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OFFSHORE WIND INVESTMENT STRATEGY

PREPARED FOR

COALITION FOR GREEN CAPITAL

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An Analysis of the National Climate Bank Act of 2019 on the Offshore Wind Sector

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ABOUT THIS DOCUMENT: This analysis suggests potential ways in which the Climate Bank can offer financial support to the offshore wind sector- it is in no way a definitive guide. The investment committee will need to conduct further in-depth analysis, as market conditions change, and modify accordingly. This analysis is conducted under a regular scenario without the impact of COVID-19.

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EXECUTIVE SUMMARY

In the United States, emissions from the electricity sector make up about a quarter (27%) of total greenhouse gas emissions, making it the second largest emitting sector (EPA, 2019). Thus, the electricity sector is a critical target in order for the US to abate their emissions. However, current financing from both the public and private sector lack the financial commitment and require an extra push toward significant emissions reductions. Thus, the National Climate Bank Act of 2019 is a proposed tool by which the federal government invests USD $35 billion in seed capital toward the creation of the National Climate Bank, a non-profit that will stimulate financial investments in clean energy solutions. The Climate Bank is expected to use the seed capital to stimulate private sector investment to leverage up to USD $1 trillion of total investments. The Climate Bank primarily focuses on investments in innovative clean technologies that would otherwise be unable to progress in the current financial markets, and with the current financial mechanisms.

This analysis reviews existing technological advancements, policy support, and financial mechanisms for offshore wind and analyzes the financial investments still needed for its successful deployment. The Climate Bank's investment in offshore wind must also ensure maximized emissions reductions in the electricity sector. While offshore wind technology is mature, has immense political support, and private investment interest, only one offshore wind farm is currently operational in the US. This is mainly due to both policy and financial barriers and the Climate Bank can accelerate this through effective financial investments, especially for fixed-bottom offshore wind projects along the East Coast, as they will see competitive and decreasing levelized costs over time. Thus, possible strategies for Climate Bank investment could include: a) direct investment in port infrastructure and 2) providing project debt and equity. This would lead to reduced capital costs for overall wind projects and stimulate regional economies of scale that are able to reduce 10-12 gigatons of CO_2 by 2050 (Project Drawdown, 2020).

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ACRONYMS

AWEA	American Wind Energy Association
BOEM	Bureau of Ocean Energy Management (Department of Interior)
CapEx	Capital Expenditure
CCD	Control co-design
DOE	U.S. Department of Energy
EESI	Environmental and Energy Study Institute
EIA	US Energy Information Administration
EPA	US Environmental Protection Agency
FOWT	Floating offshore wind turbines
GHG	Greenhouse gas(es)
GIG	Green Investment Group
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ITC	Investment tax credit
LCOE	Levelized cost of energy
LROE	Levelized revenue of energy
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and maintenance
PPA	Power purchase agreement
R&D	Research and development
RPS	Renewable Portfolio Standard

INTRODUCTION

Anthropogenic climate change is increasing critical risks to overall human productivity and well-being. The more severely humans alter the climate, the greater detriment to ecosystems, economic activity, and all components of the climate system (Pachauri, 2015). Hence, scientists have determined three global emissions reductions targets to mitigate the effects of climate change: maintaining temperatures below 1.5°C from pre-industrialized levels, achieving a 40-60% reduction in global greenhouse gas (GHG) emissions from 2010 levels by 2030, and achieving global carbon neutrality by 2050 (Pachauri et al., 2015).

The United States is the second highest producer of GHG emissions by total emissions and per capita, emitting 15% of global GHG emissions (EPA, 2018). Despite this statistic, the United States has the opportunity to invest in climate mitigation solutions. Financing such solutions will be no small feat - it is estimated that the switch to 100% renewable energy will cost the nation about USD $4.5 trillion in capital investment (Holden, 2019). Currently, private sector investments toward this goal have been slow due to uncertainties, especially in returns, and the public sector does not have the funds to make the necessary investments. One exciting approach to mobilizing both public and private sector involvement is the creation of a national green bank.

The National Climate Bank Act of 2019 proposes the federal government reduce national GHG emissions by financing USD $35 billion in seed capital toward the creation of the National Climate Bank (Climate Bank), a non-profit which seeks to match public dollars with private investment toward clean energy solutions. The bank's seed capital is estimated to stimulate up to USD $1 trillion dollars in total investment over a thirty-year period, within the timeline of global targets set by the IPCC. The bill proposes a policy solution that reduces emissions by accelerating financial investment on innovative clean technologies that would otherwise be unable to progress in the current financial markets, and with the current financial mechanisms.

The bill encourages private sector investment at a reduced risk as the Climate Bank also shoulders some of that investment, while taking the public dollar further.

The National Climate Bank’s scope includes:

- Indirect investing by supporting existing, local green banks and creating new ones
- Direct investing by financing projects
- Prioritizing 20% of investments toward climate-impacted communities, defined as communities of color, low-income, minority, rural groups and communities most impacted by climate change
- Transitioning the nation to a low-carbon economy without increasing costs to end users, while maximizing emissions reductions per public dollar
- Ensuring the consumer credit protection and labor protection mandate

The sectors eligible for National Climate Bank's financial investment include:

- Renewable energy
- Building energy efficiency, fuel switching, and electrification
- Industrial decarbonization
- Grid technology, including transmission, distribution and storage
- Agriculture and forestry
- Clean transportation
- Climate-resilient infrastructure
- Any other key areas that complies with emissions reductions, environmental justice, consumer credit protection and labor protection mandate

This analysis is part of a series that looks at how the Climate Bank can alleviate any existing financial barriers and accelerate the transition to renewables in any of these sectors. This analysis will focus specifically on offshore wind by analyzing the current situation in the industry and proposing potential investment strategies for emissions reductions. The Climate Bank’s main financing criteria supports any technology that is able to maximize and accelerate emissions reductions, while also considering returns on investment. This means prioritizing technologies that are or will be mature and ready for large-scale deployment with Climate Bank support. It will also reveal how the Climate Bank can accelerate the development of clean energy by integrating public and private capital.

OVERVIEW OF SECTOR

Mitigating global emissions requires investment and development of renewable infrastructure. Offshore wind is a critical piece of the solution as it provides reliable electrical generation with zero emissions (IEA, 2019). By the end of 2017, the total worldwide offshore wind power capacity exceeded 18.8 GW, which is only about 0.65% of total electricity generation, see Figure 1 (Enerdata 2018; Global Wind Energy Council, 2019). The European market for offshore wind has matured much faster than the United States, and thus the United States is regarded as an emerging market with investment opportunities.

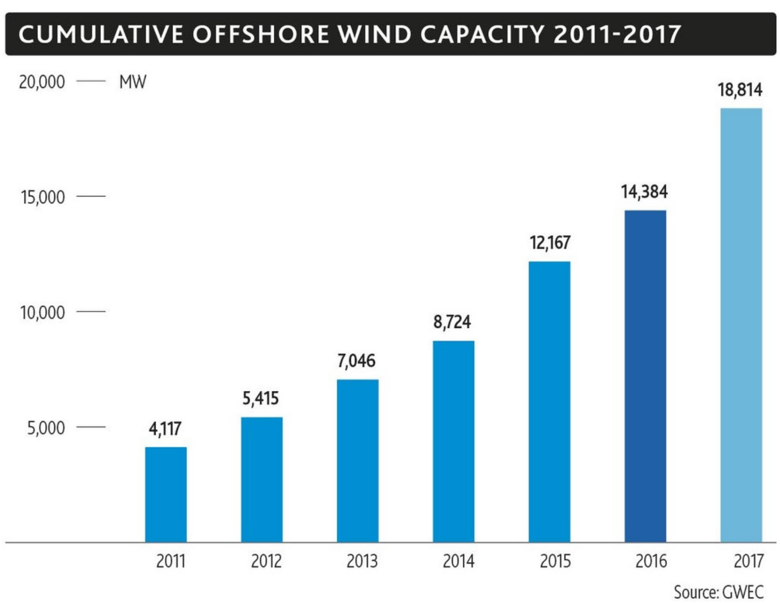


Figure 1. Growth in Offshore Wind Capacity. Source: Global Wind Energy Council

The Bureau of Ocean Energy Management (BOEM) has already issued 15 active offshore wind leases with over 21 GW total capacity (BOEM, 2019). A total of 86 GW offshore wind projects are estimated to be generated by 2050 (Department of Energy, 2016). Low-interest debt, advanced technologies and investments from European lenders and wind energy companies encourage the US offshore wind market (Business Network for Offshore Wind, 2018). At scale, the US could reach a maximum technical potential of 2,000 GW with current technologies. This amount of power is more than double the annual US electricity demand (Sopko, 2018).

Of the several available offshore wind technologies such as floating and fixed turbines, fixed-bottom turbines are best developed and widely built in multiple projects across both US and Europe. Therefore, there is huge investment potential in growing wind power capacity and investment in commercial-scale fixed-bottom offshore wind farms.

EXISTING TECHNOLOGY

Offshore wind's success relative to other wind technologies is due to coastal high pressure differential areas producing reliable winds, which is most notable along the East Coast. Thus, these consistent wind patterns are able to move turbines and convert wind energy into electrical energy. The technology is relatively straightforward: the aerodynamic nose of the turbine is oriented to face the wind, and as the wind hits the nose, the blades spin, and that energy is transferred to the rotor, the speed of which is moderated by the break and the gearbox. The turbine generator converts the wind's mechanical energy into electrical energy from the rotating force of the movement (TurbineGenerator, 2018). The design of the turbine's base is determined by a variety of factors such as ocean depth, topography, and ecosystem impacts.

With an array of different foundations used to stabilize the turbine in turbulent coastal waters, fixed-bottom wind turbines are appropriate for near-shore projects at depths of up to 80m (Bureau of Ocean Management, 2019). As developers seek more real-estate for optimizing their investments, offshore wind projects can be developed in deeper water using diversified bases. Floating offshore wind turbines (FOWTs), a relatively new technology, allow turbines beyond that depth. These turbines are fixed to mooring systems, like balloons on an anchor, that can reach much greater depths than conventional systems, allowing them to capitalize on higher wind speeds, and can be more advantageous to marine ecosystems.

CURRENT FEDERAL AND STATE POLICIES

Wind energy in the US has been rapidly developing over the last several years as both federal and state level policies put forward ambitious emissions reduction goals. State policies should help establish a framework for investment and can create target generation capacity. Massachusetts, Rhode Island, New York and New Jersey are at the forefront for forging the policy path for offshore wind. For example, the Massachusetts Energy Diversity Act of 2016 set a target of generating 1600MW of offshore wind by 2027, and in 2018 the target doubled to 3200MW, Appendix A summarizes these policy incentives.

Despite the outstanding political support, as of February 2020, no new large-scale offshore wind farms have earned both state and federal permits for official infrastructure, though some companies are in the process of submitting their requests for permit approval at both state and federal levels (BloombergNEF & Business Council for Sustainable Energy, 2019). Guidelines for auctioning permits have to do with state-specific auctioning criteria. An example for New York is provided in Table 1. Upon successful auctions, selected firms can move on to acquire both federal and state permits to build in the federal open seas as state waters typically cannot withhold large-scale offshore wind projects (A. Wolters, personal interview, February 21, 2020).

Thus, both state and federal policies are necessary to facilitate the creation of large-scale offshore wind projects. While fixed-bottom offshore wind technologies have matured in the global market, and will be optimal for meeting the renewable power demand on the East Coast, future advanced technologies such as FOWTs are developing and could expand options to the West Coast, where waters have a much deeper subsurface, creating a need for floating technology. The National Renewable Energy Laboratory (NREL) estimates the offshore potential in California alone, through floating technology is 112 GW (The Maritime Executive, 2019).

NEW YORK STATE AUCTION GUIDELINES [1]	
Auction Criteria [2]	• RES Tier 1 Procurements + Offshore specific requirements • Language, contract requirements including deadlines, bid bonds, cash bonds, and other requirements at NYSERDA's discretion • Eligibility includes project COD, location/delivery, siting, etc.
Financing Policy	All projects financed at each selected company's discretion. NYS will provide: • Up to $200 million investment in NY port facilities • $20 million in offshore wind training institute • $3 million in community and workforce benefits fund
General Timeline	Ongoing: Research and stakeholder engagement • 2019: Proposal review and contract awards • 2019 - 2023: Permitting and approvals • 2020 - 2024: Manufacturing • 2022 - 2024: Construction and installation • 2024: Commissioning • 2024 - 2050+: Operations
State Targets	• Support development of 9,000 MW by 2035, enough to power up to 6 million homes • 70% of New York's electricity to come from renewable sources by 2030 [3]
Ongoing Project [4]	2 awarded contracts: combined capacity of 1,700 MW off Long Island 1. Equinor 2. Orsted + Eversource (joint)

All currency in USD

Table 1. New York State Auction Guidelines

[1] NYSERDA, "Offshore Wind."
[2] NYSERDA, "Offshore Wind Solicitations."
[3] NYSERDA, "Offshore Wind Solicitations."
[4] Frangoul, "New York Gives Green Light for Two Huge Offshore Wind Projects in Waters off Long Island."

FINANCIAL OVERVIEW

Since 2006, the federal government began funding offshore wind projects through research and development (R&D), which has helped improve the technology, identify challenges and overcome barriers through experiments. Thus, the private sector subsequently invested in building wind farms with the resultant new technology.

Private Sector Investment

Since August 2019, BOEM has executed 15 active offshore wind leases, with over USD $473 million in bids (BOEM, 2019). Though a lease does not grant the right to construct any facilities, it gives the lessee the exclusive right to seek BOEM approval for the development of a leasehold in a certain area. For example, Block Island Wind Farm, a completed project by Deepwater Wind and located 3.8 miles off Rhode Island, can generate a capacity of just 30 MW, and was constructed on a USD $290 million budget (Valladao, 2016). The second expected offshore wind project, managed by Vineyard Wind, is slated to quickly follow and come online in 2022, with a generation capacity of 800 MW and a budget of USD $2 billion (Vineyard Wind, 2019). That progression in capacity and investment suggests high industry confidence.

According to the statistics above, the cost for Block Island Wind Farm is USD $9.67 million per MW in comparison to a cost of USD $2.5 million per MW for Vineyard Wind. Therefore, from an investment perspective, Vineyard Wind is more cost-competitive as Block Island's cost per MW is nearly 4 times higher than Vineyard. The main contributor of the disparity would be the size difference between the two farms. Vineyard by power generated is almost 27 times larger than Block Island, which means as power capacity increases, cost decreases.

By 2017, Levelized Cost of Electricity (LCOE) project estimates in the US are USD $0.12/kWh for fixed-bottom substructures, and USD $0.146/kWh for floating substructures (Stehly et al. 2018). It is estimated that LCOE for the whole offshore wind sector will drop to USD $0.115/kWh by 2025, and further down to USD $0.085/kWh by 2040 (EIA, 2020). Figure 2 demonstrates the falling LCOE associated with a generally rising capacity factor. These figures are cost competitive with grid power, which varies between USD $0.05-0.20/kWh depending on region and time of day (EIA, 2020).

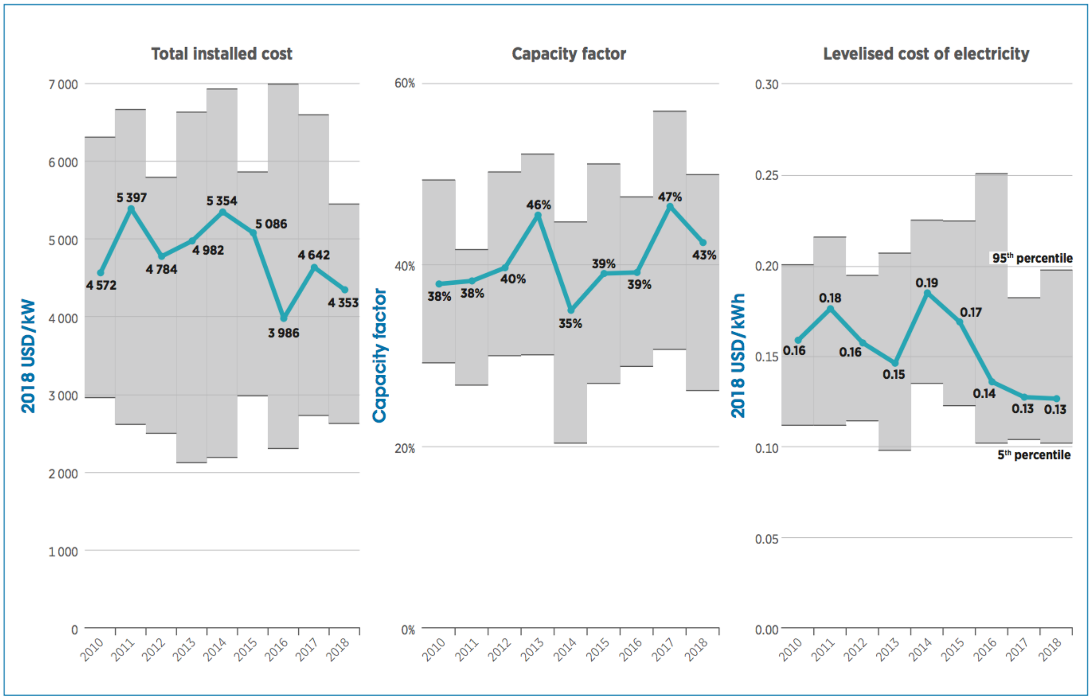


Figure 2. Global total costs, capacity factors and levelized cost of electricity (LCOEs) for offshore wind (2010-2018). Source: International Renewable Energy Agency

While costs vary by project, major costs fall into three categories: wind turbine, balance of system, and financial costs, as illustrated in Figures 3 and 4 below for fixed-bottom turbines and FOWTs (Stehly et al., 2018). The NREL projects that around 15% of total capital costs come from financial costs, as shown in the area in purple for Figures 3 and 4. The levelized capital costs make up the bulk (70%) of offshore wind Levelized Cost of Electricity (LCOE), at about USD $0.084/kWh of the current USD $0.12/kWh (EIA, 2020). The National Climate Bank may be able to provide low to no-interest financing for these projects. If the Climate Bank were able to on-take all 15% of these capital costs, the LCOE could be reduced to USD $0.107/kWh, making it competitive.

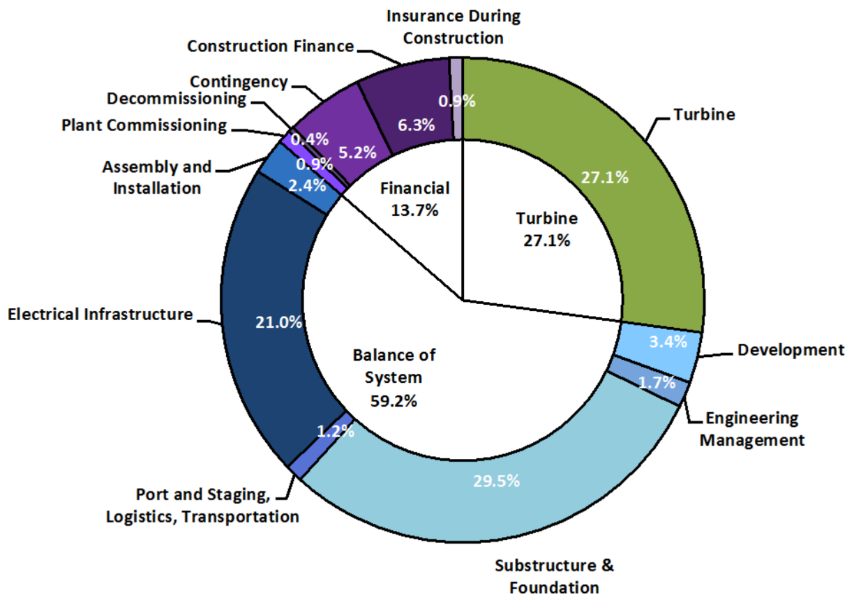


Figure 3. Capital expenditure for fixed-bottom offshore reference wind power project

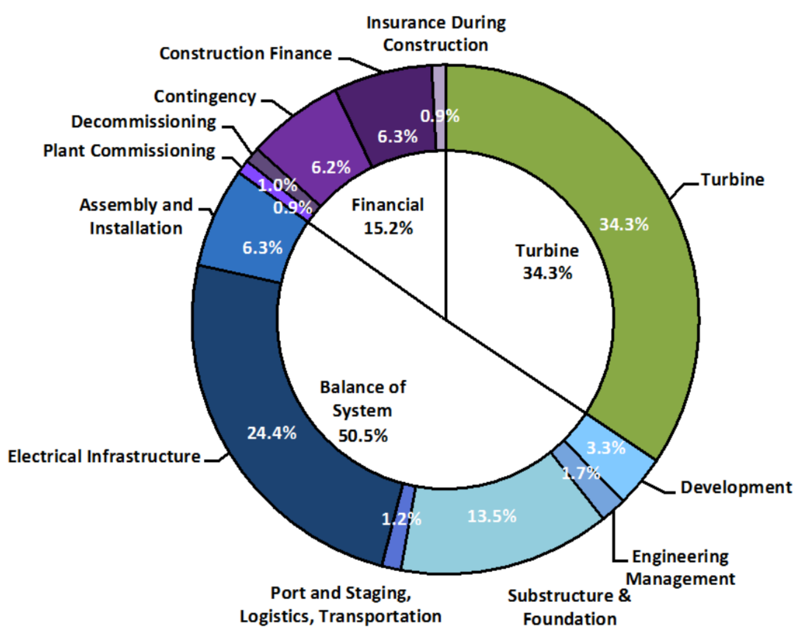


Figure 4. Capital expenditure for floating offshore reference wind power project

Public Sector Investment

According to the Environmental and Energy Study Institute (EESI), the US Department of Energy (DOE) has provided over USD $301 million in funding for 72 offshore wind R&D projects from 2006 to 2015 (Small et al., 2016). About half (54%) of the funding supported advanced technology demonstrations; 39% supported technology development activities; and 7% supported market acceleration and deployment (Small et al., 2016). In 2012, DOE helped complete the first phase of seven offshore wind advanced technology demonstration projects with USD $4 million in funding (Small et al., 2016). In May 2014, DOE funded USD $46.7 million to 3 projects in Virginia, Oregon, and New Jersey over a four-year period, hoping to lower the cost of offshore wind and show the technology is prepared for commercial application (EESI, 2016). In February 2020, DOE announced a USD $28 million funding for Aerodynamic Turbines, Lighter and Afloat, with Nautical Technologies and Integrated Servo-control (ATLANTIS), to develop "FOWTs using the discipline of control co-design (CCD)" (DOE, 2019). The long permitting and approval process creates risk and uncertainty in these developments, however. Many projects are still under environmental assessment or waiting for permission. At the same time, there is also a significant shortage of installation vessels that are qualified by the Jones Act (Todd, 2013). The Jones Act requires that the offshore wind service vessels must be US owned, so any shortage will create a significant cost of finding appropriate ships to service wind farms.

INVESTMENT POTENTIAL

One challenge of the US offshore wind market is the political uncertainty at both the federal and state level. An offshore wind farm cannot be constructed before its environmental assessment is completed, which can take up to a decade. For example, Vineyard Wind Farm had an original construction start date on Jan 1, 2020, because the environmental assessment was supposed to finish before the end of 2019. BOEM, however, claimed to "expand its environmental review to the cumulative impact of all American offshore wind development programs", and environmental assessment on Vineyard Wind Farm will not be completed before March 2021 (BOEM, n.d.; BOEM, 2020). Political uncertainty leads to increased financial costs. The possibility of delay can lower investors' confidence and increase the cost of capital for an offshore project.

Current US offshore wind projects have relatively high debt-to-equity ratios. Only a small number of investors are willing to take on offshore wind projects with unpredictable permitting times (Business Network for Offshore Wind, 2018). The share of equity is also expected to decrease even further as tax credits are on a phase down schedule (DOE, 2019). Without concern for prolonged investment horizons and uncertainty in investment returns, the National Climate Bank may invest in more offshore projects in its preliminary stages to minimize this risk and push for a faster development of the offshore wind industry, increasing renewable energy shares being the primary goal.

Fortunately, European lenders still see the US offshore wind market as profitable, and are willing to provide low interest debt financing (Business Network for Offshore Wind, 2018). European wind energy companies are also actively seeking involvement in US offshore wind.

ROLE OF THE NATIONAL CLIMATE BANK

Investment in Wind Farms

As a public-funded, non-profit organization, the National Climate Bank can promote promising emissions reduction technologies by reducing risks to build wind farms. The Climate Bank can provide low-interest loans and other financial assistance to promote the application as well as innovation of offshore wind. Currently, the sole 30 MW offshore wind farm in the US is far below the industrial average of 600-800 MW so there is a significant potential for the Climate Bank to make a difference by investing in large-scale projects. As shown in Figures 3 and 4, the purple areas would be areas that the National Climate Bank can financially support, which is roughly 15% of the total project costs for wind farm projects. However, this support does not negate the potential delay as a result of the different assessments required before construction, such as environmental assessments, but it may put pressure on the reviewers as the Climate Bank is a major stakeholder.

Investment in Infrastructure

Another investment strategy that the Climate Bank may adopt to remove barriers to offshore wind development is to invest in port infrastructures that help offshore wind farm construction. A good deep-water installation and staging port for offshore wind must include heavy-lift capacity, adequate laydown for handling and storage of large components, and easy access for large specialized vessels (Andersen, 2020). East Coast port infrastructures need to be updated to meet the specific needs of the industry (Andersen, 2020). New York State is investing up to USD $200 million in New York port facilities to support the development of offshore wind (NYSERDA, 2020).

Strategies from Existing Green Banks

The National Climate Bank may also consider strategies from other green banks as the offshore wind industry in some European and Asian countries have realized significant cost reductions as the industry and supply chain have grown and matured.

Offshore wind projects in Europe and Asia are known to have a low-cost capital and have a continuing trend of declining equity and debt rate for renewable energy asset financing in recent years. In Europe offshore, wind investments in new projects increased by 37% from 2017 to EUR €10.3 billion. Project finance dominated offshore wind investment transactions (77%) and the share of debt in European project financing has been consistently at or above 70% since 2012 until now (Windeurope, 2019). Large offshore wind farms such as Moray East (950 MW), Triton Knoll (850 MW) and Borssele III & IV (732 MW) often have high financing leverage with at least 88% debt financing and these wind farms can used up to 32 banks to finance the projects (WindEurope, 2019).

The Macquarie's Green Investment Group (GIG) is a green energy principal investment business with the mission to accelerate the world's transition into a sustainable future. In Asia, Macquarie's GIG has assisted three Formosa offshore projects in Taiwan. Formosa 1 has signed a 20-year power purchase agreement (PPA) based on the feed-in-tariff scheme, with Taiwan Power Company for power offtake. Such project finance debt was secured in June 2018 from a group of local and international banks. The Formosa 1's consortium comprises 11 international and local Taiwanese banks, along with EKF, Denmark's export Credit Agency to provide $627m in project financing over a period of 16 years (Formosa 1, n.d.). Cost-competitiveness and reduced risk perceptions have attracted domestic and international market players looking to diversify their portfolios and align with their sustainability targets.

After Formosa 1, GIG continued to invest in a 376MW Formosa 2 offshore wind power project, which was commissioned in December 2019. The Formosa 2 wind farm is expected to produce enough electricity to power 380,000 households a year and offset approximately 18.75 Mt of carbon emissions in its lifetime. The Formosa 2 offshore wind farm is being jointly developed by different investment groups such as JERA (49%), Macquarie Capital (26%), and Swancor Renewable Energy (25%) (Formosa 1,n.d.). "Macquarie earlier had a 75% interest in the project of which JERA, a 50:50 joint venture between Tokyo Electric Power (TEPCO) and Chubu Electric, acquired 49% in October 2019"(Formosa 1, n.d.).

Offshore wind projects in the United States may currently elect the investment tax credit (ITC) or production tax credit. It is commonly expected that US offshore wind projects will have a preference to elect the ITC. However, for future construction after January 1 2020, the applicable ITC rate will be 0% (Musial, 2019). With tax credits expected to phase out over the next few years, high Renewable Portfolio Standards (RPS) requirement levels are starting to take effect in coastal states, and this might mitigate some of the lost tax benefits. Experts suggest that early commercial-scale US projects may experience a relatively high contingency level compared to established European offshore wind markets (Musial, 2019). This is due to the underdeveloped US offshore wind power plant installations and operations, which run the risk of incurring delays and interruptions in the supply chain, environmental assessments, and permitting processes.

Thus, the National Climate Bank’s involvement in catalyzing investment will help the US market reach its full potential. The participation of the Climate Bank cannot only provide a large amount of capital to bridge the gap between supply and demand, but also share project risks and boost market confidence, attracting increased private capital in sustainable projects. R&D is also needed to adapt existing European technologies to the unique conditions of the US market and enable cost-effective deployment. To facilitate a robust and sustainable offshore wind industry in the US and achieve competitiveness in electricity markets, investment in technology and supply chain might also have significant cost-reduction impacts. For instance, physical site conditions along the US coastline have some similarities as the established European market. However, there is a lack of standardized methodologies for gathering data that increases uncertainty and risk, and ultimately increases the capital costs of offshore wind projects.

MONITORING OFFSHORE WIND INVESTMENTS

By 2050, the US is expected to see a completion of a total of 86 GW offshore wind projects. If the National Climate Bank were to support offshore wind projects at various capacities, it would be important for the Climate Bank to be able to monitor those projects, such that the emissions reductions are truly maximized and that there is a reasonable financial return. Thus, the Climate Bank may also want to establish a monitoring system for emissions reductions as well as a cost-benefit analysis to measure the effectiveness of the investment. This kind of oversight can reduce difficulties as the projects proceed. Monitoring details are expanded upon below.

I. Measuring Emissions Reductions

RenewableUK calculates the carbon reduction of offshore wind projects by multiplying the total amount of electricity generated by wind per year by 450 tonnes per GWh, the number of tonnes of carbon which fossil fuels would have produced to generate the same amount of electricity (RenewableUK, 2020). For the Vineyard project, the company estimated to eliminate 1.68 million metric tons of carbon dioxide emissions annually (Vineyard, 2020). Similar carbon reduction potential can be expected for projects in New York (See Appendix B).

II. Measuring Cost

The costs of an offshore wind project relate to capital expenditure (CapEx), which represents expenditures required for commercial operation of offshore wind projects in a given period (i.e., wind turbine cost, construction cost, and financial cost) (NREL, 2020). The capacity-weighted average CapEx for a fixed-bottom offshore wind farm in the US is USD $3600/kW, and this number is expected to decline in future decades (Department of Energy, 2018). The estimated lifespan of a 600 MW offshore wind farm is around 15-20 years with the annual Operation and Maintenance (O&M) cost of USD $121/kW-year (NREL, 2020). Overall, the levelized cost of energy (LCOE) of offshore wind projects, which summarizes CapEx, O&M, and capacity factor, is between USD $120/MWh and USD $160/MWh for a commercial-scale offshore wind project in the northeastern US (Department of Energy, 2018).

III. Benefits and Financial Returns

The financial return of a wind farm typically comes from power and clean energy benefits (Renewables Obligations Certificates, or ROC) sold to buyers via PPA; the price of PPA is usually determined by regional electricity prices. Vineyard Wind has negotiated a PPA price of USD 7.4 cents / kWh for phase 1 with the Massachusetts electric distribution company. NREL estimated that the LROE of Vineyard offshore wind would be USD 9.8 cents / kWh based on an 18% ITC rate (NREL, 2019). Since current electricity prices in New York (21 cents/kWh) and Massachusetts (22.2 cents/kWh) are similar, we assume the PPA price for the proposed wind farm to be USD 7.4

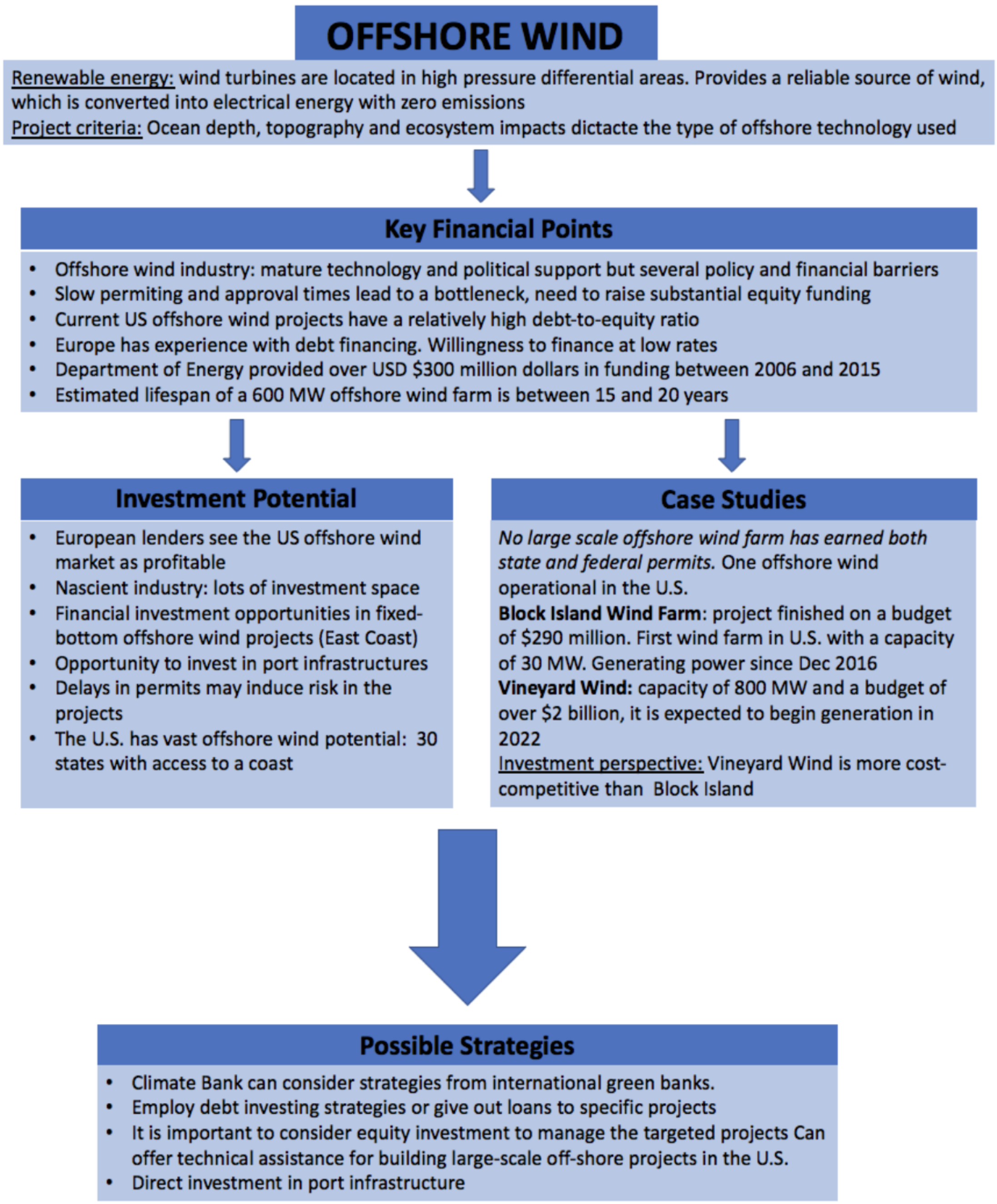
cents / kWh as well. However, ITC from the federal government is reported to be reduced to 0 for projects constructed beyond 2020, so income assumptions are left out for this tax credit (NREL, 2019). The reduction of ITC also indicates the importance of the climate bank to invest in offshore wind, as the private investments may be disincentivized. Since New York is part of the Regional Greenhouse Gas Initiative (RGGI), the project is expected to gain revenues from regional carbon trading as carbon prices go up.

IV. Challenges

In early stages, commercial-scale US projects may bear higher contingency levels compared with European ones due to the higher risks of incurring delays and interruptions in the supply chain, environmental assessments, and permitting processes (Department of Energy, 2018).

SUMMARY

The following figure shows a summary of all the key points mentioned in this analysis to help the Climate Bank's investment strategy in offshore wind. It includes the current status, investment potential and the suggested financial strategies for investment.



CONCLUSION

The Offshore Wind sector demonstrates tremendous growth potential in the US, with an opportunity for 2,000 GW of renewable power. Offshore wind is quickly becoming increasingly competitive through increasing Capacity Factor and falling Levelized Costs of Energy, and the National Climate Bank can contribute by reducing finance costs for public and private investors. One of the biggest barriers to investment is volatile and lengthy permitting, which can discourage investment. However, the political stage on the East Coast is set to grow the industry immensely by mid-century to help meet individual state's renewable energy goals, and individual state policies have been crafted to incentivize bidding and investment. Fixed-bottom technologies for the East Coast have competitive levelized costs which are continually decreasing as they have over the past decade. The National Climate Bank's investment in offshore wind thereby works on two levels: reducing financial costs of the capital asset and thus total project costs, and growing regional economies of scale. Possible strategies for achieving these ends that should be further explored are a) directly investing in port infrastructure, and b) providing project debt and equity. As the volume of offshore wind projects begins to take off, the industry will reach economies of scale and further decrease costs for developers. At global scale, Project Drawdown estimates the offshore wind sector could reduce 10.44-11.42 Gigatons of CO_2 by 2050 (Project Drawdown, 2020). Investment in offshore wind is an important piece of a dynamic energy transition necessary to mitigate the detrimental effects of climate change.

APPENDIX

Appendix A. Recent state policies in the Northeast that have driven both wind and offshore wind investments

STATE	POLICY	PURPOSE	WIND INVESTMENTS
Massachusetts	Massachusetts Energy Diversity Act (2016)[6]	Sets the target of generating 1600 MW of offshore wind energy by 2027	Distribution companies issue Request for Proposals for long-term contracts to develop offshore wind projects to meet targets[7]
	An Act to Advance Clean Energy (2018)[8]	Sets the target of building an additional 1600 MW from the previous Energy Diversity Act	Implementing a cost benefit analysis on distribution companies should they incorporate offshore wind generation solicitations
New Jersey	Offshore Wind Economic Development Act (2010)[9]	Establishes Offshore Wind Renewable Energy Certificates (ORECs) to incentivize offshore wind development infrastructure	Creates certificates for offshore development
	Clean Energy Act (2018)[10]	Establishes new clean energy and energy efficiency programs to diversify New Jersey's renewable energy portfolio standards	Offshore Wind Strategic Plan includes the creation of the WIND Institute, which has a primary role of creating investment opportunities for offshore wind
Rhode Island	Long-Term Contracting Standard for Renewable Energy (2009)[11]	Mandates electric distribution companies to form long-term contractual agreements with renewable energy developers to meet renewable energy generation targets of generating 90 MW	Provided power purchase agreements for the Block Island offshore wind project
	Affordable Clean Energy Security Act (2014)[12]	Influences electric and natural gas distribution companies to invest in alternative renewable energy sources, infrastructure, large-scale hydropower, and natural gas	Investment in renewables, including wind, and infrastructure
New York	Clean Energy Standard (2016)[13]	Sets a renewable electricity goal of 70% by 2030	NY State Offshore Wind Master Plan incentivizes supply chain investments
	Climate Leadership and Community Protection Act (2019)[14]	Addresses and mitigates the impacts of climate change through emissions reductions, increased energy production from renewables, create green jobs and address environmental justice	Allocates investments to underserved communities and increased accessibility to renewable energy as an end-user

[6] The General Court of the Commonwealth of Massachusetts, "Bill H.4568."
[7] Commonwealth of Massachusetts, "Offshore Wind."
[8] Commonwealth of Massachusetts, "An Act to Advance Clean Energy - Session Law - Acts of 2018 Chapter 227."
[9] NJ Department of Environmental Protection, "New Jersey Offshore Wind Energy."
[10] NJ Clean Energy Program, "Offshore Wind | NJ OCE Web Site."
[11] State of Rhode Island Office of Energy Resources, "Rhode Island Energy Laws"
[12] State of Rhode Island Office of Energy Resources, "Rhode Island Energy Laws"
[13] New York State, "Governor Cuomo Announces Establishment of Clean Energy Standard That Mandates 50 Percent Renewables by 2030."
[14] NYSERDA, "New York State Offshore Wind."

Appendix B. Estimated outcome of a 600-800MW project in New York

COSTS		
Capital Expenditure (CapEx)	wind turbine cost, the balance of system, and financial cost	$3600/kW
Operation and Maintenance (O&M) cost	For lifespan of 15-20 yrs	$121/kW-year
Capacity factor		45%-50%
Levelized cost of energy (LCOE)	Taking CapEx, O&M and Capacity factor into account	$120MWh - $160MWh
BENEFITS		
PPA price	Depend of LCOE and regional electricity price	$74/MWh (Vineyard Project)
Levelized Revenue of Energy (LROE)	Based on 18% ITC	$98/MWh (Vineyard Project)
Emission Reduction	Uncertain	1.68 million metric tons of carbon dioxide/ year (Vineyard Project)

All currency in USD

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