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East Asia and Pacific Region

Energy Sector Decarbonization in Vietnam

Background Note to the Country Climate and Development Report (CCDR)

Energy and Extractives

Infrastructure Practice Group

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Table of Contents

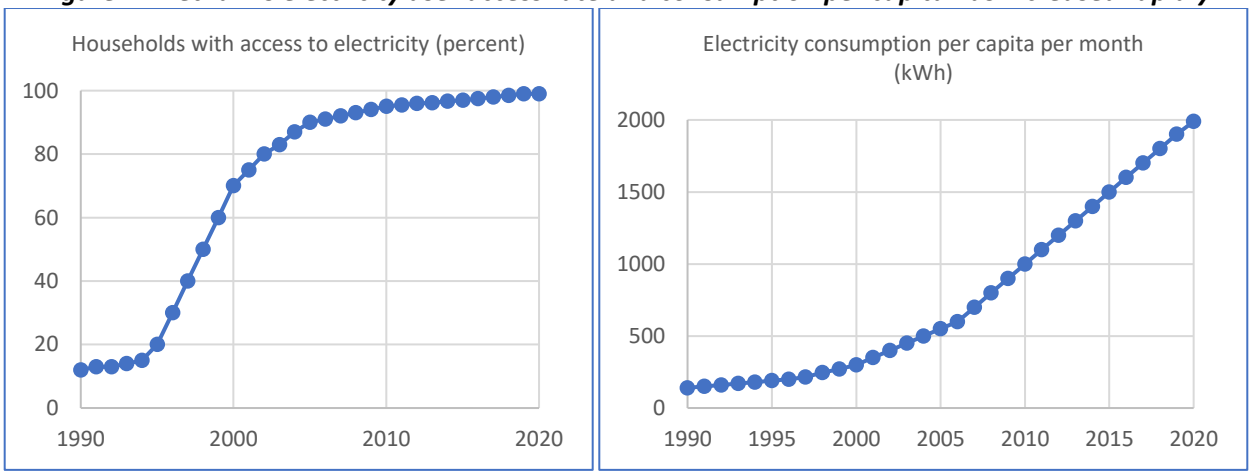
This policy note was prepared with contributions of the following World Bank staff and consultants: Rahul Kitchlu (Team Leader), Sabine Cornieti, Claire Nicolas, Bipul Singh, Chiara Rogate, Joonkyung Seong, Thi Ba Chu, Hung Tan Tran, Anh Hoang Le, Stuart Thorncraft and the IES team. Team would like to thank Jie Tang and Ranjit Lamech for their guidance and support.

Section I. Executive Summary and Key Messages

1. Vietnam has made remarkable economic progress over the past 30 years; however, growth was supported by increasing reliance on coal-based energy.

Over the past two decades, Vietnam witnessed one of the fastest Gross Domestic Product (GDP) per capita growth rates (averaging 5.5 percent a year), yielding a three-and-a-half-fold increase in average income. The power sector was able to successfully expand its services to become a fundamental enabler of inclusive economic development. Vietnam's electrification program has been a global success story for its ability to provide near universal electrification in record pace - electricity access rate increased from 14 percent in 1993 to about 99 percent in 2020. The sector was able to handle double-digit growth rates (demand grew by 10 percent between 2010-2020) which has powered industry and commerce as well as the increasing energy needs of the growing middle-class population. The installed capacity of the power sector has increased over fourteen-fold in the past two decades, from 5 GW in 2000 to 68 GW in 2020. Under the leadership of the Ministry of Industry and Trade (MOIT), national policies and targets were developed which focused on service delivery at the grassroot levels. The strong political commitment was executed by capable vertically integrated, state-owned enterprise (SOE), Vietnam Electricity (EVN).

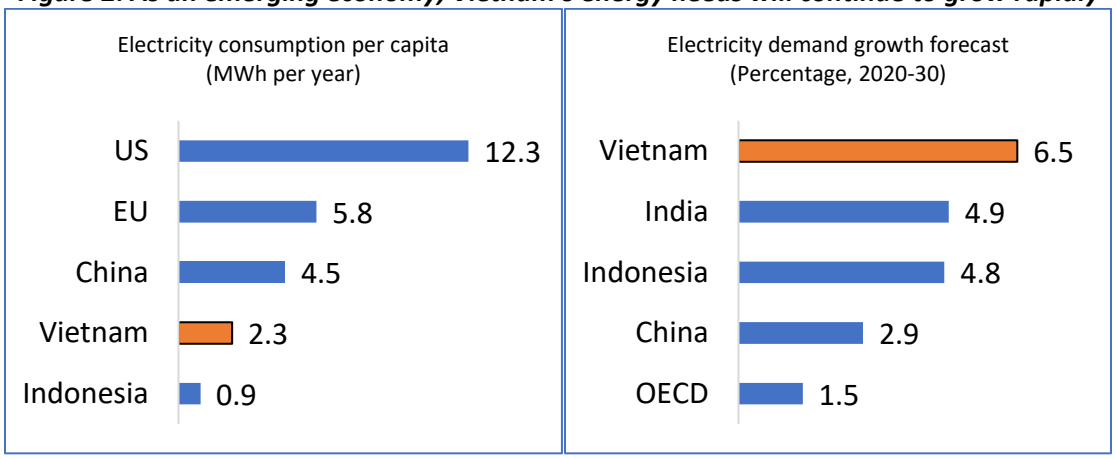
Figure 1: Vietnam's electricity user access rate and consumption per capita has increased rapidly



Source: World Bank staff estimates

In the coming years, electricity demand is expected to continue to grow rapidly at about 6-7 percent per year, driven by the rise in economic standards of the consumers (per capita electricity consumption is 2.3 MWh per year and is still low compared to advanced economies) and by the emergence of new demand segments such as digitalization and electric mobility. At this rate, the supply of electricity would need to double every 10 years to meet the demand. Demand is also impacted by inefficient electrical equipment, appliances, and industrial and commercial usage. Many of the large state-owned industrial enterprises (steel, cement, and sugar industries) continue to demonstrate poor energy efficiency benchmarks, while there are few policies to encourage investment in energy efficiency. Currently, Vietnam remains an outlier on energy efficiency when compared to regional peers in developing Asia.

Figure 2: As an emerging economy, Vietnam's energy needs will continue to grow rapidly

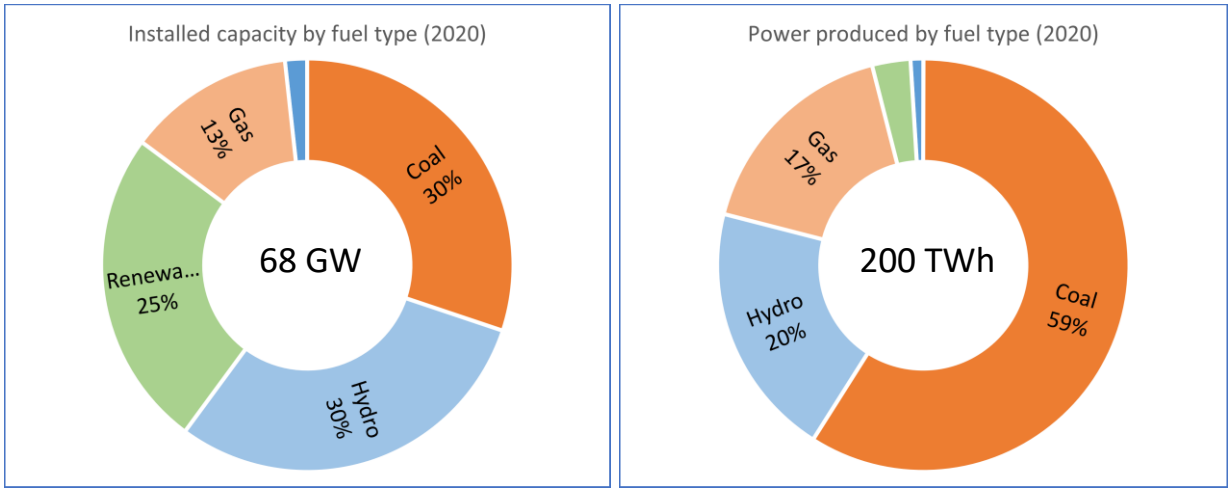


Source: World Bank staff estimates

Vietnam's annual green-house gas (GHG) emissions increased sharply in the past two decades and the country became the fastest growing per capita GHG emitter in the world with an annual growth rate of 5 percent (although, per capita GHG emissions of 3.8 tCO_2eq per year are still low compared to advanced economies).[1] With 65 percent of emissions coming from energy sector in 2020, of which, 61 percent were from the power sector alone, the energy sector was a key driver of GHG emissions, primarily due to its heavy reliance on coal-based power generation.[2]

The installed capacity of coal-based power plants quadrupled in a decade (from 5 GW in 2010 to 20 GW in 2020). Coal accounted for about 30 percent of installed power generation capacity in 2020 and 59 percent of the electricity produced. The grid emission factor was 0.9 tCO_2e per MWh of electricity. Use of coal in the power sector accounted for 70 percent of total coal consumed which increased the annual consumption of coal to 88 million tons (1 percent of global consumption).

Figure 3: Vietnam's power sector is highly reliant on coal



Source: World Bank staff estimates

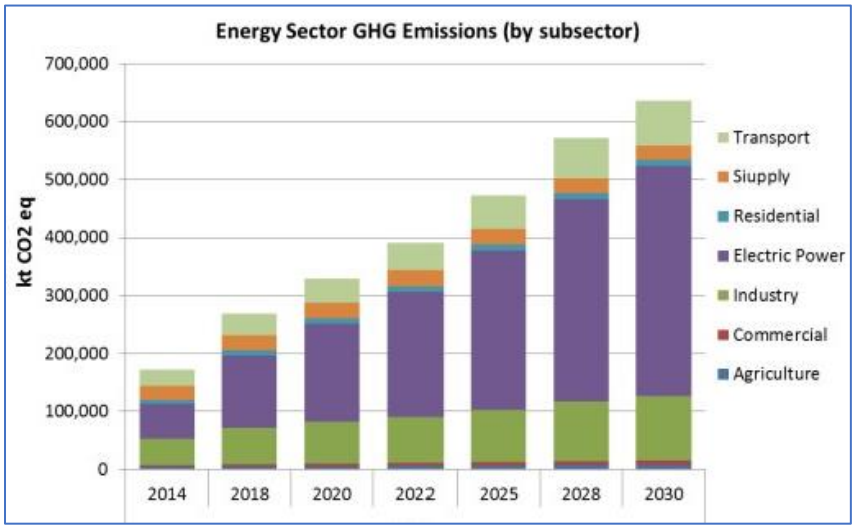
[1] World Bank Low Carbon Pathways Study: *https://openknowledge.worldbank.org/handle/10986/23522.*

[2] World Bank staff estimates based on MONRE and MOIT data, as well as https://www.wri.org/data/cait-climate-data-explorer.

2. Energy sector would continue expansion of coal-based energy with significant increase in installed capacity of coal power plants under previous plans.

The most recent (2016) master plan of the sector, the Revised Seventh Power Development Plan (PDP7), would continue the reliance on coal-based power generation. Under this scenario, coal-based power plants would nearly triple in the coming decade (increasing from 20 GW in 2020 to 55 GW in 2030) further increasing energy sector related GHG emissions. This can not only negatively impact climate related aspects but can also impede development outcomes. For instance, local air pollution levels could further increase, and the competitiveness of the economy could be impacted by the higher carbon footprint of goods under *Carbon Border Adjustment Mechanisms*.

Figure 4: Energy sector related emissions under previously approved plans (PDP7) by 2030



Source: MOIT presentation, adapted by World Bank staff

3. Vietnam has committed to achieving net-zero emissions by 2050 and to gradually phase out the use of coal for power generation.

At COP-26, Vietnam signed the '*Global Coal to Clean Power Transition Statement'* while also committing to achieving net-zero emissions by 2050. However, meeting these targets would require adjustment of current national and sectoral expansion plans. Vietnam's latest Nationally Determined Contributions (NDC) of December 2020 aims at a 9 percent emission reduction using domestic resources and a 27 percent emission reduction using international support by 2030 when compared to the baseline scenario.

The Eighth Power Development Plan[3] is considered the **current policy scenario (CPS)** which broadly aligns with the NDC. It aims at doubling renewable energy utilization (from previously planned 18 GW to a new target of 36 GW by 2030[4]) and reducing planned coal-based energy utilization by another 33 percent (from previously planned 55 GW to a new target of 37 GW by 2030). However, coal power plants would still nearly double (from the current 20 GW to 37 GW by 2030) under the CPS and this growth would largely

[3] Draft PDP8, data available as of September 2021.
[4] Based on the major renewable energy resources envisioned in the energy mix.

rely on imported coal. In addition, the National Energy Efficiency Plan (VNEEP 3) is also being launched which aims to improve efficiency by 8-10 percent by 2030.

4. Selecting lower carbon pathways for the future growth of the energy sector requires study of interdependencies of the power system through a robust analytical approach.

To inform the discussion on clean energy transition pathways, a detailed power system modeling study was carried out by the World Bank to assess lower carbon growth scenarios which extend beyond the CPS (towards the achievement of net-zero targets). The analysis was used on Electricity Planning Model (EPM), an optimization tool which simulates the current sector situation and realistic demand projections between 2020 and 2040 (based on economic growth and declining income elasticity with aggressive energy efficiency assumptions). The model selected generation resources (which compete on a level playing field with optimistic cost reduction projections assumed) on a least-cost basis.[5] The model used total system cost financing requirements as a benchmark (and not individual power plants) within specified emission constraints. Four scenarios were assessed in detail: placing a constraint of (i) 20 percent, (ii) 40 percent, (iii) 60 percent, and (iv) 80 percent emission reduction for the power system to identify a suitable generation mix. The model aimed at identifying pathways which ensure security of supply within reasonable costs.

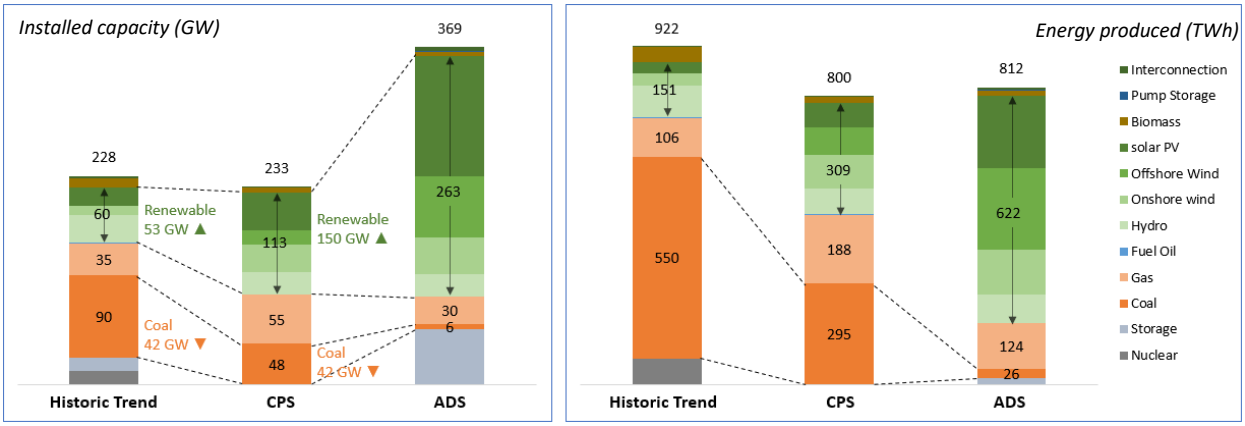
As a comparator scenario, the **accelerated decarbonization scenario (ADS)**, which reduces annual power sector emissions by 80 percent by 2040, is presented below to discuss the implications and opportunities compared to the CPS. If implemented, the ADS would be aligned with Vietnam's goal of net-zero emissions by 2050 (as stated at COP-26). Key technical highlights of the ADS are:

(i) The installed capacity of coal power plants peaks in 2025 at about 26 GW (completion of the most advanced projects which are already under construction), and coal usage is gradually phased out (through a process of early retirements), and a small footprint remains by 2040.
(ii) Power sector-related emissions peak in 2030 and are below 2020 levels by 2040.
(iii) The share of fossil fuels is less than 10 percent of the generation capacity in 2040.
(iv) Renewable energy technologies (e.g., solar, on-shore, off-shore wind) dominate the power system accounting for as much as 90 percent of all installed capacity.
(v) The analysis underscores the importance of overcoming the challenges of intermittency and reliability created by the large-scale deployment of renewable energy in the power system. This has implications both for base load power and for managing peak load.
(vi) Significant capacity of energy storage systems (e.g., batteries, pumped hydropower), should technological advancements in energy storage systems allow for it, would need to be added.
(vii) The capacity and flexibility of the power grid would need to be significantly increased.
(viii) Power system modeling should be carried out periodically to update investment decisions. As new technologies become commercially viable at scale, their role in the lower-carbon pathways would be further enhanced.
(ix) Natural gas can play a role as a transition fuel. Based on current analysis, natural gas features in the generation mix under all scenarios in 2040, until other clean technologies become more cost-efficient.

[5] For a description of the EPM model see Section IV.

(x) Unbalanced implementation or mismatch of timing of required clean energy investments (for instance, inadequate scale-up of renewable energy or grid capacity to compensate for a corresponding reduction in coal capacity) could create energy security concerns and a risk of retreating to coal.

Figure 5: Comparison of power system expansion scenarios for installed capacity and energy by 2040



Source: Power Sector modeling carried out by the World Bank staff[6]

5. Choice of decarbonization scenario should be based on careful review of implications and opportunities at the sector level as well as more broadly at the level of the economy.

The analysis highlights the tradeoffs that policy makers should consider. Informed and evidence-backed policy development is essential for the clean energy transition. Some key dimensions are discussed below:

Climate impacts: While the CPS would be able to slow down the growth rate of coal and contribute to reduction in annual emissions by about 40 percent from the historic trend by 2040, emissions would continue to increase (to 2040 and potentially thereafter). Under the ADS, coal power plant capacity peaks in 2025 (at about 26 GW) and sector emissions peak in 2030, declining to below 2020 levels between 2035-2040 (achieving 80 percent annual emission reduction by 2040). The changing climate would also entail that the power system is designed to withstand the risks of increasing temperatures, extreme weather events, and sea level rise.

Financial impacts: The ADS highlights the decarbonization opportunity stemming from the rapid reduction in price of clean energy alternatives. It also highlights that lower carbon scenarios require higher upfront investment costs. This is due to the higher total system cost associated with additional complementary capital investments needed for overcoming the integration of renewables (energy storage, grid upgrades, backup generation).

(i) The present value of the total system cost increases from $ 264 billion under the CPS to $ 297 billion under the ADS (13 percent higher). This excludes costs associated with global and local

[6] Historic trend is based on proportion of generation mix under PDP7 scaled-up to 2040.

environmental damages[7] - a common practice for power system planning in many client countries. ADS can be 5 percent cheaper than CPS if these costs are fully factored in.

(ii) However, a key financial challenge is that the present value of upfront capex cost increases from $ 109 billion under the CPS to $ 166 billion under the ADS (52 percent increase).

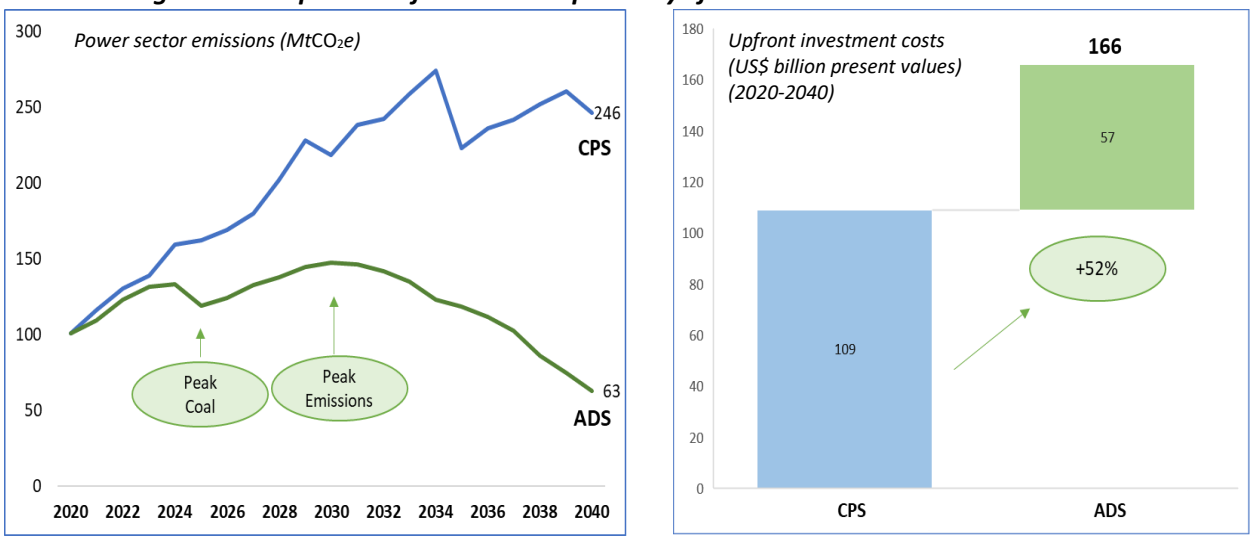
(iii) There would also be additional associated costs with regards to:

a. Financing for a 'just transition' framework for people, communities, and businesses in the coal value chain (additional studies are needed to ascertain the full nature of these costs).

b. Estimated 15 GW of coal plants would be retired early under the ADS (in addition to about 4-5 GW that will reach end of useful life in the coming years), and these *stranded assets* will incur additional economic cost of $ 12 billion (not included in system cost).

(iv) The large financing needs of the energy transition calls for accelerated investment climate reforms (for increased private sector participation and complementary public investment), as well as mobilization of additional concessional financing resources.

Figure 6: Comparison of low-carbon pathways for emissions and investment costs



Source: Power Sector modeling carried out by the World Bank staff

Price of electricity: Changing investment dynamics and power system costs could also impact the price of electricity paid by the consumers. Maintaining affordability would be an important policy consideration.

(i) If all the additional costs of decarbonizing the power system are passed through directly to the electricity consumers, then under the ADS, the price of electricity would need to increase by 26 percent by the year 2040 (average increase of 16 percent between 2020-2040).

(ii) There are various options to mitigate the risks and distributional impacts of the electricity price increases. For instance, using the broader tax base to cover the costs, better utilization of carbon markets, and mobilizing concessional financing. As a representation of the scale of the need, the Bank estimates that the overall need for concessional financing would be about $ 19 billion (in present value) between 2020-2040, to keep electricity prices under the ADS at par with the CPS.

[7] Global and local environmental damage cost amount to $90 billion, in present value. See also Table 1.

(iii) The issues associated with any potential increases in prices would need to be further studied in the context of how it would impact demand moderation policies and potential for designing cross-subsidies based on volume differentiated consumer categories.

Broader implications of decarbonization the power system: The analysis sheds a light on other economic considerations for the country. While ADS can boost the green growth aspirations of Vietnam and limit fiscal impacts of imported fossil fuels, for a country already struggling to meet its existing infrastructure investment needs, this is a tall order.

Jobs: One the one hand, decarbonizing the energy sector under ADS could impact employment of workers associated directly or indirectly with the coal industry. On the other, ADS could trigger new green jobs in the power sector. Estimates of potential new job creation impact of clean energy transition are being studied and will be included in subsequent reports.

Competitiveness: Indirect impacts of the clean energy transition could also be perceived in the manufacturing industry. If Vietnam develops its expertise in the clean energy supply chain (solar panels, wind turbines, batteries, e-vehicles), it can enhance prospects for export of such equipment and services. Estimates of potential economic impacts would need to be further studied. In addition, ADS could significantly reduce the carbon footprint of Vietnam's exports, which can in turn support improved competitiveness.

Environmental and social aspects: Increased demand for clean energy transition metals will open new supply chains from extraction to manufacturing which may place additional pressure on ecologically sensitive locations and on the land and resources of vulnerable communities. Strategic assessment of impacts, costs, and benefits of developing these metals is necessary to ensure a more secure supply chain and confidence in investments as well as to prevent harm. Where green jobs and alternative industries are unable to be located, effective multistakeholder assessment and engagement will ensure that communities impacted by the transition are involved in smart decisions about repurposing resources and land to crowd in investments and promote revitalization.

6. A clean energy policy framework would require reforms not only within the sector, but also of the broader enabling environment.

Key recommendations for developing a 'no regret' policy framework which supports the development objectives of the energy sector while also creating a foundation for clean energy transition, based on international best practices and analysis of local conditions, are presented below:

(i) **Facilitate rapid renewable energy deployment (in particular, offshore wind) by improving the regulatory framework, including transparent and competitive procurement procedures (auctions) to encourage private sector participation**: Vietnam has witnessed a period of rapid expansion of solar and onshore wind energy in the past few years through premium pricing offered under a feed-in tariff (FIT) policy.[8] This developments have positioned the country among

[8] A feed-in tariff (FIT) policy is designed to accelerate investments in renewable energy technologies. The objective is to offer cost-based compensation to renewable energy producers, providing price certainty and long-term contracts to incentivize investments in renewable energy.

the top 10 in terms of installed solar capacity as of 2020 (16.5 GW).[9] But the FIT policy is now starting to impede the energy transition by making renewable energy projects costlier than fossil-fuel projects and is leading to grid instability and curtailment. At the same time, the government's recent pledge to achieve net-zero emissions by 2050 has substantially increased the scale of the required capacity for renewable energy. The FIT should be replaced by a transparent, predictable, and coordinated auction-based scheme for procurement of energy projects, starting with solar, onshore wind, and offshore wind (for which domestic resources are amongst the best in the world), and then extending it to other technologies.

(ii) **Finalize PDP8 to align it with COP-26 net-zero commitments and implement identified investments with an enabling regulatory framework**: Improving the regulatory framework to attract investments includes fully implementing the Public Private Partnership Law of 2020 with provisions for consolidated review and approval, and mobilization of government support where necessary (e.g., through guarantees backed by a strong contingent liability management approach). There is a need for bankable power purchase agreements (PPAs) so that cheaper international capital can be attracted to the sector. There are additional opportunities for the private sector to participate in the clean energy transition in the medium-term: green bonds issued by sector utilities (SOEs), equitization and recycling of existing assets, selected grid investments (for instance, transmission lines connecting private power plants to the backbone network), as well as the energy efficiency market.

(iii) **Invest in the power grid's capacity and flexibility to absorb additional renewable energy**: Increased investments are needed to upgrade the capacity of the transmission and distribution networks and to introduce modern technologies designed for improved variable renewable energy integration. There is a need to increase public (SOE) investments to upgrade the capacity of the power transmission and distribution networks and to introduce modern technologies designed for improved variable renewable energy integration. This includes energy storage systems, power system automation tools, load dispatch management capabilities, smart grid technologies, expanded use of grid digitalization, telecommunication equipment upgrades, and systems based on high-voltage direct current (HVDC). Vietnam also needs a regulatory framework for energy storage systems (such as batteries and pumped hydropower), which is necessary to develop ancillary services as well (voltage and frequency management, peak shaving).

(iv) **Accelerate implementation of energy efficiency plans including effective pricing policies**: Despite being among the leaders in the region in supply side energy efficiency, Vietnam remains an outlier when it comes to demand-side efficiency. There are several steps that Vietnam should take to improve end-use efficiency and reduce the burden on supply expansion. Vietnam should update building codes and efficiency standards and issue comprehensive technical specifications for lighting and cooling devices, consumer appliances, and industrial equipment, supported by monitoring and enforcement. Vietnam should offer incentives for investments in efficiency improvement, as well as implement measures to enhance access to finance (e.g., capacity building

[9] IRENA. 2021. "Renewable Capacity Statistics 2021." Abu Dhabi: International Renewable Energy Agency. *https://www.irena.org/publications/2021/March/Renewable-Capacity-Statistics-2021*. In 2022, the installed capacity reached about 25GW.

of local banks as well as preferential credit and taxation schemes) and technology and build capacity for the private sector led Energy Services Companies (ESCOs).

(v) **Reform of electricity tariffs**: Electricity tariff reforms are needed not only to send the right price signals to consumers to moderate energy consumption but also to ensure that revenue requirements are based on the full cost of supply, thereby warranting the financial viability of the power sector. While fossil fuel subsidies for the power sector have been largely eliminated, designing cross-subsidies across consumer categories can address poverty and affordability concerns. The EVN is the primary off taker in the power sector and maintaining its creditworthiness is at the heart of the sector's financial viability. It is important that reforms are implemented based on the long-term goals of improved market competition and sector performance.

(vi) **Use power system planning as a dynamic investment decision tool that incorporates new technologies (and their evolving costs) as well as externalities of fossil fuels**: Identification of an appropriate power generation mix should be based on principles of least-cost power supply and strengthening of the sector's financial viability within the context of the long-term policy target of reducing emissions by eventually phasing out the use of unabated fossil fuels, starting with coal. Power sector planning should be a continuous process that periodically, perhaps even annually, examines the changes in market conditions - demand, costs, technological progress - while increasingly factoring in (currently uncaptured) local and global externalities. This approach can avoid a potential long-term carbon lock-in that is not aligned with policy goals while also shielding the economy from import reliance and price volatility of fossil fuels. Revision and timely approval of the draft PDP8 is necessary to set the power sector on the pathway for achieving net-zero emissions by 2050.

(vii) **Develop natural gas to power as a transition fuel, factoring in the risk of long-term carbon lock-in, by implementing the necessary upstream reforms and investing in selected strategic projects**: Phasing out the use of coal in two decades will be challenging. Natural gas is a lower-carbon fuel frequently used to replace coal, to provide flexible dispatch and backup capability for integration of renewables, and to meet peak load demand. Given limited domestic gas resources, Vietnam's gas supply will rely on imported liquified natural gas (LNG). LNG, as a new market segment, will require upstream policy reforms, including transparent procedures for gas procurement. Updating the regulatory framework with health, safety, and environmental standards is needed together with a policy for pass-through of gas price fluctuations. Power system planning can be used to assess the viability of carbon capture and storage and other technologies to complement LNG-to-power. Strict criteria for selectivity should be developed for investing in only those receiving ports, processing, transporting, storing, and power generating facilities that are optimally required and to identify where public investment support may be justified. Currently, Vietnam has not identified specific plans for development of nuclear power plants[10]. However, the government is keeping open the possibility of developing this technology in the future open. The government is encouraging further research and development of feasibility studies for assessment.

[10] Draft PDP8 version of April 2022.

7. Energy sector decarbonization would require development of 'just transition' oriented policies and regulations to support the people, communities, and businesses.

Decarbonization of the energy sector would require management of impacts on workers, communities, and businesses. It will also require environmental stewardship of lands and infrastructure assets (such as coal mines and power plants). Developing a framework to anticipate and mitigate these broader risks of clean energy transition is needed. This framework should be based on the following principles:

(i) Strengthening institutional policies and governance to help define conditions, rules, capacity needs, and responsibilities to implement the coal sector downsizing is needed.

(ii) Developing standards for environmental remediation for repurposing land and assets (how to regenerate natural spaces, how to reuse or recycle coal power plant equipment and facilities) and transferring them to the community, where appropriate.

(iii) Relevant compensation benchmarks, instruments, and labor market programs to address the needs of redundant workers may be needed. Developing 'green skills' in the labor force for the clean energy transition is critical which can include re-skilling and livelihood restoration activities of coal industry workers.

Box 1: Impact of the war in Ukraine on Vietnam's energy sector

The ongoing conflict has impacted fossil-fuel supply chains, and the global oil and gas prices are at a ten-year high level. Countries with direct energy trading relationships (mainly within Europe) are urgently seeking alternative sources and the short-term price volatility is expected to continue. However, the longer-term outlook remains uncertain. Historically, fuel shocks have led to producers increasing and diversifying supplies, or consumers adjusting demand patterns (efficiency, alternative sources). In the current context, it remains early to predict the degree to which the conflict will have a sustained impact on long-term energy prices.

Vietnam, as a net energy importer, will be increasingly vulnerable to external energy commodity shocks. The transportation fuel prices have seen an increase in the past months, moderated by the petroleum price stabilization fund (which now holds a negative balance, as of April 2022). Within the power sector, while coal imports have not been impacted much, thus far, the planned expansion of fossil-fuel based power generation capacity, especially the imported gas-to-power market, could face increased risks.

Some mitigation measures for Vietnam would be: (i) use power sector planning tool - PDP8 - as a dynamic investment decision platform, such that it can adapt to changing nature of fuel prices, (ii) prioritize development of domestic clean energy resources such as offshore wind, and (iii) move towards technology-neutral competitive procurement of power projects.

8. World Bank Group stands ready to provide comprehensive support for designing and implementing a low carbon future for the energy sector.

Facilitating the energy transition requires a comprehensive approach for transforming the way energy is produced and consumed. Isolated initiatives will not achieve desired decarbonization results. Reducing reliance on coal is critical for transition, but it can be achieved only if energy security, economic growth and competitiveness can be sustained, and if the costs are affordable.

The World Bank's Energy Transition Framework recognizes the complexities of clean energy transition and comprises of engagements that address the full spectrum of energy transition needs. The energy program in Vietnam includes technical assistance and financing for: (i) clean energy policy, regulatory and planning framework development, (ii) transition-oriented fuels and approaches, (iii) renewable energy deployment and grid integration, (iv) efficient use of energy, and (v) reforms to scale-up public and private sector capital mobilization.

Table 1: Summarized results of modeling of the power sector expansion scenarios in Vietnam

		2020–2040			
		CPS	**ADS**	**Amount Change**	**Percentage Change**
Power Sector: Current Policy Scenario (CPS) vs. Accelerated Decarbonization Scenario (ADS)					
Capital costs for new generation and storage (undiscounted)		$157 billion	$271 billion	+ $114 billion	+ 73%
Capital costs for new generation and storage (present value)		$84 billion	$128 billion	+ $44 billion	+ 52%
Of Which:	Coal (present value)	$27 billion	$8 billion	- $19 billion	- 72%
	Gas (present value)	$19 billion	$11 billion	- $8 billion	- 42%
	Solar (present value)	$5 billion	$26 billion	+ $21 billion	+ 429%
	Wind (onshore) (present value)	$14 billion	$22 billion	+ $8 billion	+ 55%
	Wind (offshore) (present value)	$10 billion	$48 billion	+ $39 billion	+ 402%
	Hydropower and other renewables (present value)	$8 billion	$9 billion	+ $0 billion	+ 4%
	Storage (batteries and pumped hydropower) (present value)	$0 billion	$3 billion	+ $3 billion	N/A
Grid network expansion and upgradation costs (undiscounted)		$47 billion	$81 billion	+ $34 billion	+ 72%
Grid network expansion and upgradation costs (present value)		$25 billion	$38 billion	+ $13 billion	+ 52%
Fuel costs (present value)		$102 billion	$70 billion	- $32 billion	- 31%
Variable operational and maintenance costs (present value)		$5 billion	$7 billion	+ $2 billion	+ 40%
Fixed operational and maintenance costs (present value)		$49 billion	$55 billion	+ $6 billion	+ 12%
Levelized cost of electricity, per kWh (excl. local and global env. damage costs)		$4.8 cents	$5.7 cents	+ $ 0.9 cents	+ 16%
Power system related GHG emissions (annual) (year 2040)		246 $MtCO_2e$	63 $MtCO_2e$	- 183 $MtCO_2e$	- 75%
Power system related GHG emissions (cumulative) (2020-2040)		4,280 $MtCO_2e$	2,514 $MtCO_2e$	- 1,766 $MtCO_2e$	- 41%
Local environmental damage costs (present value)		$35 billion	$21 billion	- $14 billion	- 40%
Global environmental damage costs (present value)		$109 billion	$69 billion	- $40 billion	- 37%
Total system costs (incl. local and global env. damage costs) (present value)		$409 billion	$387 billion	- 22 billion	- 5%
Total system costs (excl. local and global env. damage costs) (present value)		$264 billion	$297 billion	+ $33 billion	+ 13%

Source: Power Sector modeling carried out by the World Bank staff

Section II. Country and Energy Sector Context

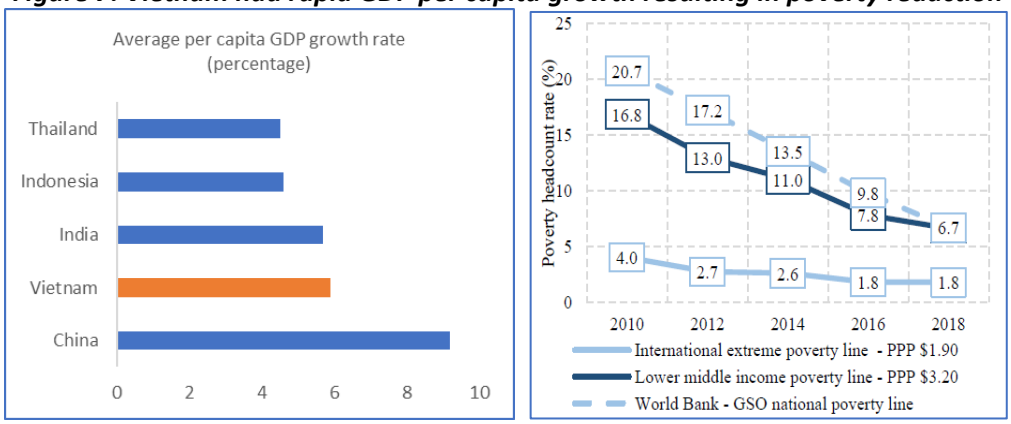
1. Vietnam's stable economic growth over the past decades have transformed the country from a low- to a middle-income economy in one generation.

Since the early 1990s, government's reform programs decollectivized agriculture, established land-use rights, and liberalized agricultural prices, thereby transforming the country from food deficient to an export powerhouse. The authorities restructured state-owned enterprises and liberalized most industrial prices. Consequently, Vietnam has had one of the fastest Gross Domestic Product (GDP) per capita growth rates (averaging 5.5 percent a year), yielding a three-and-a-half-fold increase in average income. Economic growth has brought dramatic structural transformations, with the agricultural sector's share in GDP falling from more than 40 percent in the late 1980s to less than 20 percent in recent years. In the coming years, it is expected that the domestic private sector will continue to drive economic development and job-creation, particularly as state-owned enterprise reforms progress, and as Vietnam continues a path towards its longer-term aspirations of being a 'modern and industrialized nation moving toward becoming a prosperous, creative, equitable, and demographic society' (Vietnam 2035)[11].

2. Vietnam has performed well in terms of poverty reduction and shared prosperity.

More than 40 million people were lifted out of poverty between 1990 and 2014. Extreme poverty ($ 1.90 per day) fell from 50 percent in 1993 to less than 3 percent today, and consumption for the bottom 40 percent of the population grew by 6.8 percent annually over the same period. Access to basic infrastructure services has continued to improve substantially. Electricity is now available to almost all households, up from less than a quarter in 1993. Access to clean drinking water and improved sanitation in urban areas has risen from less than 20 percent of all households in 1999 to more than 90 percent and 88 percent, respectively, in 2015. By the World Bank's measure of shared prosperity (i.e., the income growth of the bottom 40 percent of the population), Vietnam is one of the most noteworthy cases of shared prosperity globally.

Figure 7: Vietnam had rapid GDP per capita growth resulting in poverty reduction



Source: World Bank staff estimates

[11] World Bank; Ministry of Planning and Investment of Vietnam. 2016. Vietnam 2035: Toward Prosperity, Creativity, Equity, and Democracy. Washington, DC: World Bank.

3. Vietnam is one of the most climate vulnerable nations in the world.

The concentration of a high proportion of the population and economic assets (such as power plants and grid infrastructure) in vulnerable coastal lowlands and deltas is the main risk for climate change. The economic costs associated with climate risks are already large and are expected to increase rapidly in the absence of effective adaptation and mitigation policies. Rising sea levels in the Mekong Delta, bigger and more frequent natural disasters (for example, storms) along the central coast, and higher and variable temperatures are all affecting labor productivity and destroying assets and human lives. It is estimated that Vietnam's average annual disaster-related losses in 2020 are approximately $ 1.4 billion, and the total economic losses are about 3 percent of GDP.

4. Climate change is also impacting the energy infrastructure.

The power sector remains vulnerable to changes in many dimensions of climate. Increasing temperatures are already altering the demand for energy use for air conditioning, industrial cooling, and agricultural drainage pumps, which will continue to put pressure on the energy supplies in the future. At the same time, rising temperatures and changing rainfall patters have already reduced hydropower production potential by altering river flows and runoff dynamics. Sea level rise and extreme weather events threaten power transmission (high voltage grids as well as low voltage distribution to consumers).

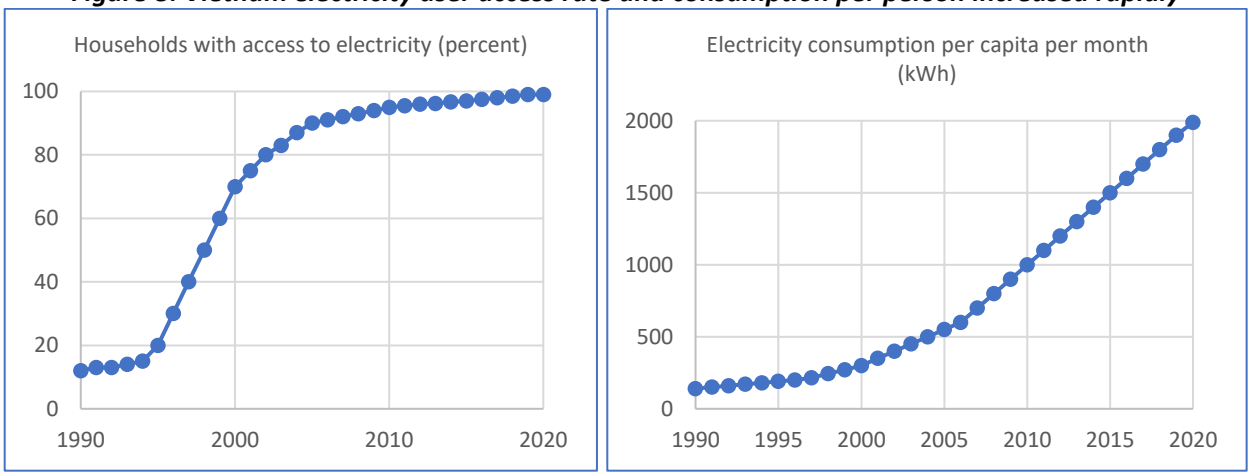
As Vietnam strives to become a modern, industrialized economy, economic growth will need to adapt to become more resource efficient and therefore less vulnerable to climate shocks on resource availability as well as to address other consequences of climate change.

5. Energy sector has been a fundamental enabler of inclusive economic development.

Vietnam's electrification program has been a global success story for its ability to provide near universal electrification in record pace - electricity access rate increased from 14 percent in 1993 to about 99 percent in 2020.[12] In just 25 years, more than 14 million households, representing 60 million people, were connected to the grid. The sector has been able to successfully handle double-digit growth rates which has powered industry and commerce as well as the increasing energy needs of the growing middle-class population in urban centers.[13] The installed capacity of the power sector has increased over fourteen-fold in the past two decades, from 5 GW in 2000 to 68 GW in 2020.[14]

[12] Data from Ministry of Industry and Trade.
[13] Per capita consumption now stands at about 1,800 kWh.
[14] Data from Vietnam Electricity.

Figure 8: Vietnam electricity user access rate and consumption per person increased rapidly



Source: World Bank staff estimates

6. Institutional and administrative arrangements were able to successfully manage growth.

Under the leadership of the Ministry of Industry and Trade (MOIT), national policies and targets were developed which focused on service delivery at the grassroot levels. The strong political commitment of the high-level authorities was executed by the vertically integrated, state-owned enterprise (SOE), Vietnam Electricity (EVN). Over the years, steady legal and regulatory reform was carried out to gradually introduce competition and to ensure long-term sustainability without jeopardizing security of supply for the fast-growing economy. This included, (i) unbundling of EVN into sub-segment specialized utilities while still maintaining state-ownership, (ii) setting prices that better reflect costs - average retail tariff stands at about $ 0.09 per kWh which covers current costs[15], (iii) promotion of private investment in power generation, and (iv) establishment of the Electricity Regulatory Authority of Vietnam (ERAV) which oversees the implementation framework towards a competitive power market with a single-buyer. The pilot phase of the wholesale electricity market was launched in 2020, while plans for retail electricity market are being prepared.

7. EVN transformed into one of the best performing power utilities in the region.

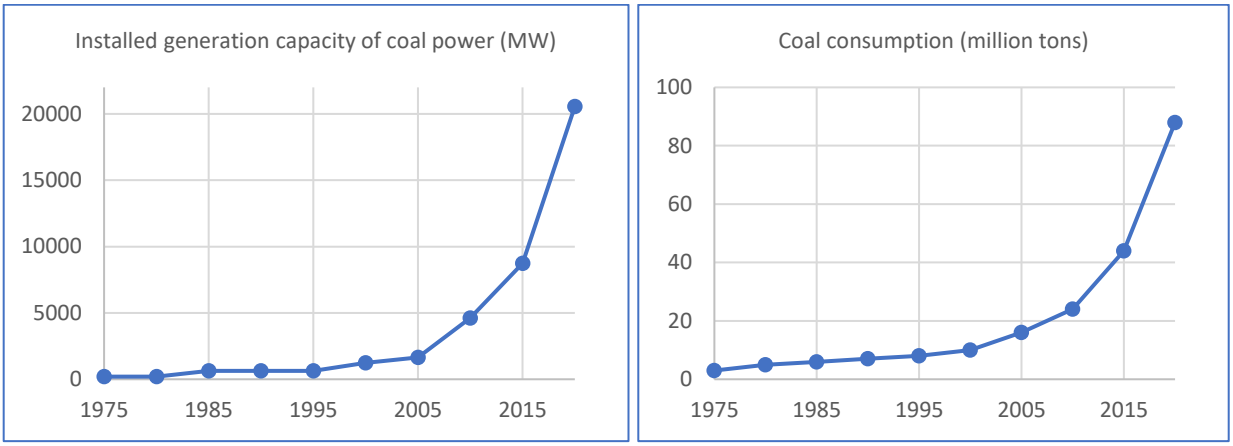
The successful development outcomes achieved by the energy sector would not be possible without its focus on capable institutions. EVN is a well-management corporation, and its skilled labor force runs the sector with technical, operational, and commercial acumen. EVN has benefited from strong sociopolitical emphasis from the highest-level down to local villages, which shared the common goal of access enhancement and network development. EVN has averted major crises of supply, despite periods of low reserve margins and seasonal outages, reliability of the power system has been steadily improving[16], technical losses are nearing global benchmarks being about 6 percent in 2020, billing and collection rates are consistently near 100 percent, and broader system performance indicators are in line with regional and international best practices. With over $ 16 billion in annual revenues, EVN is a profitable corporation and has a credit rating of BB, with stable outlook[17], which is at par with the sovereign credit rating of Vietnam.

[15] Data from Electricity Regulatory Authority of Vietnam. The tariff reforms need to continue to include cost of future investments.
[16] in 2020, momentary average interruption frequency index (MAIFI) is 1.38 per customer.
[17] Assessed by Fitch Ratings.

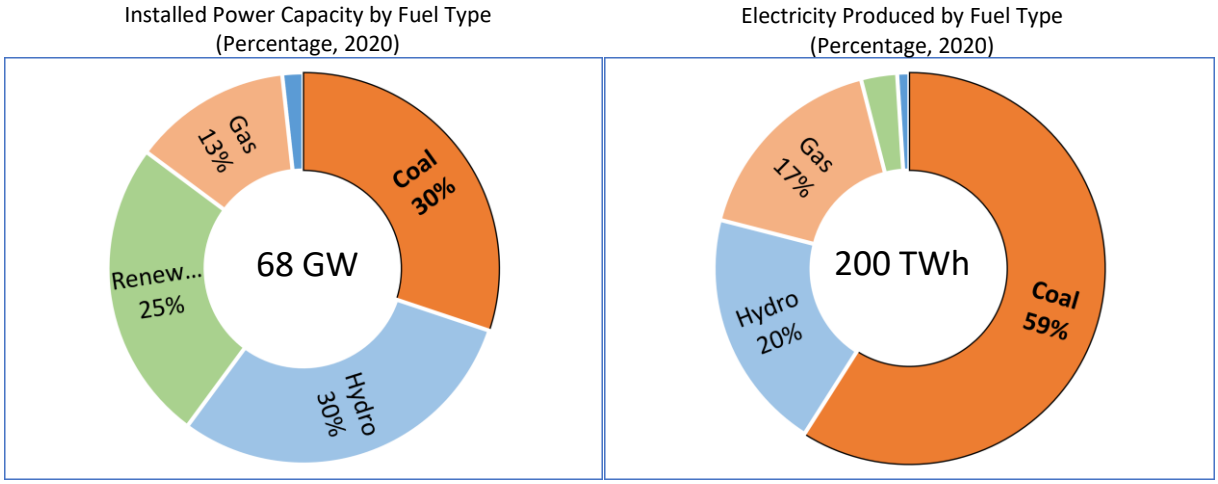
8. However, energy sector's success has increasingly relied on coal-based power supply.

While initial growth was fueled mainly by domestic hydropower resources, in the past decade, coal has become the dominant source of power generation. Vietnam's first sizeable coal-based power plants were commissioned in 1996, totaling 720 MW of installed capacity. The next large-scale coal projects would not be commissioned until late 2000s. Since then, installed capacity of coal-fired power plants has increased dramatically by four-folds, from 5 GW in 2010 to 20 GW in 2020, mostly through private-financed build-operate-transfer (BOT) projects. In 2020, coal accounted for 30 percent of installed power generation capacity, but accounted for about 60 percent of power generated. This has driven the annual consumption of coal to 88 million tons (1 percent of global consumption), compared to 135 million tons in Indonesia, and 3.8 billion tons in China. Seventy percent of coal consumed in Vietnam is used for power production.

Figure 9: Coal has become the dominant source of power generation in Vietnam



Source: World Bank staff estimates

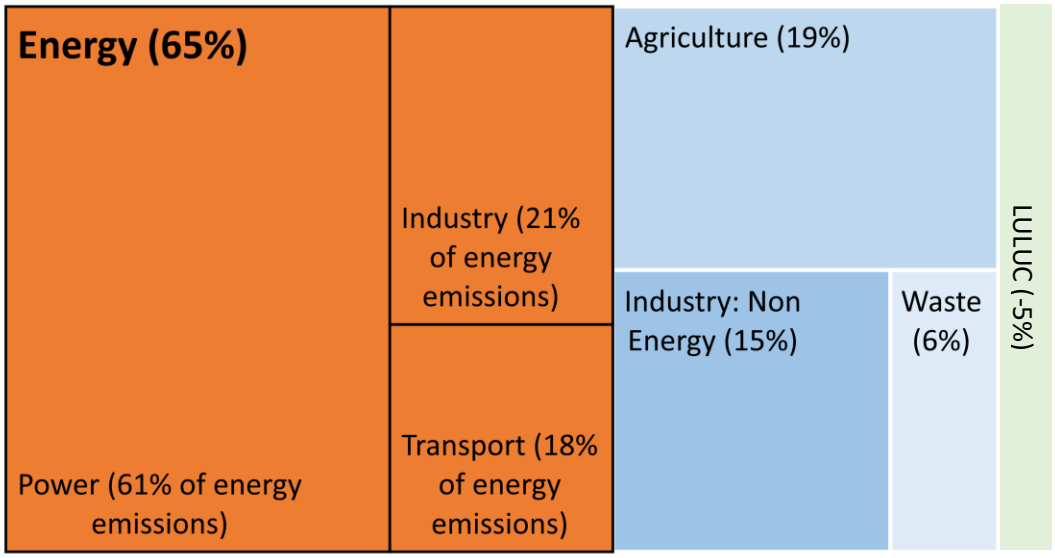


Source: World Bank staff estimates

9. Rapid rise in coal consumption has correspondingly caused dramatic increase in emissions.

During 2010-2020, Vietnam's per capita greenhouse gas (GHG) emissions increased at about 5 percent annually, which is among the highest in the world.[18] Based on estimates from last GHG inventory carried out by the government which are included in Vietnam's Nationally Determined Contributions (NDCs) as part of the Paris Accord,[19] energy sector related emissions would account for two-thirds of national GHG emissions. Of which, about 61 percent would come from the power sector alone. In addition to the global climate change related consequences of the GHG emissions, there have been severe local impacts to Vietnam - air pollution in the country's major cities that exceeds by a wide margin the health safety levels recommended by the World Health Organization (WHO) which has impacted the quality of life, and overall socio-economic well-being of the country.

Figure 10: Energy sector accounts for significant portion of Vietnam's GHG emissions



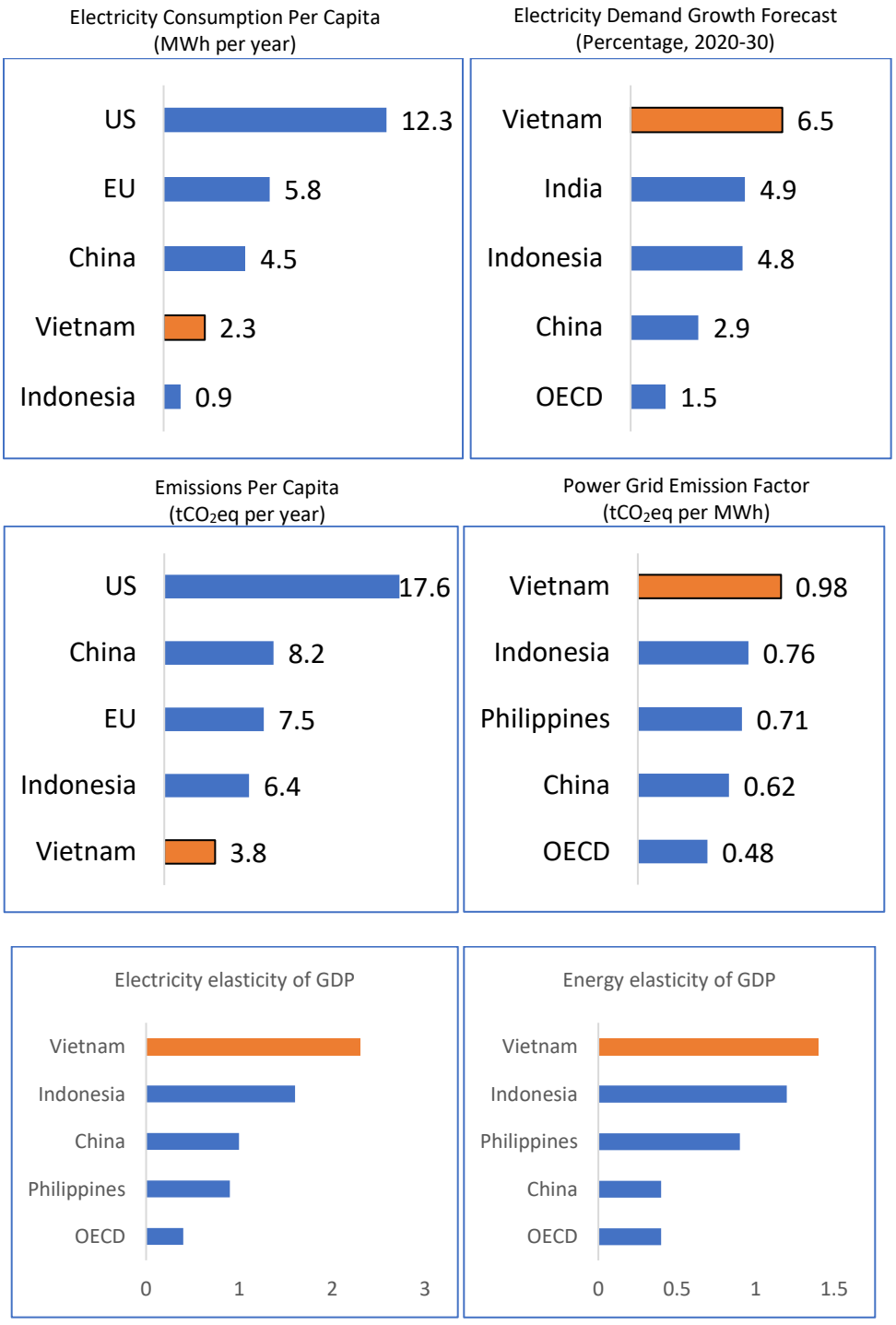
Source: World Bank staff estimates (adapted from Vietnam's NDCs)

10. Meanwhile, energy consumption has become increasingly inefficient.

Over the past decades, net reliance on domestic energy resources and a period of relatively low energy costs have driven increased energy consumption - on average, demand grew by about 12 percent annually between 1990-2010 and about 10 percent between 2010-2020. This is not only due to the rise in economic standards of consumers, but also due to inefficient electrical equipment, appliances, and industrial and commercial usage which makes Vietnam an outlier when compared to regional peers in developing Asia. Many of the large state-owned industrial enterprises, such as those in the steel, cement, and sugar industries continue to demonstrate poor energy efficiency benchmarks, while there are few policies to encouragement investment or regulatory support (both for financing and technology localization). In 2019, the energy demand elasticity of GDP was 1.4 and electricity demand elasticity of GDP was 2.3. The grid emission factor (amount of CO_2 emissions per unit of electricity consumed) was about 1 $mtCO_2e$ per MWh of electricity. Electricity consumption per capita is still low and the demand growth is expected to be faster than the regional peers.

[18] World Bank's Low Carbon Pathways Study https://openknowledge.worldbank.org/handle/10986/23522.
[19] Vietnam's latest NDC submission https://unfccc.int/sites/default/files/NDC/2022-06/Viet%20Nam_NDC_2020_Eng.pdf.

Figure 11: Demand for electricity is expected to remain high as is the carbon footprint of the grid



Source: World Bank staff estimates

Section III. The Next Phase of Growth of the Energy Sector

1. As the economy transitions to higher value-addition segments of the value chains and services sectors from the current manufacturing-led growth, a course correction to low carbon infrastructure pathways is urgently needed.

Coming decades will require a strong focus on the quality of growth of the core infrastructure sector (energy and transport), and not just the quantity of growth. The key challenges the infrastructure sector is facing include: (i) managing the transition to a cleaner and less carbon intensive solutions, (ii) ensuring adequacy of infrastructure services, and (iii) increasing efficiency and introducing new technologies to keep pace with the changing nature of the industry. Adapting to these new challenges will require a bold vision by the government authorities as well as a strong reform agenda capable of reshaping the sectors and institutional landscape.

2. Overcoming the adverse impact of the COVID-19 pandemic and taking advantage of newly emerging opportunities are priority tasks over the next 10 years.

In addition to near-term health and economic response measures, COVID-19 crisis provides an opportunity to develop a recovery pathway which is aligned with the principles of green, resilient, and inclusive development (GRID). The Government's new Socio-Economic Development Strategy (SEDS) envisions this transformation to green growth and prioritizes low carbon pathways for core infrastructure sectors. The SEDS also recognizes the strong linkages to reform and private sector participation which are key building blocks for building back better. Given the global trends towards green sourcing, low carbon infrastructure transition will be a necessary precondition for maintaining the competitiveness of Vietnam's economy in the future.

3. In the coming decade, the demand for electricity is expected to continue to grow rapidly.[20]

This would mean that the energy sector needs to double in size in just 10 years, with the decarbonization of the transport sector via electric vehicles. This phase of anticipated rapid growth will require much higher annual investments in the power sector in the coming years. There is consensus among the concerned government authorities, that the traditional delivery mechanisms focusing on SOE -led public investments will not be able to meet this need. Aggressive reforms must be carried out to improve planning, transparency, competitiveness, and the financial viability of the sector to crowd in private sector investment.

4. The Revised Power Development Plan 7 presented a plan which would continue the domination of coal-fired electricity generation.

As economic development is the government's priority, the cost of electricity generation needs to stay as affordable as possible. In 2016, it led to a decision to promote important new investments in coal generation in the country as presented in the Revised Seventh Power System Development Plan (Revised PDP7). With expected 6-7 percent demand increase per year, the installed generation is expected to almost triple in ten years. According to the Revised PDP7, the coal share in the energy mix was expected

[20] Except for 2020 as COVID-19 has slowed the demand growth to about 4 percent.

to increase from 20 GW in 2020 to about 55 GW in 2030. While this was a reduction from original PDP7 which planned for 75 GW of coal-fired power capacity, it would still nearly triple the installed capacity of coal power plants between 2020 and 2030.

Table 2: Vietnam's Projected Power Generation Mix (per previous master plans)

Year	2030	
	PDP7	Revised PDP7
Total capacity (MW)	**146,800**	**129,500**
Coal	75,749	55,300
Gas	17,300	19,000
Hydropower	17,322	25,400
Wind	6,200	6,000
Solar	5,600	12,000
Biomass	2,000	3,250
Storage	5,725	2,400
Imports	7,190	1,550
Nuclear	9,690	4,600

Sources: Adapted from MOIT data

5. Based on historic trends, GHG emissions would double between 2020 and 2030.

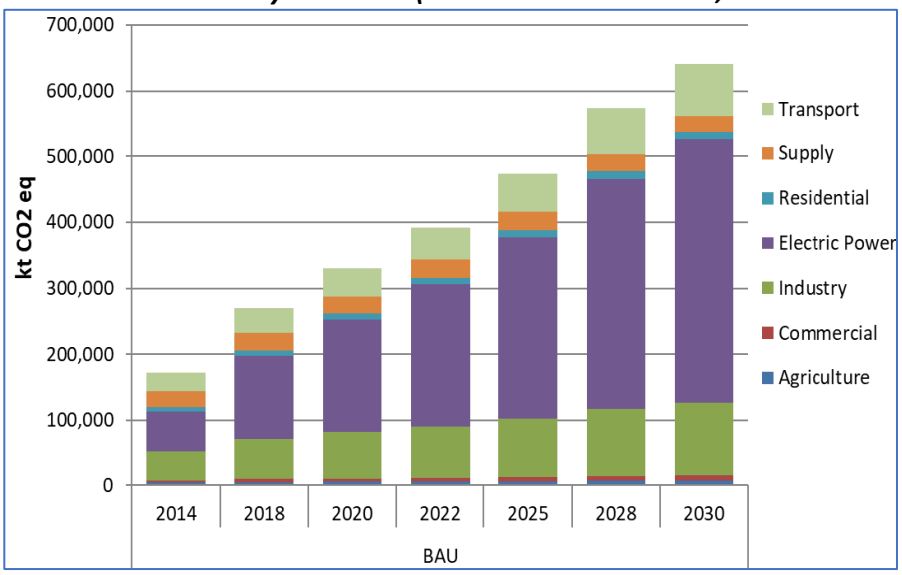
Modeling exercise conducted with the Government of Vietnam (based on GHG data collected in advance of the 2015 Paris Accord)[21] noted that the national emission would double between 2020 and 2030. Of the total national emissions, around 65 percent of these GHG emissions were expected to come from the energy sector, of which, 61 percent would be from the power sector, 21 percent from industries, and 18 percent from transport. Based on the Revised PDP7 the power sector would continue as the largest share of GHG emissions of Vietnam. While much progress has already been made since these estimates were produced, there is still more work to be done. The elasticity of electricity to GDP is about 1.8 and is a clear indicator of the high energy intensity (which stands at 5.9 MJ per GDP) in Vietnam.

Box 2: Impact of Carbon Border Adjustment Mechanisms

Carbon Border Adjustment Mechanisms (CBAM) are already in place in some regions around the world, such as California, where an adjustment is applied to certain imports of electricity. Several countries such as Canada and Japan are planning similar initiatives. The European Union (EU) is the latest to have announced that they would implement such mechanisms as a key measure to fight climate change. EU importers will buy carbon certificates corresponding to the carbon price that would have been paid, had the goods been produced under the EU's carbon pricing rules. Conversely, once a non-EU producer can show that they have already paid a price for the carbon used in the production of the imported goods in a third country, the corresponding cost can be fully deducted for the EU importer. The CBAM will help reduce the risk of carbon leakage by encouraging producers in non-EU countries to green their production processes. Vietnam by not reducing its GHG emissions/carbon intensity will be financially impacted in its imports to the EU that represents between 15 and 20 percent of its exports. From a financial perspective, it is critical that Vietnam reduces its carbon intensity for the goods that will be impacted first by the new mechanisms, namely: cement, iron and steel, aluminum, fertilizers, and electricity. In the event where Vietnam would decide to develop a carbon tax and therefore if importers to the EU can prove, based on verified information from third country producers, that a carbon price has already been paid during the production of the imported goods, the corresponding amount can be deducted from their final bill and would ensure Vietnam's competitiveness.

[21] Vietnam's latest NDC submission https://unfccc.int/sites/default/files/NDC/2022-06/Viet%20Nam_NDC_2020_Eng.pdf.

Figure 12: Projected GHG Emissions by Subsector (between 2014 and 2030, based on historic trends)



Source: MOIT presentation, adapted by World Bank staff

6. The Government is now demonstrating a strong commitment to renewable energy and energy efficiency.

At COP-26 in November 2021, Vietnam announced its commitment to achieve net-zero emissions by 2050 and to phase out the use of coal in power sector by the 2040s. These new commitments will require a careful review and assessment of power generation mix and actions within the broader energy sector.

In December 2020, Vietnam submitted its updated Nationally Determined Contribution (NDC) to United Nations Framework Convention on Climate Change (UNFCCC). The NDC unconditionally aims to reduce Greenhouse Gas (GHG) emissions by 9 percent by 2030. The GHG reduction target increases to 27 percent by 2030 if Vietnam gains access to sufficient international financial resources, capacity building and enabling technologies.

In its NDC, Vietnam has committed to: (i) increasing the share of renewable energy in the total primary energy supply to 15-20 percent by 2030 and 25-30 percent by 2045; and (ii) increasing electricity savings in the commercial sector to more than 10 percent of overall power consumption by 2030. The Polit Bureau recently adopted *Resolution 55,* which lays out a vision towards a low carbon development pathway for the energy sector which would be primarily led by the private sector, with EVN expected to own around 20 percent of power generation assets by 2030.

The upcoming *Eighth Power Sector Development Plan 2021-2030 with a vision to 2045* (PDP8)[22] builds on this strategy and is expected to further reduce planned coal-fired power generation capacity. The shift away from coal is also taking in account increasing constraints on coal project development, in particular the difficulty of securing international financing and resistance by some Provinces and local communities. Despite this, installed capacity of coal would still increase from 2020 to 2030 under the draft PDP8.

[22] Assessment in this note is based on the draft of the PDP8 as per September 2021.

Table 3: Vietnam's Projected Power Generation Mix (based on upcoming master plan)

Year	2030				
	PDP7	Revised PDP7	Change (PDP7 vs Revised PDP7)	Draft PDP8	Change (Revised PDP7 vs Draft PDP8)
Total capacity (MW)	**146,776**	**129,500**		**137,700**	
Coal	75,749	55,300	-27%	37,300	-33%
Gas	17,300	19,000	10%	28,500	50%
Hydropower	17,322	25,400	47%	25,000	-2%
Wind	6,200	6,000	-3%	18,200	203%
Solar	5,600	12,000	114%	18,650	55%
Biomass	2,000	3,250	63%	3,150	-3%
Storage	5,725	2,400	-58%	1,200	-50%
Imports	7,190	1,550	-78%	5,700	268%
Nuclear	9,690	4,600	-53%	0	-100%

Source: PDP7 and PDP8, adapted by the World Bank staff

In addition, the draft PDP8 envisages a massive scale-up of variable renewable energy (VRE) technologies making them the largest installed capacity category. Further emphasis is also being given to regional power trade utilizing excess hydropower imports from Laos and China, and development of the natural gas sector, in particular battery storage deployment and liquified natural gas (LNG), as a vital bridging fuel for balancing the system. The Government has also launched the third Vietnam National Energy Efficiency Plan (VNEEP3), which includes energy consumption reduction targets of 8-10 percent by 2030. The VNEEP3 will reduce the sector's GHG emission by 30 percent by 2030.

7. Deployment of solar and wind power plants is already showing signs of success.

The Government has incentivized independent power producers (IPPs) to develop VRE projects through a feed-in-tariff (FIT) policy. The premium purchase pricing under the FIT policies has driven strong growth of ground-mounted/rooftop solar and wind, leading to an installed capacity of over 25 GW (solar in GWdc) in 2022.

Nearly 10 GWdc of ground-mounted solar photovoltaic (PV) based power plants were installed in the past two years, mainly through domestic private sector led investments, making it the fastest growing market in the region.

Rooftop PV deployment is also expanding with over 10 GWdc installed in Vietnam to date. The green economy spurred by this transition to clean energy can have positive side-effects of creating high-paying jobs and further development of Vietnam as a regional hub for this emerging industry. In the last two years, about $ 25 billion in private investments were made in new solar and wind projects. Based on a World Bank analysis, around 80,000 jobs were created for the existing solar projects including 45,000 full-time jobs in project development, services, and O&M annually, and 35,000 full-time jobs in manufacturing.[23]

[23] World Bank, 2018, Assessment of Vietnam's Solar PV Supply Chain. Washington, DC: World Bank. *http://pubdocs.worldbank.org/en/301671539903264866/Vietnam-Solar-PV-Supply-Chain-Assessment-10May2018.*

8. As the sector grows, the Government of Vietnam aims to introduce competitive bidding between IPPs to reduce the cost of generation.

The move away from the FIT policy will bring economic benefits to the sector and consumers by attracting more experienced developers, lowering the cost of capital, reducing construction and equipment costs, thus reducing the cost of power from new VRE projects. The World Bank has supported the development of the legal, technical, and financial framework for competitive bidding for solar and is now providing transaction advisory support for a 500 MW pilot phase for a solar tender planned for 2022. In addition, the World Bank is supporting the development of offshore wind in Vietnam through policy advice and potential technical and transaction support.

9. However, further expansion of solar and wind energy is being constrained by the limitations of the power grid, with existing VRE projects experiencing a high rate of curtailment.

The existing publicly managed grid network has not been able to keep pace with RE deployment by private developers and will fall further behind unless urgent investments are carried out. The main challenges related to the integration of VRE include the limited power transfer capacity of the grid from production to consumption locations, as well as ability of the grid operator to balance the variable nature of VRE supply with enhanced flexibility. As a result, despite the positive outlook for higher levels of VRE capacity, between 15 and 25 percent of the output from existing projects is being curtailed,[24] reaching as high as 80 percent for some solar projects – in the South of Vietnam.

Public investment in grid integration and new technologies is required to support the transition to a 'VRE-friendly' grid which significantly reduces integration costs in the long-term. Grid reinforcements supporting VRE integration (as per the least-cost transmission plan) in Vietnam include: (i) addition and/or replacement of transmission lines and substations; (ii) equipment for smoothing the voltage and frequency issues, such as capacitor banks, battery storage, and reactive power compensators, together with flexible alternating current transmission systems (FACT); and (iii) equipment for faster and more efficient grid operation, such as monitoring systems, demand and production forecasting systems, and automats for controlling generation units and grid operations through automatic generation control and automatic voltage control with a strong supervisory control and data acquisition (SCADA) system.

The capacity of the transmission system and ability of the system to dispatch the generated power are critical bottlenecks to any new VRE project in Vietnam. The Vietnamese system needs to be strengthened, made more flexible from a dispatch perspective, and made more reliable.

10. The Government has increased its emphasis on energy efficiency and industries in the NDC.

Vietnam's revised 2020 NDC has clear mitigation measures for industries, for instance implementing measures for grinding blast furnace slag, fly ash, pozzolana and limestone to replace clinker in cement production; and reducing the consumption of hydrofluorocarbons.

The Government has launched the third Vietnam National Energy Efficiency Plan (VNEEP3), which includes energy consumption reduction targets of 8-10 percent of total national electricity consumption from 2019 by 2030 against the energy demand forecast in the National Power Development Plan 2011-2020 with consideration up to 2030. If successfully implemented, VNEEP3 would reduce the sector's GHG emission

[24] Curtailment is the inability of the system to utilize all available generation when available.

by 30 percent by 2030. About 60 percent of the industrial sector final energy consumption reduction would come from efficient and new technologies based on electricity savings. These savings can be achieved through high efficiency boilers, furnaces, and motors, along with measure such as efficient lighting and air conditioning, as well as through innovative and low carbon technology adoption. The iron and steel, cement, food and tobacco, textiles and leather sub-sectors are expected to provide the largest final energy consumption reductions by 2030.

11. Energy efficiency targets' implementation actions and enforcement will be critical.

With respect to the industrial sector, the availability of emission data is a critical requirement for Vietnam to enforce its NDC and energy efficiency targets. In addition, MOIT has issued a series of regulations, such as energy auditing and reporting of energy consumption data by the Designated Energy Users once every three years or reporting of compliance of specific energy consumption by the industrial enterprises from key energy intensive sectors on an annual basis. Unfortunately, those regulations have not achieved the desired results due to the lack of institutional enforcement and monitoring tools, such as an established system for data collection, reporting, monitoring, and verifying (MRV).

Section IV. Options for Decarbonization of the Energy Sector

1. This section examines different decarbonization pathways available to Vietnam's power sector in the context of national and global climate goals.

This section examines options for decarbonization of Vietnam's power sector in the context of national and global climate goals. The analysis presents power sector decarbonization pathways extending beyond the historic trends that have the potential to significantly reduce GHG emissions, while preserving affordability and generating environmental and economic co-benefits consistent with a more competitive economy. First, an overview of the modelling approach and scenarios is presented. This is followed by a discussion of trends in Vietnam's power sector CO_2 emissions, electricity generation costs, global and local environmental damage costs, investments, adoption of different generation options and technologies under different scenarios. Finally, the key uncertainties surrounding these decarbonization pathways are discussed.

2. Current Policy and Accelerated Decarbonization Scenarios are examined using World Bank's Electricity Planning Model.

The World Bank Electricity Planning Model (EPM) is a least-cost planning and dispatch model which is used to run decarbonization scenarios over the period 2020–2040. The analysis uses a state-of-the-art optimization platform which simulates current sector performance and realistic projections between 2020 and 2040 for: (i) energy demand growth, and (ii) cost and applicability of supply side technology options; to identify pathways which: (a) remain within emission thresholds, (b) ensure security of supply, and (c) maintain a reasonable cost of supply. Four scenarios were assessed: placing a constraint of (i) 20 percent, (ii) 40 percent, (iii) 60 percent, and (iv) 80 percent emission reductions in the power system.

This section provides detailed comparison of the Accelerated Decarbonization Scenario (ADS). The ADS draws on the information regarding national energy and climate plans and the policies that are proposed to underpin draft PDP8.[25] The ADS corresponds to the expansion plan that consistent with an 80 percent reduction from the EPM base case.

The ADS is aligned with Vietnam's net-zero emission pathway.

Box 3: World Bank Electricity Planning Model

The World Bank EPM is a multi-year mixed-integer programming model for capacity and dispatch analysis. The EPM considers chronological load curves for representative days for each year, solar/wind hourly profile for these days, spinning reserve requirements, and hydropower energy constraints. It is a least-cost optimization model with inputs capturing renewable resource availability, hourly demand profile and forecast, and the technical and cost parameters of infrastructure including plants and power lines. The model will display the optimal investment plan by simulating the economic dispatch in the given period. It also provides utilization rates of plants and power lines, energy trade between zones (countries), and system-wide carbon emissions.

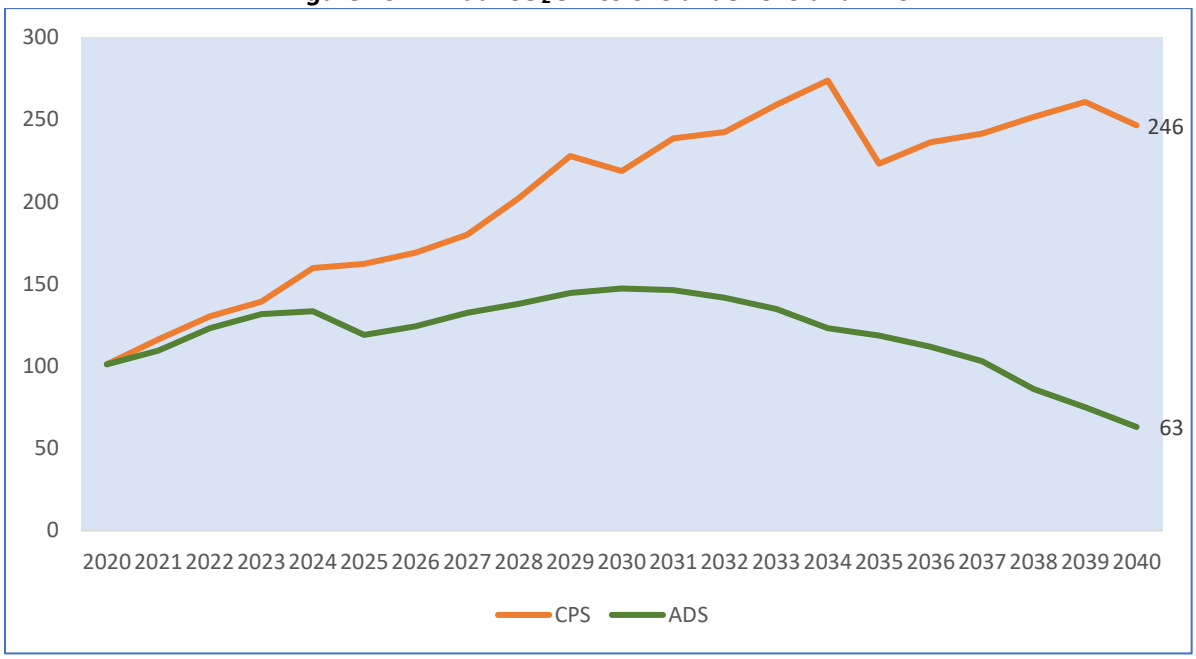
[25] As per data available in September 2021.

3. ADS delivers 74 percent less carbon reductions than CPS in 2040 with significant local and global environmental co-benefits.

A. CO_2 emissions

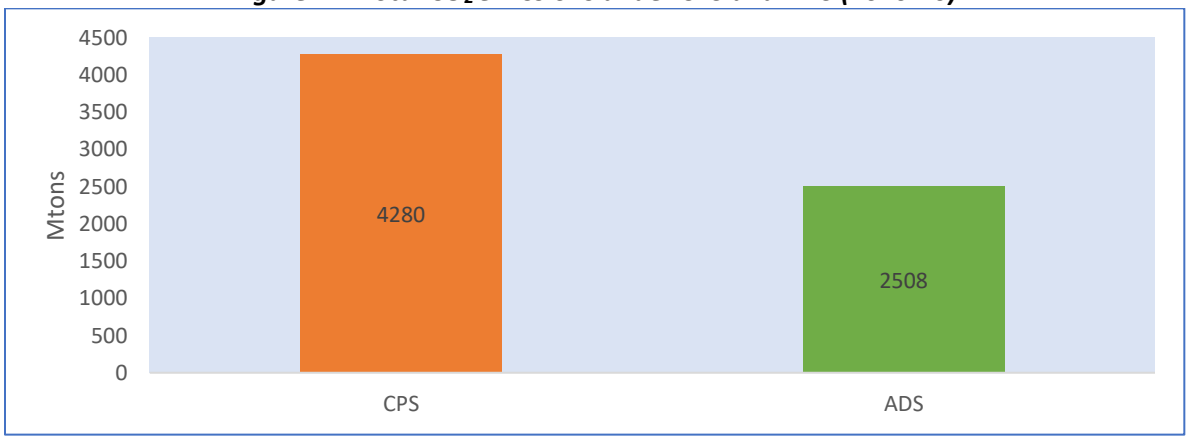
The CO_2 emission trajectory for Vietnam's power sector continues its upward trajectory in the CPS, reaching 246 $MtCO_2e$ in 2040. The CO_2 emissions under the ADS are about 80 percent lower than the CPS. Total emissions over 2020-40 are 4,280 $MtCO_2e$ under CPS and 2,514 $MtCO_2e$ under ADS.

Figure 13: Annual CO_2 emissions under CPS and ADS



Source: Power Sector modeling carried out by the World Bank staff

Figure 14: Total CO_2 emissions under CPS and ADS (2020-40)



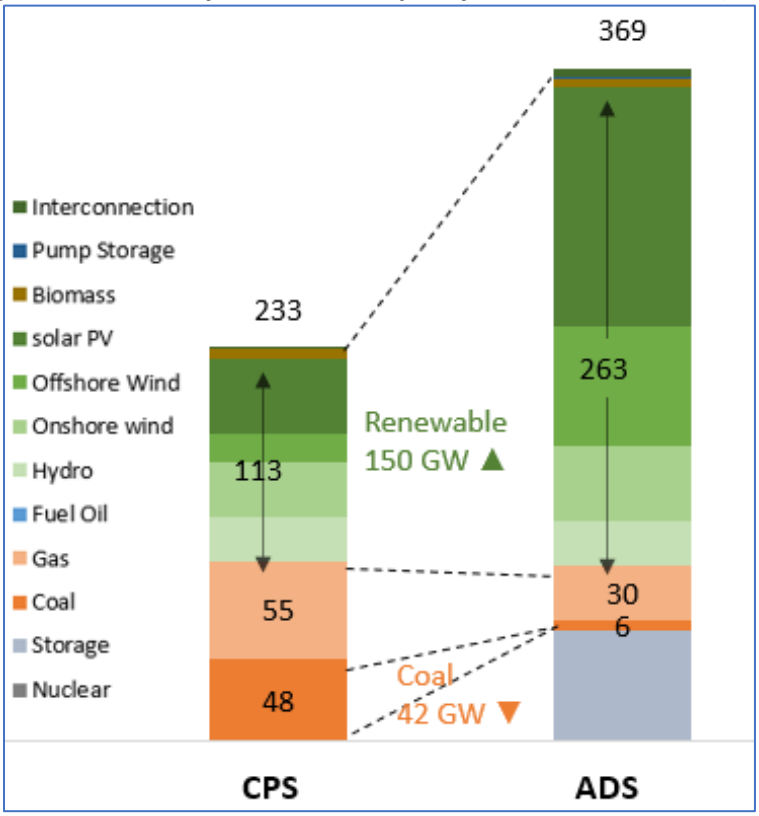
Source: Power Sector modeling carried out by the World Bank staff

B. *Electricity generation and capacity mix*

The ADS is consistent with significant VRE capacity in the generation mix. The lower capacity factors of renewable energy technologies and the need to include battery storage to counteract their short-term variability explains the increase in total generation and storage capacity requirements in 2040. However, the costs of integrating solar generation increases with its penetration on account of the additional capacity, storage and grid investments needed to meet demand reliably up to not being cost competitive with other generation options. The scenario analysis indicates that at least some level of baseload fossil fuel generation is needed in all decarbonization scenarios to meet electricity demand reliably and ensure affordability of electricity.

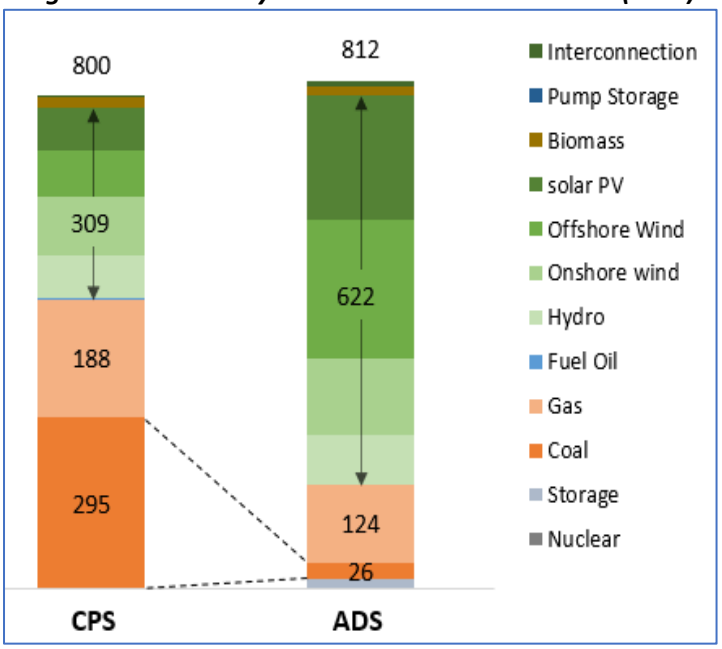
Onshore and offshore wind plays an important role in both scenarios. Off-shore wind capacity increases significantly in ADS: in 2040, 67 GW of offshore wind is installed in Vietnam in ADS compared with the 15 GW of in CPS. In 2040, wind accounts for 42 percent of the generation in ADS compared with 21 percent in CPS. Storage capacity, needed to tackle the variability and the uncertainty of wind and solar PV generation, is deployed in all scenarios. Storage contributes to spinning reserves and balances short-term fluctuations in variable generation output.

Figure 15: Electricity Generation Capacity under CPS and ADS (GW)



Source: Power Sector modeling carried out by the World Bank staff

Figure 16: Electricity Generation under Scenarios (TWh)

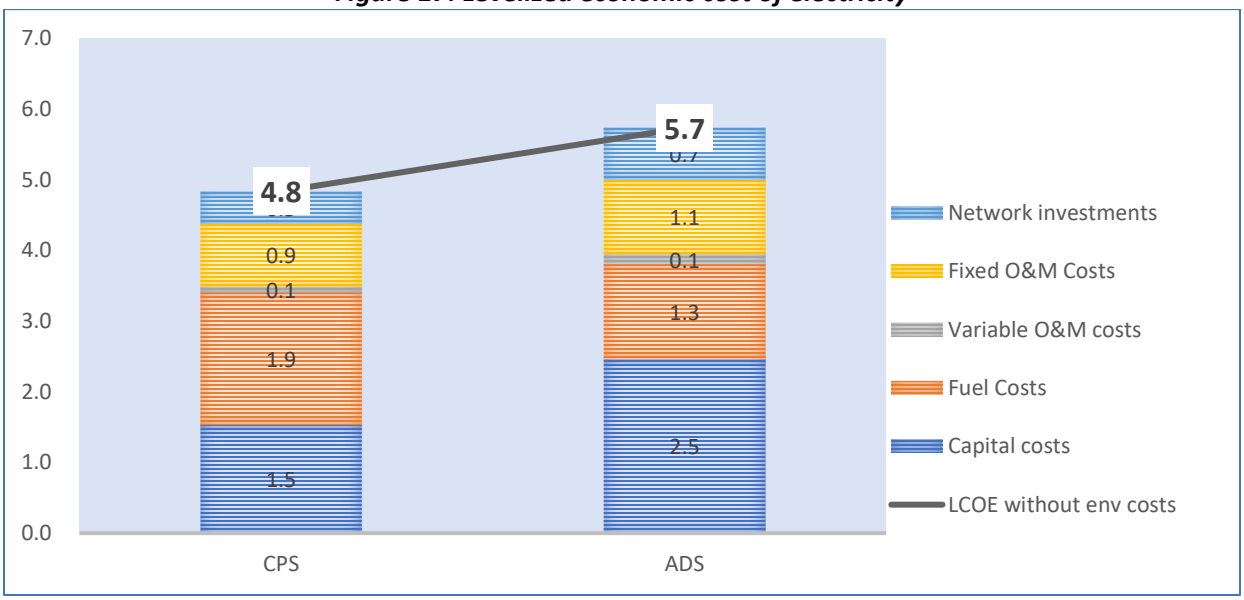


Source: Power Sector modeling carried out by the World Bank staff

C. *Electricity generation costs*

The CPS delivers the least-cost generation plan if environmental costs of fossil fuel generation are not considered while ADS becomes cost competitive if local and global environmental costs are considered. The levelized cost of electricity (LCOE) in CPS is $ 4.8 cents, which is 16 percent lower than the $ 5.7 cents LCOE in ADS, on average between 2020-2040. However, in 2040 it will be 25 percent higher in ADS versus CPS.

Figure 17: Levelized economic cost of electricity



Source: Power Sector modeling carried out by the World Bank staff

The ADS changes the composition of generation costs, increasing the share of capital expenditures (capex) while reducing that of variable operational and maintenance (O&M) and fuel costs. The capex-intensity of renewable energy technologies makes the overall cost structure more front-loaded in 2040: the share of capex and fixed O&M increases to 70 percent in ADS over 2020-40 compared to 55 percent in CPS. Share of variable operational cost (opex) including fuel falls to 30 percent in ADS from 45 percent in CPS. As expected, the average annual system expansion and operation costs is higher for ADS than CPS. The cost differences become more significant towards the end of the time horizon but are still significant before 2030 when there are fewer options to decarbonize.

Table 4: Present Value of Total System Cost under CPS and ADS scenarios (US$ billion, constant 2019 US$)

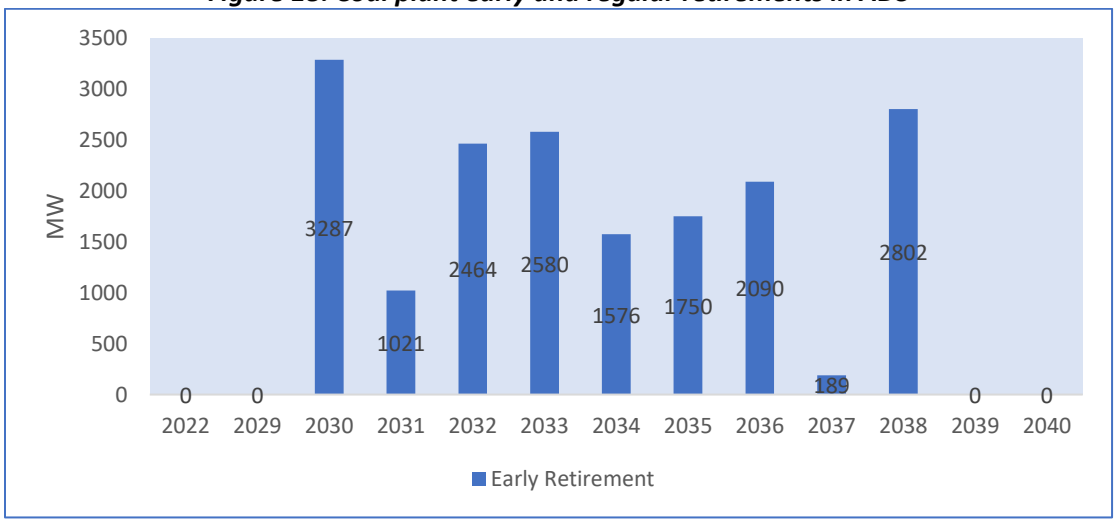
Item	CPS	ADS
Capital costs	$84	$128
Fuel Costs	$102	$70
Variable O&M costs	$5	$7
Fixed O&M Costs	$49	$55
Local environmental damage costs	$35	$21
Global environmental (GHG) damage costs	$109	$69
Network investments	**$25**	**$38**
Total System Costs	**$409**	**$387**
Total System Costs (excl. local env. damage costs)	**$374**	**$366**
Total System Costs (excl. local and global env. damage costs)	**$264**	**$297**

Source: Power Sector modeling carried out by the World Bank staff

D. Stranded costs of coal plants

In ADS, about 5 GW of coal power plants are retired after reaching their technical lifetime and an additional about 15 GW of are retired early as the most cost-effective means to achieving 80 percent carbon reductions, with an economic cost of $ 12 billion. However, these early retirements also deliver economic benefits through avoided local and global environmental damage costs.

Figure 18: Coal plant early and regular retirements in ADS



Source: Power Sector modeling carried out by the World Bank staff

The estimates of early coal plant retirements are conservative given the limitations of the modeling approach used in the analysis. With EPM, as with the other current models and databases, the short-term flexibility of coal and gas-fired combined cycle power plants and their ability to counteract the variability of wind and solar plants are likely overstated. A more accurate representation might thus reduce the value that these plants deliver to the system, leading to increased retirements.

4. Implied price of carbon for ADS to be same as CPS.

Global environmental damage costs of GHG emissions are valued using the low estimate of social value of carbon recommended by the World Bank. These recommendations value carbon emissions at $ 40 per ton in 2020 increasing to $ 78 per ton in 2050. As noted above, the present value of system costs of CPS and ADS are $ 409 billion and $ 387 billion over 2020-40, respectively. Sensitivity analysis on the Social Value of Carbon indicates that Vietnam would have to value GHG emission reductions at $ 25 per ton or above through to 2040 to prefer the generation expansion plan in the ADS over the generation expansion plan in CPS.

5. Key uncertainties, risk factors, enabling condition for achieving decarbonization.

Ambitious decarbonization in ADS is contingent on enabling policy, market and social conditions to shape the incentives of sector participants: (i) the costs of technologies underpinning the transition (solar, wind, battery energy storage systems to continue to become favorable), (ii) sector participants show the willingness and ability to make the necessary behavioral changes to transition to new technologies and business models, (iii) policy conditions are created both domestically and internationally to ensure that environmental externalities of fossil fuel generation are reflected in their prices, (iv) sufficient resources (including concessional resources) are made available for network investments to support the energy transition, and (v) economic and social disruption resulting from the transition are managed effectively. The ADS will be difficult to achieve if one or more of these conditions are not place. The cost of achieving ADS in Vietnam is significant but not prohibitive. Additional analytics are to be developed to fully assess the economic benefits (e.g., health, environment, competitiveness) of the clean energy transition and its trade-offs.

At the same time, this analysis takes a conservative approach to options for emissions. Carbon capture, utilization and storage and other relatively high-cost options for reducing emissions are not considered in the analysis. If these technologies advance rapidly and become cost effective relative to other options, it will be possible to achieve higher emission reductions. Some degree of energy efficiency and conservation are built into electricity demand projections used in the different scenarios. However, there is potential to exceed these targets by changing consumer behavior, leveraging digitalization initiatives and demand response programs, capitalizing on synergies with electric mobility and end-use electrification initiatives. These can help increase the level of emission reductions. The synergies between renewable energy development and hydrogen are not considered in the analysis either. However, this remains an area of immense potential that can help increase the viability of and deployment of RE technologies and help deliver reduction in emissions.

Section V. Implications and Opportunities of Low Carbon Pathways

1. ADS has important implication and opportunities for Vietnam.

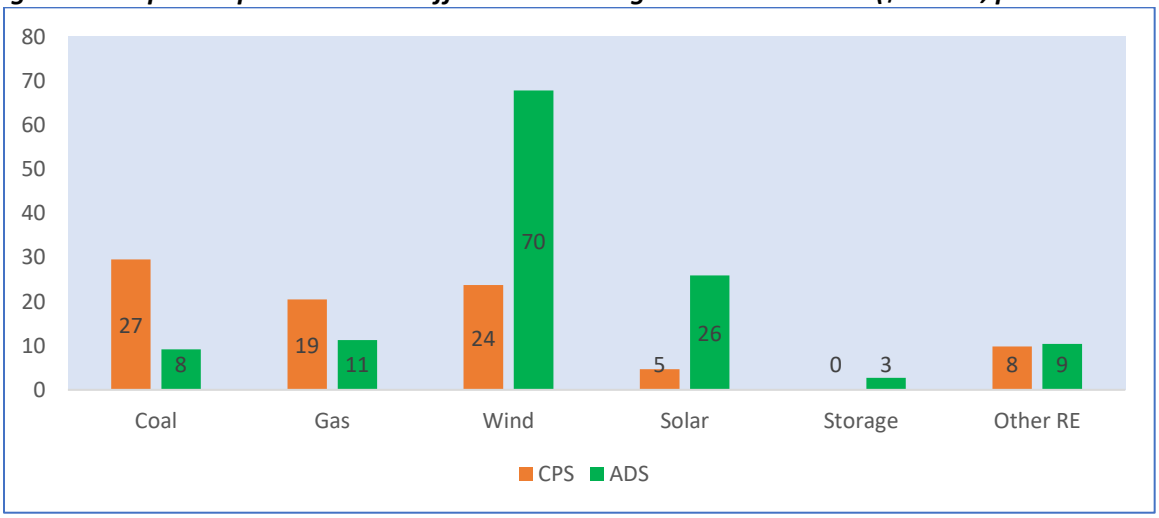
The ADS will require more of both public and private investment. Concessional finance will be important for ensuring affordability and managing social and economic disruptions of the energy transition. Vietnam must put in place an effective regulatory framework to shape incentives towards ADS. This can unlock opportunities for Vietnam in several areas. It can contribute towards making Vietnam's economy more efficient, enhance its competitiveness and deliver environmental co-benefits by lowering air pollution. Gains in clean energy employment could potentially offset the loss of employment in fossil fuel production and generation if manufacturing in clean energy is being promoted. As the gains will not always occur in the same place, or match the same skill set, as job losses, it will be important to train workers to capitalize on opportunities in new areas and to institute adequate social safety mechanisms for displaced workers. ADS will also have implications for Vietnam's higher education, TVET, R&D, entrepreneurship.

2. Several fold increase in investment in RE technologies is needed to make ADS happen.

The radical transformation of the Vietnam's power system required to achieve ADS in 2040 depends on a big expansion in investment and a shift in investment to renewable energy technologies. The present value of upfront capital investment required in ADS is $ 166 billion over 2020-40 compared to $ 109 under CPS. Capital investments equal 4.5 percent of GDP per annum in ADS over 2020-40 compared with 3.3 percent of GDP under CPS.

The shift in what capital is spent on leads to capital investments of more than $ 96 billion in solar and wind generation over 2020-40 compared with $ 29 billion under CPS. Annual investment in fuel supply however is lower in ADS: $ 70 billion over 2020-40 compared with $ 102 billion in CPS. The large increase in capital investment in ADS is partly compensated for by lower operating expenditure. Operating costs account for a large share of the total costs of fossil fuel generation: the clean technologies that play an increasing role in the ADS are characterized by much lower operating costs.

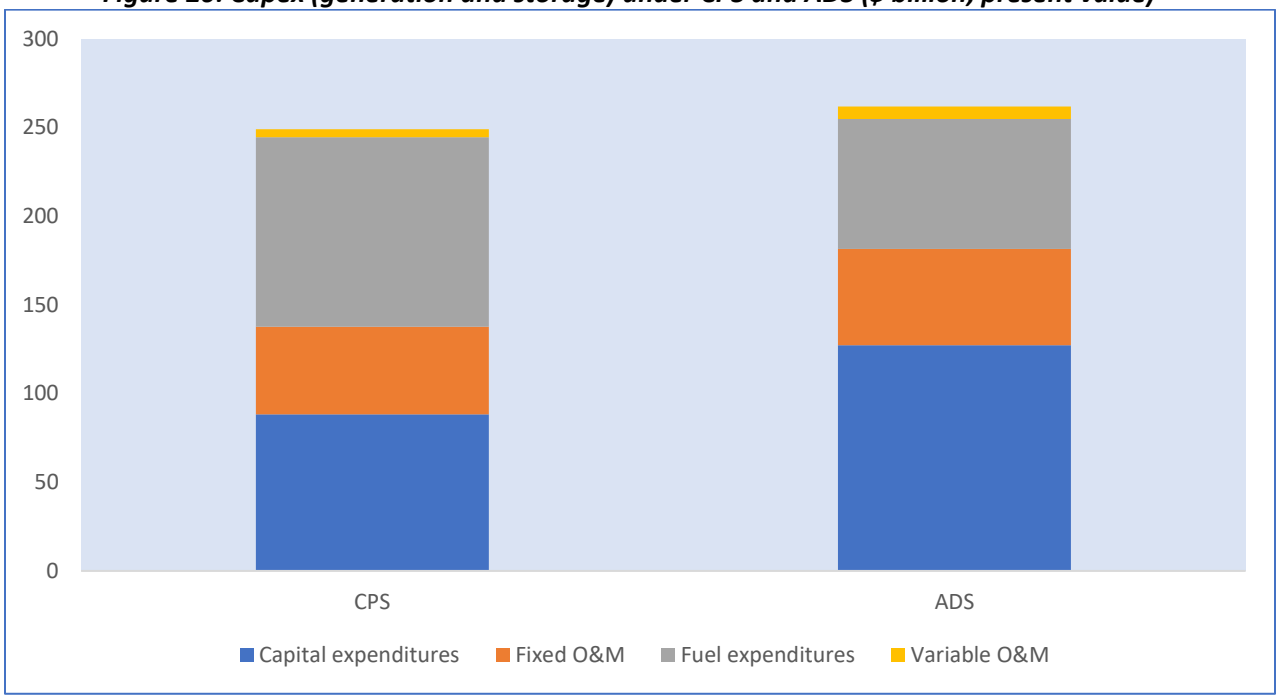
Figure 19: Capital expenditures on different technologies in CPS and ADS ($ billion, present value)



Source: Power Sector modeling carried out by the World Bank staff

In addition to more investment in electricity generation, there is an increase in investment in expansion and modernization of electricity networks under ADS. The present value of investments needed in network infrastructure is $ 38 billion over 2020-40 in ADS compared with $ 25 billion under CPS. Such investments are needed to ensure electricity security in the face of rising electricity demand and the proportion of variable generation in the power mix.

Figure 20: Capex (generation and storage) under CPS and ADS ($ billion, present value)



Source: Power Sector modeling carried out by the World Bank staff.

3. Both private and public finance is needed. Concessional finance can help ensure affordability, help manage economic and social disruptions and be used to pilot new technologies and approaches.

Financing the investment needed in ADS involves redirecting existing capital towards clean energy technologies and substantially increasing the overall level of investment. Most of this increase in investment can be expected to come from private sources, mobilized by public policies that create incentives, set appropriate regulatory frameworks, and reform energy taxes. However, direct government financing will also be needed to particularly boost the development of a smart grid and to accelerate innovation in technologies that are in the demonstration phase and lack an established track record. Policies that ensure a predictable flow of bankable projects have an important role in boosting private investment as do the scaling up of concessional debt financing and the use of development finance.

Overall, an estimated two-thirds of sector investments under the ADS, or about $ 230-240 billion between 2020-2040 (undiscounted), can be mobilized from the private sector.

a. This will be driven mainly by the power generation segment where most of the new power plants are already being developed and financed by the private sector. EVN aims to own less than 20 percent of the power generation assets by the end of the decade.

b. However, investment frameworks need to continue to evolve based on market realities. This would include implementing auctions for procurement of renewable energy projects, implementing the 2020 *Public Private Partnership Law* with provisions for transparent project selection criteria, simplified review and approval procedures, and mobilization of government support, where necessary (for instance, through guarantees).
c. The contracting architecture should reflect risk allocations conforming to prevailing local conditions and international best practices to attract new sources of financing. Greater use of non-recourse project-financing can accelerate foreign direct investment (FDI) and lower the cost of capital for power sector projects.
d. There are additional opportunities for the private sector to participate in the clean energy transition in the medium-term: green bonds issued by sector utilities (SOEs), equitization and recycling of existing sector assets, selected transmission & distribution segments (which could be opened for private sector), as well as the energy efficiency market.

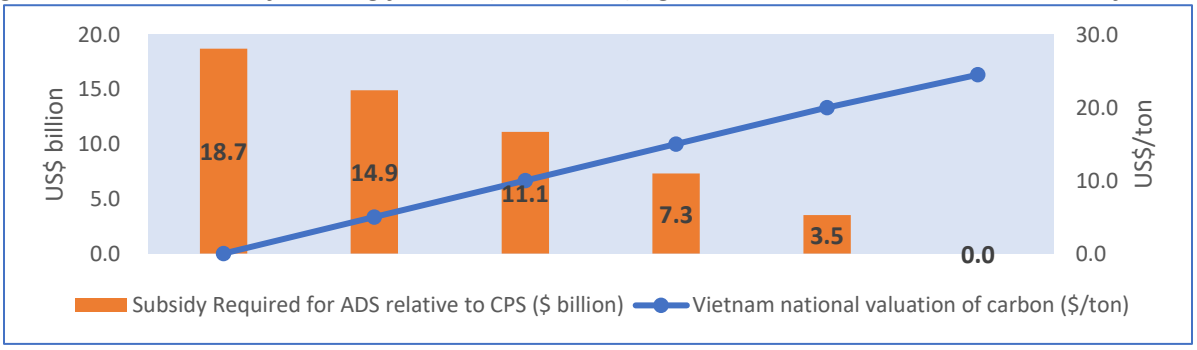
Complementary public investments under the ADS, estimated at $ 110-120 billion between 2020-2040 (undiscounted), would need to be mobilized and should be typically planned and deployed ahead of the private sector to de-risk projects and encourage investment.

a. Power transmission & distribution capacity expansion and flexibility enhancement will remain as the key areas of public investment and would be led by SOEs.
b. SOE-led investments may be needed for selected strategic national power generation assets (e.g., hydropower, LNG) required for system development and energy security.
c. It would be important that the roadmap of reforms for energy sector SOEs is implemented based on the long-term goals of improved performance, transparent environmental and social reporting, and improved corporate governance to streamline public investments.

4. There is strong economic case for increasing Vietnam's access to concessional funds to enable it to pursue a decarbonization pathway consistent with ADS.

The total system cost of ADS is $ 22 billion higher in present value terms (constant 2019 $) over 2020-40 than the total system costs of CPS after the consideration of local environmental externalities. Vietnam would have to value carbon emission reduction at $ 25 per ton to be indifferent between ADS and CPS. If Vietnam national valuation of emission reduction is $ 0 per ton, it would need a subsidy of $ 19 billion in present value terms in the form of concessional resources to be indifferent between ADS and CPS.

Figure 21: Concessional financing for ADS (US$ billion) against Vietnam's national valuation of carbon

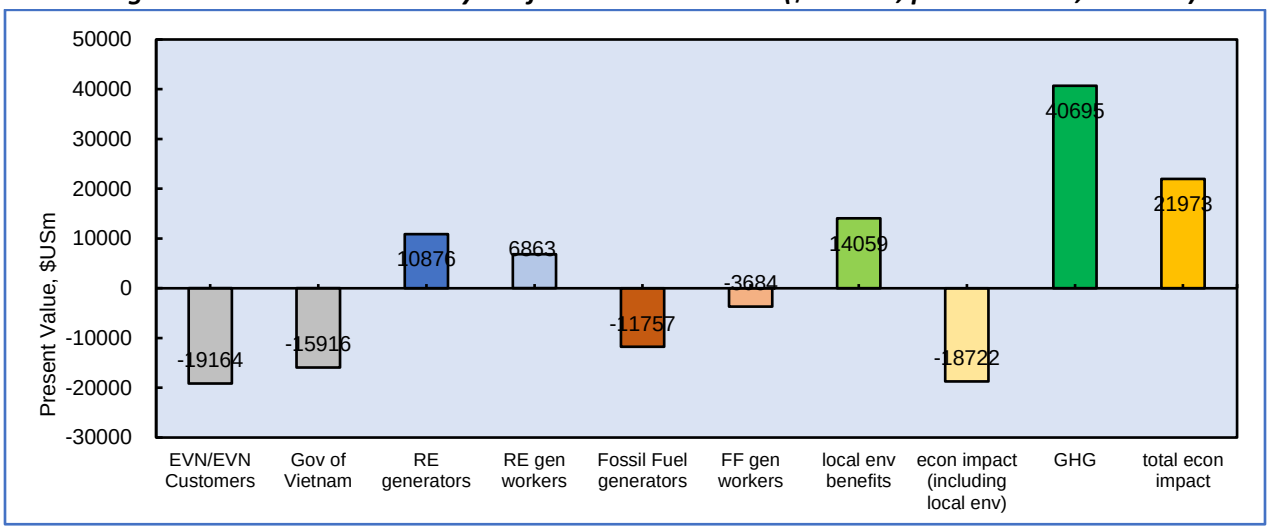


Source: Power Sector modeling carried out by the World Bank staff

5. ADS can have distributional implications. Mechanisms must be put in place to ensure than groups that will lose from the transition to RE technologies are well compensated.

A distributional analysis of ADS in relation to CPS was carried out by reconciling the economic and financial flows under two scenarios. The analysis confirms expectations. The distributional analysis indicates that the renewable energy industry in Vietnam including both owners and workers will be the major beneficiaries under ADS. The fossil fuel generation industry – both owners and workers - face the most losses due to reduced development of fossil fuel generation and early retirement of existing generation plants. Government of Vietnam faces tax losses as result of preferential tax treatment of renewable energy industry in relation to the fossil fuel generation industry. EVN faces losses as it will have to make additional investments in electricity network in ADS relative to CPS and will have to compensate RE developers at higher rate than it would be compensating fossil fuel generators.

Figure 22: Distributional analysis of ADS relative to CPS ($ million, present value, 2020-40)



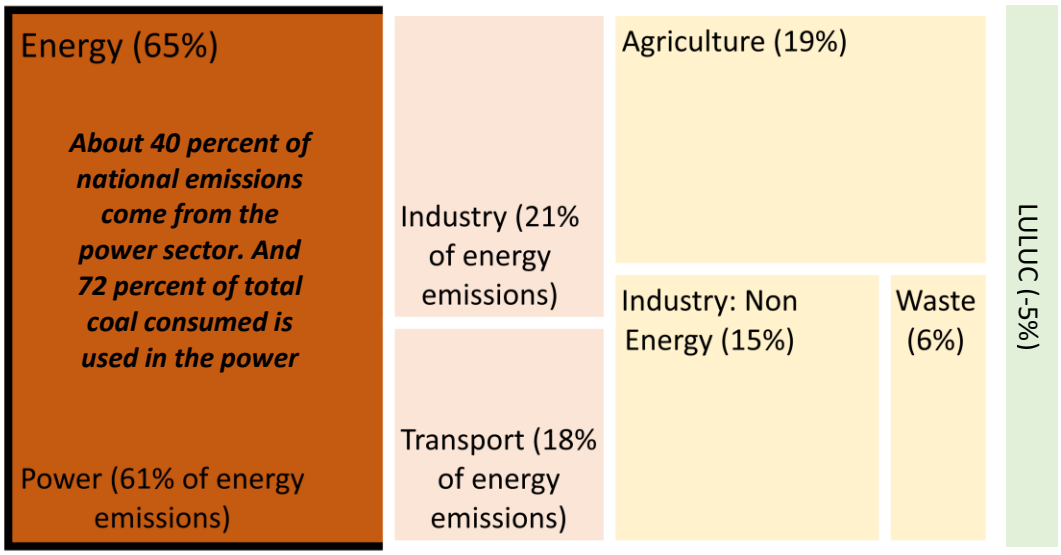
Source: Power Sector modeling carried out by the World Bank staff

6. Phasing out the use of coal would require careful consideration and a just transition for the people, communities, and businesses which rely on Vietnam's coal industry.

Roughly, half of Vietnam's coal supply comes from domestic resources and the remainder is imported. The cost of imports is about 1.5 percent of GDP in 2020 which can increase to 3.5 percent by 2040 under the CPS scenario. Around 65-70 percent of coal consumed is used for the power sector. About 75 percent of the coal power plants are owned by SOEs and the remainder is owned by the private sector.

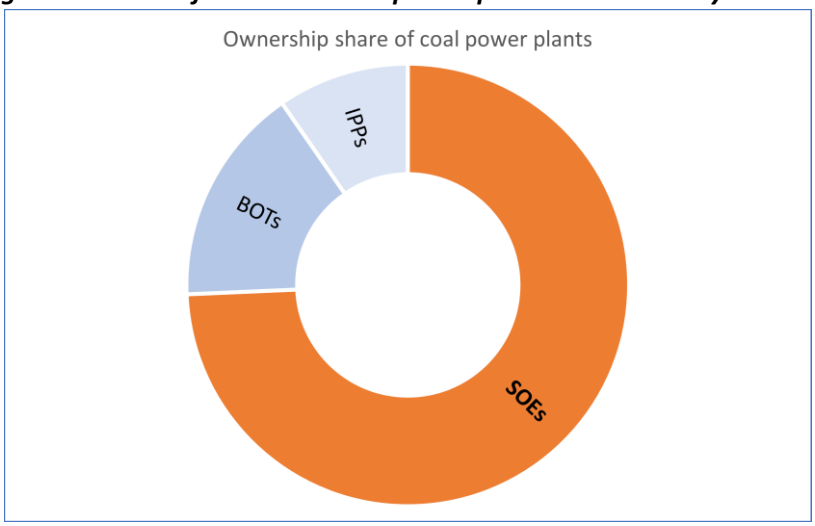
There is a need to improve the governance processes leading to coal mine and thermal power plant closures because of a selected lower carbon pathway. Most of the domestically produced coal (over 90 percent) is mined in the northern areas of the country (proximity of the Red, Da, and Ca river deltas, and particularly in the Quang Ninh Province) which tend to be economically weaker than rest of the country. These coal producing regions could face difficult circumstances as coal mines and thermal power plants incur losses and the future for workers and their communities becomes uncertain.

Figure 23: Most of coal consumed in Vietnam is used for power generation



Source: World Bank staff estimates (adapted from Vietnam's NDCs)

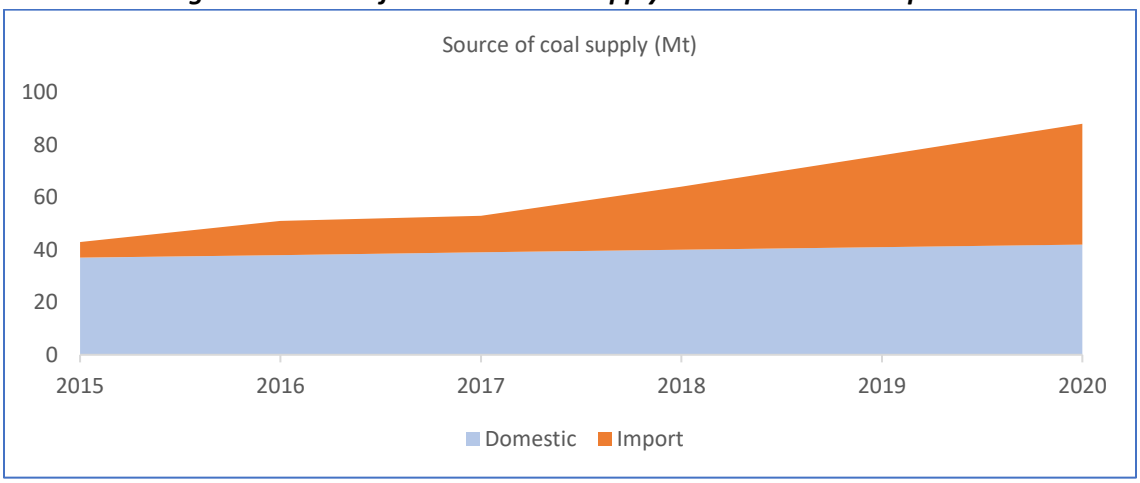
Figure 24: Most of the coal-based power plants are owned by the SOEs



Source: World Bank staff estimates (adapted from EVN data)

Geographic isolation of most coal mines means that the loss of the main regional employer can reduce overall employment potential. Narrow economic base of a coal dependent region could expose the fragility of the economy, in terms of job creation potential. Disparity of wages between coal mining and alternative professions can be a stumbling block to re employing former coal miners. Indirect job losses from subsidiary businesses accentuate the labor challenge and may be more at risk if not considered as beneficiaries of temporary income support or labor programs.

Figure 25: Most of Vietnam's coal supply is now reliant on imports



Source: World Bank staff estimates (adapted from EVN data)

Figure 26: Vietnam's domestic coal production is concentrated in the northern areas of the country

Source: World Bank staff estimates (adapted from SOE data)

Decarbonization the energy sector would also require better management of impacts on workers and communities and ensure good environmental stewardship of lands and infrastructure assets. Vietnam's 'Just Transition for All' should be underpinned by:

(i) Continuous dialogue and consultation with a wide variety of affected stakeholders to determine scope, scale, and timing of closure.

(ii) Adequate planning at the outset which is sustained through dialogue and participatory monitoring during the various stages of closure and transition.

(iii) Provision of temporary income support to workers and their families that is complementary to other existing social protection programs, and

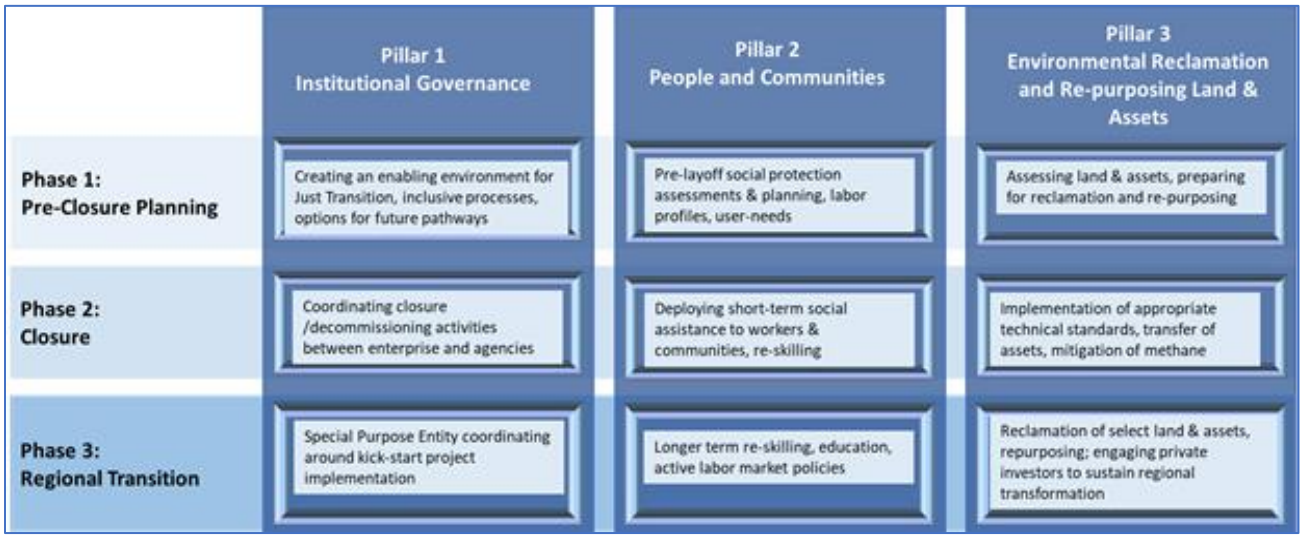
(iv) Deployment of active labor market policies that offer services, programs, and incentives to encourage and enable re-employment among laid-off workers.

There are three thematic areas to be addressed concurrently as a part of coal mine closure and thermal power plant decommissioning or repurposing: (i) *Strengthen institutional governance*: which includes the political, strategic, institutional, regulatory, budget planning - setting in place the conditions, rules, and capacity needs and responsibilities to implement the coal sector downsizing,(ii) *People and communities*: which incorporates income support instruments and labor market programs to address the needs of redundant workers, (iii) *Environmental remediation for repurposing land and infrastructure assets*: which covers physical mine closure and environmental reclamation and rehabilitation (including the removal of mine equipment), transfer of useful assets to the local community, regional government, special purpose entity to attract investors into new development opportunities.

Increased demand for clean energy transition metals will open new supply chains from extraction to manufacturing which may place additional pressure on ecologically sensitive locations and on the land and resources of vulnerable communities.

Strategic assessment of impacts, costs, and benefits of developing these metals is necessary to ensure a more secure supply chain and confidence in investments as well as to prevent harm. Where green jobs and alternative industries are unable to be located, effective multistakeholder assessment and engagement will ensure that communities impacted by the transition are involved in smart decisions about repurposing resources and land to crowd in investments and promote revitalization.

Figure 27: A systematic approach to just transition can mitigate adverse impacts

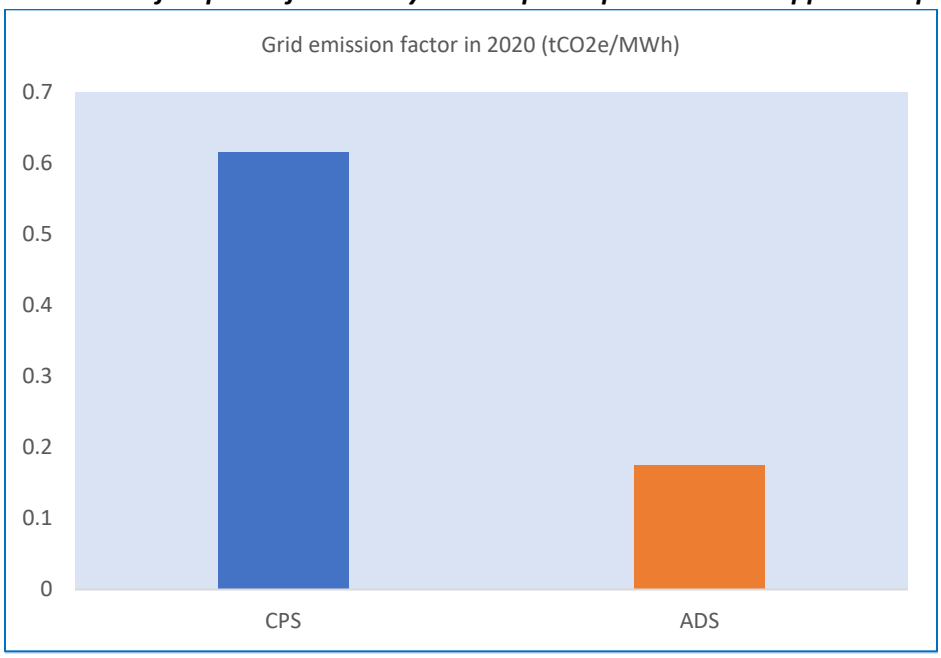


Source: World Bank just transition framework presentation

Vietnam could benefit from reducing its carbon footprints for its export industry.

Vietnam can also benefit from reducing its carbon footprints of its export industry. Under the ADS, this emission from each MWh of electricity consumed can decline to 0.2 ton of CO_2e by 2040. This will be in line with global benchmarks and can mitigate the impact of proposed *Carbon Border Adjustment Mechanisms* for Vietnamese exporters.

Figure 28: Low-carbon footprint of electricity as an input to products can support competitiveness



Source: Power Sector modeling carried out by the World Bank staff

7. Developing appropriate 'green skills' in the labor force to power the clean energy transition is critical and requires a multi-pronged strategy.

Vietnam's labor force generally is seen as having lower levels of education. Skill gaps (poor quality of skills) and skills shortages (inadequate quantity of workforce with required skills) are major constraints for engaging in/investing in firms' innovation practices and is particularly true in energy sector. The World Bank's Vietnam Development Report noted that about 15 percent of employers claimed that there was a lack of applicants for skilled professional and technical jobs and about 80 percent of employers claimed that those who applied lacked the necessary skills. The clean energy transition in Vietnam would require growing medium and high-skill levels of professional categories. This is where the skill gap is the most pronounced.

There is a need to expand not only technical vocational education and training (TVET) systems, but also to significantly focus on higher education. Vietnam's tertiary education has made notable progress in the past two decades. The gross enrolment rate at the tertiary level increased dramatically, from 10 percent in 2000 to 28 percent in 2016, more than doubling the total tertiary enrollment from 0.9 million to 2.2 million in the same period.

There is significant room for improvement across different dimensions of tertiary education. Despite the large increase, coverage in higher education is below 30 percent in terms of the gross enrolment rate. This is low compared to the regional peers such as China, Malaysia, and Thailand, whose enrollment rates are closer to 50 percent.

Table 5: Labor force skills required to support clean energy transition and relative gaps

Semi-Skilled Levels	*Medium-Skilled Levels*	*High-Skilled Levels*
Construction Labor Supervisory Staff Administrative Staff Suppliers and General Workforce	Installers Power Plant Managers Quality Assurance Engineering Technicians Health Technicians Protection Analysts	System Designers Process Engineers Landscape Architects Environmental Engineers Soil and Material Scientist Climate Analysts Industrial Ecologists Energy Auditors Business Process Managers Material Scientists Researchers Entrepreneurs Investment Bankers
Limited Skills Gap	**Moderate Skills Gap**	**Large Skills Gap**
Response: Secondary Education	**Response: TVET Education**	**Response: Higher Education**

Source: World Bank staff

8. Large financing requirements of the clean energy transition mean that investment climate reforms to promote private sector participation will be crucial.

The energy sector's traditional financing approach, which relied heavily on public investment implemented by SOEs, will no longer be sufficient nor sustainable. It is estimated that at least two-thirds of power sector investment needs will be mobilized from the private sector in the coming decades. However, constraints to private sector participation continue to hamper the scale and pace of capital deployment.

The regulatory framework for private sector participation in infrastructure is now governed by the 2020 *Public Private Partnership* (PPP) Law. The PPP law serves as the anchor legislation governing PPP transactions in the country. The new PPP law includes many positive measures, such as: (i) wider sector inclusion for PPPs, (ii) enabling a framework for 'Project Enterprise', (ii) clarifying policies and mechanisms for the availability of viability gap financing for national and local PPP projects; (iii) establishing a regime for the provision of minimum revenue guarantees that will make risk-sharing more equitable between the public and private sectors, (iv) standard form contracts for use in PPPs, (v) providing for the eligibility of bond-based financing for PPPs, (vi) ability to select third country international arbitration, and (vii) the inclusion of competitive bidding processes.

However, the PPP law still lacks elements required to optimize private sector participation. Some key issues would still need to be resolved to create transparency and a level playing field for private investors: (i) defining applicable law to govern PPP contracts acceptable to international investors, (ii) balanced risk sharing approach in power sector contracts, for instance, with regards to deemed generation payments, as well as provision of government support to mitigate any residual risks, (iii) timelines for financing which reflect market conditions, (iv) rights and obligations associated with termination cause, termination

payments, and arbitration (v) rights and obligations associated with land use and real property assets, (vi) certification and approval process.

Power project procurement still relies on ad hoc negotiations (apart from the streamlined process under the renewable energy feed-in-tariff regime). Lengthy negotiations (which can often take several years) discourage many local and foreign investors. There is an urgent need for adopting clear and timebound procedures for how such power sector projects would be procured. This not only includes transparent and competitive selection process, but also streamlined negotiations process. Furthermore, improving consistency across provinces with respect to licensing and permitting procedures is required.

9. Improving effectiveness of necessary and complementary public sector investments for clean energy transition would require continued reform of the SOEs.

Vietnam's energy sector has been traditionally dominated by SOEs. This includes EVN in the power sector, but also those in oil, gas, coal, minerals, and related industries such as PetroVietnam (PVN), Petrolimex, VinaComin.

The government has announced plans to further reform SOEs by: (i) promoting market-based fair competition, (ii) introducing good international governance in SOEs, (iii) speeding up equitization and effective divestment, and (iv) enacting effective management of state equity in SOEs. However, the pace of the reform continues to be sluggish. The equitization program and the restructuring of the SOEs (asset recycling), after a promising start in 2017, has subsequently slowed considerably. Major reforms to liberalize the gas sector are not scheduled to start until 2025.

Leveling the playing field for all participants (SOEs and private sector) through implementation of proposed Competitive Wholesale and Retail Electricity Market which envisions power project procurement and power sales through a market-based approach is still to yield significant results.

Despite strong technical and operational performance, SOEs in the power sector continue to face challenges in mobilizing commercial financing at scale. The ability of SOEs to raise commercial financing depends on the creditworthiness of the companies, as assessed by an adequate credit rating from a reputable rating agency (EVN, NPT, and five PCs received their first credit ratings in 2019-2020).

There is continued need to improve financial performance of the SOEs. Increasing creditworthiness and financial health of EVN as the single buyer would create a healthy and positive image of off takers in PPA contracts that would directly affect the confidence and profitability evaluation of investors. For instance, through continued tariff reforms which reflect full cost of service, reduction in exposure to foreign currency risks, capacity improvement to be able to draw on project financing structures (and not just corporate finance) as well as to issue bonds in local and international capital markets.

EVN and its subsidiaries incorporate societal, environmental, governance (ESG) concerns, to the level it is required by local law, in their business models. For instance, EVN performs well with regards to adherence to the *Environmental Protection Law*, it has implementing International Financial Reporting Standards (IFRS) and has improved accounting and financial reporting procedures, it carries out annual independent audit exercises, and its board includes capable and experience members to oversee and direct the

corporation. EVN's annual reports include detailed overview of its installed generation capacity, energy usage, supply, and demand projections.

Project level reports include relevant details on social, environmental impacts. EVN has also established diversity targets and a gender action plan (including EDGE certification process) to improve gender equity in its workforce. However, there are many areas of improvement, for instance, regular reporting of emissions, water usage, waste generation, to further improve its ESG performance.

Section VI. Developing a Clean Energy Policy Framework for Vietnam

To decarbonize in a sustainable and affordable manner, Vietnam needs to develop the right set of policies to support the implementation of targets. Policy changes are required not only with regards to financing of the generation itself, but also on tariff, grid integration flexibility pricing, and regional electricity trade.

A. Legal, regulatory, and planning constraints

1. Use power system planning as a flexible policy guidance tool.

In addition to updating its NDCs and defining a long-term strategy towards 'net zero' emissions, in the energy sector, it is important that an appropriate power generation mix, with clear targets for accelerating renewable energy, is included in PDP8. Vietnam should use the planning process to continuously reassess and recalibrate the power generation investments based on principles of least-cost power supply within the context of clear long-term policy targets (emission reduction, coal phase out). There is an opportunity to continue improving the power sector planning process with the incorporation of scenarios which quantify and examine the external implications (cost of environmental impacts). Energy transition and coal phase-out principles need to be trickled down across the different laws and regulations. The proposed revision of the *Electricity Law* and the *Renewable Energy Development Law* should align to the objectives established in Vietnam's *Green Growth Strategy*[26] so to ensure that the greater green growth vision of the Government of Vietnam is indeed embedded into the law. In addition, impact of the coal industry phaseout should be mitigated through a regulatory framework for 'just transition' which clarifies compensation and repurposing guidelines. It would also gain at being coordinated with re-skilling and livelihood restoration activities.

2. Enact policies for transparent implementation of investment decisions.

There is a need to improve transparency for all stakeholders and investors by standardizing the procurement and licensing process of power projects. The practice of ad-hoc negotiations of unsolicited private sector proposals for long-term power purchase agreements can lead to inefficiencies. Accelerated implementation of the government's roadmap for competitive power markets to procure power projects, together with consistent licensing and permitting procedures, can improve the efficiency of the process.

B. Renewable energy acceleration

3. Move from a feed-in-tariff scheme to competitive selection.

Moving from feed-in-tariff (FIT) based premium pricing, which was useful to seed the market, to an auction-based scheme for procurement of solar and wind technologies is critical. Global experience demonstrates that most countries who moved into competitive selection of independent power producers (IPPs) directly benefited from lower PPA prices compared to countries with FIT policies. The main difference between FIT and competitive bidding is that under FIT, Governments are fixing the price whereas under a competitive bidding process the private investors are. Under competitive bidding,

[26] Ratified with Decision No. 1658/QD-TTg approving the National Green Growth Strategy for 2021-2030 period, vision to 2050.

governments can access lower prices as IPPs will reflect in their proposed PPA price: (i) the capital expenditure (capex) cost at the time of the bid - since 2010 capex in solar decreased rapidly, in particular solar module cost and it is difficult to assess its cost a few years ahead, (ii) high competition between solar IPPs leading to reduces equity returns expectations, (iii) bankable contractual arrangements with fair risk allocation between the private and public stakeholders that enable IPPs to attract long-term non-recourse project finance that lower the cost of capital, and (iv) the scale of the market in the country and the region. Therefore, a bankable well-organized competitive selection can attract cost competitive IPPs and ensure low-cost of capital. In addition, implementing a roadmap for development of newer renewable energy technologies such as offshore wind which encompass the supply chain development is needed.

EVN as the possible lead renewable energy auctioneer would require minimal changes to the law, while being optimal from a technical and experience perspective. It is recommended in Vietnam to move into competitive selection of IPPs and such leveraging existing law, such as the *Bidding Law*, the I*nvestment Law*, and the *Electricity Law*. Current 20 April 2021 draft PM Decision on solar proposes the PPC as lead for tender but there are critical issues with that the risk of curtailment and limited link with MOIT and EVN. Based on the *Bidding Law, Electricity Law,* and *Investment Law*, EVN is a strong candidate to lead the tender. It would be recommended to ask EVN to be the auctioneer as the main signatory to the PPA is EVN (the one buying the power), and they oversee the grid and therefore responsible in case of curtailment. From a legal standpoint, it is also well aligned with the existing regulations: the Prime Minister has the option to use *Decree No. 25/2020* as a legal basis to allocate specific responsibilities to EVN for renewable energy bidding mechanisms without being limited to the option of allocating to only PPCs and their subordinate departments. Indeed, Decree 25 (Articles 1.1(c) and 16) as recently amended by Decree 31 (Article 108.7) gives room for specialized sectors to allocate responsibilities of State agencies differently under specialized laws. The general roles under current EVN's charter (including, generation, transmission, distribution, sale, and purchase of electric power) are broad enough to cover the auctioneer role. Therefore, EVN could be requested by the Prime Minister to lead the tendering process. Electricity Law: This can be considered as the law of a "specialized sector" as mentioned above. Under Article 31.2 of the Electricity Law, MOIT is requested to issue legal guidance on the pricing framework for electricity generation. It could set a new guidance requesting EVN to conduct a tender based on the official responsibility provided to EVN by the PM. Decree No. 98/2017/ND-CP dated 18 August 2017: regulating on the authorities of MOIT (Article 2.7(d) and 2.6(a)), MOIT is the competent authority for regulating the power sale/purchase price for renewable power and energy projects. Bidding Law: Under Articles 4.3(d), 4.6, the “competent State authority” or “bid solicitor” can be any State authority (including MOIT or EVN), not limited to only PPCs, while PPCs still have jurisdictions over land and investment approvals under existing Land Law and Investment Law.

4. Systematically develop the offshore wind resource potential.

Vietnam’s offshore wind resources are amongst the best in the world. In the medium-term, this resource can supply a significant portion of clean domestic energy. However, developing this new industry requires a systematic approach. A roadmap for development of offshore wind which takes a wholistic view of the industry, such as marine geospatial planning, supply chain and port infrastructure development, selection and preparation of projects, appropriate licensing, permitting, and contractual processes need to be implemented.

C. Improving variable renewable energy integration

5. Invest in expansion and modernization of the power grid.

There is an urgent need to investment to upgrade the power capacity of the grid network and to introduce modern technologies designed for variable renewable energy integration. This includes investment in system automation tools, smart grid technologies, digitalization, telecommunication system upgrades, and energy dispatch management capabilities.

The network upgrades identified in PDP8 would need to be designed with the technologies of the future in mind. Developing a 'smart grid' would not only entail accelerated digitalization but also use of innovative technologies which can improve automation and fault tolerance while, also creating new opportunities (e.g., use of high-voltage direct current, HVDC, for bulk transfer of power, improved readiness of the grid for electric mobility, etc.). The legal framework will be needed to enable HVDC investments in Vietnam by: (i) having HVDC lines included in PDP8, (ii) updating transmission tariff calculation methodology to enable the investment to be appraised by ERAV, and (iii) updating the grid code to incorporate relevant standards related to HVDC design, implementation, and operation.

As a net importer of energy, **Vietnam could prioritize electricity imports from Laos and China** given the excess hydropower-based resources available in these countries that can support a low-cost decarbonization of the energy sector. While aggregate targets are included in the draft PDP8, it would be important to: (i) agree on project-level issues with exporting nations, such as cross-border power transmission connection points, the appropriate sizing of power lines, and technologies to be incorporated, (ii) agree on the commercial framework which would underpin the regional power trade, including pricing and dispute resolution mechanisms, and (iii) establish high-level platforms to facilitating decision making on these bilateral agreements.

6. Update pricing regulations for energy storage systems and ancillary services.

The capacity of the network to effectively dispatch solar and wind power plants needs to be urgently expanded. In addition, energy storage systems (ESS), such as batteries and pumped hydropower, would need to be carefully considered and included in PDP8. This would reduce the curtailment being faced by the projects and would enable new producers to supply clean energy to the consumers. PDP8 needs to include all upgrades needed for this large increase in VRE uptake.

The current market/energy sector does not financially value ancillary services (voltage and frequency) that storage (battery and pumped) can provide. In addition, the value of load shifting is also not legally framed. It would be needed to enable EVN, and potential private investors to finance such equipment, to open from a policy perspective the financing of battery storage and pumped hydropower. To enable storage, the government would need to: (i) identify the investments in PDP8, (ii) financially value ancillary services to enable a financial assessment of the new investments, and (iii) update the grid code to incorporate relevant standards related to storage design, implementation, and operation.

7. Improve climate risk management standards for the energy infrastructure.

While decarbonizing the energy sector, it is critical to include also risks that climate change would pose and how it will impact its infrastructure. There is a need to include the impact climate change on demand, particularly, the increased number and intensity of heat waves. Heat increase will impact the demand curves which will need to be met by higher peaking generation and such change needs to be included in the generation plans. Second, due to the increase in risk of droughts and the potential impact on fuel imports, the energy mix needs to be re-focused on domestically produced generation such as solar and wind. Third, improving the resilience of the power grid would require additional capex and would likely increase with more adverse impacts of climate change. The impact of climate change with the risks of wildfire, heat increase and flooding, impacts greatly transmission/distribution lines and generation plants, in particular coal power plants that require cooling systems that are greatly impacted by increase in heat levels, and hydropower plants that can be highly vulnerable to extreme climatic conditions. A systematic review and effecting maintenance of existing power generation plants, especially hydropower plants, could be promoted such that their safety is ensured, and useful life is extended.

8. Develop natural gas to power as a transition fuel, factoring in the risk of long-term carbon lock-in, by implementing the necessary upstream reforms and investing in selected strategic projects.

Phasing out the use of coal in two decades will be challenging. Natural gas is a lower-carbon fuel frequently used to replace coal, to provide flexible dispatch and backup capability for integration of renewables, and to meet peak load demand. Given limited domestic gas resources, Vietnam's gas supply will rely on imported liquified natural gas (LNG). LNG, as a new market segment, will require upstream policy reforms, including transparent procedures for gas procurement. Updating the regulatory framework with health, safety, and environmental standards is needed together with a policy for pass-through of gas price fluctuations. Power system planning can be used to assess the viability of carbon capture and storage and other technologies to complement LNG-to-power. Strict criteria for selectivity should be developed for investing in only those receiving ports, processing, transporting, storing, and power generating facilities that are optimally required and to identify where public investment support may be justified. Currently, Vietnam has not identified specific plans for development of nuclear power plants[27] . However, the government is keeping open the possibility of developing this technology in the future open. The government is encouraging further research and development of feasibility studies for assessment.

D. Energy efficiency and demand moderation

9. Implement targets under Vietnam's *National Energy Efficiency Plan*.

Vietnam continues to be one of the most energy intensive economies in South-East Asia. Aggressive targets under PDP8 can further enhance efficiency which is not only good for the environment (reduces the need for increased fossil-fuel based generation) but also provides net savings to the consumers. The implementation of these targets will need to be very well organized and followed with clear action plans and associated penalties and incentives. Market development support for innovative business models and

[27] Draft PDP8 version of April 2022.

financing mechanisms (including carbon pricing instruments and risk mitigation strategies) for efficiency improvement, and in particular Energy Services Company (ESCO) business models, should be implemented. Also, solutions to strengthen regulations and enforcement on demand side energy efficiency, as well as adoption of a transparent MRV systems are critical.

10. Implement demand side measures and segment specific decarbonization programs.

In addition, demand moderation measures (time-of-use tariffs, consumer awareness campaigns, and appliance standards) need to be scaled-up. Demand side energy management plans should be part of PDP8 implementation (especially in residential and industrial segments).

About 60 percent of the industrial sector final energy consumption reduction would come from efficient and new technologies based on electricity savings. These savings can be achieved through high efficiency boilers, furnaces, and motors, along with measure such as efficient lighting and air conditioning, and through innovative and low carbon technology adoption. The iron and steel, cement, food and tobacco, textiles and leather sub-sectors are expected to provide the largest final energy consumption reductions by 2030.

The broader electric mobility (or e-mobility) transition comprises one part of a larger suite of initiatives to help decarbonize the transport sector and help Vietnam meet its emission and energy goals. At the same time, the transition towards e-mobility presents opportunities in the energy, power, and in manufacturing sectors. Greater uptake of electric vehicles (EVs) would require expansion of renewable energy sources to handle EV charging demand (facilitated by digitalization of energy and vehicle demand and supply) and generate economies-of-scale for expanded renewable energy generation to meet these goals. In addition, nascent private sector industries would benefit from new EV component manufacturing (not only of vehicles, but related components including batteries, chargers, etc.), spawning native innovators, possibly for export. This nexus of transport, e-mobility, urban development, energy and power, climate change, industry, manufacturing, and digitalization can be a large contributor to Vietnam's sustainable energy transition.

E. Mobilizing financing for energy transition

11. Scaling-up private sector participation.

Estimated two-thirds of sector investments under the ADS, or about $ 230-240 billion between 2020-2040 (undiscounted), can be mobilized from the private sector. This will be driven mainly by the power generation segment where most of the new power plants are already being developed and financed by the private sector. EVN aims to own less than 20 percent of the power generation assets by the end of the decade. However, investment frameworks need to continue to evolve based on market realities. This would include implementing auctions for procurement of renewable energy projects, implementing the 2020 *Public Private Partnership Law* with provisions for transparent project selection criteria, simplified review and approval procedures, and mobilization of government support, where necessary (for instance, through guarantees).

The contracting architecture should reflect risk allocations conforming to prevailing local conditions and international best practices to attract new sources of financing. Moving to greater use of non-recourse project-financing in the energy sector under the umbrella of the PPP Law can accelerate foreign direct investment (FDI), lower cost of capital and lower cost of electricity. However, for that to happen, it would

be critical that the risk allocation of the Power Purchase Agreements (PPAs) be fair and balanced and that any residual risks of such investments (especially, large-scale investment such as the LNG or offshore wind projects) be covered by sovereign guarantees.

There are additional opportunities for the private sector to participate in the clean energy transition in the medium-term: green bonds issued by sector utilities (SOEs), equitization and recycling of existing sector assets, selected transmission & distribution segments (which could be opened for private sector), as well as the energy efficiency market.

12. Mobilizing complementary public sector investments.

Complementary public investments under the ADS, estimated at $ 110-120 billion between 2020-2040 (undiscounted), would need to be mobilized and should be typically planned and deployed ahead of the private sector to de-risk projects and encourage investment. In addition, streamlining public investments in the energy sector, where it complements the private sector, is critical to de-bottleneck clean energy investments.

Power transmission and distribution capacity expansion and flexibility enhancement will remain as the key areas of public investment and would be led by SOEs. SOE-led investments may be needed for selected strategic national power generation assets (e.g., hydropower, LNG) required for system development and energy security. It would be important that the roadmap of reforms for energy sector SOEs is implemented based on the long-term goals of improved performance, transparent environmental and social reporting, and improved corporate governance to streamline public investments.

13. Continue electricity tariff and wholesale market reforms and introduce carbon pricing.

Long-term financial viability of the energy sector would require that revenue coming from the consumers is adequately able to cover the cost of the supply. EVN is the primary off taker for the power sector and maintaining its credit worthiness is at the heart of the sector's financial viability. This should also include a risk management framework for any contingent liabilities generated through contractual guarantees. Continued electricity tariff reforms are needed to ensure that revenue requirements are based on full cost of supply. While fossil fuel subsidies for power sector have been removed, there is an opportunity to design smart cross-subsidization schemes to address poverty and affordability concerns and to promote targeted clean energy policies.

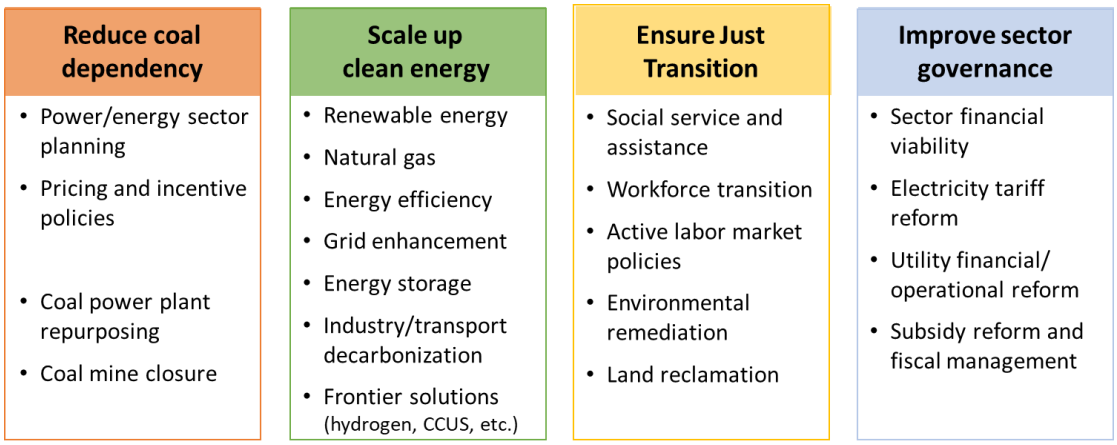
In addition, continuing power sector reforms for establishing a level playing field for all participants under the Wholesale Electricity Market (and when the time is right, Retail Electricity Market) would be important. Procuring power projects within a transparent and predictable framework (while avoiding ad-hoc negotiations) would improve speed and economic efficiency of outcomes. Continued regulatory revisions should be carried out for implementing the *Electricity Market* which promotes competitive procurement of power projects replacing the current practice of unsolicited ad hoc proposal. A roadmap of reforms for sector SOEs which includes long-term vision of equitization, improved financial performance, transparent environmental and social reporting, and improved corporate governance should be implemented. The power sector is an ideal candidate to pilot and expand carbon pricing instruments. Emission trading schemes can be established to support carbon market participation of power sector entities (for instance, the existing fleet of fossil-fuel power plants).

Section VII. World Bank Group Support for Clean Energy Transition

1. The World Bank Group (WBG) - which includes International Finance Corporation (IFC) and Multilateral Investment Guarantee Agency (MIGA) - is providing comprehensive clean energy transition support which is aligned with our Regional Climate Change Action Plan (CCAP) and our Green, Resilient, Inclusive Development (GRID) Strategy.

Facilitating the energy transition requires a comprehensive approach to transform the demand for energy, and the way it is produced and consumed. Isolated initiatives will not achieve the desired decarbonization results and underlying structural changes needed. Reducing coal consumption is a critical to the transition, but it can be achieved only if energy security, economic growth and competitiveness can be sustained, and the costs are socially affordable and politically acceptable. The World Bank's Energy Transition Framework comprise of four pillars of engagement that address the full spectrum of energy transition needs. The work program in each country would be tailored to its specific starting system conditions, feasible decarbonization pathways, economic circumstances, and political economy. For example, supporting coal power plant decommissioning and repurposing, would need different approaches and mechanisms in systems dominated by state-owned coal power plants compared to those where private independent power producers account for a large share.

Figure 29: World Bank's Energy Transition Framework



Source: World Bank

In Vietnam, the World Bank's ongoing clean energy support program in Vietnam is providing about $ 1 billion of concessional financing and grant-based resources, which can potentially increase by additional $ 2 billion in the coming years.[28] The WB's clean energy transition support program considers important tradeoffs: maintaining energy security and financial viability of sector, while not jeopardizing green growth prospects, while supporting a 'just transition' for people, communities, and businesses involved with the coal value chains. The program focuses on priority interventions for climate change mitigation (e.g., phasing out coal-based energy generation, renewable energy development), and provides some support for climate change adaptation needs (e.g., implementing resilience standards for power grids to withstand extreme weather events). The program focuses on overcoming operational and financial

[28] Estimates based on pipeline of projects for fiscal years 2022-2024 which are under various stages of development.

challenges that Vietnam is facing today and on building capacity of the government agencies to design and implement the transition program.
The success of the clean energy transition program will depend on the ambition of the government-led reform processes (which overcomes any socio-political vested interests) as well as the pace at which reliable and cost-effective alternatives can be financed at-scale and brought online in an effective manner.

2. Supporting the formulation of clean energy policy, regulatory, and planning framework.

The WBG's technical assistance is aimed at carrying out detailed assessments, modeling, and analysis work to develop a robust and evidence-based framework of policies and regulations to underpin the clean energy transition. The program supports crucial aspects of power sector technical planning which are at the core of the development of low carbon pathways in the energy sector.

- Power sector planning support (Eighth Power Development Plan, PDP8) profiling existing and future GHG emissions to identify feasible decarbonization pathways (abatement of coal-based energy) for power generation up to 2040 comparing with the policy scenario - this highlights the tradeoffs (generation resource mix, investment needs, impact to average cost of electricity for the users, stranded assets) in quantifiable terms.
- Modeling support for Vietnam's Nationally Determined Contributions (NDCs) for energy sector related GHG emissions - output used as the basis of the policy engagement and capacity building support for counterparts.
- Technical assistance for development of domestic policies: (iii) energy sector related aspects of Socio-Economic Development Plan and Strategy, (ii) energy sector related aspects of the Green Growth Strategy, and (iii) Renewable Energy Strategy.
- Technical and legal assistance for enactment of action plans and legal and regulatory revisions (including Electricity Law, grid code revision) to implements clean energy policy targets.

3. Supporting the development of transition-oriented fuels and approaches.

Recognizing that the reduction of coal-based energy generation will be carried out in a phased approach, the WBG program supports development and implementation of transitional activities.

- In addition to decarbonation policy development support, the WBG supports analysis of early retirement and potential repurposing of existing coal-based power generation plants.
- Assessment of a 'just transition' framework for the coal industry based on analysis of impacts, current policy and regulatory environment (e.g., compensation methodology).
- Support for development of the Liquified Natural Gas (LNG) industry, including recommendation of gas sector reforms, market design, revisions to regulatory framework and technical standards, options for technical and commercial design and financing for pilot LNG-to-power projects.

4. Accelerating the use of renewable energy resources.

The WBG is supporting aggressive scale-up of domestic (solar, wind) renewable energy resources and their ability to successfully integrate within the power grid, while also promoting regional renewable energy resources utilization.

- Supporting ground-mounted and rooftop solar photovoltaic (PV): (i) geospatial studies for assessing resources availability, (ii) framework for competitive bidding and procurement strategy, and (iii) business models for deployment of distributed energy resources.
- Supporting onshore and offshore wind: (i) geospatial studies for assessing resources availability (including marine spatial planning), (ii) roadmap for offshore wind development, and (iii) framework for competitive bidding and procurement strategy.
- Technical load flow studies to identify bottlenecks for integration of variable renewable energy (VRE) with the power grid, including options for energy storage systems (ESS) such as batteries.
- Supporting regulatory revisions and financing for upgrading the grid capacity for VRE integration (transmission lines, substations, ESS) as well as modernization of the grid (digitalization, dispatch management, automation systems).
- Technical assistance for advancing regional power trade in the Vietnam-Laos-China corridor which can bring assist in imports of surplus hydropower resources to Vietnam.
- Supporting electrification of rural communities to provide last-mile access which also switching consumption from biomass and fossil-fuels to modern energy resources.

5. Promoting efficient use of energy across the value chain.

The WBG supports the development of loss reduction and energy efficiency in both the supply and the demand side of the interconnected power system. The program also focuses on industrial decarbonization and market-based approaches for scaling up energy efficiency.

- Support for the development of the National Energy Efficiency Plan, development of specific sector-based and province-based targets, design, and implementation of action plans to achieve the targets.
- Technical assistance for demand moderation strategies and regulatory (tariff structure) revisions.
- Investment in power grid systems to reduce losses and to improve supply-side efficiency.
- Financing and risk-mitigation facilities for private sector to invest in demand--side energy efficiency measures, including retrofitting of industrial and commercial equipment.
- Technical assistance to identify barriers to entry for Energy Services Companies (ESCOs) and to implement regulatory revisions to mainstream ESCO models in sub-segments (building, cities).
- Supporting consumer-oriented programs such as awareness campaigns of energy usage, labeling and standardization, energy audit capability enhancement.
- Promoting decarbonization of the energy used in transport sector by supporting the development of a National Roadmap for E-Mobility as well as specific city-level implementation plans.

6. Implementing reforms to scale-up public and private sector capital mobilization

The WBG supports the development of a financially viable power sector which can optimize the use of public and private sector resources in carrying out the transition while delivering reliable services.

- Support for competitive wholesale and retail electricity market development by carrying out gap assessments, supporting market rules design, enactment of regulations to implement reforms.

- Technical assistance to improve financial performance and creditworthiness of EVN, the critical power sector SOE, by development of long-term corporate financial strategy, independent credit rating, transparent financial reporting, improved capacity, and governance.
- Supporting the development and enactment of a new Public Private Partnership (PPP) Law and design of downstream regulations to implement PPP transactions.
- Supporting private sector transactions (together with IFC and MIGA) for specific investments in the power sector (solar and wind power projects, international commercial loan mobilization).

7. Assisting in coordination of development assistance programs.

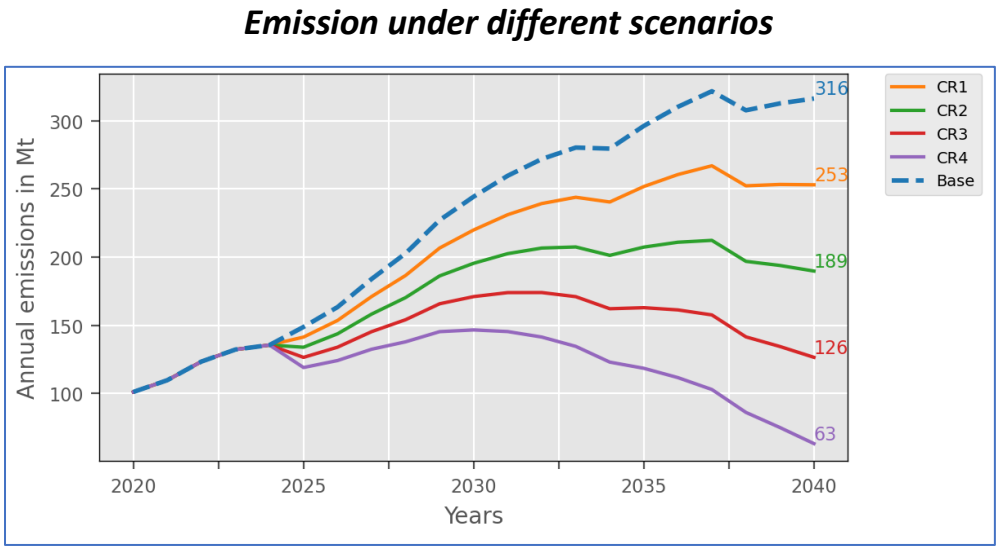
The World Bank Group's clean energy transition program is implemented in close coordination with development partners and is based on detailed consultations and inputs from the private sector, civil society, and beneficiaries.

- The World Bank Co-Chairs the Vietnam Energy Partnership Group (VEPG) together with the European Union. The VEPG is a well-organized platform which integrates development assistance across various international and local partner programs behind the government-led clean energy transition.
- The World Bank also participates in the Vietnam Energy Transition Council (ETC) dialogues and the proposed discussion related to the Just Energy Transition Partnership Platform aimed to further accelerate clean energy transition assistance programs.
- IFC Co-Chairs the Vietnam Business Forum (VBF) which includes specific working groups related to the clean energy transition. The VBF provides the needed private sector input to ensure that the policies and programs are market proofed.
- The WBG also partners with many multilateral and bilateral agencies for joint engagement at the activity-level. This includes, amongst others, DFAT, ADB, USAID, EU, UK, Germany, GIZ, KFW, Denmark, SECO, AFD, JICA, Korea, UNDP, and UNIDO.

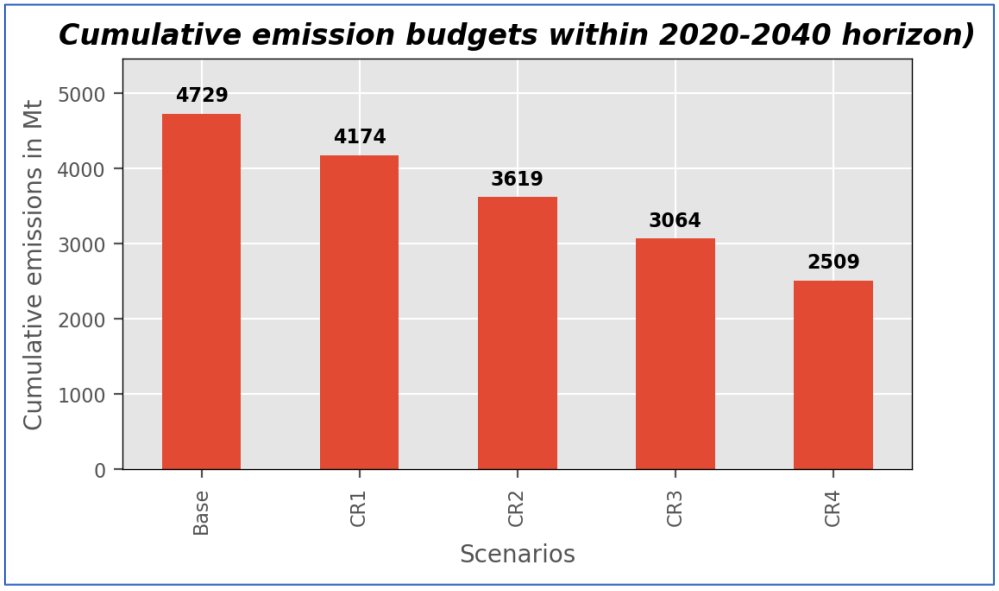
Annex 1: Detailed Modeling Results for Low Carbon Scenarios

Four 'Carbon Reduction' (CR) scenarios corresponding to 20 percent (CR1), 40 percent (CR2), 60 percent (CR3) and 80 percent (CR4) reductions in emissions from the Base case[29] scenario were modelled using EPM.

A. Scenario Results

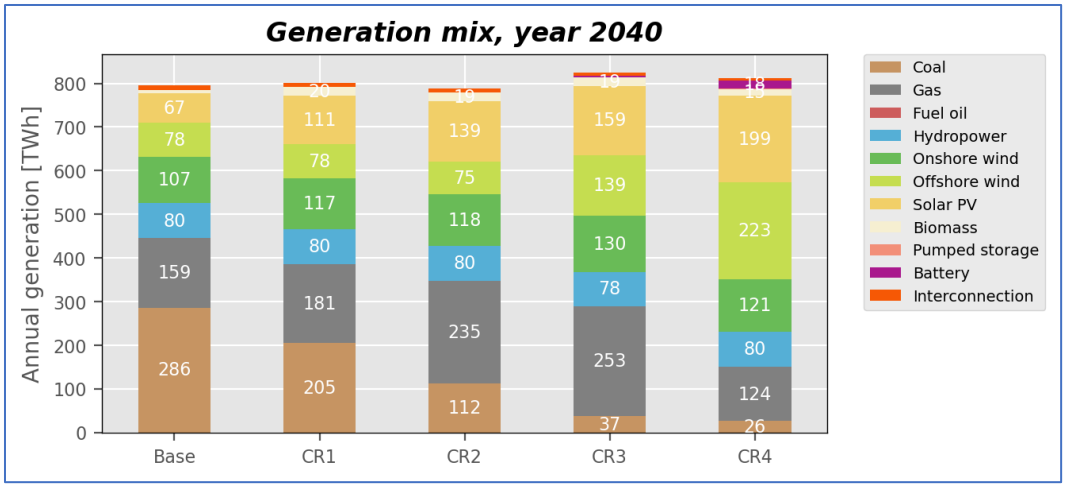


Source: Power Sector modeling carried out by the World Bank staff



Source: Power Sector modeling carried out by the World Bank staff

[29] The EPM modelled the CR1, CR2, CR3, CR4 as 20 percent, 40 percent, 60 percent, and 80 percent emission reductions against a theoretical base case least cost optimization scenario (excluding local and global environmental damage costs) that broadly reflects the CPS presented in this report.



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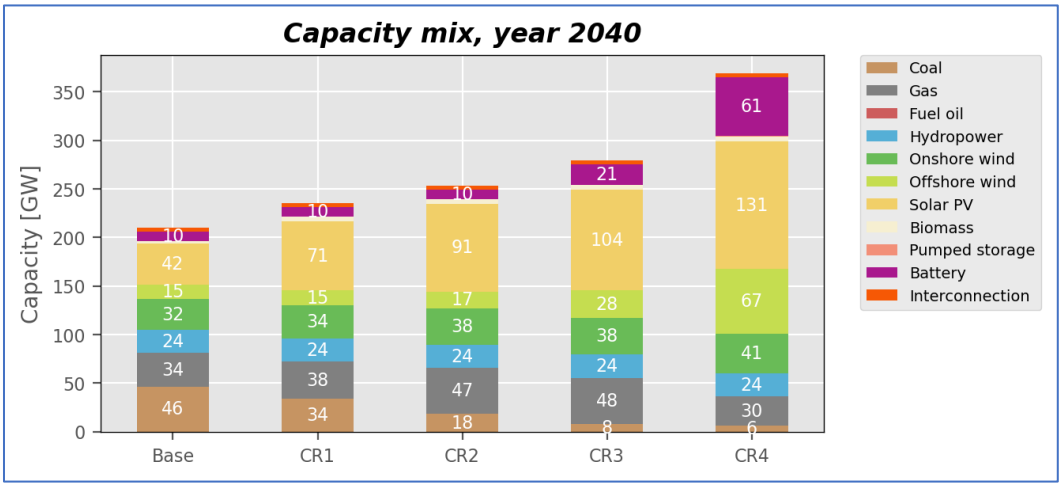

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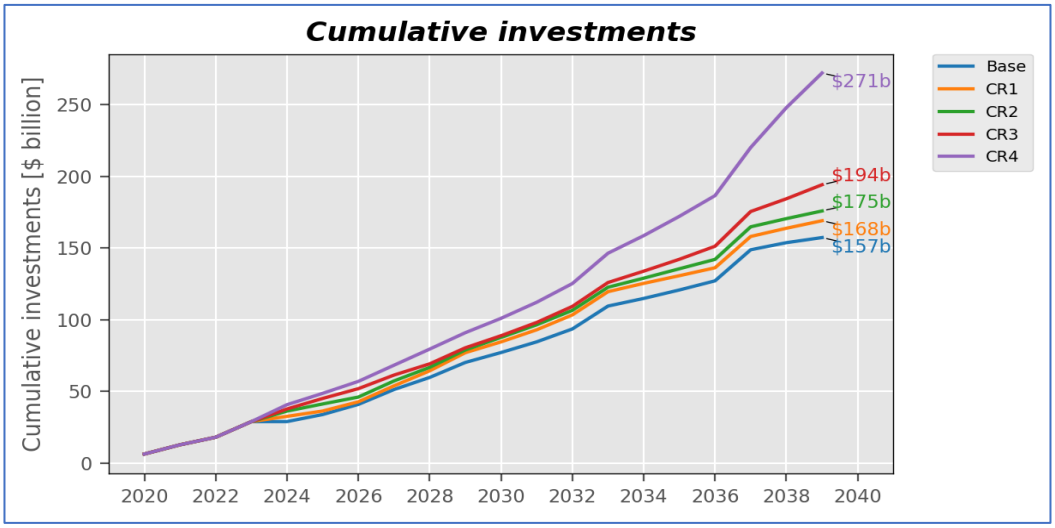
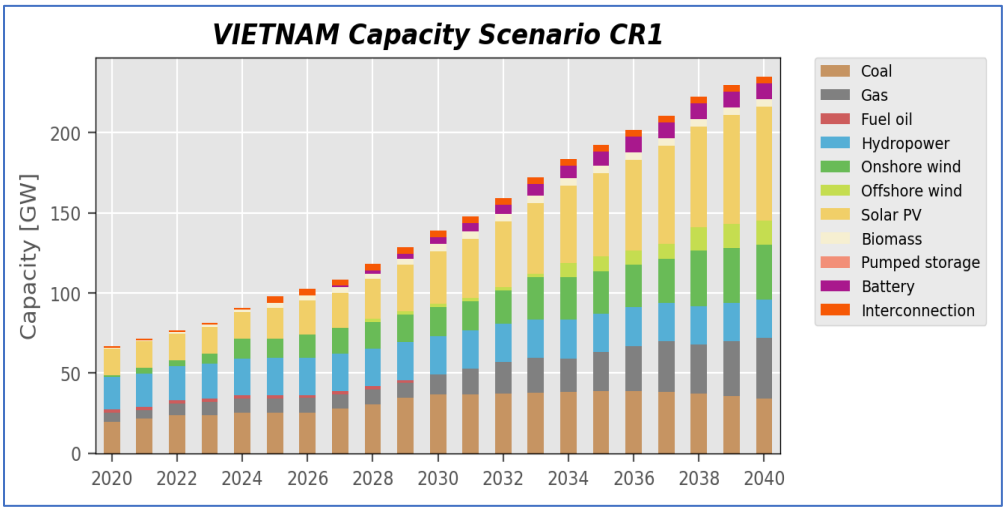


Source: Power Sector modeling carried out by the World Bank staff

B. CR 1 Results



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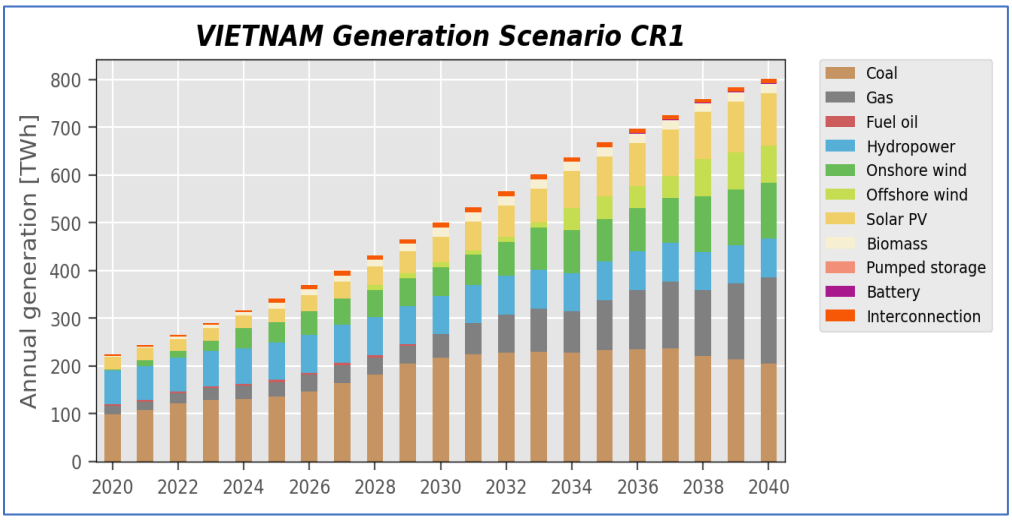

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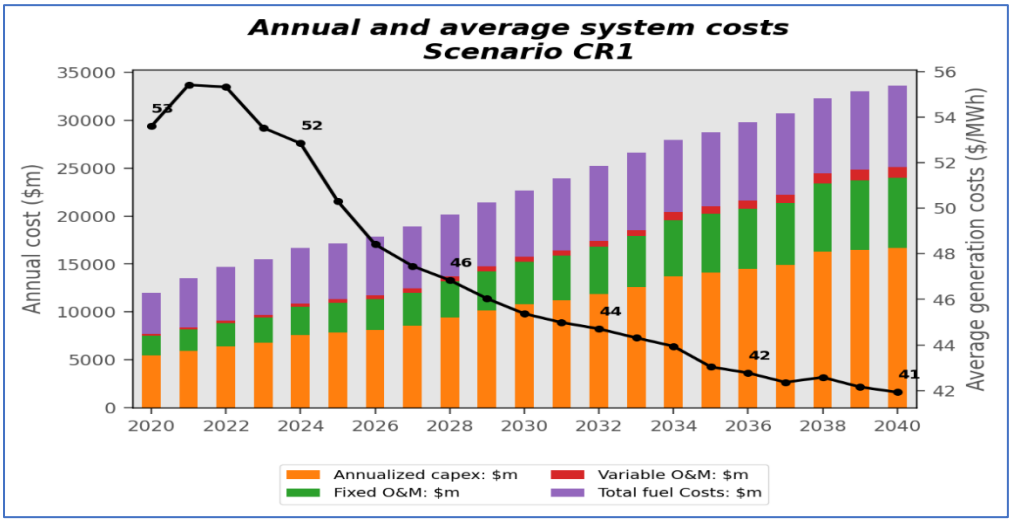
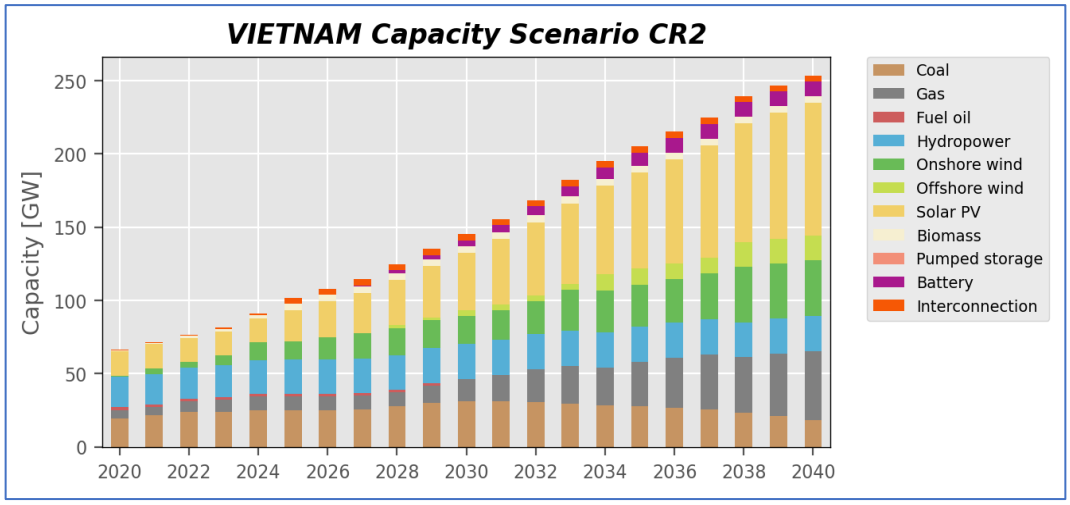


Source: Power Sector modeling carried out by the World Bank staff

C. CR 2 Results



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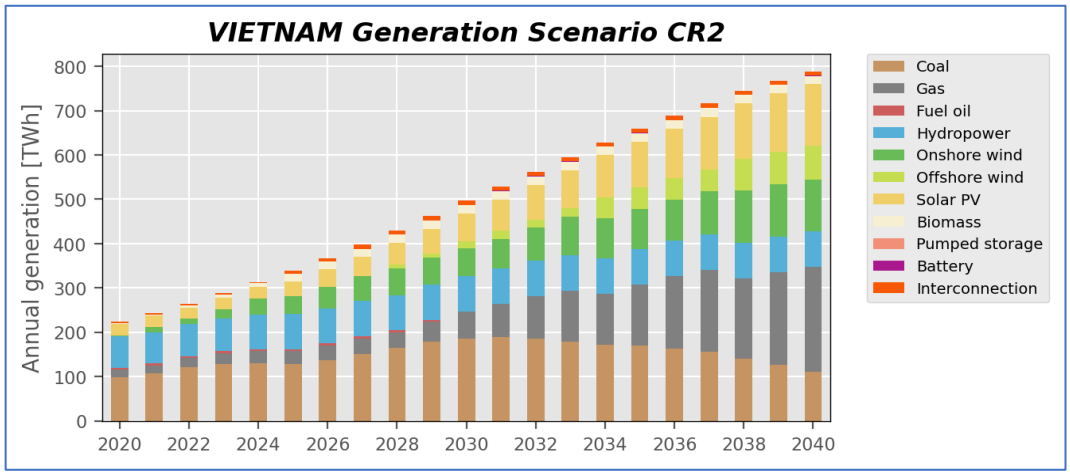

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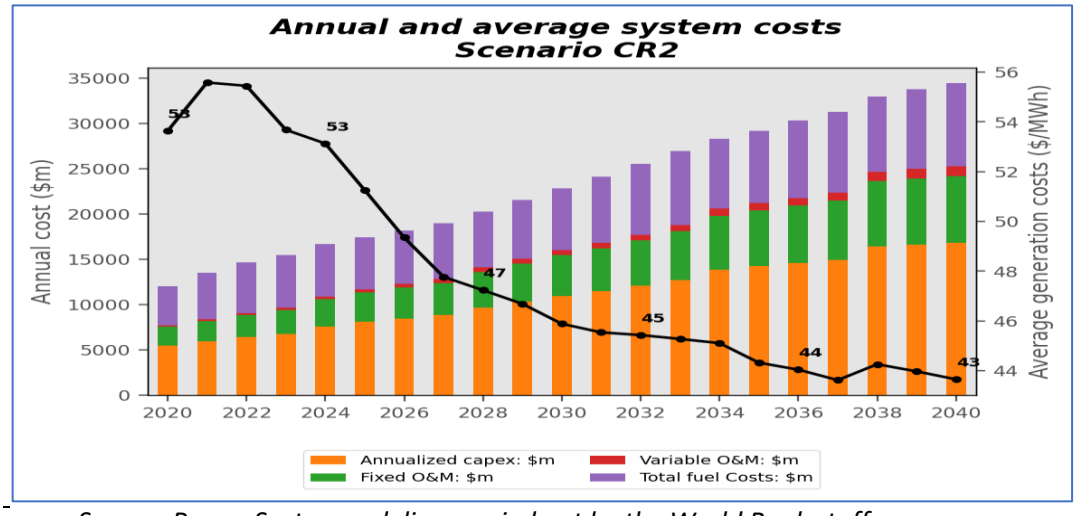
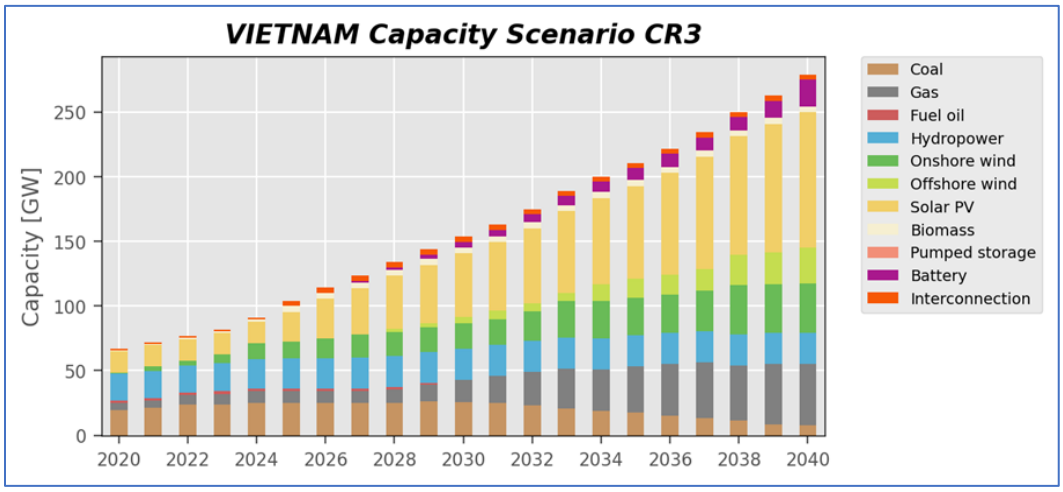


Source: Power Sector modeling carried out by the World Bank staff

D. CR3 Results



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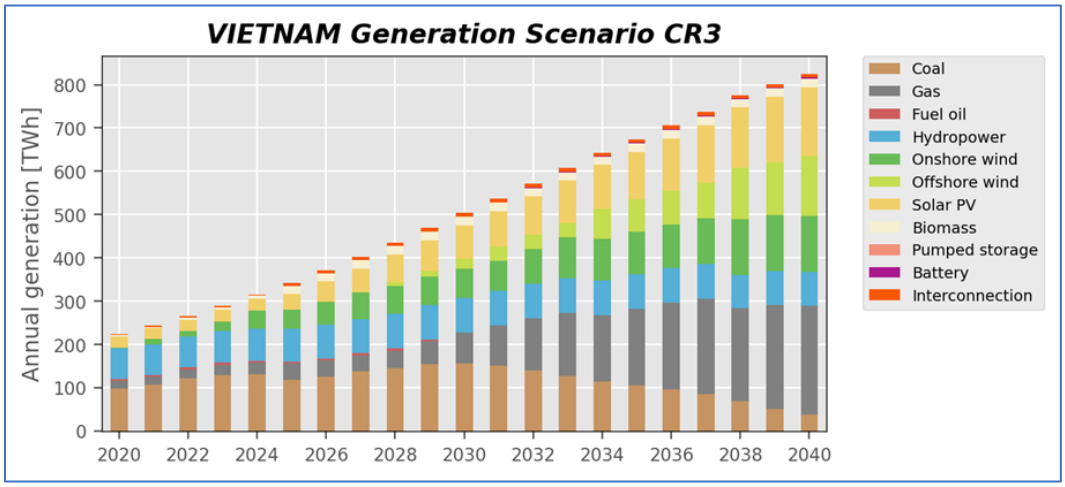

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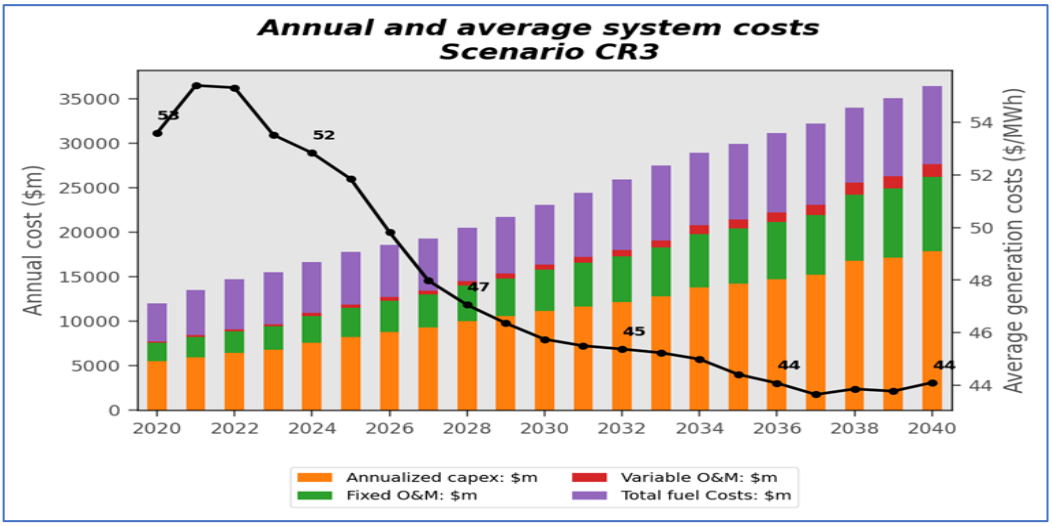
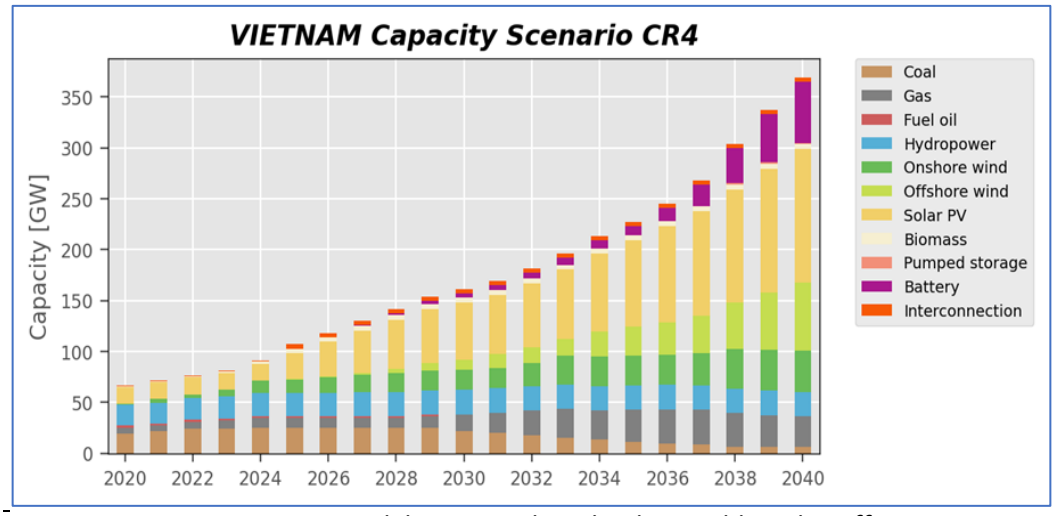
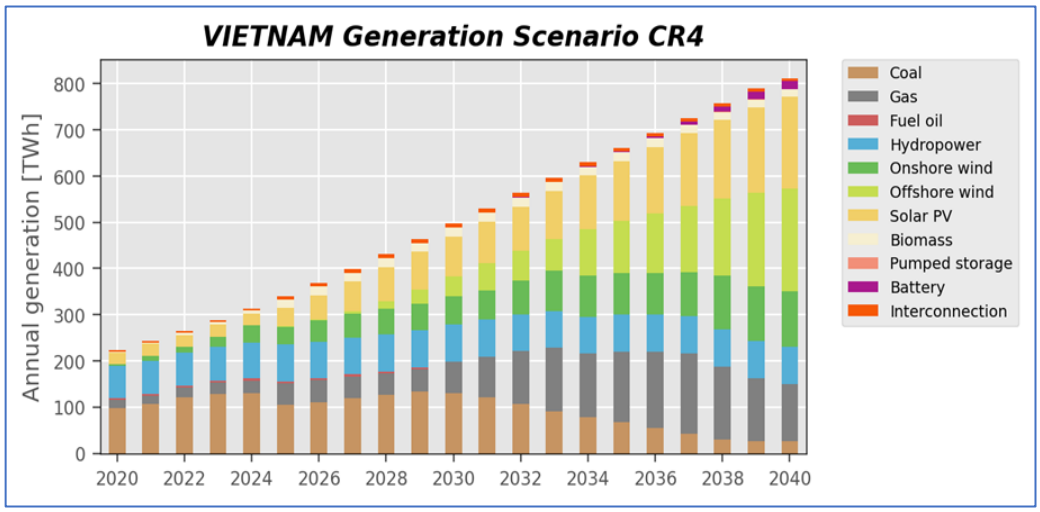


Source: Power Sector modeling carried out by the World Bank staff

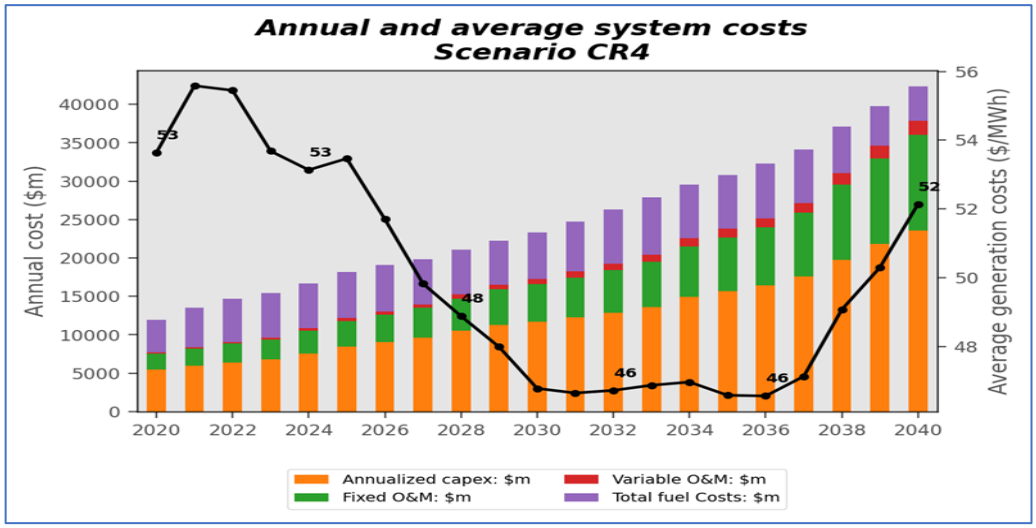
E. CR4/ADS



Source: Power Sector modeling carried out by the World Bank staff

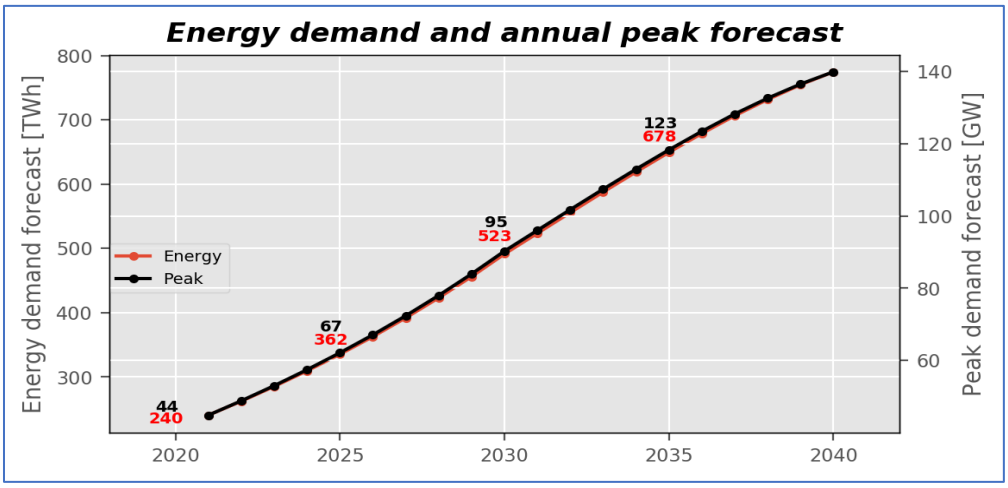


Source: Power Sector modeling carried out by the World Bank staff

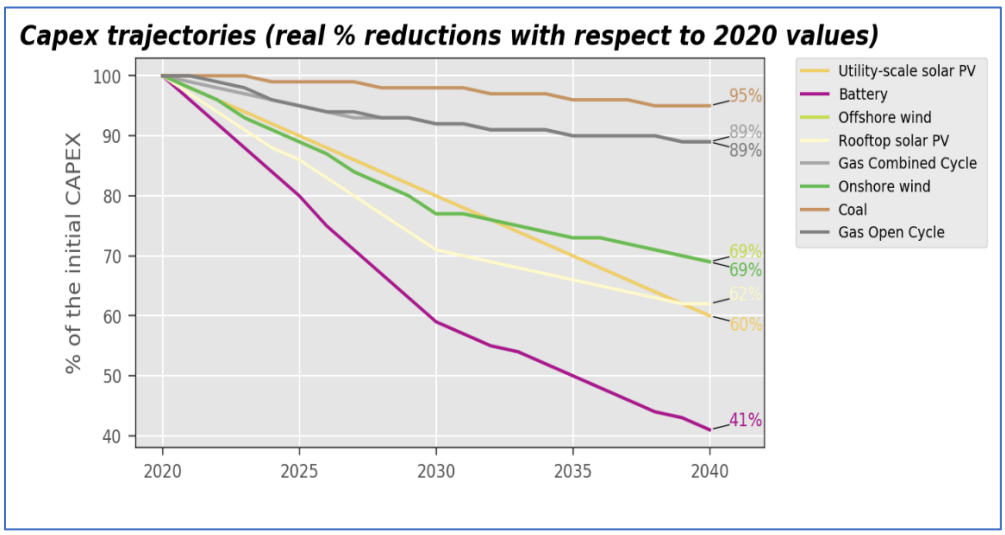


Source: Power Sector modeling carried out by the World Bank staff

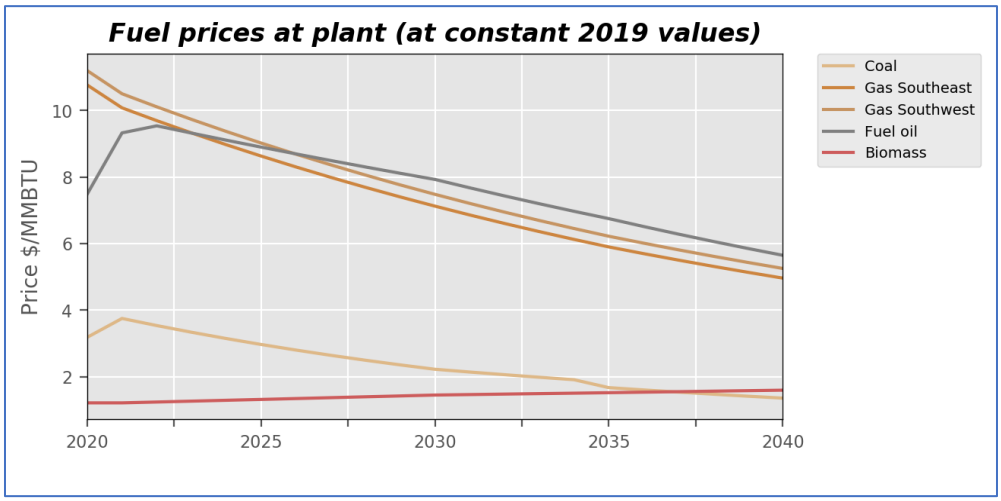
F. Demand, Technology and Fuel Cost Assumptions



Source: Power Sector modeling carried out by the World Bank staff



Source: Power Sector modeling carried out by the World Bank staff



Source: Power Sector modeling carried out by the World Bank staff