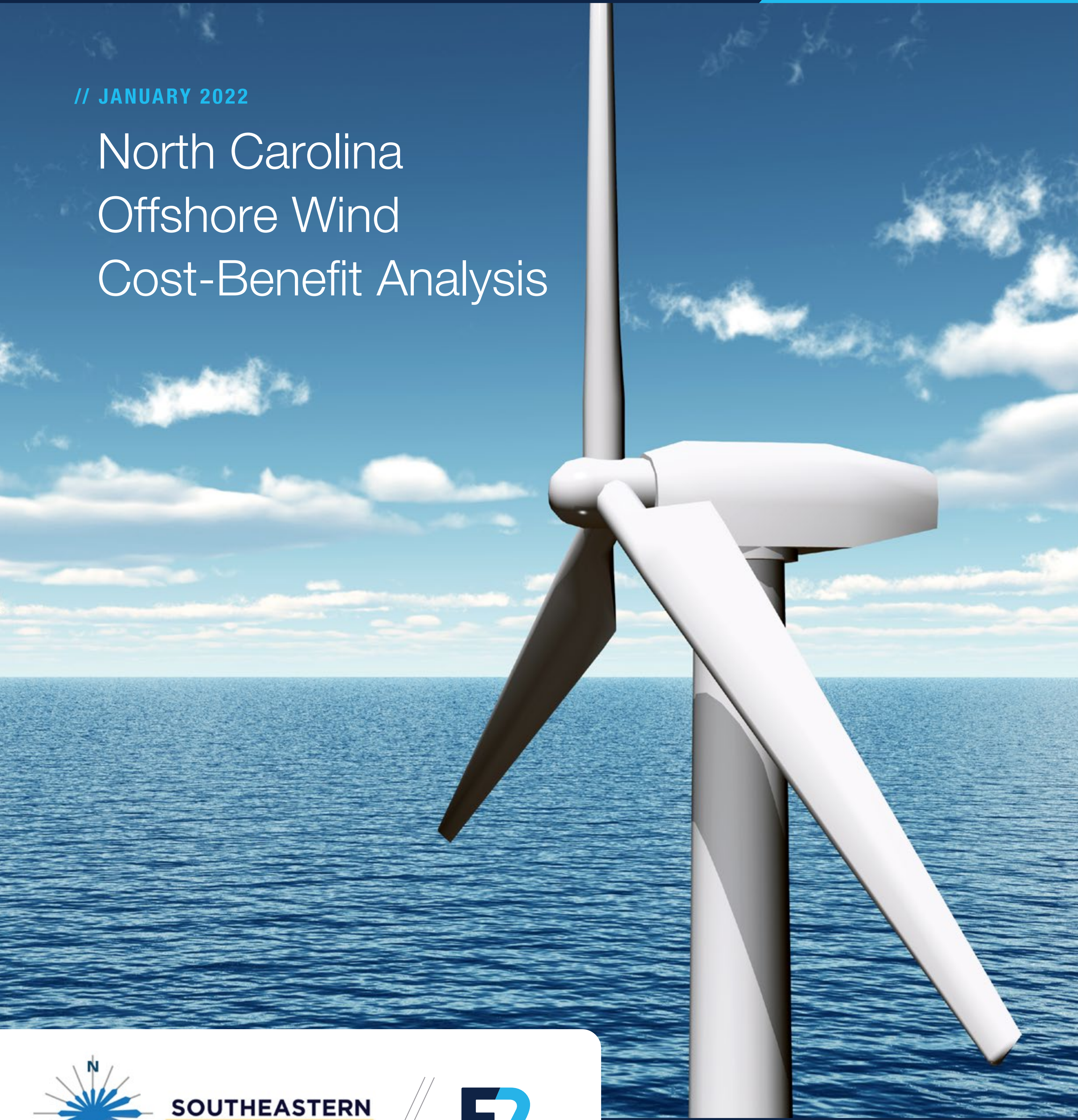
// JANUARY 2022

North Carolina Offshore Wind Cost-Benefit Analysis



SOUTHEASTERN WIND COALITION

E2

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In Partnership with E2

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About the Southeastern Wind Coalition

The Southeastern Wind Coalition is a 501(c)3 that works to advance the land-based and offshore wind industry in the Southeast. We focus on providing fact-based information on the economic and environmental opportunities of wind energy, and encourage solutions that result in net economic benefits to residents and ratepayers. For more information about the Southeastern Wind Coalition visit www.sewind.org.

About E2

E2 is a national, nonpartisan group of business leaders, investors and other professionals who advocate for smart policies that are good for the environment and good for the economy. With nine chapters working at the state, local and federal levels across the country, E2's 11,000 members and supporters bring the business case for climate action. Collectively, E2 members have founded or funded more than 2,500 companies, created more than 600,000 jobs, and managed more than $100 billion in venture and private equity capital.

For additional insight into E2's reports, including our clean energy employment reports, visit e2.org/reports. For more information about E2 and its advocacy work, visit www.e2.org.

Acknowledgments

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Acronyms

ACP	American Clean Power Association
AEO	Annual Energy Outlook
ATB	Annual Technology Baseline
AWEA	American Wind Energy Association
BOEM	Bureau of Ocean Energy Management
CAPEX	Capital expenditures
CEP	Clean Energy Plan
CF	Capacity factor
CO2	Carbon dioxide
DEC	Duke Energy Carolinas
DEP	Duke Energy Progress
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
EO	Executive order
FAA	U.S. Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FTE	Full-time equivalent
GW	Gigawatt
IPP	Independent power producer
ITC	Investment tax credit
JEDI	Jobs and Economic Development Impact model
kV	Kilovolt
kWh	Kilowatt-hour
LCOE	Levelized cost of energy
MW	Megawatt
MWh	Megawatt-hour
NCTPC	North Carolina Transmission Planning Collaborative
NGCC	Natural gas combustion cycle
Nm	Nautical mile
NOWRDC	National Offshore Wind Research and Development Consortium
NREL	National Renewable Energy Laboratory
O&M	Operations and maintenance
OEM	Original equipment manufacturer
OPEX	Operating expenditures
PPA	Power purchase agreement
PV	Photovoltaics
RFP	Request for proposals
ROW	Right of way
RTO	Regional Transmission Organization
SAM	System Advisory Model
SEWC	Southeastern Wind Coalition
SMART POWER	Southeast and Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources
WEA	Wind energy area

Executive Summary

Over the next decade offshore wind is expected to play a significant role in decarbonizing the U.S. electric sector, and especially along the East Coast. When states are considering offshore wind goals, they will certainly evaluate the myriad of associated costs and benefits. This analysis was developed to help decision makers quantify some of the economic development and environmental benefits associated with offshore wind.

This analysis calculates the costs and benefits associated with a single 2.8-gigawatt (GW) offshore wind project off the coast of North Carolina in operation by 2030. Both a base scenario, assuming a standard amount of local manufacturing/supply chain content, and a high local content (or "high") scenario, were developed.

The analysis found that in both scenarios, the theoretical 2.8GW offshore wind project provides a net economic benefit to North Carolina.

FIGURE ES. 1 // Net economic impact: cost-benefit comparison for 2.8GW offshore wind project ($ in millions)

	2030 — Base	2030 — High
Net Economic Impact	$3,781	$4,581

The high scenario assumes 100% local content for both the blades and offshore substations of a single 2.8GW theoretical project. Content assumptions are based on findings from the March 2021 offshore wind supply chain study conducted on behalf of the North Carolina Department of Commerce, which indicates these components being most likely to locate production in-state. While not within the scope of this calculation, it is important to highlight the compounded value that new or expanded offshore wind supply chain capabilities located in North Carolina will create. In addition to providing economic benefit to the state through projects developed off the coast of North Carolina, offshore wind manufacturers will also supply components for projects along the Atlantic coast or potentially across the country or the globe — generating continued economic benefit to the state, absent the cost of generating electricity.

Timing and market demand are essential when evaluating this compounded benefit. Due to the nascency of the domestic supply chain and as depicted through the first wave of manufacturing location announcements[1,2,3,] Tier-1 original equipment manufacturers (OEMs) and their sub-component suppliers are more likely to establish facilities in states that are creating demand for their product. The longer a state waits to make commitments to development, the less likely they are to attract larger manufacturers.

Benefit figures for the analysis were derived from the results of the National Renewable Energy Laboratory's (NREL) Jobs and Economic Development Impact (JEDI) model. The modeling inputs were informed by industry standards and datasets, as well as North Carolina-specific data including potential transmission injection points, existing wind energy area characteristics, and supply chain strengths detailed in the March 2021 report titled Building North Carolina's Offshore Wind Supply Chain published by the North Carolina Department of Commerce. Benefits specifically for onshore transmission upgrades were calculated through IMPLAN modeling. Cost inputs were calculated using projections for capacity factor (CF), levelized cost of energy (LCOE), and technical lifetime from NREL's 2021 Annual Technology Baseline (ATB), findings from the North Carolina Transmission Planning Collaborative's offshore wind injection study, and a weighted calculation of Duke Energy Carolinas and Duke Energy Progress' avoided cost rates.

An additional output from JEDI modeling scenarios are full-time equivalent (FTE) positions created during both construction and operations and maintenance (O&M) phases. An FTE of 1.0 represents one full-time worker. The economic value of FTE's is included in the calculated benefit.

[1] Governor Phil Murphy. (2020, December 21). *Governor Murphy Announces $250 Million Total Investment in State-of-the-Art Manufacturing Facility to Build Wind Turbine Components to Serve Entire U.S. Offshore Wind Industry* [Press release]. State of New Jersey.

[2] Port of Albany. (2020, January 14). *Port of Albany Selected as the First Offshore Wind Tower Manufacturing Site in the Nation in Partnership between Marmen Inc, Welcon A/S and Equinor Wind* [Press release].

[3] Siemens Gamesa Renewable Energy. (2021, Oct 25). *Unmatched in the U.S.: Global Leadership Grows: Siemens Gamesa solidifies offshore presence in U.S. with Virginia blade facility* [Press release]. https://www.siemensgamesa.com/en-int/newsroom/2021/10/offshore-blade-facility-virginia-usa

FIGURE ES. 2 // FTE Positions Created

	2030 — Base	2030 — High
Jobs During Construction (job years)	27,621	30,990
O&M Jobs (annual)	923	923

FTEs are categorized by specific activity during construction, operation and maintenance (O&M), as well as induced jobs created by spending of wages from jobs created in the prior two categories. The majority of FTE's created through both construction and O&M are within the manufacturing supply chain and support services. These jobs are representative of a supply chain that will provide materials and components for offshore wind projects beyond the theoretical project within this analysis, creating significant job creation beyond that of the project modeled.

Additional factors can contribute to both the costs and the benefits of offshore wind. Tax incentives like the Investment Tax Credit (ITC) and emissions reductions valued through the social cost of carbon, can be quantified. Other factors such as electricity system benefits and land-use constraints can also be quantified, but require more specific project details than this analysis provides and are therefore addressed qualitatively to provide a more complete picture of the benefits North Carolina can derive from offshore wind.

FIGURE ES. 3 // Economic Benefits to North Carolina ($ in millions)

2030 — Base Economic Benefit	ITC Extension to 2030	Economic Benefit with ITC Extension
$3,781	$2,148	$5,929

FIGURE ES. 4 // Quantifiable Benefits ($ in millions)

Economic Benefit with ITC Extension Benefits	Social Cost of Carbon	Total Quantifiable
$5,929	$8,367	$14,296

Introduction

Recently codified in state-level legislation, North Carolina has asserted the carbon-reduction goal of 70% by 2030 and to achieve carbon neutrality by mid-century[4]. To that end, the Governor's administration, the North Carolina General Assembly, and Duke Energy have all endeavored to examine pathways to reliably and cost-effectively decarbonize the state's electric grid[5,6,7,8]. While offshore wind has occasionally been an element of these discussions, due to relative cost and nascency of the U.S. offshore wind industry, it hasn't been evaluated as a primary tool for decarbonization.

Absent from any of the decarbonization modeling or stakeholder processes conducted in the state since 2018 is the consideration of the economic benefits that accompany offshore wind. According to the American Wind Energy Association (AWEA), now the American Clean Power Association (ACP), an estimated 30GW of offshore wind deployment in the U.S. by 2030 could generate as much as $57 billion in economic output[9]. As such, the inclusion of these benefits is critical when understanding the full value of the technology.

This analysis determines both the costs and benefits of a theoretical 2.8-gigawatt (GW) offshore wind project developed off the coast of North Carolina in operation by 2030 using industry-standard practices, data, and modeling tools. The costs and benefits are measured against one another to determine the net economic impact.

Background

The offshore wind industry was established in the early 1990's and has grown to over 35GW of global installed capacity in 2020[10]. The only large-scale renewable technology with a generating profile that can correspond with peak load hours, and be complementary to onshore wind and solar, offshore wind is a necessary component to a carbon-free, reliable grid. Additionally, the manufacture, installation, and maintenance of offshore wind projects have delivered substantial economic benefit to Europe, where global deployment to date has focused[11].

Consideration of offshore wind deployment in the U.S. has taken shape over the past decade and began to materialize with the development of the country's first operating offshore wind farm, Block Island, in 2016. The industry has continued to advance with a demonstration-size project off the coast of Virginia, over 35GW of state-level development or procurement commitments, and in 2021, an announcement from President Biden to pursue 30GW of offshore wind deployment by 2030[12].

European governments have long acknowledged the unique benefits of offshore wind, and as with many new industries, its initial cost premium. Through various national and multi-governmental initiatives including research, investment, industrialization, and subsidization, the European offshore wind market has realized significant cost reductions since inception[13],

[4] *Energy Solutions for North Carolina*, H. bill 951, N.C.G.A. (2021–2022). https://ncleg.gov/BillLookup/2021/h951

[5] Konschnik, K., Ross, M., Monast, J., Weiss, J., & Wilson, G. (2020). (rep.). *Power Sector Carbon Reduction: An Evaluation of Policies for North Carolina* (pp. 1–245). Nicholas Institute for Environmental Policy Solutions, Duke University.

[6] North Carolina Department of Environmental Quality (2019, October). *North Carolina Clean Energy Plan: Transitioning to a 21st Century Electricity System*. https://files.nc.gov/ncdeq/climate-change/clean-energy-plan/NC_Clean_Energy_Plan_OCT_2019_.pdf

[7] Matsuda-Dunn, R., Emmanuel, M., Chartan, E., Hodge, B. M., & Brinkman, G. (2020, January). *Carbon Free Resource Integration Study* (NREL/TP-5D00-74337). National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy20osti/74337.pdf

[8] *An Act to Modernize North Carolina's Generation and Grid Resources and Rate Making and To Invest in Critical Energy Infrastructure for The Benefit of Customers,* H. bill 951, N.C.G.A. (2021-2022). https://ncleg.gov/BillLookup/2021/h951

[9] American Wind Energy Association (2020, March) *U.S. Offshore Wind Power Economic Impact Assessment.* https://supportoffshorewind.org/wp-content/uploads/sites/6/2020/03/AWEA_Offshore-Wind-Economic-ImpactsV3.pdf

[10] Global Wind Energy Council (2021, September 9) https://gwec.net/wp-content/uploads/2021/09/GWEC-offshore-wind-2021-updated-1.pdf

[11] Wind Europe (2021, February). *Offshore Wind in Europe: Key trends and statistics 2020.* "Every new wind offshore wind turbine generates €15m of economic activity. https://windeurope.org/intelligence-platform/product/offshore-wind-in-europe-key-trends-and-statistics-2020/

[12] The White House (2021, March 29) *Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs.* https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/

[13] Schnettler, J., & Segal, K. (2020, April). *Cost-Benefit Analysis of Offshore Wind in the Kitty Hawk Wind Energy Area.* N/A. Retrieved July 2021, from https://books.google.com/books/about/Cost_benefit_Analysis_of_Offshore_Wind_i.html?id=ibXVzQEACAAJ

with the first unsubsidized projects, Vattenfall's Hollandse Kust Zuid 3 & 4, set to be built by 2022[14]. According to the UK's "Cost Reduction Monitoring Framework" (CRMF), most of these cost reductions are a result of the commercialization of larger, more efficient turbines, with supplemental reductions gained through efficiencies within the value chain[15].

As the next wave of a now-established industry, commercial-scale offshore wind projects currently under development are leveraging the progress made to date in offshore wind technology — Vineyard Wind I, which will be the U.S.'s first commercial-scale wind farm (scheduled to be in operation by 2023), has announced its selection of GE Renewable Energy's 13-megawatt (MW) Haliade-X turbine[16]. By comparison, the average capacity for turbines installed globally in 2020 was 8.2MW[17].

While the U.S. is primed to capitalize on technology advancements made abroad, given the size of turbine components and associated transportation costs, a considerable pipeline of offshore wind projects merits a domestic supply chain.

Because this supply chain does not yet exist in the U.S., the continued growth of offshore wind development across the country has the potential to create an entirely new sector of the economy, specifically in states and regions where development is anticipated.

The 30GW of planned development recently announced by the current Administration will generate more than $12 billion per year in capital investments, and more than 77,000 direct and induced jobs[18]. Establishing a domestic supply chain will further decrease the cost of offshore wind, as a robust network of suppliers in close proximity to development will create logistics efficiencies[19].

North Carolina has taken measured strides to develop an offshore wind industry. In October 2018, Governor Roy Cooper's Executive Order (EO) 80 directed the creation of a state Clean Energy Plan, which indicated multiple offshore wind objectives, including the creation of a regional offshore wind collaborative, a study of the state's supply chain and infrastructure as it relates to offshore wind, and the advancement of legislative and regulatory actions to foster development of North Carolina's offshore wind resources[20]. The first two have subsequently been accomplished — the Southeast and Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources (SMART-POWER) was signed by the Governors of North Carolina, Virginia, and Maryland to reduce regulatory barriers and regionally pursue offshore wind development[21]. Next, a study of the state's supply chain and port infrastructure was published in March 2021 which outlined the state's unique benefits in contributing to the offshore wind industry's manufacturing supply chain[22].

[14]Vattenfall. (2019, July 10). *Vattenfall wins tender for Dutch offshore wind power* [Press release]. https://group.vattenfall.com/press-and-media/pressreleases/2019/vattenfall-wins-tender-for-dutch-offshore-wind-power

[15]*Cost Reduction Monitoring Framework — Quantitative Assessment Report* (2016, December 19). UK Offshore Wind Programme Board, the Offshore Wind Industry Council, the UK Department of Energy and Climate Change, and the Crown Estate. [P. 16]. https://s3-eu-west-1.amazonaws.com/media.ore.catapult/wp-content/uploads/2017/01/24082704/CRMF-2016-Quantitative-Report-Print-Version.pdf

[16]Vineyard Wind. (2020, December 1). *Vineyard Wind Selects GE Renewable Energy as Preferred Turbine Supplier for America's First Utility Scale Offshore Wind Project* [Press release]. https://www.vineyardwind.com/press-releases/2020/12/1/vineyard-wind-selects-ge-renewable-energy-as-preferred-turbine-supplier

[17]Wind Europe. (2021, February).

[18]The White House. (2021, March 29).

[19]Musial, W. (2018, February). *Offshore Wind Resource, Cost, and Economic Potential in the State of Maine.* National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy18osti/70907.pdf

[20]NCDEQ. (2019, October). NC Clean Energy Plan.

[21]Governor Roy Cooper (2020, October). Maryland, North Carolina, and Virginia Announce Agreement to Spur Offshore Wind Energy and Economic Development [Press release]. https://governor.nc.gov/news/maryland-north-carolina-and-virginia-announce-agreement-spur-offshore-wind-energy-and-economic

[22]BVG Associates (2021, March). *Building North Carolina's Offshore Wind Supply Chain: The roadmap for leveraging manufacturing and infrastructure advantages.* North Carolina Department of Commerce https://files.nc.gov/nccommerce/documents/Policymaker-Reports/Report_North-Carolina-OSW-Supply-Chain-Assessment_BVGAssociates_asPublished-Mar3-2021.pdf

[23]North Carolina Exec. Order No. 218, *Advancing North Carolina's Economic and Clean Energy Future with Offshore Wind* (2021, June 9). https://files.nc.gov/governor/documents/files/EO218-Advancing-NCs-Economic-Clean-Energy-Future-with-Offshore-Wind.pdf

In June 2021, Governor Roy Cooper signed EO 218, which set forth an offshore wind development goal of 2.8GW of offshore wind by 2030 and 8GW by 2040[23]. Governor Cooper's EO mirrors those previously made by Governors and state legislatures along the Atlantic coast[24,25,26,] reflecting the understanding that offshore wind is an essential technology in reaching state, utility, or national carbon-reduction goals as well as the appetite for capturing as much of the multi-billion-dollar supply chain as possible that has yet to be established domestically.

As demonstrated by the recent announcements of the location of Tier-1 manufacturing facilities[27,28,29], state-level commitments to develop offshore wind have been a primary driver in securing these investments.

To support anticipated demand, additional Tier-1 as well as sub-component Tier-2 and Tier-3 manufacturing facilities will be constructed across the country in the coming years. With the location of new offshore wind manufacturing still largely up for grabs and given Governor Cooper's 2021 offshore wind development EO as well as the state's examination of decarbonization pathways, this analysis was conducted to support the consideration of offshore wind's ability to cost-effectively contribute to reaching North Carolina's carbon-reduction goals. Additionally, the high scenario helps to show how an early demonstration of North Carolina's commitment to offshore wind development can dramatically impact the state's economic benefit from both a single project and additional projects along the Atlantic coast.

[24] *An Act To Promote Energy Diversity*, H. bill 4568, The 192nd General Court of the Commonwealth of Massachusetts (2015-2016). https://malegislature.gov/Bills/189/H4568

[25] New Jersey Exec. Order No. 8 (2018, January 31). https://nj.gov/infobank/eo/056murphy/pdf/EO-8.pdf

[26] Commonwealth of Virginia Exec. Order No. 43, *Expanding Access To Clean Energy And Growing The Clean Energy Jobs Of The Future* (2019, September 16). https://www.governor.virginia.gov/media/governorvirginiagov/executive-actions/EO-43-Expanding-Access-to-Clean-Energy-and-Growing-the-Clean-Energy-Jobs-of-the-Future.pdf

[27] Governor Phil Murphy. (2020, December 21).

[28] Port of Albany. (2020, January 14).

[29] Siemens Gamesa Renewable Energy. (2021, Oct 25).

Methods

This analysis quantifies the anticipated costs and benefits of the development of 2.8GW of offshore wind along the North Carolina coast by 2030 as set forth by Governor Cooper's EO 80 and derives the net economic benefit of the theoretical project. To demonstrate the value of a localized supply chain that North Carolina could possibly recruit should the state actively pursue major offshore wind manufacturers, a high local content (or "high") case was conducted as well.

Cost Inputs

Offshore Wind Production Projection Inputs

The primary cost inputs used in this calculation were derived from the National Renewable Energy Laboratory's (NREL) 2021 Annual Technology Baseline (ATB). The ATB is a widely utilized data set that incorporates analyses from multiple national laboratories, Department of Energy (DOE) offices, and other industry reports, and details current and projected cost and performance data for multiple electricity generation technologies. For offshore wind, the 2021 ATB provides projections for Class 1 through 14 resource classes, classes 1–7 representing fixed-bottom technology, and classes 8–14 representing floating technology. Classes are further divided by wind resource, or average wind speeds, with a lower class representing a higher average wind speed. Based on the average water depths of the existing wind energy areas off the coast of North Carolina[30] as well as the average wind speeds over this area, as calculated by NREL[31], this analysis utilized the Class 5 cost projections. Projections also capture variances in anticipated technology innovations and cost drivers, which are demonstrated in "conservative", "moderate", and "advanced" scenarios for each resource class. Given the prioritization of offshore wind by the Biden-Harris Administration and therefore the likely accelerated trajectory of the industry, an "advanced" scenario, which "assumes a supply chain that generates efficiency gains above the level of the past few years"[32] is possible. However, the analysis utilized the "moderate" scenario, which anticipates the use of 15MW turbines that are currently being developed and tested by major manufacturers such as Vestas[33], GE[34], and Siemens Gamesa[35].

The analysis incorporates 2021 ATB projections for capacity factor (CF), technical lifetime, and levelized cost of energy (LCOE)[36]. The CF is represented by a percentage and demonstrates the amount of electricity that is generated on average when compared to the capacity rating of the project. For example, if a 100MW wind farm has a CF of 50%, the actual amount of electricity being produced will average 50MW over the course of a year. The 2021 ATB's Class 5 "moderate" offshore wind CF projection for 2030 is 46%.

The technical lifetime utilized in the 2021 ATB is 30 years, which according to NREL is consistent with current industry trends[37].

LCOE is a commonly used metric for the cost of electricity produced over the lifetime of a project. LCOE includes capital expenditures (CAPEX), operations expenditures (OPEX), and CF to determine average cost to produce a kWh. Due to the variances in financing structures and operations for different types of generation, LCOE is a metric that is used to more easily compare costs across generation technologies. The 2021 ATB's Class 5 "moderate" LCOE projection for 2030 is $55/MWh. Details on the assumptions behind LCOE can be found on the ATB website.

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[30] *Marine Cadastre National Viewer.* MarineCadastre.gov. (n.d.). Measurement of existing Wilmington E WEA. https://marinecadastre.gov/nationalviewer/.

[31] National Renewable Energy Laboratory [map]. (2011). United States — Annual Average Offshore Wind Speed at 90m. Retrieved from https://windexchange.energy.gov/maps-data/320

[32] National Renewable Energy Laboratory. (2021). *2021 Annual Technology Baseline — Electricity — Offshore Wind*. NREL. Retrieved July 24, 2021, from https://atb.nrel.gov/electricity/2021/offshore_wind

[33] Vestas. (Feb 10, 2021). *Vestas launches the V236-15.0 MW to set new industry benchmark and take next step towards leadership in offshore wind* [Press release]. https://www.vestas.com/en/media/company-news?n=3886820#!grid_0_content_0_Container

[34] GE Renewable Energy. (n.d.). *World's Most Powerful Offshore Wind Platform: Haliade-X*. Retrieved July 24, 2021, from https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine

[35] Siemens Gamesa. (2020, May 19). *Powered by change: Siemens Gamesa launches 14 MW offshore Direct Drive turbine with 222-meter rotor* [Press release]. https://www.siemensgamesa.com/en-int/-/media/siemensgamesa/downloads/en/newsroom/2020/05/siemens-gamesa-press-release-turbine-14-222-dd-en.pdf

[36] National Renewable Energy Laboratory. (2021). *2021 Annual Technology Baseline — Electricity — Data.* NREL. Retrieved July 24, 2021, from https://atb.nrel.gov/electricity/2021/dat

[37] NREL 2021 ATB, Offshore Wind. (2021).

Electricity Cost Inputs

To approximate the wholesale cost of electricity for North Carolina, this analysis utilized the 2020 avoided cost rate schedules for Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP)[38]. North Carolina is composed of vertically integrated monopoly utilities, therefore wholesale costs of electricity are not transparent nor available. Avoided cost is a biennial calculation determined by the North Carolina Utilities Commission that includes confidential cost details from DEC and DEP as well as forward-looking fuel assumptions to determine the compensation structure for independent power producers (IPPs). As such, avoided cost is the closest representation of the state's generation mix, and the current cost for the utility to generate electricity. The avoided cost rate structures for DEC and DEP are divided by seasons of the year and hours of the day and fluctuate based on historical "peak" and "off-peak" demand. To align the appropriate rates with the generation profile of offshore wind production and accurately predict the cost of electricity during those times, the avoided cost rate schedules were weighted against North Carolina-specific offshore wind production curves gathered from NREL's System Advisory Model (SAM)[39]. Further, based on assumptions presented in the North Carolina Transmission Planning Collaborative's (NCTPC) offshore wind integration study published in June 2021 (see more on the full inclusion of this study's findings below), resource allocation was weighted to 60% DEC and 40% DEP[40], resulting in an avoided cost value of $30.35/MWh. The full weighted avoided cost calculation can be found in Appendix E.

Given future projected avoided cost figures are not public, and overall retail electricity prices are forecast to remain relatively consistent in 2020 dollars (-0.3% annually from 2020 to 2050[41]), the 2020 avoided cost is utilized for the duration of the analysis. State and federal policy will likely have the greatest impact on local electricity prices, though these variables were not introduced into this analysis, they make keeping the avoided cost figure constant through 2050 a conservative estimate. With more intermittent generation expected on the grid, peak times will become more valuable, adding to the value of offshore wind in practice, but not included in this analysis.

Transmission Cost Inputs

The final cost input for the analysis is the cost of onshore grid upgrades necessary to interconnect 2.8GW of offshore wind to the North Carolina grid. This figure was derived from an analysis conducted by the NCTPC at the request of SEWC. The NCTPC was created by the major electric load-serving entities (LSEs) of North Carolina, including DEC, DEP, ElectriCities of North Carolina (municipal electric providers), and the North Carolina Electric Membership Corporation (cooperative electric providers). The NCTPC is led by an independent administrator and serves the function of creating "an integrated long-term transmission expansion plan that will result in a reliable and cost-effective transmission system[42]" as set forth by the Federal Energy Regulatory Commission's (FERC) Order #890 and #1000 compliance requirements. In addition to NCTPC's standard analyses and planning, the group undertakes one "public policy" request annually that studies a transmission need relating to a policy topic. In 2020, SEWC submitted a public policy request to identify three least-cost injection points along the coast, study the injection of 15 GW of offshore wind capacity at these points collectively, and identify breakpoints in upgrade costs throughout.

NCTPC conducted the analysis during the 2020 study year and published the final report in June 2021[43]. The study identified 32 total injection points, and the three points of interconnection selected for further analysis included the existing New Bern 230kV and Greenville 230kV substations, as well as a proposed Sutton North 230kV substation. NCTPC also studied the addition of a 500kV lines to carry larger amounts of power to DEP's nearest major load center in the Raleigh area. For this analysis, the New Bern to Wommack to Wake with the 500kV upgrade was selected with a total cost of $1.09 billion. This selection is the most cost-effective, and is currently being evaluated in NCTPC's 2021 public policy request study as the most viable injection point for future offshore wind projects.

[38]Biennial Determination of Avoided Cost Rates for Electric Utility Purchases from Qualifying Facilities - 2020. (2021, February 12) *DEC & DEP Supplemental Filing of Revised Energy Rate Calculation & Updated Avoided Energy Rates-PUBLIC.* [North Carolina Utilities Commission]. https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=8b078c15-7d90-499d-b743-8da852623c68

[39]National Renewable Energy Laboratory. (2021). *System Advisor Model.* NREL. Retrieved July 24, 2021, from https://sam.nrel.gov/wind.html

[40]North Carolina Transmission Planning Collaborative (2021, June 7) *Report on the NCTPC 2020 Offshore Wind Study.* http://www.nctpc.org/nctpc/document/REF/2021-06-07/2020_NCTPC_Offshore_Wind_Report_06_07_2021-FINAL.pdf

[41]EIA 2021 Annual Energy Outlook, Table: Table 54. Electric Power Projections by Electricity Market Module Region

[42]North Carolina Transmission Planning Collaborative. (2021). *North Carolina Transmission Planning Collaborative.* Retrieved July 24, 2021, from http://www.nctpc.org/nctpc/home.jsp

[43]NCTPC. (2021, June 7).

Benefit Inputs

JEDI Results

The benefit inputs were derived almost entirely from the results of NREL's Jobs and Economic Development Impact (JEDI) model. Full documentation of the inputs for this modeling can be found in Appendices A, B, and C. NREL has developed eleven JEDI models for different generation sources, which estimate the economic impact of constructing and operating these facilities. Data used for multipliers and personal consumption patterns are derived from IMPLAN Professional, a commonly used economic development resource across industries. JEDI also incorporates project expenditure and local share assumptions based on NREL research, data from existing offshore wind installations, and insight from industry professionals. The model estimates how every dollar spent on an offshore wind project in North Carolina is multiplied throughout the economy.

The model generates local content default inputs for each of the major system and development components during construction, which can be adjusted. The base case scenario retained these default JEDI inputs. For the high scenario, local share for both blades and offshore substations were adjusted to 100%. Components selected for potentially high local share were informed by the findings from the recently published supply chain report from the North Carolina Department of Commerce[44], which indicated these components as having the highest likelihood of being manufactured in North Carolina. The state is home to over 30 manufacturers currently producing wind turbine sub-components such as steel plates used in towers, glass fiber used for blades, and many electrical components used in power systems applications. Both default JEDI inputs used in the base case and adjusted local content inputs for the high case can be found in Appendix C.

The modeling assumed site characteristics similar to that of the Wilmington East wind energy area (WEA)[45] and the NCTPC Sutton North to Cumberland with 500kV scenario, such as water depth, foundation type, and distance to port, landfall, and interconnection. 15MW technology was assumed based on industry trajectory. Project cost line items were adjusted to align with 2021 ATB projections for CAPEX and OPEX[46].

Findings derived from JEDI that were used in this analysis include local economic output during construction, and during operations and maintenance (O&M). Output figures include labor and project development impacts, supply chain impacts consisting of material and components purchases made in-state, and induced impacts which are employee earnings spent at other businesses in-state.

Transmission Benefit Inputs

Transmission build also comes with significant economic development benefits. Because many of the components used in the construction of transmission lines and related infrastructure are manufactured in the U.S., there is a high economic return on this spend.

A study from the Iowa State Department of Economics looking at transmission related infrastructure to deploy renewables, showed that economic output was higher than cost for every year a transmission investment was made[47]. Similarly, The Brattle Group and WIRES have conducted multiple studies quantifying the employment and economic stimulus benefits of transmission investments, each focusing on different locations across the country and Canada. These studies utilized the input-output IMPLAN software to model the kinds of jobs and spend that occurs when transmission investments are made. The nine Brattle Group and WIRES studies indicate an economic output per million dollars of transmission capital cost to range from $.2 million to $2.9 million[48]. A broader analysis also conducted by WIRES and The Brattle Group found that "every $1 billion of U.S. transmission investment directly and indirectly supports approximately 13,000 FTE years of employment and $2.4 billion in total economic activity[49]."

To quantify the economic output (or "benefit" as referenced throughout this analysis) for onshore transmission upgrades, the values from the NCTPC report were used as inputs for an IMPLAN model. Project component percentages as well as local content were derived from a Brattle Group study conducted on behalf of WIRES that estimates the general breakdown of each portion of a transmission project based on historical transmission planning data[50]. Full documentation of the inputs for this modeling can be found in Appendix D.

[44]BVGA. (2021, March).

[45]Marinecadastre.gov. (n.d.).

[46]NREL 2021 ATB, OSW. (2021).

[47]Swenson (July 2018). *Economic Impact & Job Creation Relative to Large-Scale, High Voltage Transmission Infrastructure.* http://www2.econ.iastate.edu/prosci/swenson/Publications/The%20Interconnection%20Seam%20Study%20Amended%20Title.pdf

[48]Chang, J. W., Pfeifenberger, J. P., & Hagerty, J. M. (2013, June) The Brattle Group. *The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments.* WIRES. Retrieved October 18, 2021, from https://docs.google.com/document/d/15Ds08LSqiUas4IbJzLBWprcdvSh1btSILNaQt1sptcI/edit?usp=sharing.

[49]Chang, J et. al. (2013, June)

[50]Chang, J et. al. (2013, June)

Structure of the Analysis

Costs

To determine the annual electricity production of the theoretical 2.8GW offshore wind facility, the nameplate capacity was multiplied by the CF as derived from the 2021 ATB.

2,805 MW x 46% x (24 hrs/day x 365 days/year) =
11,303,028 MWh/year

The cost premium per MWh was then quantified by calculating the difference between the weighted avoided cost of electricity in North Carolina and the offshore wind LCOE projections from the 2021 ATB.

$55/MWh – $30.35/MWh = **$24.65/MWh**

Multiplying the cost premium per MWh by the annual electricity production provides the annual cost premium for the 2.8GW theoretical project. These figures were further multiplied by the technical lifetime of the project, 30 years, which was derived from the 2021 ATB.

11,303,028 MWh/year x $24.65/MWh =
$278,619,640/MWh/year

The transmission upgrade cost provided by the NCTPC study was then added to the lifetime cost premium to achieve the total cost figure. Costs remain the same in both the base and high scenario.

Benefits

The JEDI model requires three steps of inputs: Project Data, Project Costs, and Local Share. Project Data inputs were the same across both modeling scenarios and largely reflect both the site characteristics of the Wilmington East WEA[51], and the location of the Sutton North to Cumberland with 500kV substation[52]. Additional inputs were informed by industry standard, or JEDI default inputs. The Project Data inputs used in this study include 2,805MW of nameplate capacity as referenced in EO 218 and adjusted to utilize 15MW turbine technology. The local share differs in the two scenarios, with the low case assuming JEDI default local content allocations, and the high case assuming 100% local content of blade and offshore substation content. A full documentation of local content allocations for both scenarios can be found in Appendix C, while Project Data inputs can be found in Appendix A.

Project Costs were calculated based on the inputs from the previous step. A comprehensive table outlines the cost of each line item that contributes to total cost, separated by CAPEX and OPEX, and the amount to which each line item does so is represented as % of Total Cost. To align each respective section with 2021 ATB projections, CAPEX and OPEX were first calculated for each of the three years modeled.

CAPEX $2,622,000/MW x 2,805 MW
= $7,354,710,000

OPEX $90,000/MW x 2,805 MW
= $252,450,000

Using this figure of Total CAPEX/OPEX, line-item costs were adjusted using the existing % of Total Cost. A portion of these line items (Development and Other Costs and Soft Costs) are static based on project size. To account for these firm costs, the % of Total Costs were uniformly adjusted to arrive at a final CAPEX/OPEX reflective of 2021 ATB projections. A full documentation of these inputs and adjustments can be found in Appendix B. Results of the models are expressed as local economic output during construction, and local economic output during O&M.

[51]Marinecadastre.gov. (n.d.).
[52]NCTPC. (2021).

Results

Both scenarios resulted in a net economic benefit to North Carolina. Figure 1 outlines the final cost-benefit calculations for each scenario, and the full calculation can be found in Appendix F.

FIGURE 1 // Net economic benefit: cost-benefit comparison for 2.8GW offshore wind project ($ in millions)

	2030 — Base Case	2030 — High Case
Costs	$9,450	$9,450
Benefits	$13,231	$14,031
Net Economic Impact	$3,781	$4,581

The high scenario, as outlined in the *Benefit Inputs* section, assumes 100% local content for both the blades and offshore substations of a single 2.8GW theoretical project based on findings from the March 2021 offshore wind supply chain study conducted on behalf of the North Carolina Department of Commerce.

While not within the scope of this calculation, it is important to highlight the compounded value that new or expanded offshore wind supply chain capabilities located in North Carolina will create.

In addition to providing economic benefit to the state through projects developed off the coast of North Carolina, offshore wind manufacturers will also supply components for projects along the Atlantic coast or potentially across the country or the globe — creating economic benefit to the state, absent the cost of generating electricity.

Additionally, there are other sectors that will contribute to the success of the offshore wind industry in North Carolina where the benefits cannot be allocated to a specific project, including but not limited to the operation and construction of support vessels.

Timing and market demand are essential when evaluating this compounded benefit. Due to the nascency of the domestic supply chain and as depicted through the first wave of manufacturing location announcements[53,54,55], Tier-1 original equipment manufacturers (OEMs) and their sub-component suppliers are favoring establishing facilities in states that are creating demand for their product. The longer a state waits to make commitments to development, the more likely the small number of large manufacturers site in other states.

[53]Governor Phil Murphy. (2020, December 21).

[54]Port of Albany. (2020, January 14).

[55]Siemens Gamesa Renewable Energy. (2020, May 26).

Additional Considerations

This section includes additional factors that can impact the overall net benefit of offshore wind when quantified, but that are not included in the primary calculation of this analysis. While factors like federal investments and emissions reductions via the social cost of carbon can already be quantified, factors like electricity cost trends, grid benefits, and others require further analysis. Therefore, this section of the analysis positions these considerations as additional factors with potential influence on the present and/or future costs and benefits associated with offshore wind.

Jobs

An additional output from JEDI modeling scenarios are full-time equivalent (FTE) positions created during both construction and O&M phases. An FTE of 1.0 represents one full-time worker. The economic value of FTE's is represented in the local economic output figures used in the calculation.

FIGURE 2 // FTE positions created during construction and O&M

	2030 — Base Case	2030 — High Case
Jobs During Construction (job years)	27,621	30,990
Jobs During O&M (annual)	923	923

FTEs are categorized by activity such as Component Manufacturing and Supply Chain/Support Services during construction, and Technicians and Management during O&M, as well as induced jobs created by spending of wages from jobs in the prior two categories. The categorization of all FTEs for the 2030 high scenario is shown in Figure 3.

FIGURE 3 // FTE positions created during construction and O&M for 2030 high scenario, categorized

Construction	
INSTALLATION ACTIVITIES	
Foundation	90
Scour Protection	54
Turbine	238
Array and Export Cabling	788
Other	13
COMPONENT MANUFACTURING AND SUPPLY CHAIN/ SUPPORT SERVICES	
Nacelle	3,231
Blades	4,296
Tower	854
Foundation	2,547
Array & Export Cables	1,205
Substation	1,205
Ports and Staging	1,159
Installation, Development, and Other	7,927
INDUCED	
Induced Jobs	7,383
Total	**30,990**

Operations & Maintenance (Annual, Ongoing)	
Technicians and Management	133
Supply Chain/Support Services	521
Induced	270
Total	**923**

The majority of FTE's created through both construction and O&M are within the manufacturing supply chain and support services. These jobs are representative of a supply chain that will provide materials and components for offshore wind projects beyond the theoretical project within this analysis, creating significant job creation beyond that of the project modeled.

Emissions Reductions

The harmful effects of carbon emissions can be quantified with the social cost of carbon, which calculates the dollar value of the future economic harm inflicted by the release of each additional ton of carbon dioxide. Under the George W. Bush Administration, federal agencies began to develop their own estimates of the social cost of carbon[56]. In 2008, the U.S. Court of Appeals ruled that the federal government must account for the economic impacts of climate change in regulatory cost-benefit analyses. This spurred the formation of the Interagency Working Group (IWG) tasked with developing a measurement for the social cost of carbon to be used across the federal government. In 2021, the Biden Administration relaunched IWG as the Interagency Working Group on the Social Cost of Greenhouse Gases with the goal of establishing interim social costs of carbon dioxide, methane, and nitrous oxide. The Biden Administration's current estimate of the social cost of carbon is approximately $51 per ton[57].

Offshore wind is an instrumental part of the U.S. decarbonization strategy, emphasized by President Biden's 30GW by 2030 offshore wind development commitment[58]. The 30GW commitment is projected to avoid 78 million metric tonnes of carbon dioxide by providing pollution-free energy generation. The emissions reduction benefits not only provide an environmental benefit but a monetary value, as well. The positive economic impact of offshore wind that results from calculating both the social cost of carbon and the monetary value of emissions reductions are quantified in Figure 4. Incorporating these findings into this analysis' calculation would increase the net benefit of the theoretical 2.8GW project by $8.36B.

FIGURE 4 // Monetized annual environmental benefits for theoretical 2.8GW offshore wind project

Environmental Benefits	Annual Emissions Reductions	Total Monetized Benefits 2030–2060
CO2 (tons)	-3,509,687	$8,367,114,866

In addition to offsetting emissions produced by traditional fossil fuel generation, wind turbines also offset all emissions from construction within three to six months of operation. Offshore wind has a life cycle carbon footprint of 20 grams or less of CO2 equivalent per kWh[59]. For reference, natural gas combustion cycle (NGCC) averages to 420 to 480 grams of carbon dioxide equivalent per kilowatt-hour (g CO2-eq/kWh) and for NGCT to 570 to 750 g CO2-eq/kWh, with medians of 450 and 670 CO2-eq/kWh, respectively.

Federal Priorities, Subsidies, and Funding

The extension of the investment tax credit (ITC) is a vital cost reduction opportunity for offshore wind. The existing tax credits and proposed legislation serve as a testament to the federal administration's prioritization of offshore wind in pursuit of President Biden's 2035 and midcentury decarbonization goals.

The Consolidated Appropriations Act, 2021, signed in December 2020, extended the renewable energy and carbon capture tax credits, enabling offshore wind

[56] EDF. (n.d.). *The True Cost of Carbon Pollution.* https://www.edf.org/true-cost-carbon-pollution

[57] Interagency Working Group on Social Cost of Greenhouse Gases, United States Government (2021, February). *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates under Executive Order 13990.* The White House. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

[58] The White House. (2021, Mar 29).

[59] NREL. (n.d.). *Life Cycle Assessment Harmonization.* NREL. https://www.nrel.gov/analysis/life-cycle-assessment.html

projects to receive a new ITC at 30% for all projects that start construction by the end of 2025. The impacts of the ITC expansion were seen almost instantly, with Mayflower Wind, an 804 MW project in MA projecting decreased prices and ratepayer savings of over $25 million each year, resulting in a half a billion dollars in lower electric bills over the life of the 20-year contracts[60].

A number of proposals in Congress would extend the ITC for at least 10 years, making a 2030 project eligible for the tax credit. The 2.8GW project has an estimated CAPEX of $7.35B with turbine and balance of plant costs making up $7.16B.

With the 30% ITC applied, the project cost would be reduced by $2.15B.

Extension of the ITC is just one part of the broader federal legislative agenda prioritizing the offshore wind industry. In March 2021, the Biden Administration along with the Departments of Interior, Energy, Commerce, and Transportation announced a shared goal of developing 30GW of offshore wind by 2030[61]. Among other items, this Presidential Order includes $230 million to fund port infrastructure, and $3 billion to strengthen domestic supply chain and manufacturing. Additional proposed legislation — specifically, 45Q and 48C tax credit extensions — would help to modernize and foster additional supply chain development and domestic production. North Carolina is in a prime position to take advantage of these investments, ranking first among east coast states and fifth in the nation in the value of its manufacturing sector's Gross Domestic Product[62].

Offshore Wind Cost Declines

While the U.S. is still heavily reliant on fossil fuels, renewable energy generation is rapidly rising. In 2020, renewable energy sources for the first time generated more electricity than coal[63]. The U.S. Energy Information Administration's (EIA) 2021 Annual Energy Outlook (AEO) shows electricity generation from renewable energy sources rose from 20% in 2020 to 21% in 2021, to a projected 23% in 2022[64]. Wind — primarily onshore — continues to dominate capacity additions and has been further elevated by the Biden Administration's commitment to 30GW of offshore wind by 2030 in efforts to achieve the country's 2050 decarbonization goal[65].

In North Carolina, more than one-tenth of the electricity generated is produced from renewable energy resources[66], yet offshore wind has been largely left out of utility generation planning. The historically high upfront cost of offshore wind has posed barriers to advancement in the United States; however, recent market trends and renewed federal attention indicate rapid cost declines. An overview of the Biden Administration's clean energy policies and extension of tax incentives is outlined in the *Federal Priorities* section.

Even when excluding the tax credit and federal policy incentives outlined in the *Federal Priorities, Subsidies, and Funding* section, offshore wind costs remain on a downward trend. The *U.S. Offshore Wind Market and Economic Analysis* report projected that capital, operations, and maintenance costs for new offshore wind projects will decline 2.8% per year between 2020 and 2022, 2.1% per year between 2023 and 2027, and 1.5% between 2027 and 2028[67]. For Class 5 resource, modeled in this analysis to reflect the wind resource in North Carolina, the 2021 ATB projects a sharp decrease in LCOE from early to mid-2020s, dropping from $82/MWh in 2020 to $57/MWh before 2030. Costs continue to decline through 2050.

There are several factors that can drive additional cost declines. While the existing U.S. offshore wind supply chain is still immature, studies show the necessity of a robust domestic supply chain in achieving cost reductions[68].

[60] Mayflower Wind. (2021, January 8). *Mayflower Wind "low-cost energy" price anticipated to go even lower due to unique commitment to pass cost savings of federal tax credits to customers.* Mayflower Wind. https://mayflowerwind.com/mayflower-wind-low-cost-energy-price-anticipated-to-go-even-lower-due-to-unique-commitment-to-pass-cost-savings-of-federal-tax-credits-to-customers/

[61] The White House (Mar 29, 2021).

[62] BVGA. (2021, March).

[63] Gearino, D. (2021, February). *A Clean Energy Milestone: Renewables Pulled Ahead of Coal in 2020.* Inside Climate News. https://insideclimatenews.org/news/26022021/clean-energy-renewable-coal-natural-gas/

[64] U.S. Energy Information Administration. (2021). Annual Energy Outlook 2021. U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/pdf/AEO_Narrative_2021.pdf

[65] The White House. (2021, March 29).

[66] *North Carolina — State Energy Profile Overview.* U.S. Energy Information Administration (EIA). (2019). https://www.eia.gov/state/?sid=NC.

[67] Schnettler, J., & Segal, K. (2020, April).

[68] Musial, W. (2018, February).

A mature supply chain will support cost reduction opportunities due to its proximity to projects through logistics efficiencies and economies of scale.

Further cost reduction opportunities lie in technological innovation in the turbine support structures, improvements in offshore wind site characterization and site characterization technology, and funding for research and development[69].

The U.S. cost decline trends largely reflect those of Europe's more mature offshore wind industry[70]. The United Kingdom's LCOE for offshore decreased 11% between 2011 and 2016. Europe's average LCOE for bottom-fixed offshore wind was $133/MWh in 2019 and is projected to drop to $51/MWh by 2028. Like the burgeoning U.S. offshore wind industry, Europe's steadily declining costs can be attributed to a combination of market opportunity, technological advancement, and clean energy policies.

Electricity System Benefits

Offshore wind is one of the most promising carbon-free baseload power generation technologies due in part to its high CF of 40-50% and energy value[71]. The CF of offshore wind matches the rate at which efficient gas and coal-fired power plants are run as they are currently being operated in most regions, exceeds those of onshore wind, and is about double those of solar photovoltaics (PV). While there is still variability, the hourly fluctuations are lower than that of solar PV with offshore wind typically fluctuating up to 20% from hour-to-hour, compared to 40% for solar PV. North Carolina's current offshore wind potential can cover 465% of the state's total 2019 retail electricity sales[72], presenting a tremendous opportunity for the grid.

Offshore wind is complementary to North Carolina's existing solar generation, which powers about 6% of the grid[73]. While the solar resource is abundant, there is significant potential for balancing solar generation with offshore wind at times of day when the region sees most significant loads due to heating and cooling use.

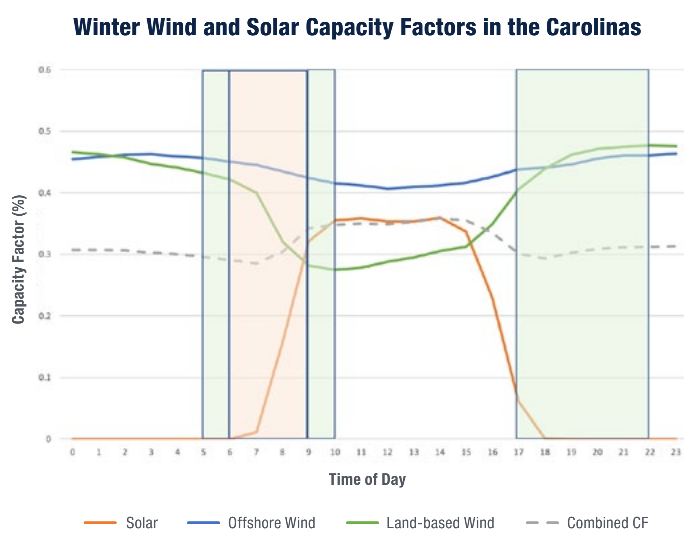
The figures below compile solar, wind, and offshore wind data specific to North Carolina from NREL's SAM model. The highlighted columns indicate when the utility has peak load requirements. The dotted lines show how when even amounts of all three generating sources are combined, variability is reduced significantly. It is also worth noting that offshore wind steadily generates significant power all winter long and provides power in the summer afternoons when it is needed most.

FIGURE 5 // Seasonal wind and solar complementarity in the Carolinas (winter/summer)[74]

Avoided Cost Peak Periods

PREMIUM
Winter: 6–9 am; Summer: 4–8 pm

ON PEAK
Winter: 5–6 am, 9–10 am & 5–10 pm; Summer: 12–4 pm & 8–10 pm



[69]National Offshore Wind Research and Development Consortium. (2021, June). *Research and Development Roadmap 3.0.* NOWRDC. https://nationaloffshorewind.org/wp-content/uploads/Roadmap-3.0-June-30-2021.pdf

[70]Schnettler, J., & Segal, K. (2020, April).

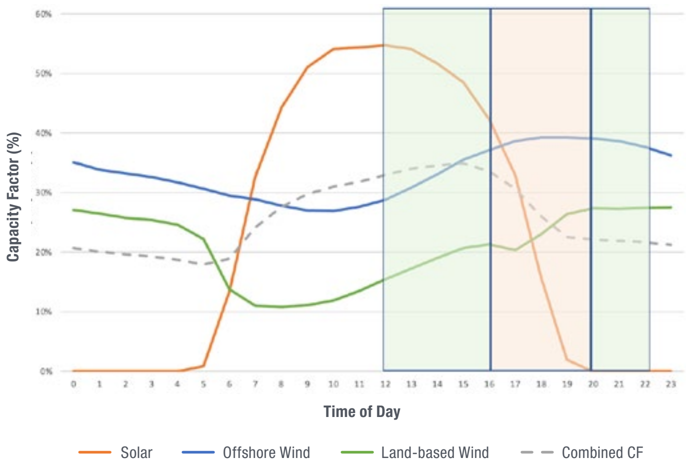
[71]IEA. (2019). *Offshore Wind Outlook 2019.* IEA. https://www.iea.org/reports/offshore-wind-outlook-2019

[72]Huxley-Reicher, B., & Read, H. (2021, March). *Offshore Wind for America.* Environment America. https://environmentamerica.org/sites/environment/files/reports/AME_Offshore-Wind-For-America_2021.pdf

[73]EIA *State Energy Profile.* (2019).

[74]NREL. (2021). *System Advisor Model.*

Summer Wind and Solar Capacity Factors in the Carolinas



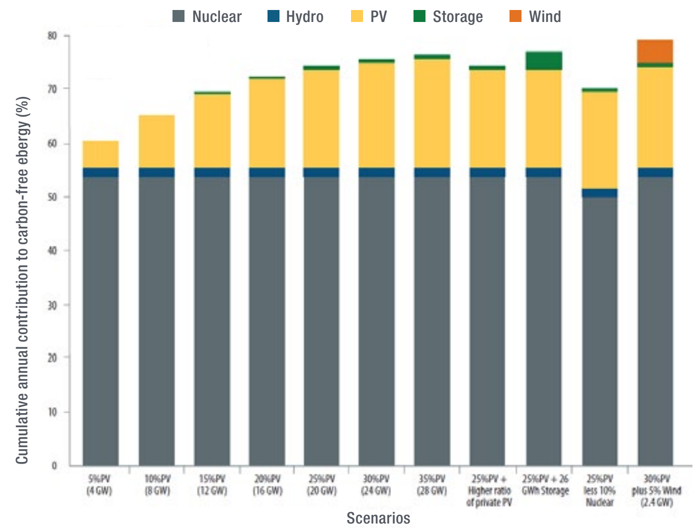
Offshore wind not only enhances grid reliability but is also key to grid decarbonization. In January 2020, NREL provided research support to Duke Energy to analyze the impacts of integrating significant amounts of new solar PV power into its service territory under a variety of scenarios[75]. In addition, among other things, the *Carbon-Free Resource Integration Study* identified possible opportunities for offshore wind. While Duke Energy predominantly relies on solar to meet the utility's carbon-free energy generation, increased solar penetration during the day requires a need for supplemental power at night.

Adding a renewable source, such as wind, is beneficial for grid reliability since wind can generate electricity at different times of the day.

The study found the scenario with 30% PV and 5% wind energy penetration, to result in the highest annual contribution to carbon-free energy at 79%.

This preliminary study was conducted at a high level to determine rough estimates of resource combinations that led to lower levels of curtailment. The study found that with the increase of solar penetration, the marginal curtailment rate rises as well given the high deployment of resource with the same generation profile. Curtailment is reduced with the addition of storage and wind as shown in Figure 6.

FIGURE 6 // Cumulative annual contribution to carbon-free energy (Duke Energy/NREL)[76]



Land-Use and Permitting Constraints

The location of offshore wind poses several advantages over other renewable energy technologies, such as solar and onshore wind. Onshore wind is difficult to develop in high density areas, as can be seen in Figure 7, which makes it easier to develop the resource at scale in places like the Midwest. Permitting of onshore wind can be more difficult at higher hub heights due to potential for local opposition to viewshed and the need for additional regulatory approvals by the Federal Aviation Administration (FAA)[77].

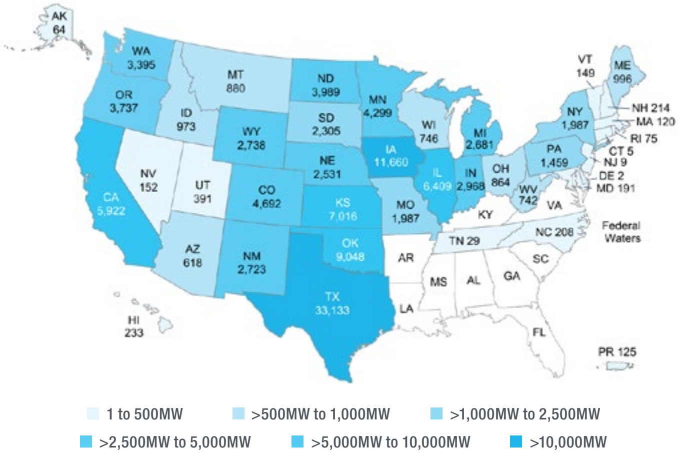
Utility-scale solar development faces similar challenges. Although the resource is developed widely throughout the U.S. with increasing state commitments, local opposition due to land-use restrictions remains a concern. In 2020, California's San Bernardino County prohibited utility-scale renewable energy projects in more than a dozen unincorporated areas and in rural living zones, resulting in more than one million acres of private land to become prohibited. Although the low-population density and the climate of the location are ideal for solar development, local residents expressed concerns about disturbance of the natural habitats. Similar concerns were voiced in Virginia in recent years over the development of a 500 MW solar farm.

[75] Matsuda-Dunn, R. et al (2020, January).

[76] Matsuda-Dunn, R. et al (2020, January).

[77] Gross, S. (2020, January). *RENEWABLES, LAND USE, AND LOCAL OPPOSITION IN THE UNITED STATES.* Brookings Institute. https://www.brookings.edu/wp-content/uploads/2020/01/FP_20200113_renewables_land_use_local_opposition_gross.pdf

FIGURE 7 // Operational wind power capacity, by state (ACP)[78]



Offshore wind avoids many of these land-use conflicts, enabling larger scale deployment closer to high-density coastal cities with larger electricity demand. Though significant consideration must be given to wildlife habitats, migration patterns, and other ocean uses throughout the siting, permitting, and development processes, responsibly-sited offshore wind provides an opportunity to develop thousands of MWs of clean energy in a matter of years, given that permitting can be done for a few very large project sizes rather than hundreds of smaller projects on land. The additional offshore siting opportunities lead to higher wind speeds, giving offshore wind farms the potential to generate more electricity at a steadier rate than their onshore counterparts[79].

Transmission Planning

As the U.S. begins to plan for the injection of large amounts of offshore wind, grid operators and regulators are grappling with how to interconnect to the bulk transmission system. To date, all projects that have secured offtake contracts will interconnect using designated transmission lines bundled as part of the project, called generator lead lines. While this is a straightforward method to interconnect the first wave of development, many industry experts claim this to be an inefficient use of onshore points of interconnection that may quickly become overloaded, leading to costly upgrade expenses that may slow down the rate of development[80].

Planned or open-access approaches are alternatives that may alleviate these constraints and bring down costs for future wind farms. These options can vary in funding mechanisms and included markets and geography, but all would require a coordinated approach to construct transmission with the anticipation of development that would have the capacity to allow for multiple projects to interconnect[81].

A planned approach has also been found to potentially decrease costs of injecting large amounts of offshore wind in the long run. According to a study conducted by the Brattle Group which focused on the interconnection of the next phases of offshore wind development in New York, a planned approach would lead to a cost savings of $500 million[82]. The study also notes that a planned approach that requires fewer points of interconnection, cables, and offshore substation platforms would reduce the potential impacts to coastal communities and marine wildlife.

In October 2020, the FERC held a technical conference with robust participation from industry, states, grid operators, and advocates to discuss offshore wind integration in organized markets[83]. Additionally, the state of New Jersey formally requested that the regional grid operator, PJM, include the state's offshore wind procurement targets into the transmission planning process[84], which according to the regional transmission operator's (RTO) State Agreement Approach, would allow for PJM and New Jersey to consider a planned, independent offshore wind interconnection mechanism.

[78] American Clean Power Association. (2020, February). *ACP Market Report: Fourth Quarter 2020.* [p. 11] https://cleanpower.org/wp-content/uploads/2021/02/ACP_MarketReport_4Q2020.pdf

[79] Colby, J. (2019, November 29). *Wind Power: Onshore vs Offshore Wind Farms.* https://storymaps.arcgis.com/stories/b96f4db23c4449849deb60c0953b2509

[80] Foxwell, D. (2021, February 10). *Shell, Ørsted among companies seeking action on offshore wind transmission.* Riviera. https://www.rivieramm.com/news-content-hub/shell-oslashrsted-among-companies-seeking-action-on-offshore-wind-transmission-63474.

[81] Burke, B.W., Goggin, M. (2020, October). Offshore Wind Transmission White Paper. Business Network for Offshore Wind. https://www.offshorewindus.org/wp-content/uploads/2021/06/GT-White-Paper-030121.pdf

[82] Pfeifenberger, J., Newell, S., Graf, W., Spokas, K. (2020, August 6). Offshore Wind Transmission: An Analysis of Options for New York. The Brattle Group. https://brattlefiles.blob.core.windows.net/files/19747_offshore_wind_transmission_-_an_analysis_of_options_for_new_york_lcv_virtual_policy_forum_presentation.pdf

[83] Technical Conference regarding Offshore Wind Integration in RTOs/ISOs, Docket No. AD20-18-000. (2020, October 27). Federal Energy Regulatory Commission. https://www.ferc.gov/news-events/events/technical-conference-regarding-offshore-wind-integration-rtosisos-10272020

[84] In The Matter of Offshore Wind Transmission, Docket No. QO20100630. (2020, November 18). New Jersey Board of Public Utilities. https://www.nj.gov/bpu/pdf/boardorders/2020/20201118/8D%20-%20ORDER%20Offshore%20Wind%20Transmission.pdf

New York and Massachusetts have also taken steps to better understand the options for planned offshore transmission[85],[86].

Whether through generator lead lines or a planned approach, upgrades to the onshore transmission network to support the injection of offshore wind can facilitate broader system benefits. This may be particularly true in North Carolina where the best solar resource in the state spans the eastern coast[87]. Due to the existing solar generation and lack of transmission corridors along the coast, the distribution system is already constrained[88] increasing overall costs. While North Carolina remains a leader in solar development, additional solar resources will be needed to achieve North Carolina and Duke Energy's carbon reduction goals. The expansion of transmission capacity along the coast will not only support the development of offshore wind, but also continued deployment of solar and increased grid resiliency.

Local Manufacturing Content

Among the most significant opportunities that the offshore wind industry presents to the U.S. is the economic value of a domestic supply chain.

According to a 2021 report published by the Special Initiative on Offshore Wind, 30GW of projected offshore wind development is anticipated to generate a $100 billion revenue opportunity to companies within the offshore wind supply chain through 2030[89].

At present, the majority of the industry's manufacturing capabilities are located in Europe and Asia, proximal to the offshore wind farms in operation. As the market for development in the U.S. increases, so too will the demand for domestic manufacturing of major turbine components such as blades, nacelles, and towers. Major component manufacturing facilities will need to be located on the coast to facilitate water transport given their size, however, the economic opportunity will stretch inland by creating an ecosystem of sub-component suppliers that will look to locate their operations nearby.

Many variables will be evaluated by the OEMs when determining the siting of major component manufacturing facilities including business atmosphere, port infrastructure, presence of sub-component suppliers, and proximity to project development. To guarantee a portion of supply chain investment, many states that are early adopters of offshore wind have included local content requirements through legislation or procurement requests for proposals (RFPs). These provisions can have an impact on both the cost and benefit of a project, as outlined in the examples below.

New York

New York has some of the most stringent local content requirements among states with offshore procurement goals. In the state's two rounds of offshore wind solicitations, the RFPs required that if awarded a contract, proposed projects "must agree to provide New York companies with the opportunity to offer to provide goods and services to developers and suppliers of the project for which there is capability in New York State" for anticipated contracts valued of $5 million or greater[90],[91]. Four contracts have been awarded through these solicitations; Sunrise Wind, a joint venture of Ørsted and Eversource, and Equinor and bp's Empire Wind 1 and 2, and Beacon Wind projects, totaling 4,186MW. According to the New York State Energy Research and Development Authority[92], the four projects

[85]New York State Energy Research and Development Authority. (n.d.). *Offshore Wind.* NYSERDA. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/Transmission-NY-Electricity-Grid.

[86]Chapter 227 of the Acts of 2018, *An Act To Advance Clean Energy.* (2018). The Commonwealth of Massachusetts. https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter227

[87]National Renewable Energy Laboratory [map]. (2020). Duke Energy — Solar Energy Resource. Retrieved from https://maps.nrel.gov/duke/?aL=eZa7RM%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=35.1%2C-80.8&zL=7

[88]*Application for CPCN for 70MW Solar Facility Located at Leisure Road near Academy Road in Lourinburg, NC in Scotland County,* Docket No. EMP-105, Sub-0. (2020, February 10). North Carolina Utilities Commission. (Proposed Order from the Public Staff, page 25). https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=fa7ea998-a4a8-4104-8d64-ca2ff5edd3b6

[89]*Supply Chain Contracting Forecast for U.S. Offshore Wind Power.* (2021, October). Special Initiative on Offshore Wind. https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/10028/files/2021/10/SIOW-supply-chain-report-2021-update-FINAL-1.pdf

[90]New York State Energy and Research Development Authority. (2018, November 8). *Purchase of Offshore Wind Renewable Energy Certificates.* [Request for Proposals ORECRFP18-1]. https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00Pt000000Fx0rjEAB

[91]New York State Energy and Research Development Authority. (2020, July 21). *Purchase of Offshore Wind Renewable Energy Certificates.* [Request for Proposals ORECRFP20-1]. https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00Pt000000OPfCVEA1

[92]New York State. (n.d.). *Offshore Wind.* NYSERDA. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/NY-Offshore-Wind-Projects.

combined are anticipated to generate nearly $12.1 billion in economic output for the state through labor, supplies, development, and manufacturing. In early 2021, Governor Cuomo announced the $350 million investment of an offshore wind tower manufacturing facility[93], a joint venture of Marmen Inc. and Welcon A/S with partner Equinor located at the Port of Albany, expected to generate 500 jobs during construction and 300 FTE positions once manufacturing begins. The two projects awarded through the 2018 solicitation, Empire Wind 1 and Sunrise Wind, have an average all-in development cost of $83.36/MWh (2018 $)[94], while contracts for Empire Wind 2 and Beacon Wind are still being negotiated.

Massachusetts

Massachusetts has also completed two offshore wind solicitation rounds, though alternatively, included few local content requirements. In both the 2017 and 2019 RFPs, the state required bidders to outline a proposed project's "demonstrated ability to create and foster employment and economic development in the state" as well as "demonstrated benefits to low-income ratepayers without adding cost"[95,96]. A contract was awarded to Avangrid Renewables and Copenhagen Infrastructure Partners' Vineyard Wind I 800MW project as a result of the first solicitation, with a levelized PPA price of $74/MWh for the first 400MW phase, and $65/MWh for the second[97]. Mayflower Wind, an 816MW joint venture of Shell and EDP Renewables, was awarded a contract through the state's second solicitation with a levelized power purchase agreement (PPA) price of $58.47/MWh[98]. No major manufacturing facilities have announced the decision or intention to locate in Massachusetts.

Additional Considerations

Many factors in addition to mandated local content requirements contribute to an offshore wind project's cost and ultimately the PPA price. For example, in both of the state's solicitation rounds, New York required, "all laborers, workmen, and mechanics performing construction activities within the U.S. with respect to the project"... "must be paid wages and benefits in an amount not less than the Prevailing Rates" determined by the state[99], and in the latter solicitation required an investment of up to $200 million to supplement the state's efforts to improve port infrastructure for the purpose of serving the offshore wind industry[100]. Also, in part to increase local content, the primary developer with offtake agreements in New York, Equinor, initially chose to use gravity-based foundations, which lead to higher local content for production[101], as opposed to standard and less-costly monopile foundation[102]. These provisions likely resulted in a higher PPA price for New York's awarded projects when compared to Massachusetts, or other states without these provisions. Finally, the average offshore wind speeds in Massachusetts are superior to those off the coast of New York[103] and directly reduce the cost of an offshore wind project. Because of these and other variances, it is impossible to draw a direct parallel between the local content requirements of a state or specific offshore wind solicitation, and the resulting PPA price.

The location of major manufacturing facilities has taken place in states absent state-level legislation or regulation explicitly requiring local supply chain content, as well. A leading turbine OEM Siemens Gamesa recently announced the decision to locate a $200 million blade manufacturing plant in Virginia's Hampton Roads area[104] due to conducive port features, the potential for significant development in the region, and in particular the passage of the Virginia Clean Economy Act which set procurement requirements for 5,200MW of offshore wind generation.

[93]Port of Albany. (2020, January 14).

[94]NYSERDA. (n.d.).

[95]Massachusetts Department of Energy Resources (2017, June 30). *Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects.* [D.P.U. 17-103]. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/9177972

[96]Massachusetts Department of Energy Resources (2019, May 22). *Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects.* [D.P.U. 19-45]. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/10738415

[97]Musial, W., Beiter, P., Spitsen, P., Nunemaker, J., & Gevorgian, V. (2018). *2018 Offshore Wind Technologies Market Report.* U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/sites/default/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report%20Presentation.pdf

[98]Business Network for Offshore Wind. (2020). *U.S. Offshore Wind Market Report & Insights.* [p. 8] https://www.offshorewindus.org/wp-content/uploads/2020/03/USOSWMarketReportInsights2020-0317_fv.pdf

[99]NYSERDA. (2018, November 8).

[100]NYSERDA. (2020, July 21).

[101]Mathern, A.; von der Haar, C.; Marx, S. Concrete Support Structures for Offshore Wind Turbines: Current Status, Challenges, and Future Trends. Energies 2021, 14, 1995. https://doi.org/10.3390/ en14071995

[102]Kessler, R. A. (2020, February 21). Equinor eyes upstate New York port for concrete gravity base foundations. *RECHARGE.* Retrieved October 22, 2021, from https://www.rechargenews.com/wind/equinor-eyes-upstate-new-york-port-for-concrete-gravity-base-foundations/2-1-760085.

[103]NREL [map]. (2011).

[104]Siemens Gamesa Renewable Energy. (2020, May 26).

Electricity Cost Trends

Offshore wind helps protect North Carolina's fuel mix against price fluctuations and while prices for traditional fuel sources can fluctuate wildly, wind remains a free source of clean energy. In contrast, costs for fossil fuel generation can be volatile, with even small reductions in the amount of energy available or changes in the price of fuel holding the potential for large economic disruptions across the nation[105].

There are a number of factors contributing to possible fluctuations in electricity cost trends[106]. Recent extreme weather events, such as periods of abnormally high or low temperatures, signify potential future fuel supply constraints or disruptions. Extreme temperatures can increase demand for heating and cooling, resulting in increased electricity demand thus increased fuel and electricity prices. Regulatory changes, whether at the state or federal level, can also cause trends outside of the current projections.

Because of this uncertainty, it must be noted that the LCOE projections included in this analysis (derived from NREL's 2021 ATB, Duke Energy's 2020 weighted avoided cost, and EIA's AEO) are subject to change. The projections through 2050 indicate a rise in electricity prices, which could increase the benefit calculation; however, a number of scenarios could influence these projections. Because of this, and the absence of projected natural gas costs in the calculation, there are limitations to our estimates.

LCOE projections are a predictor of, but not synonymous with the ultimate cost of the power to customers. There are many factors, many of which can be built into state policies, that can influence the cost of an offshore wind farm or price of the electricity purchased (PPA). Most states to date have employed a competitive bidding mechanism to procure offshore wind generation. Market conditions such as the quantity of proximal leaseholders are likely to play a significant role in project costs through this mechanism. For example, should multiple offshore wind leases exist near the coast of a particular state, leaseholders are incented to offer bids at a lower cost than would be necessary to be awarded a contract than absent market competition.

[105]U.S. Department of Energy. (2008, July). *20% Wind Energy by 2030.* DOE. https://www.nrel.gov/docs/fy08osti/41869.pdf

[106]U.S. Energy Information Administration. (2021, April 12). *Factors affecting electricity prices.* EIA. https://www.eia.gov/energyexplained/electricity/prices-and-factors-affecting-prices.php

Conclusion

This analysis is meant to provide a wide variety of stakeholders with the information they need to make informed decisions about the costs and benefits of developing offshore wind off the coast of North Carolina. With neighbors to the North moving forward aggressively and decisively, it is important for North Carolina to analyze why the discussion has been slower here and if the criteria being used is correct, and in the right way.

With cost nearly always rising to the top of the list for reasons the state has not enacted procurement mandates, this analysis provides supporting evidence that the economic benefit surpasses the initial cost. Costs are coming down rapidly, the supply chain offers unparalleled benefits to job seekers, existing businesses, and local economies, and the benefits offered to the grid will facilitate a transition to carbon-neutrality. With billions of dollars in benefits to the state on the line, now is the time to seriously consider how North Carolina can build offshore wind and add this clean energy source to the state's electricity mix.

APPENDIX A // Input Data for JEDI Model — Project Data

Category	Units	Input Value	Reference
PROJECT PARAMETERS			
Economic Analysis Area	State	North Carolina	
Wind Plan Project Area	Region	South Atlantic	
Money Value (Dollar Year)	Year	2021	
PLANT CHARACTERISTICS			
Plant Capacity	MW	2805	EO 218
Number of Turbines		187	Auto calculated
Array Layout		Grid	U.S.C.G. recommendation
Row Spacing	# rotor diameters	7	JEDI default
Turbine Spacing	# rotor diameters	7	JEDI default
TURBINE DESIGN			
Turbine Selector		15MW	Industry standard
SITE CHARACTERISTICS			
Site Depth	meters	30	Average water depth for NC WEAs
Mean Windspeed	meters/second	8.4	NREL, 2021 ATB
Distance: Port to Site	kilometers	73	Wilmington E WEA to Port of Wilmington
Distance: Site to Offshore Substation	kilometers	2	JEDI default
Distance: Offshore Substation to Landfall	kilometers	30	Wilmington E WEA to mainland (~Oak Island)
Distance: Landfall to Interconnection	kilometers	17	NCTPC – Sutton North to Cumberland with 500kV
Landfall Trench Length	kilometers	3	JEDI default
SUBSTRUCTURE DESIGN			
Substructure Type		Monopile	Industry standard for NC WEA water depth
Foundation Type		Fixed-Bottom	Industry standard for NC WEA water depth
Scour Protection	$/tonne	40	JEDI default

Category	Units	Input Value	Reference
ELECTRICAL INFRASTRUCTURE			
Export Cable Selector		XLPE 1000m 220kV	JEDI default
Redundant Export Cable		0	JEDI default
Additional Export Cable Length	%	0.00%	JEDI default
Array Cable Selector		XLPE 185mm 66kV	JEDI default
Second Array Cable Selector		None	JEDI default
Additional Array Cable Length	%	0.00%	JEDI default
# Offshore Substations		4	BVGA
PORT CHARACTERISTICS			
Port Rate	$/month	$2,000,000	JEDI default
# Cranes		1	JEDI default
VESSEL DEPLOYMENT			
Fixed-Bottom Installation	# vessels	1	Auto calculated
	day rate	$180,000	JEDI default
Feeder Vessel	# vessels	1	Auto calculated
	day rate	$75,000	JEDI default
Scour Protection Installation Vessel	# vessels	1	Auto calculated
	day rate	$120,000	JEDI default
Heavy Lift Vessel	# vessels	1	Auto calculated
	day rate	$500,000	JEDI default
Heavy Barge	# vessels	1	Auto calculated
	day rate	$120,000	JEDI default
Array Cable Installation Vessel	# vessels	1	Auto calculated
	day rate	$120,000	JEDI default
Export Cable Installation Vessel	# vessels	1	Auto calculated
	day rate	$120,000	JEDI default

APPENDIX B // Input Data for JEDI Model — Project Costs

Capital Expenditures (CAPEX)

2021 ATB CAPEX = $7,354,710,000

Category	Cost	% of Total Cost	Adjusted % of Total Cost	Cost After Adjustment
TURBINE COMPONENT COSTS				
Nacelle/Drivetrain	$2,343,210,606	31.86%	-0.2620%	$2,337,071,394
Blades	$702,374,805	9.55%	-0.2620%	$700,534,583
Towers	$494,971,983	6.73%	-0.2620%	$493,675,156
BALANCE OF SYSTEM COSTS				
Substructure and Foundation				
Monopile	$1,259,126,352	17.12%	-0.2620%	$1,255,827,441
Scour Protection	$42,657,318	0.58%	-0.2620%	$42,545,556
Spar	$0	0.00%	-0.2620%	$0
Semisubmersible	$0	0.00%	-0.2620%	$0
Mooring System	$0	0.00%	-0.2620%	$0
Electrical Infrastructure Components				
Array Cable System	$367,735,500	5.00%	-0.2620%	$366,772,033
Export Cable System	$349,348,725	4.75%	-0.2620%	$348,433,431
Offshore Substation	$366,264,558	4.98%	-0.2620%	$365,304,945
Assembly and Installation				
Foundation	$61,044,093	0.83%	-0.2620%	$60,884,157
Mooring System	$0	0.00%	-0.2620%	$0
Turbine	$104,436,882	1.42%	-0.2620%	$104,163,257
Array Cable	$58,837,680	0.80%	-0.2620%	$58,683,525
Export Cable	$475,849,737	6.47%	-0.2620%	$474,603,011
Offshore Substation	$8,825,652	0.12%	-0.2620%	$8,802,529
Scour Protection	$36,773,550	0.50%	-0.2620%	$36,677,203

Capital Expenditures (CAPEX)

2021 ATB CAPEX = $7,354,710,000

Category	Cost	% of Total Cost	Adjusted % of Total Cost	Cost After Adjustment
Ports and Staging				
Foundation	$22,064,130	0.30%	-0.2620%	$22,006,322
Mooring System	$0	0.00%	-0.2620%	$0
Turbine	$37,509,021	0.51%	-0.2620%	$37,410,747
Array Cable	$32,360,724	0.44%	-0.2620%	$32,275,939
Export Cable	$6,619,239	0.09%	-0.2620%	$6,601,897
Offshore Substation	$735,471	0.01%	-0.2620%	$733,544
Scour Protection	$19,857,717	0.27%	-0.2620%	$19,805,690
DEVELOPMENT AND OTHER PROJECT COSTS				
Site Auction Price	$140,250,000	1.67%	n/a	$140,250,000
BOEM Review	$0	0.00%	n/a	$0
Construction Operations Plan	$1,000,000	0.01%	n/a	$1,000,000
Design Install Plan	$250,000	0.00%	n/a	$250,000
Site Assessment Plan	$500,000	0.01%	n/a	$500,000
Site Assessment Activities	$50,000,000	0.59%	n/a	$50,000,000
ENGINEERING AND MANAGEMENT				
Construction Operations	$196,350,000	2.33%	n/a	$196,350,000
SOFT COSTS				
Commissioning	$13,200,000	0.16%	n/a	$13,200,000
Construction Finance	$54,900,000	0.65%	n/a	$54,900,000
Construction Insurance	$13,200,000	0.16%	n/a	$13,200,000
Contingency	$94,800,000	1.13%	n/a	$94,800,000
Decommissioning	$17,400,000	0.21%	n/a	$17,400,000
Total CAPEX	**$7,372,453,742**			**$7,354,662,361**

Annual Operational Expenditures (OPEX)

2021 ATB OPEX = $252,450,000

Category	Cost	% of Total Cost
MAINTENANCE		
Technicians	$16,914,150	6.70%
Spare Parts	$50,490,000	20.00%
Vessels	$105,271,650	41.70%
Onshore Electric Maintenance	$1,262,250	0.50%
OPERATIONS		
Operation, Management, and General Administration	$7,321,050	2.90%
Operating Facilities	$3,281,850	1.30%
Environmental, Health, and Safety Monitoring	$1,262,250	0.50%
Insurance	$54,276,750	21.50%
Annual leases and fees not included in "Financial Parameters"	$12,370,050	4.90%
Total OPEX	**$252,450,000**	**100%**

APPENDIX C // Input Data for JEDI Model — Local Content

Capital Expenditures (CAPEX)

Category	% Local — Base Case	% Local — High Case
TURBINE COMPONENT COSTS		
Nacelle/Drivetrain		
Materials	20%	20%
Labor	100%	100%
Blades		
Materials	40%	100%
Labor	50%	100%
Towers		
Materials	35%	35%
Labor	45%	45%
BALANCE OF SYSTEM COSTS		
Substructure and Foundation		
Monopile	35%	35%
Scour Protection	35%	35%
Spar	10%	10%
Semisubmersible	10%	10%
Mooring System	10%	10%
Electrical Infrastructure Components		
Array Cable System	30%	30%
Export Cable System	30%	30%
Offshore Substation	40%	100%
Assembly and Installation		
Foundation		
Vessel	50%	50%
Labor	100%	100%
Mooring System		
Vessel	50%	50%
Labor	100%	100%

Capital Expenditures (CAPEX) continued

Category	% Local — Base Case	% Local — High Case
Turbine		
Vessel	30%	30%
Labor	100%	100%
Array Cable		
Vessel	40%	40%
Labor	100%	100%
Export Cable		
Vessel	40%	40%
Labor	100%	100%
Offshore Substation		
Vessel	60%	60%
Labor	100%	100%
Scour Protection		
Vessel	40%	40%
Labor	100%	100%
Ports and Staging		
Foundation	100%	100%
Mooring System	100%	100%
Turbine	100%	100%
Array Cable	100%	100%
Export Cable	100%	100%
Offshore Substation	100%	100%
Scour Protection	100%	100%
DEVELOPMENT AND OTHER PROJECT COSTS		
Site Auction Price	100%	100%
BOEM Review	100%	100%
Construction Operations Plan	100%	100%
Design Install Plan	20%	20%
Site Assessment Plan	50%	50%
Site Assessment Activities	50%	50%

Capital Expenditures (CAPEX) continued

Category	% Local — Base Case	% Local — High Case
ENGINEERING AND MANAGEMENT		
Construction Operations	50%	50%
SOFT COSTS		
Commissioning	100%	100%
Construction Finance	50%	50%
Construction Insurance	50%	50%
Contingency	50%	50%
Decommissioning	50%	50%

APPENDIX D // Input Data for IMPLAN Model — Onshore Transmission Upgrades

Upgrade	Incremental MW	Incremental Cost ($M)
Interconnection from beach	825	$340
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
335931	100%	17%
332312	20%	30%

Upgrade	Incremental MW	Incremental Cost ($M)
Build NewBern-Wom-Wake 500kV	1,687	$570
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
335931	100%	15%
332312	20%	28%
335311	20%	2%
335313	20%	2%

Upgrade	Incremental MW	Incremental Cost ($M)
Add 2nd 500/230kV bank	1,459	$15
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
332312	20%	13%
335311	20%	17%
335313	20%	17%

Upgrade	Incremental MW	Incremental Cost ($M)
Replace with 336 MVA	2,065	$4
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
335311	20%	47%

Upgrade	Incremental MW	Incremental Cost ($M)
Replace with 336 MVA	2,372	$4
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
335311	20%	47%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,393	$47
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,413	$17
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,434	$2
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,440	$25
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Replace bus tie breaker	2,476	$1
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	42%
541330	100%	11%
335313	20%	47%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,511	$22
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,545	$15
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%

Upgrade	Incremental MW	Incremental Cost ($M)
Raise to 212F	2,599	$12
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%
Upgrade	**Incremental MW**	**Incremental Cost ($M)**
Raise to 212F	2,814	$17
NAICS CODE	% LOCAL	% OF INCREMENTAL COST ($M)
237130	100%	100%
Total	**2,814MW**	**$1,091**

	IMPLAN Results		
	Economic Output	County Tax	State Tax
Direct	$854,450,000.00	$2,670,350.77	$12,591,348.54
Indirect	$302,721,857.90	$4,288,510.65	$8,908,313.44
Induced	$339,467,237.85	$5,225,797.12	$10,545,036.35
Total	**$1,496,639,095.75**	**$12,184,658.54**	**$32,044,698.33**

NAICS Code Table	
237130	Power and Communication Line and Related Structures Construction
541330	Engineering Services
335931	Current-Carrying Wiring Device Manufacturing
332312	Fabricated Structural Metal Manufacturing
335311	Power, Distribution, and Specialty Transformer Manufacturing
335313	Switchgear and Switchboard Apparatus Manufacturing

APPENDIX E // DEC and DEP Weighted Avoided Cost Calculation

Season —Hour	NC Offshore Wind CF	% Total Generation	DEC Avoided Cost (cents/kWh)	DEP Avoided Cost (cents/kWh)	DEC $ Contribution ($/kWh)	DEP $ Contribution ($/kWh)
Winter — 0	0.454734815	0.01193	2.91	3.01	0.0347	0.0359
Winter — 1	0.457793333	0.01201	2.91	3.01	0.0350	0.0359
Winter — 2	0.461480741	0.01211	2.91	3.01	0.0352	0.0359
Winter — 3	0.462466667	0.01213	2.91	3.01	0.0353	0.0359
Winter — 4	0.459285185	0.01205	2.91	3.3	0.0351	0.0394
Winter — 5	0.456005926	0.01196	3.65	3.3	0.0437	0.0394
Winter — 6	0.450557037	0.01182	4.11	4.39	0.0486	0.0524
Winter — 7	0.445146667	0.01168	4.11	4.39	0.0480	0.0524
Winter — 8	0.434171111	0.01139	4.11	4.39	0.0468	0.0524
Winter — 9	0.424236296	0.01113	3.65	3.3	0.0406	0.0394
Winter — 10	0.415260741	0.01089	2.91	3.3	0.0317	0.0394
Winter — 11	0.411838519	0.01081	2.91	3.01	0.0314	0.0359
Winter — 12	0.40632	0.01066	2.91	3.01	0.0310	0.0359
Winter — 13	0.409678519	0.01075	2.91	3.01	0.0313	0.0359
Winter — 14	0.411524444	0.01080	2.91	3.01	0.0314	0.0359
Winter — 15	0.416514074	0.01093	2.91	3.01	0.0318	0.0359
Winter — 16	0.426095556	0.01118	2.91	3.01	0.0325	0.0359
Winter — 17	0.437634074	0.01148	3.41	3.01	0.0392	0.0359
Winter — 18	0.4411	0.01157	3.41	3.69	0.0395	0.0440
Winter — 19	0.446051852	0.01170	3.41	3.69	0.0399	0.0440
Winter — 20	0.455554815	0.01195	3.41	3.69	0.0408	0.0440
Winter — 21	0.460536296	0.01208	3.41	3.69	0.0412	0.0440
Winter — 22	0.460775556	0.01209	2.91	3.01	0.0352	0.0359
Winter — 23	0.463508148	0.01216	2.91	3.01	0.0354	0.0359
Summer — 0	0.33046776	0.00867	2.83	2.78	0.0245	0.0241
Summer — 1	0.318808197	0.00836	2.83	2.78	0.0237	0.0241
Summer — 2	0.311562842	0.00817	2.83	2.78	0.0231	0.0241
Summer — 3	0.305347541	0.00801	2.83	2.78	0.0227	0.0241
Summer — 4	0.29703388	0.00779	2.83	2.78	0.0221	0.0241
Summer — 5	0.286445902	0.00752	2.83	2.78	0.0213	0.0241
Summer — 6	0.278107104	0.00730	2.83	2.78	0.0206	0.0241
Summer — 7	0.272725683	0.00716	2.83	2.78	0.0202	0.0241
Summer — 8	0.263340984	0.00691	2.83	2.78	0.0196	0.0241
Summer — 9	0.258835519	0.00679	2.83	2.78	0.0192	0.0241
Summer — 10	0.259698907	0.00681	2.83	2.78	0.0193	0.0241
Summer — 11	0.265576503	0.00697	2.83	2.78	0.0197	0.0241
Summer — 12	0.274855738	0.00721	3.11	2.78	0.0224	0.0241
Summer — 13	0.292572131	0.00768	3.11	2.96	0.0239	0.0257
Summer — 14	0.310014754	0.00813	3.11	2.96	0.0253	0.0257
Summer — 15	0.331620219	0.00870	3.11	2.96	0.0271	0.0257
Summer — 16	0.345515301	0.00907	3.34	3.23	0.0303	0.0280
Summer — 17	0.360477049	0.00946	3.34	3.23	0.0316	0.0280
Summer — 18	0.36585847	0.00960	3.34	3.23	0.0321	0.0280
Summer — 19	0.368014754	0.00966	3.34	3.23	0.0322	0.0280
Summer — 20	0.367284699	0.00964	3.11	3.23	0.0300	0.0257
Summer — 21	0.363110383	0.00953	3.11	2.78	0.0296	0.0241
Summer — 22	0.353880328	0.00928	2.83	2.78	0.0263	0.0241
Summer — 23	0.339987978	0.00892	2.83	2.78	0.0252	0.0241

Season —Hour	NC Offshore Wind CF	% Total Generation	DEC Avoided Cost (cents/kWh)	DEP Avoided Cost (cents/kWh)	DEC $ Contribution ($/kWh)	DEP $ Contribution ($/kWh)
Fall — 0	0.460245902	0.01208	2.3	2.34	0.0278	0.0283
Fall — 1	0.455673224	0.01196	2.3	2.34	0.0275	0.0283
Fall — 2	0.450512568	0.01182	2.3	2.34	0.0272	0.0283
Fall — 3	0.446719126	0.01172	2.3	2.34	0.0270	0.0283
Fall — 4	0.445899454	0.01170	2.3	2.34	0.0269	0.0283
Fall — 5	0.443774863	0.01164	2.3	2.93	0.0268	0.0354
Fall — 6	0.440672131	0.01156	3.03	2.93	0.0350	0.0354
Fall — 7	0.438271038	0.01150	3.03	2.93	0.0348	0.0354
Fall — 8	0.442175956	0.01160	3.03	2.93	0.0352	0.0354
Fall — 9	0.432902732	0.01136	3.03	2.93	0.0344	0.0354
Fall — 10	0.418829508	0.01099	2.3	2.34	0.0253	0.0283
Fall — 11	0.410036066	0.01076	2.3	2.34	0.0247	0.0283
Fall — 12	0.40762623	0.01069	2.3	2.34	0.0246	0.0283
Fall — 13	0.403745355	0.01059	2.3	2.34	0.0244	0.0283
Fall — 14	0.401377049	0.01053	2.3	2.34	0.0242	0.0283
Fall — 15	0.403025137	0.01057	2.3	2.34	0.0243	0.0283
Fall — 16	0.411036066	0.01078	3.03	2.34	0.0327	0.0283
Fall — 17	0.427252459	0.01121	3.03	2.93	0.0340	0.0354
Fall — 18	0.438737705	0.01151	3.03	2.93	0.0349	0.0354
Fall — 19	0.443438251	0.01163	3.03	2.93	0.0353	0.0354
Fall — 20	0.448829508	0.01178	3.03	2.93	0.0357	0.0354
Fall — 21	0.456525683	0.01198	3.03	2.93	0.0363	0.0354
Fall — 22	0.458008743	0.01202	3.03	2.93	0.0364	0.0354
Fall — 23	0.460379235	0.01208	2.3	2.34	0.0278	0.0283
Spring — 0	0.430054348	0.01128	2.3	2.34	0.0260	0.0264
Spring — 1	0.430233333	0.01129	2.3	2.34	0.0260	0.0264
Spring — 2	0.423657246	0.01112	2.3	2.34	0.0256	0.0260
Spring — 3	0.419933333	0.01102	2.3	2.34	0.0253	0.0258
Spring — 4	0.411576087	0.01080	2.3	2.34	0.0248	0.0253
Spring — 5	0.404280435	0.01061	2.3	2.93	0.0244	0.0311
Spring — 6	0.394068116	0.01034	3.03	2.93	0.0313	0.0303
Spring — 7	0.386028261	0.01013	3.03	2.93	0.0307	0.0297
Spring — 8	0.372356522	0.00977	3.03	2.93	0.0296	0.0286
Spring — 9	0.356528986	0.00935	3.03	2.93	0.0283	0.0274
Spring — 10	0.350245652	0.00919	2.3	2.34	0.0211	0.0215
Spring — 11	0.342836232	0.00899	2.3	2.34	0.0207	0.0210
Spring — 12	0.345881884	0.00907	2.3	2.34	0.0209	0.0212
Spring — 13	0.356357246	0.00935	2.3	2.34	0.0215	0.0219
Spring — 14	0.371111594	0.00974	2.3	2.34	0.0224	0.0228
Spring — 15	0.385482609	0.01011	2.3	2.34	0.0233	0.0237
Spring — 16	0.407428261	0.01069	3.03	2.34	0.0324	0.0250
Spring — 17	0.41760942	0.01096	3.03	2.93	0.0332	0.0321
Spring — 18	0.424716667	0.01114	3.03	2.93	0.0338	0.0326
Spring — 19	0.431545652	0.01132	3.03	2.93	0.0343	0.0332
Spring — 20	0.439331884	0.01153	3.03	2.93	0.0349	0.0338
Spring — 21	0.42672971	0.01120	3.03	2.93	0.0339	0.0328
Spring — 22	0.428228261	0.01124	3.03	2.93	0.0340	0.0329
Spring — 23	0.423604348	0.01111	2.3	2.34	0.0256	0.0260
Average of $ Contribution					**0.0299**	**0.0310**
Conversion to $/MWh					**$29.94**	**$29.94**
60% DEC / 40% DEP (per NCTPC report)					**$17.96**	**$12.38**
Total					**$30.35/MWh**	

APPENDIX F // Cost and Benefit Calculations

2030 — Base Case

Costs			
COST INPUTS	**VALUE**	**CALCULATION**	**SOURCE**
Project Size	2,805		EO 218
CF	46%		2021 ATB
Project Size x CF x (24 x 365) = Annual Electricity Production (MWh)			
Annual Electricity Production (MWh)		11,303,028	
Weighted Avoided Cost ($/MWh)	$30.35/MWh		Appendix E
Offshore Wind LCOE ($/MWh)	$55.00/MWh		2021 ATB
Offshore Wind LCOE – Weighted Avoided Cost = Annual Cost Premium ($)			
Offshore Wind Premium ($/MWh)		$24.65/MWh	
Annual Electricity Production (MWh) x Offshore Wind Premium ($/MWh)			
Annual Cost Premium ($)		$278,619,640	
Technical Lifetime (years)	30		2021 ATB
Annual Cost Premium ($) x Technical Lifetime (years)			
Lifetime Cost Premium ($)		$8,358,589,206	
Bulk Transmission Upgrade Cost	$1,091,000,000		NCTPC
Lifetime Cost Premium + Bulk Transmission Upgrade Cost = Total Cost Premium			
Total Cost Premium		**$9,449,589,206**	

2030 — Base Case

Benefits			
BENEFITS INPUTS	**VALUE**	**CALCULATION**	**SOURCE**
Local Economic Output During Construction	$5,794,000,000		
Local Economic Output During O&M (Annual)	$198,000,000		
Technical Lifetime (years)	30		2021 ATB
Local Economic Output During O&M x Technical Lifetime – Total Local Economic Output During O&M			
Total Local Economic Output During O&M		$5,940,000,000	2021 ATB
Local Economic Output During Construction + Total Local Economic Output During O&M = Total Project Economic Benefit			
Total Project Economic Benefit		$11,734,000,000	
Bulk Transmission Upgrade Economic Benefit	$1,496,639,095.75		Appendix D
Total Project Economic Benefit + Bulk Transmission Upgrade Economic Benefit = Total Economic Benefit			
Total Economic Benefit		**$13,230,639,095.75**	

2030 — Base Case

Net Economic Benefit		
COST-BENEFIT INPUTS	**VALUE**	**CALCULATION**
Total Economic Benefit	$13,230,639,095.75	
Total Cost Premium	$9,449,589,206	
Total Economic Benefit – Total Cost Premium = Total Net Economic Benefit		
Total Net Economic Benefit		**$3,781,049,889.75**

2030 — High Case

Costs			
COST INPUTS	**VALUE**	**CALCULATION**	**SOURCE**
Project Size	2,805		EO 218
CF	46%		2021 ATB
Project Size x CF x (24 x 365) = Annual Electricity Production (MWh)			
Annual Electricity Production (MWh)		11,303,028	
Weighted Avoided Cost ($/MWh)	$30.35/MWh		Appendix E
Offshore Wind LCOE ($/MWh)	$55.00/MWh		2021 ATB
Offshore Wind LCOE – Weighted Avoided Cost = Annual Cost Premium ($)			
Offshore Wind Premium ($/MWh)		$24.65/MWh	
Annual Electricity Production (MWh) x Offshore Wind Premium ($/MWh)			
Annual Cost Premium ($)		$278,619,640	
Technical Lifetime (years)	30		2021 ATB
Annual Cost Premium ($) x Technical Lifetime (years)			
Lifetime Cost Premium ($)		$8,358,589,206	
Bulk Transmission Upgrade Cost	$1,091,000,000		NCTPC
Lifetime Cost Premium + Bulk Transmission Upgrade Cost = Total Cost Premium			
Total Cost Premium		**$9,449,589,206**	

2030 — High Case

Benefits			
BENEFITS INPUTS	**VALUE**	**CALCULATION**	**SOURCE**
Local Economic Output During Construction	$6,594,000,000		
Local Economic Output During O&M (Annual)	$198,000,000		
Technical Lifetime (years)	30		2021 ATB
Local Economic Output During O&M x Technical Lifetime – Total Local Economic Output During O&M			
Total Local Economic Output During O&M		$5,940,000,000	2021 ATB
Local Economic Output During Construction + Total Local Economic Output During O&M = Total Project Economic Benefit			
Total Project Economic Benefit		$12,534,000,000	
Bulk Transmission Upgrade Economic Benefit	$1,496,639,095.75		Appendix D
Total Project Economic Benefit + Bulk Transmission Upgrade Economic Benefit = Total Economic Benefit			
Total Economic Benefit		**$14,030,639,095.75**	

2030 — High Case

Net Economic Benefit		
COST-BENEFIT INPUTS	**VALUE**	**CALCULATION**
Total Economic Benefit	$14,030,639,095.75	
Total Cost Premium	$9,449,589,206	
Total Economic Benefit – Total Cost Premium = Total Net Economic Benefit		
Total Net Economic Benefit		**$4,581,049,889.75**

SOUTHEASTERN
WIND COALITION

E2