Electricity, Resources, & Building Systems Integration

Renewable Systems Integration at NREL

CNLS Smart Grid Seminar Series

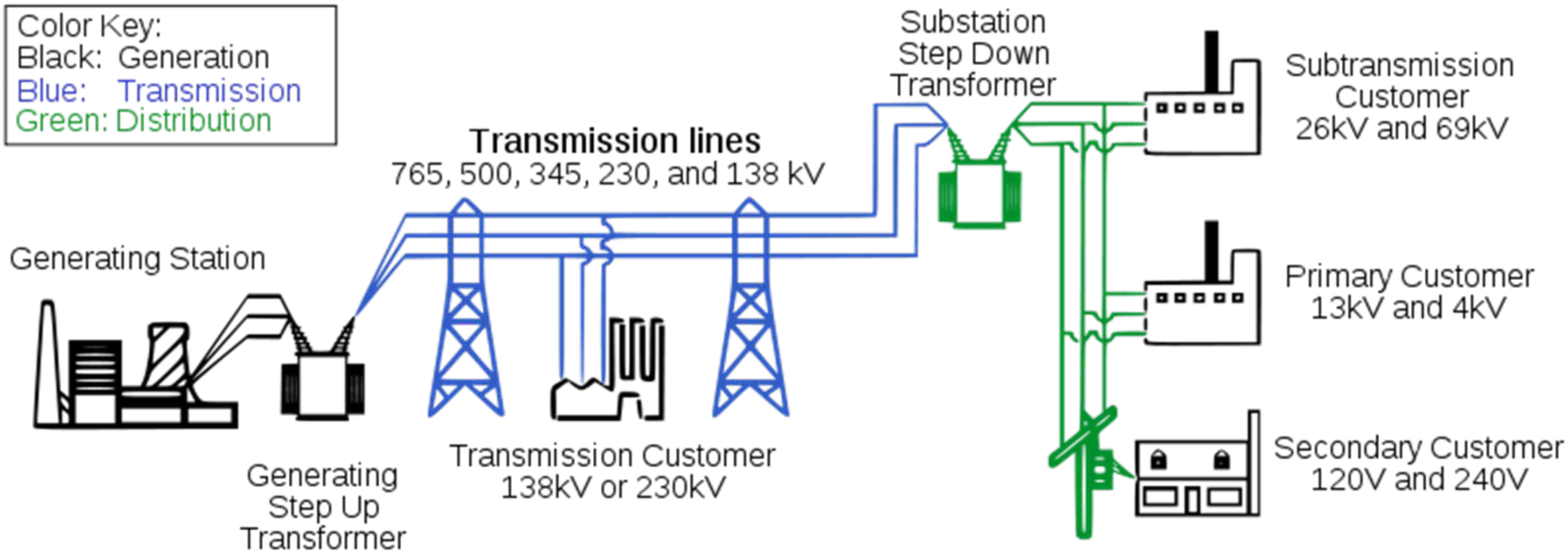
Dave Mooney

May 19, 2009

Outline

- Overview of the Electricity System
- Renewable Energy Options and Where they Interconnect
- Why We Need to Address Integration
- Modeled and Observed Impacts of Integration
- The Energy Systems Integration Facility

Overview of the Conventional Electricity System



Characteristics of the Conventional System

Generation is controllable, follows load.

- Effectively no storage
- Generation matches load in real time

Transmission system is actively operated

- Two-way power flow possible
- Three major interconnections with control areas

Distribution system not actively operated

- Power flow unidirectional
- Little communication technology in distribution

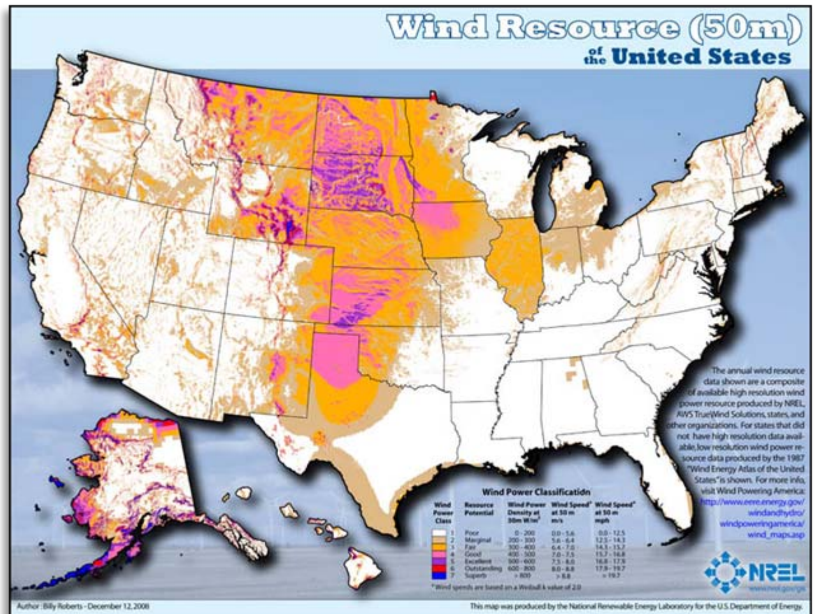
Integration and Interconnection Issues

- Access
- Variability

Renewable Generation

- ✓ Wind Energy
- ✓ Concentrating Solar Power
- ✓ Photovoltaics
- ✓ Geothermal
- ✓ Direct Fire Biomass
- ✓ Water Energy (tidal, wave, thermal)

Wind Energy

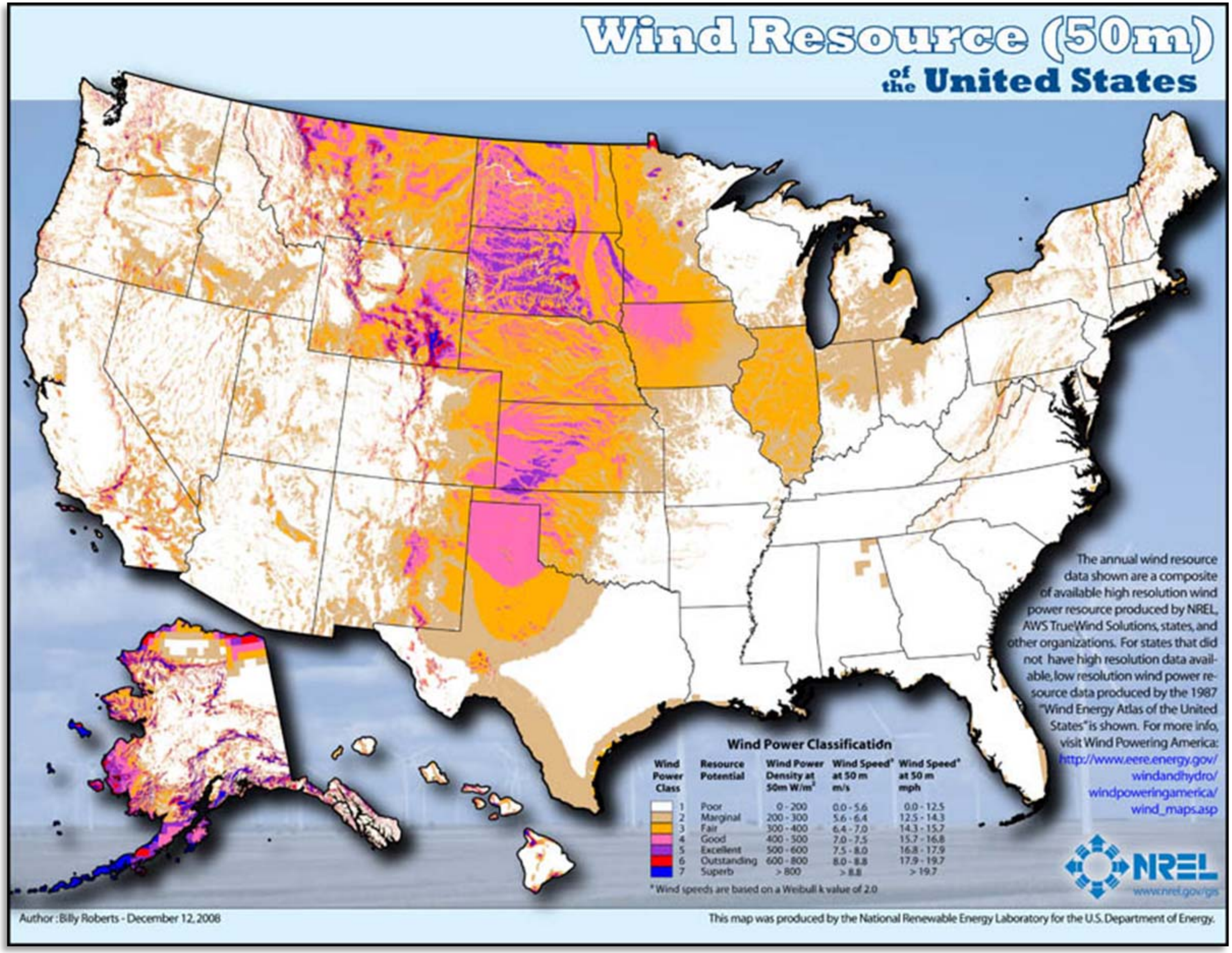


Interconnection

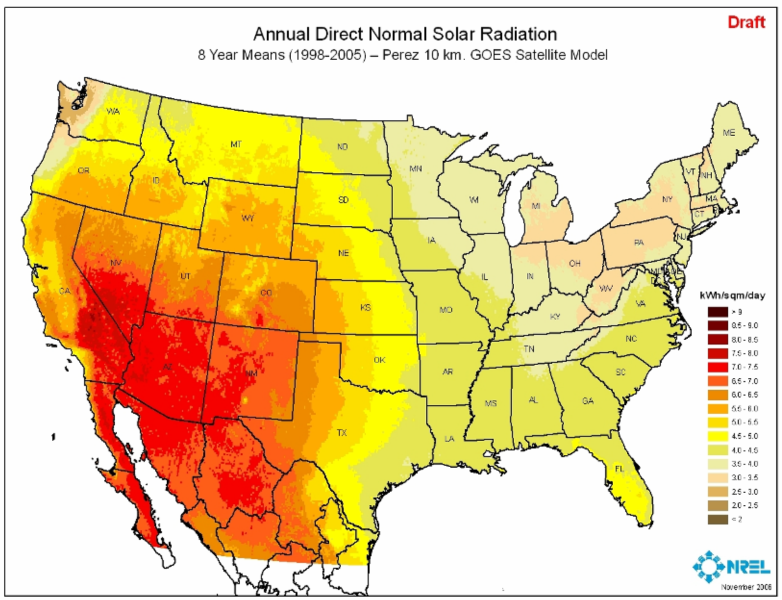
- Transmission
- Distribution

Integration Issues

- Access
- Variability


Wind Resource (50m)
of the United States
The annual wind resource data shown are a composite of available high resolution wind power resource produced by NREL, AWS TrueWind Solutions, states, and other organizations. For states that did not have high resolution data available, low resolution wind power resource data produced by the 1987 "Wind Energy Atlas of the United States" is shown. For more info, visit Wind Powering America:
http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50m W/m²
Wind Speed* at 50 m m/s
Wind Speed* at 50 m mph
1 Poor 0 - 200 0.0 - 5.6 0.0 - 12.5
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb > 800 > 8.8 > 19.7
* Wind speeds are based on a Weibull k value of 2.0
NREL
Author : Billy Roberts - December 12, 2008
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

Concentrating Solar Power

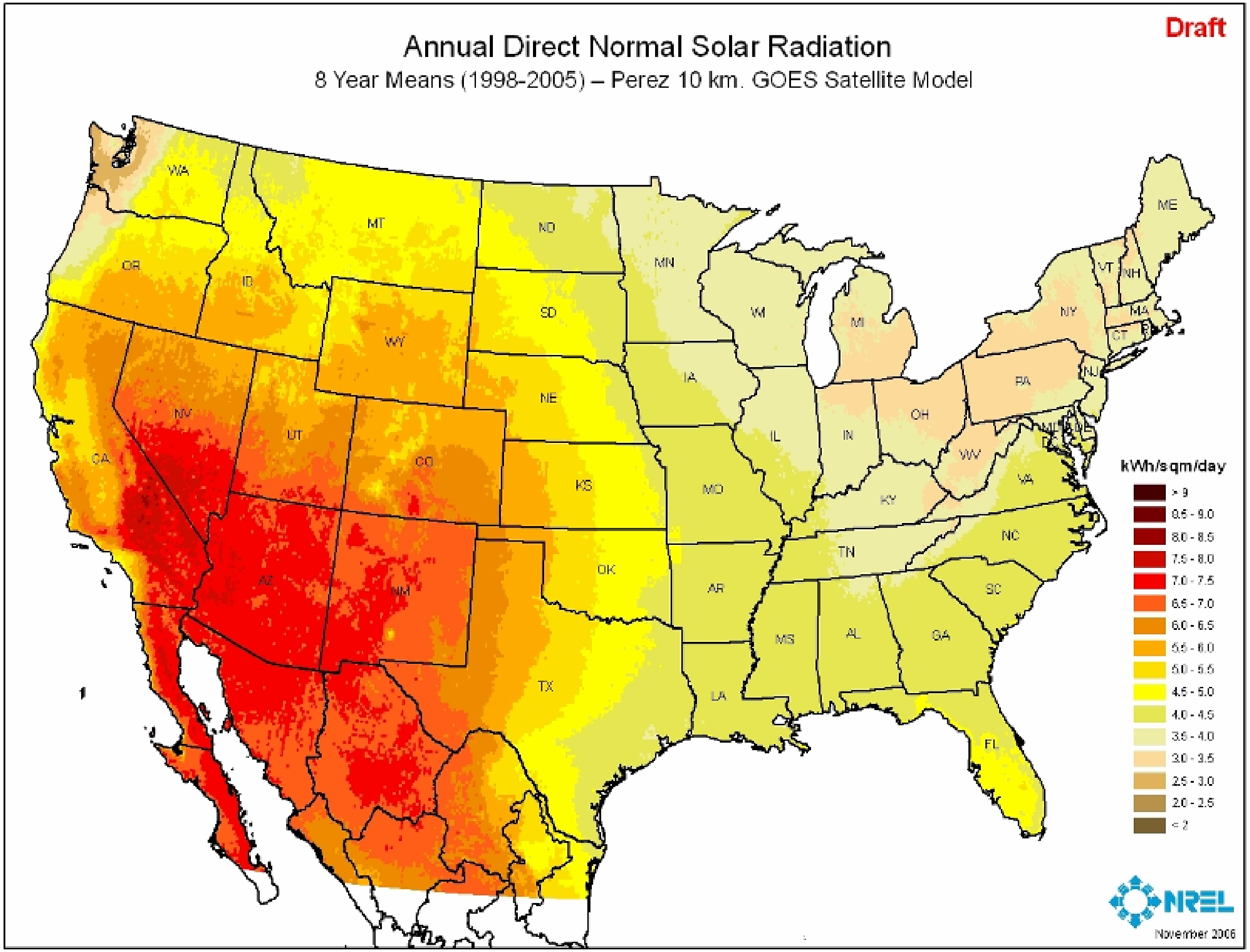


Interconnects

- Transmission

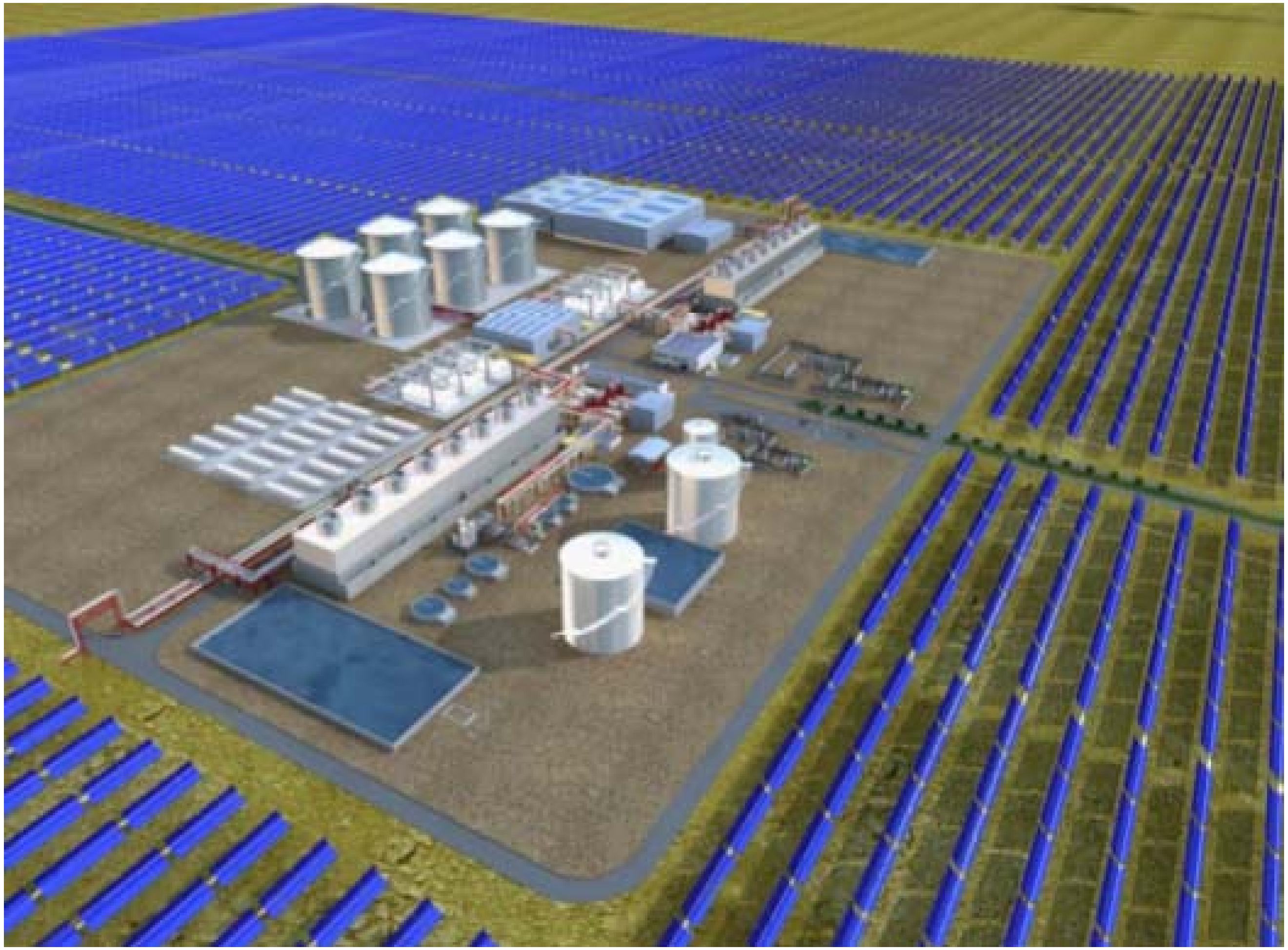
Integration Issues

- Access
- Variability


Draft
Annual Direct Normal Solar Radiation
8 Year Means (1998-2005) – Perez 10 km. GOES Satellite Model
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
VT
NH
ME
MA
CT
NJ
kWh/sqm/day
> 9
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
< 2
NREL
November 2006

Thermal Energy Storage

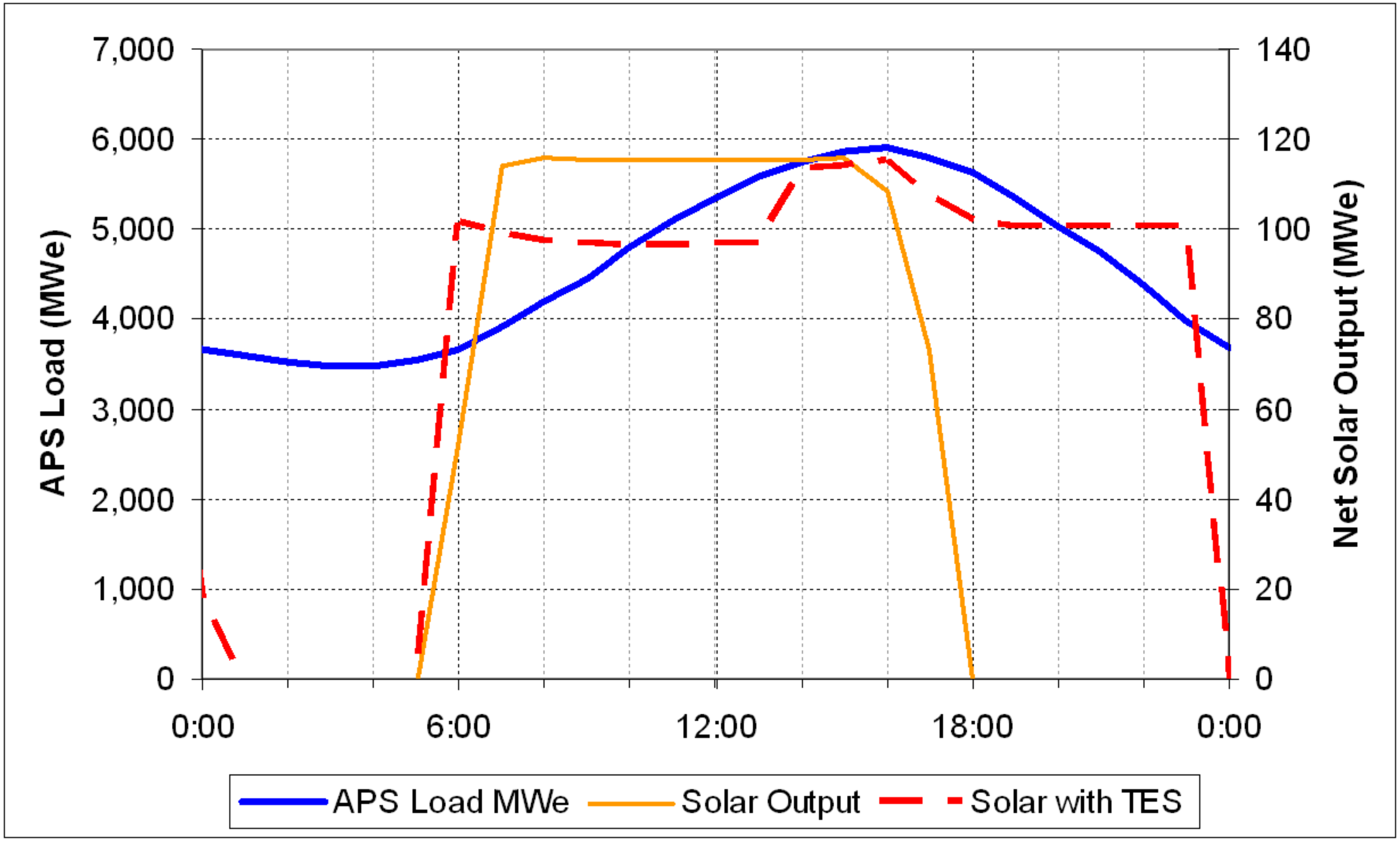
Planned 280 MW Solana Plant with 6 hrs Storage



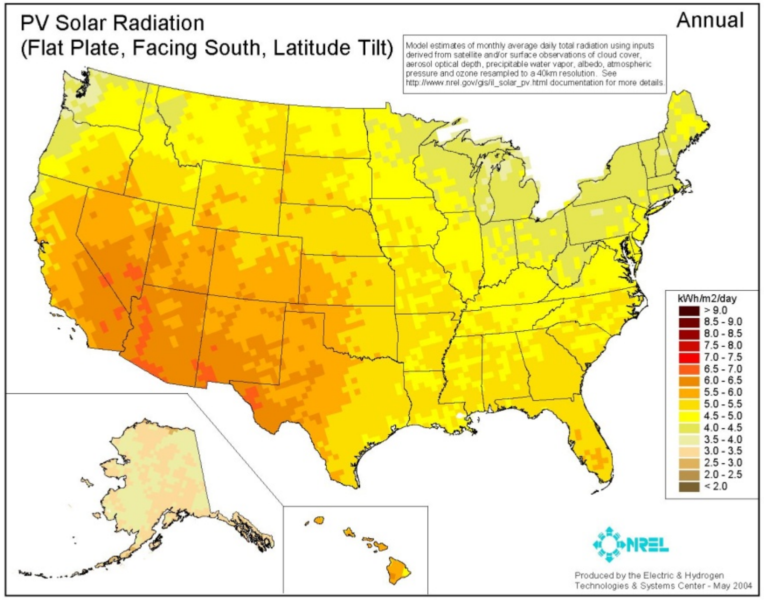
Artist Rendition

APS
Renewable Energy

CSP Trough Plant Output



Photovoltaics



Interconnects

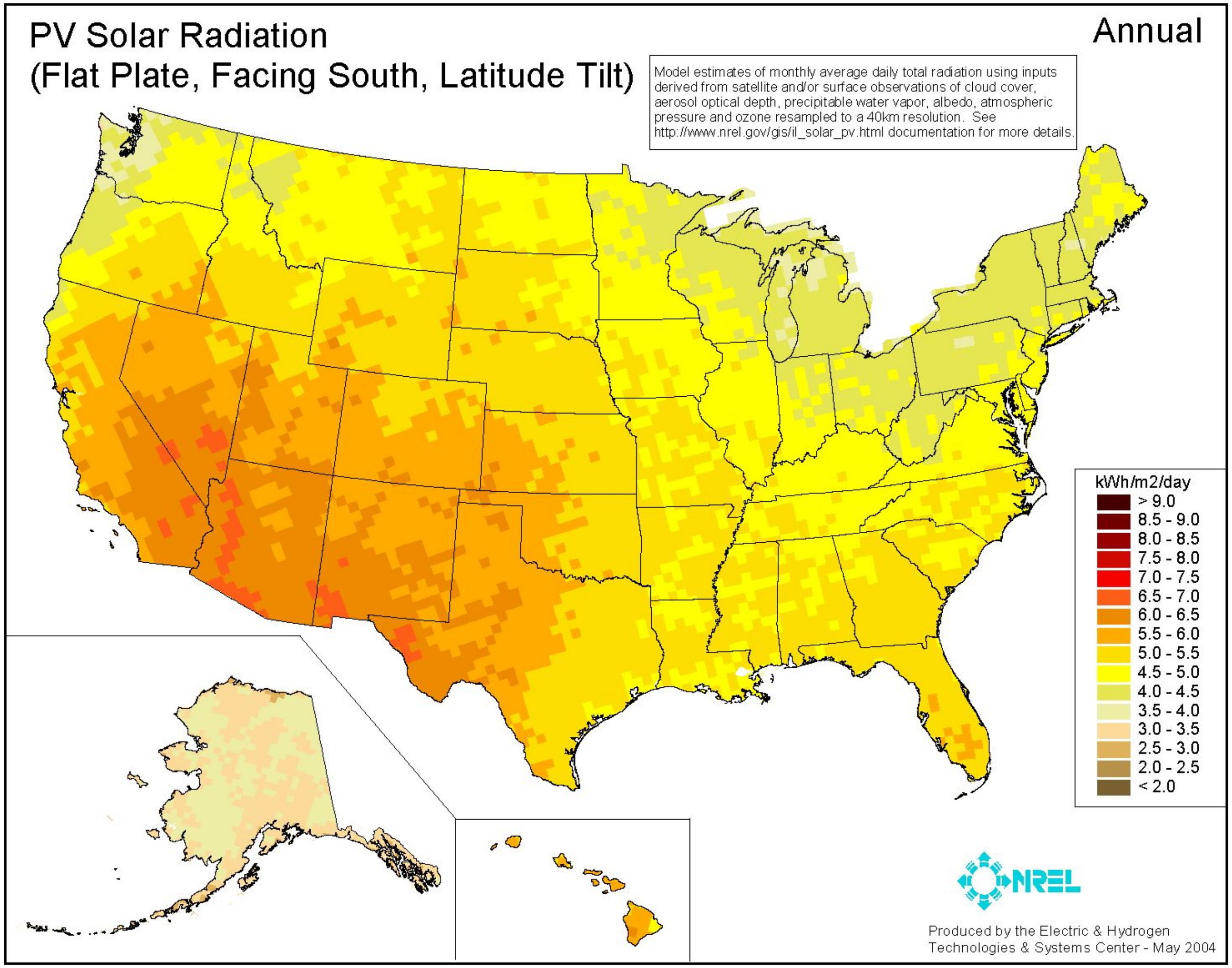
- Transmission*
- Distribution

Integration Issues

- Access
- Variability

*None currently connected at transmission voltages

Renewable Technology Integration



Xcel Energy 8 MW Plant

Utility Scale

Nellis AFB 15 MW Plant

Utility Scale

Moscone Center – 675 kW

Commercial Rooftop

Building Integrated PV

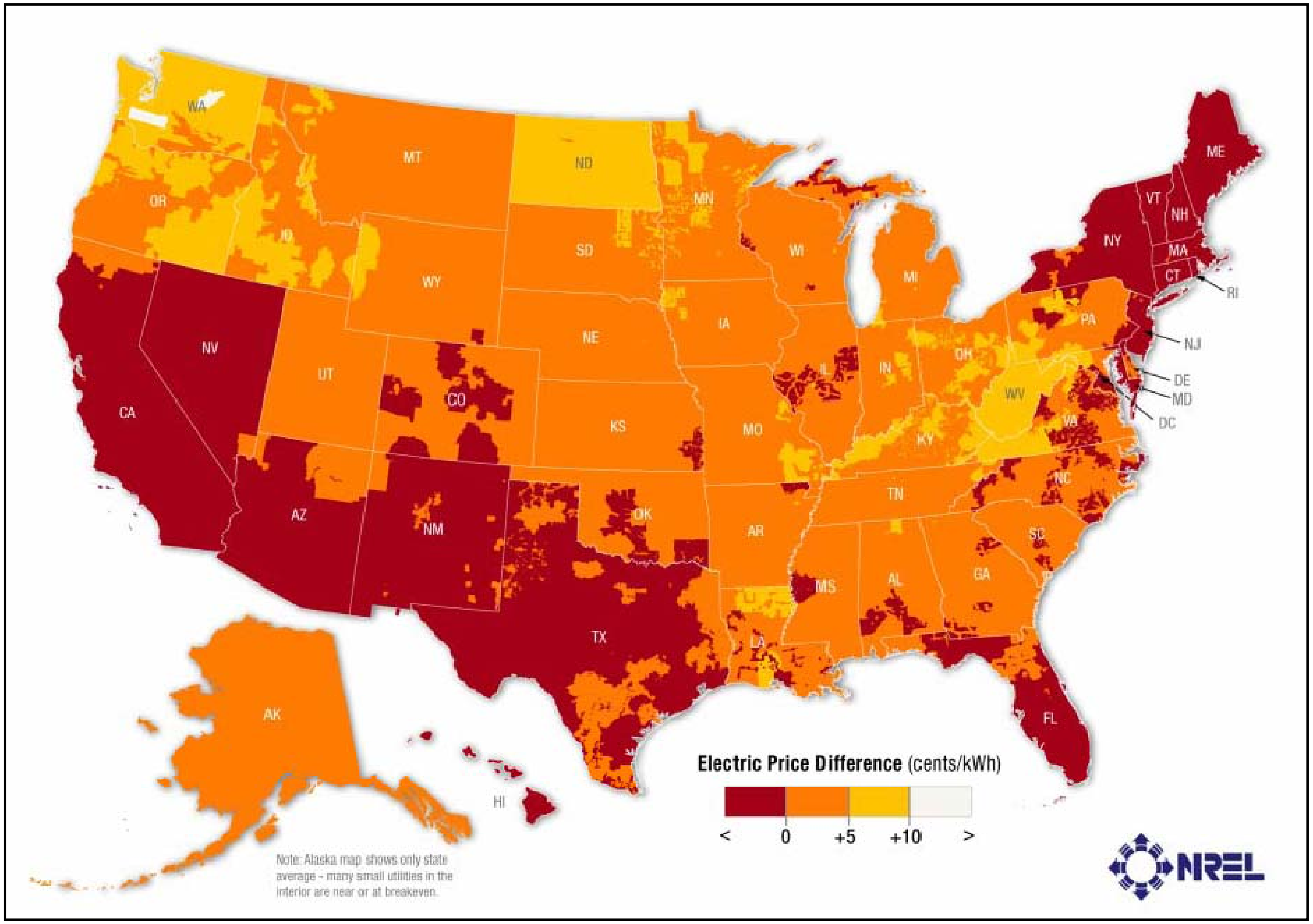
Residential PV

Residential PV

Why Worry About Integration?

2015 Price Targets

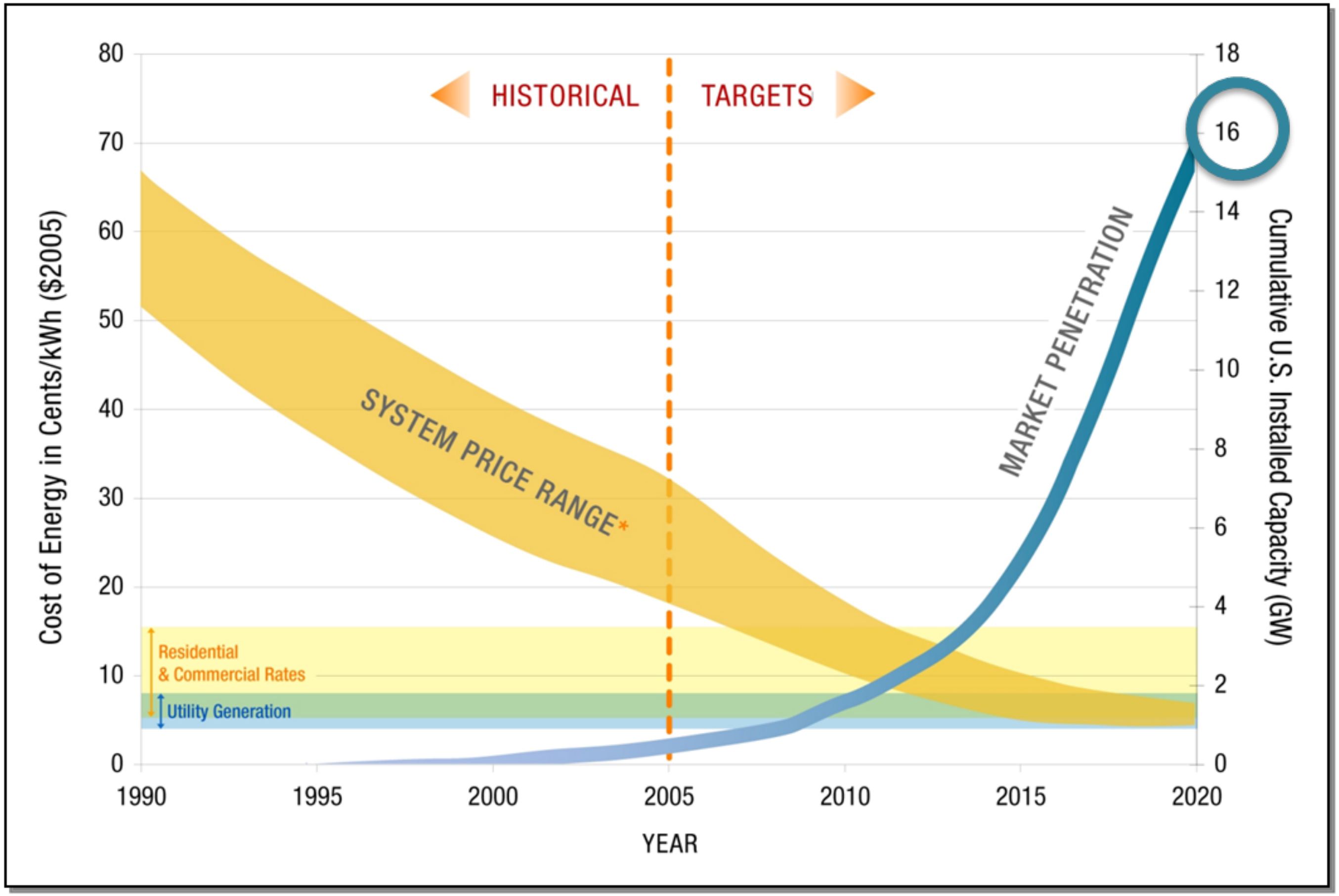
2015 residential PV prices without incentives and <u>moderate</u> increase in electricity prices



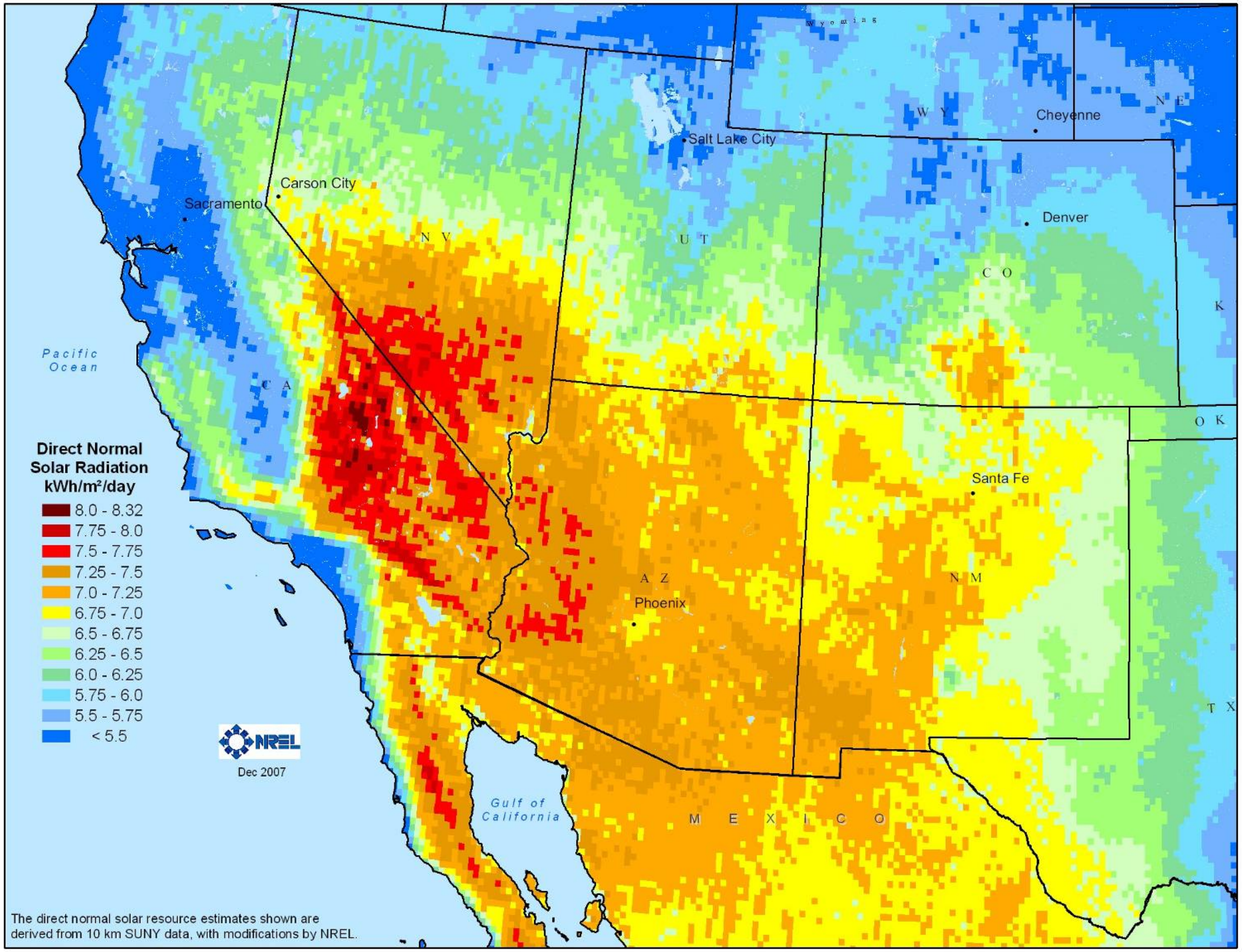
SOLAR AMERICA INITIATIVE

2015 Goals

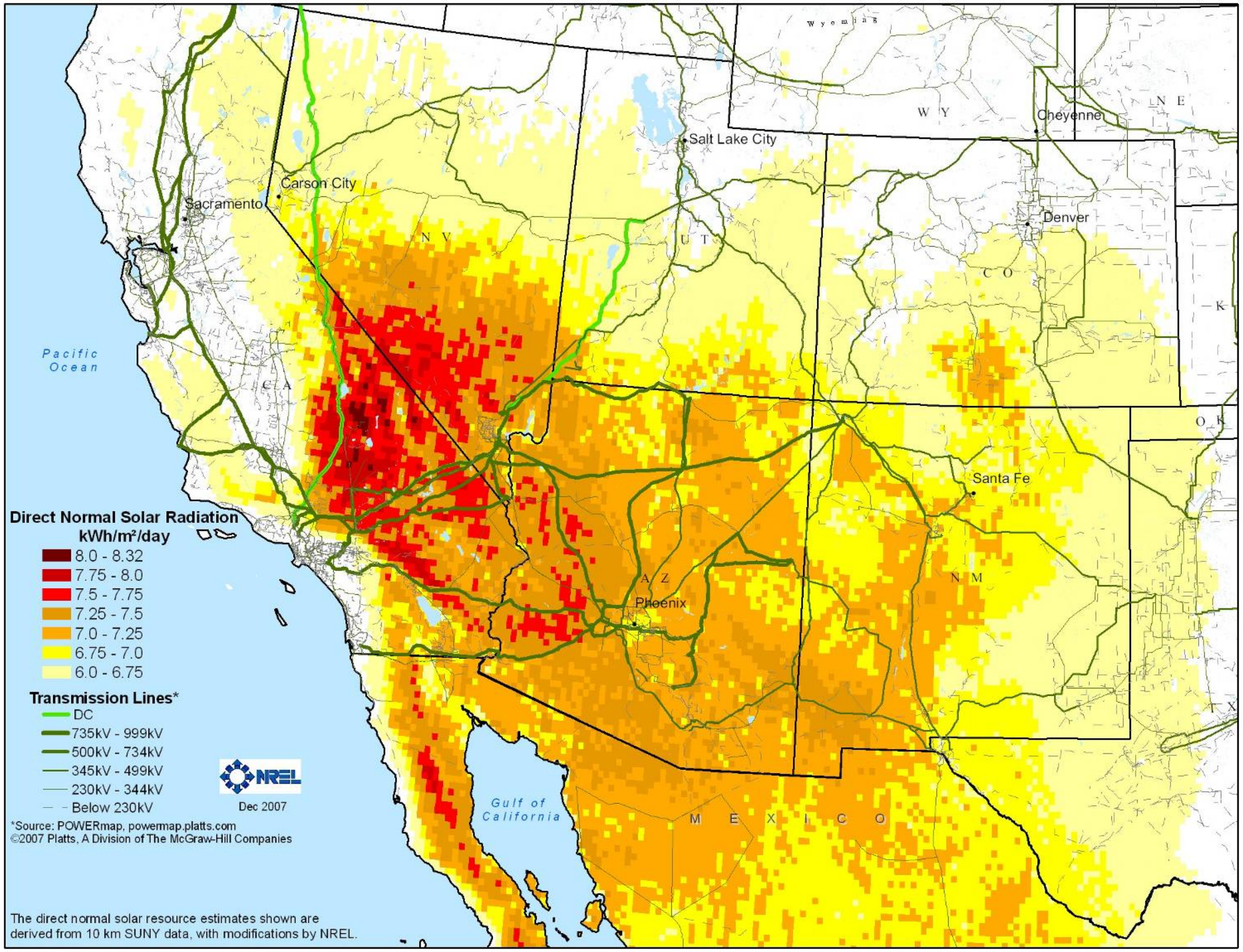
Residential 8-10 ¢/kWh
Commercial 6-8 ¢/kWh
Utility 5-7 ¢/kWh



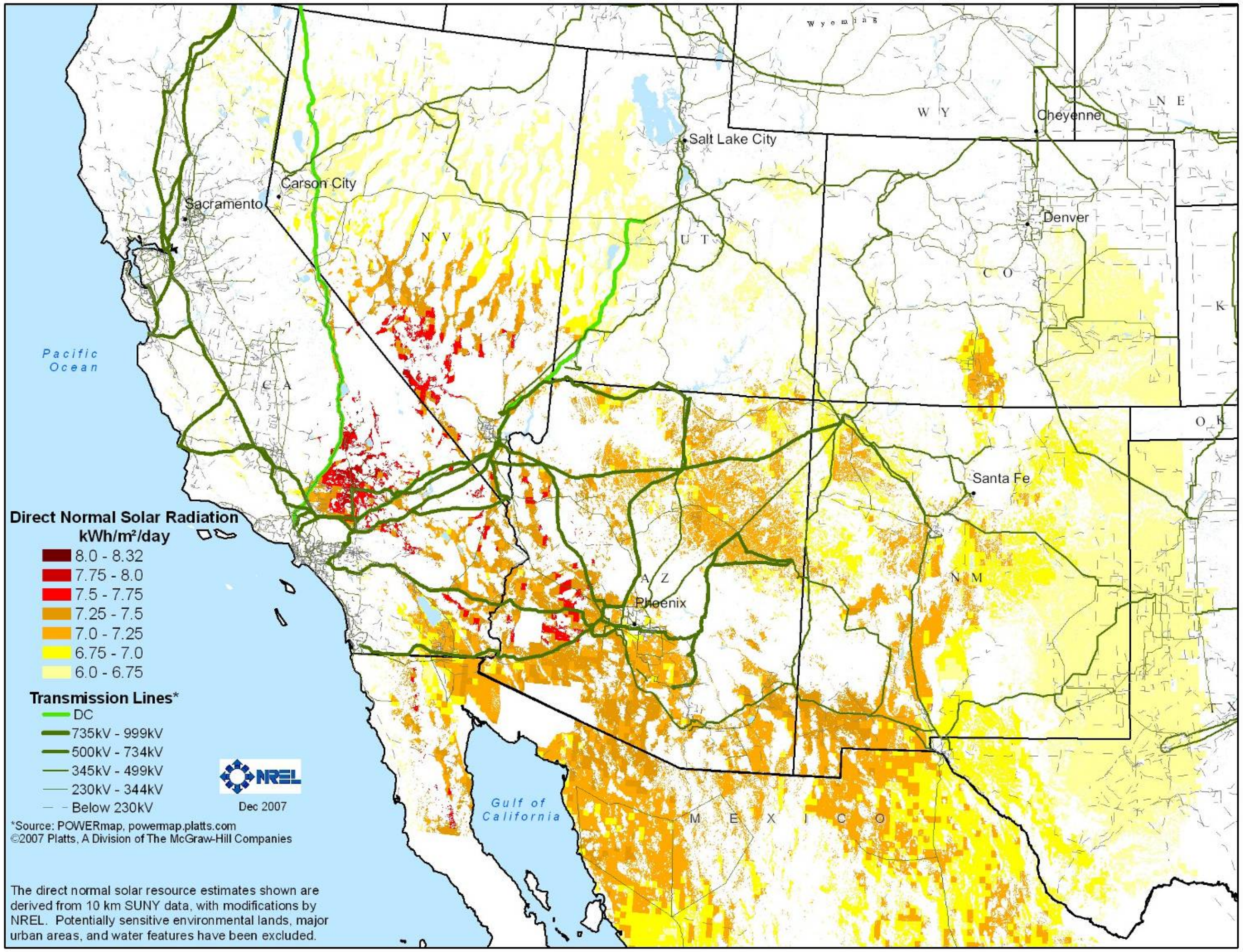
Southwest Solar Resources - Unfiltered Data



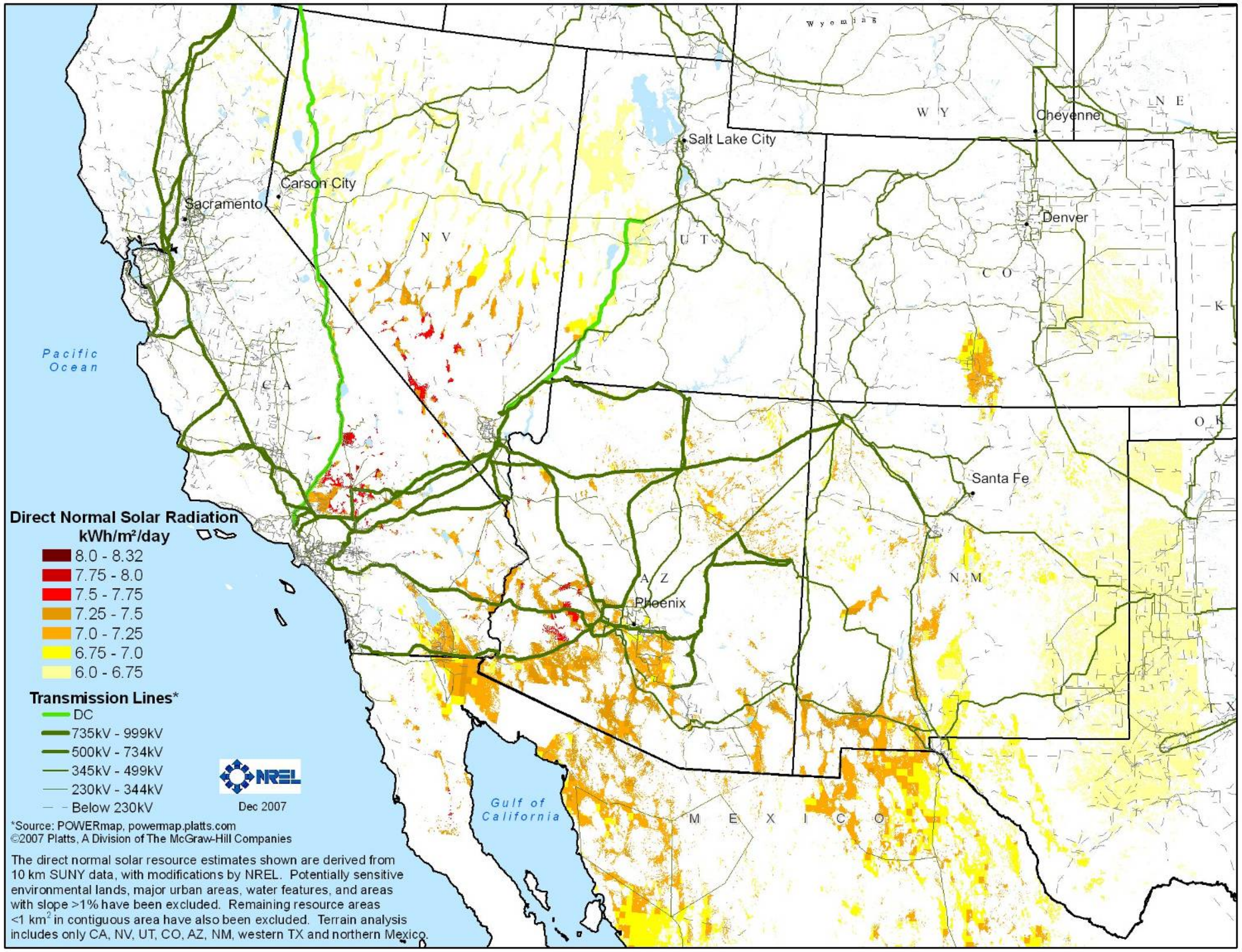
Southwest Solar Resources > 6.0 kWh/m²/day



Environmental and Land Use Exclusions

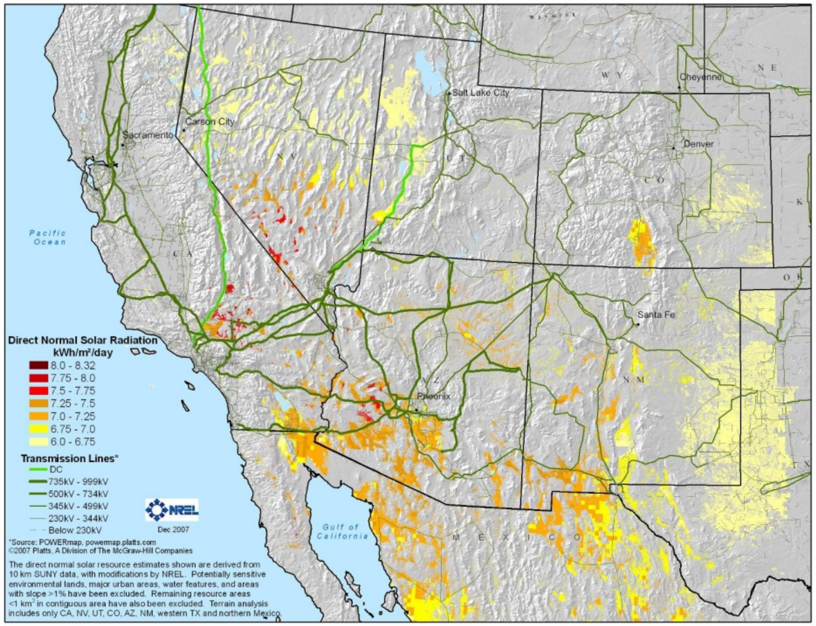


Previous plus slope < 1%



Resulting CSP Resource Potential

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	13,613	1,742,461	4,121,268
CA	6,278	803,647	1,900,786
CO	6,232	797,758	1,886,858
NV	11,090	1,419,480	3,357,355
NM	20,356	2,605,585	6,162,729
TX	6,374	815,880	1,929,719
UT	23,288	2,980,823	7,050,242
Total	87,232	11,165,633	26,408,956

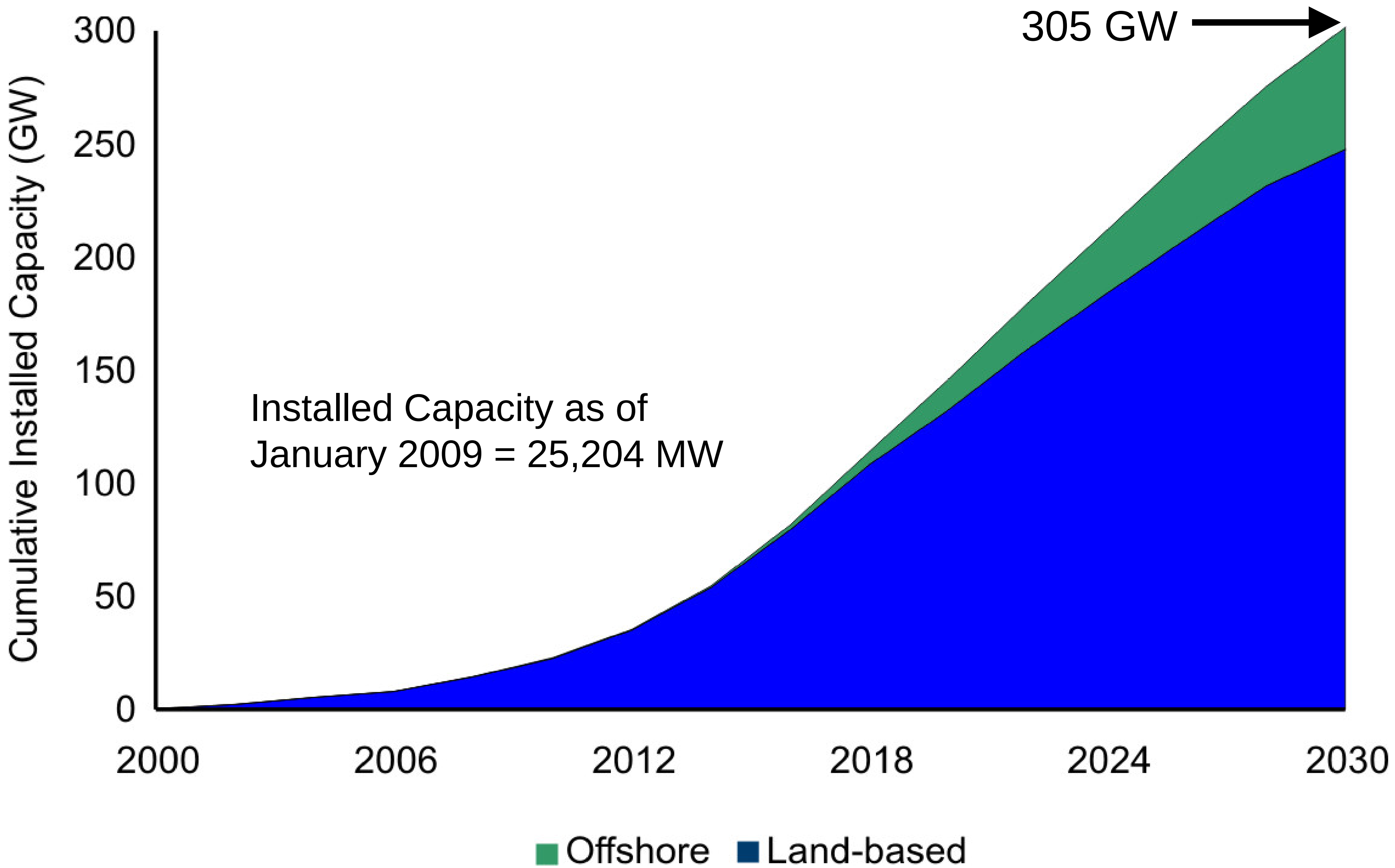


The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands.

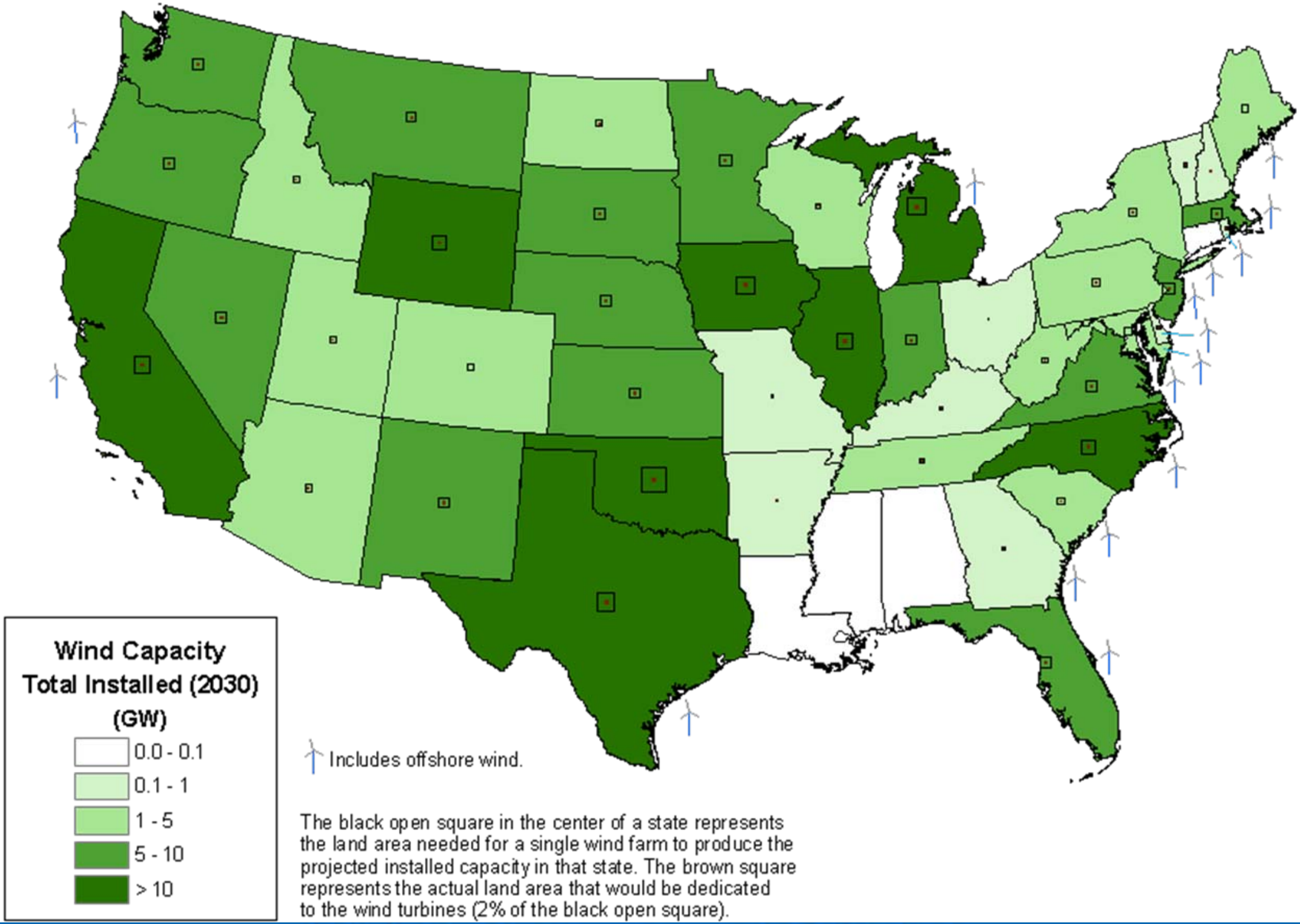
Solar Energy Resource ≥ 6.0
Capacity assumes 5 acres/MW
Generation assumes 27% annual capacity factor

Current total nameplate capacity in the U.S. is ~1,000GW w/ resulting annual generation of 4,000,000 GWh

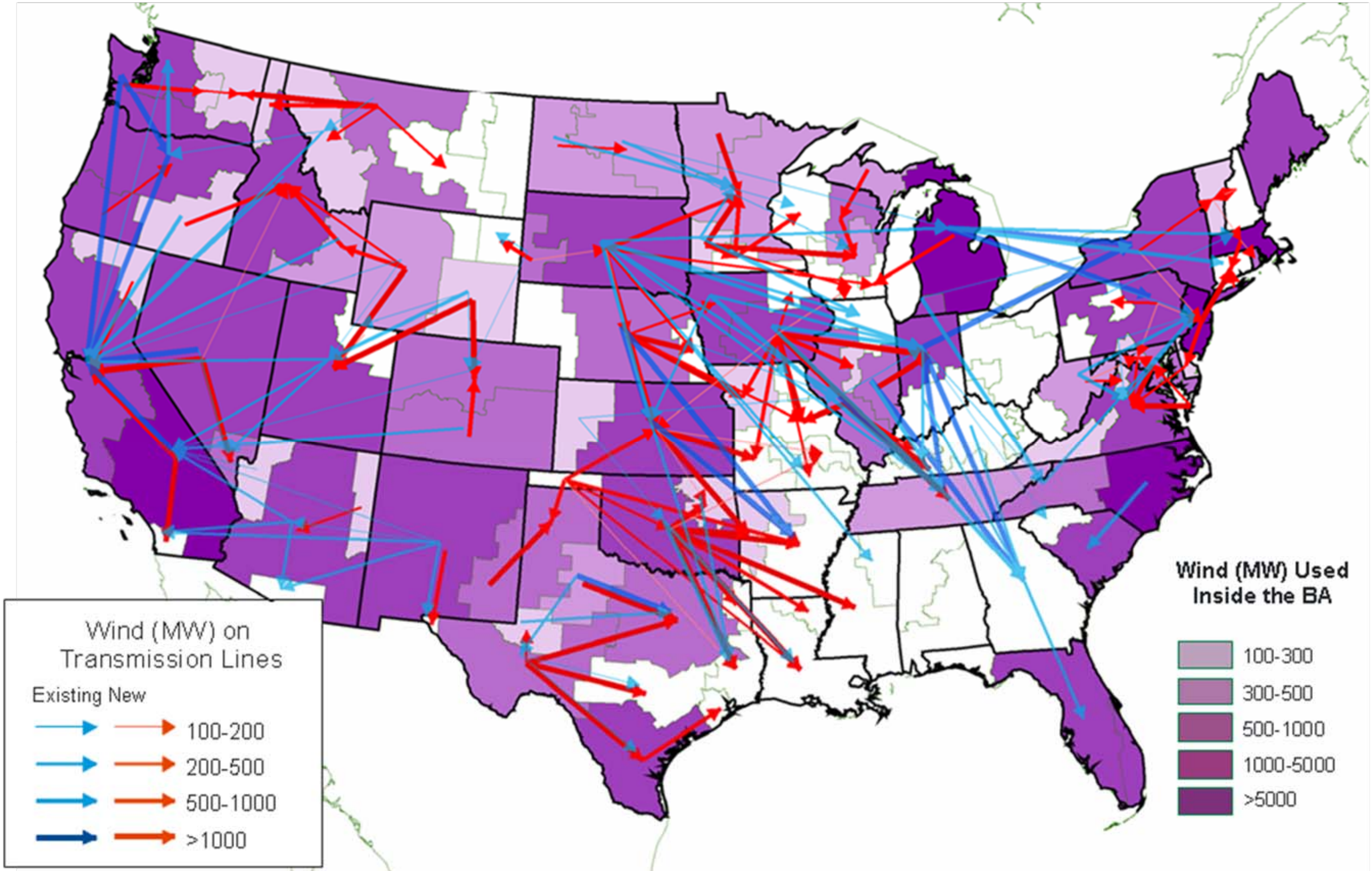
20% Wind Scenario



20% Wind Scenario – Wind in 46 States



Transmission Requirements in 2030



Example Issue
High Penetration PV

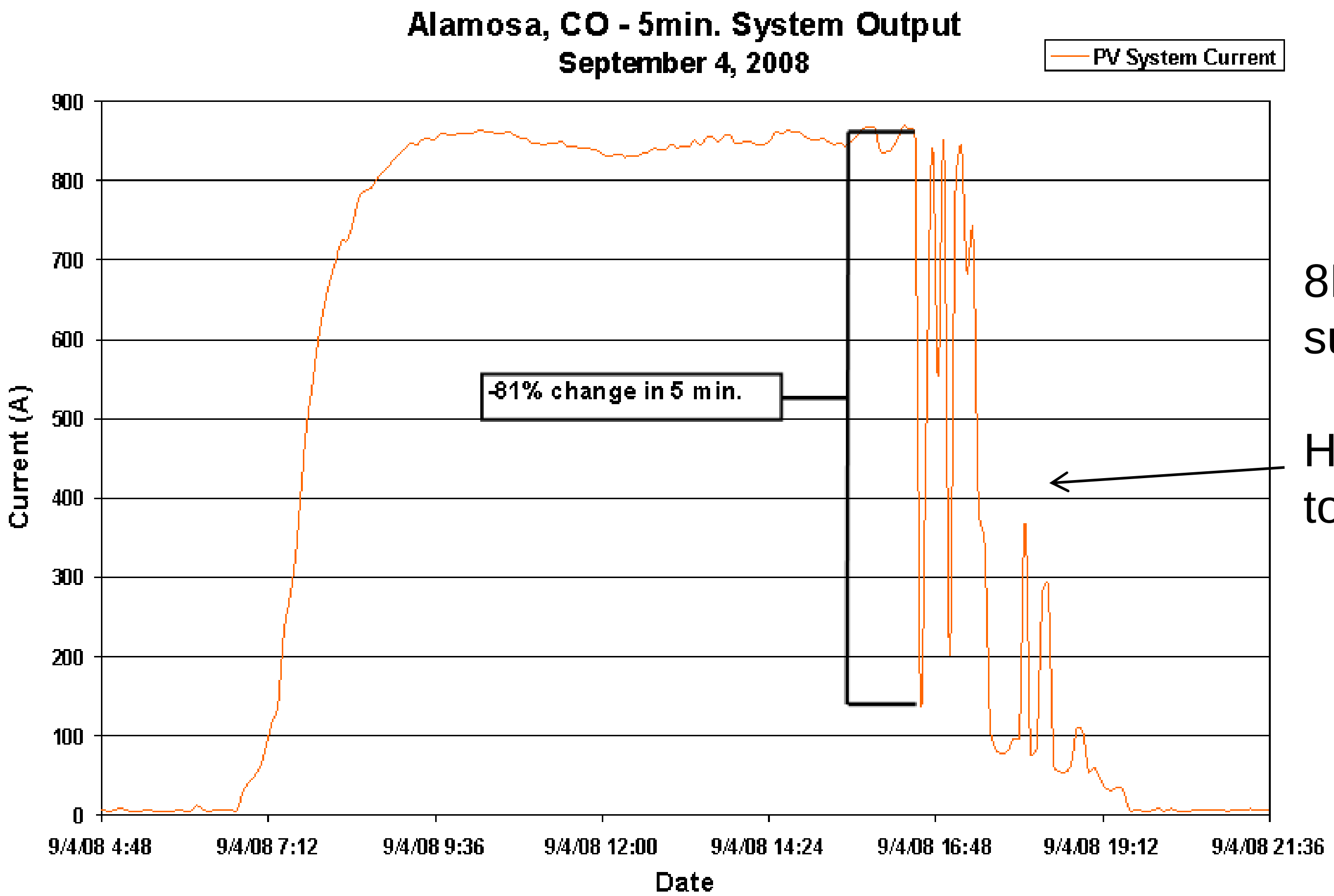
Current Situation – Low Penetration

PV viewed as demand reduction
Power flow unidirectional from substation to end use
Limited active operations at distribution level
Limited communications

Future Grid

PV at high penetration – power production technology
Two-way power flow
Smart grid with active operations
Broadband, two-way communications

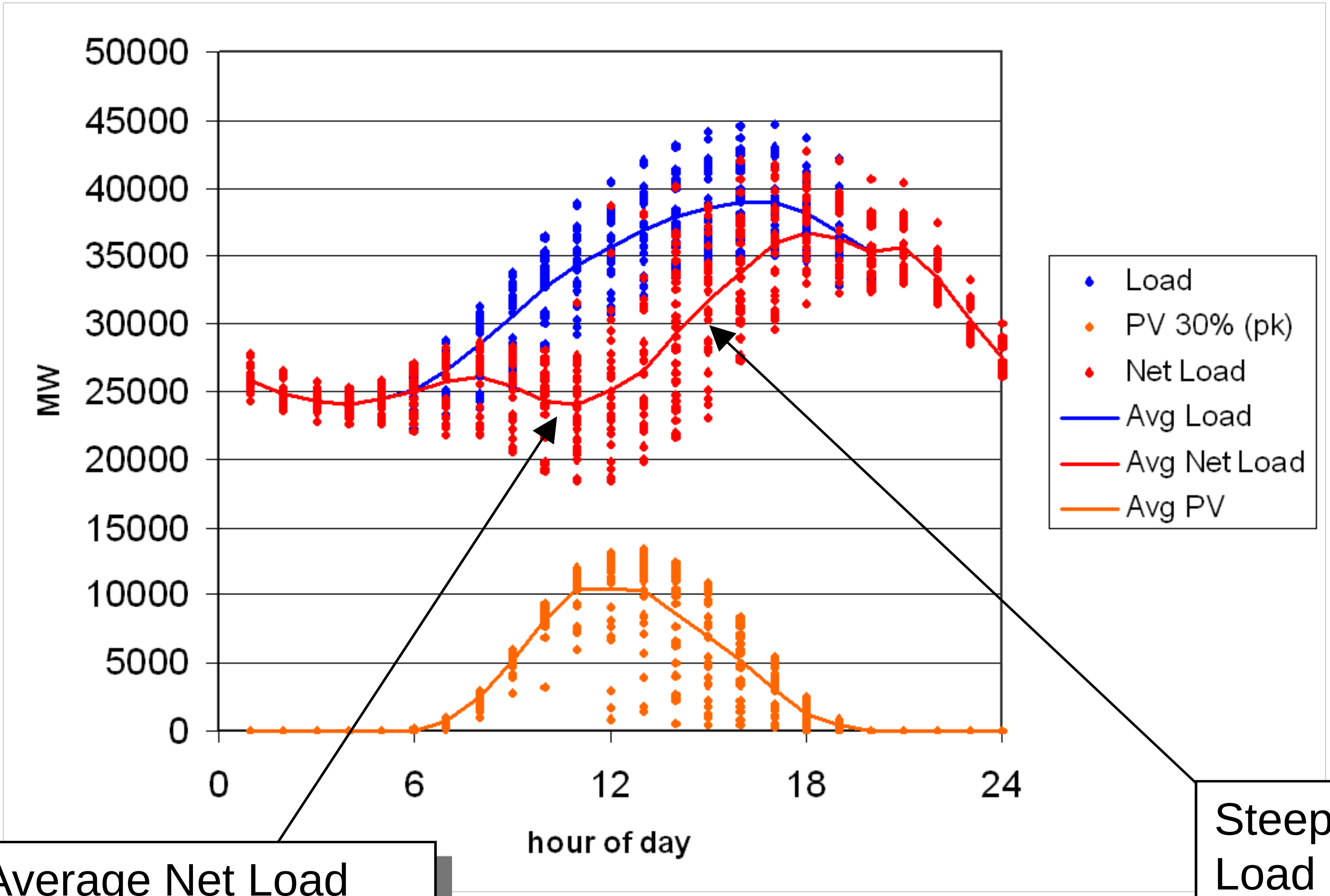
Xcel Energy – Alamosa System



8MW connected to substation

High Variability due to clouds

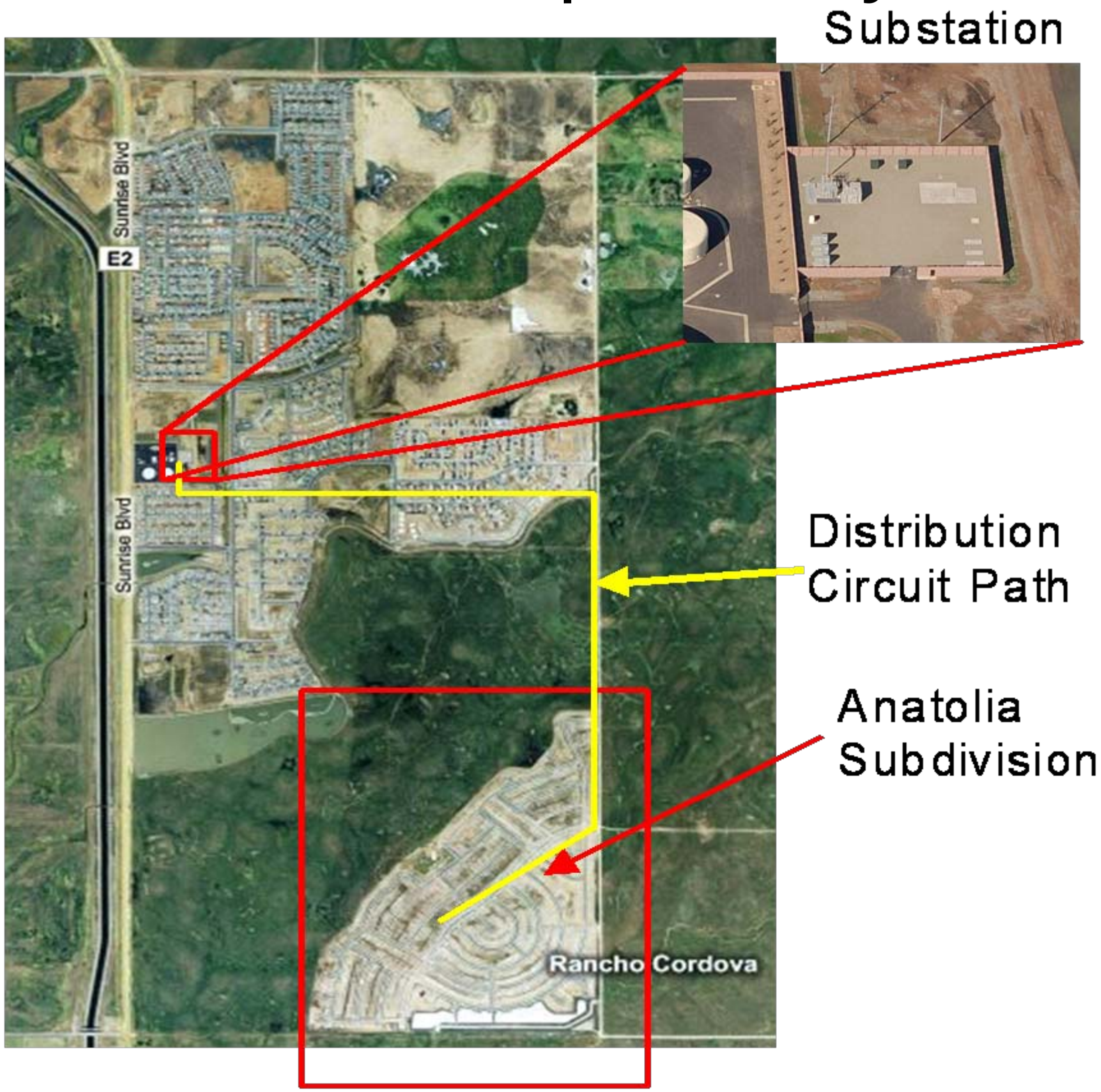
Evaluating High Penetration of PV



Average Net Load Min @ ~11AM

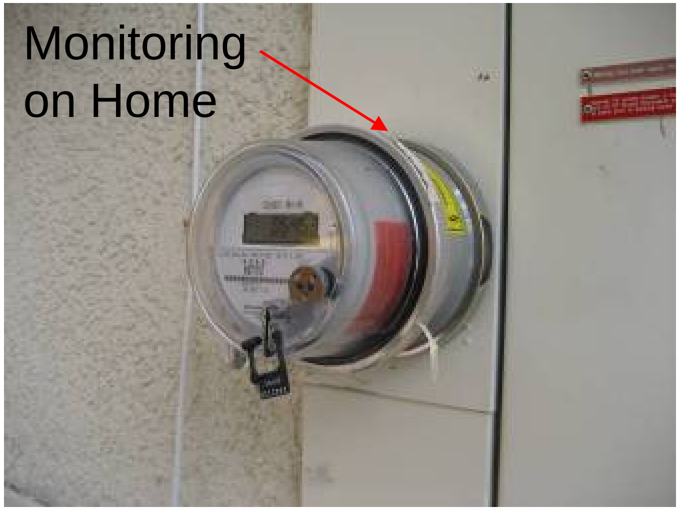
Steeper Load Rise

Sacramento Municipal Utility District

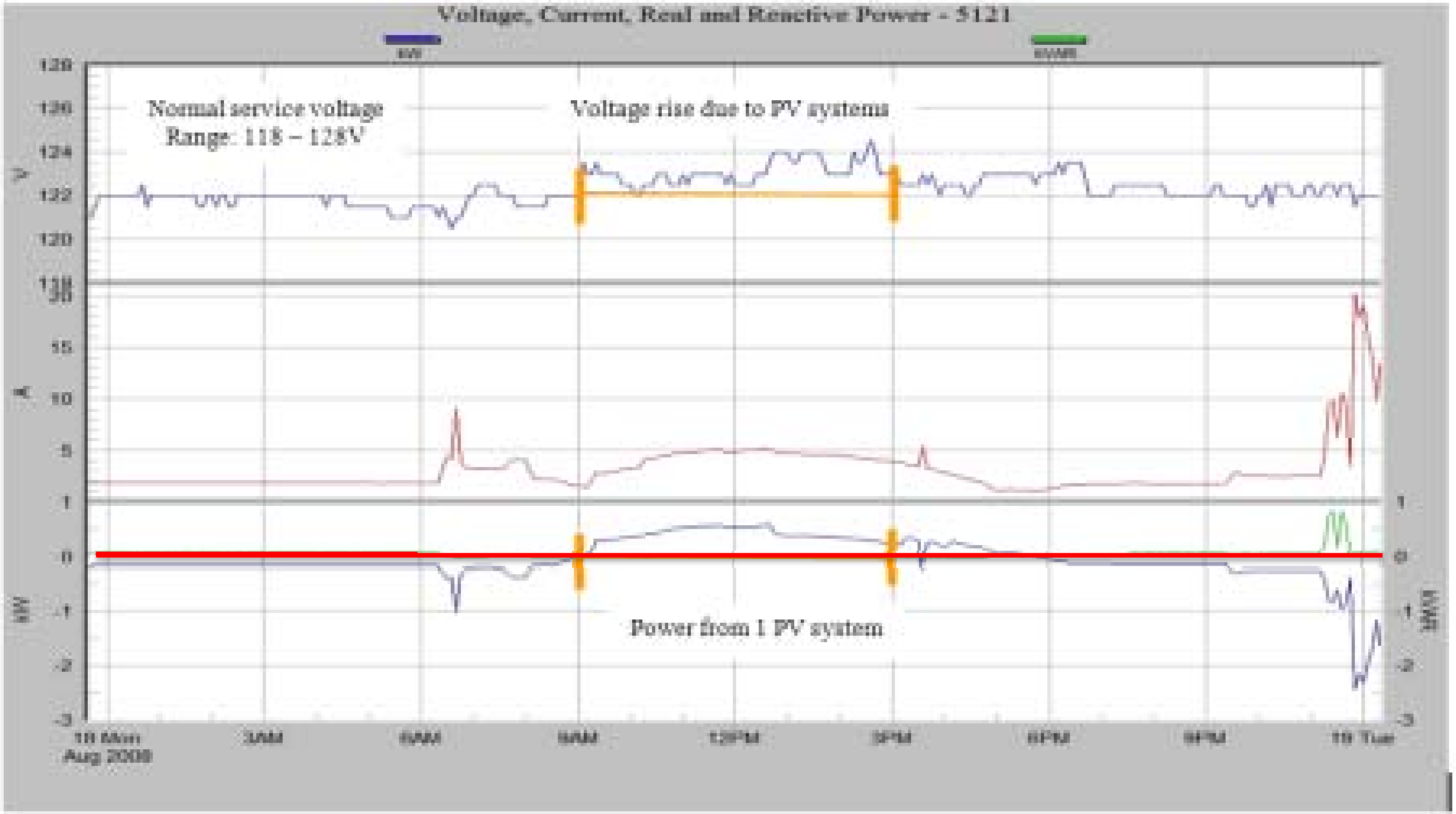


SMUD

Monitoring on Distribution Transformer

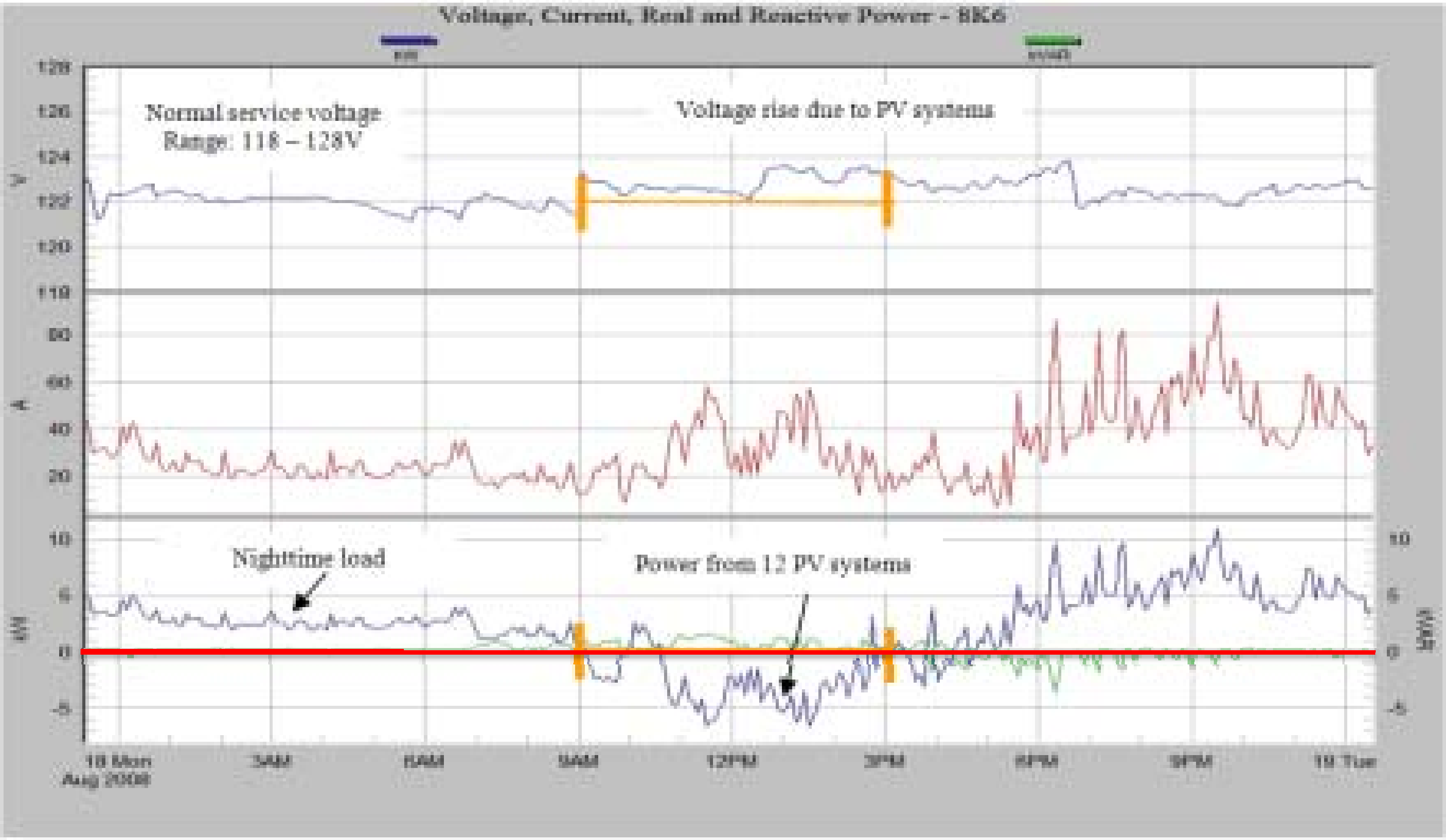


SMUD



Individual Home

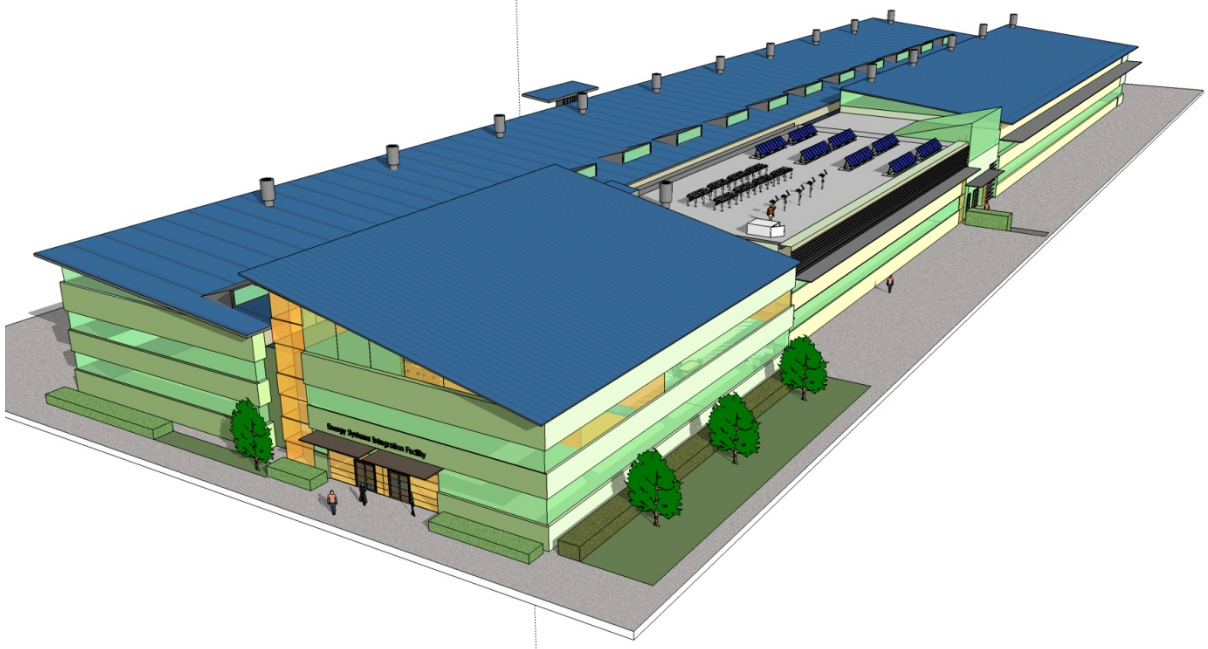
SMUD



Distribution Transformer

Energy Systems Integration Facility

Enable complex systems research and development that fully integrates the most advanced simulation, data analysis, engineering, and evaluation techniques to transform the nation’s energy infrastructure.



Capability Gap to Address Challenges

Fully assess the **performance and reliability impacts** of large-scale RE and EE deployment on the nation’s energy delivery infrastructure.

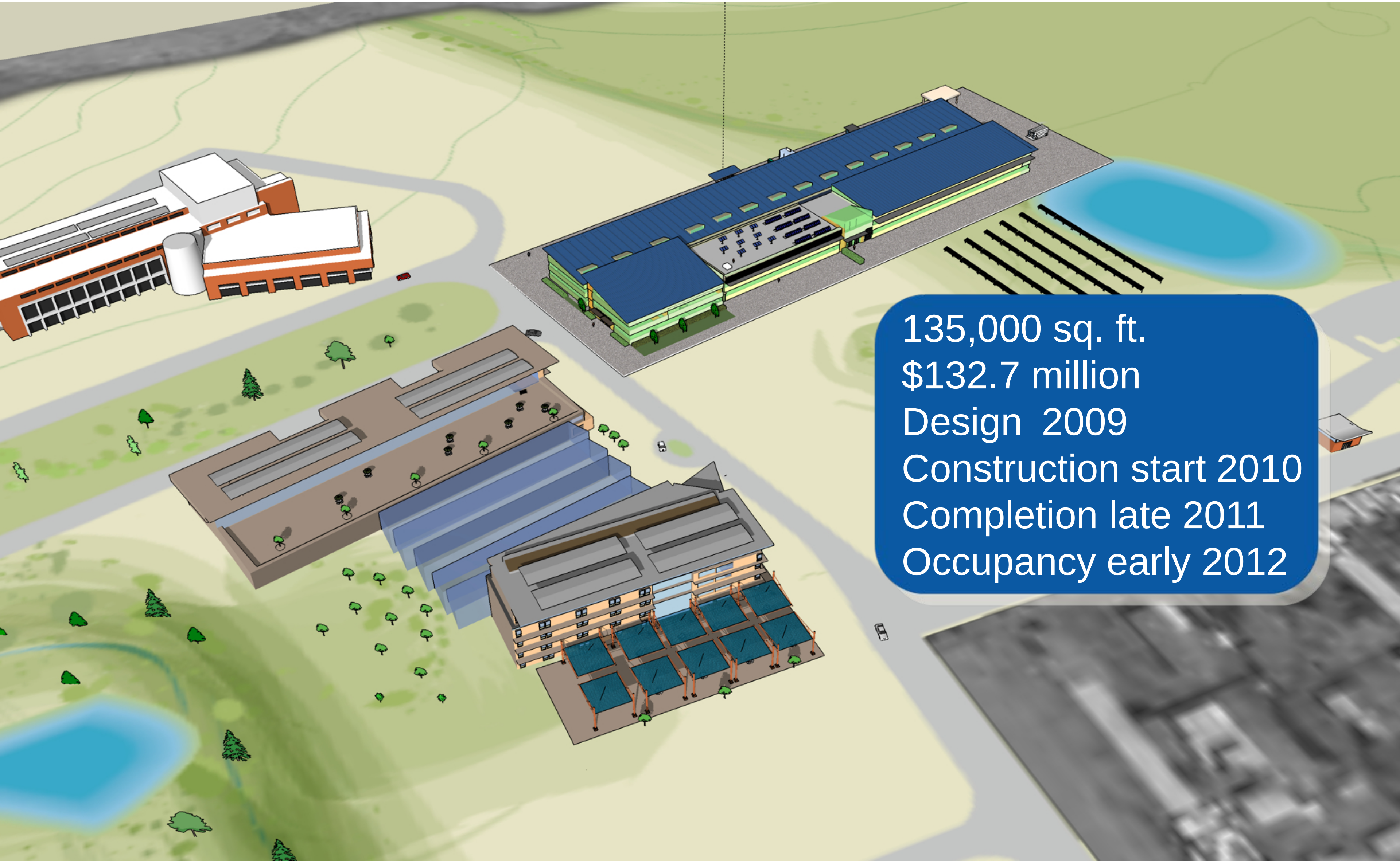
Reduce uncertainties for utilities by conducting analysis of RE and EE technologies under different operating and geographic conditions.

Explore impacts on system interfaces from large-scale EE and RE penetration.

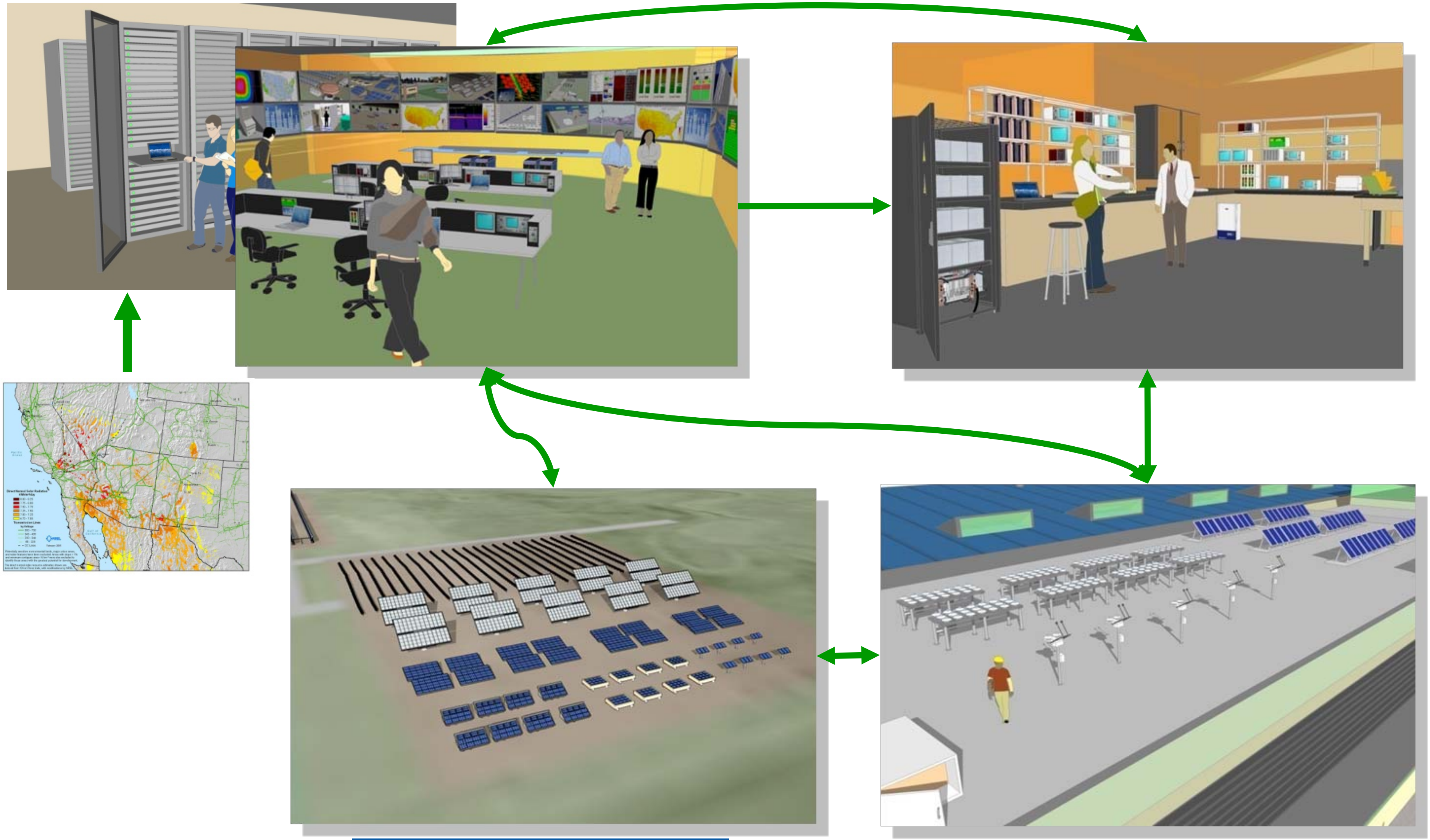
Develop **performance models for integrated RE** generation systems for a combination of resources/geographies and demand control technologies.

Optimize integrated RE and demand side systems configurations under various load and storage configurations.

Validate benefits of **storage solutions** for distributed and bulk RE and EE technologies.



135,000 sq. ft.
$132.7 million
Design 2009
Construction start 2010
Completion late 2011
Occupancy early 2012



Systems “in the loop”

Hardware “in the loop”

ESIF System Integration Capabilities

System Testing, Data Analysis, Modeling, and Visualization Across Technologies

High-Performance Computing, Data Storage, and Networking

- Solar

- Interconnection
- Power electronics
- Building integration
- Thermal and PV system optimization

- Buildings

- Sensors and controls
- PV design and integration
- Modeling and simulation
- System integration

- Hydrogen

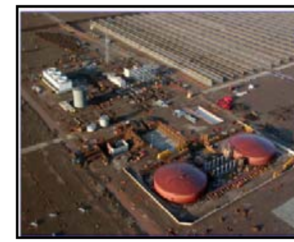
- H_2/electric interfaces
- RE electrolyzers
- Storage systems
- Standards
- Fuel cell integration
- Fueling systems

- Wind

- Models, methods for wind-grid integration
- Transmission
- Operations modeling

- Advanced Vehicles

- Plug-in-hybrids and vehicle-to-grid
- Battery thermal management
- Power electronics



- Storage

- CSP Thermal Storage
- Utility scale batteries
- Distributed storage.

Full systems interface evaluation for integration of electricity, fuels, thermal, storage, and end-use technologies

ESIF Capabilities

- Completed User Requirement Spreadsheets based on 13 initial competencies from Mission Needs Statement
  1. Renewable resource characterization
  2. Renewable systems operations and analysis support
  3. Integrated testing and field validation of components
  4. Simulation and development of system controls
  5. Analyzing storage systems
  6. Advanced energy computing capability
  7. Renewable electricity production and hydrogen synergies
  8. Buildings System Integration
  9. Market and integration analysis
  10. Economic validation
  11. Market competitiveness of zero energy buildings
  12. Codes and Standards
  13. Combined heat and power

Requirements Worksheet Example

PC.2 Renewable Systems Operations and Analysis Support

Coordinate with renewable energy manufacturers to acquire information on fielded system performance characteristics and work with them and their vendors to assist in design and modeling of advanced systems.

Activity	Organization	Inputs	Outputs	Staff	Space	Equipment	Performance	Comments
2.1 Analyze Distributed and Renewable Energy Systems	P - ESC; S - NWTC; S - NCPV	Performance Data from Fielded Systems	Calibrated Instrumentation - 2.1; Models of DE and	1 Engineer Principal; 1 Engineer Sr. II; 4 Engineer Sr.1;	9 Offices; 2 Cubes; Secure Data Center (1,500 sqft),			
Task	**Organization**	**Inputs**					**Performance**	**Comments**
2.1.1 Collect Renewable Systems Performance Data	P - ESC; S - NCPV; S - NWTC	Performa from Field Systems				2TB) by	Collect data - continuously Report data - Quarterly	
2.1.2 Collect Renewable Systems/Grid Integration Data	P - ESC; S - NWTC; S - NCPV	Data from systems t shows impa Renewables on Grid				2TB) Need to store by customer (proprietary)	Collect data - continuously Report data - Quarterly	
2.1.3 Optimize Renewable System Techno-economic operation	P - ESC; S - NWTC; S - NCPV	Data from fielded systems that shows impacts of Renewables on Grid	Models - 2.1.3; Reports - 2.1.3	Analysist Sr. I; Engineer Sr. I	2 Offices	Data storage (2TB) with backup Need to store by customer (proprietary)	Collect data - continuously Report data - Quarterly	

48 Activities
117 Tasks

Worksheet Rollup

- Approximately 135,000 sq. ft.
  - 20+ Laboratories
  - 5 Test Facilities (Outdoor, Roof, etc.)
  - ~200 person Office area
  - Specialty Areas
    - Insight Center including Visualization Rooms and Collaboration areas
    - Virtual Control Room for RE Integration and Infrastructure Visualization
  - Common Areas (Building support, maintenance, conference rooms, security, ES&H, building management)
  - 15,000+ sq. ft. Data Center

Energy Systems Integration Facility

- Total Estimated Cost: $132.7 Million

  - $89.2 Million – Design and Construction
  - $4 Million - Infrastructure
  - $5 Million - Other Costs
  - $34.5 Million - Equipment
    - $12 Million High Performance Computer
    - $22 Million in Equipment Capital

ESIF Schedule

• CD-0 (MNS) – Approved	May 2007
• Received Funding ($55M)	October 2007
• Define Internal User Requirements	July 2008
• Define External user Requirements	October 2008
• RFQ to Potential Bidders	September 2008
• RFP Preparation	Dec 08 – April 09
• RFP to Potential Bidders	May 2009
• CD-1 Package	July 2009
• Select Design Build Contractor	August 2009
• CD 2/3	January 2010
• Construction Starts	February 2010
• Construction Finishes	October 2011

Thank You

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Electricity, Resources, and Building Systems Integration
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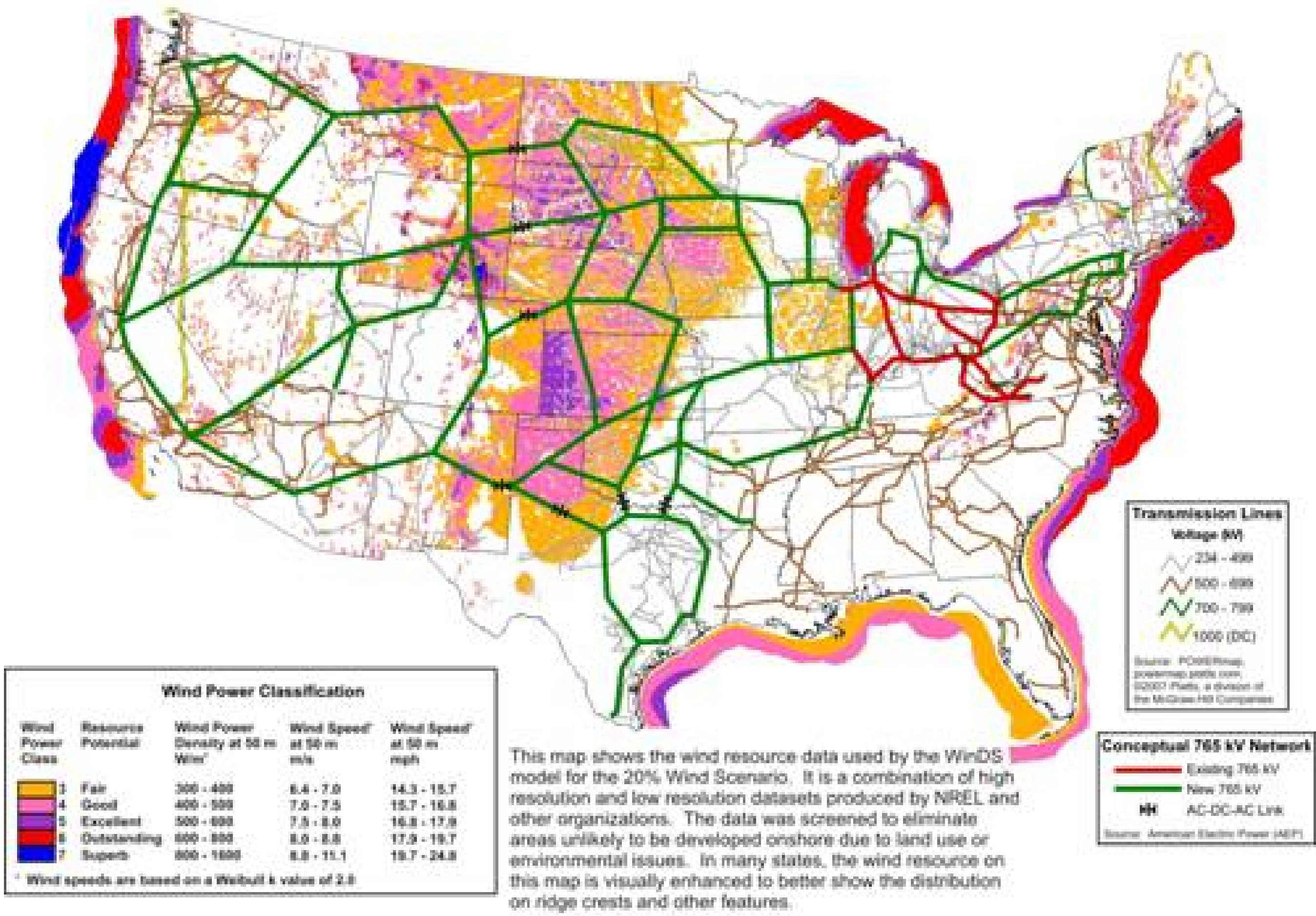
Backup Slides

20% of electric energy from Wind

- Over 300 GW of new wind plants
- Existing transmission system is inadequate
- Conceptual 765 kV EHV overlay examined by AEP
- $60 billion over 20 yrs
- 19,000 mi of line
- Delivers additional 200-400 GW
- Current transmission investment $7 billion/yr and growing



Integration and Resource Planning

- Modeling and Methods
  - Generator Dynamics –
    Validation and grid monitoring
  - Production Cost and Grid Simulators
  - Wind Farm Data
  - WinDS (econometric expansion planning)
    Load flow modeling, meso profile integration, and 20%snsitivity studies