NATIONAL IMPACT STUDY:

New Zealand Offshore Wind Industry

Contents

Glossary

Abbreviation	Definition
BCG	Boston Consulting Group
BEC	Business Energy Council
CCC	Climate Change Commission
CCUS	Carbon capture utilisation and storage
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
CSP	Concentrated solar power
DoC	Department of Conservation
EEZ	Exclusive economic zone
eSAF	Electric sustainable aviation fuels
EV	Electric vehicle
FTE	Full time equivalent
GDP	Gross domestic product
GWEC	Global Wind Energy Council
GW/(GWh)	Gigawatt/(hour)
GWEC	Global Wind Energy Council
GXP	Grid exit point
HVDC	High-voltage direct current
kWh	Kilowatt hour
LCA	Life cycle analysis
MBIE	Ministry of Business, Innovation and Employment
MPA	Marine protected areas
MPI	Ministry for Primary Industries
MW/(MWh)	Megawatt/(hour)
NIMBY	Not in my backyard
NIS	National impact study
NREL	National Renewable Energy Laboratory
NZP&M	New Zealand Petroleum & Minerals
NZTE	New Zealand Trade and Enterprise
O&M	Operation and maintenance
OWF	Offshore wind farm
PJ	Petajoule
PtL	Power-to-Liquid
PtX	Power-to-X
QMS	Quota management system
R&D	Research and development
SOSA	Security of supply analysis
TPM	Transmission pricing methodology
TWh	Terawatt hours
WCNI	West Coast of the North Island

Key messages

Our key findings are:

Economy

Offshore wind provides a transformative opportunity to propel the country towards a more sustainable economic future.

The future offshore wind industry is estimated to generate between $12b and $94b of Gross Domestic Product (GDP) over the life of the projects, half of which will be concentrated during the construction phase, and the other half during operations. By 2050, the economic impact of offshore wind could be as large as the current oil and gas sectors.

A wide range of skilled jobs will be created from offshore wind projects, with many workforce synergies being leveraged from existing sectors (e.g. oil and gas) and regions (e.g. Taranaki) impacted by the energy transition. Between 5,000 and 30,000 jobs could be created at the peak of the construction phase.

Offshore wind could unlock significant economic activity in an associated hydrogen industry, new green industry and export opportunities and will sustain economic activity and jobs in regions affected by the energy transition (e.g. Taranaki).

Investments in enabling ports and energy transmission infrastructure will need to lead the development of offshore wind farms to unlock the resource and avoid flow on delays to the development of the sector.

Environment

Offshore wind could prove vital in accelerating and scaling renewable energy to the levels required to meet our national 'net zero' emissions target by 2050.

It is perhaps best placed to unlock large scale decarbonisation of hard-to-abate transport emissions when using synthetic fuels and feedstocks produced from hydrogen. It can also play an important role in supporting electrification of the economy. We estimate that offshore wind could enable an 18% to 30% reduction in national energy related emissions (excluding industrial feedstocks).

Overseas precedent points to a number of key considerations for understanding the environmental outcomes of offshore wind, but there is still a lot we don't know about our marine environment and how this will interact with offshore wind.

Detailed environmental studies are required to understand how New Zealand's unique sea life and oceanic and atmospheric conditions will be affected and mitigations designed where needed.

Energy

Offshore wind has a number of strategic advantages which could make it an important tool in our future energy mix:

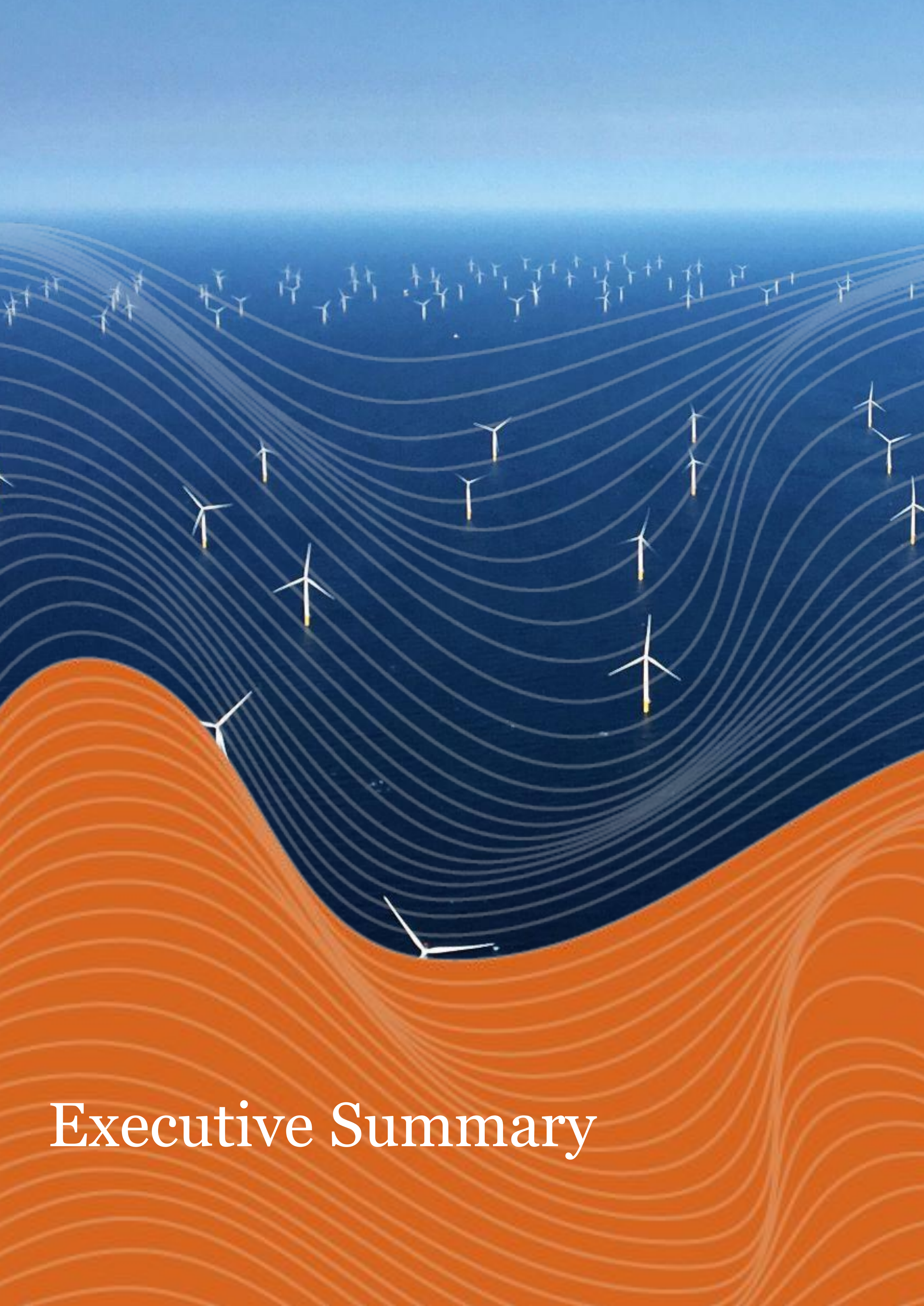
- It has the lowest emissions intensity of all renewable generation options
- It harnesses a more powerful ocean wind resource - uninterrupted by land features - which means it generates more power, more often, more efficiently
- It has the greatest potential to accelerate and scale renewable energy production which may prove critical to keep us on track to meet our net zero target by 2050
- It contributes to energy security through diversity of supply and higher levels of energy generation and availability during winter and dry years. When paired with hydrogen fuelled thermal 'peakers', electrolyser flex, and batteries it can support more firm renewable supply
- As with other renewable technologies, the cost of offshore wind is projected to fall rapidly with improvements in technology, global manufacturing scale and our understanding of the offshore resource. Based on international studies, we estimate the cost of a typical New Zealand offshore wind farm will fall to around the current cost of onshore wind by 2050.

While more mature renewable resources may continue to have an economic advantage for some time, adopting a pure economic approach to investments in offshore wind may not provide the best outcomes for our energy transition and climate change objectives. New Zealanders may be willing to recognise the social value offshore wind provides in accelerating decarbonisation and reducing local community impacts.

People

Communities near proposed offshore wind farms may have concerns about environmental and visual outcomes and noise, but generally offshore wind results in better outcomes for communities. It is likely to have lower visual and community impacts and land use constraint as it is situated far away from areas extensively used by people.

Offshore wind farms are likely to make a positive difference in communities and for iwi-Māori by stimulating economic activity and green energy related jobs. Greater participation is sought by iwi-Māori in decision making over the use of the moana and related economic opportunities.



Executive Summary

Executive Summary

The offshore wind industry provides a transformative opportunity to propel the country towards a more sustainable economic future.

The country has ideal conditions for offshore wind and with investment and support the industry has the potential to be highly beneficial to New Zealand. Investment in offshore wind would bring significant economic activity and sustain jobs in regions likely to be affected by the energy transition, such as Taranaki.

The emergence of the industry will be vital to accelerating and scaling decarbonisation of the economy to enable our 'Net Zero' national decarbonisation strategy. Offshore wind is particularly important for decarbonising hard-to-abate emissions associated with transport fuels and industrial feedstocks as it can unlock high levels of green hydrogen production and Power-to-X (PtX) synthetic fuels.

This study shows that on balance, offshore wind may provide significant benefits for the economy, environment, energy sector, and local communities. Detailed analysis and careful planning will be required to better understand and address potential consequences for the natural environment and energy markets, but offshore wind is likely to provide better outcomes overall when included in our energy mix.

Introduction

This report presents a National Impact Study (NIS) setting out the benefits, costs, opportunities and challenges associated with establishing an offshore wind industry in New Zealand.

It has been prepared to inform and progress a national discussion on the merits of offshore wind and to support investment planning, industry coordination, policy and regulatory development.

Approach

We have applied a strategic assessment framework to assess the potential national impacts. This focuses on four key themes: the economy, energy system, environment, and people (as illustrated in the figure to the right).

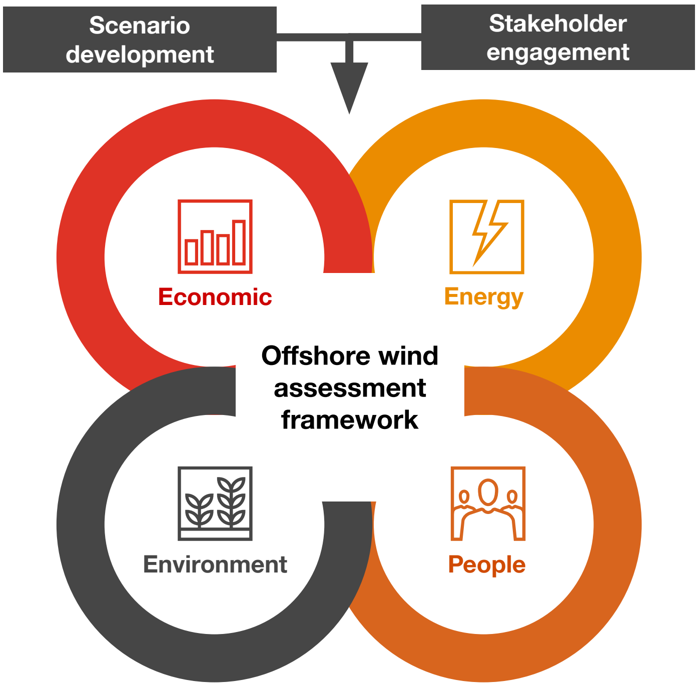
Research and analytical approaches have been tailored to each focus area to draw out a broad range of insights.

To set a foundation for our assessment, we have designed three potential future scenarios for the offshore wind industry in New Zealand. These underpin our economic, energy market and emissions analysis.

We have engaged with a wide range of energy, infrastructure, environmental and community stakeholders to gather insights, direction and feedback, and to inform and contextualise our findings.

Our analysis is out of necessity conceptual and broad ranging given offshore wind is developing globally and remains untested in New Zealand. There is significant uncertainty over how the industry may develop and as a result we have relied on scenarios, assumptions and narratives to draw a vision for the future of the sector. Input from the project Steering Group (see contributing organisations opposite), overseas precedent, existing studies and stakeholder interviews have been used to underpin and test our findings.

Figure 1: High level overview of the approach



Project steering group members:

- BlueFloat Energy / Elemental Group
- Business NZ Energy Council
- Clarus
- Parkwind
- Port Taranaki
- Powerco
- NZ Trade and Enterprise
- NZ Wind Energy Association
- Sumitomo Corporation
- Taranaki Offshore Partnership
- Te Puna Umanga Venture Taranaki
- Transpower

Energy terminology:

We use a variety of units to discuss the size and capacity of offshore wind farms. When we reference gigawatts (GW) or megawatts (MW), this refers to capacity, or how big the electric generator is. When we reference terawatt hours (TWh) or megawatt hours (MWh) we are referring to the amount of energy produced or consumed. For reference, New Zealand current electricity supply is about 43.5 TWhs.

For a list of all defined terms please refer to the glossary.

This report is structured as follows:

1. **The future of New Zealand offshore wind** Sets out future scenarios for the offshore wind sector
2. **Economic** Estimates economic impacts and employment opportunities associated with the offshore wind sector
3. **Energy** Explores the contribution offshore wind can make to decarbonisation, energy security and affordability
4. **People** Considers potential implications for local communities and iwi-Māori
5. **Environmental** Summarises environmental considerations for further work

Background

The New Zealand energy challenge

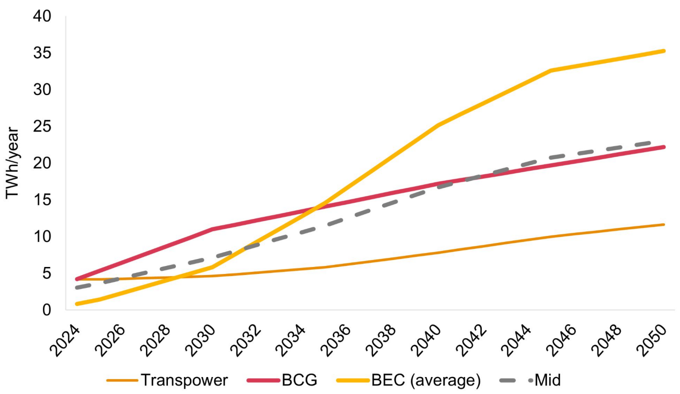
As New Zealand plots a course to 'net zero', the key challenge for the energy sector is how to affordably and reliably decarbonise energy use in transport, industrial feedstock, and process heat - our largest sources of energy related emissions.

Our electricity sector (representing 26% of national energy consumption and already 89% renewable)[1] is being called on to increase production of renewable electricity to support electrification of the economy and potentially the production of new green hydrogen based synthetic fuels.

A synthesis of the NZ energy outlook scenarios indicates that renewable generation would need to more than triple by 2050 to meet demand. This is in line with the recent global commitment to triple renewable energy capacity made at the United Nations Climate Change Conference (COP28) and the Government target to double renewables in the same time period.[2]

Wind generation (both onshore and offshore) is an efficient and powerful source of renewable energy and is expected to play a significant role in our future energy mix. Forecasts by Transpower, Business Energy Council (BEC) and Boston Consulting Group (BCG) indicate that between 12 TWh and 35 TWh of new wind generation is required just to meet grid based demand for electricity. For context, this is between 4x and 14x New Zealand's current annual wind generation of over 2.8 TWh.[1]

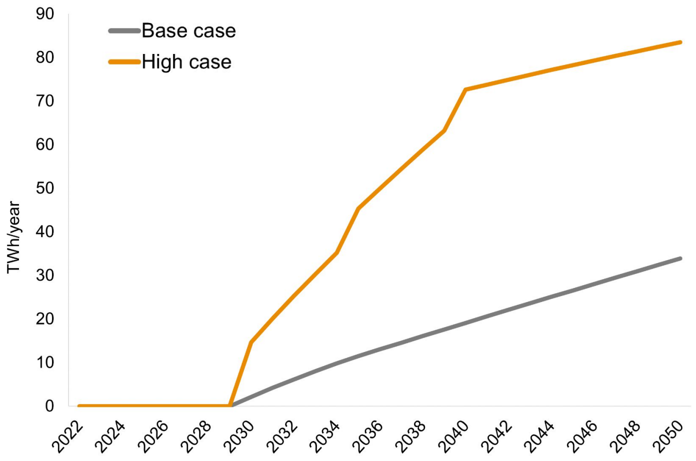
Figure 2: New Zealand scenario forecasts of new wind generation supply[3,4,5]



Source: Transpower, Business NZ Energy Council, BCG

There is also an opportunity to use renewable generation to produce large amounts of green hydrogen to decarbonise hard-to-abate transport fuels and industrial feedstocks. Hydrogen forecasting work commissioned by MBIE in 2023 indicates a further 34 TWh to 73 TWh of renewable generation could be required for hydrogen production and PtX solutions. PwC have considered up to a further 10 TWh of supply for production of synthetic international jet fuels, which were excluded from this analysis.

Figure 3: Forecast demand from hydrogen production (TWh of generation)[6,7]



Source: PwC, EY/MBIE

Scaling the energy transition

Concern is growing internationally that the global energy transition is not moving fast enough to curb global temperature rises and more needs to be done.

Scaling the use of New Zealand's rich renewable resource is vital to our decarbonisation efforts and the pace of construction will need to accelerate dramatically if we are to meet demand for electricity and hydrogen.[6,8]

Land based renewable resources (i.e. solar, wind, geothermal, hydro and bio-energy) will play a critical role in this energy transition. Whether New Zealand can build out this resource fast enough to meet projected demand has not been explored, but environmental and community concerns could be key challenges for scaling land based renewables.

The Climate Change Commission's (CCC) 2023 advice to government highlighted the cost to the country of falling behind this build schedule. It estimated that a 12 month delay could increase wholesale electricity prices by up to $35 per MWh (a 33% increase).[9]

Each form of renewable generation has its constraints, and as a country we will need to bring all forms of renewables and carbon abatement to solve the problem. In order to mitigate the potential risks of project delays due to consenting challenges, it is critical that New Zealand has a robust pipeline of new renewable generation assets under development which is diverse from both a technological and geographical perspective.

Looking overseas, environmental and community concerns, resource constraints, and more stringent regulatory approvals have restricted the role land based developments can play in the energy transition. Mitigations and policies to accelerate renewables can alleviate these issues, but residual community sentiment and environment impacts will remain.

Offshore wind

While offshore wind faces its own challenges, the constraints observed for land based projects have pushed a number of renewable developers to turn their attention to the untapped potential of the marine wind resource.

Global offshore wind capacity is growing quickly, at an annual rate of 21% over the last decade. It currently represents about 7% of all global wind capacity (64.3 GW). By 2030 it is projected to grow to 380 GW of capacity, and to 2,000 GW by 2050.[10]

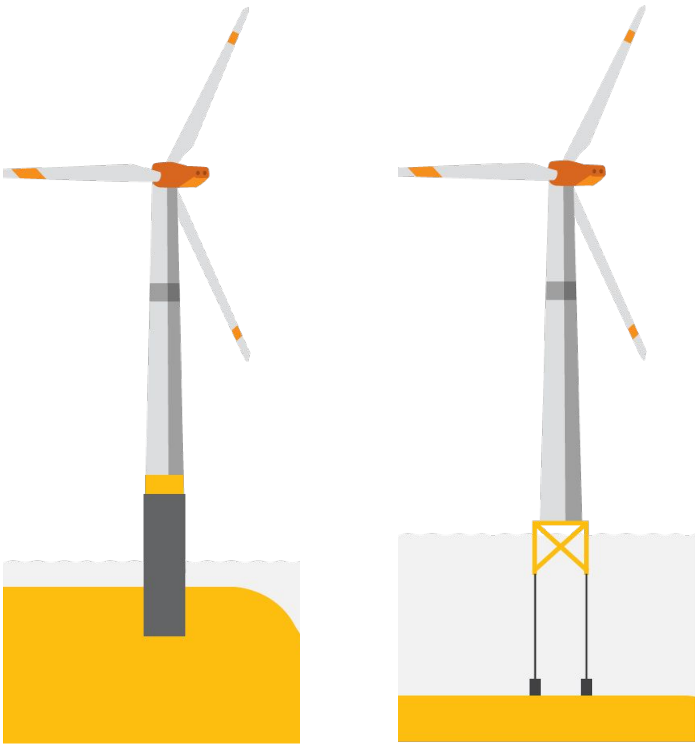
New Zealand's offshore wind resource has not yet been commercialised, but is considered ideal given our position in the 'roaring forties' latitudes and given our extensive coastline and exclusive economic zone (EEZ - the 9th largest in the world).

Four key locations with high potential for development have already been identified - South Taranaki, the west Auckland-Waikato coast and the Foveaux and Cook Straits. Some of these areas are considered among the best offshore wind resources in the world.

Many developers are now undertaking feasibility and design studies across these locations, with nearly 12 GW of offshore wind generation projects announced (illustrated on the next page). The emerging view is the first Offshore Wind Farm (OWF) may be built in the early 2030s.

There are two types of offshore wind turbines (as illustrated below). **Bottom-fixed turbines** are fixed to structures embedded in, or mounted on, the seabed. The structures can be monopile, jacket structure (lattice structure with multiple legs) or gravity base (heavy, reinforced concrete base). **Floating turbines** sit atop a floating foundation that is anchored to the seabed by mooring lines.

Figure 4: Example of a bottom-fixed turbine using a monopile base (left) and floating turbine with mooring lines (right)

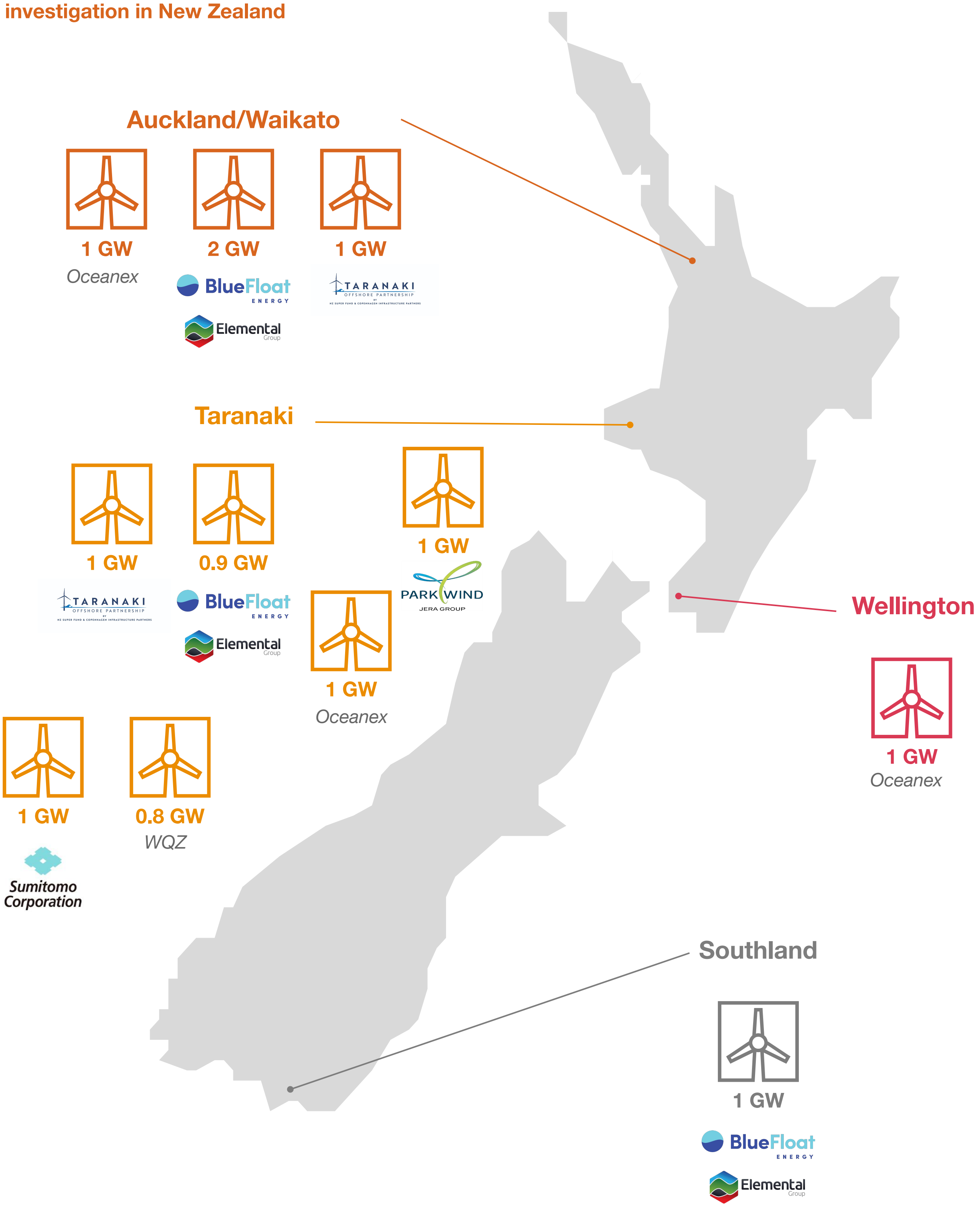


Source: Recreated from Principle Power

Bottom-fixed turbines are based on a long history of offshore engineering, thousands of successful installations in Europe, and an established and proven supply chain. The economic viability of fixed structures currently constrains the installation depth to 75m due to increasingly complex engineering and the capabilities of installation vessels.

Floating turbines are less depth constrained than bottom-fixed options, increasing their resource development potential (i.e. greater sea area utilisation) and size of resource available (e.g. greater wind speeds). They are still in development and yet to be commercialised, with costs currently some 50% higher than established bottom-fixed options.[11] However, per MWh costs are projected to reduce over time which may make them an attractive option in time.

Figure 5: Offshore wind projects under investigation in New Zealand



Source: PwC, Energy News, developer websites

Defining the future scenario pathways

Three future scenarios of demand and offshore wind uptake have been developed to explore and evaluate the future impacts of the industry.

We have used recent electricity and hydrogen outlook scenarios to synthesise a view of electricity demand and supply out to 2050. This considers both demand from grid based electrification and new hydrogen production.

This is supplemented with our own analysis of generation supply requirements for international sustainable aviation fuels (e-SAF) and new direct-connect industrial loads notionally associated with green food, metals and chemicals production.

The three scenarios are:

1. **Electrification:** New demand comes from traditional use of the grid and electrification of energy intensive industry and transport. This is based on the average of the electricity demand forecasts produced by Transpower - *Whakamana i Te Mauri Hiko*, BEC - *Time-NZ 2.0* and BCG - *The Future Is Electric*.[3,4,5]

   8.8 TWh (2 GW capacity) of offshore wind is assumed in this scenario, equivalent to 17x 'example' onshore wind farms of 148 MW capacity in the current development pipeline.

2. **Electrification Plus:** The Electrification scenario above plus domestic demand from new low carbon industries and levels of green hydrogen consistent with the base case of the EY/MBIE hydrogen modelling. We add 4.9 TWh of demand from new green industry, about equivalent to the electricity use of Tiwai Point Aluminium smelter.

   Offshore wind supply is projected to be 39.3 TWh (8 GW capacity) in this scenario.

3. **Green Vision:** The Electrification Plus scenario above plus significant growth in use of hydrogen based synthetic fuels produced from renewable electricity and new low carbon industrial loads.

   Offshore wind supply is 74.4 TWhs (15 GW of capacity) in this scenario.

The figures opposite show forecast total national electricity demand (net of losses) and required offshore wind supply under each scenario. The difference between demand and supply is made up from other renewable and non-renewable generation, but has not been explicitly modelled. On the page overleaf we summarise the key features of each scenario.

Enabling Infrastructure

The study highlights the essential role of port and energy transmission infrastructure, which will need to lead OWF developments. Critical infrastructure includes:

- Port upgrades at Port Taranaki and other ports to support assembly, installation and operations of OWFs
- Grid capacity upgrades by Transpower required to transport electricity from Taranaki and Auckland/Waikato based OWFs to key demand centres
- Potential new hydrogen storage and pipeline infrastructure to unlock higher levels of hydrogen production and offshore wind in Taranaki and transportation of larger amounts of renewable energy to the upper North Island.

Figure 6: Electrification - Forecast national demand (net) and wind supply[6]

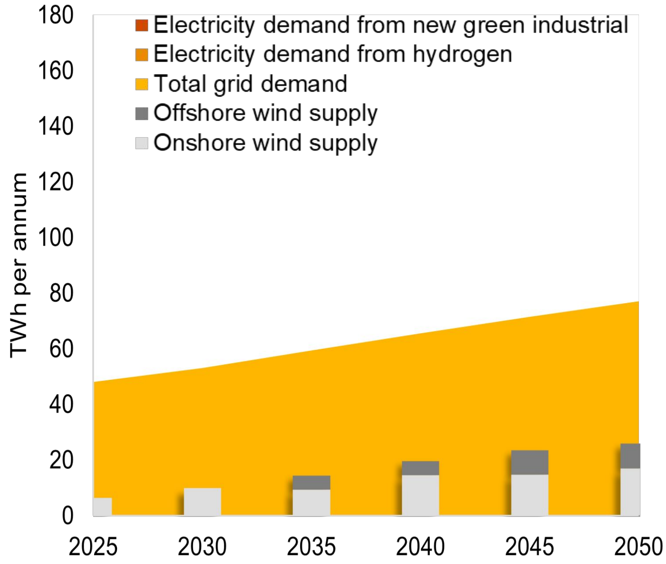


Figure 7: Electrification Plus - Forecast national demand (net) and wind supply[6]

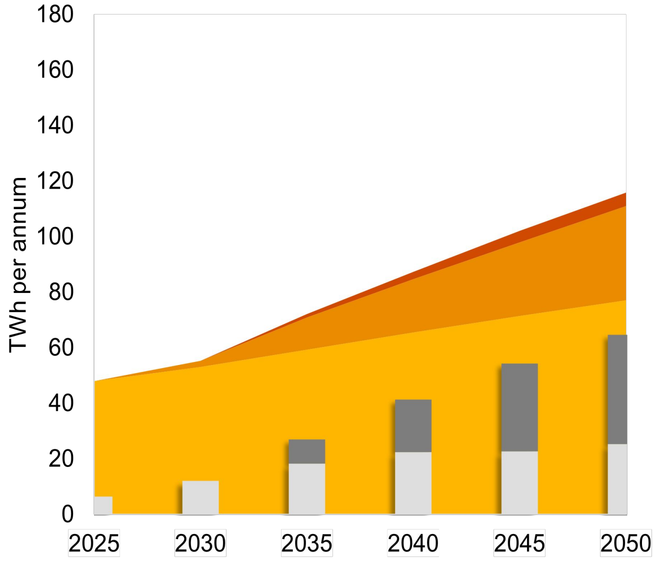
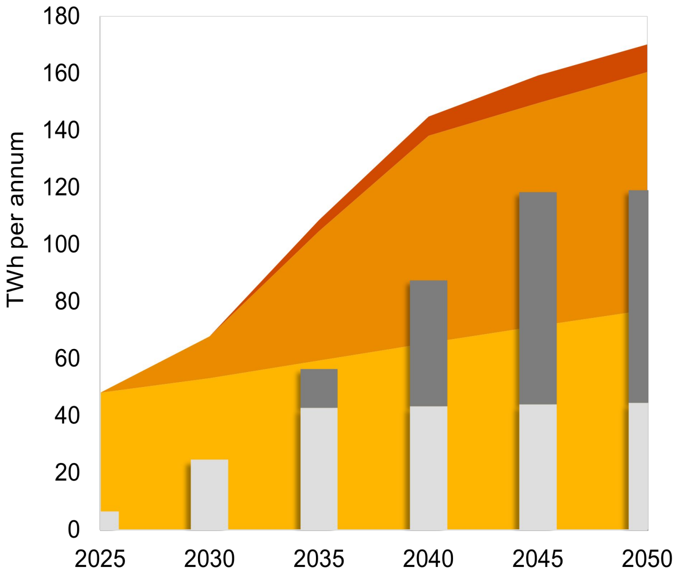
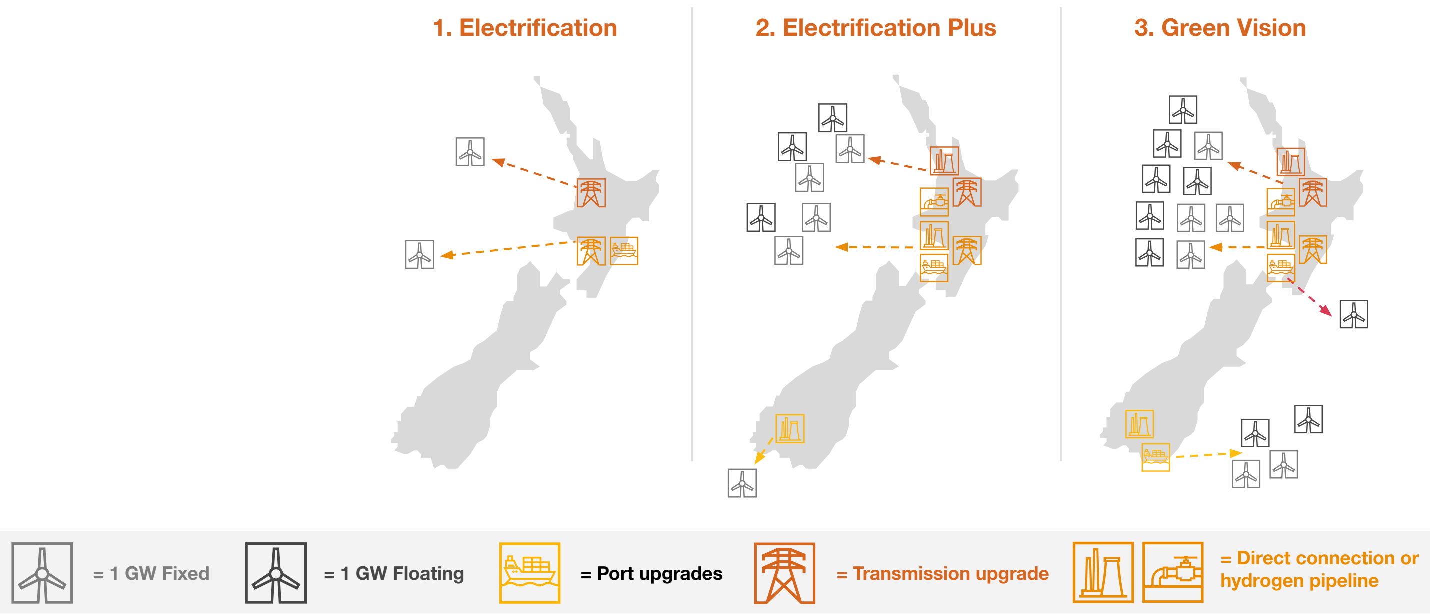


Figure 8: Green Vision - Forecast national demand (net) and wind supply[6]



Source: PwC

Figure 9: Scenario overview



	1. Electrification	2. Electrification Plus	3. Green Vision
Total national electricity demand (2050)			
Total demand (net)	**77.1 TWh/year**	**115.9 TWh/year**	**170.2 TWh/year**
New grid demand	33.6 TWh/year	33.6 TWh/year	33.6 TWh/year
Hydrogen production	-	33.9 TWh/year	83.5 TWh/year
New green industry	-	4.9 TWh/year	9.7 TWh/year
Existing demand	43.5 TWh/year	43.5 TWh/year	43.5 TWh/year
Projected new offshore wind supply (2050)			
Annual generation	**8.8 TWh/year**	**39.3 TWh/year**	**74.4 TWh/year**
Installed capacity	2 GW	8 GW	15 GW
Equivalent number of onshore wind farms*	17	76	143
Projected other generation supply (2050)			
Other generation	**68.4 TWh**	**76.6 TWh/year**	**95.9 TWh/year**
Total generation	**77.1 TWh/year**	**115.9 TWh TWh/year**	**170.2 TWh/year**
Economic contribution of offshore wind			
National GDP impact - over lifetime of projects	$11.6b	$47.4b	$93.6b
Average jobs - during construction (NZ FTE)	5,300	8,400	22,000
Average jobs - during operations (NZ FTE)	620	2,000	3,900
Total local spend - over lifetime of projects	$10.7b	$44.0b	$86.7b
Emissions reduction from offshore wind (2050)			
Emissions reduction	5.7 Mt CO_2-eq	8.33 Mt CO_2-eq	9.61 Mt CO_2-eq
Emissions reduction - % of energy emissions	18%	26%	30%

* Example onshore wind farm of 148 MW at 40% capacity factor based on current New Zealand onshore wind pipeline

1. Economic

An offshore wind sector is estimated to generate between $12b and $94b GDP (real) over the life of the projects and between 5,300 and 30,000 domestic jobs during the construction phase. About half of the economic benefit is concentrated during the construction period, with the other half sustained over a 25-35 year operational period. Under the Green Vision scenario, the estimated GDP impact would be comparable to that of the current oil and gas industry. In addition, about $2.3b - $5.1b of economic activity could be unlocked in the hydrogen production sector.

A wide range of low and high skilled jobs are associated with OWFs, with many capabilities being able to be leveraged from the existing offshore oil and gas sector and other sectors. The offshore wind industry will create a ripple effect impacting many other sectors, from maritime activities to retail and education.

Quantitative assessment

The economic impacts discussed in this report are those generated by activities within New Zealand. The charts below show the total annual GDP contribution (left) and annual employment contribution (right) of the industry for each of the three scenarios, over the lifetime of the projects. The total GDP and FTE impact of the industry is the sum of the direct, indirect and induced impacts.

Figure 10: Total GDP contribution of the sector
Under the three scenarios[6]

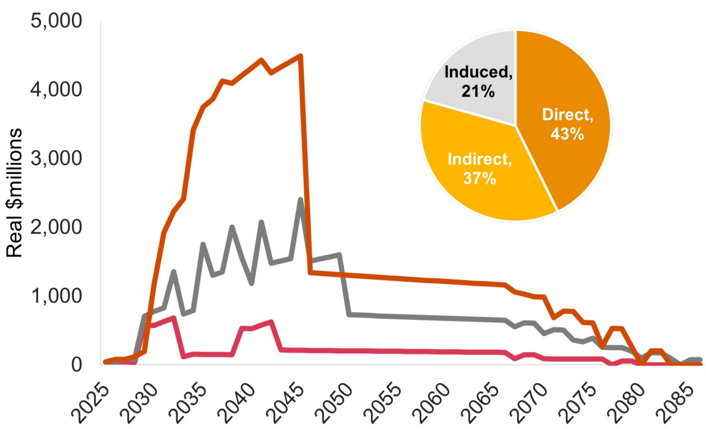
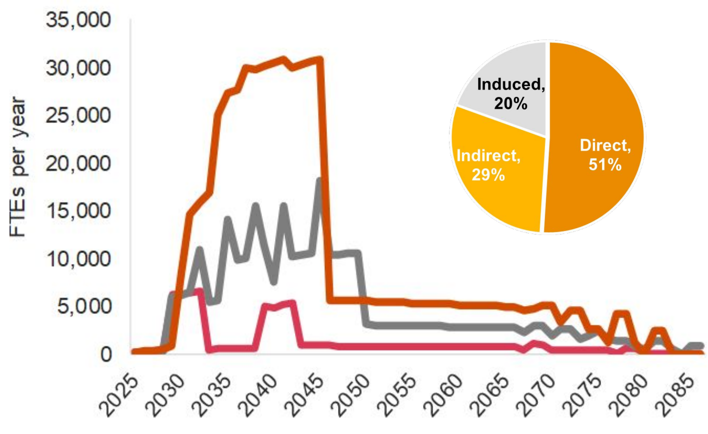


Figure 11: Total employment contribution of the sector
Under the three scenarios[6]



Source: PwC

Electrification Electrification Plus Green Vision

A summary of the average annual impact (through the construction phase) is provided below under the three scenarios. This is compared against the annual impact of the oil and gas sector.[12] This shows that under the Green Vision scenario, the offshore wind industry (in its construction phase) has the potential to contribute an equivalent amount of GDP, and twice as much employment as the oil and gas industry (in its operational phase).

Table 1: Total and annual sector impacts, compared with the oil and gas sector

Sector scenario		Electrification	Electrification Plus	Green Vision	Oil and Gas sector*
Average annual impact (averaged over 2030-2050)					
Expenditure *(Real $m)*		299	1,322	2,872	3,356
GDP *(Real $m)*	Direct	141	613	1,311	1,300
	Total	324	1,442	3,134	3,604
Employment *(FTEs)*	Direct	1,441	5,757	11,135	5,068
	Total	2,435	10,472	21,574	11,718
Total impact (over lifetime of projects)					
Expenditure *(Real $m)*		10,770	44,052	86,749	
GDP *(Real $m)*	Direct	5,024	20,203	39,445	
	Total	11,593	47,447	93,618	
Employment *(FTEs)*	Direct	40,293	150,162	279,493	
	Total	74,838	297,069	575,079	

*These figures are the total impacts to New Zealand of the oil and gas sector from Venture Taranaki's economic impact study 'The wealth beneath our feet'.[12] We've adjusted 2013 expenditure and GDP estimates to 2023 dollars using general CPI (RBNZ).

Workforce[13,14,15,16]

Type of workforce required

The labour requirement for OWFs varies greatly by project phase, both in terms of the overall number of workers needed and the types of workers:

- A mix of general and highly skilled jobs are required at each phase. The majority of lower skilled workers are employed during the construction phase.
- There is a significant demand for general skilled workers (such as health and safety, marine biology and regulation experts) and technician level workers throughout feasibility, construction and operations.

Planning, assembly, installation, grid connection, operations and maintenance (O&M) and decommissioning are all expected to occur locally and will use a significant amount of New Zealand resource.

It is anticipated that manufacturing of the turbines, blades, nacelles and towers will occur overseas and be imported to New Zealand, given the size of the global manufacturing base. New Zealand could however explore investments in manufacturing of some components, such as towers, foundations of floating structures to supplement global supply.

Workforce capability

There will be gaps in the capability and experience of the New Zealand workforce for working on offshore wind projects. Targeted training and development programmes will be essential alongside immigration policy that supports the recruitment of overseas talent. We can also draw on skills and workforce capacities in other industries (e.g. energy, metals, engineering, construction).

With careful planning, many workforce synergies could be leveraged from the Taranaki based offshore oil and gas sector. This may support the retention and transfer of local knowledge and skills over time as we transition to net zero. The offshore oil and gas workforce shares similar skills (e.g. in offshore engineering, maritime operations, safety), training requirements and workplace conditions.

Supply chain

Developing an OWF involves a complex supply chain that encompasses various components and processes. The direct elements needed in the supply chain to create an OWF include construction and installation of fixed foundations and mooring lines, turbines (nacelle, hub and assembly), blades, towers and array, export cables, substations, transmission connections and port infrastructure.

This supply chain will also require support that will unlock a chain of indirect and induced economic activity (e.g. the cafés feeding the workers).

Detailed descriptions of the supply chain are set out in the main body of this report.

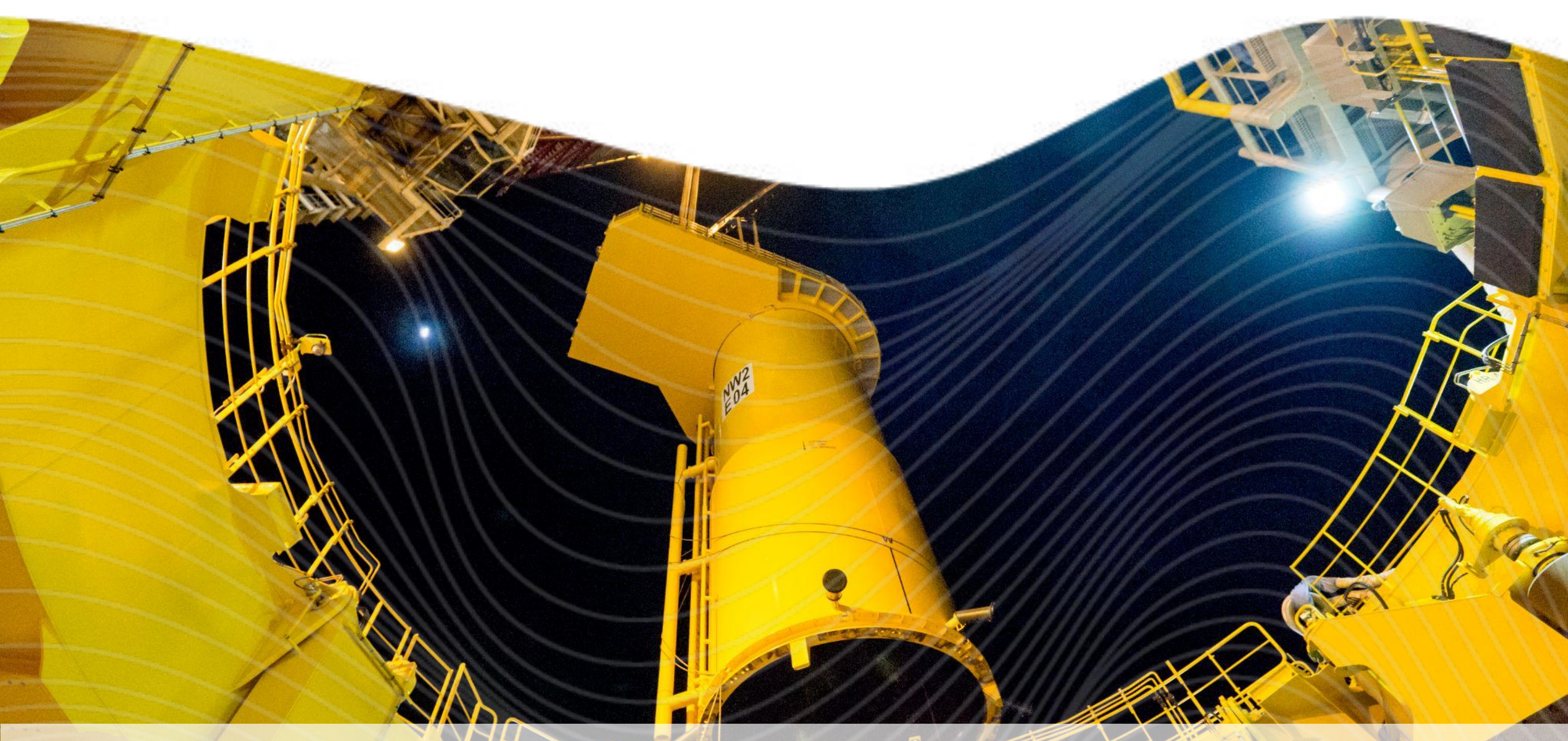
Other sector impacts

The offshore wind industry will create a ripple effect, impacting (to varying degrees) many sectors within the New Zealand economic landscape. These sectors include, but are not limited to:

- Commercial fishing and aquaculture
- Oceanic data and environment research
- Maritime activities and protection
- Education
- Transport
- Accomodation, hospitality and retail
- Seabed mining
- Tourism
- Defence

The offshore wind industry will bring prosperity to a number of sectors in locations near the wind farms, particularly during the construction phase. The industry will generate an increased demand for products and services, accommodation, and hospitality.

There is potential for the offshore wind industry to create a significant improvement in the oceanic data and environmental research sector, particularly because of the current lack of data that is available. Potential uses of this data include improving understanding of and reducing negative impacts on sea life, helping to better understand and respond to tsunamis and other hazards, and gaining a better understanding of our natural resources.



Source: Installation of Transition Piece (External Platform and Boat Landing), Northwestern 2, Belgian North Sea, Courtesy of Parkwind

2. Energy

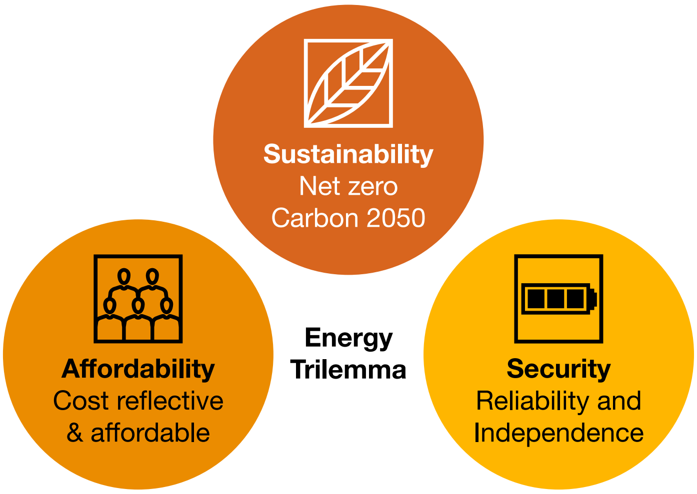
Offshore wind could make a significant contribution to New Zealand balancing its Energy Trilemma goals of sustainability, energy security and affordability. It is perhaps best placed in unlocking large scale electrification and significant green hydrogen production to enable a net zero future. The economics of offshore wind are expected to improve and it may prove cheaper and/or easier to bring to market once societal impacts are taken into account. It may also support energy security and sovereignty through diversity of supply and support for other renewable fuels.

The Energy Trilemma

Our energy analysis is framed around the three Energy Trilemma goals of:

- **Sustainability:** which explores the decarbonisation role offshore wind can play in accelerating and scaling electrification and green hydrogen
- **Energy Security:** which considers how offshore wind can support higher levels of energy security and sovereignty
- **Affordability:** which seeks to estimate the costs and consumer price impacts of introducing offshore wind into the energy mix.

Figure 12: The Energy Trilemma



Unlocking green energy

Between 34 TWh and 127 TWh of new generation production is required in 2050 to meet demand from electrification (renewable electrons) and green hydrogen (renewable molecules). This is a sizeable undertaking that will require all forms of renewables. The cost of falling behind the build schedule is significant.

When compared alongside other options, offshore wind has several strategic advantages that can help propel us to our net zero target:

1. It can be scaled quickly once infrastructure and regulatory frameworks are in place, making it one of the best renewable options for unlocking large scale electrification and hydrogen based PtX solutions in transport fuels and industrial feedstocks.

2. It has less impact on communities than land-based alternatives which means it can be developed faster at scale.

3. On average, it generates power more frequently and provides greater flexibility to develop projects at larger scale compared to most other renewable generation technologies. Typically, 45% to 55% of capacity is utilised, compared to new onshore wind (40% to 45%) and solar (15% to 22%). In the current NZ context, it provides an additional opportunity for large scale generation as compared to other renewable technologies.[17,18]

Economics and affordability

The cost of offshore wind generation is currently higher than more mature forms of renewable generation. Consistent with trends observed for other renewables technologies, like batteries, onshore wind and solar generation, we expect the cost of OWFs to fall quickly in line with improvements in technology and global manufacturing scale and as our knowledge of offshore resource improves.

Based on international costing studies and advice provided by the local developers, we estimate the average levelised cost of energy (LCOE) for a New Zealand fixed pile OWF will fall from about $115 to $225 per MWh today to about $72 to $80 per MWh by 2050 (real) - about the current cost of onshore wind.

As it is expected that offshore wind will remain a more expensive alternative to most onshore renewables, we estimate that the impact of including offshore wind for grid based electricity production will increase wholesale prices by 0.5 - 0.9 cents per kWh (real), equivalent to 1.5% to 2.7% of average household electricity prices today.

The concept of a social cost of energy (SCOE) - the LCOE adjusted for social costs - is also gaining traction internationally as it better reflects developer and community views on what type of generation can be built. For example, a recent study of Norwegian households identified a willingness to pay about 16% more for offshore wind in order to move developments further away from communities.[19]

Energy security and independence

While offshore wind is intermittent in nature, recent research indicates that it could support higher levels of energy security in the following ways:

- A diversified portfolio of offshore and onshore wind will support more consistent levels of generation as offshore wind is not highly correlated to other renewables
- Offshore wind may support improved winter energy security as production peaks during winter when solar generation and hydro lake inflows are lowest. It may also support dry year security as production is more resilient in dry years
- While offshore wind cannot guarantee instantaneous supply when required, it can support backup capacity when combined with other firm energy resources, such as batteries and flexible hydrogen electrolyser production. It can also be used in fuelling new blended hydrogen and natural gas turbine peaker units to provide instantaneous capacity with lower carbon emissions.

New Zealand is heavily reliant on primary sector exports and international tourism but is remote from key trading markets - our ‘tyranny of distance’. With the globe demanding more sustainable products and services, sustainable fuel choices will become increasingly more important. Concepts like ‘food miles’, ‘Flygskam’ (or flight shame) and carbon border adjustment mechanisms (e.g. green tariffs) put our economy at a distinct disadvantage unless we can decarbonise our transport fuels and primary sector energy inputs. Offshore wind could play an essential role in our energy independence if it were to underpin domestic production of green fuels to decarbonise long-distance aviation, heavy land freight and maritime fuels.

3. People

OWFs can make a positive difference in communities by stimulating economic activity and green energy related jobs. Communities near proposed OWFs may have concerns about environmental and visual outcomes and noise, but these have proven to be more minor compared to other alternatives. Iwi-Māori* have a special affinity to the sea (moana) that includes customary rights and a kaitiakitanga or guardianship role. Greater participation is sought by iwi-Māori in decision making over the use of the moana and related economic opportunities.

Figure 13: People impacts

1. Labour and economic

The development of a wind farm brings substantial investment into the local economy and may create a significant number of new jobs, particularly during the construction phase. This in turn supports localised spending, boosting small businesses. Once operational, there is an opportunity for smaller scale regional specialisation and retention of technical specialists.

2. Community wellbeing

As with onshore wind, OWFs can be divisive for some communities, especially smaller communities. Community engagement and complementary investment can highlight and enhance the social benefits of OWFs, and improve wellbeing and local pride, in addition to the economic benefits that occur. Potential strain on small or isolated communities' and social cohesion is an issue overseas for OWF projects but may be less of a concern in Taranaki, for example, due to experience with offshore oil and gas.

3. Construction

As with any construction project, developing an OWF will likely result in temporary impacts such as disruption, noise and constraints on local infrastructure. However, most of the activity for an OWF happens at the port or out at sea, which will mitigate these effects substantially. Investment in supporting infrastructure spurred by these projects can also increase economic activity and improve local infrastructure, leading to an enduring positive impact.

4. Observational

Personal perspectives of wind farms (i.e. noise, visual amenity, etc.) can vary depending on size, placement and distance from the observer. This is subjective and can be affected by the observer's personal preferences and attitudes to the merits of the project. A key potential benefit of OWFs is that they are typically located at large distances from communities, even over the horizon, resulting in impacts such as noise and visual impacts being less pronounced, or even negligible.

5. Recreational

The proposed locations for OWFs in New Zealand are typically far offshore in relatively inhospitable environments, and any negative impacts on recreational activities are expected to be insignificant. There may even be some positive recreational benefits from OWFs, including wind farm tourism and better recreational fishing due to the reef and fish aggregator effect created by OWF foundations.

Iwi-Māori interests

Māori have a special relationship with the sea and marine life. Agreement on the regulatory framework between iwi-Māori and the Crown will allow for both Treaty partners to make decisions on what is in the best interests of all New Zealanders. Developers are keen to work with tangata whenua to explore offshore wind opportunities together.

*The term iwi-Māori is used to collectively refer to combined iwi and wider Māori interests, and not to distinguish between different iwi, hapū, and/or other Māori community groups.

4. Environment

Decarbonisation and environmental trade offs

Rapid decarbonisation is a global priority. In order to meet our net zero targets, a significant transformation of our energy system is required, involving large investments in renewable energy, supporting infrastructure and new technologies.

This will require difficult trade offs to be made between decarbonisation and outcomes for communities and the natural environment. Ideally we can achieve positive outcomes for both by mitigating or reducing negative environmental and community effects.

In this context, it will be important to build projects that have the highest decarbonisation potential but lowest local impact. Land based generation is further along the development curve and will play an important role in our energy transition. But these generation units are smaller and less powerful and efficient at producing renewable energy than offshore wind and will require more plant to be built to deliver the same amount of renewable energy. For example, we would need to cover almost the entire Wellington City region in solar panels (some 442 km^2) to produce an equivalent amount of energy to the OWFs in our Electrification Plus scenario (8 GW).[20]

Greater efficiency of offshore wind also extends to spatial considerations. Separate studies in the USA and Europe have found that offshore wind can be more space efficient, with more than 16% higher capacity densities (i.e. MW per km^2) observed on average.[21,22] As land is much more constrained than the ocean, offshore wind developers can be much more selective to optimise production. This is amplified by the fact that New Zealand has a large EEZ relative to its land size - 96% of the country's territory is sea.[23]

The onus will be on developers to ensure sensitive siting and mitigation measures are in place for all forms of renewables, but this may be easier for offshore renewables.

Emissions

We have focused our emissions analysis on two key areas:

- Embodied carbon emissions, including the carbon payback period (the carbon footprint of building the wind turbines during the construction phase)
- Emission reduction resulting from electrification and hydrogen based displacement of fuels and feedstocks.

Embodied emissions

Of all the renewable energy solutions, offshore wind power has the lowest overall life cycle carbon footprint. Approximately 80% of the total carbon is concentrated during the construction phase, with a very low maintenance and operations footprint.

Review of process-based life cycle analysis (LCA) for offshore wind projects shows that, over the lifetime of an OWF, emission intensities are in the order of 8 to 25g CO_2 -eq/kWh.[24] This compares favourably to the emission intensities of ~1000g CO_2-eq/kWh for coal and 20 to 60g CO_2 -eq/kWh for solar PV and is slightly lower than the average for onshore wind at 15 g CO_2 -eq/kWh.

Offshore wind has a short carbon payback period of only 5-12 months, which is negligible given the general operation lifetime of 30 years.[25] Emissions were analysed across three stages of the offshore wind life cycle, set out in table 2.

Table 2: OWF life cycle emission estimates[26]

Life cycle stage	Estimated emissions (%)
1. Manufacture and installation	78.4%
2. Operations and maintenance	20.4%
3. Decommission and disposal	1.2%

Electrification

Offshore wind could support large scale renewable electrification of the economy (e.g. electric vehicles and electric boilers).

In all scenarios, electrification associated with offshore wind generation into the grid is expected to reduce emissions by about 5.7 Mt CO_2 -eq per annum by 2050.[6]

Fuel displacement

One of our key climate change challenges is how to decarbonise hard-to-abate fuels, particularly transport fuels used for maritime and heavy land freight and international aviation. These transport modes can not easily adopt battery electric technology due to weight and power density concerns.

Power-to-Liquids (PtL) fuels are being investigated both internationally and locally - by the likes of Fortescue, Christchurch Airport, Air New Zealand, and Hiringa - to resolve this challenge. PtL fuels are 'drop in' fuels produced from hydrogen and typically require a 'renewable' source of carbon (e.g. biogenic point source carbon capture or direct air capture).

Two key opportunities requiring large scale PtL production is aviation and maritime transport. New Zealand is one of the higher emitters in aviation per capita given our remoteness from the rest of the world and dependence on domestic aviation. Although international aviation and maritime emissions are not included in our emissions trading scheme (ETS), the sustainability goals of both individuals and corporates are driving companies in these sectors to investigate PtL and bio-fuels.

The scale of renewable energy generation required to support PtL is large. For example, Fortescue's proposed PtL aviation jet fuel project at Marsden Point will require 300 MW of solar generation to supply 60 million litres of jet fuel per year.[27] This is only 3% of the pre-Covid jet fuel market or enough for 500 flights from Auckland to Los Angeles.

A 2023 study undertaken by Strategy& recently highlighted the competitive advantage of countries with excellent renewable electricity resources in PtL production.[28] Some 30-40% of the cost of PtL fuels relate to renewable electricity generation. New Zealand is well placed to domestically produce PtLs given our abundance of renewables, at least for our own domestic use and to fuel outgoing jets and ships. This would bring us to an unprecedented level of fuel independence in the future global sustainable economy.

In the Electrification Plus scenario the emissions reduction potential from both displaced fuels and electrification, enabled by offshore wind is 8.3 Mt CO_2-eq and 9.6 Mt CO_2-eq in the Green Vision scenario.[6]

Fossil fuel reliant industries are the hardest to abate and failing to abate our emissions poses a significant fiscal risk to New Zealand. We estimate the cost of mitigants associated with fossil fuels in the Electrification Plus Scenario, could be up to $640 million per annum and $560 million per annum in the Green Vision Scenario (excluding exports).

Flora and fauna

The potential impacts of OWFs on flora and fauna have been considered in six distinct categories:

1. Marine mammals
2. Fish (including finfish, sharks and rays)
3. Benthic (seabed) communities
4. Seabirds
5. Flora (sea plants such as kelp)
6. Ocean and atmosphere more generally

Given the lack of relevant, specific oceanic data for the New Zealand context, we have drawn on overseas research, literature and insight on potential impacts that may provide insights for New Zealand. Many of the potential effects on marine life occur during the construction phase, predominantly as a result of the noise and vibration disruption from pile driving. The location and foundation type of an OWF will therefore be an important consideration for evaluating and reducing construction-related effects.

Once established, OWF turbine infrastructure often results in beneficial enduring support for marine biodiversity by creating new habitats and increasing food availability, through the ‘artificial reef’ and ‘marine reserve’ effects.

There is a lack of empirical evidence on decommissioning OWFs, as decommissioning of the first OWFs is only occurring today. Early studies suggest it may be beneficial for marine life to retain the newly formed reef and leave the base of the structure, instead of removing it. This has given rise to the ‘renewables-to-reef’ concept.

New Zealand has a rich and diverse seabird population, but it is currently not clear how they will be affected by OWFs. Operational effects on critical seabirds will need to be carefully modeled and understood. Overseas experience shows relatively negligible effects on overall seabird populations and the importance of siting and designing turbines to minimise impact.

For more general ocean and atmospheric considerations, the oil and gas industry in New Zealand undertakes similar activities to those associated with OWFs, with no significant disruptions or impacts being prevalent.

Considering environmental receptors is critical in determining the OWF site locations during the feasibility phase to enhance the positive effects and mitigate the potentially negative effects on marine flora and fauna.

New Zealand marine environment and species of marine flora and fauna are unique, meaning we cannot rely exclusively on overseas research and mitigations. For example:

- Many New Zealand seabirds are nocturnal, which is not so common in other areas around the world. We also do not have comprehensive data on flight paths and avian behaviour at sea at night
- New Zealand is home to many marine mammals, with 22% of them being threatened or at risk, including the Māui dolphin. Marine mammals use different frequencies for communication and navigation so the ‘noise’ associated with OWFs will have differing impacts. Potential mitigations (such as bubble curtains) will need to be targeted to address different species as they are unlikely to be ‘one size fits all’
- Ocean productivity impacts will differ based on currents and disturbances and this will be dependent on the site.

Building a detailed picture of how OWFs interact with New Zealand’s unique natural environment will be important, through data collection and well funded research and analysis in the feasibility testing stages.

Developing and firming up the evolving regulatory frameworks will also be critical in identifying and addressing the environmental impacts of offshore wind.

Table 3: 2050 emissions reduction from offshore wind (excl industrial feedstocks)[6]

Emissions reduction from offshore wind	Electrification	Electrification Plus	Green Visions
Emissions Reduction (Mt CO_2-e)	5.7	8.3	9.6
Proportion of 2021 energy emissions (%)[29]	18.0	26.3	30.3
Proportion of 2021 total emissions (%)[30]	7.5	11.0	12.6

Image: Arcadis Ost 1, Baltic Sea, Courtesy of Parkwind Ost

Introduction

Introduction

New Zealand has an excellent offshore wind resource, being situated in the ‘roaring forties’ and having the 9th largest coastline and exclusive economic zone (EEZ). The development of a national offshore wind industry will however take vision, courage and work to realise the opportunity. This National Impact Study has been commissioned as a first step in exploring the industry’s potential and in defining the breadth of the benefits and challenges for the economy, energy sector, environment and communities.

Purpose and scope

This report presents a National Impact Study (NIS) to establish an offshore wind industry in New Zealand.

The purpose of this report is to inform and progress national discussion on the establishment of offshore wind energy in New Zealand by summarising a nationwide strategic assessment of the industry’s potential, key insights for decision makers, and areas for future attention. The intention is for this study to provide a baseline for future impact assessment and tracking of the industry’s contribution as it progresses to operating/generating energy.

The breadth of potential benefits, costs, opportunities and challenges associated with an offshore wind industry are explored across four key areas - the economy, energy, the environment, and people.

We have used a range of qualitative and quantitative research and analytical approaches to assess the potential impacts. Scenario analysis, overseas precedent, existing studies and stakeholder interviews have been drawn on to strengthen our assessment and confirm findings. This approach is described the figure overleaf.

Our analysis is conceptual and broad ranging. This is necessary given offshore wind is continuing to develop globally and remains untested in New Zealand.

We do not focus on any one project, region or interest. We do however acknowledge four key regions - Waikato, South Taranaki, Cook Strait and Southland - are actively being investigated and are likely to be developed first.

The Steering Group

This NIS was commissioned and funded by a group of New Zealand offshore wind developers, infrastructure providers, economic development agencies and energy sector associations.

This group acted as a steering group for the project and assisted in defining the future scenarios, guiding the scope of analysis and in providing insights, direction and feedback.

We would like to thank the Steering Group members for their contribution and participation in this study. Without these like-minded companies, organisations and individuals this study would not have been possible:

- **BlueFloat Energy / Elemental Group**
- **Business NZ Energy Council**
- **Clarus**
- **Parkwind**
- **Port Taranaki**
- **Powerco**
- **NZ Trade and Enterprise**
- **NZ Wind Energy Association**
- **Sumitomo Corporation**
- **Taranaki Offshore Partnership**
- **Transpower**
- **Te Puna Umanga Venture Taranaki**

Scenario development

To explore and evaluate the future role and impact of offshore wind, three future scenarios have been developed based on recent energy sector outlook studies. Our purpose is not to model a new set of industry scenarios but to draw together and synthesise the work that has already been done to date on electrification of the economy and hydrogen, which until now have been discussed separately.

Stakeholder engagement

We interviewed a broad range of stakeholders to inform the development of the NIS. This group included energy companies and major energy users, hydrogen developers, environmental advocacy and research organisations, Māori leaders, regulators and energy, mining, and regional development organisations. We would also like to acknowledge the many organisations that we have referenced and interviewed as part of this project.

The NIS attempts to capture the broad and rich range of insights provided by this group. This reflects a snapshot of the opportunities and challenges and does not do justice to the depth of work being pursued by these organisations in offshore wind and related activities. This engagement process has perhaps highlighted most the need for a diverse range of voices and more detailed work to bring offshore wind to fruition.

Image: Walk to work during installation, Nobelwind, Belgian North Sea, Courtesy of Parkwind

Figure 14: High level overview of our national strategic assessment framework and approach

Scenario development

Three scenarios have been developed based on a synthesis of recent electricity and hydrogen outlook studies. These explore the future role offshore wind could play in a renewable rich future involving electrification of the economy and future green fuels.

Stakeholder engagement

We interviewed stakeholders - involved in energy, infrastructure, economic development, environmental advocacy and research, and affected communities - to provide local perspective and insights on the potential role and impacts of offshore wind.

Economic

Quantitative analysis
Economic multiplier analysis per dollar of expenditure has been used to assess the total potential economic contribution from offshore wind, in terms of **jobs** and **GDP**.

Qualitative analysis
We conducted a global literature review to assess direct **(i.e. supply chain, workforce)** and indirect **(affected sectors, including commercial fishing and any other maritime activities**) impacts.

Environment

Quantitative analysis
We undertook a quantitative assessment of **emissions abated,** including embodied carbon, to understand the net impact on our national net zero targets.

Qualitative analysis
We undertook a qualitative environmental and biodiversity assessment, leveraging international research and case studies to understand potential impacts on **flora and fauna.**

We held a workshop with environmental **stakeholders** to understand whether all key issues were identified.

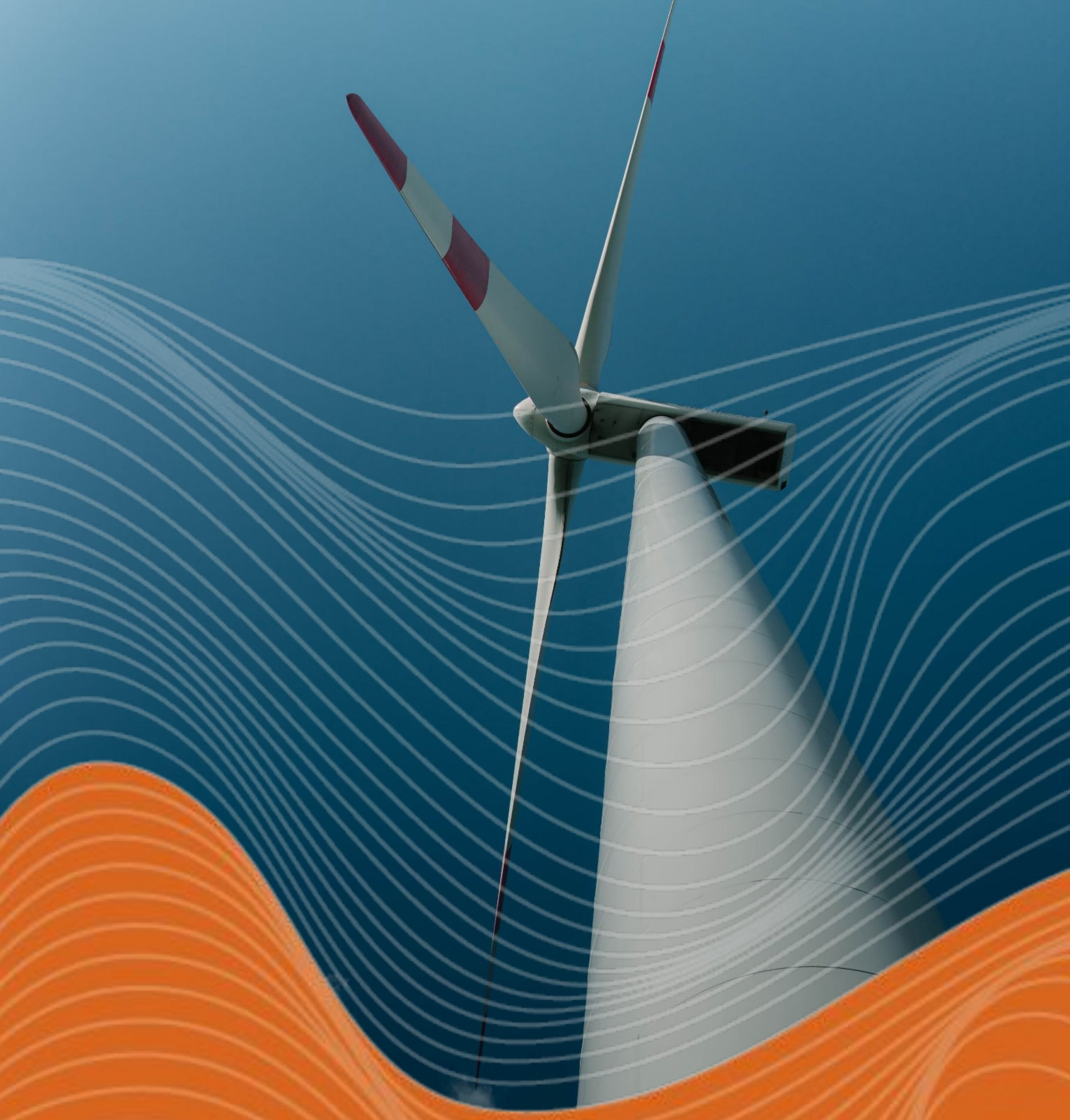
People

Qualitative analysis
We undertook a literature review on the potential impacts on **people and communities**.

We **engaged with stakeholders** and leveraged previous work on iwi-Māori participation in offshore wind.

Energy

Quantitative and qualitative analysis
We used the **Energy Trilemma to frame our energy market assessment,** by considering the contribution of offshore wind towards sustainability (including unlocking the green energy and green products economy), security of supply, and the potential price impacts at the consumer level.



The future of New Zealand offshore wind

1. The future of offshore wind

The world is turning its attention to the untapped and rich renewable resource of the ocean in an effort to accelerate the pace of decarbonisation. Offshore wind generation looks set to be a vital option for scaling global renewables, and New Zealand's excellent wind resource makes us an attractive development destination. Developing this resource could be the key to unlocking significant amounts of renewable energy to underpin our future 'net zero' economy.

1.1 Scaling the energy transition

Concern is growing that the global energy transition is not moving fast enough to curb global temperature rises. The herculean task of scaling investment in new renewables, as well as enabling infrastructure and technologies, is falling behind schedule and more needs to be done.

"To keep on track with net zero emissions by 2050 goals... annual investment in clean energy will have to rise substantially from.... $US1.8 trillion to US$4.6 trillion in 2030" - PwC[1]

"There needs to be more investment flowing into the energy transition...what we need in the energy transition is a leap of scale" - World Energy Council (WEC) secretary general, Angela Wilkinson, October 2023[2]

This sentiment has recently been formalised with a global commitment at COP28 to triple renewable energy generation capacity by 2050.

Land based investments in renewable solar, wind and bio-energy are critical to this energy transition, but face headwinds as new projects push up against the natural environment, communities and competing uses for scarce natural resource.

Renewables investors are turning their attention to the potential of our oceans, which offer a vast renewable energy resource and rich development potential. Offshore wind is a favoured technology in offshore renewables due to over 30 years of operational experience (mainly in Europe) and the maturity of wind turbine technology. Importantly, offshore wind can be scaled much faster than other renewables.

Offshore wind has grown at an annual rate of over 21% in the last decade and now represents about 7% of all global wind capacity (64.3 GW in 2022). The Global Wind Energy Council (GWEC) predicts that a further 380 GW will be added by 2030, with nearly half of that in the Asia Pacific region.[3]

1.2 The New Zealand energy challenge

New Zealand is currently plotting its own course to net zero emissions by 2050. The key challenge for the energy sector is how to affordably and reliably decarbonise transport, industrial, and process heat energy use - our largest sources of energy related emissions.

Our electricity sector - comprising 26% of total energy consumption and already up to 89% renewable[4] - is being asked to increase production of renewable electricity significantly to support 'electrification' of our economy and the potential production of synthetic fuels.

All industry forecasts indicate that a massive transformation of our energy system is required to meet our net zero targets, involving significant investment in renewable energy, supporting infrastructure and new technologies. These forecasts indicate that electricity production may need to more than triple by 2050 to support electrification and hydrogen production. This is inline with the recent COP28 renewables commitment.

Scaling New Zealand's rich renewable resource will be critical. Offshore wind is ideally suited to this role, with GW scale potential. Onshore wind, solar, and geothermal will maintain critical roles, along increased use of bio-energy and carbon capture utilisation and storage (CCUS). But the pace and scale of construction needs to dramatically accelerate, to an average annual rate of between 2.5 TWh to 5 TWh of new electricity production from 2030 to 2050, assuming we adopt e-fuels.[5,6,7,8] This is a daunting target, and whilst land-based renewables will make a significant contribution it appears absolutely necessary that offshore wind would be required to meet this demand.

As we face our energy challenge, we stand at a point in time that requires bold vision and courage. We have done this before, during the oil, gas and hydro energy booms of the 60s, which have served us well. If New Zealand can economically harness our potential offshore wind resource, we could significantly accelerate our transition to net zero and a more sustainable future for New Zealanders.

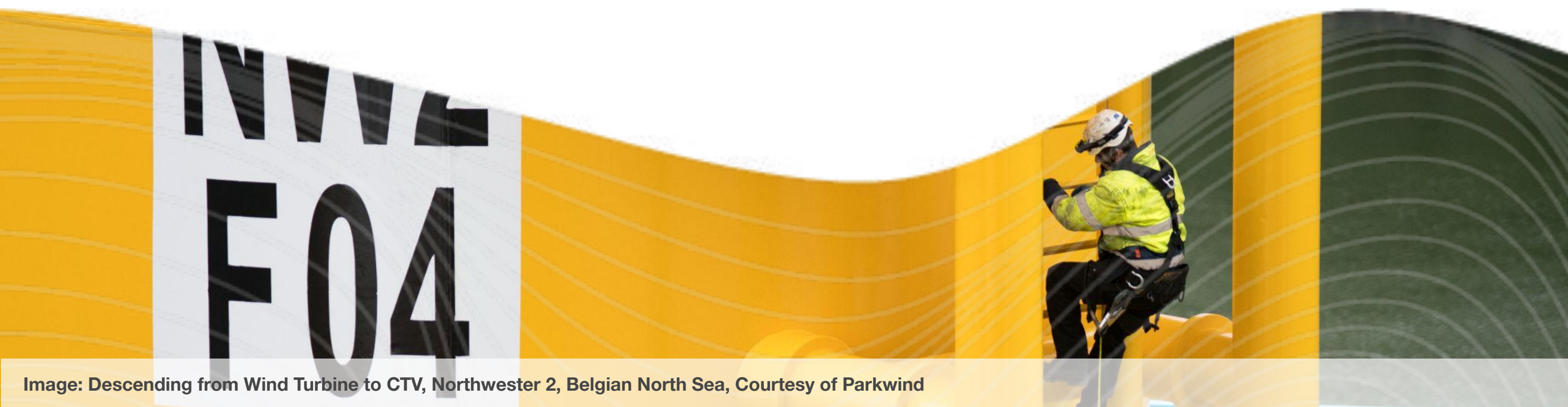


Image: Descending from Wind Turbine to CTV, Northwester 2, Belgian North Sea, Courtesy of Parkwind

1.3 Types of offshore wind turbines

Offshore wind farms (OWFs) are arrays of wind turbines located out to sea. The turbines are generally larger and more powerful versions of land based wind turbines with longer blades. The turbines now coming to market are capable of generating between 12 MW and 16 MW each, compared to about 4 MW to 8 MW for onshore turbines.[9,10,11] This is expected to increase as technology improves.

Figure 15: Relative size of offshore wind turbines[12]

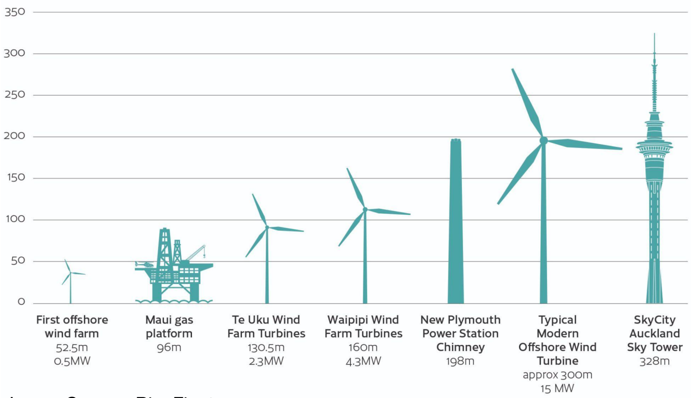


Image Source: BlueFloat

OWFs may be distinguished by their foundations, with two standard types - bottom-fixed and floating, as summarised in the figure overleaf. The appropriate solution is site dependent, based on seabed depth, type, cost, and installation considerations.

Bottom-fixed

Bottom-fixed offshore wind is an established and proven technology, which has been deployed globally for more than 30 years.

Fixed structures are embedded into or on the seabed, with the turbine mounted atop. The three main types of bottom-fixed structures are:[12,13,14]

- **Monopile -** a steel tube embedded into the seabed
- **Jacket structure -** a lattice structure with three to four legs embedded into the seabed
- **Gravity base -** a large heavy base structure that sits on the seabed, typically made from reinforced concrete.

Early deployments of offshore wind used gravity base structures, and they remain an option today. The monopile structure is the most common as it is the lowest cost foundation. It has been widely implemented globally and is currently optimal for use in shallower depths to about 60m. In shallower waters, gravity base structures are also effective.[14]

The jacket structure can be expensive but may be more appropriate for deeper installations up to 70m to 75m.[13]

The maximum installation depth is governed by the available capabilities of the vessels used to install them. As New Zealand is on the continental shelf, our water depth drops off quickly, which may limit the available area for OWFs using bottom-fixed structures.

Floating

Floating offshore wind uses floating foundations, which are anchored to the seabed by mooring lines. Floating structures are less prevalent globally than fixed structures, although they are rapidly gaining traction as they unlock the potential to develop projects in deeper waters.

UK, Norway, Portugal, China and Japan are the top markets globally for floating wind installations.[15] California is also focused on floating due to its deep coastal waters and has committed to construct 4.5 GW by 2035. Uptake of floating OWFs is expected to accelerate in the 2030s in these areas and reach commercial maturity in the 2040s.[15]

There are a variety of floating structures. Main designs include tension leg platforms, semi-submersible and spar substructures.[13]

The ability to develop further out to sea in deeper water significantly increases the resource development potential of offshore wind, including the magnitude of the wind resource (greater wind speeds). This is significant for New Zealand, given the vast size of our EEZ.

Going further offshore increases connection costs.[16] However, floating installations can also have more streamlined construction, operations, maintenance and decommissioning, depending on the site.

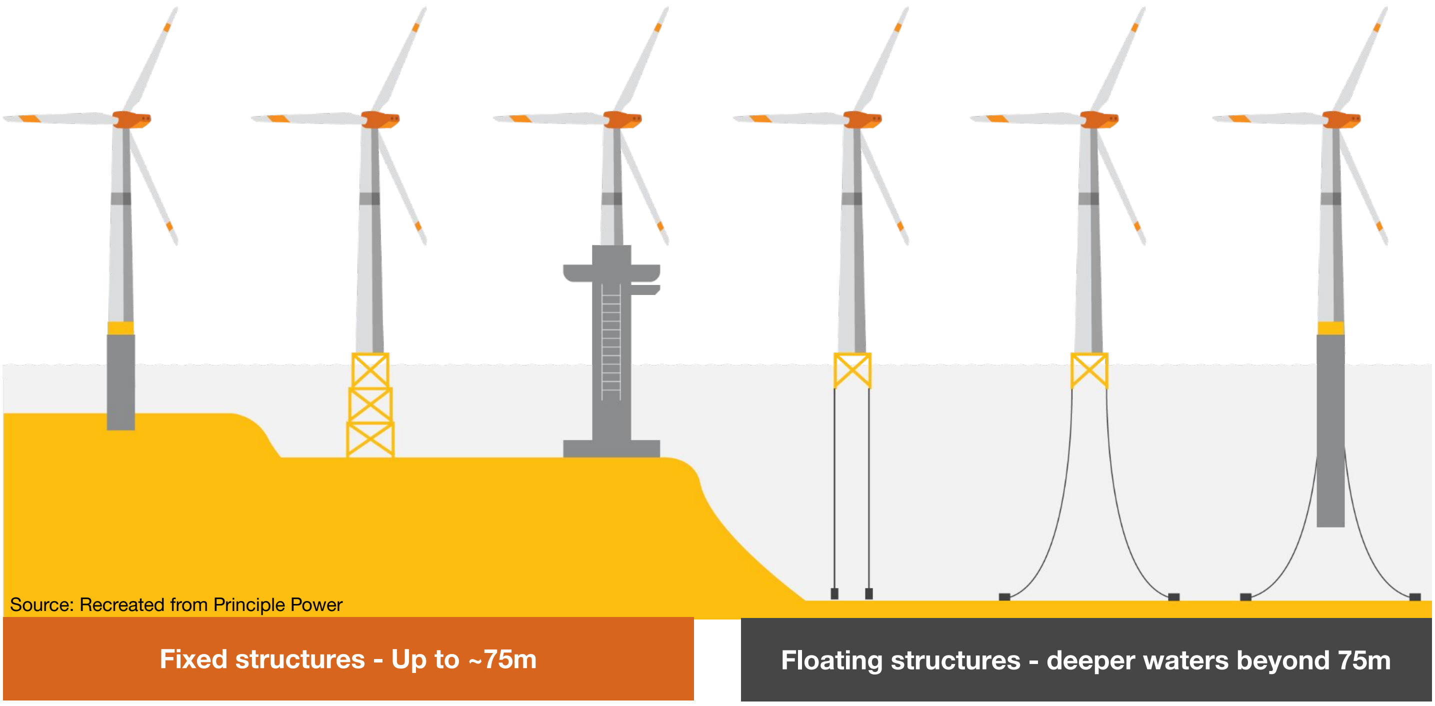
At present, floating structures are in early development stage, and have yet to be commercialised.

The current per MWh capital costs are approximately 40% - 50% higher than bottom-fixed monopile and project financing costs are likely to be higher due to the uncertainty of early stage technology.[16]

Per MWh costs are expected to decrease as larger farms are deployed, realising economies of scale, and making floating structures attractive as second wave technologies.

Ensuring port infrastructure and supply chains are fit to accommodate the large floating structures have been key challenges for developers to date.

Figure 16: Examples of offshore wind structures



1.4 New Zealand's offshore wind resource

New Zealand is recognised as having one of the best offshore wind resources in the world, being situated in the 'roaring forties' high wind latitudes and having the 9th largest EEZ.

Theoretical offshore capacity is a massive 2,252 GW,[15] which is far higher than our demand, but highlights the vast potential of our resource. 93% of this theoretical capacity is at depths currently requiring floating technology.[15]

To date, the best offshore wind resource has been identified off Taranaki, Waikato/Auckland, and the Cook and Foveaux Straits, although other areas are being explored.

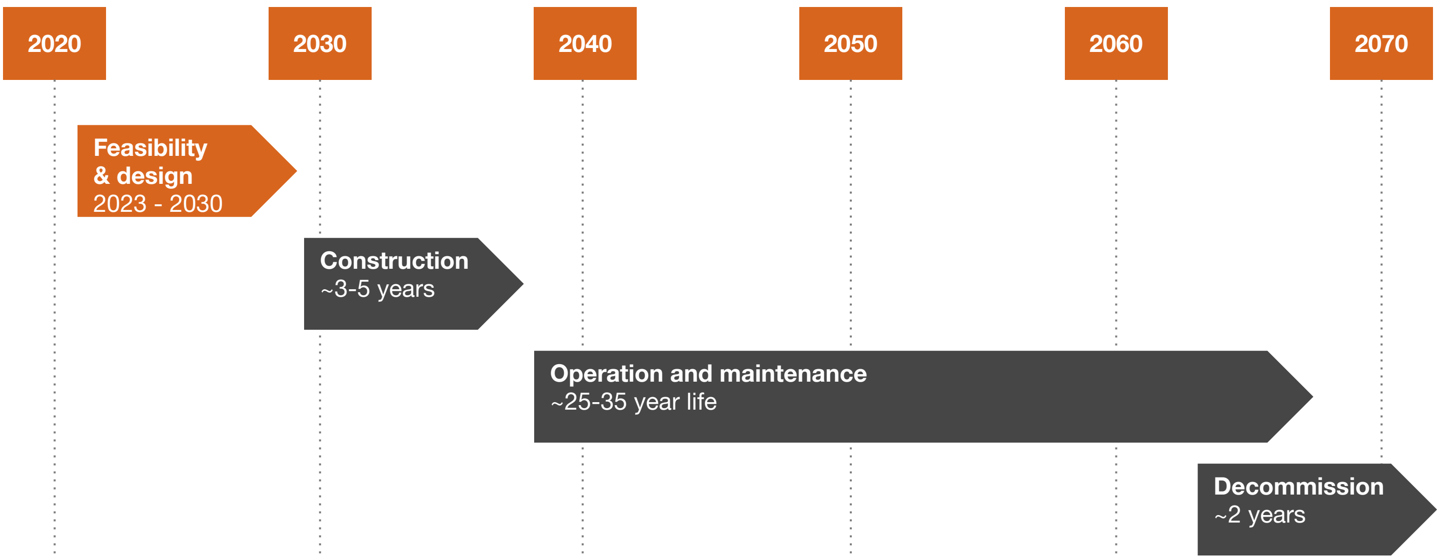
These areas combine relatively shallow coastal water depths with a strong prevailing westerly wind that has travelled uninterrupted over 1000s of km of the Southern Ocean.

There are a number of marine environment considerations in these areas which may limit potential developments. These are discussed later but generally include:

- competing uses (e.g. fishing, oil and gas production, seabed mining, recreational boating)
- Māori cultural and economic interests in the marine area (e.g. fishing and aquaculture) and role as kaitiaki
- community impacts such as visual impacts from shore
- environmental effects involving sea birds, fish, marine mammals and benthic communities.

The first OWFs could be developed in New Zealand in the early 2030s. An illustrative timeline for the first OWF is illustrated below. Currently, potential developers are in the feasibility and design phase.

Figure 17: Indicative timeline for New Zealand's first offshore wind farm



South Taranaki

The South Taranaki coast is a particularly promising area for offshore wind development. Wind speeds off Taranaki at the Maui A and B gas field platforms average 10.1 m/s and 10.7 m/s. A 'superb' wind resource is considered to have speeds above 8.5 m/s.[17]

Generation production is expected to be high in South Taranaki based on the world class wind resource. A report by Elemental estimated this region may realise plant capacity utilisation factors of 53%. In comparison, our best onshore wind farms have capacity factors of less than 45%, however some have recently reached over 50% on occasion. These capacity factors are expected to increase as turbine technology improves for both onshore and offshore wind.[18]

A study by the University of Canterbury investigated the potential for offshore wind in South Taranaki, describing it as an exceptional wind resource. The study identified 1,065 km^2 of suitable area for bottom-fixed wind farms. The suitable area was considered to be depths of less than 50m and seabed slopes less than 0.1 degrees.[17] Further investigations suggest bottom-fixed OWFs could be installed in depths of up to 75m.

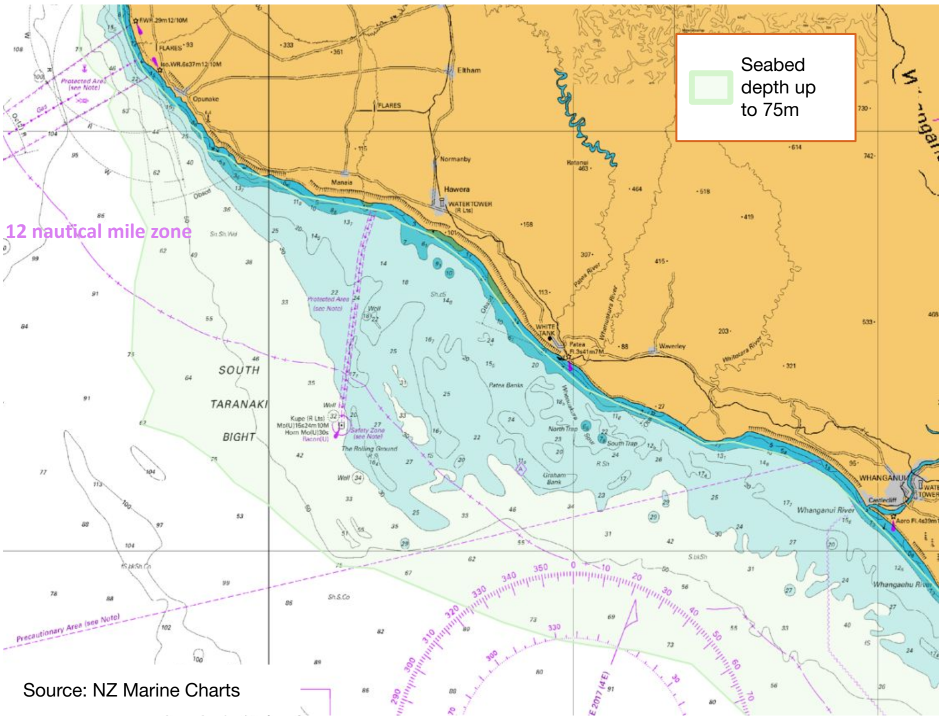
South Auckland-Waikato

The coast off the South Auckland-Waikato region is also considered an excellent location. While having lower wind speeds and expected capacity utilisation factors, this region can be connected directly into the South Auckland and Waikato demand centres, and has a more robust electricity grid connection.

There is approximately 3,700km^2 of seabed area up to 75m water depth in this area.[19] Most of this area lies within the Marine Mammal Sanctuary (which is within the 12 nautical mile zone), which could limit shallower water locations for OWFs. We assume 1 GW bottom-fixed capacity could be developed in the South Auckland-Waikato region outside the Marine Mammal Sanctuary zone.

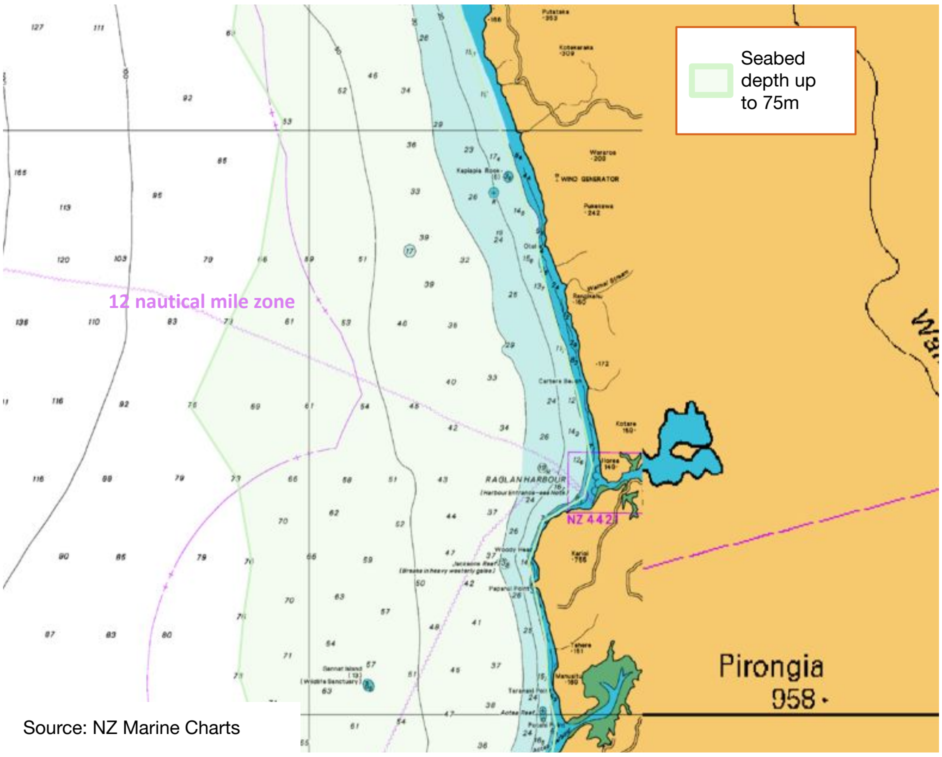
The opportunity for floating turbines is much greater off the Waikato coast and this area has future potential as this technology matures.

Figure 18: Available area in South Taranaki for bottom-fixed offshore wind development[19]



The shaded green area in figure 18 illustrates the area with depths allowing bottom-fixed structures off South Taranaki (currently <75m). This area covers approximately 4,500km^2, or 1,500km^2 excluding the Marine Mammal Sanctuary.[19] Competing uses for this area, ecological considerations, and visual effects may limit development to about 3 GW or 4 GW. The potential for floating structures is much greater, mainly constrained by the cost of connecting the OWF to land.

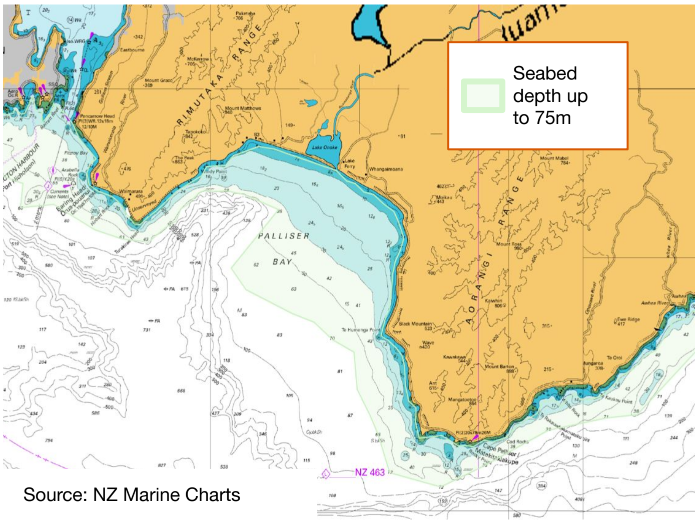
Figure 19: Available area in Waikato for bottom-fixed offshore wind development[19]



Southland and the Cook Strait

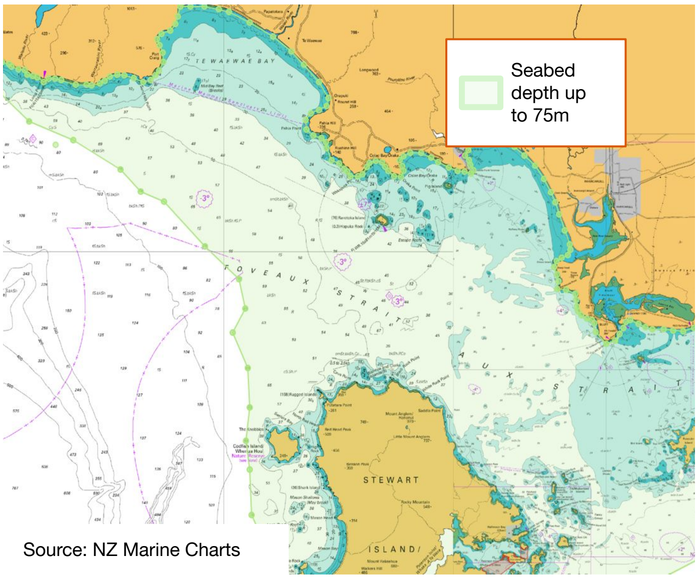
Both Foveaux Strait and Cook Strait have been identified by developers to have a high quality wind resources, and are under investigation. The 2022 report by Elemental identified Southland to have a capacity factor of 53%, similar to South Taranaki.[18] The Cook Strait is in earlier stages of investigation, but shows promise for floating OWFs. The waters are much deeper off Wellington, making it less suitable for bottom-fixed structures. Foveaux Strait is also limited and we assume only 2 GW of fixed-structure could be developed here.

Figure 20: Available area near Wellington for bottom-fixed offshore wind development[19]



Source: NZ Marine Charts

Figure 21: Available area in Southland for bottom-fixed offshore wind development[19]



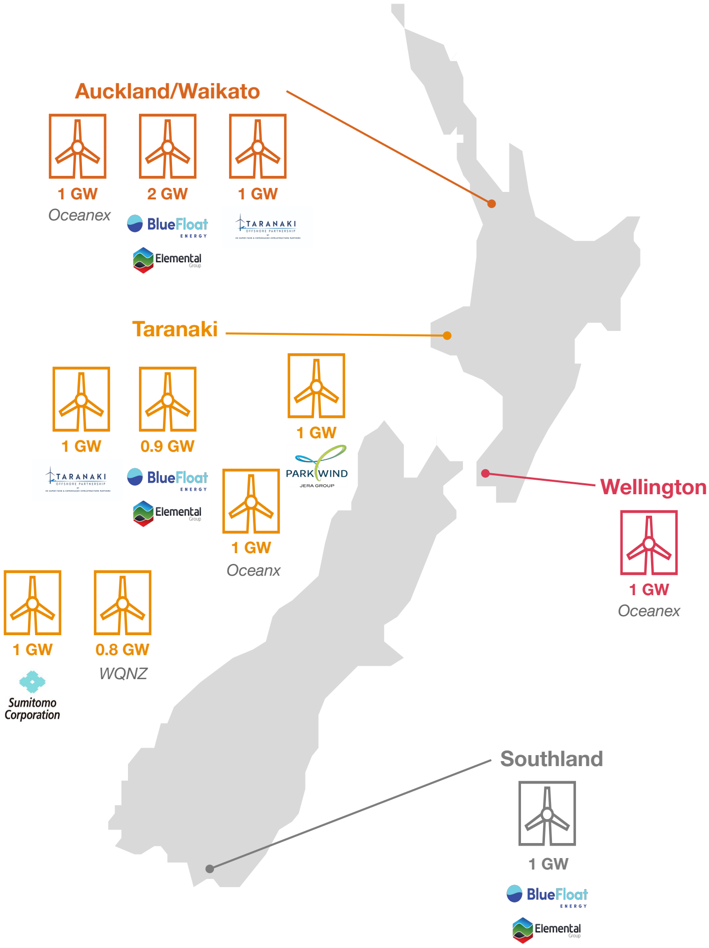
Source: NZ Marine Charts

1.5. Offshore wind opportunities in early stages of development

There is significant interest in New Zealand's offshore wind resource. Developers have announced almost 12 GW of offshore wind projects to date. Initial interest is concentrated on the west coast of the North Island, specifically South Taranaki and Waikato:

- **BlueFloat, in partnership with Elemental** has announced two first phase projects to develop up to 3 GW of fixed and floating offshore wind in New Zealand, with further projects to come.[20]
- **CIP, together with NZ Superfund,** are investigating a total of 2 GW of offshore wind, with 1 GW in Taranaki and 1 GW in Waikato.[21]
- **Parkwind** and **Meridian** have signed an MoU for exploration of offshore wind in New Zealand.[22]
- **Sumitomo Corporation** have announced plans for a 1 GW offshore wind farm in South Taranaki.[23]
- **Oceanex Energy** is planning up to three 1 GW OWFs off the coast of New Zealand, with 1 GW each in Taranaki, Waikato and the Cook Strait.[23]
- **Wind Quarry Zealandia** has proposed a 810 MW near-shore development off South Taranaki and has submitted resource consent applications.[24]

Figure 22: Proposed wind farms - size and location



1.6 Scenario development overview

To explore and evaluate the future of the industry, three future scenarios for offshore wind uptake have been developed.

These are based on existing energy outlook scenarios and reflect a potential range of offshore wind developments to 2050. They underpin our economic, energy market, and emissions analysis.

Each scenario explores differing future electricity demand outlooks involving use of offshore wind for renewable electricity ('green electrons') and green hydrogen production ('green molecules') purposes. This is used to size offshore wind generation in the overall New Zealand energy mix.

The three scenarios are:

1. **Electrification:** defines a future where growth in electricity demand is driven by electrification of key sectors (land transport and process heat). Hydrogen and other PtX fuels and feedstock don't make a significant contribution.
2. **Electrification Plus:** reflects the Electrification scenario plus a base level of green hydrogen production for use in domestic transport, industry and heat processing. It also assumes offshore wind unlocks new green industry opportunities.
3. **Green Vision:** reflects the Electrification Plus scenario with higher levels of hydrogen production and new green industry demand, including hydrogen exports and international sustainable aviation fuels (i.e. e-SAF).

The key assumptions within each scenario relate to demand building blocks, grid, green hydrogen and new industrial load - which are described in more detail in the remainder of this section.

Demand building blocks

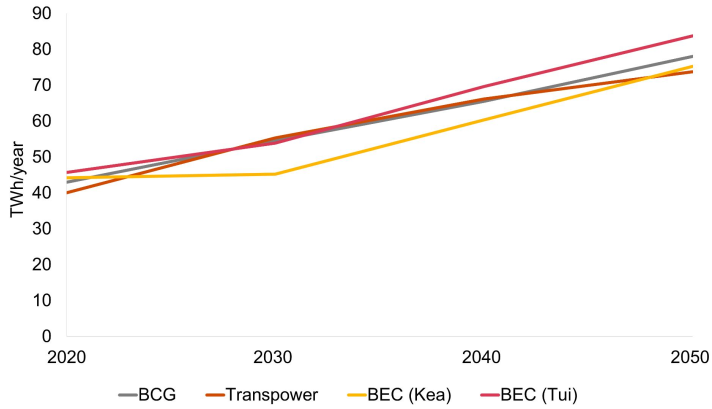
As illustrated in the figure below, we use existing energy industry scenarios to build up a synthesis view of New Zealand electricity demand growth from grid based electrification and hydrogen production. In addition, we consider the potential for offshore wind to drive new green industry opportunities in agriculture, food processing, green metal and chemical production as well as decarbonisation of international jet fuels using e-SAF.

Grid: The following energy scenarios have been used to size the market for offshore wind that may be used to supply the grid:

- Whakamana i Te Mauri Hiko (Transpower)[5]
- Times 2.0 - Business New Zealand Energy Council (BEC)[6]
- The Future is Electric - Boston Consulting Group (BCG).[7]

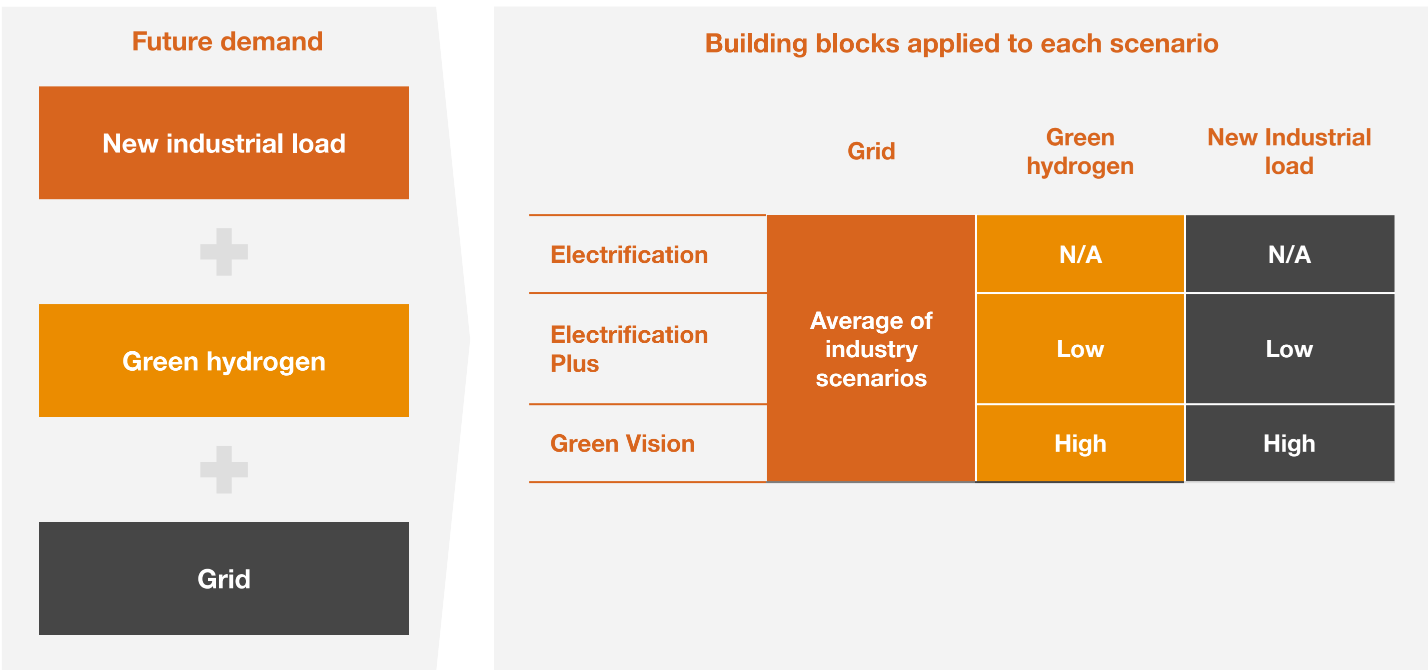
These scenarios all project national electricity demand to increase to more than 70 TWh by 2050, a 60% to 70% increase on current electricity use. We adopt the average of the scenarios, which sees national demand increase to 77.1 TWh by 2050.

Figure 23: Electricity demand forecasts to 2050[5,6,7]



Sources: Transpower, BEC, BCG

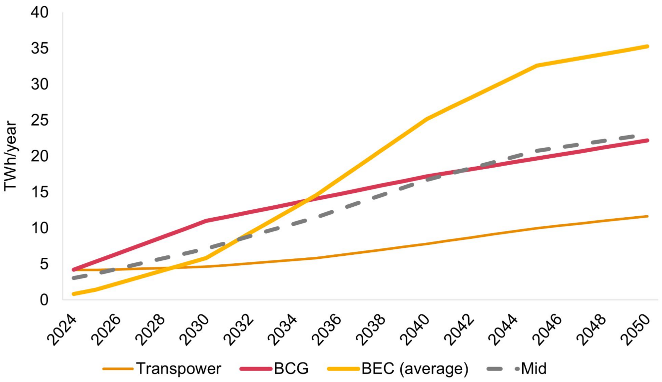
Figure 24: Offshore wind scenario building blocks



Grid

Between 11.7 TWh and 35.3 TWh of new wind generation is projected to be required to meet future electricity demand in the grid scenarios, as summarised in figure 25. An average of 23 TWh is applied in our modelling. New Zealand wind generation produced 2.8 TWh of electricity (as at June 2023), which highlights the significant role for new wind generation in all future scenarios.[4]

Figure 25: Total forecast new wind generation supply (onshore and offshore)[5,6,7]



Sources: Transpower, BEC, BCG

Green hydrogen: A potential New Zealand green hydrogen sector is also considered. This may open the door to the development of hydrogen based PtL synthetic fuels and industrial feedstocks that could be used to decarbonise our transport, commercial and industrial sectors.

Green hydrogen is produced by splitting hydrogen from water molecules using an electrolyser and renewable electricity. The sector in New Zealand is currently in its infancy, but a number of small scale electrolyser projects are underway with planning for larger commercial hydrogen schemes progressing. PwC estimates 11 trillion USD of investment is required to meet the global market outlook for green hydrogen.[25]

Demand for hydrogen is not extensively modelled in the reference grid scenarios. We have therefore supplemented the above demand scenarios with hydrogen demand forecasts which are aligned with the Government's recent consultation on a national hydrogen strategy.[26]

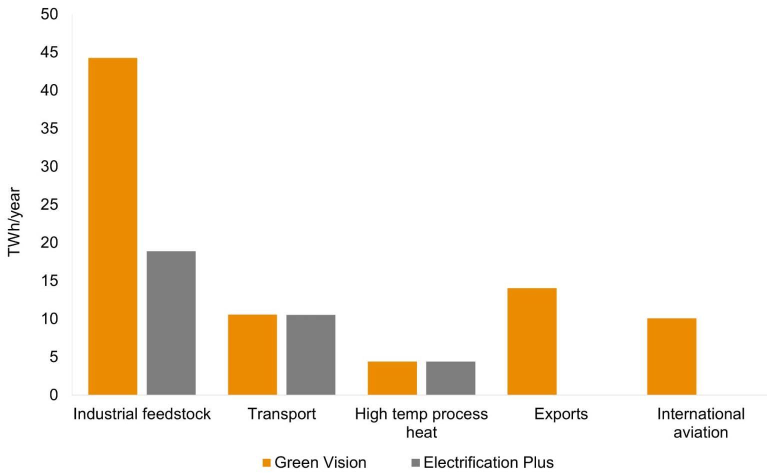
The modelling was commissioned by MBIE and undertaken by EY in 2023. We have adopted EY/MBIE's 'Base Case' as the low case for hydrogen in our Electrification Plus scenario. The demand in this case is dominated by hydrogen for industrial and transport applications domestically.

We have used EY/MBIE's 'Value add Export' case as the basis for the high case for hydrogen in our Green Vision scenario. This case includes higher levels of industrial use and exports of hydrogen and 'green' products like steel.

We have extended this demand to include domestic eSAF production for international aviation and thermal electricity peaking generation, based on our stakeholder engagement.

Based on the EY/MBIE scenarios and our additional analysis we have estimated total demand for hydrogen electrolysers, summarised in the figure below. This may be served from all generation sources.

Figure 26: Total forecast hydrogen demand in 2050 (TWh)[8,26]

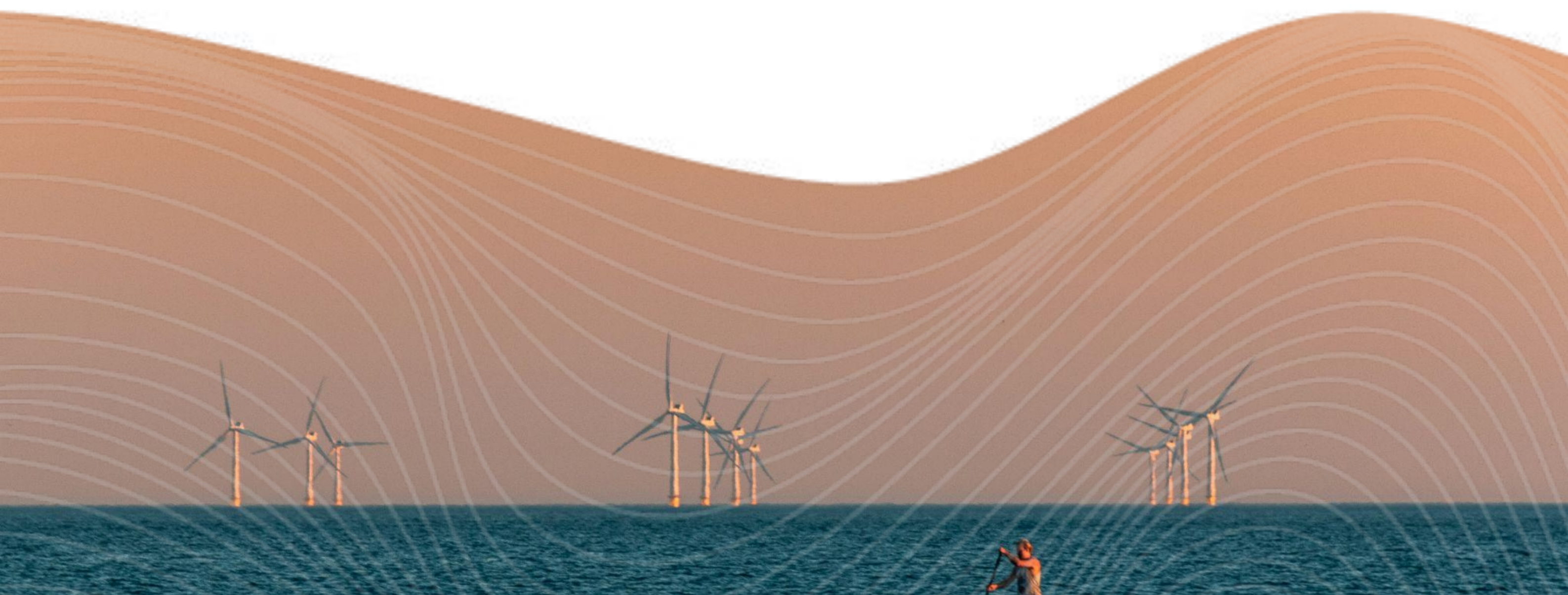


Sources: PwC, EY/MBIE

New industrial load: We have considered the opportunity for offshore wind to support growth in our industrial base using abundant renewable energy. There is significant potential for New Zealand to use our rich renewable resource to unlock value in sustainable manufacturing and processing.

Two key opportunities that have the potential to use offshore wind are increased production of green chemicals (e.g. ammonia, methanol) and metals (steel, aluminium) as well as processing of sustainable food (dairy, fermented foods, vertical horticulture).

In our Electrification Plus and Green Vision scenarios, we assume new industrial demand in these sectors equivalent to 1-2 Tiwai sized operations by 2050. To put this in historical context, over a similar time frame (e.g. 1962s to 1986), New Zealand built Tiwai Point aluminium smelter, the Marsden Point Refinery, the Glenbrook Steel Mill and Waitara and Motunui methanol plants.



1.7 Sizing the offshore wind market

The supply of offshore wind generation is derived from the total wind supply forecasts, with the timing optimised to meet grid demand growth. In the scenarios involving hydrogen, offshore wind generation contributes about 50%-60% of total electrolyser capacity.

The majority of onshore wind is built first due to its current economic cost advantage. Offshore wind comes in to meet demand in the 2030s as the best projects start to become economic in the wider generation supply stack.

Development constraints are imposed on both offshore and onshore wind to reflect supply chain and local social license limitations, as follows:

- The first OWF is commissioned no earlier than 2032 to allow time for the regulatory frameworks, feasibility and design and leading infrastructure to be completed.
- In the Electrification scenario, 3.5 GW of onshore wind capacity[27] can be built by 2050, which is about equivalent to the publicly announced development pipeline we track. The onshore wind pipeline is bigger than this, but we assume a proportion of onshore wind will not progress due to a variety of reasons.
- In the Electrification Plus scenarios, 6 GW of capacity is permitted, which is estimated to be the likely unannounced pipeline.[27] A maximum of 0.5 GW of offshore wind can be built per year in this scenario due to supply chain and port constraints.
- In Green Vision, up to 1 GW of offshore wind can be built each year following additional investment in ports and assuming supply chains bottlenecks are removed. Some 11 GW of onshore wind equivalent renewable generation is required in this scenario.

Significant hydrogen development will require all forms of generation, but offshore wind will be critical to scaling this sector. Offshore wind is primarily targeted in the scenarios to serving large scale centralised electrolyser production plant, with smaller scale renewable generation serving decentralised plant.

4.9 TWh of new industrial load is assumed in 2050 for Electrification Plus - slightly less than the electricity usage of Tiwai Point aluminium smelter. This is doubled in Green Vision to 9.7 TWh.

The resulting total demand and offshore and onshore wind supply is illustrated in figures opposite.

OWF standardisation assumptions

The size of OWF projects being investigated in New Zealand range between 0.8 GW and 2 GW, with the majority being ~1 GW. A typical wind farm is assumed to be 1 GW for the purpose of this study.

As bottom-fixed structures are currently more economically feasible; these are first to be built. Monopile is assumed to be developed first in shallower waters[12,13] with jacket-structure options built in deeper waters up to about 75 meters. Floating structures are assumed to be developed when this technology is commercialised in New Zealand in the 2040s.

Figure 27: Electrification - Forecast national demand (net) and wind supply[8]

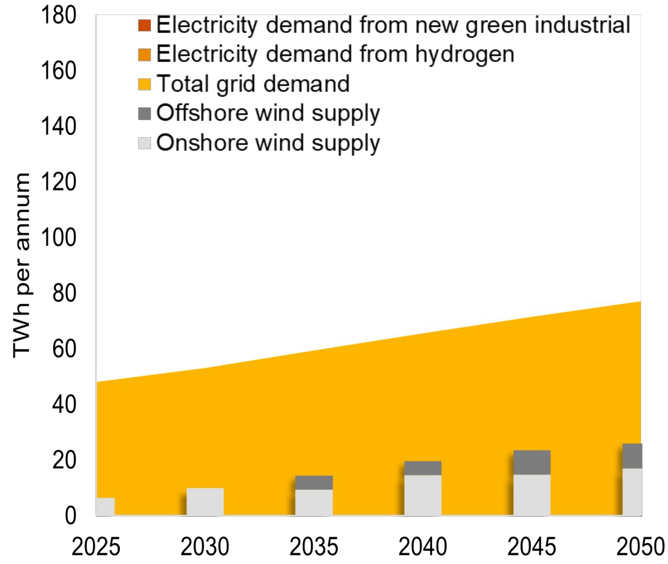


Figure 28: Electrification Plus - Forecast national demand (net) and wind supply[8]

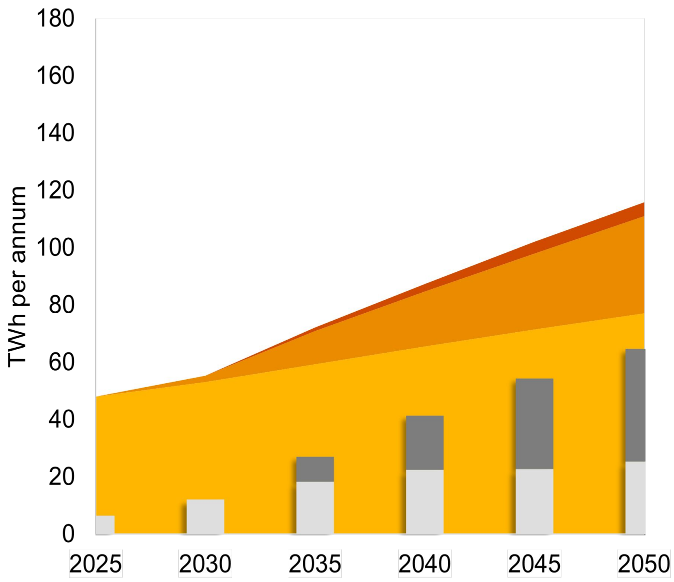
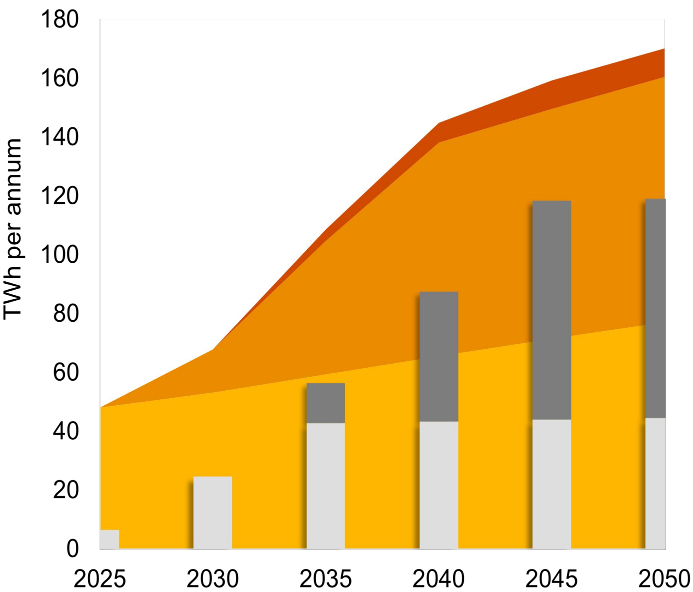


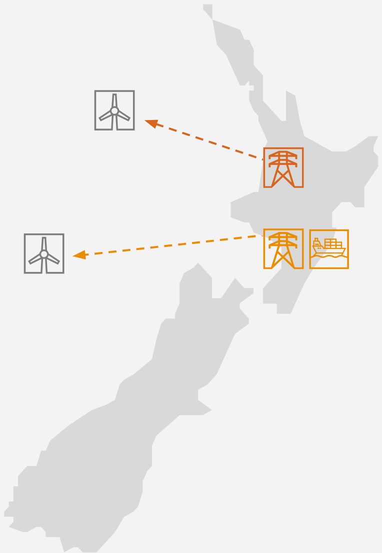
Figure 29: Green Vision - Forecast national demand (net) and wind supply[8]



Source: PwC

Figure 30: Annual offshore wind supply in 2050 for each scenario[8]

1. Electrification



Offshore wind supply serving

New industry = NA

+

Hydrogen = NA

+

Grid = 8.8 TWh per year

=

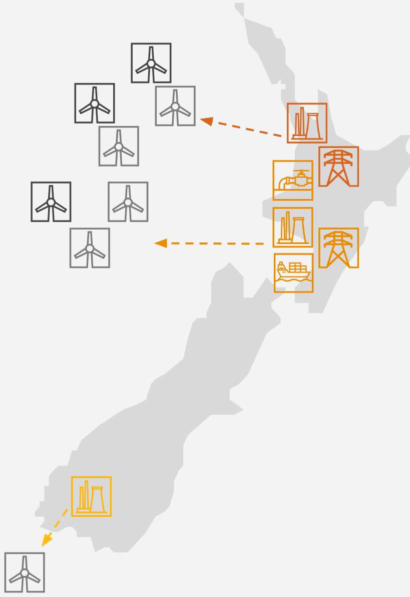
Total = 8.8 TWh @ 2 GW

Two 1 GW OWFs are built in this scenario, equating to about 8.8 TWh of annual production by 2050. Both are based on fixed bottom structures.

The first is commissioned off the South Taranaki coast after 2032 and the second off Waikato around 2042.

Total offshore wind supply is limited to 2 GW given the amount of other economic renewable projects in the pipeline. The constraints on the Taranaki grid means only 1 GW of offshore wind can economically be accommodated without a sizable investment.

2. Electrification Plus



2050 offshore wind supply

New industry = 4.9 TWh per year

+

Hydrogen = 25.7 TWh per year

+

Grid = 8.7 TWh per year

=

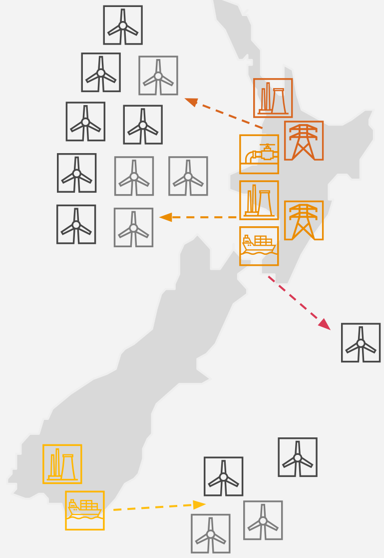
Total = 39.3 TWh @ 8 GW

8 GW of OWF capacity is built between 2032 and 2050, equating to about 39.3 TWh of annual production by 2050

Five 1 GW fixed pile OWFs are constructed first, with the remaining 3 GWs met by floating in the 2040s.

The first two wind farms will be commissioned off South Taranaki and Waikato in 2032 and 2035. A second and third Taranaki OWF are commissioned in 2038 and 2041 with 1 GW in Southland at the end of the 2030s.

3. Green Vision



2050 offshore wind supply

New industry = 9.7 TWh per year

+

Hydrogen = 56.1 TWh per year

+

Grid = 8.7 TWh per year

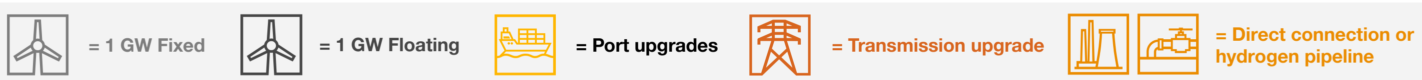
=

Total = 74.4 TWh @ 15 GW

In the Green Vision scenario, the hydrogen sector scales up to supply 189 ktH2 of sustainable aviation fuels for international aviation and 265 ktH2 for hydrogen export.

A total of 15 GW of offshore wind is built, equating to about 74.4 TWh of annual production by 2050.

While this scenario is daunting, it highlights the important role for offshore wind if we are to scale renewable generation to support a hydrogen PtX economy and new green industry. By way of illustration, the 15 GW of OWFs in this scenario will produce as much energy as 143 'example' 148 MW onshore wind farm projects in the current pipeline.



1.8 Enabling infrastructure

A significant amount of infrastructure needs to be developed to support offshore wind, including port and transmission grid upgrades, along with hydrogen infrastructure.

We consider below the enabling infrastructure required to support our scenarios.

Port upgrades

Ports are critical infrastructure, used for marshalling and assembly of wind turbines and structures, and as a base of operations for installation and maintenance work.

A multi port strategy will be required to support New Zealand's offshore wind sector. Port Taranaki will play a key strategic role in the construction and servicing of OWFs on the west coast of the North Island alongside South Port for the Southland OWFs. In addition, Picton, Northport, Centreport and Pātea could also have support roles.

In 2023, Port Taranaki and collaborating developers commissioned a feasibility study to investigate port upgrades to support the installation of 0.5 GW of offshore wind capacity per year. Costings for the upgrade ranged between USD100m and USD300m.[28] The majority of the project requires reclamation and strengthening wharves with marshalling and assembly space for 8-10 offshore wind turbines at a time.

We have adopted the midpoint of Port Taranaki's costings in Electrification and Electrification Plus scenarios of $320m NZD. In Green Vision we extend this to $720m to allow for 1 GW annual installation capacity and other multi-port upgrades. We assume 75% of port upgrade cost are attributable to offshore wind noting that these upgrades may also support oil and gas plant decommissioning.

The timing of port upgrades is critical as they are leading infrastructure. It will take about 8 to 10 years to complete the design and build of the port upgrades, meaning a commitment to the upgrade is required well ahead of when OWF developers need to commit to their own projects. There is a real risk that delays to Port upgrades could delay OWFs if not well coordinated.

Table 4: Port upgrade scenarios[8,28]

	Electrification & Electrification plus	Green Vision
Upgrade costs	**$320m**	**$720m**
Installation capacity	**0.5 GW per year**	**1 GW per year**

Electricity transmission upgrades

Transmission assets are critical leading infrastructure to enable connection of OWFs to the national electricity grid. Transpower, as the grid owner and operator of New Zealand's national grid, will play a key role to support planning, development and system integration of offshore wind generation.

In September 2023, Transpower considered options to connect offshore wind to the transmission grid at Taranaki or Auckland/Waikato. This assessment concluded that a 1 GW OWF could be connected at each location with only modest grid upgrades. Transpower has since advised that it would cost between $120m - $160m to connect the two OWFs envisaged in the Electrification scenario.

Grid constraints on existing Taranaki circuits mean the addition of a second 1 GW OWF would require a more significant upgrade, costing between $1.0b - $1.1bn. The grid is robust south of Auckland and it is likely that at least 2 GW of offshore wind could be connected at the Huntly or Glenbrook GXPs with only modest upgrades.

Figure 31: Potential points of connection for offshore wind[29]

Source: Transpower

For grid-connected generation we surmise from Transpower's analysis that the best location for 2 GW of grid connected OWF is for 1 GW to be connected in South Taranaki and 1 GW in South Auckland/North Waikato. Additional capacity could be connected in the Auckland/Waikato region without significant cost.[29]

The remaining 6 GW and 13 GW of generation capacity in the Electrification Plus and Green Vision scenarios are assumed to be directly connected to hydrogen electrolysers or industrial load. The electrolysers may be connected to the grid to supplement offshore wind generation and provide flex, but they are assumed not to require significant new grid capacity.

Electrolysers are assumed to be located near the coast to avoid major grid upgrades, but it is possible that further upgrades may be required to support local connections to hydrogen and industrial loads. For example, if Methanex converted to hydrogen using Taranaki OWFs the circuit from Brunswick to Motunui would need to be uprated.

Hydrogen pipelines

The cost of getting more than 1 GW of OWF generation out of South Taranaki is likely to be a significant limiting factor for growing offshore wind generation in this region. An alternative option being explored by Clarus is to produce and store hydrogen in Taranaki and then transport the hydrogen via a gas pipeline.

An option that has previously been explored is to repurpose the existing natural gas pipeline infrastructure to transport a blend of hydrogen and gas throughout the North Island. However, attention is currently focused on the development of a dedicated hydrogen pipeline.

Clarus estimated the cost of new hydrogen pipelines in New Zealand based on similar studies undertaken by GPA Engineering for new hydrogen pipeline costs in Australia. This pipeline could supply new hydrogen thermal generation plant (e.g. near existing plant in Huntly or further north) and future PtL opportunities in Auckland and Marsden Point (e.g. e-SAF, marine fuels). Two options that were analysed were:[30,31]

- a 273 km 250 TJ per day pipeline from Stratford to Huntly costing $0.8b
- a 549 km 500 TJ per day pipeline from Stratford to Marsden Point costing $2.9b.

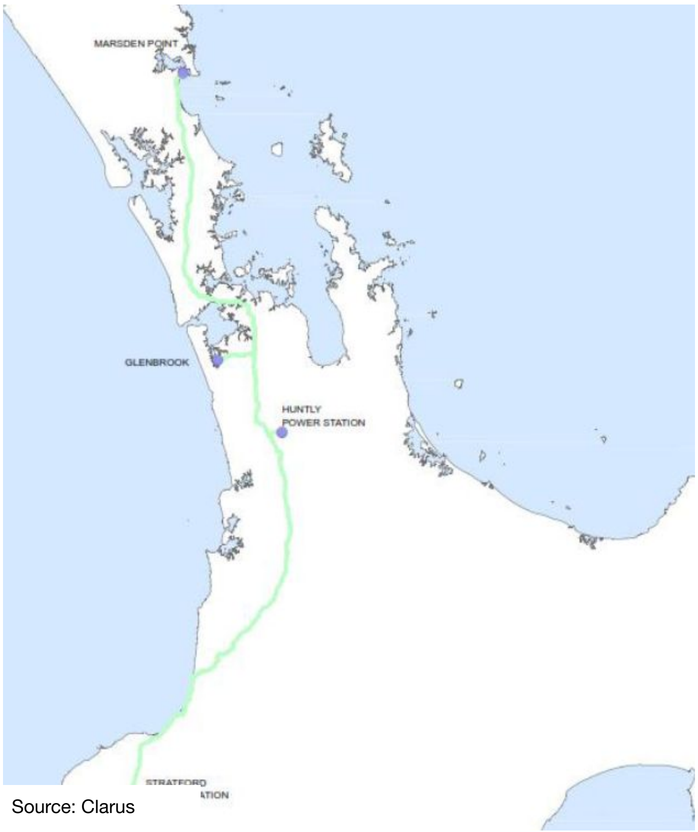
We have reflected these options in our hydrogen scenarios as they are well sized to support the levels of offshore wind and hydrogen production modelled in our Electrification Plus and Green Vision scenarios.

The relative economics of transporting renewable energy as molecules via a pipeline or as electrons via the grid will need carefully consideration as the offshore wind and hydrogen sectors develop.

Figure 32: Hydrogen pipeline 250 TJ - Electrification Plus[30]

Source: Clarus

Figure 33: Hydrogen pipeline 500 TJ - Green Vision[30]



Source: Clarus

1.9 OWF costings

We have estimated the costs of building, operating and decommissioning offshore wind for each scenario.

In addition we have included estimated costs for incremental infrastructure upgrades to ports, the North Island electricity transmission grid, and a new hydrogen pipeline to transport hydrogen from South Taranaki electrolysers. We have not modelled infrastructure costs for other renewables or hydrogen electrolysers given these may be incurred in the counterfactual scenario of no offshore wind.

Capital expenditure

OWF construction costs are compiled from a combination of international energy costing studies (e.g. NREL,[16] Lazards,[32] CSIRO[33]), PwC analysis and input from the Steering Group.

Construction costs are currently high but are expected to decline over time as technology improves. We use NREL technology curves to adjust our real capex forecasts to 2050.

The capital costs of bottom-fixed monopile, jacket structure and floating OWFs differ substantially. The substructure and foundation of a bottom-fixed system accounts for 12.8% of costs compared to 37.5% for floating systems.[16] This contributes to difference in costs per GW across our scenarios, with higher average per GW capital expenditure (capex) costs in Green Vision.

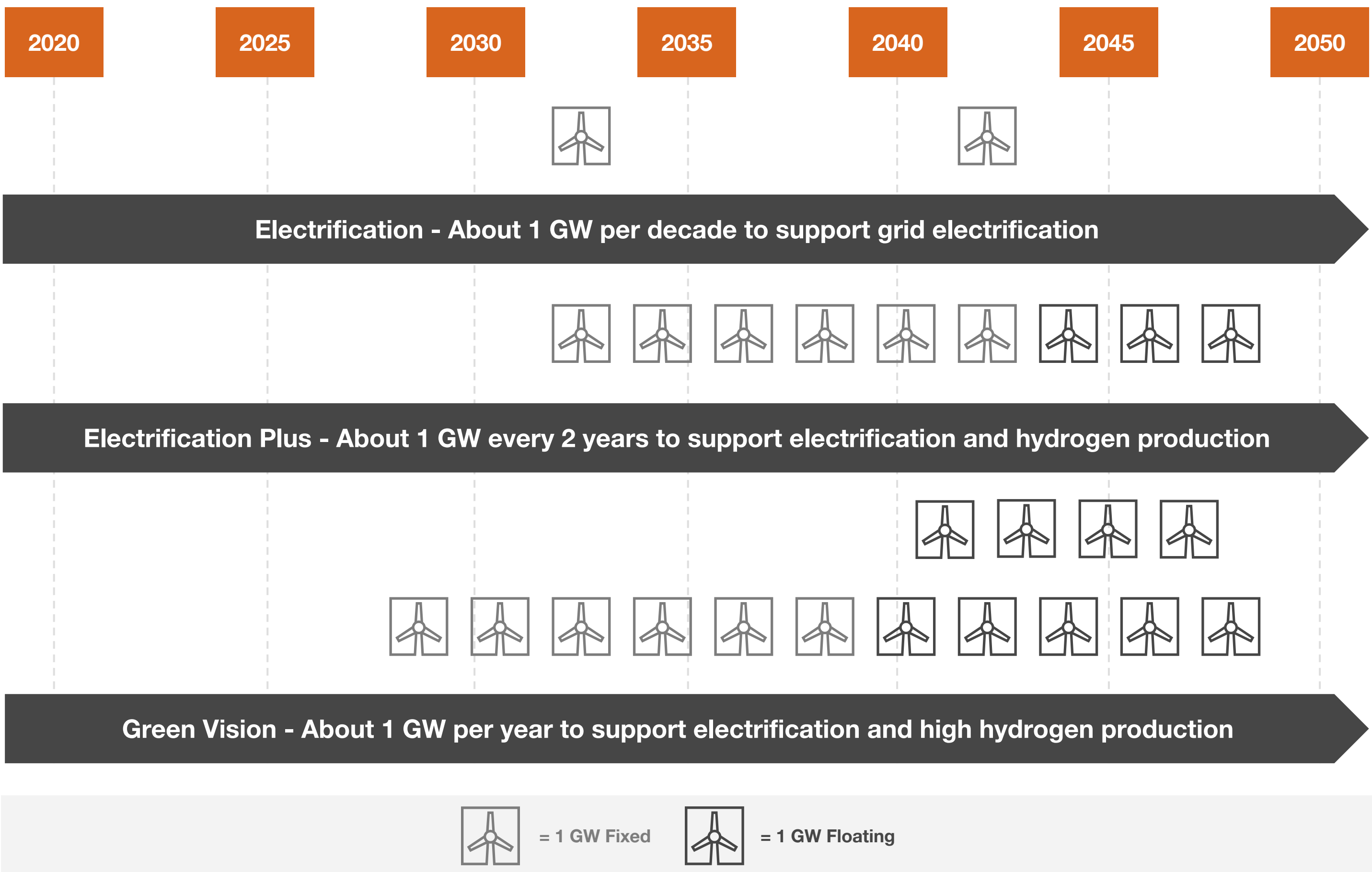
Operating expenditure

Operating and maintenance costs were sourced from NREL and are expected to decrease over time with technology improvements. Operating costs for floating structures are estimated to be about 6% higher than for bottom-fixed.[16]

Table 5: Estimated expenditure

Estimated OWF capex to 2050 (NZD real)[8]	Electrification	Electrification Plus	Green Vision
Total capex	$10.2b	$46.0b	$94.2b
Average capex per GW	$5.1b	$5.8b	$6.3b
Estimated OWF opex to 2050 (NZD real)[8]			
Total opex	$5.3b	$10.5b	$20.8b
Annual average opex	$0.2b	$0.6b	$1.1b
Annual average opex per GW	$99m	$69m	$73m

Figure 34: Staging of wind farms across scenarios



1.10 Build profile

The capital expenditure required for building OWFs is substantial.

The timing for the commissioning of each OWF under each scenario is established to optimise the build programme and meet expected electricity demand growth in each scenario. A key finding of the NIS is that smoothing the build profile of offshore wind farms will avoid boom and bust cycles in the industry and will optimise workforce and international contractor involvement.

Capital expenditure is spread across four different stages:

- Feasibility and planning: 5 years
- Construction: 2 to 5 years
- Operations: 30 years
- Decommissioning: 2 years

Allowances for other project costs such as financing costs, contingency and overheads were allocated to the appropriate stage and distributed accordingly for each wind farm to determine total spend per year.

Figure 35: Electrification - Annual capital expenditure and total cumulative capacity[8]

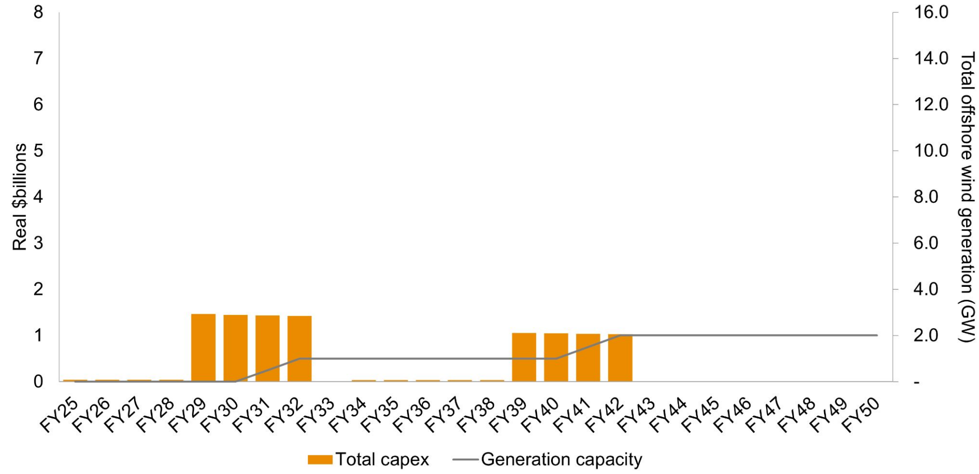


Figure 36: Electrification Plus - Annual capital expenditure and total cumulative capacity[8]

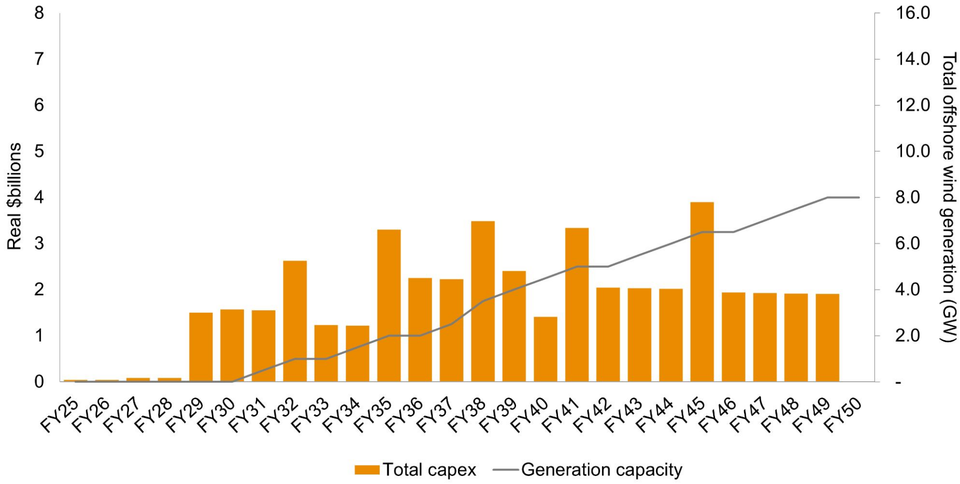
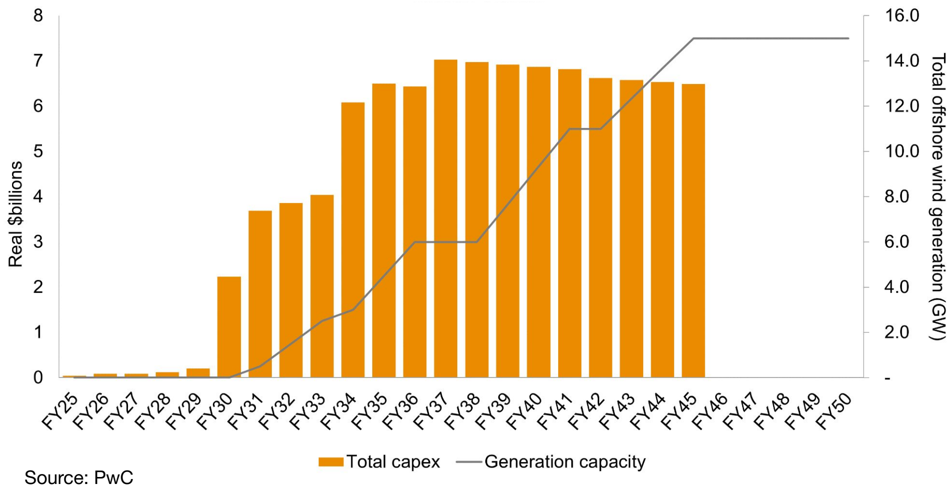


Figure 37: Green Vision - Annual capital expenditure and total cumulative capacity[8]



Source: PwC

1.11 The Counterfactual - New Zealand does not develop our offshore wind resource

We have considered the question of what happens if we do not develop offshore wind in New Zealand? How would we meet demand under each scenario and what would be the implications for decarbonisation, energy markets and the economy. This assessment highlights the potential role and importance of offshore wind to achievement of our emissions reduction targets.

A world without offshore wind has largely been explored already where there is not a significant hydrogen sector. The industry scenarios that have been developed to date assume a mix of onshore renewables and energy efficiency will be used supply the grid out to 2050. An equally detailed assessment of the generation supply options for the future hydrogen sector has not been undertaken.

The table below summarises new renewables generation required to meet grid demand in 2050 (relative to 2023 production). Onshore wind and solar in particular are key renewable generation technologies in these scenarios, although there is a diversity of views on the mix of each.

A significant observation is that in the counterfactual there will be many more smaller generation projects. The typical average size of a solar plant in the development pipeline is about 100 MW and 148 MW for onshore wind. This suggests that 25 solar farms or 8 typical onshore wind farms are required for every 1 GW OWF to provide the same amount of generation capacity.[27]

Smaller projects do have advantages of being able to be progressed relatively quickly, can more easily be timed to demand growth and provide broad diversity of supply. Larger projects by comparison have scale and synergy advantages and can bring on more GWs in a smaller time frame. They are also better able to support and coordinate with large scale industrial and P2X projects. On balance, there may be a benefit in having options for both small and large projects.

Onshore wind and solar have lower capacity factors in general meaning more plants will need to be built

While further along the development curve, onshore wind and solar generally have lower capacity factors meaning more plants may need to be installed to meet demand (as illustrated below).

Modern offshore wind turbines produce about 12 - 16 MW at capacity factors of 45% to 55%, whereas modern onshore turbines produce between 4 MW and 8 MW at 30% to 45% capacity factors.[18]

Solar is modular and can be scaled to any size but typically only has capacity utilisation of about 15% to 22% in New Zealand.[18,34] This is the lowest conversion rate of any renewable resource. For example, we would need to cover almost the entire Wellington City region in solar panels (some 442 km^2) to produce an equivalent amount of energy to the OWFs in our Electrification Plus scenario (8 GW).[35]

Land based renewables may become harder to bring to market due to competing land use issues

Land is often more contested and constrained than the ocean and there are more stakeholders and competing uses to consider. This is especially an issue for smaller countries like New Zealand, with 96% of the country's territory being sea.[36]

It could be challenging for land-based projects to deliver on our net zero commitments if we rely on these technologies alone. Onshore renewables will play a significant role in meeting New Zealand's future generation requirements. Whilst offshore renewables may also face challenges, we expect offshore wind to play a critical role in supporting onshore renewables to reach the scale and pace of deployment required.

Table 6: New renewable electricity supply required by 2050 (TWh)

TWh	Transpower (accelerated electrification)	BEC - Times 2.0 (average)	BCG (average)	Average	Number of typical onshore projects	Number of equivalent 1 GW OWF Projects
Wind (All)	11.5	35.1	22.1	**22.9**	**22 - 68***	**2.6 - 8.0**
Solar	22.3	6.3	11.9	**13.5**	**36 - 127****	**1.4 - 5.1**
Geothermal	2.9	-1.9	6.6	**2.6**		
Hydro	-1.3	-0.2	-2.9	**-1.5**		

*Typical onshore wind farm is assumed to be 140 MW based on analysis of pipeline
**Typical solar farm size is assumed to be 100 MW

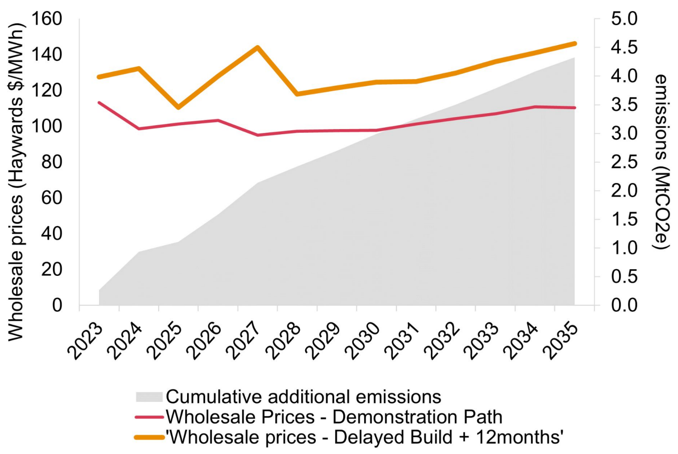
The ocean by comparison allows greater choice over location of individual turbines, which can increase output from better placement. Localised impacts and competing uses can also more easily be accommodated due to size of the areas being considered and the extensive ocean space New Zealand has available (9th largest in the world).

We are at risk of falling behind and options that allow for rapid scaling will be critical

Generation and infrastructure investors currently face a dilemma. While peak demand has increased 6% since 2019, energy usage has barely increased since 2006.[37] While most agree that large amounts of new supply are required, it is difficult to commit to major investments when demand growth remains uncertain. This has created an incentive to delay construction of new generation, which is likely to compress the build schedule to 2050.

The cost of falling behind could be significant. The CCC's 2023 emissions reduction plan advice to government suggests a one year build delay could increase wholesale prices by $35 per MWh (33%) compared to the baseline demonstration path. This is due to the creation of a consistent undersupply of generation. If this delay is sustained until 2035, the cumulative emissions impact could be 4.5 Mt CO_2-e (5.6% of annual emissions).[38]

Figure 38: Price path and emissions impacts of delayed renewable build[38]



Source: Climate Change Commission

The risk of falling behind in our build schedule is real. New Zealand has added very little net generation capacity since the Climate Change Act was introduced in 2019. With energy demand scenarios indicating we need to increase production by 1.1 TWh to 1.5 TWh each year, we need to do more. This rate of build is significant - about 2.5x to 3.4x higher than we achieved over the 1990 and 2020 period.[8]

Offshore wind is capable of providing large amounts of generation quickly and could rebalance wholesale markets quickly if there is a delay, placing downward pressure on prices.

If we build only half of the wind that is required by 2030, we will have a shortfall of between 11% to 28% of national demand (4.8 TWh to 12.1 TWh per annum). This could in turn create a less stable and secure energy supply.

Scaling land based renewables to support the hydrogen economy appears unachievable

Our analysis of industry scenarios and targets indicates that between 10.5 TWh to 20.6 TWh of new renewable generation production is required by 2050 to produce synthetic PtL transport fuels from hydrogen. In addition, 23.3 TWh to 48.7 TWh of generation is required to produce hydrogen for green industrial feedstock and commercial heat processing.

The scale of the electricity demand from hydrogen is daunting. Whilst land-based renewables will make a significant contribution to this new demand, it appears absolutely necessary that offshore wind would be required if we were to adopt hydrogen based PtX solutions to decarbonise these hard-to-abate sectors.

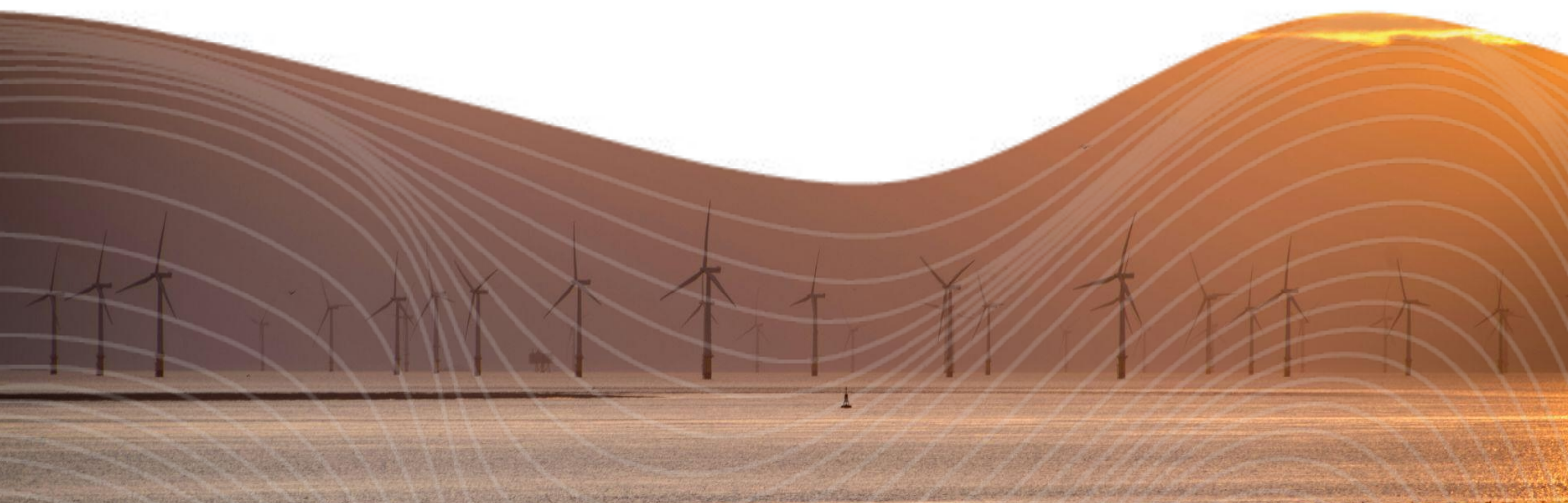
We discuss this in further detail in the Energy section.

The scenarios are unlikely to get us to net zero and more renewable energy may be needed

The Electrification and Electrification Plus scenarios do not get us to net zero in the energy sector. Even in Green Vision, offshore wind only contributes to reducing 30.3% of energy sector emissions (inclusive of transport). Other renewable generation, bio-energy, energy conservation and efficiency and CCUS are assumed to decarbonise the remaining energy system.

We need multiple options and levels of redundancy which can each be scaled significantly, in case one of the other options fails. We have already highlighted concerns over being able to scale land based renewables above. There are also equal concerns over the economics and supply of bio-energy due to limitations on access to land resources and waste material. CCUS has also not been used extensively globally and has not been tested in New Zealand. These options may not be viable, at least at the scale required.

Adding offshore wind to our toolkit of options to meet our net zero emissions target therefore appears practical given these constraints.



Economics

2. Economic

An offshore wind sector is projected to generate between $12b and $94b GDP (real) over the life of the projects and between 5,300 and 30,000 domestic jobs at the peak of the construction phase. About half of the economic benefit is concentrated during the construction period, with the other half sustained over a 25-35 year operational period for each project. Under the Green Vision scenario, the GDP impact would be comparable to that of the current oil and gas industry. In addition, it could unlock about $2.3b - $5.1b of economic activity in the hydrogen production sector.

A wide range of low and high skilled jobs are associated with OWFs, with many capabilities being able to be leveraged from the existing offshore oil and gas sector and other sectors. The offshore wind industry will create a ripple effect impacting many other sectors, from maritime activities to retail and education.

2.1 Quantitative assessment

We have estimated the GDP contributed and the FTEs required by the offshore wind sector. In terms of our GDP and FTE estimates, the total economic impact of the industry is the sum of the direct, indirect and induced effects on value created (GDP contribution) and FTEs.

- **Direct impacts** are the value-add or employment the occurs directly from the offshore wind industry
- **Indirect impacts** occur when the offshore wind industry purchase goods and services from other industries in order to operate, i.e. supply chain impacts
- **Induced impacts** are generated when the wages and salaries paid out by the offshore wind industry are spent on goods and services, stimulating further economic activity.

The analysis in this section shows the impact of the offshore wind sector from 2025 - 2090, the lifetime of the OWF projects considered in the three scenarios. Expenditure and GDP estimates are in real dollars.

The impacts in this section are those generated by activities within New Zealand. Expenditure has been adjusted to reflect that a portion of manufacturing and construction expenditure will occur overseas (~60% on average, but varies by scenario), and 20% of the feasibility and planning, operation and commissioning and decommissioning phases.

We have discussed key sources for our economic analysis overleaf.

Below is a high-level summary of the total and annual impact of the industry under the three scenarios. We have compared this with the annual impact of the oil and gas sector.

Table 7: Total and annual offshore wind sector impacts, compared with the oil and gas sector[1,2]

Sector scenario		Electrification	Electrification Plus	Green Vision	Oil and Gas sector*
Average annual impact (averaged over 2030-2050)					
Local expenditure *(Real $m)*		299	1,322	2,872	3,356
GDP *(Real $m)*	Direct	141	613	1,311	1,300
	Total	324	1,442	3,134	3,604
Employment *(FTEs)*	Direct	1,441	5,757	11,135	5,068
	Total	2,435	10,472	21,574	11,718
Total impact (over lifetime of projects)					
Local expenditure *(Real $m)*		10,770	44,052	86,749	
GDP *(Real $m)*	Direct	5,024	20,203	39,445	
	Total	11,593	47,447	93,618	
Employment *(FTEs)*	Direct	40,293	150,162	279,493	
	Total	74,838	297,069	575,079	

**These figures are the total impacts to New Zealand of the oil and gas sector from Venture Taranaki's economic impact study 'The wealth beneath our feet'.[2] We've adjusted 2013 expenditure and GDP estimates to 2023 dollars using general CPI (RBNZ).*

2.2 Total impact assessment

The table below shows the total impact of the industry, broken down by phase. We have also highlighted the duration of each phase, as the phases differ in length. The next page shows a view of impacts of the sector over time.

Table 8: Total sector impacts, broken down by phase

Scenario, phase	Duration of phase	Expenditure (Real, $m)	GDP value added (Real, $m)		Employment added (FTE years)	
			Direct	Total	Direct	Total
Electrification		**10,770**	**5,024**	**11,593**	**40,293**	**74,838**
Feasibility and planning	9 years	283	167	344	368	1,453
Construction	8 years	3,526	1,739	3,927	29,241	42,262
Operation and maintenance	46 years	6,757	3,012	7,091	8,842	28,546
Decommissioning	4 years	205	106	231	1,842	2,577
Electrification Plus		**44,052**	**20,203**	**47,447**	**150,162**	**297,069**
Feasibility and planning	20 years	1,227	724	1,490	1,474	6,179
Construction	21 years	18,364	8,522	20,229	105,951	176,313
Operation and maintenance	53 years	23,697	10,562	24,866	35,368	104,467
Decommissioning	13 years	764	395	862	7,368	10,110
Green Vision		**86,749**	**39,445**	**93,618**	**279,493**	**575,079**
Feasibility and planning	17 years	2,416	1,426	2,935	2,763	12,030
Construction	16 years	40,052	18,181	44,105	196,598	352,839
Operation and maintenance	49 years	42,860	19,103	44,975	66,316	191,292
Decommissioning	10 years	1,422	735	1,604	13,816	18,918

As demonstrated by the table above, construction and operation and maintenance phases are the most impactful phases in terms of both GDP and employment contribution to New Zealand. The operation and maintenance phase has a higher GDP contribution than the other phases, due to the longer duration of the phase. The construction phase has the highest employment contribution relative to the other phases, due to construction comprising most of the direct labour requirements, based on analysis done by IRENA[3], explained below.

Key sources for our economic analysis

The GDP and employment estimates presented in this section are derived using an input-output (multiplier) approach. Direct, indirect and induced impacts of the sector are derived, using the expenditure estimates for each scenario by phase (excluding an estimate of expenditure which takes place overseas), assumed MW for each scenario, and multipliers for each expenditure type and MW.

The GDP estimates are derived using multipliers and input-output tables published by Insight Economics.[4] The multipliers are applied to the expenditure values by phase.

For the employment estimates:

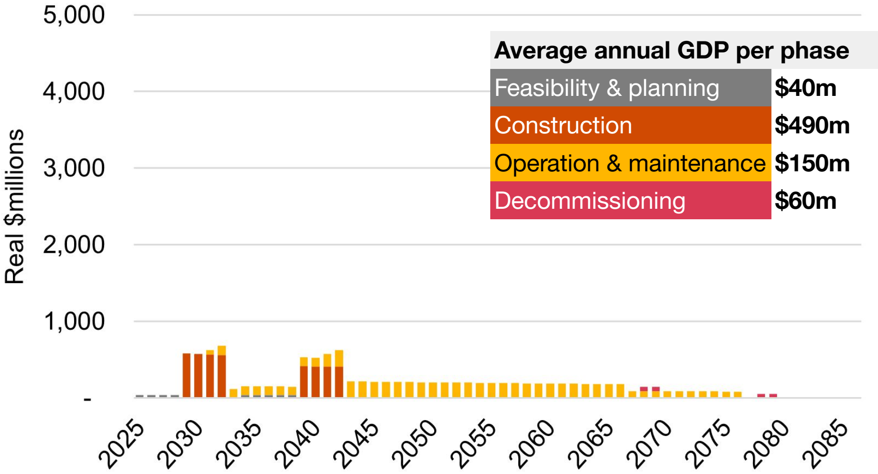
- The direct FTE estimates are derived using information from the IRENA 'Renewable energy benefits: Leveraging local capacity for offshore wind' report.[3]
- The total (across all project phases) values for direct FTEs are based on multipliers which are applied to the MW of the farm (rather than expenditure). These multipliers were applied by IRENA to a 500 MW farm.
- The per-phase values for direct FTEs were derived from the total value, split based on IRENA estimates of the percentage of people required for different offshore wind farm development activities.
- The indirect and induced FTE values were derived from the expenditure estimates, using multipliers and input-output tables published by Insight Economics (the same source as the GDP multipliers).

2.3 Total GDP contribution, throughout time (Real $millions)

The following figures show the total GDP impact over the forecast period, under each scenario. This includes GDP generated by activities within New Zealand, which has been calculated using local expenditure. Expenditure and GDP estimates are in real dollars.

Further detail on the activities associated with each of the phases are in the following section.

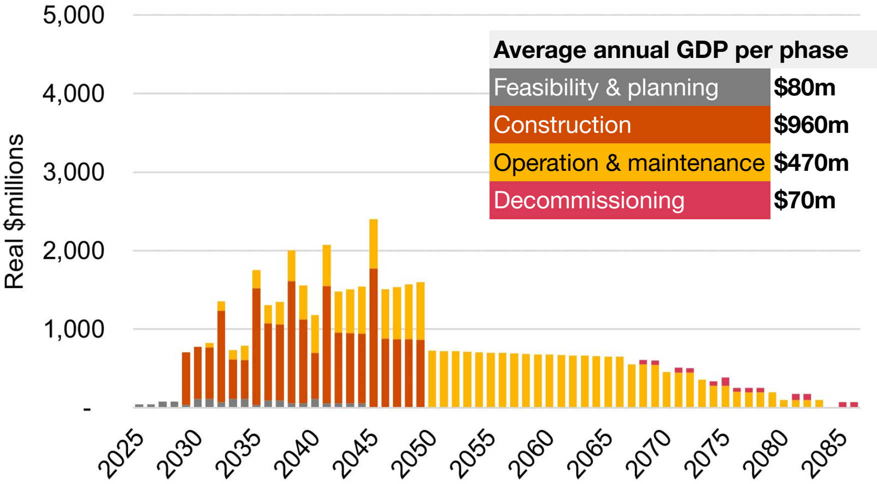
Figure 39: GDP contribution for Electrification scenario[1] | 2 GW | Total expenditure in New Zealand of $10.7b



Under the Electrification scenario, there are two peaks of GDP generation which occur during the construction phases of the two farms (2029-32 and 2039-42). During these periods, there is an average of **$490m** GDP generated each year, including contribution from construction and operational activities. This falls to ~**$150m** on average per year during the operational phase (46 years in total).

While much smaller in aggregate the GDP per OWF is similar to other scenarios.

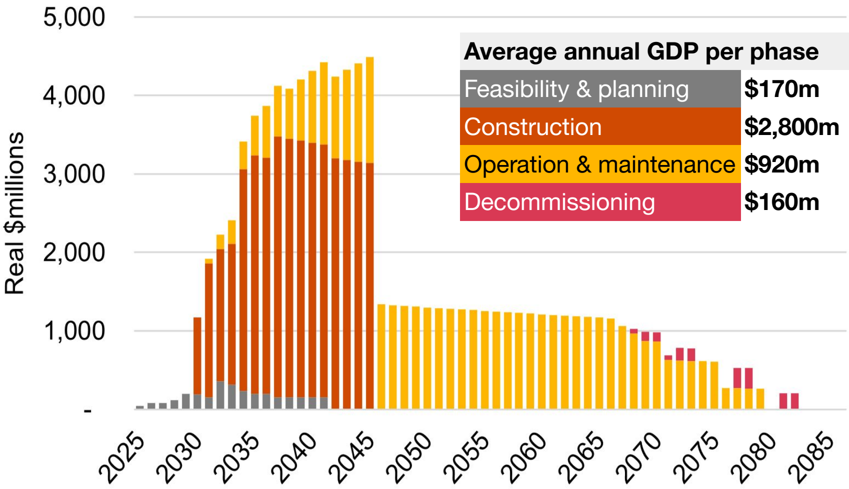
Figure 40: GDP contribution for Electrification Plus scenario[1] | 8 GW | Total expenditure in New Zealand of $44.1b



Under the Electrification Plus scenario, there is an average of **$960m** of total GDP generated by construction activity annually during the construction period, 2029-2049.

When construction ends, this falls to ~**$470m** of GDP for each year of the operational phase, which decreases as decommissioning begins.

Figure 41: GDP contribution for Green Vision scenario[1] | 15 GW | Total expenditure in New Zealand of $86.7b



GDP contribution under the Green Vision scenario peaks in 2045, with **$4,489m** of total GDP generated in one year.

This falls significantly to ~**$920m** on average for each year of the operational phase, which tapers off as farms begin to be decommissioned.

Source: PwC

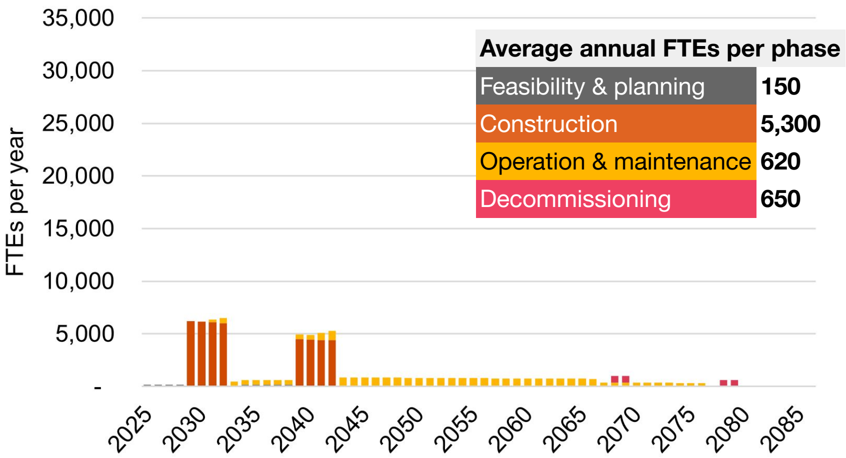
2.4 Workforce

Total employment contribution throughout time

The development of OWFs in New Zealand has the potential to support a significant number of local jobs. Many of these are transferable from other sectors, for example, the offshore oil and gas industries in Taranaki that could provide greater jobs resilience as New Zealand navigates the energy transition.

For each scenario, the following charts show the annual employment impacts over the project forecasting period and average annual FTEs required over each project development phase. The total employment impact of the industry is the sum of the direct, indirect and induced effects on employment created (FTEs), and includes employment generated in New Zealand. The direct impacts have been based on IRENA estimates of labour required for OWFs, and the indirect and induced impacts are calculated using a New Zealand multiplier method. These estimates are in line with comparable 'bottom up' studies completed by Concept Consulting (2023)[5] and IRENA (2018).[3] Workforce capabilities and activities associated with each of the phase are included overleaf.

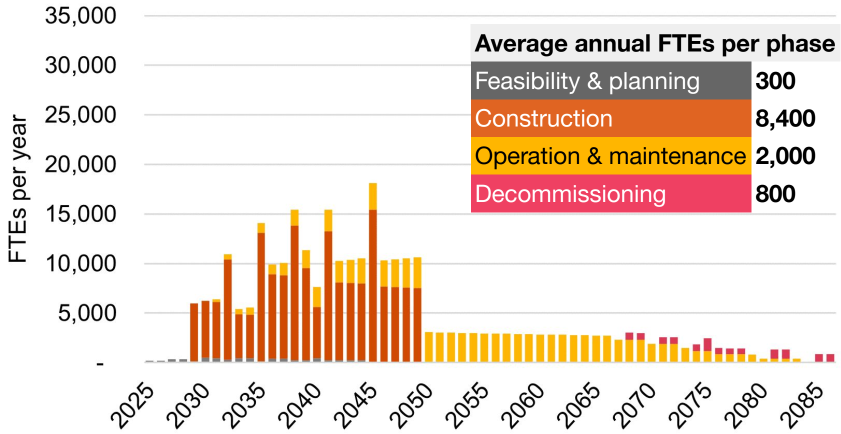
Figure 42: Employment contribution for the Electrification Scenario[1] | 2 GW



Under the Electrification scenario, the construction of the two farms each result in peak employment, beginning in 2029 and 2039. An annual average of ~**5,300** FTE jobs are required during these construction phases for each OWF.

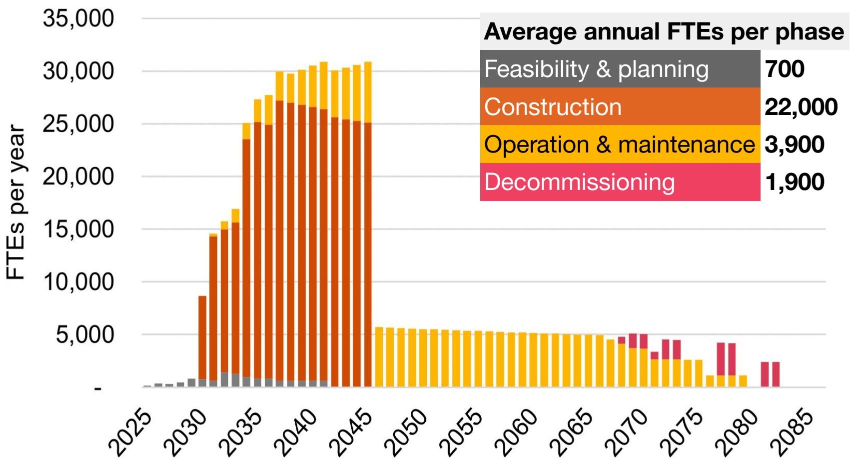
This is consistent with Concept Consulting's bottom-up approach[5] which estimated a similar number of FTEs per GW.

Figure 43: Employment contribution for the Electrification Plus Scenario[1] | 8 GW



Under the Electrification Plus scenario, a longer period of construction overlaps with operations and maintenance, resulting in total average peak of ~**10,000** FTEs from 2035 to 2050. Following construction, this falls to ~**2000** FTE jobs on average for each year of the operational phase (53 years in total).

Figure 44: Employment contribution for the Green Vision Scenario[1] | 15 GW



Source: PwC

Under the Green Vision scenario, there is a total of ~**30,000** FTE jobs required for a sustained period of about 10 years while peak construction overlaps with operations and maintenance.

There are ~**3,900** FTE jobs on average, sustained for each year of the operational phase.

Type of workforce needed [3,6,7,8]

The labour requirement for OWFs varies greatly by development phase, both in terms of overall number of workers needed and the 'types' of workers.

- A mix of low and high skilled jobs is required at each phase, however the majority of low skilled workers are required during the procurement and manufacturing phase, which are likely to occur overseas
- There is a significant demand for general skilled workers (such as health and safety experts, physicists and scientists) and technician level workers (such as turbine technicians).

Most of the work undertaken in the phases of feasibility and planning, transport, installation, operations and decommissioning will take place locally - either nearby or at the wind farm site. The majority of work associated with the construction (manufacturing and procurement) phase will take place overseas, as discussed on the next page.

In comparison to the development of onshore wind farms, OWFs require more labour due to the higher complexity of construction and installation activities. OWFs require complex foundations, substations, undersea cables and installation vessels that are not needed onshore.[3]

Workforce capability

There will likely be gaps in the New Zealand workforce's experience within the OWF context, as identified by Concept Consulting.[5] Training and development programmes will be essential to cater for the emerging needs in the offshore wind industry, which should take into account where the gaps exist (from a workforce profile and capabilities perspective).

New Zealand will need to leverage existing expertise and capabilities in other industries that can provide the necessary expertise, raw materials and intermediate products.

There are many workforce synergies that can be leveraged as we transition towards renewables. For example, the offshore oil and gas industry share similar skills, training requirements and workplace conditions as offshore wind, and many current offshore oil and gas workers are well placed to shift into offshore wind. The maritime workforce is also already well equipped to work in offshore wind. More than 85% of qualification-based maritime workforce (in roles such as deck officers and marine engineers) are already trained and ready to work in offshore wind.[9]

Table 9: Workforce required and activities undertaken in each phase of OWF development[3]

The following percentages show the FTE profile of a representative OWF, based on IRENA (2018).

Phase	Types of workforce	Activities
1% **Feasibility and planning**	Ship crew, lawyers, energy regulation & taxation experts, engineers (energy, electric, electronic, mechanical, telecom, computer, civil and naval), financial analysts, logistics experts, geotechnical experts, drilling system operators, environmental, sociological & marine biology experts, technicians, physicists, weather data experts	• Site selection • Environmental impact assessments • Technical assessments • Establishing access to the grid • Undertaking financial feasibility • Project development • Engineering design
Construction **59%** **Procurement and Manufacturing**	**Procurement:** Logistics and regulation experts, engineers (electric, electronic, material, mechanical, industrial)	• Identification of specifications and raw materials • Logistics management
	Manufacturing: Factory workers, marketing, sales, administrative & accountant personnel, quality and health & safety experts, engineers (industrial, electric, design and research and development), logistics, taxation, regulation & standardisation experts	Procurement and manufacture of: • Nacelle • Rotor • Tower • Cabling • Foundation • Substation
0.1% **Transport**	Truck drivers, ship crew, cleaning personnel, crane personnel, site security personnel, regulation, logistics & security experts	• Transportation of components
11% **Installation and grid connection**	Ship crew, crane operators, drilling systems operators, engineers (naval, electric and electronic), quality, regulation and health & safety experts, cable plough, trenching remote operating vehicles & jetting systems operators, technicians, environmental experts/scientists	• Foundation installation • Substation installation • Cabling installation • Turbine installation • Array cable laying • Grid connection
24% **Operation and maintenance**	Technicians, civil workers, admin personnel, engineers (industrial, mechanical, electric, telecommunication, computer, naval), site security and cleaning personnel, legal, safety and environmental experts, helicopter pilots, crane operators	• Operation • Maintenance
5% **Decommissioning**	Technicians, ship crew, truck drivers, engineers (mechanical, electric, electronic, naval, civil), environmental, regulation, safety & logistics experts, crane operators	• Planning • Dismantling • Recycling and disposal

2.5 Local potential for involvement in supply, manufacturing and installation

Most of the work undertaken in relation to feasibility and planning, transport, installation and grid and substation connections, operations and decommissioning can be undertaken locally - either nearby or at the wind farm site. Most O&M work is assumed to take place locally.

The work associated with procurement and manufacturing, however, can take place anywhere. Some countries have sufficient capacity to manufacture equipment locally and others import the majority of the equipment. New Zealand is unlikely to manufacture much equipment locally due to insufficient capacity, which is explored further in our discussion on supply chain, overleaf.

We have assessed the activity and costs that are likely to occur in New Zealand, compared with what will occur overseas. We have summarised our view on this below, and compared this to Concept Consulting's recent bottom up assessment of the offshore wind workforce in its report 'offshore wind industry capability mapping study' (capability mapping study).

Table 10: Location of activity

Key:

Likelihood of activity occurring in NZ	Alignment between Offshore Wind and PwC
(orange up arrow) Mostly high	Aligned
(yellow circle) Moderately high	Mostly aligned
(orange down arrow) May be practical for some elements	
(black down arrow) Appears unlikely	Not aligned

Component	Scenarios assumptions of potential supply from New Zealand sources	Capability mapping study[5] assessment of potential supply from New Zealand sources	Source alignment
Nacelle & Rotor	(Appears unlikely) Manufacturing mainly overseas, with some local content added during assembly. (May be practical) Installation mainly done by overseas ships, but NZ port, engineering and marine workforce to be involved to support installation.	(Appears unlikely) Manufacturing: Appears unlikely. Unlikely to be supplied in New Zealand as it requires specialised expertise and equipment. (May be practical) Installation: May be practical for some elements.	Aligned
Tower	(May be practical) The circumference of OWF towers is currently too big for NZ steel manufacturing and is assumed to occur overseas. Some local content added when brought into the country. May be practical for some elements in the future, depending on the scale of the industry.	(May be practical) Manufacturing: May be practical for some elements.	Aligned
Turbine Installation	(Moderately high) Bulk of offshore work to be undertaken by overseas ships and contractors, but NZ ports, marine and engineering sector involved in marshalling, assembly and installation. Local pilot and support vessels and divers.	(May be practical) Installation: May be practical for some elements.	Mostly aligned
Cabling	(May be practical) Manufacturing: NZ to produce half of offshore cables (e.g. assumes Nexans to install local plant based on their existing offshore cable technology in Germany) and all onshore cables, and will depend on the magnitude of the offshore wind industry. (Mostly high) Installation: NZ workers involved in cable connections and NZ ships could lay some array cables.	(May be practical) Manufacturing: May be practical for some elements. Possible with investment. (May be practical) Installation: May be practical for some elements. Local installation for sub-components (e.g. array cables) may be practical.	Mostly aligned
Substation / Grid Connection	(Moderately high) New Zealand manufactures everything apart from transformers and specialist switchgear. (Moderately high) New Zealand does all shore side installation and half of offshore substations which require more technical skills.	(Moderately high) Manufacturing: Mostly high for **onshore** elements. May be practical for some **offshore** elements e.g. top side components. (Moderately high) Installation: Mostly high for **onshore** elements. May be practical for some **offshore** elements. Offshore specialist vessels will be needed, however, local construction ports and support services will be needed.	Aligned
Fixed Foundation / Floating Structures manufacturing	(May be practical) New Zealand could manufacture 50% of floating structures by expanding our marine sector, and 10% of fixed foundations in each scenario. Local content increases as more floating is used.	(Appears unlikely) Manufacturing: Unlikely to be supplied locally as specialised expertise and equipment is required.	Mostly aligned
Foundation + Substructure installation	(May be practical) Assumes NZ ports involved in staging and as well as some involvement in offshore installation (pilot and support vessels, divers, support and supply). Most of the cost is overseas ships.	(May be practical) Installation: Partially supplied locally as offshore specialist vessels will be needed, however, local construction ports and support services will be needed.	Aligned

2.6. Supply chain[10,11]

Developing an OWF involves a complex supply chain which has various components and processes.

As demonstrated on the previous slide, a big portion of the supply chain may be procured overseas. However, there are small components that can be sourced domestically, especially if the opportunity to establish local industries (which will require some investment) is realised. This includes offshore structures that are specific to OWFs, but there also will be onshore cable-related structures, which may be able to be procured domestically even where the size or specification differs from what is currently supplied.

The key elements needed in the supply chain to create an OWF, together with a non-exhaustive list of existing suppliers are set out in the table below.

Table 11: Offshore wind supply chain

Inputs and suppliers for fixed and floating OWF		
Input(s)	**Description**	**Existing suppliers/potential new industry**
Turbine	The manufacturing of turbines consists of three main components: the nacelle, hub and assembly. The supply of these components should be considered together as the turbine manufacturer will ideally be near suppliers. The importance of proximity to suppliers means that closer regions such as APAC should be prioritised over European factories who may also have capacity.	Companies with factories in the APAC region: • Siemens Gamesa Renewable Energy (SGRE) (India, China, Taiwan) • Vestas (Japan, Taiwan) • General Electric (India, China) • Mingyang Wind Power (China).
Blades	Blades are usually made of epoxy resin and fibreglass-based composites, however they can also be manufactured using carbon fibres and metal inserts. A large portion of costs are in the transportation and handling of the blades.	Existing blade suppliers: • LM wind power (India China) • SGRE (India, China, Taiwan) • Mingyang Wind Power (China) • Vestas (Japan, Taiwan).
Approximately 85% of offshore wind capacity in the world has been designed and manufactured by Siemens Gamesa and Vestas; the two main companies in the industry. These two manufacturers dominate the industry worldwide outside China.		
Tower	The large steel tubes that make up the towers are made by welding rolled plates with flange bolted connections at the terminations.The key raw components needed are thick steel plates and proximity to an experienced rolled-steel fabrication ecosystem.	Towers will require the establishment of a new local industry and suppliers.This also presents an opportunity to regenerate or leverage from other industries reliant on steel production and fabrication.
Array and export cables	Subsea inter-array cables connect individual wind turbine generators to floating substations which transform and transmit energy to an onshore substation via export cables. It is important for the cables to be dynamic and of high mechanical strength to withstand ocean conditions. Array and export cables can be manufactured in factories that produce oil and gas power cables and umbilicals as they share key characteristics.	Array and export cables can have the same manufacturer as ultimately they are both high voltage subsea cables. Local supply is beneficial as cable transportation is expensive as specialist cable vessels are needed. Companies in close proximity include: • Prysmian Group (corporate location in NZ) • Nexans (corporate location in NZ) • Sumitomo electric • LS Cable and system (presence in Australia).

Inputs and suppliers for fixed OWF foundation		
Input(s)	**Description**	**Existing suppliers/potential new industry**
Fixed foundation	Different types of foundations exist depending on the depth at which the wind turbine is placed. For example, monopiles, thick cylinder foundations, are used for depths below 15 meters whereas for depths of 30 meters gravity foundations are more common. Gravity foundations are platforms made of steel or concrete. For depths greater than 30m a jacket structure is used which has 3-4 anchoring points.	The Offshore Wind Foundations Alliance consists of five key manufacturers who produce different types of foundations - Bladt Industries, EEW Special Pipe Constructions, Sif Netherlands, Smulders Projects Belgium, Steelwind Nordenham. Some others include: • Dajin Heavy Industry • Harbin Electric Wind Energy • Shanghai Electric Wind Power • China Shipbuilding Group Haizhuang Wind Power.

Inputs and suppliers for floating OWF foundation		
Input(s)	**Description**	**Existing suppliers/potential new industry**
Floating foundation	Although there are very few floating wind farms, the turbines' foundations share many components with that of the oil and gas industry which have been manufactured for decades. The foundations are usually made from steel, concrete or a combination of both.	Floating offshore wind is an emerging industry which is not yet fully developed. The current focus of this area is on technology design with key leaders being designers not manufacturers. This creates an opportunity for New Zealand steel producers and fabricators to work alongside designers and become manufactures of the foundation by fabricating and assembling the foundations. This presents an opportunity to strengthen this industry in New Zealand by manufacturing the floating foundations, cabling and mooring systems at the actual project site.
Mooring line	Lines can be Catenary (C), Semi-taut (ST) and Taut (T). Materials include steel chain, synthetic fibre rope and spiral strand wire depending on the configuration.	Suppliers for the various materials that mooring lines can be made of include: • Steel Chain (C) • Vicinay Marine • Sotra. Synthetic Fibre Rope (T & ST) - • Bridon-Bekaert Ropes Group • Delmar • Katradis.
Anchor	The type of anchor needed is dependant on mooring system, foundation type and seabed characteristics. Anchors have been manufactured for the oil and gas industry for many years. Due to the similarity between the oil and gas industry and the floating OWF industry, there are many existing manufactures capable of supplying anchors for the floating OWF industry.	Global anchor suppliers include: • Vryhof • Isleburn • Acteon • Sotra.

Image: Descending from Wind Turbine, Northwester 2, Belgian North Sea, Courtesy of Parkwind

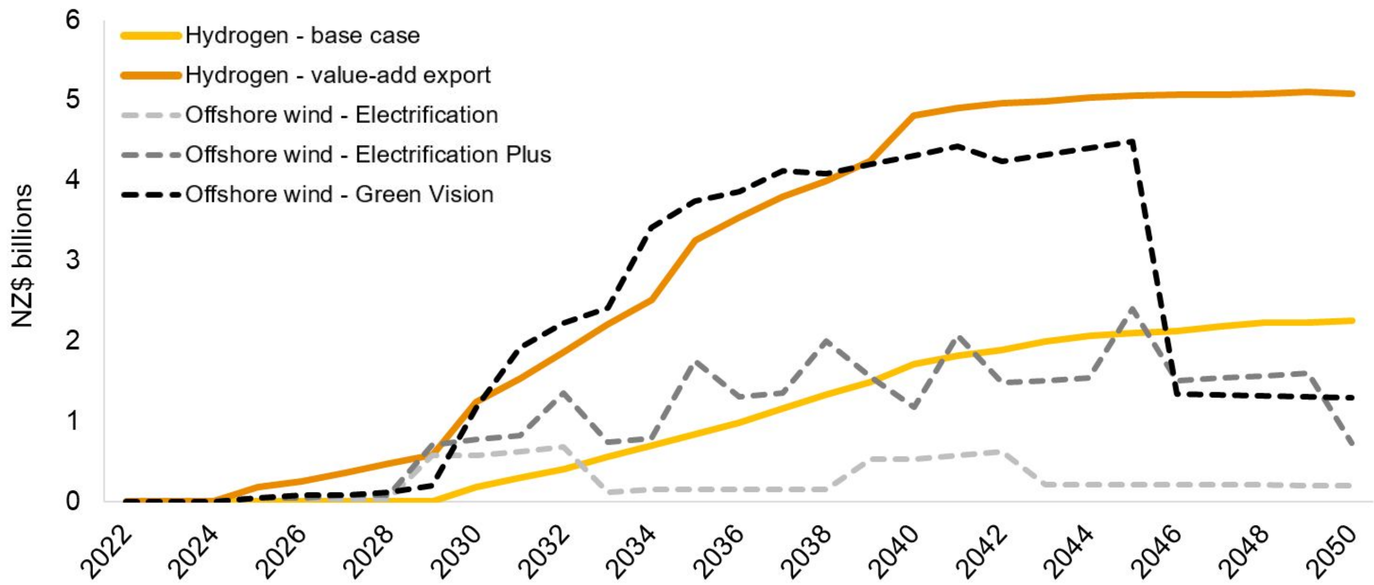
2.7 Economic impact on associated hydrogen economy

As discussed earlier, there is a significant opportunity to develop a new green hydrogen economy to support fuel substitution in hard-to-abate sectors, which could be underpinned by offshore wind power and other large-scale renewable generation.

The potential hydrogen economy will have substantial economic impacts for New Zealand. The 2023 EY/MBIE hydrogen modelling study[12] estimated the gross value-add from a domestic hydrogen economy at between $2.3b to $5.1b in GDP per annum by 2050 (in the base and value-add export scenarios used in the NIS scenarios).

The table below compares the estimated GDP contribution of the offshore wind and hydrogen economies between 2025-2050.

Figure 45: Gross value-add from domestic hydrogen and offshore wind economies (2023-2050, NZ$ billion)[1,12]



Sources: PwC, EY/MBIE

As the hydrogen and generation sectors are heavily linked, there is potentially some overlap between the economic impacts of the two industries, and hence it is not correct to add these economic impacts to derive the value for the two sectors. We understand the hydrogen economic analysis was high-level to illustrate directional impacts only. The specific methods and assumptions used by PwC and EY/MBIE to obtain these GDP estimates is likely to differ.

Table 12: Comparison of national economic contribution across scenarios 2025-2050*

Cumulative national contribution (2025-2050)		
Scenario	**GDP or gross value-add** Real $b	**Employment** FTE years, 000s
EY/MBIE hydrogen [12]		
Base case	$30.6b	159.4
Value-add export	$85.3b	452.9
PwC offshore wind		
Electrification	$7.4b	56.4
Electrification Plus	$30.5b	219.5
Green Vision	$64.5b	352.1

* These GDP and FTE estimates exclude any impacts after 2050 to align with the EY/MBIE report, so are lower than the figures quoted in Table 7, above.

Although numbers are indicative and are not additive, it is clear that the combined effect of both the hydrogen and offshore wind sectors will contribute towards substantive economic development in New Zealand.

Capital spend and job creation during the construction phase in the offshore wind industry drives a significant portion of the value added. This is reflected in the Electrification Plus and Green Vision scenarios in 2035 when construction is assumed to be well under way, tapering off in to 2050 when the OWFs are entering the operating stages.

Under EY/MBIE's scenarios, the value effect from the hydrogen economy experiences rapid growth between 2030 and 2040, especially in the value-add export scenario, when the majority of hydrogen production related capital spend is incurred.

The two industries are very much interlinked. Offshore wind has the potential to unlock large scale hydrogen, enabling much of the economic benefits from hydrogen.

2.8 Impact on other affected sectors impacts

As New Zealand's offshore wind sector emerges, it will create a ripple effect impacting many established sectors.

By providing renewable energy at scale, the offshore wind industry will play a significant role in helping other industries decarbonise and reach net zero targets. This scale will also enable the longer term shift to electrification of vehicles in New Zealand. The industry will also bring prosperity to a number of sectors in locations near OWFs, particularly during the construction phase, by generating an increased demand for goods and services, accommodation, and hospitality.

There is potential for the offshore wind industry to create significant improvements in the oceanic data sector. Potential uses of this data include improving understanding of marine species, helping to better understand and respond to tsunamis and other hazards, and gaining a better understanding of our natural resources. A number of potentially affected sectors are discussed below. Please also see the Energy and People sections for discussion of wider national effects on the hydrogen / PtX economy and local communities.

Accomodation, hospitality and retail	There is likely to be a significant impact on this sector in the location of the wind farm construction, and particularly during the construction phase. The large influx of non-local people, particularly during the construction phase, will result in increased demand for products and services such as clothing, accommodation, household goods and hospitality. The accommodation, hospitality and retail industry may benefit from the temporary (3-4 years) increase in demand.
Oceanic data	There is potential for the offshore wind industry to create a significant improvement in the oceanic data sector, particularly due to the current lack of data available. Environmental data collection and monitoring will be required during both feasibility studies as well as turbine operations. There is huge value to the data. Potential uses include reducing negative impacts on marine species, helping better understand and respond to tsunamis and other hazards and gaining a better understanding of our natural resources.
Commercial fishing and aquaculture	There is potential for the commercial fishing and aquaculture industry to be impacted by the development of an offshore wind industry. Concerns include displacement from key fishing areas resulting in additional costs, a change in the composition of species in the area, disruption to electronic signals and radar, and increased vessel traffic. With careful planning, co-existence strategies can be implemented for co-located infrastructure between OWFs and open ocean aquaculture to minimise spatial conflicts.
Export markets	In Green Vision we model exports of hydrogen, transported in the form of ammonia. While there are no significant export revenues directly associated with offshore wind power, there are likely to be a number associated industries that will generate export revenues in our scenarios. These include green metals (e.g.steel) and chemicals (e.g.methanol, ammonia), and sustainable food to name a few. While these are already exported, New Zealand may be able to grow these exports and charge a premium from using renewable offshore wind.
Marine protection	OWFs will create a noticeable increase in demand for marine protection services due to increased maritime activities. Marine protection services that may see an increase in demand as a result of OWF development include: developer request reviews, consultations and advisory and increased marine life monitoring and reporting. There is likely to be benefits from improved data availability and sharing of costs with other sectors.
Tourism	There is little evidence indicating that the tourism industry will be impacted. However, potential impacts involve recreational boating and beach goers who may perceive disruption of ocean views by turbines. Although, there are examples overseas of companies offering wind farm boat tours. Refer to the 'observational impacts' part of the People section below for more on this.
Seabed mining	Mining in the marine area can also be considered a competing use of the area, particularly as the new Government has announced it will "investigate the strategic opportunities in New Zealand's mineral resources". If development of OWFs is not timed with this consideration there may be a lost economic opportunity. For example, in Taranaki, it is estimated that there are billions of dollars of vanadium in the seabed. This may not be able to be mined if development occurs in the same place. The mining sector considers that it could operate temporarily before the OWF construction phase. Complications may arise if both sectors use the same space.
Education	The offshore wind industry may have an impact on particular areas of the education sector. As a new industry for New Zealand, many workers will need to be trained in the specialised skill sets required to support the new offshore wind industry. Existing training development programmes can be leveraged from the oil and gas industry though, due to the skillset similarities across sectors.
Maritime activities, Transport and Defence	Overseas maritime, aviation and defence industries are at risk of OWFs interfering with radar/navigation, communications and weather tracking systems. For example, shipping is at risk of OWFs interfering with navigational radars which aid them in avoiding collisions, which is an issue that has been raised by the US Department of Defense. It is anticipated that the impacts on New Zealand will be relatively minor due to the location of proposed offshore wind farm sites being situated away from major airports/ports and shipping routes on the East Coast. Reflections from the blades have also been observed to affect visibility of smaller vessels and stationary objects such as buoys. A more crowded sea can also lead to changing shipping routes and/or higher risk of collision due to having less room to manoeuvre. Both can result in higher costs.

2.9 Revenues, profit and taxes

OWFs will generate revenue, profits and tax revenue that will contribute to the wider national economy. Some $33b to $290b (real) of revenue and about $1.6b and $14b in corporate tax revenue is projected to be generation over the life of the OWF projects detailed in the NIS scenarios.

Revenue: We have summed all of the generation revenues earnt over the forecast period assuming that developers receive revenues sufficient to cover acceptable returns.

Taxable income (EBT): Taxable income (in the table) is the sum of projected earnings before tax (EBT).

Profit: Profit is the net income that remains after tax is deducted, based on achieving a 10%-12% target return on equity.

Taxes: The New Zealand corporate tax rate of 28% is applied to OWF taxable income. We note that OWFs are expected to generate notional tax losses in early years due to the high capital depreciation.

Table 13: Total revenue, profits and taxes
Forecast over project lifetime (undiscounted real $billions)

Scenario	Electrification	Electrification Plus	Green Vision
Revenue	33.3	143.2	290.0
Taxable income	5.8	23.4	50.0
Profit after tax	4.2	16.8	36.0
Taxes	1.6	6.5	14.0

Case Study[13,14,15,16]

Port Oostende - the home of the Belgium's Blue Economy

Many activities that are crucial to Belgium's offshore wind industry take place at the REBO heavyweight terminal, located at Port Oostende:

- **Assembling:** wind turbine components are brought to the terminal from all over the world and assembled at the Port
- **Installation:** turbines are installed at sea
- **Maintenance:** the terminal maintains every wind farm (399 turbines) in the Belgian part of the North Sea
- **Decommissioning** and replacing of turbines at the end of their lifecycle.

A green hydrogen plant is also being built at Port Oostende, which will have a nameplate capacity of 70 MW when it begins production in 2025, growing to 250 MW in a later phase. Port Oostende, Parkwind and GEOxyz are also proposing a new hydrogen bunkering system which will supply ships using green hydrogen produced from offshore wind.

There are also aquacultural cultivation activities that occur at Oostende Science Park, home to University of Ghent's renowned Blue Growth Research Laboratory.

Sustainable job creation with a future focus is a key pillar of Port Oostende, which is supported by the diversification of activities into those associated with the Blue Economy.

The **Blue Economy** also creates economic opportunities for ancillary businesses, such as those involved in the maintenance of wind turbines. This part of the value chain employs ~600 full-time employees, across a cluster of ~60 companies.

Taranaki has the potential to be the Oostende of Aotearoa.

The World Bank defines the concept of a **Blue Economy** as the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health.The ocean can be host to a number of industries while also playing key role in sequestering CO_2.

Our analysis and desktop research shows that it is very likely that an offshore wind industry in New Zealand will help to drive a vibrant blue economy.

Energy

3. Energy

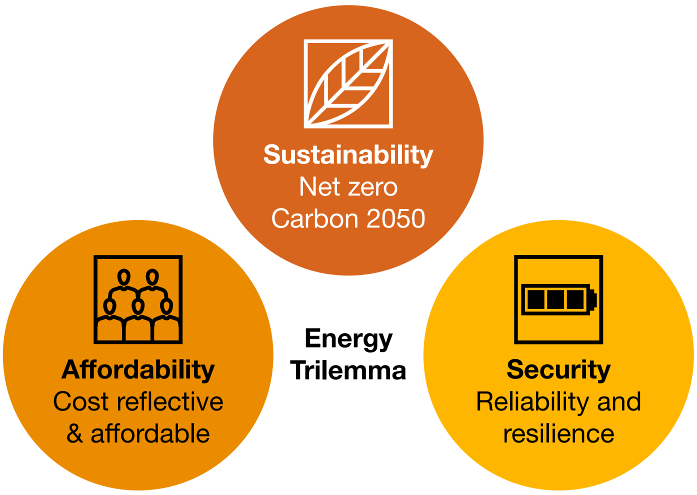
Offshore wind could make a significant contribution to New Zealand balancing its Energy Trilemma goals of sustainability, energy security and affordability. It is perhaps best placed in unlocking large scale electrification and significant green hydrogen production to enable a net zero future. The economics of offshore wind are expected to improve quickly and it may prove cheaper and/or easier to bring to market once societal impacts are taken into account. It is also likely to support higher levels of energy security and sovereignty, particularly when combined with a portfolio of other renewable energy resources.

3.1 The Energy Trilemma

Our energy analysis is framed around the three Energy Trilemma goals of:

- **Sustainability:** which explores the decarbonisation role offshore wind can play in accelerating and scaling electrification and green hydrogen
- **Energy Security:** which considers how offshore wind can support higher levels of energy security and sovereignty
- **Affordability:** which seeks to estimate the costs and consumer price impacts of introducing offshore wind into the energy mix.

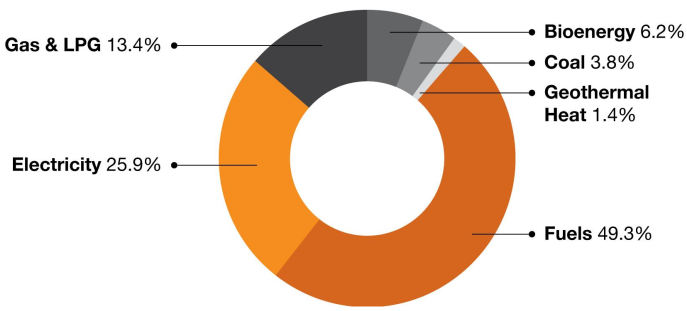
Figure 46: The Energy Trilemma



3.2 Our current energy system

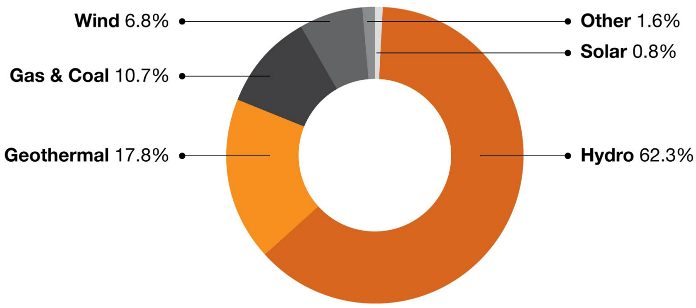
Nearly 89% of New Zealand's energy usage is from fuels (49%), electricity (26%), natural gas and LPG (13%).[1] These are also the energy sources that may be most affected from offshore wind.

Figure 47: Energy demand by source (2022)[1]



Source: MBIE

Figure 48: Electricity generation by source (2023)[1]



Source: MBIE

Already 89% renewable, New Zealand's electricity system is dominated by hydro power - predominantly fed from Lake Taupo and South Island river catchments - and geothermal and gas / coal fired thermal generation in the upper North Island. Onshore wind and solar generation are distributed throughout the country and currently contribute less to supply.

Winter is New Zealand's season of peak demand and time of greatest supply risk. South Island precipitation in the winter often falls as snow, meaning our southern hydro lakes do not refill until the spring melt. This is one of the mismatches in supply and demand in the existing power system and creates a winter energy security challenge. Thermal generation, fuelled by gas, imported coal and diesel, plays an important role in providing energy security. This backup supply is more expensive to operate and contributes to much of our electricity emissions.

The electricity industry is emerging from a period of flat demand and is now increasing investment in renewable generation and infrastructure to support electrification of the economy and decarbonisation of transport, heat processing and industrial emissions.

The gas sector is also responding to the energy transition and is exploring ways to decarbonise and support higher levels of intermittent renewables. In addition to its role in supplying gas fired generation, the gas sector is exploring alternative biofuels, hydrogen blending (both 'green' and 'blue', produced from gas), and CCUS. There is also the prospect of winding down production over time as part of the energy transition.

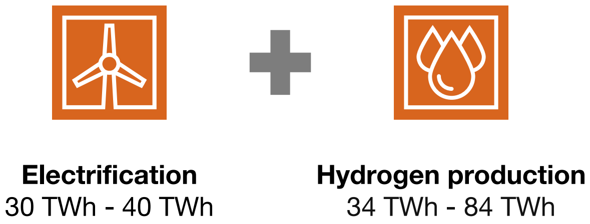
New Zealand fuels are mostly imported and include petrol, diesel, aviation and marine fuels. Emissions from fuels comprise the majority of energy sector emissions and are proving much harder to abate. Fuel decarbonisation efforts have so far focused on vehicle fuel efficiency, biofuel blending, and electric vehicles. These measures are all expected to ramp up in our energy transition. In addition, new synthetic fuels produced from hydrogen based PtL fuels are expected to be brought in to decarbonise heavy and long-distance transport that can not easily use electric batteries.

3.3 Sustainability - unlocking green energy

Offshore wind could have a significant role in unlocking green energy and in decarbonising New Zealand's energy system.

A synthesis of industry future energy scenarios indicates that our current electricity generation production needs to grow by a factor of 1.8x to 3.9x. Between 64 TWh and 123 TWh of new generation production is required by 2050 to meet demand from electrification (renewable electrons) and potential green hydrogen production (renewable molecules).

Figure 49: New electricity supply required by 2050 for electrification and hydrogen



This is a sizeable undertaking and all forms of generation will play a role in meeting future demand.

Offshore wind has several strategic advantages that could assist the country to meet our net zero target by 2050. Of note, offshore wind can be scaled quickly and has less impact on communities than land-based alternatives, given it is situated offshore and sometimes beyond the horizon.

In the following sections we explore the strategic importance of offshore wind in unlocking green energy and decarbonising our energy system.

Scaling electrification

Industry energy forecasts are unanimous in their view that New Zealand's electricity supply will need to increase significantly to support electrification of our economy; from 43.5 TWh today to somewhere between 74 TWh and 84 TWh by 2050. These scenarios largely ignore hydrogen production for the decarbonisation of domestic hard-to-abate sectors.

The future role of wind (onshore and offshore) in the generation mix is less certain, but forecasts indicate that an additional 11.5 TWh to 35.2 TWh of annual production will be required by 2050. Using New Zealand's largest wind farm as a comparator, we would need to build between 14 and 42 Turitea sized wind farms by 2050 to meet this.

Offshore wind is perhaps best able to scale and accelerate the energy transition given the significant untapped offshore wind resource, GW scale and high capacity utilisation factors.

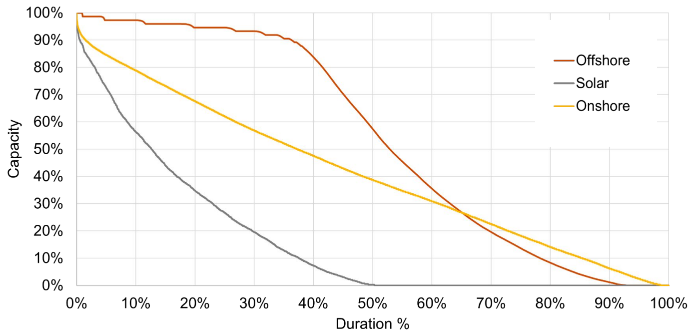
In our scenarios we project about 8.9 TWh per annum (2 GW capacity) of offshore wind could be developed by 2050 to meet grid based demand for electricity. This would require a further 14 TWhs of onshore wind to meet the average supply forecasts for wind.

The ability to generate more power for longer

A key benefit of offshore wind relative to other forms of renewables is that it has much higher capacity utilisation factors. Typically 40% to 55% of capacity is utilised in a year, compared to onshore wind (30% to 45%) and solar (15% to 22%).

Apart from hydro and geothermal, offshore wind will be the most efficient as it will typically generate at higher levels more often. For example, South Taranaki and Southland OWFs are expected to generate 90% of the time, and at 60% capacity or greater at least half of the time. In contrast, solar plants typically generate less than half the time, and at 60% of capacity quarter of the time.

Figure 50: Capacity duration curve - South Taranaki - offshore, onshore wind and solar[2,3,4]



Source: PwC, Elemental, EA EMI

A key benefit of higher utilisation is that offshore wind will more efficiently use new transmission capacity. For example, a 100 MW transmission connection to a solar plant will only be used at maximum capacity for a couple of hours a day. When considering the full cost to connect renewables, offshore wind will reduce the average usage cost of infrastructure.

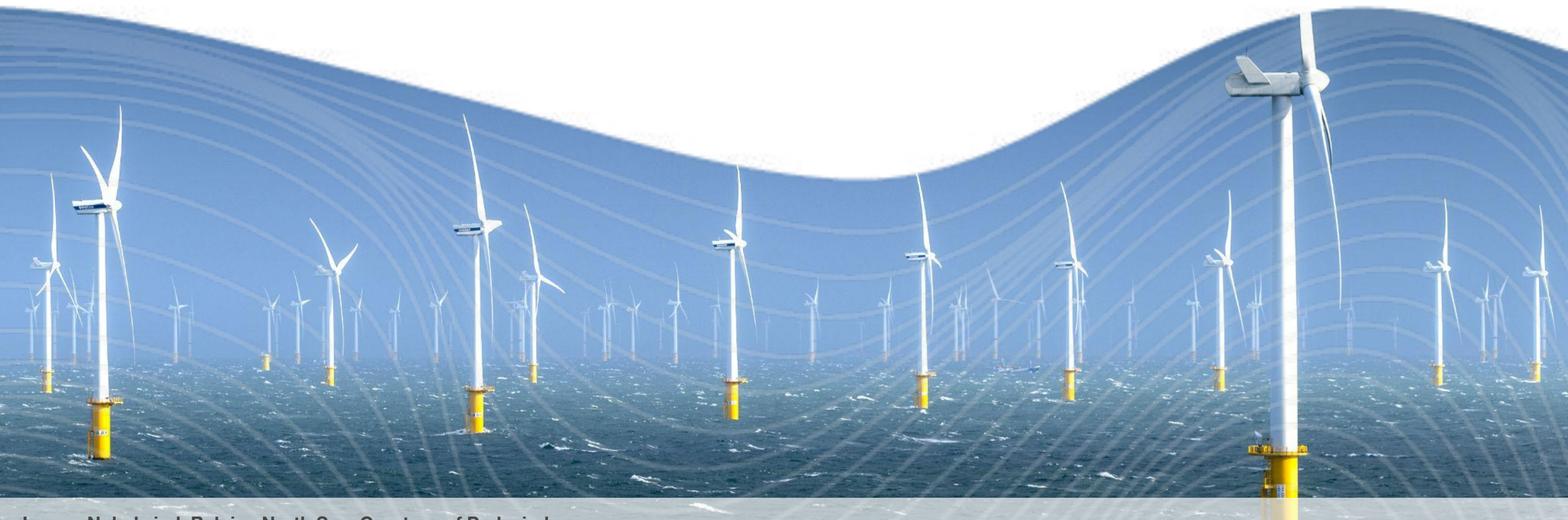


Image: Nobelwind, Belgian North Sea, Courtesy of Parkwind

Only offshore wind is likely to have the scale to decarbonise hard-to-abate fuels and industrial feedstock using PtL

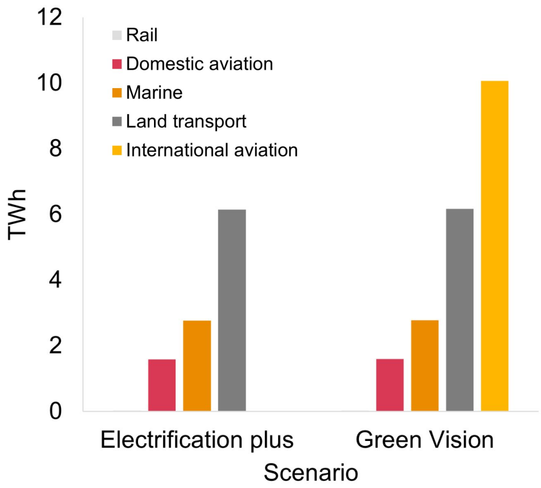
There is uncertainty about how to decarbonise hard-to-abate emissions in maritime, aviation and heavy land-based transport and industrial feedstocks. Our stakeholder engagement indicates that these industries are looking to electrification, power-to-liquids (PtL), bio-fuels and CCUS solutions.

Electrification is practical for light and short haul transport, but it is not currently feasible for long haul aviation and heavy freight due to cost and low energy density of batteries. The weight of the batteries results in less efficient transport and less cargo being carried given weight restrictions on vehicles, aircraft and roads. We observe that heavy and long haul transport businesses are looking to low or zero carbon liquid fuels to use with existing technology:

- **Aviation** - A market for bio-SAF exists, and hydrogen based e-SAF is actively being investigated for short and long haul flights. The EU recently mandated that 70% of jet fuels need to be bio-SAF or e-SAF by 2050, with a minimum of 35% e-SAF.[5,6]
- **Maritime** - There is already strong demand for e-methanol (with carbon abatement) for international shipping and hydrogen based green ammonia is expected to be a key future fuel. In July 2023, member states of the International Maritime Organisation (IMO) committed to net zero emissions in the shipping industry by around 2050. This includes a milestone of 10% zero or near-zero emission fuels by 2030.
- **Light commercial and heavy freight** - Biofuels, hydrogen fuel cells and hydrogen-diesel blends are being piloted by New Zealand freight trucking companies (e.g. HW Richardson, Toll, TR group).

Our analysis of industry scenarios and targets indicates that between 10.5 TWh to 20.6 TWh of new renewable generation production is required by 2050 to produce synthetic transport fuels. This assumes 50% of marine fuels, 40% of heavy transport, 33% of light commercial, and 30% of international aviation use hydrogen based PtL fuels. This is equivalent to between 25% and 50% of New Zealand's current electricity supply.

Figure 51: Generation supply required for transport related hydrogen production[2,7]



Source: PwC, EY/MBIE

In addition, 23.3 TWh to 48.7 TWh of generation is required to produce green hydrogen for industrial feedstock and commercial heat processing. Gas based 'blue hydrogen' with CCUS is being considered globally as an interim option to accelerate the hydrogen economy and utilise existing infrastructure, until electrolyser technologies are fully commercialised and readily available.

The scale of renewable energy generation required to support PtL is large and we believe offshore wind is the most practical way to produce domestic synthetic fuels and feedstocks to the scale required to decarbonise these sectors. Just over 4.5 GW and 11 GW of electrolyser capacity is assumed in our Electrification Plus and Green Vision scenarios. 55% to 80% of this capacity will be used by only a handful of large end users (Methanex, Ballance, NZ Steel, Auckland Airport and upper North Island ports. Large centralised electrolyser plants, generation and supporting infrastructure may therefore be favoured over sole reliance on small scale distributed energy.

Projected eSAF

eSAF is derived from PtL technology which is based on electrolysed hydrogen. It is one of the low emission options for aviation transport.

eSAF can be used as a drop-in fuel, meaning there is no need to convert jet engines to use it and it can be stored and transported through existing infrastructure. It is typically produced from a mix of hydrogen and 'renewable' source of carbon dioxide (e.g.a biogenic point source capture or direct air capture)

Earlier this year Channel Infrastructure and Fortescue Future Industries announced that they will continue to investigate the production of eSAF at Marsden Point.[8] 300 MW of solar generation will be used to produce 60 million litres of jet fuel per year. This is only 3% of the pre-Covid jet fuel market or enough for 500 flight from Auckland to Los Angeles.

Offshore wind is favourable for scaling production of eSAF.

Based on the International Energy Agency's (IEA) Net Zero Pathway scenarios, PwC global research projects that 30% of international jet fuels would need to be sourced from PtL based eSAF by 2050. This analysis has been used in this study to project demand for PtL eSAF in New Zealand for this study.

Offshore wind could provide energy sovereignty in sustainable fuels

As we move towards net zero, New Zealand is at a distinct disadvantage due to the high carbon footprint of transporting our goods and size of our market - the 'tyranny of distance'. We are a remote and isolated country, economically reliant on primary sector exports and international tourism. This means we are highly exposed to the economic implications of our choices in fuel. Concepts like 'food miles', 'Flygskam (or flight shame) and carbon border adjustment mechanisms (or green tariffs) put our economy at a distinct disadvantage unless we can decarbonise our transport supply chain.

Other countries have recognised the importance of an independent and secure supply of sustainable fuels. For example, it has become extremely difficult to secure supplies of SAF in international markets as airlines start to compete on sustainable offerings.

In this environment, it is economically essential to domestically produce zero and low emission fuels to underpin our exports and tourism industry and to support fuel security and sovereignty in the new green economy.

A 2023 study undertaken by Strategy& recently highlighted the competitive advantage of countries with excellent renewable electricity resources in PtL production.[9] With 30-40% of the cost of PtL fuels relating to renewable electricity generation, New Zealand is perhaps well placed to domestically produce PtLs, at least for our own domestic use and to fuel outgoing jets and ships. This would bring us to an unprecedented level of fuel independence in the future global sustainable economy.

Green steel has close to no emissions, compared to the current steelmaking process, which contributes more than 7% of global emissions.[10] Decarbonising the steel industry is therefore a priority in reaching net zero.

Green hydrogen is a solution for the steel industry to decarbonise. Although the process needs extreme heat which can be provided by electricity, it also needs a chemical 'reduction' process. The traditional reduction process is fed by coal or natural gas but can also be achieved with green hydrogen.

90% of New Zealand's steel is manufactured by NZ Steel Ltd at its site in Glenbrook.[11]

3.4 Security of supply

Security of supply refers to the ability of the electricity system (generation and transmission) to meet demand at all times, with a level of redundancy to provide for critical risk.

Thermal generation from fossil fuels has played a critical role to date in providing security of supply, but as we seek to decarbonise, debate has turned to whether this backup supply should be renewable.

Security of supply requires a generation source to be both a reliable source of capacity and store of energy. Transpower, as system operator, undertakes an annual security of supply assessment (SOSA) of the electricity market.[12] At a high level, this considers whether New Zealand has sufficient energy and instantaneous capacity to call on, especially during winter when our hydro lake inflows are lowest.

Transpower is investigating opportunities to evolve its SOSA approach to better understand system risk in a highly renewable future. A key issue facing the country is the increased capacity risk due to unavailability of intermittent renewable generation sources.

As an intermittent source of generation, wind power does not on its own provide a reliable store of energy or firm source of instantaneous capacity. Offshore wind can generate for longer periods of time, but supply cannot be guaranteed when required.

In a wider system of energy resources, offshore wind can however support higher levels of security of supply, by:

- Diversification of intermittent renewable supply - which decreases the risk of energy unavailability
- Displacement of more valuable renewable storage options (e.g. hydro, bio-energy) for use when they are most needed.
- Production of hydrogen for use in fuel cells or blended hydrogen-gas thermal peakers
- Hydrogen electrolyser demand flexibility, or the ramping up and down of hydrogen production facilities.

We explore each of these below.

Diversification of supply

A study by Elemental[13] in 2023 highlighted the security of supply benefits of including offshore wind in a diversified portfolio of renewables. It showed that:

- Offshore wind is not highly correlated to onshore wind production
- Offshore wind in the locations being explored in New Zealand is winter peaking and more positively correlated to winter electricity demand than land-based renewables, including hydro and New Zealand's current combined onshore wind fleet.
- North Island and South Island offshore wind is uncorrelated and there may be a diversity benefit in grid connected offshore wind generation in both islands.

To test the contribution that diversity of supply may provide to security of supply, we have simulated multiple sequences of onshore and offshore wind generation to compare availability risk of different wind generation portfolios.[13]

Our simulations showed that a diversified portfolio of existing onshore wind and new offshore wind reduced the risk of low availability when compared to onshore only.

The table overleaf shows the percentage of trading periods with no generation availability for for the portfolio of all existing onshore wind, three offshore sites in Taranaki, Waikato and Southland (together), and finally as a combined wind (onshore and offshore) generation portfolio. It shows that adding offshore wind into the energy mix decreases unavailability risk to almost zero and therefore mitigates some of the security risk caused by the intermittency of wind generation.

This demonstrates that low correlation of onshore and offshore wind and location diversity may increase the energy margin offered into the market relative to an onshore wind only solution.

Table 14: Unavailability of wind generation (%)

Existing onshore	Offshore	All wind
1.5%	2.2%	0.1%

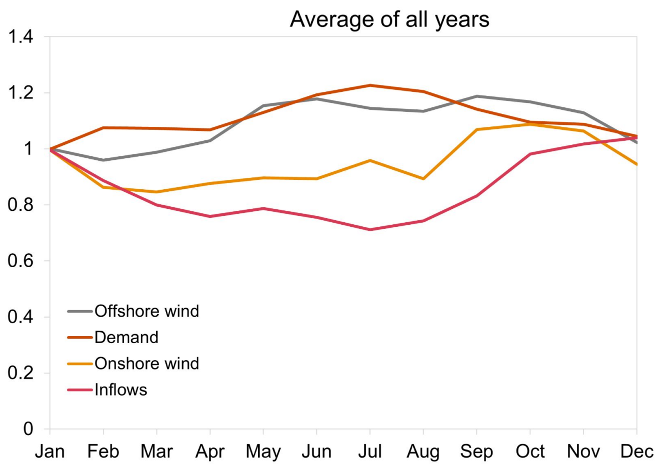
Dry year cover and recognising a higher value for water storage

New Zealand's gentailers are starting to use hydro generation to firm intermittent wind. As a result they are able to better utilise the limited water resource which can be diverted to generation during peak times and/or when other renewable generation is low.

Combining offshore wind with hydro resources will allow hydro generation to be reprioritised from base load generation to a more valuable energy security role.

Offshore wind could play a particularly important role for winter and dry year security as it is positively correlated with winter demand and negatively correlated with winter hydro inflows. As shown in the graph below, offshore wind production is highest in winter when hydro catchment inflows are lowest. Further, in assessing the performance of offshore wind in dry years, Elemental found that offshore wind production reduced proportionally much less than hydro inflows meaning it could play a useful role in dry year energy cover.

Figure 52: Load duration curve - South Taranaki - onshore and offshore wind[13]



Source: Elemental

Combining offshore wind with hydrogen fuelled peaking generation

New gas turbine technology now allows for hydrogen to substitute up to 100% natural gas, although hydrogen - natural gas blends of lower levels are being explored globally.[14] This means offshore wind can support backup capacity by enabling large hydrogen production for use in a hydrogen peaker plants.

The economics of a hydrogen thermal generation plant was explored in a 2022 study undertaken by EnergyLink (commissioned by Firstgas Group, now Clarus). This considered the economics of hydrogen fuelled open cycle gas turbines (OGCT) situated in the North Island to provide security of supply.

Their analysis concluded that 1 GW of OCGTs with 2,000 GWh[15] of hydrogen storage would be the most economic 100% renewable solution for meeting security of supply.

The overall conversion efficiency of this system is 30%, from the electrolyser (75%) to combustion in the gas turbine (45%). By comparison the conversion efficiency of the Huntly Rankine units is 37%.

One technical issue identified in this work was how to store the hydrogen and transport it to the North Island site. We understand the University of Canterbury is researching underground hydrogen storage options in Taranaki and as discussed above, Clarus is investigating the potential for hydrogen pipelines.

Quantifying the economics of hydrogen storage relative to other security of supply options is beyond the scope of this report, but a scenario of combining South Taranaki offshore wind with Taranaki hydrogen storage, a hydrogen pipeline and a hydrogen thermal peakers may deserve more detailed technical assessment.[2]

We also note this option could support New Zealand's gas transition if gas based 'blue hydrogen' was initially used as an interim fuel. This could then be replaced with green hydrogen once offshore wind is developed for hydrogen use in the late 2030s to early 2040s.

Hydrogen electrolyser demand flex

Hydrogen electrolysers are able to ramp up and down production reasonably quickly and with limited impact to production processes. This 'electrolyser flex' could be a useful source of spare capacity for the grid in the scenarios where offshore wind is effectively overbuilt to produce hydrogen.

In our Electrification Plus and Green Vision scenarios, we assume 10% of offshore wind generation can be diverted to the grid through electrolysers flexing production in response to economic price signals from the wholesale electricity and hydrogen markets. This could provide up to 2.4 TWhs of electricity supply in Electrification Plus and 5.3 TWhs in Green Vision. In the Green Vision case, this is equivalent to the generation storage of the $16 billion Lake Onslow pumped hydro scheme that was investigated in 2022-23.

Table 15: Demand response capacity associated with offshore wind (2050)[2,7]

	Electrification	Electrification Plus	Green Vision
Demand response (TWh)	N/A	2.4	5.3

Offshore wind paired with electrolyser flex provides a potential future solution to the winter energy shortfall and dry year risk in our scenarios. Offshore wind used for hydrogen production is essentially an overbuild of the renewable generation required for the grid. This overbuild can be diverted during periods of high prices to address security of supply issues on the grid.

The viability of electrolyser flex at scale is still under investigation and there are likely to be a number of operational challenges in pairing intermittent wind with electrolysers. Hydrogen electrolyers are large capital intensive equipment that need to be run at high capacity utilisation levels to optimise the economics of producing hydrogen. While offshore wind may provide a good base of renewable energy for H2 production, a portfolio of firmer or more diversified renewables may be needed to supplement offshore wind for hydrogen production.

For this reason, our scenarios assume that offshore wind only provides 50%-60% of the renewable electricity required for hydrogen production.

Our scenarios assume offshore wind used for hydrogen production is not normally connected to the grid and is only used for flex where spare capacity is available on the connecting transmission circuits. We refer to this as responsive load.

3.5 Affordability - cost of offshore wind

Economic drivers of offshore wind

Offshore wind requires a significant upfront investment, with around 80% of expenditure cash flows comprising construction capex and financing.[2] Once built, the windfarm has relatively lower operating and maintenance costs. Reducing capital and funding costs are therefore critical to the future economics of offshore wind.

Consistent with recent trends observed in other renewables (i.e. solar, onshore wind), we expect the cost of manufacturing and installing offshore wind to move down the technology cost curve over time. This is in response to global wind technology and manufacturing scale which is ramping up to meet the 2,000 GW of projects expected by 2050. New Zealand specific costs will also fall as the sector develops local capacity and capability and 'learns by doing'.

Recent work undertaken by PwC suggests that financing structures are critical to OWF economics. With financing costs making up nearly 20% of the cost of an OWF, minimising financing costs is essential.

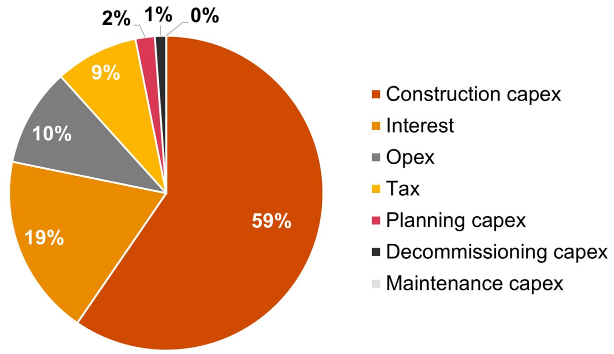
Leveraged project financing structures are favoured to bring offshore wind to market, and peak leverage has increased from 60% up to 80% in recent years, helping to reduce total funding costs (with debt being cheaper than equity).[16]

Global financial markets are starting to offer attractive long-term debt rates for offshore projects, but require revenue guarantees and insurances to be in place to mitigate project risk.

Having long-term power purchase agreements (PPAs) or hedging instruments like Contracts for Difference (CfD) is critical to underwriting project risk and accessing capital.

These risk mitigants help reduce cash flow volatility and stabilise earnings. This significantly de-risks the project, which in turn gives funders the confidence to provide higher levels of debt and lower interest rates. For example, minimum debt service coverage ratios (DSCRs) as low as 1.3x are observed where revenue supports like CfDs are in place, but DSCRs of over 1.7x are observed where significant spot price exposure remains.[16]

Figure 53: Cost breakdown of offshore wind in Green Vision scenario[2]



Source: PwC

In the UK and Europe, states are underwriting 2-way CfD contracts to de-risk offshore wind projects, reducing financing costs, and unlocking developments.[16] These CfDs offer wind farms a fixed strike price for the electricity they produce:

- When electricity prices are lower than the strike price, the Government pays the difference to the OWF
- When electricity prices are higher than the strike price, the OWF pays the difference to the Government.

CfDs are not a direct subsidy, but rather a tool for revenue stabilisation and risk management. If set right, the expected payments by the Government or OWF may be neutral. Further, these CfDs can support lower wholesale electricity prices if electricity prices are high and governments pass on the upside to consumers.

The lower risk of the project in turn lowers borrowing costs for the wind farm developers, which brings down the total cost of producing offshore wind. We estimate that a two way CfD could reduce the cost of New Zealand OWFs by $7 to $11 per MWh (real) or more due to financing cost savings.

Offshore wind CfD prices are typically determined by competitive auction for each offshore development block offer, with the lowest CfD price offer (i.e. price per MWh) typically winning the block. These overseas CfD market are rapidly maturing. In July and August 2023, developers bid in negative prices for about 8.8 GW of German offshore resource.[17] This sends a strong signal that as local markets mature and the economics of local resource is firmed up, that the need for state backing of offshore wind CfDs diminishes.

Future cost of offshore wind

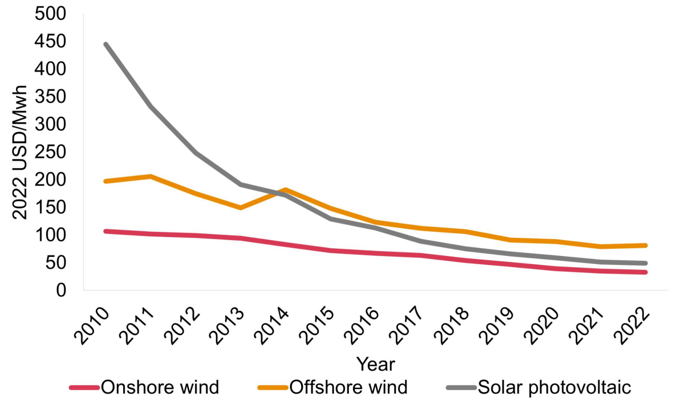
The cost of generation is typically expressed as a levelised cost of energy (LCOE), or the average cost per MWh of production over the plant's life.

We would normally see the LCOE of new generation technologies fall over time as technology and manufacturing improvements and scale reduce the per MWh cost. This trend has been observed recently for solar, batteries and onshore wind, as illustrated in the chart opposite. Similar cost reductions are projected for offshore wind.

Current estimates for the LCOE of new OWFs in New Zealand range from about $115 to $225 per MWh (real). Using international research undertaken by NREL and CSIRO we project the cost for fixed-pile OWFs will fall to $82 to $95 per MWh by 2030 and $72 to $80 per MWh by 2050 (real).[18,19] This is broadly consistent with the current cost of onshore wind in New Zealand, which we estimate falls in the range of $70 and $90 (real) depending on the site.

Costs for all wind turbines are currently high due to manufacturing constraints and high raw commodity costs. For example, Lazards observed a 32% increase in the international cost of onshore wind between 2021 and 2023.[20] Forecasts by NREL suggest these high prices are temporary and costs will fall as supply constraint and commodity prices ease.[18]

Figure 54: Comparison of historical LCOE of solar, onshore wind and offshore wind[21]

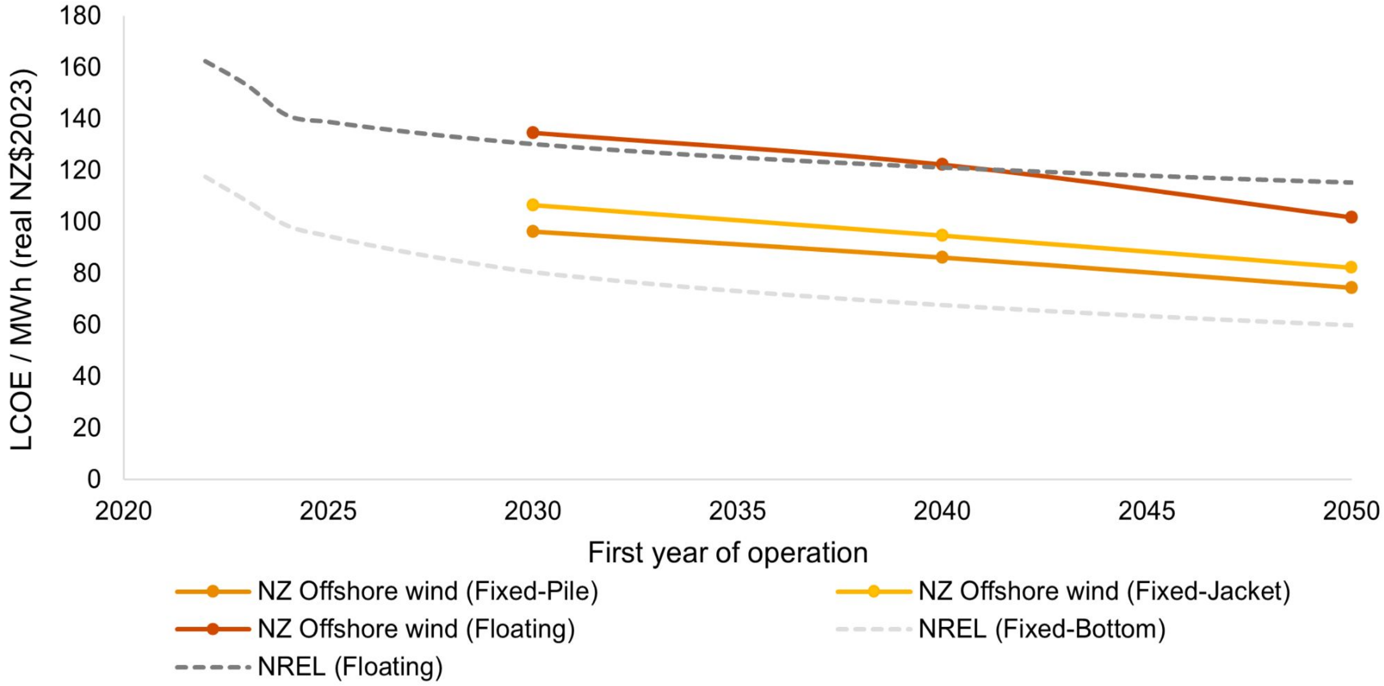


Source: IRENA

Floating technology is development stage and the economics are more uncertain. We project New Zealand floating wind technology will fall from a cost of about $135 per MWh in 2030 to $100 per MWh (real) by 2050.[2]

Our forecasts are based on international benchmarks adjusted for New Zealand specific conditions, with input from local developers.

Figure 55: LCOE offshore wind[2,18]



Source: PwC, NREL

3.6 Affordability - transmission infrastructure

An OWF will connect to the grid or major load (e.g. electrolyser) at an onshore substation. This onshore substation is connected to an offshore substation that consolidates individual array cables from each individual turbine in the OWF. The cost of the onshore and offshore substations and cables is included in our project costing.

For each scenario we consider the cost of upgrading the transmission network to support new grid connected OWFs. In Electrification Plus and Green Vision a new hydrogen pipeline from the North Island OWFs to the Auckland and Waikato demand centres - and a potential hydrogen gas peaker - is also included. These costs are considered specific to the offshore scenarios and may not be replicated in a counterfactual involving onshore wind only. The table below summarises the costs of these infrastructure projects.

Electrolyser connection costs are assumed to be included in OWF onshore substation costs. Additional grid costs associated with electrolyser flex and a hydrogen thermal peaker unit are assumed to be modest given the strength of the grid South of Auckland and that electrolyser flex will be brought on only in response to a shortfall in grid supply where there is spare capacity.

Transmission grid upgrades

In all scenarios we assume Transpower upgrades the core grid to take supply from 1 GW of offshore wind in both Taranaki and Auckland-Waikato (i.e. 2 GW total).

These grid upgrade costs are $120m - $160m if both these OWFs are developed. Based on this, we have calculated the estimated annual covered cost for each scenario based on Transpower's covered cost method applied in its Transmission Pricing Methodology (TPM).

Transpower has also analysed the cost of a second GW of offshore wind in both Waikato and Taranaki, respectively. The analysis indicates that it may not be economic to add a second GW of grid capacity to South Taranaki, with a total estimated cost of $980m to $1,150m for connecting 2 GW of offshore wind in Taranaki.

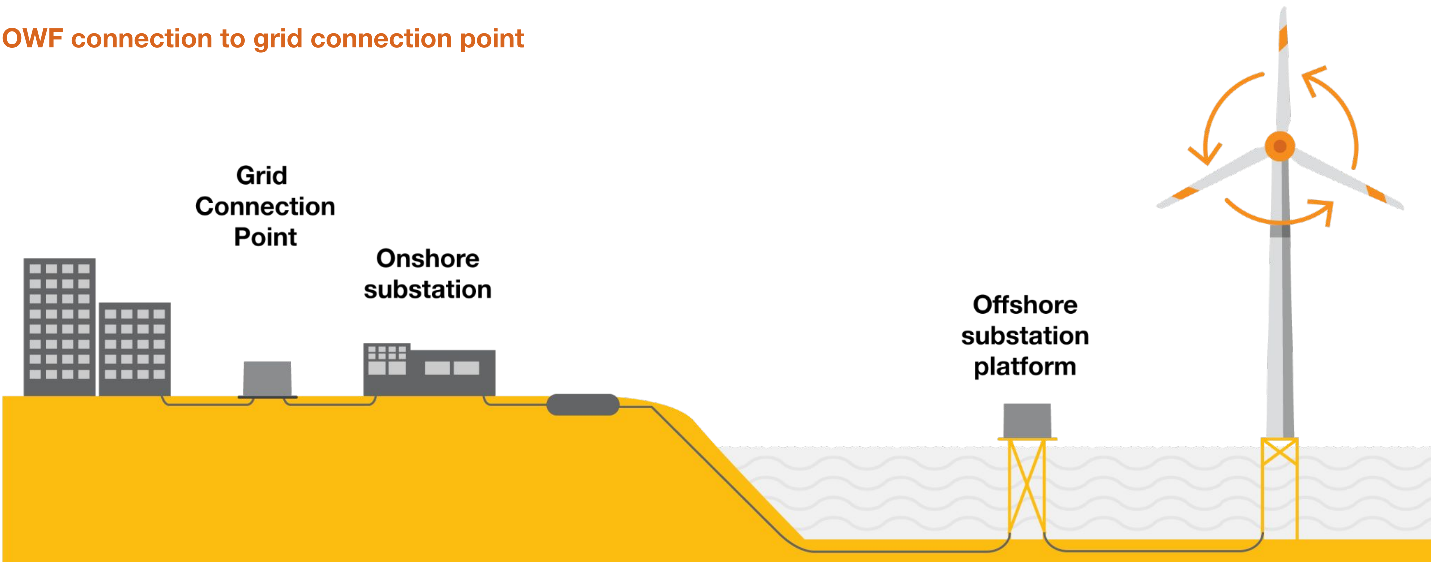
Connecting a second 1 GW OWF to the grid near Waikato is more affordable at $40m to $80m. If grid demand and economics allow, Waikato may be a good option for a third grid connected OWF. Currently our scenarios provide for up to 2 GW of offshore wind generation connected to meet grid demand.

Table 16 - Transmission grid upgrade and hydrogen pipeline costings[2,22,23,24]

Transmission grid upgrade	Grid upgrade capex (real 2023 $m)*
A. 1 GW Waikato and 1 GW Taranaki	120 - 160
B. 2nd GW at Waikato	40 - 80
C. 2 GW at Taranaki	980 - 1,150
New hydrogen pipeline	**Pipeline construction capex (real 2023 $m)****
A. Electrification Plus (273km at 250 TJ/day)	$793
B. Green Vision (549km at 500 TJ/day)	$2,857

*PwC modelling based on covered costs method which assumes grid upgrades begin in 2030. Interconnection assets only.
** Annualised costs calculated by Clarus

OWF connection to grid connection point



Source: Recreated from Dublin Array

Under the TPM, new investments in the grid required to transport offshore generation will be recovered from the users who benefit from it.

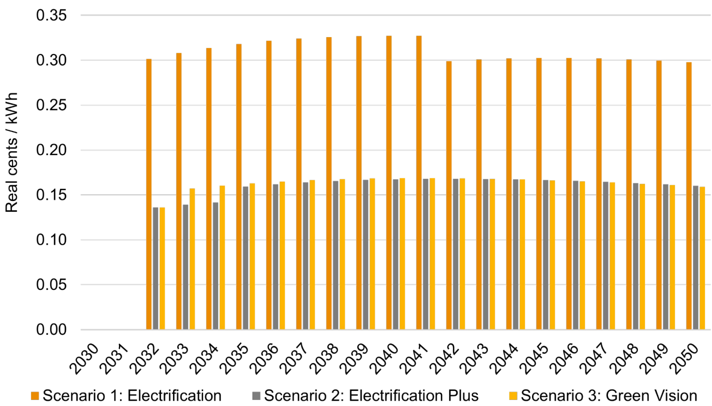
The method used to calculate annual charges for the upgrades is based on the cost recovery plus regulated rate of return.

Using this method, we estimate that the grid upgrades required to support our scenarios will cost between 0.15c and 0.3c per kWh (real). Our estimate of transmission costs per kWh of added generation is summarised in the figure below.

We expect that Upper North Island demand customers are likely to be the major beneficiaries of these investments so are likely to incur the majority of this cost. We also note that other generation and load customers may use these assets, so the cost attributed to offshore wind is likely to be overstated.

The Electrification scenario is more expensive than the other scenarios because the delay between grid upgrades in Taranaki and Waikato means that the synergies from coordinating the grid upgrade projects cannot be realised.

Figure 56: Grid upgrade charges per kWh 2030 - 2050[2,22]



Source: PwC, Transpower

New hydrogen pipeline

The development of a hydrogen pipeline is one option to unlock higher levels of offshore wind production in Taranaki.

In 2023, Clarus estimated the cost of new hydrogen pipelines in New Zealand. These were based on studies undertaken by GPA Engineering exploring new hydrogen pipeline costs in Australia. The work estimated options for transporting hydrogen from the Taranaki region to the Upper North Island, as discussed above.

The two options we have adopted in our Electrification Plus and Green Vision scenarios provide for 250 TJ and 500 TJ pipelines, respectively. The 250 TJ per day option would provide for a 1 GW hydrogen peaking plant and other uses of hydrogen. The 500 TJ per day option is longer and would support a more diverse hydrogen sector. It would be capable of transporting hydrogen to Auckland, Marsden Point or notionally Tauranga Port for use in production of, for example, green steel, e-SAF and sustainable marine fuels.

The cost of these pipelines is estimated to be $0.8b (real) for the 250 TJ option and $2.8b (real) for the 500 TJ option. Incorporating operational, maintenance and financing costs, this equates to an annual charge of about $50m and $195m (real) for the respective options.

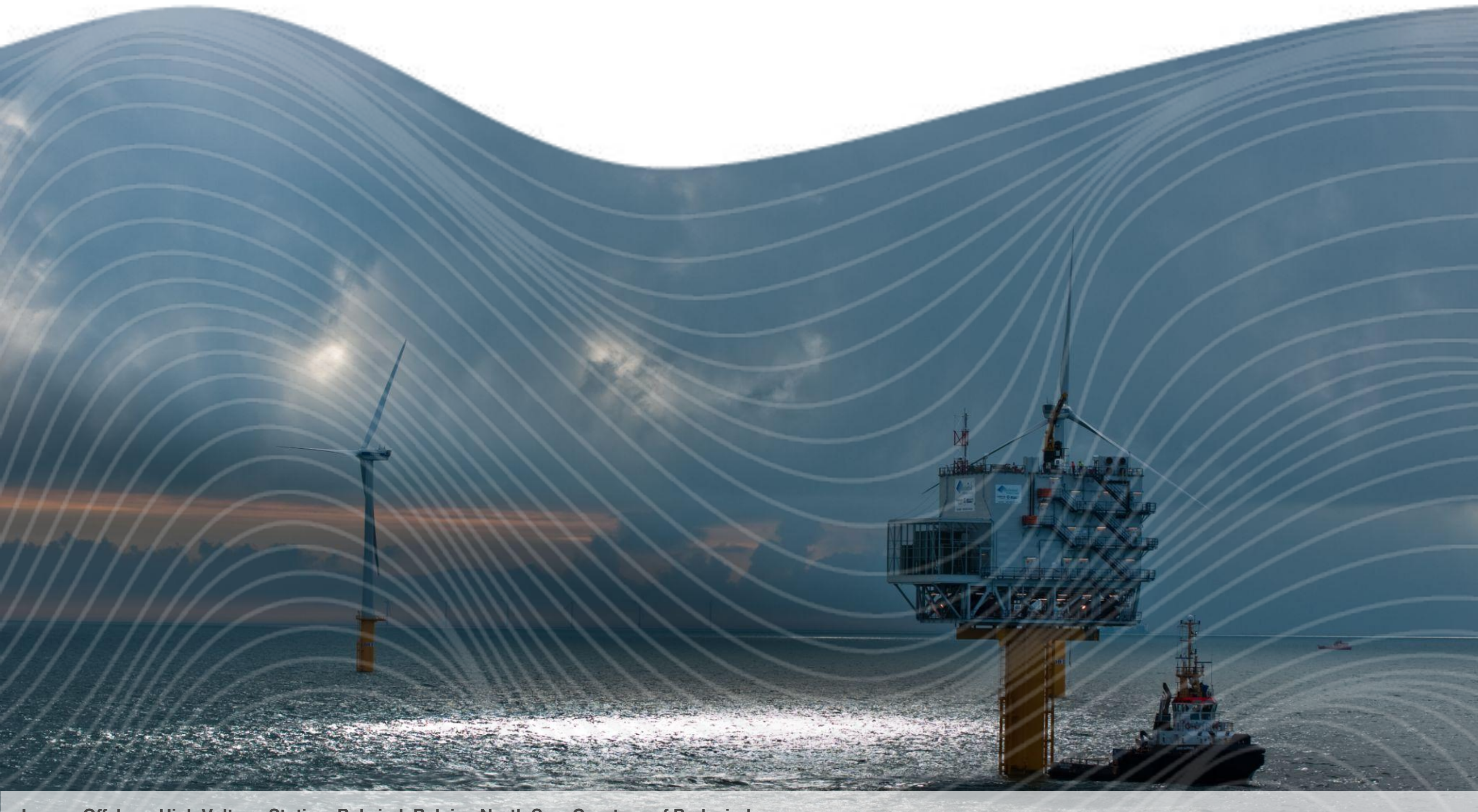


Image: Offshore High Voltage Station, Belwind, Belgian North Sea, Courtesy of Parkwind

3.7 Price implications

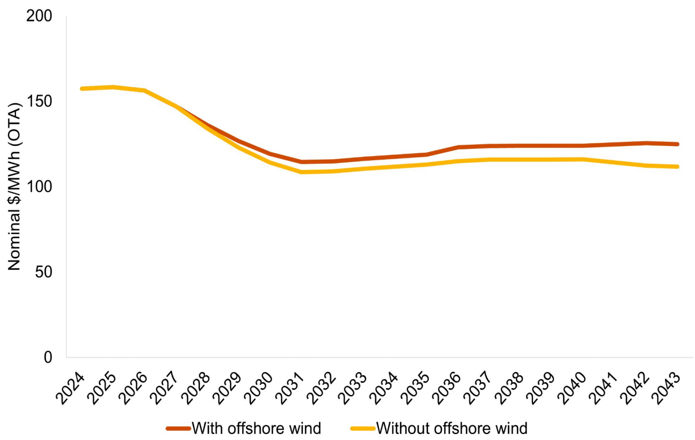
Adding offshore wind into New Zealand's energy mix will have implications for wholesale electricity prices and transmission charges, ultimately flowing through to end consumer prices.

To understand the price impacts associated with offshore wind we have applied PwC's in-house price path model to estimate long-term wholesale electricity prices with and without offshore wind.

In the short to medium term, prices are based on forward market pricing and supply and demand dynamics. In the medium to long-term our price path reverts to the long run economic cost of building and operating new generation plant to meet demand.

Our price path modelling, presented below, indicates that adding offshore wind into the wholesale electricity market will increase wholesale prices by about 0.5 - 0.9 cents per kWh (real), compared to a situation with only land based renewables. This is equivalent to 1.5% to 2.7% of the average household retail price of 32.9 cents per kWh.[2,25] This provides for a notional gas thermal peaker with a low blend of hydrogen and gas.

Figure 57: PwC - 20 year price path forecast[2]



Source: PwC

The cost of onshore wind and solar is projected to reduce in line with expected plant and cost efficiency improvements, but the rate of improvement will slow as the best sites are used. The cost of offshore wind is projected to reduce down to the current LCOE of onshore wind over the next 20 years. This means it may remain a higher cost solution compared to onshore wind over the next 20 years.

Social cost of energy

Adopting a pure economic approach to investments in offshore wind may not provide the best outcomes for our energy system and social license to operate. While the current policy direction suggest renewables will be accelerated, developers and consenting authorities may need to better weigh up the relative social costs and benefits of different generation options. Two examples of social costs are highlighted below:

- **The cost of delay**

  As discussed above, the CCC recently estimated that a 12 month delay in the build of generation could increase prices by as much as $35 per MWh and result in 4.5 Mt CO_2-eq by 2035.[26]

  The CCC estimated that overseas purchase costs could range between $3.3b to $4.2b if the price of offshore mitigation purchases for New Zealand was about $41 per tonne of CO_2-eq (carbon price assumed by the IEA for emerging and developing economies), and between $18.3b to $23.7b if priced at about $227 per tonne of CO_2-eq (carbon price assumed by the IEA for advanced economies under a scenario of enhanced global climate action).

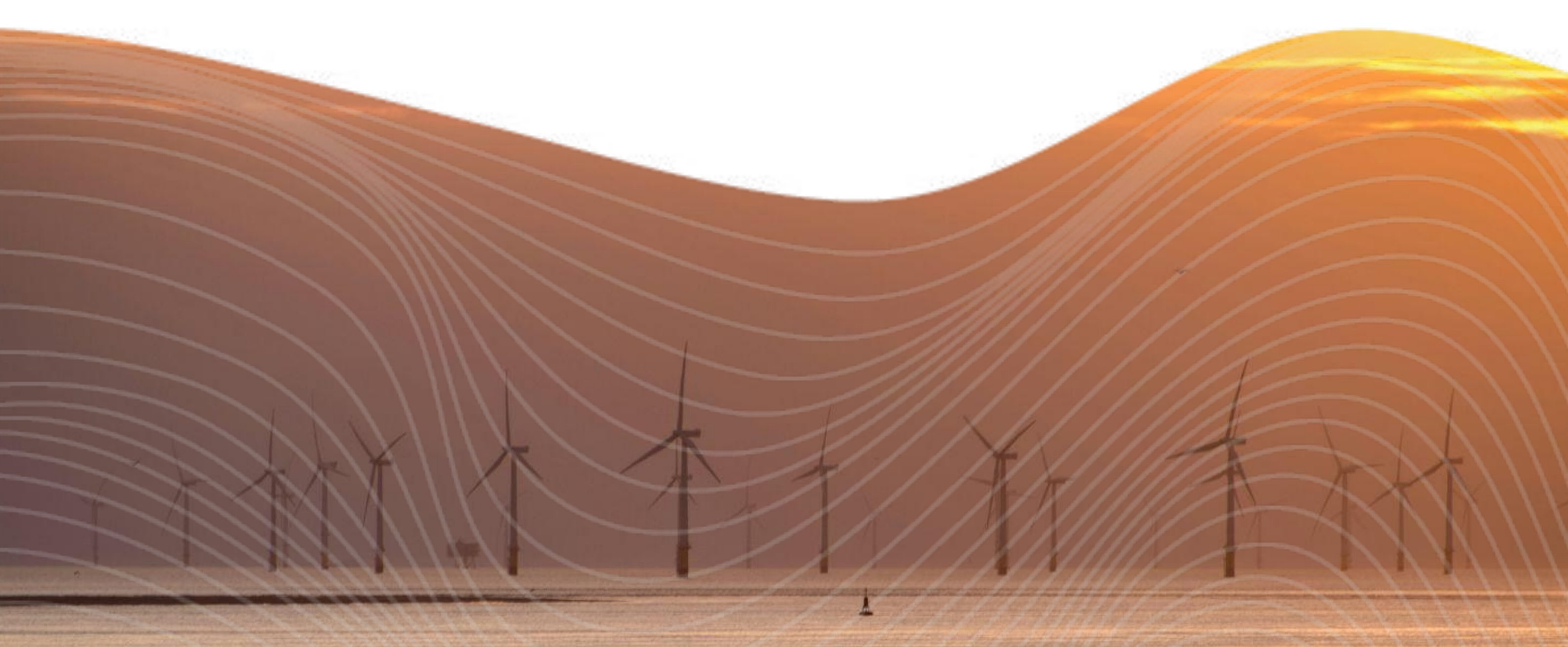
  If we don't decarbonise our fuels and industrial sectors by 2050, the cost of purchasing carbon emissions credits on international markets could justify paying more to accelerate energy through large scale investments in OWFs.

- **Reducing local effects associated with building wind farms near communities:**

  A study of Norwegian households assessing their preferences showed that citizens were willing to pay about 16% more to move developments away from nearby communities.[27]

  The perceived benefits resulting from reduced noise and visual disruption, enhanced community wellbeing and accelerating the path to decarbonisation are among the reasons why citizens were willing to pay a small premium for offshore wind.

  Current energy markets do not price the true social cost of community impacts or impairment of private property rights into the merit order of generation projects. Instead these issues are addressed in the consenting process or through political pressure. Accordingly, highly economic generation project may not always be socially feasible.



People

4. People impacts

OWFs can make a positive difference in communities and for iwi-Māori* by stimulating economic activity and green energy related jobs. However, communities near proposed OWFs may have concerns about environmental, visual and noise impacts, many of which are more perceived than real, and generally no greater and often less than onshore alternatives. In the context of iwi-Māori specifically, greater participation is sought in decision making around the use of the moana and related opportunities.
The following pages summarise local and global insights on people and community effects of OWFs, potential mitigants, and insights for New Zealand.

1. Community impacts

In this section, we consider how the development of an offshore wind industry in New Zealand could impact people and communities, in particular:

- Labour and economic impacts
- Community wellbeing impacts
- Construction impacts
- Observational impacts
- Recreational impacts

2. Iwi impacts

We also explore the potential opportunities and impacts on iwi-Māori, noting that iwi-Māori are considering what the offshore wind industry might mean for them.

At a national level, iwi-Māori are seeking to be included, alongside the Crown, in decision making on what is in the best interests of all New Zealanders when it comes to the offshore wind industry.

*The term iwi-Māori is used to collectively refer to combined iwi and wider Māori interests, and not to distinguish between different iwi, hapū, and/or other Māori community groups.

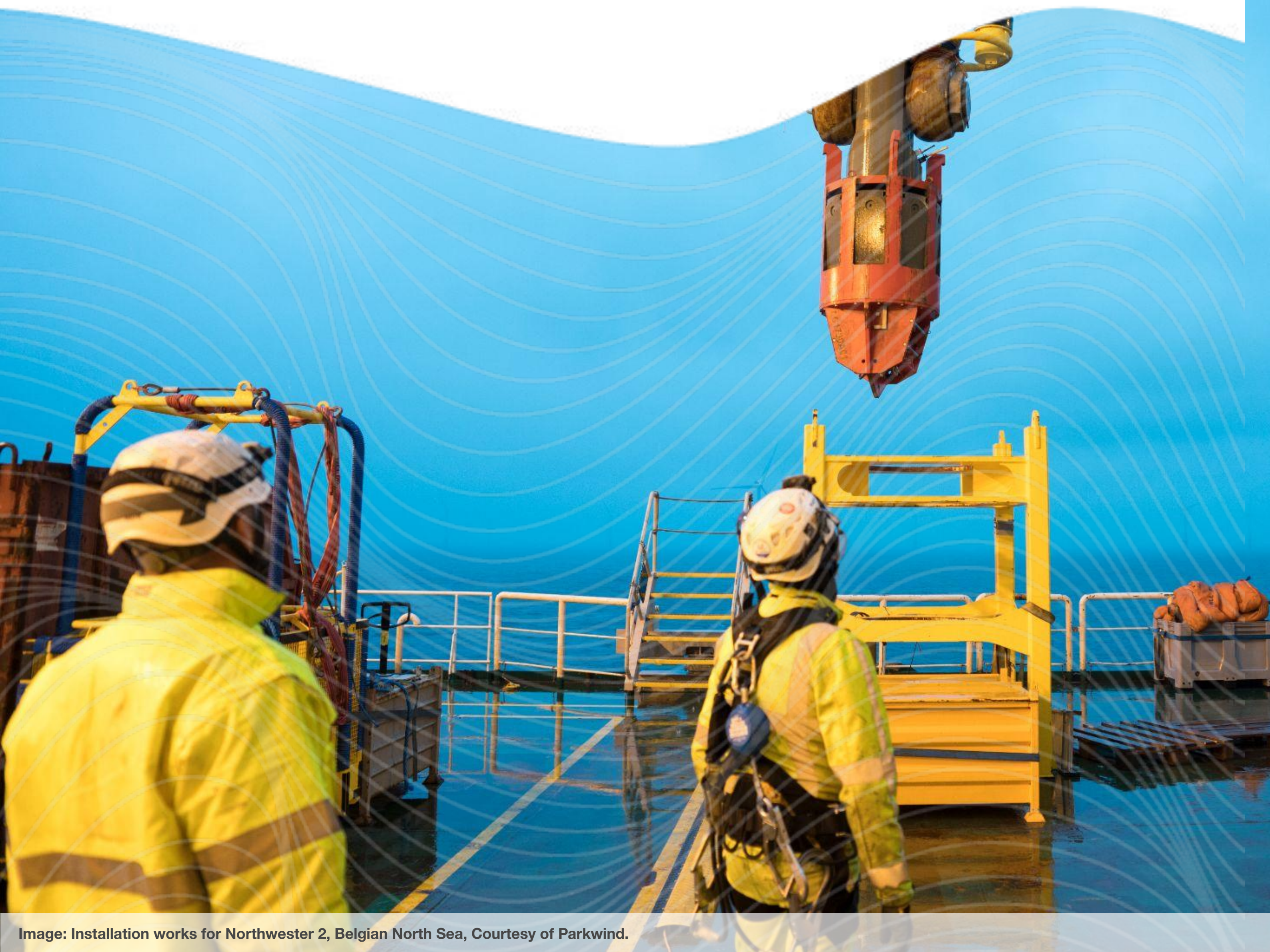


Image: Installation works for Northwester 2, Belgian North Sea, Courtesy of Parkwind.

4.1 Community impacts

Figure 58: Community impacts

We consider five areas of impact:

1. Labour and economic

The development of a wind farm brings substantial investment into the local economy and may create a significant number of new jobs, particularly during the construction phase. This in turn supports localised spending, boosting small businesses. Once operational, there is an opportunity for smaller scale (than during construction) regional specialisation and retention of technical specialists.

2. Community wellbeing

As with onshore wind, OWFs can be divisive for communities, especially smaller communities. Community engagement and complementary investment can highlight and enhance the social benefits of OWFs, and improve wellbeing and local pride, in addition to the positive economic benefits that occur. Potential strain on small or isolated communities' infrastructure should be considered in the planning and development phase for OWFs.

3. Construction

As with any construction project, developing an OWF will likely result in temporary impacts such as disruption, noise and impacts on local infrastructure (such as increased wear and tear on roads). However, these impacts will be limited for offshore wind projects given that most construction and assembly activities occur at sea, marshalled from ports.

4. Observational

Personal perspectives of wind farms (i.e. noise, visual amenity, etc.) can vary depending on size, placement and distance from the observer. This is subjective and can be affected by the observer's personal preferences and attitudes to the merits of the project. A key potential benefit of OWFs is that they are typically located at large distances from communities, even over the horizon, resulting in impacts such as noise and visual impacts being less pronounced, or even negligible.

5. Recreational

There are potential positive impacts for tourism and recreational fishing from OWFs. The proposed locations for OWFs in New Zealand are relatively far offshore, meaning negative impacts on recreational activities are unlikely.

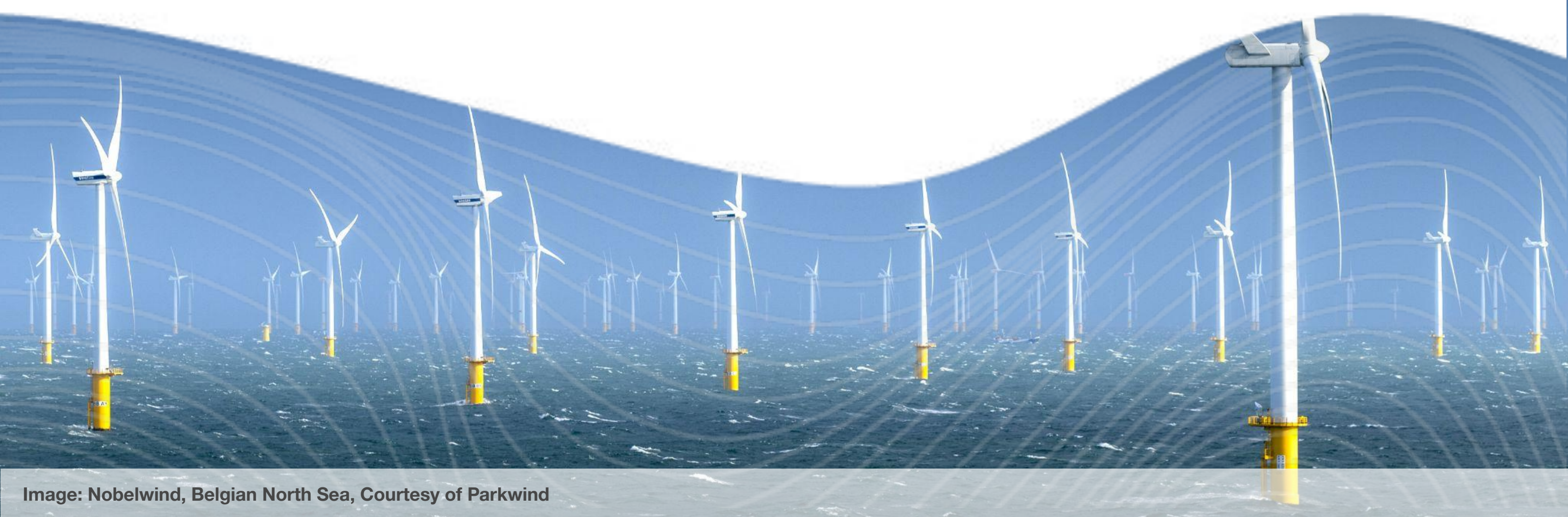


Image: Nobelwind, Belgian North Sea, Courtesy of Parkwind

4.1.1 Labour and economic

An offshore wind industry will bring substantial investment, resulting in both regional and national economic growth, higher wages, and the creation of thousands of new jobs. This will be highest during the construction phase, and material for the feasibility, operational and decommissioning phases, where opportunities will exist in specialist technical fields.

In a previous section, labour and economic impacts are quantified for each three scenario across key phases.

Economic activity and employment will be concentrated around key ports that serve the offshore development, which for New Zealand could include Port Taranaki, Pātea and Bluff. Significant employment opportunities will also arise for both local and non-local workers, directly in the OWF project and indirectly in supply chain and support roles. Migration into popular regions from overseas and the rest of the country will be necessary as the workforce and specialist skills required will not be able to be fully met locally.

As can happen with other major construction projects, local communities serving OWFs may experience a rapid migration and settlement of workers. The impact of this on the local community will depend on the size of the development relative to the existing local economy and how it is staged and managed. Small remote communities in particular can sometimes be overwhelmed by these projects.

The speed of labour influx and resulting impact on existing physical infrastructure (e.g. ports, roads, water and wastewater, energy) and social infrastructure (e.g. housing, schools, hospitals) is likely to be the main concern for communities. In some cases, this can have inflationary impacts due to high demand for housing for example.

Broad regional and national coordination is often required to mitigate these concerns. Developers also often directly invest in local communities to help address these concerns.

Labour requirements peak during the construction phase and many specialist workers will move on to the next project once this phase is complete. A smaller number of more specialised jobs will be required in the operational phase, which presents an opportunity to foster and retain specialist technical expertise.

Maintaining a pipeline of projects in offshore wind and related sectors (e.g. renewable energy, offshore oil and gas) will be important to retain talent and avoid boom and bust cycles.

Table 17: Labour and economic impacts

Positive impacts	Negative impacts	Mitigation considerations for potential negative impacts[1]
Employment		
Employment opportunities for local people will benefit local economies by reducing existing unemployment and boosting average incomes.	**The end of the construction phase can result in boom and bust cycles** for local communities where OWFs projects are not coordinated.	**Consider how to build capability in transferable skills and build out a diversified economy which can continue after the construction phase.**
Economic growth		
Increased demand for general goods and services **benefits local businesses** as workers spend money on food, accommodation and other daily requirements. **Local economic growth** is stimulated through increased demand for materials, labour, and services. This also increases tax revenues for governments, and supports economic diversification in coastal regions.	**If not properly prepared for or managed, labour influx could overwhelm small communities** including existing physical infrastructure (e.g. roads, water and wastewater) and social infrastructure (e.g. houses and schools). **In some cases, labour influx could have inflation impacts** due to high demand for housing for example.	**Multi party coordination to manage labour influx impacts**. This includes pre-investment in infrastructure and workforce. Careful planning of construction of OWFs and other large projects. **Maximise and prioritise local workforce to lower required influx** and outflow at the end of the construction phase.

4.1.2 Community wellbeing

The offshore wind industry has the potential to generate positive impacts on community wellbeing, particularly through reducing unemployment. This enhances individual wellbeing by fostering social integration, life satisfaction, and improved mental health and also positively influences family wellbeing. In smaller communities, the influx of labour associated with offshore wind projects (particularly in the construction phase) can give rise to some negative social impacts, such as disruption of local social and cultural dynamics, and strained community cohesion. Effective planning and community engagement as part of an OWF's development phase can go a long way to mitigate these potential negative impacts, as well as planning in advance/providing advance training job opportunities for locals.

The table below identifies positive and negative impacts for community wellbeing, and considers mitigations for potential negative impacts.

Table 18: Impacts on community wellbeing

Positive impacts	Negative impacts	Mitigation considerations for potential negative impacts[1]
Social dynamics		
Reduced unemployment improves wellbeing factors for individuals, including social integration, life satisfaction, and individual mental health.[2] It also improves family wellbeing, with ~40% of unemployed people in New Zealand rating their family wellbeing poorly, compared to ~18% of employed people.[3] **Presence of OWF developers in local regions could foster global linkages,** opening up the regions to new ideas, relationships, cultures and business. Similar benefits have already been observed in the oil and gas sector.	**If not managed, labour influx can create adverse social effects in smaller communities** including disrupting social/cultural dynamics and community cohesion. For example, increased demand and competition for local social and health services, as well as goods and services, can lead to price increases, crowding out of local consumers, increased volume of traffic and higher risk of incidents. Conflicts may arise between the local community and the construction workers, which may be related to religious, cultural or ethnic differences, or competition for local resources.	**Incorporate social and environmental mitigation measures into the civil works contract.** Many adverse impacts can be mitigated by developers and contractors liaising closely with affected communities and setting behaviour standards, with appropriate mechanisms for addressing non-compliance.
Quality of life		
Local pride. Communities can feel pride in projects that contribute to environmental sustainability. For example, a snowball survey conducted in Aberdeen, Scotland indicates this pride, e.g. "I see the OWF regularly as I travel around the area and I feel very proud it is there".[4] **Developer investment in communities** is common. Examples include sponsorship of community infrastructure or establishment of a fund. For example, in the Republic of Ireland there is a Compulsory Community Benefit Fund, with a contribution rate of €2/MWh,[5] and the RWE Rhyl Flats Offshore Wind Farm Community Fund in Uk committed to invest over €2 million in to projects for the community surrounding the site.[6]	**Community division** may occur as some residents support and others oppose the developments. For example, in Port Stephens, Australia, residents have differing perspectives on whether or not the OWFs are causing whale deaths. Some are protesting on social media that this is the case, whereas others believe that the idea that wind turbines kill whales is not backed by any credible evidence.[7] **Projects may impact the livability of smaller communities for some people**, for example through higher housing costs and goods and services from new workers migrating to the region. This is likely to only be an issue for small towns (e.g.Pātea and surrounding areas for Taranaki OWFs).	**Effective community engagement during the development phase** can reduce negative opinions and minimise contention. **Community investment** may be effective in obtaining acceptance and approval from the local community. **Coordination and planning:** Many of the negative effects on the livability of a region may be addressed through careful planning to ensure sufficient social infrastructure is in place to ensure the influx of workers is accommodate.

Case study - Parkwind investment initiative[8]

In Belgium, Parkwind established 'North Sea Wind', a cooperative structure (citizens' participation model) allowing Belgian residents to invest in offshore wind. Investments range from €10 - €10,000. This model aims to increase green energy by engaging communities through investment with €5 million reserved for employees and shareholders, and €15 million open to the public. Investors receive interest partially linked to the project's performance. The intention of the initiative was to improve community engagement and participation in offshore wind.

4.1.3 Construction

Manufacturing is the most labour intensive part of the construction process. While some transition pieces such as ladders, platforms and J-tubes may be manufactured in New Zealand factories, it is likely that manufacturing of the turbines and blades for New Zealand OWFs will occur overseas and then be imported. This means that most local construction activities for the development of the OWFs will occur at or involving local ports. Turbines will then either be assembled on site (e.g.monopile), or be taken out to sea for installation.

Activities outside the port are likely to include building crew accommodation and manufacturing of cable equipment, emergency systems, decking, helipad and boat landing systems. Due to the offshore nature, compared with onshore wind, these impacts would be less disruptive during the construction phase.

The table below identifies positive and negative impacts during construction of OWFs, and considers mitigations for potential negative impacts.

Table 19: Impacts of OWF construction

Positive impacts	Negative impacts	Mitigation considerations for potential negative impacts
Investment in, and improvement of, local infrastructure may occur to support and enable the activity (e.g. water systems, ports). This may support future economic development after commissioning of the OWF.	As with any other construction project, there is the potential for negative impacts: **Degradation** of infrastructure. This is more limited for OWFs as most activity occurs in the port, but their may be minor impacts on associated port and associated transport links. **Disruption** caused by construction and transportation of materials, including traffic congestion, noise, dust, road closures, safety concerns and other inconveniences. **Areas of cultural and historical importance** may be affected and this is a particular issue for tangata whenua and mana moana.	**Develop and execute a comprehensive communication plan.** **Conduct a site specific impact assessment,** including engaging with locals, iwi, hapū and whānau, to inform a project plan and choose an appropriate site. **Establish mitigation and protection measures** to potential adverse effects, and monitor adherence to mitigation measures and implement penalties for non-compliance. **Undertake post-construction restoration** on public infrastructure after completion, to restore affected areas to their original or improved condition.

Figure 59: Visual simulations of wind farm location from Ōhawe beach, off the coast of South Taranaki[9]

Source: BlueFloat and Elemental Group Limited project. South Taranaki Offshore Wind

4.1.4 Observational

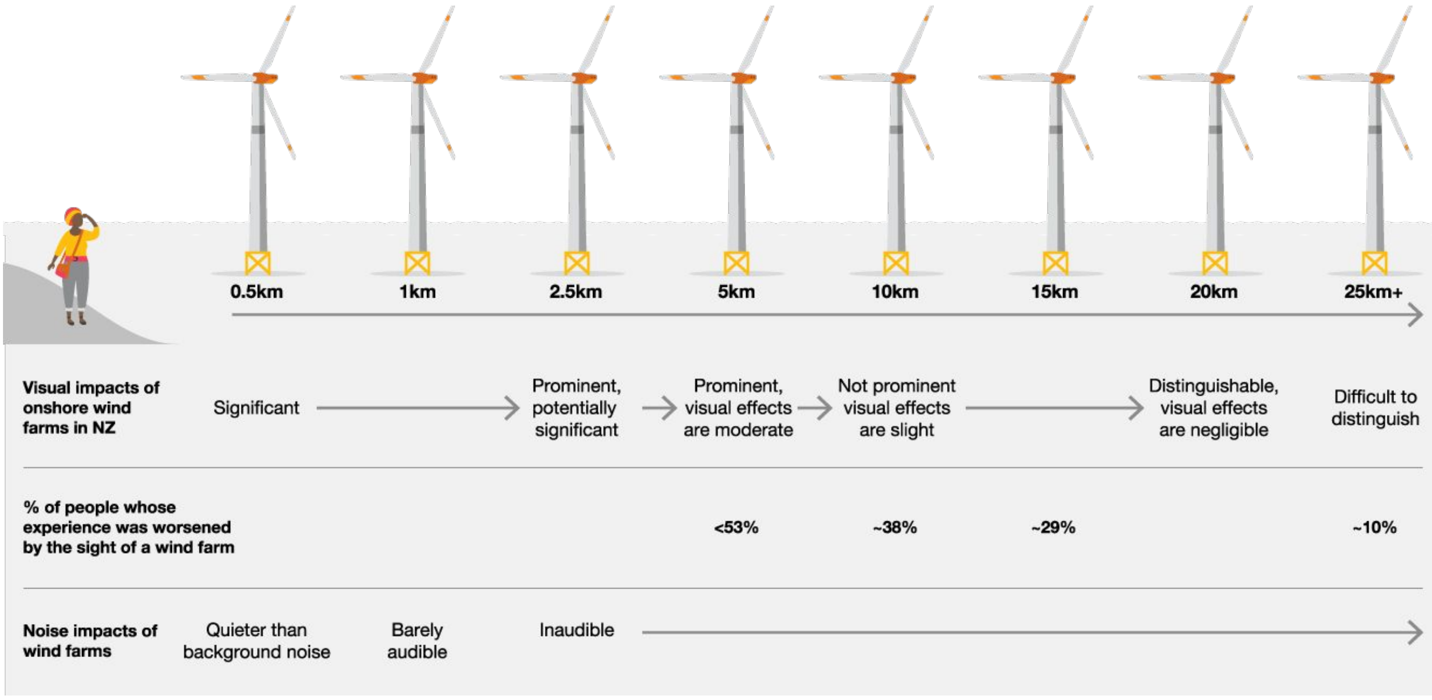
Visual and noise impacts are a key concern for communities for all wind projects, not just offshore. Observational impacts are closely related to distance. The further away they are, the less the visual and noise impact. The size, orientation, prominence of position, and horizon silhouette also influences visual effects. The figure on the previous page showing a visual simulation of an OWF from Ohawe beach gives an indication of the potential visual impact.

Most (but not all) of the currently proposed OWFs in New Zealand will be built over 22 km from shore, in the EEZ.

Another study found that those with previous experience of OWFs felt more positively about the development, than those with less or no experience of them.[10] This suggests the perceptions may be worse than reality.

Further work is underway by developers to understand local perceptions of OWFs. New Zealanders only have experience with onshore wind farms, which have a varying degree of personal and community viewpoints.

Figure 60: Noise and visual impacts of wind farms observed, by distance between observer and turbines [11,12,13]



While the turbines will be visible at this distance (e.g. a 250m high wind turbine is theoretically visible on the horizon up to 56 km due to the curvature of the earth), the observational impacts are expected to be minimal.

Visual impacts are generally negligible at distances of greater than 20km from shore. Noise impacts are even less, as at distances beyond 2.5km, OWFs are expected to be inaudible over average background noise (depending on wind direction), given onshore wind farms are inaudible beyond ~1.6km.

How people feel about observing a wind farm is often one of the most emotive and debated topics with new projects, even where the impact is negligible. Studies show that in addition to the properties of a wind farm (e.g. size and distance from shore), social and cultural associations to the wind farm are also very important. For example, if the OWF is associated with transition to a clean energy future, this can positively influence the public's impression of the farm.[14]

Wind farms often experience NIMBYism, where residents are not opposed to the idea or change in principle, but are opposed to the change occurring in their local area.

This should, in principle, be less of an issue for offshore wind.

Case study - Norway 2022:[15] A study of Norwegian households assessing their preferences showed that citizens were willing to pay about 16% more to move developments away from nearby communities.

It also found that citizens are even more concerned with maintaining local or national control both through ownership and intended use of the added electricity.

4.1.5 Recreational

OWFs have the potential to negatively impact recreational activities that take place in surrounding seas and beaches.

Placement of the farms and the distance offshore are the factors that will determine whether there are negative impacts to recreational activities. Farms closer to shore and those placed within or near to areas where recreational activities take place are more likely to cause disruption to recreation. Impacts to recreation should be considered when planning an OWF, and will be site specific.

The places in New Zealand where OWFs are likely to be developed are mostly on the West Coast and far out to sea, which generally are areas with consistently high winds and wave heights. This tends to make it undesirable for many marine recreational activities, such as fishing, kayaking and sailing. Wind farms located more than 20 km out to sea are expected to have a barely noticeable, if any, effect on wave quality for surfing.

International evidence supports that many of the impacts that recreational users fear are likely to be minimal, while others are misconceptions or anecdotes that may have occurred in an international context but are not expected to eventuate in a New Zealand context. These findings are summarised below.

Tourism[16,17]

International evidence shows the presence of OWFs alone does not tend to have a negative impact on tourism, and can actually be a tourist attraction.

- In the USA, it was found that the Block Island Wind Farm acted as a tourist attraction, resulting in a significant increase in occupancy rates (19%) in the peak-season months of July and August, relative to AirBnB properties in control cities.
- Companies offering boat tours to an OWF off the coast of Brighton, UK, have described business as “booming”.

Surfing[18,19]

OWFs can interfere with wave energy transmission, which has been observed to reduce wave size and quality. However, any impacts are small and are not expected to be observable for OWFs built more than 20km offshore. Recent evidence include:

- Scroby Sands Wind Farm (UK, 2.4km from coast) resulted in a 3-5% reduction in wave height.
- Wind farms at Hiiumaa (Estonia, 5km from coast) resulted in a reduction of a popular nearby wave of less than 1%.
- Surfers claim to have observed changes in power and swell caused by the Kent Wind Farm (UK, 11km from shore), but others believe the farm can’t have caused a change at that distance.

Recreational fishing[20,21]

Recreational fishing on the West Coast tends to be dominated by activity close to shore, reducing any impacts from OWFs. The ‘artificial reef’ effect of OWFs can also increase reef fish, and in turn attract and sustain more recreational game fishing - a positive for those participating in this activity.

A study on anglers’ attitudes toward the Block Island Wind Farm included:

- Anglers recognised the potential for the positive effects associated with artificial reefs, which may sustain and enhance fishing opportunities. Anglers reported mixed effects on catch success near or within sites, compared to their success at the same site pre-development.
- Anglers were concerned about the wellbeing of marine life.
- Anglers viewed restricted access negatively.

Sailing[22,23]

The areas of the West Coast that are likely to become OWFs are not highly valued sailing areas. Further, any impact on wind is expected to be insignificant for sailing.

However, prohibited zone conditions could be considered to avoid potential hazards such as:

- Collision hazards.
- Lengthened passage time and potential exposure to adverse conditions from needing to sail around prohibited zones.

Mitigation considerations for potential negative impacts

Placement of OWFs and consideration of prohibited zones are the key options to mitigate against potential negative recreational impacts.

Evidence shows that positive alignment and views on offshore wind from an environmental and/or socio-economic perspective may lessen perceptions of negative impacts on recreation. For example, the belief that wind farms are “symbolic of progress towards clean energy” may have greater influence on anglers’ attitudes towards OWFs than actual effects on fishing.[19]

This reinforces the importance of communication and engagement on the benefits and mitigations of consequences well ahead of any actual impacts.

Image: Offshore High Voltage Station, Nobelwind, Belgian North Sea, Courtesy of Parkwind

4.2 Iwi-Māori interests

Iwi-Māori interests in offshore wind concern use of the sea in customary iwi-hapū homelands (Mana Moana), impacts on existing fisheries and aquaculture rights, economic opportunities, and traditional roles as 'kaitiaki o te moana' (guardians of the sea).

Te Ao Māori, or the Māori worldview, provides a powerful perspective on the use and protection of natural resources that is vitally important to understanding iwi-Māori relationship with the moana. Kaitiakitanga (guardianship) implies both rights and obligations.

Affected iwi-Māori are engaging with developers and Government as individual iwi-hapū and in collective groupings to evaluate the issues and opportunities that arise. While there is no one single view, iwi-Māori are seeking greater participation in decision making over use of the moana and in investment and employment opportunities. This is to both fulfil obligations as kaitiaki, as well as ensure that the benefits of customary rights are delivered to their people. What these obligations may be will depend on the specifics of the regional marine area (including the flora and fauna within in it), and what constitutes appropriate benefits will depend on the needs of the people involved. We expect these will need to be negotiated on a case by case basis.

4.2.1 The Treaty of Waitangi

The Treaty of Waitangi (Te Tiriti) underpins the relationship between Māori and the Crown. The use of the sea for renewable generation has never been tested before under Te Tiriti, although precedent exists for use of the sea in fisheries and aquaculture and in renewable generation, for use of geothermal and hydro resources.

Further work is required to establish the important role iwi-Māori will have in offshore wind. Key areas to explore will be confirming Mana Moana (customary authority) and existing economic rights of individual iwi-hapū over parts of the sea as well as kaitiaki o te moana roles. While developers and iwi are already engaging, it is the Crown-iwi relationship that needs to resolve these matters. In setting the regulatory framework for how developers are to engage with Crown, iwi and the environment, it is essential that both partners in Te Tiriti are aligned on what is in the interests of all New Zealanders.

4.2.2 Mana Moana

Mana Moana is a concept reflecting the customary authority, interests and rights of iwi-hapū to the sea within the boundaries of their iwi-hapū territory (rohe). Our understanding at the time of writing is that there is consensus across iwi-Māori that partnership under Te Tiriti should be dealt with in terms of Mana Moana, i.e. on a regional basis, as some hapū will be more impacted than others, and there may be discussion on what Mana Moana means to each iwi-hapū. There will not be one approach that meets the needs of all Iwi-Māori but we understand that a pan-iwi collective will engage with the Crown on this. Based on this, we would expect the Crown-iwi relationship be resolved at a national level with the Government of the day, and developer relationships will need to be negotiated and formed on a Mana Moana basis.

4.2.3 Existing rights over use of the sea

Iwi-Māori have existing customary an commercial fishing and aquaculture rights over the sea that may be impacted by offshore wind, particularly if certain fishing activities are precluded. The commercial fisheries settlements are a cornerstone in Te Tiriti settlement processes. Accordingly, a perceived impingement on the rights bestowed by the Fisheries Act may be seen as an impingement on the symbolic milestone that this represents. There is also recent debate over whether these traditional fishing areas extend to other economic interests. In June 2023, iwi-Māori voted against the Government's proposed Kermadec Ocean Sanctuary at a meeting hosted by Te Ohu Kaimoana, the guardian of Māori fishing interests, partly due to the potential loss of future economic rights.

4.2.4 Economic opportunities for iwi-Māori

Offshore wind presents a rich opportunity for economic and social development for iwi-Māori, in particular for those regions with relatively high level of deprivation or undergoing an economic transition (such as in parts of Taranaki). It has been observed that in overseas locations (such as Oostende, Belgium) there has been a transition for local people to higher skilled and higher paying jobs due to offshore wind. Exploring opportunities for iwi-Māori workers to upskill and participate in OWF developments will be key.

Direct investment in offshore wind projects by individual iwi or affiliated Māori investment funds is also being explored with developers, which aligns well with iwi-Māori interests in natural resources and intergenerational investments.

The development of offshore wind also tends to result in the development of ancillary industries and symbiotic or supporting businesses, which will also provide investment and employment opportunities for iwi-Māori. Focus industries for Māori include engineering, energy and maritime contracting, port services, environmental monitoring, health and safety, and aquaculture.

4.2.5 The Economy of Mana

The Economy of Mana[24] is a framework that recognises the intrinsic value and interconnectedness of all aspects of life, including:

- environmental sustainability
- cultural preservation
- economic prosperity.

Any development harnessing the resources of Te Ao Tūroa (the natural world) should not only bring economic benefits but also align with Te Ao Māori. Te Ao Māori embodies the cultural values and aspirations of iwi-Māori. By creating this alignment in the approach to developing an offshore wind industry in Aotearoa, we see an intrinsic way to contribute to both the overall wellbeing of the local communities and the natural environment.

An Economy of Mana approach emphasises the equitable sharing of benefits and resources. This could involve:

- The use of iwi-Māori labour and businesses in development and operation
- Ensuring opportunities for economic, educational and social development for iwi, hapū and whānau so mana is maintained throughout the project lifetime
- Providing opportunities for iwi-Māori to have representation at a governance level, allowing involvement in decision-making
- The development of revenue-sharing agreements or investment initiatives that contribute to the overall wellbeing of Māori communities.

4.2.6 Sharing benefits

The creation and allocation of rights to offshore wind developers will by definition exclude others. This may give rise to a case for both economic and cultural compensation depending on the nature of the exclusion. Overseas, this issue has been recognised through policy packages that permit indigenous and local communities to share in the economic benefits of offshore wind.

The iwi-hapū most likely to be impacted by offshore wind in New Zealand are already engaging with developers and the Crown. Additionally, the collective iwi-Māori voice on matters of national significance is becoming more powerful, and the offshore wind industry is part of the discussion.

It can be expected that iwi-Māori intend to exercise kaitiakitanga over the moana and will expect any economic benefits of offshore wind to be shared.

4.2.7 Building relationships

The establishment of a values-based framework where there is alignment between iwi-Māori, the Crown and developers will be important. Creating a framework of aligned values (e.g. mana, atawhai (care), kaitiakitanga) that forms part of the regulatory framework will be important to presenting a consistent national approach to development of the offshore wind industry. This provides certainty to developers (and other industry stakeholders) and will give confidence to iwi-Māori that their interests will not be sidelined. These are two core concerns at the heart of understanding how the relationship between developers and iwi-Māori will work.

If this is initiated at the beginning of the relationship it will aid in ensuring all negotiated relationships have both strength and longevity. It is acutely important for iwi-Māori to ensure they have a voice in the design of the framework to ensure the mana of any agreement is upheld.

Image: Arcadis Ost 1, Baltic Sea, Courtesy of Parkwind Ost

Environment

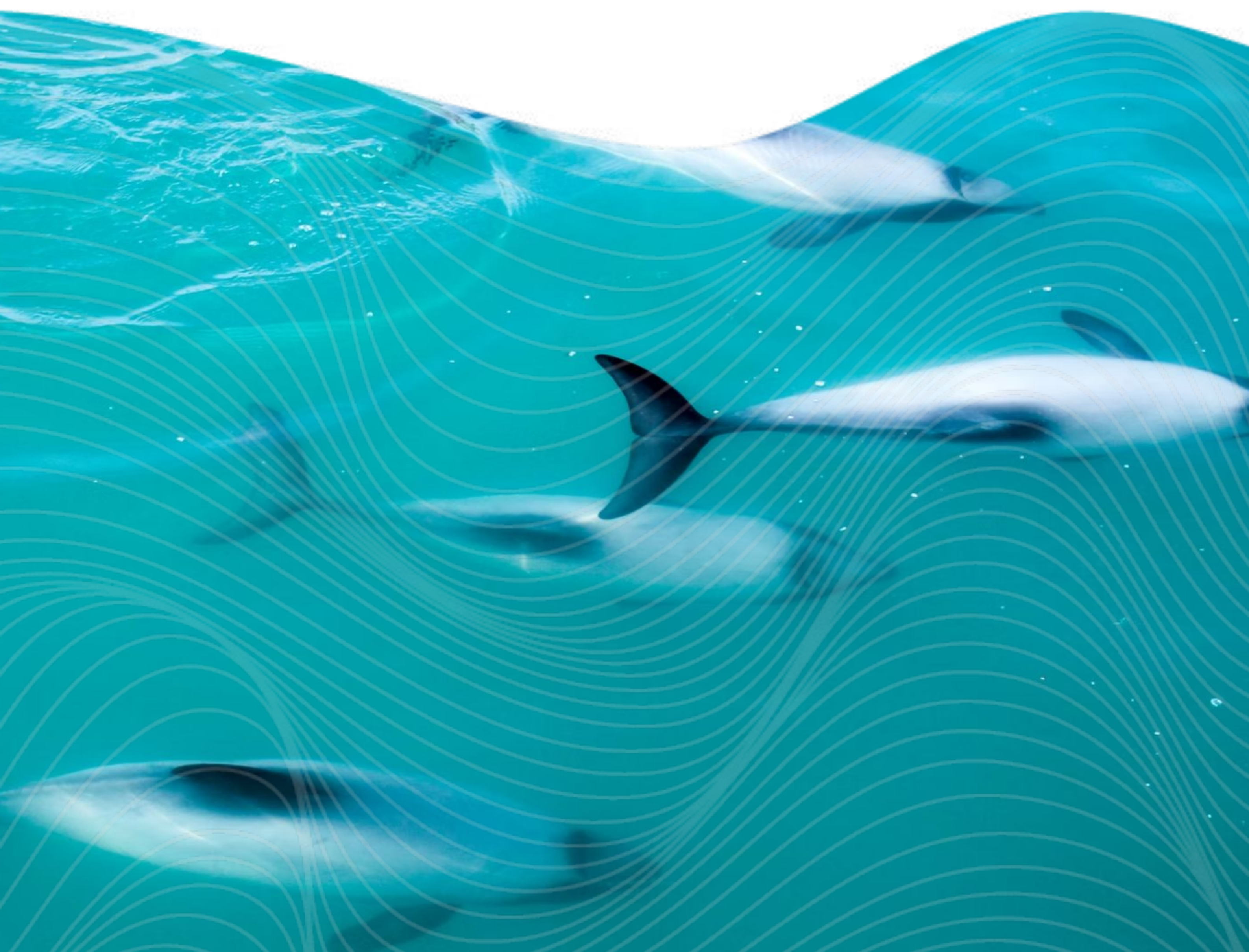
5. Environmental considerations

It is widely accepted that we need to significantly scale renewable energy in order to meet national decarbonisation targets. Any human activity will impact on the natural environment, and it will be important in building new renewable generation to find solutions that have a low environmental impact while offering high levels of decarbonisation. OWFs are potentially a great solution to this problem, as they offer abundant renewable energy with relatively lower impacts on flora and fauna. Key to maximising the OWF opportunity is prudent location choice, which the regulatory regime can facilitate.

In this section we consider:

1. **Balancing trade offs between decarbonisation and environmental risks**
   Decarbonisation is a key priority, however it may have flow on implications for our natural environment. As a result we will need to balance trade offs, ideally by finding low impact solutions that meet our energy needs.
2. **The impact of offshore wind on emissions**
   We have focused our emissions analysis on:
   - Carbon emissions associated with the construction and operation of wind farms
   - Displacement of carbon based fuels with renewable electricity and hydrogen based PtX fuels and feedstocks.
3. **The impact of offshore wind on flora and fauna**
   We explore the potential impacts to mammals, fish, benthic communities (incl. crustacea), seabirds, flora, and the ocean and atmosphere drawing on international studies.

   New Zealand's flora and fauna is unique and there is generally a lack of detailed data on critical species and how they may be affected by OWFs. We have supplemented our global survey with interviews with New Zealand environmental advocacy and research organisations to better understand the local environmental issues.



5.1 Balancing trade offs between decarbonisation and environmental risks

Decarbonisation and environmental trade offs

Rapid decarbonisation is a priority requiring large investments in renewable energy, supporting infrastructure and new technologies. Human activity of this nature will no doubt have flow on impacts on the natural environment. We will need to balance any trade offs between decarbonisation and environmental risks, ideally by finding low impact solutions that also meet our energy needs.

New Zealand's offshore wind resource provides an opportunity to accelerate and scale decarbonisation of our economy. Mitigating and minimising negative environmental impacts, while maximising positive environmental effects from OWFs where possible will be important. Our global literature review (set out in section 5.3) highlights successful mitigation of environmental matters globally.

While OWFs may have residual negative environmental impacts, without significant decarbonisation (that offshore wind can help to enable) the impacts from climate change will continue to affect a range of species. Ongoing climate change impacts will be widespread, whereas any residual impacts from OWFs will likely be localised and could be mitigated.

Multiple aspects of ecosystems are seriously threatened by climate change. There are a number of recent examples of the impact of warming ocean temperatures on the New Zealand ecosystems:

- New Zealand King Salmon thrive in 14°C water, however, in 2022 increased water temperatures lead to a mortality event where 2 in every 5 salmon in the Marlborough Sounds farms died[1]
- Warmer sea temperatures contributed to nearly 1,000 fur seal deaths along the Kaikōura coastline in 2023[2]
- Already declining, krill populations are expected to reduce by over 40% by the end of the century due to warmer sea temperatures. This trend has recently been shown to reduce the pregnancy rates of humpback whales which has fallen in recent years in line with lower krill availability.[3]

Counterfactual: We don't build offshore wind

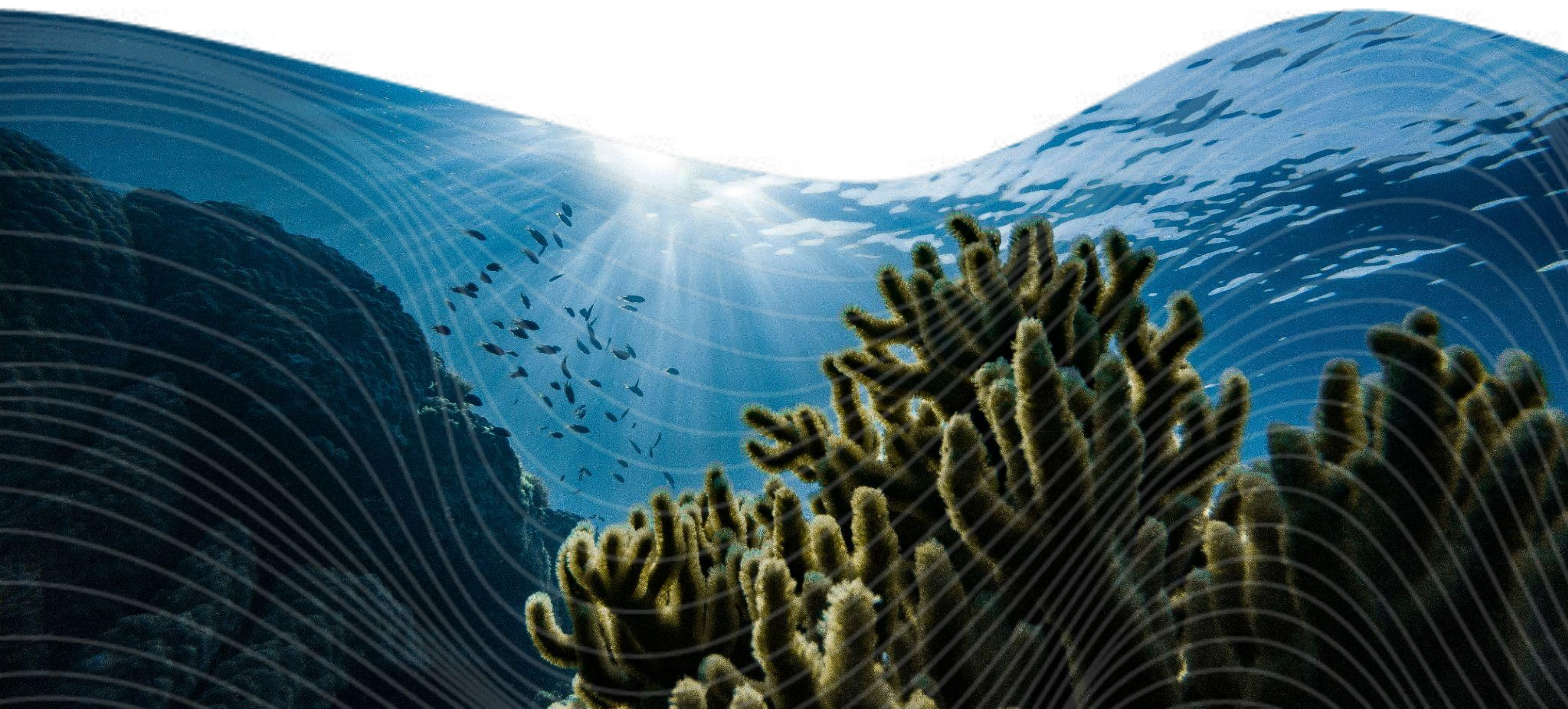
Both onshore wind and solar farms are alternatives to OWFs as renewable energy solutions. While further along the development curve, these alternatives produce less energy per MW of capacity than offshore wind and generally have a higher opportunity cost for the land they use.

Wind farms are more effective at producing energy than solar panels, as they convert 40% - 60% of installed capacity to energy, compared to 15%-22% for solar panels.[4,5,6,7] It would take about 717,000m^2 worth of land covered in solar panels (about 100 rugby fields), to produce the same amount of energy as one 15 MW offshore wind turbine.[8] New Zealand is relatively land constrained and has a high opportunity cost for productive land. Offshore wind could prove a useful tool for New Zealand to optimise use of productive land otherwise required to build solar for the energy transition[9].

Offshore wind is also a space efficient technology due to large turbine sizes and high capacity factors. The scale of the ocean allows greater choice over location of individual turbines. This is a positive attribute of offshore wind, as site suitability and availability can impose limitations for some land based generation technologies.

Offshore wind can also be more space efficient. Separate studies of onshore wind in the USA and offshore wind in Europe show their respective energy densities. From those we found that offshore wind is generally more space efficient, with more than 16% higher capacity densities (i.e. MW per km^2) observed on average.[10,11]

While further research is required, scaling land based renewables may have a similar impact on the environment. Bird impacts are a potential risk for all wind farms, whether onshore or offshore. Clearing of marginal scrub land for solar farms could also negatively impact native vegetation and wildlife through the loss of habitat.[12] The onus will be on developers to ensure sensitive siting and mitigation measures are in place for all forms of renewables.



5.2 Emission impacts

We estimate that offshore wind could enable an 18% to 30% reduction in national energy related emissions (excluding industrial feedstocks). Its advantages are its scale, low emission entensity, high efficiency, minimal footprint and lower opportunity cost of the space it uses. 78% of the embodied emissions associated with OWFs relate to manufacturing and installation, but overall offshore wind has short carbon payback period of only 5-12 months given the significant decarbonisation potential.[13]

Overview and New Zealand context

We have considered the potential for offshore wind to assist New Zealand in reaching its net zero goal by assessing:

- The embodied carbon emissions directly associated with an OWF
- Fuels displaced through electrolysed hydrogen replacing existing fossil fuel use.

Of all the renewable energy solutions, wind power has the lowest overall 'cradle to grave' carbon footprint. About 80% of the total lifecycle carbon emissions are associated with the construction phase, with a very low maintenance and operations footprint. Innovative solutions for recycling materials and components of offshore wind turbines also present significant circular economy opportunities, which could reduce embodied carbon emissions by at least 35% compared to new manufacturing.[14]

Embodied and lifecycle carbon emissions

Embodied emissions are emissions generated during the production and transportation of goods. For OWFs, embodied emissions are minimal compared to the significant decarbonisation potential of offshore wind in displacing carbon based fuels and industrial feedstock, either directly through electrification or via production of hydrogen.

Process-based life cycle analysis (LCA) includes analysis of the environmental impact of raw material extraction, manufacture, processing, distribution, transportation, use, maintenance, and final disposal over the lifetime of an offshore wind farm. LCA is standardised by the International Organisation for Standardisation.[15]

Review of available process-based LCA analyses of offshore wind shows that over the lifetime of an OWF, emission intensities are in the order of 8 to 25g CO_2-eq/kWh.[16] The table below provides a comparison of emission intensities, based on comprehensive reviews of published estimates.

Table 20:* OWF lifecycle emission estimates[17]

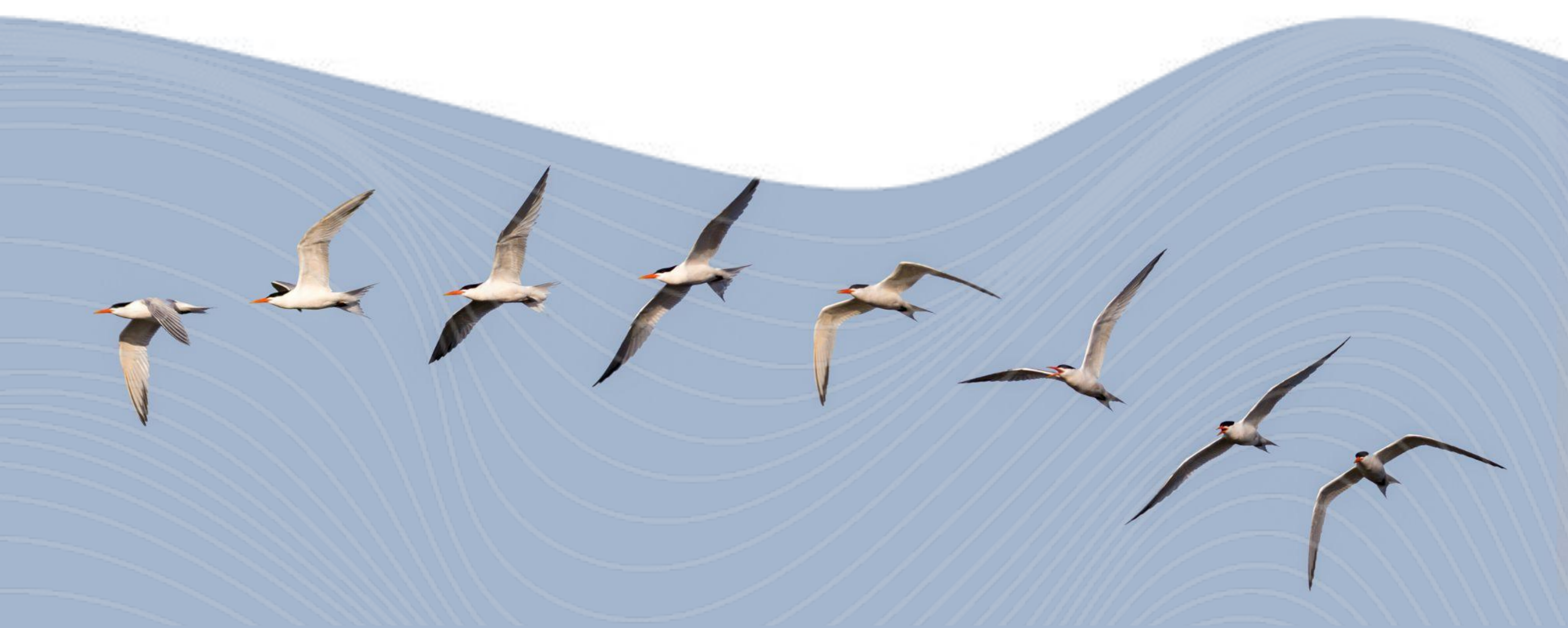
Life cycle stage	Estimated emissions (%)
1. Manufacture and installation	78.4%
2. Operations and maintenance	20.4%
3. Decommission and disposal	1.2%

* Fixture composition, mode of transport for installation, and accountancy for additional maintenance of large components have not been included in this table.

Table 21: Emission intensity comparison[18,19]

Generation source	Emission intensity g CO_2-eq/kWh
Offshore wind	8 - 25 (12 average)
Onshore wind	15 (average)
Coal	~1,000
Solar PV	20 - 60
New Zealand grid average (2010-22)	74 - 167

The carbon payback period is an estimate of how long it takes for a renewable energy project to offset the greenhouse gases emitted as a result of its construction. This period ranges from 5 months to 1 year for offshore wind, which is negligible given the assumed lifetime of 30 years.[13]



Emissions reduction

We have estimated the emissions reduction potential of the offshore wind industry. The energy sector (inclusive of transport and energy related industrial feedstocks) contributes about 40% of New Zealand's carbon emissions, illustrating the magnitude of the opportunity in meeting our 'net zero' targets.[20,21]

Offshore wind could play a important role in the transition to a low-emission future by supporting electrification of the economy (green electrons) and by enabling a green hydrogen industry (green molecules).

Accelerated electrification has been identified as a key opportunity to support rapid emissions reduction. BCG's *The Future is Electric* report estimates that the electrification of transport and heat processing will deliver a significant 70% reduction of gross emissions annually, by 2050.[22]

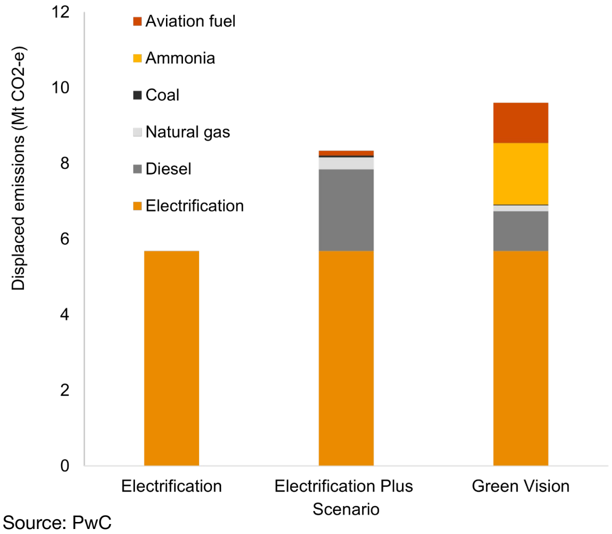
For hard-to-abate emissions that cannot readily be electrified, green hydrogen presents a opportunity to substitute fossil fuels for low carbon PtX fuels and feedstocks. This is a sizeable undertaking that will require GW levels of renewable energy capacity, which offshore wind can perhaps best provide.

Our estimates of the emissions reduction potential of offshore wind in each scenario is shown in the table below and the figure opposite:

- In the Electrification scenario, 5.7 Mt of CO_2-eq is estimated to be displaced annually by 2050 from electrification enabled by offshore wind
- In Electrification Plus, emissions reduction is estimated to be 8.3 Mt CO_2-eq per annum by 2050 due to electrification and mainly diesel fuel displacement in heavy transport
- In Green Vision, emissions reduction from offshore wind is estimated to be 9.6 Mt CO_2-eq per annum by 2050 mainly due to electrification and PtXs fuel substitution.

These estimates exclude the contribution that could be made from industrial feedstocks, which are discussed in further detail below.

Figure 61: 2050 annual emissions reduction from offshore wind (excl industrial feedstocks)[23]



Source: PwC

Electrification

Emissions reduction from electrification is based on Transpower, BEC and BCG energy scenario modelling. An average annual reduction in emissions of 21 Mt CO_2-eq in 2050 is projected across these scenarios from grid based electrification of the economy using renewable generation. This equates to a 0.65 Mt CO_2-eq per TWh reduction in emissions, attributable to the projected electrification of industries.[22,23,24,25]

Applying this to the 8.8 TWh off annual offshore wind supply in each of our scenarios would correspond to a 5.7 Mt CO_2-eq reduction by 2050, or about 18.0% of 2023 energy related emissions.

Table 22: 2050 emissions reduction from offshore wind (excl industrial feedstocks)[23]

	Electrification	Electrification Plus	Green Vision
Emissions Reduction (Mt CO_2-eq)	5.7	8.3	9.6
Proportion of 2021 energy emissions (%)[21]	18.0	26.3	30.3
Proportion of total 2021 emissions (%)[20]	7.5	11.0	12.6

Industrial feedstock emissions

EY/MBIE's hydrogen modelling did not estimate the change in emissions relating to industrial feedstock use due to the complexities involved in quantifying these for specific industrial processes and how (in the case of methanol) the fuel is utilised.[26] To give an order of magnitude of the emissions from this sector, in 2021 emissions from industrial processes and product use made up 4.6 Mt CO_2-eq, or 6% of New Zealand's gross emissions.[27]

The modelled hydrogen demand for industrial feedstock comes from NZ Steel, Ballance and Methanex.These emissions are expected to decrease in line with the modelled assumption that hydrogen will displace fossil fuel usage. To further contextualise the scale of emissions reduction impact from usage of green hydrogen production from these three large industrials, provided below is a summary of reported 2021/2022 emissions (Mt CO_2-eq).[28]

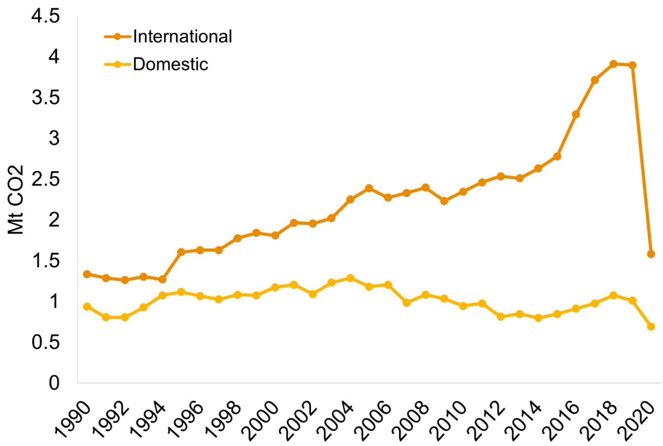
- NZ Steel = 0.04*
- Ballance = 0.59**
- Methanex = 1.86***

*Reported under industrial process emissions
**Reported under agricultural emissions
***Reported as a removal as methanol is exported

Fuel displacement

The transport sector is a major source of energy emissions. Most light vehicles are expected to be electrified with government targets set for a 41 per cent reduction in transport emissions by 2035 from 2019 levels.[29] Heavy freight, aviation and marine transport are far more challenging given battery energy density. This is an important issue for our transition to a sustainable economy. For example, we have one of the highest emissions per capita from aviation travel in the world, which was increasing rapidly prior to Covid.[30]

Figure 62: New Zealand's aviation emissions (Mt CO2)[30]



Source: Ministry for the Environment

Large scale production of hydrogen enabled through offshore wind, provides an opportunity to decarbonise these high emitting transport fuels. Green hydrogen is not considered to be a 'zero emission' fuel, as it does produce some non-carbon greenhouse gases when burned. However, provided hydrogen leakage and associated warming potential from atmospheric chemical reaction is controlled, hydrogen PtLs fuels can play a major role in the transition to a low emissions economy.[29]

In the scenarios involving hydrogen production, it is assumed that hydrogen will be used to replace heavy transport and aviation fuels (e.g. diesel and jet fuel, or 'aviation fuel'). There is some displacement of process heat fuels (e.g. coal and natural gas).

The quantification of the emissions displaced by hydrogen is dependent on the emissions intensity of the fuel being displaced and efficiency of the energy transformation process. Diesel is a relatively inefficient transport fuel and displacing diesel has a higher emissions reduction impact than displacing the same energy requirement in jet fuel for example.

In Electrification Plus, OWF generation is targeted towards PtLs applications that displace diesel and process heat applications. In the Green Vision scenario, offshore wind is targeted more towards exports and jet fuel substitution and less towards diesel substitution.

This reflects the assumption that OWFs will focus on large centralised PtL projects in Green Vision, with smaller decentralised plant focusing on displacing diesel.

Tables 23 and 24 below show the breakdown of the fossil fuels displaced by hydrogen in our Electrification Plus and Green Vision scenarios both total and from offshore wind generation.

It should be noted that the estimated displaced emissions are not necessarily consistent with what is quantified under our ETS, as we include emissions from export and international aviation fuel. For the export of hydrogen we have assumed that hydrogen would be made into ammonia (NH_3) for transportation and used directly as a drop-in green fuel. About a 15% loss of hydrogen is assumed through this process.[31]

Table 23: Fuel displacement for PtXs - Electrification Plus[23]

Fuel Displaced	Unit	Total fuel displacement*	Offshore fuel displacement
Diesel	Litres	1,288 million	796 million
Aviation fuel	Litres	78 million	48 million
Natural gas	m^3	238 million	147 million
Coal	Tonnes	41 thousand	25 thousand

Table 24: Fuel displacement for PtXs - Green Vision[23]

Fuel Displaced	Unit	Total fuel displacement*	Offshore fuel displacement
Diesel	Litres	1,288 million	387 million
Aviation fuel	Litres	571 million	418 million
Ammonia	Tonnes	265 thousand	265 thousand
Natural gas	m^3	238 million	72 million
Coal	Tonnes	41 thousand	12 thousand

*Industrial feedstock is excluded from the above analysis. Refer to note on previous page.

Cost of falling short in our decarbonisation efforts

The NIS has highlighted the critical role hydrogen could play in displacing fossil fuels in heavy and long-haul transport, and OWFs could be important in providing the scale needed to decarbonise our fuels sector.

The cost of failing to reduce these harder-to-abate emissions risks us falling short of net zero. If our domestic decarbonisation efforts do not meet international commitments, the anticipated cost of purchasing offshore mitigation could be substantial.

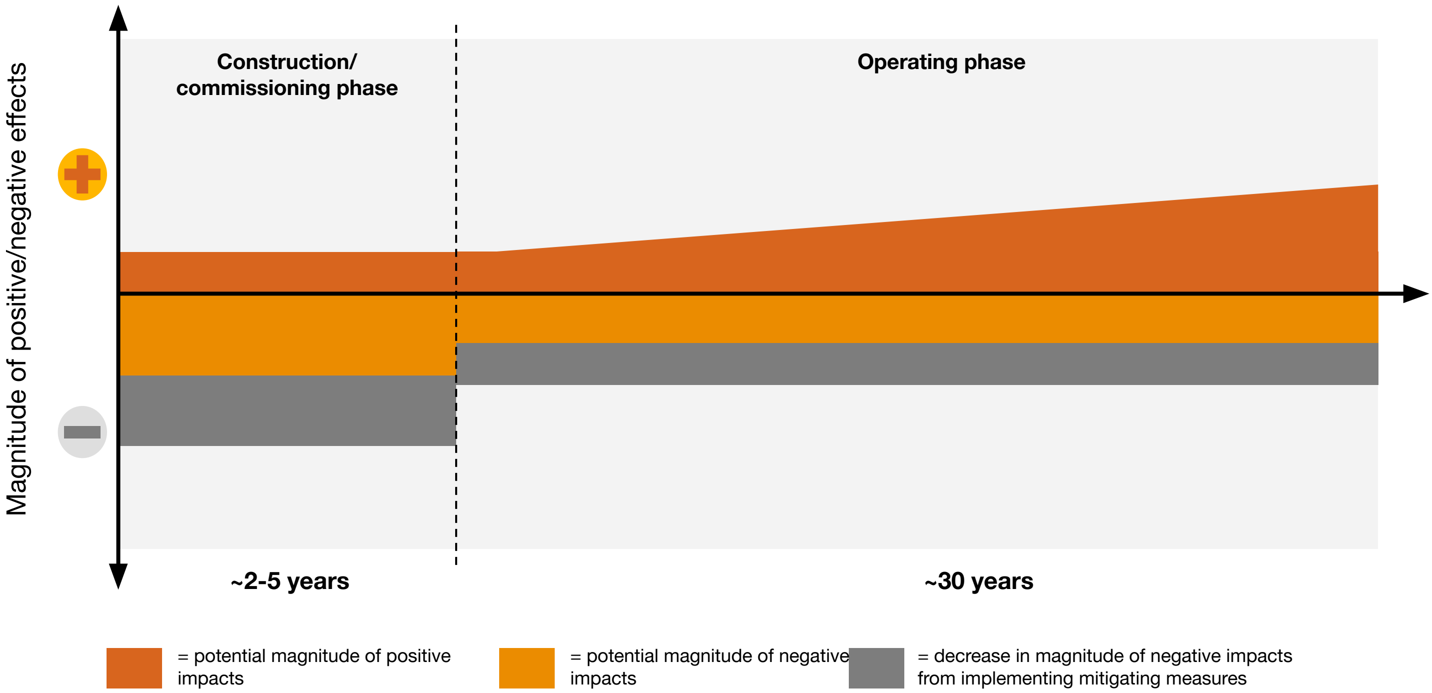
Taking the Climate Change Commission's (CCC) 2023 advise on NZ ETS price control settings out to 2028** as a proxy for the future international carbon mitigation cost, we estimate the cost of mitigants associated with fossil fuels in the Electrification Plus Scenario, could be up to $640 million per annum and $560 million per annum in the Green Vision Scenario (excluding exports).[23]

**CCC price used is average of the recommended tier 1 and 2 (2026 - 2028)[32]

5.3 Flora and fauna

New Zealand has a unique, large and complex marine environment, with a rich variety of species. Potential environmental impacts from offshore wind in New Zealand are largely unknown due to a lack of data and therefore require detailed evaluation. Identification of appropriate locations for OWFs is key as considered placement may enhance positive impacts and alleviate some of the potential risks to our flora and fauna.

Figure 63: Potential impacts on flora and fauna across phases*



*Many of these impacts are temporary

The benefit of New Zealand being a late adopter of offshore wind is that we are able to see the results of long-term studies on marine flora and fauna in other environments. As such, we were able to draw on a large body of global literature to provide a range of potential impacts that may be important considerations for any OWFs in New Zealand.

Our findings indicate that many of the environmental impacts occur during the construction phase, largely as a result of the noise and vibration disruption from pile driving. Noise impacts will vary between different installation methods. Some such as gravity base may use no piles at all.

Once established, the OWF turbine infrastructure often results in beneficial enduring support for marine biodiversity through creation of new habitats and an increase in food availability for fauna, through the 'artificial reef' and 'marine reserve' effects. Under these conditions, the installation of foundations are more likely to create artificial reefs that may provide space for the settlement, shelter and foraging for fish and benthic communities.

The operational phase may result in negative impacts on flora and fauna, including risk of bird strike, displacement and barrier effects, which is a similar concern for onshore wind farms.

An illustration of the potential magnitude of the positive and negative impacts throughout the construction and operating phases on flora and fauna is set out in the figure above. The key driver of the increasing positive impacts during the operating phase is due to the growing 'artificial reef' effect.

Decommissioning turbines at end-of-life may subsequently result in the loss of these 'new' habitats. However, there is a lack of empirical evidence on this, as the first wind farm decommissioning is only just occurring today. Early studies suggest it may be more beneficial to retain the newly formed reef and leave the base of the structure where it lies, instead of removing it. This can provide a follow on benefit as part of the 'renewables-to-reefs' concept.

Set out in figure 64 is a summary of the potential environmental impacts on marine flora and fauna, for mammals, fish, benthic communities (incl crustacea), seabirds, flora and the ocean and atmosphere.

More information is important to help make informed decisions about wind farm placement. Determining the ‘right’ wind farm placement during the feasibility phase can both enhance the positive impacts and mitigate many of the potentially negative effects on marine flora and fauna.

Good regulatory frameworks will be critical in identifying and addressing the environmental impacts of offshore wind.

In determining the exact location of a wind farm, consideration should be given to the habitats and migration pathways of threatened, sensitive or endangered species, such as the Māui dolphin and nocturnal migratory seabirds. Detailed baseline surveys will be required as a first step.

Developers can draw on past findings from the offshore oil and gas industry (which has established environmental best practice protocols for flora and fauna in New Zealand), as well as OWF mitigation measures tested overseas. Successful examples of mitigation include quieting technology such as bubble curtains, and protected species observers during construction. It is likely that developers will need to work closely with environmental agencies and interest groups (e.g. the Department of Conservation (DoC), Councils, Forest and Bird). Oceanic data collection and monitoring will also be important for mitigating adverse impacts during operation and providing feedback for future OWFs to enhance the positive impacts.

The UN Sustainable Oceans Principles[33] provide a holistic view on the impacts of marine activities on long-term sustainability and natural capital. Developers could use this framework and the practical guidance it offers as a reference point for ocean sustainability in all development phases. The Blue Economy Principles for Aotearoa provides a similar reference point, but in a New Zealand context.[34]

As discussed on page 72, delivering our net zero targets with land based renewables alone, is likely to involve a similar or greater magnitude of impact to wildlife.

Figure 64: Summary of potential environmental impacts seen overseas*

Marine mammals

+
- Gain of habitat (O)
- Artificial reef effect → increased food availability (O)

−
- Collision and vibration/noise disturbance from vessel movements (C)
- Potential electromagnetic field disorientation during migration (O)
- Potential removal of new food availability (D)

Fish (incl finfish and elasmobranchii**)

+
- Gain of habitat (O)
- Artificial reef effect → increased food availability (O)
- Sheltering effect from de-facto marine reserve (O)
- Increased biodiversity of the area (O)

−
- Vibration/noise disturbance (C)
- Sensory environment through electromagnetic fields from subsea cable may result in distress and confusion, making it difficult to detect and capture prey (O)

Benthic communities (incl crustacea)

+
- Gain of habitat (O)
- Artificial reef effect → increased food availability (O)
- Increased biodiversity of the area (O)

−
- Sedimentation (C + D)
- Vibration/noise disturbance (C)
- Concerns around the biological effects of electromagnetic fields emitted from subsea power cables (O)

Seabirds

+
- Artificial reef effect → increased food availability (O)

−
- Collision mortality (C + O)
- Extra flight costs (O)

Flora (e.g. kelp)

+
- Artificial reef effect results in: increased biodiversity of flora (O), creation of habitat for other marine life (O)
- Possibility to create ‘offshore wind seaweed farms’ which would create a new industry and have other benefits such as creation of filter feeders (O)

−
- Sedimentation (C + D)
- Removal of existing habitat during the construction period (C)

Ocean and atmospheric

+
- Potential positive impact of ecosystems as a result of enhanced mixing of sea shelves (O)

−
- Sediment plumes and ocean current changes disrupting distribution of nutrients (C + O)
- Disruption to stratified sea shelf cycles, altering and destabilising natural processes (O)

Key:
C = construction phase **O** = operating phase **D** = decommissioning phase

**Compared to counterfactual (with other renewables)*
***sharks and rays*

The following pages discuss key environmental considerations relevant for New Zealand. These considerations are not exhaustive and individual projects will need to go through robust assessments during feasibility and planning.

1. Marine mammals

Experience from overseas

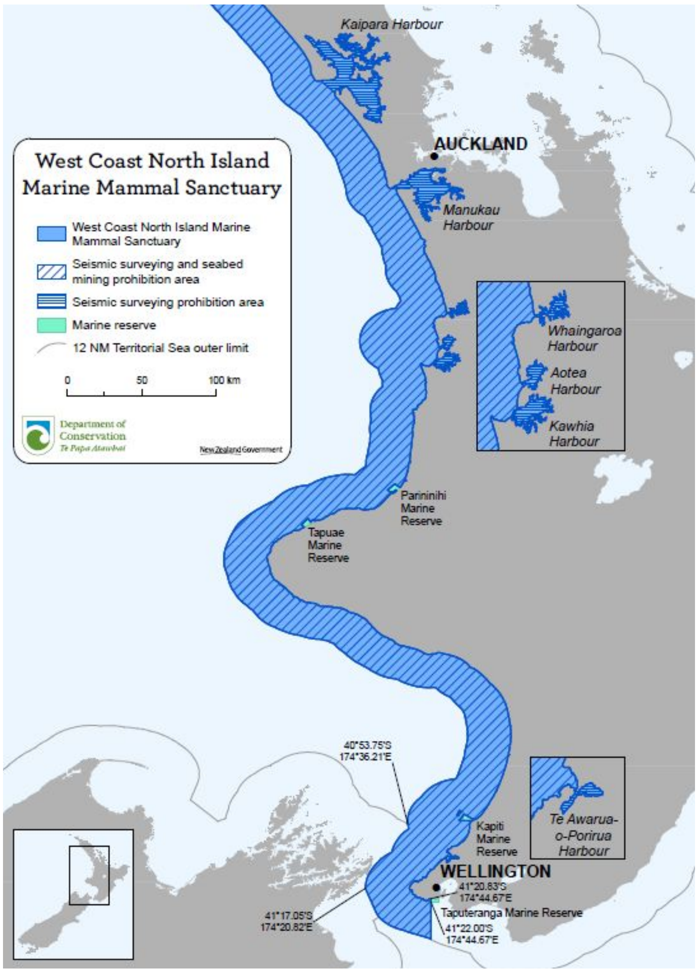
Noise disturbance, in particular from construction of bottom-fixed piles and moorings may cause hearing damage, masking of calls or spatial displacement (as can electromagnetic fields during operation). There is potential to mitigate these impacts through the selection of foundations and by adopting noise attenuation technology. There is also a risk of collision and disturbance from vessel movements during surveying and installation.

Benefits to mammals occur in the operational phase, where wind farms are frequently visited by mammals who benefit from increased food availability around the foundations,[35] encouraging them to return to the area.

Considerations for New Zealand

New Zealand is home to many marine mammals, with 22% of them being threatened or at risk.[36] The majority of the west coast of the North Island is a marine mammal sanctuary (the WCNIMMS), which covers the 12 nautical mile territorial zone (~22 km offshore).[37]

Figure 65: WCNI Marine Mammal Sanctuary[37]



Source: Department of Conservation

The sanctuary was established in 2008 as a part of the Māui dolphin Threat Management Plan (TMP), with restrictions on seabed mining, oil and gas activities and acoustic seismic survey work. The TMP does not impose specific limitations on offshore wind, although most OWF developers have avoided this area in their announced projects with only one project announced in the sanctuary. Two marine reserves also sit within the sanctuary - Parininihi and Tapuae Marine Reserve.[37]

The endangered Māui dolphin (only ~54 left and only in the WCNIMMS), Hector's dolphins, humpback whale/paikea, common dolphins/aihe, fur seal/kekeno, pilot whale/upokohue, orca whale/maki, blue whale and the southern right whale/tohorā can all be found in the WCNIMMS, many of them on their migratory paths.

Consideration should be given to the effects that pile driving may have on nearby fauna. A 2017 New Zealand study[38] used automated echolocation detectors in Lyttelton Harbour to measure the distribution of Hector's dolphins over 92 days. When pile driving for wharf reconstruction occurred, few dolphins were found near the detectors closest to the pile driving and more were detected further out in the harbour.

Most adverse effects can be partially prevented prior to construction by careful placement and design of OWFs. In order to protect marine mammals, OWFs should to be designed strategically around marine reserves and other popular areas for sensitive species with appropriate monitoring of mammal movement.

A number of mitigation measures have been developed to reduce noise and minimise impacts to wildlife. Quieting technology, such as bubble curtains[39] around the construction site, have proven to be effective at reducing noise at the source. These technologies would need to be tested in New Zealand to understand the applicability to our marine mammals.

Protected species observers or passive acoustic monitoring can monitor areas for sensitive marine life to ensure that construction does not occur when mammals are in the vicinity. Currently, prior to undertaking seismic surveys in New Zealand, DoC is notified and issues a report about any recent mammal activity in the area.[40] During the survey, qualified marine mammal observers are present to ensure no mammals are too close to vessels. If visibility is poor, hydrophones are used to listen for whale and dolphin sounds.

Given marine mammals use different frequencies for communication and navigation, monitoring and mitigations will need to be tailored to individual species.

2. Fish (finfish and elasmobranchii)

Experience from overseas

Oversea, benefits to fish from OWFs are largely evident in the operational phase. The artificial reefs that form on OWFs may benefit secondary fish production, acting as a surface to which fish and other sea animals can attach. As a result, there are increases in the number of shellfish, and the fish that feed on them, including sharks and rays (i.e. elasmobranchii). In addition, a safety buffer zone surrounding the wind turbines may become a de-facto marine reserve, increasing fish populations and biodiversity in the area.

Similar to mammals, noise disturbance, in particular from pile driving during wind turbine installation, may cause hearing damage and an acute stress response. The sensory environment during the operational phase may also cause distress (through both ongoing noise of turbines and electromagnetic fields creating confusion).

Elasmobranchii in particular use electromagnetism to navigate and find prey. Energy from subsea cables can result in confusion and interfere with navigation.

Considerations for New Zealand

The west coast of the North Island is characterised by exposed sandy beaches with stretches of rocky platforms and outcrops. Fisheries tend to be localised and of high importance to Māori and local communities. The impacts on fishing will depend on whether or not New Zealand enforces a fishing ban around OWFs. Off the West Coast, this is more likely to affect trawling for snapper, trevally, tarakihi, gurnard, tuna and barracouta.

There are approximately 66 species of shark in New Zealand[41] and the most common include: spiny dogfish, bronze whaler, school, basking shark, great white, rig, and smooth hammerhead shark. New Zealand is home to 26 species of rays and skates including the smooth skate, the giant manta ray and the eagle ray.

To minimise the negative impacts, consideration could be given to excluding OWFs from areas of sensitive fish species and fragile habitats.

The same noise minimisation actions that apply to mammals may also provide a suitable measure to mitigate the impacts on finfish.

3. Benthic communities (including crustacea)

Experience from overseas

Adverse effects on benthic communities overseas have occurred during both construction and operational phases. Like for mammals and finfish, noise disturbance during construction may cause distress among other nearby sea life. There are also some concerns around the biological effects of electromagnetic fields emitted from subsea power cables. Overseas studies show that these cables may have a mesmerizing effect on certain species of crabs.[42]

During construction and decommissioning, physical disturbances to the seabed from redistribution of sediment can also disrupt the habitat of benthic communities. Although, these disturbances tend to be temporary in nature.[43]

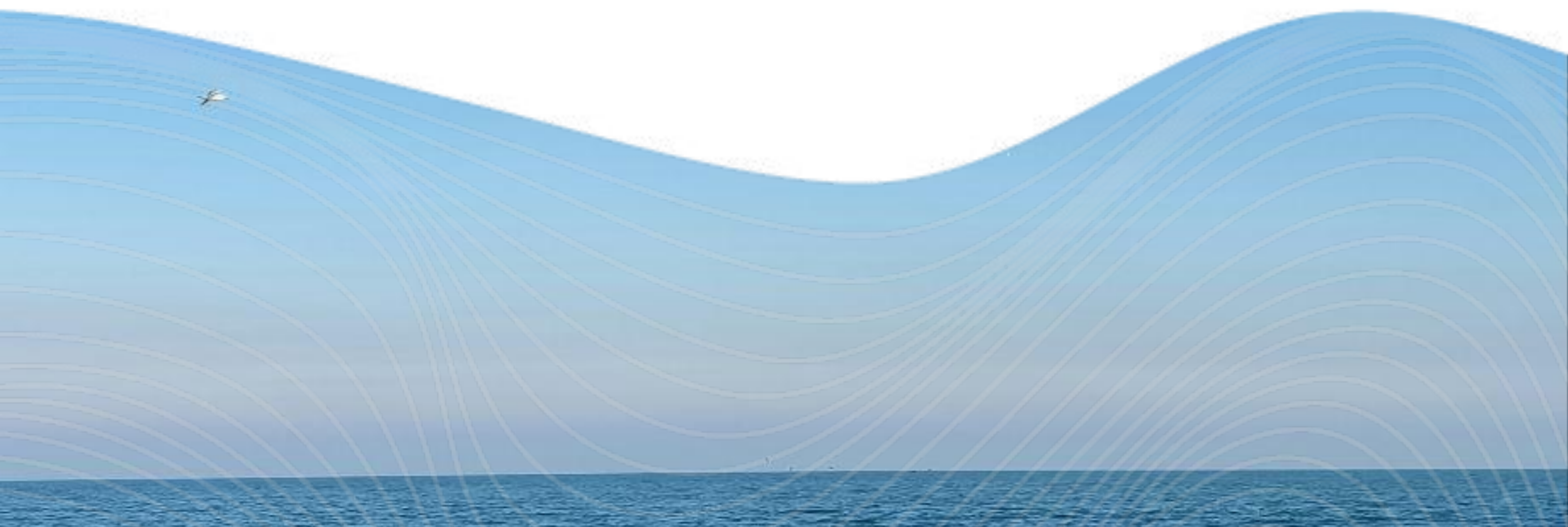
Benefits are largely evident in the operational phase where the reef effect creates new habitat for benthic communities, thereby contributing to increased biodiversity. Overseas, crabs and lobster have been appearing in increasing abundance on and around the structures. Benthic communities may also be protected by limits on fishing close to the turbines.

Considerations for New Zealand

Over 3,000 species of crustacea are known to live in New Zealand waters. The actual number of species could easily be 10 times that figure[44] because many of the groups have not been well studied (with the exception of crayfish/kōura, crabs and shrimp). A number of species are endemic to New Zealand. Careful siting and selection of construction techniques by developers is necessary to avoid disruption to the Benthic communities habitat through sedimentation.

Mitigation measures to limit the electromagnetic interference among benthic communities are not very advanced globally and behavioural changes are still being observed/monitored.[43] We are not aware of any relevant regulations or policies concerning electromagnetic fields for marine environments like there are for on land. However, efforts are being made to improve cable laying techniques to minimise the intensity of electromagnetic fields. Advancements to insulation materials and cable designs aim to reduce adverse impacts. Developers should draw from overseas experiences, utilising the most recent successful cable laying techniques and materials at the time of construction.

Like mammals, crustacea use different frequencies for communication and navigation, so the electromagnetic fields will have differing impacts and mitigations will need to be tailored.



4. Seabirds

Experience from overseas

Although there are no direct benefits of OWFs on birds, the effects on overall bird populations have been seen to be negligible, when well sited.

Many seabird species such as gannets tend to avoid the turbines, which decreases risk of collision but interrupts their normal behaviour. Examples from overseas have shown in some instances the gulls appear unaffected and local cormorant numbers even increase. Sedentary birds quickly become accustomed to wind farms and have a reduced risk of collision.

Collision mortality is a risk however for migratory birds in particular. Evidence is emerging that this risk may be lower than initially perceived. A Vattenfall study observed over two years of monitoring, thousands of birds around OWFs in the North Sea, did not record a single bird collision with a rotor blade. It concluded that seabirds seem to deliberately steer clear from wind turbine blades.[45]

Loss of functional habitat also occurs for some birds. The food supply and habitat remain intact, but the presence of the turbines discourage the birds from approaching and using such areas. The observed effect of this for overseas OWFs is small.

Considerations for New Zealand

New Zealand is the home to a wide variety of coastal seabirds. The wider New Zealand archipelago (including the sub-antarctic islands) is home to 25% of the world's breeding seabird population. There are about 86 species of seabird that breed in New Zealand - 28 of which are 'threatened' and 53 which are 'at risk'.[46]

There is much we do not know about our seabird populations, meaning it is difficult to know how they will be impacted by OWFs. Detailed assessments will need to be carried out to determine at risk bird populations and behaviour in order to improve the design and siting of wind turbines. For example, many New Zealand seabirds are nocturnal, which is uncommon in other parts of the world. We do not have comprehensive data on flight paths, flight heights and avian behaviour at sea at night, which will be important to understand impacts of OWF night operations. In addition, we need baseline data to improve the evaluation of effects and robustness of impact assessments.

Research undertaken in respect of understanding how birds interact with offshore wind could prove extremely useful for understanding these species more generally.

The design of wind turbines themselves should also take bird collision risk into account. Sound signals, lights and colour (of rotor blades) have all been tested with mixed success. However, none have been tested on New Zealand species. Research is being carried out on 'adaptable' wind turbines, which involve turbines adapting to bird behaviour, rather than the other way around.

Technologies that halt wind blades to reduce the risk of bird mortality are also being developed and trialled.

Another example currently in development is a Norwegian concept 'SKARV',[47] which is a novel active control system that makes small adjustments to the rotor speed of wind turbines after detecting the presence of birds within a certain distance of the blades. This allows the detected bird to fly through the rotor area without being hit by the blades.

5. Flora

Experience from overseas

Benefits to marine flora (e.g. seaweed such as green, brown and red algae, kelp) are mostly seen during the operational phase from increased biodiversity of the seabed resulting from the reef effect. Many different species of algae (such as filamentous green algae and more diverse and permanent vegetation of green, brown and red algae) are found on and around structures overseas. This in turn creates and sustains habitats for other marine life. There is also the possibility to create 'offshore wind seaweed farms' which is a phenomenon seen in the Netherlands.

Careful planning is necessary to ensure the resulting reef effects will enhance a range of native species/species with beneficial ecosystem effects, and not pest marine flora.

Considerations for New Zealand

New Zealand has over 1,000 species of seaweed. In addition, 80% of our over 50 coral species are only found in New Zealand.[48]

The Ministry for Primary Industries (MPI) has identified eleven unwanted marine organisms which are highly invasive and of particular concern (one of which is Undaria, a Japanese seaweed). These invasive species may cause diseases that affect New Zealand's fish, molluscs and shellfish. Diseases can cause stocks to collapse, which in turn can affect the natural balance of an ecosystem. Protecting against these introductions from overseas vessels will be an important consideration during the installation of the turbines.

There are multiple agencies/organisations which are responsible for different aspects of marine life protection. Some agencies are outlined below.

- MPI and DoC are two key biosecurity agencies. These agencies should monitor the flora forming within the OWFs to ensure pest seaweeds and other invasive species are not present, and removing these if they are
- Maritime NZ are responsible for ensuring operators have waste management standards and emergency response plans in place to protect the marine environment from both oil spills and port waste[49]
- New Zealand Petroleum & Minerals (NZP&M) is the agency which manages the Government's oil, gas, mineral and coal resources. Its role is to process and monitor prospecting, exploration and mining permits.[50]

On decommissioning, it is assumed that the removal of turbines and foundations would also result in the removal of the new reef habitat. This has led to the concept of 'renewables-to-reefs' being proposed for decommissioned wind farms, where parts of the structures are left in place to continue to act as artificial reefs. This is also beneficial as it will reduce the energy, labour costs and safety issues associated with removal of the entire wind farm.

Case study:[51]

There are two pest seaweed species that have been found in Port Taranaki: the Japanese seaweed Undaria and the red algae Grateloupia turutu. During winter or early spring, the Taranaki Regional Council works with DoC and Port Taranaki Limited to remove Undaria. This is when the individual plants are large enough to be easily identified and are not releasing many spores.

Typically, spores are released later in the spring. DoC could take on a similar role for OWFs. It is important to note that these types of seaweed tend to live and grow in water columns which are shallower than the depth proposed OWFs meaning that this adverse effect may be minimal.

6. Ocean and atmospheric

Experience from overseas

The construction of offshore wind turbines may result in sediment plumes. These are caused by the agitation of the seabed, resulting in clouding of the water. They can prevent sunlight from reaching subsurface depths and disrupt the distribution of nutrients, potentially starving marine animals and plants. The wind farms themselves can also create smaller sediment plumes from ongoing interference ocean currents.

OWFs can also impact stratified sea shelves. These are where water density varies with depth, creating distinct sea zones. Their natural cycles are important for the marine ecosystem and biogeochemical cycling. They are naturally mixed during winter, but during summer months the deeper regions stratify, with a warm surface layer overlying the cooler water below. This triggers a phytoplankton bloom which forms the base of the marine food chain, supporting fish, seabirds and marine mammals.

During the summer months following the spring bloom, phytoplankton growth is supported by nutrients stirred up from below by turbulence associated with wind and tides. This turbulence also mixes oxygen down to the deep water, where it is required for other key biological processes. Although the impact of OWFs on these processes is not yet well understood, the addition of wind turbines within the water column may fundamentally alter and destabilise these processes. Enhanced mixing may also positively impact some marine ecosystems.

Early research also indicates that OWFs can change regional air currents, which could in turn affect ocean circulation. The uneven swirling of wind can agitate the ocean surface and cause upwelling (where deep, cold water rises to the surface). This can bring nutrient rich water to the surface which marine life thrive on. One study found that OWFs alter the vertical atmosphere by reducing the wind speed and increasing vertical mixing. For a wind turbine 90m in height and 126m in diameter, the effects of vertical changes are propagated approximately 600m above the mean sea level (450m above the rotor area).[52]

Considerations for New Zealand

The magnitude of these ocean and atmospheric impacts in New Zealand are largely unknown due to a lack of research and data about our waters. The current proposed wind farms are set to be larger and further out to sea than many of those which have been observed in Europe. Ocean productivity impacts will differ based on currents and disturbances, and this will be dependent on the site.

Findings from the offshore oil and gas industry and aquaculture sector in New Zealand could assist in providing better understanding, but specific research on the potential impacts of OWFs will be required. The sooner this work can be initiated, the better informed that placement decisions can be.

Benefits of in-depth data gathering and research
Overseas precedent on how OWFs interact with the environment is useful, but there is so much we do not know about the our marine and coastal environments and threatened species in New Zealand.

Data collection and robust research and analysis of these environmental considerations will be crucial to support development of mitigation plans and the correct placement of turbines.

There is significant flow on benefits in carrying out these studies in advancing our understanding of the marine environment and affected species, flora and fauna. This could in turn support better management of our fishstock and most threatened marine mammals and seabirds.

How this research is funded and who owns the information is being discussed as part of the development of the offshore renewables regulatory environment (summarised opposite). The key tension is how to protect individual developers investment in research to support their project consenting with the wider benefits to the environment and research community of sharing this information more widely.

The current offshore renewables consenting environment
The evolving offshore wind development permitting and consenting process will be key for developers to understand. Gaining clarity on the new Government's intentions for resource consenting is also important for stakeholder certainty. The Government has signalled its intent to repeal the Natural and Built Environment Act (NBE) and the Spatial Planning Act (SPA) as a priority and amend the existing Resource Management Act (RMA). It has also indicated a different regulatory approach to environmental consents.[53,54]

For permit competition, the new Government has stated it will investigate the strategic opportunities in our mineral resources, specifically vanadium off the coast of Taranaki, and develop these opportunities.[55,56]

Thorough research during the feasibility stage of permitting will be vital in alleviating many of the potential negative impacts on flora and fauna, given the importance of OWF placement location.

We expect that there will be a need for strong alignment between the feasibility permitting and the environment consenting requirements. In particular that the right environmental information is obtained during the feasibility stage and is used in the commercial permitting and environmental consenting processes. It will also be needed to monitor compliance.

Getting the regulatory settings right in the first place will be essential to effectively mitigate the negative impacts on both the environment and on competing uses of the marine area.

Concerns about the regulatory processes focus on:

- aligning and sequencing feasibility/commercial permitting and environmental permitting processes and policies
- the need for comprehensive information to make effective environmental decisions, including the ownership and use of environmental data
- the strength of information which informs criteria to assess suitability of developers and locations
- the roles and responsibilities of offshore energy regulation, especially for iwi and hapū.

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