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REPORT

Out to Sea: The Dismal Economics of Offshore Wind

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EXECUTIVE SUMMARY

The generation of electricity by onshore wind turbines has benefited from federal subsidies and state renewable energy mandates for decades. More than 100,000 megawatts (MW) of generating capacity have been constructed in the lower 48 states,[1] 9,000 MW of which came online in 2019. Onshore wind capacity has now surpassed installed nuclear capacity (although because of its "always-on" nature, total electricity generated from nuclear plants far exceeds that of onshore wind) and is exceeded only by natural gas- and coal-fired generating capacity.[2]

But from an economic perspective, the future of onshore wind is unfavorable federal production tax credit (PTC)—which was created in 1992 and today p qualifying wind plant owners about $23 per MWh of electricity generated for years—began to phase out in 2017. The PTC has decreased by 20% per ye and wind projects whose construction begins after January 1, 2021, will no longer be eligible.[3]

The demise of the PTC is not, however, the source of onshore wind power's troubling future. Instead, given the remote location of many wind farms, expensive transmission lines are necessary to bring the electricity to cities ar towns; perhaps most significant, local opposition has intensified over the past few years and stymied the development of new projects.[4]

In response to local pushback, some states are pushing back. In March of this year, for example, New York enacted legislation to overturn the state's traditional "home rule" deference, which allows local governments to have final say over the types of facilities that can be built. Now, under the Accelerated Renewable Energy Growth and Community Benefit Act, almost all renewable energy development in the Empire State will be approved by a new Office of Renewable Energy Siting. Locations will be denied only if there are valid and substantive reasons; local opposition, however, no longer will be considered a valid reason.[5]

Nevertheless, the opposition to additional onshore wind turbines, as well as the decreasing availability of high-quality "windy" locations, has led politicians and policymakers to shift their focus to offshore projects. In January 2019, New York Governor Andrew Cuomo called for developing 9,000 MW of offshore wind capacity by 2035, up from his previous order that 2,400 MW be developed by 2030.[6] In January 2018, New Jersey Governor Phil Murphy signed an executive order requiring 3,500 MW of offshore wind capacity by 2030.[7] A 2016 law in Massachusetts requires that the state's electric distribution companies procure 1,600 MW of "cost-effective" offshore wind capacity by June 2027 and 3,200 MW by 2035.[8] Similarly, Maryland's Offshore Wind Energy Act of 2013 calls for 480 MW of offshore wind capacity to be developed.[9]

Proponents of offshore wind energy tout its clean energy bona fides and rap decreasing costs (as evidenced by recent competitive solicitations), which w enable states to meet ambitious targets to eliminate greenhouse gas emissic and reliance on fossil fuel and nuclear power. Advocates also see offshore w as an avenue to create a manufacturing and economic renaissance in their respective states, one that will create thousands of construction jobs and generate billions of dollars of new economic activity.[10]

As this paper will show, the arguments made on behalf of offshore wind are invalid.

KEY FINDINGS

- Offshore wind is not cost-effective, and the forecasts of rapidly declining costs through increasing economies of scale are unrealistic. Absent continued subsidies—such as state mandates for offshore generation and renewable energy credits, which force electric utilities to sign long-term agreements with offshore wind developers at above-market prices—it is unlikely that any offshore wind facilities will be developed. These subsidies, along with the need for additional transmission infrastructure and backup sources of electricity, will increase the cost of electricity for consumers and reduce economic growth.

- The actual costs of offshore wind projects borne by electric ratepayers and taxpayers are likely to be greater than advertised. Experience in Europe over the previous decade demonstrates that the performance of offshore wind turbines degrades rapidly—on average, 4.5% per year. As output declines and maintenance costs increase, project developers will have a growing economic incentive to abandon their projects before the end of their contracts to supply power. In contrast to the strict requirements for nuclear power plants, it is unclear whether offshore wind project owners will be required to set aside sufficient funds to decommission their facilities. This will likely m that electricity ratepayers and state taxpayers will pay to decommission offshore wind turbines or pay higher prices to keep the projects operatin

- The cumulative environmental impacts of multiple offshore wind projects the Atlantic Coast—including on fisheries and endangered species—ma significant and irreversible. Also, mining the raw materials of offshore win turbines, especially rare-earth minerals, has significant environmental imp because those materials primarily are mined overseas, where environme regulations are less stringent than in the United States. Dismissing environmental impacts that occur outside the U.S. while championing offshore wind's alleged worldwide climate-change benefits is hypocritical

The justification of subsidies for offshore wind based on increased economic growth, new industries, and state job creation is an appeal to "free-lunch" economics. The subsidies will benefit the well-connected few while imposing economic costs on consumers and businesses at large.

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I. The Rise of Offshore Wind

The first offshore wind facility was constructed in 1991, about one and a half miles off the shore of Denmark, near the town of Vindeby.[11] The facility consisted of 11 450-kilowatt (kW) turbines—a total generating capacity of just under 5 MW. Another 10 years would pass until the first utility-scale offshore wind facility was built, at Middelgrunden, off the Danish coast, which consisted of 20 1.5-MW turbines.[12] By the end of 2018, the total offshore wind capacity in Europe was about 18,500 MW. Of that total, Britain and Germany accounted for 14,600 MW.[13]

Utility-scale offshore wind turbines in Europe and the U.S. today are far large than the 1.5-MW turbines of two decades ago. The largest currently operatir turbines are 8.5-MW units manufactured by Vestas. Still-larger turbines are c the horizon: General Electric's 12-MW turbine, the Haliade-X, is scheduled tc begin commercial operation in 2021.[14] (A prototype unit, which was installe onshore, began operation in the Netherlands in late 2019.) Haliade-X stands 853 feet high and has turbine blades that are about 350 feet long. In March 2020, Siemens- Gamesa announced a 15-MW turbine, with 110-meter blad which the company hopes to have available by 2024. It will be used by Dominion Energy's 2,600-MW Coastal Virginia Offshore Wind Project.[15] However, it is unlikely that wind turbines can gain further significant cost reductions by exploiting economies of scale: the manufacture of wind turbine components and foundations, as well as their installation, is reaching the limits of current technology.[16]

The first offshore wind facility in the U.S., Rhode Island's 30-MW Block Island Wind Farm, was completed in 2016. Located about 4 miles south of Block Island (which is about 9 miles off the coast), the project consists of five 6-MW turbines. The power purchase agreement (PPA) for the project specified that utilities pay a first-year price of $245/MWh for the electricity it generates; that price escalates at 3.5% each year. (By comparison, in 2016, the average wholesale price of electricity in New England was less than $30/MWh; in 2019, the average wholesale price of electricity was $30.67/MWh, reflecting continued low natural gas prices.)[17] In 2035, the last year of the Block Island Wind Farm PPA, the contract price will be more than $470/MWh.

The Rhode Island Public Utilities Commission (RIPUC) initially rejected the Block Island Wind Farm because of its high cost and the resulting adverse impacts on electric utility ratepayers.[18] RIPUC's findings were consistent with traditional regulatory principles for electric utilities, which emphasize providing consumers with the lowest- cost power (see sidebar, **How State Regulations Favor Renewable Energy**). However, the state legislature changed the applicable regulatory laws, which then required RIPUC to approve the project.[19] (Owing to an exposed underwater transmission cable, the project will be shut down this fall to rebury the cable. It is expected to reopen sometime in May 2021.)

How State Regulations Favor Renewable Energy

Beginning in the early 1980s, state utility regulators required the electric utilities they oversee to perform a detailed economic analysis to determine how best to meet the growing consumer demand for electricity. Although much of that analysis, called "least-cost planning" (LCP) and then "integrated resource planning" (IRP), was designed to promote energy conservation as an alternative to building more generating resources, the ultimate goal was to meet the demand for electricity at the lowest possible cost.

Competitive wholesale electric markets work the same way, but instead of utility regulators determining whether a generating resource will be built, the lure of profitability drives resource choice: the lowest-cost generating resources, providing the greatest economic value to the bulk power system, will provide their owners with the most profits.

However, environmental concerns, especially climate change, have changed resource-selection objectives. Rather than lowest cost, regulators and policymakers have imposed mandates forcing consumers and utilities to use the "right" types of electricity, with direct costs given secondary consideration.

The surge in offshore wind mandates in East Coast states is the most recent example of this trend. Although states are adopting competitive solicitations for offshore wind, and although the prices offered in response to these solicitations have fallen, those prices nevertheless are far higher than average prices in wholesale electricity markets. Moreover, the prices offered by offshore wind developers encompass only direct costs of the resources themselves—that is, the costs to build, operate, and maintain the generators. They exclude the costs associated with providing backup power for times when the wind does not blow.

A much larger project, Cape Wind, first proposed in 2005, was to be built off the coast of Martha's Vineyard (an island off the coast of Massachusetts). That project envisioned 130 3.6-MW turbines, totaling 468 MW of capacity. The project attracted bitter opposition, including by many residents of Martha's Vineyard who complained that the location would spoil their ocean views. Concerns were also raised about adverse impacts on fisheries habitat and endangered species.[20] Eventually, unable to obtain financing in a timely fashion, the developer abandoned the project in 2017.

Nevertheless, the demise of Cape Wind did not stop efforts to promote offshore wind. Currently, seven states have laws or executive orders mandating, collectively, about 22,000 MW of offshore wind capacity. An eighth state, Maine, has an Offshore Wind Initiative but no specific capacity mandate (**Figure 1**).[21]

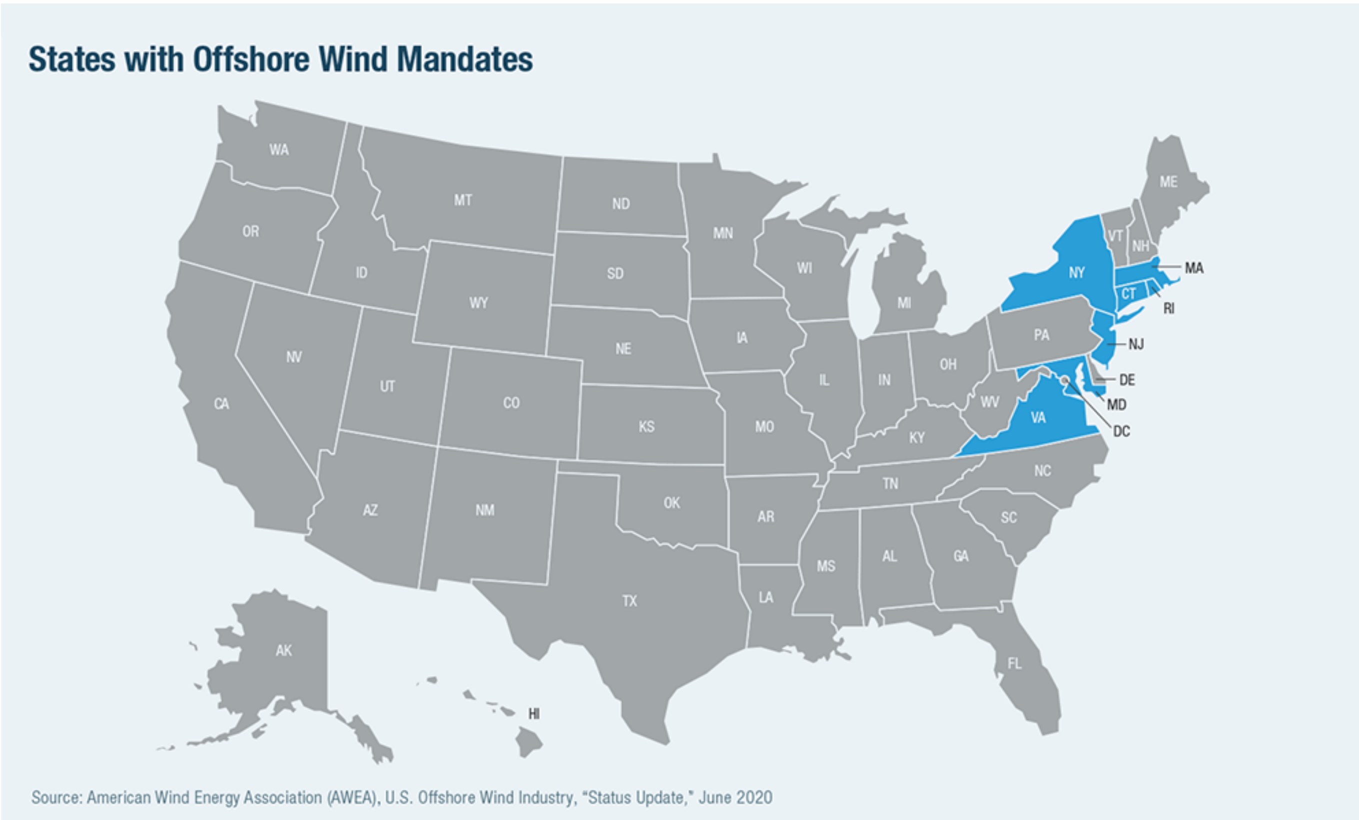

Figure 1

In autumn 2019, the New York State Energy Research and Development Authority (NYSERDA) signed 20-year PPAs for two offshore wind projects, totaling about 1,700 MW of capacity: the 880-MW Sunrise Wind Project, to located off the eastern shore of Long Island; and the 816-MW Empire Wind Project, to be located off the southern shore of Long Island.[22] Both project are slated to be operational by 2024. Sunrise Wind will rely on 110 8.0-MW turbines manufactured by Siemens. Empire Wind has not identified any spec turbines, except to state that the project will consist of 60–80 turbines having an installed capacity "of more than 10 MW each."[23] New York also intends conduct a solicitation for an additional 2,500 MW of offshore wind capacity sometime later this year. Moreover, in June of this year, NYSERDA issued a white paper recommending that it procure the entire 9,000 MW of offshore wind by 2035, as set forth under the state's Climate Leadership and Community Protection Act.[24]

In October 2019, the Massachusetts Department of Public Utilities (DPU) approved long-term agreements to purchase power from two proposed offshore wind projects: the 84-turbine, 800-MW Vineyard Wind Project, to be located about 15 miles off Martha's Vineyard; and the 804-MW Mayflower Wind Project, to be located about 20 miles south of Nantucket Island.[25] (The number of turbines for Mayflower is not known, as it will depend on the size of the turbines that the developers install.) Although construction on the first phase of the Vineyard Wind Project was supposed to begin in autumn 2019 and be completed in 2022, the project has been held up because the Bureau of Ocean Energy Management (BOEM) has not yet issued a final environmental impact statement (EIS).[26] Construction on Mayflower Wind is supposed to begin in 2022, with the project operational by December 2025.

Off the coast of New Jersey, the nation's single largest offshore wind facility—the 1,100-MW Ocean Wind facility—is scheduled to begin construction in 2021 and be online in 2024.[27] More offshore wind development is likely as states seek to increase renewable generation. As of December 2019, according to AWEA, solicitations for offshore wind energy in six states totaled almost 6,300 MW of capacity.[28] A 2018 report issued by the National Renewable Energy Laboratory (NREL), which is part of the U.S. Department of Energy (DOE), cited industry forecasts predicting 11,000 MW–16,000 MW of U.S. offshore wind-generating capacity by 2030.[29] The most recent long-term forecast of the U.S. Energy Information Administration (EIA) is less bullish, predicting 10,000 MW of offshore wind capacity by 2030, and just over 18,000 MW by 2035.[30] That sounds like a lot; but by comparison, EIA projects that, in 2050, coal-fired power plants will generate some 700 terawatt-hours (TWh) of electricity and natural gas plants will generate over 1,600 TWh, compared with 74 TWh for offshore wind.[31]

II. Offshore Wind Contracts

Most states have adopted a system of competitive solicitations to secure offshore wind projects. However, given that there are only a few offshore wind developers, the level of actual competition is unclear. Successful bidders sig contracts called power purchase agreements (PPAs), which include annual pricing, performance guarantees, and numerous other factors. Many of the contract terms are kept confidential under the rubric of "competitive market information."[32] As such, the actual costs to build and operate these wind facilities are unknown. This secrecy matters because, as discussed below, developers may well abandon facilities that are no longer profitable to operat or demand changes to their contractual agreements.

As of this writing, a total of 13 offshore wind projects have signed PPAs. Onl one of them, Coastal Virginia Offshore Wind, will be built and operated by a regulated electric utility (**Figure 2**). Although the utilities must purchase the output from offshore wind generators, the contract terms are not approved by them. In Massachusetts, the contracts are approved by that state's DPU. In New York, the contract terms with regulated utilities have been agreed to by NYSERDA, except for two contracts signed by the Long Island Power Authority (LIPA), itself a government-run utility.

U.S. Existing and Announced Offshore Wind Projects

State	Project Name	Capacity (MW)	On-Line Year	PPA Type	PPA Duration (years)
CT, RI	Revolution Wind	300	2023	Energy, ORECs	20
MA	Mayflower Wind	804	2025	Energy, ORECs	20
MA	Vineyard Wind Phase 1	400	2022	Energy, ORECs	20
MA	Vineyard Wind Phase 2	400	2023	Energy, ORECs	20
MD	Skipjack Wind	120	2023	Energy, ORECs	20
MD	US Wind	248	2023	Energy, ORECs	20
ME	Maine Aqua Ventus	12	2022	Energy	20
NJ	Ocean Wind	1,100	2024	Energy, ORECs	20
NY	Sunrise Wind	880	2025	Energy, ORECs	25
NY	Empire Wind	816	2025	Energy, ORECs	25
NY	South Fork Wind	130	2023	Energy	20
RI	Block Island (Deepwater Wind)	30	2016	Energy	20
RI	Revolution Wind	400	2023	Energy, ORECs	20
VA	Coastal Virginia Offshore Wind[a]	12	2020	na	na
	Total Capacity	6,150			

[a]Project to be built and operated by Dominion Energy, placed into ratebase.

Source: Individual state utility regulatory commissions and project websites. U.S. wind initially be 248 MW, with a planned build-out to 750 MW.

Figure 2

In Figure 2, the column labeled "PPA Type" reflects the types of contracts. Tl simplest PPAs sell the energy generated by the offshore wind farm to the bu at the contract price. This reflects the agreements for the 30-MW Block Islar Wind Farm off the coast of Rhode Island, which began operating in 2016, as well as the proposed Maine Aqua Ventus Project.

The second type of PPA involves the sale of electricity and offshore renewab energy credits (ORECs). ORECs are a specific type of renewable energy cred

(REC) that can be used by utilities in lieu of actually owning renewable energy generating resources or contracting for their output. For example, suppose that a utility expects to sell 100 million MWh of electricity to its customers next year, of which 20%—20 million MWh—must come from renewable energy resources. Of that 20 million MWh, suppose the regulator mandates that at least 25% (5 million MWh) be sourced from offshore wind and another 25% from solar photovoltaics (PV) (**Figure 3**).

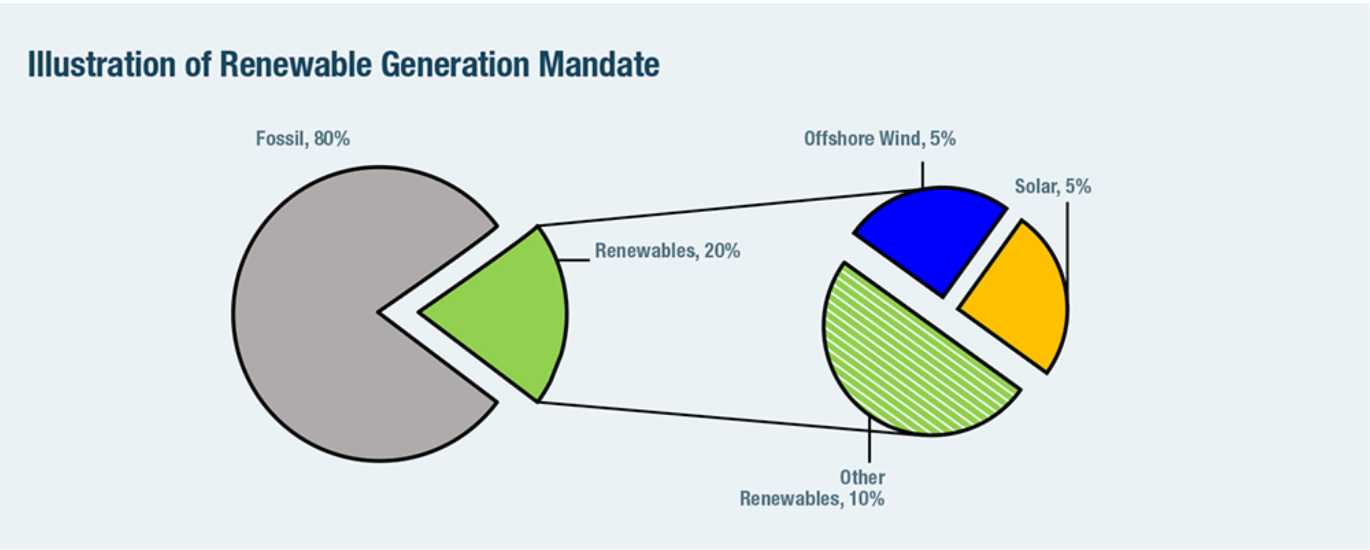

Figure 3

If the utility does not own any renewable generating plants or have existing contracts with renewable generators, it can use RECs to meet the renewabl energy mandate. Typically, an offshore (or onshore) wind project creates one REC for each MWh of electricity that it generates. As renewable energy mandates become more specific (e.g., X% of solar, Y% of offshore wind, etc they further restrict the ability of an electric utility to reduce the cost of the electricity that it sells to consumers.[33]

Almost all the East Coast states shown in Figure 1 mandate that their electri utilities purchase increasing quantities of offshore wind generation over time. Hence, the utilities must purchase offshore electricity directly or purchase ORECs in the marketplace that are "produced" by these wind projects. The market value of ORECs depends on supply-and-demand conditions. If the demand for ORECs increases faster than the supply, the price for ORECs will increase. If the supply of ORECs increases faster than the offshore wind mandates, the price of ORECs will decrease.

To address the potential volatility of future OREC prices, long-term PPAs fix their price, regardless of market conditions. This provides developers with a guaranteed income stream that they can use to secure financing for their projects.

PPA terms vary significantly. For example, in January 2017, LIPA signed a PPA for New York's first offshore wind project, the 90-MW South Fork Wind project.[34] Subsequently, in November 2018, LIPA signed an additional PPA for a 40-MW expansion of that project. But it was not until October 2019 that LIPA released the pricing for the project, with the high costs of the contract surprising some.[35] Specifically, the 90-MW project's initial price will be $160 per MWh, escalating at 2.0% per year over the 20-year contract life.[36] The 40-MW expansion project will have a first-year price of $86 per MWh, also escalating at 2.0% per year. Both are expected to begin commercial operation in December 2022. The resulting "levelized" costs in real 2019$ are $142.48 per MWh for the 90-MW project and $87.00 per MWh for the expansion project (for an explanation of levelized costs, see pp.11–12 and Appendix, pp.24–25).

By contrast, New Jersey's 1,100-MW Ocean Wind Project will sell ORECs to state electric utilities at an initial contract price of $98.10 per OREC. The two other, much larger, New York offshore wind projects— Empire Wind and Sunrise—are less costly but have very different, and more complex, pricing structures.

The Coastal Virginia Offshore Wind Project (Figure 2) will be developed by Dominion Energy, a utility. In contrast to the other projects in Figure 2, Domir will recover the costs of the project from its customers under traditional utility cost-of-service regulation. This means that Dominion will earn a regulated return on its capital investment and recover all operating expenses of its offshore wind farm.

Comparing Project Costs

Offshore wind projects have different start dates, different contract lengths, and different price structures. For example, the Mayflower Wind PPA specifies that all the electricity that the project generates will be purchased by Massachusetts electric utilities at a constant $77.76 per MWh over the entire 20-year contract term, which is expected to begin operations in late 2025. The Bay State's Vineyard Wind has a different deal. Phase 1, scheduled to be operating sometime in 2022, has a first-year price of $74.00 per MWh, which will escalate 2.5% annually over the entire 20-year contract life. Phase 2, scheduled to be operating sometime in 2023, has an initial price of $68.45 per MWh, which also escalates at 2.5% annually over its 20-year contract life. New York State's Empire Wind, scheduled to begin operation in 2025, has a 25-year PPA. The first-year price will be $99.08 per MWh, escalating at 2% per year. LIPA's two Deepwater Wind projects—a 90-MW project and a 40-MW expansion facility—are supposed to be operational sometime in 2023. They have first-year costs of $160 per MWh and $86 per MWh, respectively, escalating at 2% per year. However, unlike Empire Wind, the Deepwater Wind Project PPAs have 20-year terms.

Because these projects have different pricing terms, contract lengths, and st dates, PPA costs cannot be compared directly. Moreover, comparisons are made more difficult because the products being sold differ. Thus, a PPA selli ORECs cannot be compared directly with one that sells only energy. Nevertheless, one can compare the costs of the 10 projects selling energy a ORECs, using their LCOE, or "levelized cost of electricity" (or energy), and LACE "levelized avoided cost of electricity." EIA provides a simple explanatio these standard metrics:

> The **levelized cost of electricity (LCOE)** represents the installed capital costs and ongoing operating costs of a power plant, converted to a level

stream of payments over the plant's assumed financial lifetime. Installed capital costs include construction costs, financing costs, tax credits, and other plant-related subsidies or taxes. Ongoing costs include the cost of the generating fuel (for power plants that consume fuel), expected maintenance costs, and other related taxes or subsidies based on the operation of the plant.

The **levelized avoided cost of electricity (LACE)** represents that power plant's value to the grid. A generator's avoided cost reflects the costs that would be incurred to provide the electricity displaced by a new generation project as an estimate of the revenue available to the plant. As with LCOE, these revenues are converted to a level stream of payments over the plant's assumed financial lifetime.[37]

Levelized costs can also be adjusted by inflation. Assuming that the annual generation from the projects remains constant, the "real levelized costs" of electricity are straightforward to calculate.[38] The resulting cost can be viewed as a fixed mortgage payment in inflation-adjusted dollars. For example, the Vineyard Wind 1 Project has a first-year PPA cost of $74.00/ MWh, which escalates each year of the 20-year contract at a rate of 2.5% (**Figure 4**). Using EIA assumptions,[39] the real levelized cost (2019$) is $70.14/MWh, and the nominal levelized cost is $89.68/MWh.

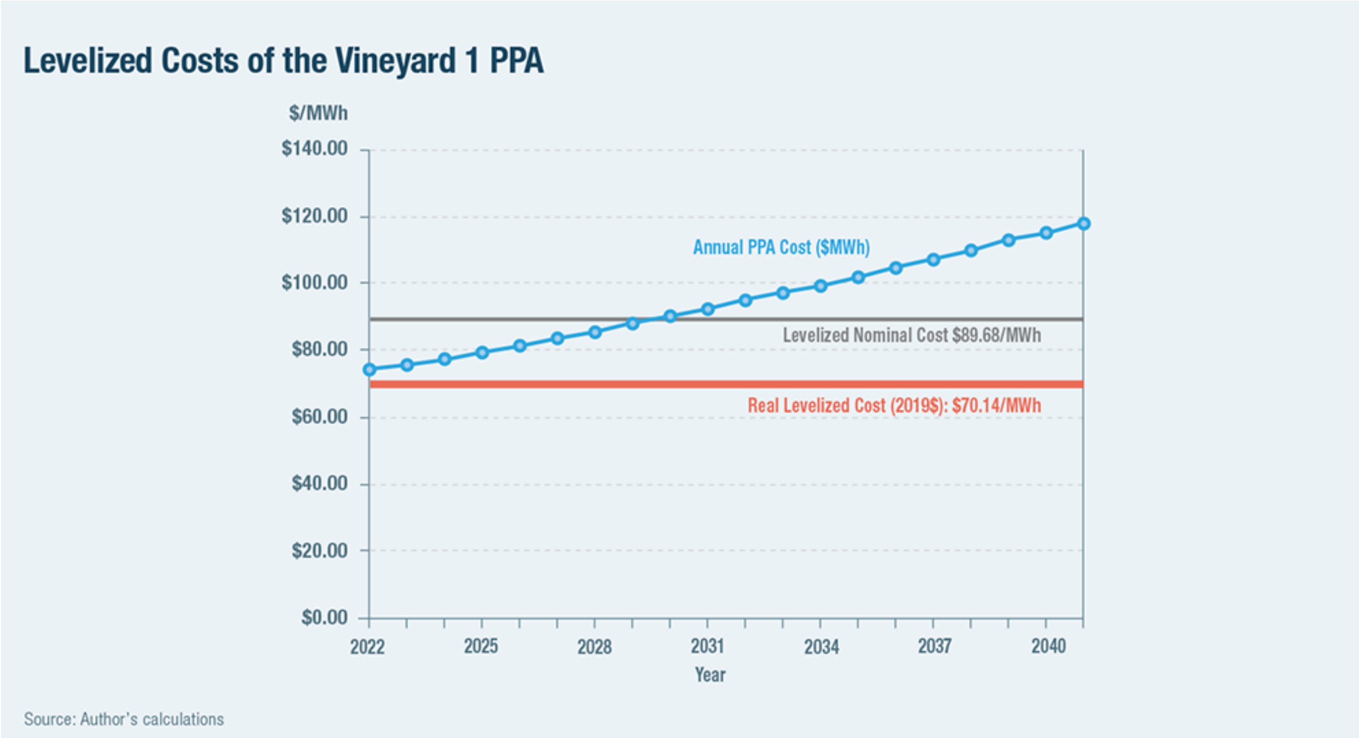

Figure 4

Figure 5 compares the real levelized costs in 2019$ for all 10 projects whose PPAs will sell ORECs to utilities. To be consistent with EIA's LCOE and LACE estimates, the levelized costs are all adjusted to reflect an online year of 2025[40] and assume that there will be no reduction in output from the projects over time. As this figure shows, the levelized costs range between $55.52/OREC (Mayflower Wind) and $179.27/OREC (US Wind).

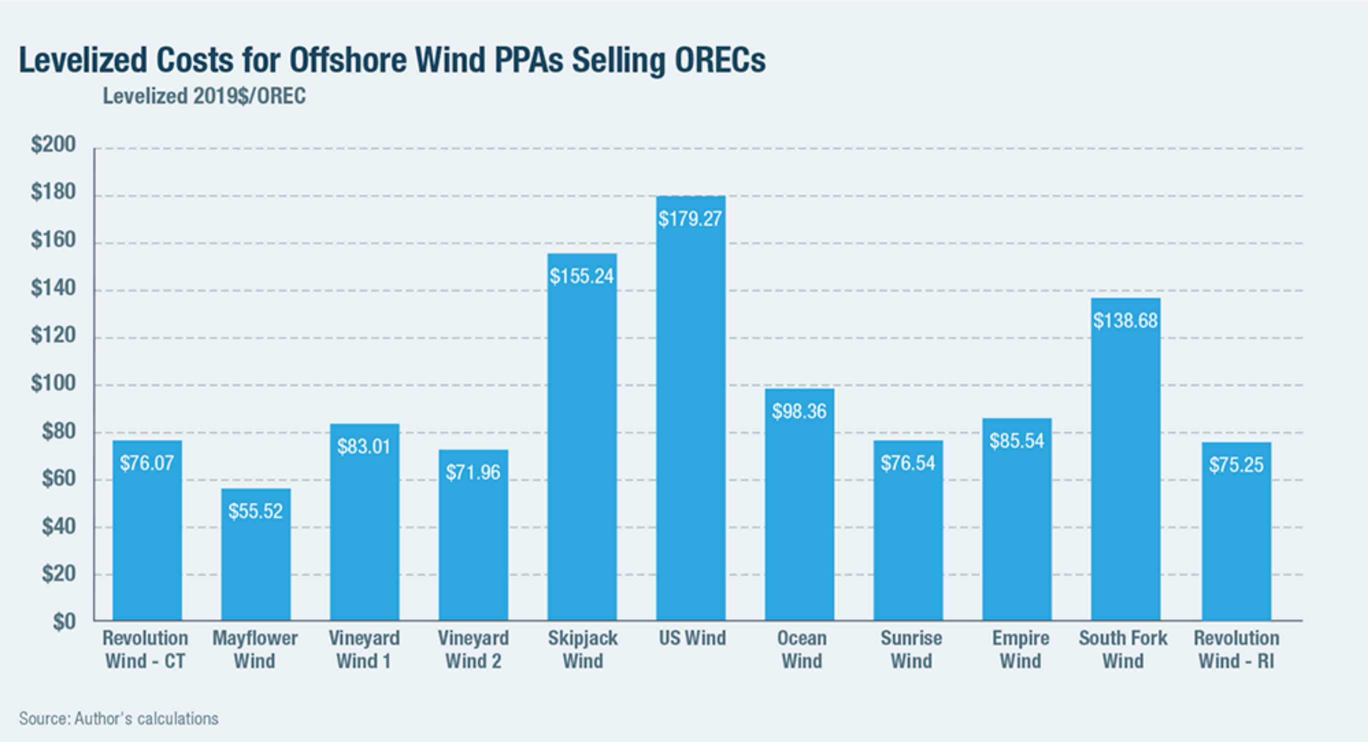

Figure 5

The three energy-only projects—Maine Aqua Ventus, South Fork Wind, and the Block Island Wind Farm Project that came online in 2016—have real levelized costs ranging between $138.68/MWh and $327.70/ MWh (2019$).

III. The Claimed Benefits of Offshore Wind Development

Several drivers are pushing offshore wind development. Onshore wind development is, for one, becoming more difficult, as local opposition to siting massive new wind farms has increased, owing to concerns about health impacts associated with low-frequency noise emitted by turbines,[41] loss of productive farmland,[42] and adverse impacts on the scenic landscape.[43] Moreover, in several East Coast states, there is not enough suitable land on which to site industrial-scale wind farms.

Another reason: the wind offshore is steadier and more frequent than onshore which means lower costs. This is why offshore wind facilities are expected to have higher capacity factors (representing the percentage of time the turbines will be generating electricity) than onshore turbines. Between 2015 and 2019, EIA calculated that the average capacity factor for onshore wind energy in the U.S. was just under 35%.[44] For offshore wind, EIA assumes capacity factors of 50%–58%.[45]

Proponents also see the decreasing PPA costs as evidence of rapidly declining costs for offshore wind, which will lead to lower electricity prices. However, as discussed below, PPA prices resulting from competitive solicitations likely suffer from what economists call the "winner's curse"; and the actual costs of these projects are likely to be higher than predicted.

States also tout the economic development benefits of offshore wind, especially new manufacturing industries and jobs. For example, a 2018 study prepared by Bristol Community College, the UMass Dartmouth Public Policy Center, and the Massachusetts Maritime Academy for the Massachusetts Clean Energy Center (MassCEC) estimated that constructing and operating 1,600 MW of offshore wind turbines in the Bay State could create 2,279–3,171 direct job-years. Taking into account the "indirect impacts" of the supply chain, as well as "induced impacts" from employees spending their earnings could bring the total to 6,878–9,852 indirect job-years.[46] A report for the 800-MW Vineyard Wind Project estimated that it would support 974 construction job-years in Massachusetts, along with 80 job-years for each year of operation and maintenance of the project, totaling 3,180 job-years.[47]

Similarly, a 2017 report commissioned by NYSERDA estimated that the state commitment to installing 2,400 MW of offshore wind would create 5,000 nev jobs in manufacturing, installation, and operation.[48] Not to be outdone, in approving the 1,100-MW Ocean Wind Project in June 2019, the New Jersey Board of Public Utilities (NJBPU) cited estimates that the project would creat $1.17 billion in economic benefits and create 15,000 jobs over the project's year expected life.[49] Massachusetts cited claims that the Mayflower Wind Project would create more than 10,000 job-years over its lifetime, creating ar additional $690 million in gross earnings for the state.[50]

In September 2019, Virginia Governor Ralph Northam issued an executive order to develop at least 2,600 MW of offshore wind by 2026 and to develop an "energy workforce plan."[51] That executive order subsequently was codified into legislation as the Virginia Clean Economy Act (VCEA), which calls for the state's two largest electric utilities—Dominion Energy and Appalachian Power—to provide power solely from renewable generating resources by 2045 and 2050, respectively. VCEA includes a requirement that no less than 5,200 MW of offshore wind power be developed.[52] According to its backers, VCEA will create up to 13,000 new jobs per year and $69.7 billion in net benefits for Virginians.[53]

Thus, states promoting offshore wind development claim that offshore wind development will create thousands of new, high-paying jobs and lead to new manufacturing industries. All are competing to gain a socalled first-mover advantage because, as one booster claimed, "Whichever states get out ahead and do the best job of managing the early growth and development of their offshore wind projects are going to garner the most investment from the industry."[54] (Of course, only one state can gain a first-mover advantage, which may well turn out to be a "first-mover disadvantage," as discussed below.)

Finally, states claim that the environmental benefits of offshore wind will advance them along the path to a future free of greenhouse gas emissions. NYSERDA says that the first 2,400 MW of offshore wind will reduce greenho gas emissions in New York by more than 5 million short tons per year and provide an annual benefit of $1.9 billion, based on estimates of the social co of carbon.[55] In January 2020, New Jersey Governor Phil Murphy released Energy Master Plan, which calls for 100% clean energy by 2050. His Novem 2019 executive order calls for 7,500 MW of offshore wind by 2035 to reduce that state's approximate 100 million metric tons of greenhouse gas emissions.[56] Maryland's 248-MW US Wind Project and the 120-MW Skipja Project claim to reduce carbon dioxide (CO2) emissions by about 24 million tons over the entire 20-year project life, or about 1.2 million tons per year.[57] A 2016 report by DOE claimed nationwide benefits from reduced greenhouse gas emissions worth $50 billion in avoided global damages through 2050 if 96,000 MW of offshore wind were installed, along with $2 billion in avoided costs associated with air pollution emissions and reduced water consumption, among other benefits.[58]

IV. The Reality: Offshore Wind's Costs Will Far Exceed Its Benefits

The combination of lower electricity costs, new manufacturing industries and thousands of new jobs, and reduced greenhouse gas and air pollution emissions makes offshore wind sound like a dream. It is a dream: in reality, offshore wind will result in higher electricity costs, less economic growth, and significant adverse environmental impacts.

The High Cost of Offshore Wind

Although offshore wind development costs and PPA prices have certainly decreased in the last decade, claims that the costs to construct and operate offshore wind facilities will decrease significantly are likely unrealistic. For example, a report by DOE projects that the real levelized costs for offshore w projects will fall below $50/ MWh (2018$) by 2030.[59] That same report projects that the capital cost of the turbines themselves (which constitute 30%–45% of total capital costs) will decline to about $1,000/kW by 2030.[6 These forecasts are almost surely too optimistic and are inconsistent with EI forecasts, as discussed below. (EIA falls within DOE.) Since the 2008 financi crisis, the cost of capital has been at historical lows, with interest rates even declining to negative values in some countries, such as Germany and Switzerland. Financing costs cannot go much lower.

As the size of offshore wind projects increases, more of the costs are devoted to related infrastructure— foundations, cables, and such. These are mature industries. It is unlikely that increasing the size of cement manufacturers will result in lower per-unit costs; they have likely captured most economies of scale. Increasing the demand for offshore wind facilities will increase the demand for these underlying materials—such as the concrete and steel needed for turbine foundations—and is more likely to increase prices than it is to decrease prices. To the extent that those materials require the use of fossil fuels, efforts to impose carbon taxes or other policies to increase the costs of fossil fuels will increase the cost of manufacturing and transporting the materials needed to develop turbine sites.

Furthermore, as discussed previously,[61] the size of wind turbines is close to its physical limits. Hence, opportunities for continued exploitation of economies of scale in turbine technology are also limited.

As part of its *Annual Energy Outlook*, which provides a long-term forecast of U.S. energy demand, EIA publishes an accompanying report on the projected costs of different types of generating resources. In its most recent report, EIA estimated the real LCOE for offshore wind facilities beginning service in 2025 as between $102.68/MWh and $155.55/MWh, with an average price of $122.25/MWh (2019$).[62] EIA estimates that the costs for offshore wind installed in 2040 will be about one-third less, with levelized costs between $74.47/MWh and $105.39/MWh, with an average price of $85.53/MWh (2019$).[63]

By comparison, the levelized cost of gas-fired combined- cycle generating u entering service in 2025 is between $33.35/MWh and $45.31/MWh, with an average price of $38.07/MWh (2019$). For 2040, EIA projects levelized cost for combined-cycle units to range between $34.27/MWh and $72.32/ MWh with an average levelized cost of $42.89/MWh (2019$). (The higher real levelized costs in 2040 are the result of higher projected prices for natural ga

So, even in 2040, EIA projects that the levelized costs of gas-fired combinec cycle units will still be half the levelized cost of offshore wind generation.

Because offshore wind is intermittent, its LACE value is less than that of reliable resources such as natural gas or coal. EIA estimates the real LACE value for a combined-cycle generating unit to be between $29.32/MWh and $45.22/MWh in 2025, with a capacity-weighted average value of $37.15/MWh (2019$), slightly higher than the capacity-weighted LCOE. For offshore wind, EIA's estimate of LACE is between $25.36/MWh and $42.76/MWh, with a capacity-weighted average value of $37.29/MWh (2019$). For a combined-cycle generating unit, LACE exceeds LCOE. Hence, for offshore wind, EIA estimates the average LCOE to be more than three times greater than the average LACE.

The upshot: from a strictly economic standpoint, EIA estimates that the economic costs of offshore wind resources will be three times larger than the corresponding economic benefits, in terms of avoided costs. As such, *the more offshore wind that is added, the greater will be the net economic cost to society.*

Worse, new research on European offshore wind turbine performance over the last decade shows that performance degrades rapidly over time, especially for newer and larger wind turbines; that means higher operating costs and reduced economic lifetimes. As more offshore wind is integrated onto the bulk power grid, the costs of addressing wind power's inherent intermittency will also increase, further increasing the costs borne by electricity consumers and requiring new gas-fired generating units to operate on standby or highly expensive battery storage systems.

More offshore wind turbines (as well as increased requirements for batteries electric vehicles and storage of intermittent wind-generated power) means more rare-earth elements, which historically have come overwhelmingly from China.[64] That increased demand will likely bring higher prices and higher turbine manufacturing costs.[65] Nevertheless, some regulators claim that offshore wind will reduce ratepayers' electric bills. For example, in its letter recommending approval of the Mayflower Wind Project, Mass DOER claimed that the project's cost would be below the cost of wholesale market power and provide an average of 2.4 cents/kWh (in real 2019 dollars) of direct savings to ratepayers.[66]

These claims are overblown; they are also an example of "free-lunch" economics. First, Mass DOER assumptions about real levelized wholesale cost of electricity appear to be overstated. Over the same period as the Mayflower PPA (2026–45), EIA's *Annual Energy Outlook 2020* forecasts declining inflation-adjusted wholesale electric prices in New England, with a levelized generation cost of 5.6 cents/ kWh (2019$), one-third lower than the 8.4 cents/ kWh value in the Mass DOER letter.[67] These far lower forecast wholesale energy prices belie the Mass DOER's claims of cost savings for consumers.

Second, it is true that adding more high-cost wind and solar resources is likely to drive down wholesale power prices. That sounds like an unambiguous win for consumers. It is not; those lower prices are the result of subsidies that will drive out unsubsidized generators, which I call "Gresham's Law of Green Energy."[68] Here is how this "law" plays out.

First: in its current *Annual Energy Outlook 2020* (AEO 2020), EIA projects greater quantities of wind and solar power and lower real (inflation-adjusted) average wholesale generation prices than its previous forecast (AEO 2019). AEO 2020 projects that average wholesale market electric generating prices decline by 20% between 2019 and 2050, from an average $61/MWh to an average $48/MWh in 2050.[69] AEO 2020 also shows an increase in renewa generation, when compared with its 2019 forecast, and lower generation pri (**Figure 6**).

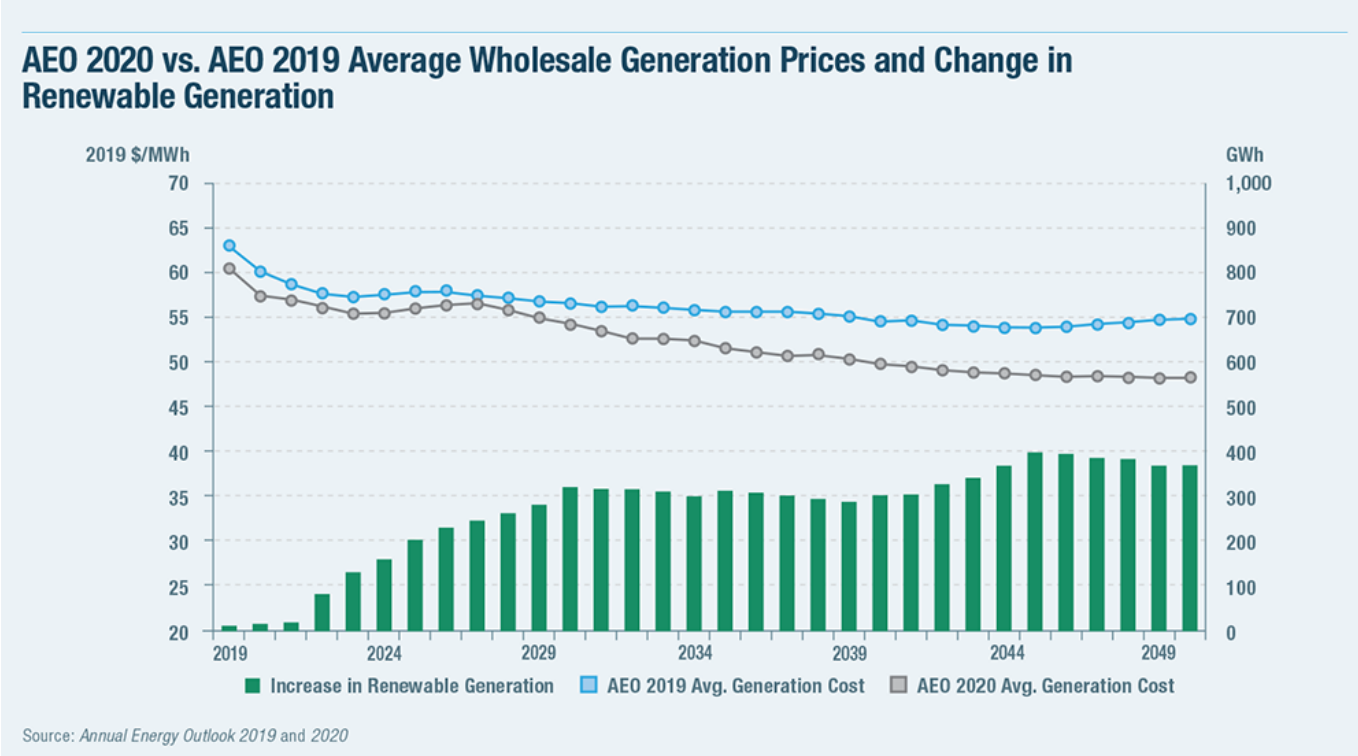

Figure 6

Second: as more offshore wind generation is added, the effect will be to lower wholesale prices while tending to drive out unsubsidized generation. Indeed, analyses of offshore wind PPAs often tout the indirect price-suppression benefits of offshore wind power to electric consumers—that is, the benefits to consumers from suppressing wholesale generating prices. Proponents of such price suppression effects argue that the increase in the supply of offshore wi will decrease market-clearing prices by more than the cost of the plant. Supposedly, everybody wins, except for competitive generators that investe their capital. This argument is wrong.

Third: by artificially driving down market prices through subsidies and mandates, states drive out legitimate competitive generators, including renewable generators that operate without the benefit of subsidies and mandates. Thus, any price reductions are temporary. The long-term damage markets is worse. By driving out legitimate competitors, these policies increa financial risk, as investors don't know if the plant that they finance will be forc out of business in the future by some other state policy action.

Finally, subsidies reduce the incentive to innovate and lower costs. Thus, in the long run, because competitive generators will be more hesitant to invest and because investors will demand higher returns to compensate for the additional financial risk, electric prices paid by consumers will end up higher than they otherwise would be.

Hidden Costs

The levelized costs estimated by EIA in its *Annual Energy Outlook*, as well as the levelized PPA prices shown in Figure 5, do not provide a complete accounting of offshore wind's costs. A more accurate picture must account for at least three factors: (i) output degradation— the tendency for offshore wind turbines to produce less electricity as they age, owing to unexpected equipment failures, which may lead to premature abandonment of offshore wind facilities; (ii) the costs of ensuring that the bulk power system can provide reliable electricity supplies, which becomes more difficult and costly, the greater the amount of intermittent generation like wind is integrated onto the system; and (iii) future decommissioning costs, which are unlikely to be fully accounted for by developers.

Output Degradation

The levelized costs published by EIA in its *Annual Energy Outlook*, as well as the levelized PPA prices shown in Figure 5, all assume that there is no reduc in the amount of power generated by an offshore wind project as its turbines age. In reality, output tends to decrease as generating units age. This can be caused by the need for additional downtime for maintenance. Or, as in the c of solar photovoltaics, by breakdowns in the solar cells themselves. For example, the electric conversion efficiency of solar photovoltaics decreases average 0.8% per year.[70]

The output degradation in offshore wind turbines has two key economic impacts. First, the more a project's output declines over time, the higher its levelized cost. Second, as costs increase as output declines, the relative benefit of continued operation decreases. Eventually, the expected costs of maintaining a project will exceed its expected revenues, at which time the rational economic response for the project's owner is to shut down.

The first large-scale study of changes in wind turbine output over time was in 2012 by Gordon Hughes, an economics professor at the University of Edinburgh.[71] He examined the performance of onshore wind farms in Britain and Denmark, as well as the performance of offshore wind farms in Denmark. Hughes's analysis found that the average load factor (i.e., the ratio of a generator's average annual output to its rated capacity) for offshore wind farms in Denmark fell from over 40%, when the units were new, to less than 15% after nine or 10 years.[72] The performance degradation of onshore wind farms in Denmark was much less, but the performance of onshore wind farms in Britain fell rapidly. (Hughes's onshore turbine findings in Britain were confirmed in a 2014 study that found that the average annual output loss from installed facilities was about 1.6%.)[73]

In 2020, Hughes published an update of his 2012 study, taking advantage of the much larger quantity of available data.[74] This updated analysis found that the performance of larger offshore wind turbines decreased an average of 4. per year for turbines installed after 2011. *In other words, after 10 years, the average output of these newer offshore wind turbines was just over half the initial output.* Hughes's analysis also showed that the performance of newer, much larger, turbines was far worse than that of older ones. His findings are relevant for the U.S. offshore wind projects because they will be relying on a newer generation of still-larger turbines, including GE's 12-MW Haliade-X turbines.

Hughes's study also noted another, less well-recognized, problem with offsh turbines: subsea transmission lines "are notorious for the severity and length their outages." (As noted earlier, the Block Island Wind Farm's offshore cable was exposed because of erosion. Repairs and reburying of the cable are anticipated to take at least six months to complete.)

Finally, Hughes's study shows that the likelihood of major outages lasting at least one month increases by at least 10% per year. In other words, in the first year of operation, a turbine has a 10% likelihood of a major outage. In its second year of operation, that probability increases to 20%, then 30% in the third year, and so forth, increasing to about an 80% probability of a major outage by the time a turbine is eight years old.

Not only are major outages costly to repair for the owners, but the lost output must be replaced. Given the propensity for major outages, this means that there will be a greater need for the bulk power systems to increase the quantity of generating capacity held in reserve, as well as higher costs paid by consumers.

Output degradation over time will increase the actual levelized costs of PPAs shown in Figure 5. For example, if output degrades an average of 2.5% per year, the resulting increase in a project's levelized cost is 22% for a 20-year PPA.[75] At the 4.5% average annual degradation rate calculated in the Hughes study, the increase in levelized cost is 58%, and, after 10 years, the expected output will be about half the initial output (**Figure 7**). Output degradation over time is likely to cause another hidden cost for consumers and taxpayers: the cost of project abandonment.

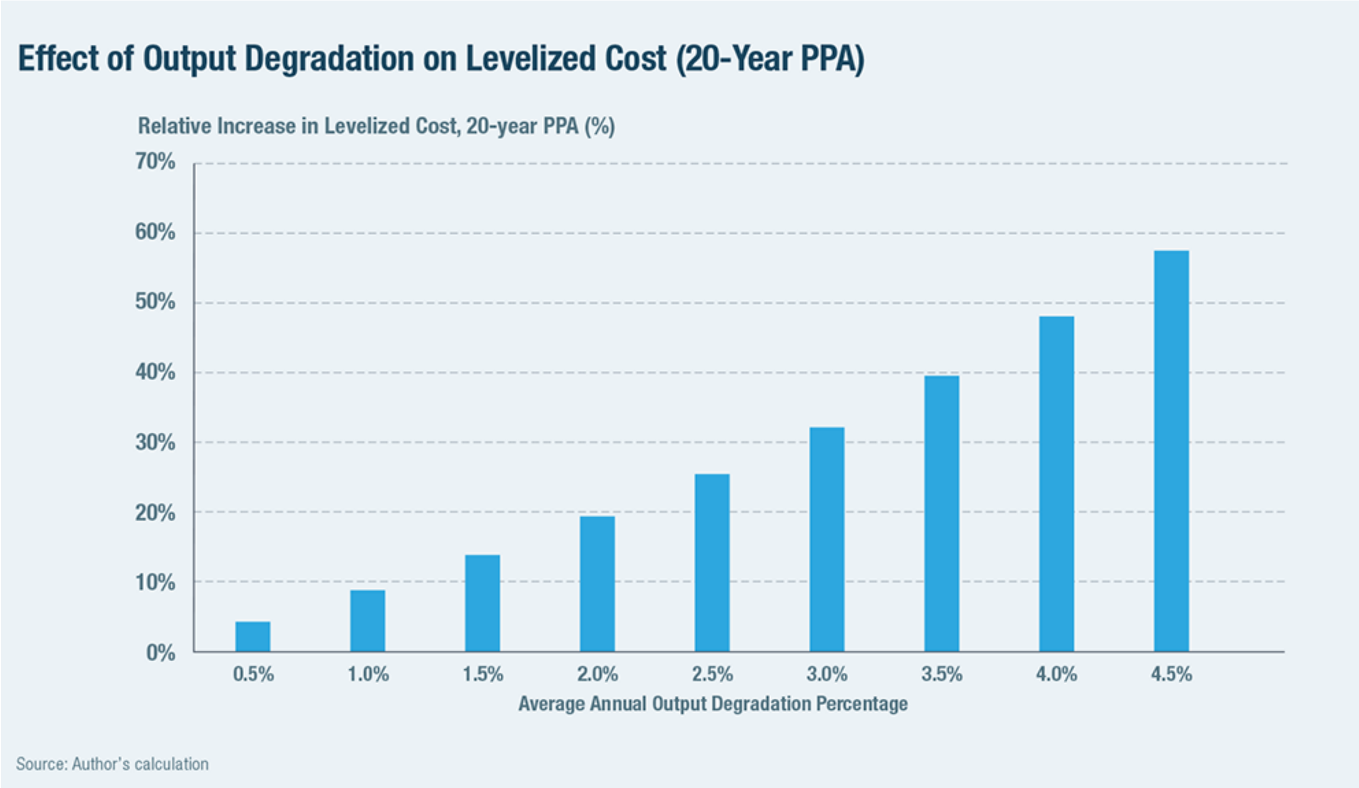

Figure 7

Project Abandonment and the "Winner's Curse"

The levelized costs of many of the PPAs shown in Figure 5 are *lower* than EIA's levelized cost estimates for offshore wind turbines—in some cases, much lower. For example, as shown in Figure 5, the levelized PPA price of the Mayflower Wind Project is $55.52/MWh, versus the EIA's average forecast fo offshore wind of $122.25/MWh. This would seem to mean that EIA's levelize cost estimates are too high. In fact, EIA's levelized cost estimate is likely to b too *low*.

As discussed previously, EIA estimated a weightedaverage LCOE for offshor wind turbines installed in 2025 of $115.04/MWh (2019$). That LCOE estima is based on an assumed lifetime of 30 years. However, offshore wind turbine are designed only to withstand the elements for 20–25 years.

Using more favorable financing assumptions,[76] NREL estimates a lower

LCOE cost, $89/MWh (2018$), based on projects installed in Europe and a study of a representative 5.5-MW turbine. Contra Hughes, NREL estimates assume that a wind turbine will never suffer any extended outages.[77] Even so, many of the levelized PPA costs are below NREL's LCOE estimate as well.

This would seem unlikely, especially as most of the cost estimates are based on data from Europe, which has an extensive history of offshore wind, while the only functioning offshore wind farm in the U.S. is the 30-MW Block Island Wind Farm Project. Yet, as discussed previously, the relatively low-cost PPAs are seen as evidence of rapidly declining costs to construct and operate offshore wind projects.

The apparent contradiction can be resolved by noting two factors. First, as Hughes (2020) points out, the costs of offshore wind projects have declined, owing to economies of scale and low interest rates, but neither trend is likely to continue to any great extent. Second, Hughes (2020) notes that the growing discrepancy between estimated costs and PPA bids may be ascribed to what economists call the "winner's curse," a familiar concept in auction theory.[78] In brief, auction winners tend to overpay. In the context of one-off wind power projects, "winners" tend to underestimate costs and overestimate benefits, a phenomenon known as "optimism bias."[79]

Coupled with the observed annual output degradation rates for offshore win projects in Denmark, which have been especially acute for the newer generation of large turbines, if the lower-cost PPA auction winners in Figure 5 above have underestimated construction and, especially, ongoing operation costs, they will be more likely to abandon the projects as uneconomic before the full terms of their contracts.[80]

Abandoned Projects

Most proposed offshore wind projects in the U.S. are structured as limited-liability, single-purpose entities. This means that the only assets of the comp will be the turbines and related equipment. If a project becomes uneconomic to operate under the terms of its PPA, the company can declare bankruptcy. Utility ratepayers and the state's taxpayers will have no recourse to recover the costs to cover decommissioning the turbines and removing them from the ocean.

Thus, if a project with a 20-year PPA is abandoned after 10 years, the available alternatives will be to renegotiate the PPA and pay more for the project's output; or decommission the project prematurely. If the former option is chosen, electric utility ratepayers lose. If the latter option is chosen, moneys set aside for decommissioning are unlikely to cover the actual decommissioning costs. These costs will have to shouldered by electricity consumers and, possibly, the state's taxpayers (see sidebar, **Who Will Pay to Decommission Offshore Turbines?**).

Who Will Pay to Decommission Offshore Wind Turbines?

The Bureau of Ocean Energy Management (BOEM) has specific requirements for decommissioning offshore wind turbines.[a] The bottom line is that all turbine components, from the blades to the foundation, must be removed to a depth of 15 feet below the mud line (what happens to the power cables is unclear).

As no offshore wind facilities have been decommissioned in the U.S., the costs to do so are uncertain. One recent article estimated the cost of decommissioning Britain's offshor wind turbines to be £80,000– £300,000 per MW, or about $102,000–$384,000 per MW at current exchange rates.[b]

Several studies have estimated decommissioning costs for U.S. offshore projects. A 201 study estimated the cost of decommissioning the canceled Cape Wind Project at $63.8 million for the project's 130 3.6-MW turbines, which translates into a cost of $136,000 pe MW.[c] A detailed 2014 study for the Cape Wind Project estimated a decommissioning cos of $71 million–$126 million, with an expected cost of $103 million and a salvage value of $23 million.[d] The net expected cost, $80 million, is equivalent to $171,000 per MW. A 2017 study of decommissioning eight offshore wind farms off the British coast estimated an average cost of over £200,000 per MW.[e] Because the larger turbines to be built off the Atlantic Coast will be more difficult and costly to remove and dispose of, the per-MW costs are likely to be higher, perhaps much more so. For example, the 12-MW GE Haliade-X turbine, which will be used for the Ocean Wind and Skipjack Projects, has 325-foot-long blades, longer than a football field. Disposal of smaller, onshore wind turbine blades, which today cannot be recycled, is already a problem.[f] GE admits that the installation of these turbines represents the limits of existing technology;[g] removal of the turbines likely will pose similar challenges.

The approved PPAs for the projects shown in Figure 1 provide little detail regarding decommissioning costs and, especially, the funds that the developers are required to set aside for ultimate decommissioning. This is in marked contrast to nuclear power plants, which have strict decommissioning requirements and regulations governing how much money nuclear plant owners must set aside each year for decommissioning.

BOEM regulations do not specify dollar amounts for decommissioning funds. PPAs typically require some bonding for the projects, especially during the construction phase, but the details regarding decommissioning funds are sparse and, in some cases, confidential.

Except for the Coastal Virginia Offshore Wind Project to be built and operated by Dominion Energy, all the other offshore wind projects will be owned by single-purpose entities. For example, Mayflower Wind will be developed by Shell New Energies and EDPR Offshore North America, two large multinational companies. However, the actual project owner is Mayflower Wind Energy, LLC, a single-purpose entity. The only assets owned by these companies will be the turbines and undersea cables connecting them to the shore. The same is true for Vineyard Wind, a joint venture of Avangrid and CIP, as well as many of the other projects in Figure 2. Once the projects are no longer economical to operate, the companies can simply walk away, leaving electric ratepayers and U.S. taxpayers to pay the decommissioning costs.[h]

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[a] The requirements can be found at 30 CFR § 585.9–585.913.

[b] Elaine Maslin, "£10 billion+ Offshore Wind Decommissioning Bill," *Offshore Engineer*, Dec. 16, 2019

c Mark Kaiser and Brian Snyder, "Offshore Wind Energy Installation and Decommissioning Cost Estimation in the U.S. Outer Continental Shelf," BOEM, November 2010, p. 215, table 12.14. The authors estimated lower costs for an alternative deconstruction alternative, "felling the turbine like a tree, rather than removing it piece-by-piece."

[d] PCCI, "Decommissioning Cost Estimation for the Cape Wind Project," report prepared for BOEM, December 2014.

[e] Eva Topham and David McMillan, "Sustainable Decommissioning of an Offshore Wind Farm,"

Renewable Energy 102, part B (March 2017): 470–80.

[f] See, e.g., "Electric Power Research Institute, "Wind Turbine Blade Recycling" 2020 Technical Report," Apr. 17, 2020. In February 2020, the Wyoming House of Representatives passed two bills that would ban the disposal of wind turbine blades in landfills and allow base materials to be buried in abandoned coal mines. See Brendan LaChance, "Bills Aim to Require Recycling of Wind Turbine Blades, Disposal in Abandoned Coal Mines," *Oil City News*, Feb. 24, 2020.

[g] Tomas Kellner, "The X Factor: Here's What It Takes to Build the Tower for the World's Most Powerful Offshore Wind Turbine," GE Reports, May 25, 2018.

[h] For a discussion of this issue as it relates to onshore wind farms, see William Stripling, "Wind Energy's Dirty Word: Decommissioning," *Texas Law Review* 95 (2016): 123–51.

None of the publicly reviewable portions of the approved PPAs provides specific information about the moneys that project owners will be required to set aside for eventual decommissioning. Although PPAs include discussions of performance bonds when the projects are under construction, discussions about decommissioning requirements are absent.

Ensuring Bulk Power System Reliability

As with all large generators in New England, New York, and the Mid-Atlantic states, the electricity produced by offshore wind farms must be integrated onto the bulk power system that provides electricity to local electric utilities and th ultimate customers. To provide safe and reliable electricity, the supply and demand must be matched continuously by a Regional Transmission Organization (RTO).[81] The reason is that electricity-consuming devices —lightbulbs, motors, the computer I am using to write this report, etc.—are designed to operate within a narrow band of voltage and frequency. If those bands are breached, the effects can range from flickering lights to a large-sc blackout.

Consequently, power systems have different types of reserves that can respo to changes in supply or demand. For example, many gas-fired generators ha the ability to "load-follow"—to have their output ramped up or down to matc instantaneous changes in electricity demand (called “automatic generation control”). Other generators are kept on hot standby, equivalent to a car that is running in neutral gear. At a moment’s notice, the generator can be engaged (put into gear) to meet demand.

Unlike fossil-fuel and nuclear plants, wind and solar are inherently intermittent, generating electricity only when the wind blows or the sun shines. Their output cannot be controlled and can change from moment to moment. This inherent intermittency must be compensated for by relying more on natural gas-fired generators that can be brought online quickly, on pumped-storage hydroelectric plants, or, thanks to additional mandates and subsidies,[82] on expensive battery storage.[83]

Although small quantities of intermittent wind and solar energy can be accommodated on the bulk power systems at a relatively low cost, these costs increase as greater quantities of these resources are integrated onto the bulk power system. A 2012 study prepared for the Organisation of Economic Co-operation and Development (OECD) examined grid-related costs for different types of generating resources in different countries. It estimated that if offshore wind accounted for 10% of the total electricity supply, the resulting grid-support costs would be $20.51/MWh. At 30%, the costs would be $28.26/MWh. For onshore wind, the study estimated the costs to be $16.30/MWh and $19.84/MWh for the 10% and 30% cases, respectively. By comparison, the study estimated the grid-support costs of natural gas-fired generators to be $0.51/MWh.[84]

Grid-support costs will not be paid by offshore wind developers. Instead, they will be socialized across all electricity consumers through electric transmission rates that are charged by grid operators that coordinate the bulk power system. For the East Coast states with offshore wind mandates, these grid operators are ISO New England, the New York Independent System Operator, and PJM Interconnection. Offshore wind proponents (and wind and solar proponents in general) either downplay these costs as de minimus[85] or ignore them altogether.

V. Claims of Economic Development Benefits of Offshore Wind Are Misleading

As noted earlier, a 2017 NYSERDA report claimed that developing 2,400 MW of offshore wind in New York State would create nearly 5,000 new jobs associated with manufacturing, installation, and ongoing operations, as well as $6.3 billion of new infrastructure spending.[86] In March 2020, AWEA claimed that offshore wind power would create 19,000–45,000 new jobs by 2025, and 45,000–83,000 jobs by 2030.[87] Offshore wind development, according to the report, would also increase economic output by $12 billion–$25 billion by 2030: "Economic benefits extend beyond initial project expenditures as project spending circulates throughout the economy, delivering additional spending job support. Capturing the initial and subsequent impacts stemming from offshore wind projects provides a full picture of the economic contributions tl offshore wind industry can deliver to the U.S."[88]

In approving PPAs for the US Wind and Skipjack offshore wind projects, Maryland imposed specific minimum in-state employment requirements. For Wind, the state mandated the creation of 1,298 direct construction-period jo and 2,282 direct operating-period jobs in the state during the project's 20-ye operational contract life, along with a $51 million investment in a new steel fabrication plant. Skipjack will be required to create a minimum of 913 direct construction-period jobs and 484 direct operating-period jobs, plus a minimum $25 million investment in the steel fabrication plant.[89] It is certainly true that subsidizing offshore wind energy development will create jobs for energy developers. It may also lead to new businesses serving the offshore wind industry, especially if, as in Maryland, developers are *required* to create minimum numbers of jobs and contribute to the development of new manufacturing facilities. When the entire economic ledger is tallied, however, the net impact of renewable energy subsidies necessarily will be *lower* economic growth and a citizenry that is worse off.

The fundamental error is to confuse economic *benefits* with economic *transfers*. In effect, claims of enhanced economic growth assume that the money that pays for offshore wind development drops out of the sky. In reality, the money is transferred from ratepayers and taxpayers to developers—there is no improvement in overall well-being. Ignoring or whistling past this reality leads to a preposterous outcome: if one ignores the economic impacts of forcibly transferring dollars from consumers and taxpayers to developers of renewables, then the most costly—and least cost-effective— renewable resources will be seen to create the greatest economic "benefits."[90]

Given its cost relative to wholesale electric prices, offshore wind energy will lead to higher electricity prices. Many public utility commissions that have approved offshore wind PPAs acknowledge the cost increases but opine that they will insignificant. For example, NYSERDA claimed that the average bill impact fo residential customers from the Empire Wind and Sunrise Wind Projects woul be $0.73/month.[91] Similar claims by offshore wind proponents based on s cost breakdowns (sometimes called the "cup-of-coffee" pricing fallacy) are disingenuous: they ignore the cumulative economic impacts of those higher costs. A $3 cup of coffee sold by Starbucks may not sound like much, but in 2019, Starbucks' revenues were $26.5 billion and the company's profits exceeded $5.7 billion.[92]

VI. Adverse Environmental Impacts

Of the 13 projects in Figure 2, only Vineyard Wind has a completed Draft Environmental Impact Statement (EIS).[93] (A supplement to this EIS was issued on June 12, 2020.)[94] The Draft EIS discusses impacts on a variety of resources, classifying those impacts as "negligible," "minor," "moderate," or "major."[95] In some instances, the EIS also noted potentially beneficial impacts, such as the creation of artificial reefs for finfish from foundations and scour protection,[96] although these claimed benefits have been challenged by fisheries representatives.[97] (Scour refers to the erosion of the seabed surrounding a wind turbine foundation, effectively creating a hole around the foundation.) However, for this category, the Draft EIS also noted potentially moderate long-term impacts from habitat disruption and moderate to major adverse impacts on commercial fisheries and recreational fishing. One key concern: the proposed spacing between the turbines will be too small to allow commercial fishing. Another: the underground cable delivering electricity to the shore may be exposed because of strong tidal currents, as happened with the Block Island Wind Farm Project cable in August 2019.

The Draft EIS ignored the environmental impacts associated with decommissioning. For example, BOEM stated that undersea cables could b retired in place but did not evaluate the potential long-term impacts of deactivated cables, or how such impacts would be monitored.[98]

The major adverse cumulative impacts determined by BOEM help explain th intense opposition to offshore wind projects by many commercial fishermen. The turbines for the proposed South Fork Wind Farm, off the eastern tip of Long Island, will not be visible from the shore, but fishermen are concerned t the underwater cable will permanently disrupt fishing efforts.[99] There is no research on cumulative impacts on benthic (seafloor) species from electromagnetic fields, underwater noise, and potential habitat changes that encourage the proliferation of nonnative species.[100] Nor is there evidence for BOEM's claim that there will be beneficial "reef effects" from turbine foundations. Perhaps the greatest direct environmental concern, however, is the cumulative impacts of all the proposed offshore wind development along the Atlantic Coast. If all these projects are developed, "temporary" disruption of marine habitats and fisheries for each project's construction will mean long-term disruptions for decades.[101] This is the primary reason that BOEM has delayed the issuance of a final EIS for the project.[102]

The Vineyard Wind Supplemental EIS issued by BOEM in June 2020 examined these cumulative impacts of developing 22,000 MW of offshore wind along the Atlantic Coast, which "would result in the construction of about 2,000 wind turbines over a 10-year period."[103] It emphasized the uncertainty of many findings because of lack of data; however, it concluded that there would be "moderate" adverse impacts on bottom fish, finfish, fish habitat, marine mammals (including whales), and sea turtles. It also found that there would be "major" adverse impacts on commercial fisheries, as well as on coastal navigation, scientific research, and military uses.

Unfortunately, as the Supplemental EIS notes, there is little research on such long-term impacts.[104] For example, it is not known how construction up and down the East Coast for many years will affect how fish migrate. There is no research on how construction will affect the migration of whales, especially tl North Atlantic right whale, of which only about 400 remain.[105] Similarly, the is no research on the potential cumulative impacts on migratory seabirds.

Indirect Environmental Impacts

Among other environmental concerns, perhaps the most significant are the rare-earth minerals required to manufacture turbines. Currently, almost all rar earth minerals are supplied by China, from mines in Mongolia. China's environmental laws are far less stringent than those in the West. Hence, by promoting "clean" wind energy, U.S. states are, in effect, outsourcing advers environmental impacts, including toxic lakes where radioactive material —primarily thorium bound up in mineral deposits—is dumped;[106] and high levels of air pollution, "the deadly and sinister side of the massively profitable rare-earths industry that the 'green' companies profiting from the demand for wind turbines would prefer you knew nothing about."[107]

Moreover, as my Manhattan Institute colleague Mark Mills's most recent report discusses, the raw materials needed to manufacture and install wind turbines dwarf those needed to manufacture and install gas-fired combined-cycle turbines.[108] Other than fiberglass blades, which currently cannot be recycled and are already creating disposal issues for landfills because of their size,[109] wind turbines are primarily made from steel (70%–80% of the total mass).[110] Steel, of course, is made from coal. The largest monopile foundations, upon which about 80% of all offshore wind turbines have been built, weigh over 1,300 tons.[111] Each 12-MW GE Haliade-X turbine weighs 2,800 tons, including the 2,000-ton steel monopile foundation.[112] To make one ton of steel solely from raw materials requires about 1.4 tons of iron ore and 0.8 tons of coal,[113] so each foundation implies about 2,800 tons of iron ore and 1,600 tons of coal. Concrete gravity foundations, the other major alternative to monopile foundations, also require large amounts of materials. A gravity base foundation for a single 6-MW turbine in the North Sea requires more than 5,000 tons of concrete and more than 700 tons of steel.[114]

The materials requirements for offshore (and onshore) wind turbines to become a major source of electricity in the U.S. will be staggering, especially as states seek to electrify their economies toward the stated goals of eliminating all greenhouse gas emissions. Along with damage to fisheries, the environmental costs associated with mining and manufacturing rare-earth elements and the vast quantities of raw materials to manufacture and install—compared with other, far more energy-dense, generating resources such as gas-fired generators and nuclear units—mean that states mandating thousands of MW of offshore wind capacity thus will create their own set of environmental problems. Yet offshore wind proponents respond to these environmental issues either by dismissing them as insignificant or ignoring them altogether.[115]

Ultimately, the environmental benefits of offshore wind, in terms of reduced air pollution and greenhouse gas emissions, are likely overstated, for two reasons. First, to the extent that the intermittent output of offshore wind plants is backstopped with gas-fired generators, the latter will operate less efficiently, producing more emissions and less output, much as a gasoline-powered car operates less efficiently in stop-and-go traffic than on a highway.

Second, offshore wind will tend to displace onshore wind. In a 2017 review, the Maryland Public Service Commission's independent evaluator, Levitan and Associates, found that the state's Skipjack and US Wind projects would reduce gas-fired generation in the eastern part of the PJM region (e.g., Delaware, Maryland, Pennsylvania) but tend to reduce electricity generated from onsho wind in the western portion (e.g., Illinois, Ohio).[116] The reason: offshore wi will increase the supply of ORECs and offset Maryland utilities' need for REC from other resources, primarily onshore wind. Hence, REC prices will tend to fall, reducing the economic value of onshore wind generation.

This Levitan review also projected that with less onshore wind, more coal-fire generation would take place in the western PJM, offsetting emissions reductions. The estimated net emissions reductions would be only about 19,000 tons per year because of these offsetting impacts on other electric generating plants, versus the projected 1.2 million tons per year claimed by t projects' developers.[117] The Skipjack Project, according to the review, would result in an average decrease in sulfur dioxide (SO_2) emissions of a mere 1.6 tons/ year and reduce emissions of oxides of nitrogen (NO_x) by only 3.4 tons/year over the project's lifetime.[118] By comparison, U.S. emissions of SO_2 and NO_x from electric generating plants in 2018 were 1.26 million tons and 1.02 million tons, respectively. Finally, the Levitan review estimated that the project would reduce CO_2 emissions an average of 6,384 tons/year.[119] By comparison, total U.S. energy-related CO_2 emissions in 2019 were estimated to be 5.1 billion tons.[120] Even if one accepted the estimated annual reduction of 1.2 million tons of CO_2 from the US Wind and Skipjack Projects, that represents 0.02% of 2019 U.S. energy-related CO_2 emissions.

VII. Conclusions and Policy Recommendations

As in the popular game show Jeopardy!, offshore wind is an "answer" in search of a policy question. The current projects slated to be built off the Atlantic Coast will raise the cost of electricity and reduce the grid's reliability, forcing bulk power systems to invest additional resources in backup generation resources or high-cost battery storage. Claims that offshore wind costs are declining rapidly, based on PPA prices, fail to consider that the winning bidders may b seriously underestimating their costs over time. The experience with offshore wind projects in Europe over the last decade has demonstrated that newer, larger turbine technologies have been accompanied by significant reliability a maintenance issues, causing the amount of electricity that these turbines generate each year to decline by almost half over 10 years.

The likely declines in output will reduce the revenues and profitability of these facilities over time. This may lead developers to abandon the facilities before term of their PPAs, leaving ratepayers and taxpayers to pay for decommissioning and dismantling the units. Even if the units do operate for their full claimed economic lifetimes, it is unclear whether they will be require set aside sufficient funds to pay for decommissioning.

Claimed environmental benefits from reduced pollution and reduced greenhouse gas emissions fail to account for offsetting impacts in wholesale electricity markets and fail to account for the increase in pollution from more inefficient use of gas-fired generators that will be required to provide backup power to compensate for the inherent intermittency of wind power. In any event, offshore wind development will make no meaningful contributions to reductions in U.S. emissions of greenhouse gases, nor will it have any measurable impacts on world climate.

The claimed economic development benefits of offshore wind are also overstated, as proponents ignore the adverse economic impacts on existing consumers and businesses from higher electricity costs. Forcing offshore wind developers to hire minimum numbers of workers and contribute to the construction of new manufacturing facilities, as Maryland has done, is absurd. Ultimately, the economic benefits of subsidized offshore wind development will accrue to the few, at the expense of the many.

In view of all the shortcomings, this report recommends that states:

- End subsidized development of offshore wind facilities, including the requirement that electric utilities purchase increasing quantities of offshore wind renewable energy credits. Developers that wish to construct and operate offshore wind facilities should bear the investm risks, rather than be allowed to transfer those risks to electricity consumers.
- Require offshore wind developers to provide full information to the pu about anticipated decommissioning costs and post surety bonds tha will fully fund those costs. As decommissioning cost estimates chang over time, project developers should be required to adjust their contributions to decommissioning funds, as is done for nuclear powe plants and for individual pipelines that are subject to asset retirement

obligations.

Require offshore wind developers to pay for the additional costs of backup generating resources needed to compensate for the inherent intermittency of their wind facilities. These developers should also be required to pay for the costs to interconnect their projects to the bulk power system, rather than having those costs be paid for by electricity customers.

Focus on ensuring that electricity demand is met with the most efficient resources possible, rather than resources that will create set numbers of jobs. States that wish to emphasize clean energy resources should ensure that reliable nuclear power generating units can be constructed, especially new modular technologies that will reduce financial risks and use natural forces such as gravity to bring a reactor to a safe shutdown.[121]

Appendix

The Mathematics of Calculating Levelized Cost for a PPA (see in PDF)

Endnotes

See endnotes in PDF

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