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# OFFSHORE WIND: A BOON TO CLIMATE GOALS AND ECONOMIC GROWTH

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## INTRODUCTION

This memo summarizes current offshore wind development and expected potential to help the United States reach midcentury zero-emissions climate goals. Plummeting costs, as well as policy and technology developments, are positioning offshore wind to become a critical renewable energy resource to meet anticipated electricity demand and zero-emissions targets around the world. Global experience can help guide policy and technology pathways federal and local governments can take to maximize offshore wind potential.

As of 2018, about 80 percent of installed global offshore wind energy capacity was located off Europe's coast.[i] Europe prompted offshore wind installs in the 1990s with an advantageous feed-in tariff and interconnection priority.[ii] In 2016, many European countries started using reverse auctions as a price-finding mechanism to reduce costs and encourage investment.[iii] Since then, more and more countries worldwide have used this policy sequence to attract developers and reduce offshore wind prices.

Other technology improvements, such as larger turbines, have contributed to cost declines and greater energy availability. High capacity factors allow offshore wind generation to coincide with customer demand and complement solar output, making offshore wind energy particularly valuable to many grids. As part of a diverse clean energy mix, offshore wind can increase grid reliability and flexibility.

The U.S. and East Asia, particularly China, are expanding the offshore wind farm pipeline at an increasing rate. Floating turbines will drastically expand this pipeline as they reach cost-effective commercial-scale by 2025. With policy support and technology advancements, 590 gigawatts (GW) of offshore wind can be installed globally by 2040.[iv] Additionally, International Energy Agency (IEA) technical analysis finds that offshore wind could produce up to eleven times expected global electricity demand by 2040.

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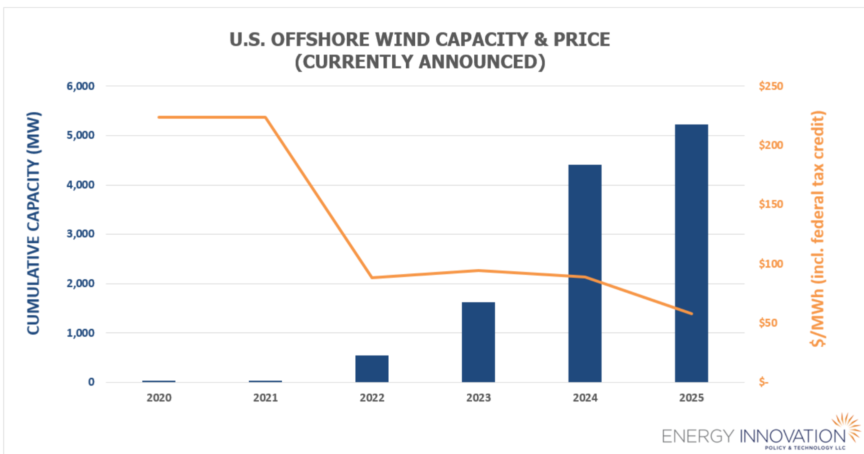
# OFFSHORE WIND BENEFITS AND OPPORTUNITIES

## COST

Offshore wind has experienced dramatic cost declines in recent years, and the trend is expected to continue. European prices for projects coming online between 2017-2019 were around $200/megawatt-hour (MWh), and are expected to fall to around $75/MWh by 2024-2025.[v] Declines in the United Kingdom, which has half the world's installed offshore capacity, have been even more dramatic, with electricity costs dropping 65 percent for projects coming online between 2018-2019 and 2024-2025.[vi] In the U.S., power purchase agreement prices for projects commencing operation in 2020 are at $224/MWh and decline to $58/MWh for projects fully installed and operational in 2025 (note that these figures do include the federal investment tax credit). Furthermore, IEA predicts the levelized cost of energy (LCOE) will decline 40 percent by 2030 and potentially 60 percent by 2040, implying a 15 percent learning rate per doubling of capacity.




*Project PPA prices fall from $224/MWh to $58/MWh and capacity increases from 30 MW to 5,218 MW between 2020-2025.*

Costs are declining for several reasons; several prominent ones stand out in the literature and informational interviews:

### *Gradual Transition from Fixed Subsidy to Competitive Procurement*

To encourage investment and development in the early days of offshore wind, European governments gave offshore wind a generous feed-in tariff. For example, Germany provided $150€/MWh in 2009, which scaled down with time.[vii] While this policy intervention brought projects online and helped developers invest in the supply chain needed to scale the industry, it also was slow to capture the cost declines that come from increased deployment. In 2016, many European governments started using reverse auctions as part of the lease process.[viii] The auctions still guaranteed a consistent price for the developer when they resulted in long-term contracts, but the auction served as a price-finding mechanism, which quickly reduced inflated costs. In 2016, Germany converted its feed-in tariff to an auction-based system, which yielded lower-cost contracts for differences with offshore wind between $0-44€/MWh. Many countries and

U.S. states have followed suit with a transition from fixed subsidy to competitive procurement.

### *Long-Term Contracts and ORECs Unlock Finance*

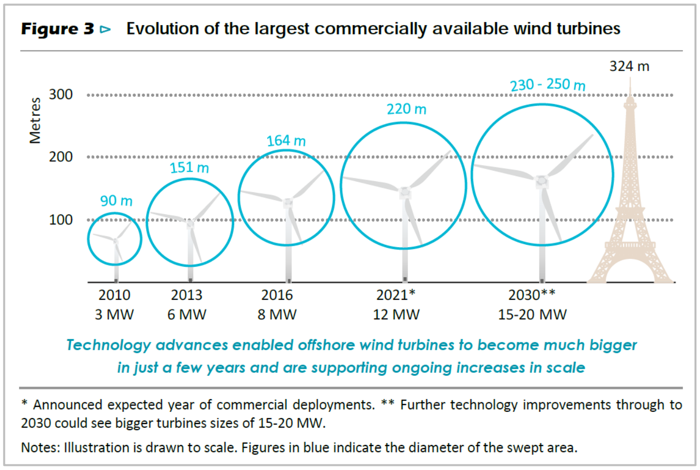
Long-term contracts provide vital support to new industries by reducing financing risk. For example, New York's Offshore Wind Master Plan recommends 20-25 year contracts for offshore wind developers.[ix] Fluctuating market prices introduce additional risk into cost recovery, which can be particularly fatal to new technologies. A long-term, highly certain price from a reliable purchaser makes it far easier to both invest capital at lower cost and raise competitive project financing. Additionally, states can create Offshore Renewable Energy Credits (ORECs), essentially a carve-out within a state renewable portfolio standard or clean energy standard. These credits create financial support for offshore wind investments while increasing exposure to real market prices. In Europe, these agreements take place as contracts for difference, which essentially provide a guaranteed price for a fixed number of years, typically 15 years. It should be noted that this price guarantee works both ways: If market prices are unexpectedly low, the government pays the operator to make up the difference; if they are higher than the contracts for difference price, the operator pays the government. This credit system trades market volatility for a guaranteed price, including losing any potential upside if electricity prices are higher than expected.

### *More Projects Improve Supply Chains, Increase Project Development Knowledge, and Create Economies of Scale*

Market players are quickly learning how to reduce costs, including creating more efficient supply chains and expanding technical expertise. Recent EU auctions indicate a 45-50 percent cost reduction over the next five years mostly due to expertise gained from projects thus far.[x] For example, one expected supply chain development trend is high-voltage direct current submarine power cables; significant forecast growing demand and increased competition is expected in response.[xi] The biggest barrier to supply chain improvements in the U.S. is weak long-term policy focus, which does not provide enough certainty to attract a robust, diverse offshore wind supply chain.[xii] The U.S. can encourage the offshore gas and oil industry to diversify into offshore wind to transition jobs and drive investment.

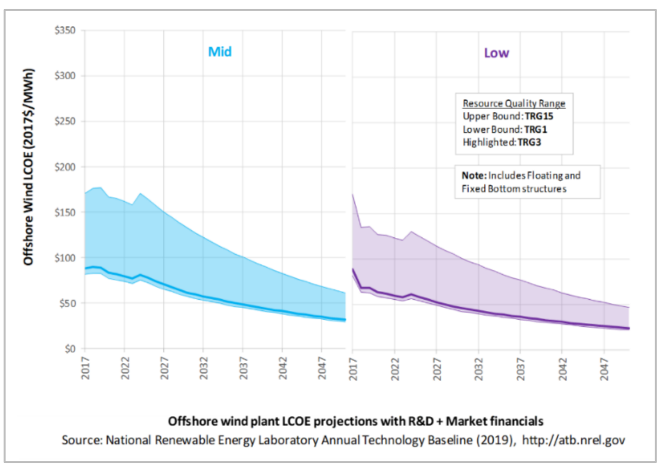
### *Larger Turbine Size Means Lower Cost of Electricity*

Larger turbines require fewer turbines to generate the same amount of capacity and energy, reducing LCOE. Similarly, larger turbines are also associated with higher capacity factors. This is because larger turbines have greater "swept area" that can access strong winds aloft, with typically lower specific power, which means that the rotor will run their generators near full capacity more of the time.[xiii] The average turbine size in 2010 was 3 megawatts (MW), rising to 5.5 MW in 2018. Over those years, annual capacity factors increased from 38 to 43 percent.[xiv] New projects have capacity factors in the range of 40-50 percent, and offshore wind capacity factors are expected to increase at least over the next two decades as turbines are installed further offshore and grow to 15-20 MW in size, if not larger.




*Source: Offshore Wind Outlook 2019, International Energy Agency.*

Future LCOE projections by the National Renewable Energy Laboratory's Annual Technology Baseline analysis for U.S. offshore wind shows the technology reaching as low as $20-30/MWh by 2050.[xv] These cost scenarios assume varying levels of technology advances, public and private R&D, and advantageous market conditions. Overall, this shows actual and expected offshore wind costs declining from $224/MWh for projects operational in 2020 to approximately $25/MWh for projects coming online in 2050, which would be a nearly 90 percent cost decline over the next three decades.




*Source: Annual Technology Baseline, Electricity, 2019, National Renewable Energy Laboratory.*

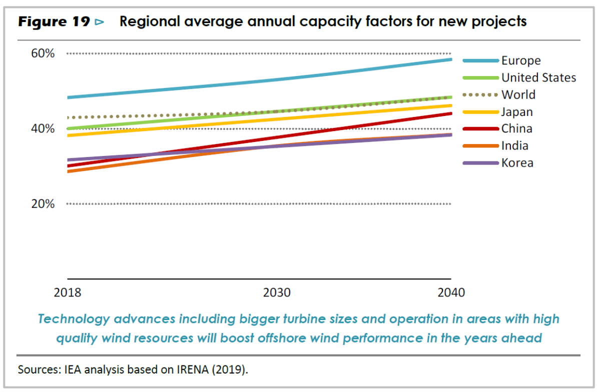
## *Opportunity to Reduce Costs*

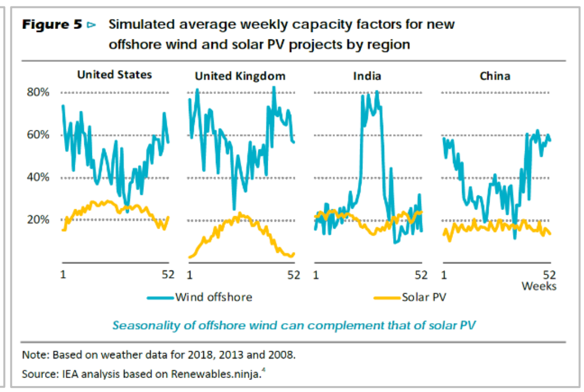
Transmission is critical to move power from offshore wind farms to large electricity demand centers. IEA found transmission costs average about 20 percent of total project capital costs. Part of this sticky cost is due to accommodating larger turbines with higher capacity factors, although technical advances, such as increasing the distance between offshore substations and upgrading the submarine cabling have offset these cost increases.[xvi]

Transmission cost as a share of total project cost is heavily dependent on existing transmission networks. North Sea offshore wind development was relatively successful in this regard because transmission networks were mostly in place to give bidders marketplace access and reduce financing costs, but this is still a challenge with unmet need for power lines. Northeastern U.S. states would be wise to coordinate an interstate transmission backbone for offshore wind, similar to Texas' Competitive Renewable Energy Zone transmission lines that provided access to market for cheap wind.[xvii]

## CREATING VALUE THROUGH GRID BENEFITS

High capacity factors create cost reductions and make offshore wind a more valuable grid asset. For reference, in 2018, solar PV had an average global capacity factor of 14 percent and onshore wind was 25 percent, while offshore wind was 33 percent. Average capacity factors for new projects in the U.S. are higher than the global average of 25 percent for solar PV and 35 percent for onshore wind, and expected capacity factors for offshore wind in the eastern U.S. are 40-45 percent.[xviii] [xix] Wind capacity factors are likely to continue increasing in the coming decades, into the 50-60 percent range.




*Source: Offshore Wind Outlook 2019, International Energy Agency.*

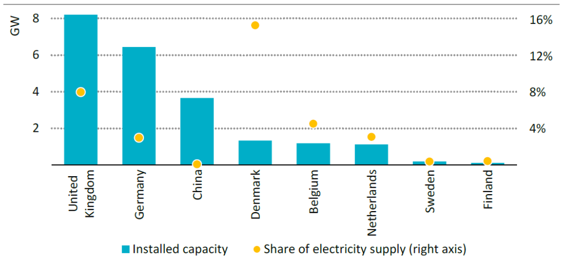
Offshore wind is not only reliable and increasingly abundant to help meet reliability requirements and resource adequacy needs, it is also flexible. Flexibility provides value to the grid and is required in a high renewables scenario; in particular, offshore wind can provide upward (if pre-curtailed) and downward ramping.

Additionally, offshore wind complements solar production globally and is coincident with customer demand. ISO New England (ISO-NE) found that offshore wind facilities provide fuel security, in particular during extreme weather events, such as the 2018 bomb cyclone. ISO-NE modeled weather conditions to test how a 1,600 MW offshore wind farm off the coast of Massachusetts would have changed its energy market response to the weather event. The analysis found natural gas consumption by generators would have been reduced by 20 percent and oil consumption would have been reduced by 7 percent.[xx] Altogether, these qualities make offshore wind a critical element of a future grid with renewables as its backbone.

## CAPACITY

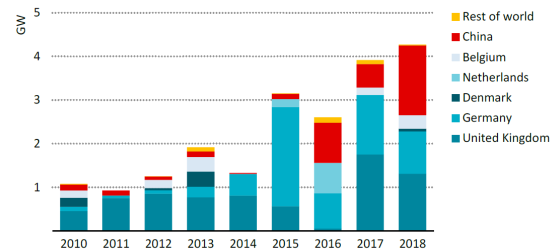
In 2018, 23 GW of offshore wind capacity was installed globally, which is 0.3 percent of global generation capacity, up from 1 GW in 2010. The only renewable energy resource to grow faster than offshore wind over the past decade is solar PV.

**Figure 2** ▷ Offshore wind installed capacity and share of electricity supply by country, 2018




*Most leading countries in offshore wind are in Europe, led by the United Kingdom, though China has quickly joined the top-three and is gaining momentum*

**Figure 1** ▷ Annual offshore wind capacity additions by region, 2010-2018



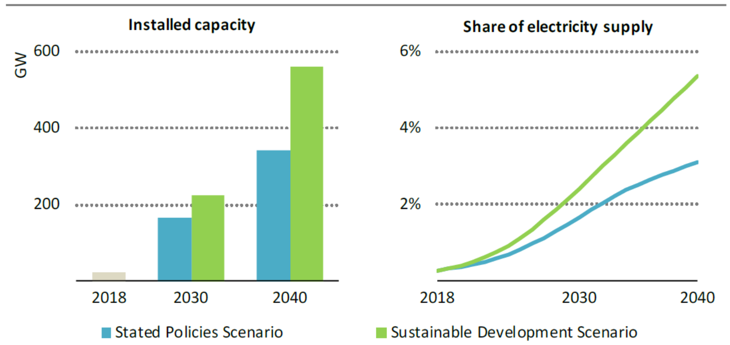

*Deployment of offshore wind has increased by nearly 30% per year since 2010, second only to solar PV, as the technology and industry have matured*

Note: Figure reflects date of connection to grid and power output, which may be before final commissioning.

*Source: Offshore Wind Outlook 2019, International Energy Agency.*

Capacity is likely to continue to scale, further bringing offshore wind toward cost-competitiveness. IEA explores two different projections for offshore wind capacity building out to 2040: a business-as-usual (BAU) scenario and a "Sustainable Development Scenario." The Sustainable Development Scenario shows 560 GW installed offshore wind capacity by 2040, which is approximately 200 GW more capacity than what the BAU scenario projects.[xxi] Offshore wind leaders are committing to significant offshore wind targets, notably the United Kingdom, which is pursuing 42 GW of offshore wind by 2030.[xxii]

**Figure 9** ▷ Projected global offshore wind capacity and share of electricity supply by scenario




*Global offshore wind installed capacity increases by fifteen-fold in the Stated Policies Scenario, raising its share of electricity supply to 3% in 2040*

*Source: Offshore Wind Outlook 2019, International Energy Agency.*

Forecasts estimate that between 11 and 16 GW of offshore wind will be deployed in the U.S. by 2030,[xxiii] though aggregated state commitments approach 30 GW, and the U.S. Department of Energy predicted the U.S. could develop up to 86 GW of offshore wind capacity by 2050.[xxiv]

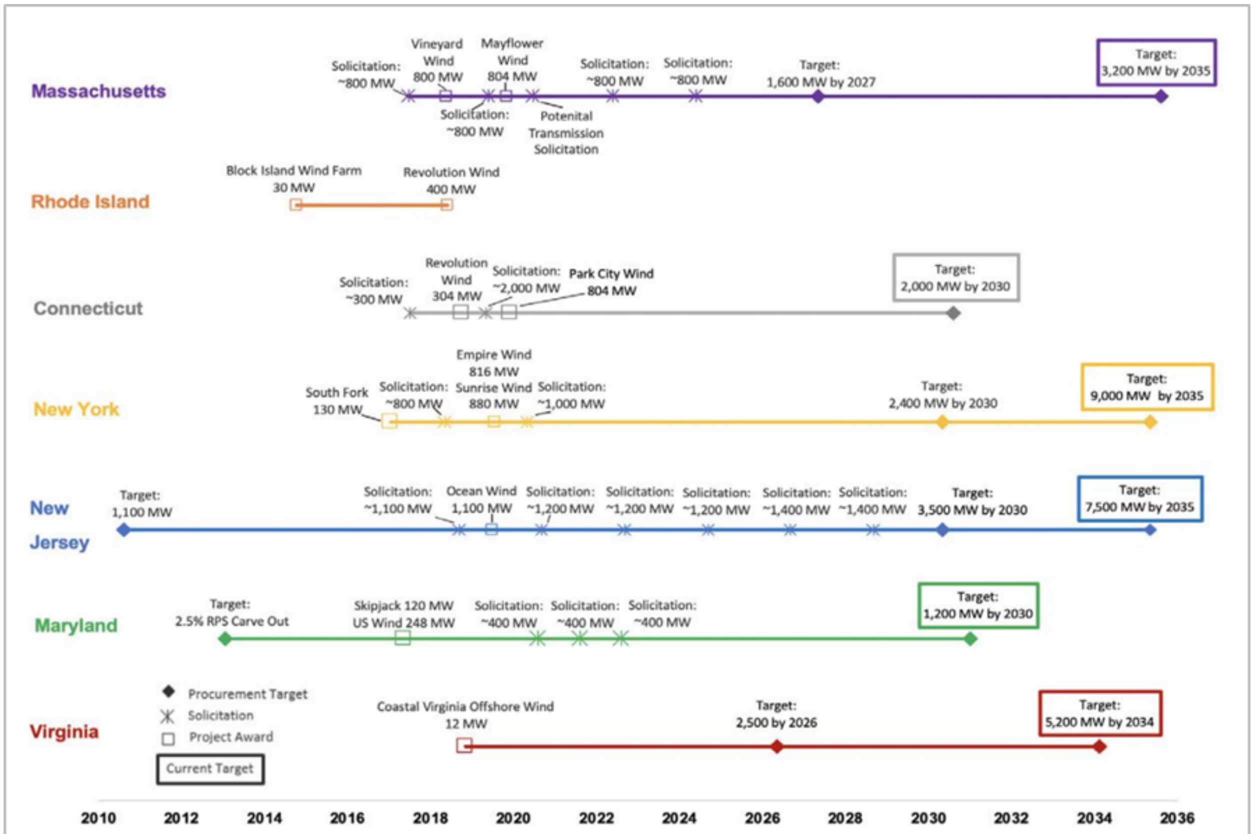



**Figure 4. Timeline of U.S. offshore wind procurement policy, solicitations, and awards**

*Source: Comparing Offshore Wind Procurement and Project Revenue Sources Across U.S. States, 2020, National Renewable Energy Laboratory.*

### *Floating Turbines Can Greatly Expand Offshore Wind Installed Capacity*

Project development thus far has mostly been limited to fixed-bottom turbines, which work well for relatively shallow waters offshore, at depths of less than 60 meters.[xxv] This is why the Northeast U.S., flanked by 100 miles of shallow waters, has a robust offshore wind project pipeline, whereas offshore wind is absent on the West Coast despite robust offshore wind resources—the steep drop of the Continental shelf along the Western seaboard makes water much too deep for much of today's commercialized offshore wind technology. 58 percent of feasible U.S. offshore wind resources are at depths greater than 60 meters,[xxvi] and globally, 80 percent of global offshore potential may require floating turbines, which are a promising solution for deeper waters that will significantly open up offshore wind possibilities around the world.

The pipeline for floating projects is growing—in 2018, 46 MW of floating capacity was already installed across eight wind farms in Europe and Asia, with 4,888 MW in the pipeline.[xxvii] Projects installed until about 2022 are still considered to be in the pilot phase, with cost-effective commercial-scale projects coming online as soon as 2025. Floating offshore wind LCOE was \$175/MWh in 2018 and is expected to reach as low as \$70/MWh in 2030.[xxviii]

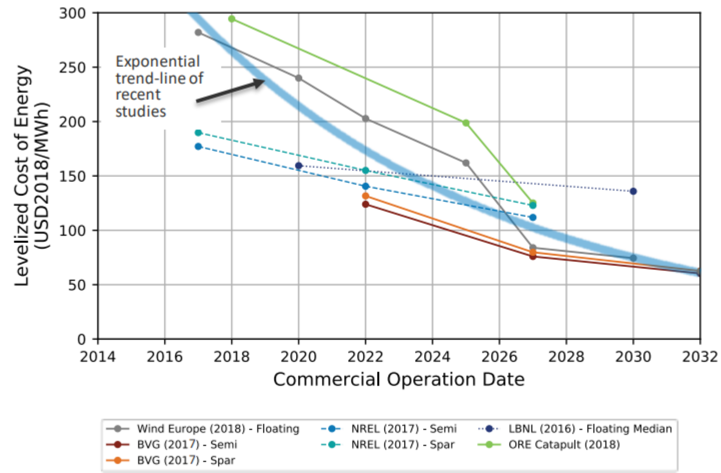



**Figure 36. Global LCOE estimates for floating technology**[72]
Sources: WindEurope (2018), Hundleby et al. (2017), Beiter et al. (2017), Wiser et al. (2016), ORE Catapult (2018)[73]

*Offshore Wind Technologies Market Report 2018, U.S. Department of Energy*

# TOP U.S. OFFSHORE WIND POLICY RECOMMENDATIONS

Policy has a large role to play in determining whether offshore wind reaches its potential to contribute cost-effective, diverse, consistent renewable energy. Like solar and wind generation, offshore wind will require upfront policy support to scale and see rapid cost declines. In particular, policies to de-risk offshore wind deployment can immediately reduce capital costs associated with these enormous projects. Procurement targets, competitive procurement strategies, contracting practices, tax support, and transmission access are key policy actions that can ensure offshore wind becomes a boon to U.S. consumer and climate goals.

## ESTABLISH AND RAMP UP OFFSHORE WIND PROCUREMENT TARGETS

Northeastern U.S. states have some of the most ambitious climate and clean electricity goals codified in statute. However, with a dearth of land usable for renewable development, offshore wind has emerged as an essential technology to meet state and regional clean electricity goals. The same could be said for West Coast states, once floating turbines are commercially viable, because they have more open land but transmission constraints still make accessing onshore wind around the region difficult.

While states have already codified offshore wind targets to support increased development, totaling 28.1 GW by 2035, state legislatures or executive offices should increase ambition to more closely match our geography's potential.[xxix] Recent cost declines indicate the economic risk to states is minimal, and increased targets would support further deployment and cost declines.

## CREATE COMPETITIVE PROCUREMENT PROCESSES THROUGH POWER PURCHASE AGREEMENTS OR OFFSHORE WIND RENEWABLE ENERGY CERTIFICATES TO MEET STATE PROCUREMENT TARGETS

### *Power Purchase Agreements*

Power purchase agreements (PPAs) are long-term contracts for purchasing electricity between a generator and a buyer based on a predetermined nameplate capacity. Long-term contracts provide vital support to new industries by reducing financing risk. For example, New York's Offshore Wind Master Plan recommends 20-25 year contracts for offshore wind developers.[xxx] Fluctuating market prices introduce additional risk into cost recovery, which can be particularly fatal to new technologies and increase the cost of capital for offshore wind. A long-term, highly certain price from a reliable purchaser makes it far easier to both invest capital at lower cost and raise competitive project financing. Typically, the state public utility commission or energy agency creates an RFP to solicit PPA proposals.

### *Offshore Wind Renewable Energy Certificates*

State legislatures can authorize Offshore Renewable Energy Credits (ORECs), which are credits that represent the environmental attributes of one megawatt-hour of offshore wind generation and are typically issued by the state energy agency. Electric utilities purchase ORECs from project developers to comply with an offshore wind carve-out within a state renewable portfolio standard or clean energy standard. ORECs can be purchased on a spot market, or bilaterally from developers, and with varying contract structures impacting developer risk. Ultimately, long-term contracts provide the lowest risk as fixed-rate credits create financial support for offshore wind investments while transitioning them to increasing exposure to real market prices.

## EXTEND FEDERAL OFFSHORE WIND INVESTMENT TAX CREDIT; CONVERT IT TO DIRECT PAYMENTS

Nascent industries need support, especially during tough economic times, and the federal investment tax credit is intended to do just that. Unfortunately, federal renewable energy tax credits have a history of needing frequent Congressional re-approval, creating industry uncertainty. Congress should extend the tax credits to provide more certainty when the offshore wind industry needs it most.

Additionally, tax credits should be converted to direct payments so that the incentive dollars are used most effectively. Today, because of illiquidity, the government only provides about 60 cents worth of incentive for every dollar it spends.[xxxi] Policymakers can accomplish this by making tax credits refundable, or converting them to direct cash grants.

## CREATE AN OFFSHORE TRANSMISSION BACKBONE WITH GOVERNMENTS AND MARKET OPERATORS

Transmission lines connect offshore wind generation to demand centers. Without proper foresight and planning, transmission and offshore wind can enter a game of "chicken and egg." Or worse, transmission requirements foisted on individual developers may prohibit development of high-quality resources that would benefit all consumers and help meet state and regional clean energy goals. The Brattle Group found up to $500 million in cost savings and reduced environmental impacts for planned, multi-use transmission system to support 9,000 MW of offshore wind development.[xxxii] The research also found planned transmission better utilizes lease areas and reduces offshore wind curtailment. In most cases, the regional transmission operator would be the primary planning entity for this effort.

Northeastern U.S. states would be wise to coordinate an interstate transmission backbone for offshore wind, similar to Texas' Competitive Renewable Energy Zone transmission lines that provided access to market for cheap onshore wind. It is important to amortize and distribute transmission costs, and not lay the cost burden solely on generators, as this may raise cost for all developers. It may also create incentives for developers to choose cheaper but less efficient technologies, and they might also unintentionally complicate land-based connections and seabed marine cabling.

### PRE-APPROVE SITING FOR LEASABLE AREAS

To align project development with offshore wind goals, offshore area should be approved for wind farms before the seabed is leased. This alleviates project delays and increases stakeholder acceptance of the projects. During the Obama administration, the Interior Department's Bureau of Ocean Energy Management (BOEM) awarded leases in areas that they had already vetted for major siting conflicts through comprehensive intergovernmental and stakeholder processes.[xxxiii] In absence of federal leadership, states can take initiative through their energy agencies by undertaking extensive research and stakeholder engagement to select ideal offshore wind siting areas and propose areas to BOEM for consideration, modeled after New York State's efforts.[xxxiv]

### ESTABLISH OFFSHORE WIND PORT INFRASTRUCTURE

Offshore wind requires significant port infrastructure to stage and construct turbines. In the summer of 2020, Governor Cuomo of New York announced a $400 million private and public investment in offshore wind port infrastructure to support the burgeoning industry and increase economic development, especially for disadvantaged and low-income communities.[xxxv] Port investment is an opportunity for continued offshore wind development and high-quality unionized job creation, and should complement any state or regional plan to scale offshore wind deployment. Executive offices of other coastal states can make similar investment decisions.

## CONCLUSION

Offshore wind is poised to become an abundant, low-cost, high-value zero-emissions energy source to help meet midcentury climate goals. Policy and technology advancements will make offshore wind lower cost as well as technically feasible in deeper waters. Policy support can reduce barriers and send a strong market signal for industry investment; some jurisdictions are already reaping benefits from these actions.

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