Options for wind power in Vietnam by 2030

Minh Ha-Duong[a], Sven Teske[b], Dimitri Pescia[c], Mentari Pujantoro[c]

2020-02-26

Abstract

Vietnam has excellent wind resources, and the cost of producing electricity from wind has decreased continuously over the past decade. After the feed-in tariff for onshore wind power was raised to 8.5 UScents / kWh in 2018, the sector is finally taking off. The inventory of existing onshore wind power projects in Vietnam shows that the sector is on track to meet the government targets for 2020 and 2025. This policy perspective explores three scenarios for wind power development in Vietnam through 2030. It argues that by 2030 the wind power installed capacity could be 12-15 GW onshore and 10-12 GW offshore. This has three policy implications. First, Vietnam's next power development plan provides an important opportunity to increase at low costs the level of ambition of wind power development. Second, flexibility should be the guiding principle of the plan. Third, to realize the large potential of offshore wind power, infrastructure planning has to start soon.

Keywords: wind energy; Vietnam; scenarios

[a] Corresponding author. Directeur de recherche CIRED/CNRS and VIET SE Executive chairman, Research. minh.haduong@vietse.vn.

[b] Institute for Sustainable Futures, University of Technology of Sydney. sven.teske@uts.edu.au

[c] Agora Energiewende, Berlin, (dimitri.pescia, mentari.pujantoro)@agora-energiewende.de

Highlights

1. **Wind power is taking off in Vietnam, with cost decline and excellent resource**. The onshore project pipeline is on track to meet the targets of the 2020 and 2025 Power Development Plan 7 revised.

2. **Wind power can contribute substantially to Vietnam's electricity mix by 2030.** The technology has become affordable, and offshore wind energy has very high capacity factor in Vietnam, making it a steadier technology.

3. **Infrastructure planning for offshore wind has to start soon.** Offshore wind contribution has been absent from previous energy plans. The Power Development Plan 8 cannot overlook it, installed capacity targets have to be defined.

4. **Vietnam wind power in 2030 could reach 12-15 GW onshore, 10-12 GW offshore.** The next power development plan of Vietnam provides an important opportunity to increase at low costs the level of ambition of wind power development.

5. **Various flexibility options can compensate the variability of wind energy.** Flexibility should be the guiding principle for Vietnam's 2020-2030 power development plan. Distribution across the different regions of Vietnam, grid reinforcement and flexible operation of thermal power plants facilitate the integration of variable power sources, while maintaining a high level of security of supply.

1. Introduction: Vietnam has excellent wind resource

As an emerging economy, Vietnam has had to consider various options to fulfill its growing demand for electricity. This policy perspective argues that Vietnam can meet its additional demand by relying on its excellent wind resources, which potential has been overlooked in past policies and in recently published modeling studies. The upcoming Power Development Plan 8 (PDP8) presents an opportunity to increase the share of Renewables electricity and could target to have several GW of installed offshore wind capacity by 2030.

Our argument follows the scenario analysis method. The next section exposes the natural and technical potential of wind energy in Vietnam. Section 3 presents an original project-level inventory of the wind power sector in Vietnam. The pipeline is large enough to meet the government targets by far. Still using our inventory dataset, section 4 reviews the stated costs of wind power projects in the country, and why they are expected to decline. Section 5 defines three scenario narratives to explore the range of possible futures. We quantified our scenarios with a top-down energy system modeling study led by the Institute for Sustainable Future, hereafter 'ISF' (Teske, Morris, and Nagrath 2019). Sections 6 and 7 discuss, respectively, two implications of the expected surge in wind power: the need for flexibility in the whole system, and the urgency to plan the offshore transmission infrastructure. Section 7 summarizes our results and concludes by reviewing the specific Vietnamese policy changes called for by the wind power opportunities.

2. Vietnam has excellent wind resource

Vietnam's wind resources mostly lie along its coastline of more than 3000 km, and in the hills and highlands of the northern and central regions. The Global Wind Atlas estimates that over 39% of Vietnam's area has annual average wind speed over 6 m/s at a height of 65 m, and over 8% of Vietnam's land area has annual average wind speed over 7 m/s (see Figure 1). This corresponds to wind resources physical potential of 512 GW and 110 GW.

Taking into account land-use restriction – excluding mountain areas with slopes of more than 30%, fractured spaces with a size of less than 1 km² and areas more than 10 km away from existing power lines – the ISF analysis found 42 GW of technical onshore wind energy potential for utility scale wind farms.

In Vietnam the offshore wind potential is much larger than the onshore wind potential, because the coastline is long. Winds over sea are stronger, more stable. Land use constraints to sit turbines and transmission infrastructure are also lower. Using the Weather Research and Forecasting (WRF) model (10-km resolution for 10 years, from 2006 to 2015), (Doan et al. 2019) found that the greatest energy potential was in the offshore area around the Phú Quý island (Bình Thuận province). This area alone can provide 38.2 GW of offshore wind power generation capacity.

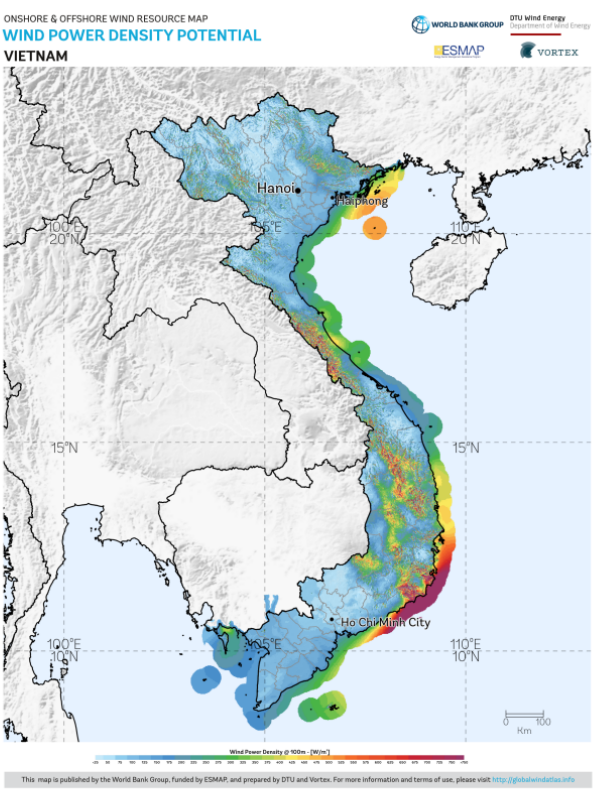

Figure 1: Wind Power Density Potential. Vietnam. Source: World Bank ESMAP (2017) [Global Wind Atlas](https://globalwindatlas.info).

(Sean Whittaker 2019) presented estimates of the wind offshore potential for Vietnam, accounting only for wind speed greater than 7 m/s and less than 200 km from the coast. He found a potential of 261 GW in waters less than 50 m deep, and an additional potential of 214 GW in waters 50 to 1000 m deep.

ISF estimates the offshore wind resource to 609 GW, spreading over a total of 3000 km coastline and area of 150 000 km². This takes into account only coastal areas with a maximum water depth of 50 m and a maximum distance to the shore of 70 km, and uses 2015 meteorological data. The ISF study further estimated the regional wind energy potential and capacity factors (for details, see Table 3 and Table 4 in the Supplementary Material). While being a variable energy source, the estimated capacity factor of wind energy in Vietnam is up to 36% for onshore and 54% for offshore wind.

3. A project pipeline on track to exceed the plan targets

The history of the sector shows fifteen years of growing pains. The Bạch Long Vĩ island hybrid diesel + wind project inaugurated on October 30th, 2004 was a false start, not appropriate to the local capacities at the time. Vietnam's first high-capacity wind farm, 30 MW, was inaugurated by REVN, in the central province of Bình Thuận on April 18th, 2012. This is where the first turbine fire event in Vietnam happened on January 5th, 2020. The next two projects – the Phú Quý island hybrid grid with 6 MW and the near-shore Bạc Liêu phase 1 with 16 MW – both completed in 2013.

No new capacity was added in 2014 or 2015. Provincial wind power development plans for eight provinces – Bạc Liêu, Bến Tre, Bình Thuận, Cà Mau, Ninh Thuận, Quảng Trị, Sóc Trăng and Trà Vinh – were published in 2016. That year the 24 MW Phú Lạc project in Bình Thuậnh province and the 83 MW Bạc Liêu phase 2 were completed. The following year, the 30 MW Hướng Linh 2 project in the Quảng Trị province was connected. By the end of 2018, the total installed wind power capacity in Vietnam had reached about 228 MW.

In 2019, Vietnam's wind power industry began to take off, although not as spectacularly as the solar power industry. By 31 May 2019, seven wind power plants were in operation, for a total capacity of 331 MW. By February 2020, we count eleven projects in operation, for a total capacity of 425 MW. To take one example: the Trung Nam project in Ninh Thuận province inaugurated in April 2019 an hybrid facility, co-locating a 40 MW wind farm with a 204 MW solar PV plant. This plant is being extended by 112 MW in phase two, by installing 28 turbines of 4MW, the largest in Vietnam so far. Installing this class of machines demonstrates that the local market has now reached the technological frontier.

The power development master plan PDP 7 revised, published in 2016, has set targets of 0.8 GW of wind power capacity by 2020, 2 GW by 2025 and 6 GW by 2030. By our estimates (see Table 2, and Table 5 in the Supplementary Materials), the number of projects under construction are on course to reach the 2020 target. The number of projects at the "groundbreaking" or "approved" stage is twice what is needed to meet the 2025 target. And if one also adds the capacity of the "announced" projects and the "planned" wind development, then Vietnam has already enough to reach its 2030 objective.

Table 1: Summary of wind projects pipeline in Vietnam, February 2020. Source: author.

Status	Total capacity (MWp)	Average size of project phase (MWp)
Operating	425	30
Construction	894	50
Groundbreaking	335	56
Approved	3 657	69
Announced, onshore & intertidal	4 318	143
Announced, offshore	5 100	427
Total	**14 730**	

We assembled a database of wind projects in Vietnam, based on publicly available sources. To the best of our knowledge, this is the most complete and up to date list, even including commercial offers. Table 1 summarizes the wind project pipeline in Vietnam. The full table is available as an electronic supplementary material.

The table shows that there is about 14.7 GW of wind power capacity from identified projects in Vietnam. The average project phase size is increasing: projects build in the past ¨were 30 MW on average, projects newly approved are 69 MW on average; and announced projects are at even larger scale.

A typical onshore wind power project cycle is about two years: one for measurements and design, one for construction. Developers have a November

2021 deadline to enjoy the best tariff. Our statistics show that the target specified in the revised seventh power development plan target – 6 GW of installed by 2030 – will be achieved much sooner.

From a provincial perspective, wind development occurs in 15 provinces mostly located along Vietnam coast lines (see Table 5). By mid 2019, operating wind farms (346 MW) were located only in 4 provinces: Bạc Liêu, Ninh Thuận, Quảng Trị, and Bình Thuận, which also have major share of wind project under construction (752 MW out of 990 MW). In the last months of 2019, the Tây Nguyên project in the Dak Lak province (central highlands) started operating. There are projects at various stages in 17 provinces (Vietnam has 63 provinces). The Northern provinces are lagging behind, with a minuscule projects capacity (0.4 MW) in the North. According to ISF analysis, up to 6.6-8.8 GW onshore wind can be developed in the Northern region.

4. Cost of wind power rapidly falling

Based on regression analysis of the announced investment cost for wind projects onshore and near shore in Vietnam of varying capacity (Figure 7), a MW of installed capacity on average costs 1.6 million USD per MW of installed capacity on average.

This number is an historical average. It includes projects onshore and near-shore that started years ago or were recently announced and is mostly based on forward-looking budgets before construction. This is close to the numbers used in the Vietnam Technology Catalogue for 2020 (Jakob Lundsager, Nguyễn Ngọc, and Mikael Togeby 2019).

As evidence of cost decline, when we used the same method with the pipeline data as of August 2019, the cost was 1.8 million USD per MW of installed capacity. Others have shown that the wind power technology costs are falling (Prakash and Anuta 2019). The Technology Catalogue (op. cit.) considers that nominal investment in onshore wind will decrease to 1.31 million USD / MW in 2030, and decrease further to 1.11 million USD / MW in 2050.

The construction cost of offshore wind farms is significantly higher than onshore, our database finds 2.5 million USD/MW capacity on average. Note that the difference with onshore is lower in terms of electricity costs, as far as offshore wind farms have a better capacity factor.

Offshore wind becomes more and more economically viable due to its higher yields, larger turbines and clusters. The auctions conducted to lease the rights to build wind farms offshore Massachusetts illustrate the cost decline in the industry. In 2014, they did not receive any bids. When the auction ran again in December 2018, the winning developers paid 405 million USD for the right to build wind farms (Gerdes 2018; Asimov 2019).

Costs will also improve because the average rated capacity size of offshore turbine units is increasing. Though it is around 7 MW per turbine today, the first 12 MW turbines are already being field tested, and the capacity is expected to reach 15 MW per turbine in 2025. The average capacity factor of current projects also ranges from 50-57% (Noonan et al. 2018). From 2020 to 2022, the cost of electricity from newly commissioned offshore wind power projects could range from 60 USD / MWh to 100 USD / MWh based on current trends and the winning bids from 2018 auctions – a significant decline compared to 140 USD / MWh in 2017.

For example, France aims to have 10 GW of offshore wind power by 2028, and recently conducted an auction for a 600 MW offshore wind farm near Dunkerque, scheduled to open in 2025-2026. The eight candidates proposed to sell electricity for 20 years between 44 € / MWh to 60,9 € / MWh (equivalent to 48 to 67 USD / MWh), with an average at 51 € / MWh (equivalent to 56 USD / MWh). Germany has held just two offshore wind auctions, one in 2017 and one in 2018. In both tenders, capacity was won by investors who offered to build parks without subsidies.

Since 2011, the Feed in tariff (FiT) for wind power project in Vietnam was 78 USD / MWh and that was not commercially viable for developers. In November 2019, the FiT was raised to 85 USD / MWh for onshore wind power projects and 98 USD / MWh for offshore wind power projects (Nguyễn Xuân Phúc 2018). The new electricity tariffs are applied to a part or whole of the grid connected wind power projects with commercial operation date before 1 November 2021 for 20 years from the date of commercial operation. Already operating projects will benefit from the tariffs retroactively from 1 November 2018 for the remaining period of the signed PPA.

As of February 2020, future tariffs for wind power projects completed after 1/11/2021 remain uncertain. The Prime Minister assigned the Ministry of Industry and Trade the task of proposing a mechanism for auctioning of wind power development and tariffs.

The decline in costs and the increase in tariff account for the success in capturing developers' interest. We expect that as more projects come into realization, economy of scale and learning by doing will drive further cost reduction in Vietnam in the next five years.

5. Upper, lower and middle scenarios for wind power in Vietnam

The previous sections have shown that early 2020, the pipeline of wind power projects in Vietnam is 9.6 GW onshore, and 5.1 GW offshore. In the ISF study (Teske, Morris, and Nagrath 2019) we examined three visions for the development of the power sector in Vietnam. We estimated future demand trajectories and looked at how various energy mixes could satisfy it. In these visions, the role of wind power is defined as follows:

Table 2: Visions for Vietnam onshore and offshore wind energy installed capacity in 2030. Source: Author.

Scenario	Onshore wind: Capacity in 2030	Onshore wind: Annual market 2020-2025	Onshore wind: Annual market 2026-2030	Offshore wind: Capacity in 2030	Offshore wind: Annual market
Old Plan	6.1 GW	300 MW/yr	1 000 MW/yr	0.15 GW	negligible
New Normal	16.6 GW	730 MW/yr	3 200 MW/yr	9.5 GW	1000 MW/yr in 2023-2025, then ramp up to 1400 MW/yr in 203
Factor Three	21.6 GW	1 530 MW/yr	3 625 MW/yr	20.9 GW	1000 MW in 2023 1900 MW in 2024, then 3000 MW/yr from 2025 on

The first scenario corresponds to the PDP7 revised, which planned for 6 GW of installed wind capacity in 2030, accounting for 2,1% of the power production. The other two scenarios respectively achieve that year a total installed wind capacity of 26 GW and 42 GW. In the most ambitious scenario, annual markets increase about 2 GW a year for both offshore and onshore wind during the next decade. While such annual market figures may seem ambitious, the country is expecting a high energy demand growth apparent from the PDP7 revised which planned to install 70 GW of additional generation capacity between 2020 and 2030 – mostly baseload plants. Indeed, high growth rates in the power supply infrastructure are required to lift a 100 million people from lower to higher middle income in ten years. Technological progress is rapidly reducing costs, leading to considerable shifts in investment patterns. For example the PDP7 solar PV objectives were 4 GW for 2025, but the installed capacity achieved more than 5 GW at the end of 2019. Gauging by the current interest of the business community, a similar trend is likely for wind energy.

The following narratives flesh out the three scenarios, explaining various development rhythms:

In the *Old Plan* scenario, a wave of new wind farms connects to the grid in time to get the FIT before November 2021. After that, the government does not renew the FIT, and legal issues delay the first pilot auction to 2022. By then a global economic crisis affects Vietnam, reducing economic growth and, by extension, domestic electricity demand. International fossil fuels prices hit historical lows as global demand dips, and producing countries try to sell their remaining reserves before they are made useless. Vietnam policy priority is on GDP growth by international trade rather than climate protection. Natural gas plays the first role in the 2020-2030 decade. A rapid improvement in energy efficiency and a strong development of solar, both utility scale and behind the meter rooftops, leave little room for wind energy to expand above the PDP7 targets revised in 2016.

In the *New Normal* scenario, after the initial wave of wind projects in 2021 there is no second FIT period due to concerns on the part of policymakers that the market will overheat. The market is driven by direct power purchase agreements – multinational companies in Vietnam procuring green electricity directly from wind project developers – and by government auctions – the 2020 pilot is a success. The government credibly commits to an auction program for 1 GW of offshore wind per year, and the expected market size leads many industries to choose Vietnam as their Southeast Asia base for manufacturing equipment and operating wind projects. The offshore wind industry is organized around two hubs: the port of Vũng Tàu serves farms in the zone facing Bình Thuận and Cà Mau coasts; and the port of Hải Phòng serves zones facing Quảng Ninh coasts.

In the *Factor Three* scenario, the Party decides to steer Vietnam into green development. The national oil and gas company PVN is redefined as a sustainable energy provider that mobilizes its offshore work capacities and the complementarity between gas and variable renewables. All announced projects meet targets. The Thang Long Wind power project by Enterprize Energy, which intends to develop large-scale offshore near the Kê Gà area in Bình Thuận province, starts operating its first 600 MW phase at the end of 2022, and extends by 600MW every year. The three other projects – in Bac Lieu by KOSY group, in Vung Tau by HBRE group and in Phu Cuong by Mainstream – add 1.7 GW of offshore wind power capacity by 2024. By end of that year, the total offshore capacity is 2.9 GW, and the sector is competitive. This convinces the government to adopt a regional leadership strategy in the wind energy sector. A national scale offshore transmission infrastructure – power centers hubs and under sea lines – starts by connecting the existing projects. Starting in 2025, the backbone strategy to meet the power demand expansion in Vietnam is to auction 3 GW of offshore wind every year.

The key early signpost indicating which scenario Vietnam is heading towards will be the government's next decision about for wind power incentives. Feed In Tariff (FIT) is by far the proven policy mechanism, it worked in Germany between 1991 and 2018, and it is working in Vietnam now. Recent experience in Germany is also an example for the *Old Plan* scenario: auction design problems can cool down the wind market. Alternatively, a decision to offer FIT over 90 USD / MWh for offshore wind after 2022 would steer towards the third scenario. Costs would be high but tendering the rights to use offshore wind development zones could recover a portion of these costs.

Previously published Vietnam power system development scenarios are close to the *Old Plan* scenario when it comes to wind power. The Renewable Energy scenario (GreenID 2018, p 39) sees 8.5 GW of wind installed capacity in 2030. The Danish Energy Agency (2017, p 45) scenarios project wind power capacity to grow to 6.2 – 6.4 GW in 2030, which is close to the PDP7 revised. The 2018 update to this Vietnam Energy Outlook (Hưng and Togeby 2019) sees more wind power generation than solar in 2030; offshore wind entering only after 2030. The ECA (2016, p 11) Made in Vietnam Energy Plan assumes that a doubling of the PDP7A target is possible, for a 12 GW of installed wind power by 2030, not mentioning offshore wind. The low-carbon development pathway report for Vietnam by the Asian Development Bank (2017, p 35) targets 16 GW of wind capacity by 2050, giving a preference to solar, nuclear and biomass energy. To sum up, up to 2018 even the most progressive previously published scenario for Vietnam targeted a maximum of 12 GW in 2030, way below the new trajectories assessed by ISF, while still overlooking the offshore wind potential. Only the Renewables-Led Pathway by (Breu et al. 2019), cited in version 2.0 of the Made in Vietnam Energy Plan (Rockhold et al. 2019), foresees 39 GW of wind capacity installed in 2030.

Yet global trends in offshore wind development are very dynamic. According to IRENA, offshore wind installation reached its first GW in 2007. Today, there are 23 GW of installed capacity worldwide, with 5 GW added in 2018. Over 5 500 offshore wind turbines are currently in operation in 17 countries (World Forum

Offshore Wind 2019). Most of the existing offshore wind capacities are located in Europe (18.8 GW), and the rest are in China, Japan, Korea, and the USA. With surging demand in the Asia Pacific, the industry will be expanding to new countries and ratcheting up its manufacturing capacity.

Now that Taiwan and Japan have both announced that they will install more than 5 GW of offshore wind power, manufacturers are already redesigning their machines and platforms to resist the typhoons and earthquakes prevalent in the Pacific area.

The *Old Plan* scenario (and previously published studies) neglects the role that offshore wind could play in 2030 in Vietnam, while the *Factor Three* scenario might seem extremely ambitious today: the commission of 42 new offshore wind farms in ten years. Both scenarios are extreme and unlikely. The most plausible future scenario is something in between. Connecting the realm of possible with extreme cases is useful for analysis.

Party resolution 55 orienting the national energy development strategy of Vietnam (Nguyễn Phú Trọng 2020) prioritize wind and solar energy for electricity generation, and mentions building 8 billion m3 of LNG import capacity by 2030. This suggests that the middle scenario is the most plausible of the three. Given the worldwide trends, the abundance of wind in Vietnam, the full pipeline of projects and the urgent need to increase electricity supply, we believe that the government will revise upwards the wind targets in the next PDP and commission several 500 MW offshore wind farms over the next ten years.

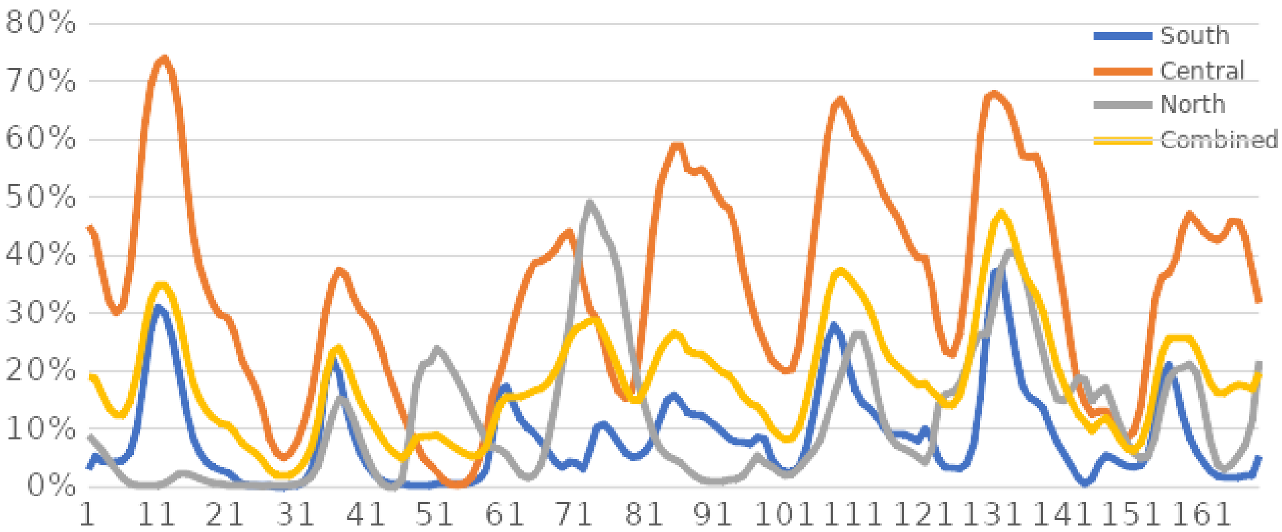

Figure 2: Wind generation profile in 3 regions, first week of January. Generation profile from Renewable Ninja.

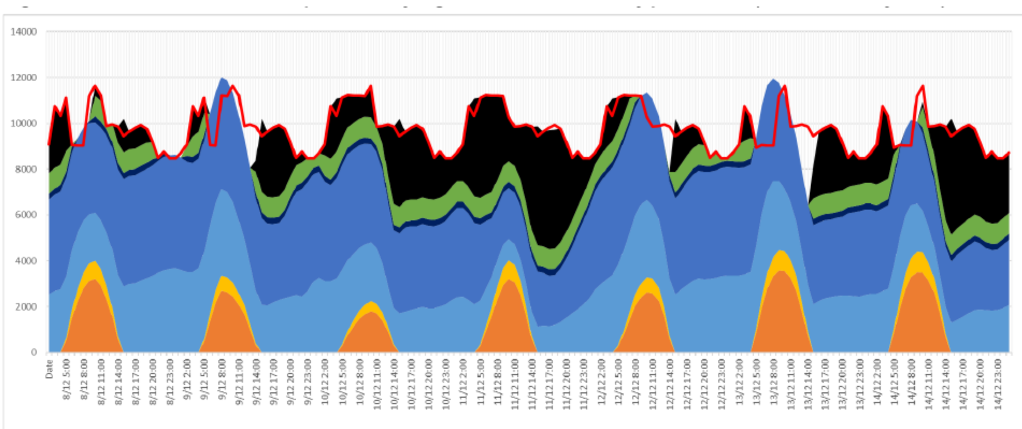

Figure 3: Power mix simulation for the Red river delta in a very windy week (16th to 23th May 2030), Factor Three scenario.

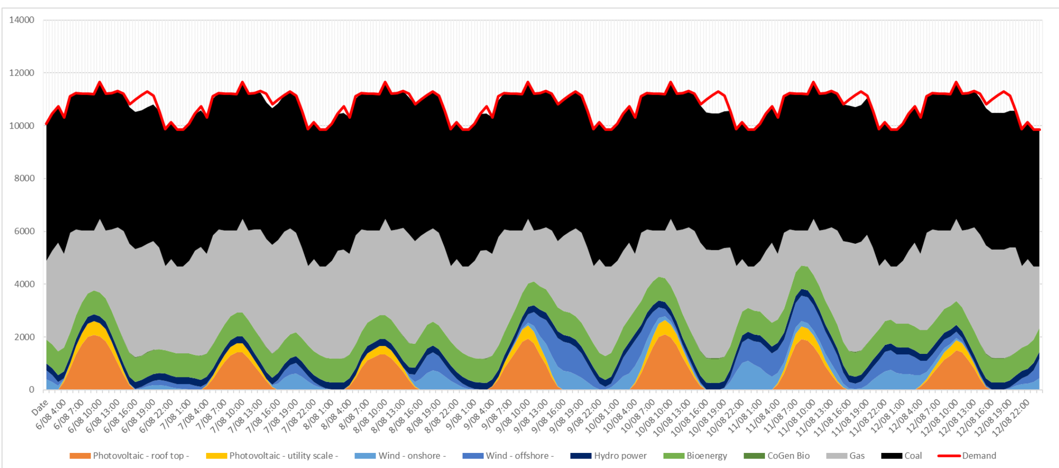

Figure 4: Power mix simulation for the Red river delta in a very low wind week (6th to 13th August 2030), Factor Three scenario. Imported electricity can be seen as white field between the red load curve and the black marked coal generation.

6. The power sector 2030 plan should address flexibility requirements

Wind power is a variable energy source: wind speed varies by day, region and season. The high wind speed season is during the north-eastern monsoon months (December, January, February) and low wind speed seasons is during the inter-monsoon months (March, April, and May). Doan et al. (2019) observed that the seasonal variability[1] in Vietnam associated with monsoon onsets and the daily variability[2] associated with the wind diurnal cycles is in the 30–50% range, and the inter-annual variability[3] can reach up to 10%.

The wind regime in the North differs from the wind regimes in the South and Center. The central and southern regions have high correlation (<80%), while the northern region shows weak correlation with the south (<5%). These fairly low correlations suggest that the wind generation would not peak at the same time within the country, as Figure 2 illustrates. Distributing wind generation deployment across the region and across intra-regional exchanges creates balancing effects that considerably reduces the variation of wind power output. The maximum change of wind generation within the central region from one hour to the next is 30%, but the Vietnam-wide maximum change is 2%.

To illustrate how the power system copes with variability, we compared simulations of the power supply under the *Factor Three* scenario in 2030 for the Red River Delta region during a windy and a windless week.

In a windy week in May 2030 (Figure 3), wind and solar provide a major share of electricity generation, while fossil fuels make up only a minor share. In this case, wind power gets shunted from the windy Northeast and/or North Central Coast to the Red River Delta and displaced coal generation in three evenings.

Figure 4 shows the windless week simulation, in August 2030. Most of the power supply during this week comes from coal and gas, while solar photovoltaic and wind have minor contributions. The Red River Delta region is self-sufficient for

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1 Normalized standard deviation of the monthly mean values of wind power density at 105 m height.

2 Normalized standard deviation of hourly data.

3 Normalized standard deviation of yearly mean from 10-year mean.

almost the entire week, importing only minor amounts of electricity from other regions during evening hours.

The variability of the two situations described in these figures is already being experienced by countries that have a much larger share of wind power in their energy mix than Vietnam does. In 2018, wind power represented 41% of the electricity produced in Denmark; 28% in Ireland; 21% in Germany; and 19% in Spain. Because of intra-annual variability, the maximum share of wind at monthly and weekly time scale is higher in some months. For example, wind satisfied 30% of Germany's electricity demand in January 2019 and only 18% in June 2019.

Experience from Europe shows that anti-correlation of the seasonal weather patterns of monthly onshore wind and PV generation yields a more stable total variable renewable energy output. There is also a seasonal-scale balancing effect between variable renewables in Vietnam. Statistically, from November to February wind speed is high, from February to June solar radiation reaches a peak, and during the wet season from July to November the water inflows are high (Intelligent Energy System and Mekong Economics 2016)

Researchers have observed that offshore wind has more stable output throughout the year than onshore. This alleviates the variability issue and contributes to reliable capacity in the medium and long term.

Another lesson from these countries is that variable renewable energy capacity is faster to install than flexibility solutions, in particular those involving additional grid infrastructure. That can lead to system congestion, high level of curtailment and sub-optimal period of negative electricity prices.

Between 2008 and 2018, China increased its renewable power generation capacity from 15 GW to 370 GW (Richard 2019), but failed to keep the same pace in transmission capacities. As a result, wind farms across China had an average curtailment rate of 17% in 2011 and 20% in 2012 (Liu et al. 2015). Increased investment in transmission in recent years succeeded to bring down curtailment rates significantly, to 17.1% in 2016 and further in 2018 to only 7% (Richard 2019).

This challenge also occurs in the Vietnam energy system, when installed solar capacity increased to 4.5 GW between April and June 2019 (Kenning 2019). Some solar farms were curtailed 30-60% on account of the grid's inflexibility.

The increasing penetration of solar and wind power requires the adoption of technical and economic flexibility solutions. The flexibility solutions are not a distant hypothetical; they are a clear and near-term need. It is time to adapt the system now. Flexibility should be the guiding principle for Vietnam's 2020-2030 power development plan.

Economic flexibility solutions aim to level the playing field for all technologies, replacing must-run and priority dispatch rules with competitive electricity markets. Mature markets include liquid intra-day trading, the balancing and ancillary services market, and the future and derivative markets. It is paramount that curtailment decisions remain transparent.

Technological flexibility solutions include: the flexible operation of thermal power plants; smart demand management; stronger interconnections with neighboring provinces and countries; hydro or chemical storage; and switching from coal to gas.

All the solutions cited above are or should be considered the PDP8. In preparation for 2050, Vietnam must also consider more innovative technical solutions such as power-to-gas; power-to-hydrogen; or vehicle to grid storage. Floating gas power plants, although not a part of the Masterplan, offer high flexibility at multiple timescales and complement offshore wind well at low investment cost.

7. A national infrastructure to focus an offshore wind program

The rapid development of Vietnam electricity grid needs national-scale infrastructure investment. The next power development plan is an opportunity to optimize the conceptual design and prepare the financing of this infrastructure. The plan serves to coordinate the anticipations of the government, the State owned enterprises EVN and PVN and the private sector, towards the prospect of having many GW of offshore wind generation capacity installed in the next decade.

According to the IEA Wind, the 2017 baseline infrastructure cost for an existing offshore project was around 638 € / kW, with total capital expenditure of 3500 € / kW. At the scale of a 500 MW farm, this translates into 320 million euros for infrastructure and 1.75 billion euros capital expenditure. At the national scale, 10 GW capacity by 2030 means to invest 6.4 billion euros in offshore infrastructure. It is thus highly profitable to find ways to optimize these costs. Besides link capacity, distance from the shore and technological progress, a key driver of these costs is the network topology.

The naive approach is to connect each offshore wind farm to the inland grid independently. The ISF study (Teske, Morris, and Nagrath 2019) argues that the new infrastructure should not only be seen as East-West transmission lines from wind farms offshore to the land. As an alternative topology, consider the offshore busbar approach. An undersea cable runs parallel to the coast line, and wind farms connect to it. In any case, Vietnam needs to reinforce its electricity transmission network integrating the North, Center and South electric systems to accommodate its expansion. Part of the new network North-South capacity could be submarine. This National Offshore Power Link would transport the power to the two load centers in the north and south and – with lower capacity interconnects – to the other coastal provinces in between.

Figure 5 shows a possible position of this offshore wind cable which has interconnections with six currently existing grid knots to each of the six coastal regions. The total length of this cable would be 1775 km, including land connections.

Existing undersea projects confirm that such infrastructure is technically possible. To date, Ultra High Voltage cables have the largest transmission capacity of around 1 GW with voltage levels of typically 1000 kV per cable. The NordLink between Norway and Germany is over 620 km long, has a 1400 MW capacity, and is estimated to cost 1.5 to 2 billion euros (Skopljak 2019). The North Sea Link between Norway and UK at 730 km long and a 1400 MW capacity is estimated to cost 2 billion euros (North Sea Link 2019). The EuroAsia Interconnector cable will have 2000 MW capacity and a submarine segment of 1208 km. The construction cost of stage 1, with half capacity, is expected to cost 2.5 billion euros (EuroAsia interconnector 2019).

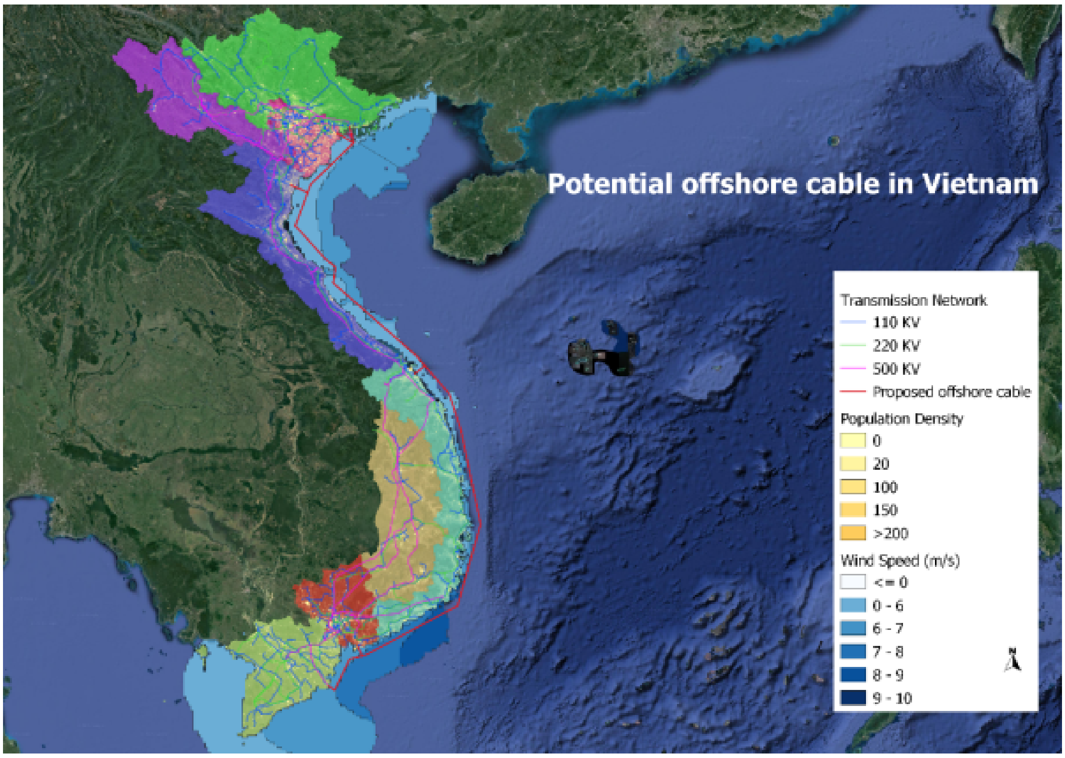

Figure 5: How an offshore busbar could fit in the national power grid topology.

Having a strategic infrastructure, not only may increase the offshore projects cost efficiency, it would also send signal that Vietnam is committed to generate electricity from offshore and near shore wind farms, and increase the' confidence of investors to build up a local industry. Diminishing returns due to the scarcity of the good onshore site will be felt in the long term, which increases the attractiveness of offshore wind. An undersea cable to reinforce the North-Center-South power system interconnection does not require sensitive discussions about land-use. The undersea interconnectors may feed discussions about the regional ASEAN super grid, which stands to be an important source of system flexibility and reliability at the 2050 planning horizon.

Vietnam is in the early stage of forming a marine economic development strategy in general and an offshore wind development plan in particular. The government should recognize that near-shore and offshore wind development is one of the key drivers for boosting the marine economy and for protecting the sovereignty of Vietnamese seas and islands. Hence, the following national plans should reflect the role and orientation of wind offshore development strategies:

- The National Marine Spatial Plan for 2021–2030 with a view to 2050. This plan provides an important legal basis for the management and exploitation of offshore wind potential. It should incorporate an interdisciplinary approach: (i) the development and selection of marine spatial exploitation scenarios should consider targets for utilizing the near-shore and offshore potential of power generation; (ii) maps for resource exploitation and maps for infrastructure development within marine space should allocate zones for near-shore and offshore wind farms, for undersea cables and for seaports that serve the energy sector.

- The National Power Development Plan for 2030 with vision to 2045 should specify annual targets for offshore wind development, consider the needs and opportunities of having submarine segments in the power transmission network, and coordinate the new offshore infrastructure with the new LNG power centers to maximize their complementarity.

- The National Seaports Plan for 2030 with a vision to 2045 should be based on the capacity assessment of current seaport systems that support the energy sector. The plan should have specific goals for the development of seaports that provide services for the energy sector such as offshore wind combined with logistics and business services for other energy types.

8. Summary and concluding remarks

There is economic and technical potential to build dozens of GW of wind power generation capacity in Vietnam. After fifteen years of growing pains, the sector is taking off decisively. By February 2020, only 425 MWp of wind power are operating, but the total projects pipeline is 14.7 GW, of which 5.1 GW offshore. We expect to see a majority of onshore projects in the pipeline today to connect before November 2021, in order to benefit from the preferential FIT of 85 USD/MWh. About 1.2 GW is under construction / groundbreaking, and among the 3.6 GW of projects at the approved stage, those with advanced feasibility studies and a standing order of wind turbines still have time to beat the deadline. The sector appears on track to exceed the plan targets – 6 GW in 2025 – by far.

Previously published studies and the *Old plan* scenario underestimate the role of offshore wind power. Offshore wind energy can contribute significantly to the mid- to long-term Vietnamese energy mix. We believe that the government will auction several 500 MW offshore wind farms during the next decade. The most plausible of the three scenarios discussed in this paper is the *New Normal*: an installed capacity in 2030 of 15 GW for wind onshore and 10 GW for wind offshore.

These numbers are orders of magnitude, more detailed analysis is needed to better understand how they will fit into Vietnam's fast moving energy supply and demand landscape. Moreover, one must identify the policy mechanisms for implementing the scenario at a reasonable cost to consumers (Nguyễn, Nguyễn, and Nguyễn 2019) The land-use constraints for onshore wind require innovative solutions that respect agricultural needs. Finally, the reliability of offshore wind turbines in East Asian conditions must be demonstrated.

When it comes to policy discussion for 2030, while a scenario can be a useful anchor, the indication of a plausible range instead of a point estimate allows for more robust planning. To propose such ranges, we have to keep in mind a few points. First, today's pipeline is 9.6 GW onshore, and 5.1 GW offshore. Second, offshore has more potential to scale up than onshore. Third, 2030 is in ten years, while it takes 2 to 5 years to realize a projects. Considering these, we propose that the policy discussions about the role of wind in the Power Development Plan 8 (PDP8) disregard the old objectives in the PDP7, and focuses on 2030 installed capacity ranges of: 12-15 GW for onshore, 10-12 GW for offshore.

To conclude, we offer three recommendations for the PDP8. First, wind energy targets for 2030 should be increased considerably over those in previous plans. Second, considering the amount of variable power generation sources already under construction and the number already in planning, increased flexibility of the electric system must be paramount in PDP8. Third, an infrastructure development plan for deploying several additional GW of offshore wind energy per year should start immediately.

9. Sources cited

Asian Development Bank. 2017. 'Pathways to Low-Carbon Development for Vietnam'. TCS179192-2.

Asimov, Noah. 2019. 'In Race for Offshore Wind, Three New Bids'. The Vineyard Gazette - Martha's Vineyard News. 16 September 2019. https://vineyardgazette.com/news/2019/09/16/race-offshore-wind-farms-around-marthas-vineyard-continues.

Breu, Marco, Antonio Castellano, David Frankel, and Matt Rogers. 2019. 'Exploring an Alternative Pathway for Vietnam's Energy Future'. ELECTRIC POWER & NATURAL GAS PRACTICE. McKinsey & Company.

Danish Energy Agency. 2017. 'Vietnam Energy Outlook Report 2017'. MOIT. https://ens.dk/sites/ens.dk/files/Globalcooperation/Official_docs/Vietnam/vietnam-energy-outlook-report-2017-eng.pdf.

Doan, Van Q., Van Nguyen Dinh, Hiroyuki Kusaka, Thanh Cong, Ansar Khan, Du Van Toan, and Nguyen Dinh Duc. 2019. 'Usability and Challenges of Offshore Wind Energy in Vietnam Revealed by the Regional Climate Model Simulation'. *SOLA* 15 (0): 113–18. https://doi.org/10.2151/sola.2019-021.

Economic Consulting Associates (ECA). 2016. 'Made in Vietnam Energy Plan'. London, UK: Report prepared for the Vietnam Business Forum. http://auschamvn.org/wp-content/uploads/2016/10/Made-in-Vietnam-Energy-Plan-MVEP-v12.pdf.

EuroAsia interconnector. 2019. 'Tenders Received for the Construction of the Converter Stations of the EuroAsia Interconnector'. EuroAsia Interconnector. 30 November 2019. https://euroasia-interconnector.com/contractnotice19-3/.

Gerdes, Justin. 2018. 'Record-Breaking Massachusetts Offshore Wind Auction Reaps $405 Million in Winning Bids'. 17 December 2018. https://www.greentechmedia.com/articles/read/record-breaking-massachusetts-offshore-wind-auction.

GreenID. 2018. 'Analysis of Future Generation Capacity Scenarios for Vietnam'. Vietnam: GreenID. http://en.greenidvietnam.org.vn/view-document/5b13fb0a5cd7e89403c94bda.

Hưng, Nguyễn Ngọc, and Mikael Togeby. 2019. 'Analysis Framework and Results. How Modeling and Scenarios Lead to the Results - Phạm vi Phân Tích và Các Kết Quả. Phương Pháp Mô Phỏng và Các Kịch Bản Dẫn Tới Kết Quả'. presented at the Vietnam Technology Catalogue Launching and EOR19 Preliminary Policy Recommendations workshop, Hanoi, May 15.

Intelligent Energy System, and Mekong Economics. 2016. 'Alternatives for Power Generation in the Greater Mekong Subregion - Volume 6: Socialist Republic of Viet Nam Power Sector Scenarios'. WWF. http://greatermekong.panda.org/our_solutions/2050powersectorvision/.

Jakob Lundsager, Hưng Nguyễn Ngọc, and Mikael Togeby. 2019. 'Vietnam Technology Catalogue - Technology Data Input for Power System Modelling in Viet Nam'. [Data set]. Hanoi: EREA/

MOIT, Institute of Energy, Ea Energy Analyses, Danish Energy Agency. http://doi.org/10.5281/zenodo.2859959.

Kenning, Tom. 2019. 'Vietnam Leapfrogs Australia in Solar Deadline Boom'. PV Tech. 5 July 2019. https://www.pv-tech.org/news/vietnam-leapfrogs-australia-in-solar-deadline-boom.

Liu, Zifa, Wenhua Zhang, Changhong Zhao, and Jiahai Yuan. 2015. 'The Economics of Wind Power in China and Policy Implications'. *Energies* 8 (2): 1529–46. https://doi.org/10.3390/en8021529.

Nguyễn, Đình Văn, Xuân Hòa Nguyễn, and Thị Thu Hương Nguyễn. 2019. 'Cơ hội và thách thức trong phát triển điện gió ở Việt Nam - Opportunities and challenges to wind energy development in Vietnam'. *Tap Chi Khoa Hoc va Cong Nghe Viet Nam*, May. http://congnghiepcongnghecao.com.vn/tin-tuc/chinh-sach/t21907/co-hoi-va-thach-thuc-trong-phat-trien-dien-gio-o-viet-nam.html.

Nguyễn Phú Trọng. 2020. 'Resolution 55-NQ/TW on the orientation of the National Energy Development Strategy of Vietnam to 2030, vision to 2045'. Resolution of the political bureau 55-NQ/TW. Central Executive Committee, Communist Party of Vietnam.

Nguyễn Xuân Phúc. 2018. 'Decision 39/2018/QD-TTg - Amending several articles of decision No.37/2011/QD-TTG dated June 29, 2011 of the prime minister on provison of assistance in development of wind power projects in Vietnam'. Decision 39/2018/QD-TTg. Hanoi, Vietnam: The Government of Vietnam. http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=1&mode=detail&document_id=194743.

Noonan, Miriam, Tyler Stehly, David Mora, Lena Kitzing, Gavin Smart, Volker Berkhout, and Yuka Kikuchi. 2018. 'IEA Wind TCP Task 26: Offshore Wind Energy International Comparative Analysis'. NREL/TP-6A20-71558. IEA Wind. www.nrel.gov/publications.

North Sea Link. 2019. 'About the Project'. North Sea Link. 3 October 2019. http://northsealink.com/en/.

Prakash, Gayathri, and Harold Anuta. 2019. 'Future of Wind. Deployment, Investment, Technology, Grid Integration and Socio-Economic Aspects'. A Global Energy Transformation paper. Abu Dhabi: International Renewable Energy Agency (IRENA). /newsroom/pressreleases/2019/Oct/Asia-Poised-to-Become-Dominant-Market-for-Wind-Energy.

Richard, Craig. 2019. 'Curtailment Reduction "Could Double Chinese Wind Fleet"'. *Wind Power Monthly*, 23 August 2019. https://www.windpowermonthly.com/article/1594722?utm_source=website&utm_medium=social.

Rockhold, John, Gavin Smith, Michael DiGregorio, Luong Ba Hung, and Peter duPont. 2019. 'Made in Vietnam Energy Plan 2.0. A Business Case for the Primary Use of Vietnam's Domestic Resources to Stimulate Investment in Clean, Secure, and Affordable Energy Generation.' Vietnam Business Forum, Power and Energy Working Group.

Sean Whittaker. 2019. 'Global Picture of Offshore Wind'. presented at the Consultation workshop on Developing offshore wind in Vietnam, Ha Noi, Viet Nam, October 17.

Skopljak, Nadja. 2019. 'NordLink Power Cable Reaches Germany'. *Offshore Wind*, 19 June 2019. https://www.offshorewind.biz/2019/06/19/nordlink-power-cable-reaches-germany/.

Teske, Sven, Tom Morris, and Kriti Nagrath. 2019. 'Renewable Energy for Viet Nam - A Proposal for an Economically and Environmentally Sustainable 8th Power Development Plan for the Viet Nam Government.' Australia: Institude for Sustainable Futures (ISF), University of Technology Sydney (UTS). http://doi.org/10.5281/zenodo.3515786.

World Forum Offshore Wind. 2019. 'Commissioned* Offshore Wind Farms Worldwide'. WFO. https://wfo-global.org/wp-content/uploads/2019/03/WFO-commissioned-offshore-wind-farms-worldwide.pdf.

10. Acknowledgements

HDM is responsible for Table 1, 2, 5, Figure 7, and the scenario narratives. The ISF study team is responsible for Tables 3, 4 and Figures 3, 4, 5, 6. All authors contributed to the writing and reviewing. Authors declare no conflict of interest. We acknowledge financial support from the European Climate Foundation grants.

11. Supplementary material: data tables and figures

Table 3: Vietnam onshore and offshore wind energy potential. Source: Table 6 page 14 in the ISF study. Onshore potential of areas within 10 km distance of existing power lines, excluding competing land use, and sloped areas. Offshore potential of areas with a maximum water depth of 50m and maximum distance to the shore of 70km. See Figure 6 for the definition of regions.

Region	Onshore Wind energy potential GW	Offshore Wind energy potential GW
Northeast	4.6	64.5
Northwest	2.8	-
Red River Delta	1.5	66.7
North central Coast	0.3	113.0
South central Coast	16.8	78.8
Central highlands	12.5	-
Southeast	3.3	27.1
Mekong Delta	0.2	259.7
Total	42.0	609.8

Table 4: Vietnam onshore and offshore wind energy capacity factors. Source: UTS/ISF Report, chapter 5 table 75ff, data from www.renewables.ninja. See Figure 6 for the definition of regions.

Region	Onshore Wind capacity factor	Offshore Wind capacity factor
Northeast	21%	27%
Northwest	21%	Land-locked
Red River Delta	23%	28%
North central Coast	22%	25%
South central Coast	30%	47%
Central highlands	20%	Land-locked
Southeast	36%	54%
Mekong Delta	34%	45%
Average	26%	38%

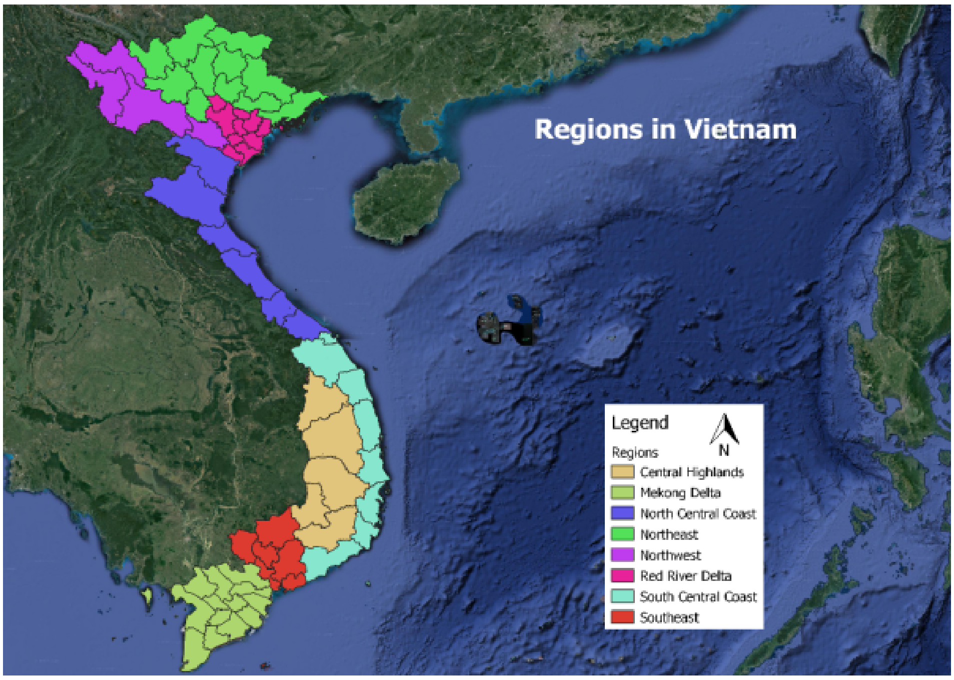

Figure 6: Regional breakdown of Viet Nam for the power sector analysis in the ISF study.

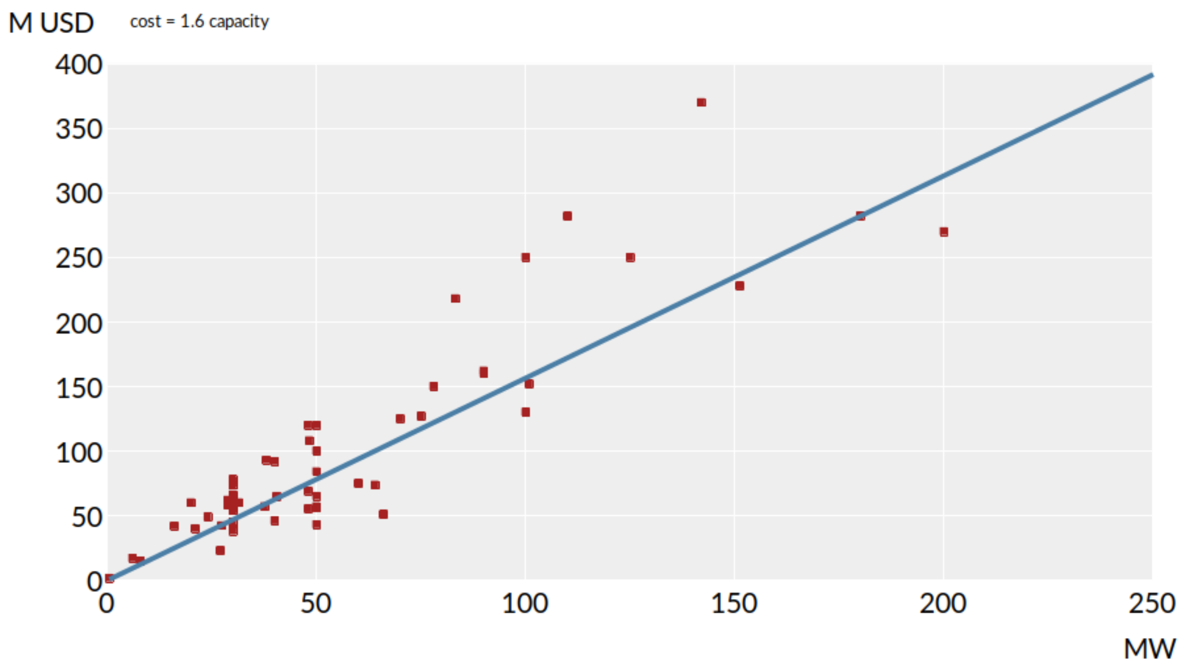

Figure 7: Announced investment costs of onshore and near-shore wind projects in Vietnam.

Table 5: Summary of the wind power projects pipeline in Vietnam, February 2020. Source Author. Detailed table available as supplementary material.

Province	Planned	Announced	Approved	Ground breaking	Construction	Operating	Cancelled	Total MWp
Ba Ria-Vung Tau		500						**500**
Bac Lieu	50	608			240.3	99.2		**998**
Ben Tre	295	544	180	30				**1049**
Binh Dinh		50	177			21	200	**448**
Binh Thuan	310	3428	611		130	60	600	**5139**
Ca Mau	25	200		175				**400**
Dak Lak		407				28.8		**436**
Dak Nong		400						**400**
Gia Lai		1253	440.5	50				**1744**
Hai Phong			0.414					**0.414**
Lâm Đồng		100			50			**150**
Ninh Thuan	98	197	596	50	112	156		**1209**
Phu Yen			200					**200**
Quang Binh		719	372					**1091**
Quang Tri			274		224	60		**558**
Soc Trang	400	868	680	30	90			**2068**
Tra Vinh	48	144	126		48		192	**558**
Total Result	**1226**	**9418**	**3657**	**335**	**894**	**425**	**992**	**16948**