Office of the Governor

DuPont

delmarva power

GORE

SELECT GREATER PHILADELPHIA

Department of Labor – Keeping Delaware First

Pennoni

Delaware Sustainable Chemistry Alliance

Delaware State Chamber of Commerce

Delaware Public Policy Institute

The News Journal

Delaware State University

Delaware Tech

University of Delaware

CREATING *the* CLEAN ENERGY ECONOMY

IN DELAWARE, THE REGION AND THE NATION

Willett Kempton

Director, Center for Carbon-Free Power Integration, College of Earth, Ocean, and Environment

University of Delaware

UNIVERSITY OF DELAWARE

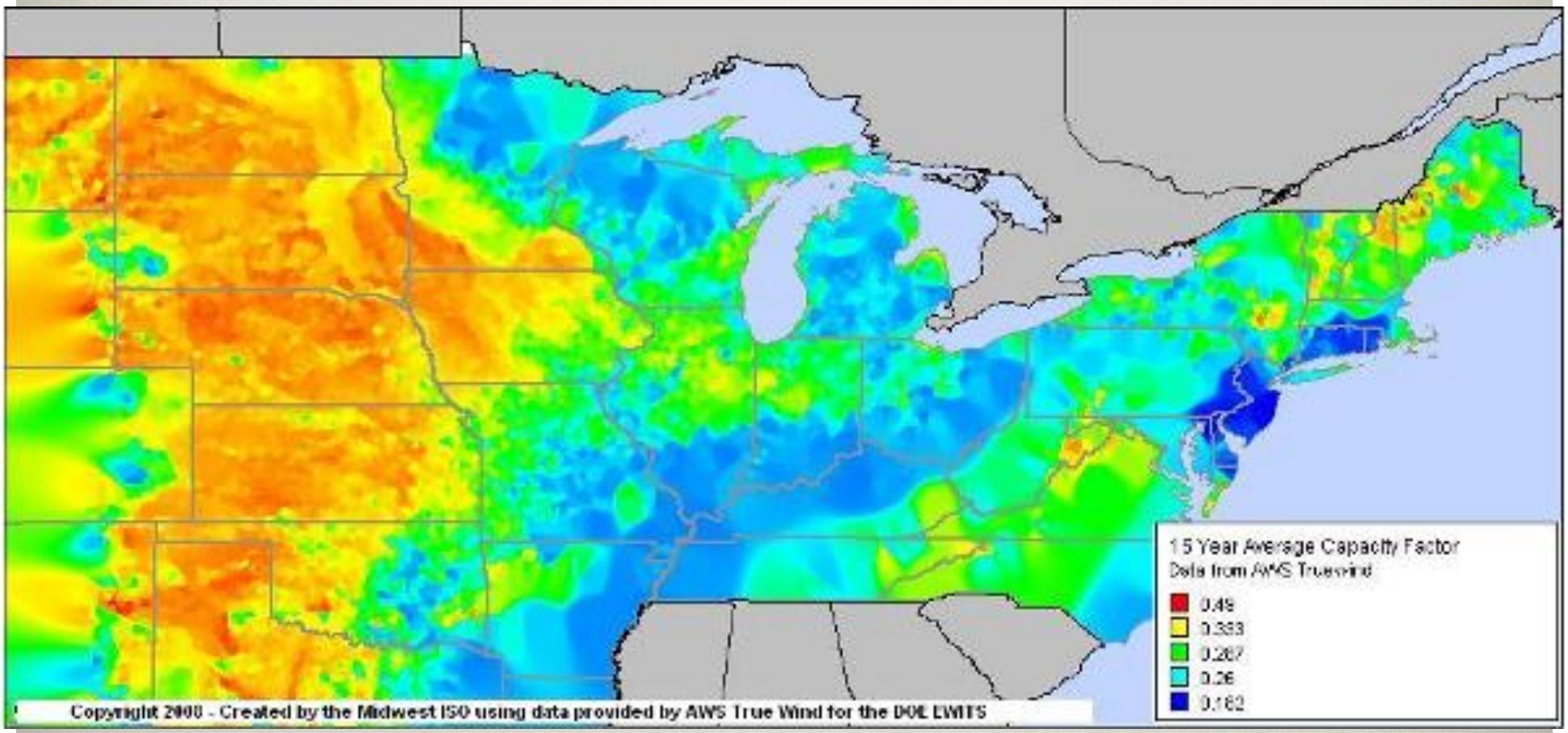
CREATING KNOWLEDGE-BASED PARTNERSHIPS

UD: Moving from R&D to Innovation to Commercialization

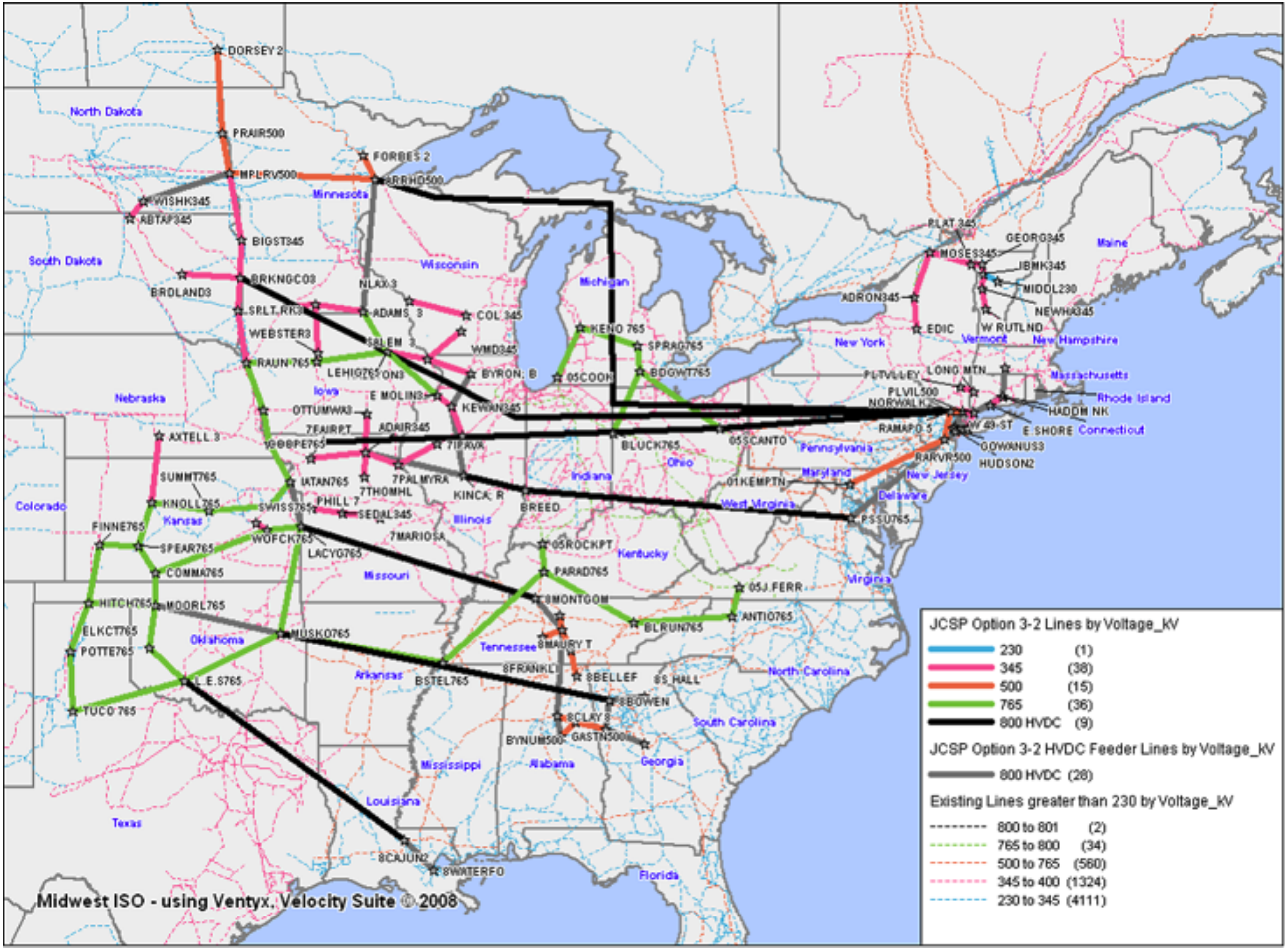
Willett Kempton
Center for Carbon-free Power Integration
College of Earth, Ocean, and Environment
University of Delaware

10 December 2010

Wind Technology



MISO Joint Coordinated System Plan


JCSP Option 3-2 Lines by Voltage_kV
230 (1)
345 (38)
500 (15)
765 (36)
800 HVDC (9)
JCSP Option 3-2 HVDC Feeder Lines by Voltage_kV
800 HVDC (28)
Existing Lines greater than 230 by Voltage_kV
800 to 801 (2)
765 to 800 (34)
500 to 765 (560)
345 to 400 (1324)
230 to 345 (4111)
Midwest ISO - using Ventyx, Velocity Suite © 2008
North Dakota
South Dakota
Minnesota
Wisconsin
Michigan
Nebraska
Iowa
Illinois
Indiana
Ohio
Pennsylvania
New York
Vermont
New Hampshire
Maine
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
West Virginia
Virginia
Kentucky
Tennessee
North Carolina
South Carolina
Georgia
Florida
Alabama
Mississippi
Louisiana
Arkansas
Missouri
Kansas
Oklahoma
Texas
Colorado
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PRAIR500
FORBES 2
MPLRV500
ARRHD500
WISHK345
ABTAP345
BIGST345
BRKNGCO3
BRDLAND3
SRLT RK3
WEBSTER3
ADAMS 3
NLAX 3
COL 345
SALEM 3
WMD345
BYRON; B
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LEHIG765
E MOLINE
OTTUMWA3
KEWAN345
7FAIRPT
ADAIR345
COOPE765
7IPAVA
AXTELL 3
SUMMT765
IATAN765
7THOMHL
7PALMYRA
KINCA; R
BREED
KNOLL765
SWISS765
PHILL 7
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FINNE765
SPEAR765
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BSTEL765
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8WATERFO
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8BELLEF
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GASTN500
01KEMPTN
PSSU765
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HUDSON2
GOWANUS3
RAMAPO 5
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HADDM NK
NORWALK
PLVIL500
PLTVLLEY
LONG MTN
W RUTLND
NEWHA345
MIDDL230
IBMK345
GEORG345
PLAT 345
MOSES345
ADRON345
EDIC

UD Research: How Much Resource?

QuikSCAT

Met. buoy

Image credit: NASA

VS

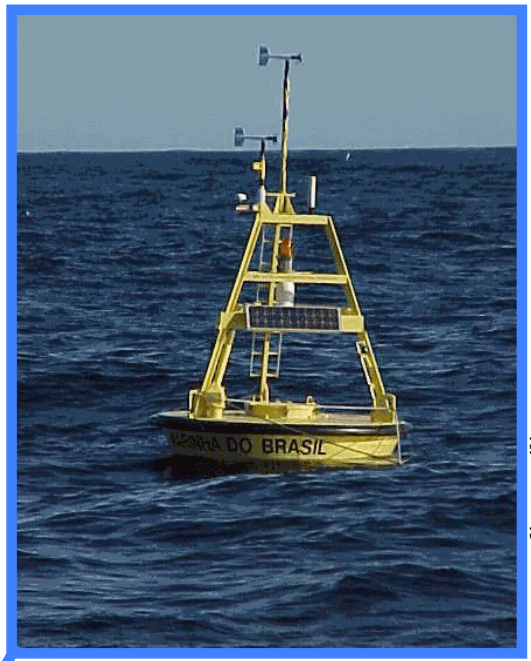
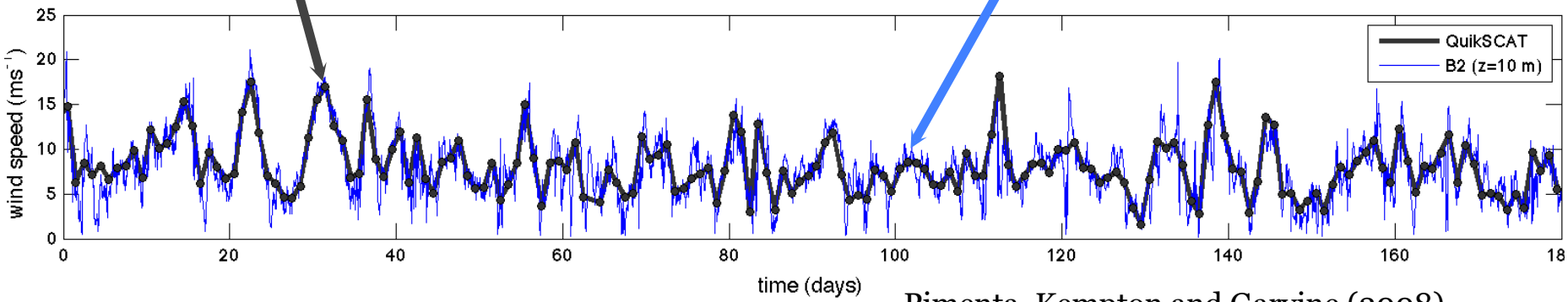


Image credit: Brazilian Navy

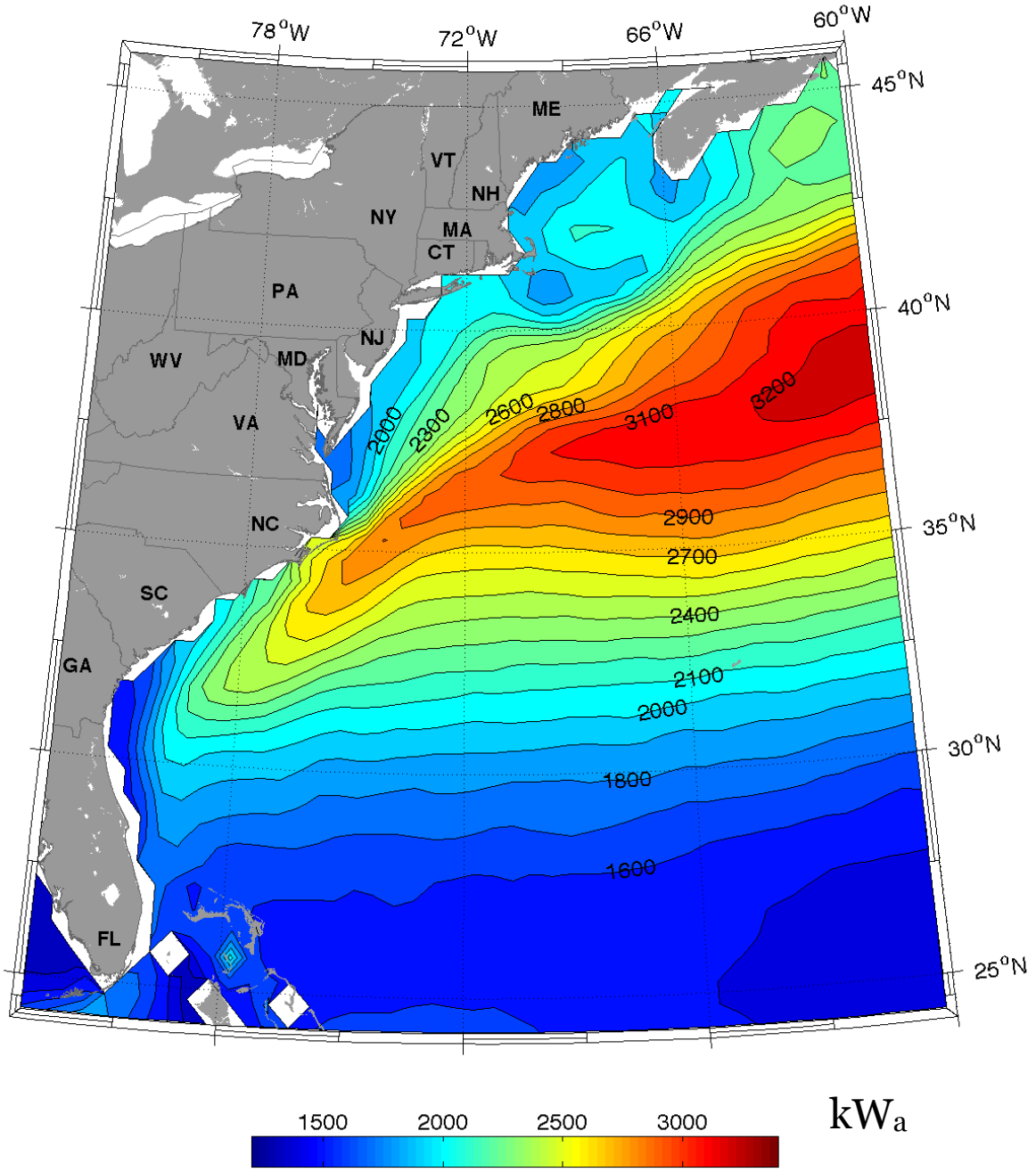


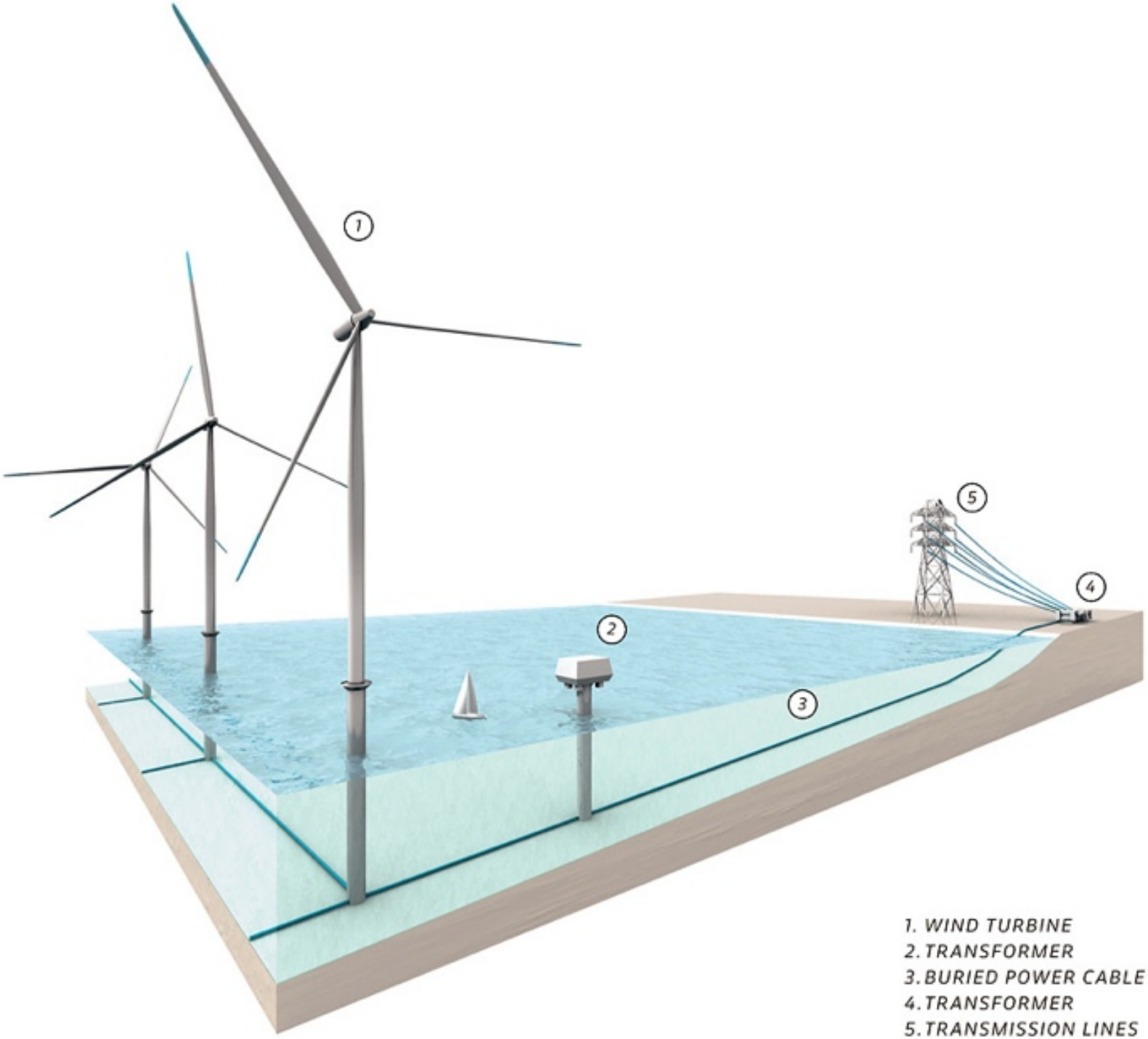
Pimenta, Kempton and Garvine (2008)

QuikSCAT

turbine output
1999-2008

Image: Repower Systems AG





Art: NY Times Magazine

Testimony by UD academics

Jeremy Firestone and Willett Kempton,
University of Delaware

Decision by three agencies + PSC

Top row, l to r: Controller General, Secretary of DNREC, Chair of PSC, OMB Director. Second row: PSC Commissioners

The News Journal

www.delawareonline.com

50¢ · FINAL EDITION

DELMARVA, BLUEWATER REACH AGREEMENT

Offshore wind pact OK'd for Delaware

About the wind farm

Bluewater Wind LLC would build between 55 to 70 wind turbines for Delmarva and municipal customers inside the site shown below.

WHAT PLANNERS ENVISION

A tanker passes a Danish wind farm that Bluewater says could be similar to its proposed project off Rehoboth Beach.

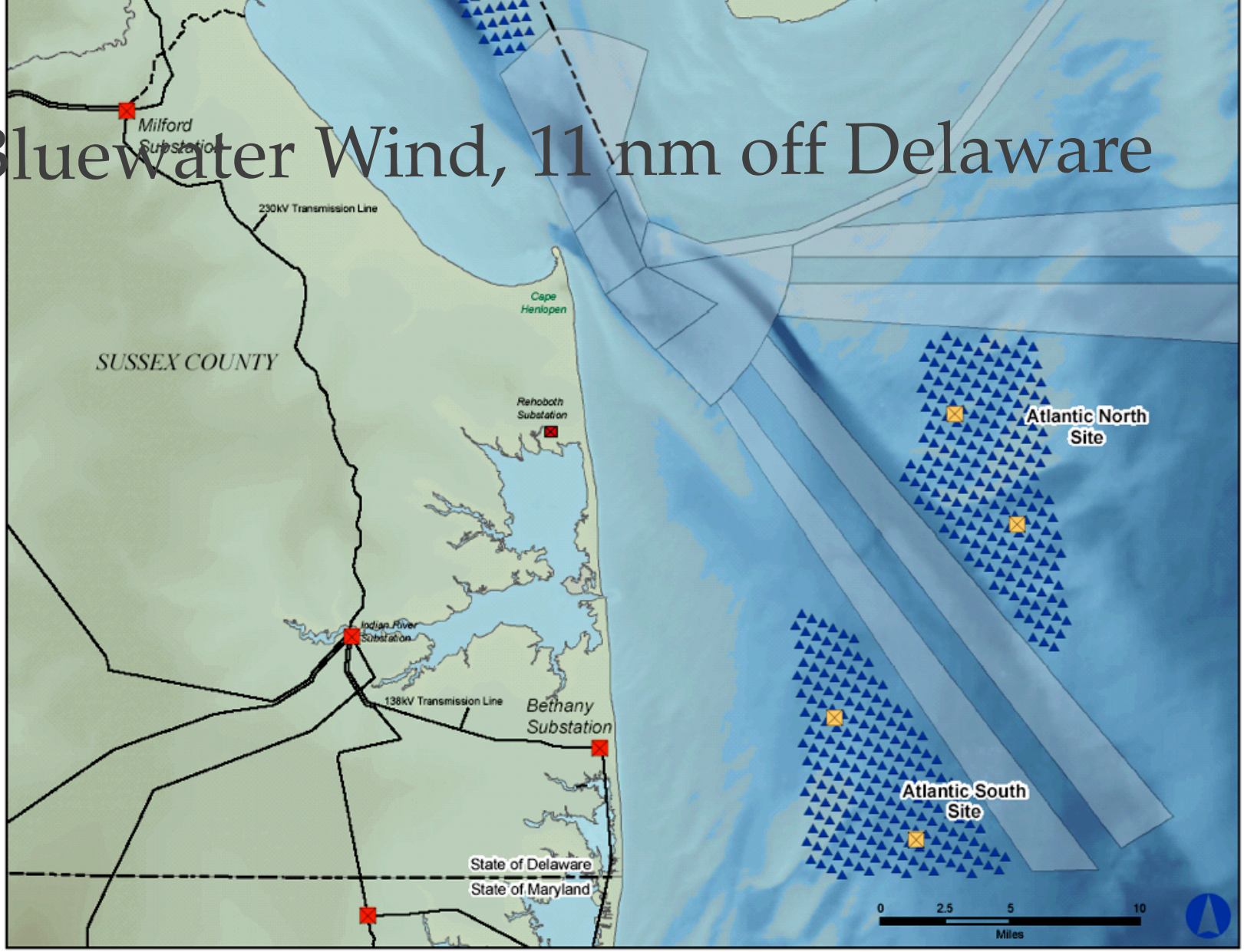
Photo courtesy of Bluewater

THE NEXT OBSTACLES FOR THE PROJECT INCLUDE:

- Delaware's General Assembly must approve bills incorporating aspects of
- Bluewater Wind will begin advanced engi-
- Work will begin to secure permits for

PPA approval

Bluewater Wind, 11 nm off Delaware



Legend

- Proposed Turbine Layout
- Preliminary Onshore Transmission Route
- Preliminary Substation Location
- Shipping Lane
- Existing Substation
- Existing Transmission Line
- County Boundary
- Delaware State Boundary

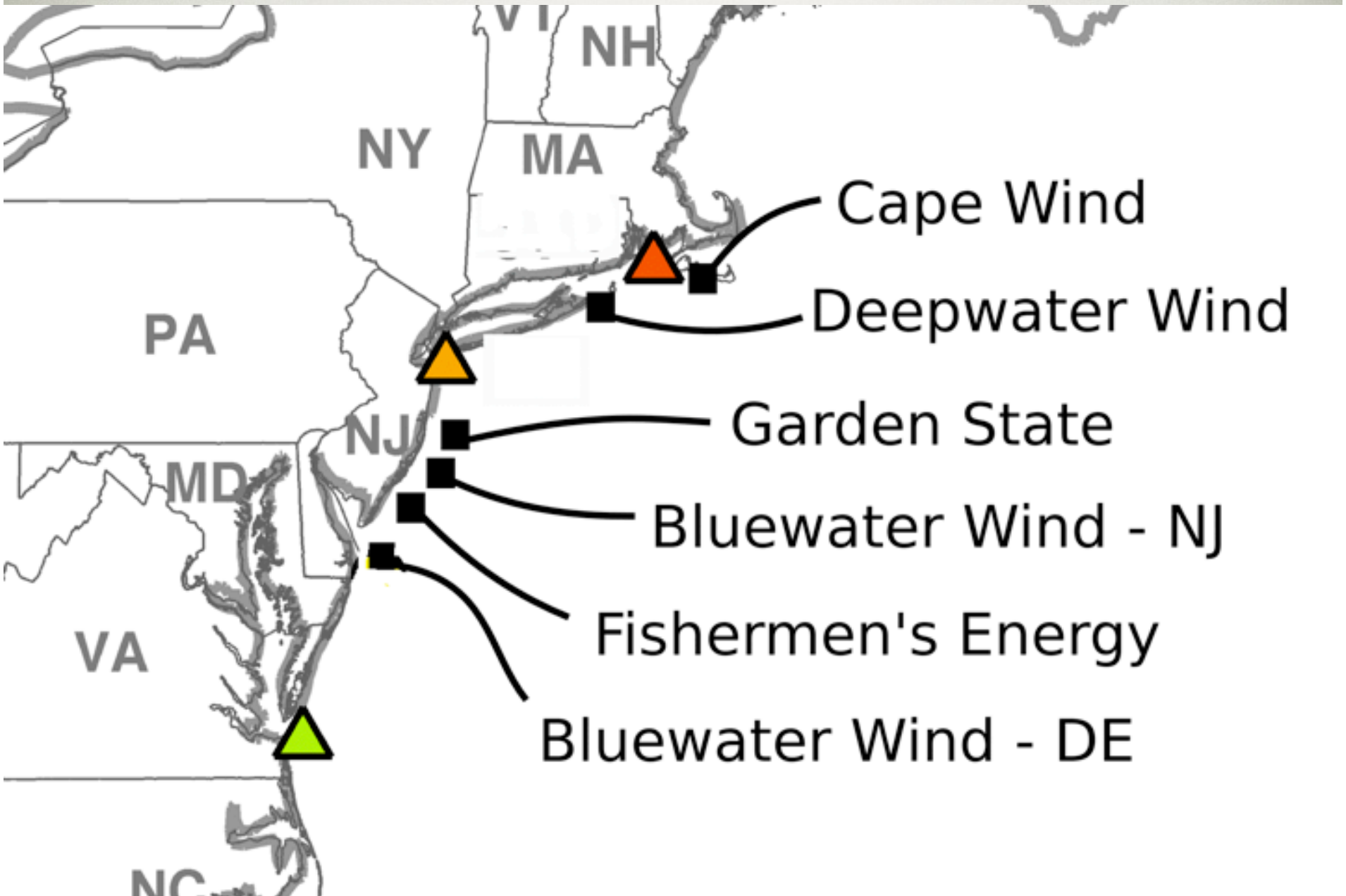
Offshore and Delaware Bay
Wind Park Sites
and Interconnections

Form M - Appendix 1

December, 2006

TETRA TECH EC, INC

US Developments Proposed



UD Wind Turbine

- On land in Lewes, DE, but in coastal winds (sea breeze)
- Gamesa G90: 90 meter blade diameter, 2 MW nameplate power
- Will power 100% of Lewes campus, with sale of excess

The Grid-Integrated Vehicle, with Vehicle-to-Grid power

UD Electric Vehicles

Urban Utility Vehicle

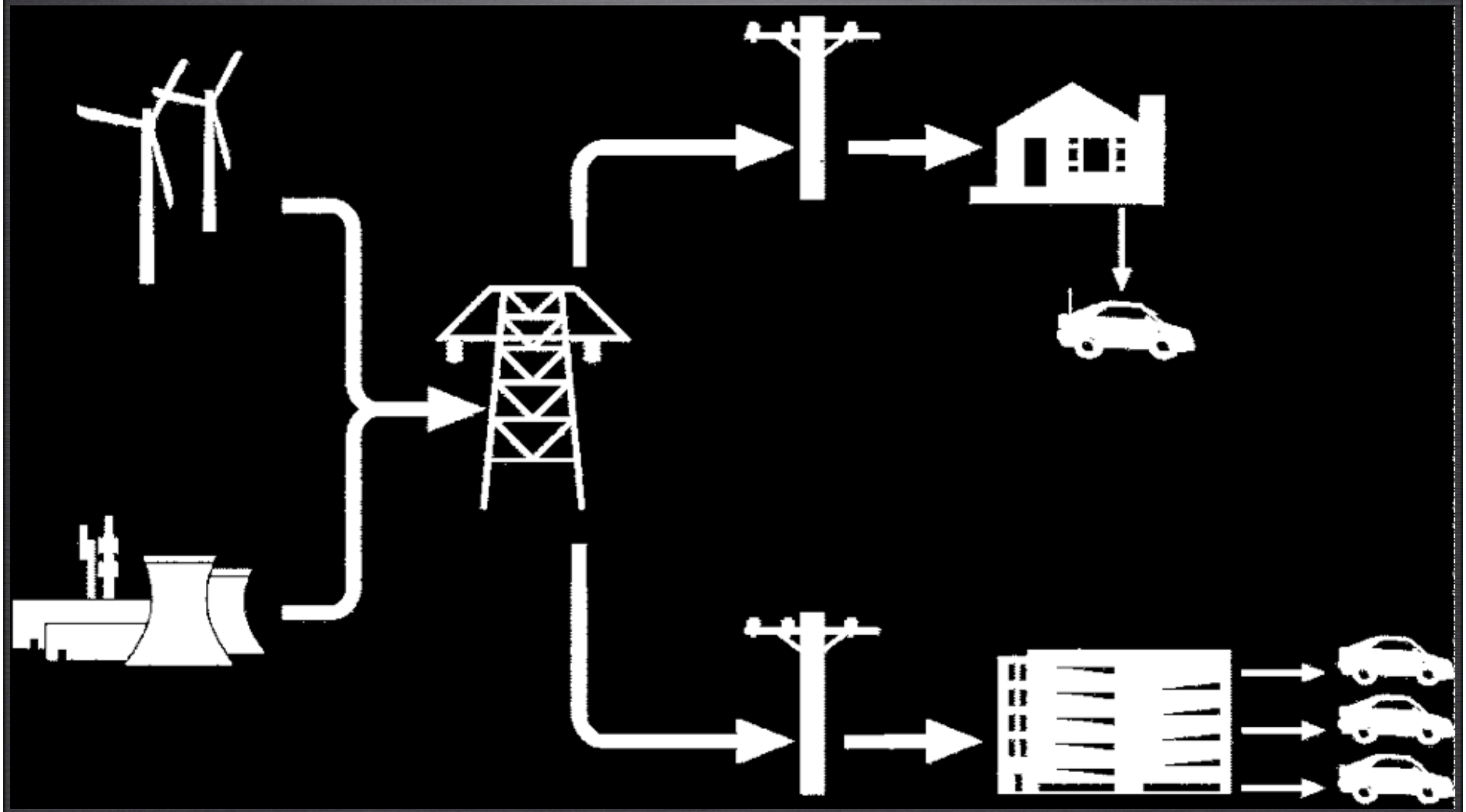
Spacious, efficient, comfortable, unique, sporty, versatile, zero emission,

Electric.

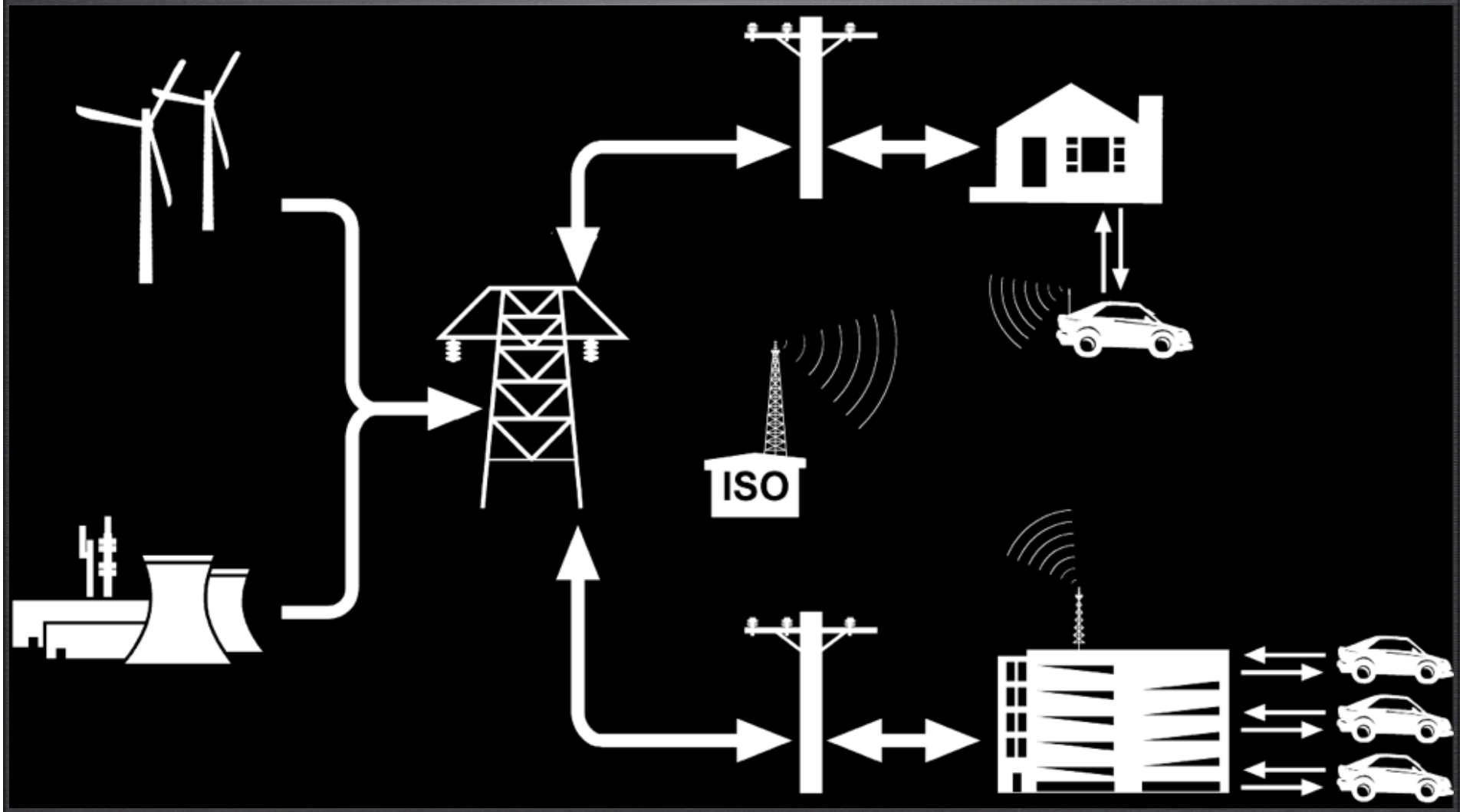
Vehicle Performance

Range	140 – 180 miles
Acceleration	0 to 60 ~ 7 secs
Top Speed	95 mph
Charge rate	30 minutes for 20 – 50 miles
Full Charge	2 hrs (fast), 5 hrs (normal)

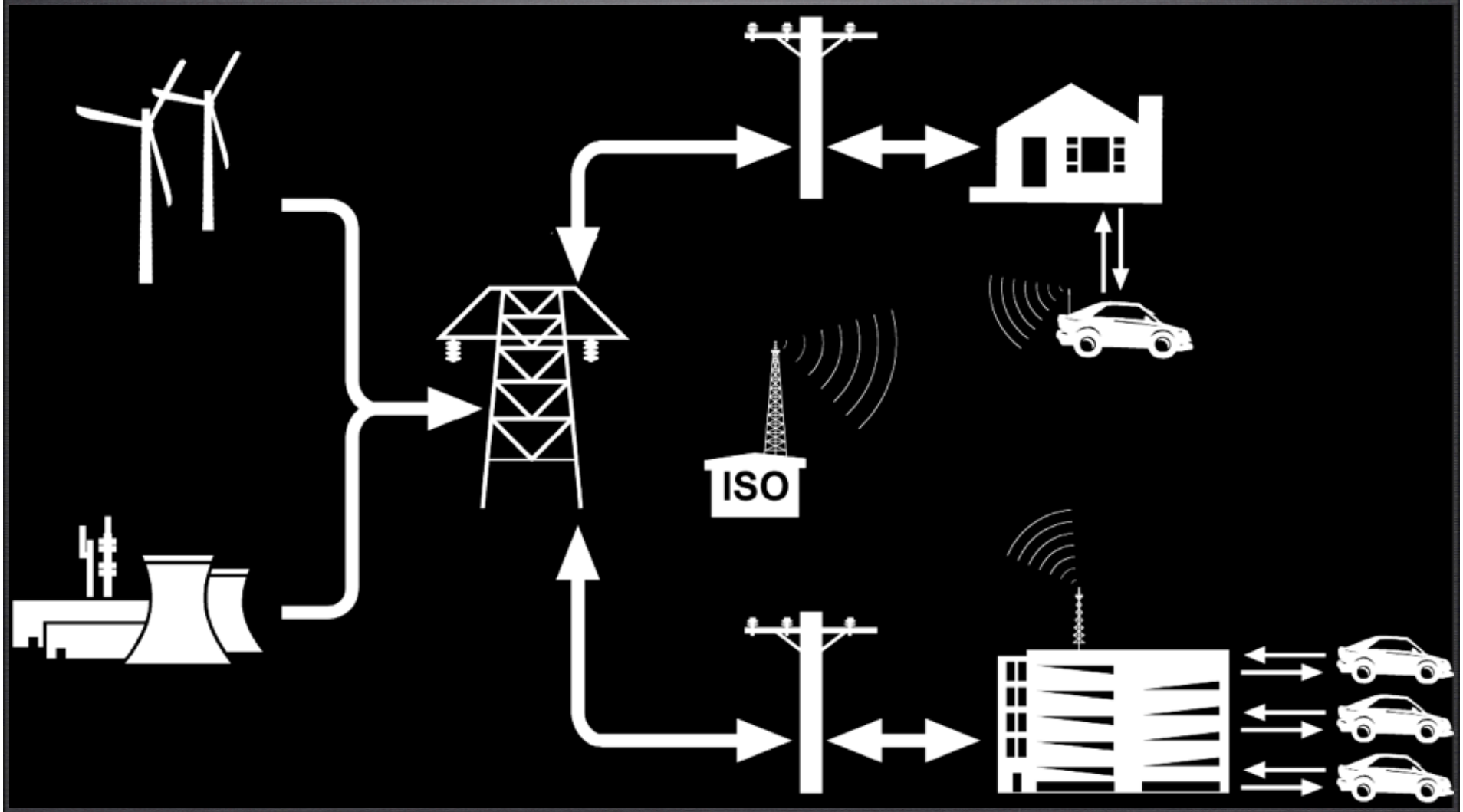
Plug-in for charging



GIV Means Control



V2G Means 2-Way Power



Law to codify interconnects, net metering for V2G

SPONSOR: Sen. Simpson & Rep. Kowalko
Sen. McDowell; Rep. Hocker

DELAWARE STATE SENATE
145th GENERAL ASSEMBLY

SENATE BILL NO. 153

AN ACT TO AMEND TITLE 26 OF THE DELAWARE CODE RELATING TO CUSTOMER SITED ENERGY RESOURCES.

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF DELAWARE (Two-thirds of all members elected to each house thereof concurring therein):

Section 1. Amend §1001, Title 26 of the Delaware Code by adding two new definitions reading as follows, and renumbering existing definitions alphabetically.

"(1) 'Aggregator' means any person or entity who contracts with an electric distribution company, electric supplier or PJM Interconnection (or its successor) to provide energy services, which facilitate battery storage systems for grid-integrated electric vehicles and related technologies.

(14) 'Grid-Integrated Electric Vehicle' means a battery-run motor vehicle that has the ability for two-way power flow between the vehicle and the electric grid and the communications hardware and software that allow for the external control of battery charging and discharging by an electric distribution company, electric supplier, PJM Interconnection, or an aggregator."

Define:

Aggregator

Grid-integrated electric vehicle

LAW TO CODIFY INTERCONNECTS

Section 2. Amend §1014, Title 26 of the Delaware Code by adding a new subsection to read as follows:

(g) A retail electric customer having on its premises one or more grid-integrated electric vehicles shall be credited in kilowatt-hours (kWh) for energy discharged to the grid from the vehicle's battery at the same kWh rate that customer pays to charge the battery from the grid, as defined in (e)(1) of this section. For electric customers with time of use rates, the kWh rate for charging and discharging shall be the rate in effect when charging or discharging occurs. Excess kWh credits shall be handled in the same manner as net metering as described in (e)(1) of this section. To qualify under this subsection, the grid-integrated electric vehicle must meet the requirements in (d)(1)a., (d)(1)b. and (d)(4) of this section. Connection and metering of grid integrated vehicles shall be subject to the rules and regulations found in (e)(2), (e)(3), and (e)(4) of this section.

Net metering for V2G

Net is at rate at time of use

Interconnection requirements, etc same as distributed renewables

Patents

- Patent Applications, 2007-2010:
  - U.S. Patent Application Publication Nos. 2007/0282495 A1 "System and Method for Assessing Vehicle-to-Grid (V2G) Integration" filed May 2007 (UD; Kempton and Tomic)
  - U.S. Patent application publication No. "Hierarchical Priority and Control Algorithms for the Grid-Integrated Vehicle", filed March 2009, (UD; Kempton)
  - Three US and PCT applications in 2010, Electric Vehicle Station Equipment for Grid-Integrated Vehicles; Electric Vehicle Equipment for Grid-Integrated Vehicles; Aggregator Server for Grid-Integrated Vehicles. Filed Sept 2010 (UD; Kempton and co-inventors)
- One signed license for VSL, in license negotiations for EVSE and for aggregator

License Manufacturing

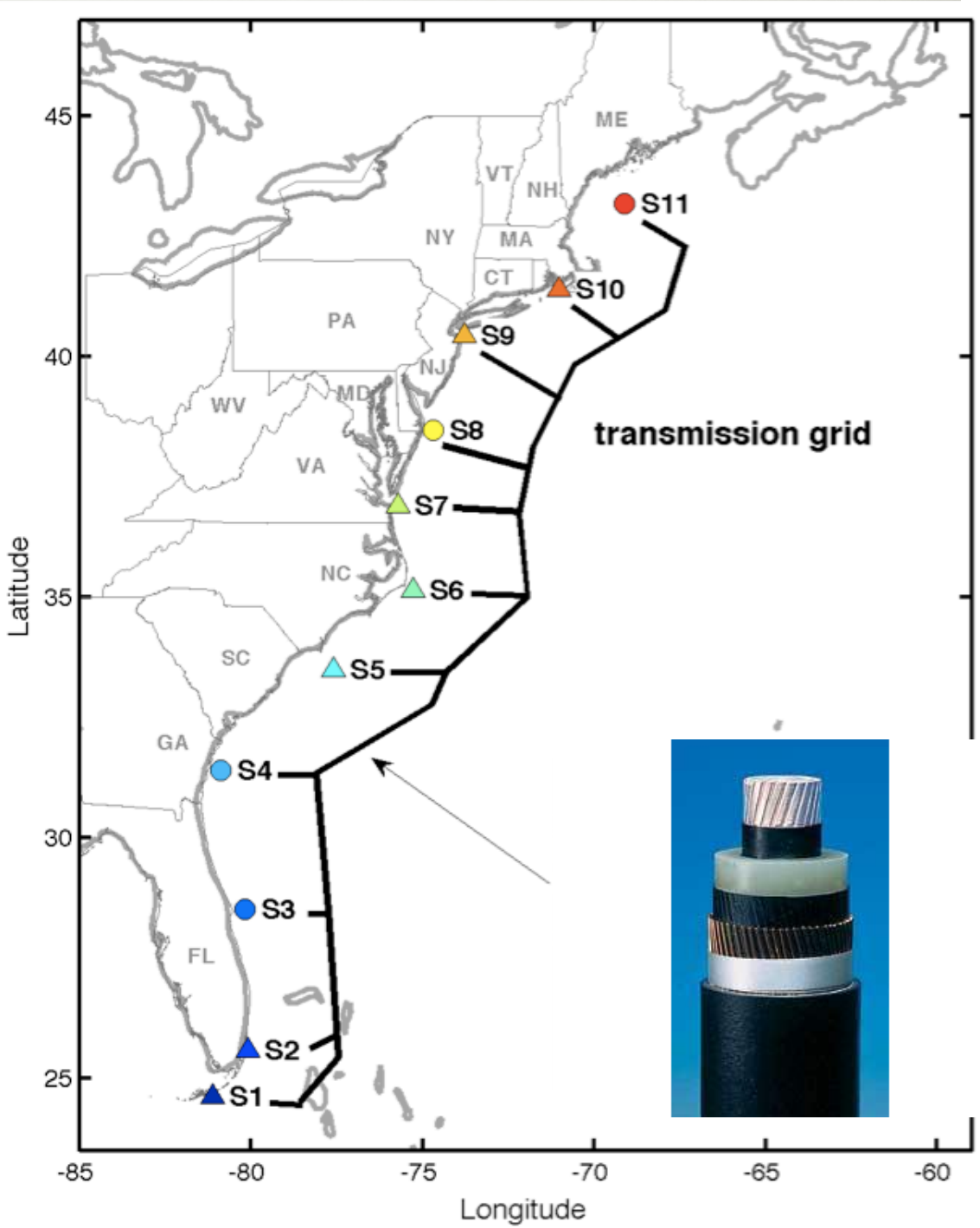
Auto Port INC.

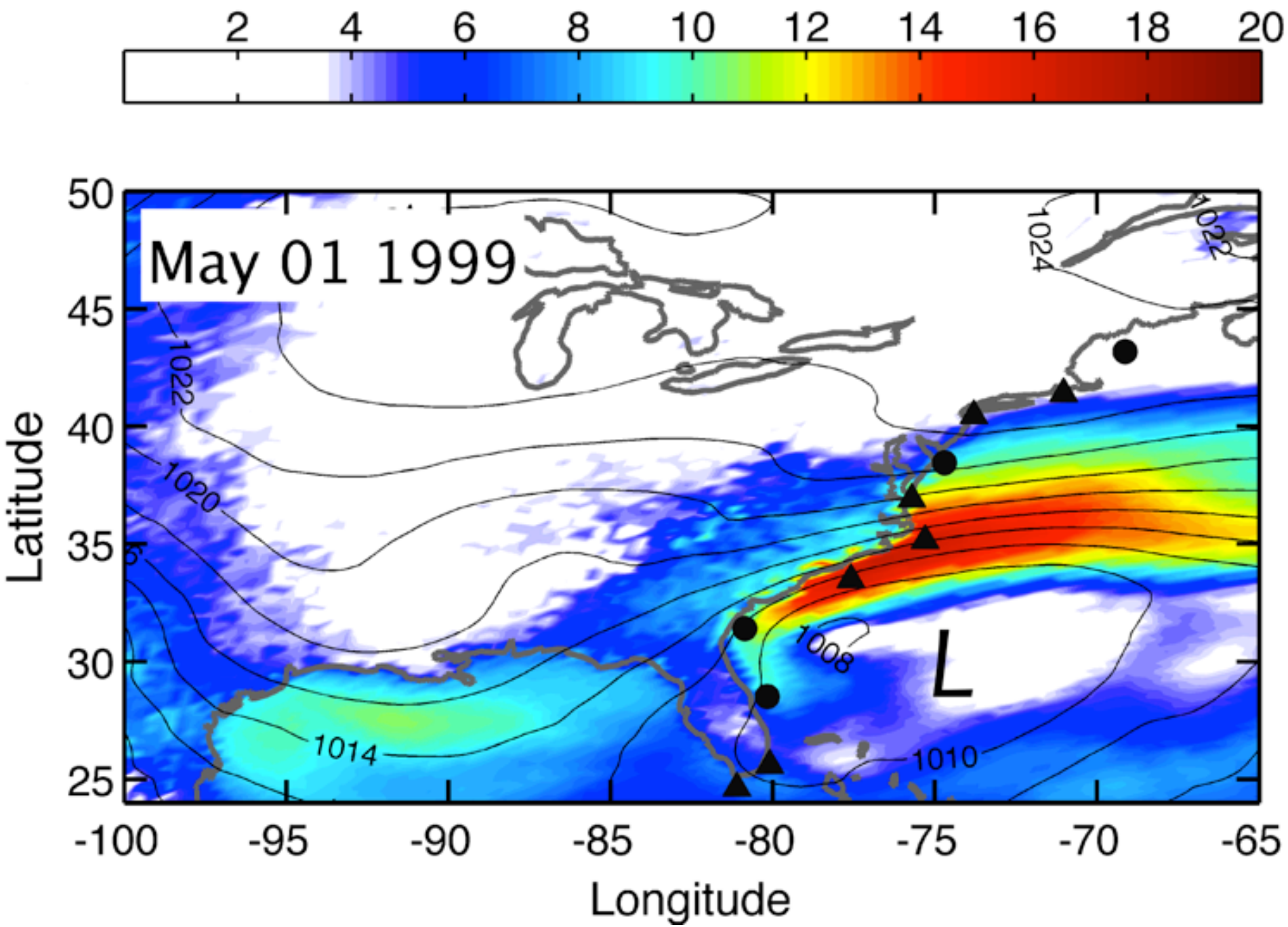
GIV with controls and V2G, licensed from UD -- Built in from factory

Offshore Transmission to Level Wind

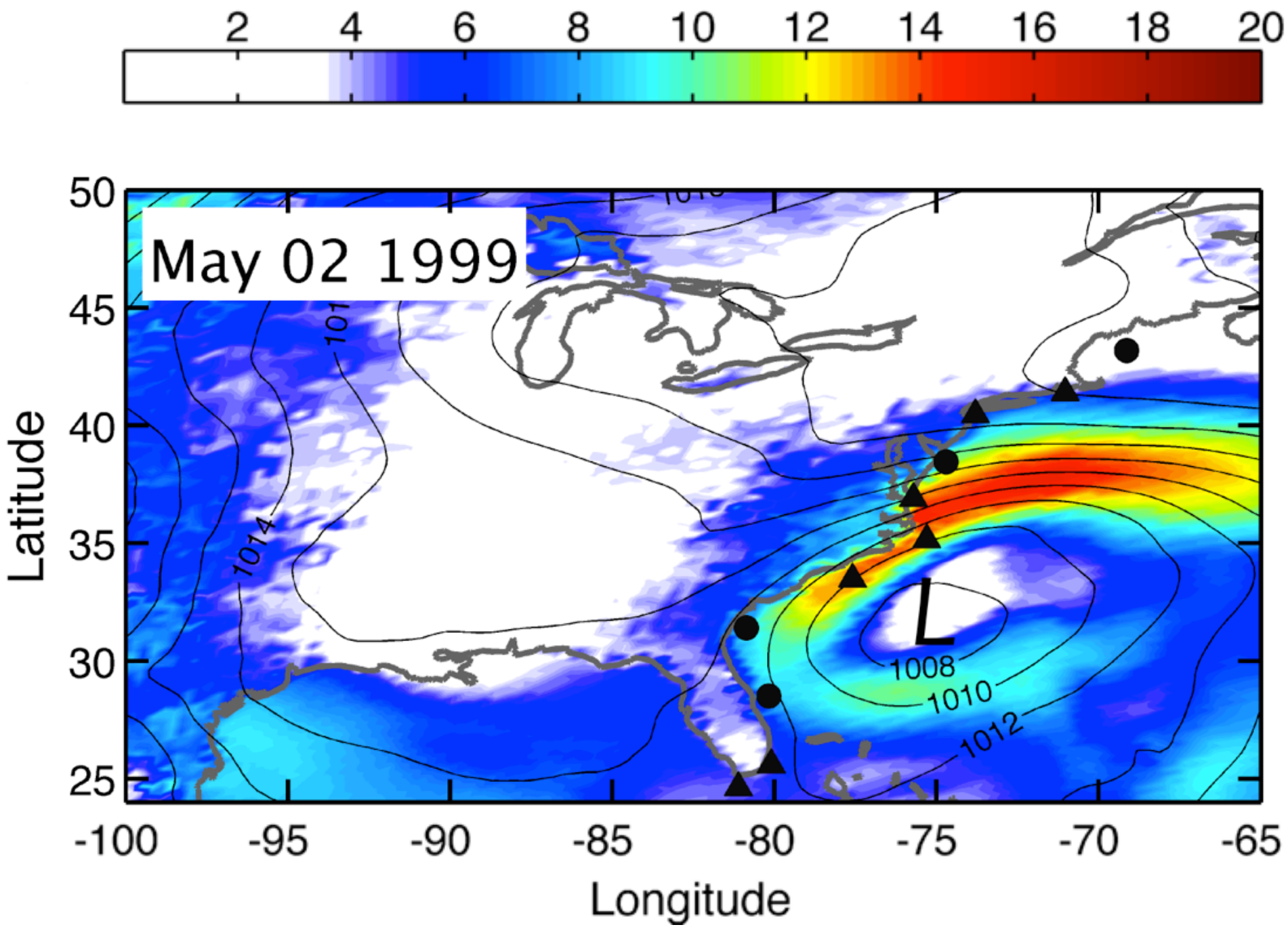
Transmission N-S on Shelf

- Weather data from each station S1 - S11
- Transmission "pools" power
- Key: Design transmission w.r.t. meteorological patterns.





Kempton et al, 2010, *Proceedings of the National Academy of Sciences*, 107 (16).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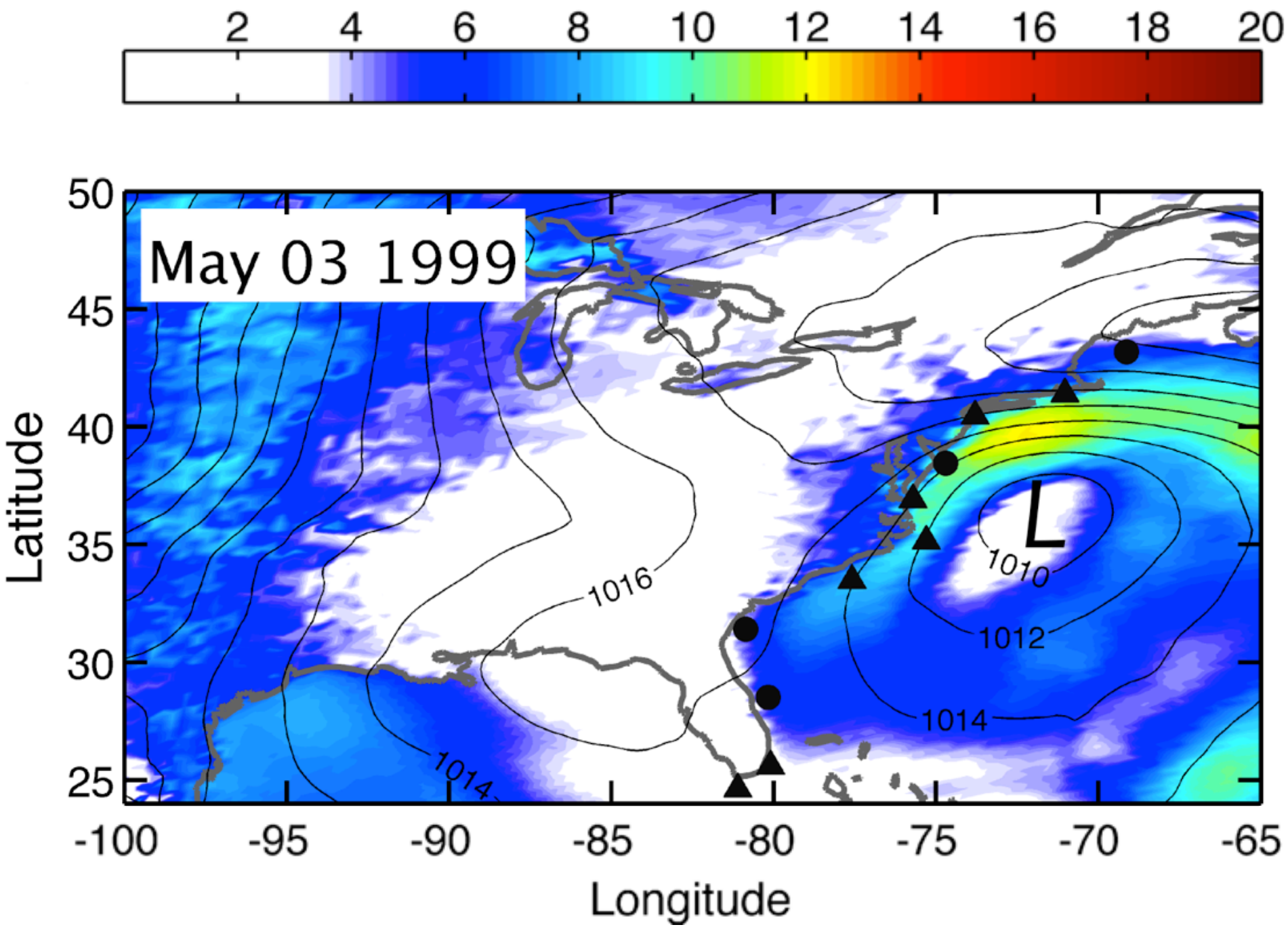
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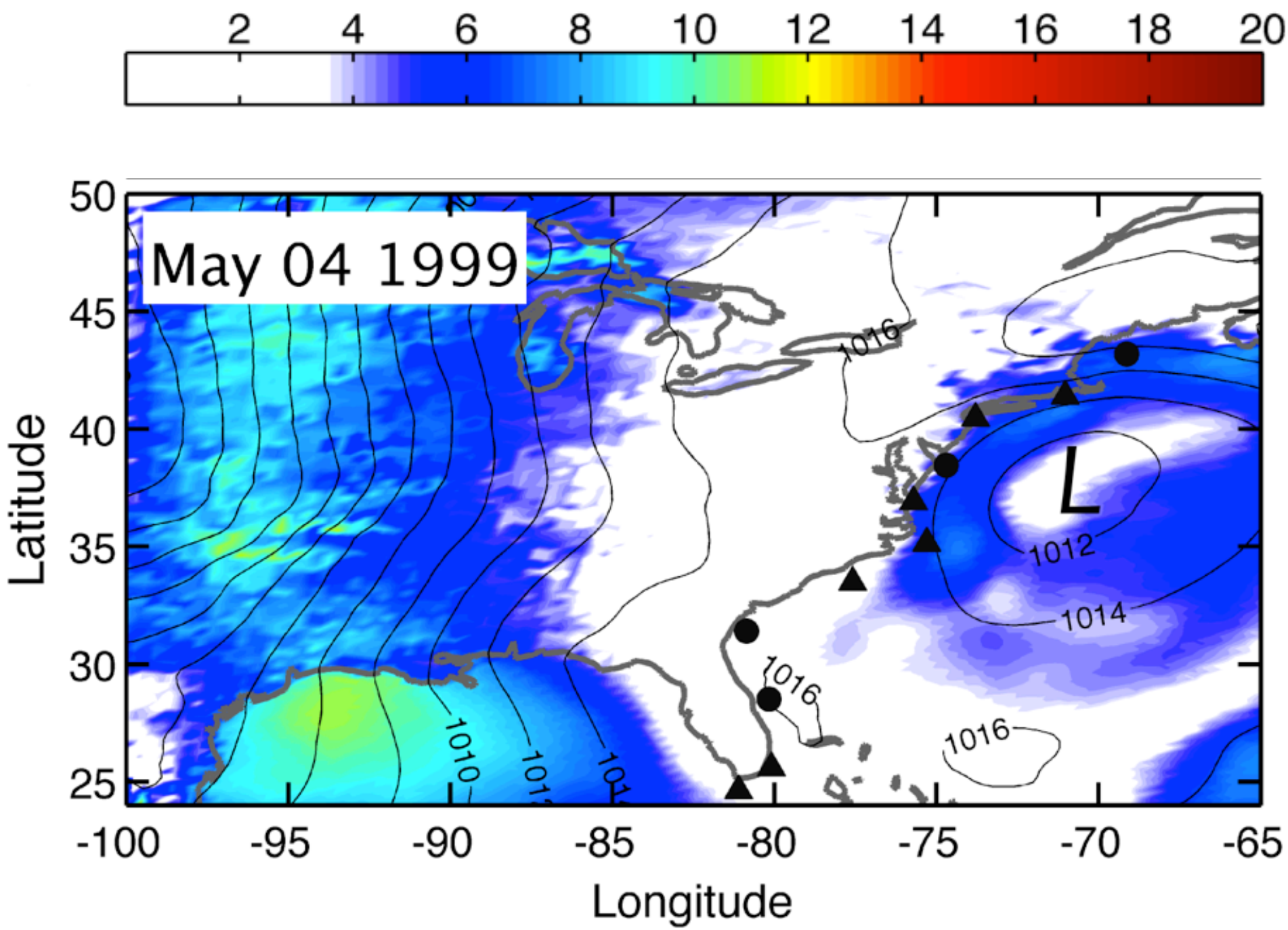
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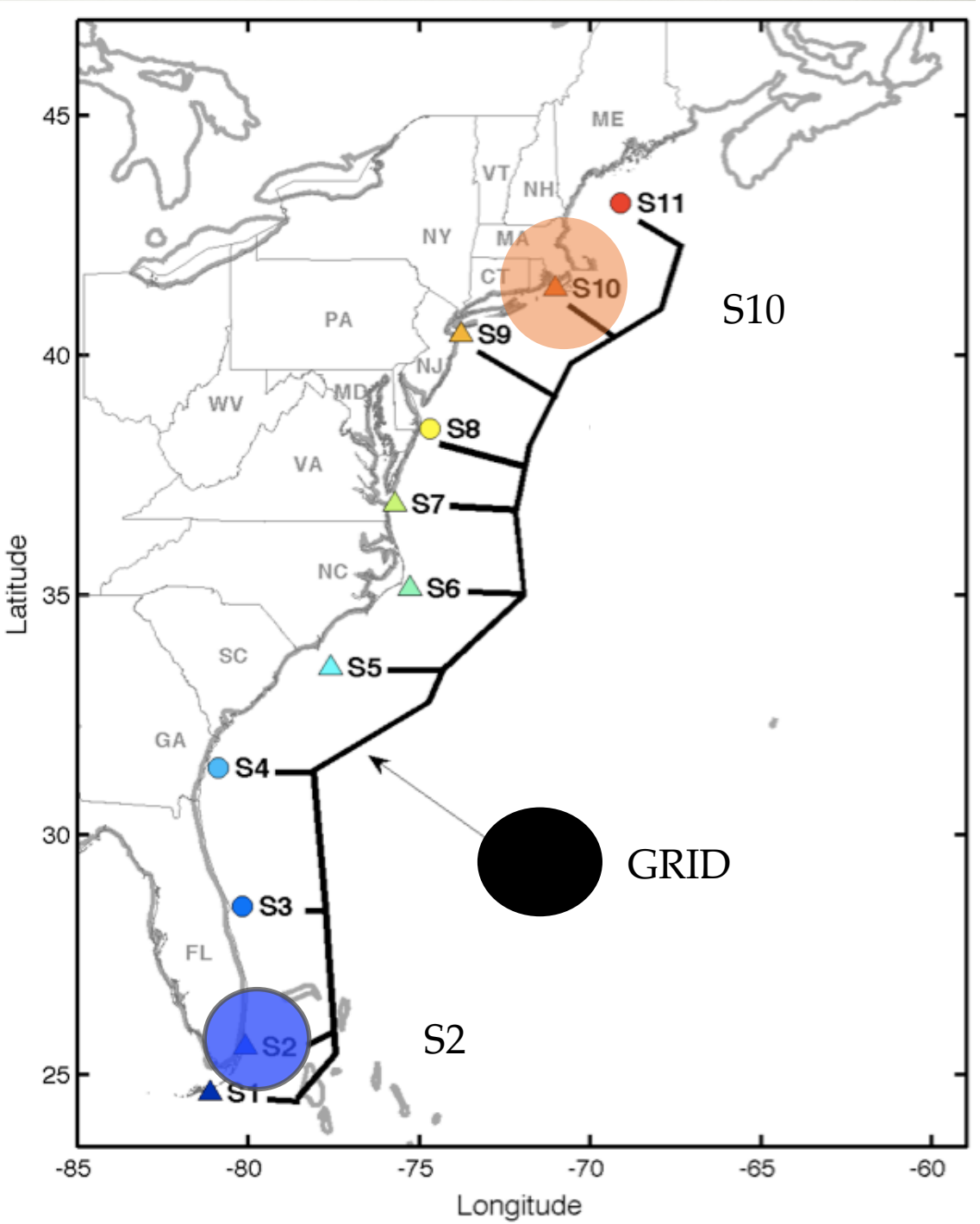
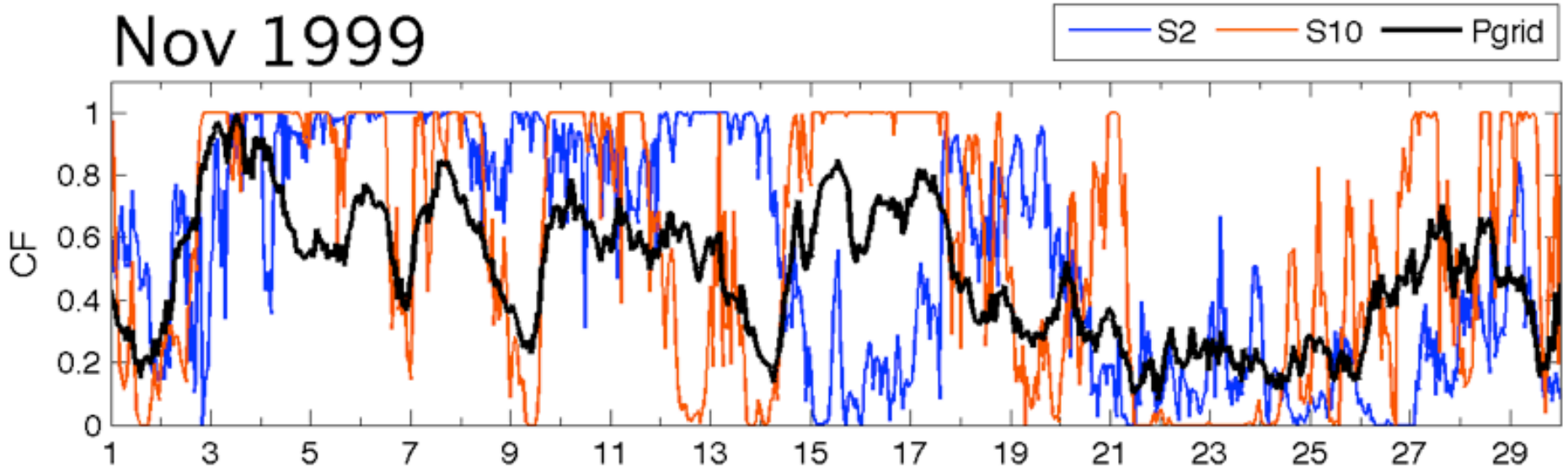
Single wind sites vs. Transmission

- Individual wind production at S2 and S10 (BLUE and ORANGE)
- Pooled production from transmission (BLACK)



Single Sites (color) vs. Grid (black)



- Individual simulated wind farms show frequent, rapid fluctuation in output
- Power from combined grid changes more slowly, rarely reaches min or max power

Kempton et al, 2010, *Proceedings of the National Academy of Sciences*, 107 (16).

Far Future or Near Term Commercialization?

Already a planned project, with Investors

Sumary: UD Examples

- Offshore wind, Grid Integrated Vehicles, offshore transmission
- R&D, public testimony, education
- Leading to policy, commercial investments and jobs
- Training the next generation of high-tech workers

END

More information:

www.carbonfree.udel.edu

Thanks to:
Delaware Sea Grant
Delaware Green Energy Fund

College of Earth, Ocean, and Environment, U Delaware