

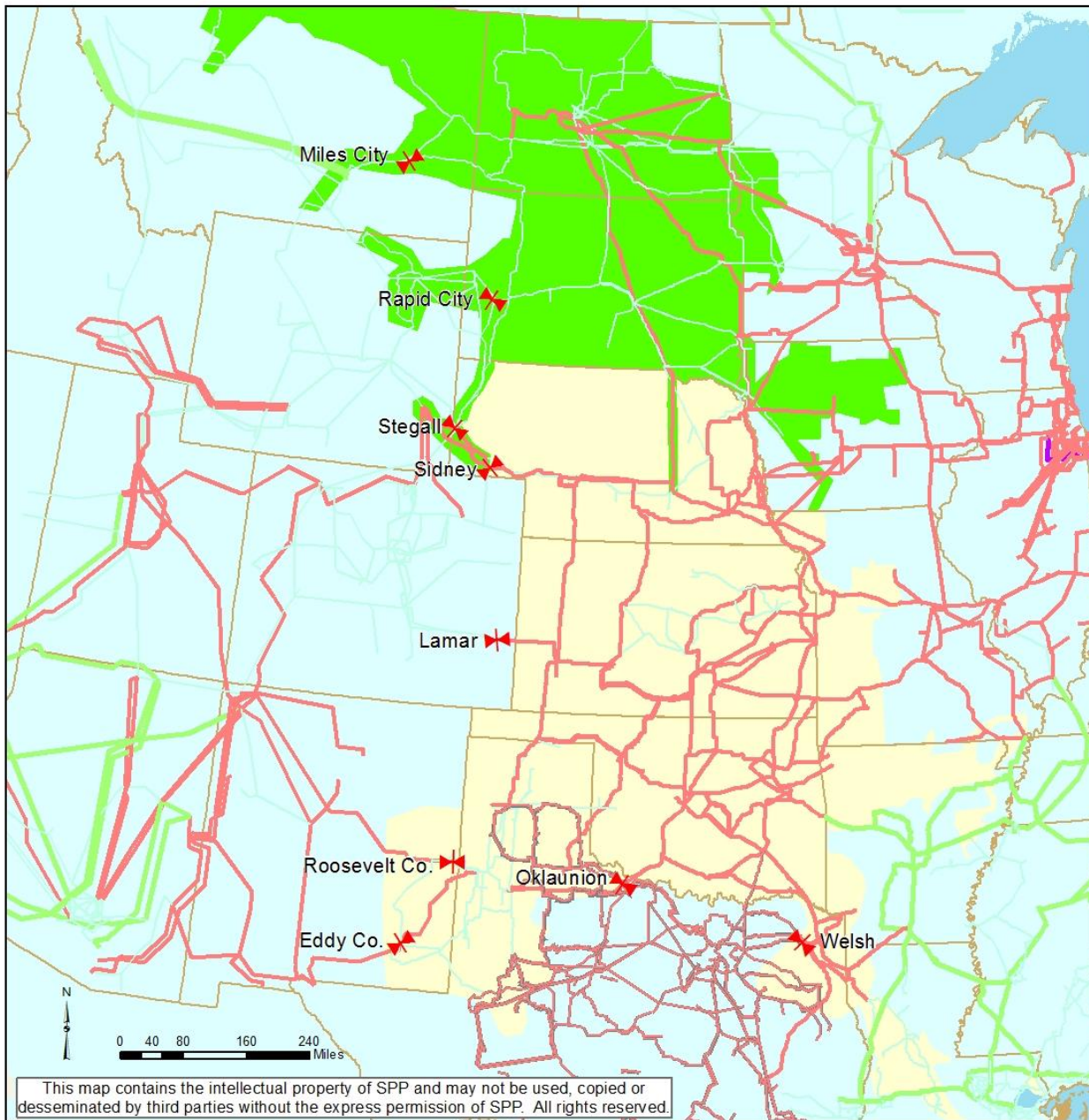


EI-WECC Seams Study Update

September 28, 2016

Opportunities presented by HVDC Transmission Panel

DOE Electricity Advisory Committee Meeting










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SPP *Southwest Power Pool*

All DC ties from EI to ERCOT and almost all from EI to WECC via the SPP/IS System

-  230 kV
-  345 kV
-  500 kV
-  345 kV ERCOT
-  AC/DC Tie
-  IS
-  Southwest Power Pool



B2B HVDC Stations between EI and WECC

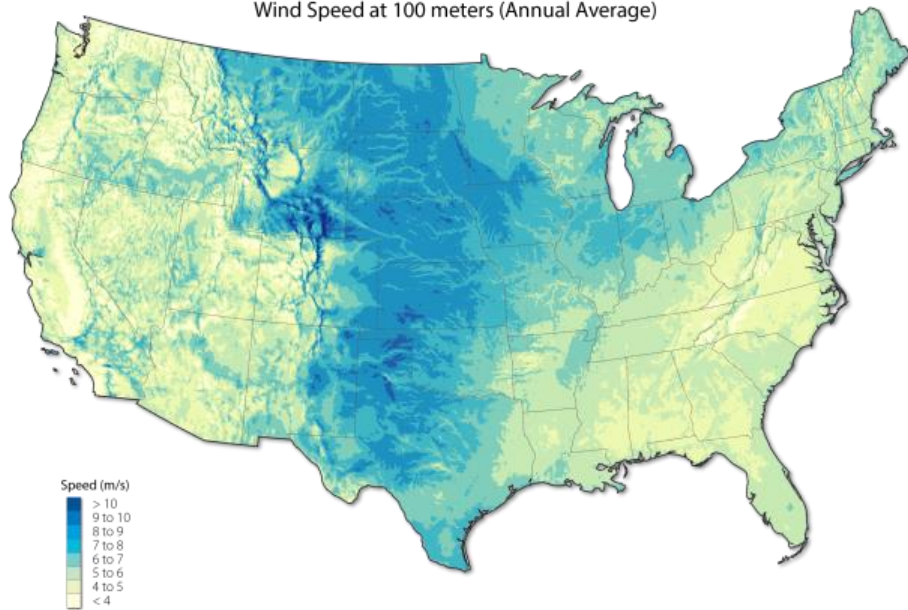
| HVDC Station | Location | Vendor | Type | kV | Power (MW) | Year |
|----------------|----------------|---------|------|------|------------|------|
| David A Hamel | Stegall, NE | GE | LCC | 50 | 100 | 1977 |
| Eddy County | Artesia, NM | GE | LCC | 82 | 200 | 1983 |
| Blackwater | Clovis, NM | ABB | LCC | 60 | 200 | 1984 |
| Miles City | Miles City, MT | GE | LCC | 82 | 200 | 1985 |
| Virginia Smith | Sidney, NE | Siemens | LCC | 50 | 200 | 1988 |
| McNeill | McNeill, AB | Alstom | LCC | 42 | 150 | 1989 |
| Rapid City | Rapid City, SD | ABB | CCC | 13 | 200 | 2003 |
| Lamar | Lamar, CO | Siemens | LCC | 63.6 | 210 | 2005 |

DOE-funded, NREL-led Seams Study

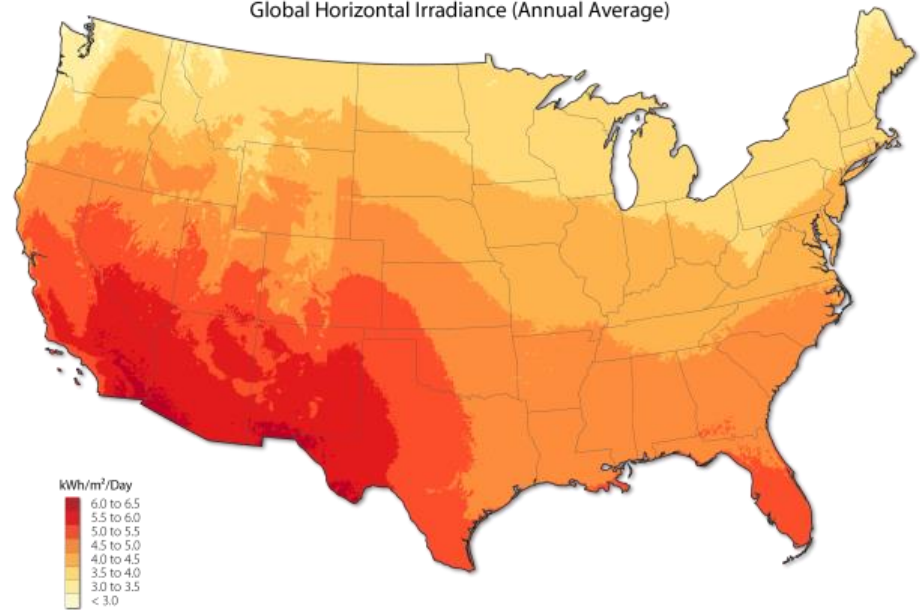
- \$1.2M, 18 month EI-WECC Seams and HVDC Overlay Study approved as part of GMLC
- Strong industry support
- Scope finalized in March
 - Opportunity to not just replace in-kind the aging B2B HVDC Ties between EI and WECC
 - Three DC Scenarios
 - Status Quo
 - Modernized/Optimized Seam with Rightsized/Relocated B2B and/or Links
 - Macro Grid Overlay
- Kickoff meeting for TRC held June 27-28.
- Promising preliminary results

Diverse Resources

Wind Speed at 100 meters (Annual Average)



Global Horizontal Irradiance (Annual Average)



Layers of Diversity

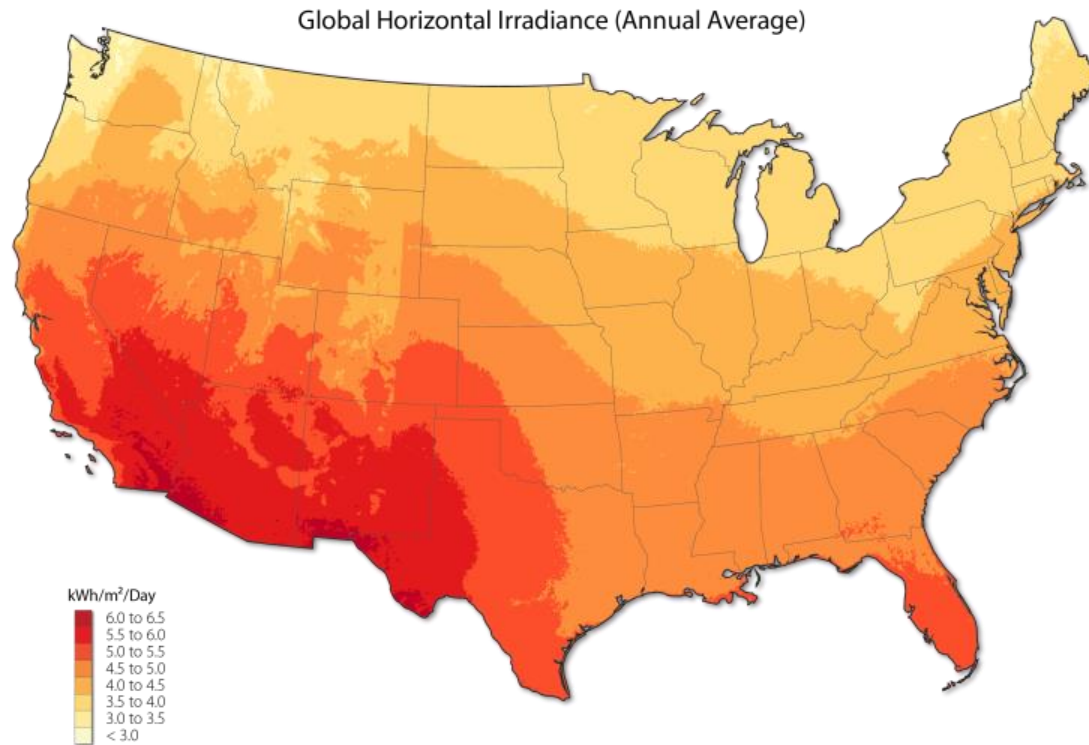
- Time Diversity



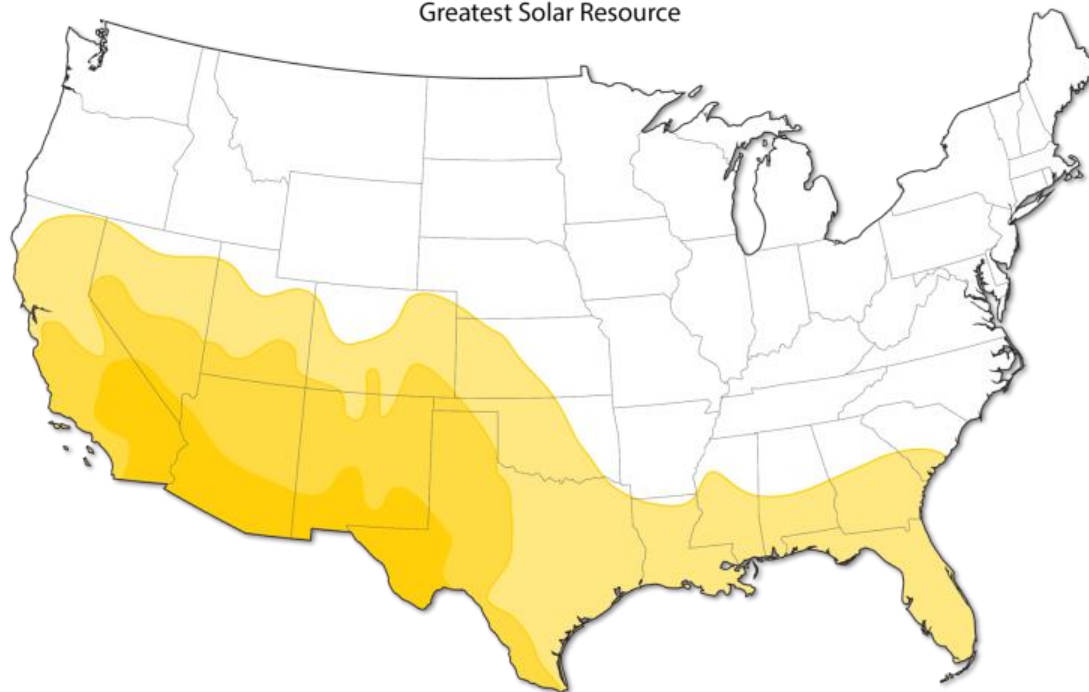
- Weather Diversity



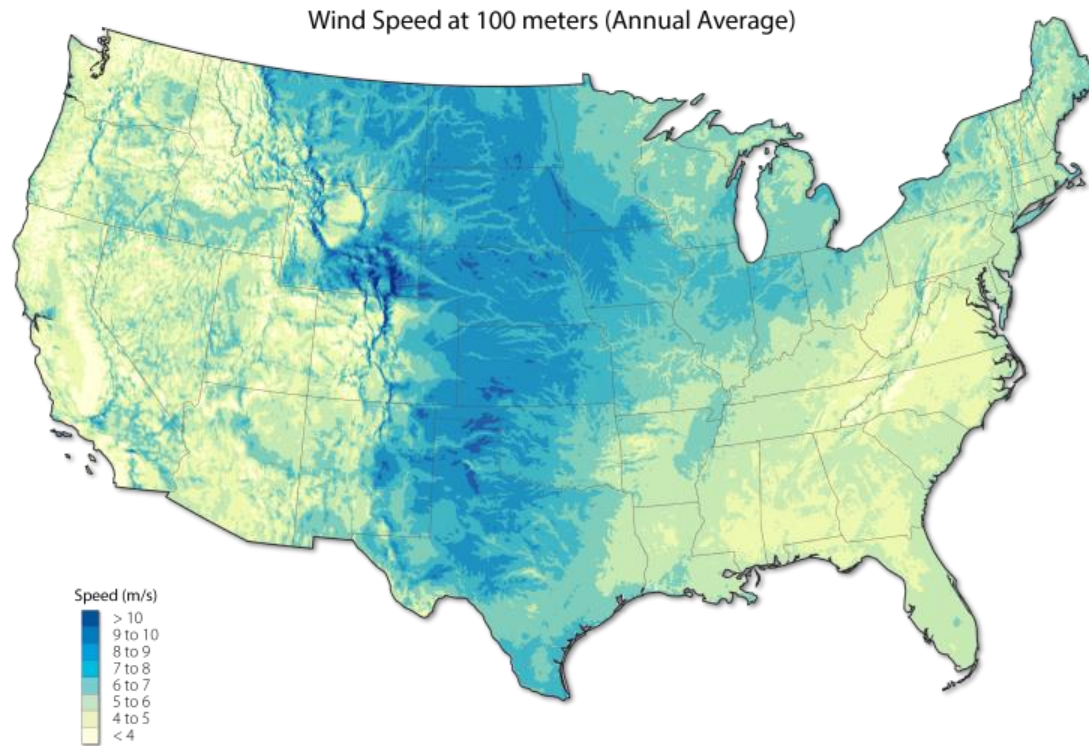
Contiguous 48 states solar resource



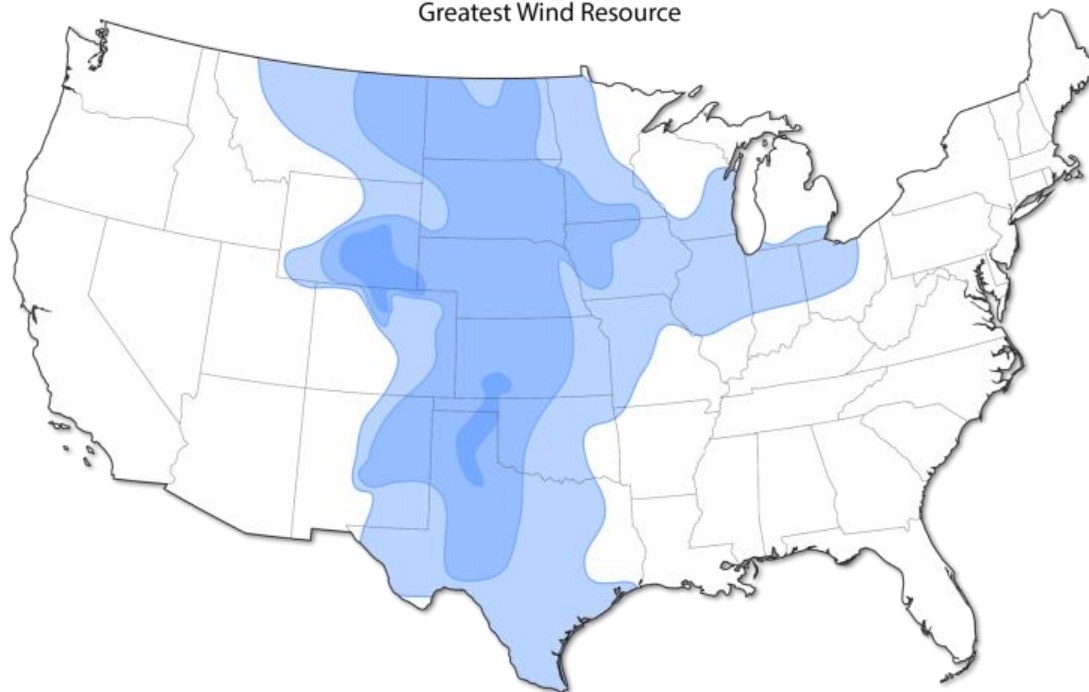
Greatest Solar Resource

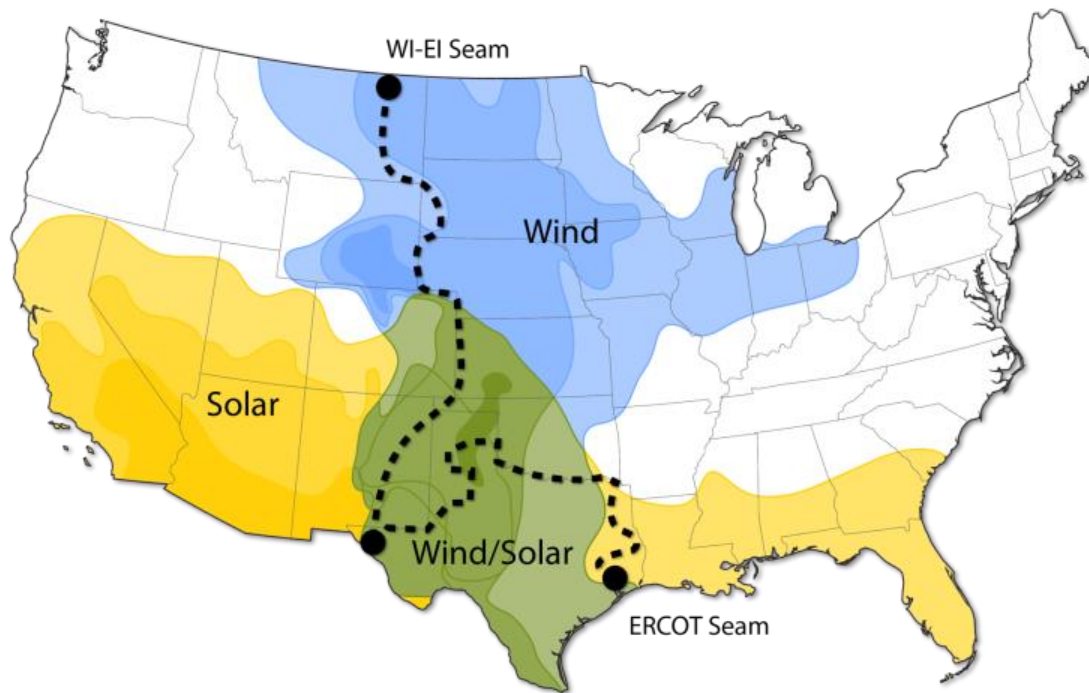


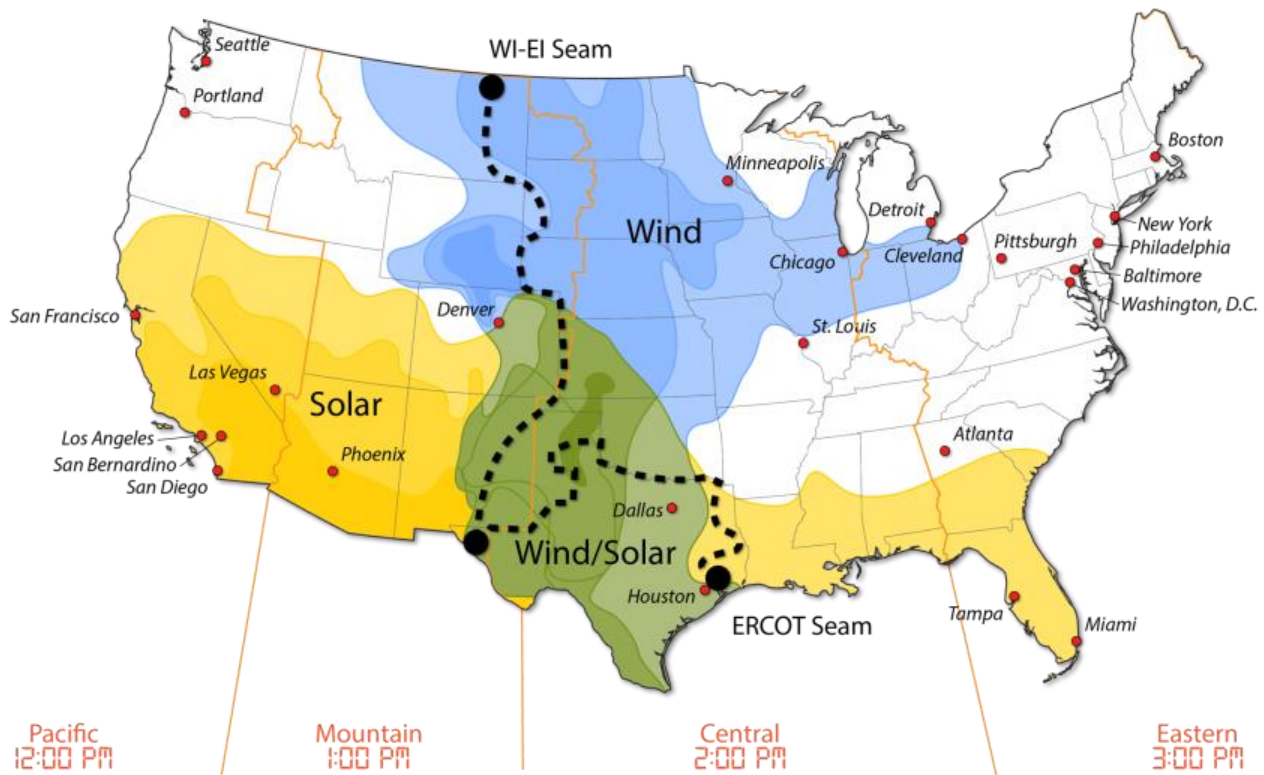
Contiguous 48 states wind resource



Greatest Wind Resource







Team, Tools, and Data Overview

Team

- National Renewable Energy Laboratory
 - Aaron Bloom
- Pacific Northwest National Laboratory
 - Yuri Makarov
- Iowa State University
 - Jim McCalley
- Southwest Power Pool
 - Jay Caspary
- Midcontinent Independent System Operator
 - Dale Osborn
- Western Area Power Administration
 - Rebecca Johnson
- Oak Ridge National Laboratory
 - Fran Li
- Argonne National Laboratory
 - Jianhui Wang

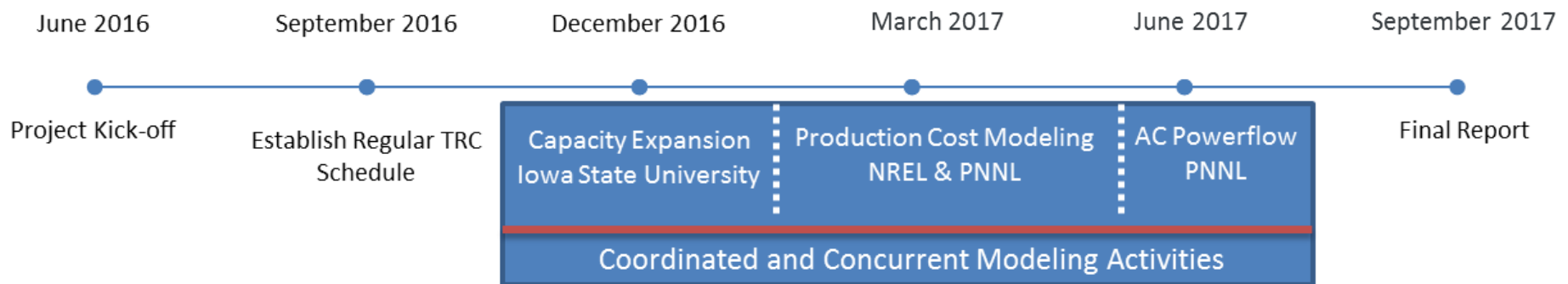
Tools

- Capacity Expansion
- Production Cost
- AC Powerflow

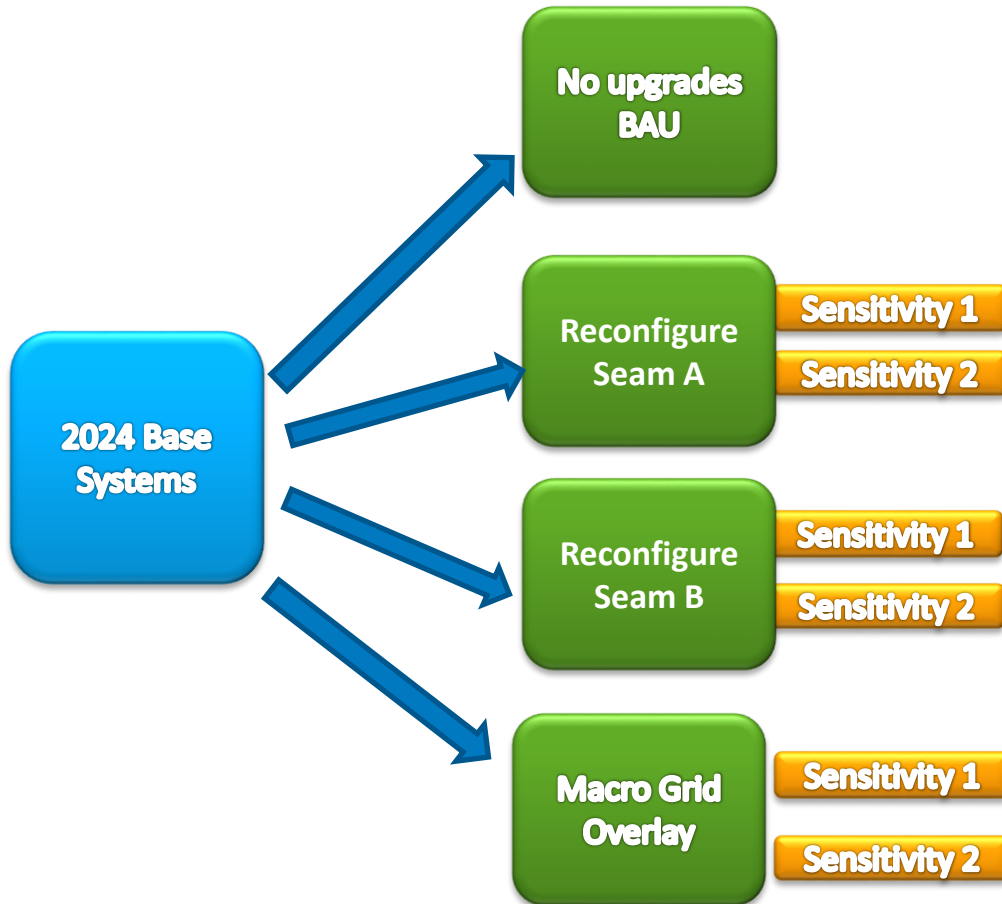
Data

- WECC TEPPC
- EIPC
- WINDToolkit
- NSRDB
- EIA

Project Timeline



High Level Scenario Overview



Proposed Metrics

| Production Cost Model (NREL/PNNL) | Capacity Expansion Model (ISU) |
|-----------------------------------|------------------------------------|
| Single-year production costs | Capital costs |
| Emissions | LOLP/LOLE |
| Operational changes | VG capacity factor/capacity credit |
| Others as determined by TRC | Others as determined by TRC |

Projects Near Seam in Process

- SPP has approved another Stegall 345/115kV XF plus an new Stegall – Scottsbluff 115kV project
- WAPA rebuilding Sidney – Sterling 115kV in 2017
- Black Hills Power Cooperative building new 100+ mile 230kV line from WY into Rapid City to reinforce area due to local generation retirements
- PSCO \$1B Rush Creek Wind Farm and 90+ mile 345kV line into eastern Colorado
- Broadview Wind Farm and 30+ mile 345kV gen tie to PNM north of Clovis NM
- Basin Electric Power Cooperative assessing options for David Hamill B2B HVDC Tie at Stegall NE

Pan-Canadian Wind Integration Study (PCWIS)

- 3 year study prepared for CanWEA by GE and published July 6, 2016
- Several planned projects like proposed Manitoba to Minnesota (MISO) 500kV tie-line, as well as several Quebec to US projects, were included in all scenarios
 - Intra-Area Transmission Reinforcements dependent upon wind development scenario as expected with new Boundary Dam – Tioga ND 230kV line(s) and phase shifting transformer in some scenarios
- Evaluated sensitivity to increasing the capability of the SaskPower – AESO HVDC B2B Tie to 1000MW

Next Steps

- Surveys under development to understand condition, spare parts, capabilities, etc of existing HVDC B2B Ties
- Interest in AC Solutions Too
 - Replacement of HVDC B2B Ties is expensive and underutilizes the existing capability of the AC system, e.g., Tolak - Eddy County 345kV line between TX and NM
 - Hybrid AC/DC solutions need be to considered since they are pragmatic to assess the transition to any potential future
 - Need discussion about SPP support and potential funding
- North American Renewable Integration Study (NARIS) funded by GMLC to kick off on October 5th and will be held adjacent to the next TRC for Interconnection Seams Study on October 4th. Meetings at NREL in Golden, CO

WECC (high_solar) + ERGIS (RTx30)

05-12 03:00 EST

