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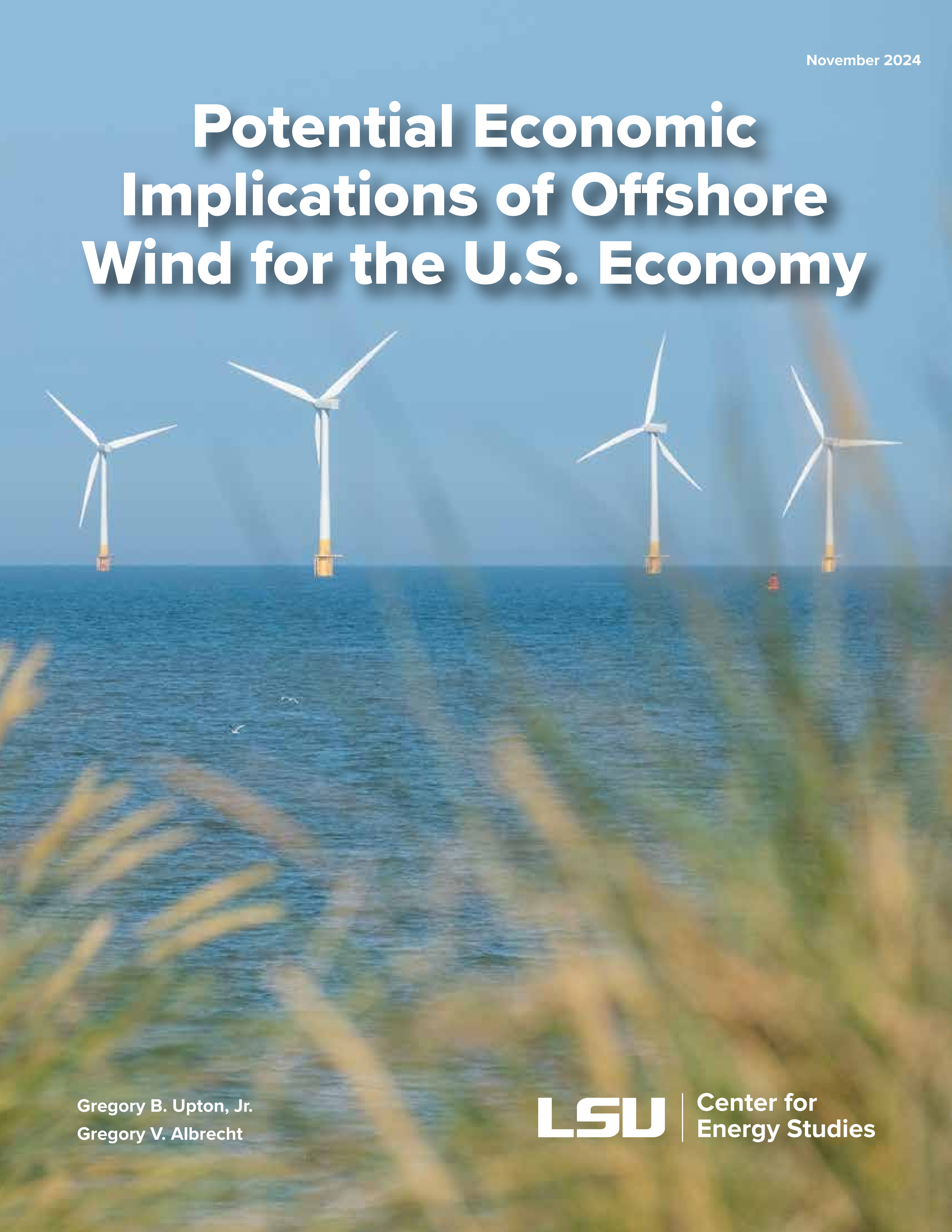
Potential Economic Implications of Offshore Wind for the U.S. Economy



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The Louisiana State University Center for Energy Studies (LSU-CES) was created by the Louisiana Legislature in 1982 with the stated mission of conducting, encouraging, and facilitating research and analysis to address energy-related problems or issues affecting Louisiana's economy, environment, and citizenry. The Center's goal is to provide a balanced, objective, and timely treatment of issues with potentially important consequences for Louisiana.

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Citizens For Responsible Energy Solutions (CRES) Forum commissioned LSU-CES to assess the economic impacts of scenarios for a National Offshore Wind Build-Out for the U.S. economy. CRES Forum was given the opportunity to review and provide feedback on this report. The analysis and opinions expressed are those of the authors alone.

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Executive Summary

In this analysis, we estimate the labor market implications of a potential build-out of offshore wind (OSW) in the United States. We consider two OSW build-out scenarios; (1) the 2023 Annual Energy Outlook (AEO) produced by the U.S. Energy Information Administration (EIA) ("AEO Scenario") and (2) the 2023 Standard Scenarios Report by the National Renewable Energy Laboratory (NREL) ("NREL Scenario"). Results of this report are summarized as follows:

- By 2050, AEO and NREL Scenarios project 23 gigawatts (GWs) and 52 GWs, respectively, of offshore wind capacity will be constructed in the U.S.
- Capital expenditures for the AEO and NREL Scenarios are estimated to be $63 billion and $142 billion, respectively, in 2024 dollars.
- Over the next decade, OSW construction is estimated to support an annual average of over 43,000 to over 80,000 total jobs per year in the respective scenarios.
- On a net present value basis, construction is estimated to support $18.5 billion to $42.3 billion in earnings, and $34.4 billion to $78.7 billion in Gross Domestic Product, discounted at four percent.
- Once fully operational, an estimated 33,000 to 73,000 jobs will be supported nationwide annually. This is estimated to support $1.9 billion to $4.3 billion in earnings per year, and $3.3 billion to $7.4 billion of GDP per year (in 2024 dollars).
- In total, inclusive of construction and operations, OSW under these scenarios is estimated to support a net present value, at a 4 percent discount rate, of $38.6 billion and $91.1 billion in earnings for the AEO and NREL scenarios, respectively.

1. Introduction

The purpose of this report is to estimate the economic impacts of the construction and yearly operations and maintenance (O&M) of a potential build-out of offshore wind (OSW) in the U.S. Such a build-out can have important implications for the future competitiveness of an economy, as companies are increasingly balancing access to affordable energy with the carbon intensity of these energy sources when deciding where to make investments. For example, companies as diverse as American Express, Apple, and General Motors have goals to reduce their emissions.

Three stylized facts are becoming increasingly relevant to companies as they consider where to expand and continue operations into the future.

First, U.S. energy demand has been relatively flat over the past decade, and this trend is expected to continue (EIA 2024a, 2023a). On one hand, economic growth increases energy demand. On the other, efficiency reduces energy demand. In net, in the U.S. these two effects are approximately in balance. More specifically, comparing 2013 to 2023 (the most recent year of data available), total British thermal units (Btus) of energy used in the U.S. economy were approximately 1 percent lower than a decade ago (EIA 2024a). Over this same time period, real GDP had grown by over 60 percent, or at approximately five percent annualized growth rate (World Bank 2024).

Second, though, electricity consumption specifically is projected to grow both in absolute terms and as a share of total energy usage[1] (EIA 2023c; Zhou and Mai 2021). For example, data centers, especially with the advent of Artificial Intelligence (AI) being incorporated into common user applications, are significant electricity users (EPRI 2024).

Third, access to low cost hydrocarbon based feedstocks and electricity has been facilitated by exports of hydrocarbon-based products, including liquid fuels, chemical products, fertilizers and polymers. Increasingly, companies are indicating that their customers from around the world are asking to (1) credibly document lifecycle emissions and (2) reduce emissions. Investors, again from all over the world, are increasingly considering the carbon intensity when deciding where to deploy capital as part of Environmental and Social Governance (ESG) plans. In other words, decarbonization and growth of these historically fossil fuel based sectors are not necessarily substitutes; the two indeed can complement one another if done deliberately and intelligently.

To attract capital and sustain demand, manufacturers of all types are balancing two objectives: First, companies must remain cost competitive. If they invest too heavily in reducing emissions, their products could become too expensive and consumers will choose to purchase lower cost products instead. But second, companies also seek competitive emissions profiles. If the manufacturing sector ignores this call to decarbonize, and exclusively focuses on cost, the sector might also find itself at a competitive disadvantage in the future. Large companies across sectors, from Shell and Exxon to Apple and Google, are advertising products as low emissions intensity.

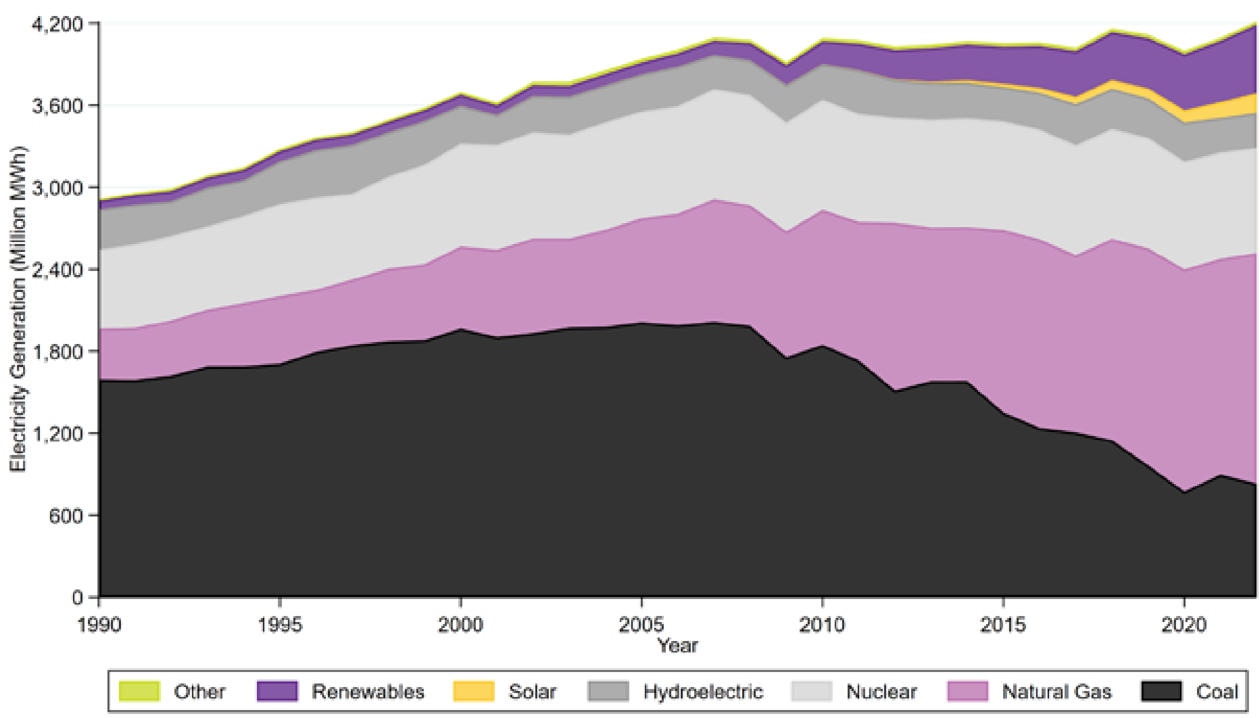
[1] The 2023 Annual Energy Outlook Reference Case projects that consumption of purchased electricity will increase by 22 percent from 2024 to 2050, growing from 17.9 percent to 20.4 percent of end-use energy consumption.

1.1 History and Potential Future of Wind Generation in the U.S.

Figure 1 shows the share of electricity generated by source in the U.S. since 1990. Renewable electricity generation has grown considerably in the U.S. over the past three decades, and in 2023, made up approximately 21 percent of the U.S. power generation (EIA 2024b).[2] For perspective, in the year 1990, renewable generation made up just 12 percent of U.S. generation, and hydro power was the largest source of this, making up 82 percent of total renewable generation (EIA 2012). In the most recent full year of data, 2023, wind generation[3] is the largest source of renewable electricity generation, making up 48 percent of renewable electricity generated or about 10 percent of total U.S. power generation (EIA 2024b).

Emissions intensity of the grid has also reduced considerably during the last decade. In 2013, 535 kg of CO_2 were emitted for each megawatt-hour (MWh) of electricity produced. In 2021, 402 kg were emitted per MWh, a reduction of 25 percent in less than a decade (EIA 2022).[4] Note that these emissions reductions can be attributed to multiple factors including the growth of renewables and natural gas, shifting away from coal[5], and efficiency improvements as older power plants are phased out for more modern technologies.

Figure 1: Electricity generation by source



Note: "Renewables" includes wind, geothermal, landfill gas, and biomass.

To date, essentially all U.S. wind generation has come from onshore wind. While electric power generation from onshore wind facilities has been growing as a share of total electric power generation

[2] Renewable electricity includes wind, hydropower, solar, landfill gas, biomass and geothermal sources. Note that Figure 1 displays solar and hydroelectric energy separately from other renewable sources.

[3] This wind generation is almost exclusively onshore.

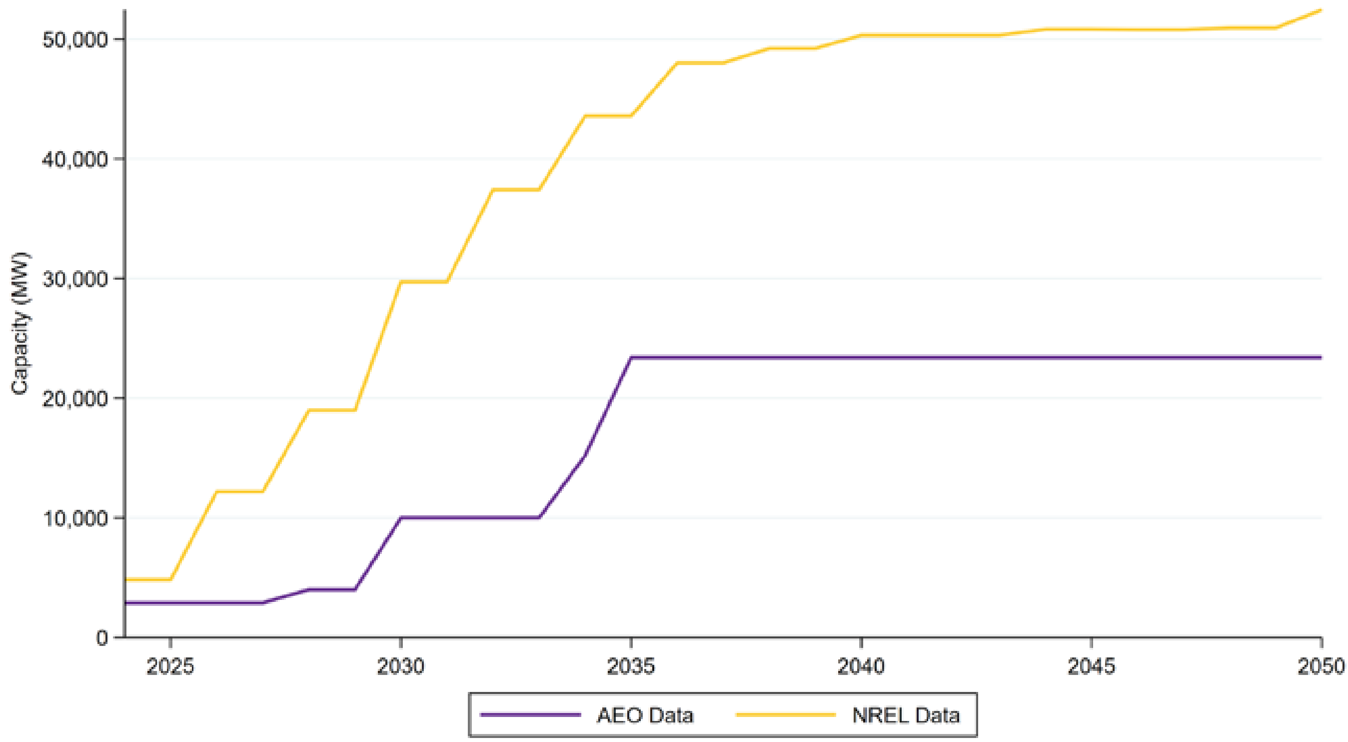
[4] Comparison of 2013 and 2021 tables of CO emissions per MWh for total United States.

[5] Coal has about twice the CO emissions intensity of natural gas (EIA 2023d).

for over a decade, offshore wind generation in the United States is still in its early stage of development. At the time of this writing, there is just 173 megawatts (MW) of operating offshore wind capacity in the United States. This comes from just three facilities.[6]

This analysis will consider two potential scenarios for offshore wind (OSW) build-out. The capacity build-out of these two scenarios are shown in Figure 2.

Figure 2: Offshore wind capacity build-out by scenario.



AEO Scenario

The first scenario will be based on the Annual Energy Outlook (AEO) produced each year by the Energy Information Administration (EIA) (EIA 2023b). This will be referred to as the "AEO Scenario." The 2023 AEO was produced in March of 2023. Note that in the current year (2024), no AEO will be produced by EIA as it is in the process of doing an overhaul of its modeling framework to more accurately account for hydrogen, carbon capture, and other emerging technologies (EIA 2023e).

As shown in Figure 2, the AEO Scenario projects 23 GW of offshore wind will be built out by 2035.[7] This build-out is estimated to cost approximately $63 billion in 2024 dollars.

NREL Scenario

The second scenario is based on the 2023 Standard Scenarios Report by the National Renewable Energy Laboratory (NREL). This report was originally published in December 2023 and has been revised in January 2024.

[6] Coastal Virginia Offshore Wind Pilot Project (12 MW), Block Island Wind Farm in Rhode Island (29 MW), and South Fork Wind in New York (132 MW).

[7] AEO's scenarios do extend to 2050, but there is no offshore wind build-out in their scenario past 2035.

The National Energy Modeling System (NEMS) is the core tool behind the EIA's AEO projections. It models U.S. energy markets through 2050, and incorporates various factors including economic conditions, global energy markets, resource availability, technological progress, and demographics. The model generates yearly equilibrium solutions for U.S. energy supply and demand. The NREL's Standard Scenarios are generated using the Regional Energy Deployment System (REDS) model. This model forecasts how the utility-scale electricity sector will develop across the contiguous U.S., and employs a comprehensive, cost-minimizing strategy while adhering to policy requirements and operational limitations.

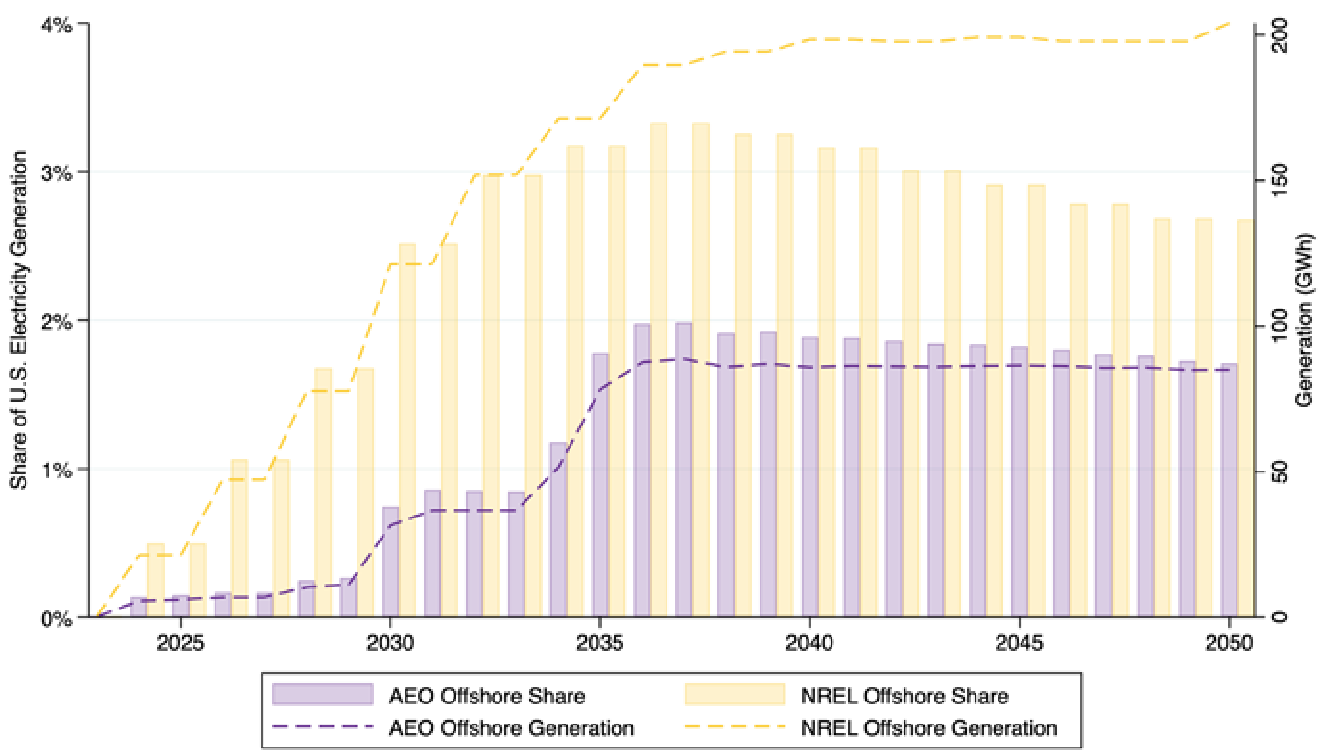
The NREL Scenario projects 44 gigawatts (GW) of offshore wind capacity by 2035, and 52 gigawatts (GW) of offshore wind capacity by 2050. This build-out is estimated to cost approximately $142 billion in 2024 dollars.

Scenarios in Perspective

Analysis of Figure 3 provides some perspective on these two potential OSW build-out scenarios by showing the projected offshore wind generation as a share of total generation for each of the OSW build-out scenarios considered in this analysis.

As shown in Figure 3, the AEO Scenario projects that offshore wind will contribute nearly 2% of its projection of total electric power generation by the year 2036. The NREL Scenario projects that offshore wind will contribute nearly 3% of its projection of total electric power generation by the year 2032. Thus, the NREL scenario considers a faster, and ultimately larger, OSW build-out than the AEO.

Figure 3: Projected offshore wind generation in the United States



2. Methodology

2.1 Economic Impacts

The purpose of this report is to estimate the economic impacts of the construction and yearly operations and maintenance (O&M) of a potential build-out of offshore wind (OSW) in the U.S. As discussed in Section 1.1, we consider two build-out scenarios of annual utility-scale offshore wind megawatt additions projected to the year 2050. The first scenario is the reference case contained in the U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook (AEO) of 2023.[8] This is referred to as the "AEO Scenario."

The second scenario is the mid-case scenario made by the National Renewable Energy Laboratory (NREL) in its 2023 Standard Scenarios Report: A U.S. Electricity Sector Outlook. This is referred to as the "NREL Scenario." We consider a range of impacts based on these two scenarios, with the AEO projection and impact estimates roughly half the projection and impact estimates of the NREL Scenario. Unless stated otherwise, results presented in sequential order will reference the AEO and NREL Scenarios respectively.

To estimate the economic impacts of the construction and yearly O&M of a National Offshore Wind Build-Out, we first utilize the Jobs and Economic Development Impacts (JEDI) Offshore Wind model (NREL 2021). JEDI is developed and maintained by the National Renewable Energy Laboratory (NREL), a national laboratory supported, in part, by the Department of Energy. The JEDI offshore wind model provides a detailed breakdown of cost categories associated with offshore wind projects, and provides a cost structure of a representative offshore wind facility, both in terms of construction and operations.

These build-out scenarios are then distributed across time where the construction begins two years before capacity comes online. Construction expenditures are allocated over the construction time period[9] that generates a cumulative percent of expenditures to each month of construction.[10] The distribution of expenditures per megawatt is then applied to the build-out projections of the AEO and NREL scenarios to generate annual capital construction expenditures associated with each build-out scenario. Annual operational expenditures and megawatts accumulate as the build-out capacity comes online over the projection horizon.

Utilizing the cost structure from NREL's JEDI model alongside the build-out scenarios, we next utilize the Regional Input-Output Modeling System (RIMS II) to estimate economic impacts. RIMS II was created and is maintained by the Bureau of Economic Analysis (BEA), part of the U.S. Department of Commerce. RIMS II is an input-output (I-O) model that is based on a detailed set of industry accounts that measure the goods and services produced by each industry. Large underlying datasets trace the flow of goods and services throughout the economy to final users. RIMS II is considered a backward linkages model, in that an increase in demand for an output results in an increase in demand for the inputs needed to create that output.

[8] A 2024 version of the AEO was not produced as the agency updates its modeling methodology. The AEO will next be published in 2025.

[9] This is conducted based on the "overnight cost" literature. Overnight cost refers to the estimated cost to complete an OSW project "overnight". This calculation allows for direct comparison of costs across projects that occur in heterogeneous economic environments (Dismukes and Upton 2015).

[10] We model construction at the monthly level and then aggregate to calendar years for purposes of estimating economic impacts and presenting results.

Both “Type I” and “Type II” multipliers are provided by RIMS II. Type II multipliers account for both the inter-industry and household spending of a final demand-change. Type I multipliers account for only the inter-industry effect. Thus, Type II multipliers, by definition, are larger than Type I multipliers. Utilizing these multipliers, we can further dissect economic impacts into “Direct,” “Indirect,” “Induced,” and “Total” impacts, where total impacts are identical to RIMS II Type II multipliers, and Direct + Indirect impacts are identical to RIMS II Type I multipliers.

We estimate impacts on employment, earnings, and value added. Employment includes counts of workers at establishments that employ workers in relevant sectors. Earnings (synonymous with “labor income”) include wages and salaries, proprietors’ income, and employer contributions to insurance, pensions, and social insurance. Value added represents the contribution to gross domestic product (GDP), and earnings are a major component of value added. We utilize the study area of the United States in total. Horowitz and Planting (2009) provides more detailed information on RIMS II and interpretation of the multipliers.

Economic Impact Analysis

Economic impact modeling tools were pioneered by Wasily Leontieff, who was awarded the Nobel Memorial Prize in Economic Sciences in 1973. The goal of this report is to estimate the national economic impacts that will be associated with a build-out of offshore wind in the United States. Offshore oil and gas workers will be particularly well positioned to take advantage of these economic opportunities, as many of the skills needed to service an offshore wind farm are similar to the skills already utilized in servicing offshore oil and gas operations, such as ship operation and marine welding (Baurick, 2021). Offshore wind will generate direct, indirect, and induced economic impacts.

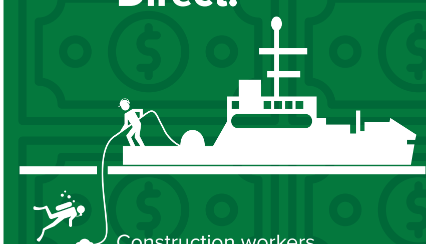
Direct — Direct effects refer to the initial change in economic activity of interest.

Indirect — Indirect effects describe the subsequent rounds of inputs purchased by supporting industries located in the study area.

Induced — Induced effects then consider the spending of workers whose earnings are affected by the economic activity. This is sometimes referred to as the household spending effect.

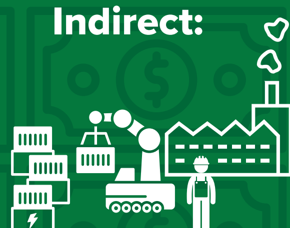
Total — The sum of the direct, indirect, and induced effects.

Direct:



Construction workers install transmission cable in sea floor.

Indirect:



Electrical equipment manufactured.

Induced:

Construction workers and manufacturing workers buy groceries at local supermarket and send children to local schools.

3. Results

3.1 Economic Impacts

Economic impacts are presented for the AEO and NREL scenarios for the study area of the United States. For each scenario, construction impacts are presented, as well as operations and maintenance (O&M) impacts as the build-outs become operational over time. Estimated impacts are broken down into direct, indirect, induced, and total, for employment, labor earnings, and value added.

Construction Impacts

Table 1 shows estimated economic impacts during the construction phase of the build-outs. The table shows economic impact estimates for the entire continental United States, based on the respective build-out scenarios analyzed. Nationwide, approximately 43,000 to 80,000 jobs per year will be supported during the years of construction. In aggregate, construction will support $18.5 billion to $42.3 billion in labor income and earnings, and $34.4 billion to $78.7 billion of U.S. Gross Domestic Product. The comparative employment results are also depicted graphically (Figure 4).

Figure 4: Comparison of offshore wind construction employment

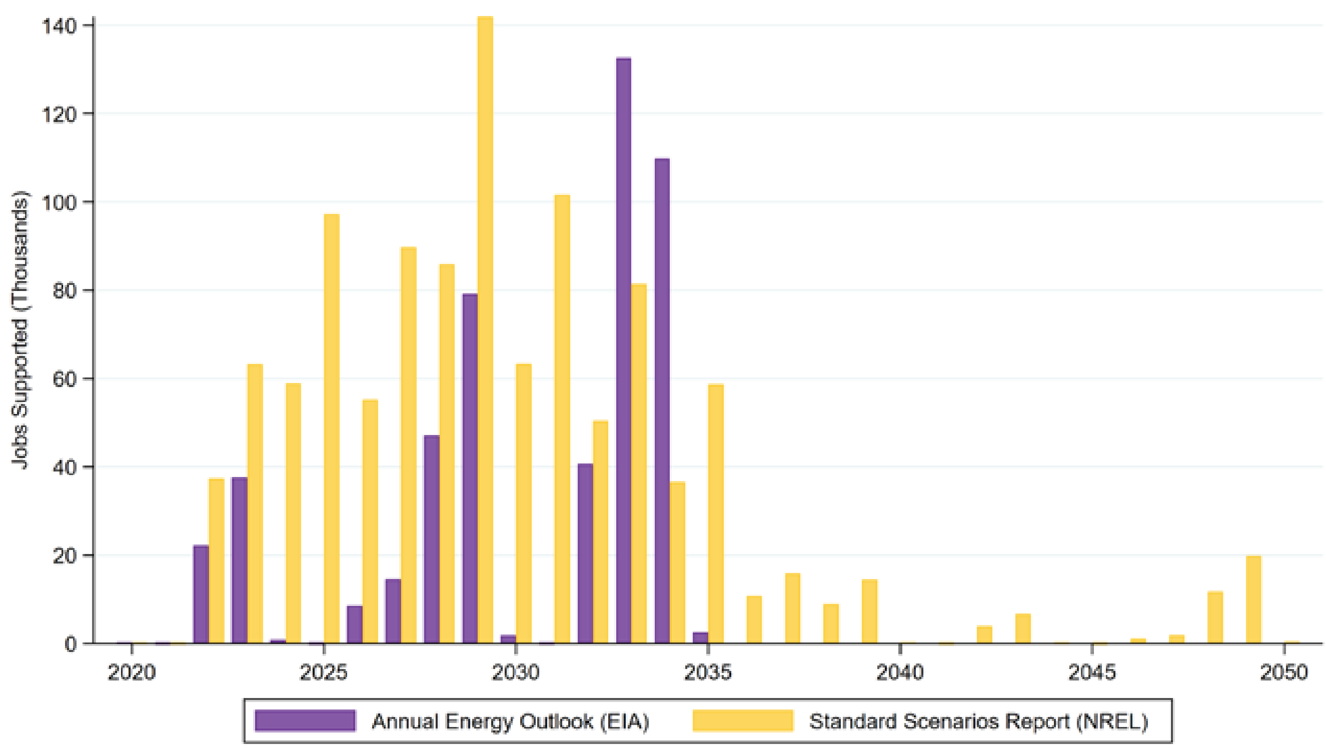


Table 1: Economic impacts of construction of a national offshore wind build-out

	(1) Average Annual Employment (Jobs)	(2) Earnings (billions $)	(3) Value Added (billions $)
Panel A: AEO Scenario			
Direct	14,400	$6.1	$12.3
Indirect	11,400	$5.7	$8.9
Induced	17,700	$6.8	$13.2
Total	43,500	$18.5	$34.4
Panel B: NREL Scenario			
Direct	26,500	$13.9	$28.2
Indirect	21,200	$13.0	$20.3
Induced	32,700	$15.4	$30.2
Total	80,400	$42.3	$78.7

RIMS II release of May 2024 and authors' calculations. Employment is the annual average over the first ten years of construction. Earnings and Value Added in billions of dollars discounted at 4% over the entire projection period. Discrepancies in totals might arise due to rounding.

Ongoing Impacts

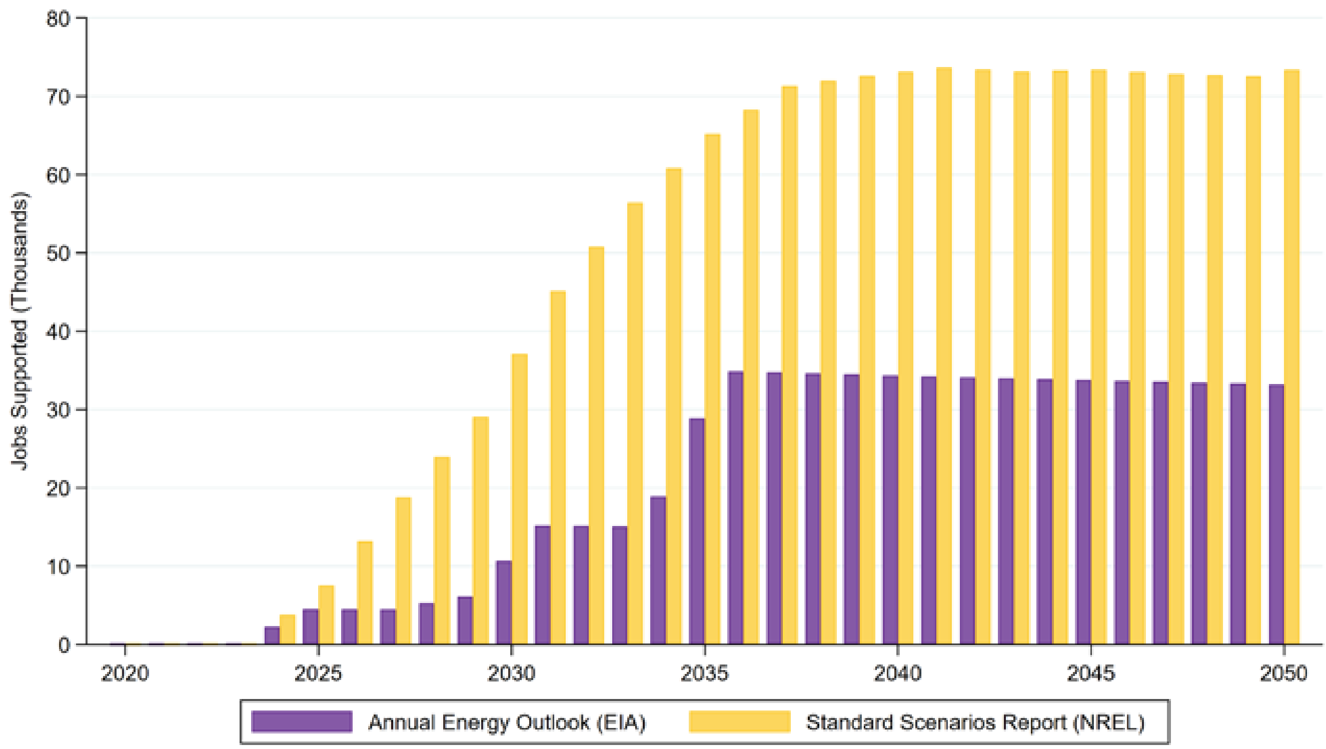
Table 2 shows economic impacts as the build-outs become operational. Nationwide, the operations will support approximately 33,000 to 73,000 jobs per year, once the respective projected build-outs are complete. Labor earnings of approximately $1.9 billion to $4.3 billion per year will also be supported, as will approximately $3.3 billion to $7.4 billion in U.S. Gross Domestic Product. The comparative employment results are also depicted graphically (Figure 5).

Table 2: Annual economic impacts of national offshore wind build-out once all capacity operational

	(1) Average Annual Employment (Jobs)	(2) Earnings (billions $)	(3) Value Added (billions $)
Panel A: AEO Scenario			
Direct	11,100	$0.7	$1.0
Indirect	6,600	$0.4	$0.8
Induced	15,500	$0.8	$1.5
Total	33,200	$1.9	$3.3
Panel B: NREL Scenario			
Direct	24,400	$1.6	$2.3
Indirect	14,600	$1.0	$1.7
Induced	34,300	$1.7	$3.4
Total	73,400	$4.3	$7.4

RIMS II release of May 2024 and authors' calculations. Direct employment, earnings, and value added were reduced by 1% per year over the projection horizon to account for historical efficiency gains in the electric power sector of the economy. Earnings and Value Added in billions of current dollars. Discrepancies in totals might arise due to rounding.

Figure 5: Comparison of offshore wind O&M employment



Next, we aggregate economic impacts from construction and O&M. Historically, the number of jobs per million MWh of generation in the electric power generation sector of the economy has declined approximately 1% per year.[11] This decline rate was incorporated into the direct employment, earnings, and value estimates of this analysis.

Table 3 presents labor earnings and value added impacts, at different discount rates[12], for the construction and operations activity combined. With zero discounting, that is, without taking into account the time value of money, the total estimated earnings associated with a National Offshore Wind Build-Out range from $62.4 billion to $142.5 billion over the projection horizon, and total estimated value added range from $110 billion to $251 billion. However, at varying discount rates reflecting the time value of money, the NPV of these earnings in the future is diminished as reflected in the table, with a greater effect as the discount rate increases.

[11] Jobs per million MWhs of electricity generation were calculated for the Electric Power Generation, Transmission, and Distribution (NAICS 2211) sector for the years 2001 through 2023. Source data from the Energy Information Administration and the Bureau of Labor Statistics (BLS 2024).

[12] The discount rate represents the tradeoff between payments made today versus in the future. A higher discount rate suggests that a dollar spent today is significantly more valuable than a dollar spent in the future.

Table 3: Total earnings supported by construction and operations of a national offshore wind build-out

	(1) AEO Total Earnings (billions $)	**(2) NREL Total Earnings** (billions $)
Panel A: Earnings		
No Discounting	$62.4	$142.5
2% Discount Rate	$48.6	$112.6
4% Discount Rate	$38.6	$91.1
6% Discount Rate	$31.3	$75.4
8% Discount Rate	$25.8	$63.5
Panel B: GDP		
No Discounting	$110.0	$250.7
2% Discount Rate	$85.9	$198.7
4% Discount Rate	$68.5	$161.4
6% Discount Rate	$55.7	$134.0
8% Discount Rate	$46.0	$113.3

Reflects net present values over 26 years in billions of dollars. Total impacts includes the sum of direct, indirect, and induced earnings.

We note that many factors will impact these estimates including without limitation changes in energy policy, economy-wide economic growth, actual capacity added and operated, and various other national and world economic conditions and policies. These are the authors' best estimates based on the build-out projections of the AEO and NREL. Actual future economic impacts may be lower or higher than those estimated here. Full knowledge and understanding of the data and assumptions used to calculate these estimates should be considered.

Average Annual Pay | Selected Jobs | United States

Heavy construction

$90,700

Specialty trade

$71,600

Professional and technical services

$121,300

Fabricated metal manufacturing

$70,100

U.S. median annual wage: **$48,000**

Source: U.S. Bureau of Labor Statistics. Quarterly Census of Employment and Wages. Private workers. United States. 2023.
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4. Conclusions

Over the next decade, OSW construction is estimated to support an annual average of over 43,000 to over 80,000 total jobs per year in the AEO and NREL scenarios, respectively. On a net present value basis, construction is estimated to support $18.5 billion to $42.3 billion in earnings, and $34.4 billion to $78.7 billion in Gross Domestic Product, discounted at four percent. Once fully operational, an estimated 33,000 to 73,000 jobs will be supported nationwide annually. This is estimated to support $1.9 billion to $4.3 billion in earnings per year, and $3.3 billion to $7.4 billion of GDP per year (in 2024 dollars). In total, inclusive of construction and operations, OSW under these scenarios is estimated to support a net present value, at a 4 percent discount rate, of $38.6 billion and $91.1 billion in earnings for the AEO and NREL scenarios, respectively.

While offshore wind energy is early in its U.S. development, consideration of the carbon intensity of power generation is increasing, and there are a number of federal tax and funding incentives available to facilitate a build-out of capacity over the future. The AEO and NREL project a future build-out, and economic impact analysis of each scenario indicates that development of the industry can support a substantial number of jobs, earnings, and overall domestic product within the U.S., during construction itself and from operations of the built-out capacity.

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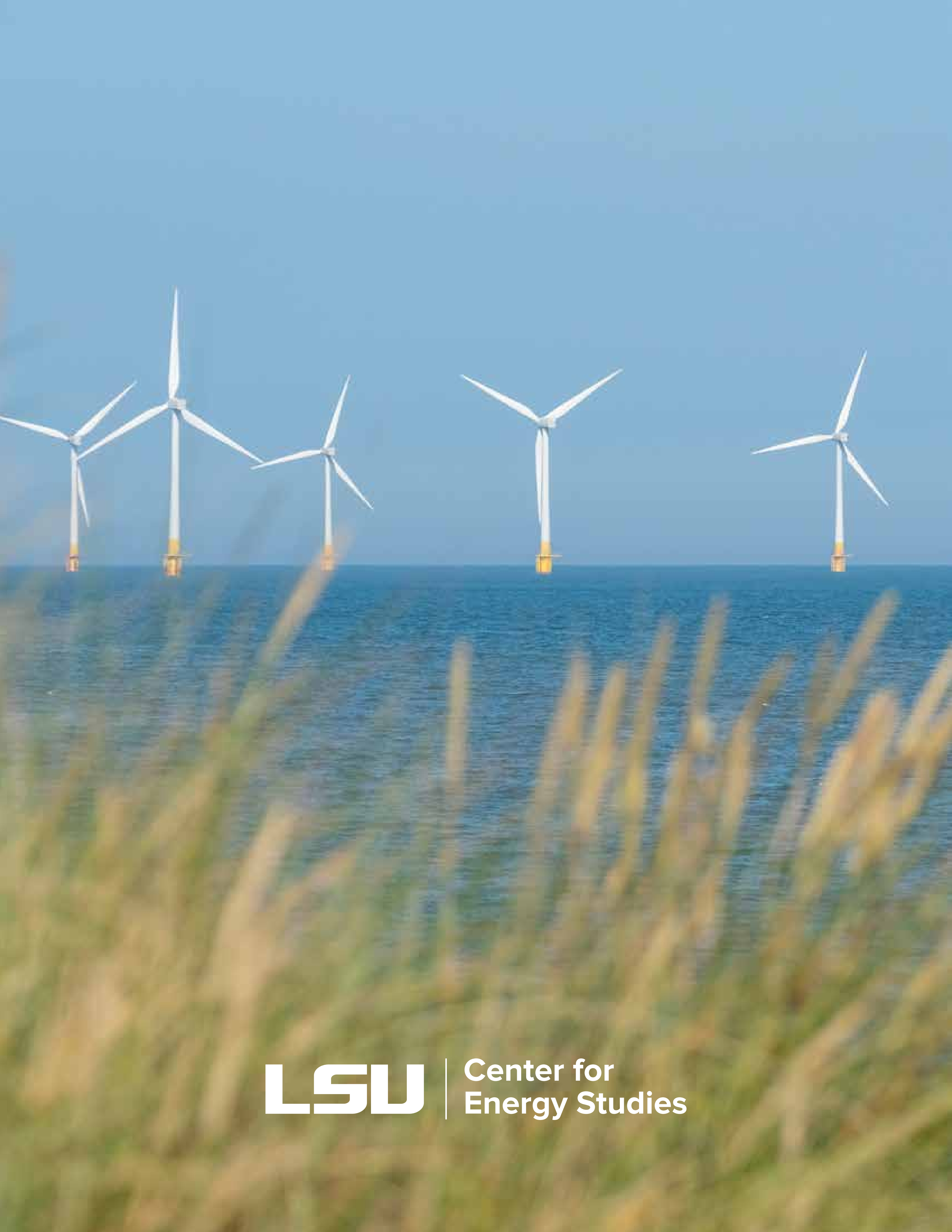

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