South Carolina
Offshore Wind Economic Impact Study
Phase 2

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Prepared for the
South Carolina Energy Office

May 2014
Revised August 2014

COASTAL CONSERVATION LEAGUE

CLEMSON
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ACKNOWLEDGMENTS

The economic and fiscal analyses in this report were performed by the Strom Thurmond Institute and supported by the U.S. Department of Energy under Award Number DE-EE0003884, CFDA #81-041. The electric rate analyses were performed by the South Carolina Coastal Conservation League (CCL) and supported by an in-kind contribution from CCL. The authors thank the following individuals and organizations for their assistance with this work: Trish Jerman, South Carolina State Energy Office ; Hamilton Davis, South Carolina Coastal Conservation League; Elizabeth A. Kress, Santee Cooper; Brian O'Hara, Southeastern Coastal Wind Coalition; and U.S. Department of Energy.

Errata: In the May 2014 version of this report the electric rate impact analysis results contained errors related to mixed use of constant and current dollar values. This version has been corrected to base all calculations on constant 2012 dollars. For a detailed listing of changes please see Appendix B.

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KEY FINDINGS

The purpose of this project is to assess the economic impact of installation and operation of a demonstration scale offshore wind farm on the state of South Carolina. This work involved two main tasks, an economic and fiscal impact analysis and an electric rate impact analysis.

Economic and Fiscal Impact Analysis

First, we estimated the economic and fiscal impact of the construction and operation of a 40 MW offshore wind farm on the state of South Carolina. This work involved estimating the impact of wind turbine and component manufacturing and construction of the wind farm in 2016, and then estimating the impact of wind farm operations and maintenance from 2017 to 2036.

CONSTRUCTION AND COMPONENT MANUFACTURING

During installation of the wind farm in 2016, some of the turbine components for 40 MW of electric power generating capacity will be manufactured in South Carolina. Construction, transportation, and engineering jobs will also be created. This activity will generate an estimated one-year economic impact on the state of South Carolina as follows:

- ✓ 959 total jobs (direct, indirect, and induced)
- ✓ $46.3 million in wages
- ✓ $148.4 million in output
- ✓ An increase in net revenue to local governments (aggregated) of $1.1 million and to state government of $2.4 million

OPERATIONS & MAINTENANCE

The post-construction (2017-2036) average annual economic impact to the state of wind farm operation and maintenance (O&M) activities is estimated to be:

- ✓ 10 total jobs (direct, indirect, and induced)
- ✓ $934,000 in wages per year
- ✓ $2.8 million in output per year
- ✓ A slight decrease in net revenue to local governments (aggregated) of $107,000 per year and to state government of $115,000 per year due to a projected increase in demand for services and infrastructure by new residents and businesses

Electric Rate Impact Analysis

Next, we estimated how the capital cost of the offshore wind farm and electric power generation from the wind farm might affect electric rates. This work included cash flow modeling of the construction, financing, and O&M costs of a 40 MW offshore wind facility. It also included simulations of utility system production costs with and without the wind farm to estimate avoided production costs.

The estimated total capital recovery and O&M cost each year of the wind farm's expected lifetime is $28.6 million when subsidies are excluded. The wind farm will avoid an estimated $6.3 million in annual production costs initially, and these annual cost savings will grow to $10.5 million by the end of the facility's life. These project costs and benefits are estimated to result in average electric bill impacts to South Carolina households and businesses as follows:

- ✓ 0.3% bill increase of $0.42 per month for residential customers
- ✓ 0.3% bill increase of $1.32 per month for commercial customers
- ✓ 0.1% bill increase of $43.45 per month for industrial customers
- ✓ A joint Carolinas or South Carolina-Georgia project could reduce South Carolina bill impacts by more than one-half.

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Background

The purpose of this project is to assess the economic impact of a demonstration scale offshore wind farm on the state of South Carolina. To do so, we completed two main tasks.

First, we estimated the current and potential economic impact on the state from the construction and operation of a 40MW offshore wind farm, including impacts on output, employment, wages and salaries, disposable income, and state and local government revenues. One year of construction is proposed for 2016 followed by 20 years of operation through the year 2036.

Second, we estimated the offshore wind farm's net impact on electric rates. This work took into consideration the financing of wind farm construction costs over 20 years, as well as the anticipated costs of operating conventional generating facilities, some of whose output would be offset by power from the offshore wind farm.

The estimated economic and rate impacts of the construction and operation of a 40MW wind farm off the coast of South Carolina will provide wind energy stakeholders with data useful to advance private and public sector efforts to install utility-scale wind energy production off the state's coast.

This project builds on work done in a 2012 study, *South Carolina Wind Energy Supply Chain Survey and Offshore Wind Economic Impact Study*.[1] Findings from this study are summarized below.

[1] Elizabeth Colbert-Busch, Robert T. Carey and Ellen Weeks Saltzman, *South Carolina Wind Energy Supply Chain Survey and Offshore Wind Economic Impact Study*. Prepared for the South Carolina Energy Office. Clemson University Restoration Institute and Strom Thurmond Institute, July 2012. http://sti.clemson.edu/notices-and-news/901-sc-wind-energy-economic-impact.

2012 SC Wind Energy Supply Chain Survey

The 2012 South Carolina wind energy supply chain survey revealed that the state is a well-defined part of the nation's wind energy supply chain. The survey identified 33 firms that had a total of 1,134 employees (14 percent of total firm employment) working part or all of their time on wind energy component production or services. Five additional firms had employees in the wind supply chain, but not in their South Carolina facilities.

In 2012, wind energy specific employment in the state included:

- Manufacture of wind energy components (8 firms)
- Engineering services (6 firms)
- Other consulting services such as site selection, regulatory and permitting (6 firms)
- Construction management (3 firms)
- Land and/or marine transportation (3 firms)

In most respondent firms, wind energy related employment was generally limited to one or a few individuals. Only five of the 33 firms reported 50 or more employees in wind energy related production or services.

Primary NAICS and/or SIC codes also were used to classify firms in the South Carolina wind energy supply chain by their primary activities. When viewed by primary industry code, supply chain activities are dominated by professional, scientific and technical services (13 firms), and manufacturing (9 firms) (Table 3).

Over three primary areas—capital investment, employment, and products and services—the future South Carolina business plans of respondent firms were very positive. For capital investment, 84 percent of firms expected to either increase capital investment from current levels or keep it about the same. These firms also were highly positive about their firms' future plans for employment and business activities in South Carolina. In both areas, 95 percent of respondents expected their firms to either maintain or increase activity over current levels.

The South Carolina wind energy supply chain survey revealed that the state is well positioned to benefit from increases in the domestic and foreign demand for wind energy specific production and services.

Economic Impact Analysis of the SC Wind Energy Supply Chain

Data from the 2012 South Carolina wind industry supply chain survey were used to estimate the economic and fiscal impact of the existing wind energy supply chain in South Carolina. This impact estimate is based solely on the data provided by survey respondents. As such, these impact estimates reported are likely conservative.

Inputs to the model are the number of in-state employees each firm reported who spend part or all of their time working on wind-related projects, along with their total wages or salaries. Employment was categorized by 5-digit NAICS industry sector for modeling purposes. All estimates are presented in 2012 constant dollars.

Supply Chain

South Carolina's wind energy supply chain made a strong contribution to the state's economy in 2012. Survey respondents reported 1,134 direct jobs in wind energy production or service provision. These direct jobs generated a total estimated jobs impact of 2,931 jobs statewide in 2012 (Table 1).

The supply chain's estimated total jobs impact indicates a jobs multiplier of approximately 2.6 for the supply chain. In other words, every job in wind energy in South Carolina generates an estimated additional 1.6 jobs in the state through indirect and induced effects. Firms have the strongest employment impact on the multicounty regions in which they are located. In South Carolina, wind energy employment is located primarily in the Upstate, Midlands, and around Charleston County.

South Carolina's wind energy supply chain contributed an estimated $146.5 million in wages paid to employees in the state in 2012 (including direct, indirect and induced jobs). This money is spent on goods and services, which helps support other economic activity in South Carolina and provides tax revenues to the state and its local governments.

Table 1
Estimated Impact of SC's Wind Energy Supply Chain 2012

	Impact
Employment (direct jobs only)	1,134 jobs
Employment (direct, indirect & induced jobs)	2,931 jobs
Total Compensation	$146.5 million
Total Output	$530.2 million
Net State Government Revenue	$29.3 million
Net Local Government Revenue	$21.1 million

1,000 MW Offshore Wind Farm

The model used in the 2012 analysis assumed a 40 megawatt (MW) offshore wind farm constructed in 2016 and beginning operation in 2017. Additional capacity was added yearly beginning in 2019, reaching a total of 1,000 MW in 2025. This large utility-scale wind farm was projected to have multiple years of economic impacts resulting from:

- Manufacture of turbine components in the state
- Construction of the offshore wind farm
- Operation and maintenance of the wind farm

Table 2 shows the average annual economic impact of construction and operation of the wind farm over its 10 year build out period.[2] Employment and other economic impacts are relatively high because each year beginning in 2017 the state is receiving benefit from the in-state supply chain for components, construction activity, and O&M of installed

[2] The average economic impact per MW per year does not equal the impact per year divided by the number of MW because the number of MW installed and O&M varies from year to year.

turbines. Table 3 shows the much smaller average annual impact of O&M activity alone after the wind farm construction is complete.

Table 2.
Average Annual Economic Impact of Construction and Operation of 1,000 MW Offshore Wind Farm, 2016 to 2025

	Impact/Yr	Impact/MW/Yr
Total Employment*	3,879 jobs	29.6 jobs
Total Compensation	$196.3 million	$1.48 million
Output	$366.1 million	$2.68 million
Net Govt. Revenue	$61.6 million	$0.47 million

*Total estimated average annual employment.

Table 3.
Average Annual Economic Impact of O&M for a Fully Operational 1,000 MW Offshore Wind Farm, 2026 to 2030

	Impact/Yr	Impact/MW/Yr
Total Employment*	678 jobs	0.7 jobs
Total Compensation	$41.8 million	$41,800
Net Govt. Revenue	$115.2 million	$115,100
Total Employment*	$13.3 million	$13,300

*Total estimated average annual employment.

Economic & Fiscal Impact Analysis of a 40 MW Offshore Wind Farm

Below we estimate the economic and fiscal impacts of constructing and operating a demonstration-scale (40 MW) offshore wind farm on the state of South Carolina. Construction is assumed to take place during one year in 2016. The model then estimates the operation and maintenance (O&M) impact on the economy for the first twenty years of the farm's operational life, through the year 2036.

The Model

To estimate the economic and fiscal impacts on the state of South Carolina of construction and operation of a 40 MW offshore wind farm, we used the Policy Insight (PI+) economic modeling engine by Regional Economic Models, Inc. (REMI).[3]

PI+ is an Input-Output (I/O) and Computable General Equilibrium (CGE) based model. It is also a New Economic Geography (NEG) model that considers distance-to-market and transportation costs in determining the supply and demand of commodities across geographic regions.

Changes to employment, income, or demand for products or services by either the private or the public sector can be used as input to the model. Based on these inputs, the REMI model generates a county or multicounty level estimate of the resultant variation from the projected baseline (status quo), as well as the effects on every industry sector

The REMI model's economic impact estimates are stated using the following metrics. All REMI estimates include direct, indirect, and induced effects.

[3] http://www.remi.com

Employment is the number of jobs in the economy that are attributable to the operation and capital expenditures of firms involved in the actual production, construction, and operation and maintenance (O&M) of the wind farm.

Total Compensation is the change in aggregate income from wages and salaries (including fringes) paid by all firms in the state to workers employed in the state. Note that this includes wages paid to non-residents who work in-state and does not include wages earned by South Carolina residents who work outside of the state.

Output is the dollar value of all goods and services produced in the state in a given year. This is similar to regional gross domestic product (GDP), but is not limited to final goods.

Net state or local government revenue is the revenue to state, county and municipal governments throughout the state from all sources, including taxes, fees and intergovernmental transfers, less expenses.

Direct effects are the workers employed in the actual production, installation, and O&M of the wind farm, their wage income, and the involved firms' actual output.

Indirect effects are the jobs, wages, and output of second- and third-tier suppliers located within South Carolina.

Induced effects are the "ripples" expanding into the broader economy from the direct and indirect effects of spending of wage income by employees of the firm and its suppliers.

Model Assumptions and Data Sources

The model used in this analysis assumes a 40 megawatt (MW) wind farm constructed in 2016 and beginning operation in 2017. Estimated costs associated with this scenario assume:

- Offshore installation of 3 to 5 MW wind turbines
- 25 meter water depth at the site
- 100 miles between the site and the staging port
- 50 miles to electrical interconnection on land
- Less than 30 miles to the servicing port

Based upon data provided by Santee Cooper, one of South Carolina's primary electric utilities, the total installed cost of turbines in the modeled offshore wind farm is assumed to be $6.46 million per MW, or approximately $258 million for a 40 MW facility. [4]

The economic impact of spending on O&M is modeled through 2036 in order to capture the first twenty years of the operational life of the facility. All costs and impacts are reported in constant 2012 dollars. O&M cost assumptions are as follows:

- Fixed O&M costs are $66.16 per kW-year in the first year.
- Variable O&M costs are 0.73 cents per kWh in the first year.
- Fixed and variable O&M costs increase at a rate of 2 percent per year beginning in 2017 to account for replacement parts and general wear and tear on equipment.

Component Manufacturing and Installation

The wind turbine component portion of the model estimates the economic impact on the state from the production of individual wind turbine components. Each component's production was assigned to one of twelve NAICS sectors, which are shown in Table 4.

The offshore wind farm installation model estimates the economic impact of labor and port services, land and marine transportation, and other activities. Proportional cost estimates for each of the activities associated with wind farm installation were derived from the National Renewable Energy Laboratory's (NREL) Offshore Jobs and Economic Development Impact (JEDI) model and from data provided by Santee Cooper.[5]

[4] Per-MW costs may be lower in a commercial scale project due to economies of scale. For example, installed cost data from EIA for commercial scale offshore wind uses $5,539/kW for a 400 MW facility. See http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf, pp. 190-191.

[5] Bruce Hamilton, Eric Lantz, and Jay Paidipati, *Offshore Wind Jobs and Economic Development Potential: DOE Offshore Wind Assessment*, presented to Offshore

Given a total installed cost per MW of $6.46 million, the assumed percentage of in-state provision of services of each activity was determined using regional purchase coefficient tables and in consultation with industry sources (Table 5).

Operations and Maintenance Activities

The operations and maintenance activities model estimates the impact of ongoing wind farm O&M on the state. This model includes the impact from technician and engineering jobs and water transportation. It also contains a levelized estimate of replacement part costs. (Costs for replacement parts increase over time as turbines age.) The proportional cost of each of these O&M activities was extracted on a per-MW basis from the NREL Offshore JEDI model and from consultation with industry sources.

The total estimated cost of operations and maintenance activities per installed MW is estimated to be $88,500 in 2017, the first year of wind farm operation. This figure includes fixed and variable per-MW costs. For subsequent years, O&M costs are assumed to increase over the life of the wind farm at a rate of two percent per year.

The in-state share of replacement part manufacturing was estimated using the same method as the turbine components model. The in-state share of the services component of O&M was determined using regional purchase coefficient tables and in consultation with industry sources.[6] The NAICS sectors for O&M activities are presented in Table 6.

Wind Working Group (Golden, Colorado, National Renewable Energy Laboratory and Navigant Consulting, 2012); and NREL and Ocean & Coastal Consulting/COWI Group, offshore wind farm cost estimates provided to Santee Cooper, Moncks Corner, SC, 2012.

[6] Due to the nature of the types of parts required for maintenance we retained 38% as the local share in the O&M model for NAICS 33361.

Table 4. NAICS Sectors Used for Turbine Component Manufacturing (includes estimated share of in-state production)

NAICS Code	Description	Components	Local Share
32551	Paint and Coating Manufacturing	Coating	0%
32619	Other Plastics Product Manufacturing	Blades, Nacelle Cover	10%
32731	Cement Manufacturing	Foundation	77%
33151	Ferrous Metal Foundries	Hub, Isolation Mounts, Support Structure	0%
33231	Plate Work and Fabricated Structural Product Manufacturing	Tower	15%
33299	All Other Fabricated Metal Product Manufacturing	Bearing/Block	15%
33341	Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Mfg.	Cooling System	0%
33361	Engine, Turbine, and Power Transmission Equipment Manufacturing	Gearbox, Main shaft, Mounting System, Brake/Hydraulics, Coupling, Generator, Switchgear	25%
33451	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	Control/Safety	0%
33531	Electrical Equipment Manufacturing	Pitch/Bearings, Electronics, Yaw	25%
33592	Communication and Energy Wire and Cable Mfg.	Cable	10%
33599	All Other Electrical Equipment and Component Manufacturing	Transformer	0%

Table 5. Industry Sectors for Wind Farm Installation Model (includes estimated share of in-state production/employment)

NAICS Code	Description	Activity	Local Share
23493	Industrial Non-building Structure Construction	Foundation/Substructure Installation (Labor cost)	75%
23493	Industrial Non-building Structure Construction	Turbine Erection/Installation (Labor cost)	50%
55111	Management of Companies and Enterprises	Management (Labor cost)	75%
23499	All Other Heavy Construction	Collector System Installation	25%
23492	Power and Communication Transmission Line Construction	Grid Interconnection	75%
54	Professional Services	Engineering/Legal	50%
48831	Port and Harbor Operations	Ports/ Staging	75%
23499	All Other Heavy Construction	Erection/Installation (equipment services only)	25%
4831	Deep Sea, Coastal, and Great Lakes Water Transportation	Transportation	90%

Table 6. Industry Sectors for O&M Model (includes estimated share of in-state production/employment)

NAICS Code	Description	Activity	Local Share
54133	Engineering Services	Technician	90%
56111	Office Administrative Services	Administration	90%
55111	Management of Companies and Enterprises	Management	75%
483	Water Transportation	Water Transportation	90%
81131	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	Subcontractors	50%
33361	Engine, Turbine, and Power Transmission Equipment Manufacturing	Replacement Parts	38%
N.A.	Demand by Speculators for Equipment & Software	Facilities & Equipment	90%

Economic and Fiscal Impacts: Turbine Component Manufacturing & Installation

Table 7 shows the average annual economic impact on the state resulting from wind turbine component manufacture and turbine installation off the South Carolina coast. Results are reported in total dollars and dollars per MW of generating capacity installed.

For the proposed offshore wind farm, we assume that 40 MW of turbine components will be manufactured, purchased, and installed in one year, 2016. In that year this activity would generate about 959 total jobs in South Carolina (including direct, indirect, and induced), or about 24 jobs per MW of turbine components installed. The estimated output multiplier for manufacture and installation is 0.58; this means that 58 cents of every dollar invested in manufacture and installation of wind farm components would remain in South Carolina through direct investment and indirect and induced effects.

In terms of fiscal impact, the economic activity associated with production and installation of turbine components generates both revenue (by way of taxes, fees, and other sources) and costs (such as demand on infrastructure). The model estimates that the increase in state and local government revenues outweighs the increase in government costs associated with the activity.

Table 7
Average Annual Economic Impact of Turbine Component Manufacture & Installation, 2016

	Impact/Yr	Impact/MW/Yr
Total Jobs	959 jobs	24 jobs
Total Compensation	$46.3 million	$1.2 million
Output	$148.4 million	$3.7 million
Net State Revenue	$2.4 million	$60,450
Net Local Revenue	$1.1 million	$28,340

Local governments (aggregated) are projected to see a positive net impact on revenue of approximately $1.1 million in 2016. At the state level, estimated revenue impacts outpace the impact on expenditures by $2.4 million in that year. This model does not assume any financing of industry inducements using state or local government general revenue funds or through tax increases.

Because these economic impacts are tied to the manufacture of turbine components and the construction activity surrounding their installation, they only persist for the single year in which this activity occurs. Once the wind farm is completed, the economic impacts reported in this portion of the model will cease. The economic impact of the production of replacement parts for wind turbine maintenance on the state of South Carolina is addressed separately in the O&M discussion below.

Economic and Fiscal Impacts: Offshore Wind Farm Operations & Maintenance

Economic and fiscal impact estimates for the O&M phase of the proposed offshore wind farm begin starting in 2017, the year after the installation of the 40 MW facility. As shown in Table 8, over the 20 years of operational life modeled, O&M activities associated with the proposed offshore wind farm are estimated to generate 10 jobs per year, on average, or around 0.26 jobs per MW installed.

Table 8
Average Annual Economic Impact of Offshore Wind Farm O&M Activities, 2017-2036

	Impact/Yr	Impact/MW/Yr
Total Jobs	10 jobs	0.26 jobs
Total Compensation	$934,000	$23,300
Output	$2.8 million	$70,900
Net State Revenue	-$115,000	-$2,875
Net Local Revenue	-$107,000	-$2,675

Wind farm O&M activities are estimated to generate average annual output valued at $2.8 million a year during the decade. Aggregated local government net revenue is estimated to decrease on average by approximately $107,000 per year; this loss will be spread across multiple counties and municipalities, depending on the geographic distribution of new residents and economic activity within the state. State government net revenue is projected to decrease by about $115,000 on average per year.

These small negative impacts in net revenue for state and local governments are due to the increase in demand for government services by new residents projected to relocate to the state due to the positive impact on relative wages from construction and the subsequent ongoing smaller wage impact from O&M. These increased demands, coupled with the small, short-term negative impact that higher relative wage rates from the 2016 construction boon is predicted to have on employment in the following years, results in an increase in state and local government expenditures that exceeds the increase in revenue.

The estimated output multiplier for O&M operations is approximately 0.67; that is, about 67 cents out of every dollar spent on O&M would remain in the state. Because O&M activities continue after completion of wind farm installation, these economic impacts will persist as long as the wind farm continues to operate.

Electric Rate Impact of a 40 MW Offshore Wind Farm

The construction and operation of a 40 MW wind farm off the South Carolina coast is also projected to have an impact on electric rates paid by households, businesses and industry. This rate impact assessment incorporates three factors:

1. Offshore wind farm capital and O&M costs
2. Avoided fuel and other production costs due to wind generation
3. Allocation of capital costs, O&M costs, and avoided production costs to customer classes

Rate impacts are estimated for average South Carolina residential, commercial, and industrial energy users.

Wind Farm Capital Costs and O&M Costs

Capital investments incurred by regulated electric utilities are recovered through uniform annual revenue collections from utility customers. These revenue requirements are allocated to different customer classes based on demand patterns. In turn, each individual ratepayer within a customer class contributes to the total class revenue requirement based on kWh consumption and other service charges. This capital recovery model is the primary driver of the rate impacts estimated in this report.

Key assumptions in the capital recovery model for the proposed 40 MW offshore wind farm are:

- The capital cost of construction is financed over the 20 year period from 2017 to 2036.
- Operations and maintenance costs for the wind farm occur during years 2017 to 2036.
- The proposed wind farm is jointly owned by South Carolina's electric utilities; accordingly, the project's weighted-average cost of capital is a blended rate based on these utilities' recent capital structures and cost of debt and equity financing.
- No financial incentives of any kind are included in the capital recovery model; that is, the project does not claim production or investment tax credits, or accelerated depreciation.[7]

Capital costs and O&M costs for the proposed wind farm were estimated using the *Cost of Renewable Energy Spreadsheet Tool* (CREST), a cash flow model developed under the direction of the U.S. Department of Energy's National Renewable Energy Laboratory.[8]

The CREST model computes the capital and O&M costs per kWh for a given facility, using generating capacity, project lifetime, installed cost, financing parameters, and available incentives. The model also computes the total cost of energy production each year over the life of the facility. The CREST model accounts for tax liability, asset depreciation, debt service, and equity investor return requirements.

Santee Cooper provided installed cost per MW of generating capacity and annual O&M cost figures based on internal research and equipment vendor contacts that were developed as part of the Palmetto Wind project. Key inputs to the CREST model are provided in Table 9. Figure 1 shows the annual capital recovery and O&M costs of the proposed wind farm over its assumed 20 year life.

[7] The value of financial incentives could be included in future analyses, where appropriate.
[8] NREL's CREST model is used to assess project economics and can be downloaded for solar (photovoltaic and solar thermal), wind, geothermal, and anaerobic digestion technologies at https://financere.nrel.gov/finance/content/crest-cost-energy-models.

Table 9
Capital Recovery Model Inputs

Input	Value
Generator Nameplate Capacity	40 MW
Project Useful Life	20 years
Total Installed Cost	$6,459 per kW
Fixed O&M Cost	$66.16 per kW-yr
Variable O&M Cost	$0.0073 per kWh
Annual O&M Cost Inflation	2% per yr
Blended After-Tax Weighted-Average Cost of Capital (WACC)	6.11%
Federal Incentives	none
State Incentives	none
Depreciation	straight-line

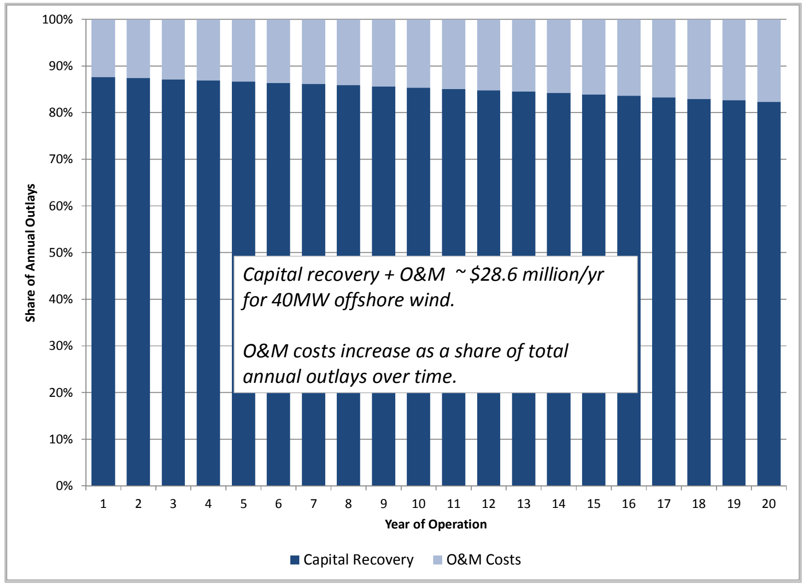

Figure 1. Project capital recovery and O&M costs

Avoided Production Costs

A secondary rate impact occurs when electricity generated by the wind farm allows the utility to avoid burning fuel and incurring other variable production costs in order to run fossil fuel-based (coal, oil, gas) generating units in its system. These avoided production costs offset a portion of the rate impacts from capital recovery and O&M costs described above.

The avoided fuel burn also represents a hedge against fuel price spikes and various regulatory risks that electric utilities face; however hedging value is not estimated here. Additionally, a larger wind farm could allow a utility to avoid or defer generating capacity investments, and could impose system integration costs to accommodate resource intermittency; these factors are excluded given the small scale of the wind farm relative to South Carolina utility system size.

The savings from avoided fuel and other variable production costs were estimated using a simple production cost model created for a hypothetical, but representative, South Carolina utility. The representative utility system is composed of existing and planned generating units located in North and South Carolina.[9] The proportion of total generating capacity within each technology and fuel class is reflective of the expected future capacity mix in the Carolinas during the wind farm's lifetime (2017-2036).

This analysis simulates how generating units would be dispatched to meet hourly customer demand throughout the year. Individual units would come online and offline based on their marginal cost of generating electricity. By comparing the fuel burn and other variable costs incurred with and without the wind farm as part of the utility system, the model estimates the production cost savings associated with the wind farm each year during its lifetime.

The results for the hypothetical utility are assumed to be representative of the total avoided production costs that would be realized by individual South Carolina utilities receiving a portion of hourly wind farm output on their systems. Figure 2 shows the estimated annual production cost

[9] Units located in both Carolinas were considered in designing the hypothetical utility because Duke Energy's North Carolina and South Carolina units function together as one system.

savings resulting from wind farm operation, broken down by cost category. Annual savings range from $6.3 million in the first year of wind farm operation to $10.5 million in 2036.

Fossil fuel price projections used in the production cost model were obtained from the U.S. Energy Information Administration's (EIA) *2013 Annual Energy Outlook*.[10] Carbon dioxide emissions costs were assumed to start at $15 per metric ton in 2017 and escalate by 5 percent each year, which is generally consistent with assumptions made by Carolinas utilities in production cost model runs presented in recent public filings.

System peak demand and annual energy requirements are assumed to grow by one percent each year, which is generally consistent with the load forecasts of Carolinas utilities. The Appendix contains further detail on the methodology and inputs to the production cost model.

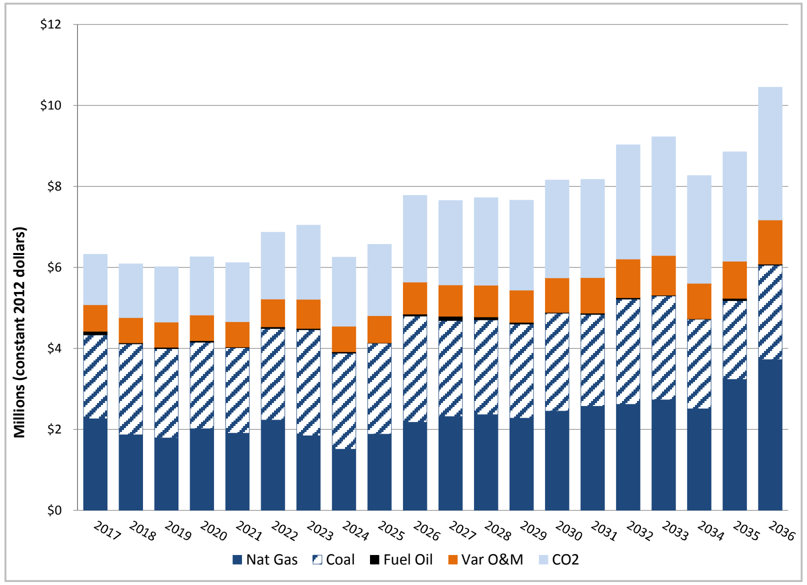

Figure 2. Avoided costs of conventional electric power generation

[10] http://www.eia.gov/forecasts/archive/aeo13/index.cfm.

Cost Allocation

The final component of the electric rate impact analysis accounts for how the capital recovery and operating costs and savings discussed above are allocated among utility customer classes. Regulated utilities use cost allocation formulas to divide the costs of capital assets and fuel fairly among all of their customers.

A key principle of cost allocation is *cost causation*, which determines how much of the utility's total revenue requirements will be collected from each customer class. Cost-of-service studies establish which of the utility's costs are being caused by residential customers, commercial customers, industrial customers, and combinations of the three. This information serves as the basis of cost allocation.

In practice, each utility's allocations are unique due to:

- Different mixes of residential, commercial and industrial customers
- Specific electric usage patterns of each of these customer classes
- The portfolio of capital assets owned by the utility (primarily generation, transmission, and distribution equipment)

Generally, capital asset revenue requirements are allocated among customer classes in a non-uniform manner based on class equipment usage, whereas fuel revenue requirements are allocated evenly among all kWhs consumed on the system, regardless of customer class.

In this study, we derived capital asset cost allocators for average South Carolina residential, commercial, and industrial customers rather than use the actual cost allocators of one or more specific utilities. These cost allocators were derived using statewide electric utility revenue data from the EIA.[11] Fuel cost savings were allocated evenly among all system kWhs.

Table 10 shows the capital asset and fuel savings allocators for each customer class. Alternative allocation schemes could be utilized to spread

[11] U.S., Department of Energy, EIA, *State Energy Data System* (http://www.eia.gov/state/seds/) and EIA Form 861 (http://www.eia.gov/electricity/sales_revenue_price/).

the costs and benefits of the project across customer classes in a different manner. For example, a per-customer allocation approach would reduce industrial customer impacts due to the much larger numbers of residential and commercial accounts on utility systems.

Table 10
Cost Allocators

Rate Class	Capital Asset	Fuel Savings
Residential	52.3%	36.5%
Commercial	29.0%	27.3%
Industrial	18.7%	36.2%
Total	100.0%	100.0%

Offshore Wind Farm Rate Impacts

The capital cost and operation of the 40 MW offshore wind farm will affect electric rates for all customer classes. Table 11 shows the average rate changes that South Carolina customers are estimated to experience over the 20 year life of the wind farm. Results are reported in 2012 dollars per kWh.

Table 11
Estimated Rate Impacts by Rate Class

Rate Class	Rate Change ($/kWh)
Residential	0.00037
Commercial	0.00025
Industrial	0.00008

Note: Estimates in 2012 dollars.

On an annual basis, the net rate impact to each customer class is expected to decline over time because the capital and O&M costs of the project are fixed and the avoided production costs rise over time as fuel and other variable costs increase.

Table 12 illustrates how these estimated rate changes would impact individual customer electric bills. Monthly kWh consumption and electric bill charges were calculated for the average customer in each class using consumption and revenue data from the US Energy Information Administration.[12]

For example, based on these benchmarks residential customers are estimated to contribute an additional $0.42 per month on average over the life of the wind farm. This would be an increase of about 0.3 percent over the average residential electric bill from 2012.

Table 12
Estimated Rate Impact of 40 MW Offshore Wind Farm (OSW) on the Average Customer Bill, by Rate Class

Rate Class	Average kWh/Mo	Average Bill/Mo	Estimated $ Rate Increase	Estimated % Rate Increase
Residential	1,119	$132	$0.42	0.3%
Commercial	5,167	$497	$1.32	0.3%
Industrial	534,380	$32,173	$43.45	0.1%

Note: Estimates in 2012 dollars.

To put this estimated rate increase from the offshore wind farm in context, between 2003 and 2013 average South Carolina residential electric rates (and by extension total charges for a given amount of kWh) rose by 20 percent in 2012 dollars. This 20 percent rate increase over the decade is equivalent to 10 years of average annual rate increases of nearly 1.6 percent each and every year. Given the average residential bill of $132 a month, these annual increases would add about $2 a year, each year, to the average bill.

Over the same period, average South Carolina commercial electric rates rose by 17 percent and average South Carolina industrial rates rose by 21 percent (in 2012 dollars). In annual terms, commercial and industrial

[12] U.S., Department of Energy, EIA, EIA Form 861 (http://www.eia.gov/electricity/sales_revenue_price/).

electric rates rose between 1.6 percent a year and 1.9 percent a year, on average over the decade. Overall electric rates are expected to continue to increase as fuel prices rise further and as utilities continue to replace aging equipment and invest to meet rising demand. The proposed 40 MW offshore wind farm is only expected to add a single rate increase of less than half a percent to the average bill paid in any rate class.

As noted above, in practice the electric rate impacts of a jointly owned 40 MW offshore wind farm would vary by utility. The key factors shaping these impacts would be:

- The utility's project ownership share and the cost of capital
- The avoided production costs on the utility system of interest
- The utility's customer mix and project cost-benefit allocation choices.

The effects of regional utility ownership and cost allocation scenarios are not considered in detail here. However, a joint Carolinas or South Carolina-Georgia project would dramatically reduce the customer bill impacts of a 40 MW demonstration project relative to the South Carolina impacts estimated in this study. This outcome would be due to a greatly expanded customer and sales base to which the project would apply.

For example, a joint South Carolina-Georgia project utilizing an allocation scenario similar to that applied here could reduce average South Carolina customer bill impacts by one-half to two-thirds.

The projected electric power rate increase that can be attributed to capital recoupment and O&M for 20 years of operation of a 40 MW offshore wind farm would add an estimated 42 cents a month to the average South Carolina residential customer's bill.

CONCLUSION

The 2012 report, *South Carolina Wind Energy Supply Chain Survey and Offshore Wind Economic Impact Study,* demonstrated South Carolina's presence in the wind energy supply chain. That report and the current report show the positive economic impacts to the state that could result from the installation and operation of an offshore wind farm—commercial scale or demonstration scale—in South Carolina's waters.

For example, a small 40 MW demonstration scale offshore wind farm would generate well over 900 jobs in South Carolina during the one year construction period, bringing an estimated $46 million in wages to the state's economy. State and local governments combined would also receive an estimated $3.5 million in tax revenue from this economic activity.

Ongoing operations and maintenance activity on the fully operational 40 MW offshore wind farm would generate 10 jobs and over $900,000 in wages yearly. The economic impact on the state of a multiyear construction and operation of a commercial scale offshore wind farm would be much higher, as discussed in the 2012 report.

This report extends the analysis in the 2012 report to examine the impact on electricity rates of the addition of 40 MW of offshore wind generation to the state's energy mix. These impacts result from:

- Offshore wind farm capital and O&M costs
- Avoided fuel and other production costs due to wind generation
- How wind farm capital costs, O&M costs, and avoided production costs are allocated among customer classes

The estimated rate impact for South Carolina residential, commercial, and industrial ratepayers is less than half of one percent of the average monthly bill. For example, the average residential customer in the state paid $132 per month for electricity in 2012. In this analysis, the projected rate increase that can be attributed to capital recoupment and O&M for 20 years of operation of a 40 MW offshore wind farm would add only 42 cents per month to this bill.

Appendix A: Production Cost Modeling

Production cost models are tools used by power systems analysts to simulate how separate generating units within a utility system would be dispatched to meet changing customer demands over time. The most sophisticated production cost models account not only for the relative economics of producing power using the different units available on the system, but also for other factors such as unit operational constraints, operating reserve requirements, and system transmission constraints.

For this study, we created a simple production cost model that dispatches units based only on the marginal cost of generation of each of the available units during hourly time segments of customer demand. Given that additional constraints on the system would raise total production costs, this modeling approach is expected to yield conservative estimates of the cost savings from displacement of conventional generation by wind farm production.

Marginal Cost of Generation

The marginal cost of generation for each generating unit during each hour of customer demand was calculated as follows, excluding unit conversion factors:

$$MC_{i,t} = HR_i * (FP_{i,t} + CEF_i * CP_t) + OM_{i,t}$$

where

i = generating unit i

t = time period t (hours)

$MC_{i,t}$ = the marginal cost of generating electricity for unit i during time period t, in \$/MWh

HR_i = the heat rate of unit i, in Btu/kWh

$FP_{i,t}$ = the fuel price applicable to unit i during time period t, in \$/MBtu

CEF_i = the CO_2 emissions factor for the fuel type applicable to unit i, in lb/MBtu

CP_t = the price of a CO_2 emissions allowance during time period t, in \$/metric ton

$OM_{i,t}$ = the non-fuel variable O&M cost for unit i during time period t, in \$/MWh

Thus, for each hour of customer demand, marginal unit costs are calculated and the lowest cost units are dispatched first, followed by progressively more costly units until customer demand for that hour is satisfied.

Figure A1 below is a generic illustration of this modeling approach, showing a 24-hour load shape and how production from different unit types is “stacked” until demand is met. Units are dispatched sequentially by their marginal cost of generation until hourly demand is met. Note that Coal Steam A is a newer, more efficient coal plant whereas Coal Steam B is older and less efficient.

The left graph in Figure A1 shows how the dispatch stack changes over a 24-hour period. The right graph breaks down the cost of different unit types for one hour of production.

While Figure A1 breaks down generating units into broad technology types, the production cost model created for this analysis includes an additional degree of granularity by using a representative mix of actual generating units operating in North Carolina and South Carolina.

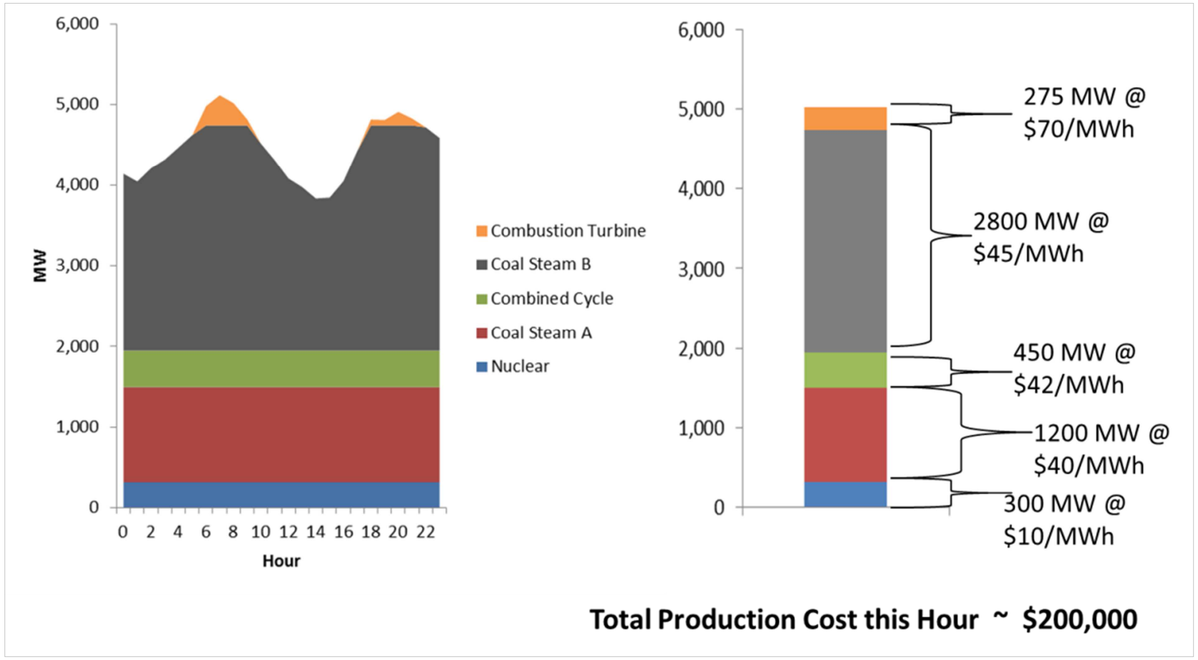

Figure A1. Sample dispatch stacking

Using the production cost model, we ran scenarios with and without wind power production, for each hour of customer demand, over a 20 year period. The total difference in hourly costs of these two scenarios is taken as the cost savings from displacement of conventional generation by wind farm production.

The production cost model relies on several types of data inputs, which are described below:

- Hourly system load
- Hourly wind turbine power output
- Existing system generating unit characteristics
- Unit additions
- Price assumptions for CO_2 allowances and various fuel types

System Load

Load inputs were derived using South Carolina Electric &Gas's historical hourly load data from 2012 as reported in FERC form 714. The majority of South Carolina's electric load is summer peaking and exhibits daily and seasonal demand patterns that are broadly similar to those of SCE&G's territorial load. (Use of a scaled-down utility system that is meant to represent production cost impacts statewide is discussed further below in the section on generating units.)

Based on the expected load growth rates reported by South Carolina utilities in their 2012 and 2013 integrated resource plans, we assume a one percent annual growth rate in summer and winter peak demand as well as off-peak demand. Figure A2 shows the hourly and average daily system load inputs as a percentage of peak load for the initial year of wind farm operation (2017).

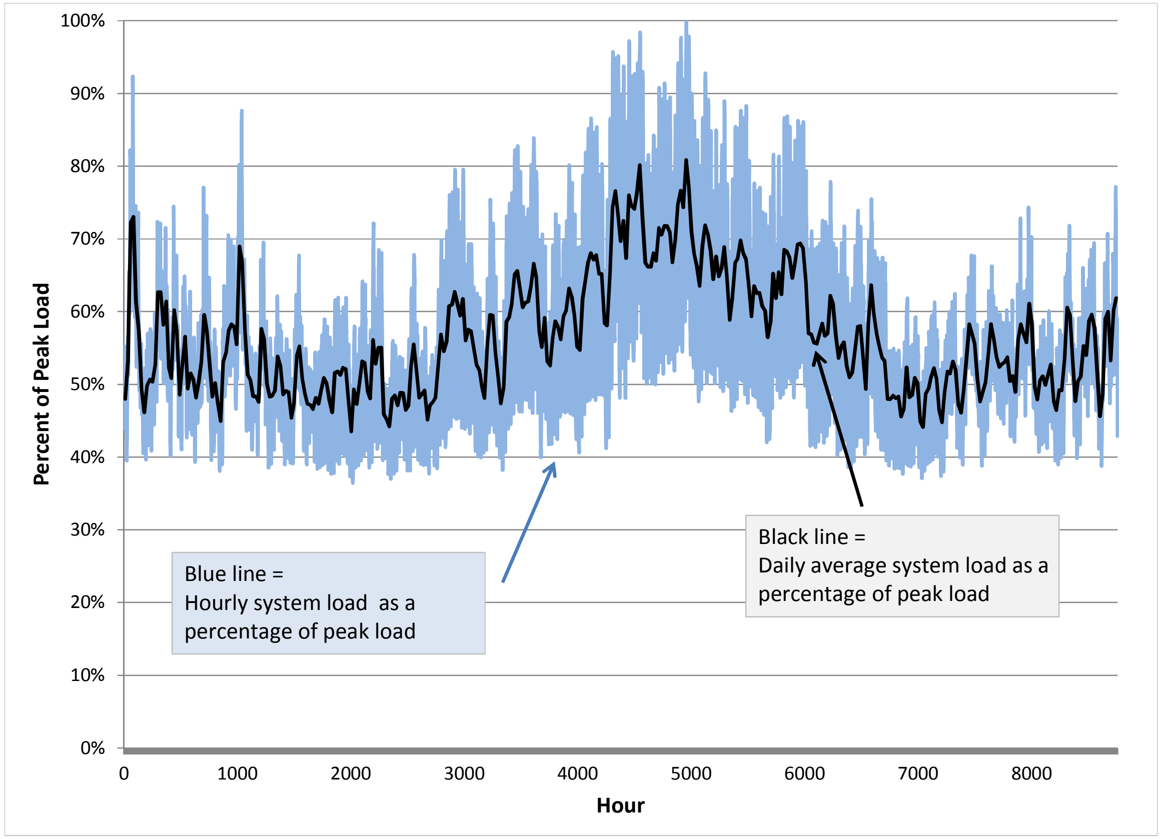

Figure A2. System load as a percentage of annual peak load

Wind Output Profile

In 2011, AWS Truepower created wind generation output data for offshore locations in the Southeastern U.S. These data were created on request in order to inform transmission infrastructure development in the region. The company used its proprietary mesoscale weather prediction model to create 10 years of wind resource data at various offshore locations in the Southeast. The modeled wind speeds were validated using measurements from offshore moored stations.

AWS Truepower also calculated gross and net power output for each location assuming 8 MW of output capability per square km and accounting for losses and typical turbine availability. The company found the calculated wind power capacity factors to be consistent with those from previous offshore wind studies.

We used AWS Truepower's Study Block 6 data corresponding to waters off the South Carolina coast at Georgetown. We averaged the 10-minute net power data into hourly values, and then scaled these values to equivalent output for a 40 MW offshore wind farm. In order to model a production scenario featuring the 40 MW offshore wind farm, we subtracted the hourly wind output values from the baseline hourly system load inputs.

Generating Units

The portfolio of generating units used as inputs to the production cost model is meant to be broadly representative of expected future capacity mixes of Carolinas utilities. Given a shared offshore wind farm ownership scenario, in reality the hourly power output would most likely be divided proportionately among utilities based on ownership share. Thus the wind power would displace some amount of fossil generation from each separate utility system.

We modeled a simplified system in which the full output of the wind farm displaces conventional generation from a single generic Carolinas utility. This generic utility system is composed of existing and planned generating units located in North and South Carolina.

Units located in both Carolinas were considered in designing the hypothetical utility because Duke Energy's North Carolina and South Carolina units function together as one system. The proportion of total generating capacity within each technology and fuel class is reflective of the expected future capacity mix in the Carolinas during the wind farm's lifetime (2017-2036).

The initial 2017 capacity mix is shown in Table A1 below. We created this capacity mix using the EPA National Electric Energy Data System (NEEDS) database, version 4.10.[13] NEEDS contains U.S. generating unit IDs, locations, capacities, technology and fuel types, heat rates, and other key unit data.

We totaled existing Carolinas generation capacity by technology type and identified the percentage contribution of each technology to the full Carolinas portfolio. We then selected individual generating units to populate our generic Carolinas utility system such that:

- The total capacity of the model utility could meet our 2017 system peak load input plus a 15-20 percent reserve margin; and
- The percentage contribution of each technology type was reflective of the actual Carolinas portfolio as represented in NEEDS, but adjusted to account for completed or expected unit additions and retirements through 2016.

Next, we created a roadmap of unit additions for our generic utility system. These units are based on expected capacity additions in the Carolinas in the next 20 years as indicated in utility integrated resource plans. The unit additions maintain a 15-20 percent system reserve margin as peak demand grows annually by one percent.

Table A1
NC-SC Electric Generation Capacity Mix vs Model Utility Capacity Mix

	NC-SC Generation		Model Utility	
Generating Technology	Capacity (MW)	% of Total	Capacity (MW)	% of Total
Coal Steam	20,642	40.5%	2,144	36.7%
Nuclear	11,447	22.4%	1,268	21.7%
Combustion Turbine	9,454	18.5%	1,090	18.7%
Hydro	3,259	6.4%	382	6.5%
Combined Cycle	3,168	6.2%	917	15.7%
Pumped Storage	2,750	5.4%	0	0.0%
Non-Hydro Renewables	162	0.3%	19	0.3%
Oil/Gas Steam	113	0.2%	15	0.3%

Source: US, Environmental Protection Agency, National Electric Energy Data System (NEEDS) database, v.4.10.

[13] http://www.epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html.

Figure A3 shows the timing, capacity, and technology type of each addition, as well as the system reserve margin over the 20-year time horizon. The vertical bars show capacity added (right-hand y-axis), the black line shows the system reserve margin (left-hand y-axis), and the dotted lines show the target reserve range (left-hand y-axis).

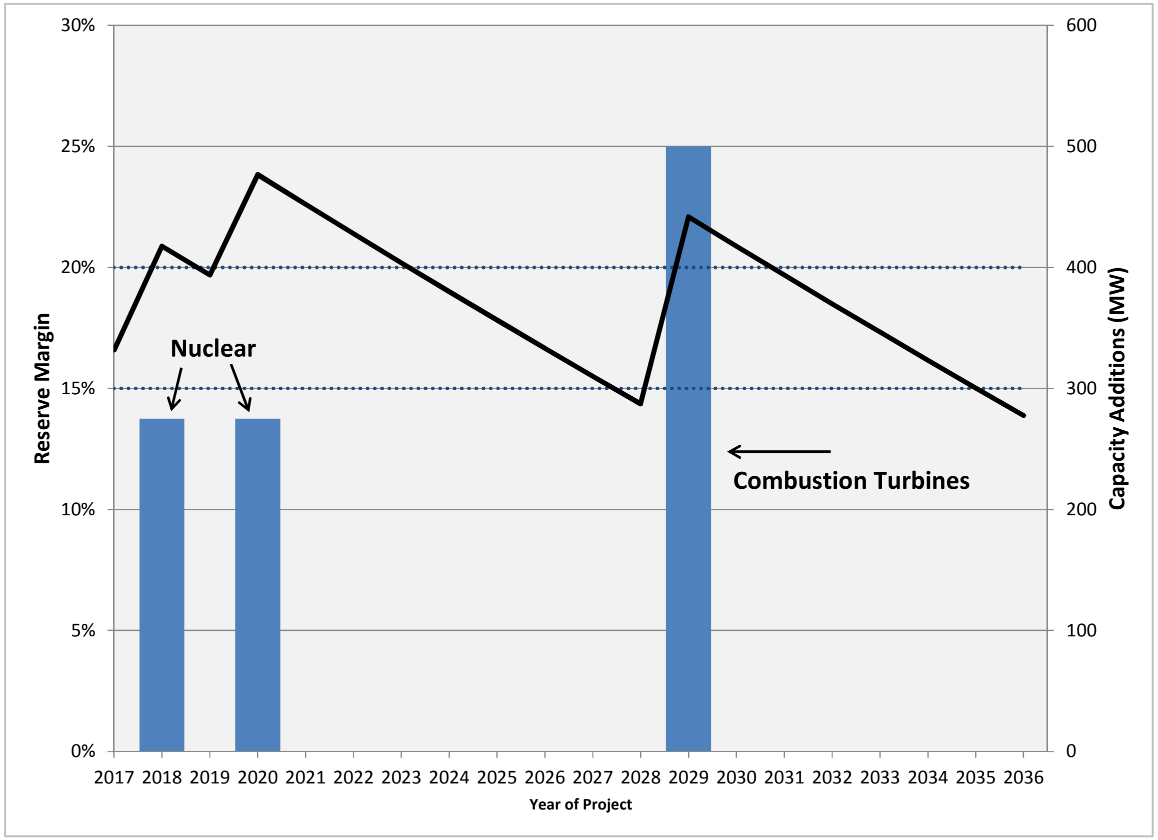

Figure A3. Generating unit additions and system reserve margin

Fuel and CO_2 Prices

For fuel price inputs to the production cost model, we used the EIA's *Annual Energy Outlook 2013* price projections for fuel delivered to the power sector in the South Atlantic region (Figure A4).

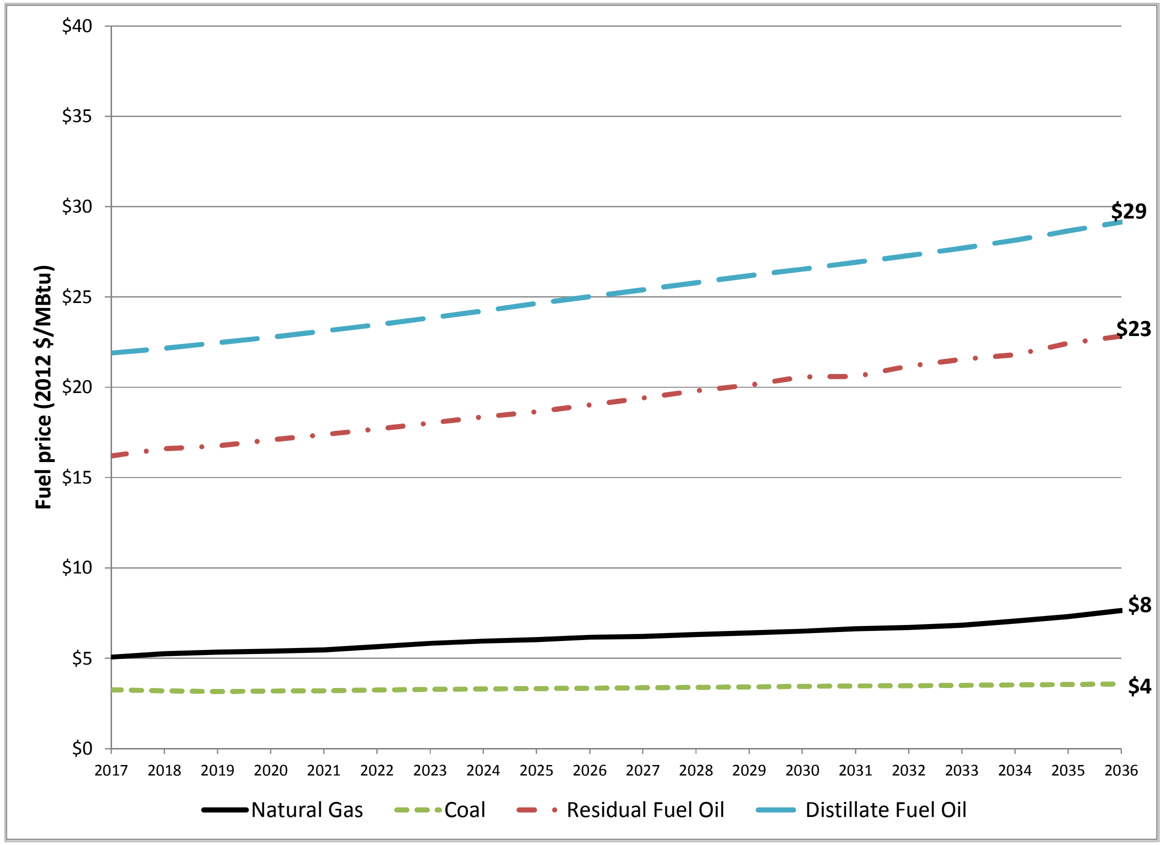

Figure A4. Conventional fuel price assumptions

For CO_2 allowance prices, we used the *Annual Energy Outlook 2013* medium ("GHG15") case trajectory, in which allowance prices start at $15 per metric ton and rise by five percent each year (Figure A5). We assume CO_2 compliance begins in 2017.

In a recent economic analysis, SCE&G evaluated CO_2 prices of $0, $15, and $30 per ton starting in 2017 and escalating at five percent annually. The utility highlighted $30 per ton as the most reasonable starting price to use. In Duke Energy's 2013 IRP, the Base Case CO_2 price assumptions are $17 per ton starting in 2020 and rising to $33 per ton by 2028.

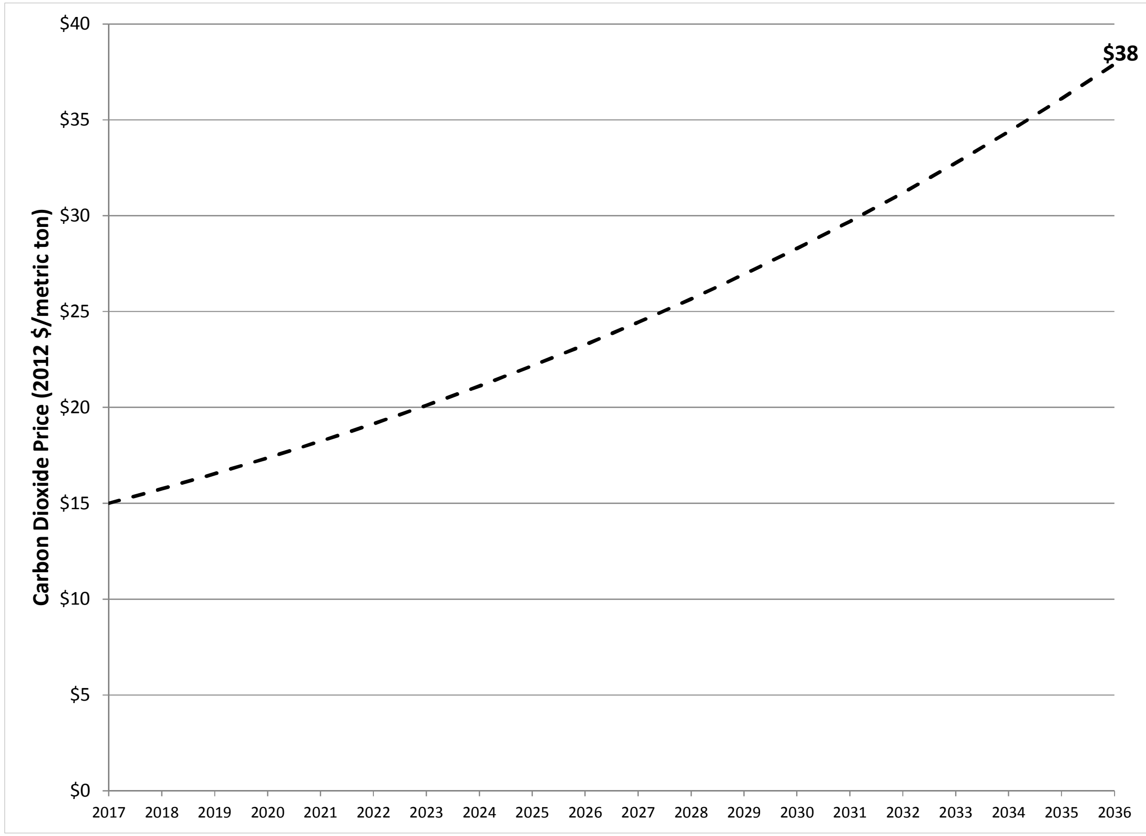

Figure A5. Carbon dioxide price assumptions

APPENDIX B: ERRATA IN MAY 2014 VERSION

In the version of this report originally published in May 2014, the electric rate impact analysis results contained errors related to mixed use of constant and current dollar values. One cost stream—the cost of capital applied to project construction costs—was mistakenly included in calculations on a current dollar basis, whereas all other costs and avoided costs were included on a constant 2012 dollar basis.

This error has been corrected so that all costs are included on a constant 2012 dollar basis, and the affected results presented in the report have been revised to reflect the correction. Overall, the corrections result in a small reduction in the originally estimated rate impacts for each customer class.

Accordingly, results presented in the following sections of the report have been revised. Changed text is highlighted and underlined:

Key Findings, page i:

"The estimated total capital recovery and O&M cost each year of the wind farm's expected lifetime is $28.6 million when subsidies are excluded. The wind farm will avoid an estimated $6.3 million in annual production costs initially, and these annual cost savings will grow to $10.5 million by the end of the facility's life. These project costs and benefits are estimated to result in average electric bill impacts to South Carolina households and businesses as follows:

- 0.3% bill increase of $0.42 per month for residential customers
- 0.3% bill increase of $1.32 per month for commercial customers
- 0.1% bill increase of $43.45 per month for industrial customers."

Page 10, Figure 1:

Input data revised and figure replaced. Average annual capital recovery + O&M in text box in figure revised downward to $28.6 million.

Page 11, text:

"Annual savings range from $6.3 million in the first year of wind farm operation to $10.5 million in 2036."

Page 11, Figure 2: Input data revised and figure replaced.

Page 12, Table 11:

Estimated Rate Impacts by Rate Class

Rate Class	Rate Change ($/kWh)
Residential	0.00037
Commercial	0.00025
Industrial	0.00008

Note: Estimates in 2012 dollars.

Page 12, Table 12:

Estimated Rate Impact of 40 MW Offshore Wind Farm on the
Average Customer Bill, by Rate Class

Rate Class	Average kWh/Mo	Average Bill/Mo	Estimated $ Rate Increase	Estimated % Rate Increase
Residential	1,119	$132	$0.42	0.3%
Commercial	5,167	$497	$1.32	0.3%
Industrial	534,380	$32,173	$43.45	0.1%

Note: Estimates in 2012 dollars.

Page 12, text:

"For example, based on these benchmarks residential customers are estimated to contribute an additional $0.42 per month on average over the life of the wind farm. This would be an increase of about 0.3 percent over the average residential electric bill from 2012."

Page 13, text:

"In this analysis, the projected rate increase that can be attributed to capital recoupment and O&M for 20 years of operation of a 40 MW offshore wind farm would add only 42 cents per month to this bill."

Page 20, Figure A4: Input data revised and figure replaced.

Page 21, Figure A5: Input data revised and figure replaced.