New York Offshore Wind Cost Reduction Study

Final Report

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Notice

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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

AEP	Annual Energy Production
AMI	Area of Mutual Interest
BOEM	Bureau of Ocean Energy Management
CAPEX	Capital Expenditure
CfD	Contract for Differences; In offshore wind, a CfD works by stabilizing revenues for generators at a fixed price level. Under a CfD, generators will receive revenue from selling their electricity into the market as usual. However, if and when the market reference price is below the fixed price the generator will also receive a payment from suppliers to bring the revenue to the fixed amount. Conversely if the reference price is above the fixed price, the generator must pay back the difference.
DEVEX	Development Expenses
DOS	NYS Department of State
EPC	Engineering, Procurement, and Construction
FC	Financial Close; triggers ability to enter contracts for construction (project financing) or draw downs for construction expenditures (balance sheet financing) ; for this study, U.S. construction was assumed to start one year after FC and last 2 years followed by 6 month site commissioning prior to wind farm operation.
FEED	Front End Engineering and Design: The work required to produce process and engineering documentation of sufficient quality and depth to adequately define the project requirements for detailed engineering, procurement, and construction of facilities and to support a ±10 percent project cost estimate.
FID	Final Investment Decision; Typically used in context of equity decision, stage in a financial agreement where conditions have been satisfied or waived and documents executed; triggers draw-downs and project execution.
FiT	Feed-in Tariff; An economic policy created to promote active investment in and production of renewable energy sources. Feed-in tariffs typically make use of long-term agreements and pricing tied to costs of production for renewable energy producers.
GG	Green Giraffe
G&G	Geophysical and Geotechnical
IEA	International Energy Agency
IO&M	Installation, Operations, and Maintenance
IRR	Internal Rate of Return
KIC	Knowledge Innovation Cluster
LCOE	Levelized Cost of Energy
Metocean	meteorological and oceanographic
nm	nautical miles
NREL	National Renewable Energy Laboratory
NYS	New York State
OCS	Outer Continental Shelf
OFTO	Offshore Transmission Operator
OFWIC	Offshore Wind Integrated Cost
OPEX	Operational Expenditure
OMS	Operations, Maintenance, and Service
OSW	Offshore Wind
POI	Point of Interconnection: The point where interconnection facilities connect to a transmission provider’s transmission system. As defined in standard large generator interconnection agreements.
PPA	Power Purchase Agreement
SIOW	Special Initiative on Offshore Wind
TCE	The Crown Estate
UXO	Unexploded Ordnance
WRF	Weather Research and Forecasting

Summary

S.1 Introduction

New York State's offshore wind (OSW) resource presents substantial potential for production of zero-emission electricity. Indeed, many believe that offshore wind energy could become the most viable option for delivering utility-scale renewable electric generation to the densely populated downstate region of New York. Although onshore wind development has expanded rapidly in the U.S., exploiting offshore resources is more challenging than onshore development. OSW presents unique and complex development, construction, and operational conditions. There is also the need to establish offshore wind specific development and operational infrastructure that does not exist today in the U.S. Consequently, current cost estimates for offshore wind energy are substantially above market electricity prices.

According to Navigant's Offshore Wind Market and Economic Analysis: 2014 Annual Market Assessment Report, the capital cost of offshore wind is in excess of $5,000 per kilowatt (kW). However, Navigant also reports that cost is declining.

This paper examines and quantifies the potential for reduced OSW project costs through technological innovation, global market maturation and actions that New York could undertake unilaterally or in collaboration with other Atlantic coast states.

S.2 Study Objectives and Approach

The objectives of this study were to identify and quantify:

- Global cost-reduction opportunities for OSW that will be transferrable to the U.S. and NYS
- Cost reductions associated with U.S. experience (or learning) as additional NYS projects are deployed
- NYS-specific interventions or actions to reduce the cost of offshore wind and their associated impacts:
    - The sequence of actions necessary to meet these cost reductions and an explanation of any identified dependencies.
    - An evaluation of the risks and challenges associated with the suggested interventions.
    - An analysis of any scaling needed to achieve cost reductions.
    - An estimate of OSW cost reductions produced by each suggested intervention.
    - An estimate of the cost to NYS for each OSW interventions.

S.2.1 Study Approach

The University of Delaware's Special Initiative on Offshore Wind (SIOW) identified a project site in the New York ocean that could be considered optimal for OSW energy production (limited distance to shore, nearby point of interconnection, and strong wind resource). On this project site, SIOW performed two analyses. First, an estimate was established of the Levelized Cost of Energy[1] (LCOE) for a hypothetical OSW project (Base Project, see Figure 1 in Section 2.3, installed capacity of 600 MW) located in NYS waters using 5 MW wind turbines, assuming U.S. OSW policy and financing are stagnant. The term stagnant is used to represent a U.S. environment that does not have any supporting OSW federal or other state policies that would lead to a more favorable OSW financing environment.

Second, an estimate was established at the same project site assuming stagnant U.S. OSW policy, but adding global innovations in technology with an increase in turbine scale to 8 MW, increased competition in the OSW supply chain, and industry-wide efficiencies driven by European market demand (collectively, global cost reductions) applied to derive a revised LCOE. This study did not include any consideration of federal incentives such as PTC, ITC or carbon credits.

According to published analyses, 5 MW wind turbines have been expected to be used in new U.S. offshore wind projects, consistent with recent European projects.[2] 6 MW and 8 MW turbines have recently become commercially available.

The SIOW team next identified four additional project sites, each having a nameplate rating of 600 MW (Projects 1 through 4, See Figure 3 in Section 2.3), having a Financial Close (FC) each year from 2020 through 2023, for a total of 2.4 GW which served as a hypothetical "Build-out scenario." LCOE's were calculated for each of these projects assuming: 1) the range of global cost reductions expected to occur and be transferable to the US market throughout the build-out time frame, 2) the benefits of experience or "learning" in the U.S. associated with increased market demand and related activities (increased efficiencies), and 3) a group of NYS-specific market interventions applied over the build-out time. NYS-specific interventions were identified through stakeholder interviews and the impacts on delivered costs for each NYS-specific intervention were estimated using expert elicitation.[3]

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[1] LCOE is the equivalent unit cost ($/MWh or ¢/kWh) that has the same present value as the total cost of building and operating a generating plant plus investor returns over the power plant's life divided by total electrical generation. Levelized Cost of Electricity Calculator, NREL, http://www.nrel.gov/analysis/tech_lcoe.html

[2] Navigant, Offshore Wind Market and Economic Analysis: 2014: Annual Market Assessment Report.

[3] The projected LCOE's did not include continuous technological development beyond FC 2023, such as 10-MW or larger turbines, which are concept and/or prototyping stages, further learning effects if U.S. scale grows by more than 3.5 GW between 2020 and 2023, nor further learning effects for market development beyond FC 2023.

LCOE is a commonly used metric for the cost of electricity produced by a power generator over the life of the project. The general inputs for calculating LCOE for OSW are capital expenditures, operating and maintenance costs, cost of capital, and the expected annual energy production of the OSW farm. This is different from a Power Purchase Agreement (PPA) price, another indicator often cited. The price of a PPA is very different from the cost of generation (LCOE) for an offshore wind project.[4] Generally, LCOE prices will be higher than PPA prices. Furthermore, it is important to note that while LCOE is a useful metric for understanding how changing technological, market, or policy conditions can affect the fixed, variable, and financing costs of a generation technology, it is of limited use as a measure of the overall comparative value of a technology in practice. This is because LCOE does not consider system benefits, system costs, or environmental and health benefits.

S.3 Impacts on NYS LCOE

The study identifies and compares the impact of three main areas of cost reduction: global cost reductions, cost reductions associated with increasing U.S. learning/scale, and cost reductions associated with NYS interventions. These cost reductions were applied sequentially to the prospective NYS projects to determine the relative and total applicable impacts to LCOE.

S.3.1 Global Cost Reductions

To achieve the first objective of the study which was to consider the impact of global cost reductions in isolation, the team first calculated LCOE of OSW using a 5 MW turbine for the study's Base project and compared that to the calculated LCOE of OSW using an 8 MW turbine including the technological innovations and industry efficiencies anticipated to be pulled to market by 2020. The team further analyzed the impact of the continuous technological improvement anticipated from FC 2020 to FC 2023 on the LCOEs for subsequent projects in the Build-out scenario.

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[4] Musial and Ram 2010, Large Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers. NREL/TP-500-40745, p. 119.

Table S-1 and Figure S-1 illustrates changes in LCOE by project attributable only to global cost reductions. Specifically, Table S-1 and Figure S-1 show that even in a stagnant U.S. policy and financing environment, a 22% decrease in LCOE can be derived from moving to larger turbines with ongoing technology improvement and industry efficiencies. The 5 MW turbine in a stagnant U.S. policy and financing environment produces an LCOE of over $290 per megawatt-hour (MWh) versus about $226/MWh after capturing global advances in technology through the use of larger turbines and global industry maturation. Moreover, anticipated continuous technological development between 2020 and 2023 are expected to result in continuous downward pressure on delivered costs, again continuing to assume an immature U.S. policy and financing environment. This decrease may be partially offset by increases in costs associated with moving to deeper water sites as projects are installed. For this period of study and the referenced cost reduction analysis, the study team assumed a U.S. installed capacity of roughly 750 MW of OSW by the end of 2020.[5] Table S-1 and Figure S-1 illustrate the changes in LCOE resulting from global cost reductions as the number of projects increases.

Table S-1. Impact of Continuous Global Cost Reduction on NYS LCOE (Stagnant OSW Policy and Financing)

Project	Financial Close Year	LCOE ($/MWh)	% Change from Base Project - 5 MW
Base Project – 5 MW	2020	291.5	N/A
Base Project – 8 MW	2020	226.5	- 22%
1[6]	2020	220.5	- 24%
2	2021	206.5	- 29%
3	2022	205.5	- 29%
4[7]	2023	222.5	- 24%

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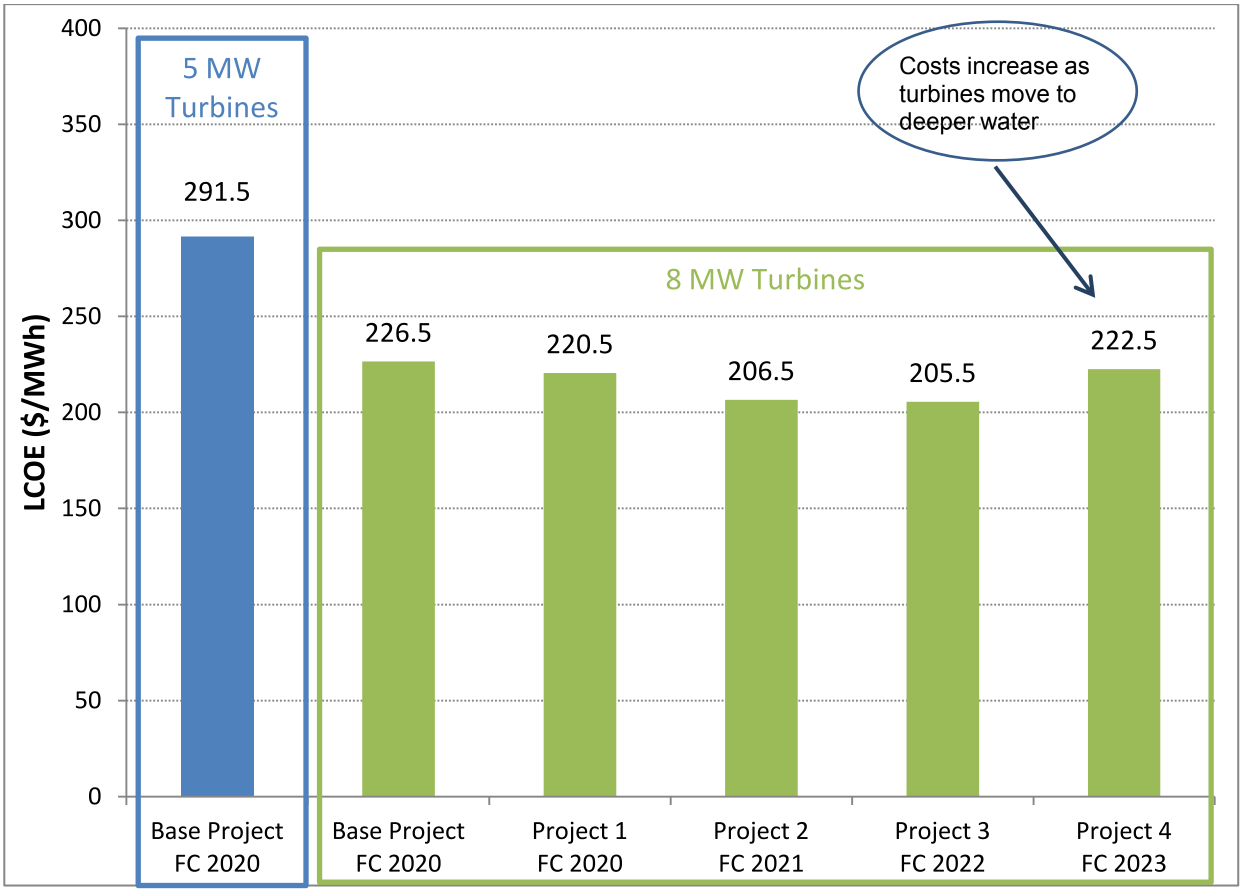
[5] The team assumed the installation of the Cape Wind project in Massachusetts, the Deepwater Wind project off Block Island in Rhode Island, the U.S. Wind project off the coast of Maryland, and the three U.S. DOE advanced technology demonstration projects under development at the time of this writing.

[6] Base project sited at 12 nautical miles (nm) from shore; Project 1 sited at 9 nm from shore.

[7] The LCOE increases with later projects as the project sites move to deeper water.

Figure S-1. Impact of Continuous Global Cost Reduction on NYS LCOE (Stagnant OSW Policy and Financing)[8]



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[8] Cost figures for the 5 MW turbine and foundation were estimated using proprietary cost data available to the team members as well as publicly available data. Cost figures for the 8 MW turbine at Financial Close 2020 came from BVG Associates (1) see Bibliography. Cost figures for the 8 MW turbine for FC 2021 – FC 2023 also came from BVG Associates (2), see Bibliography.

S.3.2 U.S. Learning/Scale

The second objective of the study is to quantify the effect of learning curves (also known as experience curves) on NYS offshore wind LCOE. Learning curves express the trend for cost of a technology to decrease as higher quantities of that technology are deployed to its market. As OSW projects are installed and operated in the U.S, acquisition of new skills and knowledge in project development and operations are expected to lower project cost and ultimately LCOE. To analyze the impact of this learning, the SIOW applied a learning rate of 5%, for every doubling of capacity installed[9] over the study period. Using this rate of learning, the study team calculated LCOE's for each project in the Build-out scenario (2.4 GW), assuming a parallel and additive market build out of 1.1 GW of OSW between the end of 2020 and the end of 2023.[10] Table S-2 and Figure S-2 illustrate the changes in LCOE resulting from acquired U.S. learning or experience as the number of U.S. projects increases. These figures reflect that global cost reductions have been achieved but still assume a stagnant U.S. OSW policy and financing environment. The associated change in LCOE is on the order of 2%.

Table S-2. Impact of U.S. Learning on NYS LCOE (Stagnant OSW Policy and Financing)

Project	Financial Close Year	LCOE Before 5% learning rate applied ($/MWh)	LCOE After 5% learning rate applied per doubling of U.S. Capacity ($/MWh)	% change
Base Project-8MW	2020	226.5	222.5	-1.8%
1[11]	2020	220.5	217.5	-1.4%
2	2021	206.5	202.5	-1.9%
3	2022	205.5	200.5	-2.4%
4	2023	222.5	216.5	-2.7%

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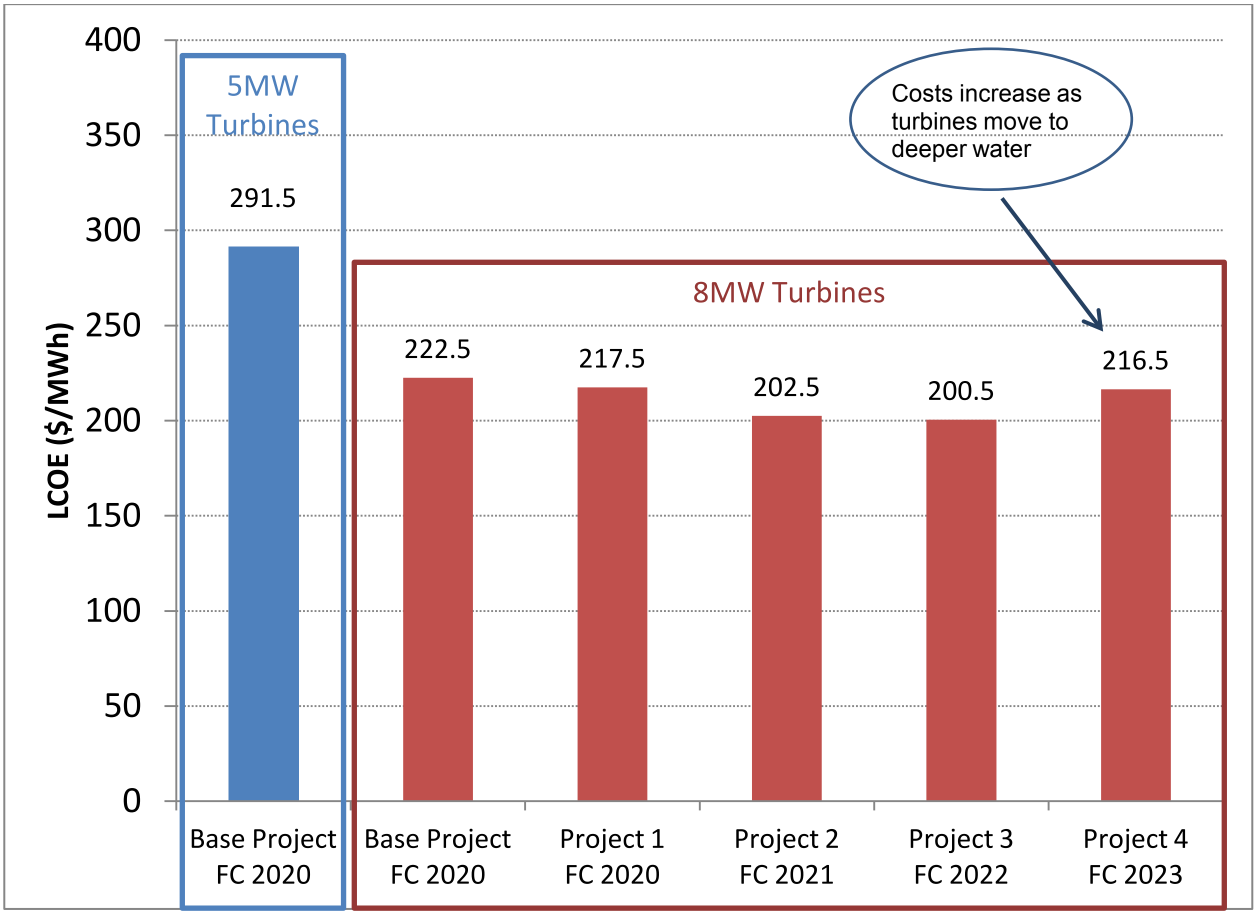
[9] Weiss, Jurgen, M. Sarro and M. Berkman (2013). "A Learning Investment-based Analysis of the Economic Potential for Offshore Wind: The case of the United States," prepared for the Center for American Progress, the U.S. Offshore Wind Collaborative, the Clean Energy States Alliance and the Sierra Club.

[10] The additional 3.5 GW of OSW between 2021 and 2023 assumed the construction of the study's hypothetical Build-out scenario (2.4 GW) and the implementation of New Jersey's Offshore Wind Economic Development Act, which supports 1.1 GW of offshore wind in that state.

[11] Base project sited at 12 nautical miles (nm) from shore; Project 1 sited at 9 nm from shore.

Figure S-2. Impact of Continuous Global Cost Reduction and US Learning on NYS LCOE (Stagnant OSW Policy and Financing)[12]



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[12] See footnote 10.

S.4 NY State Interventions

To achieve the study's third objective, the team identified and quantified potential NYS interventions that could lower LCOE beyond the reductions achieved through global cost reductions and learning/scale. Specifically, the interventions studied were those expected to result in reduced financing costs, capital expenses (CAPEX), and operational expenditures (OPEX).

New York can benefit from inherently local cost reduction interventions such as:

- Creating a visible market of scale and duration (market visibility) through a long-term commitment to a pipeline of projects.
- Making project data available to the market over successive rounds of OSW project solicitations to reduce risks and lower the cost of capital, enhance competitive forces and drive cost efficiencies.
- Providing a high degree of site characterization for early projects thereby reducing development expenses and cost of development capital.
- Designing policy to ensure revenue contracts are available that substantially reduce risk to lenders.
- Creating and using innovative financing mechanisms and exploiting favorable borrowing conditions.
- Developing infrastructure to reduce costs, including both port facilities and a trained workforce.

Interventions and impacts were identified and examined in the areas of: market visibility; pre-development activities including site characterization; contracting and revenue certainty; financing; infrastructure development (investment in facilities and training), installation, operations, and maintenance; and transmission. Table S-3 identifies the cost impacts associated with each intervention examined on CAPEX, OPEX, annual energy production (AEP), weighted cost of capital (WACC) and LCOE.

It is critical to note that the impacts identified in Table S-3 are not additive as each was derived in isolation from the others which ignores the expected correlation among impacts caused by combining interventions.

Table S-3. Summary of Impacts by Intervention (Note: Impacts are not Additive)

Intervention		Impacts					
		Cost of Intervention	Capital Expenditures (CAPEX)	Operating Expenditures (OPEX)	Annual Energy Production (AEP)	Weighted Average Cost of Capital (WACC)	Levelized Cost of Energy (LCOE)
Siting	Site at 8-9 nm from shore	$200,000[13]	- 1.7%	-14%	0%[14]	*Not estimated*[15]	-3%
Predevelopment	State obtains federal lease, conducts “enabling” offshore and onshore site assessments, including geophysical and geotechnical (G&G).	$5-$10 million	-0.5% DEVEX only[16]	0%	0%	0%[17]	-1.3%
Market Visibility 1	NYS commits to phased-in series of offshore wind projects in the New York ocean, dependent on negotiated long-term price reduction targets.	Administrative cost s of up to $1 million annually over 6 years	-15%	-20%	0%	-1.2%	Up to -30%

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[13] If NYS were to lead stakeholder engagement for siting decisions.

[14] Siting changes can impact AEP; however moving project 1 site from 12 nm to 9nm did not produce a difference in wind speeds and therefore had no impact on AEP.

[15] Siting without proper stakeholder engagement could increase risk.

[16] Reduction estimate applies to the DEVEX portion of CAPEX (those expenses incurred until the signing of main construction contracts for a project). By encouraging greater project Front End Engineering and Design (FEED) and potentially shortening permitting process, predevelopment activities can further reduce CAPEX. The impacts on CAPEX has not been quantified due to uncertainty regarding 1) how much greater FEED will become standard industry practice and 2) documented impact on permitting timelines.

[17] Whereas there are reductions in the cost of development capital, there are no reductions in WACC.

Table S-3 continued

Intervention		Impacts					
		Cost of Intervention	Capital Expenditures (CAPEX)	Operating Expenditures (OPEX)	Annual Energy Production (AEP)	Weighted Average Cost of Capital (WACC)	Levelized Cost of Energy (LCOE)
Market Visibility 2	Sharing of data after first project implemented to enhance competition and lower cost of capital in future projects	Included with Market Visibility 1	0%	0%	0%	-1.2%	-14.1%
Financing 1	Adoption of offshore wind revenue policy designed to reduce investor risk.	Ratepayer impact is beyond scope	0%	0%	0%	-0.2 to -0.4% -1.6%[18]	- 17 to -18%
Financing 2	Form an investment partnership between banks to fund offshore wind.	Opportunity costs, administrative costs.	0%	0%	0%	-0.2 to -0.4%	-1.8-2.6%
Installation, Operations, and Maintenance 1	Transfer knowledge from experienced European OSW project managers, supervisors and workers to the local workforce.	$500,000/yr. over 2 years	Already accounted for in U.S. learning rate	Already accounted for in U.S. learning rate	+ 0.75%	Not quantified[19]	-0.9%

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[18] Reflects the impacts of the two different levers on WACC: leverage ratio and reducing cost of equity.

[19] By lowering risk there may be some impact on WACC; however it is unquantifiable.

Table S-3 continued

Intervention		Impacts					
		Cost of Intervention	Capital Expenditures (CAPEX)	Operating Expenditures (OPEX)	Annual Energy Production (AEP)	Weighted Average Cost of Capital (WACC)	Levelized Cost of Energy (LCOE)
Installation, Operations, and Maintenance 2	Upgrade a New York port for the staging of New York offshore wind farms.	Range of $30 - $100 million (depending on selected location, its current infrastructure and existing assets)	-2% to -5%	0%[20]	0%	-1.2%[21]	-4.4%
Transmission	Connect wind farms via HVDC transmission "backbone."	$200,000 for transmission study to confirm actual capital cost of "backbone" (now estimated to be ~$600 million)	-	-	-	-	+ 3.6% – +9%[22]

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[20] Assumed that O&M ports and installation are different. O&M costs are unrelated to any change in installation port location.

[21] Only in conjunction with other policy interventions, not included in LCOE impact estimate.

[22] Median value of impact calculated using $600M/project, since intervention leads to an increase in LCOE, impact on separate elements of LCOE are not reported.

The relative (but not cumulative) impact of the interventions is shown in Figure S-3. Clearly the most impactful are interventions that create a market of scale and duration, contractually secure revenues for project developers and use innovative procurement mechanisms to foster competitive forces.

Figure S-3. Relative Impact on LCOE by Type of New York-specific Intervention

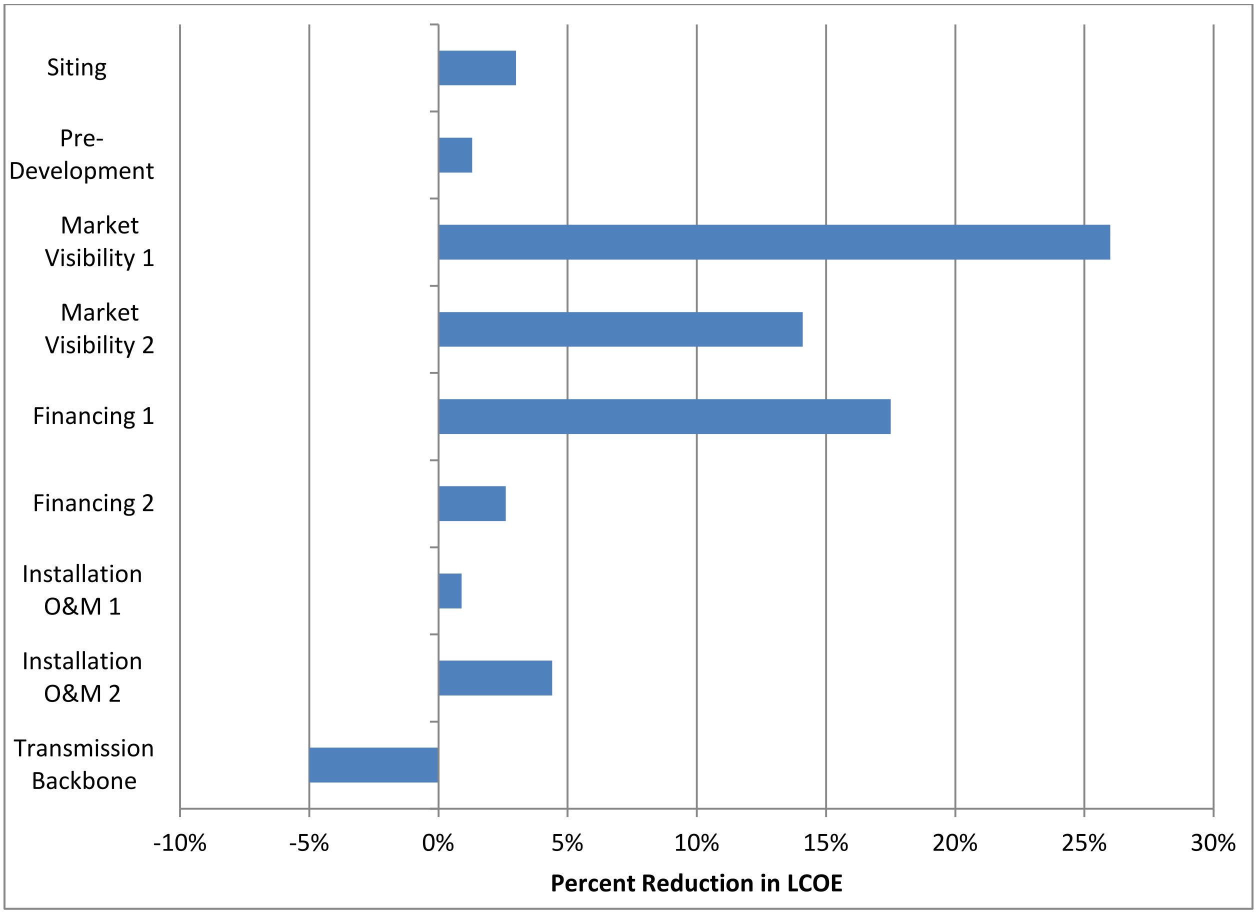

Figure S-3 shows the impact on LCOE of each intervention if applied separately (parametric analysis). Because the effects of interventions are correlated, when multiple interventions are applied to a project, the resultant total project impacts may be smaller than the sum of predicted impacts for each unique intervention.

S.4.4 Interventions: Bundled at Project Level

While Figure S-3 shows the impact on LCOE of each intervention_in isolation, the team also explored the cumulative impact of multiple interventions applied to individual projects. As projects are developed and constructed, differing interventions are most impactful and logical to pursue. SIOW selected Project 2 as representative of the four projects studied and analyzed the cumulative NYS interventions as shown in Table S-4.

Table S-4. Interventions Bundled for Project 2

Project	Applicable Interventions
2	• Siting[23] • Pre-development (assuming continuity of state sub-leasing and surveying done for full build-out area) • Continued market visibility through a pipeline of projects • Competitive bidding and project data (construction/production) made available from prior projects (either project 1, and/or similar projects in adjacent states, dependent upon length of time between Project 1 and Project 2)[24] • Risk-reducing revenue contract policy/mechanisms • Investment partnership to lend favorable borrowing conditions • Workforce training • New York installation port to stage projects

To quantify the impacts of potential NYS interventions, individually and in the aggregate, the team started with an assumption that no other policy interventions (state or federal) were in place favoring OSW, particularly those that would result in favorable financing terms as are present in Europe.[25]

After removing any co-related impacts from the bundle of NYS interventions, and applying each of the applicable interventions in a stepwise order, a corresponding impact on LCOE was produced as presented in Figure S-4.

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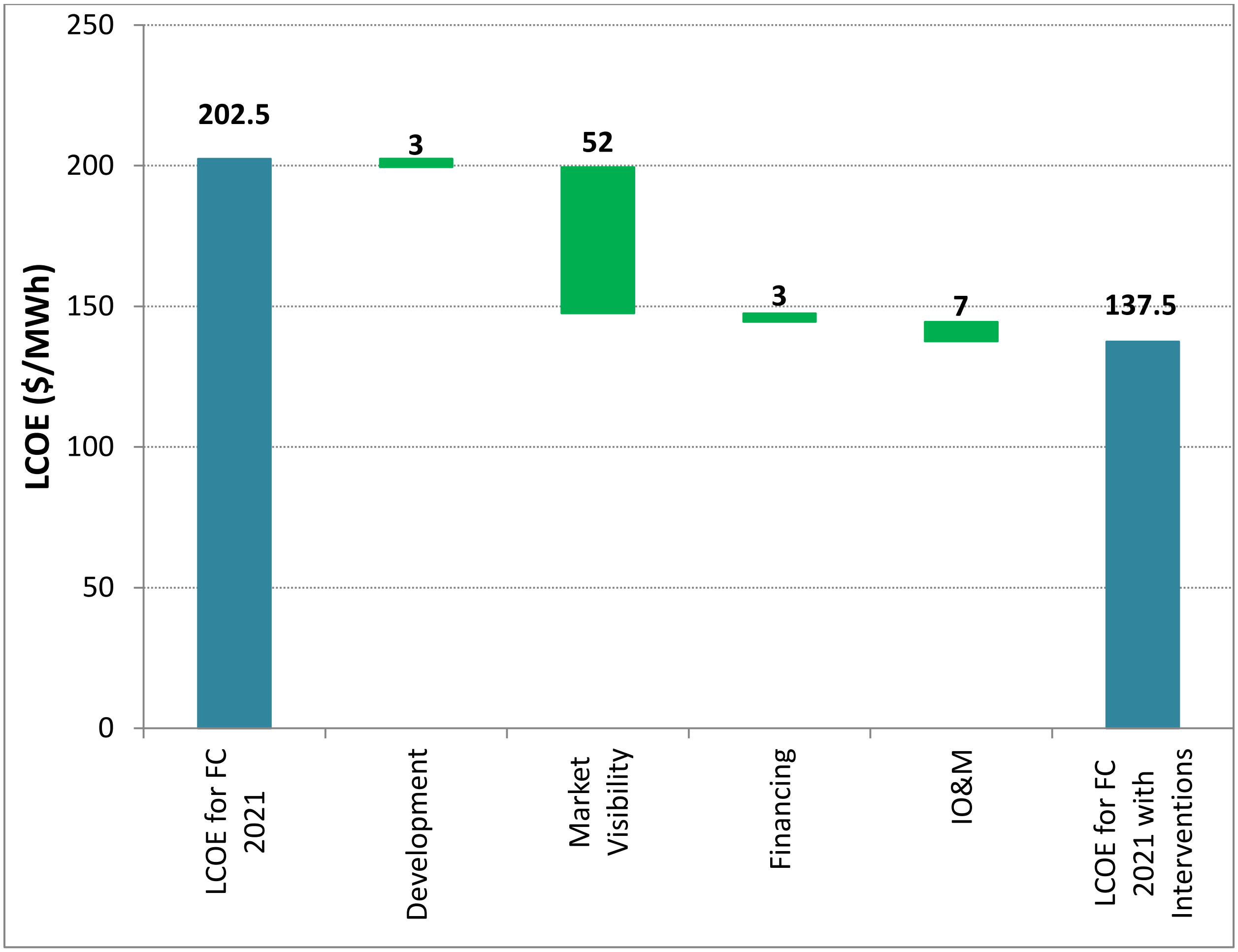
[23] Siting intervention for Project 1 and 2 was included in each project's starting point LCOE for these analyses.

[24] Financial close for the hypothetical projects occurs every year, thus construction and production data from Project 1 would not be ready by financial close of Project 2, when it could affect WACC. Nevertheless to illustrate the impact of such, the impact on Project 2 of making construction and production data available from Project I is included. To be realized in practice, such impacts would require either a greater time gap between projects than in our hypothetical sequence, and/or project data obtained from other U.S. projects.

[25] Cost of equity was assumed to be 15% for construction financing and 11% for permanent financing. Additionally, the study team set a floor of 8% on Equity IRR for the first three projects in the Build-out scenario, to prevent an unrealistic lowering of WACC. The study team did so because many of the interventions analyzed in this project lower WACC. The 8% floor was eliminated for the fourth project's analyses, per expert observations that as the industry matures, different types of institutions enter the space, in some cases taking less return than would normally be expected.

Figure S-4. Impact of Project 2 Interventions

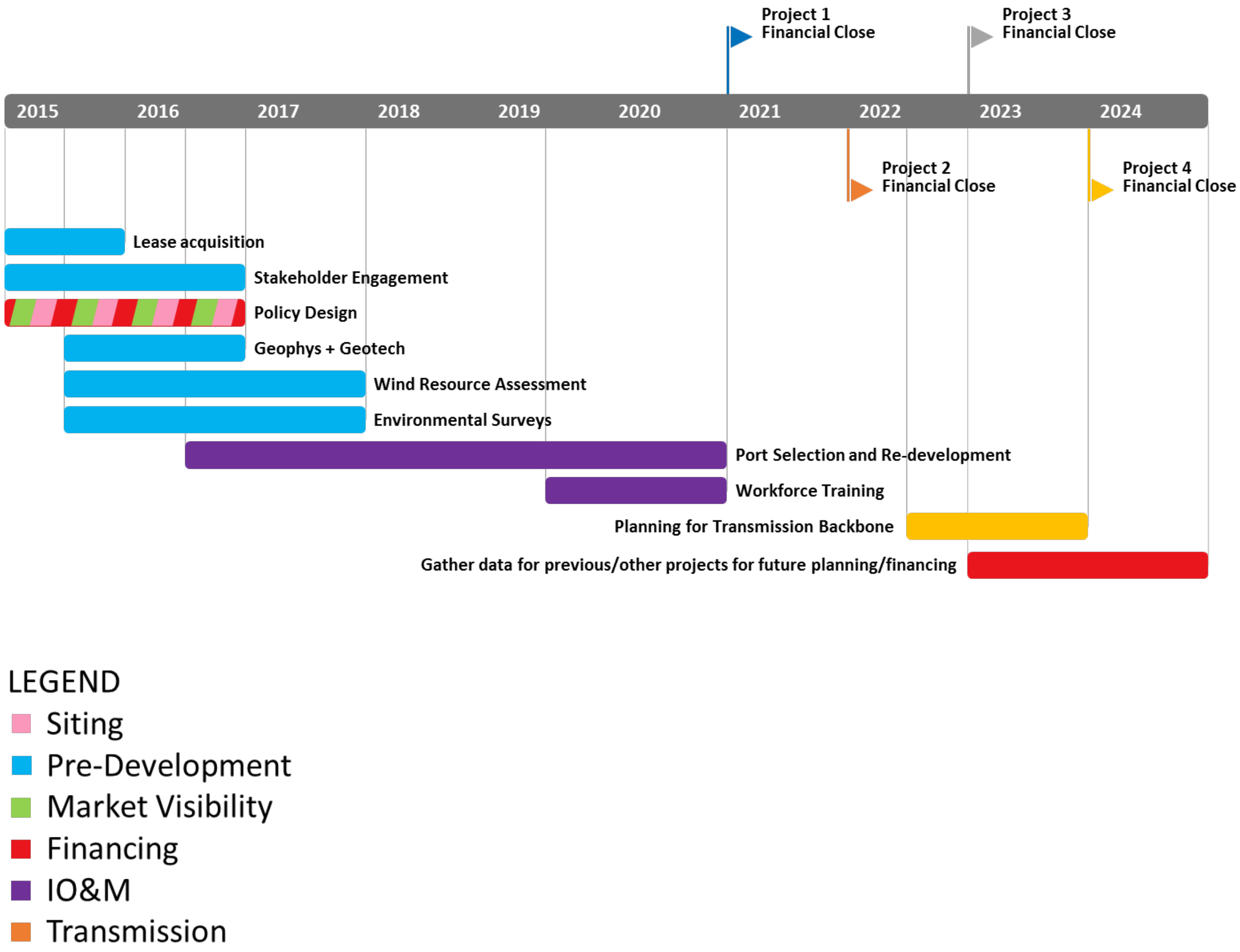


* LCOE for FC 2021 includes global cost reduction achievable by 2021, U.S. learning from previously installed capacity, cost of equity assumptions that reflect today's U.S. financing environment, and siting at 9nm.

Figure S-4 illustrates that in an environment in which global technology and global industry advancements are occurring but U.S. OSW policy development and financing are stagnant, NYS interventions can reduce LCOEs of New York OSW projects lower by about a third, to approximately $137.50/MWh. This cost reduction can be realized in NYS by enacting well-designed State policies and by making pre-development and infrastructure investments that taken together; reduce WACC, CAPEX, and OPEX.

Figure S-5 depicts a plausible timeline that would take advantage of all of the interventions detailed here that could collectively lead to a 50% cost reduction from the base case. This finding does not preclude the reality that bids could ultimately come from project developers that use some but not all of the interventions here or who have other routes to cost reduction which might be possible on a faster schedule than that shown here.

Figure S-5. Sequencing of Specific Actions Needed to Implement Interventions[26]



S.5 Conclusion and Next Steps

This study indicates that the cost of OSW energy for New York State projects with FC in 2020 and beyond is likely to be significantly reduced from baseline costs by assuming new turbines now being specified (8 MW) rather than continuing to assume the use of smaller turbines, as anticipated in previous market analyses. This finding assumes the materialization of anticipated global technological innovation, increased global competition in the OSW supply chain, industry-wide development and operational efficiencies driven by European market demand. First, these global forces will drive LCOE's for New York OSW projects with FC in 2020 roughly 20% lower than the costs for projects installed using smaller turbines.

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[26] The cost reduction estimates contained within this report are based on a timeline where contract execution commences in FC 2020. This sequence is illustrative of the associated timing and sequence of actions.

Second, additional incremental cost improvements are anticipated for New York OSW projects, as U.S. industry learning increases with increased market development in Atlantic coast states.

Third, the study shows there are direct steps that New York State itself can reduce NYS OSW project LCOE's that could reduce costs by up to another third by taking various actions:

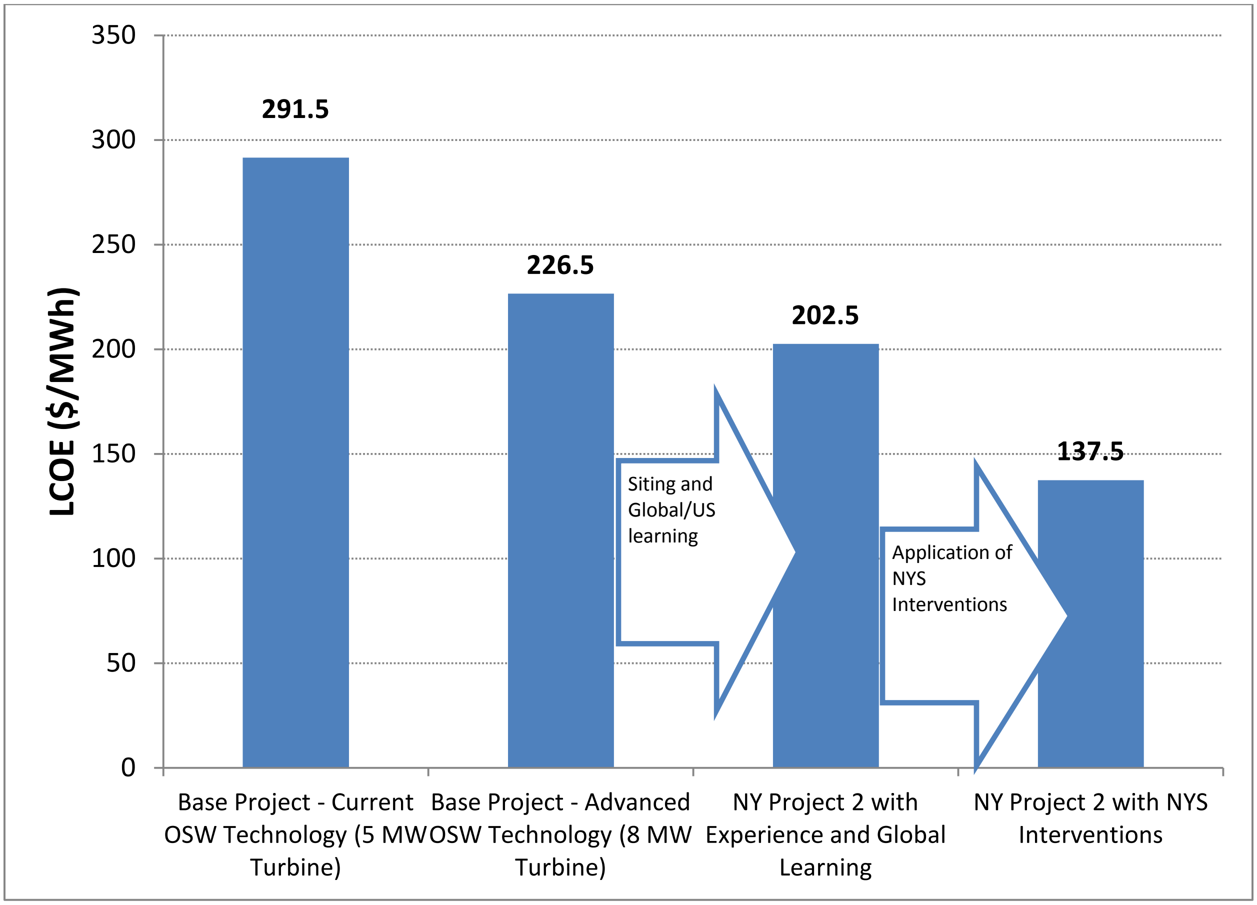
1. Creating a visible market of scale and duration (market visibility) through a long-term commitment to a pipeline of projects.
2. Making project data available to the market over successive rounds of OSW project solicitations to enhance competitive forces and drive cost efficiencies.
3. Enacting state level OSW policies and investment partnerships that reduce financing costs, CAPEX and OPEX. Enacting policies is a near-term and relatively low cost action that can set NYS on a path to add to the cost reduction that NYS is likely to see from global market advances.
4. Gaining site control and assessing the meteorological and oceanographic (metocean), environmental and ground conditions of potential sites. Relatively modest up front investments that provide site control and visibility can enhance bid precision (by both developers and through an enhanced negotiation position for NYS), lead to more developer capital invested in Front End Engineering and Design (FEED) activities that can in turn significantly reduce capital expenditures (CAPEX), potentially reduce time for permitting and provide more accurate weather risk-adjusted pricing.
5. Making extensive and longer-term infrastructure investments in OSW workforce training and potentially in port facilities to increase prospects for reaping the full benefits of economic activity associated with OSW project development and operations.

Table **S**-5 and Figure S-6 summarize the individual and aggregate impacts of these market trends and interventions.

Table S-5. OSW Cost Reduction Pathway

Project	Financial Close Year	LCOE ($/MWh)	% change	Cumulative % change
Base Project –(5 MW)	2020	291.5	N/A	N/A
Base Project –(8 MW advanced technology and global trends)	2020	226.5	-22	-22
NY Project 2 (advanced 8 MW) plus global and U.S. trends	2022	202.5	-11	-31
NY Project 2 (advanced 8 MW) plus global and U.S. trends, NYS interventions	2022	137.5	-32	-53

Figure S-6. Summary of Potential Cost Reductions for NYS OSW Projects



While this study conservatively assumes no improvements in OSW policies and financing until NYS interventions were applied, this study did not include several factors that could produce further cost reductions:

- technologies now in the conceptual or prototyping stages, including turbines 10 MW and larger[27] (10 MW turbines will likely be available during the NYS build-out; costs were not available to SIOW)
- a continued U.S. learning curve from technological and market developments beyond 2023
- potential continued development of substantial NYS offshore wind resources beyond the 2.4 GW build-out modeled in the study

In conclusion, this study identifies multiple pathways to reducing the cost of offshore wind power in New York State. The State can take actions in the near term to lower its costs substantially, independent of expected external reductions over the next decade. This study did not examine the benefits of offshore wind, which include economic, and system benefits, improving health and environmental conditions, and creating jobs and economic development. A full economic analysis of offshore wind would entail examining the total costs and benefits of energy production.

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[27] 4COffshore: http://www.4coffshore.com/windfarms/turbines.aspx (accessed February 14, 2015).

1 Introduction

New York State's offshore wind (OSW) resource presents substantial potential for production of zero-emission electricity. Indeed, some experts believe that offshore wind energy could become a very viable option available for delivering utility-scale renewable electric generation to the densely populated downstate region of New York in the next 10 to 20 years.

While onshore wind development has expanded rapidly in the U.S., exploiting offshore resources is more challenging than onshore development. Offshore wind presents an operating environment that is more challenging and more volatile to install and operate within. There is also the need to establish a development and operational infrastructure that does not exist today in the U.S. Consequently current cost estimates for offshore wind energy are substantially above market electricity prices.

To improve economies of scale, offshore wind projects in Europe have been scaled up to several hundred megawatts in size. The size of wind farms that are necessary to gain economies of scale contributes to offshore wind's high total upfront costs. Roughly 50% of those costs lie in the wind turbine technology itself; the other 50% of the cost is associated with factors such as project development, balance of plant equipment, logistics and installation, and siting.[28]

According to Navigant's *Offshore Wind Market and Economic Analysis: 2014 Market Assessment Report*, the cost of offshore wind is in excess of $5,000 per kilowatt (kW). However, Navigant also reports that cost is declining.[29]

This study examines and quantifies the potential for reduced OSW project costs through technological innovation, global market maturation and actions that New York could undertake unilaterally or in collaboration with others.

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[28] BVG Associates, Technology Workstream Report, Offshore Wind Cost Reduction Pathway Study, released June 2012.

[29] Navigant, Offshore Wind Market and Economic Analysis: 2014: Annual Market Assessment Report.

1.1 Study Objectives

The objectives of this study were to identify and quantify:

- Global cost-reduction opportunities for OSW that will apply to the U.S. and NYS.
- Cost reductions associated with U.S. experience as additional U.S. projects are deployed
- NYS-specific interventions to reduce the cost of offshore wind, providing:
    - The sequence of actions necessary to meet these cost reductions and an explanation of any identified dependencies.
    - An evaluation of the risks and challenges associated with the suggested interventions.
    - An analysis of any scaling needed to achieve cost reductions.
    - An estimate of cost reductions of each suggested intervention.
    - An estimate of the cost of an OSW program scaled to the needs of NYS.

2 Study Approach and Methods

This section describes the resources used, specific research questions, and the methods that the University of Delaware's Special Initiative on Offshore Wind (SIOW) team used in answering those questions.

2.1 Resources

This study drew upon the expertise of the SIOW's team, an advisory board, consultants, and other external stakeholders. SIOW's team includes offshore wind experts from industry and academia. The study's international advisory board is primarily from industry, but also includes representatives from government and a U.S. national laboratory, all of whom are working in offshore wind business and analysis.

2.2 Research Questions

This study sought to answer the following research questions:[30]

1. What is the expected cost reduction for offshore wind in the global market by 2019 and by 2025, assuming: (a) a global capacity of 40 GW in 2019[31] and 80 GW in 2025[32] and (b) the development of projects further offshore and in deeper water?[33] How are those cost reductions expected to be achieved?[34]
2. How and when might increasing economies of scale and innovations in the global OSW market produce cost reductions in the U.S. market?
3. How and when might NYS benefit from cost reductions in the global market? How and when might NYS undertake interventions, independently and with other states, to achieve additional cost reductions?
4. When should each NYS intervention begin? How should interventions be sequenced and how long will they take? Which actors (e.g., developers, financiers, policymakers) have the capability to carry out these actions? Can NYS influence these actors? If so, how?
5. What are the regulatory, financial, industrial, and other barriers to the suggested interventions, and what can NYS do to overcome them?
6. What volume of OSW production is needed to trigger cost reductions in NYS? What is the minimum geographical area required to support that volume? (NYS, Eastern seaboard, etc.) Does the volume need to be installed by a certain year? Must the volume be constant each year to trigger price effects?
7. How might NYS help stimulate the innovation and the market growth needed to trigger cost reductions without driving up ratepayer costs relative to other states?
8. What steps might NYS take, independently and with other states, to achieve the cost reductions needed to make OSW a viable part of the State's energy plan?

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[30] The following, ninth question, was initially requested but deleted at NYSERDA's request: 9. If NYS were to take actions to reduce the cost of energy from offshore wind, what would be the PPA cost/delivered cost at scale identified to drive cost reductions?

[31] Assuming 35GW in Europe (per EWEA), <1GW in the U.S., and allowing for growth in Asian markets.

[32] Assuming annual installations of 7.7GW growth in Europe between 2020 and 2025 (per EWEA), and allowing for modest growth in U.S. and Asian markets.

[33] EWEA estimates by 2025 projects will be developed primarily in waters less than 60 meters deep and within 60km from shore.

[34] Emphasis in this study will be placed on pre-development, foundation and construction, O&M, transmission, and financing.

2.3 Methods

To answer these questions, the SIOW team followed these steps, which are explained in more detail in the following sections:

- Conduct a literature review and review the key cost reduction studies done to date.
- Compare Levelized Cost of Energy (LCOE) from use of a 5MW turbine on a New York-specific site (Base project) with the LCOE from a wind farm built using technology associated with expected global cost reductions, on the same site.
- Develop a hypothetical offshore wind build-out scenario in the New York Bight in order to do associated cost modeling and determine LCOEs using technology with anticipated continuous improvement, and to which U.S. learning rates and NYS cost reduction interventions could be applied (Build-out Scenario).
- Estimate non-New York U.S. offshore wind likely to be built through 2025 and determine implications for project costs.
- Identify and develop NYS interventions that could reduce the cost of energy from offshore wind energy generated in New York.
- Estimate the potential impact of those interventions on the cost of energy in the hypothetical build-out scenario.
- Develop a method to estimate the combined impact of multiple interventions on the LCOE, accounting for overlapping or non-additive effects.

2.3.1 Estimating Impact of Global Cost Reduction

To estimate the impact of global cost reduction, the study team first identified a project site in the New York Bight by examining variables including water depth, wind speeds, ground conditions, exclusion areas, distance to shore, installation ports, and points of interconnection (POI). Based on this analysis, a project site was chosen that was determined to likely yield lower LCOE (hereafter referred to as “Base project.” The Base project site is illustrated in Figure 1. On this project site, SIOW performed two analyses. First, the team calculated LCOE for this site assuming use of a 5-MW turbine and that U.S. OSW policy and financing are stagnant. Stagnant is used to represent a U.S. environment that does not have any supporting OSW federal or other state policies that would lead to a more favorable OSW financing environment.

Second, SIOW calculated LCOE at the same project site continuing to assume stagnant policy and financing in the U.S. but assuming global innovations in technology including an increase in turbine scale to 8MW, and incorporating the numerous technological innovations, the benefits of increased global supply chain competition, and industry project development, installation and operational efficiencies anticipated for projects with FC 2020.

According to published analyses, 5 MW turbines have been expected to be used in new U.S. offshore wind projects, consistent with recent European projects.[35] There are 6 MW and 8 MW turbines commercially available today.

LCOE is a commonly used metric for the cost of electricity produced by a power generator of the life of the project.[36] The general inputs for calculating LCOE for OSW are capital expenditures, operating and maintenance costs, cost of capital and the expected annual energy production of the OSW farm. This is different from a Power Purchase Agreement (PPA) price, another indicator often cited. "The price of an individual PPA is very different from the cost of generation (LCOE) for an offshore wind project. Renewable energy projects receive subsidies from the federal government and include attributes such as renewable energy credits (RECs) and the value of capacity credits. These attributes produce additional revenue streams and allow project owners to sell output below the actual cost of generation."[37] Generally LCOE prices will be higher than PPA prices.

All analyses in this report were run using the NREL CREST[38] model. Inputs to the model were in part developed using proprietary databases run through a peer-reviewed Offshore Wind Integration Cost (OFWIC) model.[39]

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[35] Navigant, Offshore Wind Market and Economic Analysis: 2014: Annual Market Assessment Report.

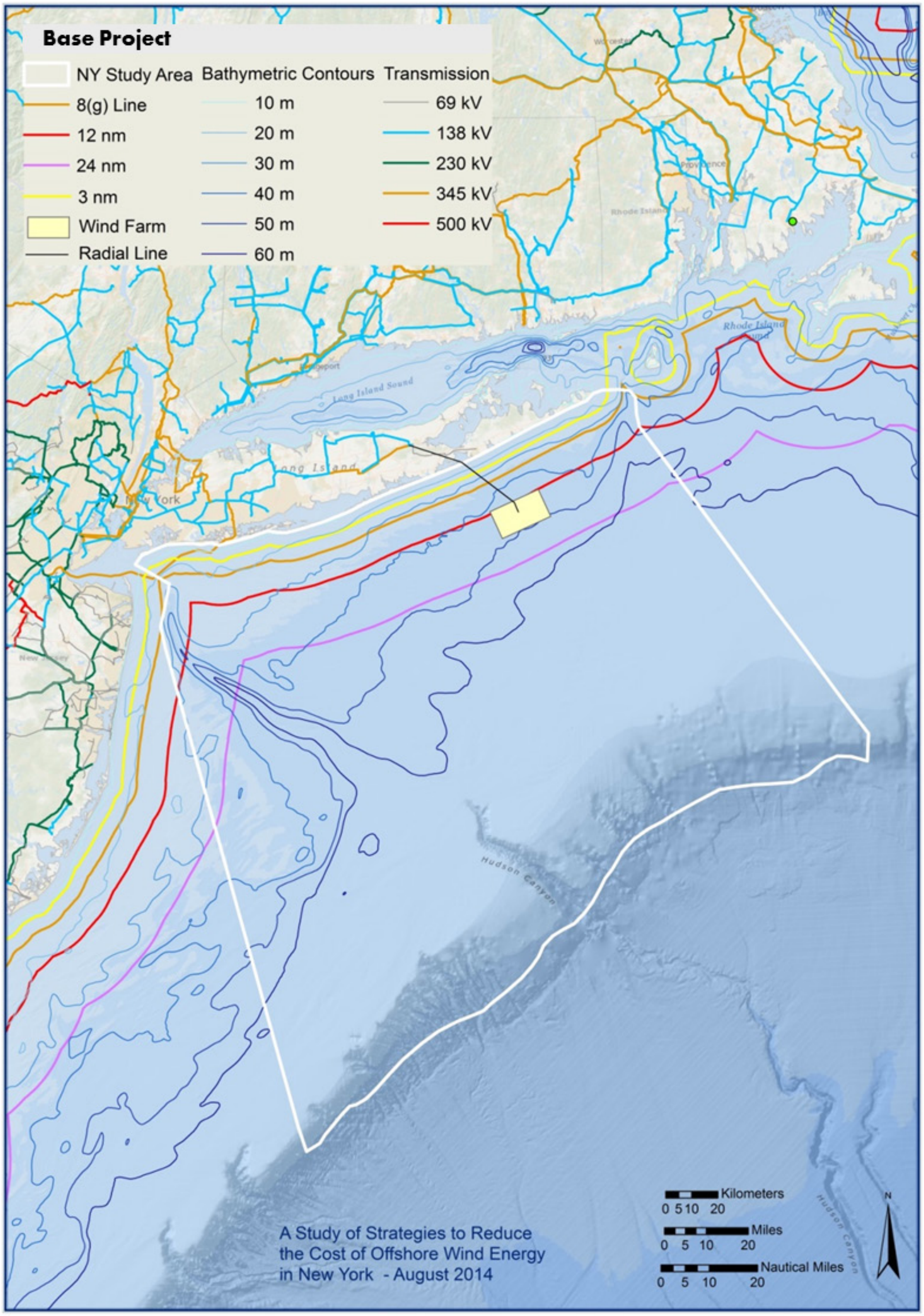
[36] LCOE is the equivalent unit cost ($/MWh or ¢/kWh) that has the same present value as the total cost of building and operating a generating plant plus investor returns over the power plant's life divided by total electrical generation. Levelized Cost of Electricity Calculator, NREL, http://www.nrel.gov/analysis/tech_lcoe.html

[37] See Musial and Ram 2010, Large Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers. NREL/TP-500-40745, p. 119.

[38] This economic cash flow model is available at https://financere.nrel.gov/finance/content/crest-cost-energy-models

[39] Ozkan, D. and M.R.Duffey (2011). A framework for financial analysis of offshore wind energy, in Wind Engineering, 35(3): 267-88.

Figure 1. Wind Farm Base Project Location



Cost figures for the 5-MW turbine, jacket foundation, and installation were estimated using proprietary cost data available to the team members as well as publicly available data.

Cost figures for the 8-MW turbine, jacket foundation, and installation, incorporating anticipated technology, global competition, and industry efficiencies between now and FC in 2020, were obtained from BVG Associates, who developed these cost figures through extensive work conducted in part for the Offshore Wind Cost Reduction Pathway Study commissioned by The Crown Estate.[40] The same source provided cost figures that anticipate additional innovations from the period FC 2020 to FC 2025, in this case based on their report for the Knowledge Innovation Cluster (KIC).[41]

The SIOW team identified four additional project sites (Projects 1 – 4) that served as the study's "Build-out scenario" or the installation of several OSW projects over time. These project sites were also identified by examining water depth, wind speeds, ground conditions, exclusion areas, distance to shore, installation ports, and points of interconnection.

The wind speeds were determined using the weather research and forecasting model (WRF).[42] The runs were done by Sailor's Energy, which specializes in wind resource estimates for offshore energy used in peer-reviewed publications, for commercial offshore wind developers and for U.S. Department of Energy -sponsored OSW analyses.[43] The New York Bight was modeled at 5km × 5km resolution, as part of a set of East Coast model runs using WRF calibrated against 23 offshore buoys and nine offshore towers[44].Wind speeds were drawn from the WRF output at 90 and 115 meters above Mean Sea Level, representing 5-MW and 8-MW hub height. Also based on the WRF multi-layer results, wind shear was calculated (close to Project 1) to have an annual average alpha = 0.104 with considerable monthly variation. A map of these proposed sites (Projects 1-4) is shown in Figure 2 (including competing uses). Figure 3 shows just the project sites, and the site characteristics are included in Table 1. LCOE's were calculated for each project in the Build-out scenario, to which global cost reduction, U.S. learning effects and NYS interventions were applied.

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[40] For a detailed description of BVG's methods, technology and innovation results for FC 2020 cost figures, see BVG Associates, Technology Workstream Report, Offshore Wind Cost Reduction Pathway Study, released June 2012.

[41] For technology and innovation assumptions from FC 2020 to FC 2025, see BVG Associates, Future renewable energy costs: offshore wind, prepared for KIC InnoEnergy Renewable Energies, released June 2014.

[42] Weather Research and Forecasting (WRF) is the most widely accepted meteorological model. For this study it was run for a 5 year period, verified to be representative of the climatological mean in the New York Bight. For wind power estimates wind speeds for 8MW turbines were drawn at 115 meters above Mean Sea Level.

[43] For example, see Dvorak, M. J., E.D. Stoutenburg, C.L. Archer, W. Kempton, and M.Z. Jacobson. "Where is the ideal location for a U.S. East Coast offshore grid?" Geophysical Research Letters, Vol. 39, L06804, 6 PP., doi:10.1029/2011GL050659. 2012. Commercial forecasts for Principal Power's Oregon commercial wind project, primary resource estimates for U.S. DOE projects "Mid-Atlantic Offshore Wind Interconnection and Transmission" and "Improving the Mapping and Prediction of Offshore Wind Resources" (with SUNY Stony Brook).

[44] Dvorak, M.J., B.A. Corcoran, J.E. Ten Hoeve, N.G. McIntyre, M.Z. Jacobson. "U.S. East Coast offshore wind energy resources and their relationship to peak-time electricity demand". Wind Energy 2013

Figure 2. Build-Out Scenario with Competing Uses

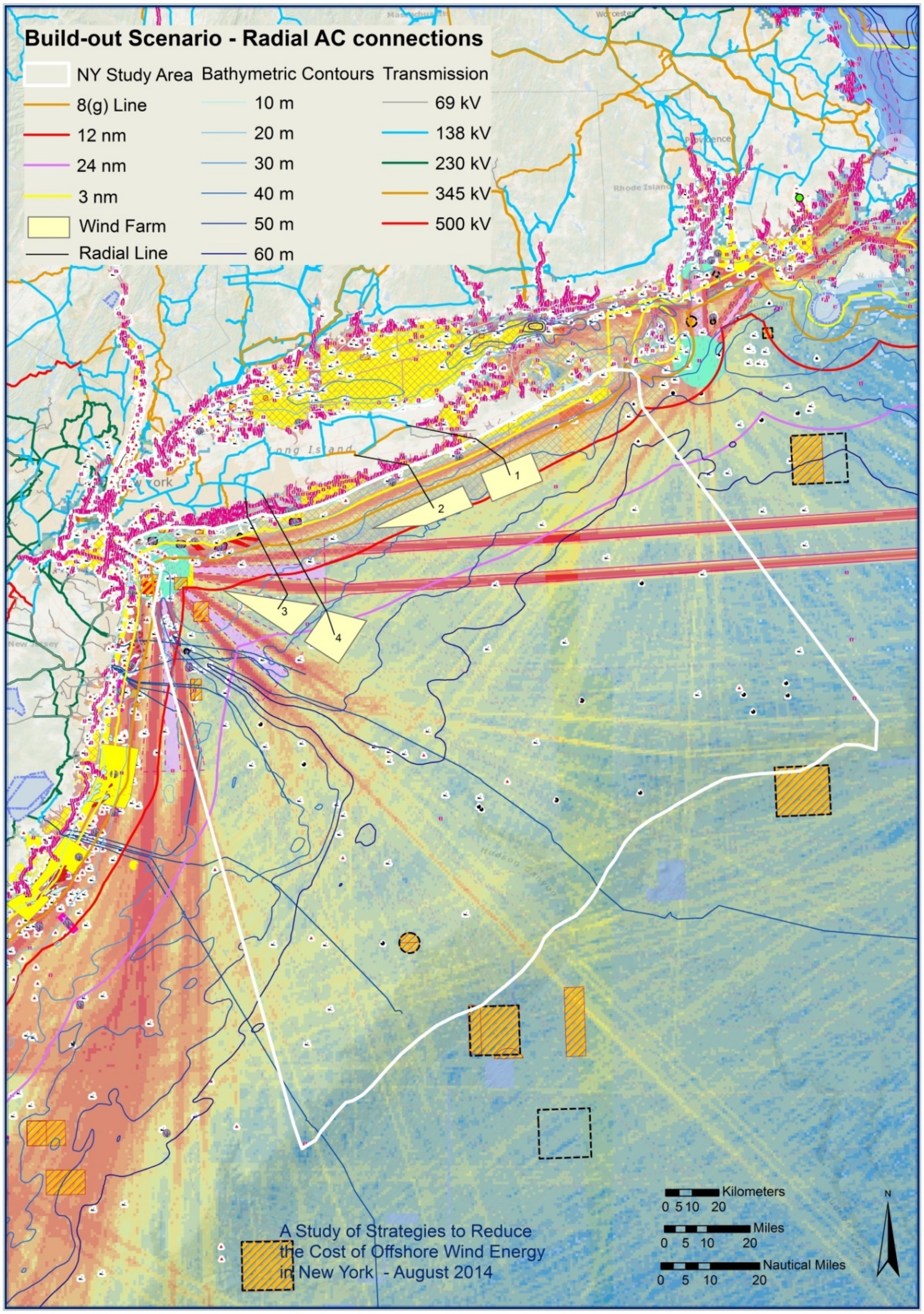

Figure 3. Wind Farm Build-Out Locations

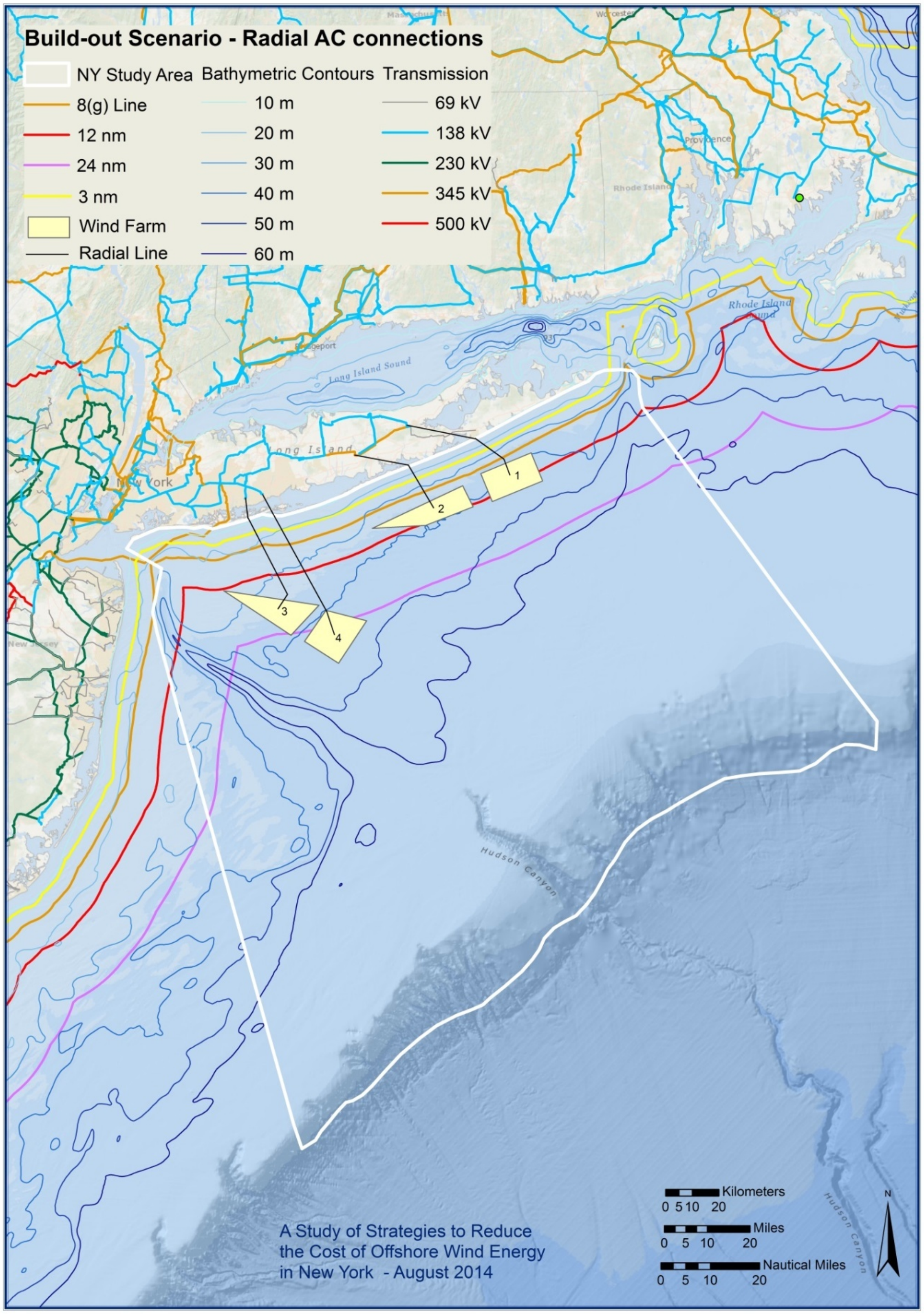

Table 1. Site Characteristics for Project Build-Out

Site	Water depth (m)	Wind speed (m/s[45])	Distance to port (km)	Distance to shore (km)	Distance to Point of Interconnection (POI) (km)		
					Offshore	Onshore	Total
Base Project (Figure 1)	45	9.2	182	27	34	16	50
Project 1[46] (Figure 3)	40	9.1	172	18	20	25	45
Project 2 (Figure 3)	38	9.0	206	18	19	21	40
Project 3 (Figure 3)	35	9.0	282	34	39	8	47
Project 4 (Figure 3)	45	9.1	270	48	50	9	59

2.3.2 Estimating the Impact of U.S. Learning

To calculate the learning effects from any further market development in the U.S. between FC in 2020 and 2025, the study team applied a 5% learning curve per doubling of capacity based on a review of top-down statistical analyses of offshore wind learning curves, conducted in 2013 by the Brattle Group.[47] The Brattle Group assessment discovered LCOE cost reductions ranging between 3% and 10% per doubling of capacity and considered some of the factors that have been driving up offshore wind costs over the past few years to be temporary.[48] These learning rates were also found to be consistent with those historically observed for onshore wind. Brattle interpreted 3% learning as a slow learning rate and 10% as high and suggested using a 5% mean. The study team applied this mean learning rate per doubling of capacity only to its estimates for installation and O&M costs since, as previously noted, equipment costs obtained by BVG Associates already incorporate learning effects within the equipment supply chain. Analyses of the effect of learning also assumed a stagnant offshore wind policy and financing environment in the U.S.

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[45] Average wind speed (m/s) at 115m hub height

[46] Represented on Map 2, includes intervention of being sited closer to shore.

[47] Weiss, Jurgen, M. Sarro and M. Berkman (2013). “A Learning Investment-based Analysis of the Economic Potential for Offshore Wind: The case of the United States,” prepared for the Center for American Progress, the U.S. Offshore Wind Collaborative, the Clean Energy States Alliance and the Sierra Club.

[48] Weiss et al, p. 23.

2.3.3 Developing NYS Interventions

To identify and develop NYS-influenced interventions to reduce the cost of offshore wind power in New York, the team first conducted a literature review of key cost reduction studies. A matrix of cost reduction opportunities was developed from the literature review and guided stakeholder interviews, conducted in May and June of 2014. Twenty interviews were conducted in the U.S. and Europe with OSW industry leaders, analysts, the project's Advisory Committee, as well as suggestions by NYSERDA.

The interviews first addressed the applicability of the European cost reduction strategies to the U.S. and NYS without any local action. Strategies that would benefit the U.S. without action were identified. Those requiring local action were explored in further detail. Interviews also solicited cost reduction strategies not included in the European reports. The estimated cost savings, the specific risks and challenges posed by the intervention, the cost of each intervention, its timing, and the set of actors required to effect impact were all discussed.

The stakeholder and policymaker interviews yielded more than 25 interventions that underwent extensive subsequent review by the team and advisors. Although we sought to obtain/calculate cost reduction values for each identified intervention, through the review process it was discovered that impacts for only some could be quantified. The interventions fall into three categories:

- Activities that would likely reduce OSW LCOE and whose effects can quantitatively be estimated;
- Activities that will likely have an effect on LCOE but that cannot be quantified; and
- Activities that do not impact calculated LCOE, but have other important impacts on such matters as developers' bid price or the State's determination of strike price or, for example, increasing the likelihood that a planned offshore wind project would be built.

This study focuses on those activities that were seen as likely to reduce OSW LCOE. The team also identified and documented the mechanisms by which each intervention could reduce LCOE. Those activities that have an unquantifiable but likely effect and those that do not impact LCOE but are important otherwise are described but in less detail.

2.4 Study Assumptions

The team made a number of assumptions in order to compare LCOEs from different technology scenarios and to develop interventions that NYS could influence.

The technology assumptions are listed in Table 2. The top row illustrates the 5MW comparison case. The second row illustrates the assumptions made regarding technology that will be commercially available and in use for projects with FC in 2020, resulting from European global cost reduction efforts.

Table 2. Technology Assumptions

Turbine	Foundation	Intra-array cable	Export cable
5MW Rotor diameter 126m Hub height 90m	Jacket	33kV	HVAC 230kV
8MW[49] Rotor diameter 180m Hub height 115m[50]	Jacket Piled Assembled offshore per current practice	66kV	HVAC 230kV

Wind farm assumptions:

- Wind farm size: 600MW each.
- Spacing between turbines equivalent to nine times the rotor diameter (9Dx9D) leading to a power density of 3.2 MW/km^2.
- Life of project (operational) is 25 years.

Meteorological regime:

- A wind shear exponent of 0.104.
- Weibull shape parameter.

Siting assumption:

- Farms sited at or beyond 12 nm, per NYS Department of State Atlantic Offshore Wind Study.

Construction and O&M assumption:

- Nacelles, foundations, and blades coming from Europe to New Bedford until Financial Close (FC) 2022, when market volume reaches a critical threshold; local manufacturing at FC 2023.
- Construction begins one year after FC and construction lasts 2 years.
- No enabling WEA specific environmental, G&G or wind speed data prior to bids.
- European installation vessels and large O&M vessels for projects through FC 2022; U.S. O&M (large) vessels at FC 2023.
- European supervised crews of U.S. workers through 2025.
- Supply chain and O&M efficiencies from 2020 through 2025 (4.8% decrease in OPEX and CAPEX per The Crown Estate [TCE] study).[51]

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[49] According to industry experts consulted for this study, additional technology possibilities exist for projects reaching FC in 2020. Both Siemens and Vestas have 10MW turbines under development with the aim to make them available for projects at that time. http://www.rechargenews.com/incoming/article1363463.ece

[50] Blade sweep clearance 25m above Mean High Sea Level, 90m rotor radius

Financing assumptions

- Economic life: 25 years.
- Cost of debt: 5-6%[52].
- Cost of equity: equity IRR requirement of 15% for construction financing and11% for permanent financing[53].
- WACC in the 7-8% (8.6% for construction, 6% for operation) range based on [55-65] % leveraging, 35% federal tax rate, and 7% state tax rate.
- Depreciation assumptions of NREL CREST model.

Leasing assumption:

- Developer obtains lease separately from power contract

Market and policy assumptions:

- 750 MW installed capacity in U.S. by beginning of study period, reflecting likely installation of offshore wind projects that are either in development. Specifically we assumed the installation of the Cape Wind project in Massachusetts, the Deepwater Wind project off of Block Island in Rhode Island,, the U.S. Wind project in Maryland, and three technology demonstration projects funded by the U.S. Department of Energy)
- 4.2 GW installed capacity by end of study period, reflecting potential implementation of New Jersey's Offshore Wind Economic Development Act of 2010[54] and this study's assumed 2.4GW in New York
- No NYS policy for long-term off-take agreements for above-market PPAs.
- No federal production tax credit, no federal investment tax credit, and no state subsidies.

Transmission assumption:

- Export straight to onshore POI; 230kV AC.

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[51] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris. This is summarized in Section 2.7.1.

[52] Based on expert observations that the full cost of debt has been relatively stable in the past years for offshore wind projects in Europe. Early U.S. projects would likely be at the top of that range.

[53] Early U.S. projects would likely have higher rates than current European rates. We assumed 15% and 11% for analyses of the impact of state interventions.

[54] We consider the Maryland project highly likely to be installed by FC 2020 given the political will, August, 2014 lease auction and forthcoming OREC regulations. We are not confident that offshore wind will be developed in New Jersey by FC due to slow action by the NJBPU, no schedule for a BOEM lease auction for the NJ WEA and their rejection of the Fishermen's Energy pilot project's OREC application.

2.5 Estimating Relative Changes in LCOE due to Interventions

Expert elicitation methods were used to determine the impacts on cost model inputs for the state-influenced interventions under consideration. Expert elicitation methods involve the process of seeking carefully reasoned judgments from experts about uncertain quantities or processes in their domains of expertise, often in the form of subjective probability distributions, and has a well-developed methodology.[55] In some fields, expert elicitation may involve interviewing 10-30 experts, yielding mean, mode and standard deviations of responses. For most measures here, only a few experts had sufficient experience to provide a reliable estimate. For example, in offshore wind finance, Green Giraffe (GG) has been a consultant to 30 offshore wind projects at different stages of development with a cumulative capacity of more than 10 GW. GG's work has included raising equity, arranging debt, and bidding for tariffs, selecting offshore wind contracts and negotiating offshore wind commercial contracts. GG has been similarly involved in a substantial number of the projects that have been considered in the U.S. Noting the difference between GG's experience and that of other expert observers of offshore wind finance, one expert reviewer commented: "[GG] will know better than I about what investors will do [in relation to interventions] because they are in the room."

Generally, due to the small size of the industry, the team's expert elicitation results place more weight on experience with other experts used to verify, rather than asking all of its advisors and consultants to provide estimates especially when they expressed doubt in ability to do so and then taking a mean.

The team worked with GG to estimate the impacts on model inputs of interventions, and subsequently with experts from the National Renewable Energy Laboratory (NREL), and offshore wind finance experts in both a U.S. NGO and a large U.S. generation company. The values derived through the expert elicitation process were then applied in the cost model to determine relative changes on LCOE due to specific interventions. Aggregating Impacts on LCOE of Multiple Interventions

The final method to be developed was to aggregate the impacts of interventions on LCOE. Because not every intervention's impact would be applicable across all projects in the build-out scenario, the team first determined which interventions would likely impact which project and then examined the likely bundle of applicable interventions to determine if there were overlaps, examining if impacts were duplicative, additive, or multiplicative.

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[55] Morgan, M. Granger (1990). Uncertainty: A Guide to Dealing with Uncertainty in Quantitative and Risk and Policy Analysis. Cambridge University Press, Cambridge, MA.

For analyses of the aggregate impacts, financing assumptions from the base case were modified. Specifically, equity IRR for construction financing used in the base case is 15% for the interventions; the permanent financing used in the base case was 11%. However, an 8% financing environment in the U.S. market is unlikely without U.S.-specific interventions. Moreover, as the interventions were applied, the study team set a floor of 8% equity IRR for permanent financing for the first three projects because a floor *less than* 8% is unrealistic for early projects, despite recommended interventions. The 8% floor was removed for the fourth project's analyses. Eliminating the 8% floor on equity IRR for the analyses of aggregate impacts of interventions on the Project 4 LCOE is based on recent observations of investor behaviors in European offshore wind projects that indicate that as the industry matures, different types of institutions (such as pension funds and insurance companies) are entering the space, and in some cases taking less return, if they see the operational asset as a long-term infrastructure asset well-matched to their needs.

After adjusting the financing assumptions, project LCOEs were then re-calculated to derive a baseline LCOE for the project portfolio. Effects of global-related cost reduction impacts and estimated U.S. learning effects were applied.

For each of the four hypothesized projects, after examining the bundle and removing overlaps of impacts and adjusting for co-related impacts, each of the applicable interventions was applied in a stepwise calculation order, and a corresponding impact on LCOE derived. From there, the relative impact of each category of interventions on the project LCOE was established.

2.6 Literature Review

In preparation for examining the opportunities to reduce the cost of energy from offshore wind in NYS, the team reviewed four key cost reduction studies conducted to date:

- Offshore Wind Cost Reduction Pathways Study commissioned by The Crown Estate (referred to as TCE).
- Cost Reduction Potentials in Offshore Wind in Germany, commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners.
- Installation, Operation and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy, a technical report of NREL, in joint authorship with the Energy Research Centre of the Netherlands.
- Future Renewable Energy Costs: Offshore Wind, by BVG Associates for KIC InnoEnergy.

2.6.1 Offshore Wind Cost Reduction Pathways Study (TCE)[56]

Involving over 100 companies, 20 workshops, 60 one on one meetings, and a steering group representing industry and government, TCE completed this Study in 2012. First, they established a baseline cost (LCOE, by Final Investment Decision [FID, when equity investors irrevocably commit the money to build the project] 2011), and

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[56] Four reports in all: OWCRP Study authored by The Crown Estate; BVG Associates (a), authored by BVG Associates; Supply Chain Workstream report, authored by E.C. Harris; and Financing Workstream report, authored by PricewaterhouseCooper. A fifth report on Health and Safety was not reviewed for this study.

developed their pathways framework (to include market development, speed of technology development, and supply chain maturity). Then they assessed cost reductions from that baseline, examining the potential from technology, supply chain and financing innovation. TCE did this assessment for four different site types under four different development scenarios. Upon understanding the cost reduction impact from the baseline, TCE formulated prerequisites that need to be achieved and key decisions that need to be made, and by when.

The TCE study concluded that reducing the cost of offshore wind by 40% by 2020 is achievable, from £174/MWh to £100/MWh, making offshore wind cost-competitive with other low carbon technologies.[57] The key cost reduction opportunities and corresponding magnitude of impact are:

- New turbines (17%): Turbine innovations such as increased power rating (from 4 MW to 6 MW, but even more so from 6 MW to 8 MW), as well as introduction of direct drive trains, improvements in AC power take off system designs, improvements in workshop verification testing, introduction of DC power take off, introductions of direct-drive super conductor drive trains, and improvements in high speed drive trains all. Impacts are expected to vary with site type.[58]
- Competition (6%): Impact of new entrants to the U.K. market, with the prerequisite market size.[59]
- Front end activity (5%): Undertaking additional detailed design studies at the Front End Engineering and Design (FEED) stage of project development. Namely, this includes additional survey data and increased depth of design for the foundation, turbine choice, and installation methods, which are usually completed later in the development process. These activities are expected to give increased accuracy of cost estimates for solutions with varying parameters such as water depth, soil conditions, and turbine choice.
- Scale/productivity (5%): Savings gained in procurement (across the value chain) due to volume, "learning by doing," standardizing processes, and "sweating assets."
- Installation (4%): Reducing overall cost of installation and lowering project risk during construction by shortening the time taken to construct wind farms through improvements in installation process for monopiles and space frames; improvements in the range of working conditions to install support structures; greater use of feeder arrangements; innovations such as concrete gravity based foundations, whole turbine installation, and float and sink installation; and optimized cable installation processes.
- Support structures (3%): The primary areas of innovation in support structures identified were improving jacket manufacturing and design, introduction of a holistic design of a tower with a foundation, single section towers, suction bucket technology, and improvements in jacket design standards.
- Other (9%)

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[57] *Offshore Wind Cost Reduction Pathways Study* commissioned by The Crown Estate, p. ix

[58] See BVG Associates (2012), pp. 45-62. According to TCE, turbine costs themselves are reported to decrease in cost by 17%. Increases in rated power will lead to a 9% reduction in turbine cost, improved blade design and manufacture a 3% reduction, changes in drive trains a 2% reduction, larger rotors a 1% reduction and other innovations collectively add another 3%. According to an unpublished comparison of TCE and Stiftung studies, the two studies' estimates of the reduction of turbine costs are very close. From *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 145

[59] See E.C. Harris, pp. 51-4.

2.6.2 Cost Reduction Potentials on Offshore Wind in Germany (Stiftung)

Stiftung conducted their study between 2012 and 2013, acknowledging TCE's study as authoritative. However, due to different framework conditions for German offshore wind power from those in the UK regarding water depth, distance to port, and grid connection and financing, and due to further developments regarding technologies for and approaches to, among others, substructures, plant configuration, logistics, and energy yield. Since the TCE study had been presented, a need was seen for a German-specific update on offshore wind cost reduction potential. The Stiftung study was based on independent data and calculations that have been verified for the German market along its entire value-added chain. Stiftung estimated costs for three different types of sites (varying by distance to shore and water depth) and two under different scenarios (incorporating wind farm size, design, etc).

Similar methods to The Crown Estate study were used including: (1) determining a cost baseline for all sites and years and modeling an LCOE, but this time Stiftung also verified that cost baseline using an expert panel; and (2) and developing optimization approaches, comprising all costs that – according to German regulatory provisions – are assigned to an offshore wind farm. These assignments include technical investment costs for he plants and their installation, approval and certification costs, annual operating costs, as well as provisions made for decommissioning the plants. Costs relating to the grid beyond the wind farm's transformer station are not part of LCOE, consistent with regulatory requirements.

Stiftung found that on average LCOE can decrease by about 30% at all sites until 2023. The main driver for the cost reduction is a continuous technological development across the entire value-added chain of the offshore wind power industry; substantially determining a projected reduction in LCOE from 14.2 ¢/kWh to 8.7¢/kWh (in 2012$). Reduction in the cost of capital (in real terms from 7.855% in 2013 to 5.68% in 2023) directly and evenly affects all parts of the investment costs, Stiftung reported.

2.6.3 Installation, Operation and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy (NREL)

The NREL report was intended to provide offshore wind industry stakeholders a basis for evaluating potential cost saving in installation, operation, and maintenance (IO&M) strategies and technologies. The report was undertaken given that the expenditures associated with IO&Ms expected to account for one-third of offshore wind LCOE in the U.S. The purpose was to identify the most practical means of reducing offshore wind LCOE through advanced IO&M techniques, integrated service providers, and preferred supporting infrastructure, and to identify preferred IO&M strategies in a case study of a hypothetical U.S. offshore wind project. Overall, the study found that IO&M improvements applied to the case study reduced LCOE by 14% compared to the baseline. The 14% reduction in LCOE was primarily attributable to the increase in Annual Energy Production (AEP) driven by increases in project availability.

2.6.4 Future Renewable Energy Costs: Offshore Wind (BVG Associates for KIC InnoEnergy)

According to BVG Associates who conducted this study for KIC InnoEnergy, the study “updated and refreshed” TCE’s Technology Workstream report, one of the four reports that comprised TCE’s Offshore Wind Cost Reduction Pathway Study, which was conducted by BVG Associates. The KIC study included additional industry engagement, and took a longer look at potential innovations and their impact.

The study examined the LCOE trajectory for projects installed in 25-m and 35-m water depths, and 40 km and 125 km from an installation port. The study focused only on technology innovations (and not supply chain or finance innovations) and found that a 27% decrease in LCOE can be anticipated for projects with FID in 2025. The key transition, BVG Associates argue, will be going from 4-MW turbines to 8-MW turbines, again for projects with FID in 2025. The study also found that key innovations will include combining larger turbines with optimized sized rotors, improving aerodynamics and control, and next generation drive trains. Note that the BVG methodology assumes new technologies enter the market gradually, so that for a given year that a new technology is available, it may be applied to only a percentage of new wind farms.

While each study utilized a slightly different methodology, overall, the literature review indicated that LCOE improvements are likely and that the areas with the greatest potential for are technology improvements, improved supply chain and industry collaboration and efficiency, improved operations leading to less downtime and increased energy production, increased pre-development activities, and improvements in financing. The detailed literature review can be found in Appendix A.

3 Findings Regarding Global Cost Reduction and U.S. Learning Impacts

This section reports the findings of the team's analyses of the impact of anticipated global cost reduction on the LCOEs of the Base project and the Build-out scenario and of the further impact of learning effects as the U.S. market matures. It is expected that global cost reductions in OSW technology and U.S. market maturation will lower the cost of OSW installations resulting in lower LCOE of NYS OSW projects.

3.1 Global Cost Reduction: Impacts on New York LCOE

European efforts to reduce cost are expected to come to fruition by or around FID in 2020, which is approximately the same as Financial Close. Cost reductions are expected to be driven by technological advancements (detailed in the literature review), greater global competition among turbine manufacturers, and industry-wide efficiencies.

The impacts from these three drivers are captured in OSW cost figures developed by UK offshore wind consultants BVG Associates and incorporated into an LCOE assessment for the New York base project assuming FC 2020 modeled on a site that is, on paper, most commercially appealing for offshore wind in New York (higher wind speed, water depth, distance to shore and closest POI, etc.; refer to Figure 1). The cost figures for the Base project assume an 8-MW turbine with jacket foundation that incorporate the technological innovations detailed in TCE's Technology Workstream report as well as the impact of additional European learning, industry efficiencies, and competition. The cost reduction figures assume additional learning in Europe from today until FC in 2020, to reflect the active OSW market there.

However, by 2020, neither the U.S. nor NYS will have achieved the learning that the Europe has. Rather, the team anticipated that by FC in 2020 in the U.S., approximately 750 MW of offshore wind may be installed (specifically completion of Cape Wind, Block Island, DOE-funded pilot projects, and a Maryland wind farm supported by legislation passed there in 2013 and implemented in 2014). Again the BVG Associates cost figures assume additional learning in Europe from today until FID in 2020, to reflect the active OSW market there. Given that the U.S. market will not yield the same learning that has been achieved in Europe, the team added 15% to BVG Associate's anticipated European costs for installation/construction and O&M, to reflect the U.S.'s lack of experience.[60] The LCOE for the Base project using anticipated FC 2020 commercially available technology was calculated to be $226.5/MWh. This assumes a stagnant policy and financing environment for U.S. offshore wind.

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[60] The 15% reduction was recommended by BVG Associates, as a part of the UK cost data BVGA provided to the SIOW team, reflecting the anticipated benefits from European-specific learning that will not immediately be passed on to the U.S.

The team also derived an LCOE for a project on the same site, using cost figures for a 5-MW turbine and jacket foundation. This size is expected to be used in new U.S. offshore wind projects, consistent with recent European projects. Since 2011, average nameplate capacity of offshore wind turbines installed globally has been 4 MW.[61]

This derivation was calculated in order to compare the LCOE for a project using a 5-MW turbine to the LCOE for the Base project, which uses an 8-MW turbine that reflects anticipated innovations, expected global competition, and industry efficiencies. As illustrated in Table 3, the LCOE for a project on the Base project site using a 5-MW turbine was $291.5/MWh, compared to the LCOE for the Base project using an 8-MW turbine: $226.50/MWh. Thus the team's modeling predicts a 22.3% reduction in LCOE assuming the technology advancements, global competition among turbine manufacturers, and industry-wide efficiency are realized.

Table 3. LCOE for FC 2020 Base Project Site: 5-MW v. 8-MW Turbines, Industry Efficiencies, Stagnant OSW Policy and Financing

Location	Water depth (m)	Wind speed m/s[62]	Distance to port (km)	Distance to shore (km)	Distance to POI (km)			LCOE ($/MWh)	
					Offshore	Onshore	Total	5MW, jacket	8MW, jacket
Base Project Site (Figure 1)	45	9.2	182	27	34	16	50	291.5	226.5

Looking beyond FC 2020 to FC 2025, the team applied cost figures from BVG Associates that were developed for their June 2014 analyses conducted for the Knowledge Innovation Cluster (KIC). The KIC cost figures projected the cost of offshore wind from FID 2020 – FID 2025 in the UK given the expected continuous technological development (not bigger turbines but continuous improvements to 8-MW turbines) as well as additional European learning and industry efficiencies.

Using these cost figures that anticipate continuous global cost reduction, the team derived LCOEs for the four project sites that make up the hypothetical Build-out Scenario. The LCOEs, assuming no additional market development in the U.S. between 2020 and 2025, stagnant offshore wind policy and financing in the U.S., and no NYS interventions, are shown in Figure 4. Table 4 illustrates both the LCOE's and site characteristics for the Base project and each project in the Build-out scenario. Note that Project 4 is in substantially deeper water and is further from shore and thus illustrates the countervailing effects of reductions against a more challenging site.

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[61] Navigant, Offshore Wind Market and Economic Analysis, 2014: Annual Market Assessment Report, p. xv.

[62] Average wind speed (m/s) at 115m hub height.

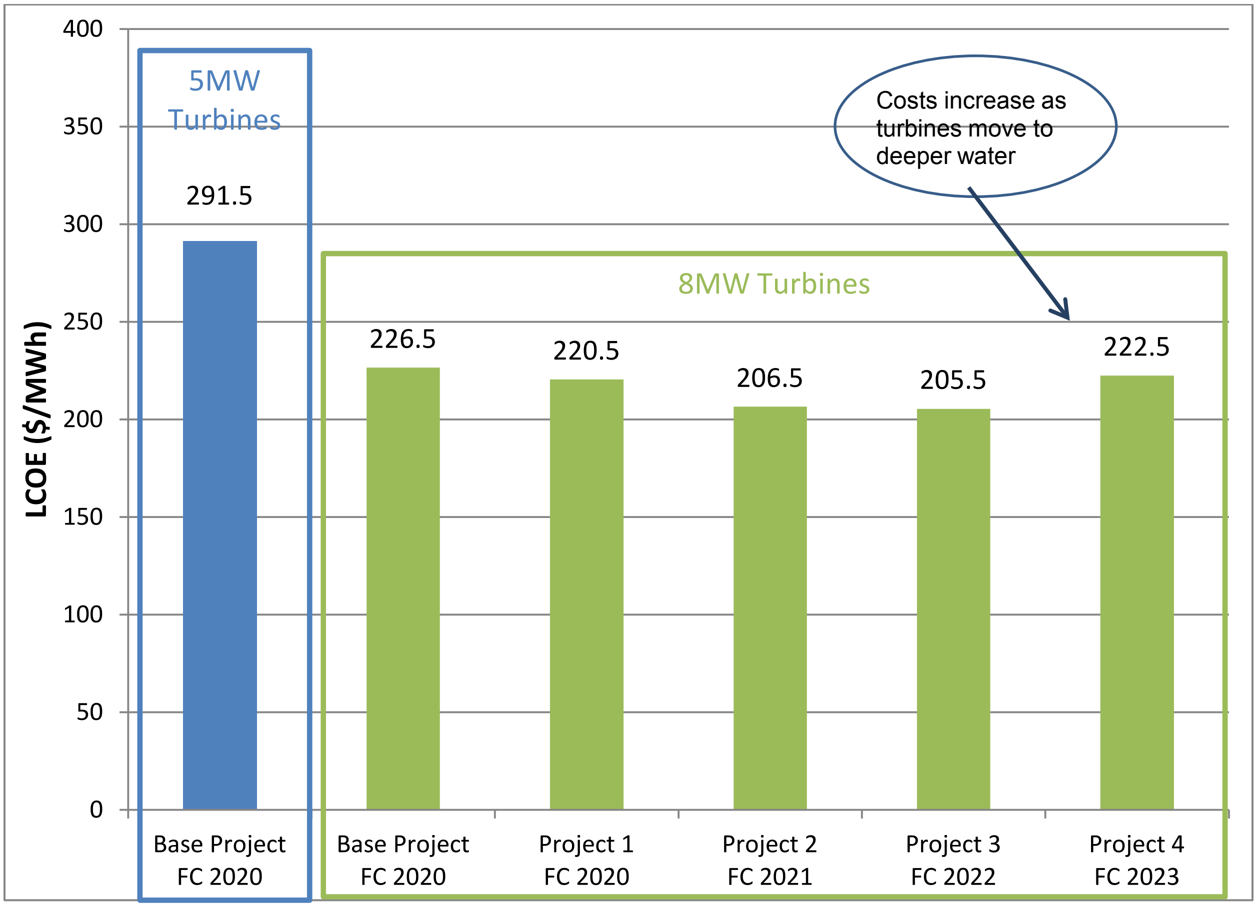
Table 4. LCOEs for FC 2020 – 2023

Calculations assume global cost reduction but no U.S. industry/policy and no NYS interventions.

Site	Water depth (m)	Wind speed (m/s)[63]	Distance to port (km)	Distance to shore (km)	Distance to Point of Interconnection(km)			LCOE ($/MWh)
					Offshore	Onshore	Total	
Base Project	45	9.2	182	27	34	16	50	226.5
Project 1	40	9.1	172	18	20	25	45	220.5
Project 2	38	9.0	206	18	19	21	40	206.5
Project 3	35	9.0	282	34	39	8	47	205.5
Project 4	45	9.1	270	48	50	9	59	222.5

Figure 4. Effect of Continuous Global Cost Reduction Efforts on NYS LCOE (FC 2020 – 2023)

Calculations assume global cost reduction but no U.S. industry/policy and no NYS interventions



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[63] Average wind speed (m/s) at 115m hub height.

The analyses indicate a relative cost change of -2.6% in LCOE from the Base case to Project 1 (both assuming FC 2020; 8MW; and construction in 2021). This result indicates the benefits of siting closer to shore (the Base Project is located 12nm from shore while Project 1 is located 8.9nm from shore).

Between Project 1 and Project 2 (FC 2021; construction in 2022) there is a relative change of -6.3%. Cost remains unchanged from Project 2 to Project 3 (FC 2022; construction in 2023); LCOE increases from Project 3 to Project 4 (FC 2023; construction in 2024) by 8%, reflecting greater distances to port, to shore and to POI as noted above. Table 5 below compares the capital costs, first of the 5MW and 8MW turbines on the Base project site, and then throughout the Build-out Scenario projects, assuming global cost reduction but no U.S. industry nor policy.

Table 5. Comparison of Capital Costs (Stagnant OSW Policy and Financing)

Technology	Project	Assuming innovation, competition efficiency by FC	Site	Capital costs ($/kW) (including reduction of supply efficiencies* and 10% contingency)
5MW	For comparison only	–	Base Project (Figure 1)	6,295
8MW	Base	2020	Base Project** (Figure 1)	5,916
8MW	1	2020	Project Site 1** (Figure 3)	5,816
8MW	2	2021	Project Site 2 (Figure 3)	5,405
8MW	3	2022	Project Site 3 (Figure 3)	5,105
8MW	4	2023	Project Site 4 (Figure 3)	5,526

* For Project 1= 4.8%, Project II=6.05%, Project III =6.88% and Project IV = 7.3%

** Base Project sited at 12 nm; Project 1 sited at 9 nm

3.2 U.S. Learning/Scale Effects Impact on LCOE

It is reasonable to anticipate the post-2020 build out of New Jersey's Offshore Wind Economic Development Act of 2010, a law requiring the installation of 1.1 GW of OSW in New Jersey. Assuming 1.1 GW is installed in New Jersey between 2020 and 2025, in addition to the 2.4 GW assumed for this study, we can anticipate installed capacity in the mid-Atlantic and Northeast growing from approximately 750 MW in 2020 to 4.2 GW by 2025.

Table 6 illustrates the effects of the 5% learning rate per doubling of capacity on the project LCOEs, assuming an even amount of installed capacity in New York and New Jersey over four years. These figures reflect that global cost reductions have been applied but still assume a stagnant U.S. OSW policy and financing environment. These final LCOEs, given all assumptions, are shown in Figure 5. Table 7 displays the differences between the global cost reduction LCOE's and the LCOE's after applying the U.S. learning rate.

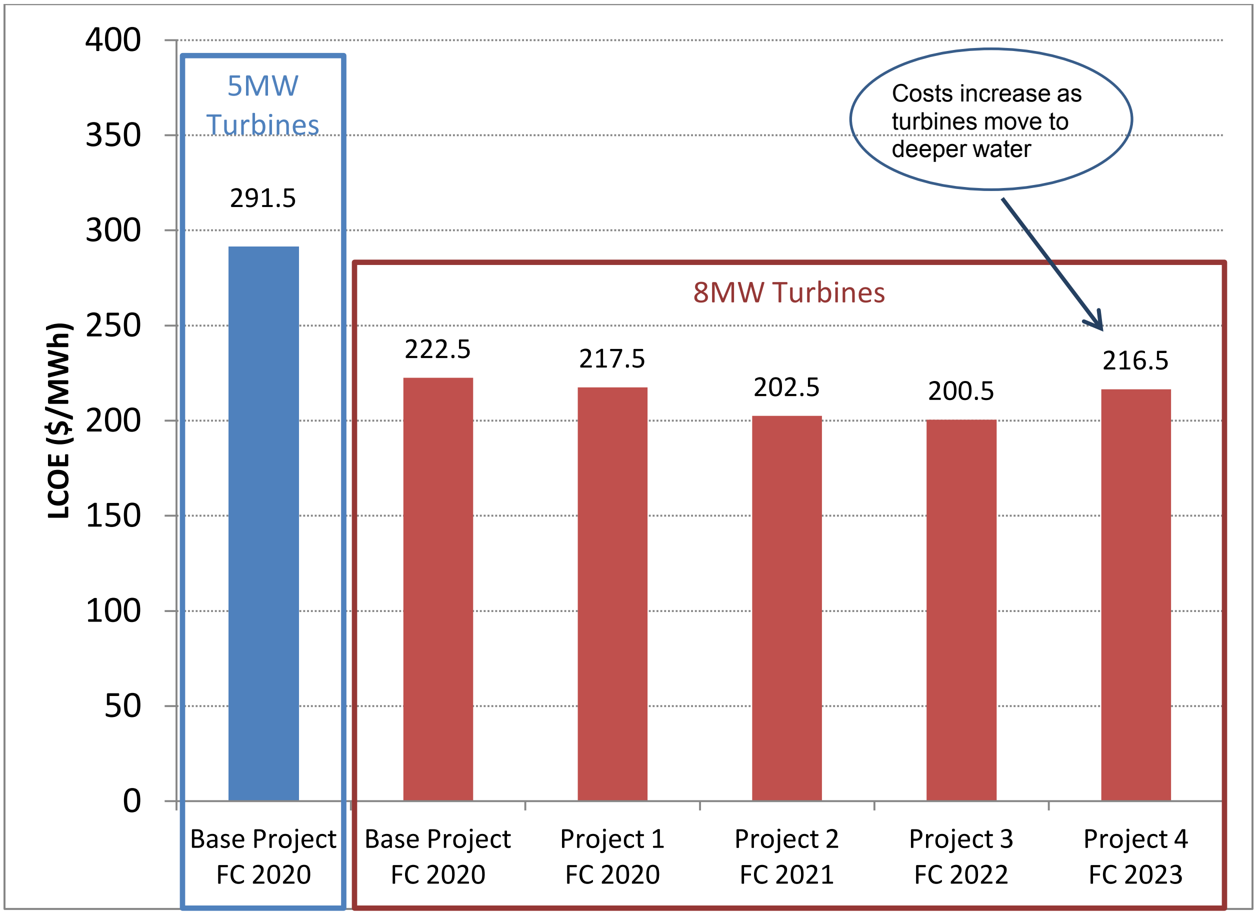
Table 6. NYS LCOEs Incorporating 5% Learning per Doubling of U.S. Capacity: Assuming Global Cost Reduction and Stagnant U.S. Policy and Financing

FC Year	Project	Capacity in NY (MW)	Capacity in NJ (MW)	Total Capacity in U.S. (MW)	Cost Ratio	Cost Reduction	LCOE $/MWh
2019	Base			~ 750	100	0.0%	222.5
2020	1	600	250	1,600	95	5.5%	217.5
2021	2	600	250	2,450	92	8.4%	202.5
2022	3	600	250	3,300	90	10.4%	200.5
2023	4	600	250	4,150	88	11.9%	216.5

Table 7. Impact of U.S. Learning on NYS LCOE (Stagnant U.S. Policy and Financing)

Project	Global Cost Reduction LCOE Before 5% learning rate applied ($/MWh)	LCOE After 5% learning rate applied per doubling of U.S. Capacity ($/MWh)	% change
Base Case	226.5	222.5	-1.8
1 FC 2020	220.5	217.5	-1.4
2 FC 2021	206.5	202.5	-1.9
3 FC 2022	205.5	200.5	-2.4
4 FC 2023	222.5	216.5	-2.7

Figure 5. Impact of Continuous Global Cost Reduction and U.S. Learning on NY LCOE (FC 2020-2023): Stagnant OSW Policy and Financing



Given these findings, the team concluded that the global cost reductions stemming from technological innovation, European learning and industry efficiency can yield a significant cost reduction versus the use of smaller turbines on a New York site. Put differently, material reduction will be seen, with migration to 8-MW advanced technologies and innovations. These findings also suggest that the LCOE may continue to decline given continuous technological improvement and local learning, as more capacity is installed in the U.S. It is important to note, however, that the realization of these reductions depends upon the global market pulling the industry towards the innovations. Conditional commercial orders already exist for 8-MW offshore wind turbines for projects reaching FC in the UK;[64] offshore wind expert observers in the UK assert that they are seeing much more technological development than in previous years; however supply chain innovations and market development continue to be slow.

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[64] http://www.nawindpower.com/e107_plugins/content/content.php?content.13317

4 Findings Regarding Impact of State Interventions

The primary purpose of this study was to identify NYS-specific interventions to reduce the cost of energy for New York State OSW projects. This study identified interventions that NYS could take and estimated the impact of each intervention on the LCOE of a New York project. The interventions and their estimated benefits are described in the following subsections organized as follows:

- Introduction of intervention category.
- Description of individual intervention(s) within category.
- Impact of intervention on CAPEX, OPEX, WACC, AEP (where applicable), and LCOE.
- Additional impacts of intervention (where applicable).
- Costs, challenges, and risks of intervention.
- Enabling action for intervention.
- Summary table of intervention.

The specific interventions independently examined, are:

- Siting
    - Site turbines closer to shore than 12 nm. (4.1)
- Predevelopment
    - Provide lease and visibility on site conditions. (4.2)
- Market Visibility
    - Creating Market Visibility. (4.3.1)
    - First Round Implementation. (4.3.2)
- Financing
    - Revenue Policy. (4.4.1)
    - Investment Partnership. (4.4.2)
- IO&M
    - Workforce Training. (4.5.1)
    - Port Development. (4.5.2)
- Transmission
    - Offshore Backbone. (4.6)

The impact on LCOE of each intervention was modeled with no other changes in assumptions. This is known as a parametric analysis. Because the effects of interventions are correlated, when multiple interventions are applied to a project, the resultant total project impacts may be smaller than the sum of predicted impacts for each unique intervention.

4.1 Siting Interventions

The first intervention that the team analyzed was the impact on LCOE of siting a wind farm between 8 and 9 nautical miles, compared to siting it 12 nm from shore.

The NYS Department of State (DOS), in its Offshore Atlantic Ocean Study, released in July 2013, examined infrastructure, biogeography, renewable energy requirements and offshore use data in an effort to determine the proper location for siting a wind farm. DOS' review led to an exclusion of electrical generation turbines within 12 nm of shore due to its finding that New Yorkers' noncommercial ocean activities occur mainly within about 12 nm of the shore, near major public access points (e.g., beaches) and coastal communities.[65]

Figure 6 shows the federally-designated wind energy areas (WEAs) and call areas. New Jersey's WEA falls within 12 nm, showing that some states have opted for siting wind farms within 12 nm of shore.

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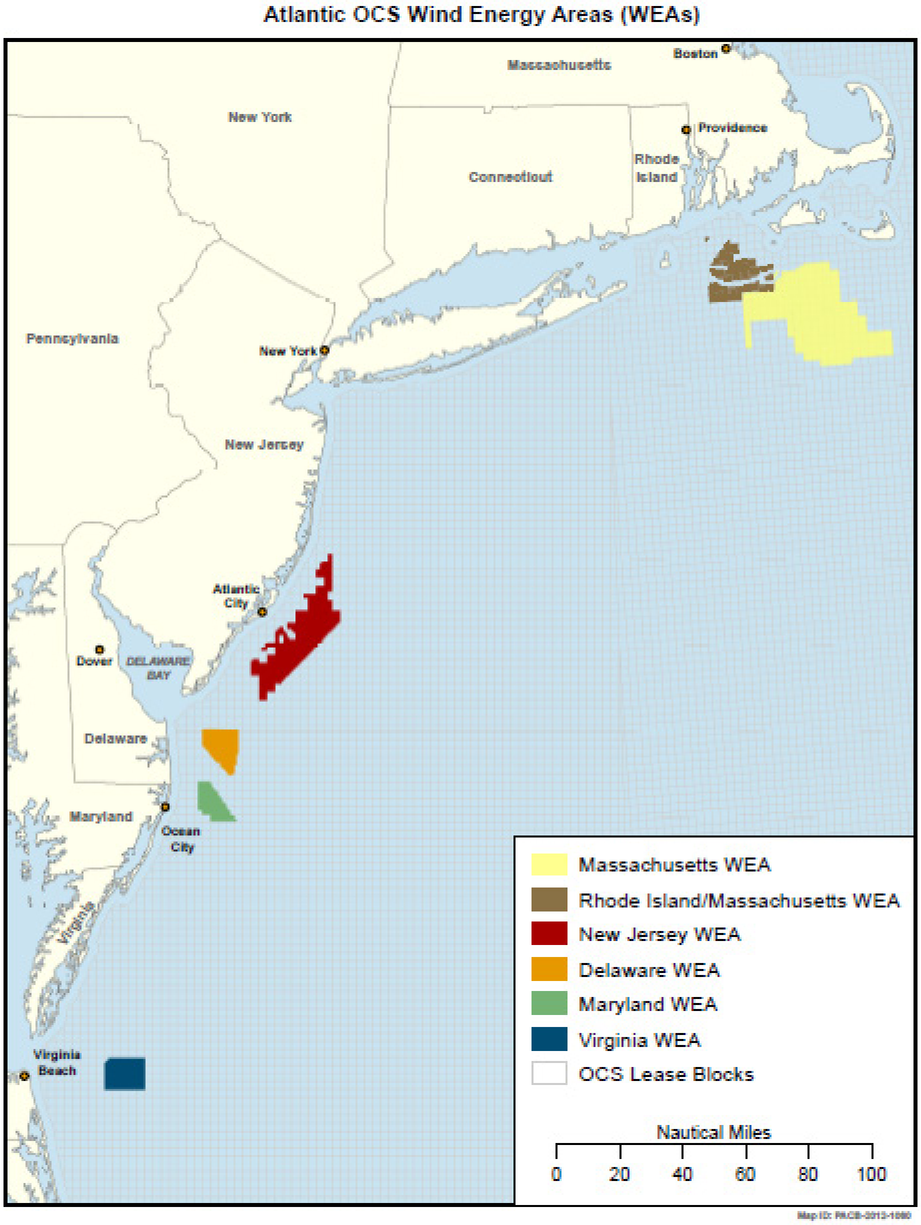
[65] New York State Department of State (2013). *New York Offshore Atlantic Ocean Study*, p. 79.

Figure 6. Bureau of Ocean Energy Management (BOEM)-Designated Wind Energy Areas[66]



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[66] BOEM. 2013. Wind Energy Areas. U.S. Bureau of Ocean Energy Management. Available at <http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/Smart_from_the_Start/Wind_Energy_Areas0607.pdf>.

The team also examined the literature on what is known about visual impacts and community acceptance, or drawback of a location, regarding offshore wind. While the DOS exclusion is not wholly driven by concerns about view-shed, research on visual impact/aesthetics of wind farms and community tolerance indicates tolerance at 9 miles. Of particular relevance is Krueger et al. (2011), which examined whether distance to shore affected how people valued wind farms. They conducted a choice experiment among Delaware residents, asking them to value certain attributes of potential wind farms, including how far out from shore turbines were located. Residents were given the choice of locating a wind farm at varying distances from shore (0.9, 3.6, 6, and 9 miles, and beyond sight distance, estimated at 20 miles) and paying an associated fee with that choice (higher fees for farther distances). They found that residents were willing to pay a higher fee to move the farm further from shore, up to the 6 to 9 mile range. After that, the fee flattened out considerably. The authors found that moving a wind farm in from beyond sight distance to 9 miles resulted in only small costs (in terms of dislike of turbines) imposed on residents.[67]

Given these results, the team analyzed the impact of siting projects between 8 and 9 nautical miles (9.2 – 10.4 miles).

4.1.1 Siting Intervention 1: Site OSW Farms Closer to Shore

Summary of intervention: Site projects within 12 nm (13.8 miles), in accordance with good siting practices and strong community engagement that may promote community tolerance.

The team compared the LCOE for its hypothetical Base project (Figure 1) to the LCOE when that project is moved within the exclusion area. Moving closer to shore decreases CAPEX and OPEX as illustrated in Table 8, but must be weighed against potential decreases in AEP or permitting difficulties. In this case, siting closer to shore had no appreciable impact on wind speed. The impact of this intervention on LCOE is shown in Table 9.

Table 8. CAPEX and OPEX Reductions from Siting Closer to Shore

Project distance from shore	CAPEX	OPEX
12 nm	$5,584	$108
9 nm	$5,488	$93
% change	-1.7%	-14%

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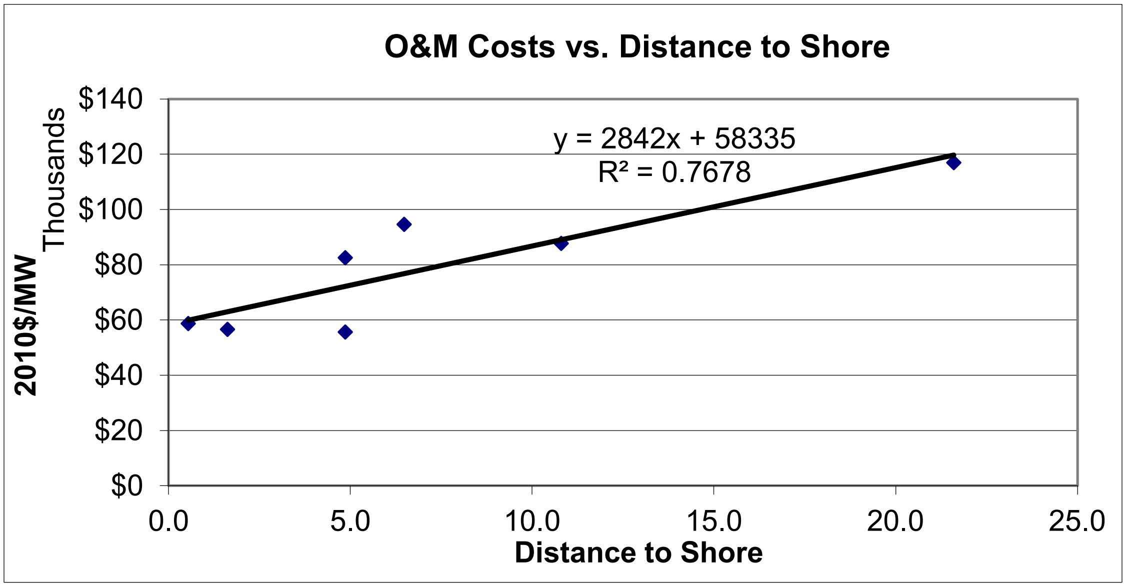
[67] Krueger, Andrew D., George R. Parsons, and Jeremy Firestone. "Valuing the visual disamenity of offshore wind power projects at varying distances from the shore: An application on the Delaware shoreline." *Land Economics* 87.2 (2011): 268-283.

Table 9. LCOE Change Due to Siting Closer to Shore

Project distance from shore	LCOE	% change
12 nm	226.5	
9 nm	220.5	-2.6%

Figure 7. O&M Costs vs. Distance to Shore[68]



The OPEX increased with distance from shore. The study team derived this relationship using distance to shore and cost per MW, based on existing projects as shown in Figure 7

4.1.1.1 Costs, Risks, and Challenges

Siting closer to shore has the potential to generate greater community opposition and permitting challenges. Strong stakeholder and community engagement and good visual renderings of proposed wind farms will be needed for any siting decisions. These needs are especially true for siting closer to shore. Leadership from NYS, in concert with at minimum local officials, commercial and noncommercial users, and BOEM would be required. The cost for stakeholder engagement can be in the area of $200,000.

Table 10 summarizes this intervention.

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[68] Analysis conducted by Deniz Ozkan using data provided to Atlantic Grid Development.

Table 10. Siting Intervention 1: Site OSW Farms Closer to Shore

Siting					
Intervention	Site at 8 or greater than 8 nm from shore				
Assumption in baseline	Offshore wind farms sited outside of DOS exclusion area (12 nm).				
Challenges	Increased interference with commercial and non-commercial ocean users.				
Specific actions	Stakeholder engagement for siting decisions; visualizations of wind farms at various locations.				
Begin	Early 2015				
End	End 2015				
Parties involved	Developer, BOEM, DOS, NYSERDA, commercial and noncommercial users, political representatives				
Cost	$200,000				
Intervention impact	**CAPEX**	**OPEX**	**AEP**[69]	**WACC**	**LCOE**
	- 1.7%	**-14%**	**0%**	***Not estimated***[70]	**-2.6%**

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[69] Wind speeds were determined to be no different between the Base project site and Project 1 site. Moving closer to shore may decrease AEP in other cases, however.

[70] Siting without proper stakeholder engagement could increase risk.

4.2 Predevelopment Interventions

As noted in the literature review, European cost reductions in wind farm development are expected to be achieved through greater project front-end engineering and design (FEED), use of advanced software tools to maximize wind farm arrays, modified cable burial depth, and the use of LIDAR.[71] These measures are expected to become standard industry practice, in both Europe and the U.S., according to industry stakeholder and policymakers. The stakeholders and policymakers did however offer additional predevelopment actions New York could take to reduce OSW costs.

4.2.1 Predevelopment Intervention 1: Obtain Lease and Visibility for On-Site Conditions

Summary of intervention: NYS obtains a federal lease and makes it available with a firm, stable revenue mechanism (per financing intervention described in next section) and state-generated data (wind resource, ground conditions, and environmental conditions) that provide early visibility on site conditions.

This approach contrasts with the approach used in Virginia, Massachusetts/Rhode Island Area of Mutual Interest (AMI), Delaware, and the upcoming lease auctions in Maryland and New Jersey. The federal leases for the Massachusetts/Rhode Island AMI and Delaware and Virginia wind energy areas (OCS blocks) were auctioned and subsequently awarded to a developer prior to the availability of any clear revenue mechanism.[72] The August 2014 lease auction in Maryland went forward with legislation authorizing Offshore Wind Renewable Energy Credits (ORECs) suggesting the opportunity for revenue certainty, but without a firm revenue mechanism in the bidder's hands. The lease auction in New Jersey, anticipated in 2015, is similarly expected to go forward with ORECs on the books, but without regulations as to how ORECs will be awarded.

According to experts interviewed for this study, the pairing of a project site lease with a firm revenue mechanism or contract opportunity can decrease the cost of capital for offshore projects by attracting infrastructure investors, who are Internal Rate of Return (IRR)-driven, rather than venture-capital type investors who target returns based on multiples of capital invested.

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[71] Note that environmental surveys are routinely done by The Crown Estate in the UK as "enabling" information for wind farm zones, and thus were not included in the UK study as a future cost reduction activity.

[72] The case of Virginia is different in that Dominion, the lease winner, is the ostensible purchaser as well and Virginia law facilitates approval of an offshore wind purchase. Additional developers participated in the auction, however, with no visible pathway to a revenue mechanism.

IRR requirements can be further effected according to experts, by packaging the lease and revenue mechanism with improved visibility on site conditions (wind resource, ground conditions, and environmental conditions): specifically, a two-year wind resource assessment campaign using LIDAR in the potential build-out area (with appropriate wave measurement technology);[73] a two-year environmental study (avian and marine mammals); and geophysical and geotechnical surveys of the WEA.

According to GG, which external experts agreed with, by providing these measures and conditions, NYS can facilitate lower IRR requirements for development capital for offshore wind projects: from the 15% to 20% range to the 12% to 15% range, and lead to more (and thus cheaper) development dollars otherwise available to projects. Using this estimate, the team calculated the LCOE when development IRR is reduced from 20% to 15%, finding an LCOE reduction of 0.9%.

If NYS engages in the work of obtaining a lease, installing equipment to collect data, and conducting ground condition and environmental surveys, these development activities will not have to be undertaken and paid for by the project developer.[74]

If NYS assumed the cost and risk of these activities predevelopment, the development stage expenditure by the developer would be reduced. Nonetheless, because the cost is still being borne by NYS taxpayers, the team analyzed the reduction in development expenses (DEVEX) from NYS engaging in met-ocean, seabed, and environmental data collection. The team calculated the DEVEX when it is funded by NYS, using an assumed 4% IRR, compared with the anticipated development capital IRR. They found that there is reduction on DEVEX of $41/kW (from $476/kW to $435/kW). The reduction in DEVEX reduces LCOE by 0.5%. Table 11 compares the development cost across projects, assuming the 5% change in development IRR and predevelopment activities funded at 4% cost of capital.

Table 11. Development Cost Reductions from Metocean, Geogphysical & Geotechnical, and Environmental Surveying

Project	Total development costs/kW (2014 dollars)	
	With no state intervention	With state intervention
Base project	476	394
Project 1	468	387
Project 2	435	359
Project 3	414	343
Project 4	445	368

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[73] Pairing LIDAR with wave measurement technology can maximize the benefit of this intervention.

[74] Developers will do more site-specific FEED work including G&G activities at the project site and environmental surveys for their EIS, and may still install a met tower as part of their business model. It would be necessary for NYS to identify with developers the activities that do have a benefit and determine the duration of those surveys or campaigns, to ensure that the benefit of NYS action is not obviated by the developer needing to duplicate expenditures.

The team calculated the reduction in DEVEX and in LCOE for each of these development activities, when done at 4% cost of capital, and found the following:

- Metocean data collected (using LIDAR) at NYS' cost of capital reduces DEVEX by $7/kW and LCOE by 0.09%.
- Ground condition surveying at state's cost of capital reduces DEVEX by $14/kW and reduces LCOE by 0.2%.
- Environmental surveying at state's cost of capital reduces DEVEX by $21/kW and reduces LCOE by 0.14%.

The cumulative impact on LCOE of the anticipated reductions in development IRR in DEVEX is a 1.3% reduction.

4.2.1.1 Additional Impacts of Intervention

Enhanced Competition and Reduced Bid Pricing

Improved information on site conditions and resource quality prior to any bidding or negotiating for a power contract can also translate into better risk assessment from the developer and could be reflected in fewer buffers for contingencies and more precise bid prices.[75]

Without ground condition data and site specific meteorological data, a developer – prior to having a power contract – would likely base its bid on desktop studies and on a resource assessment from a qualified resource assessment consultant, based on data from existing buoys. The literature suggests that buoy data with meteorological modeling is roughly 20% uncertain in terms of wind speeds. That uncertainty is reduced to approximately 10% with two years of LIDAR data.[76] From a meteorological perspective, a longer campaign is always better, but the uncertainty by adding a third year is reduced to roughly 9%. Thus, in addition to the impact of a two-year wind resource assessment campaign by New York on development IRR and DEVEX, it could be assumed that AEP and LCOE estimates would be improved in a bidding process for a power contract. Bidding is inherently a strategic action however and does not necessarily reflect underlying costs. Bids also reflect competitive pressures, as well as efforts to mitigate exposure to uncertainty and to maximize margins. The State's information on wind resource could have a rationalizing effect on bid prices in a competitive RFP by reducing uncertainty about revenue potential. The State having information on ground conditions can also improve negotiations on future overruns.

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[75] Bailey, B. H., Beaucage, P., & Bernadett, D. W. in M. Brower (Ed.) (2012). Wind resource assessment: a practical guide to developing a wind project. John Wiley & Sons.

[76] While LIDAR and meteorological tower may be viewed differently by financiers of offshore wind projects, there is not a big difference in uncertainty from a meteorological perspective.

Encouraging Greater Front End Engineering and Design (FEED)

NYS' predevelopment activities also may have the beneficial effect of allowing for greater FEED by developers which, according to the European cost reduction studies and stakeholders interviewed for this project, has the potential to significantly reduce CAPEX when it is done early enough in the process that it can lead to optimized foundation design, selection, and installation methodology. Industry experts have indicated that greater FEED will become standard industry procedure. However they also suggest that if NYS provides more visibility about site conditions up front—and in doing so frees up development dollars—then developers can invest more in earlier and greater FEED. It is not possible to estimate a reduction in CAPEX for New York projects, as we cannot predict what will become standard practice and what impact New York's development activities will have relative to standard practice. The team notes however, that the State, through revenue contracts, could encourage greater FEED to reduce CAPEX if indeed development dollars have been freed up by this intervention.

Shorten permitting time

Provision of baseline environmental data early in the process reduces risk of unknown environmental issues in the WEA and has the potential – depending upon the timing, quality and duration of data collection – to reduce the permitting timeline for an offshore wind farm. If NYS collects data that is accepted by BOEM for a developer's EIS, this could reduce the amount of environmental surveying the developer must do, and thus the amount of time to permit the wind farm. However, the team was unable to document a definitive acceptance by the federal government of such survey data done outside the scope of the specific project EIS. The study team therefore felt it imprudent to include cost reductions from a shorter timeline in our estimate of the intervention's impact, but rather chose to note it here as a potential impact.

Better pricing of weather risk

Additionally, sea state data can improve contracts for vessels. A significant cost driver is vessels being on standby during bad weather. Unknown weather risk often leads to significant pricing in the contractual framework, to ensure the full range of potential risks are covered. If the State were to provide site-specific sea state data, contracts can include maximum wave heights and wind speeds for various lifting situations based on historical data.

4.2.1.2 Costs, Risks and Challenges of the Intervention

This intervention would require expenditures by NYS in an uncertain environment. The team collected cost information for the pre-development and development activities in the intervention. By assuming these high up-front costs, the State absorbs the risk if offshore wind projects fail to materialize. Hence the intervention is best paired with other interventions that increase offshore wind's viability in New York State.

4.2.1.3 Other Enabling Pre-Development Activities

The stakeholder interviews elicited suggestions for additional actions by NYS that could make offshore wind development more efficient, orderly and cost-effective but that are unquantifiable because they either 1) are only now being implemented in Europe and as yet there is no track record of their impact, or 2) have a secondary or tertiary effect that likely is conflated with other actions.

Stakeholders identified the need to proactively zone New York's WEA for the areas best-suited for offshore wind development as well as to develop strategies at the front end to mitigate potential environmental, geophysical, and geotechnical problems in those areas. This latter practice now is being considered in Europe in response to lessons learned there, as interdisciplinary groups of engineers, environmental specialists, developers, construction professionals, and policymakers work together to plan strategically how to minimize cost and maximize output from the wind zone.

Industry stakeholders also noted that producing risk statements from the data gathered and making those risk statements public (standard practice in the oil and gas industry) can aid the industry and reduce duplication of costs and time. Typically, in the oil and gas industry, risk assessment identifies potential hazards, analyzes the impact or magnitude of the consequence of those hazards, and thus the ultimate risk, or the product of consequence and likelihood of each scenario. Compiling this information and making it available allows the developer to determine if the risk is tolerable and/or how to better manage the risk.

Table 12. Typical Development Costs for an Offshore Wind Farm

Component	Cost (millions of dollars)	Source
Floating LIDAR		
6 month deployment	0.75	AXYS Technologies
18 month deployment	1.50	AXYS Technologies
LIDAR Platform	4.50	AXYS Technologies
Met mast	10.00	AXYS Technologies
Wind resource campaign design	0.22	PMSS
Offshore Environment Assessment	5.32	PMSS
Onshore Environment Assessment and Coastal processes	0.14	PMSS
Geophysical and Geotechnical, and Unexploded Ordnance (UXO) surveys	4.16	PMSS

Table 13 summarizes this intervention.

Table 13. Predevelopment Intervention 1: Obtain Lease and Visibility for On-Site Conditions

<table>
<tr><th colspan="6">Predevelopment</th></tr>
<tr><td>Intervention</td><td colspan="5">State obtains federal lease, installs LIDAR (either floating or fixed), conducts “enabling” offshore and onshore environmental assessments, and conducts G&G and unexploded ordnance surveys.</td></tr>
<tr><td>Assumption in baseline</td><td colspan="5">Each developer engages separately in this work, using high-cost development dollars. NYS and utilities have limited visibility at time of power contract negotiation.</td></tr>
<tr><td>Challenges</td><td colspan="5">High up-front costs, meaning NYS is absorbing more of the risk of expenditures and failure of market to develop.</td></tr>
<tr><td>Specific actions</td><td colspan="5">NYS obtains permit to do site assessment, develops and implements LIDAR wind resource assessment campaign, contracts for environmental surveys, and contracts for geotechnical and geophysical surveys.</td></tr>
<tr><td>Begin</td><td colspan="5">Lease acquisition: 2015
Wind resource campaign: 2015
Environmental surveys: 2015
G&G surveys: 2015</td></tr>
<tr><td>End</td><td colspan="5">Lease acquisition: December 2015
Wind resource campaign: April 2017
Environmental surveys: 2017
G&G surveys: 2016</td></tr>
<tr><td>Parties involved</td><td colspan="5">NYSERDA, BOEM, developers, contractors</td></tr>
<tr><td>Cost</td><td colspan="5">See Table 12.</td></tr>
<tr><td>Intervention’s impact</td><td>DEVEX
- 0.5%</td><td>OPEX
n/a</td><td>AEP
n/a</td><td>WACC
0%[77]</td><td>LCOE
-1.3%</td></tr>
</table>

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[77] Whereas there are reductions in the cost of development capital, there are no reductions in WACC.

4.3 Market Visibility Interventions

Market visibility is a crucial element of OSW cost reduction, according to the literature reviewed and the stakeholders interviewed. Market visibility is a commonly used term in the offshore wind industry referring to certainty of size and timing for future market demand, which is critical for investment decisions. The experts suggested that a phased-in series of NYS offshore wind projects, dependent upon price reduction targets over the long term would directly lower costs with a mandated reduction trajectory matched to industry cost reduction expectations. Phasing also would reduce CAPEX, maintenance and insurance costs, and WACC. According to stakeholders interviewed, a minimum of 2.5GW, developed in a stable manner over a defined period of time, is needed to produce the certainty and sufficient critical mass in the U.S. to drive competitive prices here.[78]

Two potential market visibility interventions are analyzed in this study: 1) committing to a phased-in series of offshore wind projects in the New York Bight totaling a minimum of 2.5GW, and dependent upon negotiated long-term price reduction targets,[79] and 2) an initial "round" designed to generate a base of New York offshore wind competence and experience to enable multiple bidders for subsequent rounds, and to produce project data that can assist in planning and financing future rounds most cost effectively.

4.3.1 Market Visibility Intervention 1: Creating Market Visibility

Summary of intervention: Committing to a phased-in series of offshore wind developments in the New York Bight, dependent upon negotiated long-term price reduction targets.

The stakeholders interviewed suggest that New York projects are unlikely to attract the number of European equipment bidders that can generate truly competitive prices. According to the stakeholders even in a European market that is growing more competitive, "one off" projects in the U.S. are unlikely to generate multiple European supply chain bidders and thus lead to insufficient competition to lower costs. The experts contend that a series of several hundred megawatt projects, over a stable and defined period of time, would be required to spur competition of two to three bidders for U.S. projects. This scaling would lead to a reduction in CAPEX for projects as expected volume attracts greater competition.

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[78] 2.4GW is the minimum amount of offshore wind needed to achieve the LCOE reductions reported here, according to the experts interviewed for this study. This scale of development does not need to be solely in New York, but LCOE impact is dependent upon clear and consistent commitments as well as market signals.

[79] Because price reduction targets over the long term are best set with broad stakeholder input, we do not model a particular reduction target nor its potential impact on LCOEs of the build-out assumed in this study.

GG estimates, and the expert panel reviewers agree, that the CAPEX reduction from the additional players attracted to the U.S. market with New York market visibility of 2.5GW[80] would likely range between 10% and 20%. The team used a 15% CAPEX reduction as the mean. Their analyses indicate that this figure would reduce LCOE by 11.5%.

Additionally, GG estimates, and expert panel reviewers concur, that maintenance costs and insurance costs could be reduced in the 20% range, due to economies of scale. This figure could yield an LCOE reduction of 3.7%.

Clear market visibility in New York is also likely to generate repeated investment by equity investors with sector knowledge and experience, as opposed to pioneer investors, lowering the cost of equity and hence WACC.[81] GG estimated that this phenomenon could reduce the cost of equity by as much as 3% (from 15% to 12% for construction equity and 11% to 8% for operating equity). Lower equity in turn would yield a reduction in WACC for construction from 8.6% to7.2% and a reduction in WACC for operation from 6% to 5%. Total WACC falls by 1.2%, reducing LCOE by 14.1%.

Table 14. Estimated Reductions from Creating a Pipeline of Projects

LCOE element	Potential reduction from pipeline of projects
CAPEX	- 10% to - 20%[82]
Maintenance and insurance costs	- 20%
WACC	- 1.2%

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[80] The Build-out scenario used to determine the impact of technology advancements on New York-specific sites totaled 2.4GW. GG provided impact estimates of a 2.5GW pipeline. Because we do not see a significant difference between the Built-out scenario total and the minimum required pipeline, we apply GG's estimates to the Build-out scenario.

[81] Secondary but substantial effects on CAPEX could as be gained as supply chain is increasingly localized and as the U.S. develops more efficient construction management and maintenance procedures. We do not analyze these effects here to avoid duplication with learning effects assumed in previous analyses.

[82] Experts consulted for this study agree that 15% is the mean CAPEX reduction from the competition effect created by a pipeline of projects.

4.3.1.1 Costs, Risks, and Challenges

The team assumed that creating market visibility and implementing it over a five-year period would require personnel time, either through the development of an administrative office or addition of staff to manage the policy implementation. Assuming a three-person office (executive, analyst, and administrative assistant), personnel costs (salary and overhead) are estimated at \$800,000 per year over six to seven years. The risk of investing in this intervention, administratively, politically and financially, lies in the materialization of global cost reduction. If indeed NYS acts to create a market visibility thru a pipeline of projects with agreed upon price reduction targets over time, there is the risk that the global market will not have materialized to pull the market innovations needed to reduce cost. New York would then be in the position of either not being able to reach those target reductions or truncating its pipeline, creating market disruption and reducing investor confidence in NYS OSW over the long term. A pipeline of 2.5 GW of offshore would also have a ratepayer impact, estimation of which is beyond the scope of this study.

4.3.1.2 Enabling Actions to Maximize Benefit of Creating Market Visibility

The study did not assume a localization of supply chain due to the creation of a pipeline of projects. Nor did it estimate the cost reduction impact of a local supply chain. Depending on which part of the supply chain is localized (and when) costs could be higher than when manufactured in Europe, which has a longer learning curve. To maximize the benefit of the supply chain NYS could attract to New York manufacturers and fabricators for foundations, towers, nacelles, and blades and develop a proactive plan to increase U.S., regional, and local content, balanced carefully to avoid any negative consequences. Doing so may also have other beneficial effects such as keeping dollars spent in the local economy.

Table 15 summarizes this intervention.

Table 15. Market Visibility Intervention 1: Creating Market Visibility

<table>
<tr><th colspan="6">Market Visibility</th></tr>
<tr><td>Intervention</td><td colspan="5">NYS creates market visibility by committing to a phased-in series of offshore wind projects in the New York Bight, dependent upon negotiated long-term price reduction targets.</td></tr>
<tr><td>Assumption in baseline</td><td colspan="5">Fully competitive European market but insufficient critical mass in the U.S. to drive European suppliers to invest the necessary resources to market to, sell to, and service U.S. offshore wind projects.</td></tr>
<tr><td>Challenges</td><td colspan="5">Global cost reduction does not materialize; political challenge to commitment to currently over-market priced energy source (ratepayer/economic impacts).</td></tr>
<tr><td>Specific actions</td><td colspan="5">Reach consensus on building 2.5 GW of offshore wind; create an office to design and implement policies regarding where, when, and under what conditions pipeline is developed; prepare and evaluate bids, etc.</td></tr>
<tr><td>Begin</td><td colspan="5">Policy design begins in early 2015</td></tr>
<tr><td>End</td><td colspan="5">Policy design ends in late 2015; commitment made in 2016</td></tr>
<tr><td>Parties involved</td><td colspan="5">Developers, NY business community, PSC, ratepayer advocate, utilities, NYS, possibly Legislature.</td></tr>
<tr><td>Cost</td><td colspan="5">Administrative costs of $800,000 to 1 million/yr for 6 years. Range of ratepayer and economic costs.</td></tr>
<tr><td>Intervention’s impact</td><td>CAPEX
-15%</td><td>OPEX
-20%</td><td>AEP
0</td><td>WACC
-1.2%</td><td>LCOE
Up to -30%</td></tr>
</table>

4.3.2 Market Visibility Intervention 2: First Project Implementation

Summary of intervention: Implement first round projects to generate (1) a sufficient base of New York offshore wind competence and multiple bidders for subsequent rounds of offshore wind development in New York, and (2) project data that can assist in planning and financing future rounds most cost-effectively.

Stakeholders indicated that costs can be reduced in subsequent projects by ensuring that multiple developers are involved in the development of first round projects, growing the base of developers that have experience in offshore wind and thus furthering the possibility of multiple bidders in subsequent rounds. Second, depending upon the timing of subsequent projects, costs in those subsequent projects could be reduced if project data from the first round (construction costs and production) were in the public domain, for use in planning and financing later projects.[83] This work can be done in a straightforward manner by NYS if early projects are required to provide that data as part of the contract terms. Alternatively, or additionally, NYS could collaborate with adjacent states whose projects used overlapping construction techniques or contractors. States could collaborate to require developers to provide detailed data to the states that could then in turn be shared with project lenders. Thus, by either or both of these methods, by reducing uncertainty (about construction costs and/or production), equity requirements and hence WACC can be lowered. The effect, according to GG, is likely to be similar in order of magnitude to creating market visibility, by bringing in investors with slightly lower IRR requirements. Therefore, we used the same estimate as above: cost of equity falling as much as 3% from 15% to 12% for construction equity and 11% to 8% for operational equity, finding again the same impact on WACC (reduction of 1.2%).

4.3.2.1 Costs, Risks, and Challenges

As with many of the interventions, the implementation of the first round to ensure ratepayer benefits of future rounds requires strong collaboration with industry to ensure a program that works for developers, NYS and its ratepayers. For example, early collaboration may help to allay concerns from developers desiring competitive advantages of project data. The cost for this intervention could, depending upon how implemented, entail the outright purchase of project data by the state for future planning and financing and planned pipeline of projects. Administrative costs would likely be embedded in any entity managing broader offshore wind policy. Moreover, there is a potential trade-off between the benefit of a project's data being available for the next project in sequence and a compressed timeline. This challenge might be overcome with interstate agreements to obtain and share construction cost and production data from similar projects.

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[83] To maintain the impact of this intervention over the course of a build-out, it may also be necessary to put project data from subsequent projects (such as projects 2 and or 3 in this hypothetical Build-out scenario) into the public domain, to ensure that project data is well-matched to future project sites.

Table 16 summarizes this intervention.

Table 16. Market Visibility Intervention 2: First Round Implementation

Market Visibility					
Intervention	First round implemented to ensure competition and lower cost of capital in future projects.				
Assumption in baseline	First project(s) cultivate only one bidder for future projects; do not yield benefit to future projects beyond learning effects.				
Challenges	Potential pushback from offshore wind industry (developers and/or contractors) on project data release.				
Specific actions	In addition to creating an administrative unit to oversee OSW policy implementation (see above), design first round to include multiple projects, facilitate NYS's access to project data (construction and production).				
Begin	Undertake in policy design beginning in 2015; implementation in project 1 (FC 2020).				
End	Undertake in policy design ending in 2015; implementation ends at beginning of project 3.				
Parties involved	NYS, developers, contractors, BOEM, potential financiers for consultation in first round design.				
Cost	Costs embedded in administration costs of creating pipeline or "rounds" or projects; potential cost for NYS out-right purchase of project data for use in planning/financing future projects.				
Intervention's impact	**CAPEX** **0%**	**OPEX** **0%**	**AEP** **0%**	**WACC** **-1.2%**	**LCOE** **-14.1%**

4.4 Financing Interventions

Two interventions were identified by the stakeholders aimed specifically at reducing financing costs: 1) adopt an offshore wind revenue policy designed to ensure that the power produced by the OSW farm can be sold under a long-term contract; and 2) form an investment partnership between the appropriate NYS entity (or entities) and the banks that fund offshore wind, in order to pass on the state's favorable borrowing conditions.

4.4.1 Financing Intervention 1: Offshore Wind Revenue Policy

Summary of intervention: Adopt offshore wind policy designed to ensure that the power produced by the OSW farm can be sold under a long-term contract that reduces the risks that drive financing costs.

The impact of policy design on financing costs for renewable energy is increasingly well-documented. The International Energy Agency (IEA), for example, conducted a survey of renewable energy policies and concluded that designs which minimize investor risk can reduce renewable electricity costs by 10-30%.[84] Industry stakeholders and experts interviewed for this study argued that the most significant intervention to reduce financing costs (and thus LCOE) is policy ensuring offshore wind contracts include:

- A fixed price level or predictable formula, preferably indexed,[85] which will reduce price risk.
- The ability for the off-taker to include the contract in its regulated asset base and thus pass on the cost to ratepayers and, ideally, an accelerated process to have this approved by the PSC at an early enough stage of development to reduce political risk.

According to the stakeholders interviewed on this topic, policy that would most effectively lower cost of capital and hence LCOE would also include:

- Guaranteed dispatch (no curtailment risk).
- Full volume off-take (no volume risk).
- No obligation to manage access to market issues (no balancing cost risk).
- A mechanism allowing some flexibility as to the date the tariff starts, and how it applies to the construction period.

Other policy design elements to consider include:

1. A "claw back" mechanism (via a lower set price for OSW) if actual project costs are lower than anticipated, linked to an agreed upon absolute level of cost or an absolute IRR for the investor. This type of mechanism protects ratepayers while providing needed certainty for investors, which lowers the cost of capital.
2. Duration of contracts for OSW power: Longer contracts may attract cheaper equity for the operational phase of an OSW farm; shorter contracts would likely make projects more attractive in IRR terms
3. Mechanisms to limit absolute cost of the policy,
4. Mechanisms to ensure indifference of the set price for OSW to yearly wind levels, and
5. Mechanisms to deal with "route to market" issues if priority and volume guarantees are not included specifically.

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[84] de Jager, D., and M. Rathmann 2008. *Policy Instrument Design to Reduce Financing Costs in Renewable Energy Eechnology Projects*. Utrecht, the Netherlands: Ecofys International BV. Prepared for the International Energy Agency, Renewable Energy Technology Development

[85] Allowed to increase yearly by either a fixed percentage or in relation to a publicly available index (CPI, etc.).

The OSW revenue mechanism could be a Contract for Differences (CfD), bilateral Power Purchase Agreement (PPA) with a credit worthy off-taker (minimum BBB+), a Feed in Tariff (FiT) or a Reverse FiT.

GG estimated that adoption of such a policy can directly reduce WACC through increased leverage and/or longer debt maturity. Leverage ratios could increase from the 55% currently contemplated to 70% or potentially more. We calculated this change in the leverage ratio finding that it would reduce WACC by 0.2-0.4% and LCOE by 1.8-2.6%.

Adopting a policy that reduces investor risk can further reduce WACC through a reduction in the cost of equity – up to 4% is the difference observed between the UK before the Energy Market Reform was approved and Germany, where a stable revenue policy has been in place for years. If the cost of equity is reduced 4%, the team calculated that WACC would fall by 1.6%. LOCE would be reduced by 15.5%.

4.4.1.1 Costs, Risks, and Challenges

As indicated, although these design elements can be incorporated into a variety of policy mechanisms, key features of the policy design have proved difficult to implement in the U.S. First, even if price adjustment mechanisms are built in from the start, there is an inherent tension between maintaining policy stability to ensure investor confidence and adjusting the policy when unforeseen problems or new information arises.[86] Policymakers may desire to build in plans for future renegotiations.

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[86] Analyses of long-term revenue policies like FiTs for geothermal projects suggest that this concern is far less likely for projects with longer development lead times where policymakers should be able to see a problem coming with plenty of time to adjust. See Rickerson, Gifford, Grace and Cory (2012). *Geothermal FiT Design: International Experience and U.S. Considerations.* Technical Report, NREL/TP- 6A20-53320.

Table 17 summarizes this intervention.

Table 17. Financing Intervention 1: Offshore Wind Revenue Policy

Financing					
Intervention	Adoption of offshore wind revenue policy including necessary design features to reduce investor risk				
Assumption in baseline	Projects negotiate power purchase agreements on a case-by-case basis, putting credit risk on the off-taker that results in premiums to purchase a long-term hedge.				
Challenges	Politically difficult.				
Specific actions	Policy design, initiate necessary regulatory changes at PSC and NY-ISO, legislative action may be needed to affect some elements of the policy design.				
Begin	Early 2015				
End	End 2016				
Parties involved	NYS, developers, PSC, ratepayer advocates, utilities, NY-ISO, potentially Legislature				
Cost	Ratepayer impact is beyond scope of study; administrative costs embedded in entity managing offshore wind policy.				
Intervention's impact	**CAPEX**	**OPEX**	**AEP**	**WACC**[87]	**LCOE**
	0%	**0%**	**0%**	**-.2 to -.4%** **-1.6%**	**- 17 to -18%**

4.4.2 Financial Intervention 2: Investment Partnership

Summary of intervention: Form an investment partnership between the appropriate NYS entity (or entities) and the banks that fund offshore wind, in order to pass on favorable borrowing conditions.

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[87] Reflects the impacts of the two different levers on WACC: leverage ratio and reducing cost of equity.

Stakeholders interviewed for this study identified an investment partnership modeled on the German KfW program[88] as an intervention that could reduce financing costs and hence LCOE. Interviewees suggested that such a program could operate on a project level (increasing the volume of risk capital at a given price) or on a wholesale basis (reducing the banks' cost of funding). The KfW program is designed to be "market neutral," not affecting commercial terms.

In the absence of such a program, in a liquid market there will be a higher cost of debt, less optimized capital structures and hence a higher LCOE. Further, in a tight market, these conditions are exacerbated and lack of volume of project-level debt makes some projects unviable.

Such a program, either at a wholesale or project level, could directly reduce WACC through lowering funding costs by passing on the favorable borrowing conditions of NYS to lending banks, resulting in a cheaper funding pool made available to banks who pass it on to projects, but who retain project risk. If the program were implemented whereby the partnership operates at the project level, more competitive offers from commercial banks for the remaining volumes and thus better margins and/or higher gearing ratios could further improve the WACC – by increasing the amount and decreasing the cost of debt in funding sources.

Specifically, GG points to current observations in Germany, where the KfW program operates, where debt cost benefit can amount to 75-100 basis points. Leverage ratios could be anticipated to increase from the 55% currently contemplated to 70%. The team analyzed the impact on LCOE using the following ratios: for construction 58% and for operation 70%. Taken together, WACC could fall by 0.2 - 0.4%, and LCOE by 1.8- 2.6%.

4.4.2.1 Costs, Risks, and Challenges

The cost of such a program lies primarily in the opportunity to use New York's assets (borrowing authority of New York Green Bank, the New York Power Authority or the Long Island Power Authority) for other purposes. NYS's willingness to do so would ostensibly be grounded in its own analysis of the costs versus the benefits of the various "green energy" and/or infrastructure projects to which these entities could apply its borrowing conditions. The program would require the active participation of NYS (including the NY Green Bank and/or power authority) as well as private financiers. Additionally, NYS would likely need to engage in proactive recruitment of U.S. financial institutions to finance offshore projects, to broaden the capital pool for offshore wind, which is now limited.

Table 18 summarizes this intervention.

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[88] The KfW bank group is a public agency in Germany and is charged with taking support measures with an official mandate, granting loans and other forms of financing to public stakeholders, financing social measures and taking measures to promote education and to grant other financing in the interest of the German and European economy. The KfW (German Reconstruction Loan Corporation) bank group is financing the installation of up to ten offshore wind farms in the German North and Baltic Sea with credit at market rates via the special programme "Offshore-Windenergie". A total credit volume of 5 bn Euros is allocated for this purpose. http://www.offshore-windenergie.net/en/politics/kfw-programme

Table 18. Financial Intervention 2: Investment Partnership

Financing					
Intervention	Form an investment partnership between banks that fund offshore wind and the appropriate NYS entity/entities.				
Assumption in baseline	A tight market for capital, higher cost of debt, less optimized capital structures, need for multilateral financing.				
Challenges	Limited capital in NY Green Bank, competition for NY Green Bank funds, competing priorities for public utilities				
Specific actions	Recruit U.S. financial institutions to lend to New York OSW projects, determine appropriate New York entity to participate.				
Begin	July 2015				
End	July 2017				
Parties involved	NYSERDA, NY Green Bank, NYPA, financial institutions currently or potentially funding offshore wind.				
Cost	Opportunity costs, administrative costs.				
Intervention's impact	**CAPEX**	**OPEX**	**AEP**	**WACC**	**LCOE**
	0%	**0%**	**0%**	**-.2 to -.4%**	**-1.8-2.6%**

4.5 Installation, Operations, and Maintenance (IO&M) Interventions

The European cost reduction analyses point to a number of innovations in IO&M that will reduce the cost of offshore wind energy, including faster ships, a variety of incremental installation process improvements, and radically new installation methods such as whole turbine/float and sink installation. Improved vessel crew-transfer systems and range of working conditions, mother vessel ships, inter-operator maintenance, and using joint fleets and infrastructure are all expected to reduce European O&M costs.

According to the experts interviewed for this project, faster ships will materialize in the U.S. with a sufficient market, as will ships built to manage crew vessel transfer in the waters of the East Coast of the U.S., and which can be utilized in a wider range of working conditions. There are also many improvements in the installation and O&M processes that are expected to become standard industry practice, including offshore assembly and whole turbine/float and sink installation. However, gaining the benefit of these interventions requires amenable local conditions: primarily a trained workforce able to transfer improved European practices and access to near-by ports that can accommodate advanced installation methods. Therefore, the team analyzed two interventions to maximize installation and O&M cost reduction: workforce training and port development.

4.5.1 IO&M Intervention 1: Workforce Training

Summary of intervention: NYS funds training academies designed to transfer knowledge from experienced European OSW project managers, supervisors, and workers to the local workforce.

The assumption is that without the intervention workforce training proceeds through individual developer efforts. To date in the U.S., OSW developers have seeded community college programs and coordinated locally with workforce development programs on industry workforce needs. Experts interviewed for the project indicated that improving workforce training and skill transfer may reduce CAPEX (through contingency budget) and OPEX (by avoiding mistakes and thus cost overruns). Because the team applied the 5% learning rate over the course of this study's build-out scenario, they do not again estimate that on the impact of LCOE. In addition, experts estimated that having a locally trained workforce could reduce the IRR requirements of investors as investors see less risk in project execution with a trained workforce. It was suggested, however, that this was unquantifiable.

The team did account for the estimated increased production in early years through improved turbine reliability and availability. Different experts estimated between 0.2% AEP increase and a 1.5% AEP increase. The team then applied a 0.75% increase in AEP, and found that this intervention could reduce LCOE by 0.9%.

4.5.1.1 Costs, Risks, and Challenges

Massachusetts is engaged in offshore wind workforce training, as part of its development of the New Bedford Wind Energy Center. According to publicly available information from Massachusetts Clean Energy Technology Center, Massachusetts has two programs that are each budgeted between $125,000 and $250,000 per year. These programs fund other "green job" training in addition to OSW and do not appear to include direct European-U.S. worker skill transfer.

According to NYS, the State's funding for large programs to train wind installers has ranged from $300,000 to $650,000. Therefore, the team estimated a $500,000 program over two years to prepare for the first project of this study's build-out scenario. The risk of implementing a workforce training program for offshore wind is the same risk for any new technology training: failure of the industry to materialize.

Table 19 summarizes this intervention.

Table 19. IO&M Intervention 1: Workforce Training

Installation, Operations, & Maintenance					
Intervention	Fund training academies designed to transfer knowledge from experienced European OSW project managers, supervisors and workers to the local workforce.				
Assumption in baseline	OSW developers seed community college programs and work with workforce developers/labor on industry needs.				
Challenges	Risk of training workers for an industry that may never develop in NYS				
Specific actions	With interested industry partners, identify European partners, appropriate NYS workforce development programs, labor unions and businesses. Design training academy to most effectively transfer skills.				
Begin	January 2018				
End	January 2020				
Parties involved	NYSERDA, NYS workforce development/economic development agency, developers, labor unions, European OSW industry, interested New York businesses				
Cost	$500,000/yr over 2 years				
Intervention's impact	**CAPEX** **In learning rate applied**	**OPEX** **In learning rate applied**	**AEP** **+ .75%**	**WACC** **Not quantified**	**LCOE** **-0.9%**

4.5.2 IO&M Intervention 2: Port Development

Summary of intervention: New York readies a port from which New York offshore wind projects can be staged.

Optimal port locations reduce installation transfer times and required construction time windows, allowing for faster and more predictable installation. The team assumed that without any intervention, offshore wind projects installed in New York waters will be staged out of southern New England, at either the New Bedford Wind Energy Center in Massachusetts or Quonset Point in Rhode Island. Projects in the Mid-Atlantic could be staged out of the Port of Paulsboro in New Jersey.

The stakeholder interviews did not yield a consensus as to whether New York should follow in the footsteps of Massachusetts and New Jersey in preparing a port for offshore installation. Some argued that a purpose-built port in New York Harbor would significantly reduce cost. Such a port would need (1) a minimum 35 foot draft; (2) an adjacent heavy load-bearing quay with suitable crane capacity and (3) large open space for lay-down of components and subsequently for adjacent component manufacturing; and (4) few or no physical obstacles (e.g. low bridges, overhead power lines) between the quay and the open ocean.

The alternative to this approach offered by some advisors is for an industry-government partnership to supply information on and access to existing ports rather than building a port. Information might include contamination, dredging needs, for example, and facilitating access to the most cost-effective ports.

The team estimated the impact of an installation/staging port in New York on LCOE, compared to the base case of New York projects being staged out of Southern New England or New Jersey. It is noted that whereas there may be ample sites, not all sites would be suitable for all purposes, and that it is likely that none of the sites in New York Harbor would be well-suited for projects to benefit from installation innovations such as whole-turbine installation and/or float and sink installation. The team therefore examined generally the impact that a New York port could have on CAPEX and contingent budget. GG estimated that a New York port could lead to a 5% reduction in CAPEX and a reduced contingent budget, with the gain equal to 2 to 5% of total CAPEX.[89] A 5% reduction in CAPEX would reduce LCOE by 4.4%.[90]

Moreover, GG noted that New York-specific port development, when done in conjunction with creating market visibility previously discussed, sends market signals that can help build further credibility and help attract more long term and cheaper capital. As noted with the Market Visibility, this effort can lead to a 1.2% reduction in WACC and a 14.1% reduction in LCOE. This LCOE impact would not be gained by port investment and development alone.

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[89] Broadly, installation costs can vary between 10% to 20% of the total CAPEX with significant budget buffers for installation/weather windows.

[90] No reduction in development expenditure; reduction to contingency of turbine and foundation installations.

4.5.2.1 Costs, Risks, and Challenges

European experience shows that redevelopment costs could range from $275 million to $485 million, with an average cost of $360 million. Three ports have undergone redevelopment in the U.S.: New Jersey's Port of Paulsboro, the New Bedford Wind Energy Center in Massachusetts, and Quonset Point in Rhode Island. The State of New Jersey has invested an estimated $100 million on redevelopment efforts including environmental remediation of the former petroleum distribution center, as well as the construction of an access road and bridge connecting the port directly to an interstate highway. Their activities were intended to prepare the port for users to customize operations to suit their individual needs. Customized upgrades such as heavy load-bearing quays for example are expected to be funded by the developer or as a part of the lease negotiation.

According to publicly available reports, the planned marine commerce terminal in New Bedford Harbor in Massachusetts will cost between $50 and $100 million. Infrastructure improvements were made to the Port of Davisville's piers and terminals at Rhode Island's Quonset Business Park, with the help of a $22.3 million federal stimulus grant. An estimated $75 million to $100 million in wharf upgrades is expected to be privately funded.

Regarding risk, this intervention, like others cited here, carries a risk of investing capital in an industry that never takes off. A different risk would be investing in port development that does not allow the industry to take the benefit of subsequent industry installation innovations. A detailed study of the capacity of New York Harbor ports, what aspects of installation can be handled from each, and a detailed cost benefit assessment of that (or those) port(s) would be required to understand the impact on LCOE, which is beyond the scope of this study.

Table 20 summarizes this intervention.

Table 20. IO&M Intervention 2: Port Development

<table>
<tr><th colspan="6">Installation, Operations, & Maintenance</th></tr>
<tr><td>Intervention</td><td colspan="5">Upgrade a New York port for the staging of New York offshore wind farms.</td></tr>
<tr><td>Assumption in baseline</td><td colspan="5">New York offshore wind projects staged out of Southern New England or New Jersey.</td></tr>
<tr><td>Challenges</td><td colspan="5">Balancing the development of an OSW port with the need to keep options open for future port uses if OSW fails to materialize in New York.</td></tr>
<tr><td>Specific actions</td><td colspan="5">Analyze opportunities in New York for a redeveloped OSW port.</td></tr>
<tr><td>Begin</td><td colspan="5">Port selection and planning: 2015
Port construction: early 2019</td></tr>
<tr><td>End</td><td colspan="5">Port selection and planning: 2017
Port construction: end of 2020</td></tr>
<tr><td>Parties involved</td><td colspan="5">NYS, Port Authority and operators, developers</td></tr>
<tr><td>Cost</td><td colspan="5">Range of $30 -$100 million (depending on selected location, its current infrastructure and existing assets)</td></tr>
<tr><td>Intervention’s impact</td><td>CAPEX
-2% to -5%</td><td>OPEX
0%[91]</td><td>AEP
0%</td><td>WACC
-1.2%
<i>(only in conjunction with other policy interventions, not included here in LCOE reduction)</i></td><td>LCOE
-4.4%</td></tr>
</table>

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[91] Assumed that O&M ports and installation are different. O&M costs are unrelated to any change in installation port location.

4.5.2.2 Other Enabling IO&M Actions

Stakeholders identified numerous other potential NYS actions that could make O&M more efficient, orderly, and cost-effective but for which the benefits are unquantifiable because they either 1) are only now being implemented in Europe and have no track record, or 2) have a secondary or tertiary effect that is likely conflated with other actions.

For example, risk assessments from metocean, G&G or environmental data that NYS might gather can help both installation and O&M risk management. Using as a model the interdisciplinary and strategic zone appraisal planning efforts being implemented in Europe to maximize the output of wind energy zones (as described in Predevelopment Intervention section), an industry and government collaboration could work to reverse-engineer a cost-effective O&M strategy by first evaluating from the end position how projects are going to be operated and what asset management and O&M assets are required. Lastly, clear emergency response plans coordinated with industry, state, and the U.S. Coast Guard also reduce costly contingencies.

4.6 Transmission Interventions

The final opportunity for cost reduction that the team evaluated for this study is interconnecting offshore wind farms and bringing their energy to shore via a transmission "backbone." The team calculated the LCOE for a backbone connection versus individual radial connections. The team also calculated the impact of a backbone on LCOE both when the transmission is part of the cost of wind farm and when it is not to demonstrate the cost of offshore wind if the transmission were handled via an offshore transmission operator (OFTO), similar to the current regime in the UK. An OFTO might either assess fees for moving power or could absorb those costs due to other system benefits.

4.6.1 Transmission Intervention 1: Offshore Backbone

Summary of intervention: Bring energy ashore by connecting OSW farms in a single transmission backbone rather than connecting each individual wind farm to shore with radial lines.

The assumed transmission approach without this intervention is that each wind farm is connected to shore with individual radial lines. Figure 8 illustrates the radial build-out scenario in this study. Figure 9 illustrates the build-out scenario in which four interconnected wind farms are connected to shore by a High Voltage Direct Current (HVDC) backbone.[92]

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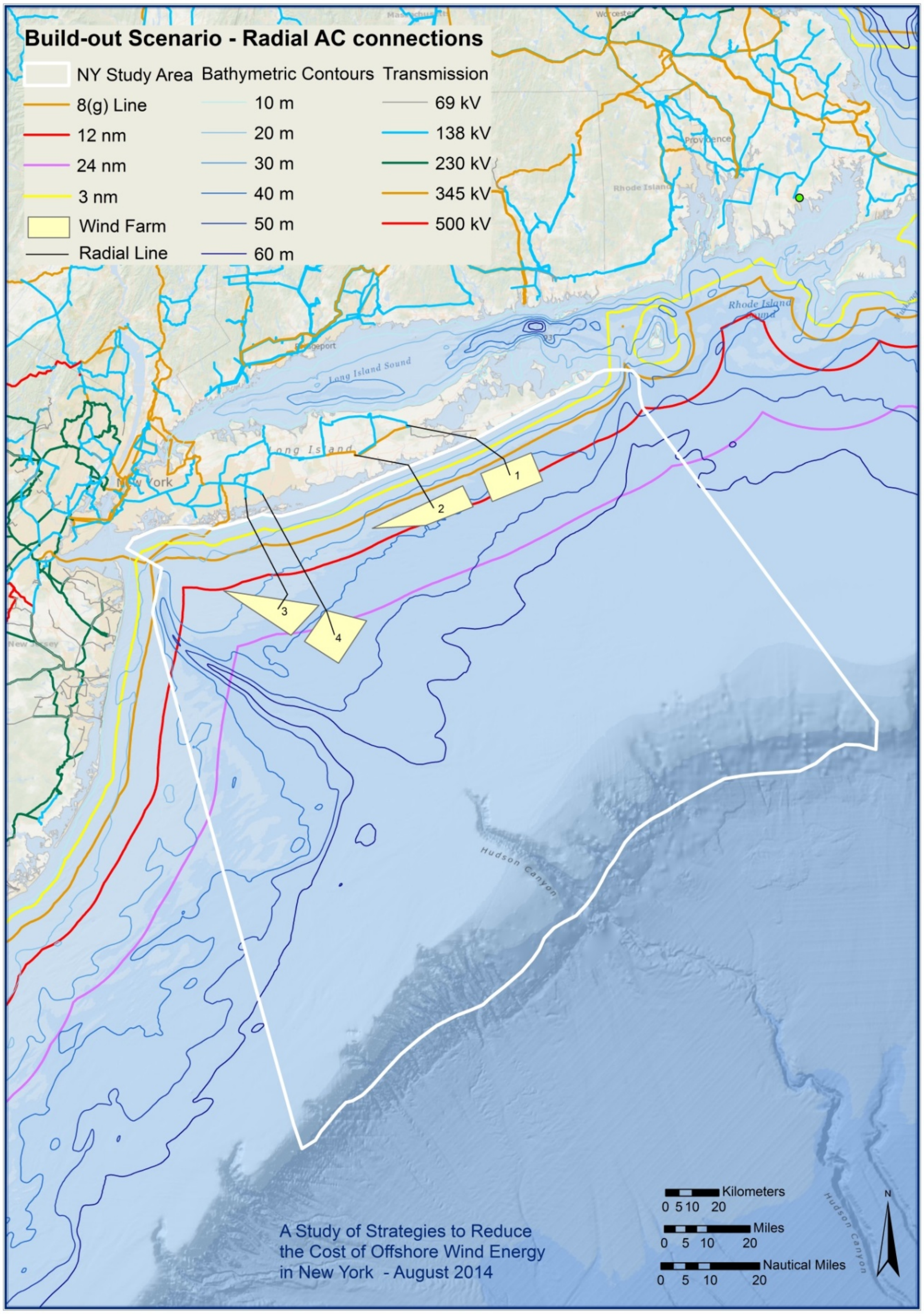
[92] HVDC is an electric power transmission system that uses direct current for the transmission of electrical power, in contrast to alternating current. HVDC can be beneficial for longer-distance transmission and for reducing losses during transmission.

Figure 8. Build-Out Sites with Radial AC Connections



A Study of Strategies to Reduce the Cost of Offshore Wind Energy in New York - August 2014

Table 21 shows the LCOEs for each project for both types of connections.

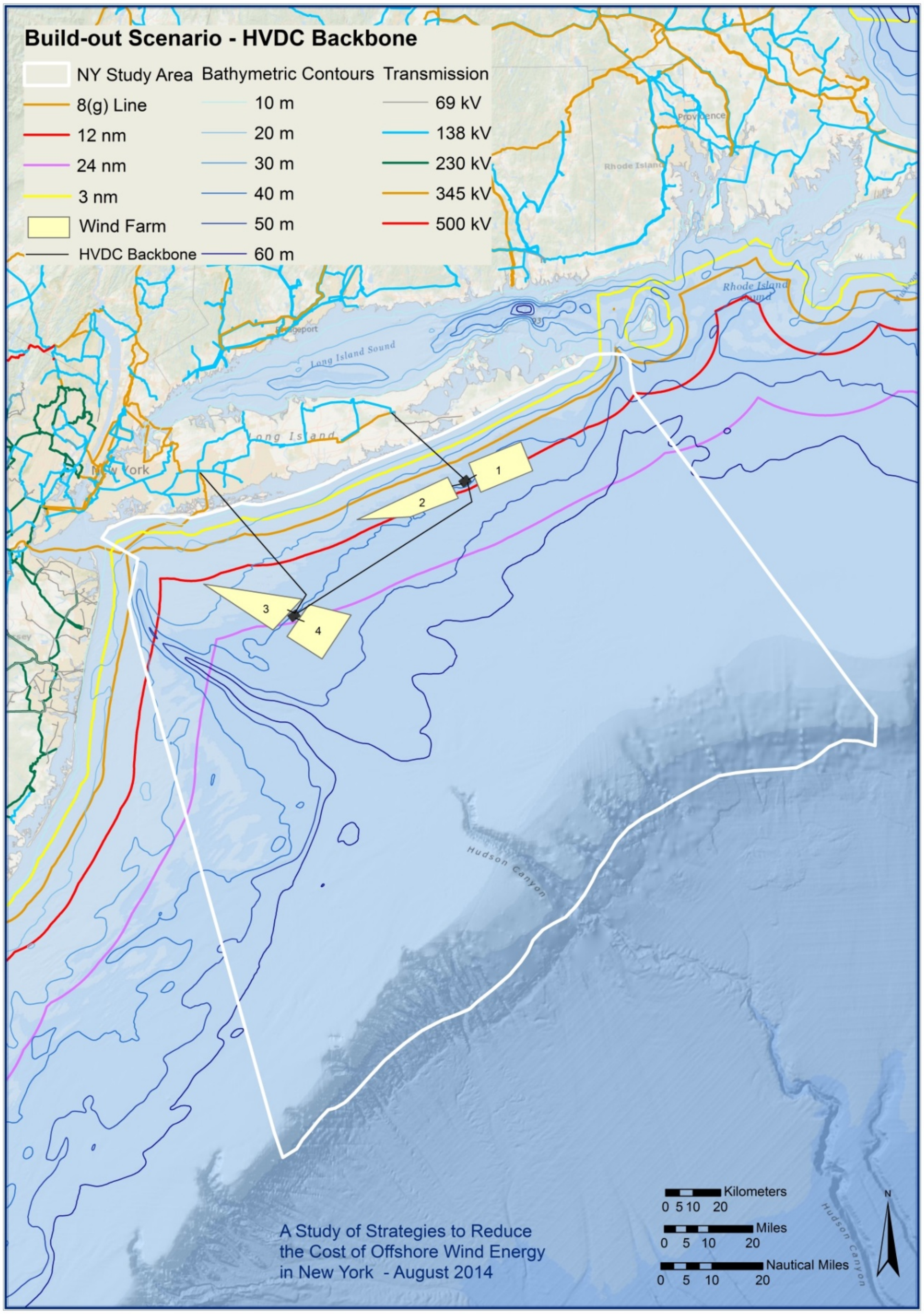
Table 21. Impact of Transmission Intervention

Project	LCOE with radial connection $/MWh	LCOE with backbone connection $/MWh	% difference
1	$220.5	$231.5	+5.0%
2	$206.5	$225.5	+9.2%
3	$205.5	$222.0	+8.0%
4	$222.5	$230.5	+3.6%

The backbone LCOEs reflect the costs of an offshore wind farm's export cables, converter platform, and onshore connections, as well as the transmission line connecting the eastern wind farms (Projects 1 and 2) to the western wind farms (Projects 3 and 4) at an approximate cost of $600 million per project. The backbone transmission system results in higher LCOEs than does radial transmission. It is important to note that these costs do not include the reduced permitting costs for the wind farms when the permitting is done for the backbone system as a whole, rather than by each individual wind farm developer.

The finding that a backbone increases the cost of offshore wind is unlikely to hold true at some level of Build-out scenario larger than the 2.4 GW contemplated in this analysis. Moreover, a backbone may also become more beneficial for projects further offshore, which realize more benefits from HVDC. If NYS moves forward with OSW, it may want to investigate at what scale an HVDC backbone begins to reduce cost and how radials can be implemented in a way that does not reduce the potential future benefit of a backbone, and indeed, that can allow a network to evolve.

Figure 9. Build-Out Sites with HVDC Backbone



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the Cost of Offshore Wind Energy
in New York - August 2014

The team also calculated the LCOE for offshore wind if the transmission costs were not included in the LCOE for the wind farm (illustrated in Table 22). They did so for two primary reasons. First, the extent to which the transmission costs for an offshore wind backbone could be "socialized" by the NY-ISO, if it were found to have additional system-wide benefits is unknown. Socialization of costs is the concept that costs of an asset should be spread across beneficiaries. A Federal Energy Regulatory Commission's (FERC) objective is that all beneficiaries of transmission lines should pay for their cost. It is a policy whereby the costs of high-voltage transmission facilities (e.g. 500kV), that have regional benefits, are spread broadly across the utilities in a region (and their ratepayers), according to each utility's contribution to the aggregate load. Second, industry stakeholders pointed to the potential benefits of European OFTOs as a model for NYS to follow. The implementation of an OFTO is different in the UK and in Germany, for example but an OFTO can be simply described as a separate entity that takes responsibility for offshore transmission assets. The OFTO assets link offshore generation to the onshore network. The OFTO will normally have ownership of the offshore electricity transmission infrastructure, an onshore substation and the electrical equipment relating to their operation. The owner recovers investment in the transmission assets by charging fees to the wind project owner for transmitted power.[93, 94]

Table 22. Impact on LCOE of Including Offshore Wind Transmission Costs

Costs assume stagnant U.S. OSW policy and financing environment.

Project	LCOE Including radial transmission cost $/MWh	LCOE Including backbone transmission cost $/MWh	LCOE Excluding any transmission cost $/MWh
1	$220.5	$231.5	190.5
2	$206.5	$225.5	184.5
3	$205.5	$222.0	182.5
4	$222.5	$230.5	192.5

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[93] KPMG (2012). *Offshore Transmission: An Investor Perspective*. Prepared for The Electricity and Gas Markets Authority.

[94] The German model requires the TSO to build HVDC connection for qualified wind projects within a certain timeframe. The TWO owns assets out to the offshore converter station (not including substation or export cable from substation to converter station). Capital costs are socialized through customer rate adders.

Table 23 summarizes this intervention.

Table 23. Transmission Intervention 1: Offshore Backbone

Transmission					
Intervention	Connect wind farms via HVDC transmission backbone.				
Assumption in baseline	Offshore wind farms connected to shore with HVAC radial transmission lines.				
Challenges	Understanding at what build-out scenario (scale, siting, etc.) it becomes more cost-effective to interconnect wind farms.				
Specific actions	Transmission planning study to understand implementation issues for Projects 1–4 to allow a network to evolve in any future build-outs. Transmission planning study to understand the long-term build-out scenario (scale and siting) for which a backbone is cost-effective.				
Begin	2016				
End	2017				
Parties involved	NYS, developers, ISO, public and/or private transmission operators				
Cost	$200,000 for transmission study to confirm				
Intervention's impact	**CAPEX** **-**	**OPEX** **-**	**AEP** **-**	**WACC** **-**	**LCOE** **+ 3.6% – +9%**

4.6.1.1 Costs, Risks, and Challenges

The cost of the transmission system, private or public, is borne by ratepayers. Benefits from reduced congestion and more wheeling also benefit ratepayers. However the costs, risk, challenges, benefits, impacts and potential fee structure of an OFTO-operated backbone are beyond the scope of this study. Overall, the interventions have varied impacts on LCOE (Figure 10).

Figure 10. Impact of Interventions on LCOE[95]

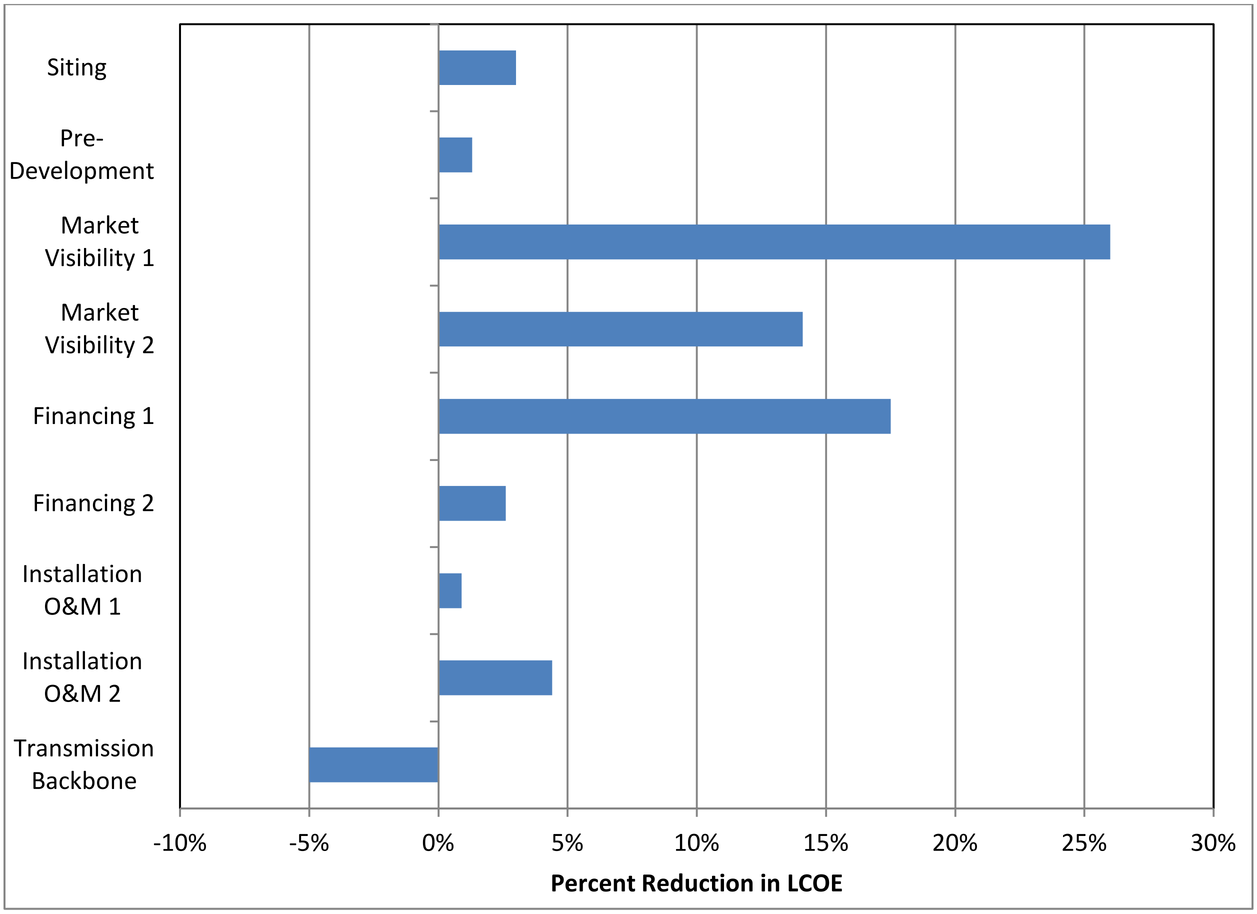

Figure 10 shows the impact on LCOE of each intervention if applied in isolation (parametric analysis). Because the effects of interventions are correlated, when multiple interventions are applied to a project, the resultant total project impacts may be smaller than the sum of predicted impacts for each unique intervention.

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[95] This graph is meant to compare the impact of each intervention, in isolation. The percentage reductions cannot be added. Comparison is not intended to compare interventions' efficacy on a per-dollar-invested basis.

5 Findings Regarding Impacts of Interventions Bundled at Project Level

To this point, this study has reported the interventions identified in stakeholder and policymaker interviews and their estimated impacts on the CAPEX, DEVEX, OPEX, AEP, WACC and Dev IRR, and hence LCOE. Here, the report highlights the impact of the interventions when bundled appropriately at the project level.

For each of the four hypothesized projects, after examining the bundle and removing overlaps of impacts and adjusting for co-related impacts, each of the applicable interventions was applied in a stepwise calculation order, and a corresponding impact on LCOE derived. From there, the relative impact of each category of interventions on the project LCOE was established.

5.1 Financing Assumptions for Analyses of Aggregated Impacts

To analyze the aggregated impacts of the identified NYS-level interventions, the team utilized the same Build-out scenario and financing assumptions

As reported in Section 4, many of the NYS-specific interventions can reduce WACC. Thus, to prevent an unrealistic lowering of WACC, the study team set a floor of 8% equity IRR for permanent financing for the first three projects. The 8% floor was eliminated for the fourth project's analyses, per expert observations that as the industry matures different types of institutions enter the space, in some cases taking less return than would normally be expected.[96]

5.2 Applicability of Interventions to Specific Projects

The team's first step was to determine which interventions applied to each project – either directly when first applied or its lasting impact when it was applied earlier. Then the bundle of interventions was applied to each project as shown in Table 24.

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[96] Eliminating the 8% floor on equity IRR for the analyses of aggregate impacts of interventions on Project 4's LCOE is based on recent observations of investors in European offshore wind projects that indicate that as the industry matures, different types of institutions (such as pension funds and insurance companies) are entering the space, and in some cases taking less return, if they see the operational asset as a long-term infrastructure asset well-matched to their needs.

Table 24. Interventions Bundled by Project

Project	Interventions applicable
1	Siting[97] [Section 4.1] Pre-development (lease, revenue mechanism, metocean, G&G, env.) [Section 4.2] Creating a market visibility with a pipeline of projects [Section 4.3.1] Risk reducing revenue contract policy/mechanisms [Section 4.4.1] Investment partnership to lend favorable borrowing conditions [Section 4.4.2] Workforce training [Section 4.5.1] New York installation port to stage projects [Section 4.5.2]
2	Siting [Section 4.1] Pre-development (assuming continuity of state sub-leasing and surveying done for full build-out area) [Section 4.2] Continued market visibility with a pipeline of projects [Section 4.3.1] Competitive bidding and project data (construction/production) made available from prior projects (either project 1, and/or similar projects in adjacent states, dependent upon length of time between project 1 and project 2)[98] [Section 4.3.2] Risk reducing revenue contract policy/mechanisms [Section 4.4.1] Investment partnership to lend favorable borrowing conditions [Section 4.4.2] Workforce training [Section 4.5.1] New York installation port to stage projects [Section 4.5.2]
3	Pre-development (assuming continuity of state-subleasing and surveying done for full build-out area) [Section 4.2] Continued market visibility with a pipeline of projects [Section 4.3.1] Bidders and project data from first round [Section 4.3.1] Risk reducing revenue contract policy/mechanisms [Section 4.4.10] Investment partnership to lend favorable borrowing conditions [Section 4.4.2] Workforce training [Section 4.5.1] New York installation port to stage projects [Section 4.5.2]
4	Pre-development (assuming continuity of state-subleasing and surveying done for full build-out area) [Section 4.2] Continued market visibility with a pipeline of projects [Section 4.3.1] Bidders and project data from first round [Section 4.3.2] Risk reducing revenue contract policy/mechanisms [Section 4.4.1] Investment partnership to lend favorable borrowing conditions [Section 4.4.2] Workforce training [Section 4.5.1] New York port to stage projects [Section 4.5.20]

5.3 Impact of Bundle of Interventions on LCOE

LCOE for each project was calculated with the applicable interventions enacted.

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[97] Siting intervention for project 1 and 2 was included in each project's starting point LCOE for these analyses.

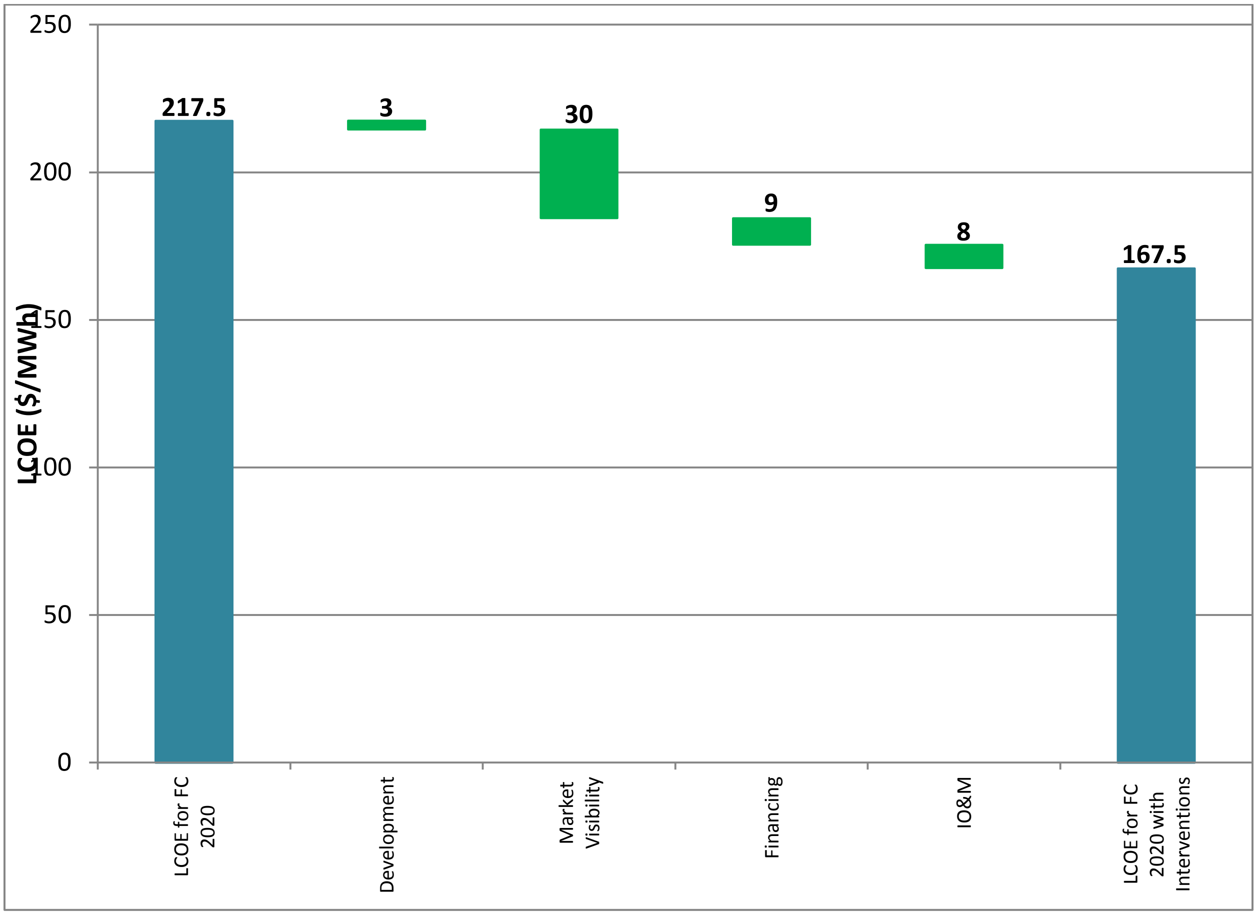
[98] In our hypothetical Build-out scenario financial close for projects occurs every year, thus construction and production data from Project 1 would not be ready by financial close of project 2, when it could affect WACC. Nevertheless to illustrate the impact of such, we include the impact on project 2 of making construction and production data available, noting that it would require either a greater time gap between projects than in our hypothetical sequence, and/or project data obtained from other U.S. projects (e.g. DOE pilot projects, earlier projects in neighboring states, etc.).

5.3.1 Project 1

The analyses show, and as illustrated in Figure 11, the combined NYS interventions in the areas of predevelopment, market visibility, financing, and IO&M can yield a 23% reduction in LCOE. The majority of that reduction comes from creating market visibility. The impact of creating market visibility when bundled with other interventions is different from its impact reported in Section 4.3 where each intervention was treated independently. Section 4.1 explains these changes in financing assumptions and the application of a WACC floor. As detailed in Section 4.3.1, creating market visibility reduces CAPEX and OPEX due to increased competition in the U.S. as equipment suppliers and contractors see a sufficient critical mass that make it worthwhile to market to, sell to and service U.S. projects.

Figure 11. Impact of Project 1 Interventions

LCOE for FC 2020 includes global cost reduction achievable by 2020, U.S. learning from previously installed capacity, sited within 12 nm, and financial assumptions detailed in Section 2.4.

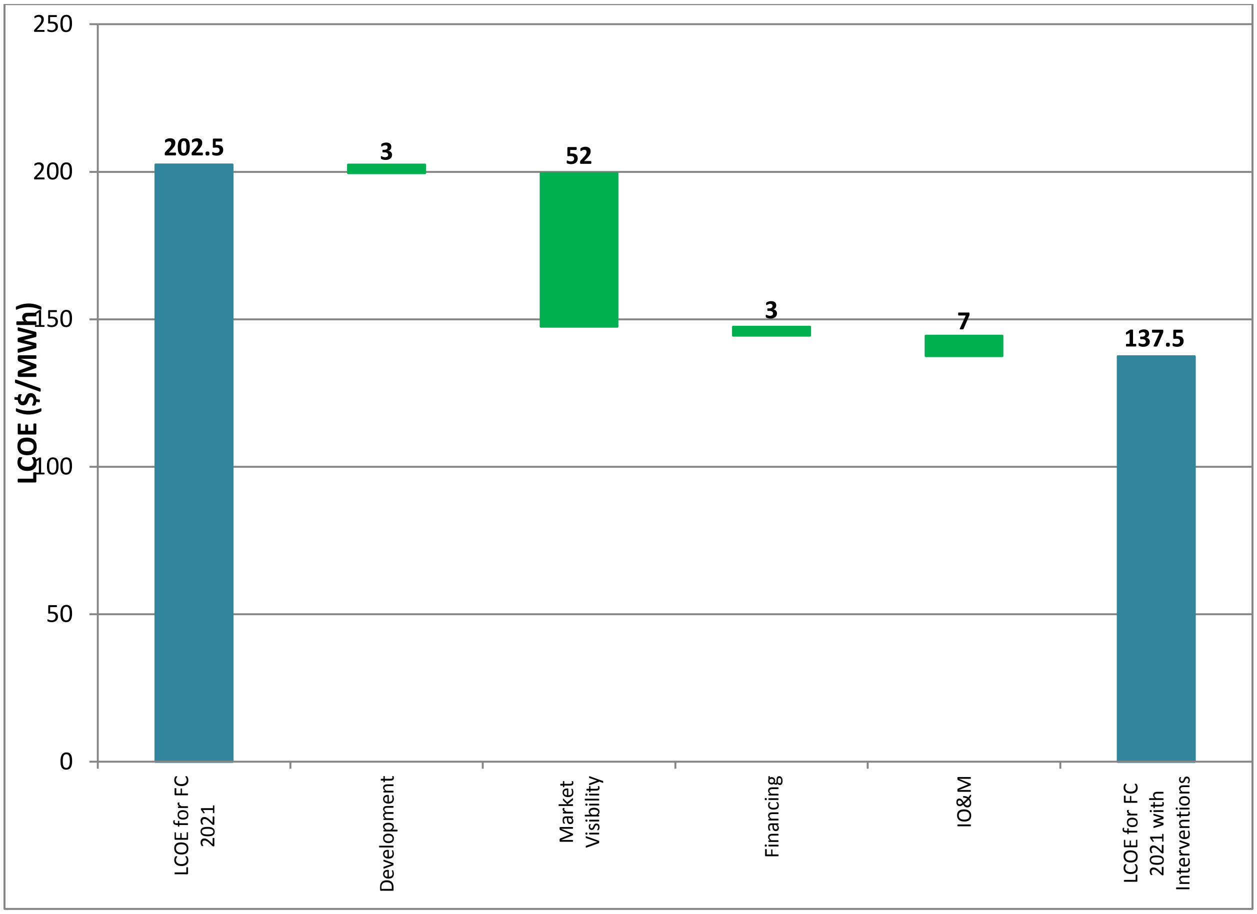


5.3.2 Project 2

As illustrated in Figure, the Project 2 interventions further reduce cost. This is a result of the impact of an additional intervention in Project 2: utilizing construction data generated by Project 1 (or perhaps from projects in nearby states) to assist in Project 2's financing and planning. The total LCOE reduction is 32%.

Figure 12. Impact of Project 2 Interventions

LCOE for FC 2021 includes global cost reduction achievable by 2021, U.S. learning from previously installed capacity, sited within 12 nm, and financial assumptions detailed in Section 2.4.1.

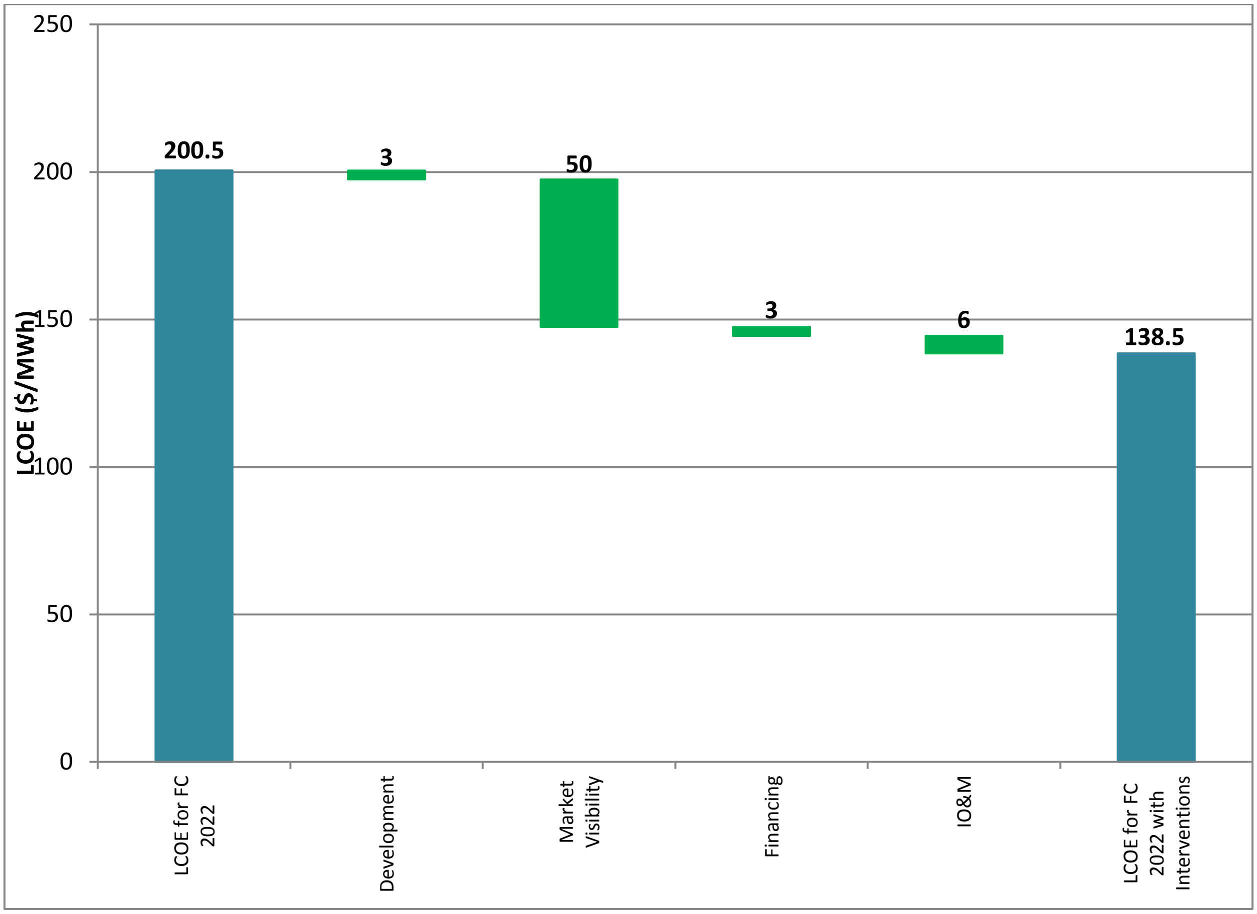


5.3.3 Project 3

There were no discernible differences between the interventions applied to Project 2 and Project 3 or in their resulting impact. The starting LCOE for Project 3 was slightly lower than the starting point LCOE for Project 2, reflecting the learning rate from increased capacity between the two projects (Figure 13).

Figure 13. Impact of Project 3 Interventions

LCOE for FC 2022 includes global cost reduction achievable by 2022, U.S. learning from previously installed capacity, and financial assumptions detailed in Section 2.4.1

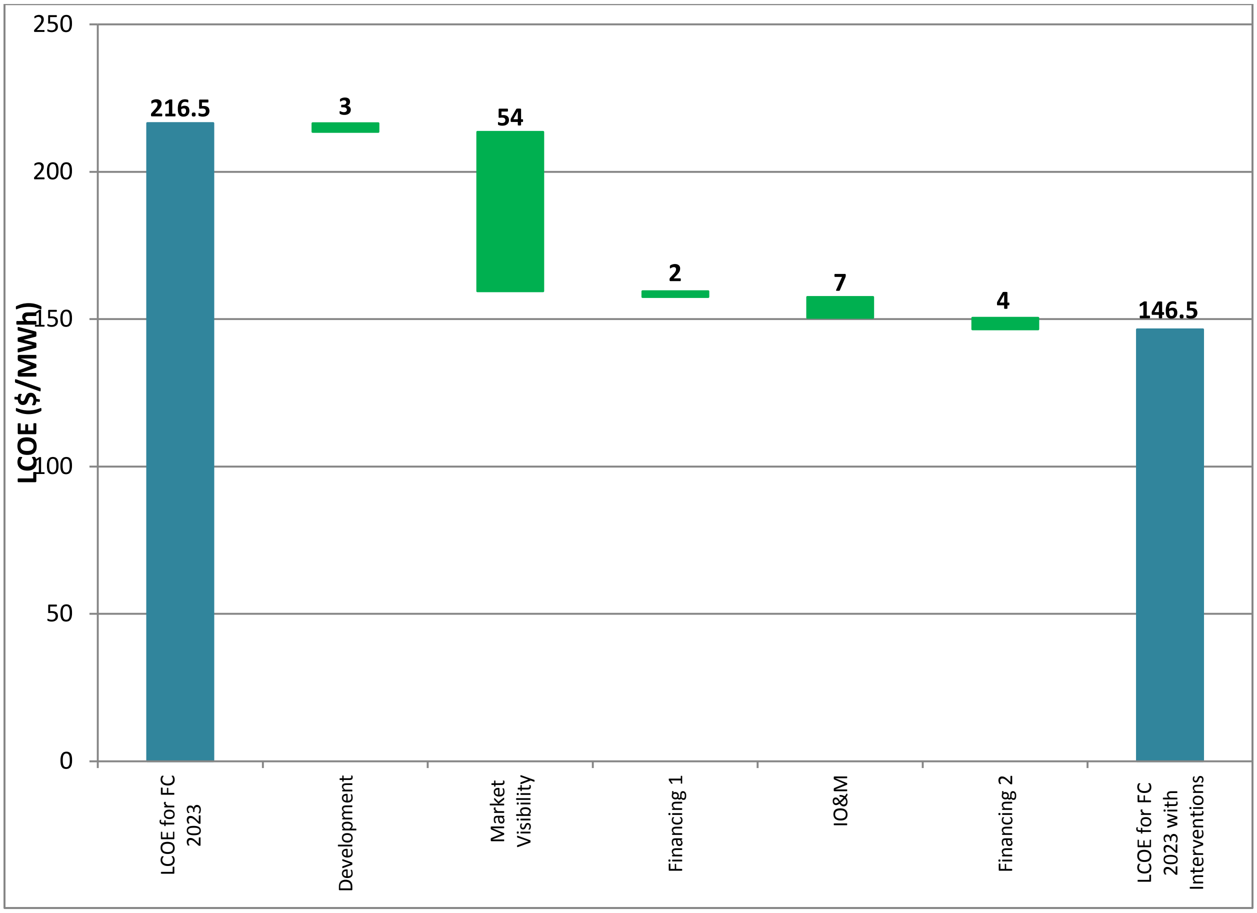


5.3.4 Project 4

As indicated in the methods section, the team applied a floor of 8% on equity IRR to for the aggregation analyses for Projects 1 – 3 and eliminated that floor in Project 4, anticipating a more mature U.S. market by FC 2023 and the attraction of a different type of investor. Thus, Project 4 includes both financing interventions, rather than just the one applied in the analyses for Projects 1–3. Figure 14 illustrates that even considering increased costs associated with greater distance from shore (deeper waters), further reductions are possible with the full complement of financing interventions and with assumptions about acceptable equity IRRs 5-10 years into development of a U.S. offshore wind industry.

Figure 14. Impact of Project 4 Interventions

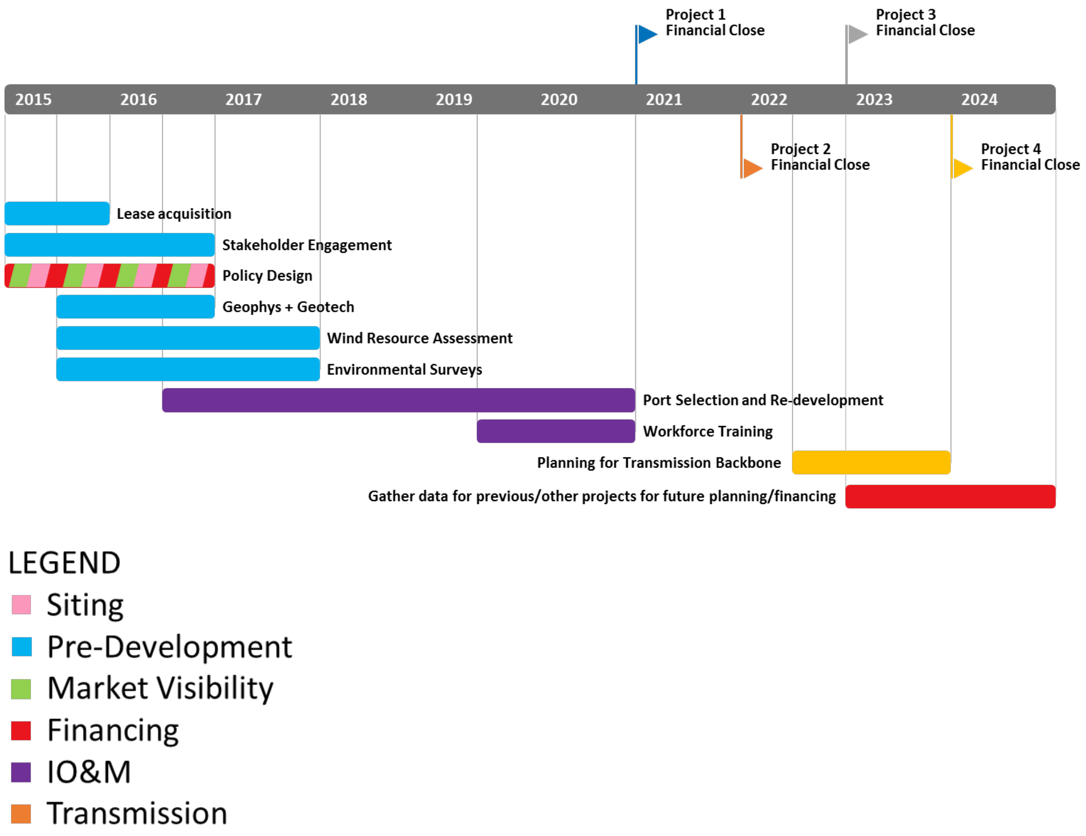
LCOE for FC 2023 includes global cost reduction achievable by 2023, U.S. learning from previously installed capacity, and financial assumptions detailed in Section 2.4.



5.4 Sequencing Interventions

Figure 15 is a plausible timeline that would allow NYS to take advantage of all of the interventions detailed here that the SIOW identified can lead to a 53% cost reduction for the base case. That does not preclude that bids could come from project developers that use some but not all of the interventions here or who have other routes to cost reduction which might be possible on a faster schedule than that shown here.

Figure 15. Sequencing of Specific Actions Needed to Implement Proposed Study Interventions



If NYS were to implement actions for a full suite of interventions, first steps would include, in active collaboration with industry:

- Initiating the process to obtain a lease from BOEM for project sites in the New York WEA.
- Beginning stakeholder engagement in coastal communities to determine siting preferences.
- Policy design, including:
  - Market visibility commitments.
  - Revenue policy.
  - Public/private partnership for financing offshore wind projects.
  - Revenue contract policy.
  - Siting/exclusion areas.
- Design and conduct wind resource and wave assessment campaign.
- Contract for and conduct G&G surveys.
- Contract for and conduct environmental surveys.

As previously indicated, regulatory and/or legislative changes may be required; they are not however reflected in the timeline in Figure 15.

Port selection and re-development would likely begin two years prior to anticipated financial close of the first round. Workforce training is last in the sequence, preparing workers one year prior to the beginning of construction. Depending upon gap between construction and FC of Projects 2, 3, and 4, construction data from earlier projects may be used to help plan and finance later projects. Last in the sequence is transmission backbone planning, beginning in 2022. This reflects the finding that a transmission backbone would not lower LCOE for the 2.4 GW analyzed in this study, but may be beneficial for larger build-outs further offshore.

6 Conclusion

This study finds that New York OSW project LCOEs are likely to be roughly 20% lower by FC 2020 than they would be if installed in 2014, if the expected technological innovation, increased global competition among OSW industry supply chain, and industry-wide efficiencies materialize as anticipated. Moreover, anticipated continuous technological development between FC 2020 and FC 2025 can lower costs by a further, albeit smaller amount (roughly -6%).

As U.S Atlantic coast states gain more experience with offshore wind projects, the U.S. offshore wind industry will improve efficiencies of offshore wind project installation as the market develops. This learning will have the effect of adding incremental improvements for New York OSW projects

With action, NYS can further benefit from cost reduction strategies that are inherently local (predevelopment, policy, and infrastructure). The analyses demonstrate that the following NYS-level actions can lower the LCOE for New York OSW by an additional third, and have other significant if not quantifiable impacts. These actions include:

- Providing a high degree of site characterization for early projects and thereby reduce DEVEX and the cost of development capital.
- Lending the State's favorable borrowing conditions.
- Facilitating through policy revenue contracts that substantially reduce risk to lenders.
- Creating market visibility that draws greater competition among suppliers and contractors and draws a different class of investor to New York projects.
- Develop policies related to siting and offshore transmission that support OSW projects.
- Developing the infrastructure to reduce costs, including both port facilities and a trained workforce.

The impact of these interventions varies greatly in both quantity and type. By assessing the meteorological, ocean and environmental and ground conditions of potential project sites, NYS can achieve a reduction in LCOE (-1.3%). Although this LCOE reduction is relatively modest, there are possibly larger but unquantified benefits that can accrue the state from these actions. These site studies can lead to enhanced competition and greater bid precision (both by developers and through an enhanced negotiation position for the State), more developer capital invested in FEED activities that can in return significantly reduce CAPEX, reduced time for permitting, and more accurate weather risk-adjusted pricing.

The impact of learning by doing (assuming market development in New York and New Jersey as described in section 3.2) reduces LCOE from 1% to 2.6% as scale grows. Policy interventions that substantially reduce revenue and volume risk can reduce LCOE by 15%; setting and committing to a pipeline of projects can have an even greater impact (up to 25% reduction in LCOE). Installation infrastructure development (depending on port capabilities) may reduce cost through shortening transit times and if a New York Harbor port is fully capable of taking the benefit of advanced installation methodologies, may reduce LCOE by 4.4%. It can also lower the cost of capital if port development is undertaken in concert with policy measures that, taken together, send market signals that NYS is committed to a stream of projects.

To properly interpret the results, one must be mindful of what the analyses did not cover. This study has not included any consideration of federal incentives such as PTC, ITC or carbon credits. Technology now in the conceptual or prototyping stages, including turbines 10 MW and larger, were not included in this study. 10-MW turbines will likely to be commercially available for projects with FC during the period 2020 to 2023. Cost data for 10-MW turbines was unavailable to the team. Finally, there is no discussion of the potential for continued deployment of the significant OSW potential of the New York Bight (only a small fraction of which is required for the 2.4 GW build-out studied).

The proposed interventions do not come without cost. Although the ratepayer impact of 2.4 GW of offshore wind is beyond the scope of this study, the team estimated the cost of implementing many of these interventions. Designing and implementing policy interventions results in personnel costs as well as opportunity costs (financial and political).

The analyses suggest that investing in the appropriate policies can have tremendous pay-off. NYS expenditures on pre-development might not only be a market enabler and help reduce site uncertainty leading to reduced power price but would likely pay for itself through reduced LCOEs of power purchase agreements.

This study did not examine the benefits of offshore wind, which include economic, and system benefits, improved health and environmental conditions and jobs and economic development. A full analysis of offshore wind entails examining the total-economy costs and benefits of energy production.

7 Bibliography

4C Offshore 4C Offshore Turbine Database. Web. 14 February 2015. http://www.4coffshore.com/windfarms/turbines.aspx

Bailey, B. H., Beaucage, P., & Bernadett, D. W. 2012. Wind resource assessment: a practical guide to developing a wind project. M. Brower (Ed.). John Wiley & Sons.

BVG Associates. 2012. Technology Workstream Report, Offshore Wind Cost Reduction Pathway Study, June.

BVG Associates. 2014. Future Renewable Energy Costs: Offshore Wind. prepared for KIC InnoEnergy Renewable Energies, May.

Crown Estate. 2012. Offshore Wind Cost Reduction: Pathways Study. United Kingdom, May.

De Jager, D., Rathmann, M., Klessmann, C., Coenraads, R., Colamonico, C., & Buttazzoni, M. (2008). Policy instrument design to reduce financing costs in renewable energy technology projects. Ecofys, by order of the IEA Implementing Agreement on Renewable Energy Technology Deployment (RETD), Utrecht, ther Netherlands.

EC Harris. 2012. Supply Chain Workstream Report, Offshore Wind Cost Reduction Pathway Study, May.

Hobohm, Jens et al. 2013. Cost Reduction Potentials in Offshore Wind in Germany, Prognos AG and The Fichtner Group. Commissioned by German Offshore Wind Energy Foundation, Stiftung OFFSHORE-WINDENERGIE

KPMG. 2012. Offshore Transmission: An Investor Perspective. Prepared for The Electricity and Gas Markets Authority under Con / Spec / 2011-99A.

Krueger, Andrew D., George R. Parsons, and Jeremy Firestone. 2011. "Valuing the visual disamenity of offshore wind power projects at varying distances from the shore: An application on the Delaware shoreline." Land Economics 87.2: 268-283.

Maples, B., Saur, G., Hand, M., van de Pietermen, R., & Obdam, T. 2013. Installation, Operation, and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy. NREL, Denver.

Morgan, M. Granger. 1990. Uncertainty: A Guide to Dealing with Uncertainty in Quantitative and Risk and Policy Analysis. Cambridge University Press, Cambridge, MA.

Musial, Walt and Bonnie Ram. 2010. Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers. NRELTP-500-40745. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/wind/pdfs/40745.pdf.

Navigant. Offshore Wind Market and Economic Analysis: Annual Market Assessment Report, 2014.

NYS Department of State. 2013. Offshore Atlantic Ocean Study. New York Department of State, July.

Ozkan, D. and M.R.Duffy. 2011. "A framework for financial analysis of offshore wind energy." Wind Engineering. 35(3): 267-88.

PricewaterhouseCoopers. 2012. Finance Workstream Report, Offshore Wind Cost Reduction Pathway Study, April.

Rickerson, W., Gifford, J., & Grace, R. 2012. Geothermal FIT Design: International Experience and U.S. Considerations. Contract, 303, 275-3000.

Weiss, Jurgen, M. Sarro and M. Berkman. 2013. A Learning Investment-based Analysis of the Economic Potential for Offshore Wind: The case of the United States. The Brattle Group, February.

Appendix A: Literature Review

In preparation for examining the opportunities to reduce the cost of energy from offshore wind in NYS, the SIOW team reviewed four key cost reduction studies conducted to date:

- *Offshore Wind Cost Reduction Pathways Study* commissioned by The Crown Estate (referred to as TCE)
- *Cost Reduction Potentials in Offshore Wind in Germany*, commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners (referred to as Stiftung)
- *Installation, Operation and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy*, a technical report of NREL, in joint authorship with the Energy Research Centre of the Netherlands
- *Future Renewable Energy Costs: Offshore Wind*, by BVG Associates for KIC InnoEnergy (referred to as KIC study).

A.1 Overview of cost reductions, by category

This literature review separates out the hardware cost reductions and the cost reducing impact from "soft cost" (that is, those not directly part of the turbine) innovations/interventions that New York State (NYS) has expressed interest in: wind farm development, installation, O&M, supply chain efficiencies, and financing.[99]

A.2 Improvements in offshore wind technology/hardware

This section provides a broad overview of what the literature revealed about the anticipated innovations in offshore wind hardware that will likely have a significant impact on the LCOE from offshore wind, through reductions in Capital Expenditures (CAPEX) and/or Operational Expenditures (OPEX), and/or increases in Annual Energy Production [100](AEP), namely turbines, nacelles, support structures, and array cables.

Stiftung found that investment costs, including turbines, support structures, cabling, wind farm transformer platforms, installation, certification and approval, and contingency, will decrease between 14% and 22% between 2013 and 2023.[101] Whereas Stiftung did not specifically describe anticipated innovations, TCE's Technology Workstream assessment, did. The following is a summary of the findings from TCE's Workstream report.

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[99] Transmission is also being examined for the NYS study, however neither Stiftung nor TCE addressed this issue as a potential cost reduction lever.

[100] According to the unpublished comparison of TCE and Stiftung reports, there appear to be wide variations in the estimates of 2020 costs for hardware (turbine, support structure, and array cables). Turbine costs are virtually identical, support structure costs have a 6% difference between the two, and array cables have a 22% difference, the Stiftung cost estimate being 22% lower than TCE's estimate.

[101] *Cost Reduction Potentials in Offshore Wind in Germany*, p. 7; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

A.2.1.1 Nacelle innovations

TCE's "Technology Workstream" report (one of the four sub reports that comprise TCE) identified turbine power rating (increasing from 4 MW to 6 MW) as one of the most significant innovations expected with the potential to reduce LCOE from offshore wind energy.[102] According to the study, this innovation will dominate and cause an 8% reduction in LCOE.[103] In addition, the report indicates as turbines increase in size from 4MW to 6MW, a series of new introductions in drive trains and other nacelle components can reduce cost of energy. Introductions of direct drive trains and of mid-speed drive trains, improvements in AC power take off system designs, improvements in workshop verification testing, introduction of DC power take off, introductions of direct-drive super conductor drive trains, and improvements in high speed drive trains all are expected to make a significant impact, acknowledging that that impact will vary with site type.[104]

Moreover, the same report identified that going from 6MW to 8MW turbines will have an even greater impact on reducing LCOE, especially again from turbine power rating. According to the study, the increase in turbine power rating for a 6MW turbine will reduce LCOE by 8.5% and the increase in turbine power rating from a 4 MW turbine to an 8MW turbine will reduce LCOE by 11.1%.[105]

A.2.1.2 Rotor innovations

TCE's "Technology Workstream report" suggests that there will be a number of important rotor innovations by 2020, including: optimization of rotor diameter; improvements in blade pitch control, blade aerodynamics, the process of blade manufacture, blade design standards and process, hub assembly components, blade tip speed, blade materials, coatings and lightning protection; and introduction of inflow wind measurement, active aero control on blades, and passive aero controlled blades. The KIC study update indicates that rotor innovations will yield a 2.5% - 5% reduction in LCOE between 2014 and 2025.[106]

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[102] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. ii

[103] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 45

[104] From *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 45-62. According to TCE, turbine costs themselves are reported to decrease in cost by 17%. Increases in rated power will lead to a 9% reduction in turbine cost, improved blade design and manufacture a 3% reduction, changes in drive trains a 2% reduction, larger rotors a 1% reduction and other innovations collectively add another 3%. According to an unpublished comparison of TCE and Stiftung studies, the two studies' estimates of the reduction of turbine costs are very close.

[105] Offshore Wind Cost Reduction Pathways Study: Technology Workstream commissioned by The Crown Estate and conducted by BVG Associates, p. 45-62

[106] Future Renewable Energy Costs: Offshore Wind Study commissioned by KIC InnoEnergy, p. 31

A.2.1.3 Support structure innovations

In addition to the introduction of turbines with a higher rated capacity and larger and more efficient rotors that are more reliable and deliver higher energy production, TCE noted that the introduction of mass produced support structures for use in water depths of 35 meters and above will be critical. Innovations in support structures are anticipated to reduce LCOE by roughly 5%, with the largest savings for projects using 6-MW class turbines.[107] The reduction in LCOE comes primarily from reducing CAPEX rather than impacting OPEX or AEP. The primary areas of innovation in support structures are: improving jacket manufacturing and design, introduction of a holistic design of a tower with a foundation, single section towers, suction bucket technology, and improvements in jacket design standards. The KIC study reiterated TCE's findings, noting that monopoles will not be used in 8-MW turbines. Stiftung also notes that continuous production of support structures will be a main driver for the cost reduction of this component.

A.2.1.4 Array cable innovations

Overall, innovations in array cables are expected to reduce LCOE by less than 1%. The largest savings in array cables will come from introducing higher operating voltages.[108] KIC notes that this innovation – going from 33 kV to 66kV – will be critical as the industry moves towards turbines with higher MW ratings. In addition, there are expected to be improvements in array cable standards and client specifications, introduction of alternative array cable core materials, improvement in array cable insulation materials and design, and improvements in array cable design to increase redundancy.[109]

A.2.1.5 Transformer platform

Stiftung asserts that standardization of the technical dimensions of the wind farm transformer platform will account for cost reduction, as will intensified competition.[110]

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[107] Offshore Wind Cost Reduction Pathways Study: Technology Workstream commissioned by The Crown Estate and conducted by BVG Associates, p. 83

[108] Offshore Wind Cost Reduction Pathways Study: Technology Workstream commissioned by The Crown Estate and conducted by BVG Associates, p. 101

[109] Future Renewable Energy Costs: Offshore Wind Study commissioned by KIC InnoEnergy, p. 41

[110] *Cost Reduction Potentials in Offshore Wind in Germany*, p 21; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

A.2.2 Wind farm development

Wind farm development, as referred to in TCE's study, includes the activities of procuring all necessary approvals, soil examination, unexploded ordnance (UXO) searching, environmental impact and wind studies, certifications, project development and project management costs and wind farm design and array. According to TCE, wind farm development costs are 3-4% of total CAPEX on a wind farm. The factors making up these costs are project management (44% of development costs), environmental surveys (7% of development costs), geophysical and geotechnical surveys (14% of development costs), resource characterization (11% of development costs), and engineering studies (24% of development cost.[111]

Stiftung finds that by increasing generator capacity from 4 MW to 6 MW, certification and approval costs will decrease from €377,000/MW in 2013 to €351, 000/MW. Going to even larger turbines and moving towards uniform certifying standards will reduce these costs even more.

Together by reducing CAPEX, OPEX and increasing AEP, improvements in wind development methodology can reduce LCOE by 2 to 2.5%, while perhaps increasing development money spent.[112]

Again, TCE detailed a number of wind farm development innovations that can drive cost reduction. They are described in the following section, with additional information taken from the KIC study.

A.2.2.1 Greater level of Front-end Engineering and Design (FEED)

TCE indicates there will be an impact of undertaking additional detailed design studies at the FEED stage, namely including additional survey data and increased depth of design for the foundation, turbine choice, and installation methods, which are usually completed later in the development process. Primarily, a greater level of FEED is expected to give increased accuracy of cost estimates for solutions with varying parameters such as water depth, soil conditions and turbine choice. This allows for an increased certainty of design progression that is optimal at a wind farm level. It is anticipated that increased optimization during development will lead to a 2% increase in wind farm development CAPEX, a decrease of 3% in support structure CAPEX, a decrease of 1.5% in array cable CAPEX and a reduction of 3% in installation CAPEX.[113]

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[111] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 35

[112] The KIC study update reiterated this estimate, noting that the impact of wind farm development innovations will mostly be seen in projects using 4MW turbines.

[113] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 37-38

A.2.2.2 Introduction of multi-variable optimization of array layouts

Wind farm array design is a major development cost reduction lever identified by Stiftung. This, however, can be seen as an artifact of high wake losses in German wind farms.[114]

Although UK wind farms have not seen as high wake losses, TCE nonetheless noted that further reductions in cost of energy may be achieved through improving the location of turbines while accounting for the constraints of multiple design criteria. Cost reduction comes through better spacing and placement by reducing support structure and installation costs, avoiding more challenging areas of the site, reduced electrical array costs, and an increase in energy yield through reduced wake losses and/or electrical array losses. Savings may also be available in OPEX due to less fatigue loading and therefore less frequent replacement or repair of components. It is important to note that progress in this area is expected to be gradual, as optimization tools are still in development.[115]

A.2.2.3 Greater level of Geophysical and Geotechnical (G&G) surveying

Extending G&G surveying beyond turbine locations can significantly reduce uncertainties relating to other areas of the site or on soil conditions closer to the survey of the sea-bed. Although this process is a riskier expenditure because it needs to take place before FID and any revenue, it can lead to cost reductions in array cable and installation CAPEX, and lead to the prevention of conservative overdesign or late design changes. Additional core samples taken at turbine locations can also reduce support structure CAPEX. The benefits of G&G surveying are seen mostly when done alongside a greater level of optimization during FEED, that is, a greater level of G&G surveying only generates cost reductions if the results are analyzed and applied with a greater level of optimization during FEED.

TCE found that this work impacts the level of risk associated with the support structure installation because it has the benefit of reducing uncertainties for installation methods and costs. Although it is anticipated that the typical impact would be to increase wind farm development CAPEX, it would lead to a 2% decrease in support structure CAPEX, a 3% reduction in array cable CAPEX and a 2% reduction in installation CAPEX.[116] TCE and Stiftung analyzed the reduction of financing costs separately from these innovations. However, it is acknowledged in the TCE study that reducing uncertainties for installation methods and costs will reduce the cost of finance.

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[114] German wind farms have found to be up 10% less cost effective than in the UK due to wake effects, both internal within wind farms due to lower spacing than planned in UK and also external, due to wake effects between wind farms. This is primarily due to the geographical size of wind areas in Germany versus the size of offshore wind zones in the UK.

[115] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 41

[116] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 39

A.2.2.4 Introduction of reduced cable burial depth requirements

TCE identified that increased survey requirements, to understand cable burial depths, could lead to a small increase in wind farm development CAPEX but lead to a 2% decrease in total installation CAPEX.[117]

A.2.2.5 Introduction of floating meteorological stations

Floating meteorological stations are cheaper to install and quicker to deploy than a conventional met station due to simpler permitting requirements and less complex or site-specific design. Floating met stations can also be reused within the site or in other sites. However, while fixed platform met stations are seen as quite comparable to met masts, floating systems had not yet been proven at the time of the study and were only analyzed as a future technology. This is because waves, tides and currents cause the LIDAR unit to move and could lead to inaccurate wind speed measurements. Structures can be designed to prevent movement, and software algorithms can be used to correct the motion. By moving toward the use of floating LIDAR, it is anticipated that a 6% reduction in overall wind farm development CAPEX can be realized, compared to the estimated CAPEX for an installed met mast.[118]

A.2.3 Installation

According to Stiftung, the single largest installation cost is rental for special ships for the installation of turbines, support structures, cables, and transformer platforms. A reduction in installation logistics cost is anticipated by Stiftung, due to larger, faster ships and adaption of installation processes. Additionally, Stiftung anticipates that in the future, installation costs will decrease mainly due to improved logistics concepts and increased competition, with even greater reductions coming 10 years from now. This will yield, according to Stiftung, cost reduction of 5%.[119] Costs to install turbines will decrease due to improved logistics and larger and faster ships; installation costs for support structures will decrease with improved logistics as well as through innovations in new monopile and jacket installation procedures.

The NREL study similarly identified strategies to reduce installation costs, namely land-based versus offshore assembly, direct delivery of components, purpose-built installation vessels, and reduced electrical and foundation installation. NREL found that the degree of assembly carried out on land versus offshore, has the potential to make the biggest impact on Balance of Plant cost, reducing it by almost $300/kW.

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[117] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 39

[118] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 40

[119] *Cost Reduction Potentials in Offshore Wind in Germany*, p 7; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

TCE conducted the most in depth analysis of installation innovations and anticipates that LCOE will be reduced by 3-5% by 2020.[120] In the KIC Study update, BVG Associates asserts a 2.5% reduction in LCOE between 2014 and 2025.[121] Improved installation not only reduces overall cost of installation but also lowers project risk during construction by shortening the time taken to construct wind farms.

A.2.3.1 Improvements in the installation process for monopiles

TCE indicates that installation cost reductions through improved installation of monopiles comes primarily from the use of well-specified vessels rather than the jack-ups that are currently used. By moving to floating vessels, a 20% reduction in time will be achieved.[122] The KIC study notes that monopiles will not be used for larger turbines, however.[123]

A.2.3.2 Improvements in the installation process for space frames

Similarly, improving the installation for space frames also will be achieved through more efficient and optimized vessels, shortening the support structure installation process. Decreases in the average day rate for vessels can also be accomplished with more specialized vessels, by not using over-specified vessels for more general tasks. This innovation is relevant to projects using jacket foundations.[124]

A.2.3.3 Improvements to the range of working conditions for support structure installation

The types of vessels selected and the use of jack-up barges limit what can be done, and in what weather. Waiting on weather is estimated by TCE to account for a third of the support structure installation cost (regardless of type). Costs can be reduced if the working range of vessels is increased (maximum wave height is most important, though wave period, wind speed, tidal flow and predicted length of a working window also have a significant impact).[125]

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[120] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 109

[121] *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 43

[122] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 119

[123] *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 38

[124] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 120

[125] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 120

A.2.3.4 Greater use of feeder arrangements in the installation of support structures

Costs can be reduced by using feeder vessels to maximize the efficiency of using expensive installation vessels by reducing the amount of time they spend in port and in transit. Feeder vessels typically are less expensive (no crane) but have similar operating range.[126]

A.2.3.5 Introduction of flexible sea fastenings

Sea fastening that can be modified to handle both turbine and support structures and variations in size and design can reduce costs as well. This can also maximize vessel utilization by allowing vessels to handle more than one kind of installation.[127]

A.2.3.6 Introduction of buoyant concrete gravity base foundations

According to the KIC study, these foundations reduce installation costs by removing the need for specialized vessels, as these designs can be towed to site using standard tugs then positioned and sunk without the use of an expensive installation vessel. These foundations are also anticipated to deliver a saving on support structure costs on some sites, depending on ground conditions and current steel prices.[128]

A.2.3.7 Introduction of float and sink installation

Transitioning to assembling the complete structure quayside and then floating the structure out to site has the potential, according to the TCE and KIC studies, to significantly reduce CAPEX. TCE reports a possible reduction of up to 25% in total wind farm installation cost.[129]

A.2.3.8 Introduction of whole turbine installation

Reduces installation time and weather downtime, as the turbine is fully assembled and then transported to site and installed in one lift onto the foundation. TCE indicates a potential 6% CAPEX reduction.[130]

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[126] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 121

[127] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 121-2

[128] *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 46

[129] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 129; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 46; This is consistent with the cost reductions seen in a U.S. DOE-sponsored study using U.S. and European suppliers, U.S. vessels, and suction-bucket seafloor fastening.

[130] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 128

A.2.3.9 Greater level of optimized cable installation equipment and processes

Reducing the use of specialty vessels and increasing working conditions for laying cable can be achieved by earlier engagement between cable suppliers and support structure designers.[131]

A.2.4 O&M

NREL estimates that the two O&M strategies with the highest potential to improve availability and reduce revenue losses are investment in an improved crew transfer system (e.g., application of a workboat with less restrictive weather limitations) and using a mother vessel to provide accommodation at the wind plant instead of daily transfer from the harbor. Both strategies focus on a reduction of the waiting time caused by bad weather conditions, which is the primary driver for the low wind plant availability in their baseline scenario. Individually, each of these strategies has the potential to reduce the total O&M effort from the baseline by more than $20 million. Other O&M strategies, like helicopter access and advanced Condition Based Monitoring, also yielded improvements, albeit much smaller than for the improved crew access system and mother vessel accommodation. On the other hand, some strategies, like ordering spare parts directly from the factory, rather than storing them onsite, cause longer downtimes and could decrease availability compared to the baseline.

Stiftung asserts that O&M and insurance costs can be reduced by 5.5 - 7.8% in the short term by using larger and faster ships and by improving infrastructure.[132] And, in the longer term, as projects are further offshore, O&M costs can be reduced by interoperator maintenance and logistics agreements, such as using a joint fleet and infrastructure. Larger (and thus fewer) turbines will also reduce O&M costs, according to Stiftung.

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[131] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 132-3; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 47

[132] *Cost Reduction Potentials in Offshore Wind in Germany*, p 20; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

TCE estimates that improvements in O&M and services have the potential to reduce LCOE by 1.5% to 2%, by increasing AEP and decreasing OPEX.[133] KIC notes that a 2% reduction in LCOE between 2014 and 2025 can be anticipated.[134] The most significant innovation TCE identifies is the introduction of holistic condition-based monitoring and improvements to personnel access especially from transfer vessel to turbine.[135] However, the improvements made in O&M vary based on site conditions: sites with the highest average wind speeds are likely to benefit the most from improvements in O&M because wind farms at these sites have maximum operating time and so there is increased fatigue on components. Lastly, they are likely furthest from port and in conditions that offshore wind operators have less experience with. Improved processes and the opportunity to introduce innovations will yield the greatest results in these types of sites. Key innovations anticipated are described in the following sections.

A.2.4.1 Introduction of turbine condition-based maintenance

Improved prognostic and diagnostic systems and processes can reduce OPEX and losses. Innovative systems are anticipated to be available for projects with FID in 2020.[136]

A.2.4.2 Improvements in jacket condition monitoring

Annual inspection visits for jacket foundations are greater in number than those for monopiles. Installing permanent sensors and implement autonomous subsea inspection systems can reduce unplanned OPEX and losses due to unavailability.[137]

A.2.4.3 Improvements in personnel access from transfer vessel to turbine

Innovations on vessels are anticipated to increase accessibility by 70-95%, reducing availability losses and unplanned OPEX. Increased AEP, according to TCE, was estimated conservatively at 0.5%.[138]

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[133] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 135

[134] *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 49

[135] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 142

[136] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 148; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 52

[137] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 147

[138] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 151; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 53

A.2.4.4 Improvements in personnel transfer from base to turbine location

Improved vessel designs will allow for larger crews to be transported, as well as more materials and tooling, reducing availability losses and unplanned OPEX. The technical impact of this innovation is anticipated to be a 0.3% reduction in operational and planned maintenance OPEX, a 1% reduction in unplanned service OPEX and a 0.1% increase in wind farm availability.[139]

A.2.4.5 Improvements in inventory management

Reductions in planned and unplanned OPEX can be achieved by better dispatch and management and will be available for projects with FID in 2020.[140]

A.2.4.6 Improvements in weather forecasting

By maximizing activity during weather windows, staff and expensive vessels can be used more efficiently. Innovations that will extend reasonable accuracy to a 21-day forecast will be used in some projects by FID in 2020 and in most projects by FID in 2025. According to BVG Associates, "the technical impact of this innovation is anticipated to be a 0.5 per cent reduction in operational and planned maintenance cost and a one per cent reduction in unplanned service cost. When fully realized (sic), it is anticipated that this innovation has the potential to increase wind farm availability by 0.05 per cent."[141]

A.2.4.7 Operations, Maintenance, and Service (OMS) strategy for far-from shore wind farms

Mother ships that allow for greater working and living conditions will be available in Europe for projects with FID 2020, but not widely available until FID in 2025, providing the opportunity for significant OPEX savings.[142]

A.2.4.8 Wind farm wide control strategies

Moving toward systems that are able to maximize residual life and account for market prices, for example, can increase CAPEX but reduce OPEX and increase AEP. Such systems are expected to be available for projects with FID in 2020.[143]

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[139] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 151; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 53

[140] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 147-8

[141] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 146; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 51

[142] *Offshore Wind Cost Reduction Pathways Study: Technology Workstream* commissioned by The Crown Estate and conducted by BVG Associates, p. 145; *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 52

A.2.5 Supply chain efficiencies

Supply chain efficiencies here refer to the potential to reduce LCOE through reducing costs in the value chain – not through technology or hardware innovations but rather through mechanisms that can encourage/facilitate the supply chain to bring in components at lower costs. That is, it refers to actions taken by key equipment manufacturers, suppliers and manufacturers of subcomponents.

Stiftung did not address these opportunities, but TCE's "Supply Chain Workstream" did. Specifically, TCE's supply chain analysis (conducted by EC Harris) found that opportunities exist to reduce UK's LCOE by 15% through the following six factors described in the next six sections.

A.2.5.1 Competition (4%)

To determine the impact of competition, the TCE study looked at the cost savings expected after new entrants to the U.K. market. The prerequisite for new entrants, they assert, is market size; new players will not enter the space without a market. They also need capacity for prototype testing sites.[144]

A.2.5.2 Vertical integration (4%)

Vertical integration refers to the way in which the supply chain interacts and is organized to deliver on a project. It involves incorporating supply chain concerns earlier in the development process, and can include facilitating shared space (like Bremerhaven) when appropriate, and can involve various contract models, such as engineering, procurement and construction (EPC), mini-EPC, and multi-contract. Like competition, the prerequisites for the supply chain to work better together include market visibility, common standards, and de-risking the permitting/approval process. Vertical integration and better integration of installation interfaces and long term relations can lead to a 10% reduction in installation costs, and a 5% reduction in wind turbine costs. For example, by involving support structure fabricators early on, there can be coordination between support structure assembly and planning for its integration into the balance of plant components, through which total project costs can be reduced significantly.[145]

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[143] *Future Renewable Energy Costs: Offshore Wind Study* commissioned by KIC InnoEnergy, p. 54

[144] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 51-4

[145] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 55

A.2.5.3 Asset growth and economies of scale (3%)

This cost reduction lever involves getting savings in procurement due to volume and market consistency through "learning by doing," standardizing processes, and "sweating assets." Savings can be created not just in production facilities but also ports and vessels. It is anticipated by TCE that asset growth and economies of scale can reduce installation costs by 10% by FID in 2020 and wind turbines and support structures by less than 5% each, if the supply chain is localized.[146]

A.2.5.4 Horizontal collaboration (2%)

This cost reduction lever involves how market players work together as well as reducing direct competition among market players. Specifically, TCE found that encouraging greater industry collaboration can reduce installation costs, and can reduce the costs of wind turbines and support structures when the market puts pressure on the supply chain to cooperate.[147]

A.2.5.5 Contract terms (1%)

Initial projects in the UK have mainly been contracted on a lump sum, fixed-price basis with poorly defined contract terms and inadequate incentives and penalties for performance and delays. Moving away from lump sum contracts, tightening terms and conditions, and the introduction of more appropriate incentive mechanisms may lead to cost reductions.[148]

A.2.5.6 Uncontrollable risk (1%)

TCE asserts that there may be opportunity to reduce costs as they relate to uncontrollable risks such as unpredictable weather (sea state and wind) and ground conditions, and consequential loss due to delays attributed to parties outside of a particular contract scope. A better understanding and apportioning of uncontrollable risk can accrue savings by reducing their impact. For example, unforeseen ground conditions can be mitigated by gathering greater knowledge of the seabed prior to installation. Weather risk could be better mitigated by investing in vessels that can operate in greater swells and through long term agreements, since weather patterns tend to even out over a period of time. Longer term contracts (covering a number of installation cycles or a program of projects) can also ameliorate

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[146] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 55-7

[147] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 57-8

[148] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 58-9

the impact of downtime due to breakdowns, spreading their impact over a longer period, and result in better optimization of resources, by sharing vessels across projects and/or installers and sharing spares. Also, as installation methods evolve and more work is undertaken offshore, it will be possible to reduce the contingency set aside for weather risk.[149]

As previously mentioned, Stiftung did not address reductions in LCOE from such efficiencies. Stiftung did address approval and certification standards and dismantling offshore wind farms, issues not addressed otherwise. Uniform approval and certification standards as well as a growing experience regarding project planning contribute a cost reduction potential of 1.6%. As specialization regarding the dismantling of offshore wind farms increases, LCOE can be reduced by up to 1.3%.[150]

A.2.6 Financing

Stiftung found that increased planning, constructing and operating experience, and the higher reliability of generators can contribute to a 9.6% cost reduction through decreased risk premia for financing. Stiftung asserts that banks will require less equity and since debt usually requires less return than equity, financing costs further decrease. Cost of capital and thus LCOE is reduced due to a changed risk profile of the technology together with more experience. Stiftung assumes that by 2023, cost reduction potential due to lower risk premia will constitute one of the key drivers of cost reduction.[151]

Stiftung assumes higher financing costs in the UK, driven by the different financing structure that is assumed. Lower liquidity in the British market results in financing that includes bonds with higher return requirements that increase WACC, according to Stiftung.

Also noting differences between the two markets, TCE found that there are savings that can be achieved in the cost of capital, though not as much as in supply chain and technology. According to TCE's Project Finance Workstream report, authored by PricewaterhouseCoopers, the drivers of the cost of capital will include reliance on bridge equity for projects reaching FID in 2014 and 2017, due to funding shortfalls before 2020. Additionally, increased uncertainties in installation and O&M costs, when developing on riskier sites or with the introduction of larger

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[149] *Offshore Wind Cost Reduction Pathways Study: Supply Chain Workstream Report* commissioned by The Crown Estate and conducted by EC Harris, p. 59-60

[150] *Cost Reduction Potentials in Offshore Wind in Germany*, p 21; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

[151] *Cost Reduction Potentials in Offshore Wind in Germany*, p 21; Commissioned by the German Offshore Wind Energy Foundation in partnership with their industry partners

turbines, will lead to higher financing costs and developer equity premiums. Reducing risk around installation and O&M will require that investors have confidence that projects will be delivered with lower construction risks.[152]

The Project Finance Workstream report identifies the following as potential actions to reduce the cost of capital.[153]

A.2.6.1 Revenue certainty mechanisms

According to TCE, this involves giving clearer policy signals on offshore wind ambition and volume targets, providing clarity on long-term subsidy funding limits, and accelerating decisions and frameworks for revenue certainty. These actions would impact the capital structure and revenue risk reduction.

A.2.6.2 Reduction of risk

TCE identifies a number of risk reduction measures, such as including greater cooperation between stakeholders on industry best practice, standardizing installation methods, moving away from multicontracting, focusing on deployment of proven technology, obtaining longer service and warranty periods from equipment suppliers, promoting early grid investment, and negotiating longer O&M contracts. These actions would impact capital structure, specific risk premiums, additional developer equity premiums, and revenue risk reduction.

A.2.6.3 Attracting new equity capital

Actions to attract new equity capital include promoting the sector to international investors, governments, and financial investor groups to identify and remove unintended obstacles and to identify incentives, identifying optimal project size to attract financial investors, and encouraging developers to pool offshore wind assets to facilitate portfolio diversification. These actions primarily would affect capital structure.

A.2.6.4 Facilitate debt financing

Facilitating debt financing would lower the cost of capital by benefiting from interest tax shields and by reducing the potential reliance on more expensive sources of funding.

Prerequisites for all of these activities, according to TCE, will be market visibility and long term growth prospects of the industry, with a level of support that can make the previously described details happen as well as lowering risk in the installation and operational phases.

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[152] *Offshore Wind Cost Reduction Pathways Study: Project Finance Workstream Report* commissioned by The Crown Estate and conducted by PricewaterhouseCoopers, p. 8

[153] *Offshore Wind Cost Reduction Pathways Study: Project Finance Workstream Report* commissioned by The Crown Estate and conducted by PricewaterhouseCoopers, p. 9-13