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Case Studies on the Best Practices of Wind Energy Development in APEC Region

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Case Study on The Development of the Wind Industry in New Zealand







Report for APEC

September 2016

Eric Pyle, CEO, NZ Wind Energy Association

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Structure of this report

This report outlines the development of the wind industry in New Zealand. The structure of this report is as follows:

- A timeline of the development of the wind industry in New Zealand.
- An outline of the characteristics of New Zealand's electricity system. Wind needs to be integrated into an electricity system. When considering how wind developed in New Zealand and the issues that have been addressed it is important to have a broad understanding of the electricity system.
- Understanding how wind became recognised as being an effective source of generation in New Zealand.
- Grid integration. The issue of integrating wind has been a focus of considerable study in New Zealand because of the electrically weak nature of the power system.
- Consenting[1] issues, such as managing noise, impacts on wildlife etc.
- Operations and maintenance. New Zealand's wind resource is extreme potentially placing significant stress on turbines.
- The important roles of the New Zealand Wind Energy Association (NZWEA) in helping the industry develop.

Timeline of the wind industry in New Zealand

- 1970s: University researchers explore New Zealand's wind resources, including details such as understanding turbulence.

- 1970s: Research programme is established in response to the oil crises under the overview of a wind energy task force. Alternatives are sought for oil-fired generation and work starts on understanding the wind resource, with the work being done mainly by researchers.

- Early 1980s: Researchers recognise that New Zealand has a world class wind resource and that turbine developments internationally will lead to a commercial wind sector.

- 1985: Key report is published on the wind resource of New Zealand, power generation possibilities, power system integration issues etc. This report forms the basis for an informed debate about wind generation in New Zealand.

- Late 1980s: New Zealand's domestic electricity utility (ECNZ) plans a trial turbine on the hills overlooking Wellington, New Zealand's capital city.

- Early 1990s: Commercial wind prospecting begins.

[1] The term "consenting" means all aspects of environmental planning for windfarms.

- 1992: First wind conference held at a university, attended by a mix of enthusiasts and academics.
- 1993: A Vestas V27 225kW turbine is installed by ECNZ and quickly sets world records for wind generation for that type of turbine – capacity factor is above 50%.
- 1994: A 40 turbine windfarm – New Zealand's first large windfarm proposal – at the entrance to Wellington Harbour (New Zealand's capital city) is denied planning permission because of impacts on landscape values.
- 1996: A community-owned lines company establishes NZ's first multi-turbine wind farm using seven Enercon turbines (500kW). These turbines are still operating in 2016 with some maintenance/refurbishment.
- 1996: Annual wind energy conferences are organised by the Energy Efficiency and Conservation Authority, a government agency with responsibility for promoting renewable energy.
- 1997: New Zealand Wind Energy Association (NZWEA) is established with considerable support of the Energy Efficiency and Conservation Authority (a government agency). NZWEA begins to take over running the annual conference.
- 1998: Completion of first large windfarm (Tararua 1), using forty-eight 660kW V47 turbines (31.7MW). the windfarm is built by a community-owned lines company,
- 1998: Major electricity reforms create uncertainty for the electricity sector and wind development stalls.
- 1998: First domestic standard developed for windfarm noise.
- Early 2000s: Investigations and monitoring regains momentum all over New Zealand to identify potential windfarm locations funded by a mix of generation companies and independent companies on a commercial and confidential basis.
- 2003: New Zealand designed and built turbine (Windflow 500) commissioned at Gebbies Pass.
- 2004: Tararua 2 winfarm completed – fifty five V47 660kW turbines. A government initiative to reduce carbon emissions (Projects to Reduce Emissions (PRE)) assists with project economics of this windfarm and a number of others.
- 2004: First grid connected wind farm (Te Apiti) which comprised multi-MW turbines (fifty-five 1.65MW). New electricity market rules developed to accommodate wind. Wind bids into the electricity market at 1 cent and achieves the clearance price but does not have to accurately determine the amount of generation. PRE assists with project economics.

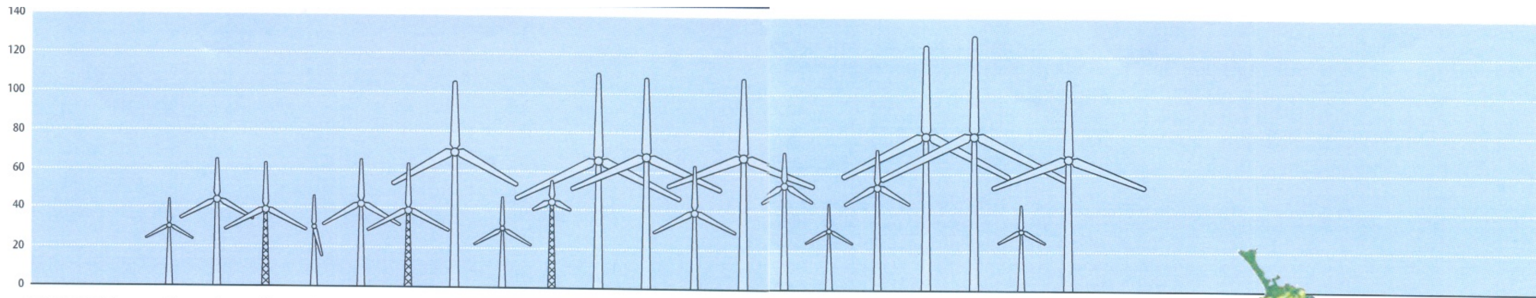
- 2006: Planning permission sought for a 630 MW windfarm. In 2009 planning permission for this windfarm is declined on the basis of impact on landscape values.
- 2006: Transmission System Operator commences a major study looking at Wind Integration.
- 2006: Developers announce plans for 1+ GW of wind generation in a number of locations around New Zealand.
- 2007: Tararua III (3MW V90 90MW) and White Hill (2 MW V80 58MW) windfarms commissioned.
- 2008: Public concern about wind turbines increase and local groups form to oppose a number of the wind farm proposals. Planning permission becomes contested and it can take years to work through the planning process.
- 2009: A 142 MW windfarm completed 20 minutes drive from the centre of Wellington using Siemens 2.3MW turbines. The windfarm has some unexpected noise issues that take some months to resolve.
- 2010: In excess of 2GW of wind generation is being scoped or planning permission sought.
- 2010: The New Zealand wind turbine noise standard is revised and a revised standard is published.
- 2011: The largest wind conference with 250 registrations.
- 2011: The Mahinerangi windfarm is commissioned (3 MW V90 36 MW).
- 2011: The Te Uku windfarm is commissioned (2.3 MW SWT 101 64 MW).
- 2011: The government prepares domestic policy to assist consenting in response to highly contested resource consents resulting in considerable costs to all participants in the process.
- 2012: Flat electricity demand and an oversupply of electricity generation results in companies putting many wind development projects on hold.
- 2013: 500MW of coal generation mothballed and then retired. The thermal generation is uneconomic compared to renewable generation.
- 2014: Mill Creek windfarm commissioned near Wellington (SWT80, 2.3MW, 60MW).
- 2015: Flat Hill windfarm (6.8 MW, Gamesa 850kW turbines) is commissioned at an estimated LRMC of NZ$70/MWh, demonstrating wind is now the cheapest form of new generation in New Zealand.

- 2015: Generators in New Zealand announce the closure of 1.5GW of thermal plant (gas and coal) on the basis of economics over the next 3-6 years. These retirements will result in a shortfall of generation creating a significant opportunity for wind development.

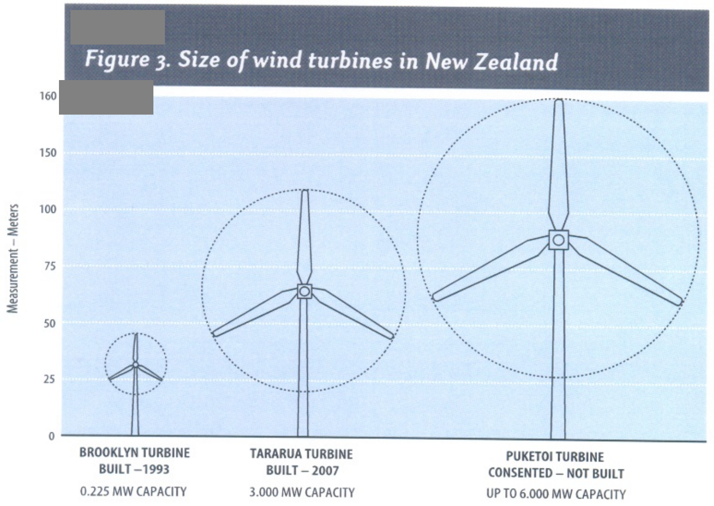
- 2016: The electricity regulator seeks views on how wind should be able to be offered into the market like any other form of generation.

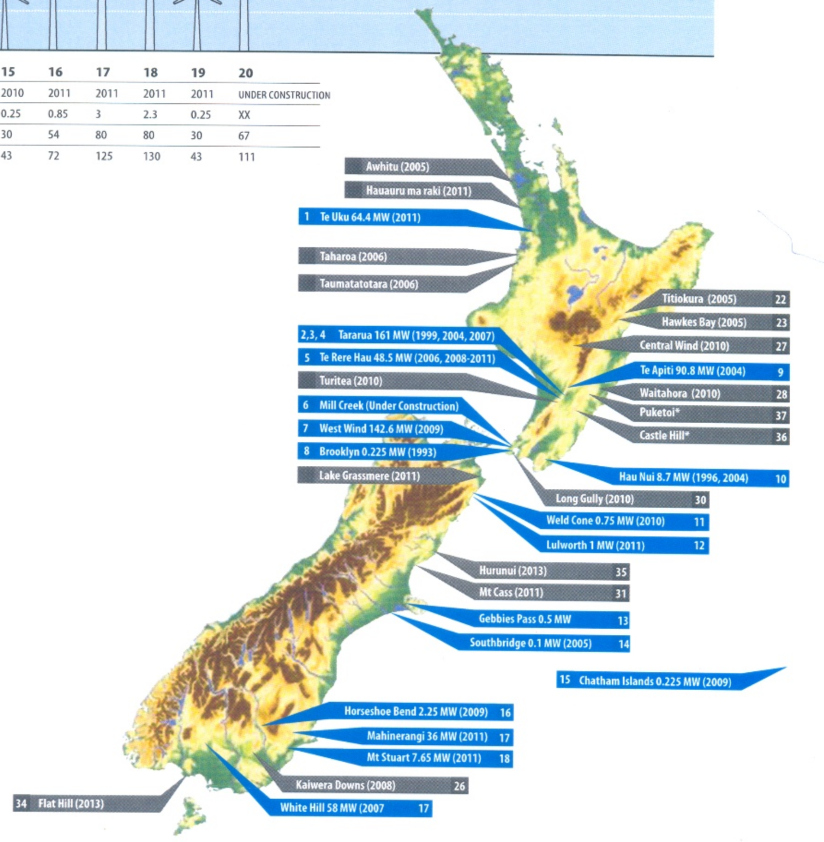
Recommendations:

In the early stages of the wind industry having a research strand is important to help understand the details of the wind regime in a economy. The early research needs to be very applied and should focus on characterising the wind resource ideally at hub height (e.g. 80+ meters) and linking that characterisation to the operation of the electricity system. Various wind development scenarios should be modelled and electricity system integration issues assessed. Funding a research programme is an action that a government can take to support the development of an industry.



NZ MAP LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
YEAR OF INSTALLATION	1993	1996	1999	2003	2004	2004	2004	2005	2005	2007	2007	2009	2009	2010	2010	2011	2011	2011	2011	UNDER CONSTRUCTION
TURBINE CAPACITY (MW)	0.225	0.55	0.66	0.5	0.6	0.66	1.65	0.5	0.1	3	2	0.75	2.3	0.225	0.25	0.85	3	2.3	0.25	XX
TOWER HEIGHT (M)	31	46	40	30	43	40	70	30	45	65	67	40	67	55	30	54	80	80	30	67
TIP HEIGHT (M)	43.5	66	63.5	47	66	63.5	106	47	55	110	107	62	111	70	43	72	125	130	43	111





NZWEA | WIND FARM DEVELOPMENT IN NEW ZEALAND 11

Figure 1: Locations of windfarms in New Zealand, growth in turbine size and heights/rotor diameters of built windfarms and windfarms with planning permission.

The New Zealand electricity sector

To understand the development of wind generation in the New Zealand electricity system it is first necessary to understand the development of the whole electricity system. This section outlines the development of the electricity sector in New Zealand, covering both the physical aspects and the institutional aspects.

Basic information 2015

- Total installed generation capacity: 10,539 MW
- Peak load 6,414 MW
- Electricity production (2014) 39.7 TWh
- Thermal plant (gas and coal)[2] 20%
- Wind generation 6%
- Hydro generation 59%
- Geothermal generation 15%

New Zealand is a long (1500 km), narrow (200km) economy with rugged terrain and extreme weather. The economy lies in the Southern Ocean between 35 and 47 degrees latitude and has two main islands separated by some 50km of ocean. New Zealand is isolated with the nearest neighbour being Australia some 2000 km distant.

New Zealand has plentiful rainfall and steep rivers amenable to hydro development. Geothermal resources are plentiful. In addition New Zealand discovered a significant quantity of natural gas in the 1970s and 80s. Located in the "Roaring Forties[3]" New Zealand has one of the best wind resources in the world for electricity generation.

Up until the 1950s New Zealand's electricity system comprised a number of disconnected grid systems built to meet local needs and supplied by local generation, mostly hydro. Over time these were connected together using high voltage transmission. New Zealand's electricity system is characterised by a long, "stringy" grid system. In technical terms the grid is considered to be "electrically weak".

Electricity demand grew in New Zealand steadily over many decades. The electricity industry frequently struggled to supply enough electricity. From the 1950s to 1980s the New Zealand government focused strongly on building sufficient generation to meet demand.

Hydro is the mainstay of New Zealand's electricity system. But herein lay a problem. The best hydro development sites are in the South Island but the majority of the load and population are located in the North Island.

In the 1950s and 60 the government embarked on an ambitious electricity development plan that now shapes the electricity system in New Zealand. Hydro resources in the South Island

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[2] By generation – the figures below are all by generation rather than installed capacity.

[3] The Roaring Forties, Furious Fifties and Screaming Sixties are terms used by sailors to describes the winds in the Southern Ocean. The terms have been adopted into New Zealand language.

were developed. A world leading 500km overland and undersea high voltage direct current (HVDC) link[4] was established to transport electricity from the large South Island hydro developments to the load centres in the North Island. A large aluminium smelter representing some 20+% of load (at the time) was built in the lower South Island. In 2015 the aluminium smelter represented some 15% of load.

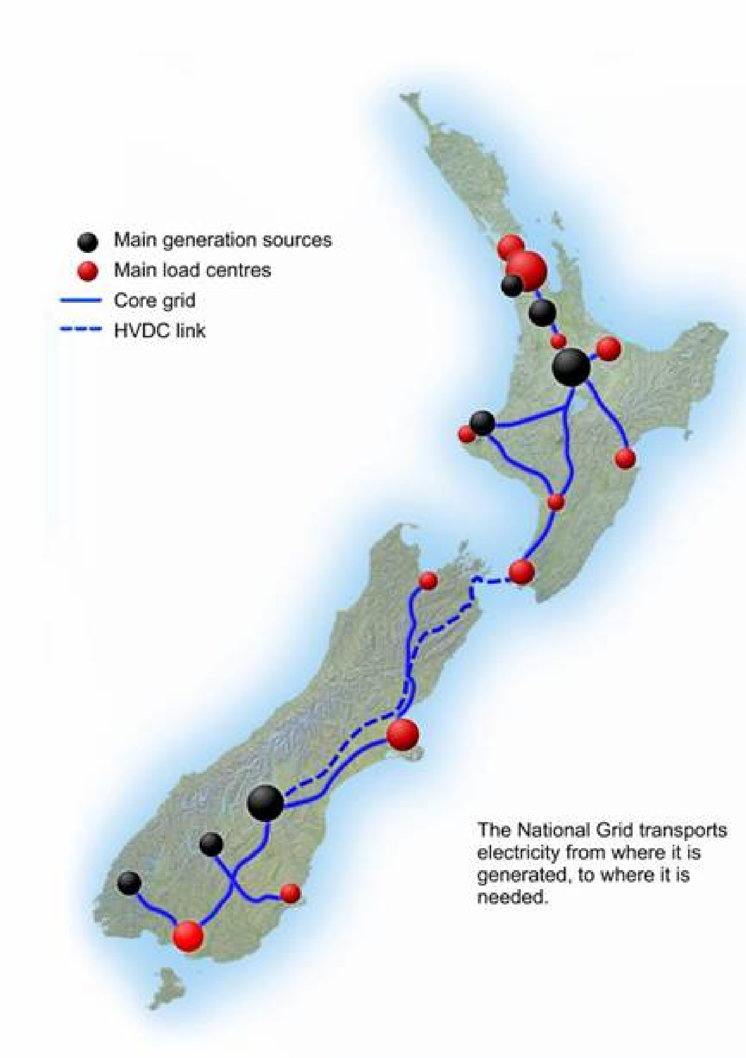

Figure 2: Map of the New Zealand Electricity System showing the main load centre and main generation sources

Prior to the HVDC link being developed New Zealand pioneered geothermal development. In the 1950s the world's largest geothermal power plant was developed and it used wet steam. This power station set the scene for a vibrant geothermal industry that today produces around 15% of New Zealand's electricity.

In the 1970s New Zealanders became concerned about the loss of rivers and raising of lakes for hydro generation purposes. After widespread opposition a number of lakes and rivers were protected in New Zealand. Hydro engineers needed to work harder to find suitable

[4] At the time (1960s) the HVDC link was the longest in the world, the previous longest HVDC link was approximately 50km.

sites, resulting in increased costs. The last large hydro scheme was the Clyde Dam (464MW) completed in 1992.

In the 1970s New Zealand discovered a large gas field. The government signed a "take or pay" gas agreement that required it to pay for gas even if it did not use it. In the late 1980s industries based on gas failed to be established in New Zealand. The government, worried about paying for gas it did not use, sought to use gas to generate electricity. In the 1990s New Zealand commissioned two 400 MW combined cycle gas plants, converted a 1000MW coal power station to run on natural gas and in 2004 the government underwrote a third 400MW combined cycle gas plant. In the late 2000s New Zealand had some 2.4GW of thermal plant.

In the 1980s New Zealand embarked on a major transmission upgrade and improvements to the way the grid was operated[5]. The major programme involved physical infrastructure, such as transmission lines, communications systems, SCADA, and training. Over the course of a decade New Zealand evolved its grid system into a reliable and modern electricity system with highly skilled and well trained personal. This period of upgrade laid a solid foundation for future developments, such as the development of the wholesale market and the development of wind generation.

In the 1980s the government became concerned about costs in the electricity sector spiralling out of control, particularly hydro development. True costs of development were not clearly visible and the government together with industry leaders explored the idea of a wholesale electricity market where market participants would decide which power stations would be built. A market would enable the true costs of electricity production and supply to be visible.

With the market the government's role in the electricity sector changed. It went from the developer and operator of the power system to the regulator. Development of generation was no longer an area that the government was strongly involved in.

The government created four State Owned Enterprises by splitting up the state-owned electricity generator. These Enterprises were set up as autonomous entities to compete in the electricity market.

An electrically weak power system

The New Zealand power system is considered by electrical engineers to be "electrically weak". Compared with strongly meshed continental grids, the NZ power system experiences very large frequency and voltage excursions. Frequencies as low as 47 Hz occur a few times per year. The long stringy New Zealand grid means that the electrical characteristics of the grid vary across the economy.

A number of windfarms in New Zealand have been built in the distribution network. These networks can be very weak electrically. Windfarms in New Zealand have been carefully designed to help provide grid or distribution level services and on occasions both.

[5] Reilly H; 2014; Keeping the Lights on – the history of System Operation in New Zealand; Transpower.

At the domestic level a significant project in the mid 2000s explored how wind could be effectively integrated into the power sector. This key study gave the System Operator comfort that significant amounts of wind generation could be accommodated on New Zealand' electrically weak power system. The Wind Grid Integration Project is outlined in a subsequent chapter.

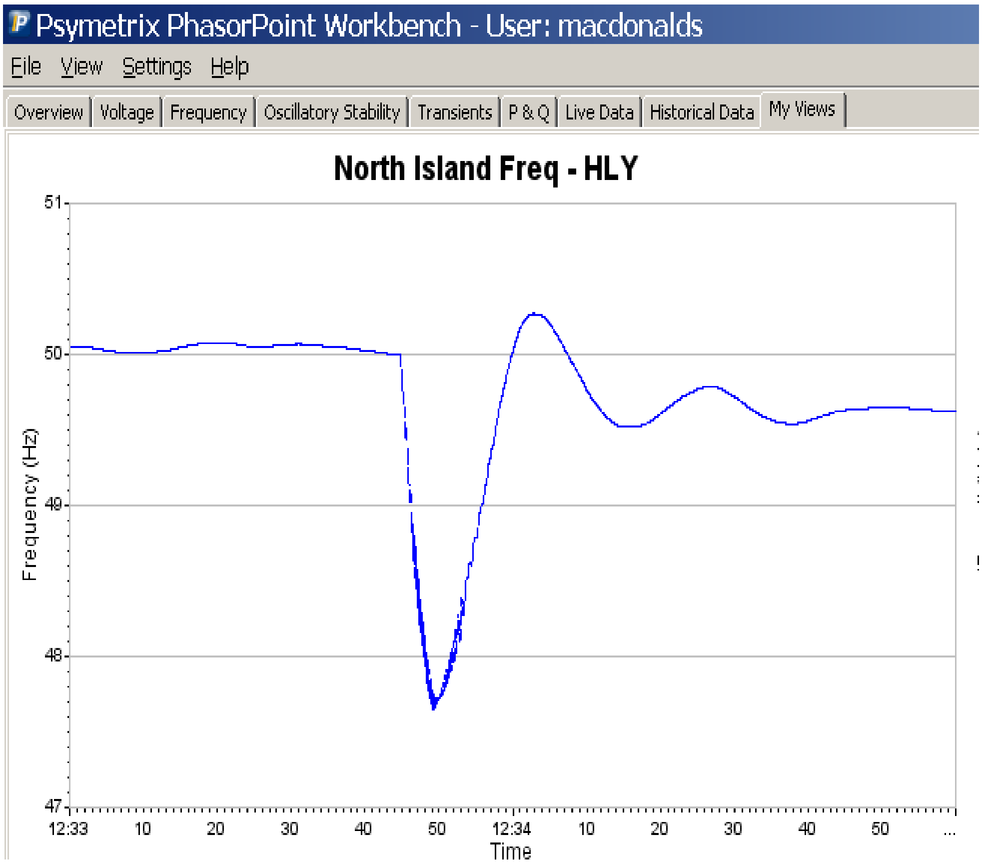

Figure 3: A dip in frequency caused by an event on the grid. Note that the frequency dips below 48 Hz.[6]

The wholesale electricity market

In the 1990s the world first locational marginal pricing electricity market was established in New Zealand. Wind developers in New Zealand have worked with the market since its inception – in effect the wind industry in New Zealand knows nothing other than the wholesale electricity market. It has operated with a high level of satisfaction across the electricity[7].

The dispatch system in the New Zealand electricity market operates on two principles:

- Security of the system, such as reserves etc.
- Most economic dispatch at any time.

[6] Sourced: Transpower.

[7] The market model was adopted by PJM Interconnection some two years after it was established in New Zealand. PJM Interconnection generally regarded as the largest electricity system in the world.

The electricity market covers both the demand-supply balance and also the provision of ancillary services. Key points of the New Zealand electricity market:

- 220 nodes (grid exit point) where prices are set.
- 30 minute trading periods.
- Dispatch every 5 minutes.
- Generation over 10 MW that is grid connected must offer into the market.
- Embedded generation (in the distribution network behind a grid exit point) over 10 MW may be required by the SO to offer into the electricity market.
- Rules of intermittent generation are similar to must-run generation.
- Clearing price can drop to zero but not go negative.
- Markets exist for ancillary services such as; instantaneous reserve, spinning reserve, frequency keeping, voltage support, black start.

The forecasting timeframe for the electricity market is as follows:

- 6 months -1 year: Long term outlook such as weather patterns (e.g. droughts), planned major plant or transmission outages.
- 1 week – 6 months: Planned outages etc.
- 24 hours to 1 week: Short outage planning.
- 12-24 hours: Market scheduling.
- 6-12 hours: Slow start plant scheduling.
- 2-6 hours: Intermediate start plant.
- 2 hours: Gate closure and firm offers.

In 2004 the first wind farm in New Zealand (Te Apiti) was connected directly to the main electricity grid. The Te Apiti windfarm was required to participate in the electricity market. Prior to this the windfarms in New Zealand were located in distribution networks. This meant that they cannot be dispatched, however, there is a requirement that the SO understands how much generation will be coming from power plants in the distribution system that are over 30 MW.

The locational aspect of the New Zealand electricity market influences decisions on where to build new generation. The figure below shows areas of the economy where electricity prices are higher than average (red) and lower than average (blue). In the North Island geothermal generation east of Lake Taupo results in lower prices (dues to geothermal generation) and prices are lower near the area of main hydro generation in the South Island. Developers do consider the variation in nodal prices when considering where to build windfarms. For example, in recent years companies have focused on gaining planning permission for wind farms in the “red” parts of the economy.

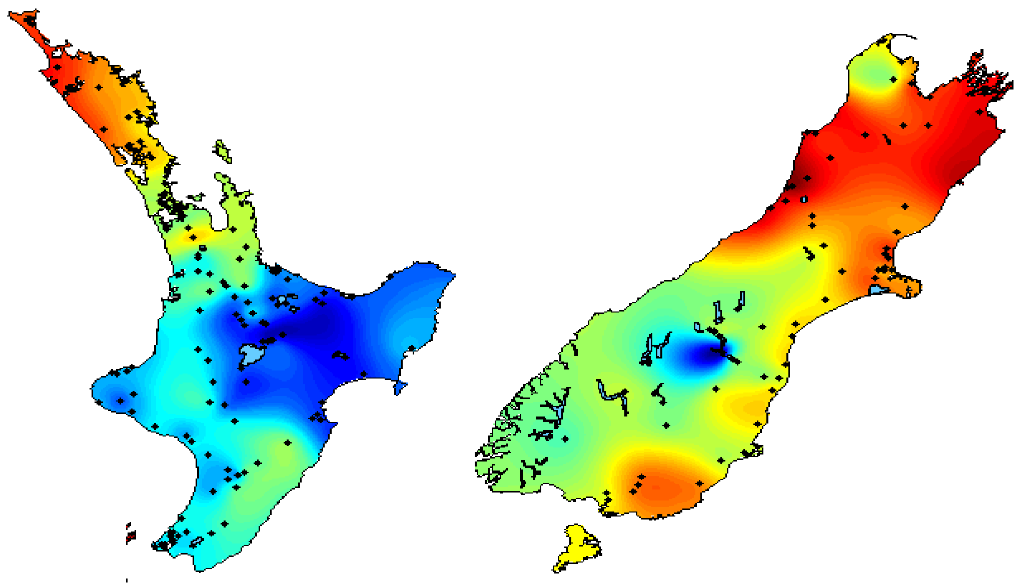

Figure 4: Higher(red) and lower (blue) prices across grid exit points in New Zealand[8].

The policy and institutional setting

The institutional setting has been an important influence on the development of windfarms in New Zealand, as it is in any economy. When the wind industry started in New Zealand in the mid 1990s the pioneers were the lines companies not the main generators. While the first commercial-scale turbine was installed (1993) by the state owned domestic electricity generator (ECNZ), it was lines companies who built the first wind farms in 1996 (Haunui) and 1998 (Tararua 1).

Further, it was lines companies who commissioned most of the monitoring of the windfarms in New Zealand. Almost all the current windfarms in New Zealand were first investigated by lines companies and other developers. For example, all of Meridian Energy's[9] windfarm sites were first monitored by other entities, often by the local lines.

The key point is that the centralised generation agency in New Zealand was slow to embrace wind and recognise wind as a new form of viable generation technology. It was the organisations that were looking for new opportunities and keen to innovate that explored wind and started to develop the first projects.

[8] Presentation to the NZ Wind Energy Conference by Dr James Tipping, Trustpower, 2012.

[9] New Zealand's largest wind farm operator by MW of wind capacity.

The 1980s and 1990s

In the 1980s and early 1990s New Zealand had a centralised generation system. The New Zealand Electricity Department was responsible for large scale generation and the transmission system. Electricity was sold to consumers by lines companies. The lines companies were natural monopolies (and still are) and were owned by municipalities or community trusts, i.e. they were seen as part of the community's infrastructure.

The lines companies, which were also the electricity retailers, charged consumers for:

- The cost of the distribution infrastructure that the lines company ran.
- The cost of domestic transmission that the NZ Electricity Department charged the lines companies.
- The cost of energy, which the NZ Electricity Department charged the lines companies.

Lines companies encouraged by the Government to develop local generation in the 1970s. But after some financially disastrous outcomes the government put in place barriers to lines companies developing generation. These barriers were lifted in 1992 and the lines companies began focusing on generation again.

Wind was seen by some in the lines companies as an ideal form of generation[10]:

- New Zealand has good wind resources.
- Wind generation is scaleable.
- The technology is straight forward to install, as compared for example, to hydro schemes which in New Zealand's diverse and earthquake-prone landscape can have significant geotechnical issues.
- Wind was profitable for lines companies because it meant they did not have to buy electricity from the domestic generator and they could pay less for domestic transmission.

The result of the policy settings coupled with an ability to innovate quickly wind meant that it was the lines companies who did much of the early investigation and development of wind farms in New Zealand. Unfortunately these developments came to a shuddering halt later in the 1990s due to central government reforming the electricity sector.

In 1996 the New Zealand electricity market was established. The lines companies responded quickly and started developing entities to bulk buy electricity from the State Owned Enterprises that the government established out of the old electricity department. Some in the electricity sector had concerns about the potential ability of lines companies to use their monopoly income position to finance new generation development, i.e. to in effect subsidise new development such as wind.

In 1998 the government passed a new law that required lines companies to either:

[10] Allan Jenkins pers comm. Allan has recently retired as the CEO of the Electricity Networks Association, which represents all the lines companies in New Zealand.

- Run the distribution network only or
- Become a retailer and or/generator.

Lines companies were not allowed to own generation or be a retailer. Some lines companies chose to become generators. But most chose to remain with the lines business.

As a consequence of this policy and institutional turbulence, wind generation development ceased in 1998 and did not get underway again until the early-mid 2000s, a period of 6 or so years.

The late 1990s onwards

The pattern of institutions in the NZ electricity system was largely set through the 1998 reform, which saw lines companies being constrained operating only the distribution network and have to sell off their retail and generation operations.

Four large generators had been created from the former NZ Electricity Department. These entities had to learn about the characteristics of wind generation and how to integrate the generation into their portfolio system which delayed the growth of the wind industry in New Zealand.

Only one of the large generators, Meridian Energy, developed significant wind generation capacity. All of Meridian Energy's windfarms were first explored by lines companies. The work by the pioneers in the wind industry in the early-mid 1990s and the institutional settings of that time have shaped the wind industry today.

In the 1990s and 2000s demand for electricity continued to grow and sources other than large hydro were sought. Potentially the wind industry could have grown rapidly over this time but three key factors constrained the growth of the wind industry:

- Restructuring of the lines companies (discussed in the previous section) that were the organisations most actively involved in wind generation development.
- Geothermal development grew rapidly from 5% of generation to 15%. New Zealand invested significantly in geothermal development as a consequence of a long history of development, considerable depth of expertise and a subsidy from the government in the form of research funding to help define geothermal fields. During electricity restructuring the geothermal teams were transferred largely intact from the government electricity department to the new smaller generation companies.
- Gas fired generation. In 2004 New Zealand suffered an electricity shortage caused by drought. The government was concerned that the electricity market would not deliver sufficient generation in time. It underwrote one of the state-owned generators to develop a new combined cycle plant. That plant (400MW) was commissioned in 2007. The development of this power plant had the added benefit for providing a large customer for the gas industry that enabled a new offshore gas field to be developed. Ironically in 2008 electricity demand growth in New Zealand ceased. This decision to in effect subsidise a gas-fired power plant resulted in a lost opportunity for the wind industry amounting to some 800MW-1000MW.

Institutional and policy settings summary

The wind sector would have grown more quickly in New Zealand if:

- The lines companies had been allowed to develop generation. These companies realised the opportunity related to wind and that wind could be developed locally and was scalable. The large domestic generator could not realise or access these opportunities as quickly as the more nimble lines companies.
- Institutional reform meant that knowledge and capacity to develop wind was lost and had to be re-built. The reforms of 1998 set the wind industry back by some 5+ years, just at a critical stage of development.
- Government intervention – underwriting a large thermal power station – meant that wind was not given the opportunity to develop. Without this one intervention the New Zealand wind industry could be twice the size that it now is.

Recommendations relating to the overall electricity sector:

- Large generators will be slow to learn about wind generation. Ensure policy settings support the small, innovative players – they are the organisations who will explore and understand the opportunities around wind.
- Electricity sector restructuring needs to be very carefully worked through to ensure that unintended consequences do not occur, for example, constraining innovation.
- Governments should not pick and subsidise particular generation projects. If the government does wish to develop generation market-type mechanisms should be developed, such as tenders.

Getting the industry started

Throughout the interviews for this study, a common theme is that a good understanding of the resource is absolutely critical to developing a wind farm.

1970s and 80s – the early years

In the 1970s and 1980s a small number of academic staff at universities in New Zealand explored the idea of generating electricity from wind[11]. These academics recognised that New Zealand was windy and that research programmes in the US were exploring the development of wind turbines. As part of a broad R&D effort by the government to develop new sources of energy following the oil shock in 1973[12] a wind research programme was established.

The research work was important from a number of perspectives:

- Collecting accurate data on the wind regime. Up until this time there were no high quality wind datasets in New Zealand. Wind data were generally collected at airports etc but these data were of varying quality, for example, collected relatively low to the ground.

[11] Professor Richard Flay, Auckland University, interviewed 23rd February 2016.
[12] A number of economies around the world developed energy R&D programmes at this time.

- Understanding how to collect good quality data and how important good quality data is. At this time few people in New Zealand knew how to collect good quality wind data, nor did they realise how important good quality data is.
- Characterising the wind resource. The early researchers explored issues such as wind shear, extremes, such as gustiness and calm periods.

The wind researchers inspired a small number of students and generally raised the profile of the possibility of wind generation in New Zealand. They were able to demonstrate, using world comparable methods, that New Zealand had a wind regime that was well suited for wind generation.

Two academic researchers were pivotal to the development of understanding of the wind industry in New Zealand. Neil Cherry (Lincoln College, Canterbury University, Christchurch) and Keith Dawber (Otago University, Dunedin). These visionary individuals were critical to the establishment of the wind industry.

Dawber led monitoring efforts in the South Island of New Zealand and was the first to collect sufficiently accurate wind data to be useful to develop windfarms. He also explored wind resource issues that could impact wind farm development, such as turbulence[13]. Dawber was active internationally, keeping abreast of the development of the wind industry and imparting knowledge about the wind industry to New Zealanders.

Cherry led the first domestic survey of the wind resource in New Zealand in the 1970s[14]. This study used data from existing meteorological stations. The wind industry made extensive use of this original report. It provided very useful information on where the windy sites were. More detailed monitoring campaigns were developed using the information in that early study.

An important ingredient was a report published in 1985[15] by Cherry on the wind resource in New Zealand and potential generation characteristics of windfarms. The report identified potential windfarming regions based on wind resource and proximity to load. Some 12 windfarms in New Zealand were modelled assuming 2.5MW turbines[16] generating around 20% of total electricity production[17]. This modelling enabled wind generation characteristics to be explored in relation to the electricity system. The wind data in the report were from meteorological stations upscaled to a 50m hub height and atmospheric wind speed data (from tracking weather balloons) downscaled to 50m. Cherry's 1985 report provided a solid foundation for an informed debate about the wind industry in New Zealand.

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[13] http://www.energywatch.org.nz/issues/EW7_8_1997.pdf accessed 15th February 2016.
http://www.windpowermonthly.com/article/956239/keith-dawber-dies

[14] http://www.nzine.co.nz/views/windflow.html

[15] Cherry N; (1985); Wind Energy Resource Survey of New Zealand; New Zealand Energy Research and Development Committee.

[16] The largest turbines at the time were around 100kW.

[17] In 2012 the New Zealand Wind Energy Association produced a vision document for the wind industry in 2030. The target is for 20% wind generation by 2030, i.e. the identical target to the 1985 report.

Cherry was also involved in international work. For example, he worked with the Battelle Laboratories, reviewing the US wind resource assessment programme. Cherry also had a sabbatical in the US, working on the wind programme in California. Through these sabbaticals and international interactions Cherry brought knowledge back to New Zealand.

As well as the academic researchers, two or three experts helped drive interest in wind generation. These experts had worked overseas and had practical experience in developing windfarms. These experts linked with the work of Cherry and Dawber and were able to put a compelling case for investigating wind generation in New Zealand. The experts were pivotal to the development of the industry.

The key ingredients

So what convinced the electricity sector in New Zealand to start investing in wind? The following elements were important:

- A very small number of academic researchers (Dawber, Cherry) had collected some good quality wind data that demonstrated New Zealand had a world class wind resource. Further, the researchers had begun the process of characterising the wind resource, exploring turbulence, shear, the most windy locations etc.
- An effective report on the potential of wind generation in New Zealand and how wind may interact with the electricity system (published in 1985 by Neil Cherry).
- A small number of experts (2-3) with international experience who linked with the academic research and convinced the electricity industry that wind generation was worth investigating.
- Distribution companies[18] were keen to develop generation in their local areas. They recognised that wind generation could be built at different scales and was a significant change in thinking about generation from large centralised power plants.
- The domestic generation organisation (before being split into a number of companies) focused on wind generation, recognising wind to be a potential future form of generation.

Collecting the data – detailed understanding of the wind resource in New Zealand

The work of Chery, Dawber and colleagues provided very useful broad information. The industry recognised that to successfully develop windfarms accurate local datasets were needed. In the early 1990s the industry, mainly lines companies, started monitoring the wind resource around New Zealand. Existing wind data sets in New Zealand were not adequate to support the development of the wind industry. For example, the existing data was collected to the nearest knot, which is not sufficiently accurate to design a windfarm.

Importantly, the people returning from overseas understood the importance of measurement standards and well-designed measurement campaigns. These practitioners assisted New Zealand start well up the learning curve in terms of wind resource assessment techniques; they could explain why the existing wind datasets in the economy, for example, from the

[18] Companies that run the distribution-level networks.

Meteorological Service, were not adequate for wind resource assessments and why site-specific data are essential.

30m towers were the common measuring platform reflecting the hub heights of the early 1990s. Later these measurements had to be supplemented by measurements at 70-80m reflecting the growth in wind turbine heights. A lesson is that monitoring campaigns should be designed for future turbine technology rather than current.

Modelling now provides some of the information that the wind resource study provides. However, practitioners in New Zealand consider that the broad-scale monitoring or modelling helps paint a broad picture of the resource. Detailed information is still needed and can only be provided through site-specific monitoring programmes, ideally measuring wind speed at the likely hub height of the wind turbine.

Recommendations: Starting the industry

- Encourage a research programme focused on wind resources.
- Support the key researchers who are leading wind research efforts.
- Ensure that monitoring is done to internationally accepted standards to ensure high quality data collection.
- Develop and publish robust information on the wind resource and make this information widely available.
- Collect site-specific data to characterise the wind at a particular location.
- Collect wind speed data at the potential hub height of future turbines, not just existing turbines. This height is likely to be a minimum of 80m, possibly as high as 140m.

Getting the first few projects underway; successes and some learnings

The wind industry in New Zealand grew slowly until 2004 when the first large (>1MW) turbines were installed to create the 90MW Te Apiti windfarm. This section outlines how the first few windfarm projects were developed. These first few projects were instrumental in establishing the industry.

Figure 5: Windfarms in New Zealand.

The Brooklyn wind turbine - The first commercial scale wind turbine in New Zealand; 1993

In 1993 a 225kW 27m rotor diameter Vestas turbine was installed on a prominent hill overlooking Wellington, New Zealand's capital city. The Brooklyn Turbine (named after the local suburb) was replaced in 2016 after some 23 years in service. The wind regime at the turbine site is Class 1A with high levels of gustiness and turbulence.

The turbine was installed by the Electricity Corporation[19] to gain experience and understanding of wind generation and to answer questions such as[20]:

- Would the turbine work effectively in the New Zealand wind conditions?
- What were the maintenance issues?
- Would the public accept the turbine from a visual perspective?
- What are the issues associated with wildlife, such as birds?

[19] A government agency that ran nearly all generation in New Zealand.
[20] Peter Browne pers comm. Peter Browne led the turbine project for the Electricity Corporation of New Zealand.

In terms of industry learning and public education this turbine was an outstanding success. In the first 6 months the turbine set a world record for output from a 225kW turbine. The turbine proved that in New Zealand's tough wind conditions pitch controlled turbines can survive and not have significant maintenance issues. The gearbox has been replaced once but other than that the turbine has worked well at a capacity factor of around 50% and availability of around 97+%.

The turbine is next to an urban area. There are houses (i.e. suburban dwellings) within 500m of the turbine. There have been no noise complaints since the turbine was installed.

The turbine is also a great success from a public relations perspective. Stunning views of Wellington City can be had from the turbine site and it is one of the most popular tourist destinations in Wellington. A manager of the wind turbine commented that in its first year or two it was time consuming to run – because so many school groups wanted to visit and have someone talk to them about the wind turbine! In response to public demand a comprehensive interpretation display was developed.

In 1999, 6 years after the turbine was installed, a wildlife sanctuary was established with a boundary only meters from the turbine. The sanctuary, a world first, is enclosed by a predator proof fence[21]. In the absence of predators a number of rare and critically endangered birds species have been introduced into the sanctuary.

Figure 6: The new Brooklyn Turbine under construction in 2016. Note the predator proof fence in the left of the left hand photo and on the right of the right hand photo. The Brooklyn Turbine is right next to the most significant bird sanctuary in New Zealand.

To date no rare and endangered birds, which have now breed to large numbers in the absence of predators, have been killed by the turbine. Given the large numbers of visitors to the turbine, if it had killed birds these deaths would be been widely reported in the media. The Brooklyn turbine's location on the boundary of what is now New Zealand's premier bird sanctuary, has demonstrated that wind turbines can have minimal impact on New Zealand's rare and endangered bird species, provided they are located in the right place.

[21] The fence is designed to ensure that cats, rats, mice, stoats, ferrets, weasels etc do not enter the Karori Wildlife Sanctuary.

In 2013 Meridian Energy, the company that owns the turbine, sought the views of the people of Wellington on whether they wanted the turbine removed or replaced as the turbine was coming to the end of its useful life. In a poll run by the local Wellington newspaper some 84% of people voted to replace the turbine. Local residents established a facebook page focused on promoting the replacement of the turbine. In April 2016 the 27m rotor diameter Vestas turbine was replaced with a 44m (rotor diameter) 900kW Enercon turbine.

Learning from a failure – Baring Head and Te Uku

In the early 1990s a 40 turbine wind farm was proposed for Baring Head at the entrance to Wellington Harbour[22]. The project was proposed by the local lines company.

Wellington Harbour is a stunning landscape and the heads are largely free of large scale human development. A small number of suburbs in Wellington have views across the harbour of the heads and these people became very concerned that the heads would, over time, be covered in wind turbines like some of the images of early windfarms in California.

The local community became organised and launched a campaign against the windfarm. The consenting authority turned down the application for the windfarm on the basis of landscape impacts. The decline of this application highlighted that the wind industry needed to be very careful about how it designed windfarms and worked with local communities.

Those involved in the project considered that they made some significant mistakes in the design and consultation process. For example, the company sought planning permission for 40 turbines, even though it was not planning to build all 40 in the near future. It is plausible that a windfarm with five or six turbines would have been granted planning approval.

Figure 7: The site of the proposed 40 turbine windfarm at Baring Head, Wellington Harbour. Strong local opposition meant the windfarm did not receive planning permission.

In the mid-2000s the Waikato Electric Lines Company was investigating a windfarm in a coastal environment that was a similar stunning landscape. A local town was nearby the proposed windfarm and residents would be able to see the windfarm from the town. Many of the ingredients were similar to the Baring Head windfarm. The number of wind turbines was less, but not much so, at around 30. But the turbines were bigger with 100m rotors vs the 37m rotors proposed for Baring Head.

[22] Based on an interview with Mike Underhill, Chief Executive of the Energy Efficiency and Conservation Authority and former Chief Executive of the lines companies involved in the Baring Head and Te Uku Windfarm proposals.

The developers of the Te Uku wind farm had been involved in the Baring Head proposal and had learned from that experience. They worked very closely with the local community and sought to allay their concerns. Further, the windfarm was designed to deliver benefits to the local community. Examples of the approach including:

- Taking residents who had concerns about wind turbines to other windfarms in New Zealand so they could experience what the wind farm would look like, what the noise issues might be etc.
- Strengthening the local distribution system so that power outages would be reduced. The local town suffered regular power outages and the strengthened distribution system would result in significantly improved reliability.
- Assuring the community that environmental impacts associated with construction could be managed. The wind farm is in a harbour catchment and sediment run off from the roading was a significant concern in relation to potential impact on the fishery in the harbour.

The windfarm proposal easily gained planning permission. During the construction phase the windfarm won an environmental award for its innovative and effective ways of minimising sediment runoff from road construction. The Te Uku windfarm comprises twenty eight 2.3MW turbines, 80m towers and 101m rotors. It was constructed in 2011.

Figure 8: The Te Uku windfarm – the largest rotors in New Zealand at 101m.

Haunui – the first multi-turbine windfarm; 1996

The Haunui windfarm – seven 500kW turbines – was built by one of New Zealand's smallest electric lines companies in 1996[23]. Wairarapa Electricity saw a future in small generation that was distributed around the district. The company knew that there were a number of

[23] Interview with Dave Paton, former development manager at Wairarapa Electricity.

windy areas in the region and monitoring confirmed that it was indeed very windy and precisely characterised the wind resource.

Wairarapa Electricity relied on the very small number of experts New Zealand had in wind generation. These experts advised Wairarapa Electricity and guided the company through the various stages, such as monitoring the wind.

At this time New Zealand only had one commercial wind turbine. Wairarapa Electricity pioneered the industry and through this windfarm introduced a number of companies to the wind industry. For example, transport and crane issues needed to be worked through, from logistics through to financial aspects such as insurance.

The windfarm is embedded in the local network and connects directly to a 33kV feeder. Some electrical engineering design work was needed but this was of limited extent and well within the existing capability of New Zealand expertise.

The windfarm has operated successfully. Wairarapa Electricity had planned to develop more small windfarms, but policy changes meant that lines companies could no longer develop generation. Further the government policy changes required lines companies to sell their generation assets along with their customer base in 1998.

In 2004 the company that bought Haunui added a further 8 turbines – an indication of this early project's success.

Figure 9: Haunui windfarm. Haunui is a Maori word meaning "big wind".

Tararua 1 – the first large wind farm (48 turbines); 1999

In the 1990s Central Power operated the electricity distribution system in the Manawatu Area[24]. The company saw wind as something that the company could develop both from a technical and financial perspective.

Central Power started investigating wind generation in 1992. There was a sense that the Manawatu area was windy, but no-one knew quite how windy. The company sought advice from local experts[25] and internationally.

[24] Based on an interview with Derek Walker, former General Manager Development for Central Lines Company. Like all lines companies Central Power also had a retail base

Staff from Central Power visited California to better understand the wind industry. This visit greatly helped with understanding the technology and the issues associated with it, such as economics, monitoring the wind resource, the types of turbines available etc. During this visit connections were made with wind experts in the US who continued to act as advisors as the project developed.

Subsequently the Manawatu became the wind farming capital of New Zealand. The Vestas V90 turbines in the Manawatu, installed in 2007, have produced more kWh than any other wind turbine in the world, i.e. the V90s are the most productive land-based wind turbines in the world[26].

Figure 10: V47 turbines at Tararua Windfarm – one of the most productive sites in the world.

Te Apiti – the first wind farm using large turbines; signalling the market-driven switch from hydro to wind

The Te Apiti wind farm – 90 MW, 1.65 MW turbines – marked a step change in the wind industry in New Zealand. The project, commissioned in 2004, was notable because it used large turbines (>1MW) and was much larger than any other wind farm developed in New

[25] As discussed previously a small number of experts with overseas experience were pivotal to the development of the wind industry.
[26] Presentation to the NZ Wind Energy Conference, 2015 by Vestas.

Zealand. Further, it was the first wind farm that connected to the domestic grid and therefore had to operate in the electricity market.

Te Apiti signalled the point that wind started to take over from large hydro as a major form of electricity generation. For a number of decades hydro planners had been exploring a large hydro scheme in the South Island's Waitaki catchment. The Waitaki catchment has eight hydro stations of 1700MW installed capacity – nearly 20% of New Zealand's generation fleet. The project, titled "Project Aqua" would complete the development of hydro in the catchment, at least in the minds of hydro planners.

In the 1990s Meridian Energy[27], a government company that operated the power stations in the Waitaki catchment commenced a detailed planning exercise to scope and cost "Project Aqua". After many detailed studies Meridian Energy concluded that Project Aqua would not be economic. A key reason was uncertainty around the geotechnical aspects. At the time Meridian Energy was also exploring wind and wind stacked up economically compared to hydro.

This demise of Project Aqua and the rise wind highlights the value of electricity markets in choosing the most cost effective form of generation. Before the market was developed it was highly likely that Project Aqua would have been built by the government. Any cost over runs would be met by the tax payer. The discipline of the market forced Meridian Energy to focus on the least cost form of generation and that proved to be wind generation.

The market also assisted the development of wind generation in two other key ways. First Meridian Energy realised that wind energy could be built in small increments as demand required it, i.e. moving closer to "just in time" electricity development. This thinking was crucially different to large hydro.

The second aspect of wind that the market assisted was the location of wind farms. New Zealand has good wind resources in many parts of the economy. With a location-based pricing system the market sends signals for where in the economy there are generation shortages.

The ability to scale wind and locate it in different place around the economy in response to market signals was a radical transformation in the electricity sector. The traditional approach of building large power stations and significant transmission (i.e. the Project Aqua model) was replaced by more nimble thinking about small wind farms distributed across the rural areas.

The key point is that wind can thrive in a modern electricity market when the true costs of alternatives are clearly visible.

[27] Meridian Energy was formed from the break up of the New Zealand Electricity Department.

Figure 11: Te Apiti Windfarm.

Gebbies Pass - The Windflow 500 turbine

In 2003 the first New Zealand designed and built wind turbine was commissioned. The 500kW “Windflow” 500 turbine was installed near Christchurch. The turbine is a 2 bladed design, with a “teetering action” to reduce stress on the drive train. It is certified as an IEC Class 1 turbine and is designed for New Zealand’s tough wind conditions. A class II turbine is under development.

To date over 100 turbines have been built with the vast majority installed in New Zealand. A small number have been installed on the Scottish Isles.

Figure 12: The first Windflow 500 turbine at Gebbies Pass.

Three phases; small, large and medium-scale development

The wind industry in New Zealand started small. Initially a single commercial turbine was installed. A few years after this single turbine a seven turbine windfarm (Haunui) was developed, followed by Tararua 1 with forty-eight turbines. A decade after the first turbine was installed turbines in excess of 1 MW were installed in the 90MW Te Apiti development.

But once companies saw that wind was viable in New Zealand some very large projects were proposed. Wind farm projects as big as 800MW were on the drawing boards and some received consent, whereas some others did not for a range of reasons, such as landscape.

The industry has now settled on medium scale development – windfarms in the 8MW-70MW range. The last four windfarms built in New Zealand were; 64MW, 36MW, 69MW and

8MW. This small-medium size of wind farm suits the electricity system of New Zealand and is manageable from a range of perspectives, such as logistics, landscape impacts and public perception.

A plan for the industry

In the mid 2000s the public were becoming alarmed at the prospect of vast wind farms being developed over significant areas of New Zealand. Consenting started to become difficult and the public started asking what the overall plan was and where were the limits.

In response in 2012 the wind industry published its vision for 2030[28]. The vision document proposed that 20% of New Zealand's electricity could be met by wind in 2030. The document outlined where the windfarms would most likely be built to help provide certainty and the sense of a "plan" for the public.

Helping the industry learn and reducing costs

In New Zealand data on cost reductions are hard to obtain due to competition and confidentiality in the industry. Data for the cost of developing wind generation from other economies indicates that as the industry learns costs reduce. For example, in South Africa the cost of wind in auctions has reduced as from USD 143/MWh to USD 52/MWh[29] over four auctions rounds.

New Zealand had one scheme to encourage renewable energy development. The Programme to Reduce Emissions (PRE) offered carbon credits to projects that could demonstrate would reduce CO_2 emissions. These credits could then be sold in carbon markets generating revenue for the project. This scheme was developed under the Kyoto protocol[30]. The government invited tenders for projects that would reduce emissions.

A number of windfarms received PRE funding totalling 320+MW – nearly 50% of the total developed. The PRE scheme finished in the mid 2000s and was to be replaced by a carbon tax, which was not implemented.

In hindsight the PRE scheme was complicated. It did assist the wind industry develop projects and it not interfere directly with the wholesale electricity market. Little evidence exits to suggest that PRE's focus was to bring costs down for projects, for example, through increasing industry learning. It appears at the time there was a perception that renewable energy projects were expensive and would always be expensive. PRE was designed to get projects over the line rather than assist the wind and other industries move more quickly down the cost reduction curve.

Many economies have trialled approaches to assisting the wind industry in its early stages to help the industry move down the cost reduction curve. Electricity auctions currently seem to

[28] NZ Wind Energy Association 2012: Vision 2030.
[29] http://www.gsb.uct.ac.za/files/PPIAFReport.pdf
[30] https://www.beehive.govt.nz/speech/projects-reduce-emissions-key-climate-change-policy

be best practice. The International Renewable Energy Agency (IRENA) has published a summary of these and has looked at the pros and cons[31].

Recommendations from the first few projects and the evolution of the wind industry in New Zealand

According to people interviewed for this study and who were involved in the early stages of the industry the following aspects are important to developing a wind industry:

- Focus on collecting accurate wind data. Accurate wind data is very important, at hub height. For many economies that means at 80-100m. Broad studies and manipulation of existing datasets, such as from meteorological stations, are not sufficient for detailed wind farm design. A well designed wind farm that performs as expected requires good data.
- Bring in experienced people. In New Zealand a couple of experts with overseas experience and who were effective communicators played a key role in advising, promoting and designing windfarms. These experts helped build confidence in wind generation.
- Support companies that are prepared to innovate. In the case of New Zealand it was the smaller companies who were prepared to take a risk and could quickly move a project through the design and financial closure process. This process can be easier for smaller companies.
- Visit operating windfarms to gain an understanding of windfarms. An important part of developing the industry in New Zealand was visiting operating windfarms in other economies and learning about issues in developing and operating windfarms.
- Encourage cooperation between companies. A windfarm requires a diverse set of companies that need to learn to work together to deliver the project. For example, in the first few projects construction disciplines such as road construction and cable laying had to work together. In some cases it took time for the different disciplines to understand each others' needs.
- Understand community concerns and be prepared to modify or even withdraw a project. In some cases it may be better to withdraw a project than continue against intense public opposition. Where possible work to bring the community on board by listening to and allaying concerns the community may have.
- Build the "right size" of project. Wind farms can be built in a range of sizes. Large may not necessarily be more economical and the size of the windfarm needs to recognise a number of factors, such as grid stability, landscape aspects, community concerns etc.
- Develop a vision for the wind industry as the industry starts to grow. The community may ask questions like "will wind turbines be everywhere". A strategy can help the industry communicate its vision and assist with dialogue between the wind industry and the community.

[31] http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Auctions_Guide_2015_1_summary.pdf

- Provide assistance to the wind industry in its early stages to help move the industry along the learning curve more quickly. New Zealand used an approach of granting carbon emissions units[32]. Auctions are used in many economies where the electricity market is not fully liberalised.

Many of these points are remain relevant today even for a relatively mature wind industry like New Zealand. For example; accurate wind monitoring is still critical, wind developers still need to stay abreast of latest developments and gain experience in the latest developments, companies being able to work together well remains a very important part of a successful project.

Grid and market integration

In the early 2000s grid connected windfarms were being planned in New Zealand. Wind posed a number of challenges to the electricity market and dispatch system, which is based on the premise of firm generation offers and penalties for not complying with the offers. Wind is a variable form of generation and it became apparent that wind could not comply with the existing electricity market and dispatch rules, but the government was keen to promote wind generation as a renewable and modern technology. So a way was needed to enable wind generation to participate in the electricity market.

New Zealand's electricity dispatch system has two key principles[33]:

- System security, i.e. ensuring that there is enough electricity being generated to meet demand.
- Economic dispatch. Making sure that the most economically efficient set of generators run at any time.

To provide certainty to all participants and the System Operator, the market has a final gate closure of two hours[34]. What this means is that 2 hours out from real time generation offers were confirmed and there are significant penalties for non-performance. The difficulty with wind generation in New Zealand is that output from windfarms can vary significantly within two hours[35] (discussed later).

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[32] It is not clear whether the New Zealand initiative was designed in relation to industry learning or whether it was viewed as a means for getting projects "over the line" financially.

[33] Doug Goodwin pers comm. Doug is a former senior manager at the System Operator.

[34] Gate closure will be reduced in 1 hour in 2017. Some wind generators are promoting having a half hour gate closure.

[35] A two hour gate closure, as compared to 1 hour or 3, was chosen because it was the shortest time that a "solve" could be computed using standard existing computers in the mid-1990s. At the time it was acknowledged that having gate closure as close to real time as possible was best practice, but computing power at the time was a limited factor.

In 2004 the 90MW Te Apiti windfarm was connected to the grid. Up until this time windfarms were embedded in local distribution networks and not subject to domestic dispatch rules. The development of this windfarm triggered the following programme covering:

- Temporary changes to the electricity market rules to enable wind to participate in the electricity market.
- Tactical studies to collect data on the issues that were being experienced with around 170MW of installed wind generation, 160 MW of which was in one location from a grid management perspective.
- A long term study called the Wind Grid Integration Project (WGIP) jointly run by the System Operator and the electricity regulator.

The focus of the studies was related to the two key principles of the electricity dispatch system:

- System security: Understanding the nuances of wind generation to develop ways to ensure that wind did not increase system security risk and ideally reduced system security risk.
- Economic dispatch: The studies aimed to develop rules for the electricity market to enable wind to operate in the market. Under the existing rules wind would be deemed non compliant and would either not be allowed to operate or would face the prospect of significant fines.

This chapter outlines the various studies and initiatives related to grid integration; temporary rules, tactical studies and the WGIP.

Wind and the electricity market – new market rules to accommodate wind generation

In order to be paid for the electricity they produced wind farm owners needed to participate in the electricity market. In order to participate wind farms needed to comply with the electricity market rules. Therein lay a problem: The electricity market rules were not designed to cover variable generation. The paradigm under which the market rules were developed was certainty of generation offers and penalties for not meeting the generation offer.

A working group comprising the wind industry, System Operator and Transpower[36] was established in the early 2000s. It was tasked with developing temporary rules that allowed wind to participate in the market.

The closest form of generation to wind was "must run" generation. This is generation that is offered into the market at $0.01/MWh which means that it is always at the bottom of the generation stack and is therefore always dispatched. This type of generation receives the settlement price – the price of generation offered to meet the demand. The working group decided that wind should also offer in at $0.01/MWh and would therefore be dispatched alongside must run generation.

[36] Transpower is the domestic grid operator.

The wind working group had to report to three different formal groups in the electricity system:

- The dispatch working group.
- The market rules working group.
- The pricing-liabilities working group.

In practice participants in these groups were a tight knit community and often sat on more than one group. The various groups worked well to focus on the aspects of wind generation.

Wind generators are required to forecast their potential generation at gate closure, i.e. 2 hours out from real time. In practice it was found that persistence forecasting is most reliable at this time frame. Persistence means that the amount of wind in the last time period will be similar to the amount of wind in the next time period, i.e. the windfarm would continue to run at its current output.

Since the early 2000s various attempts have been made to improve forecasting. To date none have proven to be more reliable than persistence forecasting over the 2 hour period, i.e. current wind generation provides a good estimate of wind generation in the immediate future. New Zealand is possibly unusual compared to other economies in accuracy of forecasting. New Zealand's weather is very dynamic and there are no offshore weather stations with which to verify computer-generated forecasts[37]. In practice this means that the timing of weather events cannot be forecast to the level of accuracy needed for a 2 hour gate closure. Hence the agreement that persistence forecasting is the best approach.

The market arrangements for wind generation have largely proved satisfactory and remain in place in 2016, although the electricity regulator has indicated that it will review these. In addition some in the wind industry wish to see a reduced gate closure and the ability for wind to bid into the market rather than receiving the settlement price.

The tactical wind project

In 2004 150MW of wind had been built in the same area from a grid management perspective. Generation data were collected from these windfarms using meters installed on the windfarms. The metering results caused the SO some concerns:

- Ramp rates for 150MW of windfarms exceeded the frequency keeping generation ramping in the North Island, which was 10MW/minute[38].
- Variations in output from the 150MW of windfarms was greater than 50MW/5 minutes, which is the limit for frequency keeping plant under the market rules.

The study identified roughly 1 event per month that exceeded the market rules for changing output - 10MW/minute and 50MW/5 minutes. Some of these events pushed frequency in the North Island outside the normal frequency band of 49.8Hz to 50.2. In addition the tactical study also identified that transmission lines could be overloaded before the System Operator

[37] Presentation by Andy Zeigler NZ MetService to an NZWEA "Wind and Forecasting workshop" 2014.
[38] SO (2005) Manawatu wind generation Observed impacts on the scheduling and dispatch processes

could re-dispatch generation. There was no requirement for windfarms to control their ramp rates which is generally possible when windfarm output increases. It is more difficult to achieve when the output decreases in a falling wind.

The tactical wind integration study resulted in:

- Recognition that there were some potentially significant issues associated with wind generation which needed to be investigated, clarified and impacts quantified.
- A solid justification for a much larger study – the Wind Grid Integration Project (WGIP).
- Greater clarity as to the scope for WGIP and the kinds of issues that needed investigation.
- Recognition that while wind generation introduces new challenges, these challenges are manageable, i.e. the study gave the SO a level of comfort in relation to wind farms.

Wind and system security – the wind grid integration project

In the mid 2000s it seemed plausible that some 2GW of wind could be constructed, which is significant in a 10GW system[39]. The electricity industry in New Zealand had little understanding of exactly how wind generation would be integrated into the grid. The kinds of questions that were be asked across the electricity industry were:

- Would there be long periods when there would be no wind generation in New Zealand?
- Would the wind blow everywhere in NZ at once?
- Could all the wind farms start up and once and create huge ramps?
- What was the correlation between wind generation and hydro inflows?

There were two main drivers for the study:

- The variable nature of wind. The System Operator was comfortable with dispatchable generation, but considered that wind was not dispatchable and could arrive at any time in relatively unknown quantities.

[39] Some results have been published in international journals:

- Integration of large scale wind generation in the New Zealand power system and electricity market, Ancell, G.B. ; Transpower New Zealand Ltd., Wellington ; Clarke, J.W. . http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4596442
- Where the wind blows, Power and Energy Magazine, IEEE (Volume:7 , Issue: 6), http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5233739
- Effect of wind generation on small-signal stability — A New Zealand Example, Vowles, D.J. ; Sch. of Electr. & Electron. Eng., Univ. of Adelaide, Adelaide, SA ; Samarasinghe, C. ; Gibbard, M.J. ; Ancell, G. , http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=4596444
- Effects of large scale wind generation on transient stability of the New Zealand power system, Samarasinghe, C. ; Transpower New Zealand Ltd., Wellington ; Ancell, G., http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=4596110

- The nature of the generation equipment in a wind turbine. Most modern wind turbines use inverter technology and have an AC-DC-AC configuration. This arrangement has a number of implications for the grid system, both positive and negative. A positive is that a wind turbine can provide reactive power and can act as a static compensator. A negative is that a wind turbine can reduce inertia on the system.

The objectives of the WGIP were to:

- identify and quantify the technical and market impacts of increased wind generation on the New Zealand power system over the next ten years;
- recommend any amendments to the Electricity Governance Rules (EGRs) and other relevant processes required, to ensure future power system security and market outcomes are consistent with the Government Policy Statement on Electricity Governance (GPS) and the Electricity Commission's Principal Objectives and Outcomes;
- recommend an implementation plan for proposed changes (to the extent that this is required).

The issues that the WGIP focused on were[40]:

- Impacts arising from large sudden changes in wind generation output.
- Impacts arising from the variability and unpredictability of wind generation output.
- Asset capability of wind generation turbines and related equipment, e.g. can wind generators help support the grid, for example, assist with frequency and voltage stability?
- Rule drafting – issues needing specific consideration and specific recognition of intermittent generation in the rules.

WGIP which used the following approach:

- Scenarios for wind development, i.e. how much wind generation might be developed in what locations around New Zealand.
- Implications of the scenarios in terms of operating the electricity system.
- Options for ensuring the electricity system could operate effectively.
- Preferred options.

An important context for the WGIP is that New Zealand has an electrically weak grid system. The frequency variation in the New Zealand system is much larger than overseas and that advanced protection systems are needed to ensure against a cascading failure that could have catastrophic consequences leading to a blackout. System security is paramount in the New Zealand, as it is in all electricity systems. But an electrically weak system has a number of nuances that are significantly different to strongly meshed systems.

[40] https://www.systemoperator.co.nz/sites/default/files/bulk-upload/documents/wind-gen-project-so-rationale.pdf SO (2005); Tactical Wind Generation Project - Rationale for proposed rule changes to accommodate the connection of further wind generation until the Wind Generation Investigation Project is complete.

The System Operator worked with the electricity regulator to identify the issues and work through them. An independent chair for the process was appointed. Representatives from key stakeholders, including the New Zealand Wind Energy Association (NZWEA) were appointed as a group to overview the process. The System Operator and Electricity Commission[41] jointly funded the work. A brainstorming approach was used to identify the key issues to focus on. NZWEA played the important role of obtaining accurate information from members on the technical aspects of wind turbines including their generation characteristics[42].

The issues were grouped into three main categories with a number of sub-projects in each of these, as set out in the table below.

WGIP used two main sources of data:

- Actual operating data from New Zealand's windfarms, such as generation output on a 10 minute basis. At the time of the study New Zealand had around 200MW of wind farms with the turbines in two main locations some 1000km apart.
- Synthetic data for wind farm output derived from wind monitoring data.

In addition, information was sought from turbine manufacturers on the technical aspects of wind turbines. NZWEA played a key role in working with the manufacturers.

An important aspect of the study was communication with the industry. All reports were made publicly available. The results of the studies were outlined in NZWEA's newsletters to its members. The issue of wind integration was discussed at the annual NZ wind energy conferences.

The WGIP agreed on four scenarios for wind farm development in New Zealand. These covered both the total amount of wind generation installed and also potential locations of windfarms. Location is important because of the differences in wind regimes and the level of correlation between windfarms, which was one of the issues the WGIP focused on.

The WGIP took into account specific characteristics of the New Zealand electricity system. For example, a particularly issue confronting the wind industry in New Zealand is that wind farms were being developed near to the terminal of the HVDC link. At times the link can carry 1000MW and the North Island load could be less than 3GW. When the HVDC "trips" voltage and frequency can vary significantly in the lower North Island – exactly the area where a substantial windfarm was being planned. The System Operator wanted wind generators to stay connected during grid disturbances and contribute to grid stability rather than contributing to grid unreliability.

Areas of concern	**Specific studies to address the concerns**
Pre-dispatch	• Effect of unpredictability of wind generation output on pre-

[41] The Electricity Commission (now Electricity Authority) was the electricity system regulator.
[42] Graham Ancell pers comm. Graham led the Wind Grid Integration Project when working for the System Operator.

processes	dispatch processes.
Dispatch process	• Effect of variability on wind generation output on dispatch processes. • Effect of variability of wind generation output on asset loading.
Power system security	• Impact of wind generation on steady state voltage. • Effect of wind generation capability on management of frequency excursions. • Effect of wind generation on voltage stability. • Effect of wind generation capability on power system transient stability. • Effect of wind generation capability on oscilliatory stability. • Effect of wind generation on dynamic voltage stability.

Table: Areas of concern covered in the Wind Integration Project.

An example of the process the WGIP to explore issues is set out in the Figure 13 below. In this example, variability was the focus of the investigation:

- Actual data from a wind farm was used to assess variability.
- Variability across all windfarms was explored using the four scenarios for wind farm development.

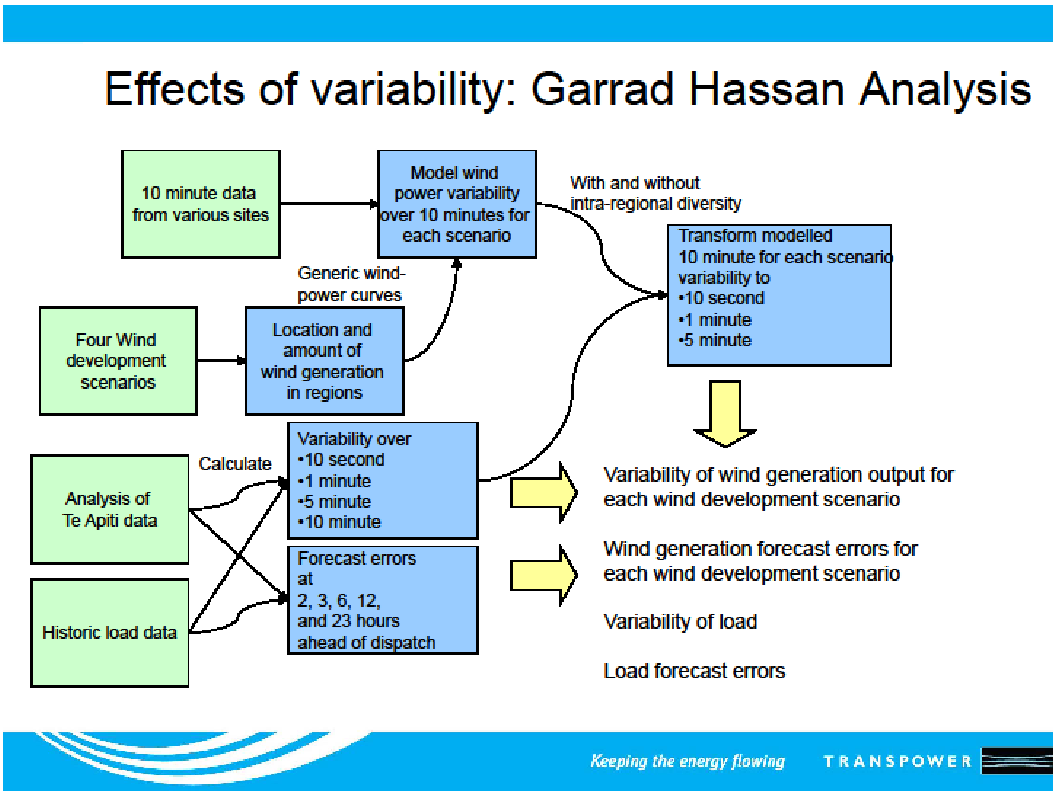


Figure 13: Model of the effects of variability in generation on the power system and the modelling needed to understand the impact of that variability for safe electricity system operation[43].

Results from WGIP

WGIP greatly assisted in developing a good knowledge base about how wind could operate in the New Zealand electricity system. The main outcome from WGIP was a much greater confidence as to what the issues were with wind integration and how to address them. WGIP also built understanding and confidence in the performance of wind turbines on the grid.

In particular staff in the System Operator came to understand what services wind turbines could offer and how they could offer these. The knowledge gained about the behaviour of wind turbines led to some very innovative power system designs in New Zealand, particularly at the distribution level. These are outlined in a case study below. At this time wind turbine manufacturers were continually enhancing the electrical capability of wind turbines to meet grid codes. Some of the enhancements addressed issues raised in the WGIP.

In addition to increased understanding and confidence the wind grid integration project resulted in:

- Confirmation of the interim rules for wind generation in the electricity market.
- Rules for wind turbines in terms of fault ride through, frequency support requirements etc.

[43] Presentation to a meeting of the Wind Grid Integration Project Team Meeting in 2005.

Using information and experience developed through WGIP in 2007 the SO published an updated document covering the connection and dispatch of new generation. The new document has a chapter specifically on wind generation[44]. Issues the document focuses on includes:

- Voltage control relating to connection to weaker parts of the grid.
- Connection issues, particularly where there are line limits and line protection systems, such as run back schemes, might be needed.
- Fault ride through requirements – down to 47Hz in the South Island and 47.5Hz in the North Island.
- Wind farm modelling requirements on the basis that each wind farm is different as is each brand of wind turbine.
- Power quality studies to ensure that wind farms do not negatively impact on power in the area.
- Commissioning studies. These are developed in relation to the specific characteristics of the wind farm.

The key point is that WGIP assisted the System Operator to identify the kinds of issues to explore. A clear theme has emerged of impacts on an electrically weak system – the WGIP identified that wind farms will tend to be built in the more remote and therefore electrically weaker parts of the power system, i.e. the weakest parts of an electrically weak grid system. New Zealand has developed considerable expertise in designing windfarms to functions effectively in electrically weak situations.

Case study: Inertia

A primary concern associated with an increasing proportion of wind generation is a loss of "inertia". In New Zealand's electrically weak power system the System Operator relies on the inertia of generators to ride through voltage and frequency variations. With the AC-DC-AC configuration and sophisticated electronics wind turbines would disconnect from the grid during a grid event. This disconnection aspect concerned the System Operator because it could lead to a cascading failure and blackout. Part of the issue was that wind turbines were developed for strongly meshed grid systems where voltage and frequency vary by a comparatively small amount. In New Zealand generators are expected to stay connected over a frequency of 47-52Hz, well outside the range wind turbines were set to operate in other grid systems. Turbine manufacturers and owners responded by exploring "virtual inertia" – using the software in the wind turbine to create what would look like "inertia" to the grid[45].

[44] https://www.transpower.co.nz/sites/default/files/publications/resources/connecting-dispatching-new-generation-nz.pdf

[45] Pellieter M; 2012; Inertia in the New Zealand Power System and its effect on the System; Presentation to the NZ Wind Energy Association Conference, Transpower NZ.

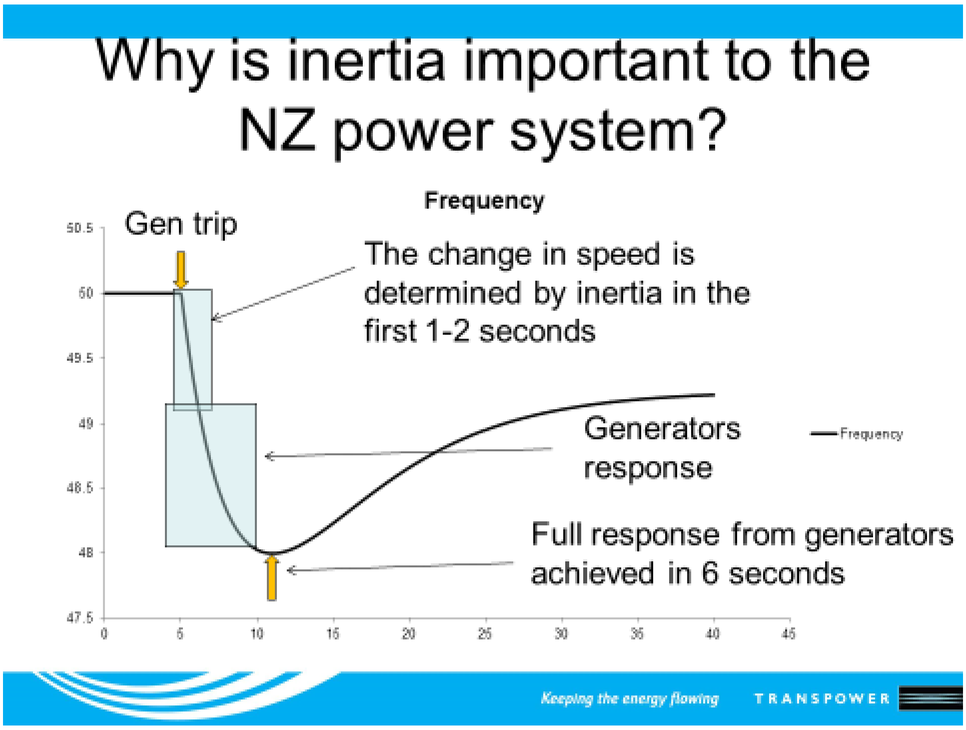


Figure 14: Inertia is important for ensuring the power system stays stable during a grid event. Inertia is critical for providing grid support in the first few seconds after a grid event.

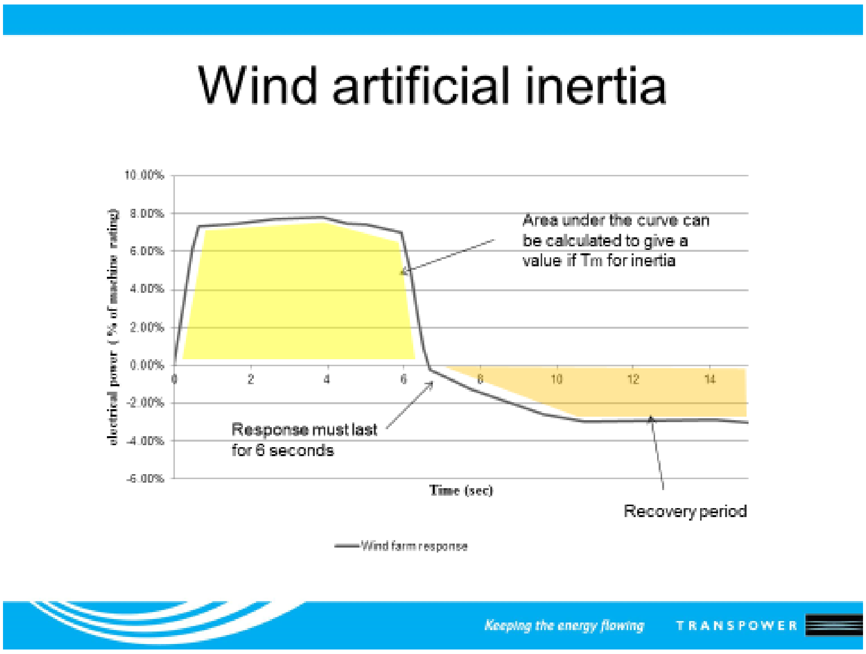


Figure 15: The amount of inertia a wind turbine needs to supply to play a role in supporting the New Zealand grid system during a grid event.

Case study: How correlated are the outputs from windfarms?

The WGIP explored just how variable wind would be. The System Operator gained some important "comfort" around wind. For example, through the WGIP it became clear that high rates of wind ramping were statistically unlikely to occur simultaneously across much of New Zealand. Understanding of how weather systems moved across New Zealand confirmed the statistics. As wind became established in more locations across New Zealand the kinds of issues seen at the grid level from the first few wind farms would not be amplified and if anything reduced.

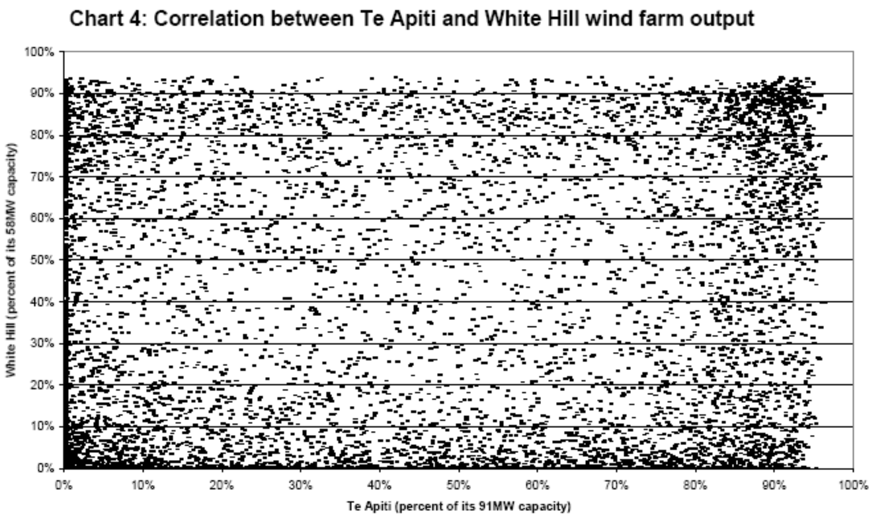


Figure 16: Correlation between two windfarms 1000km apart in New Zealand. Te Apiti in the lower North Island and White Hill in the lower South Island. Data is for half hour intervals.

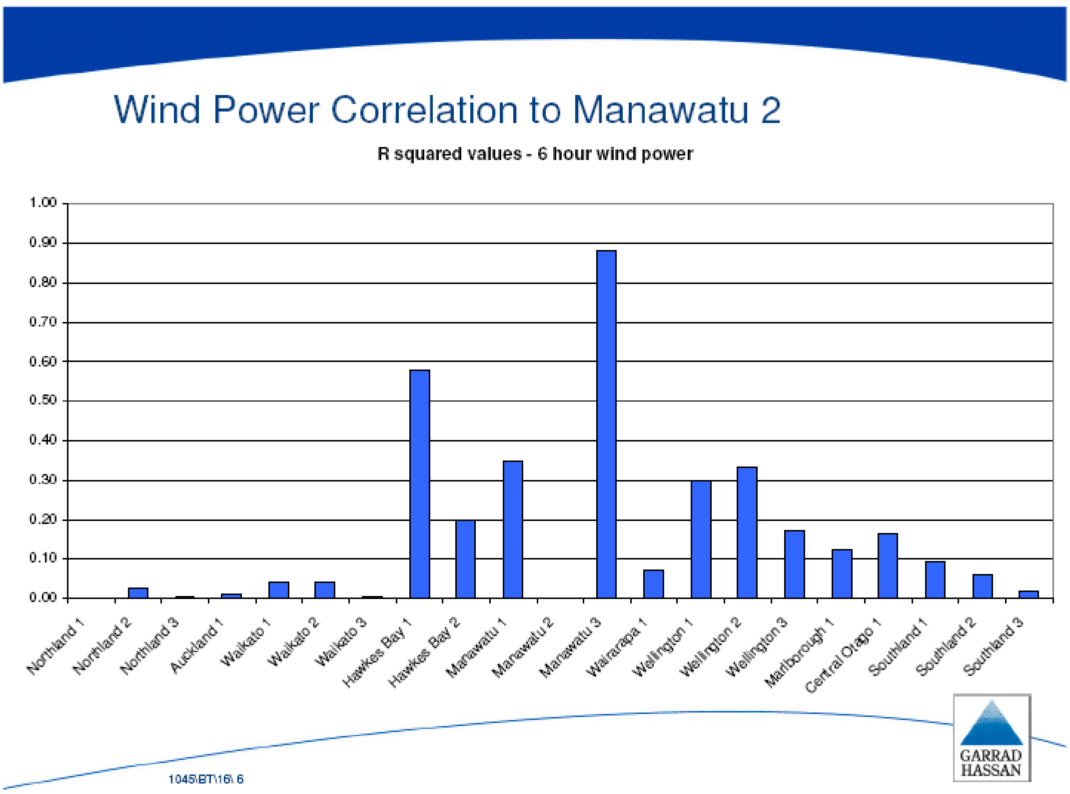


Figure 17: Correlation between a theoretical windfarm in the Manawtu (lower North Island in New Zealand) and other windfarm sites around New Zealand. The correlations were developed using wind data rather than actual output from windfarms.

The predicted results of the study have been shown to be largely correct as more windfarms were developed. For example, the two graphs below show the results of more windfarms added to the grid. The first graph of the West Wind windfarm shows a significant variation in output (10 minute data) – the output from the windfarm can vary from maximum to zero to close to maximum over a 24 hour period. But when a number of other windfarms are added in (second graph) the variations in one wind farm tend to be balanced out be the variation in the others.

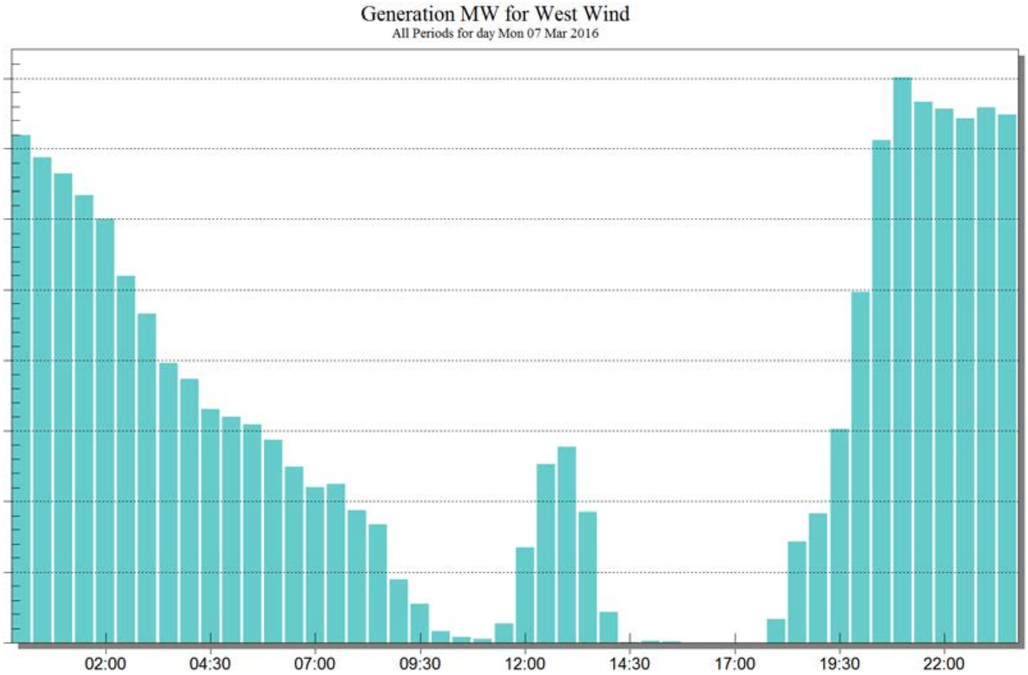


Figure 18: Electricity output from West Wind (142 MW), on a day with extreme variability.

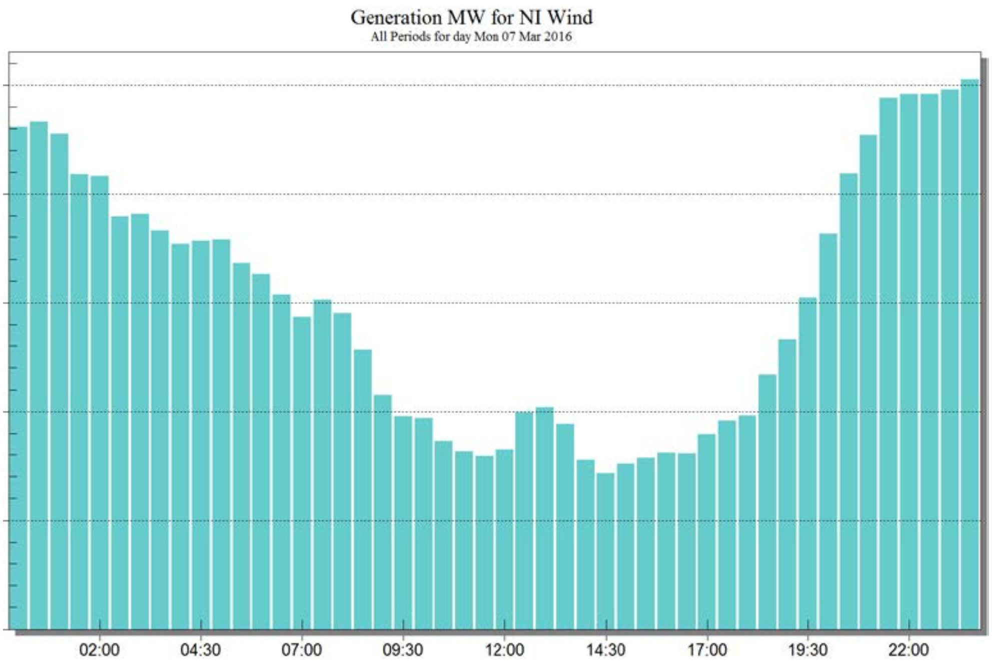


Figure 19: Electricity Generation from 3 North Island windfarms[46] showing the smoothing effect of multiple windfarms compared to a single windfarm(Figure 18). These three windfarms are spread across 350km.

[46] Presentation to the NZ Wind Energy Conference, 2016, Mike Roan, Meridian Energy.

The WGIP also enabled some of the issues associated with wind, such as ramp rates were able to be understood from a whole of electricity system perspective. In practice ramp rates for wind are little different to ramp rates in electricity demand, something the SO is very used to dealing with. When framed in this way wind was not seen as “scary” and while creating challenges wind could be integrated into the electricity system.

Wind spread geographically can lead to wind becoming, in effect, baseload generation, with wind generation. A single windfarm does have variability (Figure 18). Many windfarms spread across New Zealand results in a much steadier amount of electricity generated (Figure 19). Hydro can “fill” the gaps in wind generation and help ensure that electricity demand is met (Figure 20). In effect geographically distributed wind can be considered “baseload” generation and a good annual energy source, while controllable generation can provide power as and when required.

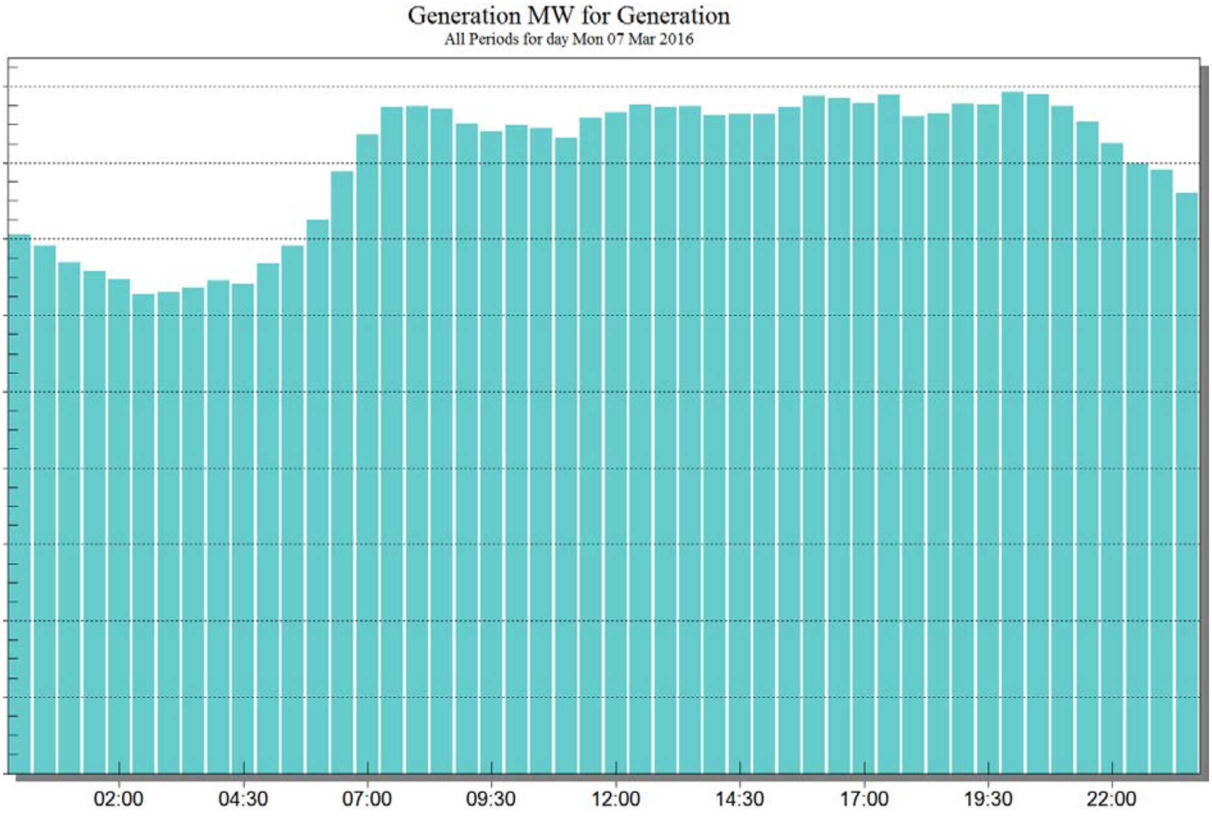


Figure 20: Wind combined with hydro generation provides an excellent electricity supply in terms of meeting the demand profile.

WGIP – outcomes and next steps

An interesting aspect following the study is that no significant changes have been made to the electricity system rules, despite wind growing from 170MW to 700MW and contributing up to 40% of generation in the North Island grid system at times. Some proposals are being worked on, such as requiring wind turbines to have fault ride through characteristics that vary in different parts of the economy, but this has not been seen as an urgent priority. The lack of changes confirms that one of the most important aspects of the study was building understanding and confidence.

Understanding the opportunities associated with wind generation is particularly important. Windfarms can be designed in such a way that they can actually improve grid characteristics, such as voltage stability (see case study on Te Uku windfarm next chapter). Discussions on innovative designs were made easier via the relationships and knowledge built up through the WGIP.

In a nutshell, the industry learnings and relationships, which are difficult to quantity, are probably the most important aspects of the WGIP.

Fault ride through

As wind generation in New Zealand has grown the System Operator has become increasingly concerned about the ability of wind generators to ride through faults in the electricity system. Wind turbines have generally been designed for large strongly meshed grid systems. The fault ride through characteristics of wind turbines generally do not meet the expectations of the New Zealand regulator (Electricity Authority) and the System Operator.

The Electricity Authority and the System Operator are working on new rules for fault ride through[47]. The proposed rules vary regionally because the requirements to stay grid connected vary around the economy. For example, close to the HVDC connection variations in voltages and frequency are larger than elsewhere and it is important that generators stay connected during an HVDC-caused disturbance, otherwise a cascading failure may result. The proposed rules for fault-ride through are still being developed.

Wind bidding into the electricity market.

With a two hour gate closure wind cannot bid into the electricity market with certainty. The difference between forecast generation and actual generation is too high. In 2015 the Electricity Authority agreed that gate closure would be reduced to 1 hour – the wind industry would prefer half an hour (Figure 21). In 2016 the EA plans to explore how wind can offer into the electricity market[48]. The "interim" rules that have been in place since the early 2000s[49]. The work is not complete but one option being considered is treating wind like any other form of generation, i.e. wind being able to offer at a price the generator decides with the possibility of wind not being dispatched if the price is too high.

[47] https://www.ea.govt.nz/development/work-programme/wholesale/fault-ride-through-project/

[48] https://www.ea.govt.nz/development/work-programme/wholesale/bid-and-offer-provisions-of-the-code/consultations/

[49] Wind offering at $0.01/MWh and being paid the clearance price.

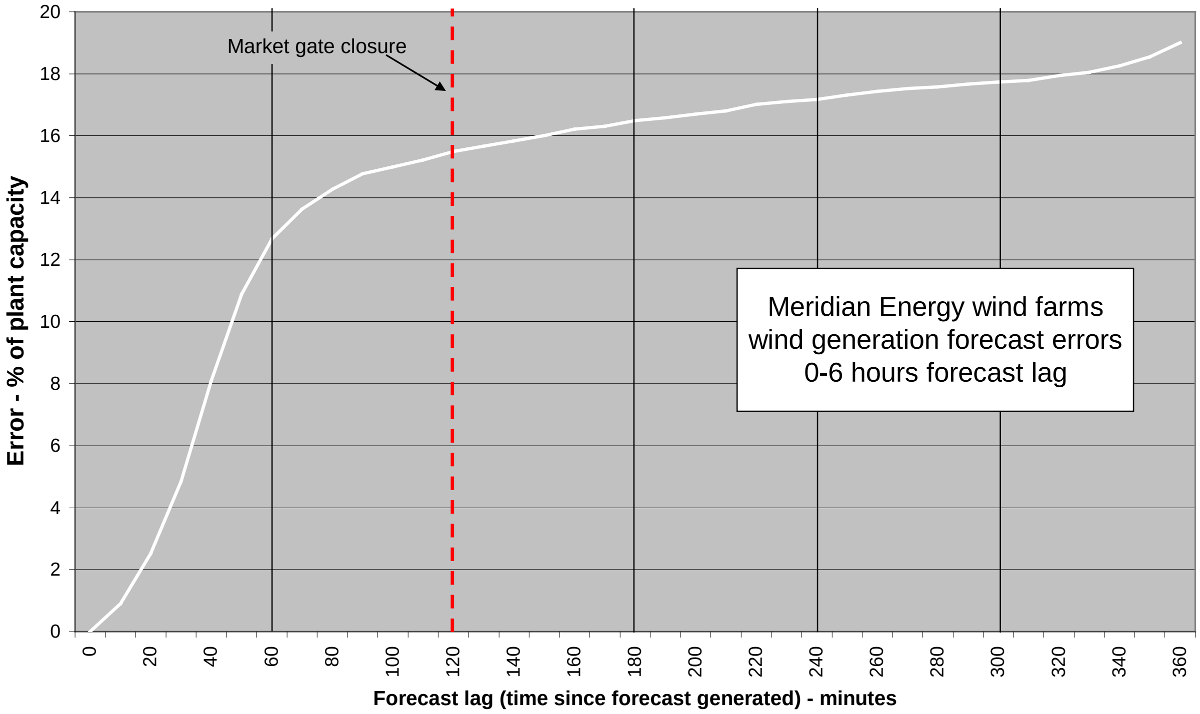


Figure 21: Accuracy of wind farm generation prediction versus the time of the forecast. A half hour market gate closure would result in comparatively high accuracy predictions for windfarm output.

Recommendations – Market and grid integration

To help build understanding of the characteristics of wind generation establish a wind-grid integration project that:

- Develops a range of scenarios for wind generation.
- Explores issues associated with wind generation, such as correlation between windfarms in different parts of the grid, ramping etc.
- Identifies how windfarms can be designed and operated to contribute to grid and distribution network stability.
- Involves all stakeholders in a collaborative and open process so that all the stakeholders learn together and have the same understanding.
- Proposes amendments to rules governing electricity system operation.

Performance of windfarms

How have windfarms in NZ performed? Data from Vestas shows that in early 2015 V90s at the Tararua 3 windfarm had produced more kWh than any other wind turbine in the world. For the Vestas V90 global fleet, New Zealand wind turbines rank; 1st, 2nd, 4th, 6th and 9th in terms of the amount of electricity produced. Clearly windfarms in New Zealand are among the most productive in the world[50].

Wind turbines have performed well in New Zealand's turbulent and high wind speed sites:

[50] Presentation by Vestas to the New Zealand Wind Energy Conference 2015.

- The Brooklyn Wind Turbine, a 225kW turbine, was replaced in April 2016 after some 23 years of operation.
- The Hau Nui Windfarm celebrates its 20^{th} birthday in 2016. This site is regarded as very turbulent by international standards.
- Vestas reports that turbines at New Zealand windfarms achieve a lost production factor (based on MWh) of less than 1.8% for modern turbines (V80, V90).

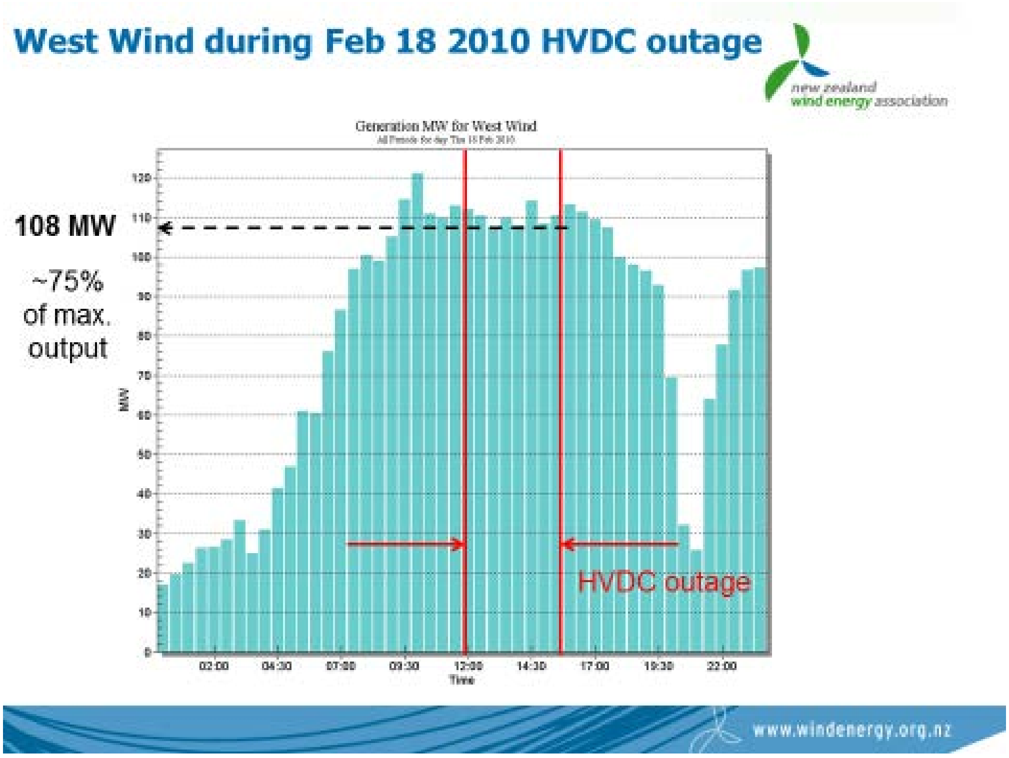
In addition, windfarms provide grid services and in some instances have helped keep the lights on.

Case study: Wind keeps the lights on in New Zealand's capital city

On 18 February 2010 in the middle of the day the HVDC link tripped. This trip had the potential to cut power to Wellington, New Zealand's capital city, during a busy week day. At the time of the trip the West Wind windfarm (142MW) had a high level of production (Figure 22) as did windfarms some 200km north of Wellington. Together these windfarms supplied sufficient power to "keep the lights on" in New Zealand's capital city.

This was not the first time that wind generation has helped "keep the lights on". On 22^{nd} September 2009 a fault reduced power flows through the HVDC link. The West Wind Windfarm was producing some 100MW which helped keep the lights on in Wellington. Electricity demand in Wellington was 250-390MW and the reduced HVDC could provide 130MW. Without West Wind Wellington would have faced a shortage of electricity resulting in a potential black out.

While wind generation can't always be guaranteed to be available when needed, wind farms generate for around 95% of the time. So the chances that a windfarm will be generating some power to help with an outage is very high.



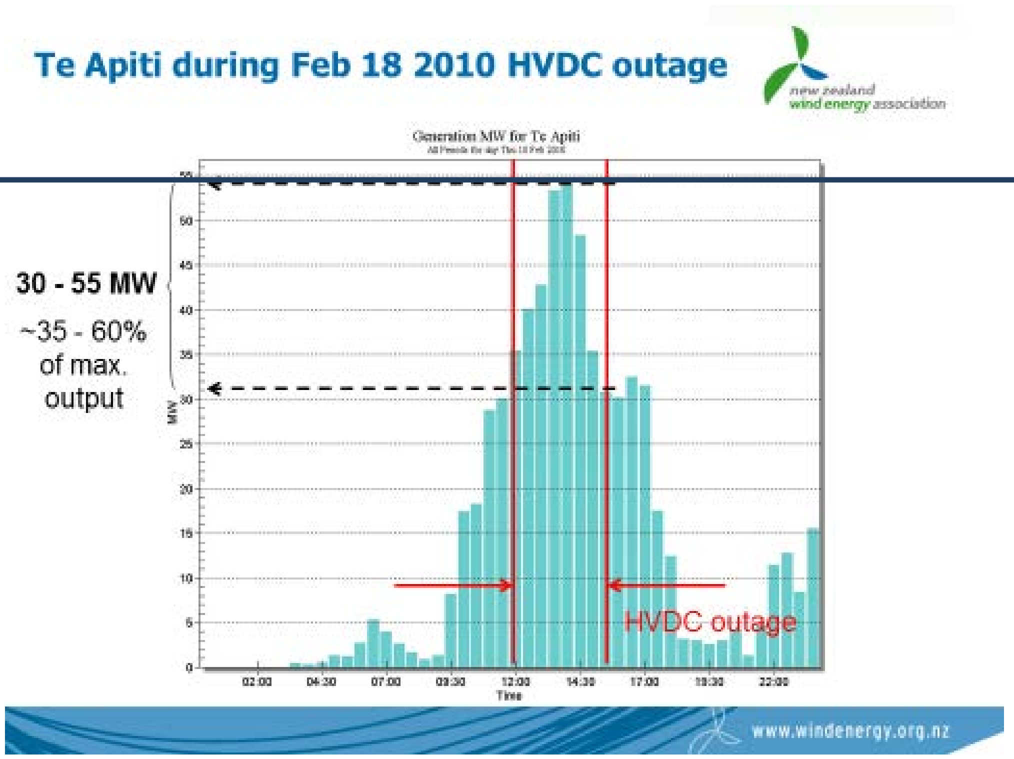


Figure 22: The output of West Wind and Te Apiti Windfarms (10 km and 200km from Wellington) when the HVDC link tripped.[51] Together West Wind and Te Apiti helped keep the lights on in Wellington, New Zealand's capital city.

[51] Presentation to the NZ Wind Energy Conference, 2011, Fraser Clark CEO, NZ Wind Energy Association.

Case study: Wind farms strengthening the grid at the distribution level

A number of wind farms in New Zealand have been embedded in local distribution grids, usually at the 33kV level. Embedded generation has its own challenges but installing wind farms can provide a range of opportunities.

The Te Uku windfarm (64MW, commissioned in 2011) is embedded in a local distribution grid. The windfarm can supply over 100% of the distribution grid's electricity needs and at times exports through the grid exit point to the Domestic Grid (220kV).

Te Uku is connected to two distribution substations, one close by, the other some 25km away, by a 33kV line that was doubled in capacity to handle the load. This doubling had the benefit of added system security for the local network which served a town of some 3000 people. Strengthening the local network was promoted to the community as a benefit of the windfarm – the windfarm is clearly visible from the town.

A network protection system, including a runback system, with reliable communications was installed to ensure that in the event of a failure the windfarm would not damage the system. For example, if one of the 33kV lines fails the windfarm reduces production automatically.

The windfarm was designed to also help address a domestic grid issue. The 220kV line that provided the grid exit point for the local network suffered voltage stability issues under certain circumstances. The inverters in the windfarm provide voltage support via the 25km 33kV line through the grid exit point and to the domestic 220kV line. The windfarm continues to provide this service even when there is no wind and the turbines are not generating.

In a second example, a windfarm (58MW) was designed to substantially improve voltage stability in the local distribution network. The result was that voltages in the nearby town (population 2000), some 60 km away, stabilized and remained within normal ranges, which had not been the case for decades.

Recommendations – strengthening the grid and distribution systems

Design windfarms to take advantage of the power electronics in wind turbines and provide services to both the grid and distribution networks. The power electronics in wind turbines can be programmed to help provide grid services such as inertia but these features need to be considered at the early design stages of a wind project.

Operations and maintenance – creating local jobs

As the number of wind turbines in New Zealand grew so too did operations and maintenance activities. NZWEA commissioned a survey in 2012 to determine the number of people involved in the wind industry[52]. The data were collected via interviews of companies that were involved in the wind industry.

[52] BERL (2012); Economic Benefits of windfarms in New Zealand. Report prepared for the NZ Wind Energy Association.

It was estimated that there are 0.17 jobs created for each MW of installed capacity. For 700 MW that equates to approximately 100 jobs. Many of these jobs are in remote locations of the economy where there are few well-paying jobs for technically trained people. Windfarms therefore create employment opportunities in rural areas.

New Zealand has found that wind technicians sit "between" mechanics and electricians in terms of their skill sets. Wind technicians' work is so specialised their training does meet traditional training course requirements for either mechanics or electricians. Although highly skilled it is possible that wind technicians may not be able to claim a recognised qualification.

In recent years there have been moves to provide more formal training for wind technicians. The training aims to combine electrical and mechanical skills into a wind or more broadly energy-specific training qualification.

An important part of highly skilled staff is health and safety training. New Zealand companies are part of the Global Wind Organisation training programme. New Zealand has a GWO-accredited training provider who provides training and refresher courses.

Case study: Ashurst Engineering

A small, specialist engineering firm near the Te Apiti and Tararua windfarms became involved with the wind industry via a $25 job for the Te Apiti windfarm[53]. According to the owner of the company that one job led to further work and over the years the business has grown and grown. Windfarm work now represents at least 20% of the company's turnover, supporting up to eight families.

Ashhurst Engineering's work in and around wind farms has taken them all over the world. They have built specialist equipment for use at wind farms and create innovative solutions to new challenges. The company finds that it is important to be on-site because to see what the real problems are and generate practical ideas to fix them. Some of Ashhurst Engineering's solutions have been applied overseas, such as the US, providing opportunities for staff to travel to implement the engineering solutions.

Staff are highly motivated to work on wind turbines – they enjoy the working with state of the art technology. The company ensures its staff are trained to operate in the turbine, for example, staff receive health and safety training and ensure that their training is kept up to date.

The engineering company is now one of the largest employers in Ashurst.

Recommendations: Operations and maintenance

- Encourage and support local businesses to provide operations and maintenance solutions.

53 http://www.windenergy.org.nz/store/doc/Wind_Energy_Case_Study_You_Never_Know_Where_Wind_Will_Take_You.pdf

- Develop a formal training programme involving local trainers.
- Establish an industry-wide health and safety programme and link this with the Global Wind Organisation.

Natural resource management and consenting (environmental planning)

The main natural resource management issues for wind farm development issues in New Zealand are:

- Noise: New Zealand has developed a robust science-based framework for managing noise issues.
- Birds: Some effective approaches have been developed for designing windfarms to ensure they have minimum impacts on birds.
- Landscape/visual: The potential impacts of windfarms on landscape values has been a fraught area in New Zealand and continues to be so.

The New Zealand experience is that a small section of society will always be strongly opposed to windfarms.

Noise issues

Noise from wind farms has been raised at a number of wind farm proposals in New Zealand. Noise issues were reported from Hau Nui, New Zealand's first multi-turbine windfarm. Corrective measures were put in place and the tonal noise ceased. However, in terms of public perception damage was done and noise became and remains an issue to this day.

One of the learnings from the Hau Nui experience was that New Zealand lacked a framework for assessing and managing sound from wind turbines. The Energy Efficiency and Conservation Authority promoted and funded the development of a domestic standard[54] for assessing and managing noise from windfarms that drew on best international practice[55].

A domestic standard is developed by an expert committee. The noise community in New Zealand is small and key members were invited to be on the committee. In this way "buy in" to the domestic standard was gained from the key members of the noise management community.

The noise standard was used in a number of consents. But increasingly it was seen to have limitations particularly in terms of the monitoring regime. Councils were setting more and more complicated monitoring conditions for each successive windfarm consent. In the late 2000s the standards committee on windfarm noise reconvened and revised the domestic

[54] A domestic standard is developed by the New Zealand standards organisation, which is affiliated to the international standards body.

[55] Fiona Weightman, former General Manager Renewable Energy at the Energy Efficiency and Conversation Authority.

standard to take account of learnings around monitoring. The revised standard was published in 2010[56].

The flash point for revising the first noise standard was the consent conditions set for the West Wind windfarm, approximately 20 minutes drive from the centre of Wellington, New Zealand's capital city. Residents living near to the windfarm were very concerned about noise. In response to these concerns the consenting authority set very specific and unusual noise conditions. The conditions were complicated and were difficult to monitor against.

Unfortunately the turbines at West Wind produced tonal noise. The problem was identified as a new model gearbox. The turbines produced two tones; one at low speed and one at high speed. A successful solution was developed involving both software and hardware.

During the development of the wind industry a number of lessons have been learned and shared at the wind energy conference and workshops. Key lessons include:

- Wind turbines can, unexpectedly, create noise.
- Systems need to be in place to enable communities to easily report noise issues.
- The owner of the windfarm needs to engage with the community and respond to complaints about wind farms.
- A system for assessing and managing windfarm noise needs to be developed that has wide buy-in from noise experts.

A difficulty with windfarm noise is that once a community becomes sensitive to wind farm noise the issue can escalate. In the West Wind example above noise complaints were received even when the entire windfarm was shut down (grid fault). In this example, it took many months and considerable effort responding to community concerns for the noise issue to be satisfactorily resolved (Figure 23).

[56] Chiles S; (2010); A new windfarm noise standard for New Zealand: NZS6808(2010); Proceedings of 20th International Congress on Acoustics, ICA 2010, Sydney, Australia. http://www.acoustics.asn.au/conference_proceedings/ICA2010/cdrom-ICA2010/papers/p33.pdf

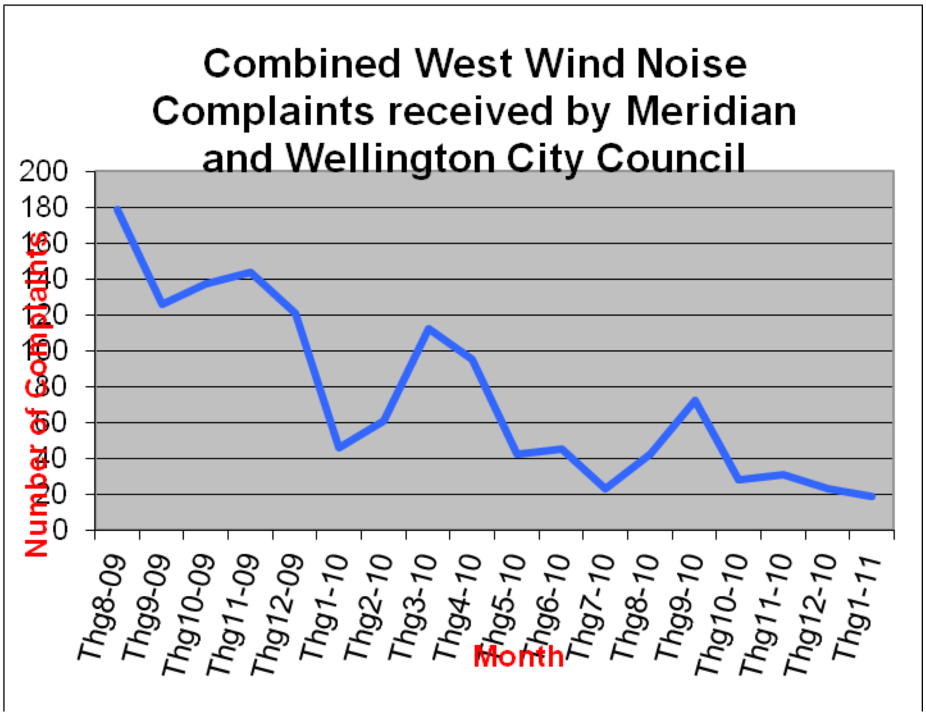


Figure 23: Noise complaints from the West Wind Windfarm[57].

Recommendations: Noise

- Develop a robust noise management framework that draws on best international practice but is adapted for local conditions.
- Ensure that local noise experts are engaged in the development of the noise management framework so that they understand it and can successfully apply it.
- Encourage developers to put in place effective procedures for managing and addressing noise complaints and noise issues.

Wildlife issues – birds a key issue

New Zealand is a global biodiversity hotspot particularly for its native birds. Many of New Zealand's bird species are threatened with extinction due to introduced predators such as cats and rats. New Zealand has a strong conservation movement and concerns have been raised about the impact of wind turbines in native birds[58], particularly given reports of bird deaths from wind turbines in other economies.

Impacts of birds have been raised at many windfarm consenting processes in New Zealand. At some sites there has been considerable investigation into potential bird impacts. Developers have made the call early in the investigation stage that bird impacts might be significant and have decided to not continue with some sites[59].

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[57] Presentation from Wellington City Council, NZWEA Conference, 2011, Wellington.

[58] New Zealand has limited bat populations and only 2 bat species, one of which is extremely rare. To date few bat issues have been raised, but this is more a function of the limited populations in New Zealand.

[59] This information is commercial and confidential and cannot be released in this report.

Issues around impacts of windfarm roads on waterbodies (runoff) and clearance of native vegetation have been raised as issues. But unquestionably a key issue is potential impacts on birds.

In the early days of the wind industry in New Zealand impacts on birds did not feature. The reasons largely was that the farms were built in areas of the economies where there are no significant native bird populations.

As windfarms were proposed in more areas of the economies the key bird issues that emerged were potential impacts on:

- Raptors, particularly the New Zealand falcon which listed as “endangered”.
- Birds that migrate within New Zealand and international migratory species.
- Local bird populations that could be impacted by wind turbines.

General principles

The first step in assessing possible bird impacts is to understand that patterns of bird behaviour. Many bird species tend to follow certain flight paths that can be identified and mapped. For example, at one potential windfarm site in New Zealand, shags took a defined route each day from their nesting site to the ocean and a windfarm built in the shag’s flightpath could have resulted in significant mortalities.

The second step is to make a broad assessment as to likely impacts. Some ecologists in New Zealand use a framework as follows:

- The windfarm has the potential to have significant impact on birds and there is little that can be done to avoid significant bird mortalities. It is likely another site would be investigated.
- The site may result in significant mortalities, but more work is needed to confirm either way.
- The site will work but turbines may have to be sited carefully or some areas avoided. In the shag example above a decision was made to avoid the corridor used by shags.
- There are unlikely to be any problems with birds.

Monitoring is very important to both identify issues and to assure the public that there are no issues.

Raptors

Raptors have been identified as a potential issue at some wind farms. The New Zealand falcon, listed as a vulnerable species, is found around some windfarms. To date monitoring shows no falcon mortality association with windfarms.

Hawks, a common New Zealand species, have been associated with some mortality at New Zealand windfarms. It seems that juvenile hawks enjoy playing on the lift and turbulence created by turbine blades. Unfortunately at times they collide with the blades. Monitoring of the hawk populations show no reduction in the overall population around the windfarms.

The point with both of these issues is to be able to demonstrate to the public, through effective monitoring, what the impacts on bird species actually are.

Migratory bird species

New Zealand has a number of bird species that each year migrate from the braided rivers of the South Island to the large estuaries in the north of the economy and back. Like most native bird species in New Zealand these species are declining in numbers and threatened with extinction due to predation.

In the mid 2000s some 600MW of wind farms were proposed in the area that the migratory birds were thought to fly. Conservationists raised concerns about the potential impact of the windfarms on the migratory birds.

Very little was known about the details of the flight path of the birds. A data collection programme was established to understand the bird's behaviour.

The first issue was where exactly did the birds fly, at what height, under what weather conditions etc? In order to gain planning permission the wind farm developers established a detailed bird monitoring programme. Radar was used to track the bird species and identify the height, direction, numbers etc of birds travelling through the area.

Some 40,000 birds were tracked using the radar[60]. This was an extensive exercise involving up to 85 people and the costs became significant in relation to project costs.

Overseas mortality estimates were used to assess the impacts on the New Zealand bird populations. Because the bird species are under threat in any case (due to predation), an offsetting programme was agreed. Under this innovative approach predators would be controlled where the birds breed.

Recommendations: Birds

- At the early stages of considering a windfarm development, determine whether bird issues are likely to be significant.
- If birds are likely to be a significant issue, determine the pattern of bird activities.
- Avoid placing turbines in bird corridors. While designing a windfarm around bird issues may slightly reduce the productivity of the windfarm, that is likely to be a better outcome than having to deal with ongoing public concern about bird impacts.
- Be prepared to abandon a potential project if bird issues could be significant.
- Design a monitoring programme, including statistical procedures, as part of the windfarm design.
- Ensure monitoring takes place to the appropriate standards and review results from the monitoring programme.

Landscape issues

New Zealand has stunning landscapes. Wind is the first large technology that can impact on the New Zealand landscape significantly. Planning laws were largely silent on windfarms,

[60] Presentation by Stephen Fuller to the NZ Wind Energy Conference 2011.

which did not mean that communities were prepared to accept windfarms in their landscapes. Planning documents simply failed to cater for windfarm development and provided little, if any guidance. Some windfarms in New Zealand faced protracted opposition in terms of landscape. One 500+MW windfarm failed to gain planning permission due to impacts on the landscape.

A key issue is what comprises landscape values? The Environment Court in New Zealand has found that the landscape[61]:

- Is a biophysical entity, encompassing the shape of the land and its vegetation.
- Is valued, used and modified by people; and
- It is also perceived and experienced by people.

Landscape architects in New Zealand use a framework of “zones of visual influence” for assessing visual impacts in relation to viewing distance:

- Less than 1 km the impacts of turbines can be significant.
- At 1-3 km turbines are prominent and the potential for effects is significant.
- At 3-6km while still prominent, the potential for visual effects is moderate.
- At 10km the turbines are not prominent and impacts are slight.
- At 20km the turbines are distinguishable but impacts negligible.
- At 25km the wind turbines are difficult to distinguish.

The process for assessing landscape used by many landscape architects is as follows:

- Preliminary assessment of the landscape character at and near the proposed windfarm.
- Identify the values associated with the landscape to help with shaping the windfarm proposal.
- Assess the sensitivities of the landscape to the proposed windfarm development.
- Input to the design of the windfarm, location of turbines etc.
- Prepare visual simulations for communication with the public.
- Engage with the community and review potential impacts on houses etc.
- Prepare a landscape impact report covering; a description of the windfarm site and landscape setting, analysis of landscape change, assessment of effects of the change.

Recommendations: Landscape

Landscape issues have proven to be very difficult in New Zealand and have been a key source of debate about windfarms:

- Develop clear guidelines for the landscape assessment process.
- The wind industry should work with the landscape community to help ensure that the landscape community understands and can effectively assess windfarm proposals.
- Visual simulations are important for understanding landscape impacts.

[61] Quoted in Bray S (2011); Review of best practice landscape assessment of wind farms. Unpublished report for NZ Wind Energy Association.

- Ultimately decisions have to be made – wind turbines are large structures that cannot be "hidden". Effective decision-making processes are needed to make judgements on landscape issues.

The New Zealand Wind Energy Association

NZWEA has proved to be an important part of helping the wind industry grow in New Zealand. It has helped with coordination and cooperation across companies that are competitive, such as turbine manufacturers. It has enabled the industry to present a united view on contentious issues. And it has provided an authoritative voice on behalf of the whole industry. Importantly the association has also helped build connections and relationships across the industry. In short the wind industry association has helped the industry to grow and develop.

At a wind meeting/conference held in 1992[62] attended by some 40 people a proposal to form a wind energy association was unanimously approved by attendees. But progress setting up the new association was slow and by 1996 the association had not been formally set up.

Government support proved to be critical to establishing NZWEA - the Energy Efficiency and Conservation Authority played a key role in helping establish NZWEA. This agency organised meetings, provided secretarial services, ran an annual conference etc. Over the industry stepped up and ran the organisation. The NZ Wind Energy Association was established in 1997. Its mission, objectives etc are set out in the box below.

1. The Association promotes the responsible, sustainable and significant uptake of New Zealand's abundant wind resource as a reliable, renewable, clean and commercially viable energy source. The Association considers that wind energy has a substantial role to play in New Zealand's power generation portfolio, and strives to ensure that New Zealand's world-class wind resource is harnessed in a responsible and sustainable manner.
2. The Association is a non-Governmental, non-profit organisation. Our activities are funded by our members and by industry events such as our annual conference.
3. The Association's Mission and Objectives are:

   Mission

   The mission of the Association is to promote the uptake of New Zealand's abundant wind resource as a reliable, sustainable, clean and commercially viable energy source.

   Objectives

   The objectives of the Association are to achieve its mission ... by means of:

   (a) policy advocacy with local and central government officials

[62] Sims EH; (1992); Wind farming in New Zealand – Potential and Prospects. Proceedings of a Seminar 11th December 1992, Massey University.

and elected representatives, regulatory bodies, industry groups and other interested organisations to raise the awareness of, and develop the concept of wind energy in New Zealand;

(b) *organising seminars, conferences and other promotional and educational events, and to distribute information, relating to wind energy in New Zealand;*

(c) *providing a forum for external and internal networking, discussion and co-operation amongst persons with an interest in wind energy in New Zealand;*

(d) *promoting the economic, environmental, social and other benefits of wind energy in New Zealand; and*

(e) *promoting research and development of wind energy technology in New Zealand.*

Evolution of the association

A critical stage in the evolution of the NZWEA was developing the constitution for the organisation. This was developed through full consultation with interested organisations. It sets out the purpose of the organisation, how it will operate etc. The constitution has remained largely unchanged to this day.

NZWEA has an elected board. It has three levels of membership:

- Corporate: Companies that have a very strong wind focus.
- Associate: Companies that have an interest in wind, but wind is not a core business.
- Individuals.

Initially academics and enthusiasts were the main members of the New Zealand wind industry. Over time more companies become involved. Currently the board of NZWEA comprises industry representatives.

As the association developed its role became well established and has changed little over the years. Categories of activities include:

- Communications – raising the profile of wind generation and communications around the "myths" of wind generation.
- Policy, such as energy, climate change and environmental policy. Included under this category is developing a standard for wind turbine noise.
- Electricity system issues, such as fault ride through for wind turbines. Under this category NZWEA participated in the Wind Grid Integration Project.
- Supporting the industry. This area includes running the annual conference and specific initiatives, such as the Health and Safety initiative.

Case Study: The annual wind energy conference

A key role of NZWEA is organising the annual conference. The conference is the "family gathering" where all the key players in the wind industry meet. An important role of the conference is to help participants in the industry meet, maintain and build relationships.

Building and operating a windfarm requires many companies and organisations to work together and the conference is an important place for people to meet and build relationships.

A significant conference was held in 1992. Generators, the domestic transmission system operator, academics industry representatives and government officials attended the conference. At that time there were no operating commercial wind turbines in New Zealand, although one turbine was planned to be installed in 1993. Experts from Denmark presented on the development of the wind industry there.

In 1996 the "inaugural" wind industry conference was held, which was organised by the Energy Efficiency and Conservation Authority. Some 90 people attended the conference. Topics covered included:

- Projects underway.
- Understanding the wind resource, including wind prediction, turbulence etc.
- Consenting.
- Electricity system issues.
- Operations and maintenance.
- Government policy.

In 1997 the second conference was held, again organised by the Energy Efficiency and Conservation Authority. This conference celebrated the work of one of New Zealand's leading wind generation researchers, Keith Dawber. Keith's work focused on the wind regime in New Zealand at the local scale, such as turbulence.

From 1998 onwards the wind industry conference has been an annual event organised by NZWEA. It provides a forum for debate discussion, sharing knowledge and building social capital.

The topic areas have changed little from the first conference. What has changed is the discussion of those topics. For example, while the grid continues to be a focus, the emphasis has changed from wind integration to new technologies, such as the role batteries can play.

The conference presentations provide very valuable information about the development of the industry and a record of the growth and development of the industry. Conference presentations are available on the NZWEA website.

Case study: Health and safety programme

In 2011 a wind farm employee who had worked in the United Kingdom suggested that NZWEA should establish a health and safety programme. The NZ Wind Industry considered that safety was a key issue and NZWEA established a H&S initiative. The initiative connects globally including with the Global Wind Organisation (GWO)[63], which is the umbrella organisation for health and safety in wind farms.

[63] For example, in 2013 the Chair of the GWO, Clause Rose, presented at the NZWEA annual conference.

The H&S programme runs a 4 all-day meetings a year. A key aim is to share learnings across the industry based on the principles that:

- "my accident is your accident" and
- There is no competitive advantage in health and safety.

Learnings are shared from incidents, construction of new wind farms, development of improved procedures etc. The programme takes the view that H&S is an integral part of work place productivity; a safe working environment and a productive working environment go hand in hand.

The quarterly meetings are attended by a mixture of wind turbine owners, manufacturers and contractors. The terms of reference for the H&S programme are set out in the box below.

Background – the need for a whole of industry approach

- Health and safety is an industry good
- The industry needs to work together on H&S for the good of the industry (while competing in the market)
- In the public's mind the industry is as good as the last incident
- The public sees an industry not individual companies, including contractors.

Aims

- To develop, maintain and update a common set of relevant guidelines for wind farm health and safety.
- To develop shared training resources/system and gain global recognition of these with the Australia; Europe; US etc, i.e. internationally consistent training systems that are relevant to the NZ situation (e.g. legal arrangements).
- To share best practice.
- To connect the wind industry H&S work with relevant H&S work in related industries, for example, the electricity industry.

Scope

The focus should be on operations and include public access. This initiative should cover suppliers and contractors, i.e. not just windfarm operators. It should cover:

- Operations
- Maintenance
- Construction
- Public visitation.

Measures of success

- Development of resources that are used by the industry and are updated as needed.
- A forum where views can be aired, information exchanged, learnings discussed etc.
- A skills training system that is actively used by industry players.
- Consistent reporting systems and sharing of data (using appropriate confidentiality systems).

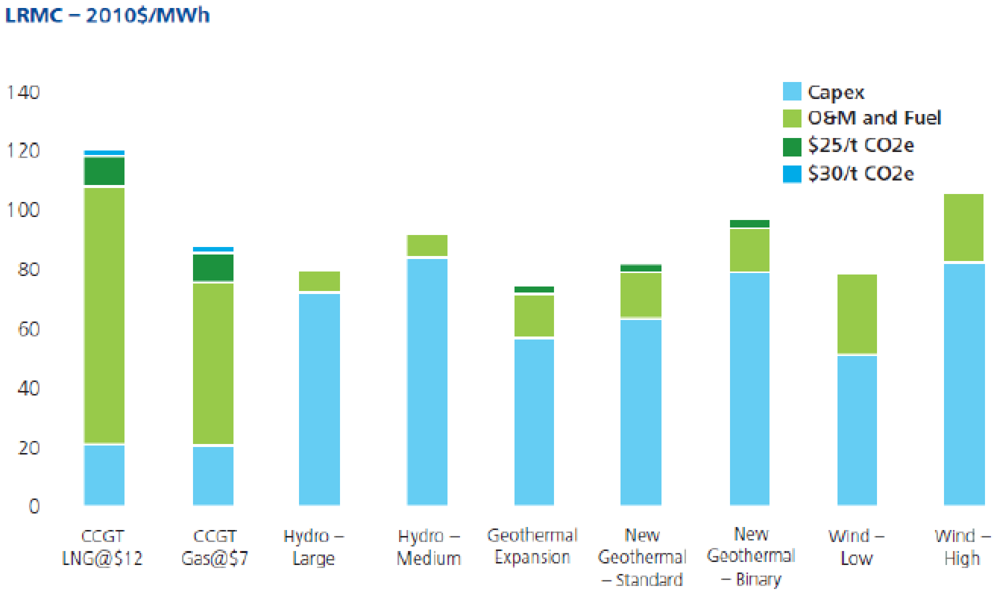
Case Study: A report on the cost of wind energy versus other forms of generation

In the late 2000s commentators, government officials and the media were quoting figures for wind which were significantly higher (>30%) than was actually the case. A general perception had been created that wind was expensive and could only be cost effective with subsidies.

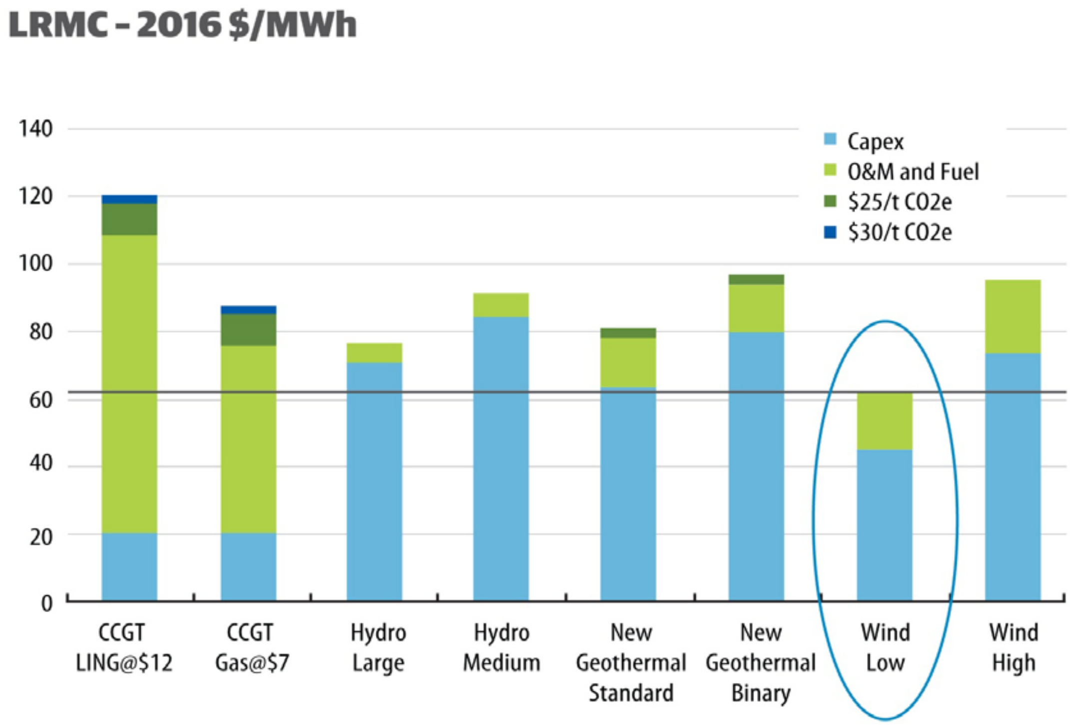
A problem in exposing the "true" numbers is that in New Zealand these are commercially sensitive. A further problem is that authoritative information was needed.

NZWEA contracted Deloitte to prepare that compared the costs of wind generation with other forms of generation. Members of the industry were interviewed by Deloitte and Deloitte were given access to confidential information on individual projects. Deloitte aggregated the data which meant the data on individual sites could not be identified, which got around the confidentiality problem.

NZWEA published the Deloitte Report and has used it extensively to communicate the true cost of wind generation. NZWEA went a step further and applied cost reduction curves to the figures Deloitte generated to get a cost estimate of wind generation in 2016. At a good site NZWEA estimated that costs for wind generation could be around NZ$65/MWh in 2016. A project that reached financial closure in 2014 had a cost of just over NZ$70/MWh so, NZWEA's estimates of 2016 costs, whilst optimistic may be close to reality.



Source: Meridian Energy, Deloitte analysis



Recommendations

A wind energy association is a very important part of developing the wind industry. It is recommended that:

- Governments support the establishment of a wind energy association - government support was critical to the New Zealand association becoming established.
- Over time government should encourage industry to run the organisation.
- The association should have a clear constitution, elected board and as funds become available employ staff.
- The association organises an annual conference and meetings/workshops on specific topics.
- The association develops a work programme involving:
    - Public awareness.
    - Coordinating whole of industry responses to issues such as noise.
    - Support consenting (permitting) efforts.
    - Engage in discussions with government on policy and government initiatives that impact the whole industry.
    - Health and safety in the wind industry.
    - Providing and actively communicating accurate information on the wind industry.

Research

Researchers led the early stage of the development of the wind industry in New Zealand. The research was funded by the Government which was keen to see New Zealand's sources of energy diversified following the oil price shocks of the 1970s. Two or three researchers were absolutely critical to the development of the wind industry. They systematically collected data, made international connections and promoted New Zealand's wind generation potential to students.

Once the wind industry started to build farms connections with researchers dropped off. Current links between the research and wind sectors in the wind area are not strong in New Zealand. In comparison there are comparatively strong connections in the geothermal area between the research community and the electricity industry. It is not clear why there are comparatively poor links between the wind industry and research communities. Possible reasons include:

- Key researchers passed away and no researchers filled their place.
- The government substantially reduced funding for energy research in the 1980s as oil prices stabilised.
- New Zealand relied on imported technology. Some in the industry suggest that there is little need for New Zealand research given the wind regime is now well understood.
- Wind data for a site are commercially sensitive and a private good.
- Generally poor connections between the research and industry sector in New Zealand compared with many other jurisdictions.
- Generic knowledge that can be applied to the New Zealand situation, i.e. a limited number of issues that require New Zealand research.

Summary and conclusion

Supporting the following areas will assist with the development of the wind industry:

- Academics: Early academic interest resulted in NZ having a good understanding of its wind resource and an awareness of the wind generation potential. The academics played an important role in raising the profile of wind generation and identifying the opportunities of wind generation.
- "First mover" individuals. The early stages of the wind industry in New Zealand was driven by individuals.
- Smaller companies that can move quickly: In New Zealand it was the smaller organisations in the electricity sector that did the early exploring of wind generation. These organisations can move more quickly than the larger ones to develop wind projects.
- Trials. In New Zealand installing a single wind turbine substantially lifted confidence in wind technology.
- First projects. The first projects will be expensive as the industry learns to develop wind projects. Government support for first projects is helpful to reduce costs.

- Develop a wind integration project that develops scenarios for wind development. Understanding the characteristics of wind in a economy's electricity system will greatly assist the system operation and grid management part of the electricity system to understand the characteristics of wind generation and the benefits wind generation can bring to grid systems. Grid integration studies build confidence in integrating wind into grid systems and create a platform for the development of innovative solutions that harness the benefits of the modern power electronics in wind turbines.
- Local solutions to maintenance issues. Local engineering companies will make a significant contribution to the wind industry. Companies and organisations need to be engaged early in the development of the wind industry and may provide innovative solutions to operations and maintenance issues.
- Smaller as well as larger projects. There is a tendency to "think big" when considering windfarms. Smaller, distributed windfarms may have a range of benefits, from greater public acceptance to improved grid resiliency.
- A wind Industry association is a very important part of helping a wind industry become established. An industry association should be set up as the industry develops. Government support may be needed to help the association become established. Industry association is very important to help the industry grow.
- Develop a set of planning and management tools for windfarms, such as a noise assessment framework, landscape methodologies, good understanding of particular environmental issues, such as potential impacts on birds. Government needs to take a leadership role so that the planning and management tools are seen as having independence from the industry.
- Development of monitoring and complaints procedures. Industry should established clear procedures for identifying and managing issues that arise. The New Zealand experience is that issues will arise. The affected community will expect robust procedures to be in place to deal will issues that arise.
- Robust environmental decision-making processes. Some people will remain opposed to wind generation for a variety of reasons. There is little that can be done to work with this section of society. A clear and robust decision-making process is needed that enables opponents to be heard.

Case Study on

Best Practices of Wind Energy Development in Thailand

Submitted by

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1. EXECUTIVE SUMMARY

The demand for electricity is growing across the APEC region and especially for Thailand. The Thailand Power Development Plan projected the doubling of electricity demand for Thailand in 20 years. Renewable energy sources have the main advantage of power generation as stand-alone or grid connected and suitable for the remote areas. Therefore, it can also help support the energy security in the last mile of the grid connection. However, the cost for generating electricity from renewable energy sources is still considerably high, therefore, there is a need to develop the most efficient and appropriate renewable energy systems. Thailand Integrated Energy Blueprint 2015-2036 (TIEB) aims aligned 5 energy master plan together which include the Power Development Plan (PDP), Energy Efficiency

Development Plan (EEDP), Alternative Energy Development Plan (AEDP), Oil Roadmap and Gas Roadmap. The TIEB focused on securing Thailand Energy Supply, providing Fair Energy Pricing and supporting Energy Conservation. The wind energy development is under the AEDP master plan. The AEDP focused on three pronged approach for cost effective scale up of renewables with goal of 30% renewables in total energy consumption by 2036. For the wind energy, the AEDP concentrates on providing power generation if the investment cost will be able to compete with the power generation using LNG. Wind energy target is 3,002 MW by 2036, however, at present, there are 12 wind farms with COD in Thailand and the installed capacity of 231.06 MW. So there are high opportunities for wind energy industry development in Thailand. The obstacles that were identified during the wind energy development are problem with the permission mountainous or forest reserve areas; lack grid connectivity in the high wind potential sites; and environment related issues such as obstruction of scenery, noise pollution, and impact on wild life.

The interests in wind energy for power production have begun in the past 20 years. The wind map and wind energy potential were evaluated several times to determine the most feasible region for wind energy development. Several low wind speed turbine and high wind speed turbine demonstrations projects were installed to evaluate the appropriate wind energy technology that are suitable for Thailand. Only in the past 5 years that large scale wind farm have been installed and commissioned. Most of the farms are in the North eastern and South of Thailand. These are the location with higher wind speed. The high wind speed area is in eastern coastal line. High mountainous areas also have high wind speed (Wind Power Class 1-5 of 0 – 6.4 m/s). The feasible regions are some part of the Eastern, North Eastern, and Southern part of Thailand. However, the average wind speed in most area of Thailand are at 3-5 m/s. Based on Thailand wind potential, the high speed wind turbine should be focused in the off-shore region. This will prevent the noise pollution to the nearby community. In the mainland, low wind speed turbine should be focused. Due to the high cost of creating the infrastructure such as roads and power grid to install the large scale wind turbine, Thailand should aim at smaller low wind speed turbine in the main land area. The small wind farms should be distributed across the economy to the community sector. With small and widely distribution, the benefit is ease of instalment and less disruption to the main grid line. Small and low wind speed wind turbine also produce less noise and have less wildlife and environmental damage during the installation and operations.

Since Thailand wind energy development until now has been most on evaluation and demonstration sites, there is very little to none of the local content for wind turbine industry. Therefore, for the near future, the direction of wind energy development in Thailand should focuse on the developing the appropriate technology, technology transfer, implementing and sustainable inclusive to economy and Southeast Asia because of similarity of resources. Appropriate technology should be developed and create cycle in the value chain. Due to the initial high risk of wind industry investment, therefore, Thailand government should support the development of our own wind industry from upstream to downstream; technology development that are appropriate for Thailand wind potential; wind turbine production; implementation and management. In addition, the direction of wind energy development between the government sector, state enterprise, industries and academia should also be aligned because each institution is focused on different direction in wind development. All stakeholders must work together in the same direction in order to develop the wind industry in Thailand and achieve the AEDP goal.

2. THAILAND RENEWABLE ENERGY POLICY AND STATUS

2.1 Thailand Integrated Energy Blueprint 2015-2036

The Energy Policies under General Prayuth Chan O-cha, Prime Minister of Thailand, aims to secure Thailand Energy Supply, provide Fair Energy Pricing and support Energy Conservation. In 2015, Thailand has launched the Integrated Energy Blueprint 2015-2036 (TIEB) which aligned 5 master plans as pillars for Thailand's energy development. The 5 master plans are Power Development Plan (PDP), Energy Efficiency Development Plan (EEDP), Alternative Energy Development Plan (AEDP), Gas Roadmap and Oil Roadmap [1]. These plans provide the "bold moves" to shape Thailand energy outcomes. The objectives of the TIEB are

1) Security: to create stability for domestic energy need/demand and support the Economic and Social Development plan by distributing fuel to reduce risk on depending too much on a fuel's kind
2) Economy: to create reasonable energy cost for both people and business which will not be hurdle for long-term domestic development, including to promote energy efficiency
3) Ecology – to reduce effects on environment and community

The description and impact of each plans are described in Figure 1. The wind energy development is under the AEDP master plan. The AEDP focused on three pronged approach for cost effective scale up of renewables with goal of 30% renewables in total energy consumption by 2036 [2]. For the wind energy, the AEDP concentrates on providing power generation if the investment cost will be able to compete with the power generation using LNG. Wind energy target is 3,002 MW by 2036 (Figure 2).

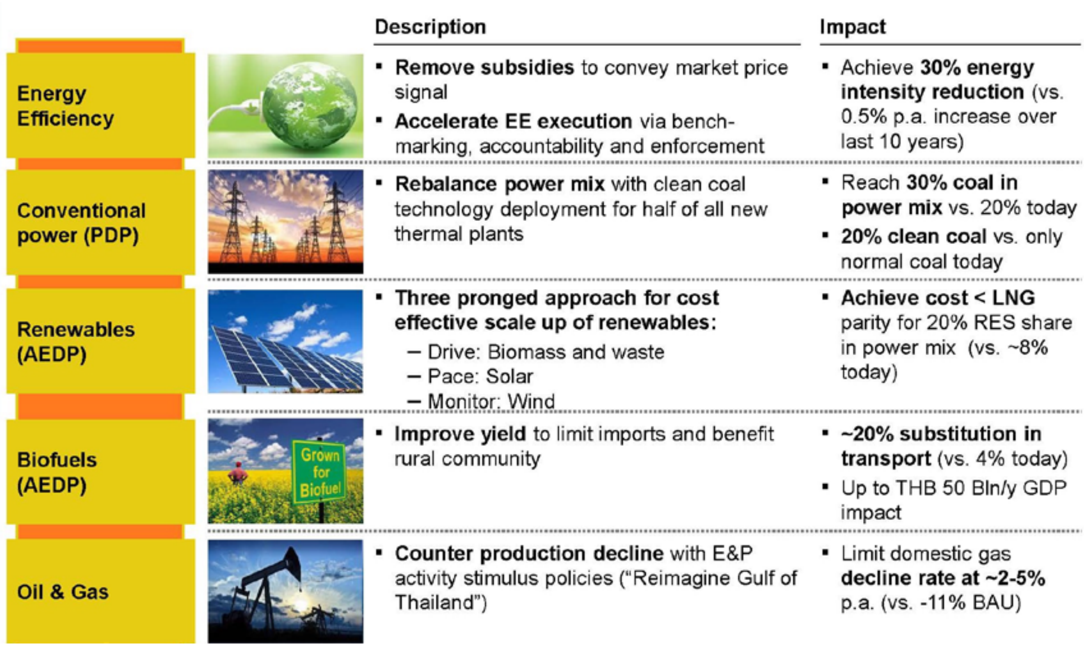


Figure 1: Highlight of Thailand Integrated Energy Blueprint - 5 Master Plans [1]

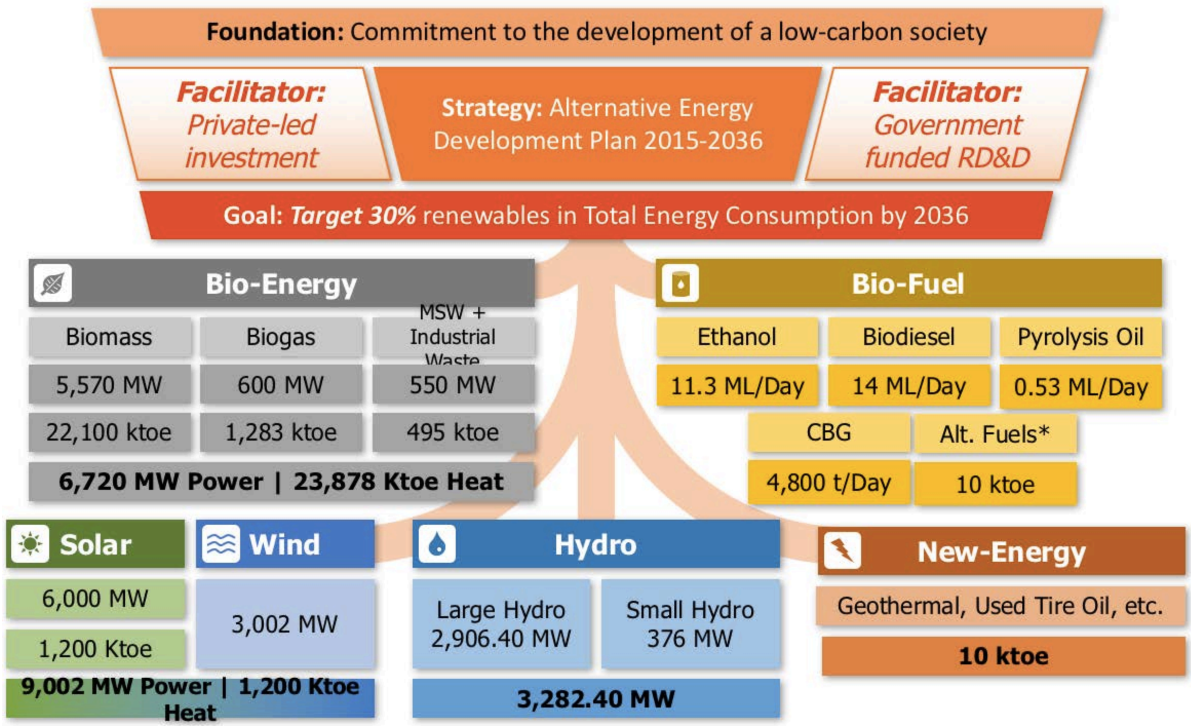


Figure 2: Alternative Energy Development Plan 2015-2036 [2]

2.2 Status and Target of Renewable Energy in Thailand

The status of renewable energy consumption in Thailand is shown in Table 1. The main renewables are from Large Hydro Power, Biomass and Solar Energy. However, other renewables have high potentials for being develop based on the AEDP targets. Especially for wind, 243.82 MW has been produced and consumed as of January to April of 2016 while the target in 2036 is 3,002 MW.

Table 1: Alternative Energy Consumption in Thailand (MW) and AEDP Renewables Target

Alternative Energy	**Target in 2036**	**2012**	**2013**	**2014**	**2015**	**Jan-Apr 2016**
Solar Energy	6,000.00	376.72	823.46	1,298.51	1,419.58	1,783.63
Wind Energy	3,002.00	111.73	222.71	224.47	233.90	243.82
Small Hydro Power	376.00	101.75	108.80	142.01	172.12	172.12
Biomass	5,570.00	1 ,959.95	2,320.78	2,451.82	2,726.60	2,776.14
Biogas	1,280.00	193.40	265.23	311.50	372.51	396.25
MSW	550.00	42.72	47.48	65.72	131.68	146.38
Large Hydro Power	2,906.40	-	-	-	2 ,906.40	2,906.40
Total	**19,684.40**	**2,786.27**	**3,788.46**	**4,494.03**	**7,962.79**	**8,424.74**

Source: Department of Alternative Energy Development and Efficiency on 16 June 2016 [3]

2.3 Status of Wind Energy in Thailand

At present, there are 12 wind farms with Commercial Operation Date (COD) in Thailand with the installed capacity of 231.06 MW (Table 2). Figure 3 showed the location of the wind farms in Thailand. Most of the farms are in the North eastern and the South of Thailand. These are the location with higher wind speed. The average wind speeds in most area of Thailand are at 3-5 m/s.

Table 2: Wind Farm with COD

No.	**Company**	**Province**	**Installed Capacity (MW)**
1	Lamtakhong Wind Farm	Nakorn Rachasima	2.50
2	First Korat Wind (West Huay Bong 3)	Nakorn Rachasima	103.50

3	K.R. Two	Nakorn Rachasima	103.50
4	Theppana Wind Farm	Chaiyaphum	6.90
5	Chang Hua Man Royal Project	Petchaburi	0.05
6	Samut Green Energy (Thailand)	Samutsakorn	0.92
7	Ko Tao	Surat Thani	0.25
8	Laem Phrom Thep	Phuket	0.192
9	Tha-le Pang (Hua Sai District)	Nakhon Sri Thammarat	0.25
10	DEDE Wind Energy Power Generation	Nakhon Sri Thammarat	1.50
11	Sating Phra District	Songkhla	1.50
12	Inter Far East Wind International Co., Ltd	Nakhon Sri Thammarat	10.00
Total Installed Capacity			231.06

Source: ERC, EGAT, MEA, PEA and DEDE on March 2016 [4]

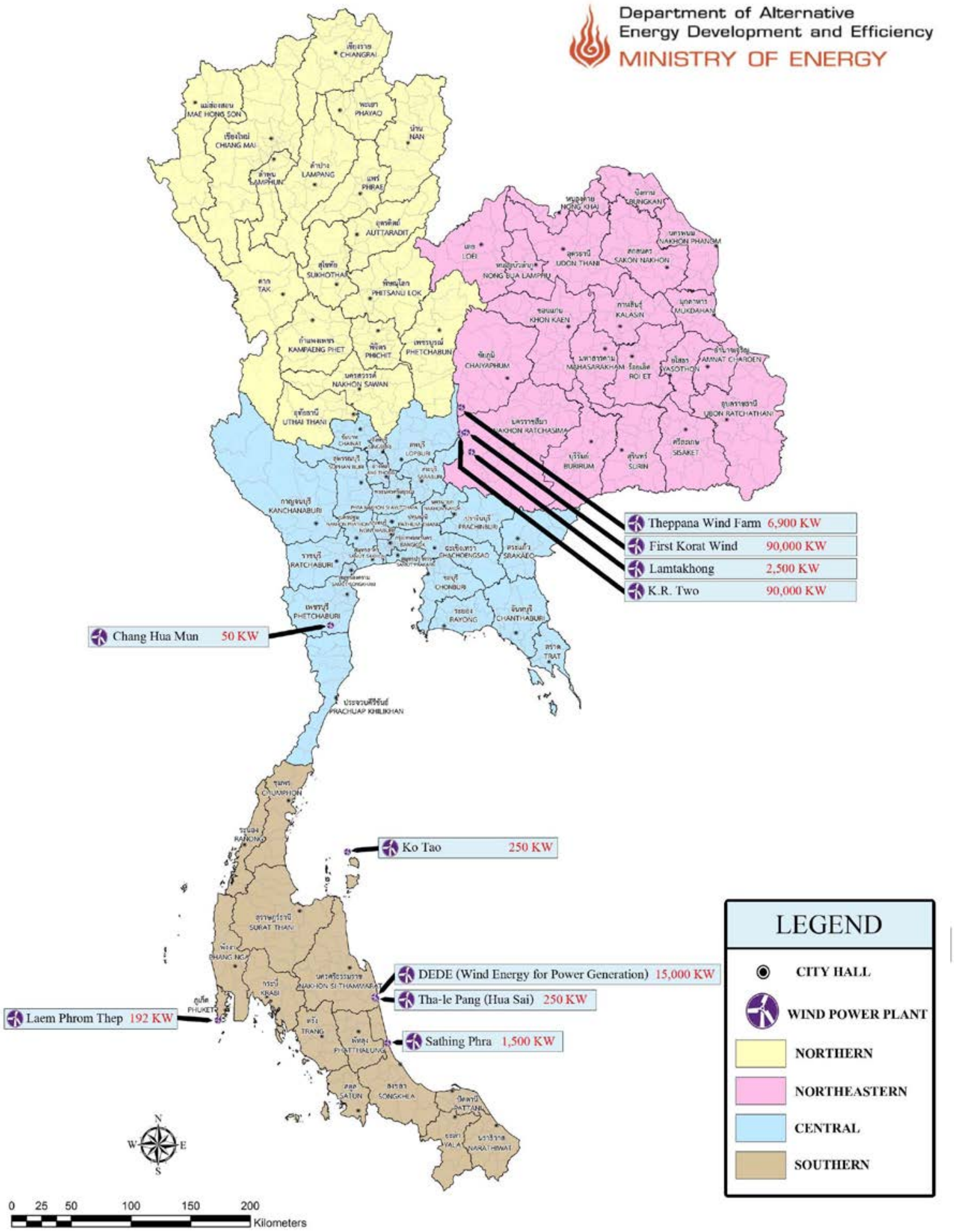


Figure 3: Map of Wind Energy Farm in Thailand [4]

2.4 Wind Energy Incentive in Thailand

Based on the new incentive FiT scheme, wind energy would have a higher FiT than other renewable energy at 6.06 baht/kWh. So there are currently good and profitable incentives for wind industry project developers. However, the main obstacle in wind energy development is in the power grid infrastructure mainly the availability of feeders. To overcome this barrier, project developers and researchers are focusing on using with wind energy in the hybrid system to provide off grid type power to the community at the end of the grid line. With this method, the grid line will not be disrupted from the renewable energy power production.

Table 3: Feed in Tariff for AEDP Renewable Energy Targets

Capacity (MW)	FiT (THB/kWh)			Period of Subsidy (Year)	FiT Premium (THB/kWh)	
	FiT_F	$FiT_{V,2017}$	$FiT_{(1)}$		Biofuel Project (first 8 years)	Project in Southern Territory Area (2) (Throughout Project Period)
1 (MSW (Hybrid Management)						
Existing Capacity ≤ 1 MW	3.13	3.21	6.34	20	0.70	0.50
Existing Capacity > 1-3 MW	2.61	3.21	5.82	20	0.70	0.50
Existing Capacity > 3 MW	2.39	2.69	5.08	20	0.70	0.50
2 (MSW (Sanitary Landfill)	5.60	-	5.60	10	-	0.50
3 (Biomass						
Existing Capacity ≤ 1 MW	3.13	2.21	5.34	20	0.50	0.50
Existing Capacity > 1-3 MW	2.61	2.21	4.82	20	0.40	0.50

Existing Capacity > 3 MW	2.39	1.85	4.24	20	0.30	0.50
4 (Biogas (Waste Water/Sewage)	3.76	-	3.76	20	0.50	0.50
5 (Biogas (Energy crop)	2.79	2.55	5.34	20	0.50	0.50
6 (Hydropower						
Existing Capacity ≤ 200 kW	4.90	-	4.90	20	-	0.50
7 (Wind	6.06	-	6.06	20	-	0.50

(1) This FiT rate applies to a project that delivers power into the grid in the year 2017. After 2017, the FiTv rate will be increased based on the core inflation rate. This only applies to waste (integrated waste management), biomass and biogas (energy plants) projects.

(2) Projects located in Yala, Pattani, Narathiwat and 4 Sub-districts in Songkla (Jana Sub-district, Tepha Sub-district, Sabayoi Sub-districtand Natawee Sub-district) only.

3. WIND ENERGY DEVELOPMENT IN THAILAND

3.1 History of Wind Energy Development in Thailand

Thailand has been using wind energy in several formats from simple technology such as bamboo turbine to complex technology. The main usage of wind energy is for water pumping and producing electricity. In the past, Thailand has long been using wind turbine for water pumping in the agricultural sector and salt field. The water pumping turbines do not need high wind speed in operation because the average wind speed in most part of Thailand is 3-5 m/s. Therefore, many areas in Thailand with wide field and few obstacles can use these types of water pumping turbines. Within the past 20 years, wind turbine for generating electricity had been the interest of the Ministry of Energy, Utility Companies and Universities research and exploratory activities. Several demonstration sites and wind turbine technology evaluations had been conducted. Just the past 5 years, large scale wind farms have been commissioned. Below is the history of wind energy development based on chronological order.

1975 – The Department of Energy Affairs of the Energy Policy Office made a wind speed map. The average wind speed was supplied by the Thai Meteorological Department. There were many obstacles in making the wind map and only low elevation were available [5].

1981 – The first survey of wind turbine was initiated. The water pumping turbine that were made from canvas or woven bamboo mats were evaluated (Figure 4). Then, the usage of wind turbine decreased rapidly because of the conversion from agricultural based to industrial based area.

Figure 4: Traditional Wind Turbine for Water Pumping

1981 – The study of the wind energy potential in Thailand was initiated to determine the wind speed level for each region (Figure 5). The work was in collaboration with the Meteorological Department of Thailand. The wind speed was in the level of medium to low at 4 m/s.

1983-1986 – King Mongkut's University of Technology Thonburi and Prince of Songkla University collaborated to construct and install the wind turbine.

1983-1996 – Electricity Generating Authority of Thailand (EGAT) tested wind turbine at the renewable energy power plant in Laem Phrom Thep, Phuket Province. The wind energy was used in the power plant. This is the first electric wind turbine testing facility in Thailand. In 1992, EGAT installed two more turbines at total capacity of 10 kW. The data was recorded continuously for 3 years (1994-1996) and were used for technical and economic evaluations of wind energy for provincial power distribution potential through Provincial Electricity Authority (PEA).

1987 – The Department of Energy Development and Promotion installed the demonstration wind turbine at the Huay Sai Royal Development Project in Cha-am District, Petchaburi Province.

1991-1992 – The survey of traditional wind turbine were being conducted in Samut Sakorn and Samut Songkram Province because of the high concentration of salt fields. The results revealed 167 traditional turbines were being used effectively as the water pumping system.

1996 – King Monkut's University of Technology Thonburi installed 2.5 kW and 10 kW wind turbine at Phu Kradueng Park in Loei Province and Tarutao Park in Satun Province, Respectively.

1996 – Recycle Engineering Company Limited installed 150 kW turbine at Koh Chan Sub District in Chonburi Province for electricity usage in buildings.

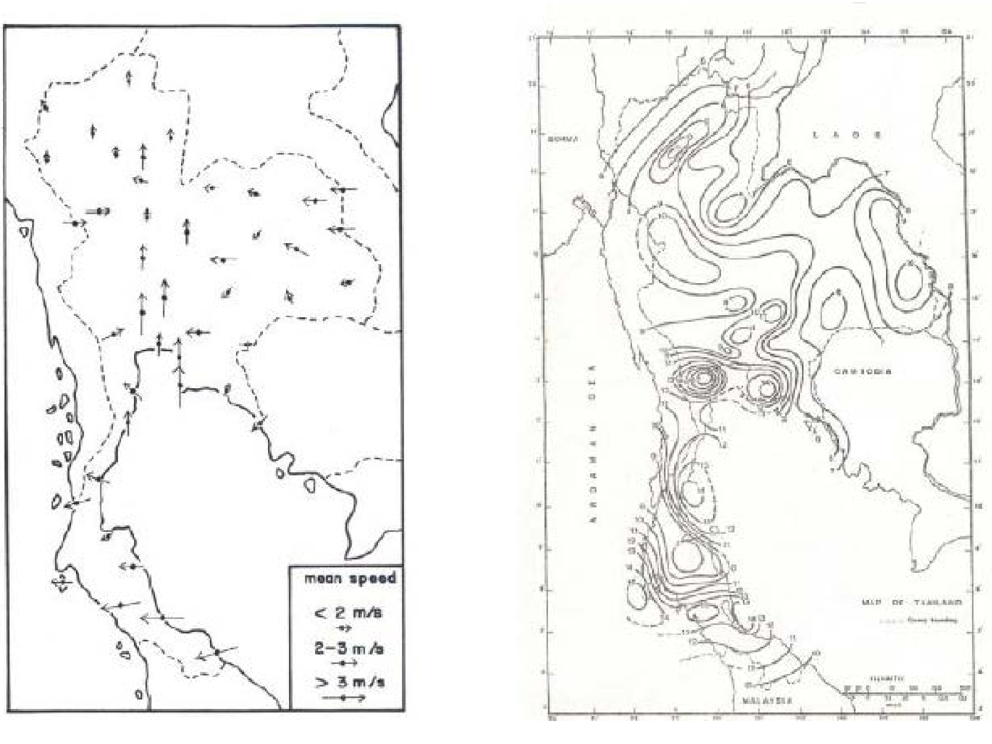
1999 – Another demonstration project for wind turbine with 18 blades was applied to the demonstration farm in Paktor District, Rachaburi Province. The demonstration farm was based on His Majesty the King's New Theory of Agriculture Concept. The successful demonstration leads to the development and usage in the Regional Energy Development and Transfer Center in Rachaburi Province.

2001 – The Department of Energy Development and Promotion provided funding to the Regional Energy Development and Transfer Center in Rachaburi Province to further developed the wind turbine for water pumping system.

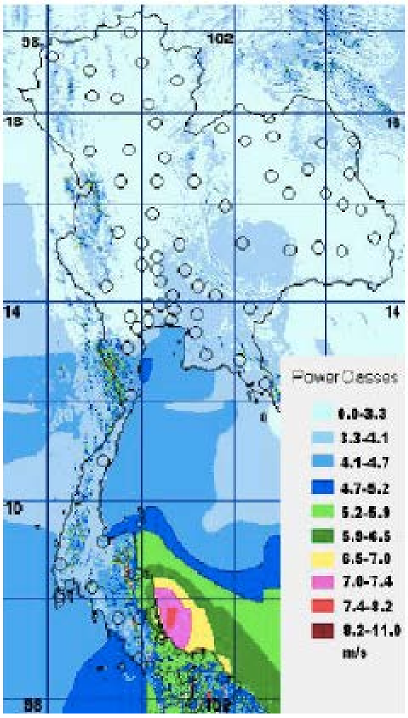
2001 – The map of wind speed potential was improved at higher elevation. The suitable area had the average wind speed of greater than Class 3: 6.4-7.0 m/s. The data indicated that the coast area of the Gulf of Thailand has the best wind energy potential (Figure 5).

2001 – World Bank proposed a wind energy map for Southeast Asia Economies (Figure 5). The report used simulation based on global wind [6].

2003 – PEA installed one 250 kW wind turbine at Ko Tao, Pangngan District, Surat Thani Province. The power generated provided 10% of Ko Tao Island total power consumption.



(a) (b)



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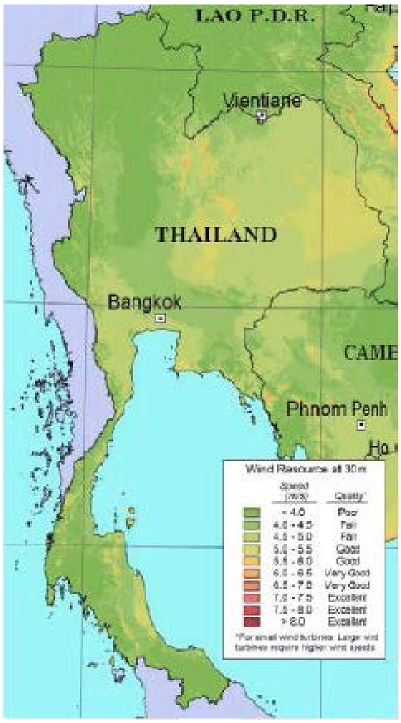


(d)

Figure 5: Thailand Wind Map in the Past

(a) Wind map from Asian Institute of Technology (AIT), Exel (1981)

(b) Wind map from King Mongkut's Institute of Technology (KMUTT), Suwantrakul et. al. (1984)

(c) Wind map from the Department of Energy Development and Promotion (DEDP) (2001)

(d) Wind map from World Bank, TrueWind Solutions (2001)

2006 – The United States Department of Energy collaborative project initiated the hybrid system with solar energy, wind energy and diesel generator to provide electricity to the islands in the South of Thailand. In addition, anemometers were installed on the eastern shoreline at Panang District, Nakorn Sri Thammarat Province and Sating Phra District, Songkla Province as well as on the western shoreline at Tung Wa District, Satoon Province and Takuapa District, Pangnga Province.

2007-2009 – DEDE, Ministry of Energy installed one 250 kW and 1.5 MW turbine for power production at Huay Sai District in Nakorn Sri Thammarat Province.

2007 – The first small wind farm was built in Lan Island, Pattaya District (Figure 6). The area had the wind speed at 13 m/s. 45 units of 4.5 kW wind turbine were installed at 200 kW capacity. The wind farm was connected to the power distribution line to provide electricity to the people on the island. The Pattaya District reduced their diesel usage at 200 L/day. The wind farm design and operations were from the team of Rajamangkala University of Technology Thanyaburi.

2008 – The Department of Alternative Energy Development and Efficiency installed the wind turbine for electricity generation for 3 systems of 1 kW. These wind turbines were used to power the lightings in the area of the Sirindhorn International Environmental Park, Petchaburi Province. The system used small wind turbines with batteries. The inverters converted DC power to AC power for lighting in the beach areas.

Figure 6: The First Thailand Wind Farm 200 kW at Lan Island

2008 – Six wind measurement stations were set up along the coast of the southern of Thailand. Sensors were placed at 20, 30 and 70 m. From these data, estimation of the wind speed at height 80, 90 and 100 m were determined at 3.4-9.5 m/s [7]. Afterward, the economic analysis were made for Very Small Power Producers (VSPP) and showed that in the long term the wind turbine generators of 1.0, 1.5, and 2.0 MW can generate about 1,018, 1,038, and 1,148 MW of electricity from wind energy, respectively.

2009 – Low wind speed turbine wind farm was demonstrated at Chang Hua Man Royal Project to produce electricity to the PEA power grid. The wind farm was designed and installed by the wind energy team of Rajamangkala University of Technology Thanyaburi. The 5 kW turbine could produce power at 2 m/s with maximum power at 9 m/s. The wind farm consisted of 20 low speed wind turbine with total installed capacity of 100 kW.

Figure 7: Chang Hua Man Royal Project Wind Farm Diagram

Figure 8: Chang Hua Mun Royal Project Wind Farm Picture

2009 – The first large wind power generation turbine in Thailand was installed by EGAT and connected to PEA. Two sets of 1.25 MW turbines with total capacity of 2.5 MW were installed at upper reservoir of Lamtakong Cholapawattana Power Plant in Khlongphai Sub-District, Nakorn Ratchasima [8]. Chinese-made D6-1250 models wind turbines were used with three-blade horizontal-axis and a blade diameter of 64 m. The turbines turn at wind speeds of 2.8 m/s - 12.5 m/s for electricity generation. Afterwards, PEA installed 1.5 MW wind turbine at Sating Phra District in Songkla Province.

2012-2013 - First Korat Wind and K.R. Two Project for wind power generation were established by Wind Energy Holding Co., Ltd with 45 2.3 MW wind turbine for each project. The site of Huay Bong Subdistrict, Dan Khun Tod District at Nakorn Ratchasima had the average wind speed for both project of 6.2 m/s at 99.5 m height. These projects are considered as one of the first large scale wind farms in Thailand and have the highest capacity in Southeast Asia [9].

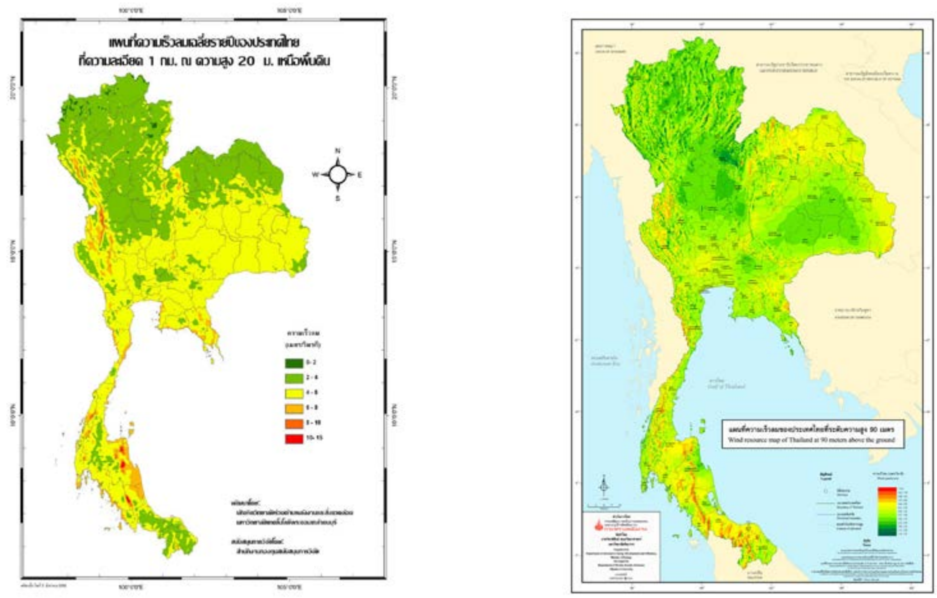
Based on the history of wind development in Thailand, in the past 30 years, Thailand used wind turbine for water pumping. The interests in wind energy for power production have begun in the past 20 years. The wind map and wind energy potential were evaluated several times to determine the most feasible region for wind energy development. Several low wind speed turbine and high wind speed turbine demonstrations projects were installed to evaluate the appropriate wind energy technology that are suitable for Thailand. Only in the past 5 years that large scale wind farm have been installed and commissioned. Therefore, for the near future, the direction of wind energy development in Thailand should focus on the technology transfer, implementing and sustainable inclusive to economy and Southeast Asia because of similarity of resources. Appropriate technology should be developed and create cycle in the value chain. In addition, the direction of wind technology development between the government sector, state enterprise and universities should also be aligned because each institution is focused on different direction in wind development.

3.2 Wind Potentials in Thailand

DEDE have reported the wind speed map and wind energy potentials in Thailand (Figure 9). The average wind speed for most area of Thailand is 4-5 m/s. Therefore, Thailand should also focus the wind industry development toward the low wind speed turbine with plant factor of 20-25%. However if the wrong turbine (for 7-8 m/s) was used the plant factor would be only 8-10%.

The high potential areas have Wind Power Class 1-5 of 0 – 6.4 m/s. The high wind speed area is in eastern coastal line. High mountainous areas also have high wind speed. The feasible region are some part of the Eastern, North Eastern, and Southern part of Thailand The promising provincial area for wind energy production are in the mountainous area of Kanjanaburi, Lopburi, Chaiyapum, Nakorn Rachasima, Loei and Petchaboon Provinces. In addition for the southern part of Thailand, the feasible area is in Prajuabkirikan to northern of Songkla province.

Based on Thailand wind potential, the high speed wind turbine should be focused in the off-shore region. This will prevent the noise pollution to the nearby community. The large wind farm can also produce freshwater for the fisherman, military and the industry. The Gulf of Thailand has the depth of 30 meter, therefore, the environment is appropriate to set up the large wind turbines at 3 km from shore. In the mainland, low wind speed turbine should be focused. Due to the high cost of creating the infrastructure such as roads and power grid to install the large scale wind turbine, Thailand should aim at smaller low wind speed turbine in the main land area. The small wind farms should be distributed across the economy to the community sector. With small and widely distribution, the benefit is ease of instalment and less disruption to the main grid line. Small and low wind speed wind turbine also produce less noise and have less wildlife and environmental damage during the installation and operations.



(a)

(b)

Figure 9: Current Wind Map of Thailand (a) 20 m elevation and (b) 90 m elevation [10]

3.3 Obstacles in Wind Energy Development

In Thailand, there are several obstacles in wind energy development. There are 3 main obstacles [5, 11]. Firstly, the area with high wind energy are often in the mountainous or reserved forest. The private organization will face problem with the permission to use the area with the government agencies. The second problem is the cost of producing and installing the wind turbine and the appropriateness of the site grid connection. The site should be within the 10 km radius of the grid, however, most of the appropriate site are further from the grid line. Therefore, the cost of installation would become too high. The third obstacles are the environment related, for example, obstruction of scenery, noise pollution, and impact on wild life. Currently, these are the obstacles that are found during the wind energy development projects. Since, Thailand still do not have many wind development projects, the issues regarding social and environmental are still quite minimum.

4. STAKEHOLDER ROLES IN WIND ENERGY DEVELOPMENT

Thailand Electrical Energy Stakeholders include the state enterprise, government and private sector. The details of energy stakeholders and roles are indicated in Table 4. Mainly, DEDE and EPPO under the Ministry of Energy will provide the main policy for the renewable energy direction. ERC is the Power entity that will carry out the policy. The State Enterprise (EGAT, PEA, MEA) are the energy producer and distributor. The private sectors are the power producers which are the project developers for the wind farms. They must file the Power Purchase Agreement (PPA) through ERC and get approval from PEA and the community in order to set up the wind farms.

Figure 10 display the process of planning for renewable energy incentive program [12]. The Ministry of Energy (MoE) drafts the program and proposes it to the Energy Policy Commission. The ERC has legal authority to set rules and regulate the implementation of power policies, including the FiT measure, in Thailand.

Table 4: Thailand Electrical Energy Stakeholder and Roles

Energy Stake Holder	Institutions	Role
State Enterprise	EGAT: Electricity Generating Authority of Thailand	Power Producer
	PEA: Provincial Electricity Authority MEA: Metropolitan Electricity Authority	Power Distributor
Government	DEDE: Department of Alternative Energy Development and Efficiency	Renewable Energy Policy Maker
	EPPO: Energy Policy and Planning Office	Energy Policy Maker
	ERC: Energy Regulatory Commission	Regulator
Private Sector	IPP: Independent Power Producer (>90 MW) SPP: Small Power Producer (<90 MW) VSPP: Very Small Power Producer (<10 MW)	Power Producer

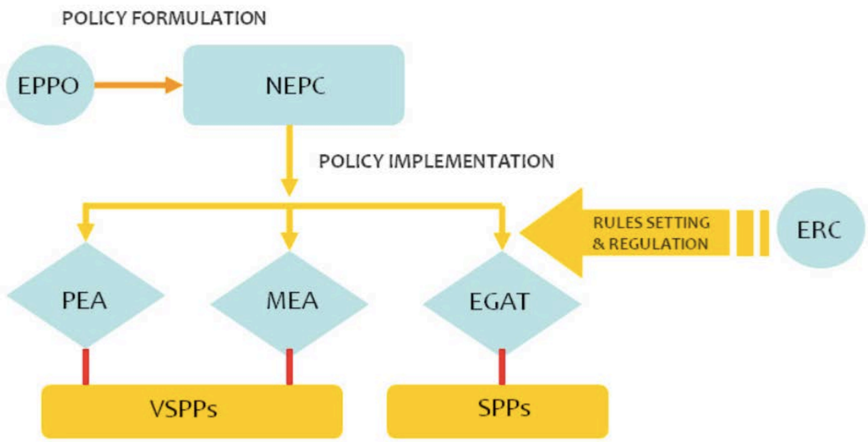


Figure 10: FiT Policy Process [12]

In Section 3.1 on the History of Wind Development in Thailand, universities and research institutions had worked closely with the government and state enterprise in the exploratory research, wind potential assessment, wind technology development, technology verification and implementation. The university researchers had accumulated the knowledge from the experience of wind energy projects and translated the experiences into academic and training programs. The goal was to provide awareness and correct information to the general public regarding to wind energy potential and development for Thailand. In addition, the universities were also providing education and capacity building to technicians and engineers to operate and maintain the wind energy industry in the future. However, only a few universities have specific wind energy program. Most of the university provided a more general program for renewable energy but focusing more on solar energy. Therefore, this is one of the reasons that wind energy development in Thailand have been going quite slow. Higher and faster capacity building for wind energy industry must be implemented in achieving the AEDP target of wind energy goal of 3,002 MW in 2036.

Since Thailand wind energy development until now has been most on evaluation and demonstration sites, there is very little to none of the local content for wind turbine industry. Thailand does not have the upstream process or our own wind turbine technology. All parts must be imported from abroad and Thailand is the assembly side. This is another reason that the government is reluctant to fully support the wind energy programs. However, it is very difficult to start because we do not have the experience and a lot of error could occur during the wind turbine production. So the entrepreneurs and investors are quite reluctant to start because of high risk. Due to the initial high risk, therefore, Thailand government should support the development of our own wind industry from upstream to downstream; technology development that are appropriate for Thailand wind potential; wind turbine production; implementation and management. Government, industry and academia must work together in the same direction in order to develop the wind industry in Thailand and achieve the AEDP goal.

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United States Wind Development:

Three Case Studies

Submitted by: Terry Surles

<u>Table of content</u>

I. Introduction

This review focuses on case studies that can provide useful background information for the development of larger scale wind projects in Viet Nam. To provide background, a brief history of development in the United States will be in the first section. In the second section, a discussion of enabling legislation on a federal and state level will provide a basis for how the deployment of wind energy systems is encouraged by government.

The final three sections will provide case studies in three states – California, Hawaii, and New York. There is a need to explain how the federal nature of the United States works in this regard. Each state can development initiatives that may have the same final goals, but use different approaches to achieving those goals. Thus, in the case of Hawaii, the only investor-owned utility in the state must develop agreements with both the regulatory agency and with the company that will develop the site and eventually sell electricity to them.

In the case of California, there has been a strong push to develop renewable resources, similar to Hawaii. However, a developer of a renewable technology must work with more than just the utility that will purchase the electricity. While the utility will address the regulatory issues with the regulators, the developer must also deal with the Independent System Operator and with a large number of societal and environmental requirements.

The example used for New York State is one in which the state agency, in this case the New York State Energy and Research Development Agency (NYSERDA), put forward a solicitation to “kick-start” getting large-scale wind generators put in place. This required a solicitation from NYSERDA that specified that up to 50% of the development costs would be shared by the state with the developer. The case study provides the details related to one of the winners of the solicitation.

These case studies will serve to inform Viet Nam as to the different approaches that can be used for increasing the amount of renewable energy resources in Viet Nam. It should be noted that other states in the United States follow other approaches. Therefore, it should be understood that, while these three state examples inform future decisions, these should not be considered to be the only approaches that could be successful for Viet Nam.

An additional caveat is also necessary. While the focus of this report is about wind resources being used to generate electricity, it is extremely important that the insertion of wind into the grid be treated as part of the energy system and not considered as simply a stand-alone technology. The resulting focus should be on the fact that this technology is part of a larger system. And, the focus should also be on the fact that wind energy provides an opportunity to meet economic, environmental, and energy security goals. Thus, wind power is part of a broad set of tools, both in terms of generation and energy efficiency, which will allow a economy to meet these goals in a holistic, integrated manner. If planned and implemented correctly, wind power as part of an integrated system will be able to help government address sustainability, energy security, and climate change policy goals.

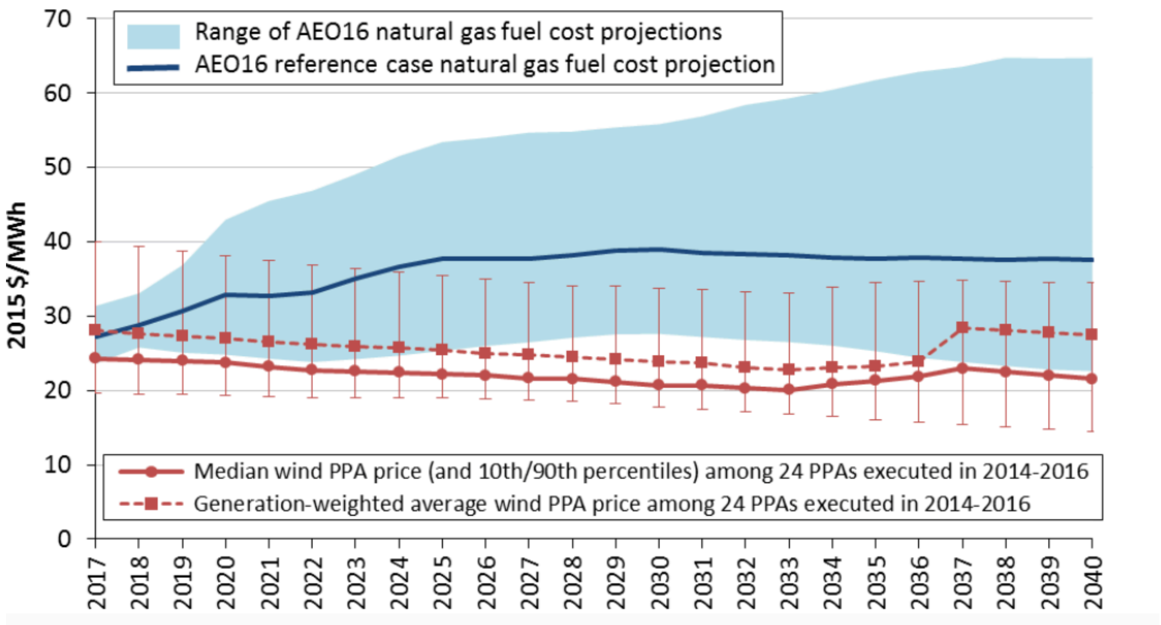
II. Growth of Wind Energy in the United States – A Snapshot

While wind power has been utilized for centuries, the practical origins of wind for electricity use essentially begin with the two "oil shocks" in the 1970s. These energy-related events led to the creation by President Carter, in 1978, of the Solar Energy Research Institute. The name was changed to the Renewable Energy Laboratory (NREL) in the 1980s under President Reagan.

Under the Carter Administration, the federal government provided the first significant funding for wind technology research and development. While this funding was reduced significantly under the Reagan Administration, funding continued to be provided to NREL and to wind technology developers. This led to significant developments in wind technology and reductions in technology costs as part of public funding of private technology developers. As a result of these partnerships, the price for wind-generated electricity dropped 90% between 1980 and 2015.

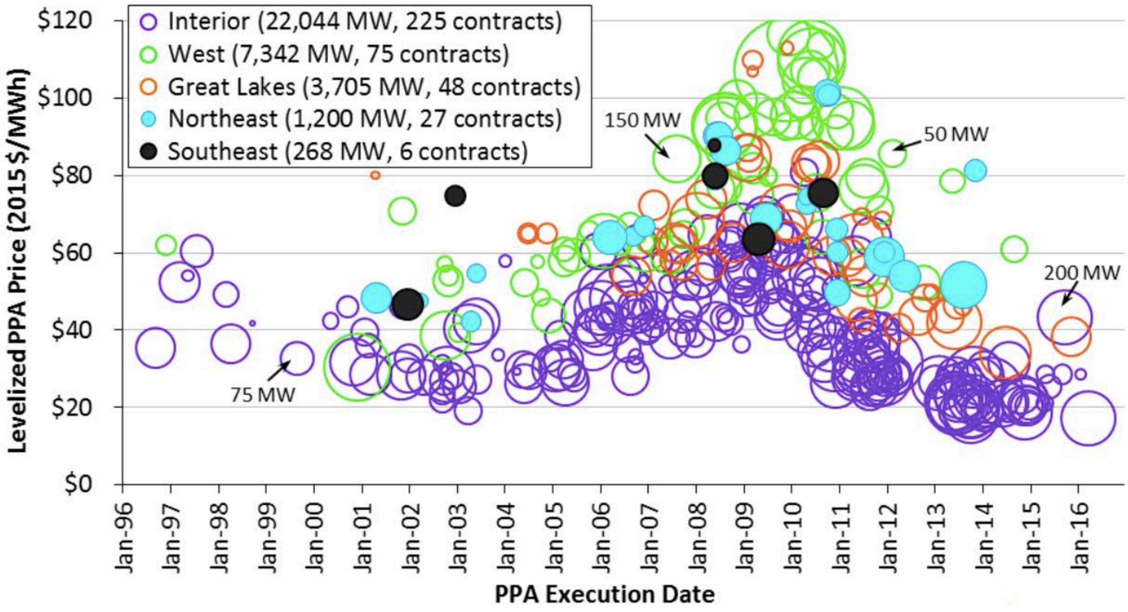
Wind is now considered on par with natural gas in terms of electricity pricing. Figure 1 illustrates the emerging parity between wind power and natural gas fired systems.

Figure 1. Price Projections for Wind and Natural Gas PPAs



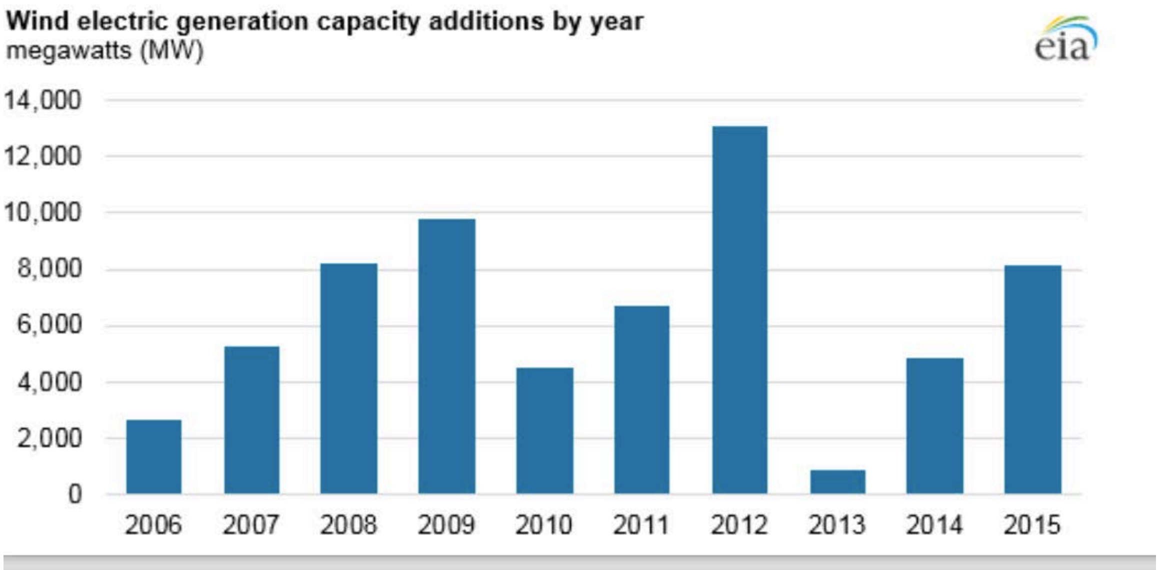
As seen in a more detailed view (Figure 2), Power Purchase Agreements (PPAs) between electric utilities and independent wind energy power producers continue to trend downward.

Figure 2: Trajectory of Power Purchase Agreement Costs



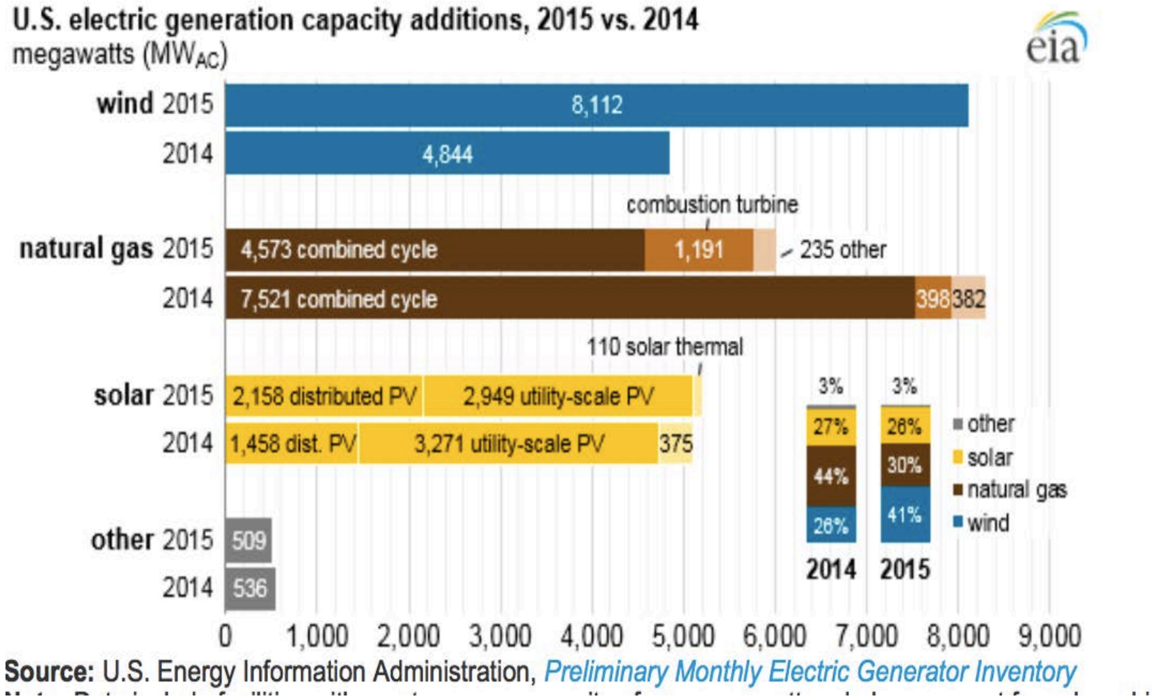
As a result of the overall growth in wind, at the end of 2014, over 73 GW of wind had been installed in the United States (Figure 3).

Figure 3. Year-to-Year Growth of Wind Capacity in the United States



In fact, in 2015, more wind capacity was put on the US grid than natural gas (Figure 4).

Figure 4. US Electric Generation Capacity Additions



The US grid added 1,291 megawatts (MW) of new renewable power in the first quarter of 2016: wind (707 MW), solar (522 MW), biomass (33 MW) and hydropower (29 MW). To put these numbers into perspective, natural gas added only 18 MW of new generating capacity and no new capacity was added for coal, oil, or nuclear power.

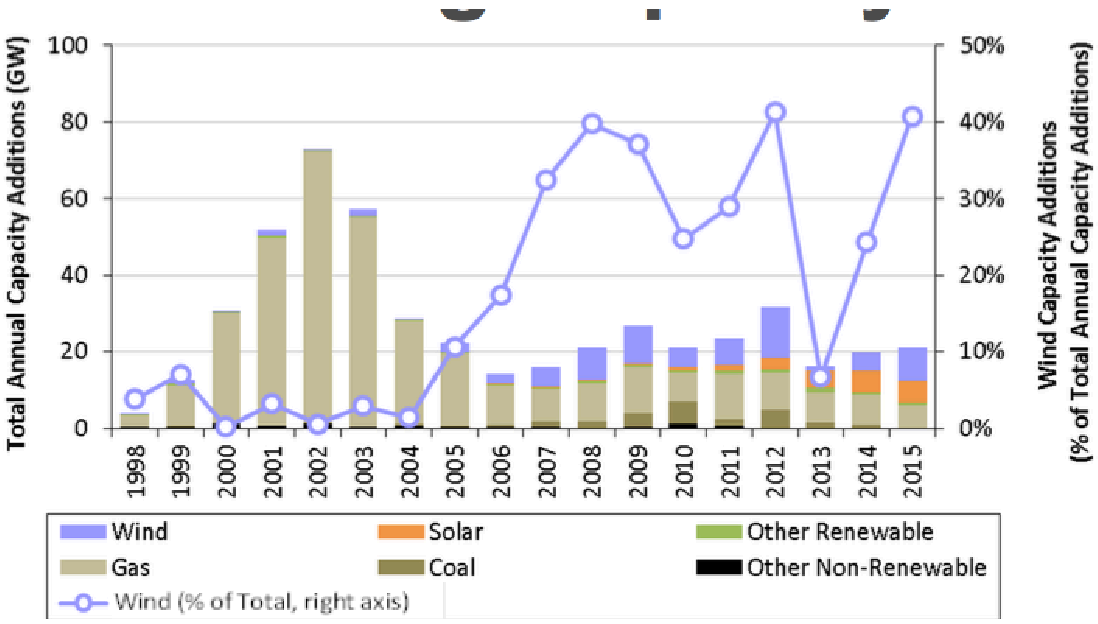
The next section will discuss how various state incentives and federal tax law has helped increase the amount of wind on the US grid.

III. Impact of Federal Production Tax Credits and State Energy Policies on the Wind Industry

The application of Production Tax Credits (PTC) has had a significant effect on the development and the installation of wind resources across the United States. In 2013, the wind PTC temporarily expired, leading to a significant drop in wind installations in that year. This was directly due to the expiration of Production Tax Credits (PTC) on a federal level. The drop in wind system installations from 13,000 MW in 2012 to only 300 MW in 2013 is illustrative of the need to maintain the PTC for the time being. Recently, Congress enacted legislation to extend the PTC through 2019.

As seen in Figures 3 (above) and 5 (below), when these incentives are dropped, the result is for a significant decrease in the amount of wind systems being installed on the North American grid. It should be noted that, over the past several years, wind generation has been the second most installed electricity generation resource, following natural gas. And, as shown in the previous section, more wind came on line in 2015 and in early 2016 than natural gas or any other resource.

Figure 5. Installation of Electricity Generation by Resource



Of equal importance is the move by many states to develop Renewable Portfolio Standards (RPS) in order to reduce carbon emissions from fossil-fired power plants. Figure 6 summarizes the current status of RPS legislation in the states, while Table 1 provides the percentages of wind energy on a state-by-state basis.

Figure 6. Renewable Portfolio Standards by State

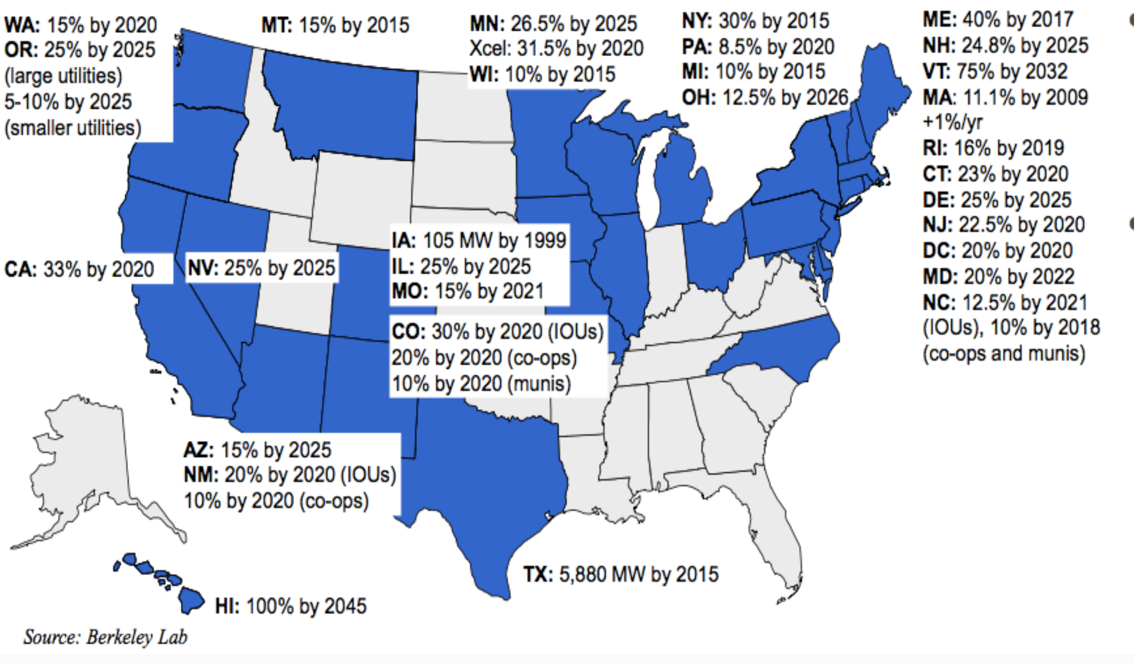


Table 1. Installed Capacity and Percentages of Electricity Generated by Wind Power by State

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2015)		Cumulative (end of 2015)		Actual (2015)*	
Texas	3,615	Texas	17,711	Iowa	31.3%
Oklahoma	1,402	Iowa	6,209	South Dakota	25.5%
Kansas	799	California	5,662	Kansas	23.9%
Iowa	524	Oklahoma	5,184	Oklahoma	18.4%
Colorado	399	Illinois	3,842	North Dakota	17.7%
Illinois	274	Kansas	3,764	Minnesota	17.0%
New Mexico	268	Minnesota	3,235	Idaho	16.2%
North Dakota	258	Oregon	3,153	Vermont	15.4%
Minnesota	200	Washington	3,075	Colorado	14.2%
California	194	Colorado	2,965	Oregon	11.3%
South Dakota	175	North Dakota	2,143	Maine	10.5%
Maine	173	Indiana	1,895	Texas	10.0%
Indiana	150	New York	1,749	Nebraska	8.0%
Nebraska	80	Michigan	1,531	Wyoming	7.7%
Arizona	30	Wyoming	1,410	Montana	6.6%
Maryland	30	Pennsylvania	1,340	Washington	6.5%
New Hampshire	14	New Mexico	1,080	New Mexico	6.3%
Ohio	8	South Dakota	977	California	6.2%
Connecticut	5	Idaho	973	Hawaii	6.1%
New York	1	Nebraska	890	Illinois	5.5%
Rest of U.S.	0	*Rest of U.S.*	5,203	*Rest of U.S.*	1.0%
TOTAL	**8,598**	**TOTAL**	**73,992**	**TOTAL**	**4.7%**

[11] * Based on 2015 wind and total generation by state from EIA's *Electric Power Monthly*.

From a United States political perspective, it is important to note that politically "less-liberal" states in the United States, such as Iowa and Texas lead the economy in percentage of electricity generated (Iowa) and total installed capacity (Texas). Thus, there are economic reasons for installation of wind systems that go beyond a simple focus of carbon reduction.

It is important to note that states that have clearly developed policies that go along with federal tax incentives and reasonable wind regimes will have increases in wind energy systems. Clearly developed governmental policies provide a level of certainty to energy developers and other participants. Thus, these clear policies will allow utilities, project developers, technology providers, and, perhaps most importantly, the banking and investment community to work together to develop project which, as shall be seen, can take years to come to fruition.

States that are more aggressive in pursuing more stringent RPS goals have specific political agendas to reduce carbon emissions that reinforce the level of certainty. The following three sections will discuss case studies in three states with aggressive renewable portfolio standard policies, one in California, one in Hawaii and one in New York State.

IV. California Case Study – a Cautionary Tale

IV.A. Introduction and Background

Geographically, California is much like Viet Nam. It is a long state (over one thousand miles from north to south), but is relatively narrow (about 200 miles from east to west). Thus, it would be assumed that the case study for this state would be most appropriate for Viet Nam. However, as will be discussed in this section, certain local requirements and environmental laws make the California experience less applicable to Viet Nam. Of particular note is the fact that all siting approvals are made by a county – not the state. Thus, the approach taken in California may make less sense to a more centralized economy. The only major state action is to approve the Power Purchase Agreement between the wind developer and the electric utility. The California Public Utility Commission does this approval process. The approach to the approval process is summarized in the below.

The wind program is part of the state Renewable Portfolio Standard (RPS) program established in 2002 under Senate Bill 1078, accelerated in 2006 under Senate Bill 107 and expanded in 2011 under Senate Bill 2. California's RPS is one of the most ambitious renewable energy standards in the economy. The RPS program requires investor-owned utilities (IOUs), electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources to 33% of total procurement by 2020. In 2015, SB 350 expanded the RPS to 50% by 2030. The three Investor Owned Utilities (IOUs) are well on their way to meeting the goals for 2020 (Table 2).

Table 2. Renewable Procurement Status Percentages

Actual RPS Procurement Percentages in 2014	**Current RPS Procurement %**
PG&E- 28.0 %	PG&E- 37.0%
SCE – 23.2%	SCE – 36.9%
SDG&E - 36.4%	SDG&E - 43.1%

California's three large IOUs collectively served 22.7% of their 2013 retail electricity sales with renewable power. (Note the increase that has occurred in just one year.) As noted in this status report, there are currently (as of February 2016) 124 renewable energy projects that are operational and meet the legislative requirement under California's RPS program. This listing is too voluminous to reproduce in this report, but is accessed through the CPUC's RPS home page, http://www.cpuc.ca.gov/RPS Homepage/ where the additional project information for the large IOUs that can be found by downloading the latest RPS Monthly Project Status Table (updated February 24, 2016).

The California Public Utilities Commission (CPUC) implements and administers RPS compliance rules for California's retail sellers of electricity, which include IOUs, electric service providers (ESP), and community choice aggregators (CCA). Note that the CPUC does not regulate publically owned utilities, such as Los Angeles Department of Water and Power.

The California Energy Commission (CEC) is responsible for the certification of electrical generation facilities as eligible renewable energy resources, and adopting regulations for the enforcement of RPS procurement requirements of Publicly Owned Utilities (POUs), such as LADWP and Sacramento Municipal Utility District (SMUD).

The California Independent System Operator (CAISO) is responsible for ensuring that generation meets load requirements. In that aspect, they are also responsible for ensuring that new generators are meeting power quality and other related requirements for connecting to the grid.

IV.B. California Case Study – Hatchet Ridge

Hatchet Ridge is located along a ridge top spanning an area of roughly 2,700 acres in Shasta County, CA on land owned by two private landowners, with whom long-term lease arrangements were developed. The developer is Pattern Energy, based in San Francisco. As noted in the previous section, it was Shasta County administrators who approved this facility's permit. Hatchet Ridge is a 101 MW project located in Burney, California. The project consists of 44 2.3 MW Siemens turbines and commenced commercial operations in December 2010.

The California Public Utility Commission (CPUC) approved the project in February 2009. The project sells 100% of its electricity generation to Pacific Gas and Electric Company (PG&E) under a 15-year power purchase agreement that expires in 2025. The Hatchet Ridge project is connected to the PG&E transmission system and is situated where it can utilize large transmission lines that connect the hydropower in the Pacific Northwest with California. The contracted price is $103.25/MWh. It is anticipated that the contract will be met by providing PG&E 303 GWh/year.

Note that, in addition to the two-party contractual arrangement between PG&E and Hatchet Ridge Wind LLC, CAISO also entered into the decision-making process for delivery of electricity based on overall grid-wide requirements. More information related to these somewhat complicated interactions can be found in the docket, which authorized the approval of the project. (Resolution E-4222 – wherein PG&E requested approval of a renewable resource procurement contract with a new renewable facility, which resulted from PG&E's 2005 Renewables Portfolio Standard (RPS) solicitation. This contract was approved without modification by the CPUC.

Figure 6. Site Location

IV.C. An Uncertain Future for California Renewables

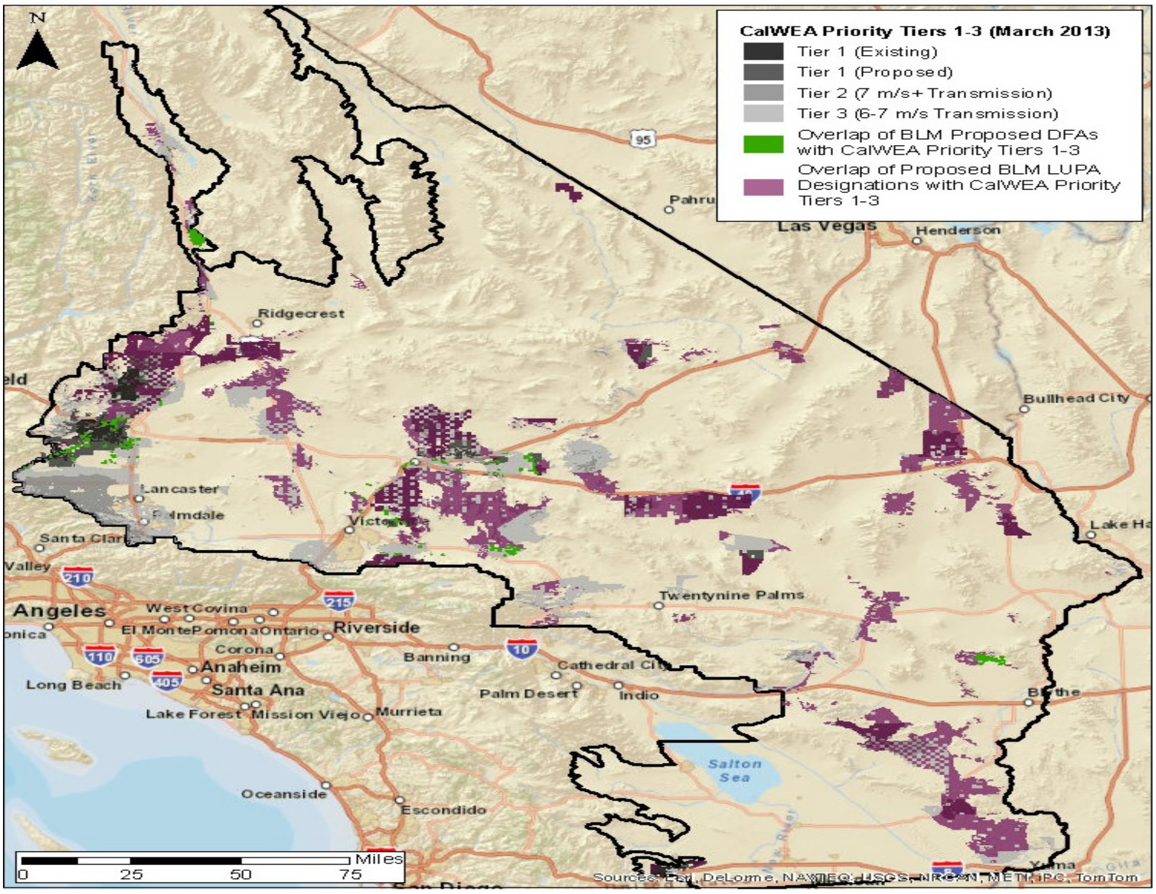
IV.C.1. Desert Renewable Energy Conservation Plan

Despite the goal of 50% electricity delivered to end-users by 2030 (which does not count residential and commercial solar production or large-scale hydropower), there are new impediments, primarily in the form of environmental restraints that may inhibit more large-scale development of renewable energy systems. Two of these new laws and regulations are worth noting.

A new plan recently released by the federal Bureau of Land Management (BLM) focuses on a vast resource area that offers many prime sites for renewable energy growth in Southern California. This plan has outlined a different approach to balancing environmental impact with renewable energy development: a system of "no-go" zones, which threatens to lock up most of the promising sites for wind energy for decades.

The California Wind Energy Association (CalWEA) notes that a number of sites in the southeastern desert of California will now be off-limits to wind (or solar) energy development. (Figure 7.)

Figure 7. California Land Restrictions Facing Wind Energy



The plan, called the Desert Renewable Energy Conservation Plan (DRECP), states a planning goal of 20,000 megawatts (MW) of new renewable energy, yet is expected to dramatically limit the amount of new renewable energy growth in Southern California.

The DRECP planning area is vast, approximately 22 million acres. But, while the BLM plan provides nine million acres for conservation and recreation, it provides less than 400,000 acres for renewable energy exploration, and will allow a maximum of just 121,000 acres for actual renewable energy development.

The plan puts approximately three million acres that had been available for solar and wind development completely off-limits. The limited area for renewable energy provided for by BLM will therefore make it difficult to achieve the California planning goal of 20,000 MW of renewable energy. It should also be noted that developing desert land in Nevada – and transmitting electricity to California – faces similar challenges due to federal regulation as BLM Solar PEIS imposes similar restrictions on solar.

IV.C.2. Native Americans Environmental Quality Act

California is home to many numerically small (in population) Native American tribes. Unlike large-scale reservations, such as those for the Navajo and Comanche, the lands of the California tribes are numerous, but small in size and population. This reflects the nature of these peoples prior to Europeans coming to California. As a result, that while these tribes are numerically small, they are as a group politically powerful politically powerful. This has lead to the passage in 2014 of the Native Americans Environmental Quality Act (NAEQA) that is modeled along the lines of the California Environmental Policy Act (CEQA). CEQA, in turn is more rigorous than federal regulations under the Environmental Quality Act (NEPA).

This law requires that public agencies must try to avoid damaging effects to any tribal resource. From the standpoint of wind energy developers, NAEQA is a dramatic expansion of CEQA that, as a practical matter, grants Native American Tribes broad, irrefutable authority to determine anything is a Tribal Cultural Resource entitled to CEQA protection. The current language presents significant obstacles for new public and private development across the state and opens up new avenues for CEQA litigation.

Because NAEQA leaves the definition of what constitutes a Tribal Cultural Resource so open ended, it will dramatically expand the frequency that Tribal Cultural Resources become an issue for public projects throughout the state, particularly in areas where there is good wind resource potential. The costs of the CEQA evaluation and unavoidable litigation spawned by the law's ambiguity will be borne potential developers.

In conclusion, this new law will create a disincentive to invest in land, whether it is to build affordable housing, build public schools and universities, or construct needed public infrastructure projects such as renewable energy projects, or roads and highways.

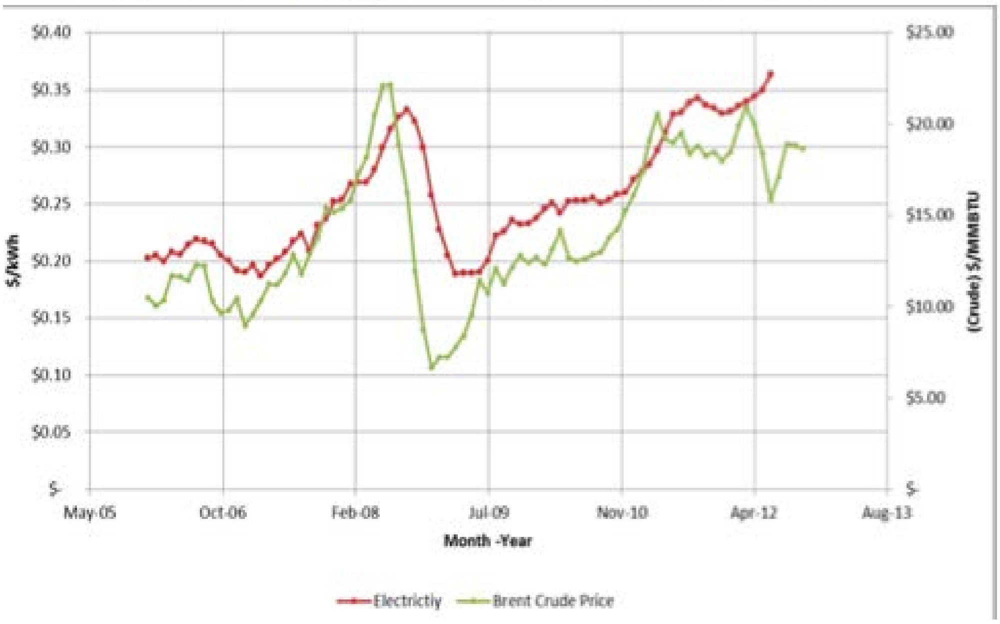
V. Hawaii – A Case Study

V. A. Introduction and Background

The Hawaiian Islands are the most isolated heavily populated area in the world. While there are considerable renewable resources, the state has, to date, been primarily reliant on fossil fuels and, in particular, oil. As a result, electricity prices track the price of petroleum. In the recent past, this has meant that some Hawaii counties (Maui, Kauai, and the Big Island of Hawaii) have electricity prices well over 40 cents/kwh – over twice what these prices are for the continental United States.

Figure 8. Electricity and Oil (Low Sulfur Fuel Oil) Prices for Hawaii

Figure 2: Electricity Price Compared to Crude Oil Price



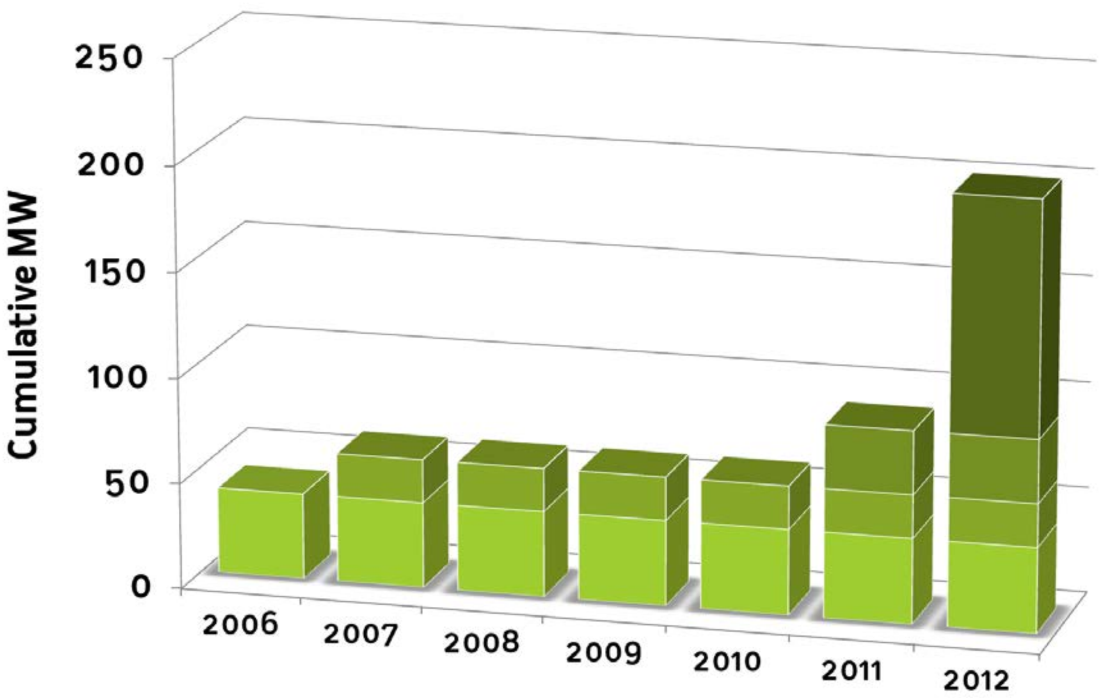
However, in 2008, with the support of the US Department of Energy, Hawaii launched the Hawaii Clean Energy Initiative (HCEI). The goal is to reduce fossil fuel usage by 70% between 1990 and 2030. For the electric utility sector, the 70% goal is to be achieved by a 30% improvement in energy efficiency and 40% conversion from fossil fuel to renewable resources. The aggregate goal includes both the transportation and electricity sectors. As a result there has been considerable effort to expand all renewable resource development.

In 2008, over 90% of all electricity generated in the state of Hawaii was from fossil fuels. With the exception of one coal-fired power plant on Oahu, all of this power came from oil-fired (or smaller diesel-fired) power plants. In 2008, the peak load on Oahu was almost 1500 MW. Due to efficiency advances and residential solar (photovoltaic) power, the peak load in 2015 was less that 1200 MW.

While the recent decade has seen an exponential increase in residential and commercial solar, wind has also continued to grow. While Figure 9 is slightly out of date, it demonstrates the rapid increase in wind-generated electricity in the state. There is now almost 300 MW of wind energy capacity in Hawaii, with over 100 MW on Oahu. Approximately 200 MW of wind energy capacity have been added since the start of HCEI.

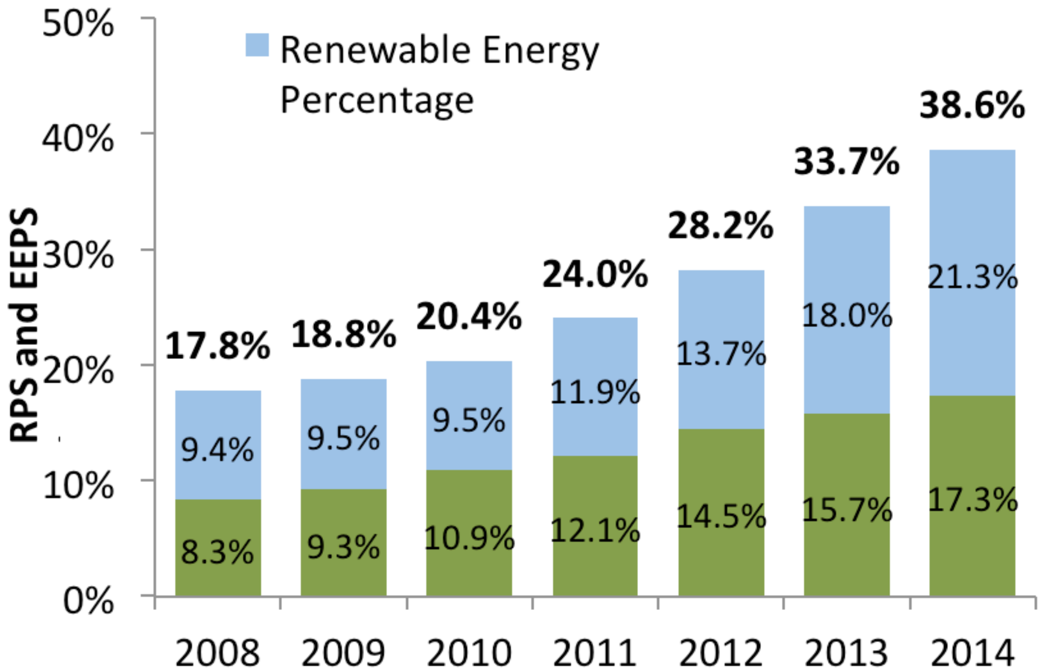
The island of Oahu effectively had no wind power at the onset of the HCEI program. This island is the major load center, including the city of Honolulu, and is the subject of our case study.

Figure 9. Installed Wind Capacity in Hawaii (through late 2012)



This effort to develop more wind, coupled with the installation of new utility-scale solar energy farms, the expansion of the H-Power waste-to-energy facility, and development of biomass facilities on both Oahu and the Big Island, has allowed the state to be ahead of its interim HCEI goals. These goals are also being met, as stated earlier, by the dramatic increase in residential and commercial on-site solar energy. These are all part of the previously developed state law for Renewable Portfolio Standards (Figure 10). Since it's passage last decade, it has been amended twice to reflect the fact that the RPS goals are being met sooner than anticipated.

Figure 10. Hawaii Goals and Accomplishments for RPS and EEPS



Source: Renewable Portfolio Standards Reports, 2008-2014 (Hawaii Public Utilities Commission. KIUC not included pending KIUC's Annual RPS Status Report for year ending 2014.

V.B. Kaiwaloa Wind Farm – Case Study

V.B.1. Introduction

The following section discusses the competitively awarded project that followed the winning Independent Power Producer's (IPP) submission in response to the Hawaiian Electric Company (HECO) request for proposal (RFP) to supply renewable electricity to the Oahu grid. This case study is informative for Viet Nam as it demonstrates the significant time involved to develop competitive proposals and then have that followed by rigorous review by the utility and the regulators. The original RFP was approved by the HPUC for the utility to put out for bid in June 2008.

The successful bidder was Kaiwaloa Wind, LLC. Due to various aspects of American litigation, First Wind, Inc. (the developer), formed a limited liability corporation (LLC) as signatory with the HECO for the Power Purchase Agreement (PPA). Thus, Kaiwaloa Wind, LLC, is related to First Wind, with a minority interest held by Makani Nui Associates, a Hawaii-based LLC. Thus, the LLC was developed with the express purpose of developing a wind power facility at Kamehameha Schools' Kawailoa Plantation.

The negotiations between the successful bidder and HECO lasted for about six months from April 2011 until September 2011. During that time, HECO and Kaiwaloa Wind agreed upon a price and length of service. The agreed upon levelized (busbar) price was 23 cents per kilowatt-hour. The term of service was from the start-up date of 2012 until at least 2032.

V.B.2. The Regulatory Approval Process

Following negotiations between HECO and Kaiwaloa Wind, the PPA was submitted to the Hawaii Public Utilities Commission (HPUC) for their review and approval. HPUC filed the docket (Docket Number 2011-0224) for approval of the proposed Power Purchase Agreement (PPA) between them. The filing date was September 23, 2011.

To give a sense of necessary documentation, this filing was 307 pages long (similar to the filing submitted by Hatchet Ridge in California).

The proposed PPA agreement needed to be filed with the HPUC, since the State had to rule on and provide the overall approval to the PPA so that:

1. Finding that the purchased energy charges to be paid by Hawaiian Electric pursuant to the PPA are just and reasonable;

2. Finding that the purchased power arrangements under the PPA, pursuant to which Hawaiian Electric purchases energy on an as-available basis from Kaiwaloa Wind, are prudent and in the public interest;

3. Authorizing HECO to include the purchased energy charges (and related revenue taxes) that they incur under the PPA through Hawaiian Electric's Energy Cost Adjustment Clause ("ECAC") to the extent not included in base rates (Note that the ECAC is also used to adjust prices based on the cost of the low sulfur fuel oil received by the utility;

4. Determining that the 46 kV line extensions included as part of Company-Owned Interconnection Facilities should be constructed above the surface of the ground. (Note that this is true in many jurisdictions in the continental United States, as either the utility or the developer needs to construct power lines that will connect the renewable energy resource to the rest of the grid. Further, these costs [approximately $18 million US] were borne primarily by Kaiwaloa Wind as part of the contractual agreement); and

5. Grant such other (financial) relief as may be just and reasonable under the circumstances.

Between the time that the docket proceeding was started in September 2011 and when the project was approved by the HPUC (and the docket closed), there were twenty-five substantive communications concerning this project. A number of these communications were from the Office of Consumer Advocate. This agency, which is within the HPUC, is charged with ensuring that the electricity rates are reasonable for the end users (rate payers). To give a sense of this interaction, some selected Consumer Advocate comments follow:

- "[I]f this and any other renewable energy project are judged primarily or solely based upon a price comparison to avoided costs, the result will be a rejection of these projects" – cost to ratepayer
- "The State of Hawaii needs renewable energy immediately and that the Commission cannot wait until fossil fuel prices increase significantly before approving renewable energy projects." – government policy

- "The [Kawailoa] project is consistent with the North Shore Sustainable Communities Plan and the community efforts of Kamehameha Schools." – social impact

In 2012, the HPUC approved this PPA under docket 2011-0224 in the decision #30012 on December 12, 2012. The approval allows for the operation of this facility until 2032.

V.B.3. Steps Following Regulatory Approval

Once a Power Purchase Agreement (PPA) was signed between Kaiwaloa Wind and HECO, HECO was proactive in working with the wind energy provider on resolving any outstanding societal and environmental issues in preparation for review and approval by the HPUC.

For example, the facility is on Kamehameha Schools property and, therefore, is a collaborative effort for working with local community leaders. HECO also worked with Kaiwaloa Wind to ensure that social issues, such as setbacks for noise pollution, and environmental issues, such as developing plans to curtail power during bat mating season (protected under the Federal Threatened and Endangered Species Act), were addressed.

Following approval, other more practical issues between HECO and the IPP could be addressed. In particular there was a need to coordinate activities on many logistics issues. For example, moving the very large turbine blades into place required approval by other state and local authorities to block roads due to the very long "wing span" of the turbine blades. Another practical issue was working with the military in Hawaii to ensure that installation and operation of the facility did not interfere with United States Army helicopter training area, which was located nearby.

It should be noted that, in the Western United States, a very large amount of land owned by the US government (over 70% in Nevada), primarily the Bureau of Land Management, creates additional issues in the ability to site large wind farms as discussed in the California example.

A substantive practical issue related to the grid is the ability of the transmission lines to accept the electricity produced by the wind farm. For the continental United States, this issue is addressed by Independent System Operators (such as the California ISO) or Regional Transmission Operators (such as PJM). However, in Hawaii, no such authority exists, thus HECO works directly with the IPP to develop a plan for the proper delivery of electricity. In the case of Kawailoa, this requires that 50MW of capacity be delivered on one line, while the remaining 19MW are delivered on another line.

The facility's capacity is 69 MW. This facility consists of thirty Siemens wind turbines (rated at 2.3MW apiece that are mounted on 99.5 meter towers). These turbines can control voltage on their own and, thus, provide greater stability and improved power quality to the grid. HECO system operators stated that they like the way these turbines operate, but do note flicker issues above 50 MW.

When this application was made, the utility was eligible for the Federal Investment Tax Credit of 30%, which then could also provide benefit to the ratepayers with lower electricity rates. The original proposed agreement that was submitted to the HPUC requested that the contracted payment rate be $205.40/MWh in 2012 (20.54 cents/Kwh) escalated at 1.75% annually. The final decision by the HPUC delayed the cost escalation by one year.

In summary, the time between when the RFP was released in 2008 to the approval by the HPUC in 2012 was four years. Then, as noted above, permits (environmental, building, etc.) needed to be obtained for the actual construction and development of the site. The Kawailoa Wind Farm came on line in 2014, six years after the RFP was issued.

Figure 11. Kaiwaloa Wind Farm on the North Shore of Oahu

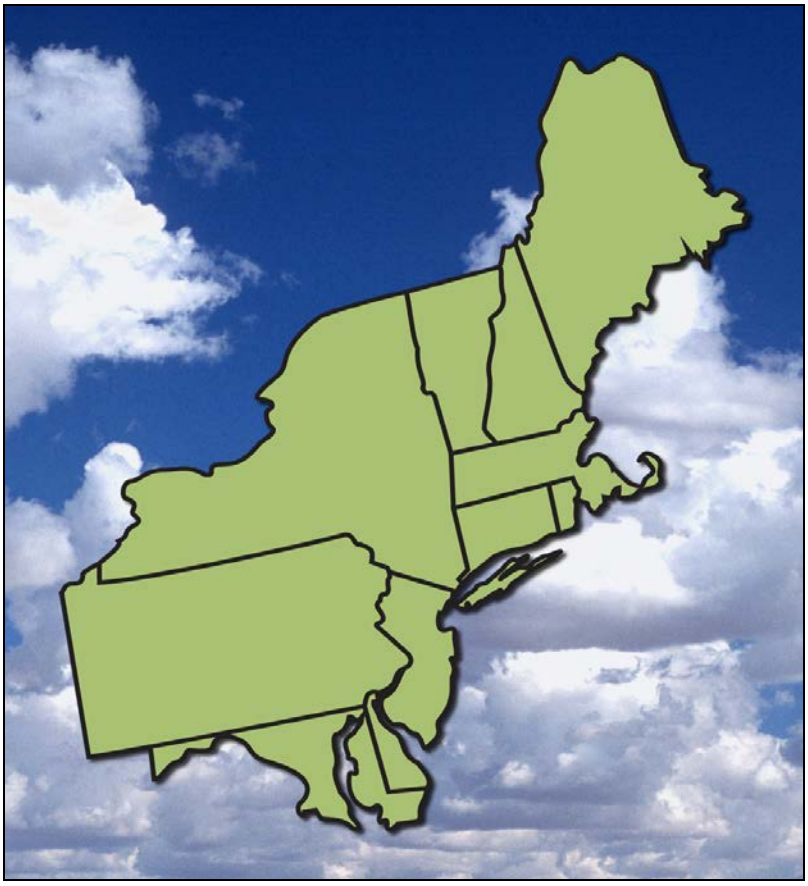
VI. New York State Case Study

VI.A. Background

In 2004, New York established a Renewable Portfolio Standard as a policy to increase the amount of renewable energy used by New York consumers. Last year, the New York Public Service Commission, acting on a goal set by Governor David Paterson, expanded the RPS goal to increase the proportion of renewable electricity sold in New York from 25 percent to 30 percent by 2015. To meet this goal, since 2000 NYSERDA has conducted competitive solicitations to award contracts for projects that deliver renewable energy to the New York wholesale power market.

New York State also took pioneering steps in 2008 to address greenhouse gas emissions related to energy. New York also became a charter member of a cooperative effort by nine Northeast and Mid-Atlantic States called the Regional Greenhouse Gas Initiative (RGGI). RGGI was the first mandatory, market-based effort to limit greenhouse gas emissions in the United States.

Figure 12. States Participating or Have Participated in RGGI



Proceeds from auction and trading of carbon dioxide allowances help fund some of NYSERDA's programs. (It should be noted that, since RGGI was instituted, California has adopted a cap-and-trade regime that now includes other political divisions, such as the Province of Quebec in Canada.) In 2016, RGGI continued to demonstrate success. About $1.8 billion was received by the participating states by selling carbon credits. New York State received $728 million of that total.

In addition to NYSERDA, the New York Independent System Operator (NYISO) must also be part of any approval process for developing large-scale wind farms that will be linked to the grid. Currently, in May 2016, the NYISO load is almost 23 GW. Peak load in the summertime is approximately 40 GW.

In 2006, NYSERDA began its On-Site Wind Turbine Incentive Program with a Request for Proposal (RFP). The Maple Ridge Wind Farm was one of the winning bids. In order to push for rapid development of wind energy in the state, NYSERDA paid 50 percent of the total installed cost of the wind energy system to eligible installers. The installer must pass the entire incentive through to the electricity end-user. Thus, Maple Ridge was able to take advantage of this program to install the first large wind energy farm in the state, since all previous wind farms were relatively small projects.

VI.B. The Maple Ridge Project

Maple Ridge Wind Farm commenced operations in 2006 in Lewis County, a rural county in northern New York State. As the first large wind farm in the state, it has 195 Vestas model V82 1.65 megawatt (MW) wind turbines, with the turbines having a rated or nameplate capacity of 320 MW.

Maple Ridge Wind Farm is a joint venture between Horizon Wind Energy (based in Houston, Texas, part of the EDP Renováveis group) and Iberdrola Renewables (based in Portland, Oregon). Horizon Wind Energy and Iberdrola Renewables worked together to develop, finance, construct and sell the power from Maple Ridge Wind Farm.

Horizon Wind Energy managed the construction of Maple Ridge, with civil construction activities led by DH Blattner and Sons; electrical construction led by Alliant Energy Corporation; wind turbine installation led by Vestas-American Wind Technology; and power scheduling led by Iberdrola Renewables.

The Maple Ridge project is situated at the eastern edge of the Tug Hill plateau, an area that frequently experiences strong lake-effect weather and has long been known for its exceptional snowfalls and as a wind resource. The Wind Farm area includes the towns of Lowville, Martinsburg, Harrisburg and Watson in Lewis County, New York on the Tug Hill Plateau, about 75 miles northeast of Syracuse (Figure 11).

Figure 13. Map of Maple Ridge Wind Farm Location

Maple Ridge Wind Farm’s 320 megawatts (MW) capacity provides energy to supply the annual electricity needs of 96,000 New York homes. The electricity produced by Maple Ridge Wind Farm flows directly into the New York state energy grid. Renewable Energy Credits (RECs), the clean environmental attributes of wind power, are contracted to the New York State Energy Research and Development Authority (NYSERDA) and to the New York Power Authority (NYPA) and various third parties.

Maple Ridge construction brought over $55 million into the local economy through the purchase of local materials and supplies for access road and turbine foundation construction. In addition, construction of the Wind Farm created over 400 construction jobs, the vast majority of which were filled by New York-based employees. Operation of the Wind Farm has created 35 full-time local jobs and brings annual revenue payments of over $1 million to the landowners involved. The 320 MW facility provides annual tax payments to the municipalities, county, and school districts that are millions of dollars annually, including more than $2 million to three local schools. When it came on line, Maple Ridge increased the amount of wind power in New York by 600 percent.

While the entire project area spans approximately 21,000 acres, the actual footprint of the turbines uses less than one percent of the total acreage. Landowners will continue using the remainder of the land for pastures, timberland, farming, and leisure activities. The view of the project is shown in Figure 12.

Figure 14. Maple Ridge Wind Farm

In order to demonstrate their commitment to the environment, the Maple Ridge Wind Farm and its owners, Iberdrola Renewables, LLC and Horizon Wind Energy are conducting the most extensive post-construction avian and bat mortality studies ever performed at an eastern United States wind project.

VI.C. Recent Regulatory Developments

Based on knowledge gained from the early development of wind power in New York State, new regulations were developed to make the process of siting and constructing wind farms more efficient. Thus, in a significant reform aimed at encouraging investment in clean energy technology, Governor Andrew Cuomo on August 4, 2011, signed into law the Power New York Act of 2011, Chapter 388 of the Laws of 2011, enacting Article 10 of the Public Service Law, establishing a unified siting review process for major electric generating facilities. This was for electricity generation facilities with a capacity of 25 MW or more. The New York Department of Public Service and the New York Department of Environmental Conservation adopted implementing regulations on July 17, 2012: Chapter X Certification of Major Electric Generating Facilities, 16 NYCRR Part 1000 and Analyzing Environmental Justice Issues in Siting of Major Electric Generating Facilities, 6 NYCRR Part 487. After July 17, 2012, all applicants for permits to construct major electric generating facilities must follow Article 10. In addition, applicants who had applied for permits or licenses before that date, along with applicants for permits or licenses for certain other types of electric generating facilities excluded from Article 10, may elect to follow Article 10.

New York developed these regulation to respond to an electric industry is in transition. Technological innovation and increasing competitiveness of renewable energy resources, combined with aging infrastructure, extreme weather events, and system security and resiliency needs, are all leading to significant changes in how electricity is generated, distributed, managed and consumed. New York State must lead the way to ensure these trends benefit consumers, whose lives are so directly affected by how they procure energy.

The availability of reliable, resilient, and affordable electric service is critical to the welfare of citizenry and is essential to New York's economy. To ensure continuing economic growth and prosperity for New York, Governor Andrew M. Cuomo laid out an ambitious energy agenda for the State in 2015, with the Public Service Commission (PSC) playing an important role in crafting the significant regulatory changes needed to make the Governor's agenda a reality.

Under Governor Cuomo's "Reforming the Energy Vision" (REV) strategy, New York is actively spurring clean energy innovation, bringing new investments into the State and improving consumer choice and affordability. In its role, the PSC is aligning markets and the regulatory landscape with the overarching state policy objectives of giving all customers new opportunities for energy savings, local power generation, and enhanced reliability to provide safe, clean, and affordable electric service.

The REV initiative will lead to regulatory changes that promote more efficient use of energy, deeper penetration of renewable energy resources such as wind and solar, wider deployment of "distributed" energy resources, such as micro grids, roof-top solar and other on-site power supplies, and storage. It will also promote markets to achieve greater use of advanced energy management products to enhance demand elasticity and efficiencies. These changes, in turn, will empower customers by allowing them more choice in how they manage and consume electric energy.

The preceding section is presented as an example for one state in terms of how the state must proceed to meet future requirements of the grid. A discussion of future United States utility business models, while beyond the scope of this paper is reflected in this New York legislation

VII. Summary Discussion of Case Studies

The preceding case studies are different in many ways. However, there are a few common themes that should be repeated in this summary section. Some of these may be more pertinent to Viet Nam than others, but should be highlighted anyway.

1. There should be approved government goals that the utility and the wind energy developer, and the banking and investment sector understand. This is because government goals create a level of certainty for energy developers. This certainly allows them to have a greater level of comfort in making decisions that will require a lot of capital investment.
2. There should be a clear regulatory process for both the utility and the wind energy developers. If this is the case, all parties involved in the development can plan based on the anticipated amount of time it will take to obtain all of the necessary permits and approvals for the wind energy systems.

3. It is critical for the wind energy developer to be working with the electric utility as soon as early contractual agreements are signed. This is because a significant amount of work will need to be done by both parties to ensure a timely project completion. This work would include development of all necessary supporting grid related systems that would allow for the connection of the wind site to the grid.
4. For the United States, many independent power producers need to be part of a limited liability corporation (LLC). This was true for all three case studies, but may not be necessary in Viet Nam.
5. Government subsidies are important. As shown in these three cases, subsidies can take two forms. In the case of New York, the state provided funding for the construction of the project. In the cases of Hawaii and California, it was more of an indirect subsidy being promoted by government policy, understanding regulators, and state-based tax programs. The regulators (Office of Consumer Advocate) were accepting of the fact that the electricity costs for wind were more expensive that those for fossil-fired systems. In all cases, having a federal production tax credit allowed the projects to go forward.
6. All three states recognized that changes would continue for the electricity grid, being most evident in New York. In this instance, governments must recognize that the centralized model for electricity generation and distribution may change over time. Thus, utility business models may change. The point will be to ensure that:
   a. Utilities, as private sector companies, can be profitable
   b. The electricity prices for end users are reasonable
   c. Regulations are flexible enough to continue to adapt to technological advances.

These six items are some summary highpoints. In addition to these common themes, there are other aspects covered in each of the sections that are specific to each individual state. In conclusion, it will be important for Viet Nam to determine which processes and approaches are useful to them and which are not.

CASE STUDY

NEAR-SHORE WIND PROJECT DEVELOPMENT IN VIET NAM

(Draft) Report APEC

Submitted by research team:

Nguyen Huong Tra

Nguyen Duc Cuong

May 2016

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Abbreviations

CapEx	Capital Expenditure
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFADS	Cash Flow Available for Debt Service
CO_2	Carbon dioxide
DSCR	Debt Service Cover Ratio
EVN	Electricity of Viet Nam
FiT	Feed in Tariff
GDP	Gross Domestic Product
GE	General Electric
GHG	Green House Gas
GIS	geographic information system or geographical information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IPP	Independent Power Producer
IRR	Internal Rate of Return
LCOE	Levelized Costs of Electricity (equivalent LEC)
LEC	Levelized Electricity Cost (equivalent to LCOE)
LCR	Local Content Requirement
O&M	Operation and Maintenance
OpEx	Operational Expenditure
PDP	Power Development Plan
PM	Prime Minister
PPA	Power Purchase Agreement
PPP	public private partnership
PV Power	the PetroViet Nam Power Corporation
PV solar	Photovoltaic solar

RE	renewable energy
REDF	Renewable Energy Development Fund
REVN	the Vietnamese Renewable Energy Joint Stock Company
USD	US Dollar
VDB	Viet Nam Development Bank
VND	Vietnamese Dong
WACC	Weighted Average Cost of Capital
WB	World Bank
PIRR	Project Internal Rate of Return
EIR	Equity Internal Rate of Return

Units:

GW	Giga Watt
GWh	Giga Watt hour
km	Kilometer
kV	Kilo Volt
kW	Kilo Watt
kWh	Kilo Watt hour
m	Meter
m/s	Meter per second
MW	Mega Watt
MWh	Mega Watt hour

Vietnamese Institutions:

IE	Institute of Energy
DOIT	Department of Industry and Trade (at the provincial level)
DONRE	Department of Natural Resources and Environment (at the provincial level)

DPI	Department of Planning and Investment (at the provincial level)
MOF	Ministry of Finance
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
PC	People's Committee
PPC	Provincial People's Committee

Executive Summary

According to the domestic power development plan period 2011-2020, with vision to 2030 and revision according to Decision No. 428/QD-TTg dated 18 March 2016 by Prime Minister of the Government, total capacity of wind power will increase from present level of 135 MW to 800 MW in 2020, 2000 MW in 2025, and 6000 MW in 2030. In order to support wind power development, series of preference policies are developed with introduced FiT of 7.8 UScent/kWh as specified in Decision No. 37/2011/QD-TTg.

Cong Ly wind power plant in Bac Lieu province is a nearshore project, however, FiT is not applied according to Decision No. 37/2011/QD-TTg for this project but temporarily calculated tariff is 9.8 UScent/kWh. Therefore, it is very difficult to have general picture of wind power development at present in Viet Nam when many investors considered that present electricity tariffs are not attractive and it needs to increase if Government wants to achieve set target of wind power development.

With support from a study of GIZ, Germany, one new FiT of 11.2 UScent/kWh for nearshore wind power projects was proposed to the Ministry of Industry and Trade at the end of 2014. However, so far it is not approved yet. At present, there are some studies in more details, for projects in operation are being conducted in order to clarify FiT proposed in 2014.

Report of this case study will focus on analysis, evaluation of only one existing nearshore wind power project in Viet Nam. Details of analysis and evaluation include comparison of estimated data (from consultant preparing F/S report, suppliers of wind turbines, appraisal agency on loan) with actual operation data of each wind turbine and wind farm. Arrangement of wind turbines of wind farm related with output of each turbine is also reviewed and factors relating to cash flows of the project are also simulated based on reliable data.

Apart from the above mentioned Chapter, the report also presents situation of Viet Nam power sector development, potential of wind resource and orientation of wind power development. Present challenges to wind power development are also reviewed and included in one detailed analysis and evaluation. Reasons for wind power development, reasons for Government to support wind power development are also presented.

However, it is noted that though all 62 wind turbines of Cong Ly coastal wind power plant have been installed but actual operation data are available for only 16 turbines (only those turbines which were in operation for at least 1 year are considered as qualified for data to be used in comparison, analysis and evaluation).

1 Introduction

1.1 Background

There is an increasing focus on the development of alternative energies, given the urgent needs for combating climate change and reducing CO_2 emissions, and at the same time for fueling economic growth. The Asia-Pacific Economic Cooperation (APEC) is home to 21 member economies of diversified development levels but on fast growth in common. Reliable sources of energy remain important to all member economies for the shake of stability and prosperity.

Accounting for around 60 per cent of world energy demand, the APEC region includes four of the world's five largest energy users, namely China, the United States, Russia and Japan. According to the Asia Pacific Energy Research Centre (APERC) Publication, by 2035, APEC members' demand for energy is forecasted to increase by 34% above 2013 levels. The region includes some of the world's most energy-intensive users and some of the fastest growing energy users such as China and South-East Asian economies. These factors make energy cooperation an increasingly important agenda item for APEC. Collaboration on energy aims to help progress towards two specific aspirational goals announced by APEC Ministers and Leaders, specifically:

(i) to double the share of renewable in the APEC energy mix, including in power generation by 2030, as set out in the 2014 APEC Economic Leaders Declaration; and

(ii) to reduce APEC's aggregate energy intensity by 45% from 2005 levels by 2035, as set out in the 2011 APEC Economic Leaders' Declaration.

Bearing in mind these goals, APEC is working hard to develop different forms of renewable energy (RE) and to increase the impetus behind energy efficiency policy.

At present wind energy is the most prominent form of renewable energy being developed in the APEC region, thank to its large wind potential and rapid technological advancements. Though awareness of the importance and advantages of wind energy is raised, it is still difficult to produce wind energy on a large scale and/or to reduce the price. Firstly, wind energy features unstable source and is only feasible in certain geographical areas which have plenty of wind and spacious land, and hence, it is not easy to apply widely. Secondly, it requires high and complicated technology to deploy wind energy on a large scale. Thirdly, it is quite expensive because of high maintenance cost and limited use.

In this context, APEC is implementing the Project EWG 24 2015A to contribute to its shared green growth and energy cooperation objectives through information and experience sharing on best practices in wind energy development from the APEC region.

1.2 Scope and approach

This report features the case of Viet Nam on wind energy development. It is one among a series of case studies developed in the Project EWG 24 2015A by a number of APEC member economies, specifically New Zealand, Thailand, the United States and Viet Nam.

and at a later stage, holding a seminar to disseminate the outcomes of the case studies, information will be exchanged on wind energy development, raising understanding and awareness of opportunities for wind energy development among APEC economies. In addition, experiences, lessons and opinions on balancing economic, environmental, and social objectives whistle developing wind energy will also be shared. The practices and experiences shared on the selected cases among APEC members are expected to help the member economies promote and facilitate wind energy development in their home economies, and help APEC to explore effective and appropriate ways to further develop this renewable energy source.

Wind energy in Viet Nam is developed for multiple purposes, ranging from water pumping, cereal milling to electricity generation. This report only outlines the deployment of wind energ for electricity generation. Wind energy for other purposes is out of the scope of this stud. There are two types of wind power plants in Viet Nam: grid-connected plants and offgrid (unconnected) plants. The offgrid plants often have very small installed capacity and are supposed to serve research purposes or limited areas with difficult access to the domestic grid. They are not included in this study, either. The scope of this case study is confined to grid-connected wind power projects in Viet Nam.

There have been only three wind power projects operational and grid-connected so far. A dozen of other projects are still in various stages of development. Taking into account the number of projects and the implementation progress, the Vietnamese research team decided to take the qualitative approach for the study. It first described in greater details the wind power plants which have been completed and grid-connected. Opinions of investors of the incompleted wind power projects and information from investors in other forms of energy and the government were used to outline the challenges and expectations for wind power development, including those related to policy making. And then the study especially drilled down on the Bac Lieu wind power project as a typical case of best practices. With special features of a nearshore project, the Bac Lieu case can give important implications to private investors, technical and financial experts, research community and policy makers. The best practices and lessons learned from this case can be disseminated and applied at different levels in Viet Nam and in the APEC region.

1.3 Objective of the case study

The case study of Viet Nam aims at two specific objectives as follows:

- To explore good practices in wind energy development in Viet Nam and raise understanding on various aspects of wind energy development, including, the role and forms of legislations and regulations, how stakeholders (the public sector, investors,

non-governmental organizations (NGOs), local communities, etc.) react to environmental and social impacts of wind energy development; and
- To suggest recommendations to APEC economies on the way forward to develop wind energy.

The case study targets the following audiences: government agencies in charge of energy in general and wind energy in particular; related-policy makers; industrial sector (multi-national corporations (MNCs), small and medium-sized enterprises (SMEs) and related associations in the wind energy industry); academic sector (in the areas of industry, investment, wind energy etc); researchers and professors on related subjects.

1.4 Report structure of the case study

Following the introduction in Part 1, the report is structured with four parts, including:

Part 2. The wind resource in Viet Nam

- Part 3. Situation of power sector and wind power in Viet Nam
- Part 4. Near-shore wind power projects – potentials and development level
- Part 5. Conclusions

2 The wind resource in Viet Nam

2.1 Describing the wind resource

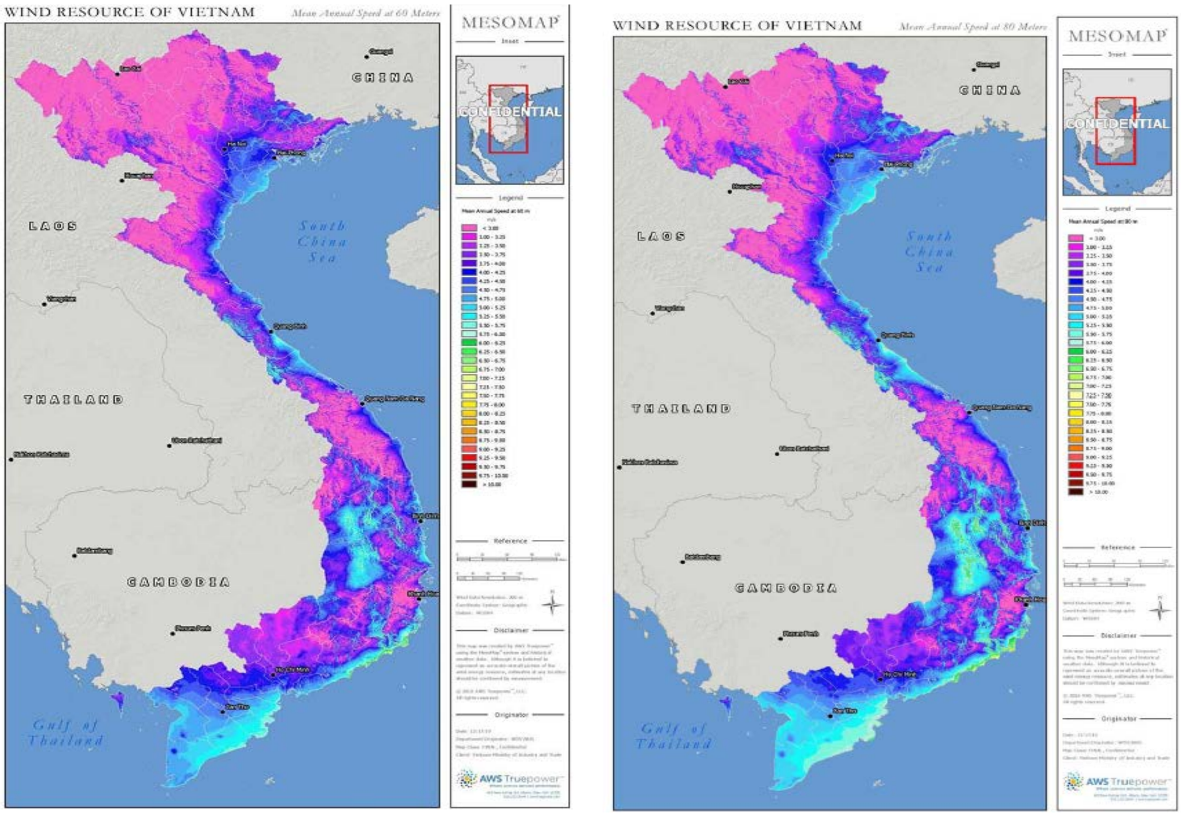
Although the wind potential in Viet Nam is considered favourable, there is no available appropriate planning at the domestic level to support investors and promote the deployment of wind power. At the provincial level, there are until now only seven wind power development plans in which wind potential areas are identified.

In early 2010, the Ministry of Industry and Trade (MOIT), with the support of the World Bank (WB), awarded a contract to AWS Truepower to create a new Wind Resource Atlas of Viet Nam. The main goal of this project was to update the previous Wind Energy Resource Atlas of South East Asia (2001) using state- of- the- art methods verified by the latest available wind measurements. In addition, the project aimed to make the wind resource maps available to developers and other interested groups through an interactive web site.

Based on the data collected from three wind measurement stations at the 60-meter height in the Central coastal region and data from meteo stations and the meso-scale modelling at the 80-meter height, in 2011, AWS Truepower updated the Wind Atlas for Viet Nam and the developable wind resource potential of Viet Nam has been re-estimated (see **Error! Reference source not found.**2.1 and Table2.1).

Figure 2.1: The potential of Viet Nam's wind power at the height of 60 & 80 meter[64]

[64] https://www.esmap.org/sites/esmap.org/files/MOIT_Vietnam_Wind_Atlas_Report_18Mar2011.pdf



Source: AWS Truepower, 2011

Table 2.1: The areas of wind power potential

Average wind power (m/s)	5-6	6-7	7-8	8-9	>9
1. Area (km^2)- updated version of 2011 (MOIT/WB, 80m)	40,473	2,435	220	20	1
2. Area (km^2)- older version of 2001 (WB, 65m)	197,342	100,361	25,679	2,187	113
% difference between two assessments (2-1):2	79.5%	97.6%	99.1%	99.1%	99.1%

Source: TrueWind Solutions, 2001 Vs. AWS Truepower, 2011

According to the WB report in 2001, the land area of wind potential at the height of 65m is large, over 300,000 km^2 for mean speed above 5m/s, of which wind speed above 6 m/s accounted for 39.4%. The area of wind potential at 80m will be much higher than the one of 65m. It is obvious from Table 2.1 that the total land area with wind potential (wind speed of more than 5 m/s) in the updated version of 2011 decreases by 79.5% compared to the old version of 2001 (40,473km2 in comparison to 197,342 km2). The estimated potential area in

2011 with the wind spreed of 6-7 m/s decreases by at least 97.6% and by 97.9% with the wind speed of 6 m/s.

2.2 Significance of wind resource in the near-shore

With more than 3,000 km long coastal line and its location in the moonson climate zone, Viet Nam is expected to have a good potential for wind energy. However, like in many other developing economies, assessment of wind potential in Viet Nam has not been studied to any significant extent.

The coastal areas, especially the near-shore, experience higher wind speed than the main land areas (onshore), by around 0.5 to 2 m/s.

Several studies have been applying those data. For example, the Institute of Energy (IE) examined sites with average annual wind speed of 3 m/s and higher and on the ground of on-site inspection and survey of topography, orography and infrastructure. It made some conclusions on wind energy potential in Viet Nam. The study "*Investigation Studies on Renewable Energy Resources in Asia: Wind Energy Resources around Asia Continental*", published in the journal "Nature and Societies", 1996, was also based on these data and concluded that some coastal areas of Viet Nam experience mean annual wind speeds of up to 8-10 m/s.

Several studies have been carried out on the basis of the World Bank data. For example, Nguyen (2007) estimated the technical potential of wind energy in Viet Nam with the help of a geographic information system (GIS). First, the wind speed layer is combined in a GIS with topographic and political data. The Weibul function is used to calculate a wind potential layer. From this layer, areas that are unsuitable for wind power such as high altitude areas, political areas, water areas, protected areas and living areas are excluded, incorporating buffer areas appropriate to the feature class being excluded. This yields the total areas available for wind development. The GIS is then used to determine how wind turbines can be fit into this area without interfering with each other. This study concludes that 224 TWh could be potentially produced in Viet Nam every year.

The EC-ASEAN Energy Facility Program reports a lower technical potential of wind energy as it considers areas classified as "relatively high", "high" and "very high" only. It assumes that 20% of these areas are technical potential, equivalent to 22,400 MW.

The Wind Atlas of the World Bank is, however, thought to be too optimistic. This is indicated by Table 2 which compares the average wind speeds from the Wind Atlas and the actual values for some sites. It could have also a large margin of error as it was created by a simulation model. Although the results were validated by the data from meteorological stations, but those data were themselves not accurate because the measurements were taken at a low height of around 10 m with few readings per day and measuring devices were not calibrated. This is likely the reason for the proposal of the Study of the World Bank to carry out measurement at 25 sites to confirm the potential.

Table 2.2: Comparison of average wind speed of EVN and the World Bank

No	Site	Annual average wind speed at 65 m above the ground (m/s)	
		EVN	WB
1.1	Mong Cai, Quang Ninh	5.80	7.35
1.2	Van Ly, Nam Dinh	6.88	6.39
1.3	Sam Son, Thanh Hoa	5.82	6.61
1.4	Ky Anh, Ha Tinh	6.48	7.02
2.1	Quang Ninh, Quang Binh	6.73	7.03
2.2	Gio Linh, Quang Tri	6.53	6.52
2.3	Phuong Mai, Binh Dinh	7.30	6.56
2.4	Tu Bong, Khanh Hoa	5.14	6.81
3.1	Phuoc Minh, Ninh Thuan	7.22	8.03
3.2	Da Lat, Lam Dong	6.88	7.57
3.3	Tuy Phong, Binh Thuan	6.89	7.79
3.4	Duyen Hai, Tra Vinh	6.47	7.24

3 Situation of power sector and wind power in Viet Nam

3.1 Overview of the power sector in Viet Nam

The power sector in Viet Nam is driven by the fast growing economy, increasing household income, heavy public investment and radical sector reforms.

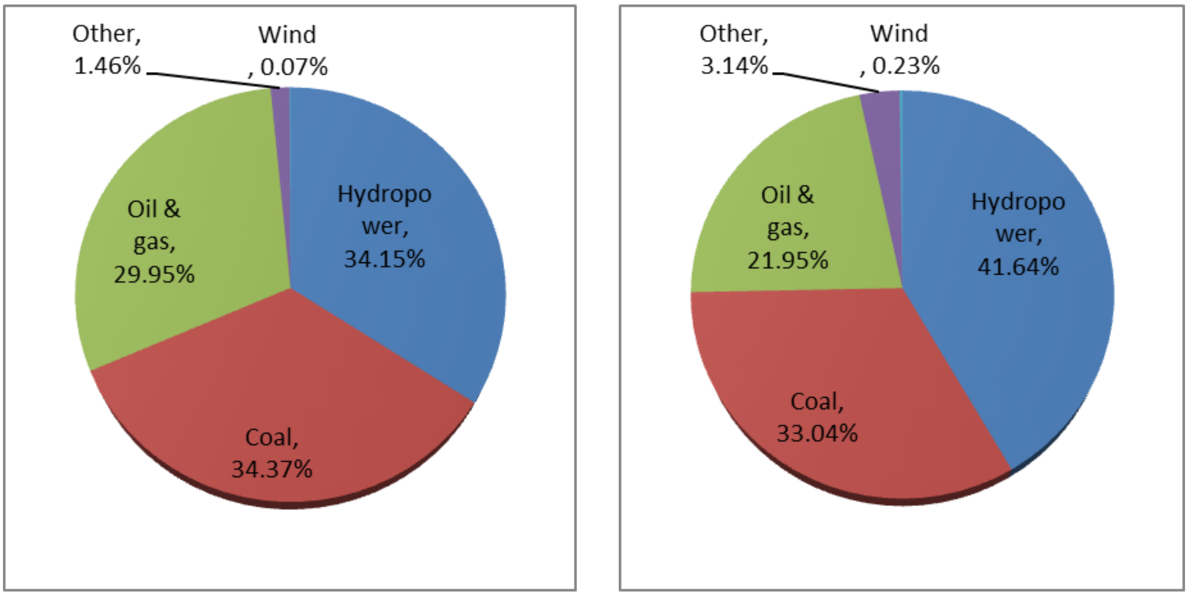
Installed capacity: The installed capacity for generating electricity comprises a mix of hydropower, coal-fired, gas-fired and oil-fired thermal power, and other types, including wind and import. (see Figure 3.1). Hydropower capacity, including pump storage, comprises of large hydropower plants with capacity of more than 30MW. Total hydropower capacity in 2015 is 16,569MW. Hydropower is dominant in the domestic power sector, accounting for about 42% of total installed capacity in 2015. Coal-fired capacity comes second with 33% of total in 2015, followed by oil and gas-fired with 22%. Wind power for electricity generation started in 2012 at 30 MW, growing to 90 MW by the end of 2015 and accounts for just 0.25% of total installed capacity.

Generation: Throughout the 1990s, Viet Nam relied mostly on hydropower generation for its power needs. However, to meeting the challenge of fast growing power demand, the government resorts to increasing fossil fuel sources for thermal generation. Thermal generation from coal, gas and oil (including diesel) has become the dominant power source since 2006, when thermal's share of total generation was 66% compared to 34% for hydropower. This mix has not changed much for the last 10 years. In 2015, the share of hydropower generation is 34% and thermal generation remains dominant at 64%. A tiny share of generation is from renewable energy, including wind power, and import from China (Figure 3.1). During 2006-2015, generation has been rising significantly faster than GDP, with an average annual growth rate of 13.8% versus 6.2% for GDP (calculated by authors with data from EVN and GSO).

Figure 3.1: Capacity & generation mix of Viet Nam in 2015

Electricity production 2015: 164,312GWh

Installed capacity 2015: 39,787MW

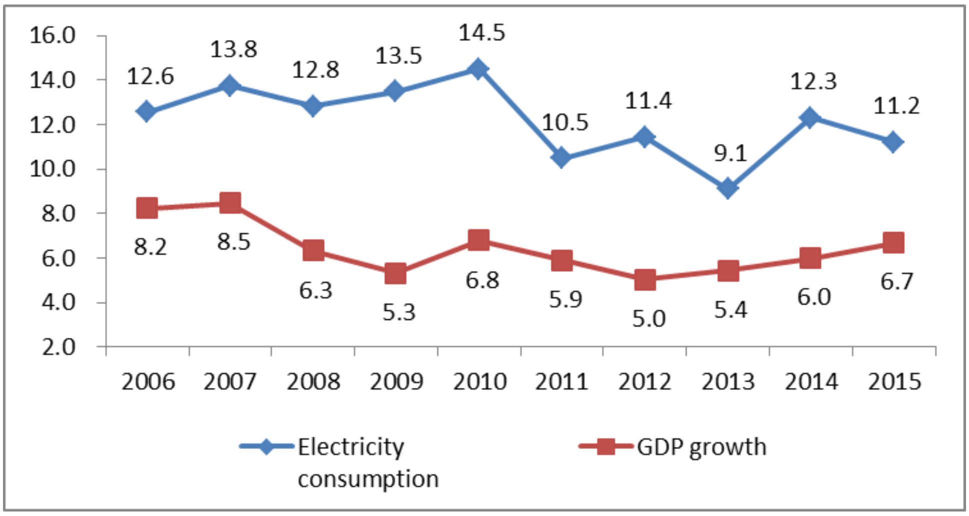


Source: MOIT 2016, EVN 2016

Transmission and Distribution: The power transmission system and the distribution grid of Viet Nam incorporate 500-kV and 220-kV high-voltage lines, and 110-, 35-, 22-, 10-, and 6-kV medium-voltage lines. In 2013, the 500-kV lines had a total length of 4,887 km and substations with a total capacity of 19,350 MVA, which connect all regions of the economy. The 220-kV systems have a total length of 12,116 km and substations with a total capacity of 30,251 MVA. The distribution network includes 15,602 km and 35,653 MVA of 110-kV grid, which serves 63 separate regional territories. In addition, the distribution system includes 138,971 km of medium voltage and 230,437 km of low voltage distribution lines (ADB, 2015).

Consumption: Total electricity consumption grew from 51,372 gigawatt-hours (GWh) in 2006 to 143,682GWh in 2015, with an average annual growth rate of 13.8% during the period. The peak demand is estimated at 26 GW. The growth in Viet Nam's electricity consumption is driven mainly by manufacturing and households, together taking up almost 90% of total consumption. The electricity consumption growth well outstrips the GDP growth rate of Viet Nam and the electricity/ GDP elasticity ratio remain high at 1.7 (Figure 3.2, Table 3.1).

Figure 3.2. Viet Nam's electricity consumption growth (%) and GDP growth (%)



Source: own calculation based on EVN and GSO data

Table 3.1: Viet Nam's electricity consumption growth, GDP growth and electricity/ GDP elasticity, 2006-2015

Year	Electricity consumption growth rate (%)	GDP growth rate (%)	Electricity/ GDP elasticity ratio
2006	12.6	8.2	1.5
2007	13.8	8.5	1.6
2008	12.8	6.3	2.0
2009	13.5	5.3	2.5
2010	14.5	6.8	2.1
2011	10.5	5.9	1.8
2012	11.4	5.0	2.3
2013	9.1	5.4	1.7
2014	12.3	6.0	2.1
2015	11.2	6.7	1.7

Source: own calculation based on EVN and GSO data

3.2 Power sector development

The power sector of Viet Nam has a long history. The first thermal power plants were constructed by the French during the colonial time, mainly to serve the offices and families of the French and some Vietnamese elites in the big cities. The first hydropower plant in Viet Nam was completed in 1945 and started to generate electricity in 1946 in Da Lat with the installed capacity of 0.6MW. When Hanoi was handed over to the government of Viet Nam Democratic Republic in October 1954, the total installed capacity of the power sector was only 31.5MW and annual electricity production was about 53 GWh per year, mainly based on coal-fired thermal generation.

The Directorate of Electricity was established in 1955 as the first government administration body of the power sector. It was restructured and renamed many times since then and now become the General Directorate of Energy under the Ministry of Industry and Commerce (MOIT). With heavy investment of the governments of the Northern and Southern Viet Nam and technical and financial assistance from abroad, the power sector of the economy enjoyed rapid development despite of the hardship and devastation of the Viet Nam war. By the end of 1975 the total installed capacity increased to 1,326.3 MW and the annual electricity production was nearly 3,000 GWh per year. Beside thermal generation based on coal at that time, some large hydropower plants were built and connected to the distribution grid, typically the Thac Ba hydropower plant (Yen Bai province, 1971, 108MW) in the North and the Da Nhim hydropower plant (Lam Dong province, 1964, 160MW) in the South.

Viet Nam built the first Power Development Plan (PDP I) in 1981 for the 1981-1985 period, followed by six more PDPs for consecutive periods of time. Some of the most significant developments of the power sector in the last four decades (1975 – 2015) include:

- **the construction of two largest hydropower plants in South East Asia, namely the Hoa Binh hydropower plant (Hoa Binh province, 1979-1994, 1,920 MW) and the Son La hydropower plant (Son La province, 2005-2012, 2,400MW). The connection of the Hoa Binh plant to the domestic grid paved the way for hydropower to replace coal-fired thermal power as the dominant type of generation during the 1990s;**

- **the completion of the 500-kV high-voltage line (1992-1994, 1,487km, one line in 1994, now 4,887km, double lines), which for the first time linked up the electricity networks in the North, the Centre and the South of Viet Nam. This was also the first time a large infrastructure project in the power sector was designed and constructed solely by Vietnamese people;**

- **the establishment of the Viet Nam General Corporation of Electricity (1995, now the Electricity of Viet Nam or EVN) as a State-owned enterprise (SOE) to manage generation, transmission, distribution and investment in the power sector based on the market-oriented mechanism. It marked the definite separation of the commercial role and the public administration role in the power sector. The public administration role is now undertaken by the General Directorate of Energy and the Energy Regulatory Authority of Viet Nam, both are under MOIT;**

- **the issuance of the Electricity Law (2004) and the subsequent start of the power sector reforms (2005) and of the competitive electricity market (2006). The Level 1 of the competitive electricity market (planned for 2005-2014) is being implemented to create a competitive market in electricity generation. It will be followed by the Level 2 (2015-2022) for a competitive electricity wholesale market and the Level 3 (after 2022) for a competitive electricity retail market. The government, through EVN, will only keep the monopoly power in transmission;**

- **the inauguration of the Phu My Electricity Center (2005) with six gas-fired thermal power plants, including two foreign-invested plants operating on BOT (Build-Operate-Transfer) mechanism. It was the beginning of gas-fired thermal generation as well as of foreign direct investment in electricity generation in the power sector of Viet Nam.**

The economy is now implementing the Adjusted PDP VII for the 2011 – 2020 period with the vision to 2030[65]. According to the Adjusted PDP VII fossil fuel-based thermal power and hydropower will still take the largest shares of total installed capacity and electricity production. However, the Plan pays more attention to new types of generation, including renewable energy and nuclear power (Table 2 and Table 3). In the future, Viet Nam expects two huge projects in generation to be implemented by EVN. They were approved by the Assembly in 2009 to get financing from the government. The first one is the Lai Chau hydropower plant, which will be the last large-scaled hydropower plant of the economy with the installed capacity of 1,200MW. A part of the plant has been completed and connected to the domestic grid by the end of 2015 with the installed capacity of 400MW. The remaining workload will finish one year earlier than originally planned, adding 800MW more to the grid by the end of 2016. The second one is the Ninh Thuan nuclear power project, which will consist of two plants with the total installed capacity of 4,000MW. On the contrary to the first project, the Ninh Thuan project has been delayed and it is not expected to generate electricity until 2030, as we can see in the Adjusted PDP VII.

Table 3.2: Capacity mix of the Viet Nam power sector in 2020-3030 (MW)

Type of generation	2020	2025	2030
Hydro (incl. pump storage)	18,060 (30.1%)	20,362 (21.1%)	21,886 (16.9%)
Oil & Gas	8,940 (14.9%)	15,054 (15.6%)	19,037 (14.7%)
Coal	25,620 (42.7%)	47,575 (49.3%)	55,167 (42.6%)

[65] full name: the Prime Minister's Decision No. 428/QĐ-TTg dated March 18th, 2016 on Approval of the Adjusted Electricity Development Master Plan for the 2011-2020 period with Vision to 2030

RE (incl. wind)	5,940 (9.9%)	12,063 (12.5%)	27,195 (21.0%)
Nuclear	-	-	7,382 (5.7%)
Import	1,440 (2.4%)	1,448 (1.5%)	1,554 (1.2%)
Total	60,000 (100%)	96,500 (100%)	129,500 (100%)

Source: Viet Nam Adjusted PDP VII

Table 3.3: Generation mix of the Viet Nam power sector in 2020-3030 (GWh)

Type of generation	**2020**	**2025**	**2030**
Hydro (incl. pump storage)	66,780 (25.2%)	69,600 (17.4%)	70,928 (12.4%)
Oil & Gas	43,990 (16.6%)	62,400 (15.6%)	96,096 (16.8%)
Coal	130,645 (49.3%)	220,000 (55.0%)	304,304 (53.2%)
RE (incl. wind)	17,225 (6.5%)	27,600 (6.9%)	61,204 (10.7%)
Nuclear	-	-	20,592 (3.6%)
Import	6,360 (2.4%)	6,400 (1.6%)	6,864 (1.2%)
Total	265,000 (100%)	400,000 (100%)	572,000 (100%)

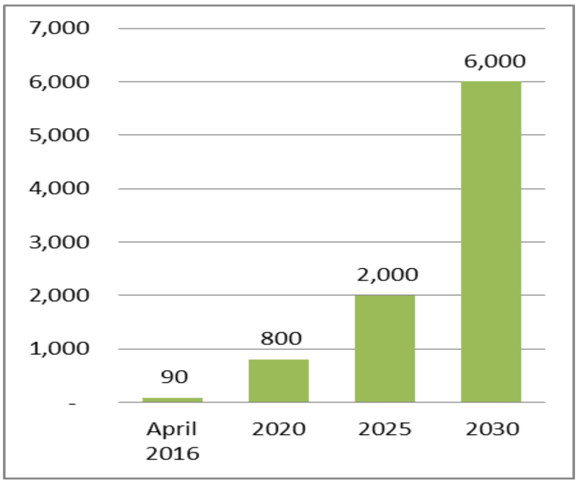
Source: Viet Nam Adjusted PDP VII

3.3 Wind power development: Government targets

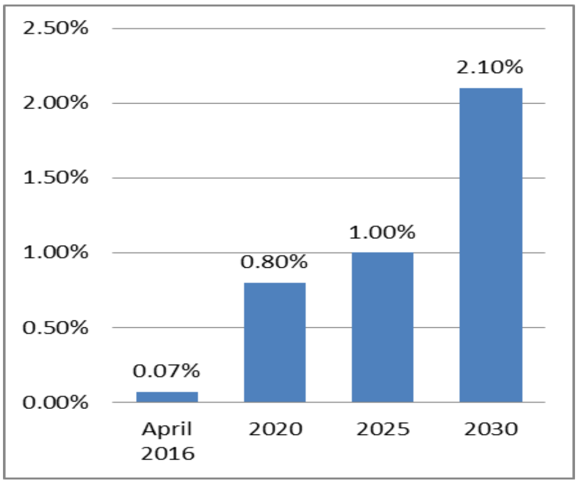
Unlike the previous PDPs, in the Adjusted PDP VII the government of Viet Nam set specific targets for wind power generation. It is expected to increase the wind power installed capacity from a negligible level now to 800MW in 2020, 1,000MW (equivalent to the electricity generation capacity of one nuclear power reactor) in 2025 and 6,000MW (equivalent to the electricity generation capacity of six nuclear power reactors) in 2030. Accordingly, the contribution of wind power as a type of electricity generation is expected to increase by 11 times to reach 0.8.% of the total electricity production in 2020, by 14 times to reach 1.00% in 2025 and by 30 times to reach 2.1% in 2030 (Figure 3.3).

Figure 3.3. Viet Nam wind power planning in 2015-2030 period

Wind power installed capacity (MW)



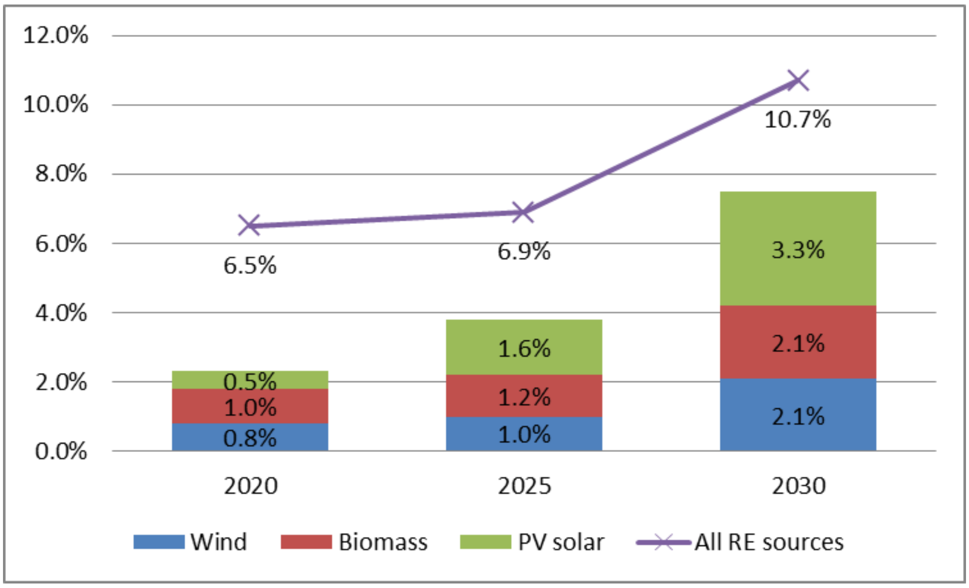
Share of total electricity production (%)



Source: EVN, 2016 and Adjusted PDP VII

The Adjusted PDP VII reflects a shift of focus of the Government to renewable energy sources for electricity generation purpose. It is responsive to the greater need for sustainable development of the economy as well around the world. Similar to wind power, specific targets are set for each key source of renewable energy, in addition to all RE sources. The difference between the column underneath and the purple line on top implies the target contribution of small hydropower plants, which has an installed capacity of up to 30MW. We can see that the expected role of wind power and biomass is more or less the same. Meanwhile the photovoltaic (PV) solar will start at a low level and hopefully accelerate from 2025 to 2030. Small hydropower is expected to move in the opposite direction, starting from a large share and reducing gradually to almost the same size as PV solar by 2030 (Figure 3.4).

Figure 3.4. Government targets for renewable energy share in total electricity production (%), 2020-2030



Source: Adjusted PDP VII

3.4 Existing policy for wind power projects

Viet Nam's wind power policies are driven by the needs to supply sufficient energy and electricity for economic development and ensure environmental protection. Since energy demand is expected to increase four times from 2005-2030 and electricity demand by nine times from 2005-2025, developing wind power as a renewable generation capacity will help Viet Nam reduce its reliance on foreign sources and fossil fuel and ensuring ample energy security in the future. Keeping this position in mind, the economy's policies for wind power projects have to be aligned with the Electricity Law, the PDP, the domestic green growth and domestic renewable energy policies. They are also influenced by related policies from other sectors, such as land master planning or natural resource mining policies. In addition, policies should be considered from the aspects of laws and policies and of master planning for wind power projects. All together, they provide a regulatory framework for wind power projects.

Laws and policies: The most influential policies for wind power projects in Viet Nam include the Prime Minister's (PM) Decision No. 37/2011/QĐ-TTg on Support Mechanism for Development of Wind Power Projects in Viet Nam (2011), EVN's Decision No. 246/QĐ-EVN on Negotiation, Signing and Implementation of Power Purchasing Agreements with Electricity Projects (2014) and the Circular No. 32/2012/TT-BCT of the Ministry of Finance on Regulation for Project Development and Power Purchase Agreement Template with Wind Power Projects (2012).

Pursuant to the policies, the fit-in-tariff (FiT) for grid-connected wind power projects is 7.8 US cents/ kWh, of which 1.0 cent/ kWh is the subsidy from the Viet Nam Environmental Protection Fund. The electricity buyer is EVN or its authorized subsidiary. It is responsible for buying 100% of electricity production volume generated by the wind power projects. The sale and purchase of electricity takes place based on the Power Purchase Agreement (PPA). PPA is valid for 20 years and can be extended.

A quick observation is that the policies confirm the monopoly position of EVN in power purchase transactions. It does not work in favor of the investors of wind power projects. Another note is that the FiT is rather low in Viet Nam compared to FiT in other economies, including both developed economies at a much higher level of economic development and wind power market maturity and developing economies near Viet Nam at quite the same level of development. It makes the wind power projects in Viet Nam less attractive to investors.

To facilitate the sector development, the policies provide additional incentives to wind power projects. They include import duty exemption on imported fixed asset items and goods that cannot be manufactured locally, land use and land lease fee waiver or reduction, corporate income tax exemption for the first 4 years and 50% reduction for the next 9 years, 1.5 higher depreciation rate and improved conditions for public private partnership (PPP).

A few articles are related to responsibilities of the electricity seller, meaning the wind power project investor. It has to invest in the transmission line to the connection point to the domestic grid. If the connection point is unavailable since the grid extension project has not been implemented, the seller has to agree with the buyer to make sure the wind power project and the grid extension project are on the same pace. The investor also has to invest in, operate and maintain the transmission line and substation, if any, from its plant to the agreed connection point. Construction is not allowed until the project has the license, the signed PPA, the grid-connection agreement and the wind measurement report for at least 12 consecutive months.

On top of those three policies, two more legal documents are very important as they provide the underlying conditions and targets to make investment in the wind power sector. They are the Electricity Law (2004) and the Adjusted PDP VII[66] (2016). As described earlier, the Adjusted PDP VII sets the specific targets for wind power development by 2020, 2025 and 2030. Although the Electricity Law does not explicitly mention wind power projects, it provides the legal basis for independent power producers (IPP) to make investment in the electricity sector. We should bear in mind that before the Electricity Law, the electricity sector was supposed to be the sole monopoly of the government, through EVN, and no other players were allowed. The Law paved the way for non-EVN investors, including SOEs, private domestic and foreign investors to enter the market. We will see later that all investors in wind power projects so far are non-EVN SOEs and private companies. It is obvious that the stipulation has a large effect on their penetration. The Electricity Law also stipulate that FiT should allow reasonable profit, natural resource saving, deployment of non-polluting renewable energy sources, and contribution to socio-economic development of rural, mountainous and remote areas. This law article can be the basis to revise under-code legal documents, e.g. the PM’s Decision No. 37/2011/QĐ-TTg, etc. to adjust wind FiT in harmonization of IPPs’, EVN’s and electricity consumers’ benefits.

Besides, some policies from other sectors have influenced wind power projects, too, although they do not have this specific purpose. The typical one is the Inter-Circular 58/2008/TTLT-BTC-BTN&MT dated July 4th, 2008 of the Ministry of Finance (MOF) and the Ministry of

[66] full name: the Prime Minister’s Decision No. 428/QĐ-TTg dated March 18th, 2016 on Approval of the Adjusted Electricity Development Master Plan for the 2011-2020 period with Vision to 2030

Natural Resource and Environment (MONRE)[67] for CDM projects in Viet Nam to which wind power projects are eligible. As the selling price of CER (Certified Emission Reduction) was used to calculate and end up with the current FiT, the Inter-Circular clearly has a direct effect on wind power projects as it facilitates the improvement of the project's cash flow through subsidy.

Master planning: The PM's Decision No. 37/2011/QĐ-TTg demands that the wind power development master plan be developed at the domestic and local levels for the 2011-2020 period with vision to 2030. However, by the time of this study the domestic master plan has still been a draft. For the provincial level MOIT has approved master planning of wind power development for only eight provinces, of which five provinces will develop coastal wind farms (Soc Trang, Tra Vinh, Bac Lieu, Ca Mau and Ben Tre).

Meanwhile wind power projects usually face obstacles and delays caused by overlapping land master planning. This problem should have been avoided. The Electricity Law has one important article that explicitly holds the local government (the People's Committees) accountable for allocating sufficient land for electricity projects once they have been included in the approved electricity master plan. It is a big pity that there has been no master plan to secure land for wind power projects. Lack of an appropriate master plan also means that the investors do not have a concrete basis for investment, which is adjusted to updated research finding and assessment of wind potentials in different periods of time.

3.5 Current status of the development of wind power projects in Viet Nam

Wind power has been exploited for a long time in Viet Nam for various purposes, including water pumping and rice husk milling. However, its deployment in electricity generation is still rather new. Wind power projects for electricity generation consists of household-scaled wind turbine projects with capacity of 150-200kW for unconnected areas like islands, hybrid wind turbine – diesel generator projects with capacity of 2-30kW, and industrial scaled projects to be connected to the grid. The power plant may or may not be connected to the grid. Some of the unconnected projects have been completed here and there all over the economy but there has not been any reliable statistics so far. In this report we only discuss the grid-connect projects.

Up to the end of April 2016, three wind power projects have been completed in full or in part and connected to the grid. They include the Tuy Phong wind power plant and the Phu Quy wind power plant in Binh Thuan province, and the Bac Lieu wind power plant in Bac Lieu province. The total installed capacity that has been completed in the three projects is 90MW and the total electricity production is 121 GWh in 2015 and 38GWh in the first four months of 2016.

[67] It specifies the object of subsidy, the conditions of subsidy, and the method of calculating the subsidy rate for one unit of production, the annual subsidy amount, the term of subsidy, and the application process to request the subsidy for CDM projects in Viet Nam.

The first wind power project for electricity generation in Viet Nam is the Tuy Phong wind power plant. It is an onshore project. It is located in Binh Thanh commune, Tuy Phong district, Binh Thuan province in the South Central Coastal Region of Viet Nam. The investor is the Vietnamese Renewable Energy Joint Stock Company (REVN). The project uses the German technology and has two phases. The total design capacity is 120MW with 80 Fuhrländer FL MD/77[68] wind turbines of 1.5MW per turbine. The first phase was completed and 20 wind turbines with the total capacity of 30MW were installed and connected to the domestic grid in March 2011. The Tuy Phong 1 wind power plant was officially inaugurated later in April 2012. The second phase of the project is supposed to continue with 60 more turbines to add an additional 90MW of installed capacity. However, as an onshore project it faces the challenge of low FiT and is being delayed for better policies.

The second project comes from the same province. The Phu Quy power plant is located in Long Hai and Ngu Phung communes, the island district of Phu Quy. It is an onshore project using the wind/diesel hybrid system. The investor is the PetroViet Nam Power Corporation (PV Power). The project used the Danish technology with three Vesta V80/2000[69] wind turbines of 2.0MW per turbine. The project was fully completed and put into operation in August 2012 with the installed capacity of 6MW. The Phu Quy wind power plant was officially inaugurated in July 2014.

The third project comes from the Southern Western Region of Viet Nnam. The Bac Lieu wind power plant is located in Vinh Trach Dong Commune, Bac Lieu city, Bac Lieu province. Although it is often categorized as an offshore project on international wind power websites, in fact it can be regarded as near-shore. As the wind farm is located in a submerged coastal area the wind towers are exposed fully for a part of the day during the low tide. The investor is the Cong Ly Construction-Trade-Tourism Company Ltd. (Cong Ly). The project uses the U.S. technology and has two phases. The total design capacity is 99.2MW with 62 GE 1.6-82.5[70] wind turbines of 1.6MW per turbine. The first phase was completed and 10 wind turbines with the total capacity of 16MW were installed and connected to the domestic grid in May 2013. 22 more turbines were installed in the second phase and grid-connected, too. The remaining of the second phase is under construction now and is planned to complete in 2016. This project is special in many ways and much more details and analyses will be presented as the case study in this report.

Besides the three grid-connected projects, there are a few more wind power projects ranging from 30 MW to 150 MW at different development stages all over the economy. The list of the project is presented in Table 3.4. In overall, the South Central Coastal Region has the largest

number of projects and installed capacity. In other economic regions of the economy, Bac Lieu is the only province that has a project under construction.

Table 3.4: On-going wind power projects in Viet Nam

[68] power 1 500 kW, diameter 77 m

[69] power 2 000 kW, diameter 80 m

[70] power 1 600 kW, diameter 82.5 m

No	Project	Province	Investor	Turbines	Designed capacity (MW)	Grid-connected capacity (MW)	Status
1	Tuy Phong Phase 1	Binh Thuan	REV	Fuhrländer 20 x 1.5MW	30	30	In operation
2	Phu Quy	Binh Thuan	PV Power	Vesta 3 x 2.0MW	6 (+3MWdiesel)	6	In operation
3	Bac Lieu Phase 1	Bac Lieu	Cong Ly	GE 10 x 1.6MW	16	16	In operation
4	Phuong Mai 1	Binh Dinh		12 x 2.5MW	30	-	Planning
5	Phuong Mai 3	Binh Dinh		14 x 2.5MW	35	-	Planning
6	Bac Lieu Phase 2	Bac Lieu	Cong Ly	GE 55 x 1.6MW	83.2	38	Under construction
7	Trung Nam	Ninh Thuan		14 x 2.5MW	35	-	Planning
8	Tuy Phong Phase 2	Binh Thuan	REV	Fuhrländer 60 x 1.5MW	90	-	Planning
	Total				**295.2**	**90**	

Source: EVN, 2016

3.6 Key challenges for wind power development

The challenges for wind power development in Viet Nam can be categorized in five groups: financing, policy, data, capacity and infrastructure. Each group of challenge is discussed below.

Financing: There are three sets of challenge about financing, namely pricing, subsidy and access to finance. In *pricing*, the low FiT, resulted from one of the lowest electricity consumer prices in South East Asia, is most often cited as the biggest challenge for wind power investors in Viet Nam. The current average electricity consumer price in Viet Nam is 7.5UScents/kWh, the FiT for wind power generation 7.8 US Cents/kWh, while the production cost is around 10-14 USDcent/kWh (Long Nguyen, 2015; Nguyen Duc Cuong b, 2015; Vu Quang Dang b, 2015). There is no different FiT for off-shore wind power projects despite of much larger investment than onshore. After the Kyoto Protocol expired the selling price of CERs decrease sharply and the CDM projects loose a significant additional financing source which reversely influence the projects' cash flow[71]. The thin profit margin puts a pressure on EVN to keep FiT as low as possible through PPA (power purchase agreement) negotiation with the IPP (independent power producer). It seems a mission impossible to negotiate FiT with EVN, whose position is often backed up by MOIT, due to the bargaining power of the monopolist buyer. On top of that the Decision 18/2008/QD-BTC provides no regulation on PPA negotiation duration. The selling price is based on financing costs of the buyer and IPPs always have disadvantage in power transaction with EVN during operation[72].

There is still a *subsidy* from the government for fossil fuel (coal) for electricity generation. On the contrary, the FiT for wind power generation only covers considered internal costs and does not reflect the external costs (environment and social costs). Environment and social benefits are not assessed.

Access to finance is challenging to investors. Wind power projects are long and their upfront capital cost always high, on average 1.6 million US dollar/MW abroad (GEF, 2010) and 1.7-2.0[73] million US dollars/ MW in Viet Nam. At the average level of installed capacity of 30MW a wind power project would cost the investor from 51 to 60 million US dollars. The high and uncertain project development cost adds up to the capital burden of investors. It usually takes 2 to 3 years for project preparation, measurement and study. This process is rather costly given that the capacity of wind power generation is just a few dozens to hundred MW compared to thousands MW of coal and gas-fired generation projects and international consultants must be hired to prepare FS, technical design, bidding requirements and the likes in Viet Nam.

Not everyone can get a soft loan from international donors with a low interest, long duration and extra technical assistance in project development like the Tuy Phong (German loan), Phu Lac (KfW) or Bac Lieu (US Eximbank and USTDA) projects at as low as 2% of interest. The investor often has to pay a high interest rate of 10-15% per year from local banks, who insist to charge high even when they are financed by loans from overseas development banks at a low preferential interest rate. In the domestic financial market wind power is a non-prioritized and unfamiliar sector. As local bankers do not have much interest or knowledge about the sector, they often add up to the interest rate and offer short duration of 7-10 years and short grace period of 1-2 years while the project life is 20 years.

[71] 15USD/CER was used when designed FiT for wind power. The selling price was cut down to 1-2 USD/CER after Kyoto from 15-20 USD/CER before.

[72] In principle, EVN has to buy 100% generation from wind power projects. In practice, EVN often take the reason of technical breakout to refuse wind-generated electricity due to expensiveness.

[73] 1.7 million US dollars for Chinese technology, 2,0 million US dollars for European/ US technologies.

In short, the financing challenges to wind power projects can be summarized that investment in wind power is more costly than in conventional power while FiT is too low and uncompetitive to attract investors, who have difficulty in access to bank loan at a reasonable rate (see Annex 1 for comparison of generation costs, FiT and subsidized conventional generation, Annex 2 for upfront capital costs of wind power projects in Viet Nam).

Policy: The complexity of the regulatory environment, consisting of law and policies, master plans and procedures, represents a big challenge for domestic and foreign wind power investors. The *policy* incentives are not strong enough to offset for a too low FiT. The support mechanisms for wind power projects are neither predictable nor consistent. During implementation a lot of delays have happened due to irrelevant policies and poor coordination among ministries and between the domestic and provincial level. In the field of technology transfer and R&D policy, there is no specific policy incentive for innovation and production of wind power technologies.

The lack of a wind power *master plan* at the domestic level and in most potential provinces and the overlap in land planning causing a lot of confusion and delay for investors. Viet Nam only has a domestic master plan for renewable energy. However, wind power master planning requires a large amount of detailed assessment and data, so the overall renewable energy plan has little practical value for wind power projects.

The *procedures* for wind power projects are long and complicated and involved many government authorities instead of a one-stop authority, causing a lot of delays on the investor. There are several permissions and papers to be obtained from different government bodies. The government acts slowly in legal permissions, licenses, additional planning, land use certificate. Their comments on the submitted application and reports are often unclear. It is unpredictable time to get approval and permission from government authorities

Data base: *Access*, *quality* and *consistency* of wind data and information (e.g. wind measurements) is a big challenge for project developers and investors. Although it is universally agreed that Viet Nam is a promising economy for wind power generation, medium and large wind turbines can only be installed in the areas with technical potential[74]. Wind measurement data to locate those areas are quite different and inconsistent between WB, EVN and MOIT data sets and they are difficult to access for investors (WB, 2001; EVN, 2007; MOIT 2007). Local investors/ developers do not have standard measurement. Pursuant to the PM's Decision QD 37-2011-TTg, investors must produce wind measurements for at least 12 months. If the data are slow, their licensing and commencement of the project must be postponed, too.

Reliability in wind measurement accounts for 24% of investor-named obstacles to Viet Nam's wind power development (Long Nguyen, 2015). For policy makers the lack of reliable wind measurement data combined with shortage of information and low level of awareness about technologies, costs and operation have prevented them from working out an appropriate wind power development master plan.

[74] Average wind speed is at least 6 m/s at 60-meter height.

Capacity: There is a general shortage of local capacities for wind power projects during *development and construction* as well as post-construction *operation and generation*. There are only a few local consulting organizations such as PECC2, PECC3, IE for project development, and a few local constructors with adequate specialized equipment and devices for construction in the power sector. Viet Nam lacks in professional knowledge and technical capacities to operate the key technologies and services after construction, including operation and maintenance (O&M). Government authorities have no expertise or experience in review and evaluation of the reports. With regard to long-term development of local human resources, technicians and engineers for wind power plants cannot be trained in the economy as no course is provided at universities, colleges or vocational schools. There are neither teachers nor appropriate curriculum.

Infrastructure: Both infrastructure for construction and for operation and electricity generation of wind power plants are weak and inadequate in Viet Nam now. In project *development and construction,* transportation of bulky turbines and equipment for wind power plants is very difficult on Viet Nam's road system. Many areas with large wind potential are inaccessible due to the lack of roads and bridges. Ocean ports are not large enough for imported turbines and equipment. Sometimes the investors have to import appropriate super-long and supper-heavy vehicles, cranes and equipment for transport and installation as they are unavailable inside the economy.

The limited grid capacity is the key challenge in *operation and generation*. The distance to the domestic power transmission network represents a regular risk for wind power project developers and investors. According to the PM's Decision QD 37-2011-TTg, the buyer (the same as the investor/ developer) has to invest in, operate and maintain the transmission line and substations, if any, to the connection point and implies that the developer has to slow down the wind power project to be on the same progress with the grid extension projects run by EVN.

Going 6 years back to 2010 Viet Nam had a list of 37 registered projects in wind power development with the total installed capacity of 3,837 MW, increasing to 52 projects with registered installed capacity of 4,252MW in 2014 as recorded by IoE (Nguyễn Hoàng Dũng, 2010; Long Nguyen, 2015). However, by the time of this study, only three projects totaling 90MW in installed capacity have been grid-connected. The huge difference means many things to us. Perhaps investors are lost in the jungle of procedures and paperwork. They may have been scared away by banks and financing institutions. Or they simply keep the land to wait and see. Taking the low FiT and unfavorable regulatory framework together, the wind power sector of Viet Nam is still not attractive enough for both domestic and foreign investors. It seems that the long list of registered wind power projects is "sitting on paper to wait for higher FiT", as shared by a dozen of investors in in interviews for this study and in various renewable energy fora in Viet Nam.

3.7 Expectations of wind power project developers and investors

Wind power project developers and investors basically expect improvement of FiT and access to finance, more enabling policies and better data service. They are related to the first three groups of challenge described in 3.6. The capacity and infrastructure-related issues can be addressed later when these challenges improve and the market becomes more mature.

Higher and more flexible FiT: Above information show an example of how investor's expectation about FiT is different from what they get from the government. It also shows that the wind power plant is likely running below its production cost. As mentioned earlier, FiT in Viet Nam is considerably lower than that in developing economies in the same region, not to say in developed economies. Interviews revealed that wind power project developers and investors obviously expect improvement and flexibility in FiT pricing[75] from the government. Otherwise, more rapid development of the sector cannot take place.

Improved access to finance: To improve access to finance, investors and developers expect three things:

- **A development fund with long-term loan and more incentive interest rate is set up for wind power and other renewable energy sources. This fund would be used to provide better access to finance of the investors as well as subsidy for higher FiTs;**
- **Project preparation grant and capital grant (in part or in full) for only some first technology applications like off-shore wind power, renewable energy for rural electrification (as well as other RE technologies a solar rooftop, geothermal, tidal energy);**
- **Education and training for local banks on wind power investment.**

More enabling policies: In order to facilitate the development of wind power projects, the government of Viet Nam is expected to issue more enabling policies and make sure their implementation is improved, specifically.

- **The FiT pricing mechanism and establishment of the development fund and the grant system mentioned above obviously require new policy revision and issuance of the government;**
- **Better policy incentives such as more favourable tax break, import duties, etc. are expected to improve the project internal rate of return (IRR) and make wind power projects more attractive to investors;**
- **The domestic and provincial wind power master plans should be completed and issued as soon as possible. At the same time, wind power master planning should**

[75] Expected general FiT of 10.4 US cents/kWh according to GIZ Wind FiT Study in 2014 and FiT may change for different onshore and offshore projects.

be coordinated with land master planning and related policies through cooperation among competent authorities at the domestic and provincial levels;

- **The one-stop-shop mechanism is expected during project licensing and implementation. Specific transaction deadlines are expected to be followed by the relevant government bodies to avoid unreasonable delay for investors.**

Better data service: Wind power investors and project developers expect improvement of data and information supply through both government and private services.

- **It is expected that wind power mapping is provided by the government and SOEs as a public service and investors can pay a fee for wind data access instead of own collection and measurement;**

- **Besides, the local private sector is expected to provide better service in preparation of pre-FS and FS for all potential sites and implement the bidding for the sites to be developed by wind power investors.**

4 Near-shore wind power projects-potential and development level

4.1 Economy context of the first near-shore wind power deployment

Though Viet Nam has high technical potential of wind power in many areas, including onshore locations (as mentioned above), there may be limitation of land for wind power development in those areas. The key reasons include:

(i) Big demand of land use for development of residential areas, urban areas, industrial areas (at present, the population density of Viet Nam is relatively high and it will be higher in future); and

(ii) Overlapping with mineral areas (such as titan area); in electricity load centers (not suitable for power transmission and connection to the power grid and power transmission capacity), etc. Therefore, development of wind power onshore of Viet Nam has been slowed down. So far, only few onshore wind power projects with the total installed capacity of 36MW has been put into operation.

In this context, the first nearshore wind power project has been formulated and put into operation.

This project, with a capacity of 99.2 MW, was proposed by one Vietnamese private investor and accepted by the Government of Viet Nam for implementation. The location of installation of 62 wind turbines (capacity of each turbine is 1.6MW) is a coastal area. This is a mixed area where some foundation of wind turbines are inundated only at the high tide level and some turbine foundations are totally submerged under sea water at the low tide level.

The initial results (upon successful installation and operation) of the above project have opened new development orientation for coastal wind power projects in Viet Nam. So far, MOIT has approved planning of wind power development for eight provinces, of which five provinces will develop coastal wind farms, these provinces are Soc Trang, Tra Vinh, Bac Lieu, Ca Mau and Ben Tre with total anticipated installed capacity over 2,000 MW. These provinces are located in the Mekong delta of Viet Nam.

The Mekong delta of Viet Nam has coast line of 732 km with many estuaries and lagoons, formed from alluvium sediments gradually cumulated due to sea water level changes through centuries; there are sand banks along the coastal line. The total area is about 480,000 ha, which is very suitable for development of wind farms in combination with planting and rearing sea products.

The Bac Lieu wind power project is located in in Vinh Trach Dong Commune, Bac Lieu city, Bac Lieu province. The total occupied land area of the project is 2,100ha (mainly the area of sea surface).

The site selected for construction of wind power plant is considered very convenient because it satisfies the following requirements:

- This is a non-residential area with one side adjacent to breakwater dike and the other side is sea.

- The site has relatively good wind regime in the Mekong delta, with North-East and South-West directions of wind.

- The project construction site is convenient for transportation of equipment (by sea) as well as building materials (by road) for construction of power plant.

- This area is far from the residential area at present and in the future according to the socio-economic and residential development plans. Therefore, construction of a wind power plant in this site does not impact ecological environment of the whole area.

Because this area was formed from young sediment land, its ground is weak, with organic mud layer 0.7 – 1.7m thick, clay mud layer 1.3 – 1.4m thick. Therefore, structures seating on weak mud layer need treatment of foundation bed, anti-subsidence and subsidence annulment and this affects the construction costs.

Because elevation of area is low, this area is considered heavily affected by climate change and sea water level rise. In the course of designing items of the project, this issue must be specially paid attention to in order to have suitable measures.

The project area is located in the tropical monsoon wind climate zone, with two clear seasons, the raining season from May to November and the dry season from December to

April of the next year. The annual average rainfall is 2,000 – 2,300 mm. The average temperature is 26^0C, the highest is 31.5^0C and the lowest 22.5^0C. Annual sunshine hours is 2,500 – 2,600 hours. The average humidity in dry season is 80%, in the raining season is 85%. This area is rarely affected from typhoons and tropical low pressures; it is not directly affected by flood of the Mekong river system but strongly affected by tides of East Sea and partially affected by diurnal tide of the West Sea.

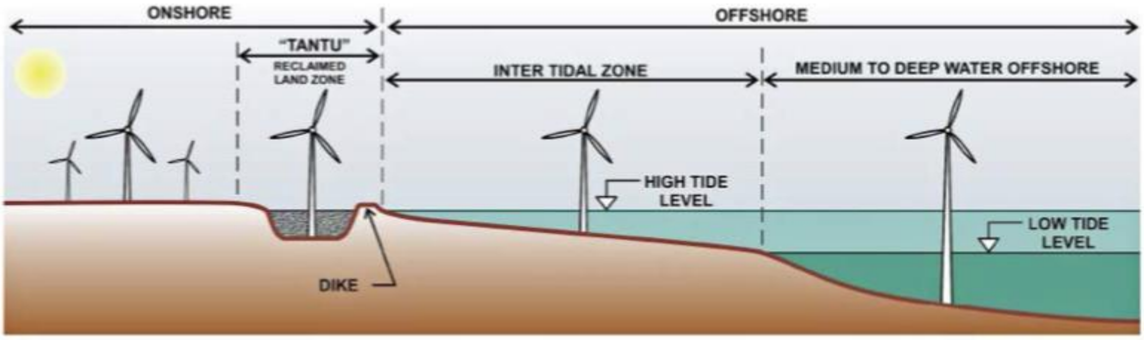
Tide regime

- Uneven semi diurnal tide: in one day there are 2 times raising tide and 2 times falling tides. Elevation of tide foots and tops is various.
- Maximum amplitude of tide: ~ 3.25m.
- Minimum amplitude of tide: ~1.4m.

Water level:

- Annual highest water level: +1.58m => +2.08m
- Annual lowest water level: -2.60m => -2.06m
- Annual average water level: -0.24m => +1.00m

Figure 4.1: A reference simulation of coastal wind power



Source: https://www.ntnu.no/documents/7414984/202064323/Offshore+Wind+in+China+2014.pdf/b0167dd4-6d47-40cc-9096-b3139c1459ef

4.2 The rationale for government support

The era of cheap fossil fuels that has played a central role in the economic development of Viet Nam is seen by many persons as going to an end in the very near future. Yet very shortly Viet Nam will become more exposed to international energy prices because its economic growth is expected to outpace its own domestic fosil energy resources. While the potential for large hydropower stations will be exhausted in this decade, limited domestic supplies of gas and coal mean that Viet Nam will soon need to import coal for power generation.

Thus the Government of Viet Nam recognizes the importance of making sure that Viet Nam's renewable energy resource endowment, e.g. wind power is fully developed, and that the institutional, regulatory and financial barriers are overcome so that renewable energy sources can make its proper contribution to economic development.

In addition to the purely economic arguments based on the increasing cost of fossil fuels, renewable/ wind power projects have other attributes that make them desirable:

- Renewable/ wind power projects are generally located in rural areas, and are more likely to catalyse rural development and generate rural employment opportunities. Construction activities in such rural areas often require development of local roads that improve access of rural communities.

- Renewable/ wind power projects can tap the sources of debt and equity finance not available to EVN (or IPPs) for large projects, thereby contributing to the most stressful problem of Viet Nam's power sector, namely the mobilization of capital. For example, Viet Nam would be able to tap loan funds from sources of finance seeking to invest in renewable energy, an area of increasing interest to investors.

- Renewable/ wind power projects energy displaces thermal generation, and thereby reduces environmental damage costs from coal, gas and oil-based projects. While the magnitude of these impacts is uncertain (particularly when compared to other emission sources, notably urban transportation), the human health consequences of fossil fuel emissions represent a real economic cost to the economy.

- Because Viet Nam needs to develop its domestic coal resources to meet the growing electricity demand for economic development, as a responsible member of the global environmental community the economy wishes to demonstrate that it will at the same time develop its renewable energy resources – particularly if the main barrier to RE development lies in institutional and regulatory constraints.

- Renewable energy plays the same role in a portfolio of electricity generation assets as treasury bonds play in a portfolio of financial assets. The diversification of energy generation sources acts as a hedge against the uncertainty of international fossil energy markets, which will become increasingly important as Viet Nam begins to import coal to meet its electricity requirements.

4.3 How the market could start for near-shore wind farms

According to PDP VII, the total wind power installed capacity should rise from the current level to 800 MW by 2020; 2000 MW by 2025; and 6000 MW by 2030. To support wind power development, policy incentives have been developed, including the introduction by the Decision 37/QĐ-TTg (2011) of a FiT at 7.8 US cent/kWh, as described in Part 3.

To date, three wind power projects with a total installed capacity of about 90 MW[76] are in operation in Viet Nam. Being the first wind farm in Viet Nam, the Tuy Phong wind power plant of 30 MW developed by REVN in Binh Thuan province, was approved before the Decision 37 and thus granted a special financial agreement untill the end of 2013. The second project, the Bac Lieu wind power plant developed by Cong Ly in Bac Lieu province is a near shore project and the general FiT of 7.8 US cent/kWh is not applied in this case. Next, the Phu Quy wind power plant, developed by PV Power on Phu Quy island, is a wind-diesel hybrid system that applies the general FiT. Beside the three projects that have been put into

[76] Total designed capacity 135 MW when the whole projects will be completed.

operation, the Phu Lac project, located in Binh Thuan province, developed by EVN is still under construction. This is the last project under construction which applies the general FiT of 7.8 US cent/kWh.

The Bac Lieu wind power project developed by Cong Ly gets a very special ODA (official development assistance) soft loan that no commercial project could have access to. On top of that the project may get a special FiT. Under the MOIT project "Scaling-Up of Wind Power Project", a new FiT of 10.4 US cent/kWh was proposed to MOIT at the end of 2014[77]. However, it has not been approved yet, and the government requested MOIT to conduct a further comprehensive study in order to:

- Evaluate the feasibility of the three currently existing wind power plants in Viet Nam with the current tariffs; and

- As a result of the first output, propose adjustments for the current incentives if necessary.

The outcome of this study will become supporting materials for the Government to make a revision of the Decision 37/QĐ-TTg if needed, in order to meet the target of 6,000 MW wind power installation by 2030.

In other site, in implementation of the green growth strategy and policies on clean energy investment of the Government as well as energy development strategy of Viet Nam aiming to diversify power resources, ensuring energy security, with active support of the Government, ministries and PPCs of the Mekong delta provinces, many wind power investors and developers have been accelerating activities to identify investment opportunities on nearshore wind power in the Mekong delta region.

Although the wind power sector of Viet Nam is at the initial stage, when the Bac Lieu project was broken ground, there had only been one onshore wind power plant in Viet Nam. The Bac Lieu project is the first nearshore wind power project in Viet Nam and also the first in ASEAN economies. Therefore, successful installation of turbines in submerged nearshore area and putting the project into commercial operation can be considered as a lesson for drawing experience, sharing advantages and disadvantages. It would lay the foundation for later steps of development of wind power projects in coastal areas not only for Vietnamese private investors, but also for foreign investors who planned to invest in wind power in Viet Nam or in other economies with similar nearshore area conditions.

[77] Proposal of an appropriate support mechanism for wind power in Viet Nam (Short Version), Project study, Cuong, N.D. and Dersch, D., 2014

Box 4.1: Suitable conditions for the market development of nearshore wind farms

GE, MOIT develop 1,000MW wind energy[78]

HÀ NỘI — The Ministry of Industry and Trade (MOIT) and General Electric (GE) in Hanoi signed a Memorandum of Understanding to accelerate the development of renewable energy in Việt Nam.

Accordingly, the two parties aimed to develop a minimum of 1,000 MW of new wind farms by 2025. The farms are expected to ensure energy to approximately 1.8 million Vietnamese homes.

Vietnamese President Tran Dai Quang and United States President Barack Obama witnessed the signing ceremony.

Under the agreement, the US-based global power corporation would utilise its global wind development expertise and work with domestic developers to identify potential projects. General Electric (GE) would support the implementation of Viet Nam's domestic target programme through the local manufacturing of wind turbine equipment and components.

Speaking at the signing ceremony, Director general of the MOIT's General Department of Energy, said the Vietnamese government has accorded priority to renewable energy development to resolve the energy challenges for socio-economic development.

Viet Nam has a lot of potential for wind power development including geographic diversity, and extensive hydropower assets.

The development of wind power would play an important role in maintaining energy flexibility and security of Viet Nam in the future.

GE played a key role in the development of Viet Nam Mekong Delta's first wind farm in Bac Lieu Province. GE supplied 62 wind turbines, totalling more than 99.2 MW of power generation capacity. The first phase of this wind farm connected to the domestic grid in June 2013.

In 2009, GE established a wind-turbine components manufacturing plant in northern Hai Phong Port City. The facility has created over 600 local jobs and exported thousands of units of generator systems and wind turbine components that contribute to global energy solutions.

GE Viet Nam currently employs more than 900 people and offers products and services in the power, energy connections, renewable energy, oil and gas, healthcare and aviation sectors. Jeffrey R. Immelt, GE's CEO said they wanted to contribute in key areas such as healthcare and aviation in Viet Nam. — VNS

Source: vietnamnews.vn, posted 24th May, 2016

78 http://www.renewableenergy.org.vn/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=3844&cntnt01origid=15&cntnt01returnid=54

4.4 Bac Lieu near-shore wind power plant: Case study

4.4.1. Site description

In implementation of the green growth strategy and policies on clean energy investment of the Government as well as the energy development strategy of Viet Nam that aims to diversify power resources and ensure energy security, the Cong Ly Construction-Trade-Tourism Company Ltd. (Cong Ly), with active support of the Bac Lieu PPC, decided on investment - construction of the Bac Lieu nearshore wind power project in Bac Lieu province in the Mekong delta of Viet Nam It is located in a shallow intertidal zone near the coast. The proposed turbine locations are up to 2km from the shore. The deepest water at high tide is estimated to be 2.5-3 m deep. As a result, raised foundations are required. The standard hub height of the GE 1.6 series turbine, 80m, is therefore increased to 86m once the foundation height is included.

The geography of the land near the turbines is simple and very flat. The background roughness can be broadly classified as roughness class 0.0 for the sea, and class 1.5 for the land. The closest land to the coast is used for fish ponds. There are 5-6m tall mangrove trees along the coastline. Geographical coordinates is Northern latitude: 9^o 12’13’’ -9^o 14’49’’; Eastern longitude: 105^o 45’32’’ – 105^o 49’35’’

The total installed capacity is 99.2 MW with 62 wind turbines. The total investment cost of the project is 4,894 billion VND, conducted in two phases. Phase I involves experimental installation of ten wind turbines; and Phase II - installation of 52 wind turbines. The main items of the wind power plant include construction of foundation of turbines; construction of internal 22 kV power lines to collect electricity generated from turbines to 22kV/110kV substation placed inside the power plant; construction of operation house and working house; construction, installation of 22kV/110kV and 110kV overhead line (17 km) for connection of the power plant to the domestic electricity grid.

After the project document dossier was completed, the construction of the first foundation of wind turbine of this project was started in July 2011 and the Phase 1 of the project took more than 2 years to complete. In August 2013, the first ten wind turbines were put into commercial operation.

Difficulties met in the Phase I of this project include:

(i) the project owner and local construction contractors have no experience in construction of turbine foundation, installation of turbines in submerged coastal areas;

(ii) construction of turbine foundations at areas submerged in tide is relatively complicated in terms of weather and hydro-geological conditions. Therefore, the duration of construction and installation has been extended much longer than the original schedule (on average it takes more than two months for one turbine). Construction and installation cost increased 2.4 times in comparison with the estimated costs;

(iii) Installation of 22kV power line for collection of electricity generated from turbines to 22kV/110kV substation located onshore must have been also changed in comparison to original plan. This also makes increased project cost.

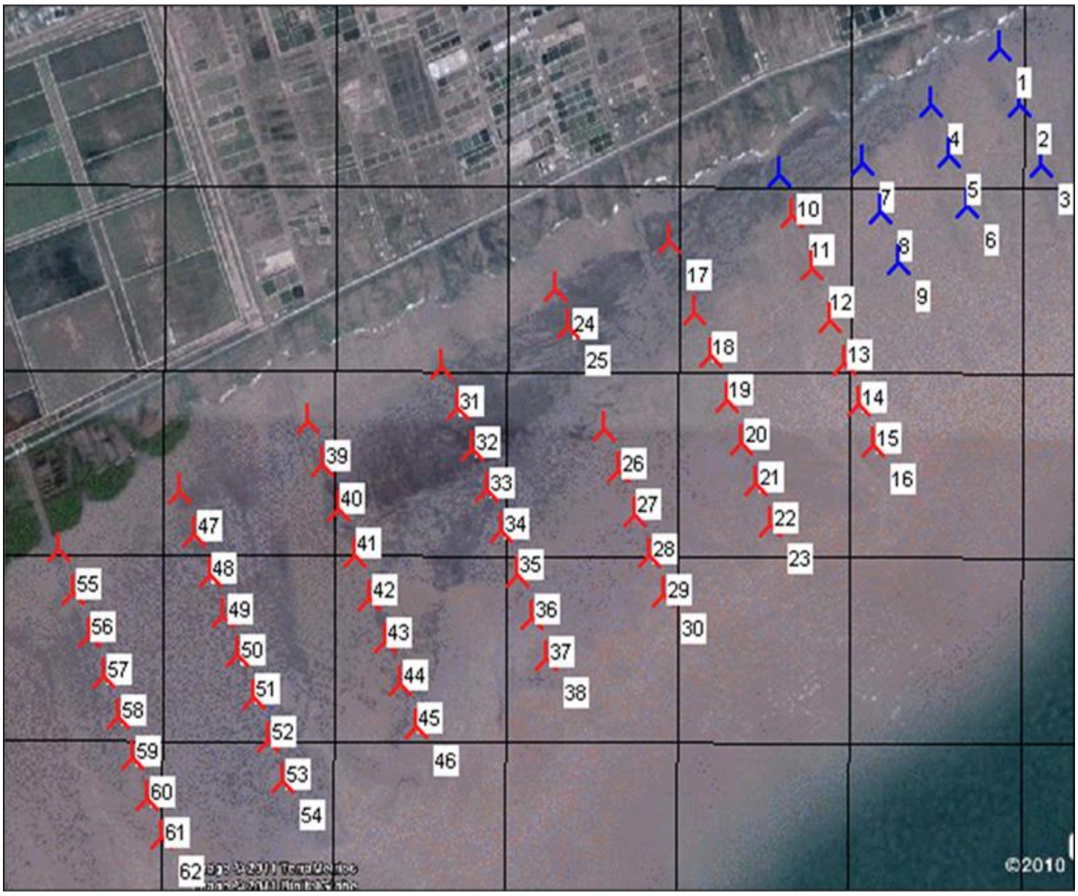
The lessons learnt from the Phase I will be applied for the Phase II. So far, after more than one year, 52 additional wind turbines were installed, making a total of 62 wind turbines of the project installed. Some of them have been put into operation.

As soon as all the 62 wind turbines with total installed capacity of 99.2 MW have been operated for at least one year, evaluation of economic – environmental - investment effectiveness of coastal wind power project will be conducted based on the actual operation data.

At present, actual operation data of 16 wind turbines which are operated for at least one year (10 wind turbines of Phase I have been being operated for over two years and 6 wind turbines of Phase II operated for one year) and costs (initial investment cost, loan cost, O&M cost of 16 turbines) are used in analysis and evaluation in this case study.

The GE optimised layout for the Bac Lieu Phase I & II wind farm is shown in Figure 4.1 below as red symbols. The grid is set as 1x1km squares. Phase I of 10 turbines is shown as blue symbols.

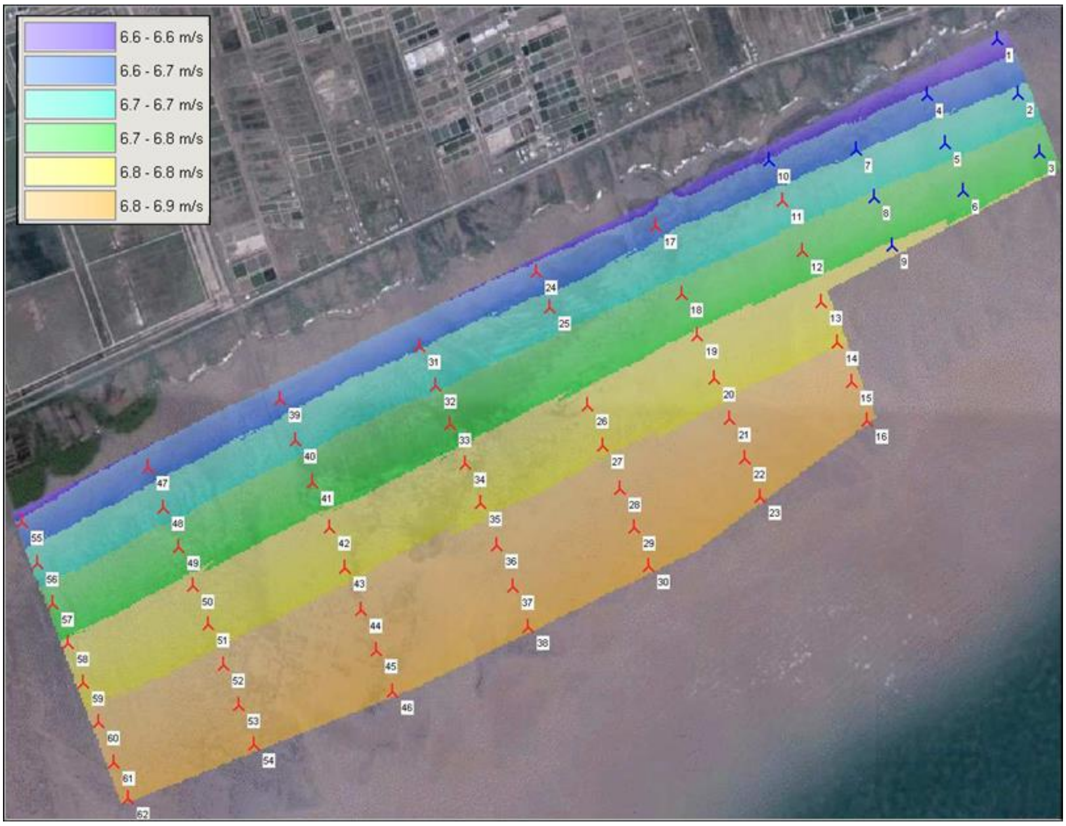
Figure 4.1: GE optimised layout of Bac Lieu wind farm



Source: Cong Ly wind farm

Figure 4.2 below shows the site wind resource map at 80 m above ground level based on data from Mast 1.

Figure 4.3: Wind resource map at 86m for the Bac Lieu site[79]



Source: Cong Ly wind farm

The wind power project in Bac Lieu province is the largest one in Viet Nam, and operating under special conditions due to its location in a tidal area off the coast of the Mekong delta of Viet Nam.

The construction of the first phase of the wind farm started in July 2011 with 10 turbines. It was operational and connected to the domestic grid in August 2013. The supplier of the turbines is General Electric (GE), USA. With the expansion into a second phase, the wind farm is now housing a total 99.2MW. For the third phase to start in 2018, it is planned to expand the total capacity of the wind farm up to 142 MW.

To transmit the power to the domestic grid, approximately 17 km of 110 kV transmission lines were built. Spanning a project area of 1,000 ha, the wind farm has an estimated

[79] GE optimised layout shown

electricity output of 300 GWh per annum, purchased by Electricity of Viet Nam (EVN) at a price of 9.8 USCents/kWh. Approxiamtely 150,331 tons of CO_2 emissions are expected to be offset annually.

4.4.2. Electricity generation and capacity factors

The Bac Lieu wind farm is installed in different phases. Phase I with 10 turbines (GE 1.6-82.5[80]) has been fully operating since August 2013. Phase II with additional 52 turbines of the same type is currently under completion. As of May 2016 additional 33 - or total of 43 - wind turbines are operating.

Two data sets of measured electricity generation are analysed: i). Phase I: electricity generation of each turbine (10) for the full calendar years 2014-2015; ii). Phase II: electricity generation of 6 turbines for the period April 2015 – April 2016.

The production figures are complemented by wind audits from AWS True Power and the turbine manufacture GE. Both audits provide capacity factor estimates for each turbine. However, AWS True Power analyses phase II turbines only, whereas GE estimates capacity factors for each turbine (phase I and phase II).

The data analysis and capacity factor calculation are described in the following. First, the data set of phase I electricity production on a turbine level is compared with the GE estimates. The production figures are shown in the table below. The orange lines are above the average, the grey lines are below the average. Corresponding wind speed measurements on a monthly base are shown in the Appendix.

Table 4.1: Realized & estimated electricity production and capacity factors of first 10 turbines-Phase 1

Unit: GWh

Turbine No	GE estimated annual prod.	Annualized real production (2014-2015)	GE Capacity factor	Realized Capacity factor
1	4.8	3.85	34.2%	27.4%
2	4.8	3.35	34.2%	23.9%
3	4.9	3.80	35.0%	27.1%
4	4.5	3.35	32.1%	23.9%
5	4.5	3.53	32.1%	25.1%
6	4.7	3.78	33.5%	27.0%
7	4.3	2.92	30.7%	20.8%
8	4.4	3.42	31.4%	24.4%
9	4.7	3.98	33.5%	28.4%
10	4.5	2.83	32.1%	20.2%
Average	4.61	3.479	32.9%	24.8%

Source: Cong Ly wind farm

[80] power 1 600 kW, diameter 82.5 m

The realized average capacity factor of the sample of ten turbines is 25%. GE estimates a capacity factor of 33% which is substantially higher. It is, therefore, prudent to deploy the realized capacity factor of 25% in the model.

The Table 4.2 below shows a comparison of Phase II realized electricity production and audits for turbine 11-16. The colour code of the columns is similar to the above scheme.

Table 4.2: Realized and estimated electricity production and capacity factors of 6 phase II wind turbines

Unit: GWh

Turbine No	GE estimated annual prod.	AWS Truepower estimated prod.	Real production (4/2015-4/2016)	GE Capacity factor	AWS Truepower Capacity factor	Realized Capacity factor
11	4.4	3.34	3.60	31.4%	23.8%	25.7%
12	4.5	3.41	3.91	32.1%	24.3%	27.9%
13	4.8	3.84	4.24	34.2%	27.4%	30.3%
14	4.9	3.92	4.11	35.0%	28.0%	29.3%
15	5	3.98	4.60	35.7%	28.4%	32.8%
16	5.1	4.08	4.59	36.4%	29.1%	32.7%
Average	4.78	3.76	4.18	34.1%	26.8%	29.8%

Source: Cong Ly wind farm

For the given sample of six turbines the GE wind audit overestimates the realized capacity factor by about 10%, at the same time the AWS True power audit underestimates by about 10%. It is therefore considered prudent to deploy the average capacity factor reported in the two wind audits for the complete set of phase II wind turbines in the LCOE analysis[81]. One advantage to rely on the wind audit is the consideration of loss effects like wake and shadowing losses within the wind park and correction to long term wind conditions. In this study the two phases of the Cong Ly wind park are analysed. First the phase I wind farm with 10 turbines only and secondly the phase I&II wind farm with a full set of 62 turbines. The following table summarizes the results.

Table 5.3: Summary of Cong Ly capacity factor calculations

Phase	Realized	AWS	GE	Used in model
Phase I	24.8%	NA	32.9%	**25%**
Phase II	29.8%	26.8%	34.1%	NA
Phase I&II	NA	24.0%	32.5%	**28%**

Source: Cong Ly wind farm

LCOE calculation and cash flow modelling applies capacity factors of 25% (phase I) and 28% (phase I&II) as shown in the last column of Table 4.3.

[81] This is a common approach in electricity production assessment performed by banks. In case more than one wind audit is available average values are calculated.

4.4.3. Investment cost

Investment costs are provided through questionnaires and interviews. Investment costs for Cong Ly are broken down in Phase I only and Phase I&II. Phase I costs are realized costs for the first ten turbines in operation. Phase II investment costs are based on current planning figures. However as two third of the total installation is already realized, the planning figures seem to be very reliable. In the Tuy Phong projects, the REVN investment costs are based on realized figures, too. In the Phu Lac project, investment costs are planning figures only.

The construction process is close to completion; therefore, the provided planning figures are expected to be met. They include an additional 5% contingency. Investment costs are consistent with figures provided previously in the 2014 GIZ FiT study. Investment and O&M costs are summarized and discussed below.

4.4.4. O&M cost

O&M costs are provided through questionnaires and interviews. Similar to investment costs they are based on realized and planning figures which are discussed in more detail. Summary and discussion of investment and O&M cost.

Table 4.4: Specific investment and O&M cost in USD/MW

Variable	Cong Ly Phase I	Cong Ly Phase I&II	REVN	Phu Lac
Investment Cost	2,910,273	2,390,793	2,635,602	1,818,358
O&M Cost	25,622	24,987	40,647	51,764

Source: Cong Ly wind farm

Cost positions are scaled to the installed capacity for better comparison. The Bac Lieu project is shown for Phase I only and Phase I&II. The specific investment costs are significantly lower for the combined phases. This may be explained by two effects:

- **Cost allocation Phase I versus Phase II:** A strict cost allocation to Phase I and Phase II is difficult. Expenses for roads, transformer station, office space or other infrastructure components might be designed to satisfy Phase II requirements also. Therefore expenses incurred in Phase I could be partially allocated to Phase II.

- **Learning curve and economy of scale:** Experience from Phase I installation may bring down cost in Phase II. In addition Phase II is more than five times larger than Phase I which allows negotiating price reductions and cost dilution of fix cost components like installation equipment.

Specific O&M costs also benefit from the above effects as fixed cost components dilute the specific cost.

It is interesting to note that the above effects absorb anticipated cost increases due to the fact that Phase II installation is further away from the shore line – and thus more expensive - as compared to the first ten turbines installed in Phase I

As a result Bac Lieu Phase I&II is considered as the more relevant case whereas Phase I only serves as a reference only.

4.5 Analyzing and assessing the economics of Bac Lieu wind power project

The LCOE is a pre-tax figure depending on investment cost, O&M cost and total electricity output over the complete lifetime of the project. It is an important reference figure to benchmark a project against given electricity tariffs and assess the financial viability.

The LCOE is the sum of investment cost (Invest) and the present value of O&M cost divided by the present value of the generated energy over the lifetime of the project. The following equations define the LCOE in rigorous mathematical terms. Equation 1: The LCOE parameterized by investment cost, O&M cost and energy generation.

$$LCOE(T,r) = \frac{Invest + PV(OM,T,r)}{PV(Energy,T,r)}$$

with

$$PV(OM,r,T) = \sum_{i=0}^{T} \frac{OM_i}{(1+r)^i}; \qquad PV(Energy,r,T) = \sum_{i=0}^{T} \frac{Energy_i}{(1+r)^i};$$

The parameter r is the discount rate in percentage that discounts the annual ‘$O\&M_i$‘ cost and electricity production ‘Energy $_i$’ over the project lifetime. O&M and Energy in each year are not necessarily constant, but may be subject to indexation or degradation.

The wind farm parameter introduced above, are sufficient to calculate LCOE values for each project. The following LCOE parameters are applied throughout the calculations:

- Project lifetime T: 25 Years
- Discount rate r: 9%
- Indexation of O&M cost: 3%

In addition to the LCOE values a set of key performance figures are derived. Here a customized version of an Excel based cash flow model is parameterized for each project (compare Footnote **Error! Bookmark not defined.**).

Three key figures are derived to evaluate financial soundness of the investment in general (Project Internal Rate of Return, PIRR), bankability of the project (Debt Service Coverage Ratio, DSCR) and financial viability from an equity investor‘s perspective (Equity Internal Rate of Return, EIRR). The financial figures are defined as follows. Equation 2: The definition of the Debt Service Coverage Ratio (DSCR).

$$DSCR_i = \frac{CFADS_i}{DebtService_i}$$

The DSCR in each period 'i' is the 'Cash Flow Available for Debt Service' ($CFADS_i$) divided by the Debt service (interest and redemption). Typically the minimum DSCR and the average DSCR during the loan period are reported.

The PIRR is that discount rate at which the investment cost (Invest) is equal to the present value of the project cash flows (PCi). The project cash flows are discounted with the PIRR. Equation 3: Definition of the project value Internal Rate of Return (PIRR).

$$Invest \overset{!}{=} \sum_{i=0}^{T} \frac{PC_i}{(1+PIRR)^i}$$

The PIRR is a useful measure to judge if a project is economically sound before debt funding is considered. The pre-tax PIRR can be directly compared with the discount rate of the LCOE calculations.

The EIRR is a performance measure for the invested equity. It has the same structure as the PIRR formula but applies it to the invested equity (Equity).

The EIRR is that discount rate at which the invested equity amount is equal to the present value of distribution payments (Di). The cash flows Di are discounted with the EIRR. Equation 4: Definition of the Equity Internal Rate of Return (EIRR)

$$Equity \overset{!}{=} \sum_{i=0}^{T} \frac{D_i}{(1+EIRR)^i}$$

Sound investments should show an EIRR which is significant higher than the PIRR, as well as the interest rate of the loan. In this study DSCR, PIRR and EIRR are calculated for each project.

This section presents the LCOE calculation of the three projects. The LCOE is defined according to **Error! Reference source not found.**. The discount rate is set at 9%. Indexation of annual O&M cost is 3%. LCOE components for investment and O&M cost are listed separately (compare **Error! Reference source not found.**).

The LCOE input parameter and the resulting LCOE values in US cent/kWh are summarized in the Table below. For Cong Ly two different cases are analyzed: project phase I and the combined phase I&II. For phase I real electricity generation figures are available for the years 2014-2015. The average capacity factor during that period is 25% (compare Table 4.1). The LCOE calculation applies a capacity factor of 25% as a reasonable approximation, rather than using the exact figures.

Table 4.5: LCOE input and output values for Cong Ly in Phase I and I&II.

Num	Variable	Unit	Cong Ly Phase I	Cong Ly Phase I&II
1	Investment Cost	[USD/MW]	2,910,273	2,390,793
2	O&M Cost	[USD/MW]	25,622	24,987
3	Capacity Factor	%	25.0%	28.0%
4	LCOE (Invest)	[USDcent/kWh]	14.07	9.92
5	LCOE (O&M)	[USDcent/kWh]	1.47	1.15
6	**LCOE**	**[USDcent/kWh]**	**15.54**	**11.07**

The Phase I wind farm as stand-alone project would require a prohibitive high tariff. The high value is caused by the high specific investment cost (investment component of the LCOE is 14.07 US cent/kWh). The O&M component accounts for 1.47 and 1.15 US cent/kWh respectively which is about 9% (10%) of the overall LCOE value. The combined project phase I&II requires an overall tariff of 11.07 US cent/kWh which is above the 9.8 US cent/kWh currently earned by the project.

4.6 Summary of results

This section performs a sensitivity analysis and summarizes the LCOE calculation. Bac Lieu Phase I is only ignored in the subsequent analysis due to the ambiguous cost allocation between Phase I and Phase II.

4.6.1. Sensitivity analysis

The above analysis assumes constant electricity production and O&M costs – indexed by 3% annually - during the lifetime of the project. In order to evaluate the robustness of these assumptions a sensitivity analysis is performed. This provides insight how a persistent change affects the LCOE. The table below summarizes the results.

Table 4.6: LCOE sensitivities with respect to capacity factor, O&M cost and indexation

Variable	Unit	Cong Ly Phase I&II	REVN	Phu Lac
Capacity factor 1%	[USDcent/kWh]	0.4	0.5	0.4
O&M 10k USD/MW	[USDcent/kWh]	0.5	0.8	0.6
O&M 5% indexation	[USDcent/kWh]	0.3	0.6	0.6
Discount rate 1%	[USDcent/kWh]	0.8	1.5	0.6

A 1% change in capacity factor has a similar impact on the change in the LCOE in each project. It is interesting to note, that the weakest project (REVN) is more sensitive to such a change. A change in specific annual O&M cost by 10,000 USD per MW and year (10K USD/MW) causes a change of LCOE in the range of 0.5-0.8 US cent/kWh and is of comparable magnitude as the 1% change of the capacity factor. Again REVN is most sensitive to changes. The analysis of LCOE assumes a 3% indexation of O&M cost in each project. The sensitivity to indexation is shown in the second last line of Table 4.64.7 below. An increase to 5% p.a. causes an increase in LCOE by 0.3 (0.6) US cent/kWh for Cong Ly (REVN and Phu Lac). It is not surprising that the project with the lowest specific O&M cost (Cong Ly) is the least sensitive to a change in indexation. The last line shows the sensitivity of LCOE to the discount rate. A 1% change in the discount rate causes a change in LCOE in the range of 0.6-1.5 US cent/kWh. The interpretation of this result can also be reverted. A tariff change of 0.6-1.5 US cent/kWh causes a change in the PIRR of 1%.

Summary of LCOE calculation: The Table provides an overview of LCOE input parameter and results for the three reference projects.

Table 4.7: Summary of LCOE calculations.

Variable	Unit	Cong Ly Phase I&II	REVN	Phu Lac
Investment Cost	[USD/MW]	2,390,793	2,635,602	1,818,358
O&M Cost	[USD/MW]	24,987	40,647	51,764
Capacity Factor	%	28.0%	25.0%	28.0%
LCOE	**[USDcent/kWh]**	**11.07**	**18.94**	**10.26**

The LCOE for nearshore is higher than the LCOE for onshore.

This section explores financing properties of the reference projects in more detail by analyzing key financial indicators. The Table lists the key performance indicators for debt and equity investors. The average interest rate of debt funding (line 5) and the electricity tariff (line 6, both in grey) are shown as a reference. The PIRR is calculated pre-tax in order to compare it with the discount rate applied in the (pre-tax) LCOE calculation. PIRR measures the soundness of a project net of tax and debt funding. The EIRR is calculated post-tax to measure the net performance of an equity investor.

Table 4.8: Summary of key financial indicators for debt and equity investors

Num	Variable	Unit	Cong Ly Phase I&II	REVN	Phu Lac
1	Project IRR	%	7.32%	-0.41%	4.34%
2	Equity IRR	%	5.00%	-8.19%	7.00%
3	Min. DSCR	Ratio	0.60	-1.28	0.80
4	Average DSCR	Ratio	0.72	0.70	0.87
5	Average Interest Rate	%	9.69%	4.83%	2.30%
6	Tariff	[USDcent/kWh]	9.80	7.80	7.80

4.6.2. Financial viability

For Cong Ly, the average interest rate of the debt funding instruments is higher than the PIRR. The projects exhibit ‘negative leverage’, e.g., the EIRR is lower than the PIRR. The financial performance of Cong Ly is partly owed to the tariff of 9.8 US cent/kWh.

The financial indicators fall to the following values: PIRR 4.44%, EIRR 0.85%, Min DSCR 0.47 and Average DSCR 0.56.

4.6.3. Liquidity issues

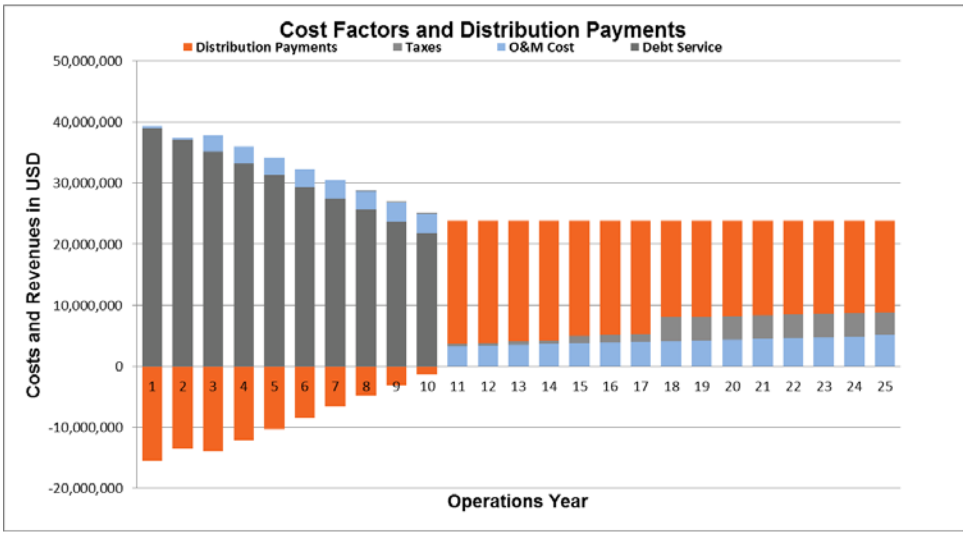
A DSCR (minimum or average) below 1.0 indicates periods of liquidity shortage. The CFADS does not cover the ongoing interest and redemption payments. Strictly speaking a project company with non-recourse lending and no cash reserves defaults when the DSCR falls below 1.0 in a given period. The DSCR is thus the most important key figure in the loan approval and monitoring process of banks. Projects which cannot demonstrate strong DSCR values in the range of 1.2-1.3 are considered as not bankable. In addition the 'banking case' typically requires safety buffers with respect to cost and electricity generation (like P90 scenarios) which would further worsen the situation.

None of the projects would be considered as bankable according to typical DSCR standards.

4.6.4. Modified loan conditions as key to enhanced financial viability

When funding rates are higher than the PIRR, debt funding makes no economic sense which is reflected in negative leverage. But even if a project is economically sound (sufficient PIRR) it still requires appropriate funding conditions to be bankable. The Phu Lac case demonstrates that dilemma. Although the PIRR is larger than the funding rate, and a positive leverage is observed (EIRR > PIRR), the DSCR falls below 1.0 during the loan period (compare **Error! Reference source not found.**, last column). There are three possible adjustments to the loan conditions to overcome the problem and lift the DSCR. First, the loan amount can be reduced (higher equity ratio). Second, the interest rates can be reduced (lower debt service) or third, the loan redemption period can be stretched. Prolonging the loan period from 13 years to 16 years would in fact lift the min. Therefore the impact of adjusted loan conditions is analyzed for the project developed by Cong Ly in more detail.

Figure 4.4: Cash flow diagram of Cong Ly phase I & II with different debt funding conditions



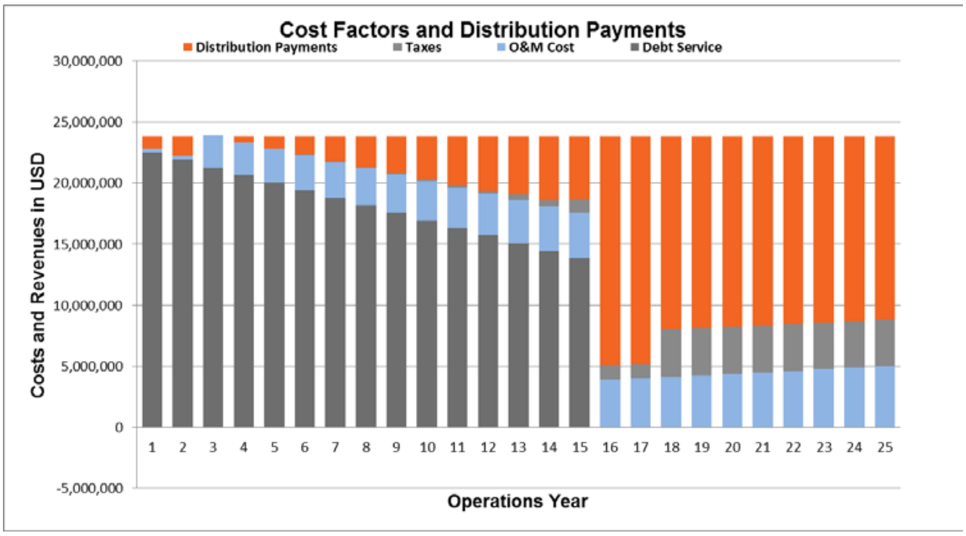


Figure illustrates the cash flow diagram for Cong Ly Phase I&II with different loan conditions. The graph (top) shows the original simulation. The effective loan conditions are 9 years maturity and 9.96% interest rate. The bottom graph applies 15 years loan maturity and a 5% lower interest rate of then 4.69%. The modified loan conditions turn periods of negative cash flows (period 1-10 years, top) into positive cash flows by reducing and stretching the debt service. As result the min. DSCR increases to 1.0.

4.6.5. FiT for nearshore wind projects

The implementation of a nearshore FiT is justified if higher costs are partially compensated by higher capacity factors. However such a tariff requires a rigorous definition of "nearshore" versus "onshore".

For nearshore there does not exist a similar sample size as for onshore. Cong Ly can not be used as a perfect example for nearshore but it could support the assumptions and create a plausible base case for nearshore. With respect to onshore higher CapEx and OpEx but also a higher capacity factor due to the more favorable wind conditions are assumed. Like the onshore case, the nearshore scenario set consists of seven scenarios (base case plus six scenarios) defined as follows:

Table 4.9: Scenario set for nearshore wind farms[82]

Scenario	**CapEx** **[million USD/MW]**	**O&M** **[T USD/MW*year]**	**Capacity Factor**
Base case	**2.50**	**45.00**	**35.0%**
CapEx+	**2.75**	45.00	35.0%
CapEx-	**2.15**	45.00	35.0%
O&M+	2.50	**55.00**	35.0%

[82] Beside the base case scenario two additional scenarios are derived for each factor CapEx, OpEx and capacity. Base case and variations in each factor are shown in bold.

O&M-	2.50	**35.00**	35.0%
Capacity+	**2.50**	**45.00**	**40.0%**
Capacity-	2.50	45.00	**30.0%**

As a general property of nearshore we assume better wind conditions (+5% capacity factor) at the expenses of higher installation and operating cost as compared to the onshore case. We assume higher CapEx in the amount of USD 500,000 per MW installed due to more complex construction cost and higher technical requirements caused by adverse environmental conditions. This assumption is supported by the observed CapEx of 2.5 million USD/MW for the nearshore project Cong Ly. We assume higher OpEx of 10,000 USD/MW/year installed as compared to onshore installations. This amount seems fair given adverse weather conditions, the impact of wear and tear and through additional cost for logistics. The OpEx for the nearshore model departs from the cost quoted for Cong Ly which are in the range of 25,000 USD/MW only. **Error! Reference source not found.** summarizes the LEC values as a function of required project IRR and scenario. The period of operation is assumed to be 20 years.

Onshore and nearshore tariffs are very similar and differ by just less than one cent. We could therefore expect a similar qualitative result for the nearshore simulation. In the following we focus on the most interesting case of strategic debt financing at 6% interest rate and 10 year maturity, as well as on the results for the base case scenario. **Error! Reference source not found.** shows equity IRR and min. DSCR for the three different nearshore tariffs that provide a target project IRR of 6%, 10% and 16% in the base case respectively. With the current onshore tariff of 7.8 USCents/kWh no scenario provides a bankable project. At 8.75 USCents/kWh only two favorable scenarios deliver a bankable project. For a tariff of 11.18 USCents/kWh even projects under adverse scenarios are bankable. Equity IRR values range from 7.3% to 17.4%.

The above analysis is repeated for debt financing with 10 and 16 years maturity and 2%, 6% and 10% interest rates. Only the results for the base case scenario are presented. **Error! Reference source not found.** shows min. DSCR and equity IRR for the three different tariffs that provide the project IRR of 6%, 10% and 16%.

The overall results are in line with the results obtained for the onshore case. A nearshore tariff of 11.18 USCents/kWh that delivers a pretax project IRR of 10% could result in a financial viable project if strategic debt financing of 6% interest rates can be secured. For a tariff of 11.18 USCents/kWh and higher, a project becomes more financial stable (higher min. DSCR) and profitable (higher equity IRR) if the loan maturity moves from 10 to 16 years in the base case scenario. Annex 3-2 presents a sample cashflow model for nearshore (10% project IRR, 10 year loan at 6% interest rates)

5 Conclusions

The compiled data set based on realized technical and financial data has been found to be sufficient and consistent to calculate LCOE figures for each project. The LCOE calculations utilize realized figures, thus a high confidence can be granted to the results.

At the same time the results are within a very narrow range of the GIZ FiT study performed in 2014 where 11.20 US cent/KWh for nearshore wind projects were proposed. The close proximity of the results is an additional reassurance of the derived FiT values. Further evidence for the gap between actual and required FiT is the lack of market response. No additional wind projects which rely on the FiT have been initiated recently.

It is concluded that a higher FiT in the above range is required in order to meet the targets of the revised Master Plan for Power Development (Decision No. 428/QĐ-TTg dated 18 March 2016, PDP VII), of 800 MW by 2020, 2000 MW by 2025 and 6000 MW by 2030.

The LCOE calculation reconfirms that a higher FiT is a necessary prerequisite to achieve the targets on wind power development in Viet Nam. The detailed analysis of PIRR, EIRR and DSCR in Part **Error! Reference source not found.** reveals that further accompanying measures are imperative to create financially viable projects in the economic market conditions. The most promising measures are:

(i) Prolonged loan periods which are aligned with the economic lifetime of wind power project; and

(ii) Lower interest rates of debt funding instruments

Both measures reduce the financial burden of the debt service by stretching (i) and absolutely reducing debt payments (ii). Infrastructure projects are typical long-term ventures. According to international best practices, loan conditions are aligned with the economic lifetime and the risk profile of projects. Such a request for longer maturities and lower interest rates is justified due to the favorable properties of wind power projects like long-term and stable FiT based revenues, low O&M expenses with little cost fluctuation as compared to 'fuel driven' conventional power investments and low off taker counter party risk. Financial institutions should be engaged in assessing the risks of wind projects more favorable and in comparison with other infrastructure or real-estate projects with less favorable conditions. In addition Part **Error! Reference source not found.** reveals that an adjusted tax incentive scheme which better aligns with the earnings profile of wind power projects could also improve the financial viability. Foreign exchange rate risk caused by non-USD denominated loans has to be properly assessed and accounted for.

Wind' or green bonds issued by governmental backed agencies could provide funding and liquidity to wind power projects. Lower interest rates for these bonds are justified due to the financial strength (rating) of the issuing agency. The interest rate advantage could be passed on to wind power projects. In the US, agency bonds are popular instruments to improve lending conditions to different sectors like farming, residential housing or student loans to fund university fees.

Government-sponsored private equity funds that provide equity tranches to infrastructure projects are a relatively new instrument. However it has been successfully implemented in Croatia to support different sectors like RE investments and the tourism industry. The Croatian Bank for Reconstruction and Development (HABOR) provides matching equity for each euro invested through a private equity fund. Higher equity levels reduce the burden of the debt service. In return the fund participates in the economic success of the project.

The Renewable Energy Development Fund (REDF) has the objective to disburse support payments for renewable energy development. However, a number of general criteria must be satisfied for such a fund to disburse subsidies in a cost-effective manner:

- Clarity of objective: Each disbursement window of the fund needs to have clear objectives, and quantitative criteria by which applications for subsidy can be evaluated.

- Certainty and timing: the subsidy revenue stream will only be useful to secure financing if its magnitude is known with some certainty at the time of financial closure. This also implies a requirement for secure funding of the fund.

- Form of subsidy: the worldwide experience suggests that one-time capital grants are to be preferred to open-ended subsidies (as VND per kWh delivered) during operation. However, for certain category of RE project and area, the open-ended subsidies should not be excluded.

- Technology-neutral: disbursement of subsidies should be technology neutral, except where there is a demonstrable rationale why support for a particular technology is warranted.

- Incentives for CDM: the subsidy structure should provide incentives to maximise CDM revenues.

- Cost-effectiveness: whenever possible, subsidies should be awarded on the basis of competitive solicitation, and subject to an upper bound that follows from the objective for that particular subsidy window.

The Government needs to take a more active role in promoting renewable energy development. Renewable energy needs support from Government. In the case of grid-connected renewables, the rationale is to correct for market failures. The avoided cost tariff (ACT) for grid-connected renewables is based on the buyer's *financial* rather than economic costs, and the prices in the competitive generation market do not reflect the environmental damage costs of fossil energy generation.

The important priorities are as follows:

- *Wind data development,* Large scale grid-connected wind farms are not presently economic. However, it is not unlikely that in the future, wind turbine capital costs will decline, and that carbon prices will increase, at which point wind power has the advantage that it can be implemented on a fairly large scale using standard technology. At that time, it will be very important that adequate wind resource data is available to support robust designs. Wind is subject to the same type of annual and seasonal fluctuation as hydro, and therefore requires adequate time series of data at representative hub heights to ensure good design.

- *Environmental damage costs of fossil generation*: This report finds that there is presently no reliable basis to quantify the environmental damage cost of fossil energy generation, and there is therefore little basis to assign a specific damage cost as VND/kWh for purposes of setting an economically efficient renewable energy target, Indeed, for this reason, the proposed avoided cost tariff methodology developed by ERAV presently does not reflect these costs – though the structure of the tariff would permit this charge to be added once the basis is more reliable. We therefore recommends that a detailed study of the health damage costs of local air emissions be prepared, based on Vietnamese epidemiological and health cost data (rather than on data extrapolated from other economies). Such a study would not only guide policy for renewable energy and power generation, but also provide a basis for environmental policy in the transportation and industrial fuels sector.

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