New York Offshore Wind Cost Reduction Study

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Jacques Roeth
Project Manager

Prepared by:

University of Delaware
Special Initiative on Offshore Wind

Stephanie McClellan, Ph.D.
Director

Deniz Ozkan, Ph.D.
Atlantic Grid Development

Willett Kempton, Ph.D.
Andrew Levitt, M.M.P.
Heather Thomson, M.S., MPSA

Notice

Acknowledgments

The Rockefeller Brothers Fund, the Mertz Gilmore Foundation and the New York Community Trust provided funding to the Special Initiative on Offshore Wind at the University of Delaware to prepare this study.

This study was prepared for NYSERDA to provide information on various technology and regulatory mechanisms to assist in achieving cost reduction as New York develops its offshore wind strategy. NYSERDA provided project management, content development, and editorial review for the study.

The Special Initiative on Offshore Wind would like to thank the following people for their help:

Project Advisory Committee

Adam Bruce
UK Offshore Wind Programme Board

Jens Eckhoff
German Offshore Energy Foundation

Jérôme Guillet
Green Giraffe Energy Bankers

Chris Long
AWEA

Jan Matthiesen
The Carbon Trust

Paul McCoy
McCoy Energy Consulting

Doug Pfeister
Past President, OSWDC; PMSS America

Jan-Fredrik Stadaas
Statoil

Bruce Valpy
BVG Associates

Expert Panel Reviewers

Walt Musial
National Renewable Energy Laboratory

Gary Norton
U.S. Department of Energy

Aaron Smith
National Renewable Energy Laboratory

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]

---

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.

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)

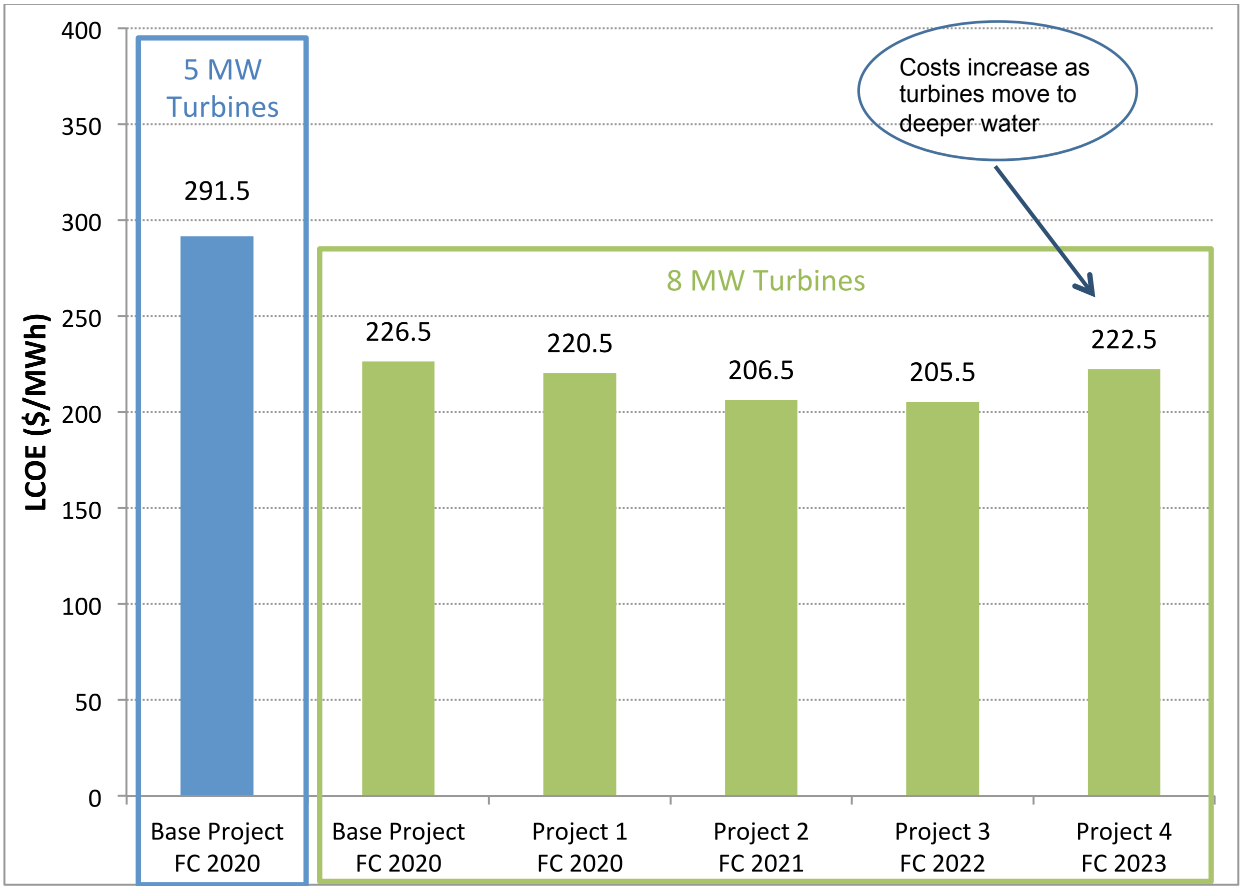
Project	Financial Close Year	LCOE ($/MWh)	% Change from Base Project - 5 MW
Base Project – 5 MW	2020	291.5	N/A
Base Project – 8 MW	2020	226.5	- 22%
1[6]	2020	220.5	- 24%
2	2021	206.5	- 29%
3	2022	205.5	- 29%
4[7]	2023	222.5	- 24%

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]



[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)

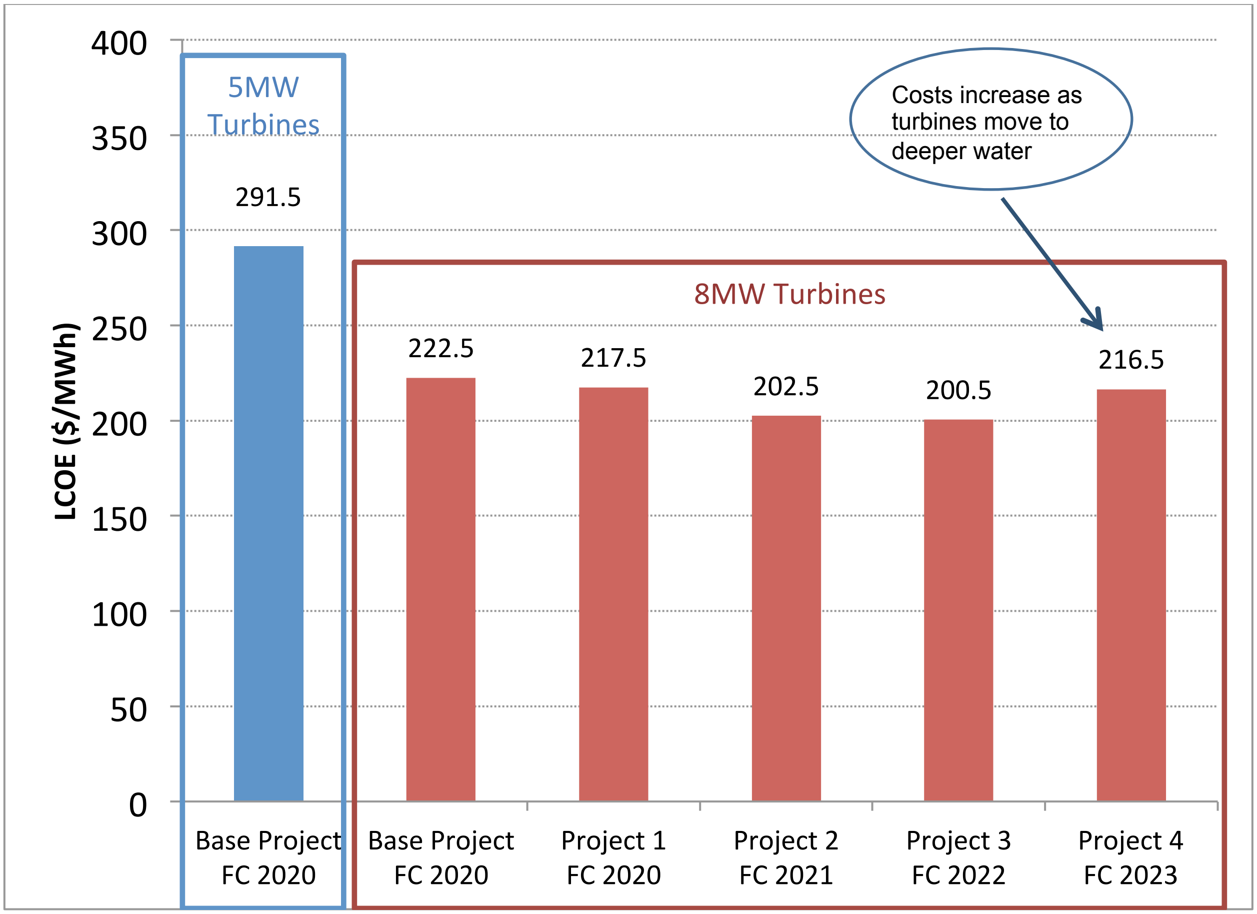
Project	Financial Close Year	LCOE Before 5% learning rate applied ($/MWh)	LCOE After 5% learning rate applied per doubling of U.S. Capacity ($/MWh)	% change
Base Project-8MW	2020	226.5	222.5	-1.8%
1[11]	2020	220.5	217.5	-1.4%
2	2021	206.5	202.5	-1.9%
3	2022	205.5	200.5	-2.4%
4	2023	222.5	216.5	-2.7%

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]



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.