Wood Mackenzie
POWER & RENEWABLES

August 2020

ECONOMIC IMPACT STUDY OF NEW OFFSHORE WIND LEASE AUCTIONS BY BOEM

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Dr. Zhang is a Managing Consultant with a focus on the North American wind and solar technology trend, market development and O&M. Feng lends his significant expertise to provide business strategy, technology assessment, market study, due diligence support, competitive benchmarking, LCOE analysis and digital solutions strategy support.

Prior to Wood Mackenzie, Dr. Zhang was Director of Global Digital Energy Center for Envision Energy in Houston, TX. Concurrently, he is also Director of Global turbine engineering and research and is a member of Envision executive committee. As one of the key Envision executives, Dr. Zhang led many strategic efforts and new initiatives for Envision, including digital transformation of wind business, digital strategy for future networked energy and Energy Operation System (EnOS), product management of cloud-based energy analytics software, technical due diligence for M&A and investment, establishing R&D center, global wind turbine system engineering, wind turbine product management, wind farm operation and maintenance and advanced technology research, etc.

Dr. Zhang began his career as a Senior Researcher for Powertrain in Ford Motor Company. He joined GM and SAIC joint venture in China where he led large scale engine program with annual budget for more than 100 million USD, in charge of the entire lifecycle of diesel engine development and manufacturing, from prototype, test validation to series production and launch.

Dr. Zhang received his PhD from Mechanical Engineering in University of Houston. He earned both BS and MS from Tsinghua University in Beijing, China. He is based in Wood Mackenzie's Houston office.

1. EXECUTIVE SUMMARY

The offshore wind industry is poised for significant growth in the United States. This paper studies the economic impact of offshore wind activities as a result of potential Bureau of Ocean Energy Management (BOEM) lease auctions this year as well as 2021 and 2022. Based on existing activities and optimistic policy assumptions for future offshore wind development, two million acres of federal waters in the New York Bight, California, North Carolina and South Carolina could be auctioned for commercial leases in 2020 and 2021. This could support 28 GW of offshore wind development and generate $1.2 billion in US Treasury revenue. Other auctions for lease areas in the Gulf of Maine and additional areas in California could also occur in 2022 which could generate an additional $500 million in US Treasury revenue and support 9 GW of offshore wind development.

In addition to delivering clean energy to millions of households, the offshore wind industry will also contribute a variety of economic benefits to the US economy, including supporting tens of thousands of jobs and billions of dollars in capital investment. If the assumed BOEM auctions happen this year, in 2021 and 2022, total full time equivalent (FTE) job creation from the resulting offshore wind activities, including development, construction and operation could support approximately 80,000 jobs per year from 2025 to 2035. Turbine manufacturing and supply chain will support 31,000 jobs per year. The construction industry will support 16,000 jobs per year. The transportation and port industries will create 4,000 jobs per year. In addition, general service industries, like restaurant, hotel and day care, will create 19,000 induced jobs. Operations and maintenance (O&M) jobs and O&M-induced jobs will grow from 2,000 per year in 2025 to 6,000 per year in 2030 and 20,500 per year in 2035. Those O&M-related jobs are expected to last beyond 2050. About 3,500 jobs per year will be created from 2022 to 2024 for project development and establishing a turbine supply chain along the East Coast.

Significant capital investment will be injected into the US economy to support offshore wind activities. Total investment in the offshore wind industry will be $17 billion by 2025, $108 billion by 2030 and $166 billion by 2035. From 2022 to 2035, capital investment of $42 billion will go to the turbine OEM and supply chain, $107 billion will go to the construction industry, and $8 billion will go to transportation industry and ports. Annual capital investment for O&M activities will increase to $2.4 billion in 2035.

Table 1.1: Summary results – Economic impact created by assumed BOEM lease auctions from 2020 to 2022

	2025	2030	2035	Beyond 2035
Operating Offshore Wind Capacity	4 GW	25 GW	37 GW	37 GW
Offshore Wind Jobs	Average 80,000 per year			16,000 per year
Total capital investment	$17 billion	$108 billion	$166 billion	$60 billion

Source: Wood Mackenzie

2. ASSUMPTIONS AND METHODOLOGY

The magnitude of economic impact depends on three key inputs: annual installed offshore wind installation capacity; local content of the components and services required to develop, build and operate offshore wind projects; and the overall cost to develop and operate offshore wind projects.

This analysis first estimates the total capacity in megawatts (MW) that can be developed in offshore lease areas. A 14MW offshore wind turbine with a 222-meter rotor is used to estimate the capacity density (MW/km^2) required to achieve the best balance of wake loss, project economics, visual impact and other industry considerations, such as fishing. The result yields an assumption of 3.6 MW/km^2 installation density which corresponds to an 8-rotor diameter (D) by 10D grid for turbine siting arrangement.

The Jobs and Economic Development Impact (JEDI) models from the National Renewable Energy Laboratory (NREL) were used to forecast the jobs, wage and capital investment from the development and operation of offshore wind projects through 2035. Economic benefits include the direct, indirect, and induced economic impacts on the local economy associated with its construction and operation phases. The JEDI model assesses offshore wind related activities in three categories:

1. **On-site labor and professional services**: dollars spent on labor from companies engaged in development and on-site construction and operation of power generation and transmission.
2. **Local revenues and supply chain results:** dollars spent in supporting industries, including turbine OEM and supply chain.
3. **Induced**: dollars spent via reinvestment and spending of earnings by direct and indirect beneficiaries, such as local restaurants, hotels, and retail establishments, child-care providers and any other entity affected by increased economic activity and spending occurring in the first two categories.

Project cost and local content data used in the model were derived from existing offshore wind projects, literature reviews, and conversations with industry professionals, and are presented in Table 2.1.

Table 2.1: Offshore Wind CAPEX and Local Cotent Assumptions

	2025 ~ 2030	2030 ~2035
Call Area	New York Bight, Carolinas	Gulf of Maine, California
Technology assumption	Offshore fixed bottom	Offshore floating
Project total CAPEX	$4000/kW	$4800/kW
Annual O&M Cost	$68/kW	$60/kW
Local Content - turbine and foundation	From 32% to 60%	From 32% to 60%
Local Content - Construction labor	80%	80%
Local content - project development services	100%	100%

Source: Wood Mackenzie

3. TARGET LEASE AREAS FOR STUDY

Based on offshore wind conditions and local interests, BOEM has established many offshore wind lease call areas along the US East Coast, West Coast and Hawaii. The targeted lease areas for this study are limited to existing call areas in the New York Bight, off the California Coast, Gulf of Maine, North Carolina and South Carolina.

New York Bight Region

The New York Bight represents an area of shallow waters between Long Island (to the north and east) and the New Jersey coast (to the south and west). BOEM has divided the call area into four distinct sub-areas, named Hudson South, Hudson North, Fairways South, and Fairways North, comprising approximately 1,735,116 acres of federal waters. Within the overall New York Bight call area, BOEM identified 315,268 acres of “primary areas” and 793,862 acres of “secondary areas” which could go to auction as soon as 2020. Wood Mackenzie (Woodmac) estimates the lease of both the primary and secondary areas could support up to 11.5 gigawatts (GW) offshore wind development based on 3.6MW/Km^2 or 15 kW/acre.

The offshore wind development in the New York Bight will support offshore wind demand from both the State of New Jersey and the State of New York. New York Governor Andrew Cuomo upped the ante in his 2019 State of the State and Executive Budget address by calling for expanding the state’s offshore wind target from 2,400 MW by 2030 to 9,000 MW by 2035. On July 18, 2019, the governor officially signed this new target into law through the Climate Leadership and Community Protection Act (CLCPA). On November 19, 2019 New Jersey Governor Phil Murphy signed Executive Order #92. This order effectively raised New Jersey's offshore wind goal from 3,500 megawatts by 2030 to 7,500 megawatts by 2035. Existing leases in the New York and New Jersey area (not including Massachusetts area) cover 422,864 acres of federal waters with the potential to develop 6GW of offshore wind. The additional lease areas that could be auctioned this year and next will be a critical step in meeting both States’ offshore wind targets.

California Coast Region

There are currently three BOEM call areas off California coast: Morro Bay and Diablo Canyon off the central part of the state, and Humboldt off the North California coast. The three call areas comprise approximately 687,832 acres of federal waters but have sufficient water depth to necessitate floating offshore wind technology. Despite aggressive renewable targets in California, the relative technological immaturity and high levelized cost of electricity (LCoE) of floating offshore wind technology are delaying the deployment of California offshore wind. Based on 14 companies expressing interest in the three call areas, Woodmac estimates BOEM could auction about 50% of the call areas, effectively 343,916 acres of federal waters, in 2020 and 2021. Approximately, 5 GW of offshore floating wind could be installed from 2030 to 2035 as a result of the anticipated auction in

2020 and 2021. Additional 273,846 acres could be auctioned in 2022 and support additional 4 GW of offshore wind development. In order to meet the goal of 10 GW offshore wind in California by 2040, additional call area beyond the existing three call areas will need to be established.

Carolinas' Coast Region

Currently there are three proposed wind energy areas off the North Carolina coast: Kitty Hawk, Wilmington West and Wilmington East and one active lease within Kitty Hawk covering 122,405 acres of total 877,818 acres in Kitty Hawk. These three areas comprise approximately 1,220,714 acres of federal waters. Further south, there are four call areas off South Carolina coast: Grand Strand, Cape Romain, Charleston, and Winyah. These four call areas cover approximately 853,938 acres of federal waters. Compared to the high interest in the New York Bight and along the California Coast, the level of interest in the call areas off Carolinas' coast is lower due to various project economics factors such as a lack of an offshore mandate or offshore renewable energy credit (OREC) program, lower power prices, and lower capacity factors. However, if relevant policy was in place to improve offshore wind project economics, for example offshore wind REC and state renewable mandates, 30% of the North Carolina wind energy areas and 50% of South Carolina call areas could go into BOEM lease auction in 2021. These potential auctions would be able to support a combined 11.5GW offshore wind development from 2025 to 2030.

Gulf of Maine

There is no active offshore wind call area in the Gulf of Maine. However, the opportunities for offshore wind development in the Gulf of Maine have been actively studied by many offshore wind developers and local governments. Given the regional nature of offshore wind energy development, in January 2019 BOEM established a Gulf of Maine Task Force, including representation from New Hampshire, Massachusetts, Maine and federally recognized Tribes in the area. Currently, there are approximately 800,000 acres of federal waters being studied and assessed for offshore wind development, and the State of Maine is targeting to install 5GW offshore wind by 2030. Therefore, Woodmac anticipates 44% of the area, effectively 350,000 acres, currently being surveyed in Gulf of Maine could go to auction in 2022 to support renewable initiatives. Like California, the critical path for offshore wind development in the Gulf of Maine is in floating offshore wind turbine technology development. The timeline for floating offshore wind installation in Gulf of Maine is assumed to be from 2030 to 2035.

Input assumption for economic impact study

The development capacity assumptions for offshore wind installations as a result of assumed BOEM auctions this year, 2021 and 2022 are listed in Table 3.1. The total resulting offshore wind installation would be 37 GW. These offshore wind projects would

generate approximately 160 billion kWh per year, enough to power 20 million US households.

Table 3.1: Offshore wind installation timeline and capacity

Call Area	Installation Year	Foundation type	Capacity
New York Bight	2025 to 2030	Fixed	11.5 GW
California Coast	2030 to 2035	Floating	9 GW
Carolinas Coast	2025 to 2030	Fixed	11.5 GW
Gulf of Maine	2030 to 2035	Floating	5 GW

Source: Wood Mackenzie

4. BOEM OFFSHORE WIND LEASE REVENUE FOR US TREASURY FORECAST

Historical lease price

In 2009, the US Department of the Interior (DOI) announced final regulations for the Outer Continental Shelf (OCS) Renewable Energy Program, which was authorized by the Energy Policy Act of 2005 (EPAct).

These regulations provide a framework for issuing leases, easements, and rights-of-way for OCS activities that support production and transmission of energy from sources other than oil and natural gas.

DOI's Bureau of Ocean Energy Management (BOEM) is responsible for overseeing offshore renewable energy development in Federal waters. Since the regulations were enacted, BOEM has worked diligently to oversee responsible renewable energy development. As of the date of this paper, there are a total 15 active offshore wind leases with 21 GW total potential capacity, given out through 8 competitive lease sales. The 1.7 million acres of federal waters that have been leased generated $473 million in bids. The competitive auctions since 2015 are listed in Table 4.1.

Table 4.1 Competitive auctions since 2015

	OCS-A 0500	OCS-A 0501	OCS-A 0498	OCS-A 0499	OCS-A 0512	OCS-A 0508	OCS-A 0520	OCS-A 0521	OCS-A 0522
Year auctioned	2015	2015	2015	2015	2016	2017	2018	2018	2018
Closest state	MA	MA	NJ	NJ	NY	NC	MA	MA	MA
Unique bidders	2	2	3	3	6	4	11	11	11
Area (km2)	759	675	649	742	321	495	521	516	536
Winning price (US$)	$ 281,285	$ 166,886	$ 880,715	$ 1,006,240	$ 42,469,725	$ 9,066,650	$135,000,000	$135,000,000	$135,100,000
Winning bid price (US$ per km2)	$ 371	$ 247	$ 1,357	$ 1,356	$ 132,304	$ 18,316	$ 259,117	$ 261,628	$ 252,052
Winning bid price (US$ per acre)	$ 2	$ 1	$ 5	$ 5	$ 536	$ 74	$ 1,049	$ 1,059	$ 1,020
Current holder	Ørsted/ Eversource	CIP/ Iberdrola	Ørsted	EDF/Shell	Equinor	Iberdrola	Equinor	EDP/Shell	CIP/Iberdrola

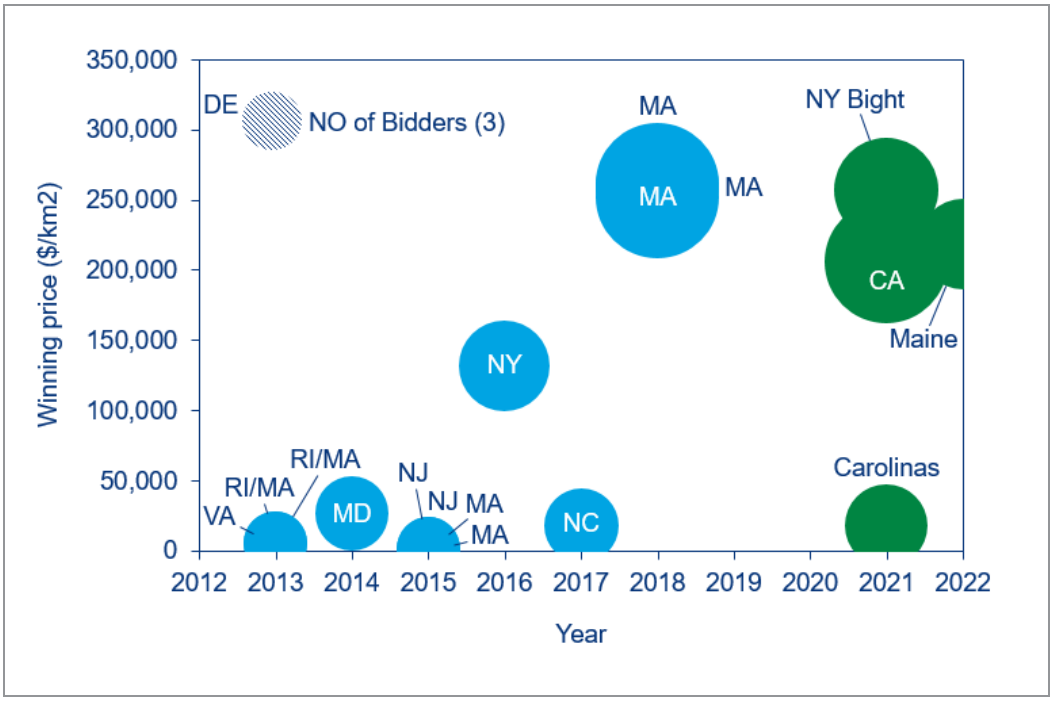
Source: BOEM

Offshore wind lease auction price forecast

If the lease areas discussed above go to auction in 2021, the amount of US Treasury revenue generated from the competitive bids will be determined by auction results. In this section, we estimate the auction price based on historical lease prices and project economics determined by state renewable energy policies and power price forecasts. The auction price estimation is based on existing policy where projects are located. Any future policy change, such as offshore Renewable Energy Credit (REC) or Investment Tax Credit (ITC) extension etc., will alter the economics of offshore wind projects significantly and therefore fundamentally change auction dynamics.

Historical auction information (year, winning price, number of bidders, location) is presented in Figure 4.1. The blue bubbles represent the past auctions and the green bubbles represent estimated future auctions. The number of bidders and winning auction prices have increased significantly in the Northeast over the past few years. In 2015, just three companies (two in consortium with each other) participated in BOEM's auction of lease areas offshore New England, winning leases at a simple average price of $309 per square kilometer. Just one year later, six companies competed for a single lease auctioned off of New York, with a winning bid of $132,304 per square kilometer. By 2018, 11 companies vied to win three New England lease areas with a simple average winning price nearly $257,599 per square kilometer, a seemingly incredible increase of over 83,000% compared to the 2015 results for directly adjacent lease areas. This increase reflects the impact of state governments in the Northeast setting capacity-based offshore wind goals amid declining technology costs, and the resulting increase in the number of participants in BOEM's auctions for a limited number of lease areas. The single auction for a lease offshore North Carolina in 2017 yielded a more modest winning bid of a little over $18,300 per square kilometer.

Figure 4.1 Historical auction winning price and future forecast ($/km^2)



Source: Wood Mackenzie

However, given the current state-policy landscape, Woodmac estimates that winning auction prices in the Carolinas in the near-term will be significantly lower than in the New York Bight region. Woodmac assumes the future auction price will be at the same level as the first North Carolina "Kitty Hawk" lease auction in 2017. There are several reasons for

this. First, the Carolinas do not have meaningful REC programs (South Carolina lacks a Renewable Portfolio Standard [RPS], and North Carolina's RPS tops out in 2021) nor do they have any specific offshore wind targets. As a result, projects in the Carolinas will not have a REC revenue stream compared to projects in southern New England and New York where the value of offshore wind's environmental attributes is estimated to be $34/MWh in 2025. Second, projects in the Carolinas will have lower capacity factors compared to projects in southern New England and New York due to weaker wind resources. Third, the more southern locations of the projects limit their opportunity to sell into PJM market, reducing the number of potential offtakers. Projects in these areas will be reliant on PPAs or, more likely, build-transfer agreements with a small handful of regulated Southeastern utilities that lack any policy-driven demand for incremental renewables.

BOEM received two nominations of interest for its South Carolina call areas, which is consistent with our observation that there is currently lower interest by industry players in this region compared to the Northeast. That said, the rapid increase in winning lease prices in the Northeast between 2015 and 2018 indicates that changes in policy and technology can rapidly lead to a step-change in interest. Due to the auction structure, the addition of just a small number of bidders seeking a long-term investment in the area could lead to a tipping point, with winning bid prices increasing by multiple orders of magnitude. Though not modeled here, there is thus significant upside potential for revenue to the US Treasury, particularly if state policymakers in the Carolinas implement some form of offshore wind carve-out.

The California call areas received significant attention during the initial nomination process. A total of 14 unique parties expressed interests in commercial leases. Although there is no specific offshore policy yet, the state has a lucrative REC market and high power prices making offshore wind project economics similar to the Northeast region. However, Woodmac estimates the auction price will be lower than the Massachusetts auction in 2018 due to the higher cost for floating offshore technology and the need to build a completely new west coast offshore wind supply chain.

In Maine, although the policy and power market conditions are similar to New York and Massachusetts, the relatively higher cost of floating wind technology will erode into project economics and therefore reduce the auction price. Future auction prices in Maine will be slightly lower than recent auction prices in Massachusetts. A summary of estimated auction prices is listed in Table 4.2.

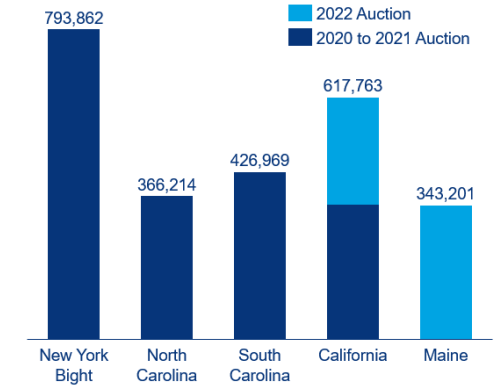
The potential near-term (2020 and 2021) offshore wind lease areas and additional lease areas (2022) needed to fulfill state offshore wind targets by 2035 are presented in Figure 4.2. The corresponding US Treasury revenue is estimated and presented in Figure 4.3. The anticipated near-term auction will generate $1.2 billion in US Treasury revenue. The auctions for additional areas in Maine and California could generate additional $500 million in 2022.

Table 4.2: Estimated future auction price

Call Area	New York Bight	Carolinas	California	Gulf of Maine
NO. of Bids	8	5	11	6
Price ($/km^2)	258,000	18,000	206,000	219,000

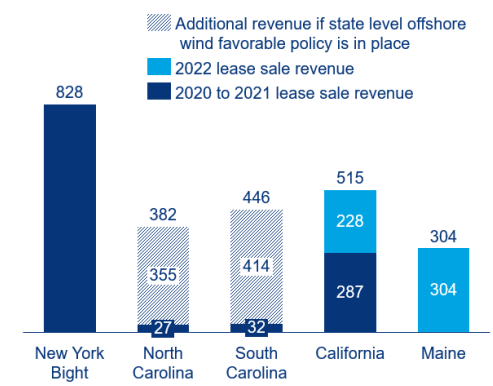
Source: Wood Mackenzie

Figure 4.2 Offshore wind lease area (acre)



Source: Wood Mackenzie

Figure 4.3 Revenue to US treasury ($MUSD)



Source: Wood Mackenzie

5. ECONOMIC IMPACT ANALYSIS

This paper reports the economic impacts of developing offshore wind for two principle phases of activities: 1) project development and construction, and 2) project operation and maintenance (O&M). Project development and construction impacts are the result of one-time expenditures required to build and commission the project. The resulting economic impacts last only during the project development and construction phases. Project O&M expenditures are required every year during the entire project operational life, which is assumed to be 25 years in this study.

The economic impacts of the development and construction phase of offshore wind installation are listed in Table 5.1. The majority of the job creation will come from the project construction related activity. An average of about 70,000 domestic job annually will be created in development and construction phase of the offshore wind activities from 2025 to 2035. In addition, those activities will generate total $2.2 billion in state tax revenue from 2025 to 2035. The total capital investment to support the offshore wind installation in US will be $158 billion by 2035. Some of the project development activity and initial supply chain investment might happen before the actual project construction starts. Woodmac estimates that pre-construction activities will support about 3,500 jobs per year from 2022 to 2024.

Compared to the construction phase, which creates significant short-term impact, the O&M phase creates lasting economic impact for decades. The result is summarized in Table 5.2. By 2035, it will generate 20,500 jobs, $1.2 billion in state tax revenue and $2.4 Billion capital investment annually.

The state-level combined employment impacts for both phases are presented in Figure 5.1. The majority of the employment generated by offshore wind projects in the New York Bight area will be in the states of New York and New Jersey, and adjacent states. The majority of the employment generated by offshore wind projects in the Gulf of Maine will be in the states of Maine and New Hampshire (as well as potentially Massachusetts). The projects in the New York Bight and the Carolinas will create the majority of jobs during the construction phase from 2025 to 2030, while the projects in the Gulf of Maine and California will create jobs after 2030 and the decades that follow.

Offshore wind activities will not only contribute to economic output in the wind industry, but also many related industries, such as transportation and ports, construction and general service industries. The amount of capital that will be invested in different industries due to the offshore wind activities in the response to the assumed BOEM auctions in 2020-2022 is presented in Figure 5.2. Over $100 billion will be invested into the construction industry, while $42 billion is invested in turbine manufacturing and supply chain.

The detailed state-level jobs created during the development and construction phase by industry is shown in Figure 5.3. The job number presented in Figure 5.3 is average annual

jobs supported from 2025 to 2035. The job creation in the O&M phase is presented in Figure 5.4. O&M job and O&M activities induced job will continue to increase as the total offshore wind installation increases. The job creation presented in Figure 5.4 for New York, New Jersey and the Carolinas refers to Year 2030 when all offshore projects as a result of assumed BOEM auctions in 2020 and 2021 are completed. Those jobs are expected to last until 2055. The job creation presented in Figure 5.4 for California, Maine and New Hampshire is referring to Year 2035 when all offshore projects as a result of assumed BOEM auctions 2021-2022 are complete. Those jobs are expected to last until 2060.

Table 5.1: Economic impact of development and construction phase

Call area	Project Phase	Main Impact Time Period	Annual Job Supported	Economic impact (Real 2020 $ Million)		
				Annual Wage Creation	Annual State Tax Creation	Total Capital Investment
New York Bight	Development	2022 to 2029	100	$ 11	$ -	$ 195
	Construction	2025 to 2030	32,200	$ 3,260	$ 183	$ 45,703
	Total		32,300	$ 3,271	$ 183	$ 45,898
Carolinas	Development	2022 to 2029	200	$ 20	$ -	$ 390
	Construction	2025 to 2030	37,000	$ 2,987	$ 233	$ 44,596
	Total		37,200	$ 3,007	$ 233	$ 44,986
California	Development	2025 to 2034	100	$ 9	$ -	$ 195
	Construction	2030 to 2035	38,000	$ 3,476	$ 385	$ 44,020
	Total		38,100	$ 3,485	$ 385	$ 44,215
Gulf of Maine	Development	2025 to 2034	100	$ 8	$ -	$ 195
	Construction	2030 to 2035	20,200	$ 1,555	$ 144	$ 22,746
	Total		20,300	$ 1,563	$ 144	$ 22,941

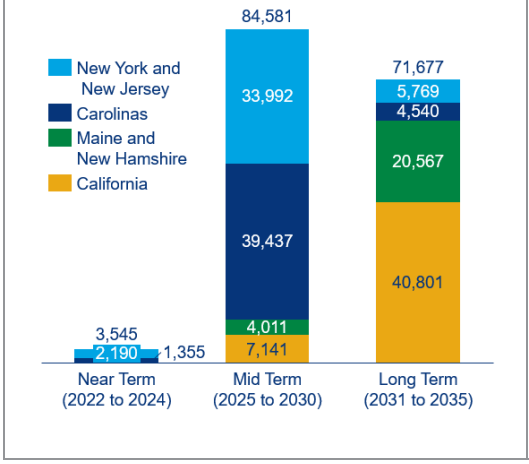
Source: Wood Mackenzie

Table 5.2 Economic impact of O&M phase

Call area	Project Phase	Main Impact Time Period	Annual Job Supported	Economic impact (Real 2020 $ Million)		
				Annual Wage Creation	Annual State Tax Creation	Annual Capital Investment
New York Bight	Operation	2025 to 2055	5,800	$ 573	$ 235	$ 786
Carolinas	Operation	2025 to 2055	6,700	$ 507	$ 693	$ 786
California	Operation	2030 to 2060	5,000	$ 449	$ 233	$ 540
Gulf of Maine	Operation	2030 to 2060	3,000	$ 209	$ 119	$ 300

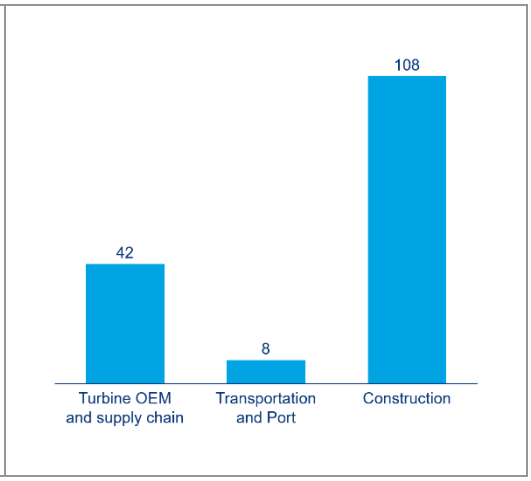
Source: Wood Mackenzie

Figure 5.1 Annual job supported by states



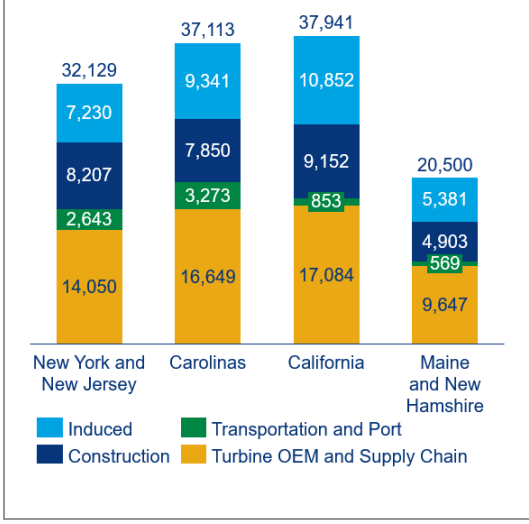
Source: Wood Mackenzie

Figure 5.2 Capital Investment by industry (Real 2020 $ Billion)



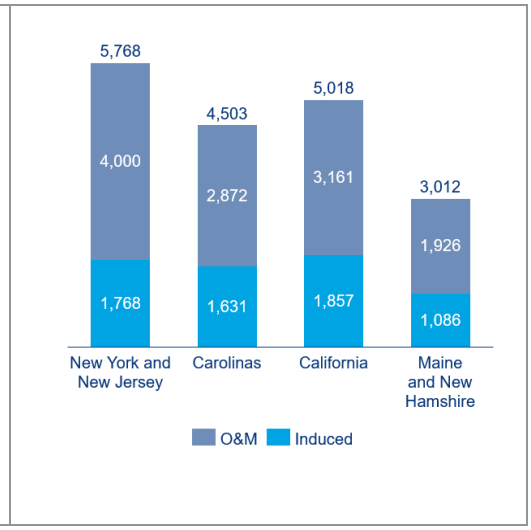
Source: Wood Mackenzie

Figure 5.3 Average annual jobs by industry - Development and construction phase



Source: Wood Mackenzie

Figure 5.4 Average annual jobs by industry - O&M phase



Source: Wood Mackenzie

6. CONCLUSION

The growth of US offshore wind will not only deliver clean energy in the US, but also generate significant near-term, mid-term and long-term economic benefits. BOEM has designated a number of call areas along the East and West Coasts that are expected to be leased in the near future. This paper studied the direct and indirect economic impacts that could be realized if those auctions occur this year and next. A significant near-term benefit will be $2 billion in US Treasury revenue. Even more significant, is the mid-term development and construction of offshore wind farms created by these leases would support 80,000 jobs annually and generate hundreds of billions of dollars of investment into construction, transportation and port-related development. Long-term, these projects will provide sustainable green energy to 20 million households and support 20,500 jobs annually beyond 2035 that continues for decades.

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