The Economics of Making Offshore Wind a Reality in Virginia

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Offshore Wind Cost of Energy and Opportunities for Cost Reduction
Offshore Wind Project Cost
Estimated by VCERC Cost Model

Capital cost estimated in March 2008 dollars using NREL parametric model for wind turbine & tower, Virginia maritime supplier bids for foundations & installation, and published data for balance of plant

- **Plant cost at offshore busbar:** $1,763 million
- **Transmission cost to Fentress:** $153 million
- **Total project investment:** $1,916 million (~ $3,260 / kW)

588 MW installed rated capacity
(7 x 7 turbines per lease block)

38% annual capacity factor

20% PJM summer capacity factor
(JJA 3pm – 6pm)
VCERC Modeled Costs Compared with Actual European Costs for Turbines and Foundations

European offshore wind turbine supply would cost ~$2,150/kW for 3 MW to 3.6 MW turbines, and ~$2,300/kW for 5 MW turbines.
Cost Benefit of Domestic Turbine & Tower Supply

- Cost of turbine & tower package for U.S. land-based wind projects in 2011: ~$1,250/kW (source: Fig. 32 of http://eetd.lbl.gov/ea/emp/reports/lbnl-4820e.pdf)

- This reflects ~60% domestic content (see Fig. 15 of above report) and cost would be even less for a 100% domestically produced turbine & tower package

- Adding 20% for marinization (double the percentage assumed by DOE) yields ~$1,500/kW

- Domestic turbine supply $650-800 per kW less than European supply
Domestic Offshore Wind Supply Chain would Benefit from Lower US Manufacturing Labor Costs


Foundation Supply for Lincs Project Indicates Effect of Manufacturing Labor Cost Difference

At ~$430 per kW, domestic monopile foundation supply is $230 per kW less than European supply.
VCERC Modeled Costs Compared with Actual European Costs for Submarine Power Cables

VCERC reference design site is only 29 km offshore, with export cable supply cost of $160 per kW.

Projects in Virginia Wind Energy Area could have export cable route lengths of 44 km to 68 km.

At $5.50 per kW-km export cable supply would cost $240 to 370 per kW, depending on where substation platform is located in Call Area.
VCERC Energy Cost Estimates Compared with Recent National Academy of Sciences Study

**Baseload**
- Coal CCS
- Coal
- NGCC-CCS
- NGCC
- Nuclear
- Geothermal
- Biopower

**Interruption**
- Solar CSP
- Solar PV
- Wind-On
- Wind-Off

Coal costs now increasing; offshore wind would increase price stability of Virginia’s energy supply portfolio; see backup slides

VCERC: ~06-07¢/kWh
VCERC: ~10-12¢/kWh
VCERC: ~11¢/kWh
VCERC: ~13¢/kWh
Largest Upside Potential is Optimizing Turbine Design for Mid-Atlantic Winds
Hub height mean wind speed = 8 to 9 m/s; prevailing wind direction from NW-N-NE in winter and from SW-S in summer.
VCERC Analysis of two Turbine Fleets for Productivity as a Function of Rotor Swept Area

Enercon fleet represents direct-drive permanent magnet generator

Vestas fleet represents multi-stage gearbox drive

Enercon @ 98 m
\[ y = 1.128E-04x + 1.855E-01 \]
\[ R^2 = 9.717E-01 \]

Vestas @ 98 m
\[ y = 8.35E-05x + 2.29E-01 \]
\[ R^2 = 9.71E-01 \]
VCERC Analysis of two Turbine Fleets for Productivity as a Function of Rotor Swept Area

Enercon fleet represents direct-drive permanent magnet generator.

Gearbox TG requires 16% greater rotor swept area for 50% annual capacity factor.

**Graph:**
- **Enercon @ 98 m**
  - \( y = 1.128E-04x + 1.855E-01 \)
  - \( R^2 = 9.717E-01 \)
- **Vestas @ 98 m**
  - \( y = 8.35E-05x + 2.29E-01 \)
  - \( R^2 = 9.71E-01 \)
Estimated Turbine Capacity Factor off Virginia for New Offshore Turbine Designs with Large Rotors

- Vestas 3 MW with 112 m diameter rotor = 3,284 m$^2$ swept area per MW
- Vestas 7 MW with 164 m diameter rotor
- Alstom 6 MW with 150 m diameter rotor = 2,945 m$^2$ swept area per MW
- NREL reference turbine design: 5 MW with 126 m diameter rotor
- VERC baseline design: Vestas 3 MW with 90 m diameter rotor
- Nordex and Siemens also have direct-drive 6 MW turbines with 150 m diameter rotor
Larger Rotor Swept Area Imposes Larger Thrust Loads on Turbine Drive Train

Conventional turbine drive train transmits thrust loads and drive shaft bending moments THROUGH gearbox to tower structure.
Larger Rotor Swept Area Imposes Larger Thrust Loads on Turbine Drive Train

Alstom *PURE TORQUE™* drive train transmits rotor thrust loads and drive shaft bending moments via cast frame to tower structure, such that generator is isolated from these loads and experiences only simple torque.
Future Utility Electric Rate Increases due to Fossil Fuel Price Volatility
Dominion Meets Approximately a Third of its Demand by Purchasing Wholesale Power in PJM

KEY STATISTICS
- PJM member companies: 550+
- Millions of people served: 51
- Peak load in megawatts: 144,644
- MWs of generating capacity: 164,895
- Miles of transmission lines: 56,499
- GWh of annual energy: 729,000
- Generation sources: 1,287
- Square miles of territory: 168,500
- Area served: 13 states + DC

26% of generation in Eastern Interconnection
23% of load in Eastern Interconnection
19% of transmission assets in Eastern Interconnection
19% of U.S. GDP produced in PJM
Dominion Virginia Power purchases approximately one-third of the power needed to meet its customer demand from the PJM regional market. As with fossil fuel prices for its owned generation plants, any changes in purchased power price are passed on to customers, and businesses wanting to relocate to or remain in Virginia will be concerned about future rate hikes.
Wholesale on-peak prices forecast to double by 2020 from 7.5 to 15.0 ¢/kWh
Wholesale off-peak prices forecast to double by 2016 from 5 to 10 ¢/kWh.
In Virginia’s Regulated Energy Market Utilities Pass on Fuel Price Increases to Customers

U.S. Retail Electricity vs. Wholesale Input Prices, 1986-2009

All Commodities Expressed as Index of 1984=100. Source: Bureau of Labor Statistics.
Even Coal is No Longer Stably Priced

NYMEX Central Appalachian Coal Futures Near-Month Contract Final Settlement Price History

Data as of 12/31/2011
Note: No data available for Western PRB and Eastern CSX prior to 6/30/09.
Thank You!

VCERC Offshore Wind Studies Final Report:
www.vcerc.org/report.htm

Any questions?

Email: hagerman@vt.edu
Composite income tax rate: 38.8% (35% Federal, 5.85% State)

General depreciation declining balance is used

- GDS life of 15 years for coal- and gas-fired generation
- GDS life of 5 years (bonus depreciation) for wind generation

100% of project is financed up front

- 43.2% Debt and 56.8% Equity
- Debt real rate of return 5.586%
- Equity real rate of return (13.75% common, 7.174% preferred)
- Includes 3-year construction loan (7.5% real debt rate)

Debt is paid monthly, equity return paid quarterly

Service life: 25 years for wind, natural gas; 50 years for coal

Levelized annual fixed charge rate (FCR):

- Real (constant dollars): 7.55% for wind, 10.50% for gas; 9.06% for coal
- Nominal (current dollars, assuming 2.5% annual inflation rate): 9.55% for wind, 13.07% for gas; 10.06% for coal
Wise County Coal-Fired Project

Capital cost basis

- Plant cost: $1,800 million
- Transmission cost: $23 million
- Total project investment: $1,823 million (~$3,120 / kW)

585 MW rated capacity

90% annual capacity factor

Plant heat rate:
10.00 MMBtu per MWhr

Coal heat content:
15.4 MMBTU per short ton

Actual in-service date: 2013
(used 2012 for all projects)
Recent Delivered Coal Prices

Coal prices are rebounding more quickly than assumed in original VCERC report.

Assumed price range in first year (2012)

(www.eei.org/whatwedo/DataAnalysis/IndusFinanAnalysis/Documents/2010_Q2_Fuel_Final.pdf)
Near-Term Forecast of Central Appalachian Coal Spot Market Prices

(www.eei.org/whatwedo/DataAnalysis/IndusFinanAnalysis/Documents/2010_Q2_Fuel_Final.pdf)

6% nominal annual escalation rate
Updated fuel market scenario
2012 price: $60-80 per short ton
4% to 6% real annual escalation
(from EEI coal cost projections)
Cost of Energy Comparison Between Offshore Wind and New Coal-Fired Generation

588 MW Offshore Wind vs. 585 MW Wise County Coal

Levelized Cost of Energy (Mar 2008 $ per MWh)

- $50 per ton CO2
- $25 per ton CO2
- $0 per ton CO2

Year One (2012) Central Appalachian Coal Price (Mar 2008 $ per short ton)

- 2008 High ($143 per short ton)
- 2008 Low ($56 per short ton)
- 6% real annual escalation rate
- 4% real annual escalation rate
- 2% real annual escalation rate
- 0% real annual escalation rate

CO2 capture & storage cost

Forward fuel market scenario 2012-2062

European turbine supply

Domestic turbine supply
PJM Cost of New Entry (CONE) Combined Cycle Gas Turbine (CCGT) Project

Capital cost basis

- Based on 660.9 MW PJM CONE (29 Aug 2008 update) applied to Dominion’s Bear Garden project in Buckingham County
- **Plant cost:** $775 million
- **Transmission cost:** $5 million
- **Total project investment:** $780 million (~ $1,340 / kW)

580 MW rated capacity

90% annual capacity factor

Plant heat rate:
GE Frame 7FA CCGT
7.315 MMBtu per MWhr

Actual in-service date: 2011
(used 2012 for all projects)
Near-Term Forecast of Henry Hub Natural Gas Spot Market Prices

Cost of Energy Comparison Between Offshore Wind and New Gas-Fired Generation

Updated fuel market scenario
2012 price: $5.50-6.00 per MMBTU
2% to 4% real annual escalation
(from EEI natural gas cost projections)
Cost of Energy Comparison Between Offshore Wind and New Gas-Fired Generation

588 MW Offshore Wind vs. 580 MW PJM CONE CCGT

Levelized Cost of Energy (Mar 2008 $ per MWh)

- Offshore Wind
- Domestic turbine supply
- European turbine supply

Year One (2012) Henry Hub Natural Gas Price (Mar 2008 $ per MMBTU)

Forward fuel market scenario 2012-2037

- 2008 High ($13.60 per MMBTU)
- 2008 Low ($5.30 per MMBTU)
- 6% real annual escalation rate
- 4% real annual escalation rate
- 2% real annual escalation rate
- 0% real annual escalation rate

CO2 capture & storage cost

$50 per ton CO2

$0 per ton CO2