW in 2040, and 253.2 GW in 2045. The detailed electricity sources are described in Table 10. According to PDP VIII, renewable and new energy (wind, solar, biomass, Waste incineration) is promoted to increase the capacity and consider the stability of the power system and each region. From 2035 up to 2045, the total installed of the coal thermal power plant is stable, while it is different for renewable energy resources which have significantly increased since 2035. This number rise to 62.5% in 2035, 138% in 2040, and 219% in 2045 in comparison to 2030.

The total installed capacity of the onshore wind power plants is 11.32 GW in 2025, 17 GW in 2035, and a jump to 27.1 GW in 2045. Meanwhile, the capacity of offshore wind power plants is only 5.5 GW in 2035 and significantly rises 4 times in 2045. The installed capacity of offshore wind is expected to be higher in case of fulfilling technology and economic requirements.

Solar energy includes rooftop solar, floating solar and solar farm. The total
installed capacity of solar is 17.2 GW in 2025 and starting increase from 2035 with 10 GW more and about 35 GW more in 2045. This value reach 51.5 GW in 2045.

PDP VIII also promotes biomass, waste incineration power plants and new energy sources. In Table 10, the total installed capacity of biomass increases 2 times, and waste incineration rise 10 times from 2025 to 2045.

Today, the total installed capacity of hydro power plant is reaching the maximum potential, thus PDP VIII focuses on improve the efficiency of existing hydro power plants, implementing new potential medium and small hydro power plants. Therefore, the total installed capacity of hydro power plant is not much between 2025 and 2045, i.e. 4 GW.

According to draft PDP VIII, new coal-fired power plants are stopped, and gas-fired is promoted, especially LNG. Therefore, the total installed capacity of gas significantly increases from 2025 to 2045. This number is 27.3 GW with 2030, 38.7 GW with 2035, 52.7 GW in 2040 and 62 GW in 2045. The total installed of gas-fired (LNG) power plant rises more than 10 times from 2025 to 2045.

The increment of renewable energy and the stability of thermal power plants require the flexibility of electricity sources such as storage or pump hydro aiming to support the stability of the system due to the unpredictable of renewable energy. The installation of flexibility sources is shown with 2400 MW in 2030, then increases 37% in 2035, 175% in 2040, and 375% in 2045.

Table 10: Vietnam Power mix from 2025 - 2045 (Draft PDP8, Sept 2021)

Installed capacity (MW)	2025	2030	2035	2040	2045
Coal	29,429	40,649	50,699	50,699	50,699
Gas	9,857	14,783	14,783	14,783	14,783
LNG	3,500	12,550	23,900	37,900	47,150
Oil	898	138	138	0	0

Installed capacity (MW)	2025	2030	2035	2040	2045
Hydro	25,389	25,484	27,767	28,567	29,077
Onshore wind	11,320	11,820	17,010	22,110	27,110
Offshore wind	0	0	5,500	13,000	21,000
Solar	17,240	18,640	27,640	38,940	51,540
Biomass and others	1,170	1,170	3,260	4,650	5,250
Storage	0	1,200	3,300	4,800	6,600

Table 11 presents the installed capacity of thermal power plants by regions and years. Most thermal power plants are built in the North and South of Vietnam with 66% of the total installed capacity on average. However, the North-Central of Vietnam is known as the new location of thermal power plant since the total capacity of thermal power rise three times from 2025 to 2045. It can be explained by the new gas-fired (LNG) power plant will be developed in these regions, such as Hai Phong, Quang Ninh, Thai Binh, Thanh Hoa, Ca Na, Son My, Dong Nai, Long An, etc.

Table 11: Installed capacity of thermal power plants by regions (Draft PDP8, Sept 2021)

Installed capacity (MW)	2025	2030	2035	2040	2045
North	14,119.00	19,139.00	24,439.00	28,939.00	31,289.00

Installed capacity (MW)	2025	2030	2035	2040	2045
North-Central	4,295.00	9,445.00	15,745.00	18,945.00	20,545.00
Central-Central	0.00	5,290.00	5,290.00	5,290.00	5,290.00
Highland-Central	30.00	30.00	30.00	30.00	30.00
South-Central	5,767.82	8,767.82	10,267.82	10,267.82	10,267.82
South	19,067.56	31,717.56	36,517.56	38,767.06	38,767.06
Not yet defined	0.00	0.00	4,200.00	4,200.00	8,100.00
Total	43,279.38	74,389.38	96,489.38	106,438.88	114,288.88

Table 12 presents the installed capacity of hydro power plants by region and years. It is similar with thermal power plant; the North of Vietnam has the highest installed capacity of hydro power plant. The Highland-Central of Vietnam seems that developing hydro power plants much more than thermal power due there are many rivers, waterfalls. The total capacity of hydro power plant is more or less the same by years. In conclusion, the development of hydro power plants is near the upper bound of the total potential exploitation of Vietnam. It should be noted that there is 572 MW is imported from Laos through two inter-connectors (Laos – Central – Central and Laos – Highland – Central).

Table 12: Installed capacity of hydro power plants by regions (Draft PDP8, Sept 2021)

Installed capacity (MW)	2025	2030	2035	2040	2045
North	13,045.50	13,045.50	14,064.50	14,614.50	15,124.50
North-Central	2,057.90	2,152.90	2,402.90	2,652.90	2,652.90
Central-Central	3,569.70	3,569.70	3,569.70	3,569.70	3,569.70
Highland-Central	3,226.00	3,476.00	3,586.00	3,586.00	3,586.00
South-Central	1,766.00	1,846.00	1,906.00	1,906.00	1,906.00
South	1,850.90	1,850.90	2,600.90	2,600.90	2,600.90
Laos	572.00	572.00	572.00	572.00	572.00

Installed capacity (MW)	2025	2030	2035	2040	2045
Total	26,088.00	26,513.00	28,702.00	29,502.00	30,012.00

Table 13 shows the power planning of renewable energy by region and years. From this table, Vietnam is towards green energy since the total installed capacity of renewable energy significantly rises two times from 2030 to 2045. The South and North of Vietnam are occupying the first position in the share of total installed capacity of renewable energy, followed by South-Central and the North. Here, most of the installed capacity of onshore and offshore wind energy is implemented in the South of Vietnam leading this region to rely on renewable energy in the future. This is explained by the potential of solar and wind in the South of Vietnam is very high with 4,6-4,8 KWh/m^2 day (solar radiation map of Vietnam) and wind speed is 8-10 m/s.

Table 13: Installed capacity of renewable energy by regions (Draft PDP8, Sept 2021)

Installed capacity for solar and onshore wind (MW)	2025	2030	2035	2040	2045
North	1,017.00	1,604.00	4,464.00	8,064.00	11,064.00
North-Central	850.00	1,022.00	1,022.00	1,022.00	1,022.00
Central-Central	1,530.40	1,625.40	1,625.40	1,625.40	1,625.40
Highland-Central	4,717.60	5,117.60	5,117.60	5,117.60	5,117.60

Installed capacity for solar and onshore wind (MW)	2025	2030	2035	2040	2045
South-Central	8,832.60	8,932.60	8,932.60	8,932.60	8,932.60
South	11,945.00	13,201.00	24,531.00	37,331.00	51,931.00
Installed capacity for offshore wind (MW)	**2025**	**2030**	**2035**	**2040**	**2045**
Offshore wind (total)	0.00	0.00	5,500.00	13,000.00	21,000.00
Total	**28,892.60**	**31,502.60**	**51,192.60**	**75,092.60**	**100,692.60**

The detail of cost, efficiency, economic and technical constraints, timeline, investment cost are collected including:

- Name and location of generator
- Number and capacity of units
- Primary fuel type
- Date of operation
- Retirement date
- Maximum and minimum capacity
- Capacity factor of each type of power plant depending on the year of start-operating
- Variable and fixed operating and maintenance cost (O&M) of thermal, hydro and renewable unit
    - ✔ Thermal power plant specific data:

- Fuel cost of coal, oil, gas is the energy input of thermal units by year. They are divided into domestic and imported source
- Detailed heat rate characteristic
- Ramping up and down of thermal unit depend on technology
- Start up and down characteristic and cost depend on technology

✔ Hydro power plant specific data: The economic and technical constraint of the hydro power plant is considered to depend on the size of the hydro power plant (small and large). In the dispatch economic model, waterway flow and Water-head are one of the main parameters. Therefore, from the historical average value of each month of each power plant, the value for each hour is calculated. From the beginning of September until the end of December, the water storage period of the hydro power plant is started.

- Type of power plant (small and large hydro power plant)
- Units of one hydro power plant
- Reservoir size and characteristic (maximum and minimum volume)
- Waterway flow and Water-head of reservoir for each month
- Maximum and minimum of water through turbine

✔ Renewable power plant: Assessments of individual wind and solar farms, specifically modeled for Vietnam, were included – with adjustments for relevant losses and weather factors. For full details on renewable energy.

- Hourly profile output of each unit

Grid simulation setup

In this report, the modeling scenario is set up in the DIgSILENT/Power Factory software to cover the simulation of the Vietnam power system in 2025. This software was developed by DIgSILENT GmbH, providing highly specialized services in the field of electrical power system simulation, development, and planning. Several basic analysis modules of this software are load flow analysis, short-circuit analysis, and optimal power flow. Besides, DIgSILENT/Power Factory also provides a wide range of additional functions that are significantly useful for the analysis in this report, such as Quasi-Dynamic Simulation and renewable energy resources modeling.

Based on the geographical characteristics and structure of the Vietnam power system, the transmission system is divided into 6 regions and 19 sub-regions. The regional division is equivalent to the setting in the GAMS model, while the sub-regional division is used for ease of data management and setting up simulation scenarios in DIgSILENT/Power factory.

The Vietnamese transmission grid in 2025 is developed from the grid configuration in 2020 by adding the following data:

- List of power plants (classification according to generation types) expected to operate in the period 2021 – 2025 according to the Draft PDP 8 (September 2021).
- The peak load (Pmax) and the yearly load profiles by region in 2025 according to the Draft PDP 8 (September 2021).

- 500-kV and 220-kV transmission lines and substations approved in the Draft PDP 8 (September 2021).

- The location of potential generation sources in each region (classification by generation type)

According to the forecasted peak load by regions in 2025, the national load peak will be 69.76 GW and the location of load center is distributed unevenly among regions. While the whole central region of Vietnam only consumes about 19.5% of the total generation, the North and the South accounts for around 40% and 40.5% of the total consumption, respectively. The model of the Vietnam power system simulated in DIgSILENT/Power factory represents an equivalent network of up to 110-kV nodes. The power factor cos ϕ at each load node is chosen as 0.95. The yearly profile of each load is calculated from a typical regional load profile provided in the Draft of PDP 8.

For the simulation of traditional power plants (coal thermal, LNG, hydro power plants), the developed model represents up to the unit-level (225 units with the total installed capacity of 69.8 GW). There are about 300 small hydro power plants with the total capacity of about 7.4 GW (including potential sources). The location of these small hydro power plants has been clearly identified based on provincial planning data.

In the period 2021 – 2025, renewable energy sources (including solar, wind and other sources) account for 28% of the total generation mix. The location of the power plants that are already put into commercial operations, as well as the approved projects, is completely identified. The location of potential RE projects in 2025 is chosen and distributed among regions based on the Draft of PDP 8 (September 2021) and the planning data of each province. The rooftop solar projects are the main difficulty in grid simulation as they are distributed everywhere in the grid. Therefore, in the grid simulation, the rooftop solar projects are treated as negative loads located evenly among regions. The total capacity of solar and wind power sources is about 28.9 GW (17.2 GW of solar power and 11.3 GW of wind power).

The location of the added RE sources in more ambitious scenarios is determined by comprehensively evaluating the grid capacity in 2025. The added 2.5 GW of rooftop solar recommended to be in commercial operation in the period 2021 – 2025 (the Green and Cyan-EE scenario) is treated as negative loads at the regions having high technical potential, according to the Draft of PDP 8. The expected 4.2 GW of offshore wind power is distributed as follows:

- 2.4 GW of offshore wind power in Zone 3 (Binh Thuan province) is sent to Long Thanh 500-kV substation through the VSC-HVDC transmission line.
- The energy from 0.6 GW offshore wind power in the South-Central region is collected and relieved to load through the Hong Phong 500-kV substation.
- 0.6 GW of offshore wind power in Zone 4 (Ba Ria – Vung Tau province) is connected to Vung Tau 220-kV substation.
- Another 0.6 GW of offshore wind power in Zone 4 (Bac Lieu province) is connected to the Bac Lieu 500-kV substation.

With the above analysis, until 2025, the total installed capacity of generation mix, including under-commercial operation, approved power plants and recommended additional capacity, reaches about 105.4 GW.

Economic input

This section examines the assumptions and methodologies utilized in the economic analysis. The primary output for the economic analysis is the total net present cost[2] of the future electricity system. Along with other outputs (including individual cost categories and fuel prices, balance of payments impact, etc.) this allows for comparison across scenarios at an equivalent basis. For each scenario described in scenario narrative, calculating the net present cost for the electricity system in Vietnam incorporates distinct cost streams calculated for each technology, as outlined below:

- Capital costs
- Operating expenses
- Fuel costs
- Energy efficiency program costs
- Transmission and distribution upgrade costs
- Emissions costs

The costs associated with developing and constructing generation units are calculated based on the capital costs of various technology types. The operating expenses to maintain and run the units are calculated based on the operating expenses of said technology types. To determine fuel pricing, electricity generation forecasts from the output of the GAMS model were utilized. For each fuel-based technology type, a typical plant efficiency (heat rate) was used to determine the required fuel to generate the required electricity.

For transmission and distribution costs, the costs of upgrading the grid systems to accommodate various generation sources are estimated for each case. The components of the smart grid system are explored in this analysis, to determine the appropriate costs of upgrades for the different generation sources in the scenarios.

The details and sources of the assumptions utilized in the analysis for the cost streams mentioned above are described in the following section.

Input Assumptions

The inputs used to calculate the net present cost of each scenario can be divided into four categories, as mentioned above: Electricity Generation and Fuel Consumption, Capital and Operating Expenditures (CapEx and OpEx), Transmission and Distribution (T&D) Assumptions, and Energy Efficiency Assumptions. The assumptions in the Electricity and Fuel category are case-dependent, while most of the assumptions in the latter two categories are mainly constant across scenarios with a few exceptions. The details and sources of each assumption are explained in detail.

[2] The total net present cost (by scenario) includes all cost categories, for each year until 2045, discounted to a current single value using the standard discount rate of 5 percent (other discount rates were examined in a separate sensitivity). When outputs from the GAMS model were aggregated into five-year periods, a straight-line approach was used to allocate those costs between years.

Electricity Generation and Fuel Consumption

Electricity generation is used as the basis for calculating the fuel consumption, as an output of the GAMS modelling. For each scenario, generation from each fuel/technology type is provided for the years 2025, 2030, 2035, 2040 and 2045.

To calculate the fuel consumption, average heat rates for coal, gas and oil plants are used. These values are obtained from the 2021 Vietnam Technology Catalogue and are provided in Table 14.

Table 14: Heat rates of power plants

Fuel Type	Heat Rate (%)	Details
Coal	39%	Assumed to be a supercritical pulverized coal plant
Gas/LNG	55%	Assumed to be a combined cycle plant
Oil	35%	Assumed to be a simple cycle plant

To calculate the costs associated with fuel consumption, the following fuel costs are used as the basis for calculating the fuel costs over time. Fuel prices are based on the 2020 prices and assumed to escalate at 1% annually over time.

Table 15: Fuel pricing assumption

Fuel price forecast ($/GJ)	2020	2025	2030	2035	2040	2045
Coal 4b	3.6	3.96	4.36	4.79	5.27	5.8
Coal 5a	3.54	3.9	4.29	4.71	5.19	5.7
Coal 5b	3.4	3.74	4.11	4.52	4.98	5.47
Coal 6a	3.37	3.71	4.08	4.48	4.93	5.43
Coal 6b	3.36	3.69	4.06	4.47	4.91	5.41
Import coal	2.79	2.99	2.99	3.19	3.23	3.27
Domestic gas	5.77	6.34	6.98	7.68	8.44	9.29
Oil	17.15	18.86	20.75	22.82	25.1	27.61
Import LNG	9.86	8.53	8.53	8.63	8.72	8.82

Source: Imported fuel cost projection from PDP8 - Sep 2021; Domestic fuel cost in 2020 taken from http://minhbach.moit.gov.vn/; Domestic fuel cost projection based on the increased rate of 10% as for the 2015 - 2020 period.

To calculate the costs attributed to carbon emissions, the following emissions factors have been taken for existing coal, oil and gas from Calculation of Emission factor of Vietnam's power grid 2019 (MONRE). EF for new coal is taken from Report on Determination of GHG control measures in coal power sector 2015 by Institute of Energy. For biomass and waste incineration, emissions factors obtained from the 2006 IPCC Guidelines for Natural Gas Inventories are utilized.

Table 16: Emission Factors

	Existing coal	New coal	Oil	Gas
Emission factor ($kgCO_2/kWh$)	1.062	0.931	0.773	0.451

Fuel	**Emission Factor (kg CO_2 eq/TJ)**
Biomass	54,655
Waste Incineration	101,942

CapEx and OpEx Assumptions

Capital (CapEx) and Operational (OpEx) costs were estimated using per unit CapEx and OpEx values provided in the September 2021 draft of PDP8. The capital and O&M costs are assumed to apply over the course of the 25-year period of the study. When new LNG power capacity is installed, increased CapEx investment for LNG supply chain infrastructure (e.g., LNG depot projects, pipeline, receiving terminals, etc.) is also required. The estimated average CapEx cost of added LNG supply infrastructure is $0.83 USD per GJ of LNG produced.[3]

Table 17: CapEx and OpEx per technology

[3] Vietnam Energy Master Plan for Period 2021-2030 with a Vision to 2050

Technology	Construction cost (including IDC) (kUSD/MW)	Fixed O&M costs (kUSD/MW)	Variable O&M costs (excluding fuel costs) (USD/MWh)	Performance (%)	Technical operating time (year)	Capacity Factor
Supercritical coal power plant	1804	32	2	38	30	0.74
Ultra-Supercritical coal thermal power	1960	43	2	43	30	0.74
Combined cycle gas turbine	1000	29	2	60	25	0.55
Hydroelectric	1500	38	0		50	0.5
Wind onshore (Averag	1947	48	5		27	0.29

Technology	Construction cost (including IDC) (kUSD/MW)	Fixed O&M costs (kUSD/MW)	Variable O&M costs (excluding fuel costs) (USD/MWh)	Performance (%)	Technical operating time (year)	Capacity Factor
e wind speed)						
Offshore wind turbine (fixed foundation)	3100	81	4		27	0.43
Concentrated solar power	1009	9	0		25	0.18
Biomass electricity	2010	48	3	31	25	0.6
Waste to electricity (direct	4986	235	24	28	25	0.6

Technology	Construction cost (including IDC) (kUSD/MW)	Fixed O&M costs (kUSD/MW)	Variable O&M costs (excluding fuel costs) (USD/MWh)	Performance (%)	Technical operating time (year)	Capacity Factor
incineration)						
LNG combustion engine (ICE)	740	15	5	48	35	0.18
Pumped-storage hydroelectricity	950	22		80	40	

Transmission and Distribution Assumptions

Integrating the fossil and renewable energy generation assets including in PDP8 and each of the scenarios presented here requires improvements and expansion in the transmission and distribution (T&D) system. In total, these costs vary from $40B to $46B, with each scenario being assess based on projected asset installation and smart grid requirements.

The T&D upgrade cost assumptions are based on the costs associated with renewable energy integration and smart grid upgrades. As such, the costs for the components of the smart grid are estimated for the BAU case and adjusted for each scenario by means of adjustment factors.

As renewable energy penetration increases on the system, the grid needs to undergo certain upgrades to reliably deliver power from the intermittent generation sources. The total cost of upgrading the T&D system over the next 10 years is estimated to be $7.4 billion USD for the BAU case[4]. This total cost can be attributed to the various components of the smart grid, as shown in Table 18 below, with estimated shares of the total cost.

Table 18: Smart Grid Components

Component	Share of Total Cost
Variable Renewable Energy (VRE) Forecasting	1%
Wide Area Measurement Systems (WAMS)	1%
Online Dynamic Security Assessment (DSA)	2%
High Voltage Direct Current (HVDC)	24%
Flexible Transmission System	12%
DTCR	1%
Distribution Automation	3%
On Load Tap Changers	10%
Smart Inverters*	-
Advanced Metering Infrastructure (AMI)	20%
Demand Side Management (DSM)*	-
Demand Response*	-
Distributed Energy Storage	28%
Total	100%

[4] Per GIZ Report: Smart Grids for Renewable Energy and Energy Efficiency, 2019: Adjustment factors were used to allow Korea's planned smart grid costs to approximate required costs for Vietnam (scaled to the RE integration needs).

http://smart-grid.vn/wp-content/uploads/2020/02/SGREEE_AA1_GapsAnalysis_Report_final_EN.pdf

**These technologies are part of the smart grid mix, but their costs are already incorporated by either the renewable energy or energy efficiency interventions in scenarios.*

The projected future smart grid upgrades involve a mix of hardware and software enhancements. These enhancements are largely responsible for enabling safe deployment of renewable energy onto the grid. To increase the amount of renewable energy deployment, there could be a need for higher numbers of certain hardware on the grid. Similarly, with more intermittent resources it could become more expensive to operate certain software such as the Online DSA. Therefore, certain adjustment factors were utilized to account for the higher costs of upgrading and maintaining a renewable energy heavy grid. These adjustment factors lead to increased T&D costs for the high renewable Green and Cyan scenarios, whereas the Blue scenario stays the same as the BAU case.

Energy Efficiency Assumptions

The costs of implementing energy efficiency measures are estimated to be $0.08/kWh, an estimate of total program costs based on prior long term energy plans.

Social input

This section lays out the assumptions and methodologies employed in the social impact assessment. The primary objective of this assessment is to determine the employment implications of each scenario, based on the total investments made. The employment outcomes influence the economic development goals of Vietnam and help support critical social goals for the Government.

The methodology to calculate the number of jobs created is primarily based on the "Employment Factor Approach" outlined in the Ram et al. (2021) study. The analysis involves inputs from multiple sources, including Ram et al. (2021), Rutovitz et al. (2015) (which Ram et al. (2021) references consistently), and the GAMS model. Table 19 describes the inputs related to job calculations and identifies the source.

According to Ram et al. (2021), the Employment Factor approach can be modified across specific contexts and geographic regions, including Southeast Asia. Thus, the inputs derived from the study are more relevant to the Southeast Asia region. The only input specific to Vietnam is 'Regional Employment Multiplier', which was derived from several Vietnamese studies and calculations of fuel jobs.

The total number of jobs includes jobs created from different stages of energy generation including manufacturing, construction and installation, operations and maintenance, decommissioning, fuel, and transmission and distribution. Fuel jobs include those created from coal, oil, biomass, waste incineration, and gas generation. The definitions of each job type are as follows (adapted from Ram et al., 2021):

- **Manufacturing**: Jobs necessary to manufacture a unit of power, heat, storage, or fuel production. These jobs are considered relatively temporary in comparison to the full duration of a plant's lifetime. In addition, the proportion of local production is assumed to be equal to 100% to see the potential of this sector.
- **Construction and Installation:** all jobs involved in constructing and installing a unit of power and heat generation, energy storage, or fuel production and processing capacity throughout the construction period of a power plant. These jobs are considered temporary and last for the construction period.
- **Operation and Maintenance (O&M):** all jobs associated with operating and maintaining an energy plant over its lifetime. These jobs are more long-lasting and are considered for the lifetime of the energy plant.

- **Fuel jobs:** all jobs involved with fuel production and supply, including the import and export of fuel sources.
- **Decommissioning:** all jobs necessary to retire installed energy plants at the end of their lifetimes. These jobs are considered temporary and for the duration of the decommissioning period.
- **Transmission and distribution:** all jobs associated with the transmission and distribution of energy across a grid. These jobs tend to be longer-term.

Table 19: Description of inputs to the social model and relevant source

Input	Description	Source
Installed Capacity (MW)	Output of electricity for each technology types; represented in the model as newly installed capacity.	GAMS model, Draft PDP8 Sep 2021
Electricity Generated (MWh)	Amount of electricity for each technology type produced over the transition period (2025-2045). Used to calculate fuel jobs created from biomass and waste incineration.	GAMS model
Fuel Volume (GJ)	The volume of fuel used to generate electricity. Includes domestic coal, imported coal, domestic gas, imported LNG, and domestic oil.	GAMS model, Draft PDP8 Sep 2021
Employment Factor (EF)	For manufacturing, construction, operations and maintenance, and decommissioning jobs, this is expressed as the number of jobs per unit of installed capacity for each five-year period of the transition (2025-2045). Specifically, manufacturing, construction, and O&M EFs are applied to newly installed capacity whereas decommissioned EFs are applied to decommissioned capacity. For fuel jobs, this is expressed as jobs per unit of annual primary energy production. For transmission and distribution jobs, the Employment Factor is expressed as job per unit of electricity generated for transmission and distribution.	Ram et al. (2021) and Rutovitz et al. (2015)
Annual Decline Factor	Reflects the notion that job creation can be expected to reduce as technologies age and mature.	Ram et al. (2021)
Regional Employment Multiplier	Adopted to account for different labor intensities in various regions. For BAU, Blue, Green, and Cyan EE scenarios the multiplier more closely reflects Vietnam's economic activities whereas for the Cyan, Green EE, and Blue EE scenarios, the multiplier reflects Southeast Asia and is derived from the Ram et al. (2021) study.	Ram et al. (2021) and Rutovitz et al. (2015)

Input	Description	Source
Local production factor (fuel jobs) (%)	Represents the share of fuels produced locally in different regions, including Southeast Asia.	Ram et al. (2021)
Time	The number of years accounted for manufacturing, building (construction), and decommissioning the plant.	Ram et al. (2021)
Total Investment (billions of CAD)	Total amount of investment into transmission and distribution upgrades (in billions of Canadian dollars).	Pfeifenberger and Hou. (2011), Draft PDP8 Sep 2021

Calculations and Assumptions

Several assumptions underlie the social model, which are described below:

- The total number of jobs refers to the newly created jobs, rather than net jobs (i.e. sum of jobs created and jobs lost).
- The regional employment multiplier for the BAU, Blue, Green, and Cyan EE differ from the regional multiplier for the Cyan, Blue EE, and Green EE scenarios. These differences (as referenced in Table 19) are reflective of values more specific to Vietnam or the region as a whole.
- For manufacturing and construction, employment factors (EF) are applied to newly installed capacity, whereas for decommissioning, the EF applies specifically to the decommissioned capacity.
- An annual decline factor is applied to construction, operations and maintenance (O&M), and manufacturing jobs. Following VIET-SE's guidance, for each technology, two different annual decline factors applied to the periods of 2025-2030 and 2035-2045.
- Each scenario separately calculates added LNG and wind capacity, where applicable, to reflect differences in the number of jobs created from varying levels of LNG imports and wind (both offshore and onshore) generation.

The formula and assumptions, where relevant, for each calculation are described below:

- **Total number of jobs =**

  Manufacturing Jobs + Construction Jobs + Operations & Maintenance Jobs + Decommissioning Jobs + Fuel Jobs + Transmission and Distribution Jobs
- **Number of Manufacturing Jobs =**

  Installed capacity (MW) x Manufacturing Employment Factor x Regional Employment Multiplier x Annual Decline Factor / Manufacturing Time
- **Number of Construction Jobs =**

  Installed capacity (MW) x Construction Employment Factor x Regional Employment Multiplier x Annual Decline Factor / Construction Time

- **Number of Operations & Maintenance Jobs =**

  Installed capacity (MW) x O&M Employment Factor x Regional Employment Multiplier x Annual Decline Factor

- **Number of Decommission Jobs =**

  Decommissioned capacity (MW) x Decommission Employment Factor x Regional Employment Multiplier x Annual Decline Factor / Decommission Time

The BAU and Blue scenarios do not include any decommissioned capacity (as no plants are decommissioned across the transition period). Green and Cyan include 1140 MW of decommissioned coal capacity.

- **Number of Fuel Jobs**

  Total number of fuel jobs =

  Coal jobs + Gas jobs + Oil jobs + Biomass jobs + Waste incineration jobs

  Coal, oil, and gas fuel jobs =

  Fuel Volume (GJ) x Fuel Employment Factor (jobs/ PJ) x Regional Employment Multiplier x Annual Decline Factor x Local Production Factor (%) / 1,000,000

Given that the Fuel Employment Factor is jobs per PJ, to convert Fuel Volume (gigajoules) to PJ, the calculation is divided by 1,000,000.

  Biomass and waste incineration jobs =

  Electricity Generated (MWh) x Fuel Employment Factor (jobs/MWh) x Regional Employment Factor x Local Production Factor (%) x Plant Efficiency Factor

Given that the Fuel Jobs for Biomass and waste incineration were calculated based on Electricity Generated (MWh), the Fuel Employment Factor had to be converted from jobs per PJ to jobs per MWh. Additionally, the calculation includes a plant efficiency adjustment to account for differing efficiencies of the biomass and waste incineration plants.

- **Transmission jobs =**

  Employment factor (jobs/ billion CAD) x Investment (billions of CAD/ 1,000,000) x Regional Employment Factor

Transmission jobs are only calculated for the BAU, Blue, Green, and Cyan EE Scenarios since these are the only scenarios that involve transmission upgrades and investments.

8. Potential GHG emission reduction in the power sector

8.1. Technical feasibility options

This section presents the result of the power balance of each scenario for five-year time step from 2025 to 2045. The result is obtained from two optimization models: (i) Power balance and (ii) Hourly mixed profile. The first one is developed based on a linear problem, while the second is Mixed Integer Linear Problem. The result of the power balance model shows that the installed capacity is properly validated for further analysis. The hourly mixed profile of each type of source of the Vietnamese power system is shown in 2025 supporting as an input of DigSILENT which is used to run power flow to identify the congestion.

Power balance

The power balancing model is run for BAU, BLUE, and GREEN with the consumption in PDP VIII, while the CYAN scenario is run with the Elastic Electricity scenario. Table 20 shows the added capacity of LNG for the BLUE scenario and onshore wind for the GREEN and CYAN_EE scenario. This number means that the installed capacity is not enough, thus the added capacity is needed to ensure the power balance for each scenario. From Table 20, the total installed capacity is enough in 2025, but lack of source from 2035 for the BLUE scenario, from 2030 for the GREEN scenario, and only in 2040 for the CYAN_EE scenario.

Table 20: The added capacity of each scenario in GW

	2025	**2030**	**2035**	**2040**	**2045**
BLUE	0.00	0.00	2.36	4.76	1.65
GREEN	0.00	9.45	43.24	62.62	70.57
CYAN_EE	0.00	0.00	0.00	0.47	0.00

The total electricity generation in one year for each scenario is shown for BAU, BLUE, GREEN, and CYAN_EE in numbers and Figures, respectively. From this information, the total electricity generation of each type of source is known. It should be noted that the capacity factor of each type of source is used to present the total dispatched hours at the maximum capacity in one year.

Table 21: The total electricity generation of BAU scenario in TWh

Power generation (TWh)	2025	2030	2035	2040	2045
Coal	151.90	241.17	276.82	276.82	276.82
Gas	22.56	47.33	47.33	52.14	53.70
LNG	16.86	75.64	139.80	187.74	210.87
Oil	0.03	0.03	0.03	0.03	0.03
Hydro	106.36	108.48	117.20	120.32	122.13
Biomass	1.67	4.02	4.02	4.02	4.02
Offshore Wind	0.00	0.00	21.77	52.19	85.45
Solar	31.69	34.45	53.40	78.87	109.25
Waste incineration	0.00	0.00	0.00	0.00	0.00
Wind	32.14	24.42	45.38	68.60	84.55

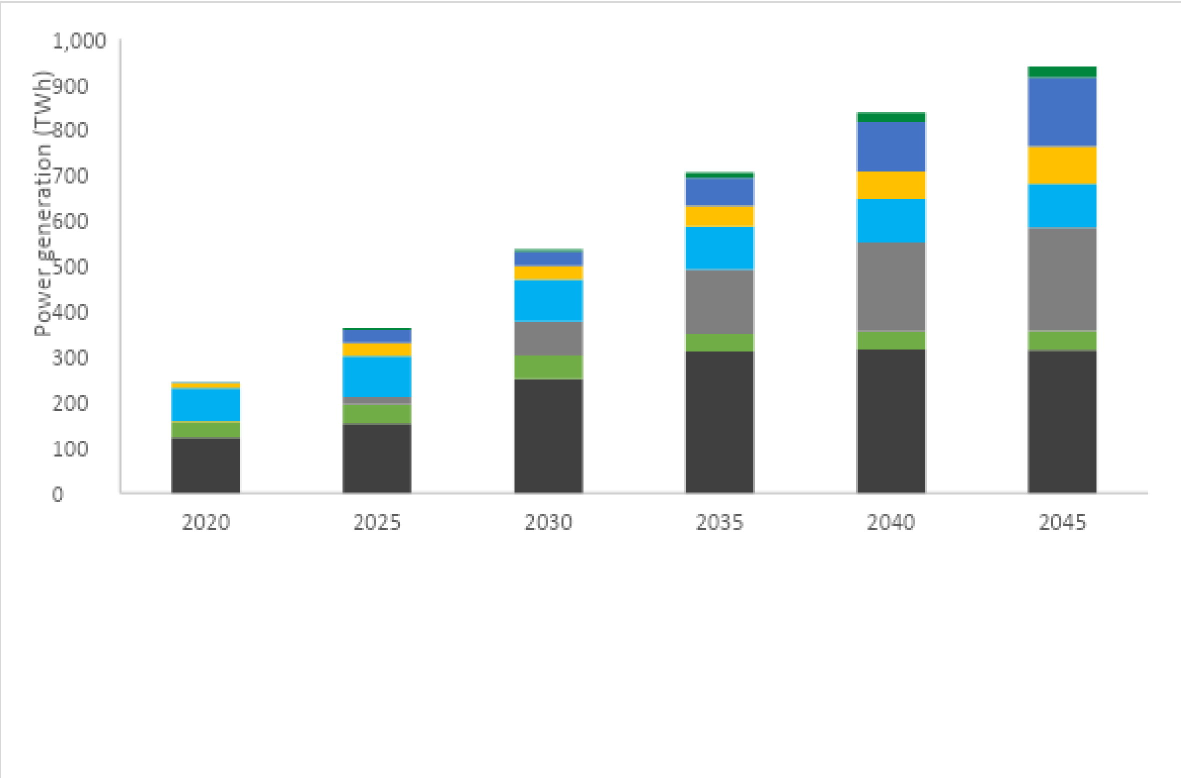


Figure 15: The total electricity generation of BAU scenario

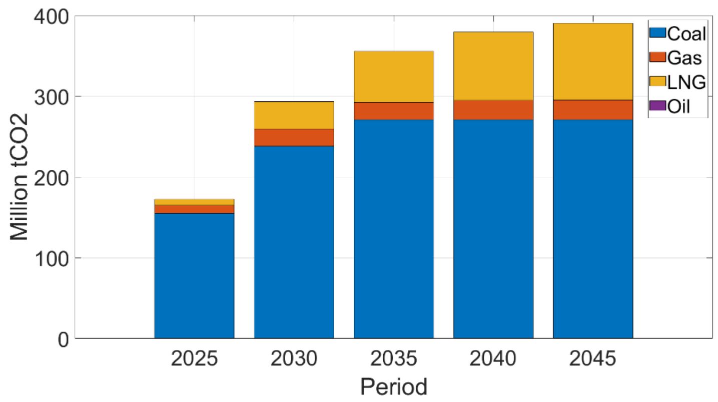


Figure 16: Total CO_2 emission of BAU scenario

From Figure 15, the total electricity generation of each type of source is presented. The coal-fired power plant is the highest dispatched source with approximately 50% of the total electricity generation in 2025. From 2030, LNG is developed, thus the total electricity generation of LNG significantly increases year by year. Although the installed capacity of solar is nearly the installed capacity of LNG (see Table 10), the electricity generation of solar is lower than that of LNG due to the lower capacity factor. Figure 16 shows the total CO_2 emission for every 5 years, the total CO_2 emission of 2045 is 390.5 million tCO_2. The coal-fired power plant is producing the most CO_2 emission.

Table 22: The total electricity generation of BLUE scenario in TWh

Power generation (TWh)	2025	2030	2035	2040	2045
Coal	142.70	165.10	173.99	173.99	173.99
Gas	22.56	78.85	78.85	78.85	78.85
LNG	16.86	75.64	168.86	228.41	252.92
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	117.00	120.77	130.35	133.78	135.78
Biomass	1.67	4.02	4.02	4.02	4.02
Offshore Wind	11.30	20.45	42.22	72.64	105.91

Solar	31.69	34.45	53.40	78.87	109.25
Waste incineration	0.00	0.00	1.56	1.56	1.56
Wind	19.44	36.26	52.49	68.60	84.55

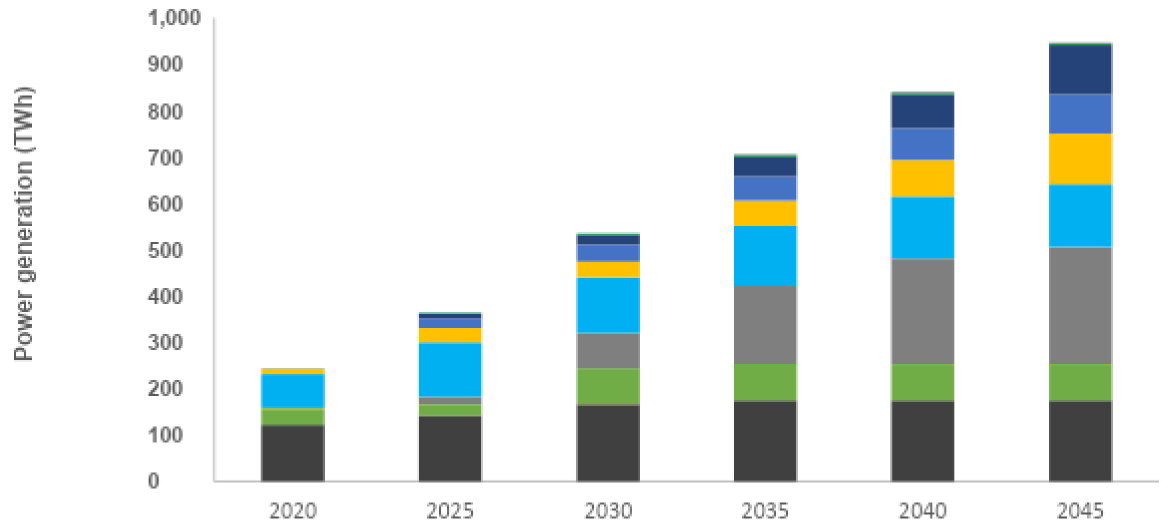


Figure 17: The total electricity generation of BLUE scenario

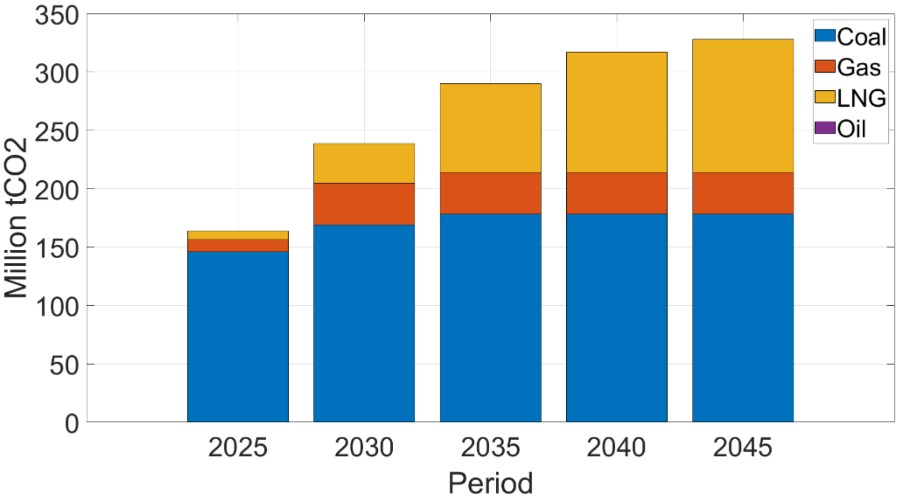


Figure 18: Total CO_2 emission of BLEU scenario

From Figure 17, the total electricity generation of each type of source of BLUE scenario is presented. The electricity generation of the coal-fired power plants is lower than that of the BAU scenario, but LNG is vice-versa. The total CO_2 emission of the BLUE scenario is lower than that of the BAU scenario due to the reduction of the coal-fired power plants and the increment of gas-fired (LNG) power plants. The CO_2 emission of the BLUE scenario reduces a minimum of 5% in 2025 and a maximum of 18% in 2030 in comparison to the BAU scenario (Figure 18).

Table 23: Total electricity generation of GREEN scenario in TWh

Power generation (TWh)	2025	2030	2035	2040	2045
Coal	138.73	167.38	167.38	167.38	167.38
Gas	22.56	78.85	78.85	78.85	78.85
LNG	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	117.00	120.77	130.35	133.78	135.78
Biomass	1.67	4.02	4.02	4.02	4.02
Offshore Wind	14.96	38.99	60.75	91.18	124.44

Solar	35.63	58.75	77.70	103.17	133.55
Waste incineration	0.00	1.56	1.56	1.56	1.56
Wind	32.66	65.22	185.12	260.78	301.24

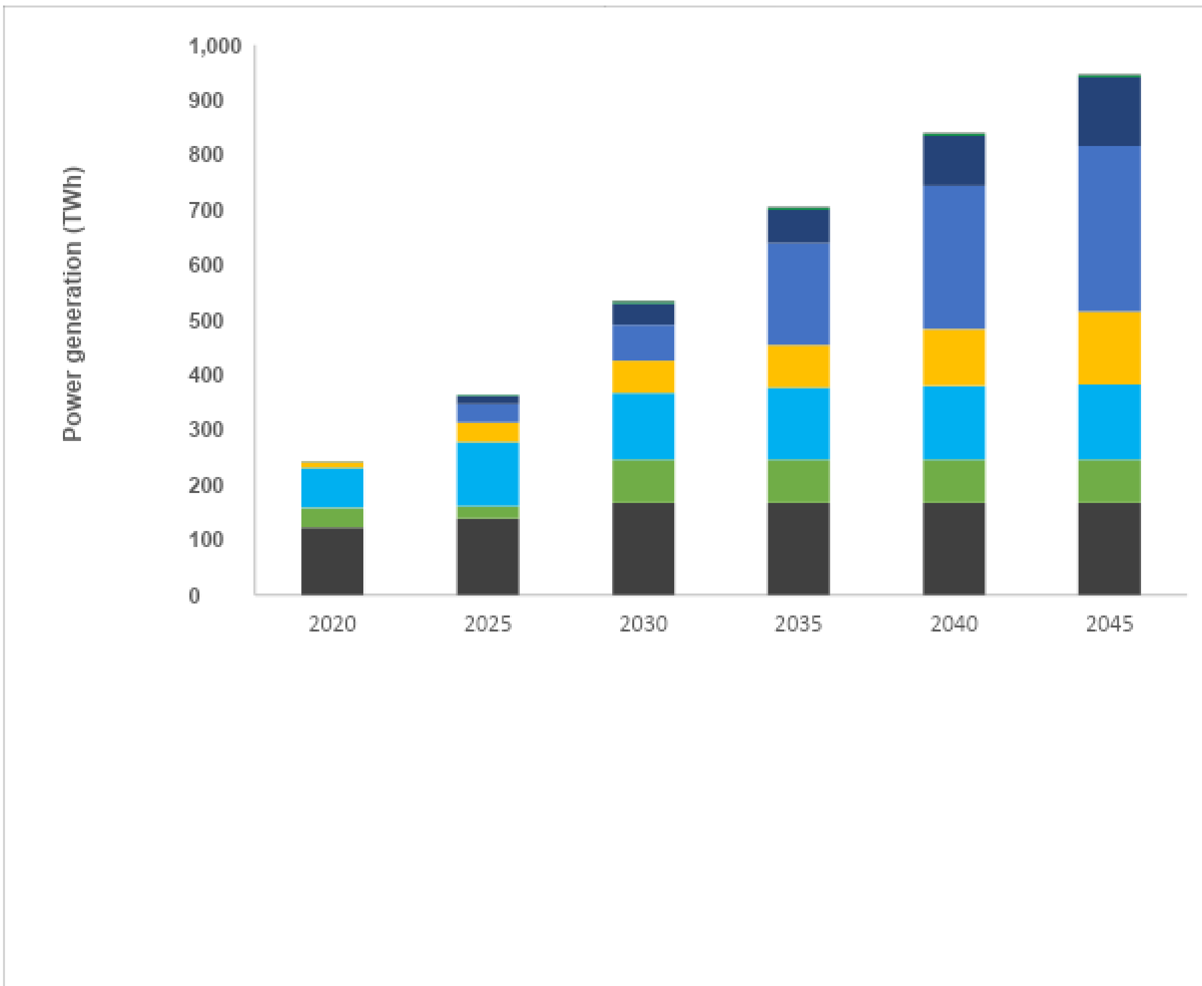


Figure 19: The total electricity generation of GREEN scenario

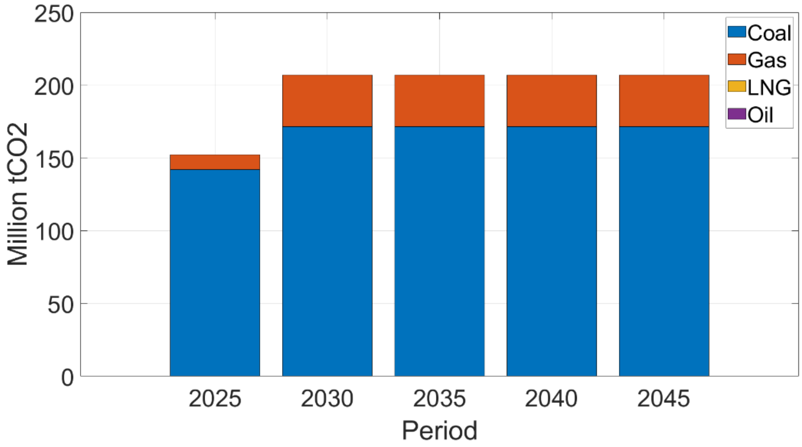


Figure 20: Total CO_2 emission of GREEN scenario

From Figure 19, the total electricity generation of each type of source of GREEN scenario is presented. This scenario aims to promote renewable energy; thus, the coal-fired power plants are phased out and stop implementing a new one, and gas-fired power plants (LNG) are not considered to develop. This assumption leads to a high electricity generation of renewable energy and results in the reduction of CO_2 emission in Figure 20. CO_2 emission of the GREEN scenario reduces a minimum of 12% in 2025 and a maximum of 47% in 2045 in comparison to the BAU scenario.

Table 24: Total electricity generation of CYAN_EE scenario in TWh

Power generation (TWh)	2025	2030	2035	2040	2045
Coal	138.73	146.51	150.51	167.38	155.05
Gas	22.56	47.33	78.85	78.85	78.85
LNG	7.23	28.91	51.55	66.01	77.33
Oil	0.00	0.00	0.00	0.00	0.00
Hydro	117.00	120.77	130.35	133.78	135.78
Biomass	1.67	4.02	4.02	4.02	4.02
Offshore Wind	0.00	38.99	60.75	91.18	124.44
Solar	35.63	58.75	77.70	103.17	133.55
Waste incineration	0.00	0.00	0.00	1.56	1.56
Wind	25.75	35.33	52.49	70.05	84.55

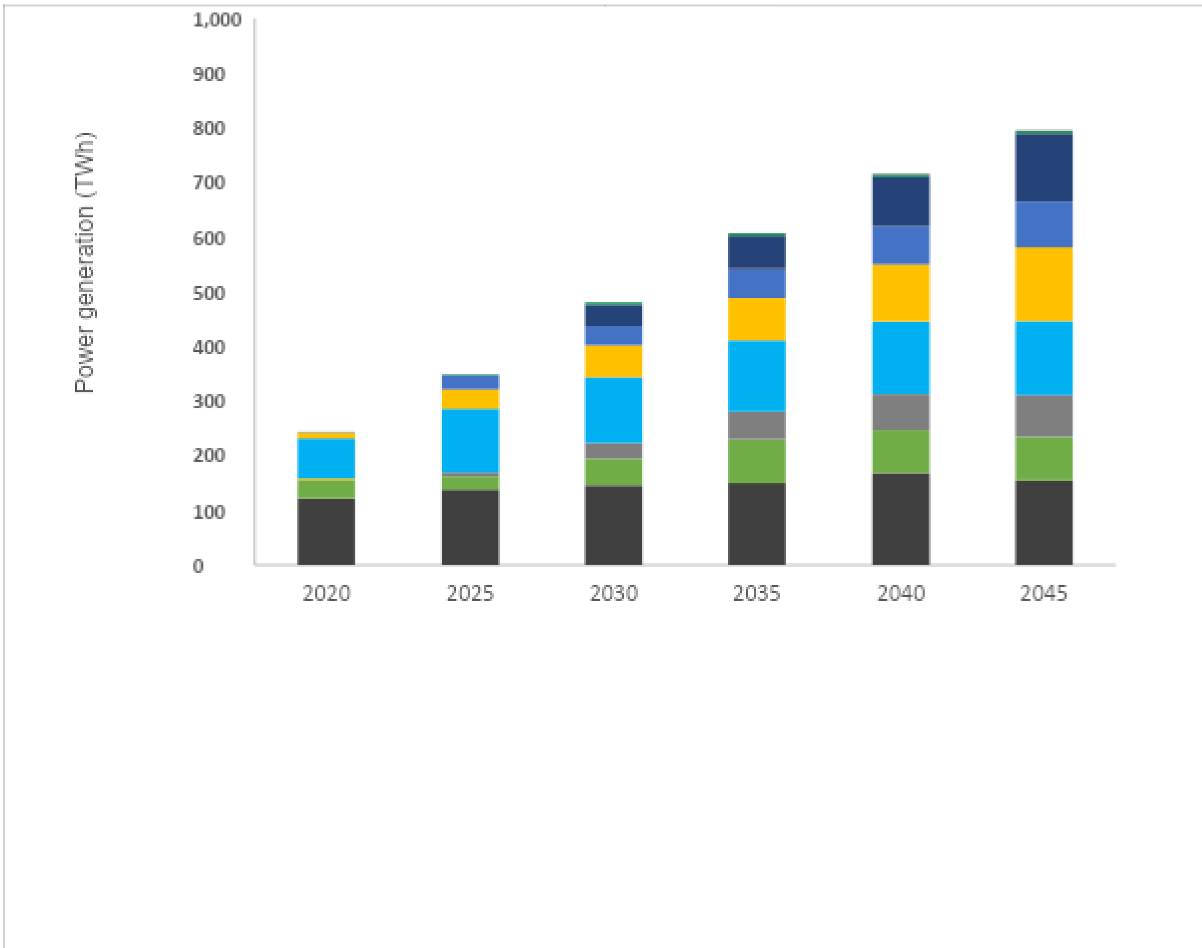


Figure 21: The total electricity generation of CYAN_EE scenario

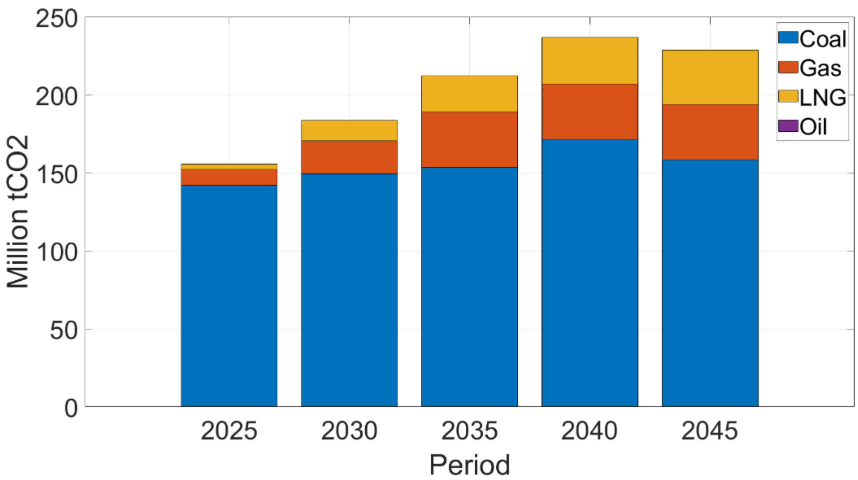


Figure 22: Total CO_2 emission of CYAN_EE scenario

From Figure 21, the total electricity generation of each type of source of the CYAN_EE scenario is presented. This scenario aims to promote renewable energy and keep 30% of gas-fired power plants (LNG) in comparison

to the BAU scenario; thus, the coal-fired power plants are phased out and
stop implementing a new one. It is interesting to emphasize that the highest total CO_2 emission is in 2040 (Figure 22). This can be explained that the installed capacity of renewable is not enough this year, thus the coal-fired power plants are dispatched to fulfil the requirement of demand. Therefore, 0.47 GW of onshore wind is added in this scenario (see Table 20). Thanks to 10 GW of offshore wind being added in 2045, this case does not happen anymore. The total reduction of CO_2 emission of the CYAN_EE is lowest at 2025 with 10% and highest at 2045 with 41.4% in comparison to the BAU scenario.

In conclusion, the total electricity generation of four scenarios of developing power sources is presented in this section. The total CO_2 emission of the BAU scenario is the highest, the next one is BLUE, CYAN_EE, and GREEN, respectively. This can be achieved due to the reduction of the coal-fired power plant and substitutive by gas-fired power plant (LNG) in the BLUE scenario, renewable energy in GREEN scenario, and both gas-fired power plant (LNG) and renewable energy in CYAN_EE scenario. In general, the CYAN-EE and GREEN scenario is promising because these scenarios have more than 30% of CO_2 reduction of 2030 in comparison to the BAU scenario. The capacity factor of solar is low, thus even the installed capacity of solar is highest but the electricity generation is not the highest (Figure 19).

EMISSION REDUCTION POTENTIAL

Ministry of Natural Resources and Environment published the Vietnam Third Biennial Updated Report for UNFCC – BUR3 (April 2021). The national GHG inventory for 2016 applied the IPCC guidelines, corresponding a total net GHG emissions in 2016 at 317 $MtCO_2eq$, of which 206 $MtCO_2eq$ came from the energy sector, accounting for the largest proportion of 65%. Among 158 emission sources/sinks calculated, fuel combustion for electricity generation was rated as the largest source, accounting for 20.6%.

In July 2020, Vietnam has been one of the first 20 countries to submit the updated NDC, in which the Government commits an emission reduction of 9% compared to the BAU with only domestic resources and up to 27% with international supports in 2030. Among the total national emission of 927.9 MtCO2eq in 2030, 73% is accounted for the whole energy sector, in which the power sector is the largest emitter, accounting for about half of the country's total emission by 2030. And therefore, it is one of the most focused sectors for mitigation efforts.

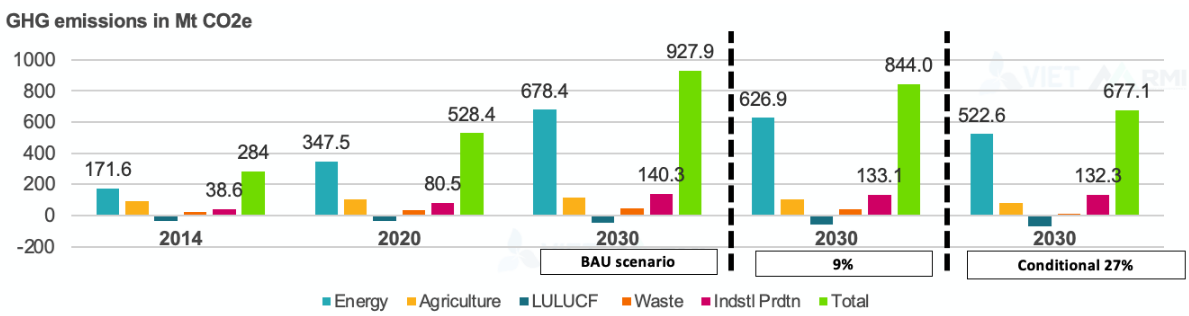


Figure 23: Updated Vietnam NDC

The Table 25 summarized the emission (in $MtCO_2eq$) in different scenarios comparing the referenced NDC emissions. Among proposed alternative scenarios, the highest potential of emission to be reduced for only power sector could significantly achieve 59%, equivalent to nearly 29% of total emission from overall sectors of the country in 2030, from the Cyan_EE scenario.

Table 25: Emission reduction comparison among four scenarios

	N	BA	Blu e	Green	Cyan_ EE
CO_2 emission (Mt) in 2030	45	26	238	207	183
Reduction (%)	-	41	47 %	54%	59%

ENERGY SECURITY ASSESSMENT

In this part, the energy security of the country was analyzed based on the dependency on imported fuel of international market. The Figure 24 represents the power generation of different resources (imported and domestic) in the total power generation of the country.

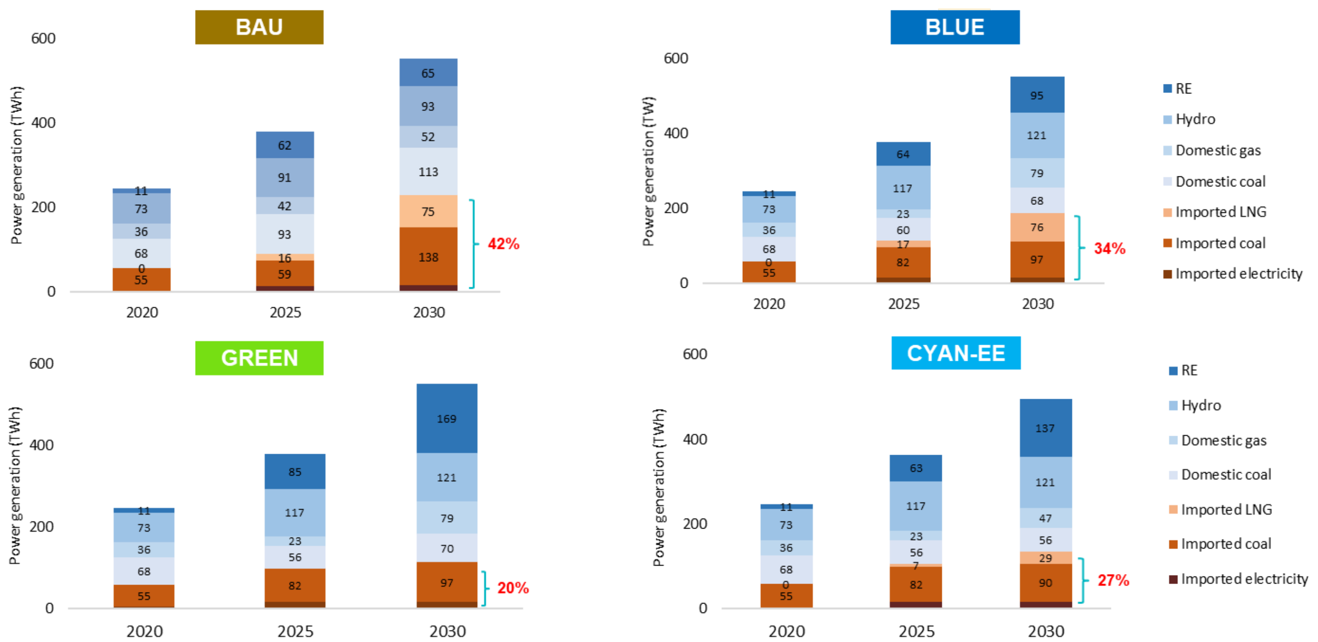


Figure 24: Energy security assessment of each scenario

The BAU scenario represents the highest level of energy dependency (42% in 2030) and shows that the power system is still relying on the imported fuel for electricity production in the future, that will raise significant issues on the national energy security and create more challenges for decarbonizing the economy. The Blue scenario is presenting a reduction on import dependency compared to the BAU of draft PDP8: 34% in 2030 and 39% in 2045. The Green scenario is prioritizing the development of renewable energies, resulting to a lower level of independence: 20% in 2030 and 13% at 2045. The Cyan_EE scenario is presenting the most suitable and appropriate road-map for power sector development in Vietnam, abilities to develop power and lower risk on the national energy security by importing less fossil fuels from international markets: 27% in 2030 and 25% in 2045.

Hourly power mixed generation

In this section, the hourly power mixed generation of each scenario in 2025 is computed based on an optimization model which considers economic and technical constraints of the network, power plants. The output of this model is the hourly dispatched power for all power plants in one year (8760 hours). The period of reserving water of hydro powers from the beginning of September until the end of December. However, in this section, the power mixed of some typical days are presented and the total congestion hours of inter-regional connection is presented.

- Case 1: low demand in one year (day 31)
- Case 2: high demand in one year (day 152)
- Case 3: low demand of drying season (day 31)
- Case 4: high demand of drying season (day 91)
- Case 5: low demand of raining season (day 307)
- Case 6: high demand of raining season (day 153)

In general, thermal power plants and hydro power plants are dispatchable sources and the system consumes maximum renewable energy. In the middle of sunny days, solar power is produced, hydro power plant and thermal power plant must decrease their output power. In case of renewable power decrease, the thermal and hydro power plant must increase their power output to fulfil the demand. Due to the technical constraints of the thermal power plant, the increase and decrease of power take time than hydro power plant.

The high demand is usually at 10:00-14:00 or 19:00 – 21:00. Case 1 is the lowest demand condition (usually the first day of the Lunar new year) in one year. At the period 19:00 – 21:00 in the evening, the load is high while solar is null, thus traditional power plants (coal, gas, and LNG fired power plants and hydro power plants) must produce power to fulfill the demand. In cases 2, 4, and 6, the wind is low, but the demand is highest.

a) Case 1

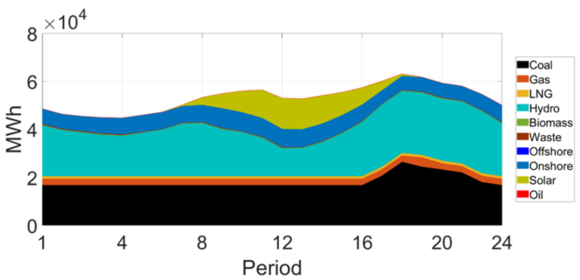


Figure 25: Hourly mixed power generation of BAU scenario

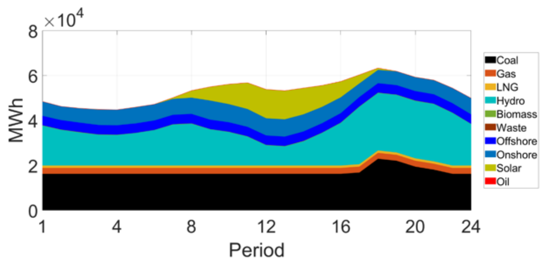


Figure 26: Hourly mixed power generation of Case 1 of BLUE scenario

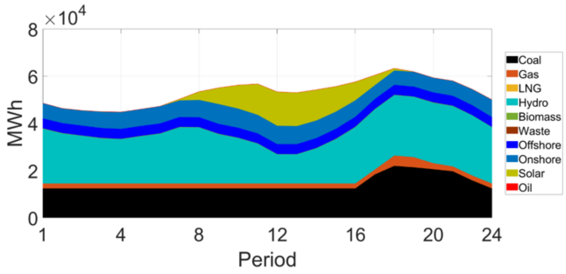


Figure 27: Hourly mixed power generation of Case 1 of GREEN scenario

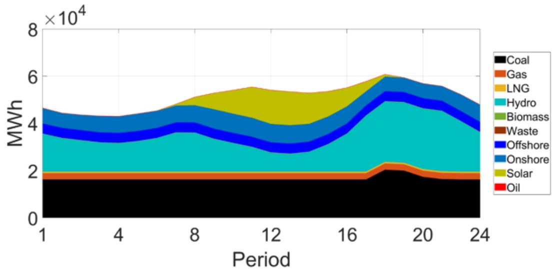


Figure 28: Hourly mixed power generation of Case 1 of CYAN_EE scenario

b) Case 2

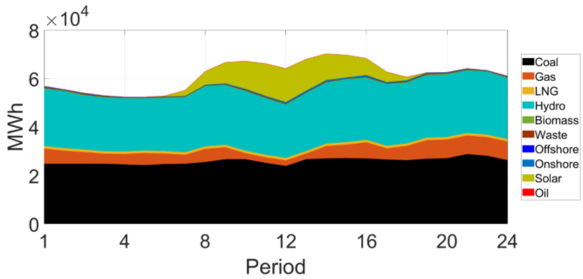


Figure 29: Hourly mixed power generation of Case 2 of BAU scenario

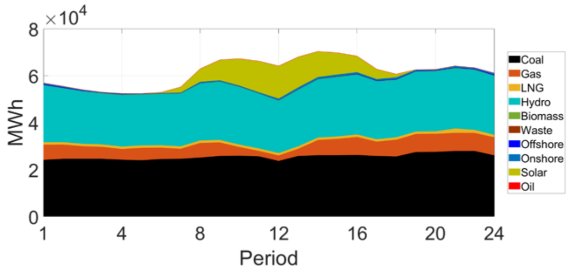


Figure 30: Hourly mixed power generation of Case 2 of BLUE scenario

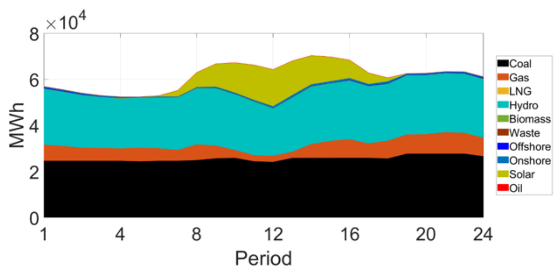


Figure 31: Hourly mixed power generation of Case 2 of GREEN scenario

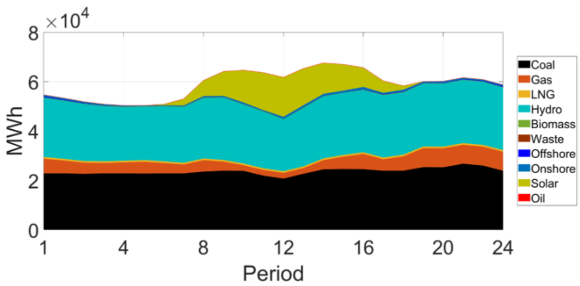


Figure 32: Hourly mixed power generation of Case 2 of CYAN_EE scenario

c) Case 3

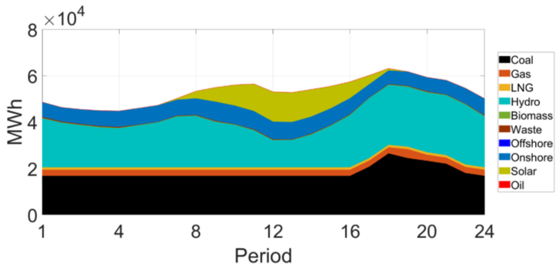


Figure 33: Hourly mixed power generation of Case 3 of BAU scenario

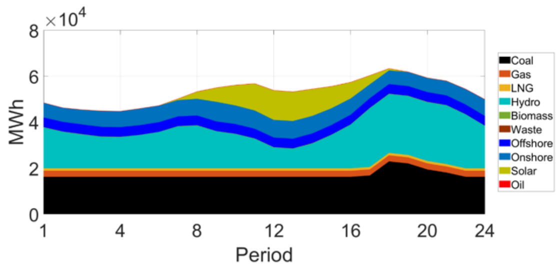


Figure 34: Hourly mixed power generation of Case 3 of BLUE scenario

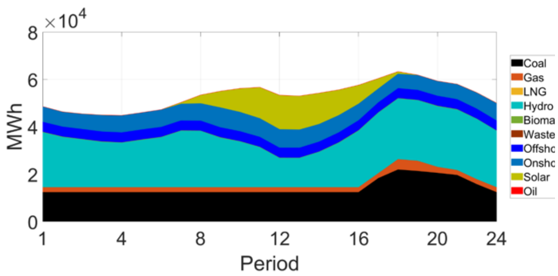


Figure 35: Hourly mixed power generation of Case 3 of GREEN scenario

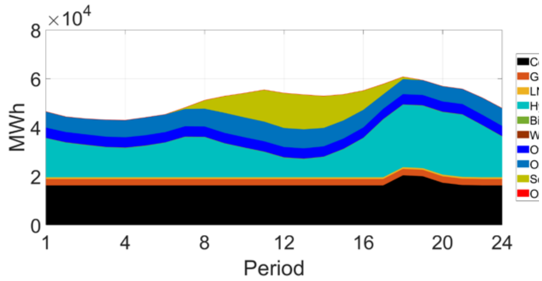


Figure 36: Hourly mixed power generation of Case 3 of CYAN_EE scenario

d) **Case 4**

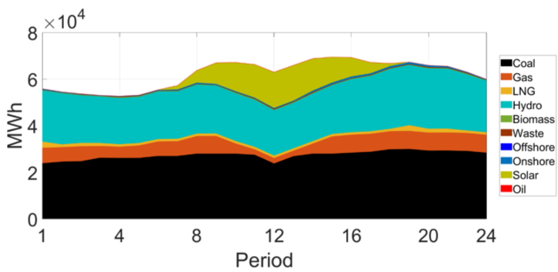


Figure 37: Hourly mixed power generation of Case 4 of BAU scenario

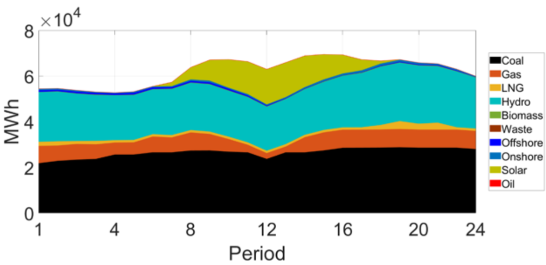


Figure 38: Hourly mixed power generation of Case 4 of BLUE scenario

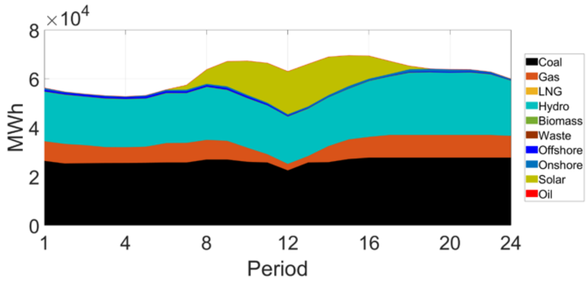


Figure 39: Hourly mixed power generation of Case 4 of GREEN scenario

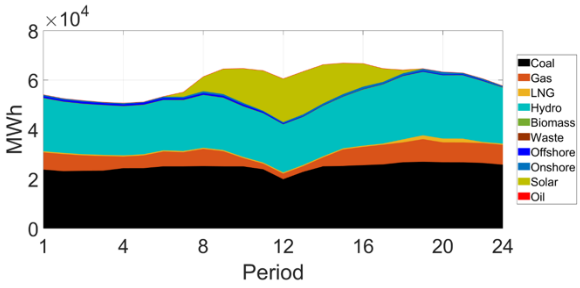


Figure 40: Hourly mixed power generation of Case 4 of CYAN_EE scenario

e) ## Case 5

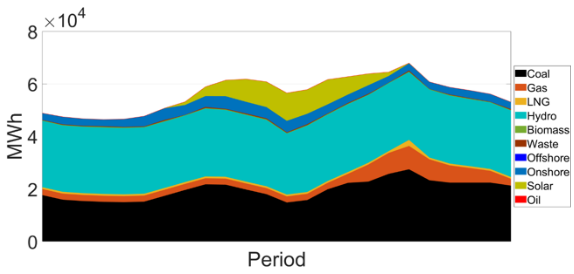


Figure 41: Hourly mixed power generation of Case 5 of BAU scenario

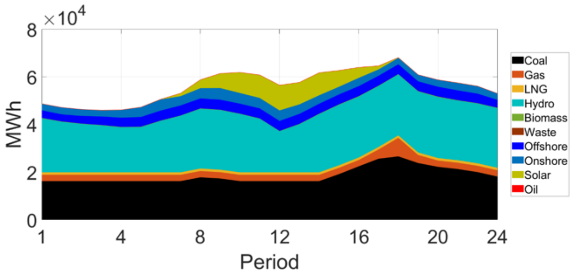


Figure 42: Hourly mixed power generation of Case 5 of BLUE scenario

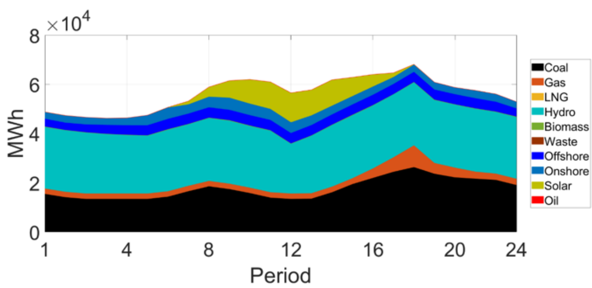


Figure 43: Hourly mixed power generation of Case 5 of GREEN scenario

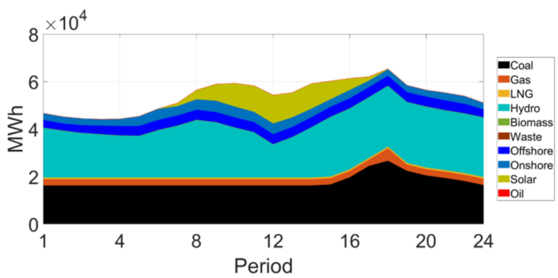


Figure 44: Hourly mixed power generation of Case 5 of CYAN_EE scenario

f) **Case 6**

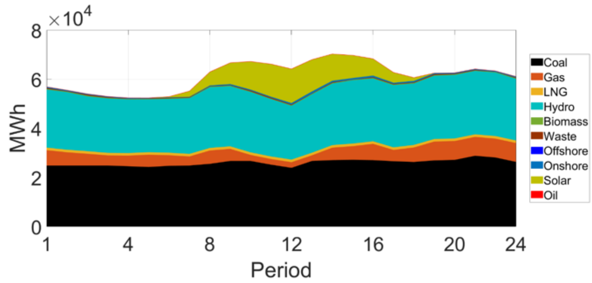


Figure 45: Hourly mixed power generation of Case 6 of BAU scenario

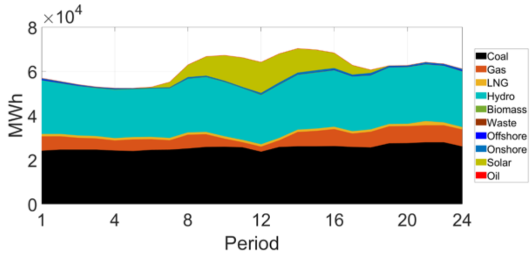


Figure 46: Hourly mixed power generation of Case 6 of BLUE scenario

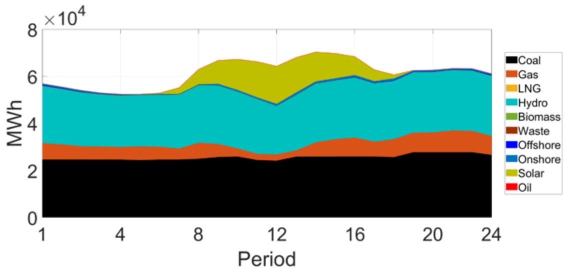


Figure 47: Hourly mixed power generation of Case 6 of GREEN scenario

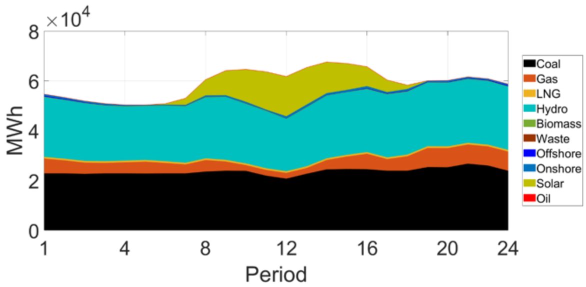


Figure 48: Hourly mixed power generation of Case 6 of CYAN_EE scenario

g) **Congestion**

In this subsection, the percentage of hours in 2025 when the inter-regional connections are congested is presented. This value can provide a pure view of critical connections which need to be considered to upgrade in the next step. From these figures below, the most critical connection is NAM_TRUNG_BO and NAM_BO with 9% for BAU scenario and rising to more than 20% with three proposed scenarios. This is explained by the development of renewable energy in the South of Vietnam is very vibrant, while the old coal-fired power plant is phased out in the North of Vietnam.

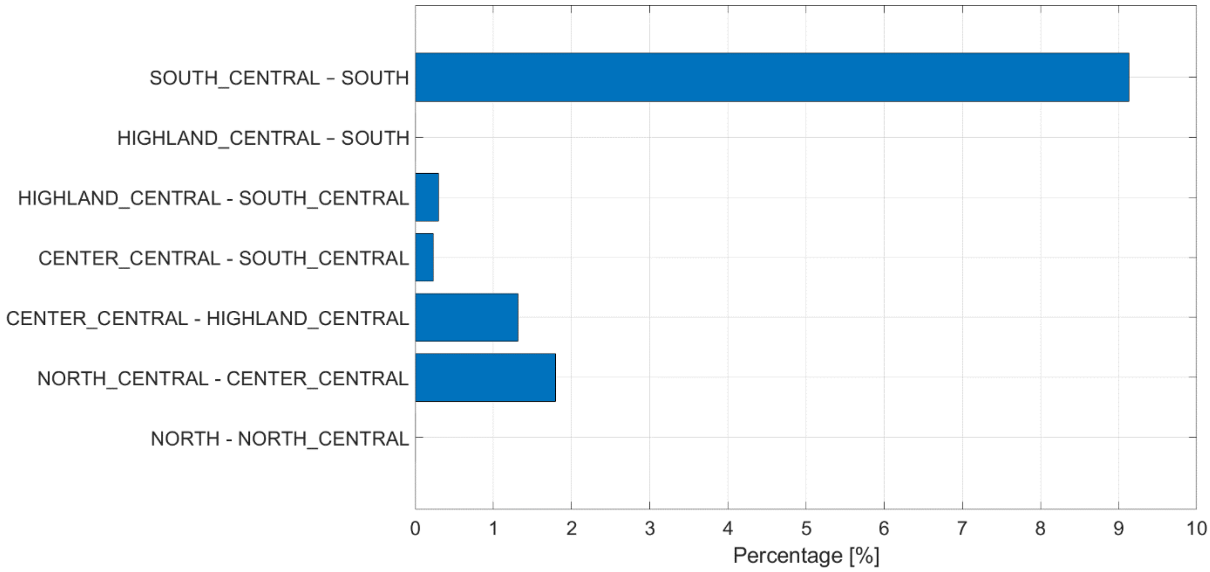


Figure 49: Percentage of congested hours of each inter-regional connection in 2025 of BAU scenario

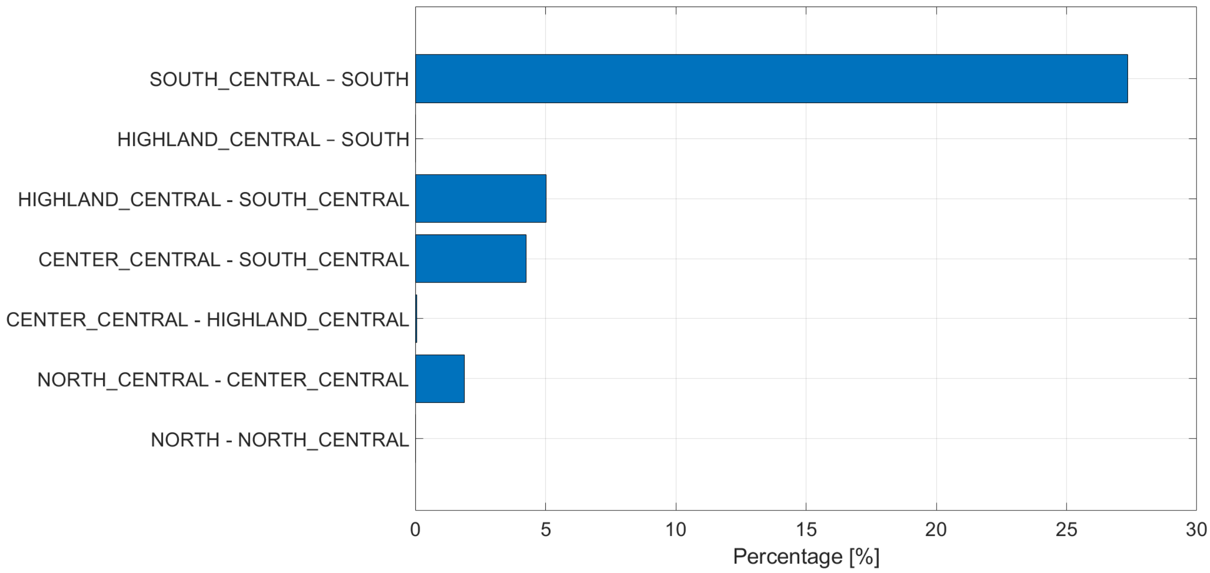


Figure 50: Percentage of congested hours of each inter-regional connection in 2025 of BLUE scenario

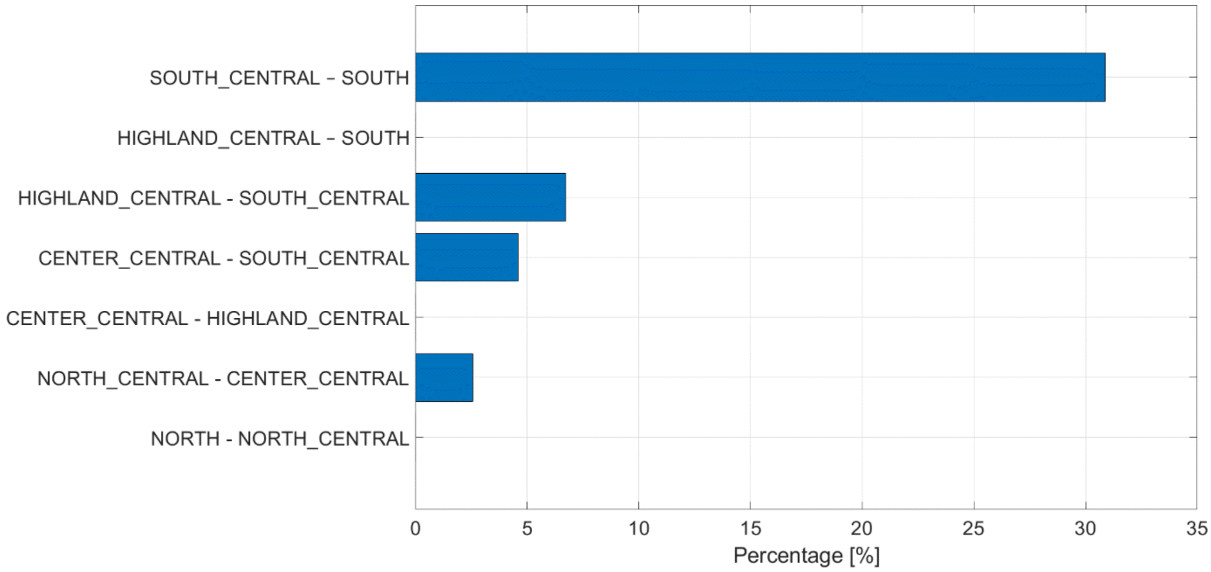


Figure 51: Percentage of congested hours of each inter-regional connection in 2025 of GREEN scenario

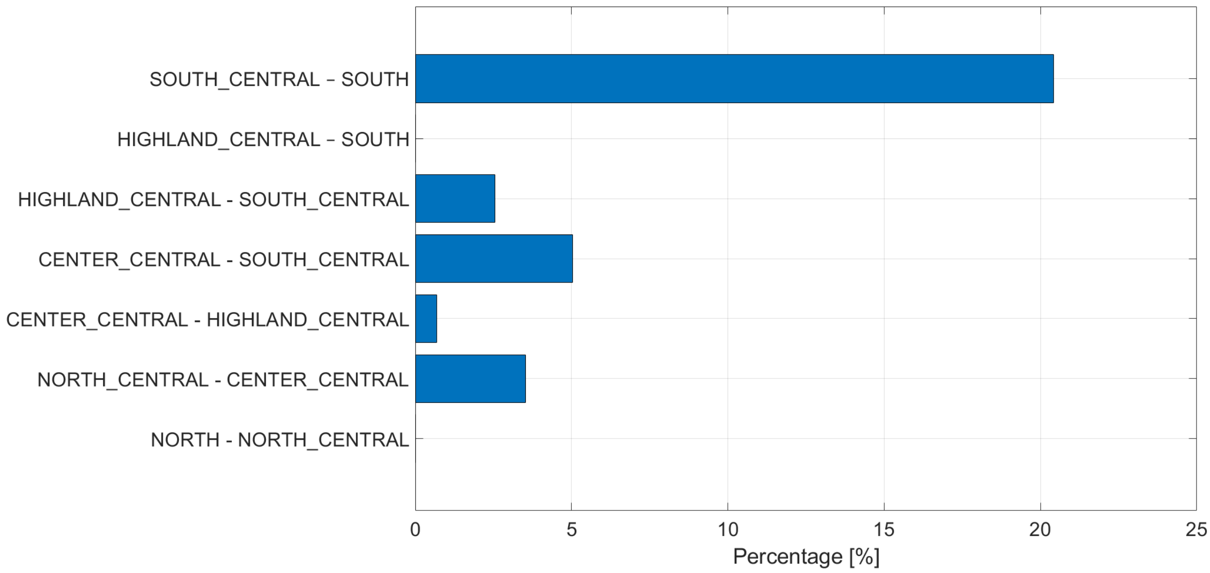


Figure 52: Percentage of congested hours of each inter-regional connection in 2025 of CYAN_EE scenario

8.2. Grid capability assessment

Loss of Load Probability Analysis

The reliability and responsiveness of the power generations from proposed scenarios are analyzed based on the probability model. Parameters that affect the model include load randomness, renewable energy resources and the availability of traditional power sources. The Monte-Carlo simulation was performed with 10.000 iterations for each generation mix scenario to determine the Loss of Load Probability (LOLP index) and expected one-year outage time (LOLE index). The results (see. Figure 52) are compared with the requirement from EVN (LOLE ≤ 24 hours/year) to evaluate the practical possibility of the proposed scenarios.

2025 Scenarios	LOLP [%]	Lower	Upper	LOLE [hr.]
BAU	0.236%	0.210%	0.261%	20.7
BLUE	0.158%	0.137%	0.179%	13.8
GREEN	0.475%	0.439%	0.511%	41.6
CYAN-EE	0.076%	0.062%	0.090%	6.7

Adding 2.2 GW offshore wind to reduce 1.6 GW thermal

Adding 2.5 GW solar PV & 2.2 GW offshore wind to reduce 6.2 GW thermal

Figure 53: The results of LOLP and LOLE index in different proposed scenarios in 2025

In 2025, the BLUE scenario with the introduction of 4.2 GW of offshore wind power to offset 1.6 GW of the thermal power has LOLP and LOLE values that meet the stability requirements. In the GREEN scenario, replacing more than 6 GW of thermal power with 2.5 GW of rooftop solar power and 4.2 GW of offshore wind power will affect the system's capacity to meet the power supply. Therefore, prioritizing the early development of pumped hydro storage (1 – 1.2 GW) with a flexible operation is essential for this scenario.

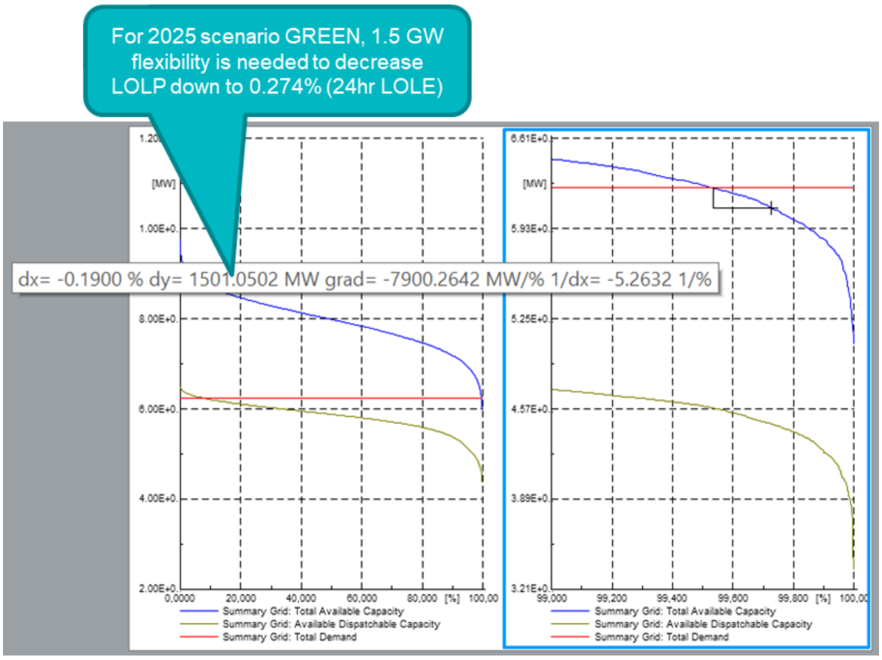


Figure 54: Summary of LOLP and LOLE index in 2025, Green scenario

In 2030, Blue, Green, and Cyan scenarios all show their impacts on system reliability. In the Blue scenario, although there is a significant amount of offshore wind power with the capacity of 10.2 GW, the probability of load loss is still higher than the BAU scenario. Especially, in the Green scenario, because of the installed capacity of thermal power plants is reduced by over 30 GW compared to the BAU scenario, the aggregation of other mobilized sources has not yet met the demand requirement, leading to the increase of LOLP index (1.905% and 0.524% in the Green and Cyan scenario, respectively). It is recommended to develop more flexible sources such as pumped hydro storage (3.5 GW) to bring the LOLP index down to the allowable level (0.247%). The Cyan-EE scenario, with the recommendation to develop ancillary services such as demand side response program, has slightly met the requirement (0.275%, equivalent to 24.1 hours loss of supply in a year).

2030 Scenarios	LOLP [%]	Lower	Upper	LOLE [hr.]
BAU	0.144%	0.124%	0.164%	12.6
BLUE	0.384%	0.352%	0.416%	33.6
GREEN	0.739%	0.695%	0.784%	64.7
CYAN-EE	0.006%	0.002%	0.010%	0.5

For 2030 scenario GREEN, 3.5 GW flexibility is needed to decrease LOLP down to 0.274% (24hr LOLE)

Figure 55: LOLP and LOLE index in different proposed scenarios in 2030

Grid simulation results

There are 8760 load flow calculations to be performed to determine the annual energy from certain power plants. The profile of each load is generated by scaling its corresponding forecasted regional load profiles provided in Appendix 6 of the Draft of PDP8 (September 2021). The yearly operation of PV and wind power plants are determined based on the forecasted solar irradiation and wind speed data of the corresponding regions, respectively. Meanwhile, the generation profiles of remaining power plants are produced by the

output of GAMS model. However, not all 8760 snapshots are critical
operations of the grid. Therefore, only results of several most critical operation modes are presented to identify the impact of proposed scenarios on both the local grid and all interconnections, as follows:

- Snapshot 1: Dried season (March), weekend, 12:00 (lowest load, with highest Solar)
- Snapshot 2: Dried season (March), weekday, 19:00 (highest load, no Solar)
- Snapshot 3: Raining season (June), weekend, 12:00 (lowest load, highest Solar)
- Snapshot 4: Raining season (June), weekday, 21:00 (highest load, no Solar)
- Snapshot 5: water reserve season (December), weekend, 12:00 (lowest load, highest Solar)
- Snapshot 6: water reserve season (December), weekday, 18:00 (highest load, small amount of Solar)

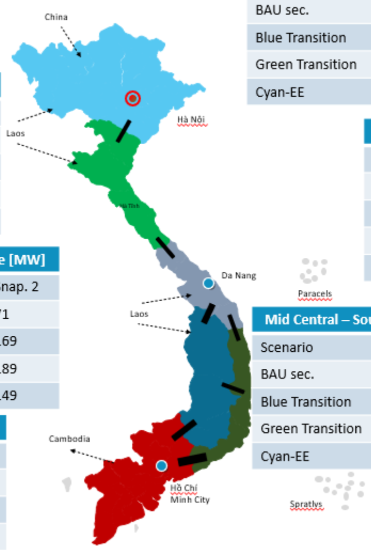
✔ **Dried season (March) snapshots**

The snapshots in the dried season (March) are used to validate the grid operation when dispatching of the hydro power plants is low, and the power output of solar power plants is at highest level (snapshot 1) and zero (snapshot 2). Under normal operation conditions, the results can be summarized as follows:

- There are increases of load flow that exceed the capacity on the North Central – Mid Central, and North – North Central interfaces, as the results of adding a significant amount of offshore wind power in the North-Central region. Therefore, the net transfer capacity of these interfaces needs to be upgraded.
- There are three 220-kV transmission lines are overloaded in the snapshot 2. Bim Son – Thanh Hoa 220-kV transmission line, which interconnects the North and North-Central regions, shows the most critical overloading level (32.5%). Other 220-kV transmission lines, such as Phu Lam – Dam Sen, DMT_BIM – Thuan Nam, and ND_LONG_PHU – DG_12ST, which relieve power from nearby renewable energies, have high loading level in both snapshots.
- In these snapshots, there are 14 substations are under heavily loading condition (> 80%). High loading level occurs mainly due to the large integration of offshore wind power in the North-Central region.
- The Cyan-EE scenario shows lowest inter-regional power flow compared to other proposed scenarios, as the results of demand-side response programs that change the demand profile and promote local consumption.

Inter-Regional Power Flows

- 2025 Scenario:
  - *Dried season March*



North – North Central interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	-4964	-4171
Blue Transition	-5548	-5566
Green Transition	-6025	-5764
Cyan-EE	-4157	-5096

Mid Central – High Land interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	-1249	-1590
Blue Transition	-1770	-2980
Green Transition	-2176	-3049
Cyan-EE	-1379	-2838

North Central – Mid Central interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	-1648	-1441
Blue Transition	-2754	-3589
Green Transition	-3435	-3791
Cyan-EE	-2595	-3601

High Land – South Central interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	-355	71
Blue Transition	-377.9	169
Green Transition	-442	189
Cyan-EE	-423	149

Mid Central – South Central interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	-5	-39
Blue Transition	-435	-825
Green Transition	-788	-915
Cyan-EE	-259	-850

High Land – South interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	2869	2075
Blue Transition	2567	726
Green Transition	2178	512
Cyan-EE	2733	742

South Central – South interface [MW]		
Scenario	Snaps. 1	Snap. 2
BAU sec.	5984	5314
Blue Transition	6055	7506
Green Transition	6185	7450
Cyan-EE	6029	7188

Figure 56: Inter-regional power flow results in March 2025

✔ **Raining season (June) snapshots:**

In these snapshots, the grid operation is checked under the condition that hydro power sources are dispatched at high level, the power output of solar power plants is at highest level (snapshot 3) and zero (snapshot 4). The results are summarized as follows:

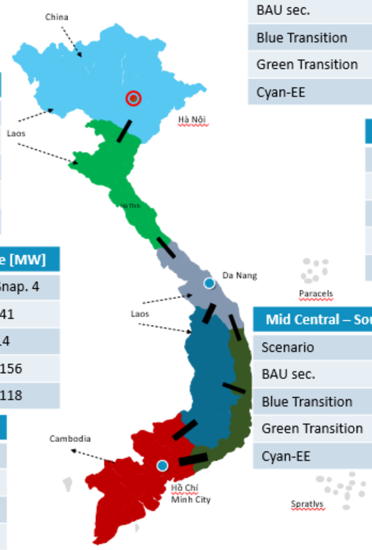
- The inter-regional power flow on the North Central – Mid Central interface significantly exceeds the capacity as both powers from hydro power plants and offshore winds are transmitted to the North region through 500-kV and 220-kV transmission lines. Similar to the dried season snapshots, Bim Son – Thanh Hoa 220-kV transmission line has highest overloading level (57% in snapshot 3)

- Several internal transmission grids are operated in heavily loading condition, such as Phu Lam – Dam Sen, ND_NHON_TRACH – Cat Lai – Thu Thiem, Song May – Long Binh, that need to be upgraded limit capacity to transmit power of nearby renewable energy sources.

- All proposed scenarios do not result in exceeding capacity on the remaining interfaces.

Inter-Regional Power Flows

- 2025 Scenario:
  - *Raining season June*



North – North Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-5364	-3377
Blue Transition	-6275	-3722
Green Transition	-6607	-4282
Cyan-EE	-5053	-3549

Mid Central – High Land interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-2333	-1106
Blue Transition	-3506	-1269
Green Transition	-3620	-1582
Cyan-EE	-3403	-1385

North Central – Mid Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-2816	-489
Blue Transition	-4483	-1755
Green Transition	-4765	-1844
Cyan-EE	-4664	-1748

High Land – South Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-233	-41
Blue Transition	2	14
Green Transition	10	-156
Cyan-EE	-74	-118

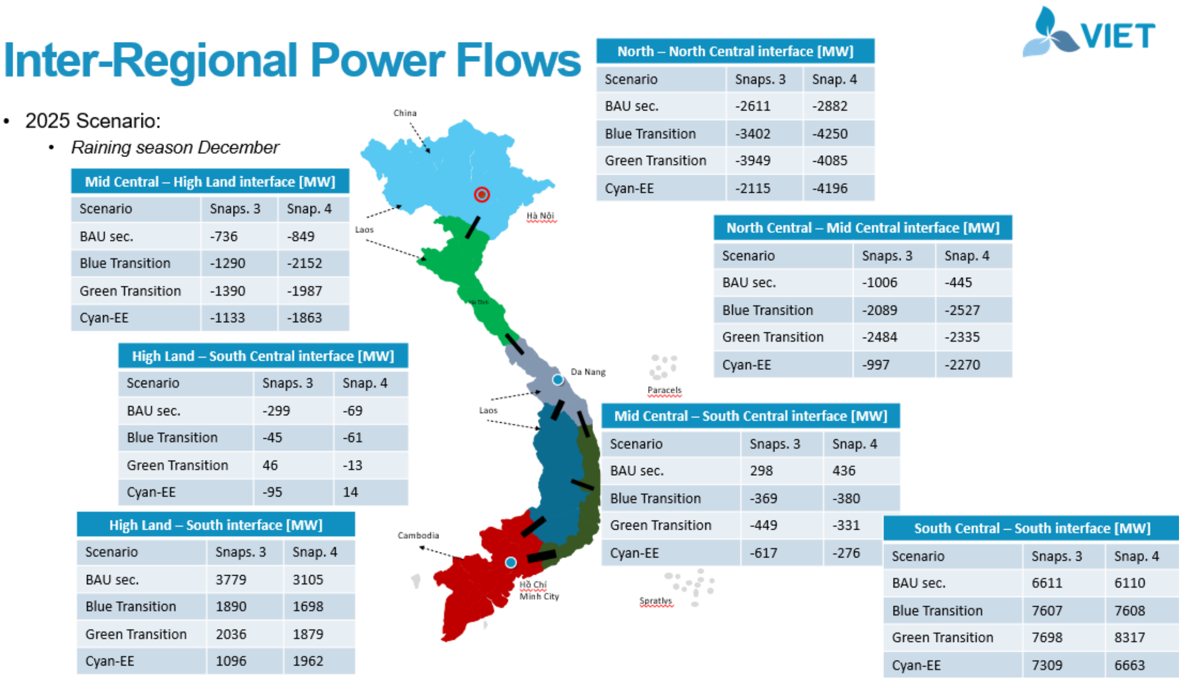
Mid Central – South Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-543	287
Blue Transition	-1120	144
Green Transition	-1239	80
Cyan-EE	-1203	-74

High Land – South interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	2490	2542
Blue Transition	1168	3092
Green Transition	933	1853
Cyan-EE	1066	2148

South Central – South interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	5744	4783
Blue Transition	6849	8354
Green Transition	6815	7135
Cyan-EE	6928	7299

Figure 57: Inter-regional power flow results in June 2025

✔ **Water reserve season (December) snapshots**



North – North Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-2611	-2882
Blue Transition	-3402	-4250
Green Transition	-3949	-4085
Cyan-EE	-2115	-4196

Mid Central – High Land interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-736	-849
Blue Transition	-1290	-2152
Green Transition	-1390	-1987
Cyan-EE	-1133	-1863

North Central – Mid Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-1006	-445
Blue Transition	-2089	-2527
Green Transition	-2484	-2335
Cyan-EE	-997	-2270

High Land – South Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	-299	-69
Blue Transition	-45	-61
Green Transition	46	-13
Cyan-EE	-95	14

Mid Central – South Central interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	298	436
Blue Transition	-369	-380
Green Transition	-449	-331
Cyan-EE	-617	-276

High Land – South interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	3779	3105
Blue Transition	1890	1698
Green Transition	2036	1879
Cyan-EE	1096	1962

South Central – South interface [MW]		
Scenario	Snaps. 3	Snap. 4
BAU sec.	6611	6110
Blue Transition	7607	7608
Green Transition	7698	8317
Cyan-EE	7309	6663

Figure 58: Inter-regional power flow results in December 2025

Grid reinforcement assessment

As shown in the results of the grid simulation (below), there are unavoidable grid reinforcements required to fulfil the requirement of grid operation under proposed development scenarios. The major recommendations are as follows:

- It is recommended to consider building a VSC-HVDC transmission line to connect offshore wind power in Zone 3 to Long Thanh 500-kV substation. Accordingly, Long Thanh 500-kV substation will need to be put in operation in the period 2021 – 2025.
- There are three new substations that are required to relieve power from offshore winds in Zone 3 and 4: Hong Phong 1800 MVA in South Central region, Bac Lieu 900 MVA and Bac Chau Duc 900 MVA in South region.
- Due to the large amount of offshore wind power transmitted from South Central toward North region, the net transfer capacity of these interfaces is not guaranteed in high solar power snapshots. Therefore, it is necessary to reinforce about 229.5 km of 500-kV transmission line for the North Central – Center Central interface, and 34 km of 220-kV transmission line (Thanh Hoa – Bim Son).
- Considering strengthening internal transmission grids to absorb more energy from renewable energy sources. The detail of the proposed grid reinforcements is presented in Table 26 and Table 27.

Table 26: Transmission lines needed to fulfil requirement of coal abatement scenarios compared to PDP 8 (BAU scenario) (09/2021)

	Name	Location	Length (km)	Expected Capacity (MVA)	Note	Explanation
						500 kV Transmission lines
	VSC-HVDC	South-Central region		2400	Newly built	This DC transmission line is used to collect and transfer energy from 2400-MW offshore wind-farm in Zone 3 to Long Thanh 500kV substation
	Interface North Central - Center Central		1 x 229.5	1300	Newly built	This project is necessary to increase the net transfer capacity of the North Central - Center Central interface. In the currently configuration, this interface is utilized more than 81% of installed capacity in some critical operating conditions.
						220 kV Transmission lines

	Name	Location	Length (km)	Expected Capacity (MVA)	Note	Explanation
	Thanh Hoa - Bim Son		1 x 34	300 MVA	Newly built the second line, increase capacity of b	This project is necessary to increase the net transfer capacity of the North Central - North interface. In the currently configuration, this interface is utilized more than 81% of installed capacity in some critical operating conditions.

	Name	Location	Length (km)	Expected Capacity (MVA)	Note	Explanation
					othlines.	
	BIM Ninh Thuan - Thuan Nam		1 x 8	300 MVA	Newly built, increase capacity	Increase capacity to absorb energy from RE in this region
	Thu Thiem - Cat Lai		1x 11.5		Increase ca	In some critical conditions, the utilized capacity exceeds 80%

	Name	Location	Length (km)	Expected Capacity (MVA)	Note	Explanation
					pacity	
	Phu Lam - Dam Sen		1 x		Increase capacity	In some critical conditions, the utilized capacity exceeds 80%
	Ba Ria - Vung Tau		2 x		Increase capacity	Increase capacity of this transmission line to transfer energy from Vung Tau Offshore wind

Table 27: Substations needed to fulfil requirement of coal abatement scenarios compared to PDP 8 (BAU scenario) (09/2021)

N	Name	Location	Cu	Expected Capacity (MVA)	Note	Explanation
500 kV Substation						
1	Long Thanh	South region	0	180	Newly built	This substation is expected to collect energy from offshore wind-farm in Zone 3 (Binh Thuan province). The proposed development scenario added 2400-MW offshore wind to Long Thanh 500kV substation through HVDC
2	Hong Phong	South-Central region		180	Newly built	This substation is expected to operate in 2030. However, in order to relieve energy from offshore wind-farm Hong Liem (600 MVA), it is recommended to speed up the construction progress and put it in operation in the period 2021 - 2025
3	Bac Lieu	South region	0	900	Newly built	This substation will be used to collect energy from offshore wind-farm in Zone 4 (Bac Lieu province). The construction location can be at the area expected to construct 500kV substation for LNG BAC LIEU (expected to be in operation in 2030)

N	Name	Location	Cu	Expected Capacity (MVA)	Note	Explanation
4	Bac Chau Duc	South region		900	Newly built	Consider using this substation to collect energy from offshore wind-farm in Zone 4 (Ba Ria - Vung Tau province), instead of directly connecting to current 220 kV transmission line from Vung Tau substation to Ba Ria substation
						220 kV Substation
1	Lao Bao	Center - Central region	50	750	Increase capacity, adding one more 250 MV	In some critical working conditions, there is more than 82% of this substation capacity is used to relieve the energy from renewable power plants nearby. To fulfil the development of RE in the region and safety operation in N-1 condition, it is recommended to add one more 250 MVA transformer to this substation.

N	Name	Location	Cu	Expected Capacity (MVA)	Note	Explanation
					A transformer	

8.3. Economic Assessment

For the economic assessment of the scenarios, we modeled the changes, compared to BAU, in investment cost (capital expenditure), the changes in operating cost, fuel costs, together the total costs, the net present value of these costs as well as the impact of the on the money leaving the country (balance of payments) through purchase of equipment, fuel, etc. Each of the seven coal abatement scenarios that model various pathways of capacity expansion are explored, with a particular focus on the BAU, Blue, Green, and Cyan EE scenarios.

The economic potential of all the decarbonization scenarios is compelling, with savings (versus Business as Usual) up to 16% over the total time frame, for a total savings of $176 billion USD ($68 billion USD discounted). The section below explains the resulting total costs for each of the described scenarios and all associated investments and operations.

All the potential alternative future scenarios (Blue, Cyan, and all scenarios with energy efficiency measures) provide cost savings, and therefore a beneficial savings for Vietnamese power consumers and economic objectives. The implications of the analysis are further described in this section, followed by the results of the Balance of Payments analysis and sensitivity analyses.

Scenario Results

Figure 58 illustrates the net present cost (discounted) of each scenario, which are also illustrated in Table 28. Overall, the Cyan EE scenario resulted in the lowest net present cost whereas the BAU scenario resulted in the highest net present cost. The green scenario, which includes the greatest renewable installed capacity, tracked closely to the BAU case, resulting in a very slight cost advantage to the BAU case, Energy efficiency measures generally resulted in the lowest net present costs. In the non-energy efficiency cases, the Blue scenario resulted in the lowest present cost, followed by Cyan, Green and BAU. Energy efficiency enables savings across a multitude of cost types, which is explained more below.

Table 28: Net Present Cost of each scenario to 2045

Scenario	B	B	Gr e e r	C	Blue E E	Green EE	Cyan E E
Cost (USD bn)	4	4	43 4	4	407	370	367

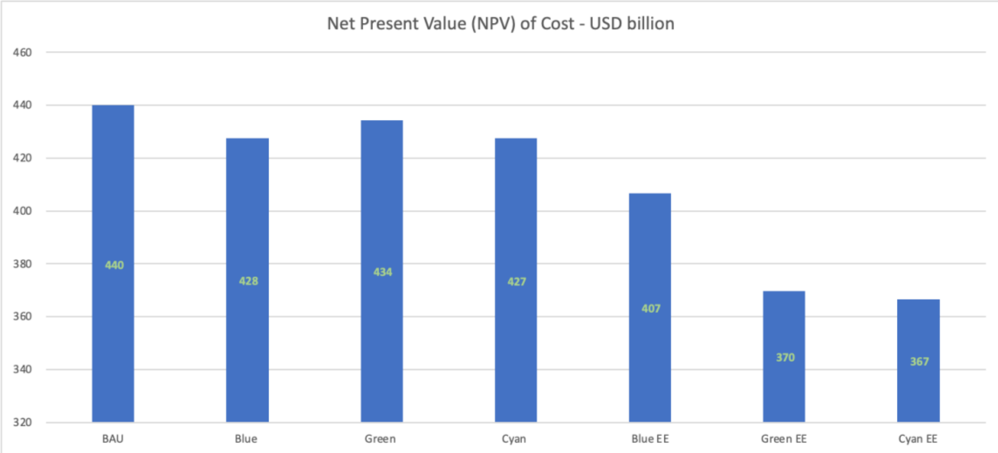


Figure 58: Net Present Cost of each scenario

Focusing on the BAU, Blue, Green, and Cyan EE cases, Figure 59 illustrates the breakdown of the investment costs by technology type. The main technology types that differ between scenarios are coal, wind, solar, LNG, and T&D. More specifically, most of the investment costs in the BAU case are due to coal, T&D, and offshore wind investments. In contrast, the large investment costs for the Green scenario are predominantly driven by the onshore wind costs, due to the additional 70 GW of installed wind capacity in this scenario. In terms of T&D costs, BAU and Blue cases necessitate the least amount of upgrades to the grid system, resulting in the lowest total investment costs. LNG is the dominant technology in the Blue scenario, which has the lowest investment costs compared to coal and wind. This is a primary driver of the Blue case requiring the lowest investment costs.

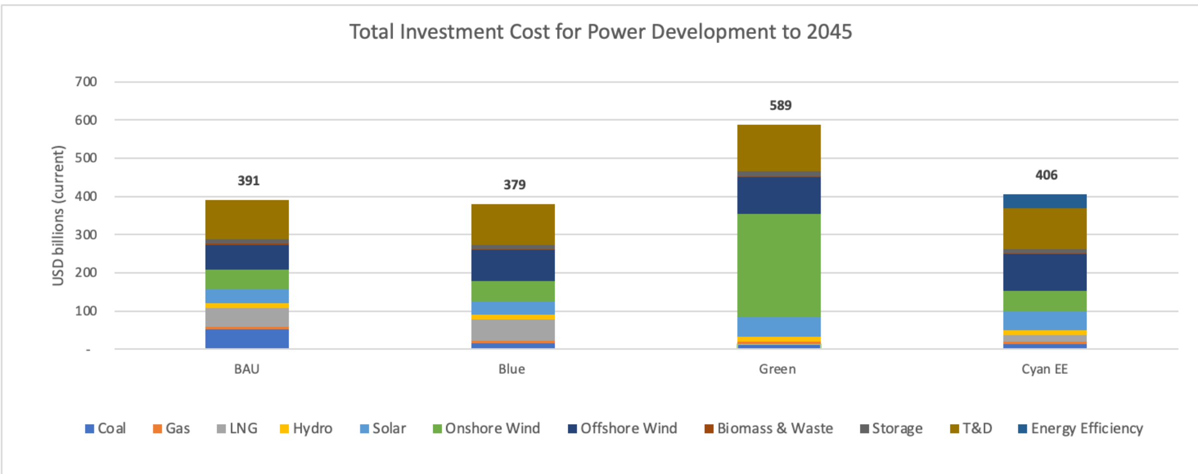


Figure 59: Breakdown of investment costs for select scenarios by technology type

Breaking down the total costs by type in Figure 60; capital expenditure costs dominate the Green case, whereas the BAU and Blue cases are mostly driven by fuel costs. This is due to the large amount of renewable development in the Green case. Renewable development usually includes tasks that range from resource assessment, site selection, material acquisition and construction. In addition, renewable technologies tend to be less mature than fossil fuel generation technologies. Thus, capital investment for onshore wind is materially more expensive than LNG investments. Thus, the Blue case showed the lowest capital expenditure for generation, followed by BAU and Cyan EE.

The larger capital expenditures in the Green and Cyan EE cases are largely offset by fuel costs in the BAU and Blue cases. Overall, operating expenses between the different scenarios did not show significant variation. In terms of T&D costs, Green and Cyan EE cases need to accommodate for a larger renewable penetration on the grid, therefore, the costs of upgrading and maintaining the grid tend to be higher. However, it is important to note that energy efficiency measures in the Cyan EE scenario are able to offset some of the grid upgrade costs due to the impact on demand. Cyan EE case also includes the costs of energy efficiency, which can range from infrastructure investments or software upgrades to implement various energy efficiency measures. However, these costs only account for 9% of the total costs of the Cyan EE scenario. Therefore, it can be concluded that the benefits of implementing energy efficiency measures outweigh the costs.

As mentioned above, energy efficiency has impact on costs across a variety of cost types. Firstly, demand reduction achieved by energy efficiency requires less generation capital investment to meet demand. On a per kWh basis, the capital costs of implementing energy efficiency measures tend to be cheaper than the capital costs of constructing and operating a generation unit. Similarly, cost benefits are realized in operating expenses and T&D costs with energy efficiency measures. Figure 58 above shows that the energy efficiency cases resulted in the lowest net present costs across all the scenarios. This illustrates the cost savings associated with energy efficiency measures.

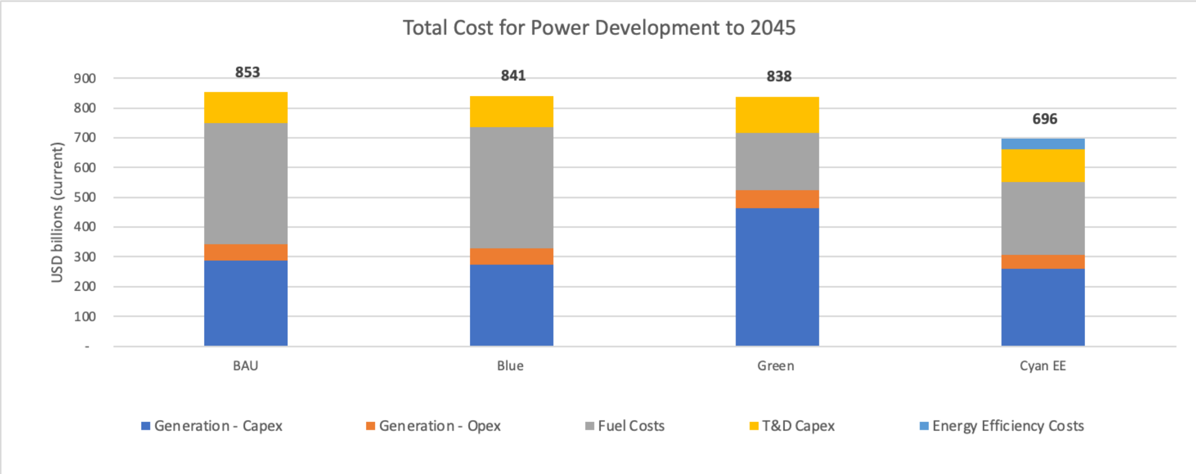


Figure 60: Breakdown of costs for select scenarios by cost type out to 2045

Figure 60

shows the total costs of the power generation system out to 2045. Fuel and energy efficiency savings realized in the Cyan EE scenario resulted in the lowest development costs across all scenarios. The blue and green scenarios had roughly the same development costs, with the green scenario showing a slight cost advantage. The higher capital expenditure for generation and T&D upgrades required in the Green scenario is offset by the savings in fuel costs. The BAU case showed the highest total costs, mainly driven by the fuel costs and generation capital expenditure. Coal generation, which is the highest in the BAU, has a higher capital expenditure compared to LNG generation. This enables the Blue and Green scenarios to recognize cost savings bench-marked against the BAU scenario.

The cost dynamics are dependent on the time frame in which they are evaluated. For instance, focusing on the development out to 2030 in Figure 61, the trends show some differences in the short term. The Blue scenario resulted in the cheapest costs, followed by BAU. The Green scenario resulted in the highest cost, mostly from the required generation capital expenditure for renewable development. This suggests that significant cost savings from fuel costs are not recognized in the short term. The Cyan EE case also showed a different trend than in Figure 60. The main driver for this difference is the generation capital expenses. In the long term, generation capital expenses in the Blue and Cyan EE cases are within 5 percentage points of each other. In contrast, in the short term the generation capital expenses are approximately 20% higher in the Cyan EE case. This suggests that the benefits of energy efficiency are realized in the long term and focusing on the short term paints a different picture.

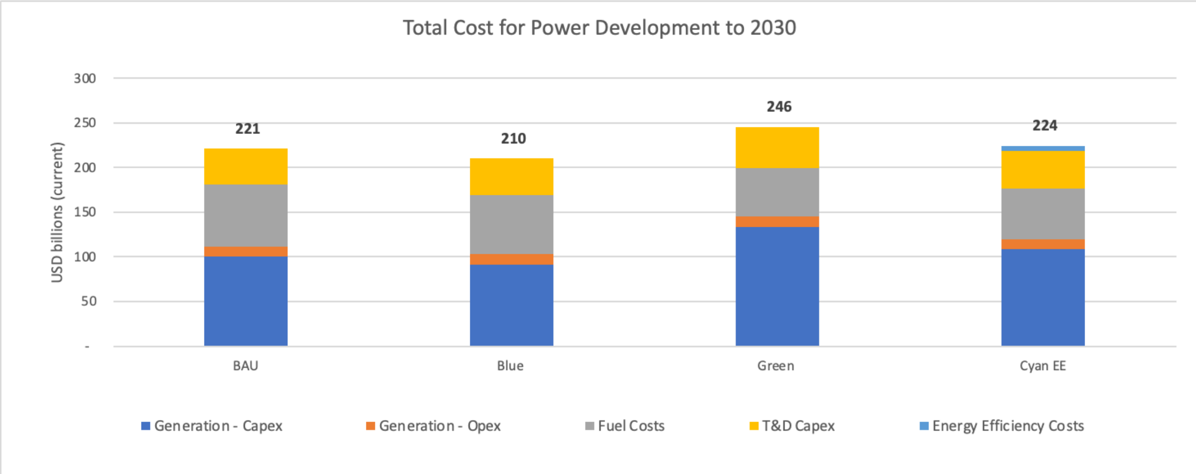


Figure 61: Breakdown of investment costs for select scenarios by cost type out to 2030

The development scenario also impacts the costs associated with T&D infrastructure upgrades. For the BAU case, the cost of grid upgrades was estimated by scaling South Korea's planned smart grid upgrade costs to Vietnam by an amount proportional to the forecasted electricity demand for the next decade of both countries. For the Blue scenario, the cost of grid upgrades is estimated to be the same as the BAU scenario. The Blue scenario relies mainly on LNG to replace the coal generation. LNG generation, while more flexible than coal generation, is dispatchable and more consistent than renewable generation.

Therefore, the costs of smart grid upgrades in the Blue scenario were assumed to be the same as the costs of the BAU scenario. Over the next 10 years, the total cost of smart grid upgrades is estimated to be $7.4 billion USD for the BAU scenario. This estimate includes an increase in variable renewable energy forecasting systems, high-voltage direct current systems, advanced metering infrastructure, distributed energy storage, and flexible transmission systems.

For the Green and Cyan scenarios, the costs of grid upgrades were assumed to be higher to account for the higher penetration of variable renewable energy. The current state of the grid is not perfectly equipped to accommodate high penetrations of variable generation in a safe manner. For instance, Flexible Transmission Systems (FTS) are key components of smart grids that maintain grid stability. As variable generation increases on the system, it becomes increasingly important to regulate the grid frequency to avoid any stability issues. Therefore, further deployment of components like FTS are needed to ensure proper variable renewable energy development and integration. The costs for the Green scenario and Cyan scenarios are estimated to be $10.9 billion USD and $8.6 billion USD, respectively.

Energy efficiency, as mentioned above, can enable developmental cost savings through demand reduction. Demand reduction plays an important role in helping alleviate grid stress and avoiding stability issues. Thus, the Blue energy efficiency scenario showed the lowest grid upgrade costs, and the Green and Cyan EE cases showed reductions compared to their respective non-energy efficiency scenarios.

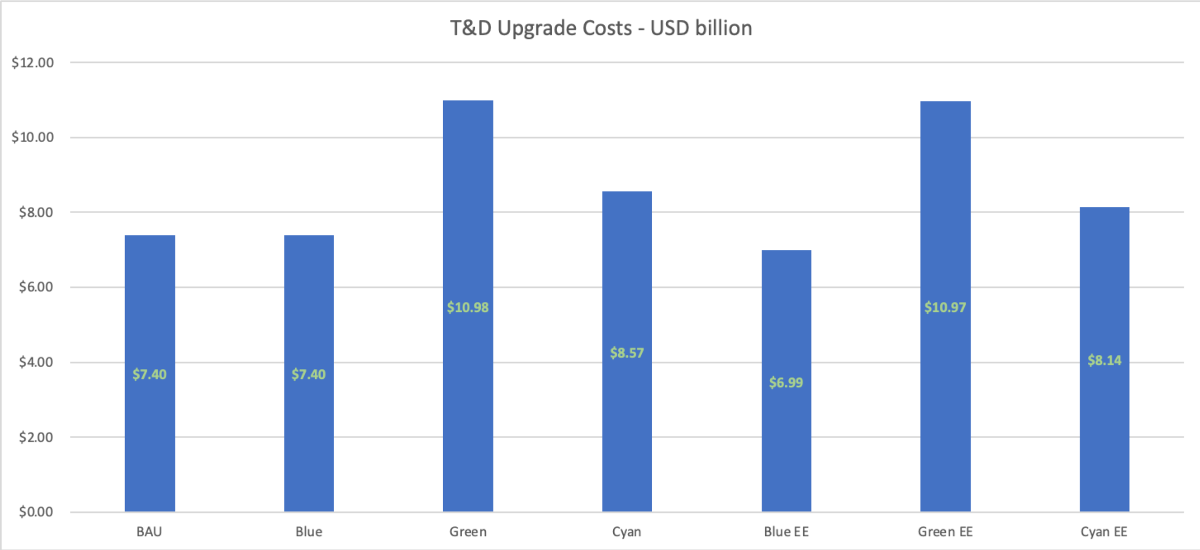


Figure 62: Grid upgrade costs for the next 10 years

Balance of Payments

Following the scenario results, a Balance of Payments analysis was conducted for each scenario. The total impact on balance of payments is significant, with all lower carbon scenarios reducing the fuel, equipment, and labor deficit – essentially increasing domestic investment while reducing the capital outlay required to purchase foreign fuel and equipment. In total, in the years up to 2045, up to $190 billion US (Green EE scenario) can be reduced from the balance of payments deficit (i.e. increasing domestic investment).

Compared to the BAU scenario, the Blue scenario increases domestic investment by approximately $21 billion US. All other scenarios show a greater increase in domestic investment, compared to the BAU scenario. A summary of how much each scenario reduces international investment is shown in Figure 63.

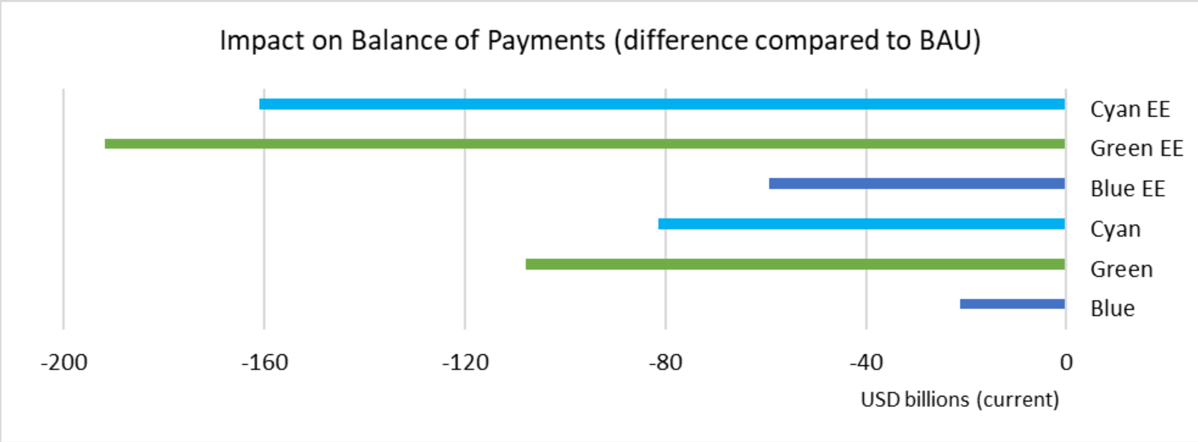


Figure 63: Impact on balance of payments (for all fuel and equipment costs) by scenario, calculated out to 2045 – and compared to BAU

The benefits of energy efficiency are made clear, with each scenario benefiting significantly from the domestic employment and installation required for an energy efficiency industry (as described in the Social Assessment section).

Specifically examining the coal costs, as shown in Figure 64, including the proportion of imported coal finds significant savings (up to $56 billion in total), much of which would directly reduce the imported category (reduced by one third in the Cyan EE scenario versus BAU).

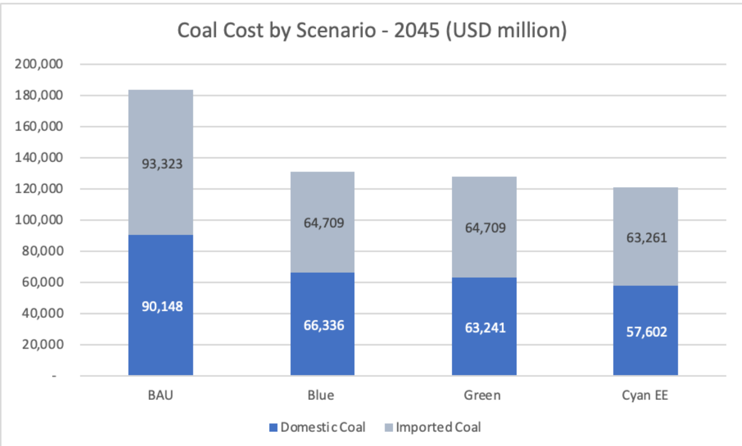


Figure 64: Coal cost for select scenarios out to 2045, including import and export split

Coal reductions is only one component of the broader impact on national balance of payments, which was calculated across all technologies and installations in each scenario.

When examining the year-by-year capital flows (specific to the electricity sector) as shown in Figure 65, further trends are revealed.

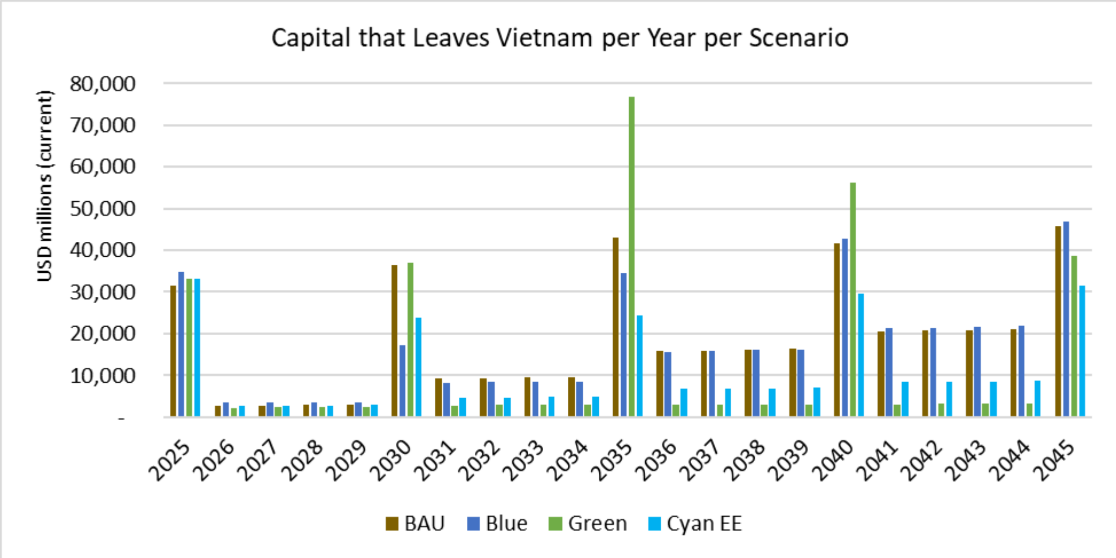


Figure 65: Year by year capital flows (for all fuel and equipment costs) by scenario

All scenarios require some foreign investment and continued fuel imports, causing a consistent flow of capital (and beneficial trade). Large outlays for investments such as offshore wind farms may cause periodic spikes in the balance of payments deficit. Over the coming years, this impact on balance of payments deficit is scheduled to increase along with the growing total costs of the electricity sector.

When compared to the BAU scenario (as in Figure 66), it becomes clear that the steady reduction in balance of payments deficit due to reduced fuel imports is a consistent and powerful trend benefiting national budgets in Vietnam.

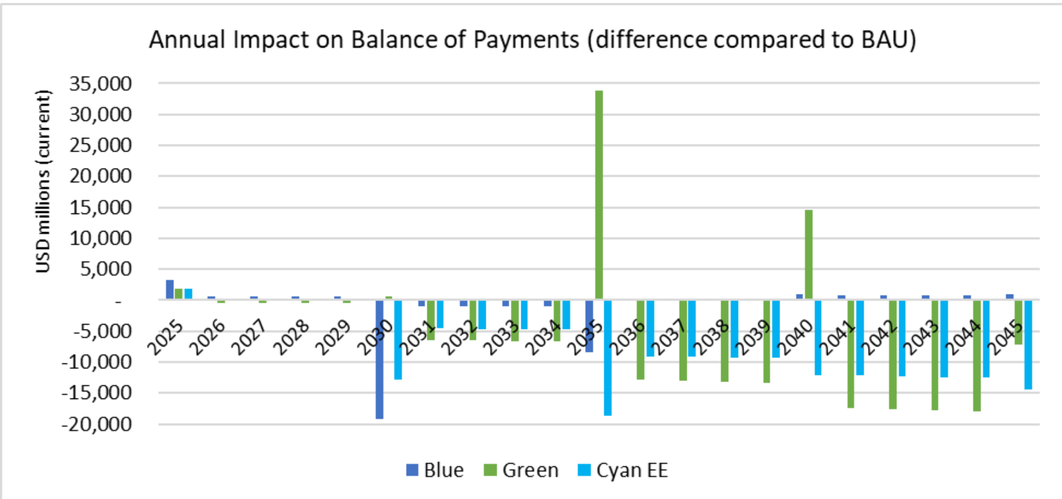


Figure 66: Net capital flight, as compared to BAU (for all fuel and equipment costs) by scenario

All low carbon scenarios benefit the national balance of payments situation
by increasing domestic investment, with Cyan EE, and Green EE offering the greatest benefit, and Blue offering the least advantage (while remaining beneficial compared to the BAU scenario).

Sensitivity Analysis

The above results are calculated using an assumed annual increase in fuel prices of 1%. A sensitivity analysis that examines larger annual increases in fuel prices shows that the BAU, Blue, and Blue EE scenarios are most sensitive to fuel price. Scenarios with higher amounts of renewable installed capacity showed less variation in net present cost due to larger annual increases in fuel prices. The results are summarized in Figure 67.

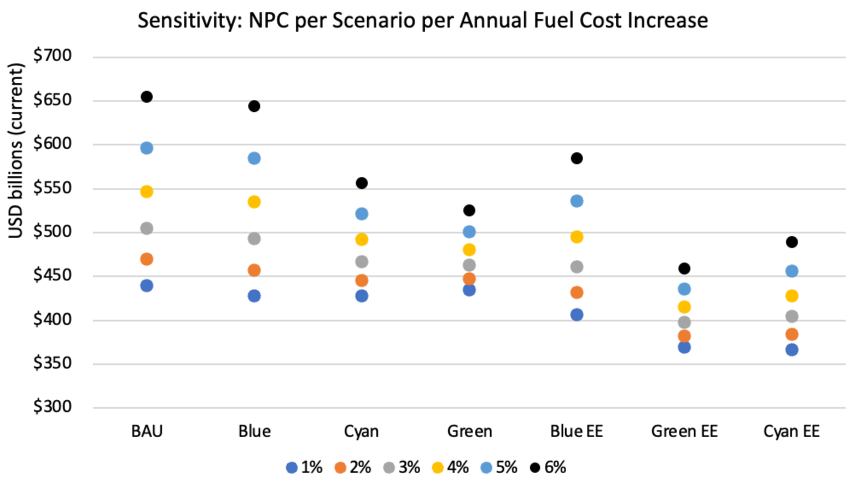


Figure 67: Net present cost of each scenario with varying rates of fuel price increase

Figure 67 shows that if fuel prices increase at an annual rate greater than 2%, the Green and Cyan scenarios begin to have total net present costs lower than that of the BAU and Blue scenarios. For example, with the assumed 1% annual increase in fuel price, the Blue scenario is expected to have a net present cost approximately 2% lower than that of the Green scenario. In comparison, if fuel prices increase annually by 3%, the Green scenario has a net present cost that is 6% lower than the Blue scenario. If fuel prices increase at an annual rate that is larger than 3%, the difference between the Green and Blue scenarios' net present costs becomes even greater.

A similar sensitivity analysis was performed on varying discount rates with rates ranging from 2% to 7%. The analysis shows that although the Green EE and Cyan EE scenarios have a net present cost that is least sensitive to the discount rate, the overall trends of how the net present costs of each scenario compare to others remains the same. An exception to this trend is between the Blue and Cyan scenarios. At a 7% discount rate the Blue scenario has a net present cost approximately 1% lower than that of the Cyan scenario. However, when the discount rate is 2%, the Blue scenario has a net present cost approximately 1% greater than that of the Cyan scenario. A summary of how the net present costs vary given different discount rates is shown in Figure 68.

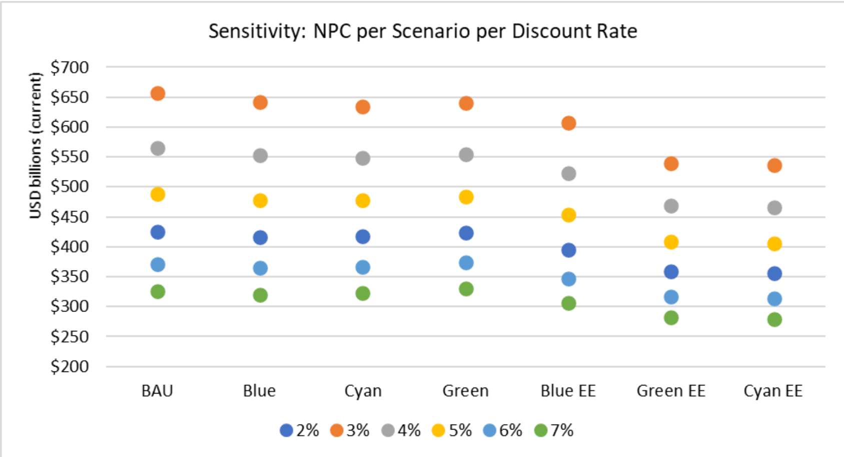


Figure 68: Net present cost of each scenario with varying discount rates

Conclusions

In summary, the economic analysis of the various capacity expansion pathways shows that low carbon development by means of renewable energy sources and LNG can unlock cost savings when bench-marked against the BAU scenario as outlined in the PDP 8. The Green scenario illustrates that over the next 25 years, fuel savings gained from renewable sources can break even the capital expenditure to develop these generation assets. In the shorter term, LNG can enable cost savings through lower capital expenses compared to the coal development forecasted in the BAU case. The analysis finds that energy efficient scenarios yielded the lowest cost to the system across all other cases explored in the analysis. This indicates that energy efficiency can play a key role in cost savings by leading to significant cost savings across a variety of cost categories, ranging from capital expenditure to T&D, and can contribute to lower system costs by lowering overall electricity demand. In turn, this can result in favorable decreases to the balance of payments as the energy efficiency scenarios can improve domestic production of energy through renewable and reduce fossil fuel imports. Overall, Vietnam can realize the greatest cost benefits by prioritizing solar and wind development, energy efficiency and LNG in the short term.

8.4. Social assessment

The primary output of the Social Assessment (as performed in the Social Model) is the number of jobs created from each coal abatement scenario. The optimal scenario for job creation is the Green Scenario, with the Cyan – EE Scenario also offering significant benefits for job creation. The Blue scenario is effectively equivalent to the Business as Usual (within 3 percent difference). The results of the analysis are further described below.

Analysis of Model Outputs

illustrates the total number of jobs per scenario and Table 1 gives the exact values. The Green scenario, which includes greater installed capacity of renewable, decreased capacity of fossil fuel sources, and decommissioned capacity, creates the greatest number of jobs (over 8 million) whereas the Blue scenario generates the least number of jobs (approximately 5.7 million). However, the BAU and Blue Scenarios generate a similar number of jobs, with BAU generating nearly 130,000 more jobs than the Blue Scenario.

The BAU and Blue scenarios create approximately 2.2 million less jobs than the Green and approximately 780,000-890,000 less jobs than the Cyan EE scenario, respectively. Since a large proportion of Green and Cyan EE scenarios jobs are created from increasing renewable generation, it is likely that the lowered renewable generation in BAU and Blue result in a fewer number of total jobs. Lastly, for all scenarios, most jobs are created during the construction period and the least number of jobs are created for operations and maintenance.

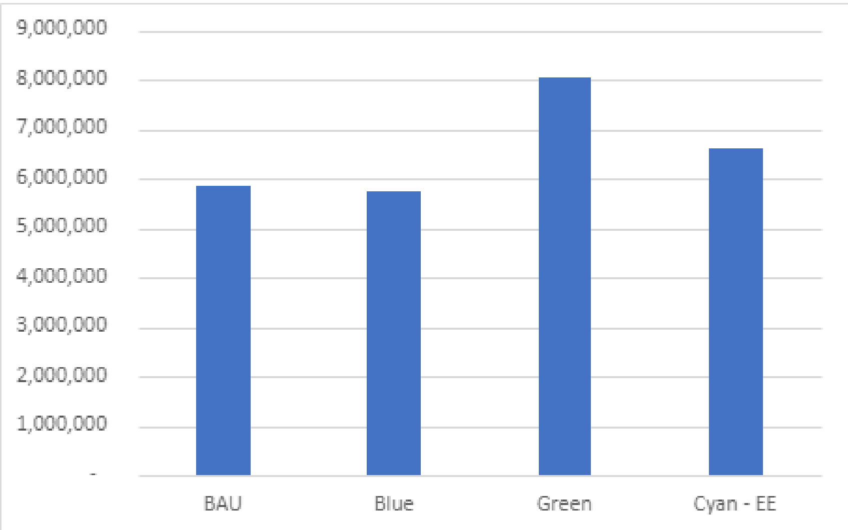


Figure 69: Total jobs created by scenario

Table 29: Total jobs created by scenario

Scenario	Total Number of Jobs
BAU	5,838,632
Blue	5,726,150
Green	8,060,059
Cyan EE	6,621,069

Figure 70 illustrates the number of jobs per year for each scenario, across the transition period of 2025-2045. The number of jobs generated per year for each scenario is generally proportional to the total number of jobs generated across the transition period. The average number of jobs created each year is as follows: 1,167,726 (BAU); 1,145,230 (Blue); 1,612,012 (Green); and 1,324,214 (Cyan EE). On average, the Green scenario generates the greatest number of jobs created each year, while the Blue scenario generates the least average number of jobs created each year.

Similarly, across the transition period, Green generates the greatest number of jobs per year. whereas Blue generates the least number of jobs per year. The maximum number of jobs generated in a year is approximately 2.16 million (Green scenario in year 2030) and the minimum number of jobs generated in a year is approximately 568,000 (BAU scenario in year 2025). For both the Green and Cyan EE scenarios, the number of jobs peaks in the year 2030. In comparison, the BAU and Blue scenarios experience a large growth in number of jobs from 2025 to 2030 but generate the greatest number of jobs in 2045 (when renewable capacity is greater than fossil fuel capacity).

In addition, the Green and Cyan EE scenarios produce similar levels of growth in jobs across the time horizon, with Green generating more jobs overall. Similarly, the BAU and Blue scenarios both project steady growth in the number of jobs across the transition period, with BAU slightly exceeding Blue by less than 100,000 jobs each five-year period. In addition, Although Cyan EE initially generates a large number of jobs, particularly in 2025 and 2035, it eventually creates less about 100,000 less jobs than both the BAU and Blue case each five-year period. Overall, by 2045, BAU, Blue, and Cyan EE generate similar number of jobs (approximately 1.7 million) with Green exceeding these three scenarios by approximately 200,000 jobs.

The forecast of jobs suggests that many short-term jobs will be created initially as plants are built and, jobs will steadily increase as renewable sources (particularly solar) are added into the energy mix. For example, the BAU and Blue scenarios initially observe a large increase in the number of jobs (likely due to sharp increase in LNG imports and coal generation, which levels out after 2030), and then a steady increase from 2030 to 2045 as renewable generation exceeds fossil fuel generation and imports. In particular, the Green and Cyan EE scenarios generate the most jobs in the short-term. The sharp decline in jobs between 2030 to 2035 for the Green and Cyan EE scenarios results from decreased solar capacity between these two time periods; however, the number of jobs increases again as solar, wind (onshore and offshore), and hydro capacity are added in subsequent years.

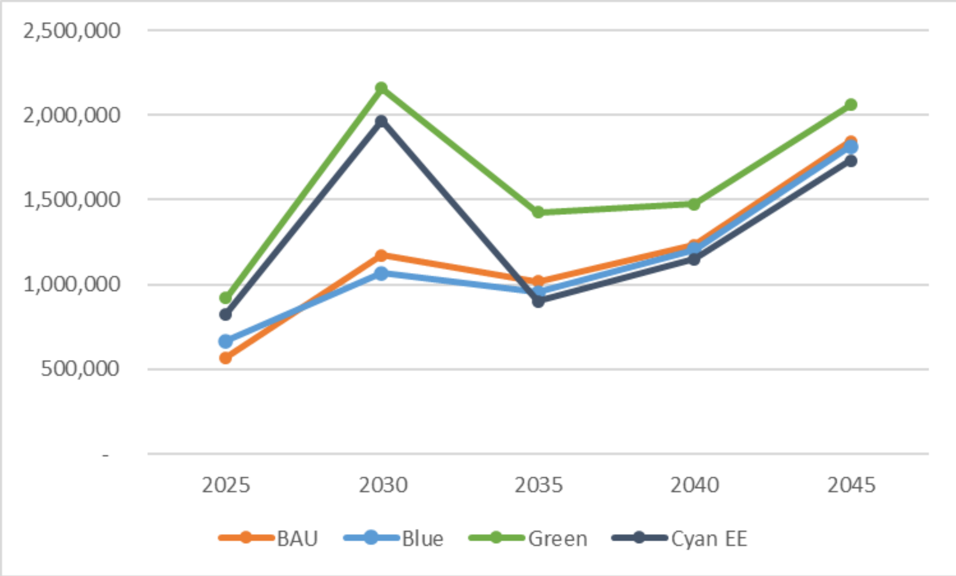


Figure 70: Number of jobs per year for each scenario from 2025-2045

The jobs by technology type are illustrated in Figure 71 to Figure 74. Across all scenarios, renewable (Solar, Onshore and Offshore Wind, and hydro power) generate more jobs in comparison to coal, oil, gas, and LNG, on a per MWh basis. This is likely due to the increased labor requirements involved with renewable generation (particularly construction and manufacturing). Furthermore, solar generates the largest proportion of jobs across all scenarios; this is particularly evident in the Green, Cyan, Green EE, and Cyan EE scenarios where solar grows rapidly to compensate for lack of coal generation. Additionally, though most wind jobs are generated in the year 2025 across the scenarios, a large proportion of jobs in 2035 and 2040 for the Green and Cyan scenarios come from onshore and offshore wind generation. Among renewable sources, hydro power (both Hydro and Storage – Pumped Hydro) generates the least number of jobs across all scenarios.

In comparison to renewable sources, fossil fuel (coal, gas, oil, LNG) generate less jobs across scenarios. The number of coal jobs generally decreases over time across the scenarios, except for BAU, which sees an increase in coal jobs between 2025 to 2030. This follows, given that the scenarios do not add coal capacity after 2030. Across the scenarios with LNG capacity (BAU and Blue), LNG generates 50,000-100,000 jobs. Additionally, the various cases generate about 50,000-170,000 gas jobs, with the Blue and Green scenarios generating the most. Additionally, nearly all scenarios do not generate any jobs from oil (except for BAU, which creates about 42 oil jobs).

Lastly, jobs created from transmission and distribution upgrades contribute greatly to the total number of jobs for each scenario. Specifically, for BAU and Blue, transmission and distribution jobs make up nearly half the jobs created in 2030. This follows given that increases in installed capacity between 2025 to 2035 will likely require upgrades to transmission and distribution infrastructure.

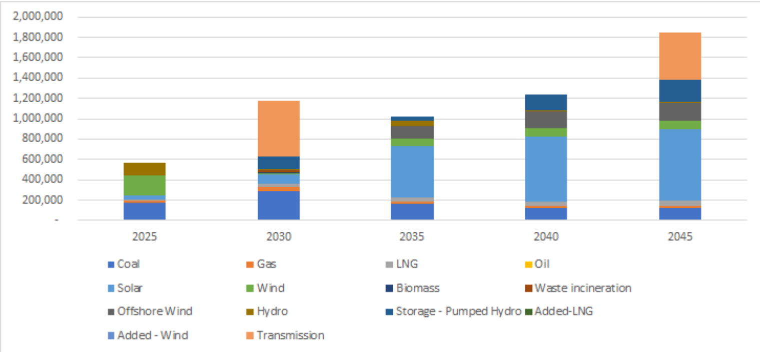


Figure 71: Jobs by technology type for the BAU Scenario

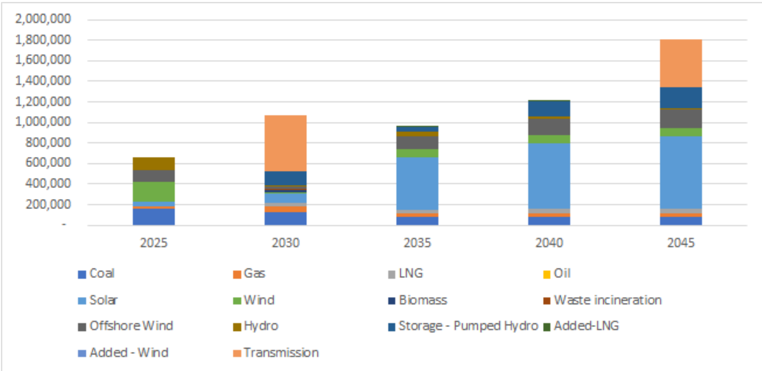


Figure 72: Jobs by technology type for the Blue Scenario

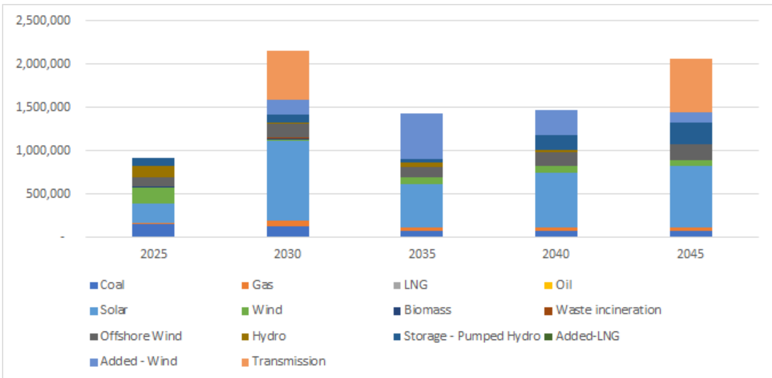


Figure 73: Jobs by technology type for the Green Scenario

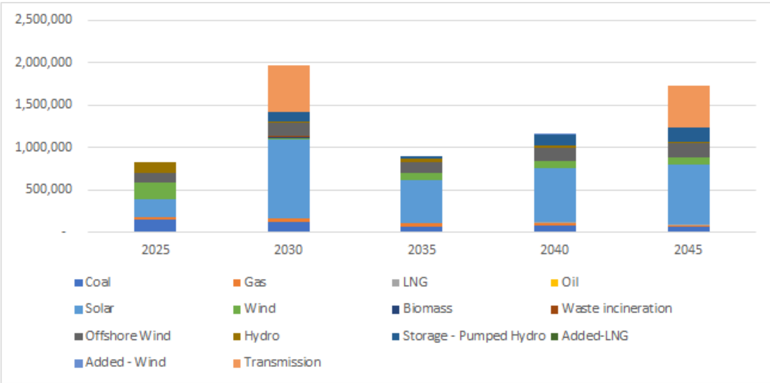


Figure 74: Jobs by technology type for the Cyan EE Scenario

Discussion of Job Creation Implications

This section discusses the implications of the jobs created for the BAU, Blue, Green, and Cyan EE scenarios. The analysis finds that most jobs would be created in the construction and installation of energy generation technologies, which follows a regional trend for Southeast Asia described by Ram et al. (2021). In addition, this model focuses on direct employment, meaning jobs created specifically from fuel production, manufacturing, construction, and operations and maintenance. The analysis does not incorporate indirect jobs in secondary industries that support energy generation (Rutovitz et al, 2015).

The BAU scenario, which represents the energy mix described in PDP8, involves the most coal generation and steadily increasing LNG. The analysis finds that for the BAU scenario, coal generation will create over 880,000 new jobs over the transition period, with most jobs coming from fuel supply (76%) and manufacturing (16%). Specifically, over 500,000 jobs are created from importing coal from 2025-2045, which indicates most fuel-related coal jobs will be located at import sites. In addition, manufacturing jobs include those necessary to manufacture power; in coal's case this likely involves mining and processing coal. Trends indicate that Vietnam may move from open-pit (or open-cast) mining to underground mining; therefore, manufacturing jobs would likely support underground mining operations in the future (MOIT, 2020).

Both the BAU and Blue scenarios observe increasing LNG capacity and imports after 2030. However, Blue generates about 200,000 more LNG jobs over the transition period as coal capacity is replaced by LNG after 2030. For both BAU and Blue, more jobs are created for LNG imports than in-country production. Therefore, it is likely that most of these jobs will be created at LNG import hubs to support the regasification and storage process. Such plants will require a regasification plant as well as cryogenic storage tanks; thus, local and existing expertise will need to be enhanced to support the increasing LNG imports in the BAU and Blue scenarios. Given that LNG is absent in the energy mix for Green and Cyan EE scenarios, it is unlikely any further training or recruitment of the workforce at the import terminals is needed under these scenarios (over and above current forecasts).

In contrast to the increased coal capacity for BAU, the Green and Cyan EE scenarios see the share of fossil fuel related jobs decline across the transition period as fossil fuel generation is replaced by increased renewable capacity, particularly with solar and wind generation. The greatest proportion of solar jobs come from construction and installation periods, which in this case, refers to solar plant installations. Solar plant installations require installers to inspect sites and assemble, set up, and maintain solar systems. While not required, solar installers would likely benefit from solar installation certifications that cement their credibility as well as technical expertise and knowledge. In Asia, such certifications include the REC Solar Professional

Program. Solar construction jobs also make up a large portion of BAU, Blue,
Green, and Cyan jobs but, given the high solar penetration outlined in the Green scenario, it is likely that fulfilling this scenario will require more installers than both BAU and Blue. Lastly, solar power plant construction involves construction laborers, equipment operators, structural iron and steel workers, as well as welders; these laborers are typically trained on the job (BSL.gov).

Across the four scenarios, about 34% of solar jobs come from manufacturing. The manufacturing process involves engineers to design and test components as well as laborers to produce the components. There is a wide variety of engineers related to solar manufacturing, including mechanical, chemical, electrical, industrial, and materials engineers (Hamilton, n.d.). Therefore, given the high solar penetration in all scenarios, highly-skilled engineers in Vietnam will likely need to be trained or prepared for the workforce. In terms of components production, manufacturing jobs could consist of semiconductor processors, computer operators, welding/soldering/brazing workers, glaziers (to install, replace, or remove glass like materials), machine setters, and electrical/ electronic installers and assemblers (Hamilton, n.d.).

As these components (i.e. electrical circuitry, mirrored panels) are relatively delicate, solar manufacturing likely requires trained production managers to plan, direct, and coordinate factory work. Such manager roles typically require college degrees in business management, engineering, or industrial technology. Overall, the four scenarios will likely require a mix of skilled laborers to manufacture and install equipment as well as construct power plants, plus a proportion of laborers with technical engineering background to supervise and manage solar operations. However, given the high amount of solar capacity observed in the Green scenario, it is likely that a majority of jobs created throughout the transition will be concentrated within the solar industry.

Though renewable penetration increases in subsequent years across all scenarios, onshore wind generation makes up a major proportion of jobs in Green and Cyan EE as compared to BAU and Blue. Whereas the BAU and Blue scenarios include some wind generation, particularly in the year 2025, the Green and Cyan EE scenarios see increasing levels of wind generation from 2035 to 2045. Wind generation has many infrastructure requirements, mainly related to the installation and manufacturing of wind components and grid infrastructure. Wind infrastructure consists of three main components: blades, the tower, and a nacelle. Typical production and manufacturing jobs include machinists, control operators, assemblers, welders, inspectors, and industrial production managers (BLS.gov). While production managers may require a degree, other manufacturing occupations can utilize on-the-job training or formal apprenticeships (Hamilton and Liming, n.d.). Given that approximately 55% of wind jobs in the Green scenario come from manufacturing, it is likely this scenario will require a huge amount of labor to participate in the manufacturing and production of wind components. In addition, manufacturing could require research and development jobs to support the design, testing, and development of turbines; thus, engineering experience is likely required to support wind generation (Hamilton and Liming, n.d.). Given that most of the wind capacity in BAU and Blue comes from offshore wind generation, these scenarios likely require local expertise in seismic, wind, or other geotechnical engineering to specifically support the identification of appropriate offshore wind sites. This is particularly important as offshore wind replaces coal capacity in the Blue scenario.

All scenarios require a similar number of transmission and distribution jobs to support the T&D upgrades, but the Green scenario requires at least 800,000 more than BAU, Blue, and Cyan EE to accommodate the higher penetration of non-hydro renewable sources. While this analysis does not dis-aggregate transmission jobs (i.e. into construction, manufacturing, operations), given the assessment on transmission upgrades, it is likely that transmission jobs involve the construction of new power plants, distribution substations, and distribution systems as well as the manufacturing of relevant components (i.e. transmission lines, service connection, transformers) ("Transmission and Distribution Infrastructure", 2014).

In summary, the social model analysis finds that the Green scenario creates
the most jobs over the transition period, with a majority of jobs created from solar and wind power. More broadly, across scenarios, non-hydro renewable sources (particularly solar and wind) create more and an increasing number of jobs whereas fossil fuel sources and imports generate few and decreasing number of jobs from 2025-2045. Both highly technical (i.e. engineering) and locally-sourced skilled labor (i.e. construction and manufacturing) will be required to carry out the assumptions in each scenario and it is likely most jobs will support the construction and manufacturing of plants and components. Lastly, though many jobs are created in the short-term to support fossil fuel generation and imports, as renewable generation increases in subsequent years to replace fossil fuel generation, in the long-term, more jobs will be generated in the long-term to support solar and wind generation.

9. Recommendations

Given the rapid changes in energy technologies in recent years, the importance of power development planning has never been higher. Vietnam has exemplified a commitment to green growth and inclusive economic development. Vietnam now has an opportunity to further advance objectives of national development, energy security, job creation, and environmental protection by exploring deep decarbonization pathways. In forthcoming planning processes, Vietnam should continue to consider and examine various pathways, including those that exceed current national climate targets for the power sector.

With continued leadership in deploying energy efficiency and renewable energy, further opportunities will emerge with the related transportation and heavy industry sectors. As urban environments become more critical and exposed to the dangers of a destabilized climate, Vietnam can also find interconnections to improve environmental performance at the city level.

Clean technologies, especially variable renewable energy (VRE) such as wind and solar have seen a huge uptake in Vietnam through their early stages of adoption and can help meet Vietnam's fast growing energy demand cleanly and cost-effectively. However, they face some significant barriers

- VRE resources such as solar and wind face a unique challenge in Vietnam in the lack of contractual protection against curtailment. Many of the initial utility scale solar capacities have struggled with significant curtailments as more resource continues to be added on the grid, struggling to recover their upfront capex. This could raise challenges for capital raising for continued investment in VRE, especially as Vietnam looks to replace higher cost FiTs with more competitive auctions.
- Adequate grid capacity, to transmit the electricity generated through the system is imperative to continue to meet both quality and security of supply needs on the one hand, and to reduce the risk of curtailment or under-utilization of capacities on the other hand. However, Vietnam has struggled in recent years on this front. Extending monopoly grid capacity has a much longer gestation period than building new generation capacity, several of renewable projects already being under construction, creating a time lag between capacity addition and capacity integration, expensive for both suppliers and consumers.

The government of Vietnam has taken cognizance of both of these issues, with the PM issuing Decision 13 in April 2020, instructing EVN, the sole off taker, to purchase all power generated by renewable energy sources. However, technical and capacity constraints at the system level and commercial constraints from the financial health of EVN make these directions difficult to follow, especially unless concerted efforts are made – both short term interventions and implementation of medium-term systemic solutions.

Vietnam and its power planning need to factor specific interventions within its pathways, to match its low carbon transition ambitions:

- Energy efficiency, including the residential, commercial, and industrial sectors, to save up to 16% of total demand projected on the BAU pathway for 2045. This, when combined with the resources below, will create cost optimal scenarios and increase job creation, with the added benefit of a positive impact on Vietnam's balance of payments by improving domestic energy production and reducing fossil fuel imports. MOIT can continue to show a powerful leadership role in driving energy efficiency across multiple sectors and engaging with customers through programs and incentives.

- Investments in renewable energy can be expanded including solar (rising to 51.5 GW in 2045, with a potential for further 14.6 GW), onshore wind (increasing to 27.1 GW in 2045), and offshore wind (increasing to 26.4 GW in 2045, with the potential for additional 10.2 GW)
- Selective LNG installations (in the range of 16 GW equivalent capacity instead of the 50 GW projected) can support the grid in the coming decades. These investments are justified based on their economic benefit and support for grid reliability. While these investments help diversify the energy mix, Vietnam will remain exposed to price risks from the international market, and could run the risk of asset stranding in the future as other cleaner balancing and flexibility resources reach price competitiveness.
- Expanding the flexibility range of existing resources and adding new capacity for balancing and flexibility can greatly increase the scope for greater generation from cleaner and cheaper VRE sources and even manage the need for expensive LNG capacity and infrastructure spend. Some pathways to explore:
    - Improve flexibility within existing infrastructure through decision support system for hydro power introducing real-time monitoring, and introducing virtual power plants mechanism
    - Upgrade infrastructure of power system, to improve flexibility ranges (reducing P_{min}, and increasing P_{max}), and where relevant for gas pulverizing systems can increase capacity factor and P_{max}
    - Upgrade cross-section of transmission line and electricity poles and invest in substation automation systems, measurement data collection, better monitoring and detecting of substation breakdowns, GIS, and wide area monitoring systems (WAMS)
    - Invest in equipment to increase safety and reliable supply such as Static VAR compensator (SVC) and Thyristor Controlled Series Capacitor (TCSC)
    - Upgrade of substations to increase load capacity by up to 50%
    - Battery storage to firm the grid and displace some of the required gas investments.
- Other energy vectors and utilization should be considered for further study and preparation
    - Vehicle electrification to improve environmental outcomes and eventually firm up the grid through trans-active services and pricing.
    - Hydrogen (ideally green hydrogen – produced from renewable energy) to enable longer duration energy storage
- Finance mechanism
    - Insurance for RE curtailment
        - One of the primary risks to attracting renewable energy investments in emerging economies is the risk posed by the counterparty. This risk, called off-take risk, is because of the poor credit quality of the counterparty – often the state-owned distribution company, or integrated energy company. In the case of Vietnam, this is a rampant practice for renewable energy projects in Vietnam because of inadequate grid capacity.
        - Extending grid capacity has a much longer gestation period than that of new renewable energy projects, several of which are already under construction. In order to address this time mismatch, and create the conditions required for adequate grid

strengthening measures to be undertaken, we propose the design and implementation of a grid-integration guarantee that provides renewable energy generators coverage from loss of revenue due to curtailment by EVN. The government has also taken cognizance of this issue, with the PM of Vietnam issuing Decision 13 in April 2020 that requires the purchase all the power generated by renewable energy sources. However, technical constraints of the grid and commercial constraints because of the financial health of EVN will lead to this decision being violated, unless short term interventions and medium-term systemic solutions are put in place.

    - Designing a financial intervention that underwrites a critical barrier to the flow of capital into renewable energy projects would have multiple benefits, primary among them being addition of clean energy capacity at lower prices. The cost of capital can contribute as much as 80% of the total cost of renewable power, reducing the risk of investment can significantly lower the cost of borrowing for such project, and the rates paid to equity investors – in turn making renewable power cheaper, and accelerating the pace of the energy transition due to the enhanced competitiveness of renewable.

  - Emission Trading System
  - Pilot CRM (State company) from the lesson learn to the realistic strategy consider country context and Energy Storage and Emission score.

- Develop ASEAN Power Market
  - Interconnection Grid code
  - Region Power market mechanism

These explorations and investments will create significant job benefits for Vietnam (up to 8 million new jobs, with greater capacity addition possible with exploration of new energy vectors and expansion of the balancing and flexibility capacities), but the distributional effects will require support for displaced working populations (coal supply chain) through a managed just transition process. This process can consider the differential impacts on regions in Vietnam, as well as the potential for high-skill career development and retraining available to any sectors impacted by the energy transition. By emphasizing the options for energy equipment and services that come from inside Vietnam, the national balance of payments can be improved by $190 billion in the coming decades.

With effective and thorough planning in place, as has already been the hallmark of the Power Development Planning processes, the Government of Vietnam can access new and emerging climate finance flows for new energy efficiency and renewable energy options. These are summarized above, but include opportunities from existing development partners, as well as newer vehicles such as the Green Climate Fund.

Leaders in Vietnam should examine embedded subsidies for fossil fuels, from market developments, and seek ways to create a level playing field by reducing current fossil fuel subsidies (as has already been underway since 2011 as part of Power Development Planning processes). By continuing to advance low-carbon planning and development, Vietnam can remain a leading partner for global business and offer options to support corporate goals as that sector also addresses environmental concerns.

By aligning public and private entities, through an inclusive process, Vietnam can prepare to support any communities and industries impacted by the shift away from legacy energy assets. A council or committee for energy transition, involving both the private and public sector, is recommended (as per the Chile example), to ensure a coordinated and directed transition. As the electricity, transportation, and urban planning sectors all increasingly intersect – the opportunity for an energy transition council to provide valuable guidance and coordination is bound to increase.

Leaders from the Ministry of Industry and Trade, particularly from the Electricity and Renewable Energy Authority, would be well placed to chair this committee and continue the valuable momentum and growing power of Vietnam's economic development.

To ensure the recommendations and analysis summarized above is incorporated into Vietnamese power planning processes will require a focused and multi-pronged communications strategy **(described in Section 1 above)**, consistent messaging on the opportunity of deeper decarbonization options while recognizing the value and integrity of PDP 8, and an accurate and updated understanding of global funding opportunities for the technical assistance and infrastructure required for the recommended shifts. This will be ever more critical given the announcement of the net zero ambition, and the requirements of aligning planning to that future state.