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# Vietnam at the dawn of its energy transition

Minh HA-DUONG [1], 2023-09-22

## Abstract

Vietnam's Power Development Plan 8 (PDP8) sets a course for the country's energy transition to carbon neutrality by 2050. The plan targets significant growth in renewable energy, diversification of energy sources, and reduced reliance on imported coal. However, implementing PDP8 poses considerable challenges, including securing an estimated $13 billion annually for new power capacities and grid upgrades, expanding the power grid to accommodate more renewables, and managing the risk of dependence on imported liquefied natural gas (LNG). The success of this plan could provide a model for other middle-income countries undergoing similar energy transitions.

## Keywords

Vietnam, Sustainable development, Energy transition, Carbon neutrality, Power Development Plan, Energy security, Just Energy Transition Partnership, Renewable energy

## JEL

L52; O21; Q48

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# Le Vietnam à l'aube de sa transition énergétique

Minh HA-DUONG

## Résumé

Le Plan de Développement Électrique 8 (PDP8) du Vietnam vise une transition énergétique vers la neutralité carbone d'ici 2050. Sans lancer de nouvelles centrales à charbon et avec un objectif ambitieux de croissance des énergies renouvelables, le plan fait face à des défis de taille : mobiliser 13 milliards de dollars par an pour augmenter la capacité de production électrique et améliorer du réseau, tout en gérant les risques liés à la dépendance vis-à-vis du gaz naturel liquéfié importé. La réussite de ce plan pourrait servir de modèle pour d'autres pays à revenu intermédiaire en pleine transition énergétique.

## Mots clés

Vietnam, Développement durable, Transition énergétique, Neutralité carbone, Sécurité énergétique, Partenariat pour une Transition Énergétique Juste, Énergies renouvelables

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# 1. Introduction

Vietnam is at the dawn of its energy transition, aiming to achieve carbon neutrality by 2050. There has been significant growth in renewable energy deployment, and sustainability plans are taking shape. Nevertheless, the road to full implementation of the May 2023 Power Development Plan 8 (PDP8, the power plan for the 2021-2030 period) and meeting long-term goals is paved with considerable challenges.

Our analysis examines Vietnam's progress towards a sustainable electricity system and the obstacles it must overcome. The shift from fossil fuels to renewables, as guided by PDP8, will involve dealing with issues around capacity growth, fundraising, infrastructure improvement, energy security, and reliance on imported fuels.

While previous efforts to expand solar and wind power have yielded encouraging results but were also hampered by setbacks, delays, and problems with the power grid. The revised PDP8 aims to diversify energy sources, shifting focus from coal towards renewables and liquefied natural gas (LNG). However, concerns persist over these gas strategies and the ability to attract the large-scale investments needed.

International partnerships and financial support may play a significant role in Vietnam achieving its PDP8 and sustainability objectives. Yet, there are key challenges to navigate:

1. To secure at least $13 billion annually to create new power capacities and upgrade the grid.
2. To expand and strengthen Vietnam's power grid to accommodate higher percentages of renewables.
3. To reduce the risk of dependence on imported LNG, considering the decrease in domestic gas production.

How Vietnam tackles these obstacles will shape the effectiveness of its energy transition and can provide a model to many other middle-income countries.

This study delves into Vietnam's journey, future challenges, and potential solutions within its sustainability and decarbonization goals. After setting the stage, we will review the changes in Vietnam's power system over the last decade, then highlight the primary objectives of the PDP8 up until 2030. Following this, we will unpack the earlier challenges and discuss possible solutions.

## 2. Context: A performant middle-income country

In recent decades, Vietnam has seen rapid economic growth and development, transforming from a poor economy in 1986 to a lower middle-income country by 2010. Vietnam aspires to become a high-middle-income country by 2030 and reach high-income status by 2045 (Vương Đình Huệ, 2023 resolution 81).

As shown in Table 1, Vietnam's Human Development Index has surpassed 0,7, signifying a 'high HDI.' Economic growth durably outpaces population growth. Though it slowed during the pandemic, GDP per capita rose by 33% from 2015 to 2020. As measured by the GINI coefficient, income inequality hovers around 0,4 - higher than most European countries but on par with China, the US, and the global average. Vietnam's development trajectory has been a success story, with solid resilience amid the COVID-19 crisis.

However, challenges remain. CO2 emissions per capita are below the world average but increasing rapidly due to economic growth, stagnant energy efficiency, and reliance on coal. Vietnam's environmental performance from 2015-2020 was worse than that of many other countries.

Energy intensity has remained around 400 ToE/kUSD for the past five years, indicating that Vietnam uses more energy than most other countries to generate wealth, mainly due to inefficient technologies and the industrial development stage. Despite energy efficiency initiatives, energy demand is surging, partly due to high economic growth rates and near-total grid connectivity. Vietnam's coal extraction, primarily used for power generation, has not kept up with demand, resulting in increased coal imports that add financial pressure. Oil and gas reserves are depleting. The potential for hydropower, biomass, and geothermal energy is being exploited or explored but is limited due to various constraints. With high solar radiation levels and wind speeds, the potential for renewable energy is substantial, despite the limitations of population density and variable production (refer to supplementary material S1 for more details).

Nonetheless, signs suggest Vietnam is at the dawn of its energy transition. In 2019, it was the world's most robust market for solar farms. At COP26 in 2021, Vietnam pledged to achieve net-zero emissions by 2050 (Vương Đình Huệ, 2023).

*Table 1: Vietnam's key statistics in 2015 and 2020.*

| Year | 2015 | 2020 |
|---|---|---|
| Population | 92 229 thous. pers. | 97 583 thous. pers. |
| Human Development Index | 0,688 | 0,706 |
| Share of population in urban areas | 33,5 % | 36,8 % |
| GDP per capita | 2 596 USD | 3 552 USD |
| Index of income inequality (GINI) | 0,42 | 0,37 |
| Share of rural households using electricity | 97,9 % | 99,4 % |
| $CO_2$ emissions | 179 $MtCO_2$ | 290 $MtCO_2$ |
| $CO_2$ emissions per GDP | 1,4 $kgCO_2$/USD | 1,7 $kgCO_2$/USD |
| $CO_2$ emissions per capita | 1 960 $kgCO_2$/person | 2 971 $kgCO_2$/person |

Source: Statistical Yearbook of Vietnam 2021 (General Statistics Office of Vietnam, 2022a).

## 3. Vietnam's electricity sector under PDP7 (2011–2020)

The Power Development Plan 7 (PDP7A) period in Vietnam's power sector history, 2011-2020, was characterized by significant achievements overcoming stark challenges.

Table 2 shows the historical and planned evolution of Vietnam's power system. At the start of the period, Vietnam's power system could be introduced as "Under 100 TWh produced per year, the North uses hydroelectricity with coal appearing, the South makes power from gas" (Nguyen et al., 2010). Nine years later, supply security was maintained. This required tripling the electricity production capacity (see Drawing 1). Coal and hydro dominate in the North, gas is in the South, and solar is mostly in south-central provinces, reflecting the distribution of natural resources.

PDP7A accurately predicted the 2020 total national commercial power output. However, the distribution of this power across regions did not align with forecasts. The demand in the North was underestimated, while that in the South and the Centre was overestimated. This is disrupting the traditional transmission patterns, previously from North to South. Nowadays, the North needs to receive power.

An even more significant issue was the failure to adhere to the proposed electricity mix (see Drawing 2). The PDP7A had envisioned 26 GW of coal-fired, 9 GW of gas-fired, 18 GW of hydro, 0,85 GW of solar, and 0,8 GW of wind power by 2020. However, only about 60% of the proposed thermal power sources were constructed for various reasons, including the late release of PDP7A, conflicts with local communities, and financial risk/reward ratio. On a positive note, the scale of renewable energy far surpassed expectations, with capacity exceeding targets by an astounding 480% (Do et al., 2021).

The expansion of solar and wind power was significant during this period. Feed-in tariff policies for Solar PV were introduced in 2017 (Decision 11, Nguyễn Xuân Phúc, 2017), followed-up by (Decision 13, Trịnh Đình Dũng, 2020). Vietnam rose as the third-largest market for PV in 2019-2020. The nationwide electricity feed-in tariffs led to installing 7,9 GW of rooftop PV and 8,6 GW of ground-mounted PV by the end of 2020, surpassing nations like the UK and South Korea. However, these successes were marred by various issues, including the lack of time to verify many projects' legal and technical conformity.

The Feed-in Tariff (FIT) for wind energy projects, issued in 2018, also led to a great dynamic in the sector (Decision 39, Nguyễn Xuân Phúc, 2018). By October 31, 2021, Vietnam had commissioned 4 GW of wind power, equivalent to the combined capacity of South Korea, Thailand, and the Philippines in 2020. The wind industry surge was not without issues. Substandard environmental and safety standards, logistical and engineering mishaps, and project delays due to the Covid-19 pandemic were some of the significant challenges that surfaced. Many projects failed to meet the October 2021 deadline due to these issues.

The rapid deployment of solar photovoltaic (PV) and wind farms substantially strained the grid, leading to congestion problems. The transmission network could not keep up with the surge in renewable energy production, leading to significant wastage of electricity generated by solar and wind farms that could not be transmitted to consumers. The lack of a suitable legal framework to remunerate renewable energy projects that missed the deadline further exacerbated the issue, resulting in an inefficient scenario with 85 idle projects (8 solar, 77 wind) in 2022 representing 4,7 GW of unused capacity (see Drawing 1) (Nguyễn Sỹ Hiệp, 2023).

The institutional combination of centrally decided private sector invitations and a decentralized implementation can explain the excess offer situation. As the tariff was uniform, developers went to the same sunniest provinces. The provincial authorities had no legal basis for prioritizing projects and rejecting those beyond the local grid capacity to absorb.

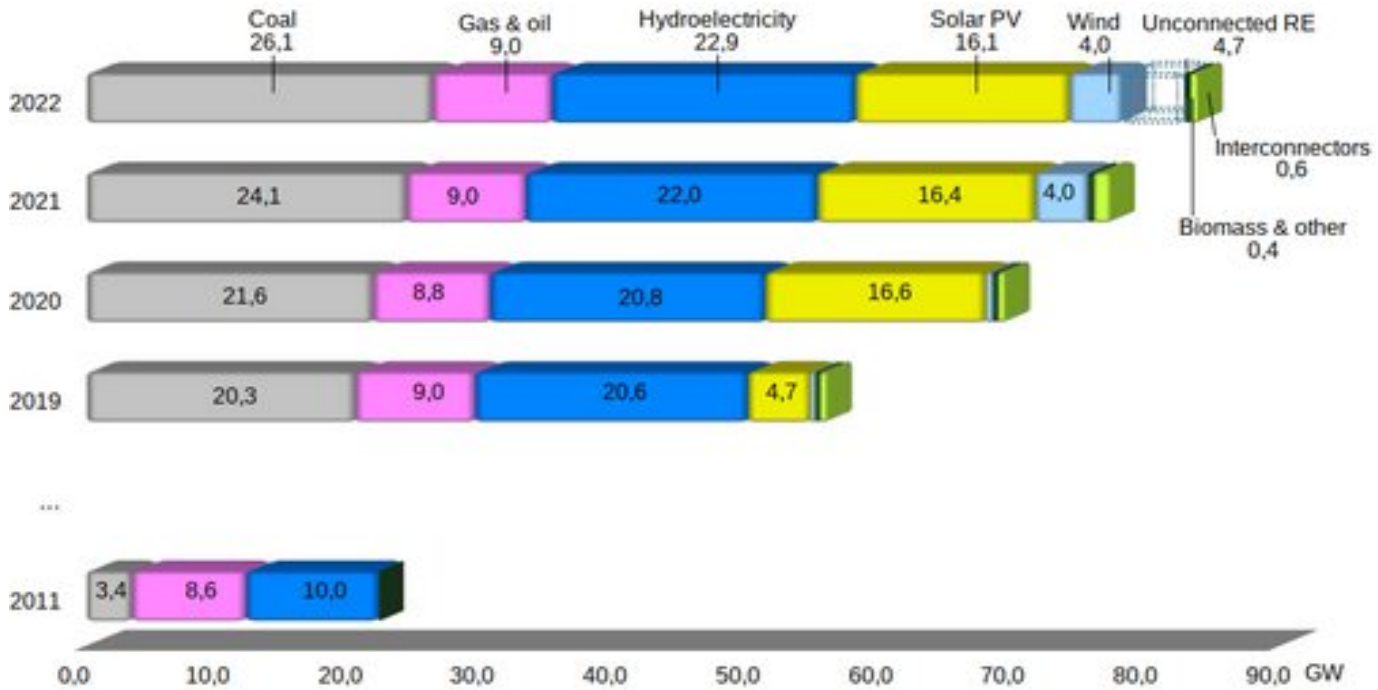
The situation in 2023 exposed the fragility of the electric situation inherited from the PDP7. After an adequate supply in 2020 due to reduced demand during the COVID-19 crisis, supply constraints emerged due to economic recovery in 2021 and 2022. However, 2023 brought forward a stark reality. The shift from a La Niña mode to an El Niño mode brought about lower rainfall and increased summer temperatures, leading to higher power demand for cooling with less hydroelectric power available. This highlighted the fragility of the energy system, leading the government to implement urgent energy-saving measures to alleviate power shortages, particularly in the North (Phạm Minh Chính, 2023).

In conclusion, while the PDP7 period led to a spectacular increase in power output and an unprecedented scale-up of solar and wind energy, it also left many issues for the PDP8.

*Table 2: Vietnam power generation mix: 2010, 2020, 2022, the 2030 plan and 2050 vision*

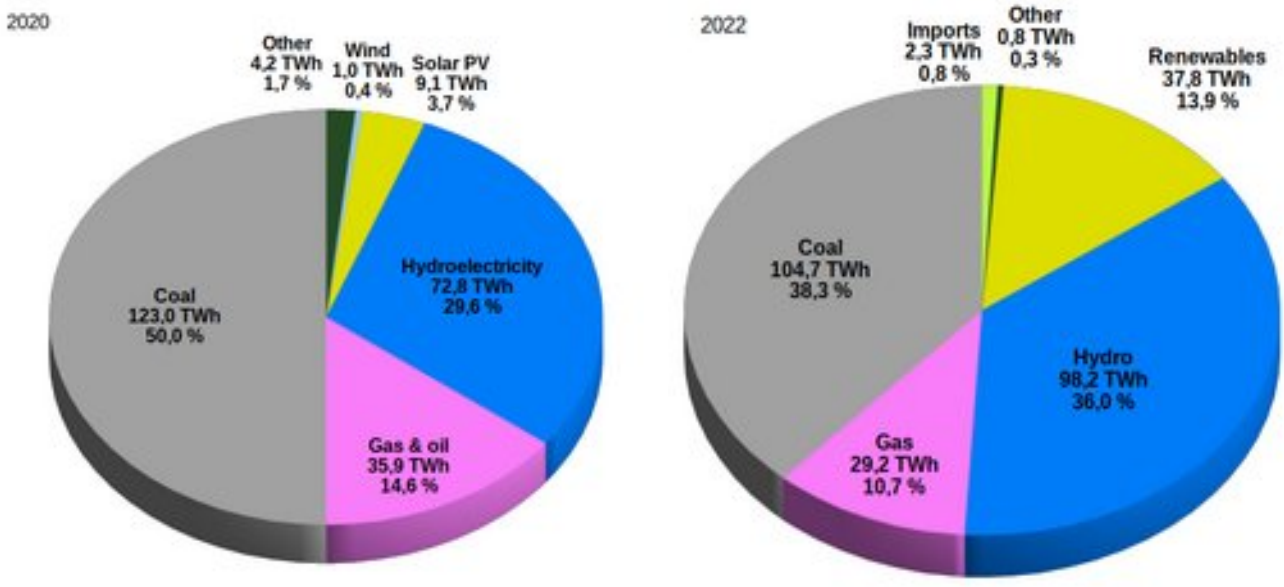
| Capacity (GW) | Past 2011 | Recent 2020 | Current 2022 end | Plan for 2030 | Vision to 2050 |
|---|---|---|---|---|---|
| Coal, domestic and imported | 3,4 | 21,6 | 26,1 | 30,1 [a] | 0 |
| Coal plants repowered to use H2/NH3 | - | - | - | - | 25,6 – 32,4 |
| Oil and Diesel | 1,3 | 1,4 | 1,6 | 0 | 0 |
| Gas domestic, including some using LNG | 7,4 | 7,4 | 7,4 | 14,9 | 7,9 |
| Gas domestic repowered to use H2 | - | - | - | - | 7,0 |
| LNG new plants | - | - | - | 22,4 | 0 |
| LNG new plants cofiring or full H2 | - | - | - | - | 25,4 [h] |
| Flexible sources using LNG/H2 | - | - | - | 0,3 | 30,9 – 46,2 |
| Hydroelectricity, including small | 10,0 | 20,8 | 22,9 | 29,3 [b] | 36,0 |
| Wind on/near-shore | - | 0,5 | 4,1 | 21,9 | 77,0 – 60,0 |
| Wind offshore | - | - | - | 6,0 | 91,5 - 70 |
| Solar, including rooftop | - | 16,6 | 16,6 | 20,6 [c, d] | 189,3 – 168,6 |
| Biomass + other renewable | 0,05 | 0,4 | 0,6 | 2,3 | 6,0 |
| Interconnectors | - | 0,5 | 0,6 | 5,0 [e] | 11,0 |
| Storage, hydro + battery | - | - | - | 2,7 [f] | 30,6 – 45,6 |
| Cogeneration | - | - | - | 2,7 [g] | 4,5 |
| **Total capacity (GW)** | **22,0** | **69,3** | **79,8** | **158** | **573 – 490** |
| Maximum load (Pmax GW) | | 38,6 | 45,4 | 90,5 | 185 – 209 |
| Commercial electricity | 97 TWh | 238 TWh | 271 TWh | 505 TWh | 1 114 – 1 255 TWh |
| Offshore wind to H2/NH3 | | - | | 15 GW by 2035 | 240 GW |
| GHG emissions | | 273 [i] | | 204 – 254 Mt [j] | 27 - 31 Mt |

Source: Col. 2011 from EVN Annual Report 2010/2011 p. 12. Col. 2020 from EVN Annual Report 2021. Col 2022 from VEPG 2023/06 meeting. Col. 2030 and 2050 from PDP8 Decision 500.
Notes: [a] "*coal sources having difficulties in deploying will be replaced by LNG or renewable sources.*" [b] "*can be developed further if technical-economic conditions allow.*" [c] Includes rooftop projects under legal review. [d] Solar auto production is prioritized for unlimited development. [e] "*can be up to 8,0GW*". [f] includes 2,4 GW of hydro storage and 0,3 GW of battery. [g] can increase according to industry needs. [h] includes 16,4 GW to 20,9 GW on 100% H2, the other cofiring H2 with LNG. [i] Emission estimate for all the energy sector. j "*Aim to reach peak emissions of no more than 170 million tons by 2030 with condition that commitments under JETP are fully and substantively implemented by international partners.*"




*Drawing 1: Installed power generation capacity in Vietnam (GW) in 2010 and 2019-2022.*

*Source: Author, data: ERAV communications to the Vietnam Energy Partnership Group*




*Drawing 2: Vietnam's electricity production in 2020 and 2022 by primary energy.*

*Source: Author, data: ERAV communications to the Vietnam Energy Partnership Group.*

## 4. Vietnam's new Power Development Plan 8 (PDP8) for 2021–2030

The new Power Development Plan 8 (PDP8) defines the power sector trajectory until 2030, with a vision to 2050, see Table 2 and annex S2. The plan aims to:

1. Ensure energy supply security by diversifying power sources, balancing supply and demand within regions, and promoting decentralized electricity production to meet Vietnam's growing demand.
2. Reduce dependence on imported fuels by promoting investment in domestic fossil fuel-based and renewable energy sources.
3. Control greenhouse gas emissions from the power sector by targeting emissions of 204-254 million tons by 2030 and 27-31 million tons by 2050 (unconditional goals). With international assistance, the aim is to peak emissions at 170 million tons by 2030, in line with the Just Energy Transition Partnership agreement signed with G7+ nations.
4. Contribute to green growth and economic performance by exporting green energy and developing renewable energy clusters within Vietnam's industrial strategy.

The PDP8's targets include doubling Vietnam's power generation capacity to 150 GW by 2030 while shifting from coal to LNG and renewables. The PDP8 bets on LNG but hedges this bet with a series of provisions formulated as qualitative notes ancillary to the quantified objectives, which open the door to deploy low-carbon energy sources faster than in the plan's baseline.

- The plan notes that renewable energy projects that serve on-site loads not connected to the grid are encouraged without a capacity limit. The plan aims to have rooftop solar power for on-site consumption in 50% of office buildings and 50% of residential houses by 2030.
- Waste and biomass plants are prioritized without a capacity limit.
- The hydroelectricity goal is a minimum, but the LNG goal is a maximum.
- Even if nuclear is not included in the key projects, the land currently planned for nuclear power development is retained and not released for other planning purposes.
- Electricity trade can be increased if there is a reasonable selling price and a suitable connection.
- The solar sector target is provisional, pending the resolution of legal issues with legacy projects.

Overall, Vietnam's PDP8 is a milestone in Vietnam's move to a net-zero future. It aims to shift from coal to renewable energy sources like hydropower, wind, solar, and biomass in 2050, building LNG power plants to fill the gaps until 2035.

## 5. Challenges facing the implementation of PDP8

Implementing the Power Development Plan 8 (PDP8) 2030 goals faces significant challenges:

1. Capital mobilization: Implementing the PDP8 will require an estimated $13 billion annually for new generation capacities and grid upgrades through 2030. Given Vietnam's current capabilities, securing this financing from public and private sources will take much work.
2. Grid development: Vietnam must rapidly expand and strengthen its transmission grid to support higher demand and higher shares of variable renewable energy. Planned grid investments have lagged behind generation expansion in the past. During the PDP7A period, only approximately 80% of the planned new transmission infrastructure was constructed, with most projects experiencing delays of 1-2 years.
3. Reliance on imported LNG: The PDP8 relies heavily on importing LNG to power thermal plants. Vietnam currently has limited LNG import infrastructure: by mid-2023, it had just finished building one of two terminals and was still waiting to receive its first cargo. Domestic gas production is in decline, pointing to uncertainties around securing sufficient imported LNG supplies from volatile international markets.

Overcoming these challenges in time leads to power project delays and implementation risks.

Delays in thermal power projects (Hoàng Quốc Vượng, 2020 ; Nguyễn Thái Son, 2020) undermined the primary energy policy objective of the PDP7A—enhancing supply security to meet the electricity demand. These delays were due to the late release of the plan, conflicts with local communities, and low financial reward/risk ratio. They translate into financing issues, unsigned power purchase agreements, and ultimately the abandonment of coal as the backbone of the power system. There are concerns that history may repeat itself.

Renewable power projects also suffer from delays and implementation risks. The wave of PV projects exceeded the available resources to verify ex-ante the legal and technical conformity of that many projects. Some project developers cheated; they registered more capacity than installed at the end of 2020 to benefit from the feed-in tariff. In September 2021, the government instructed MOIT to correct the situation of the wrongly declared projects. Drawing 1 shows that the solar PV generation capacity marginally decreased in 2021 and 2022. The surge in the wind industry also led many projects, characterized by sub-par environmental and safety standards, to suffer from logistical and engineering mishaps such as road damage, overturned trucks, and turbine breakdowns during commissioning. Government-enforced lockdowns during the Covid-19 pandemic and intense competition for limited specialized equipment like barges, cranes, and trucks caused considerable project delays. Many projects failed to meet the October 2021 deadline.

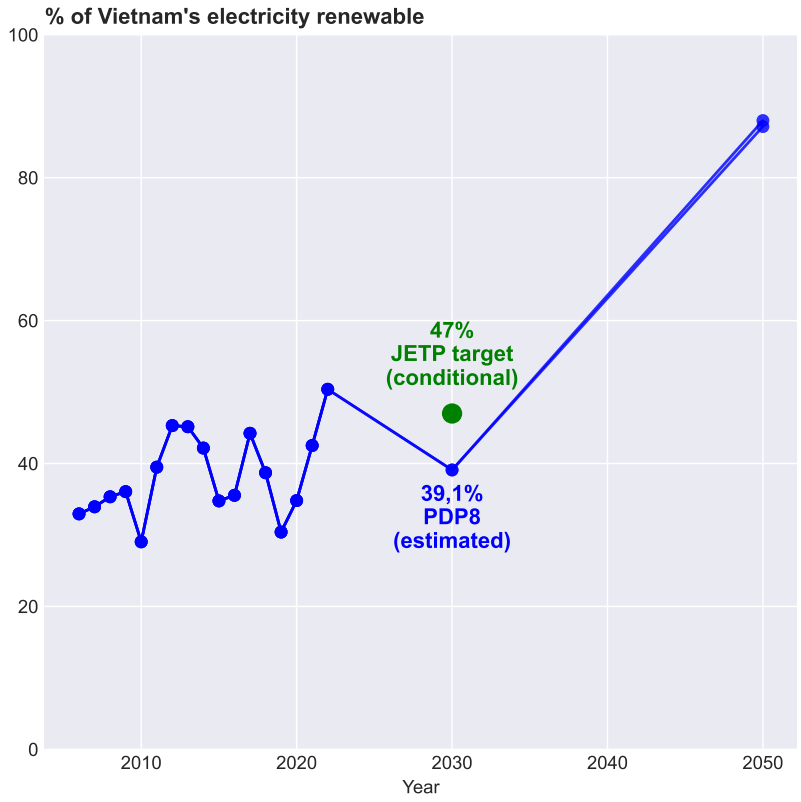
Inadequacy of the grid led to a country-wide freeze in new solar and wind projects. Grid congestion is a well-documented issue associated with integrating intermittent energy sources. The transmission network failed to anticipate the unprecedented surge in renewable energy production, which departed significantly from the original plan. As a result, in 2020 and 2021, a large portion of the electricity generated by solar and wind farms was wasted as it could not be transmitted to consumers. From January to April 2021, curtailment resulted in the loss of 13,3% of PV generated electricity (447,5GWh) and 4,8% of wind-generated power (19,7GWh) (Ha-Duong, 2021). The curtailment costs fall upon the project owners, as the national electricity company EVN is not obligated to pay for electricity that cannot be safely delivered to the end users.

Moreover, the long-term vision for net zero in 2050 is also challenging:

The plan's feasibility in terms of technology and economics needs to be clarified. Technologically, the utilization of hydrogen and ammonia in thermal power plants is still under research, yet to be commercialized and unverified. Producing biomass may require more land than is available. The efficiency of using offshore wind to produce electricity, to produce green ammonia/hydrogen, to transport it onshore, and to burn it to produce electricity is likely lower than using a submarine electricity cable and batteries. The cost of retrofitting existing installations for co-firing and then fuel switching is still unknown. Implementation must ensure legal compatibility with the existing agreements to build-operate-transfer power plant owners and articulation with the upcoming national carbon market.

Renewable sources accounted for 48% of Vietnam's electricity output in 2022. Yet, it's premature to conclude that half of the electricity produced in Vietnam is green. As illustrated by Drawing 3, the share of carbon-free electricity has fluctuated significantly over the past 15 years, mainly due to variations in water availability. Looking normatively at the percentage of Vietnam's electricity that should be carbon-free, to shift from 40% in 2020 to 100% by 2050, a 20% increase is needed every ten years. This implies that the PDP8 goal for 2030 should be that around 60% of electricity is produced carbon-free. The current 30-39,1% goal, with ambitions to reach 47% with international assistance, still needs to catch up.

In summary, successfully implementing the PDP8 targets within the envisioned time frame and transitioning Vietnam's energy system will require overcoming significant hurdles related to financing needs, infrastructure development, energy security, and efficient execution. International cooperation and partnerships could help address some of these implementation challenges.




*Drawing 3: Past and planned share of carbon-free electricity in Vietnam. Source: Author.*

## 6. Solutions and Pathways to Achieve PDP8 Goals

The extant literature on Vietnam's key power sector challenges offers a wide range of solutions.

Regarding capital mobilization, (Nam Hoai Nguyen et al., 2019) found that it was a concern for EVN related generation companies, while foreign firms have an better financial capacity. They recommend improving the legal and policy framework, reforming administrative procedures, and enhancing the electric power market to attract investment. The case study by (Abdullah et al., 2023) clarifies that the post-COVID-19 fiscal consolidation limits the public budget capacity to fund green projects required for achieving the green energy transition target. (Do et Burke, 2023) found that the ambition to attract international support for green growth motivated Vietnam's coal power phase-out decision and pointed out the JETP agreement as evidence that this strategy was paying dividends. The recommendation to increase Feed Tariffs for wind and solar (Mallon, 2019) was indeed a practical idea, but for reasons we will discuss further, it is not timely any more in Vietnam. One of the most exciting instruments may be green bonds (Ha-Duong, 2022), which are very new in Vietnam (Thai, 2021) even if (Maweni et Bisbey, 2016) suggested the solution some years ago.

Regarding the power grid expansion and renewables integration, (Nga Vu et al., 2019) recognize that investment is an issue for HVDC cables today but will be integrated on a middle-term basis to stabilize the network. (Thanh et al., 2022) found that integrating battery energy storage systems into the transmission grid could effectively reduce solar and wind curtailment, but (EREA et DEA, 2022) saw that storage would only play a central role after 2030. Accordingly, PDP8 postpones significant investments in HVDC and storage after that year.

Regarding the role of LNG, (Dang, Huynh et Ta, 2016) warned early on that due to the dwindling domestic natural gas supply, LNG imports would have to start as early as 2019 and that the lack of a long-distance national gas pipeline network will constrain the location and configuration of the LNG terminals to be build (Nguyen, 2009). (Hoang et Doan, 2021) argues that promoting the exploitation of domestic gas projects is much more beneficial than importing LNG. This does not imply that the domestic supply is large enough. (Le et al., 2019) are very bearish on the role of natural gas in the energy transition in Asia, noting that a carbon price will decisively tilt the economics against coal. However, (Friends of earth, 2022) shows that financing fossil fuels may be a problem as pressure groups shift their focus from coal to gas. In this context, the time window to develop the gas-to-power infrastructure may close soon. The PDP8 is clear about this: no new gas after 2035.

In our view, several levers will help Vietnam achieve energy security of supply, lower its energy dependence and reduce the electricity sector's greenhouse gases emissions:

1. International financing and partnerships: International financing and cooperation will be critical in overcoming Vietnam's domestic financing constraints. For example, Viêt Nam, with G7 countries plus Denmark and Norway, signed a Just Energy Transition Partnership (JETP) on December 14, 2022. This agreement aims to mobilize at least 15,5 billion USD over the next 3 to 5 years, half as private finance and half as public sector finance. The quantified objectives include peaking electricity sector emissions at 170 MtCO2e in 2030, peaking the coal-fired power generation capacity at 30,2 GW, and producing 47% of electricity from renewable sources in 2030.
2. Prioritizing decentralized renewable energy projects: The PDP8 encourages renewable energy projects for on-site loads without capacity limits to accelerate Vietnam's transition from fossil fuels. Promoting distributed renewable energy, rooftop solar, micro-grids, and other decentralized solutions, especially in rural areas, could help diversify Vietnam's energy mix and reduce import dependence.

3. Regulatory reforms: Reforms to allow renewable energy projects faster access to the grid, negotiate power purchase agreements, and acquire land use permissions could reduce implementation delays. Establishing a legal route to permit offshore wind as early as possible is critical if the 2030 targets are to be met.
4. Effective incentive schemes: Feed-in tariffs, auctions, and other incentive schemes that reward project performance and outcomes could help avoid the inefficiencies of the previous fixed-price incentives. It won't be easy to attract gas-fired power plant investors without a mechanism to recoup their capital costs, such as capacity payments, for example, and a mechanism to purchase electricity that allows them to cover their operation costs, given the price of LNG.
5. Optimizing LNG plans: Optimized utilization of available domestic gas supplies for flexibility could help complement renewable energy sources. Due to economies of scale, building only three LNG receiving, re-gasification, and storage facilities at the 10Mm3/year scale may be more optimal. The LNG targets in the PDP8 will have to harmonize with the import and transmission infrastructure to be defined in the upcoming national energy master plan and the marine spatial plans.
6. Energy efficiency improvements: Catching up with more advanced economies in energy efficiency and conservation through institutional reforms, market mechanisms, and behavioural changes is urgent to reduce demand and costs.

In summary, a combination of international financing, prioritizing renewables, deploying decentralized solutions, institutional and market reforms, optimized LNG utilization, energy efficiency gains, and performance-based incentives could help Vietnam navigate the challenges of implementing the PDP8 and transitioning its energy system towards sustainability.

# 7. Conclusion

As underscored in the introduction, Vietnam has indeed been a beacon of developmental success, even against the backdrop of its rapidly escalating $CO_2$ emissions. A retrospective examination of its recent energy system history revealed that the Power Development Plan VII (PDP7) bore a mixed legacy. Notably, it succeeded in expanding total power production from 97 TWh in 2021 to 271 TWh in 2022. However, recurrent power shortages in the North in 2023 hinted at inherent problems within the expansion process. While impressive, the solar and wind energy boom suffered the grid's limited capacity, resulting in severe curtailment.

Furthermore, numerous projects fell by the wayside. A deadline mechanism for the feed-in tariff (FIT) left a substantial 4 GW of renewable energy projects languishing for over a year without market access. Despite these hurdles, Vietnam has positioned itself as a frontrunner in ASEAN's energy transition race.

Unveiled in May 2023, the PDP8 charts the course for Vietnam's power sector for the forthcoming decade. It is aligned with the commitment to achieving net-zero emissions by 2050. The plan envisages a halt in coal power expansion and hinges on massive LNG imports. The approval of the PDP8 gives back hope to the clean energy industry after two difficult years. It outlines ambitious targets for onshore and offshore wind energy, grid connectivity, and strategies to manage solar and wind power variability. A particular emphasis is placed on consumer-generated solar power and stimulating the local green economy. The inherent adaptability of hydroelectricity and gas generation sources aligns well with the natural variability of solar and wind power.

Ensuring a stable electricity supply while tackling environmental and developmental challenges remains a Herculean task. The first challenge lies in mobilizing the projected annual investment of over $13,5 billion. The second is that investment in grid enhancements must keep in stride with the surging demand for energy and clean electricity. Third, assuming a rebound of domestic gas production seems optimistic, and how many of the proposed LNG-to-power chains will entice investors remains to be seen. Securing imported fuel supplies is a remarkably complex issue, given the high volatility of international spot market prices for coal and LNG. The urgency to realize PDP8's goals exerts pressure on government officials, developers, and financiers alike.

The need for international cooperation to address these challenges is paramount. A successful Just Energy Transition Partnership could augment the proportion of renewable energy and decrease $CO_2$ emissions relative to the unconditional baseline of the PDP8. On a domestic level, it's vital to advance the regulatory framework to remove administrative barriers currently impeding investment in renewable energy projects. This includes but isn't limited to decentralized power generation, offshore wind, or floating solar. The push to create a more attractive power market is crucial to lure private sector involvement.

Addressing the financing of the energy transition requires significant work. Future research should focus on a comprehensive understanding of the opportunities presented by the Just Energy Transition Partnership. Analysing the PDP8 planning process could offer valuable insights into how a country can transition from a coal-based to a renewable-based future. Such knowledge is invaluable for energy transition researchers and practitioners globally.

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# Electronic supplementary materials

## Annex S1. Vietnam's energy system overview

The energy intensity of Vietnam's economy has remained relatively stagnant at around 400 ToE/kUSD over the past five years, as depicted in Table S1.1. This suggests that Vietnam utilizes more energy than other countries to generate wealth. This pattern is partly due to the structural nature of the country's stage of industrial development. Still, it can also be attributed to the usage of outdated, inefficient technologies in industries spurred on by the competitive advantage of low energy prices. Consequently, the lack of significant improvement in energy efficiency has led to a seemingly unbounded increase in total primary and final energy demand.

Over the past few decades, the government has undertaken initiatives to promote energy efficiency, as illustrated by the 2003 Decree 102/ND-CP on Energy Efficiency and Conservation. The resulting regulations and national programs have included energy labeling requirements to inform consumers about the energy efficiency of appliances, vehicles, and equipment they purchase. Furthermore, specific energy consumption mandates have set standards in various industrial sectors and building development. These efforts have also led to mandatory energy audits and management plans for large energy users. Nevertheless, this latter mechanism suffers from a sort of "chicken and egg" problem: the absence of a robust market for energy audits and energy services has not created a viable energy services industry.

By 2020 over 99% of households were connected to the public grid. According to our analysis of the Vietnam Households Living Standard Surveys (Ha-Duong et Nguyen, 2021), the share of households using less than 30 kWh of electricity per month halved between 2010 and 2018, dropping from 12,9 % to 6,2 %. Vietnam has reached a juncture where the marginal costs of rural electrification are high. For example, the investment cost for the submarine cable to connect the Côn Đảo island to the national grid exceeds 210 million USD (Trần Hồng Hà, 2023b) for a permanent population of 5 000 persons. This money could fund over 5 million improved cookstoves (assuming a $40 unit price), potentially yielding a much more significant impact towards the SDG7 *Clean and affordable energy for all*.

With high economic growth rates and the high energy intensity of the Vietnamese economy, the electricity demand continues to outpace economic growth. In response, Vietnam has been expanding its power supply remarkably over recent years, registering a 49% increase in five years, as indicated in Table S1.1.

Turning our attention to primary energy sources, Vietnam has been extracting anthracite coal from the Quang Ninh area for over 150 years. There are reserves available in the Dong Bac basin up to -300m and a considerable resource of sub-bituminous coal in the Red River Delta is at the exploration stage (Nguyễn Tấn Dũng, 2016). In 2020, Vietnam produced 44,6 Mt of coal, with the overwhelming majority allocated for power production. Since 2015, the domestic expansion of coal mining has not been able to keep pace with the growing demand from the power sector, leading to a steady increase in coal imports. In 2016, Vietnam imported 13,2 million tons of coal, which included 1,13 million tons for Vinacomin, and by 2020, this figure had risen to 54,48 million tons, with 9,6 million tons designated for Vinacomin (Vietnam Energy Online, 2023). In 2023, the national coal company Vinacomin plans to produce 38,67 Mt and import 9,2 Mt (Lê Quang Dũng, 2023).

Table S1.1 reveals that the value of coal imports reached 3,8 billion USD in 2020. This figure rose to 4,5 billion USD in 2021, contributing to the 12,07 billion USD national trade deficit (General Statistics Office of Vietnam, 2022a, 617, 646). In 2022 the national coal bill surged to

7,2 billion USD (General Statistics Office of Vietnam, 2023), putting pressure on the national trade surplus of 11,2 billion USD (General Statistics Office of Vietnam, 2022b). This is 1,8% of Vietnam's Gross Domestic Product that year, 409 billion USD (World Bank).

The oil and gas situation in Vietnam is also one of depleting reserves, with domestic production declining, as evidenced in Table S1.1 for gas. Each of these four projects provides enough gas to justify constructing a multi-GW power center, but they have yet to be exploited for various reasons discussed in Text S1.2. Attempts to set up gas-to-power value chains for baseload power have failed for over ten years. Using gas to generate electricity at peak demand times and for flexibility may be more valuable. However, the opportunity window for fossil fuel extraction is closing, and the government is considering a "no new gas power plants after 2035" policy. Some of these reserves may ultimately stay in the ground.

Regarding renewable energy, the potential for large hydropower plants in Vietnam is already being exploited, with approximately 20 GW in operation and growth mainly arising from the extension of existing projects. The economic potential for small hydro (<30 MW) in Vietnam is about 7,2 GW, of which less than 2 GW is installed today, limited by environmental and social constraints. About 10 GW of pumped storage sites have been identified, and among those, the Bac Ai 1,2 GW project commenced construction in 2020.

Modern usage of biomass for energy is only beginning to expand in Vietnam. With potential estimates of 5 GW for biomass and 1,5 GW for waste, this source is likely to will likely remain a minor contribution to the national energy budget. Prospects for geothermal energy are even lower, with Vietnam having minimal experience in using geothermal energy industrially, unlike countries like the Philippines and Indonesia.

Vietnam's solar radiation levels are high as a subtropical country, especially in the Southern half. The economic potential for solar energy is about 386 GW, further constrained by the severe land-use restrictions given Vietnam's concentrated population density. For wind energy, the potential for onshore wind at high speeds is 24 GW, plus an additional 30 W at medium wind speeds (5,5 – 6 m/s), considering land and grid constraints. The offshore wind potential is much higher, around 163 GW. However, wind farms only produce 35% to 50% of their nameplate capacity over a year on average, while solar PV capacity factors range between 15% and 23%.

The Sankey diagram S1.2 complete the picture of Vietnam's energy situation. It displays the 2020 energy balance Sankey chart from the International Energy Agency. It shows the dominance of coal in the national primary energy supply. The chart also shows that coal and oil imports outmatch domestic production, while there is no gas import.

*Table S1.1: Vietnam's key energy statistics in 2015 and 2020.*

| Year | 2015 | 2020 |
|---|---|---|
| Total final energy consumption (TFC) | 52 962 ktoe | 67 297 ktoe |
| Energy intensity of the economy TFC/GDP | 399,2 kgOE/kUSD | 406,0 kgOE/kUSDb |
| Electricity production, annual | 158 TWh | 235 TWh |
| Electricity consumption/TFC | 22,9 % | 27,6% |
| Electricity consumption per capita | 1 535 kWh/person | 2 211 kWh/person |
| Domestic coal production | 41,6 Mt | 44,6 Mt |
| Value of imported coal | 547 MUSD | 3 778 MUSD |
| Domestic gas production | 10,6 $Mm^3$ | 9,2 $Mm^3$ |

Source: Statistical Yearbook of Vietnam 2021 (General Statistics Office of Vietnam, 2022a).

Vietnam is home to four undeveloped offshore gas fields, each facing a unique blend of geological, commercial, and geopolitical challenges.

In 2020, Spanish operator Repsol relinquished its interests in the delayed Ca Rong Do project and offshore exploration permits to national company PetroVietnam, following reported instances of Chinese harassment that led to multiple setbacks.

PetroVietnam, after acquiring Chevron's interests in 2015, stalled the Block B gas project for years due to complex price negotiations. The field's reserve estimate stands at 107 billion cubic meters. However, the fragmented nature of the reservoir necessitates drilling hundreds of wells for gas production, escalating costs to unattractive levels for the Electricity of Vietnam (EVN). The notion of selling rights to Thailand, which has experience exploiting a similar field just 50 km away, has yet to be seriously contemplated. Recently, amid a fossil fuel price crisis that strained EVN's financial capacity, the government shifted the responsibility of investing in the project's downstream segment – specifically, the construction of the O Mon 3 and O Mon 4 gas-fired thermal power plants – to PetroVietnam (Vietnam Energy Online, 2023b).

ExxonMobil has yet to make a Final Investment Decision for the Blue Whale (Cá Voi Xanh) project, with resource estimates of around 150 billion cubic meters. Discovered in 2011, the Front End Engineering Design was only completed in 2020. Plans involve an 80 km pipeline to process gas near Danang City, supplying four power plants in Central Vietnam's Quang Ngai and Quang Nam provinces. Key factors influencing the decision include obtaining regulatory approvals, government guarantees, executed gas sales agreements, and ensuring economic competitiveness. The field's high $CO_2$ content adds to the challenge; responsible exploitation would entail separating and reinjecting $CO_2$ underground, a process of considerable cost. If Petrovietnam chooses not to purchase ExxonMobil's share, the project might be sold to a Chinese company (Hang, 2021).

Finally, Eni discovered significant reserves in the Ken Bau Block 114 field in 2020. While there is hope for its development, a cautious approach is necessary given the issues observed in the other projects.

*Text S1.2: Unexploited potential: difficulties and delays in Vietnam's offshore gas projects*

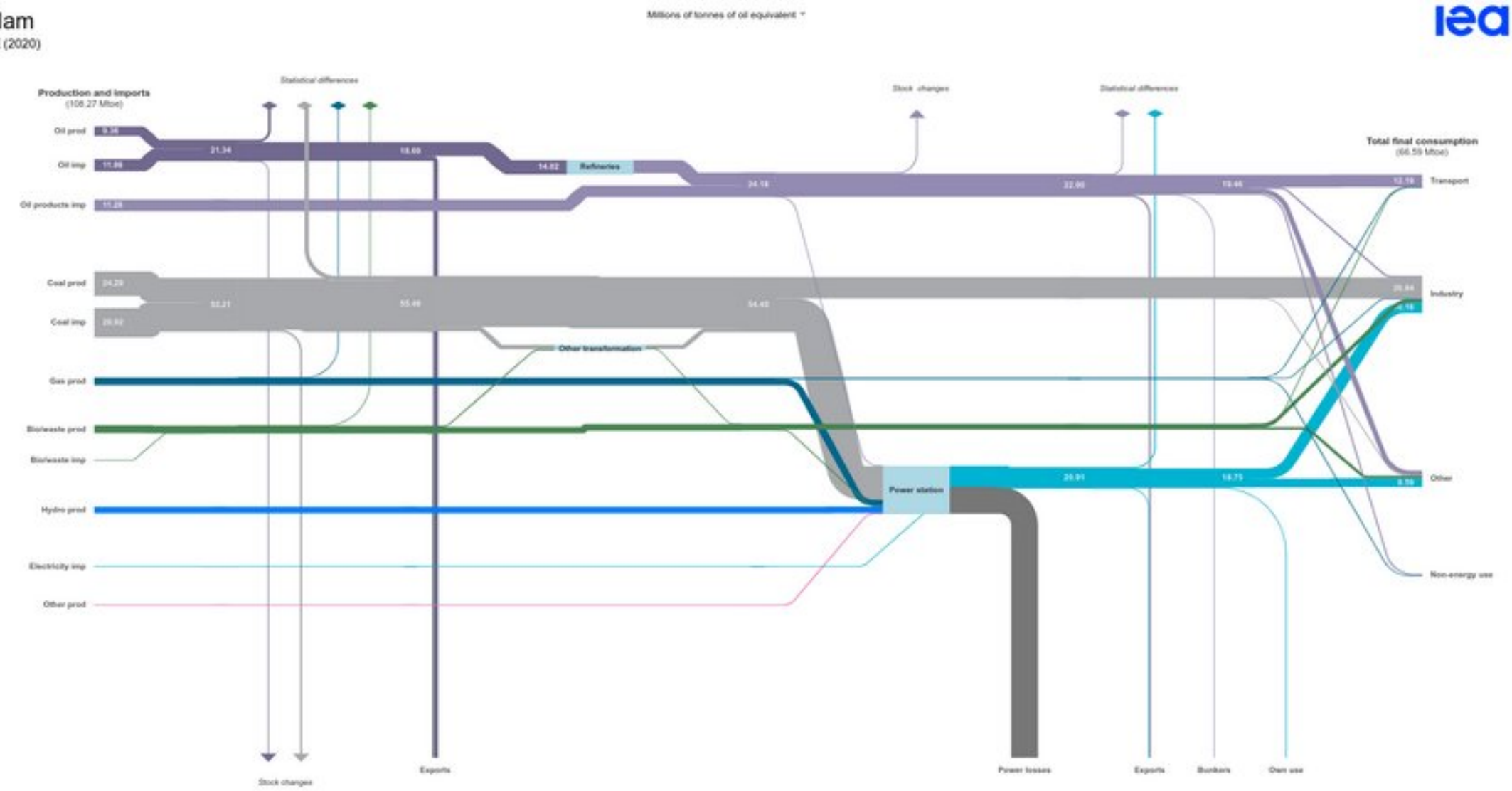


*Diagram S1.2: Sankey diagram of Vietnam's 2020 energy balance. Source: IEA.*

## Annex S2. Vietnam's Power Development Plan 8 contents

Vietnam's Power Development Plan 8 was published on May 15, 2023 (Trần Hồng Hà, 2023a decision 500). Here are the details of the plan by energy source:

**Coal.** The PDP8 adds no new coal-fired thermal power other than those already under construction and does not open any new coal power plant after 2030, making good on the COP26 pledge on coal. Coal-fired power projects unable to confirm their feasibility by 2024 will be terminated (The Long Phu I and An Khanh - Bac Giang projects, on top of the five projects already listed in PDP8 annex table 3, appear at risk). The long-term vision to exit coal is to convert the power plants to use biomass and ammonia after 20 years of operation, provided the cost of conversion is economically viable, or to shut down after 40 years if a fuel conversion is not feasible (Do et Burke, 2023 ; Thu Hường et Cấn Dũng, 2023). Despite its potential (Ha-Duong et Nguyen-Trinh, 2017), carbon capture and storage is only mentioned as a solution to be researched; there is no vision to implement the technology in the PDP8.

**Natural gas**. The PDP8 adopts LNG to replace coal as the backbone of Vietnam's power system development for baseload power generation. It sets to double the capacity of domestic gas-to-power generation in 2030 to 14,9 GW and to develop up to 22,4 GW of new imported LNG generation capacity over the next seven years. The long-term decarbonization vision is to use hydrogen. The 2050 simulations use 240 GW of offshore wind power to generate hydrogen and ammonia.

Most gas-to-power projects were already in the previous plan and suffered delays. As discussed above, domestic natural gas production is shrinking. As for LNG, Vietnam has only two receiving terminals under construction, and by June 2023 has yet to receive its first LNG cargo. To mitigate the risk of further thermal power project delays, the PDP8 over-provision the power supply by 15%.

Natural gas is also used in flexible power generation sources, like internal combustion engines, which can ramp up and down quickly to regulate the supply in a grid with lots of wind and solar power. The target is 300 MW in 2030, as the hydroelectricity capacity available compared to the target for solar and wind capacity only requires more flexible sources at this time horizon. In 2050 however, the vision of a grid dominated by intermittent renewable requires much more flexible power sources to maintain the power system stability.

The plan recognizes the risk with thermal power projects and provides a backup list for projects that can not be implemented. It promotes the role of the National Steering Committee on Electricity Development to monitor key electricity projects.

**Hydroelectricity and biomass** are prioritized and encouraged but constrained by technical and economic conditions. The plan allows for development at a larger scale if there are enough raw materials, high land use efficiency, environmental treatment requirements, grid conditions, electricity prices, and reasonable transmission costs.

The total capacity of **wind power** purchasing agreements signed by EVN was 8,2 GW at the end of 2021. The operating capacity was about 4,1 GW in 2022, leaving a large buffer of projects at various stages of completion. In addition, 6 GW of onshore wind projects and 44,6 HW of offshore were proposed for inclusion in the Masterplan in 2020. The PDP8 aims for 21,9 GW of onshore/nearshore wind and 6 GW offshore wind by 2030. The latter objective appears ambitious, as the legal framework for offshore wind still needs to be completed in 2023. The 2050 offshore wind target is 70-91 GW, with an additional 240 GW for hydrogen and ammonia production: Vietnam ambitions to establish a strong position in these sectors.

The PDP8 goals for **solar power** add 4 GW by 2030. This is a severe cool-down for a sector that succeeded in installing 16 GW in two years. The industry needs a correction, and the curtailment issues must be resolved. However, the plan allows unlimited behind-the-meter installations. Rooftop PV projects in the commercial and industrial sectors with a limited capacity do not need to be authorized by the Masterplan and are not included in the target. The role of solar could be revisited in the coming years after the legal clean-up. Besides decentralized production, floating solar or solar plus storage projects could enter the market for direct power purchase agreements or bid at electricity procurement auctions.

**Interconnectors** and **storage** capacities are essential in the long run. The interconnects' sizes are politically determined; they are not a control variable in the PDP8 calculation. Vietnam and the Lao republic signed MOUs to build 11 GW of transmission interconnectors. Vietnam and Singapore signed an MOU to provide the city-state 4 GW of offshore wind. Vietnam aims to build 5 to 10 GW of electricity export capacity by 2030.

Trading electricity is not just trading kWh; it also contributes to grid stability. Connecting to a grid rich in dispatchable hydro, Laos, will be an asset for a grid rich in must-run intermittent renewable, Vietnam. Storage is also a requirement to integrate a high share of solar and wind. The PDP8 includes completing two pumped hydro storage projects with a unit capacity of 1,2 GW. The battery storage target is only 300 MW: the technology is deemed too expensive at the moment for Vietnam.

Finally, the plan encourages the **cogeneration** of heat and power in the industry, even coal-based.

Regarding the overall balance between carbon-free versus fossil-based investment, the plan implies opening 4,9 GW of new thermal power plants per year over the next seven years until 2030 versus 5,1 GW of renewable power generation capacity. The share of renewable energy sources for electricity production is planned to reach about 30,9–39,2% by 2030, towards the target of 47% renewable energy rate, provided that the JETP pledges are realized.