DE-EE0005368
Carolinas Offshore Wind Integration Case Study
(COWICS)

Technical Progress Report

December 2, 2014

Problem Statement

The project's objective is to provide a thorough and detailed analysis of specific issues, impacts, and costs associated with integrating various amounts of offshore wind generation (1000 MW, 3000 MW, 5600 MW) into the Duke Energy Carolinas system.

Partners, Subcontractors, and Collaborators

Principal Investigators

Duke Energy

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Harvey Seim

Project Tasks	Status
• Task 1 Site Selection	Complete
• Task 2 Capacity and Energy Profile Analysis	Complete
• Task 3 Interconnection and Delivery Study	Complete
• Task 4 Dynamic Stability Analysis	Complete
• Task 5 Operating Reliability Impacts	Complete
• Task 6 Production / Operating Cost Impact Analysis	Jan 2015
• Task 7 Final Report	May 2015

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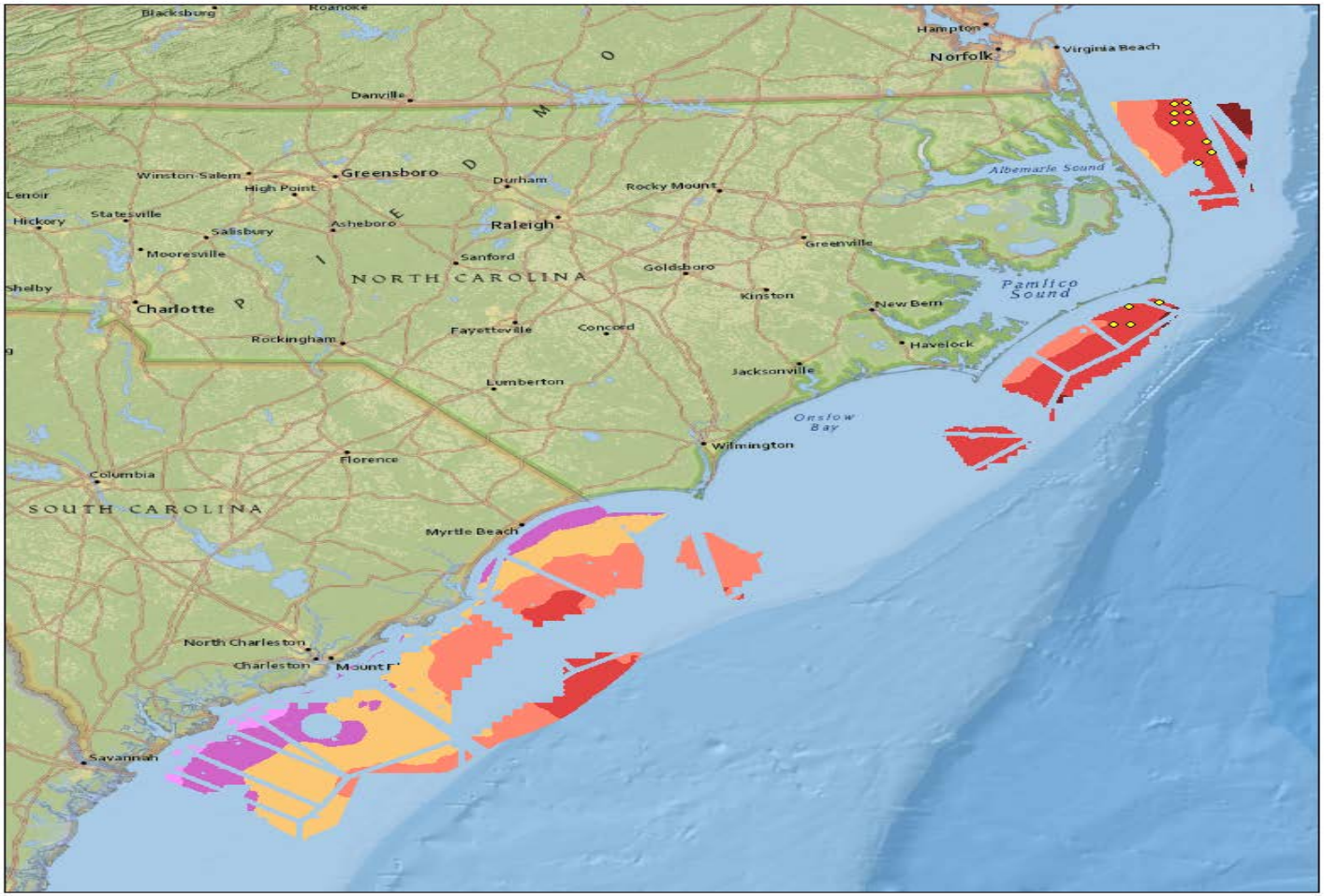
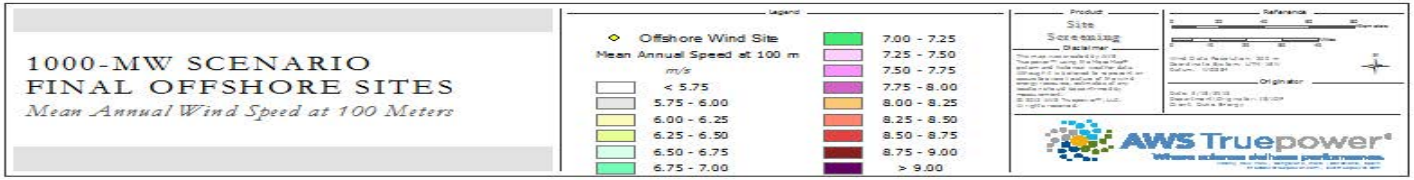
Carolinas Offshore Wind Integration Study

Task 1: Site Selection 1000 MW





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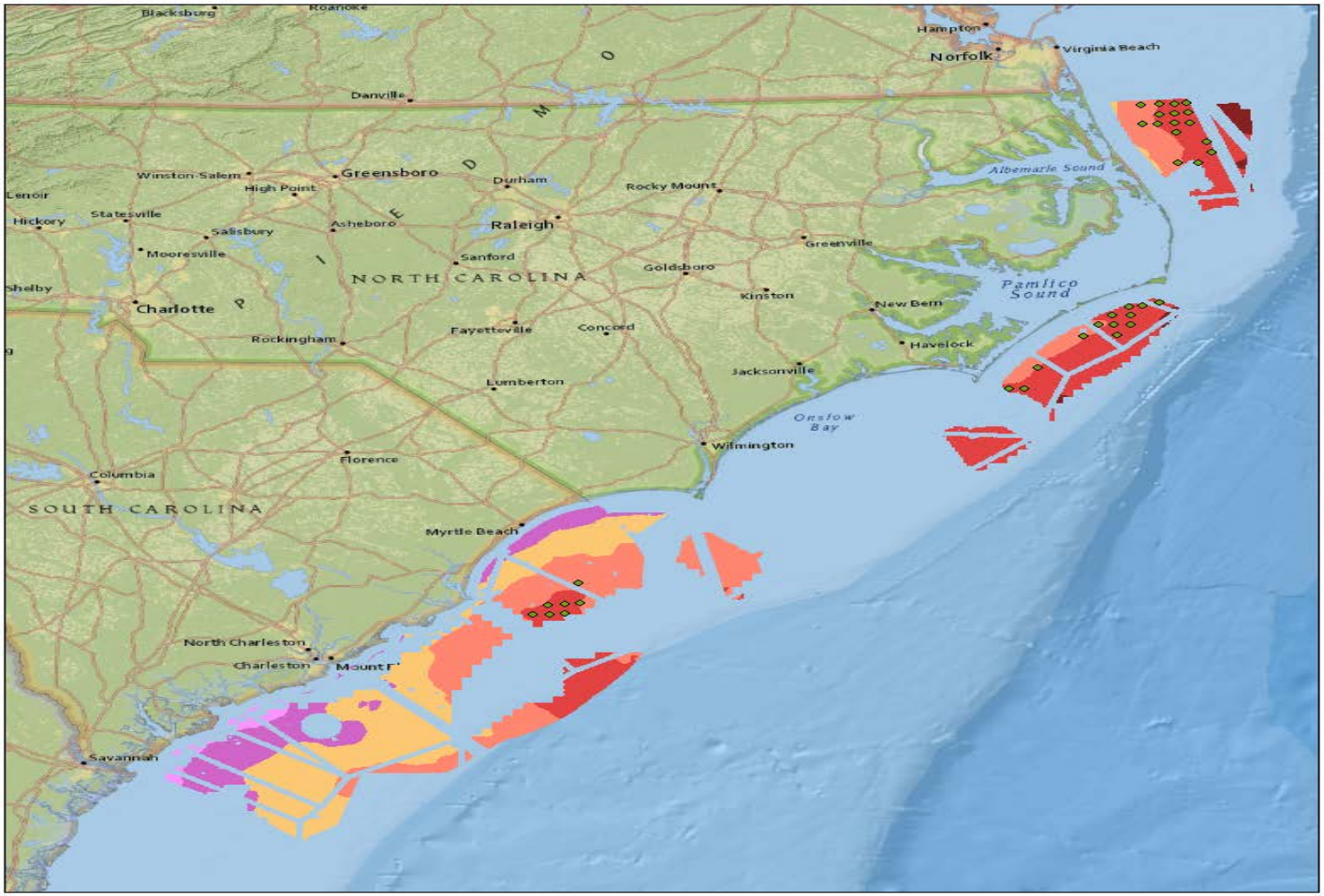
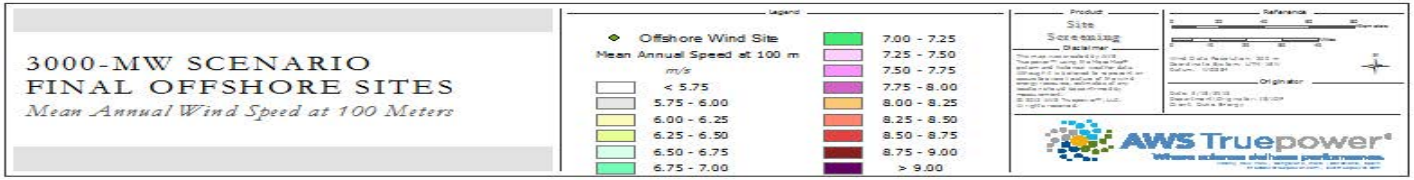
Carolinas Offshore Wind Integration Study

Task 1: Site Selection 3000 MW





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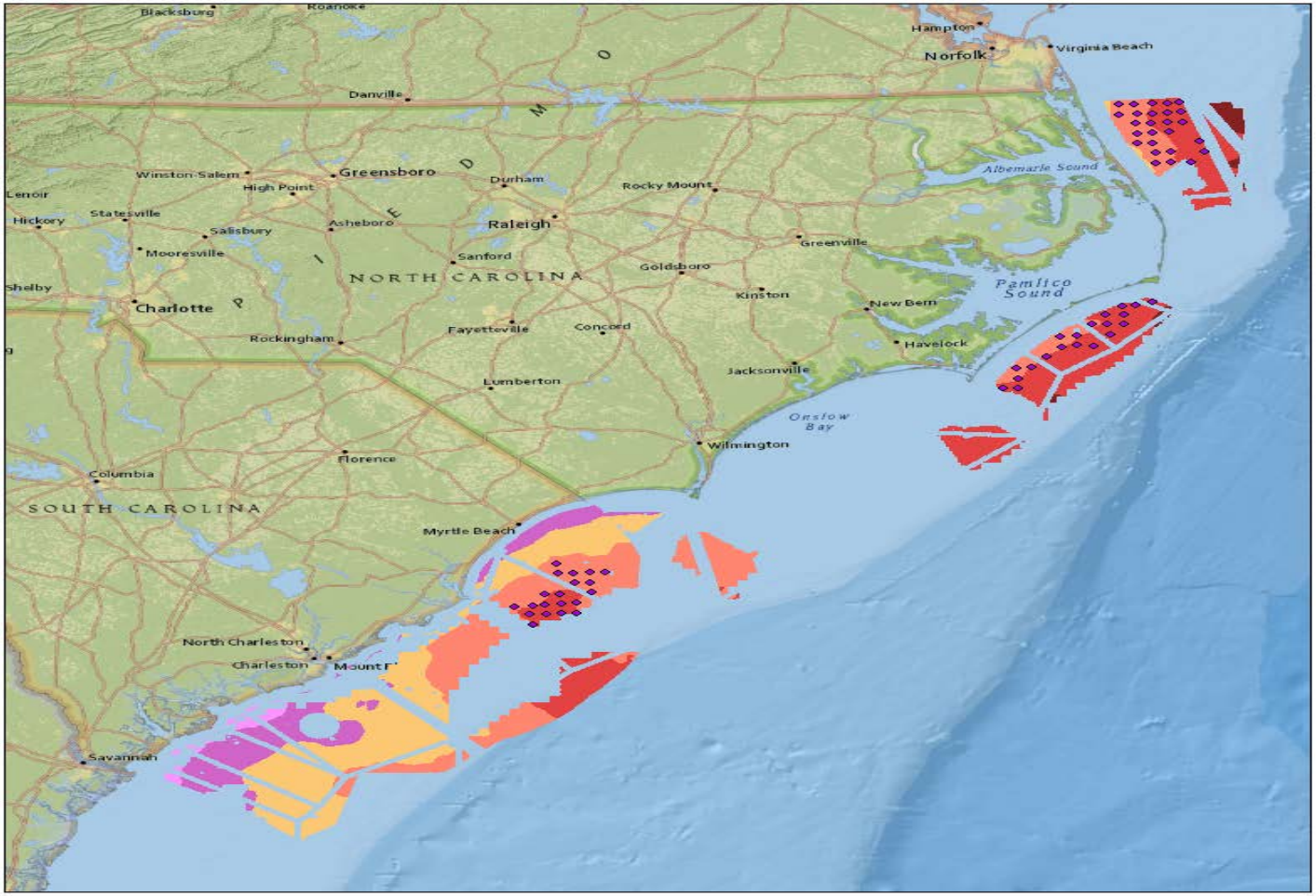
Carolinas Offshore Wind Integration Study

Task 1: Site Selection 5600 MW



5600-MW SCENARIO
FINAL OFFSHORE SITES
Mean Annual Wind Speed at 100 Meters

Legend

Offshore Wind Site

Mean Annual Speed at 100 m

m/s

< 5.75
5.75 - 6.00
6.00 - 6.25
6.25 - 6.50
6.50 - 6.75
6.75 - 7.00
7.00 - 7.25
7.25 - 7.50
7.50 - 7.75
7.75 - 8.00
8.00 - 8.25
8.25 - 8.50
8.50 - 8.75
8.75 - 9.00
> 9.00

Product: Site Screening

Disclaimer

Reference

Originator

AWS Truepower

Task 1: Site Selection

Exclusion Zones

Site nameplate capacity ranges from 40–100 MW, and all sites are within 58 km (32 n mi) of the coast in water depths less than 30 m. These are the final sites that were used for all subsequent tasks in the study.

Constraint	Offset	Source
Anchorage Area	300 m	NOAA
Beacon	30 m	NOAA
Buoy	30 m	NOAA
Cables	1100 m	NOAA
Cables (International)	1500 m	NOAA
Coastline	5 km	NOAA
Dumping Ground	300 m	NOAA
Fairway Shipping Channel	1 nm	NOAA
Fog Signal	30 m	NOAA
Lights	30 m	NOAA
Military Practice Area	Layer Extent	NOAA
Obstruction	30 m	NOAA
Offshore Platform	30 m	NOAA
Precautionary Area	Layer Extent	NOAA
Shipping Lane	1 nm	NOAA
Wreck	30 m	NOAA
National Marine Sanctuaries	1 mile	NREL
Marine Protected Areas	1 mile	NREL
Shipping Lane	1 mile	NREL
Sanctuary Preservation Area	1 mile	NREL
Significant Natural Heritage Areas (NC)	1 mile	NREL
Sea Turtle Sanctuaries (NC)	1 mile	NREL
Crab Spawning Sanctuaries (NC)	1 mile	NREL
Refuges (SC)	1 mile	NREL
Ocean & Coastal Resource Management Critical Area (SC)	1 mile	NREL
Wind Energy Exclusion Area	Layer Extent	DoD

Task 2: Capacity & Energy Profile Analysis

- Ten-minute energy output profiles for the period 1999–2008 were provided for each of the selected sites.
- Composite turbine power curve valid for the standard sea-level air density of 1.225 kg/m^3 at 100-m hub height.
- Validation - In the absence of offshore wind farm data, measured wind speeds were used to validate the simulated wind speeds via observed measurements from NOAA's National Data Buoy Center.
- Because of the relatively small inter-annual variability it was determined that year 2000 data would be used to simulate wind turbine power production. Likewise, because of the relatively large inter-monthly variability and also to evaluate electrical network conditions during peak summer and winter peak load periods and spring/fall shoulder load conditions, the hours of: January 8 am, May 4 pm, July 4 pm were selected to model wind turbine power production.

Average output in 2000 at selected times by scenario and zone.

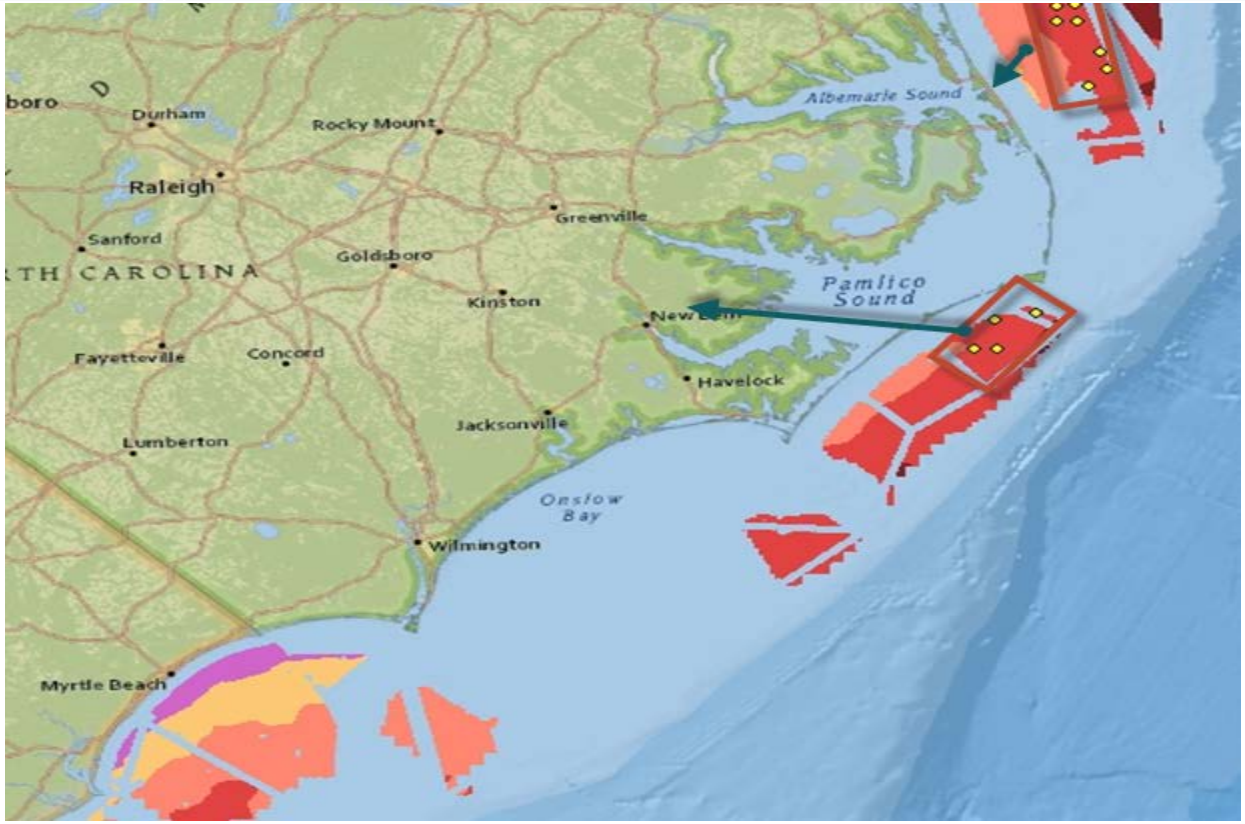
Scenario/ Zone	Num Sites	Capacity	Jan - 8 AM		May - 4 PM		July - 4 PM	
		MW	MW	% Cap	MW	% Cap	MW	% Cap
1000N	9	701.6	376.13	0.536	308.09	0.439	243.23	0.347
3000N	16	1304.5	688.72	0.528	571.52	0.438	454.82	0.349
5600N	26	2220.4	1151.94	0.519	946.36	0.426	778.11	0.350
1000C	4	297.6	161.35	0.542	163.87	0.551	96.76	0.325
3000C	13	1034.0	559.19	0.541	571.71	0.553	324.25	0.314
5600C	20	1639.4	892.14	0.544	919.09	0.561	512.26	0.312
3000S	7	660.8	371.67	0.562	330.53	0.500	217.84	0.330
5600S	20	1739.5	977.49	0.562	880.69	0.506	573.95	0.330

Task 3: Interconnection & Delivery Study

- NERC MMWG powerflow models were used representing 2018 summer and winter peak load and shoulder conditions with Duke Carolinas detail added.
- 1000 MW, 3000 MW, 5600 MW wind scenarios displaced Duke Carolina resources.
- Offshore collector stations interconnected to onshore substations at north, central, and south locations via AC and/or DC cables dependent on distance (i.e. 50 mi.).
- Network upgrades at each interconnection point determined from NERC Category A, B (now TPL P0, P1) contingency testing.
- Results – minimal upgrades required
  - North Zone
    - Increase capacity of 2 – 230 kV circuits
  - Central Zone
    - New 230 kV circuit
  - South Zone
    - Upgrade future 230 kV and 115 kV circuits and add 230-115 kV transformer

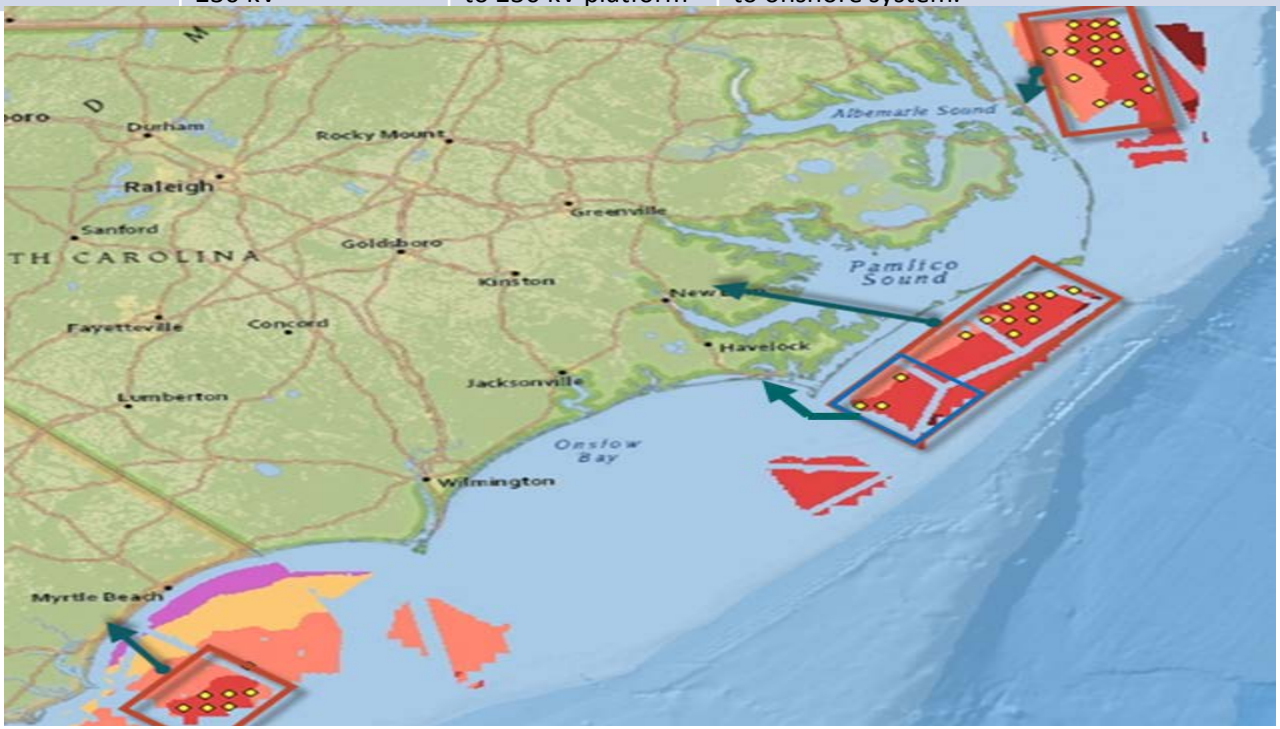
Task 3: Interconnection & Delivery Study

1000 MW Scenario				
ZONE	**ONSHORE LOCATION**	**ONSHORE DESIGN**	**OFFSHORE DESIGN**	**CHARACTERISTICS**
North	Kitty Hawk	AC connection to 230 kV	34.5 kV AC collector to 230 kV platform	Connects to PJM market.
Central	Silver Hill (Bayboro area)	DC/AC converter to 230 kV	34.5 kV AC collector to AC/DC converter	Bayboro location requires a DC cable across the Pamlico Sound.
South	N/A	N/A	N/A	N/A



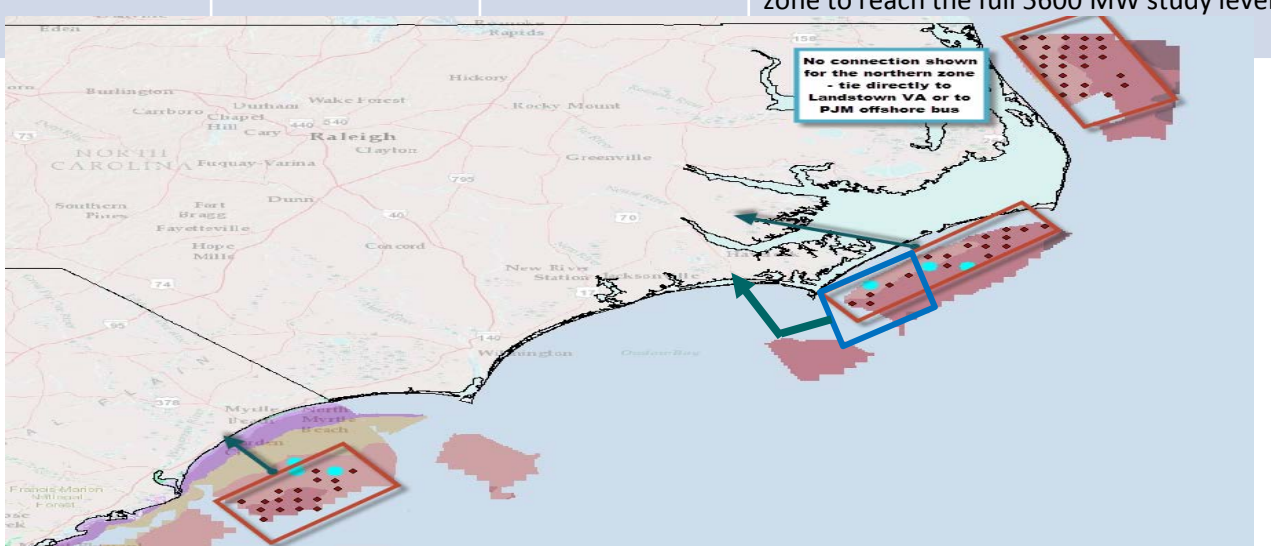
Task 3: Interconnection & Delivery Study

3000 MW Scenario				
ZONE	**ONSHORE LOCATION**	**ONSHORE DESIGN**	**OFFSHORE DESIGN**	**CHARACTERISTICS**
North	Kitty Hawk	AC connection to 230 kV	34.5 kV AC collector to 230 kV platform	Connects to PJM market.
Central	Silver Hill (Bayboro area)	DC/AC converter to 230 kV	34.5 kV AC collector to AC/DC converter	Bayboro location requires a DC cable across the Pamlico Sound.
Central	Morehead-Wildwood (Morehead City area)	AC connection to 230 kV	34.5 kV AC collector to 230 kV platform	Sites located too far south to connect to Bayboro area.
South	Bucksville	AC connection to 230 kV	34.5 kV AC collector to 230 kV platform	Reactive compensation likely to be required or DC connection to onshore system.



Task 3: Interconnection & Delivery Study

5600 MW Scenario				
ZONE	**ONSHORE LOCATION**	**ONSHORE DESIGN**	**OFFSHORE DESIGN**	**ISSUES**
North	Landstown (Virginia Beach area)	DC/AC converter to 230 kV	34.5 kV AC collector to AC/DC converter or DC collector to DC bus	Connects to PJM market. Requires connection to Virginia Beach, VA area substation or directly to PJM offshore DC bus.
Central	Morehead-Wildwood (Morehead City area)	AC connection to 230 kV	34.5 kV AC collector to 230 kV platform	Sites located too far south to connect to Bayboro area.
Central	New Bern	DC/AC converter to 230 kV	34.5 kV AC collector to AC/DC converter	New Bern location requires a DC cable across the Pamlico Sound.
South	Bucksville	DC/AC converter to 230 kV	34.5 kV AC collector to AC/DC converter	Required removing 6 outlier wind sites that were too far from the main body of wind sites to reasonably connect. The next 6 "less preferable" sites (blue dots on map) were selected – 3 in the Central zone and 3 in the South zone to reach the full 5600 MW study level.

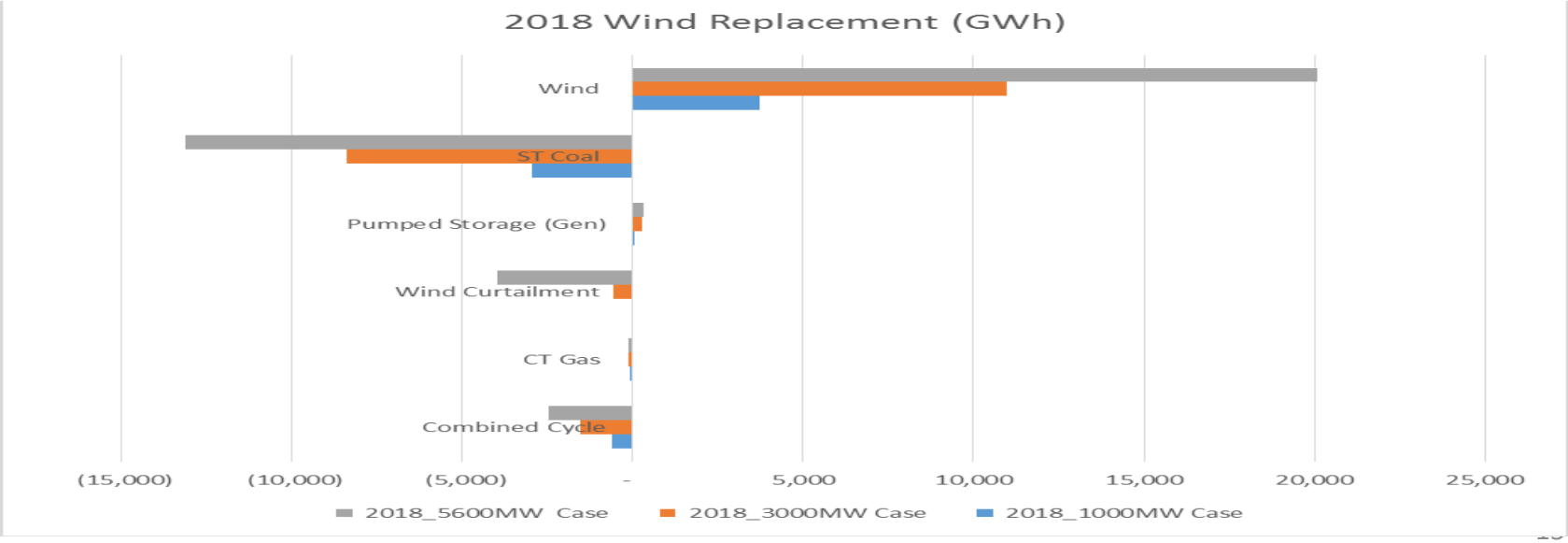


Task 4: Dynamic Stability Analysis

- Results show network remains stable during NERC Category A, B (now TPL P0, P1) conditions with offshore wind interconnected to system during peak and light load periods.

Task 5: Operating Reliability Impacts

- Capacity Reserves – use capacity credit of 39%.
- Contingency Reserves – no change required.
  - Redundancy in North & Central zones collection systems necessary for 5600 MW scenario.
- Regulating Reserves – increase in existing requirement of 110 MW to:
  - 114 MW for 1000 MW offshore wind turbine capacity
  - 127 MW for 3000 MW offshore wind turbine capacity
  - 155 MW for 5600 MW offshore wind turbine capacity
- Frequency Response Reserves – wind deemed capable of contributing inertial response and Primary Frequency Response. To do so, estimated power output levels would be de-rated 0.26%.

Task 6: Production Cost Analysis – in progress

Case Name	Prod Cost ($M)	Prod Saving ($M)	Wind Energy (GWH)	Wind Curtailed (GWH)
2018 Base	2,183			
2018 1000 MW	2,058	125	3,731	19
2018 3000 MW	1,844	339	10,977	558
2018 5600 MW	1,655	528	20,091	4,167
2021 Base	2,381			
2021 1000 MW	2,258	123	3,711	77
2021 3000 MW	2,043	339	10,909	585
2021 5600 MW	1,842	540	19,972	3,089