Renewable Technology Integration

Sustainable Energy and Atmospheric Sciences Seminar Series

Dave Mooney

March 19, 2009

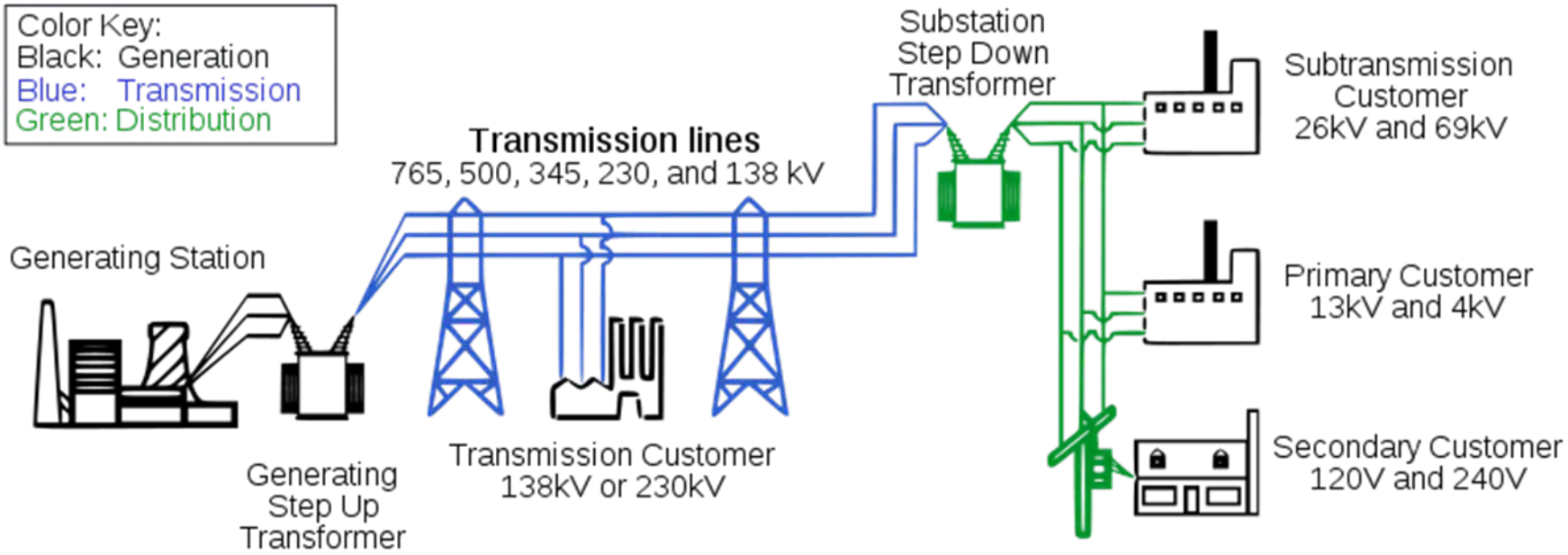
NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

NREL is a national laboratory of the U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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

Overview of the Conventional Electricity System



Integration and Interconnection Issues

Access → Resource Measurement
Historical Data

Variability → Resource Forecasting

Renewable Generation

Wind Energy

Concentrating Solar Power

Photovoltaics

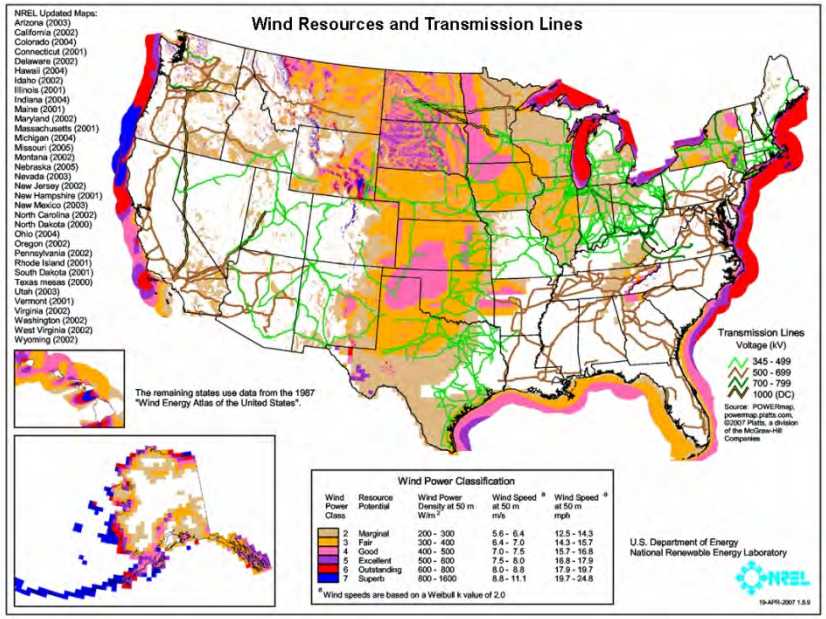
Renewable Generation

Geothermal

Biomass

Ocean Energy

Wind Energy

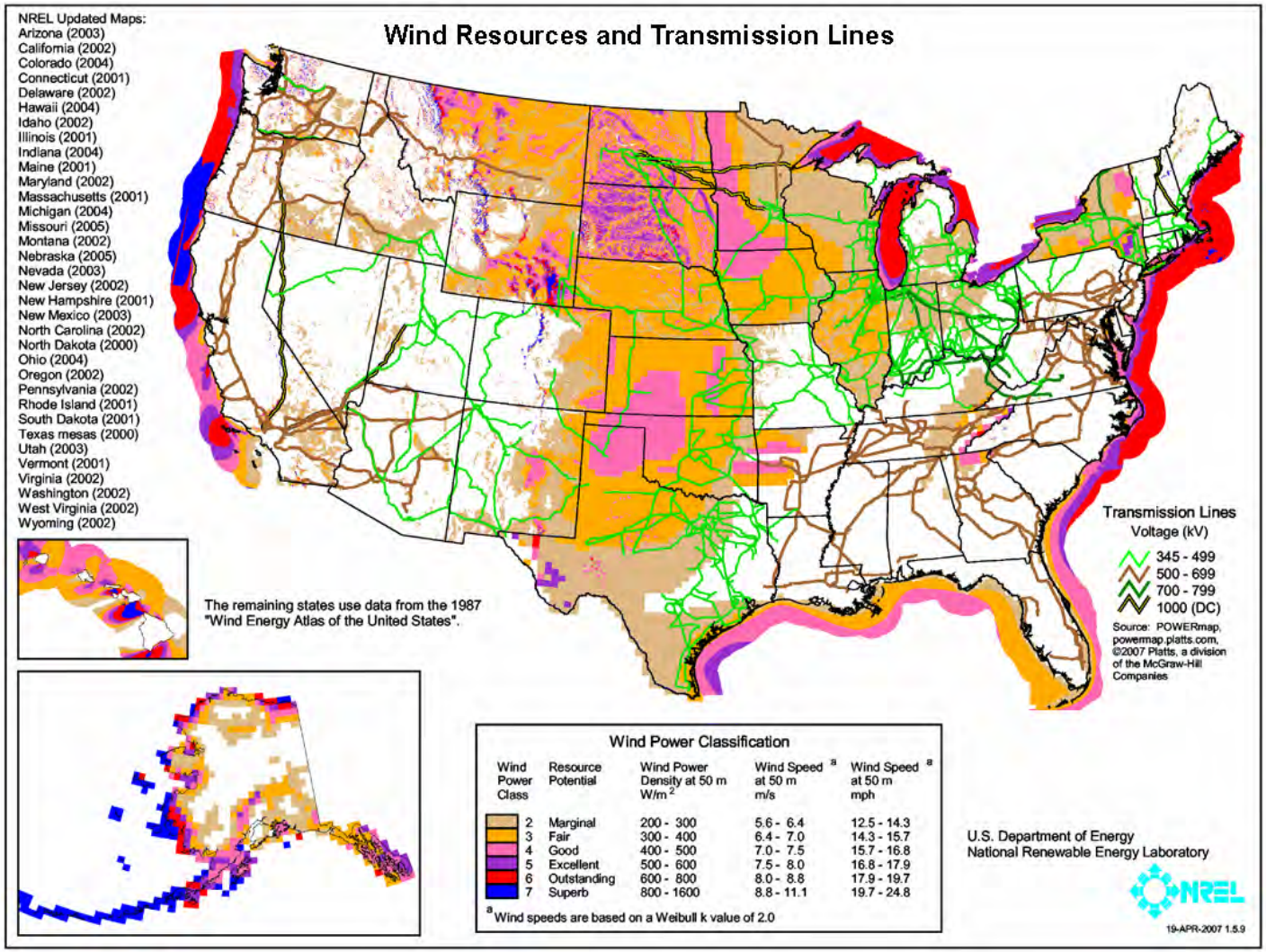


Interconnection

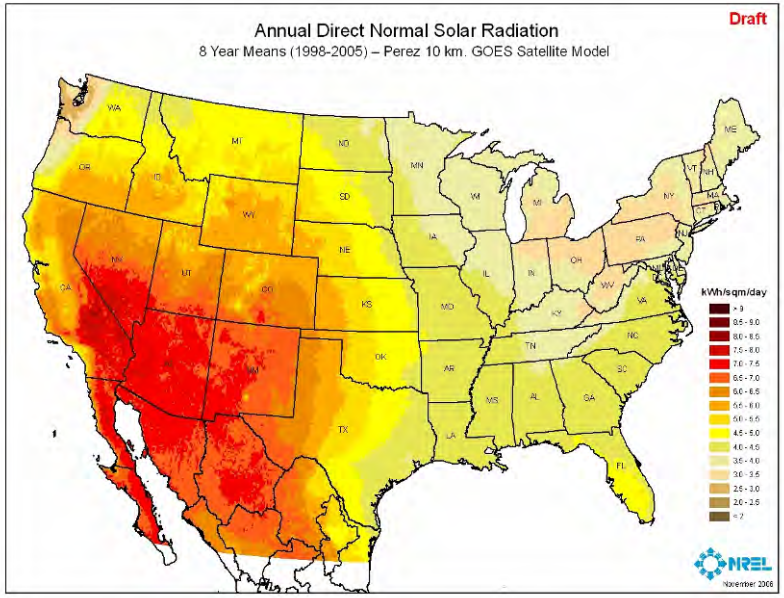
- Transmission
- Distribution

Integration Issues

- Access
- Variability


Wind Resources and Transmission Lines
NREL Updated Maps:
Arizona (2003)
California (2002)
Colorado (2004)
Connecticut (2001)
Delaware (2002)
Hawaii (2004)
Idaho (2002)
Illinois (2001)
Indiana (2004)
Maine (2001)
Maryland (2002)
Massachusetts (2001)
Michigan (2004)
Missouri (2005)
Montana (2002)
Nebraska (2005)
Nevada (2003)
New Jersey (2002)
New Hampshire (2001)
New Mexico (2003)
North Carolina (2002)
North Dakota (2000)
Ohio (2004)
Oregon (2002)
Pennsylvania (2002)
Rhode Island (2001)
South Dakota (2001)
Texas mesas (2000)
Utah (2003)
Vermont (2001)
Virginia (2002)
Washington (2002)
West Virginia (2002)
Wyoming (2002)
The remaining states use data from the 1987 "Wind Energy Atlas of the United States".
Transmission Lines
Voltage (kV)
345 - 499
500 - 699
700 - 799
1000 (DC)
Source: POWERmap, powermap.platts.com, ©2007 Platts, a division of the McGraw-Hill Companies
Wind Power Classification
Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m2 | Wind Speed a at 50 m m/s | Wind Speed a at 50 m mph
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 - 1600 8.8 - 11.1 19.7 - 24.8
a Wind speeds are based on a Weibull k value of 2.0
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
19-APR-2007 1.5.9

Concentrating Solar Power

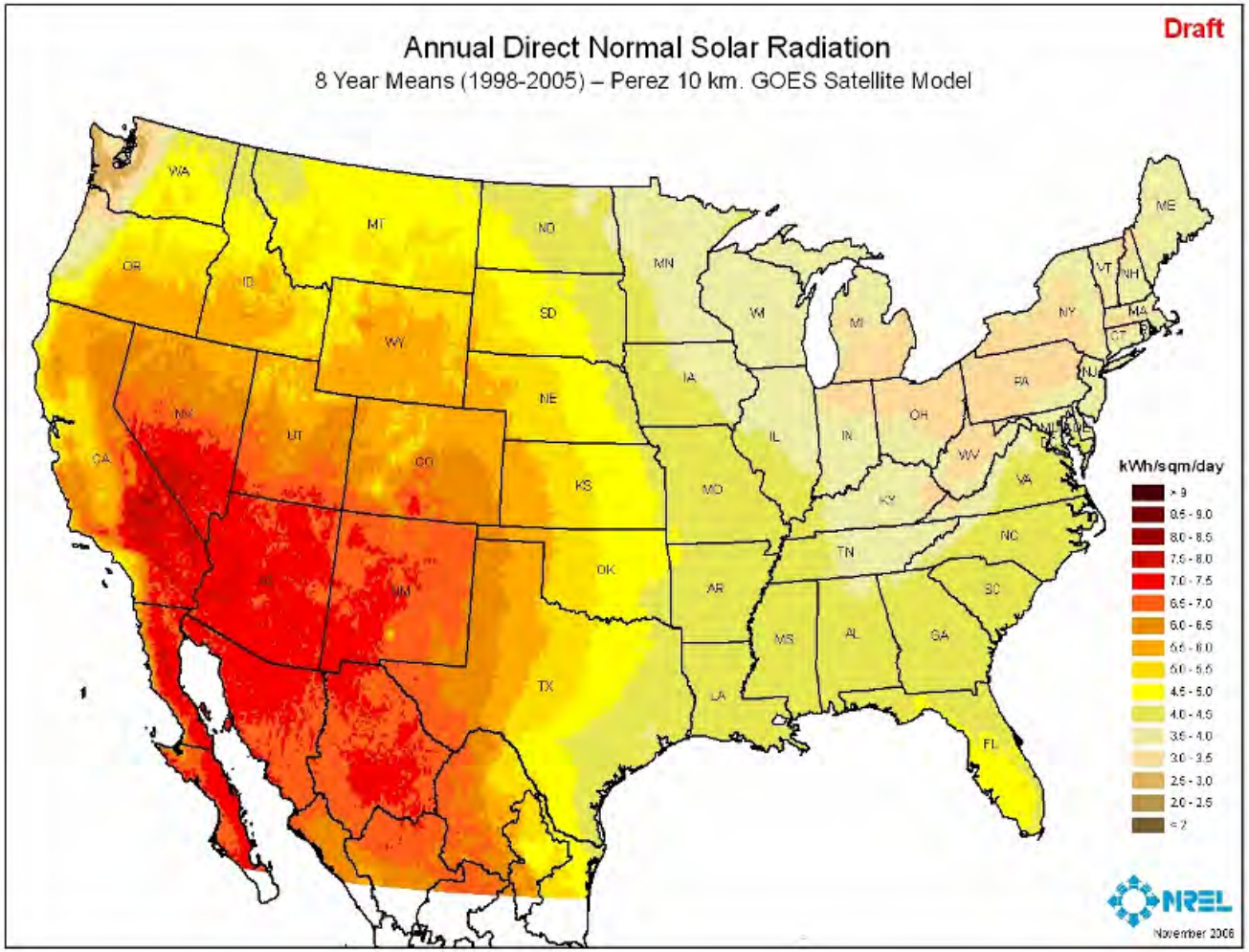


Interconnects

- Transmission

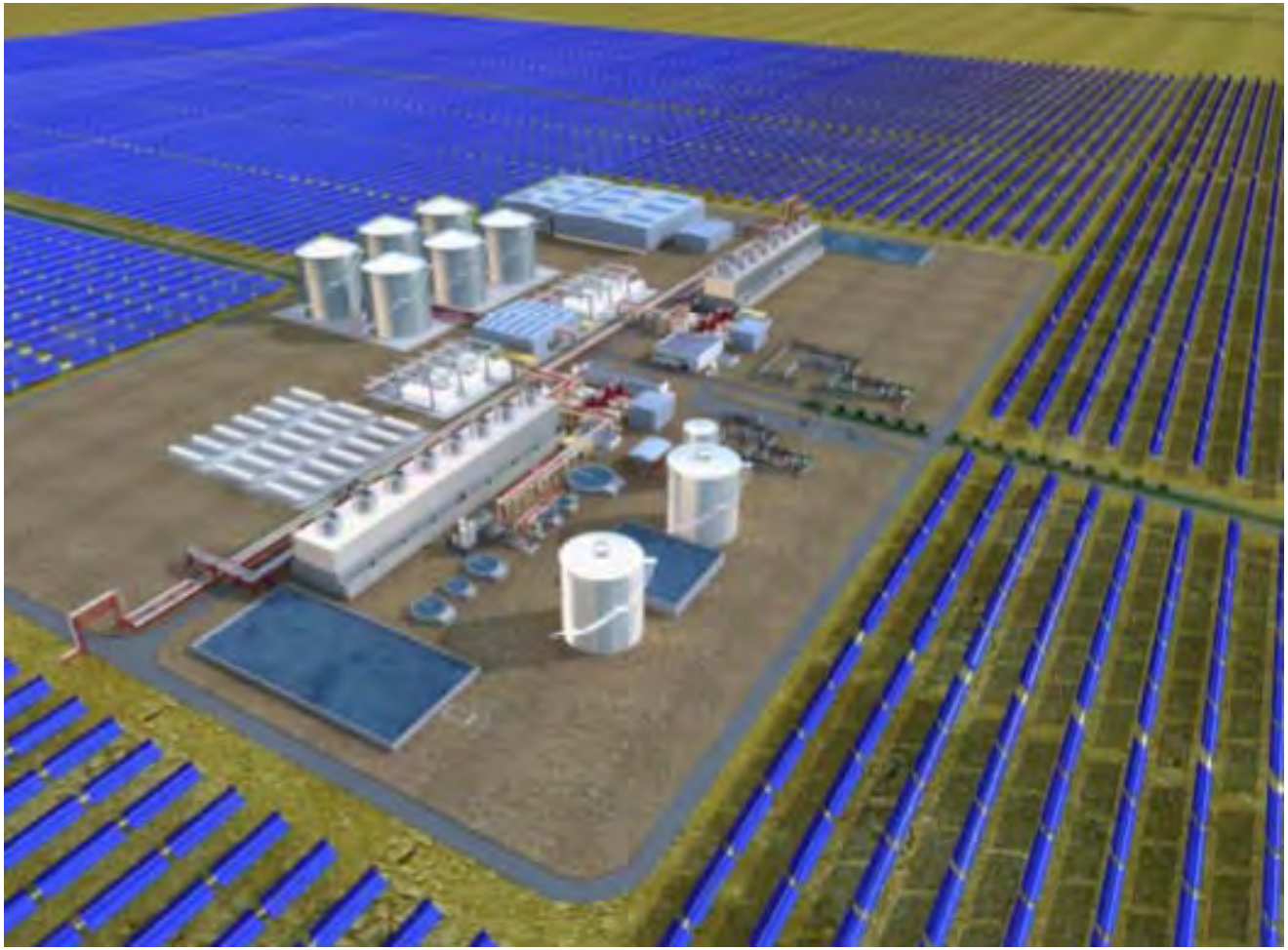
Integration Issues

- 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
RI
NJ
DE
MD
kWh/sqm/day
> 9
9.5 - 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

1500 construction jobs over two years

85 permanent jobs

APS

Renewable Energy

Xcel Energy

Company | Residential | Business | Energy Partners | Customer Service

News Releases

1/9/2009

Xcel Energy announces all-source generation RFP for its Colorado customers

DENVER – Xcel Energy will seek to acquire approximately 2,200 megawatts of electric generation supply for its Colorado customers between now and 2015, through an all-source request for proposal (RFP) issued today by the company. The RFP is part of the most recent 2007 Colorado Resource Plan (CRP) approved by state regulators in December.

Xcel Energy is seeking to add up to 700 megawatts of additional wind and solar generation through the RFP. In addition, the company will consider acquiring up to 600 megawatts from solar thermal generation with storage capability or natural gas backup.

Under Colorado Public Utilities Commission (CPUC) rules, all forms of electric generation greater than 30 megawatts – both fossil fuels and renewables – can be bid, although this RFP restricts coal-fired bids to those from facilities that capture and sequester at least 50 percent of their carbon dioxide emissions.

"Our request today marks the next important chapter in meeting the future energy needs of Colorado, and it will have significant emphasis on ensuring that we add those generation sources that are in keeping with Xcel Energy's environmental leadership strategy and the state's New Energy Economy," said Tim Taylor, president and CEO for Public Service Co. of Colorado, an Xcel Energy company.

Xcel will sponsor a pre-bid conference on Jan. 28 in Denver, with parties interested in offering power supply proposals to the company through this RFP. Proposals are due on April 10. Xcel Energy expects to offer "self-build" proposals to compete in the overall process.

Xcel Energy expects to complete the resource evaluation process by the fall of 2009. An independent evaluator selected by the CPUC will perform a parallel evaluation of proposals.

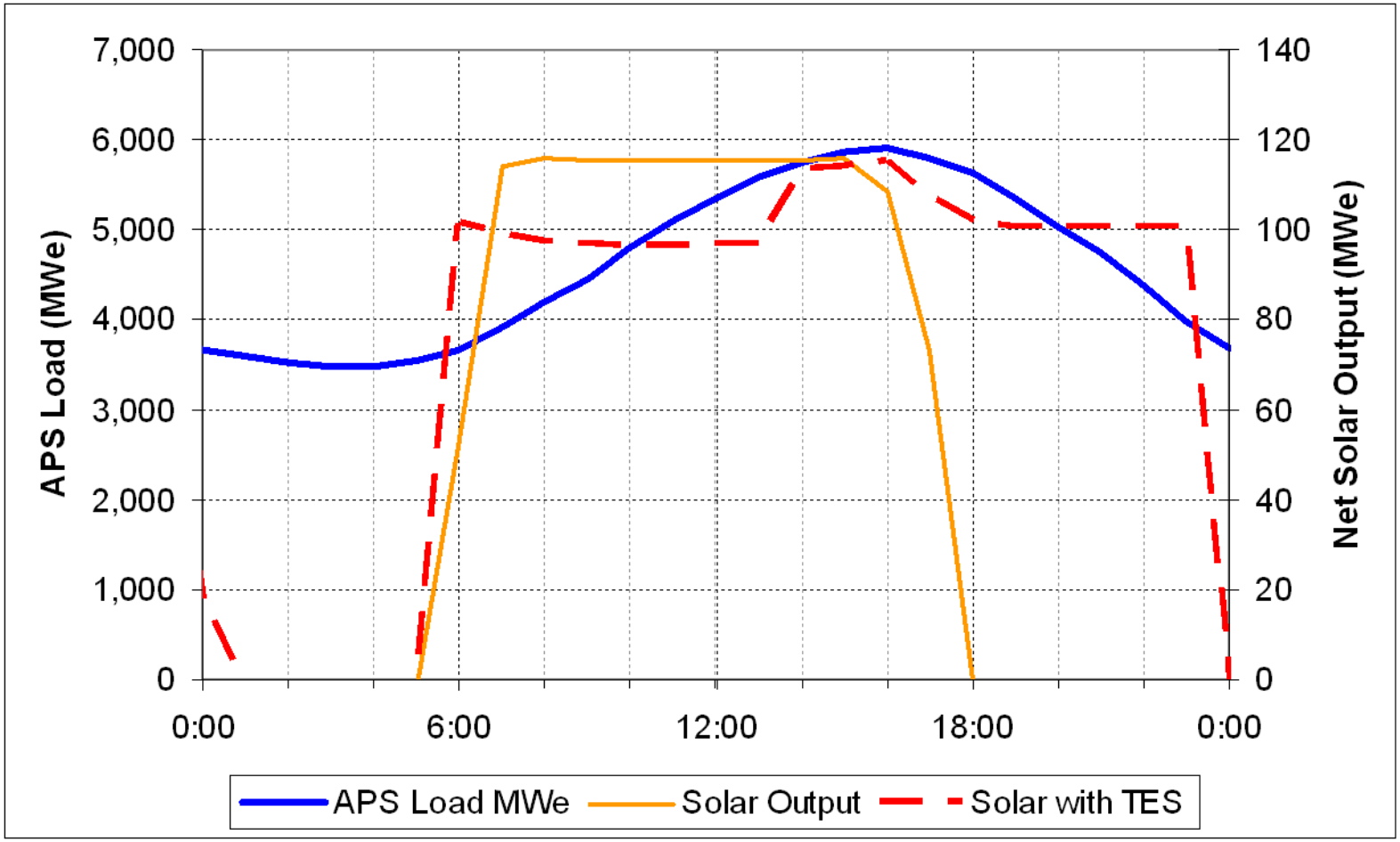
Request for Proposals documents that comprise this resource solicitation can be found online at www.xcelenergy.com (Select Colorado in the State Selection Box at the left then select Top Menu item "Company" then select Left Menu item "About Energy and Rates" then select Left Menu item "Energy RFPs" and finally select item "2009 PSCo All-Source RFP").

One megawatt of generation in Colorado typically serves the needs of approximately 750 homes. Xcel Energy currently has about 7,700 megawatts of generation capacity available on its system, either owned or secured through power-purchase agreements.

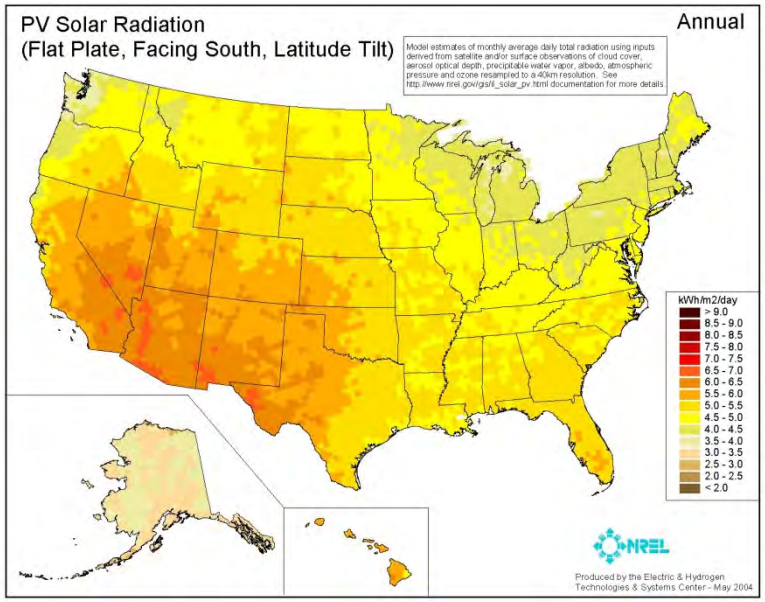
Xcel Energy (NYSE: XEL) is a major U.S. electricity and natural gas company with regulated operations in eight Western and Midwestern states. Xcel Energy provides a comprehensive portfolio of energy-related products and services to 3.3 million electricity customers and 1.8 million natural gas customers through its regulated operating companies. Company headquarters are located in Minneapolis.

"Xcel Energy is seeking to add up to 700 MW of additional wind and solar generation through the RFP. In addition, the Company will consider acquiring up to 600 MW from solar thermal generation with storage or natural gas backup."

CSP Trough Plant Output



Photovoltaics



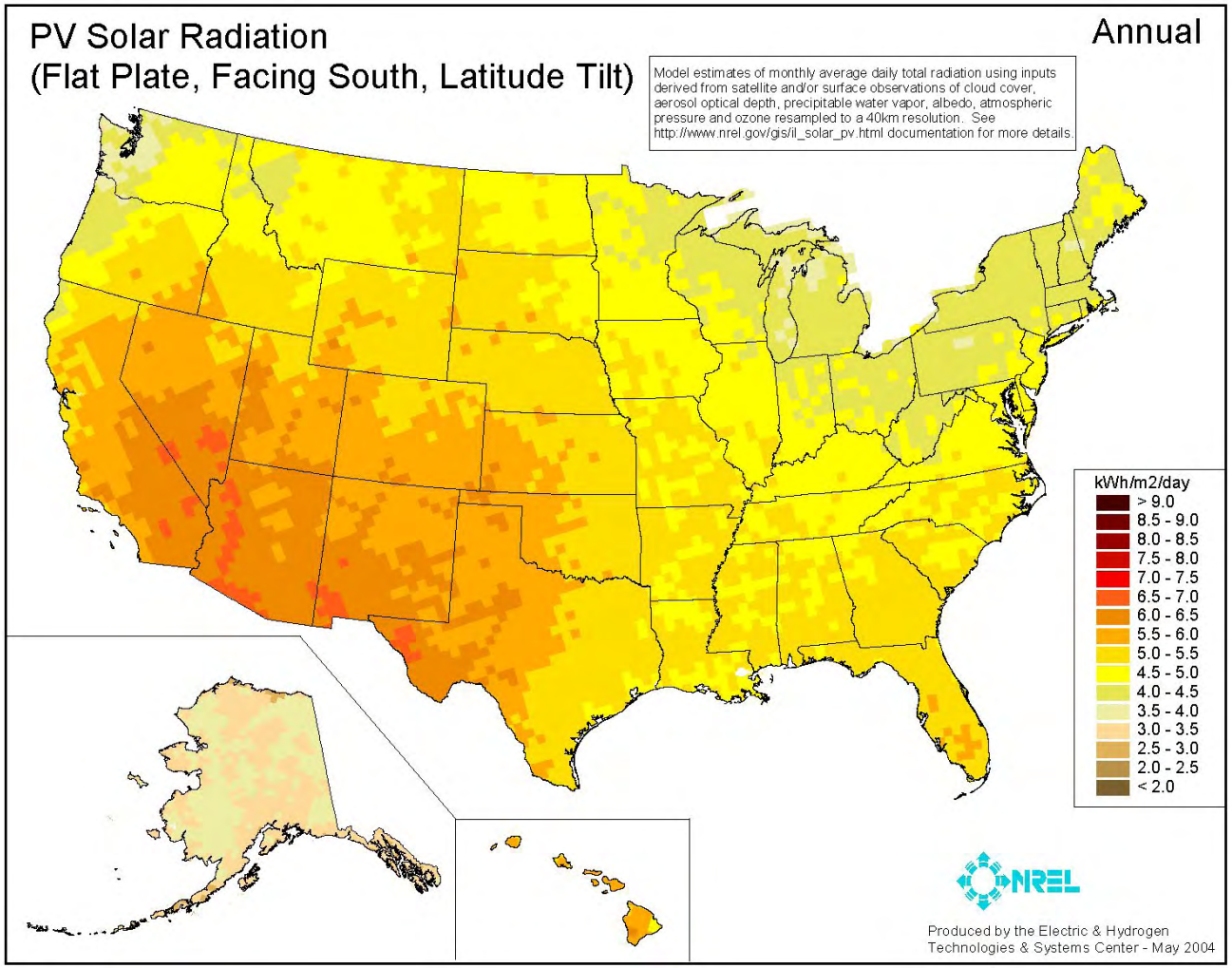
Interconnects

- Transmission*
- Distribution

Integration Issues

- Access
- Variability

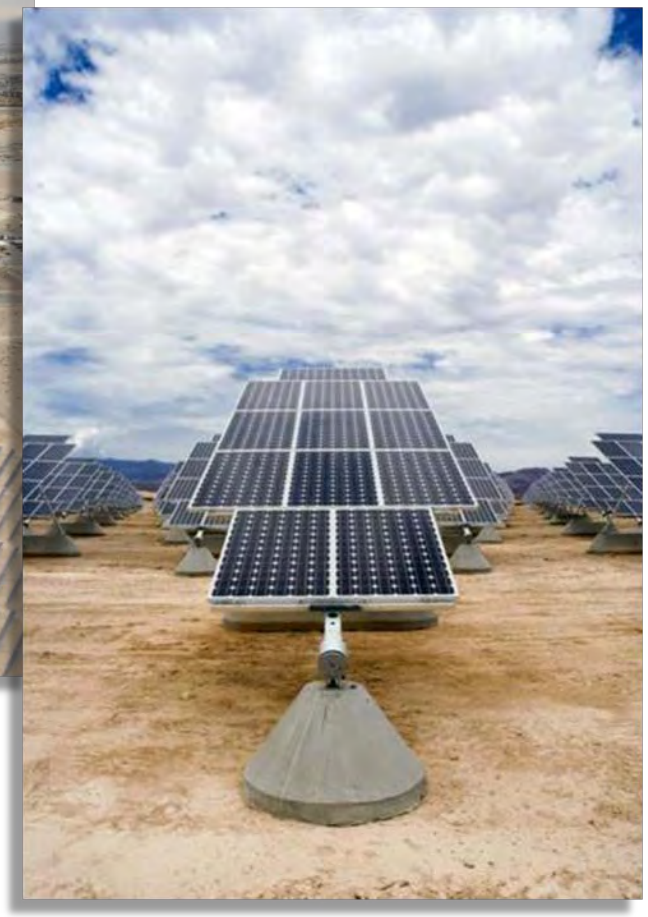
*None currently connected at transmission voltages


PV Solar Radiation
(Flat Plate, Facing South, Latitude Tilt)
Annual
Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See http://www.nrel.gov/gis/il_solar_pv.html documentation for more details.
kWh/m2/day
> 9.0
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
< 2.0
NREL
Produced by the Electric & Hydrogen Technologies & Systems Center - May 2004

Xcel Energy 8 MW Plant

Utility Scale

Nellis AFB 15 MW Plant



Utility Scale

Moscone Center – 675 kW

Commercial Rooftop

Building Integrated PV

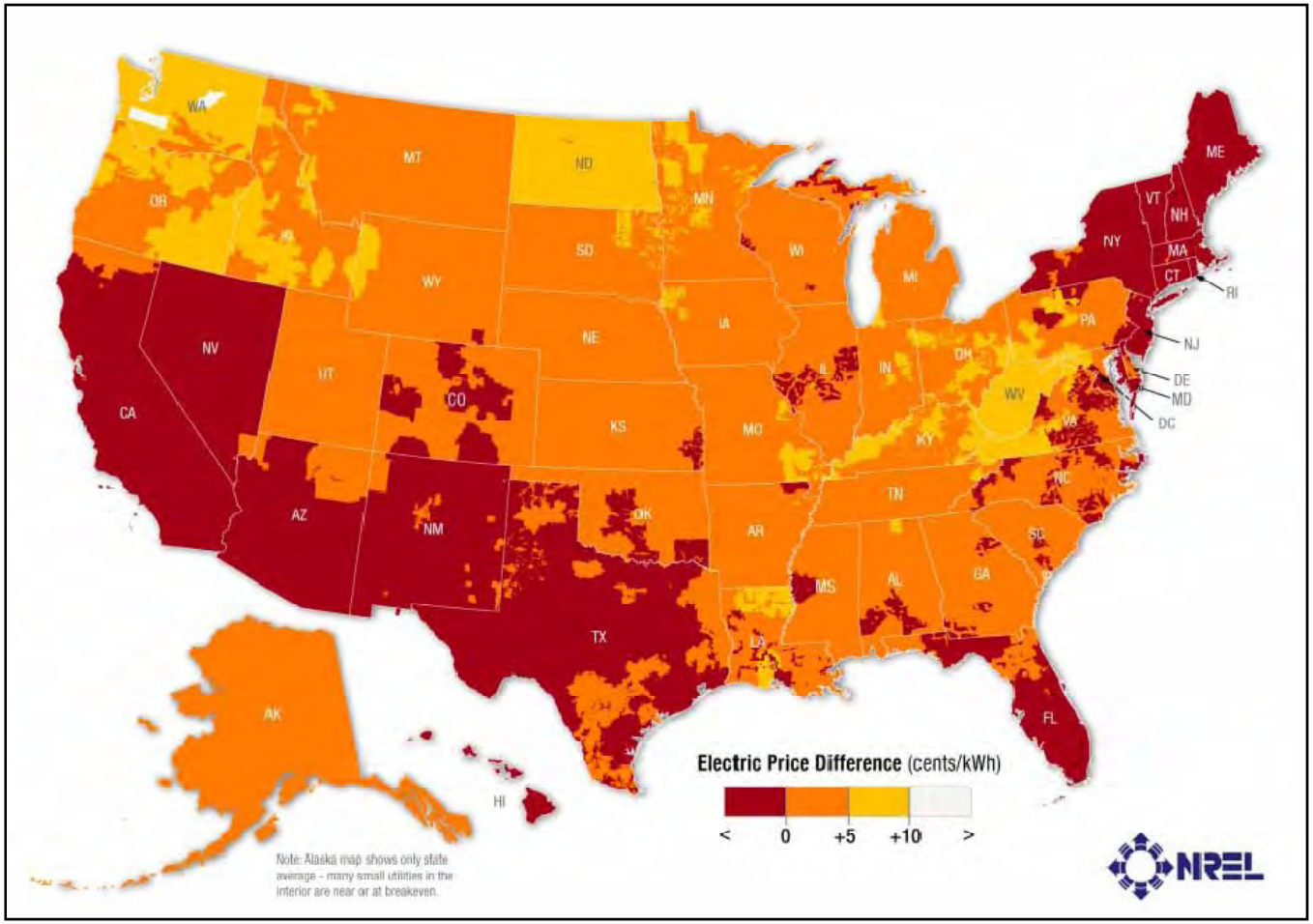
Residential PV

Residential PV

Why Worry About Integration?

2015 Price Targets

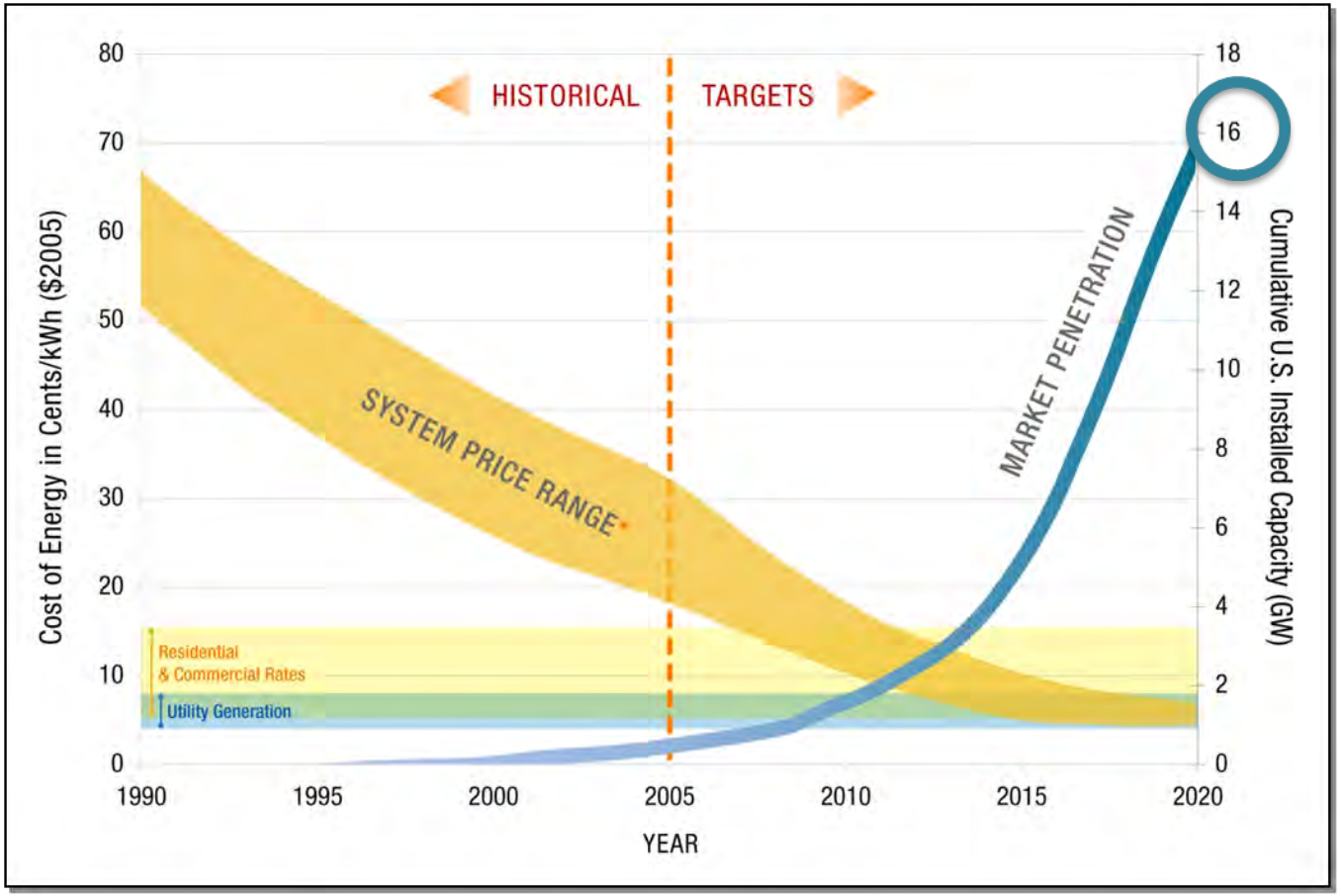
2015 residential PV prices without incentives and <u>moderate</u> increase in electricity prices



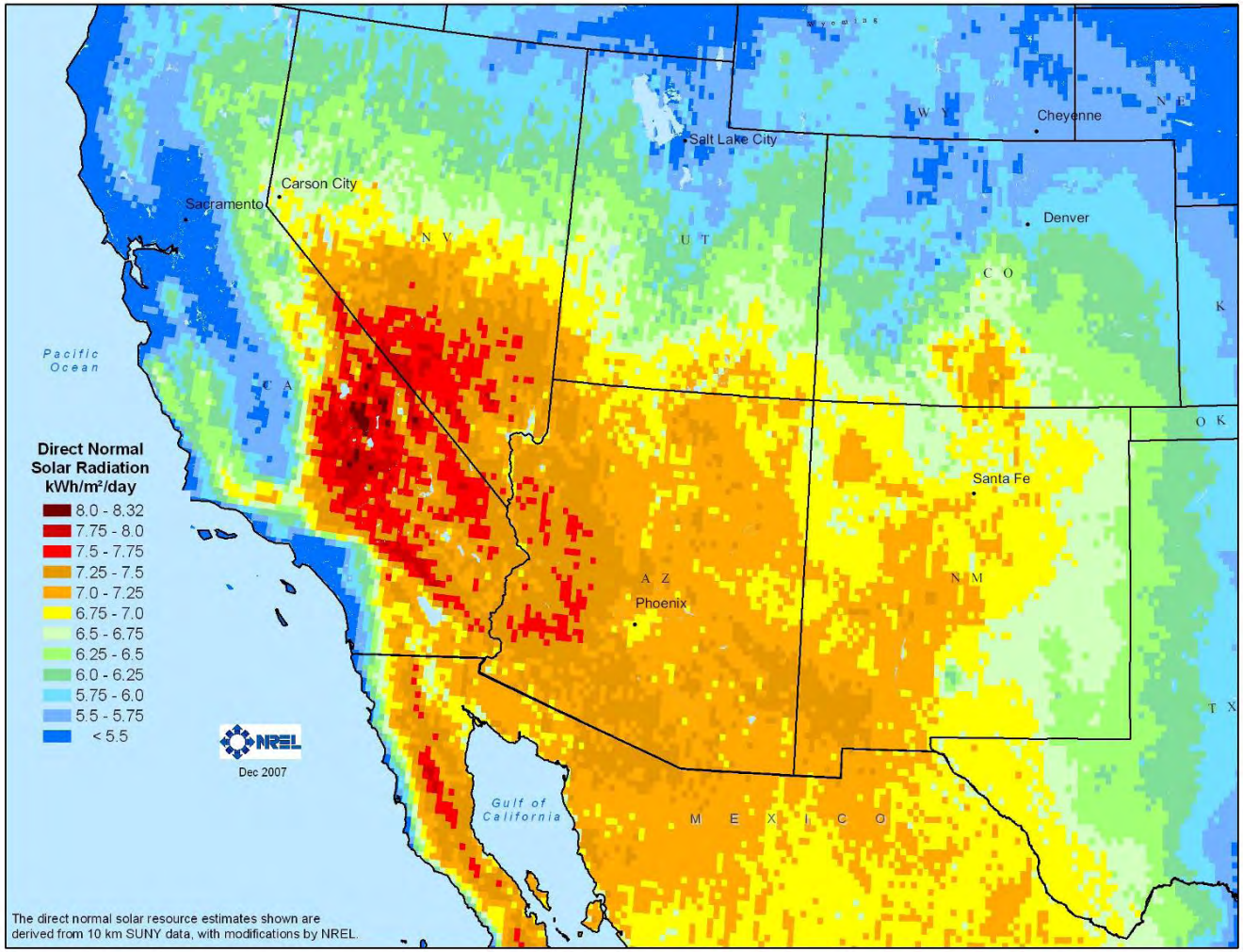
SOLAR AMERICA INITIATIVE

2015 Goals

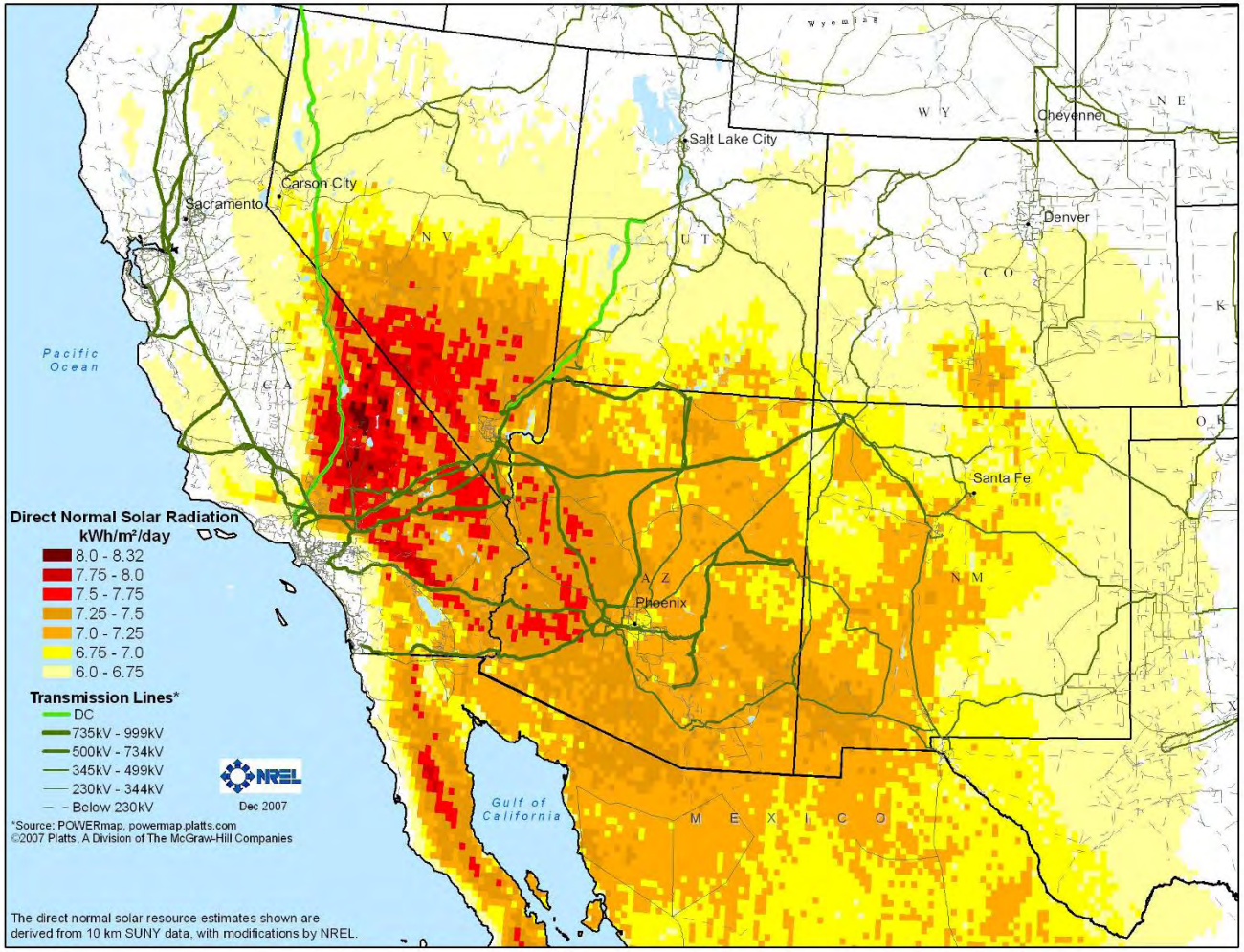
Residential 8-10 ¢/kWh
Commercial 6-8 ¢/kWh
Utility 5-7 ¢/kWh



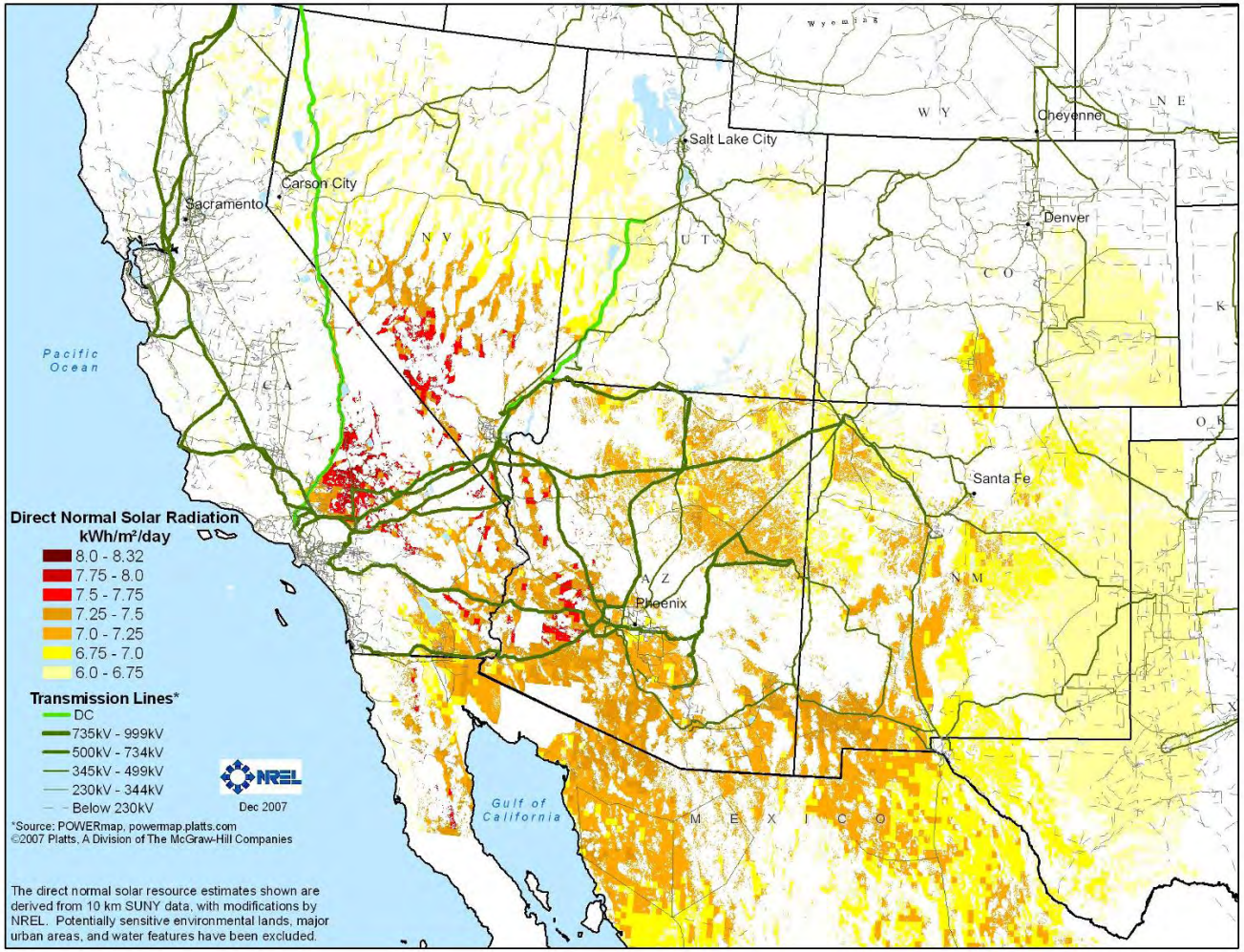
Southwest Solar Resources - Unfiltered Data



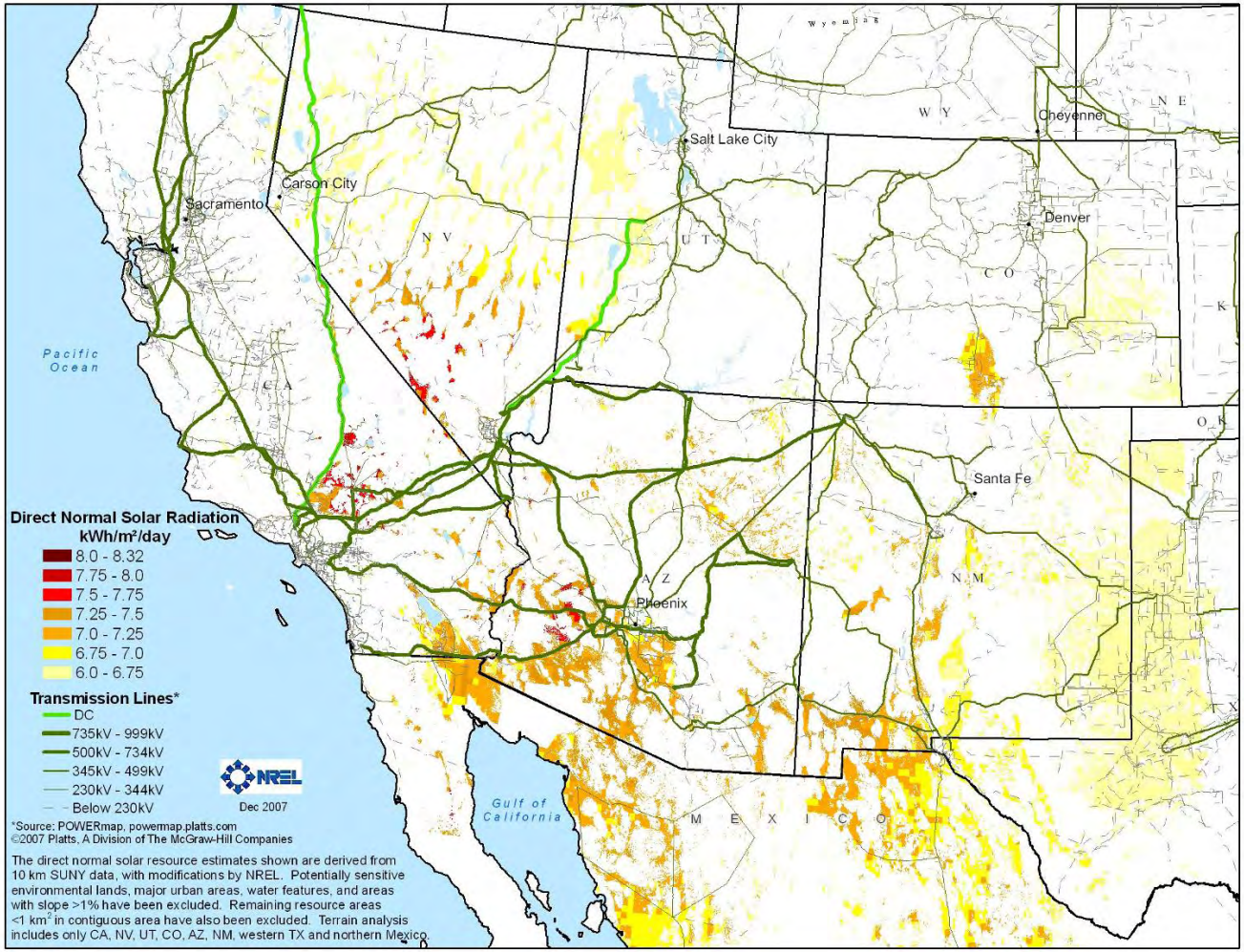
Southwest Solar Resources > 6.0 kWh/m²/day



Environmental and Land Use Exclusions

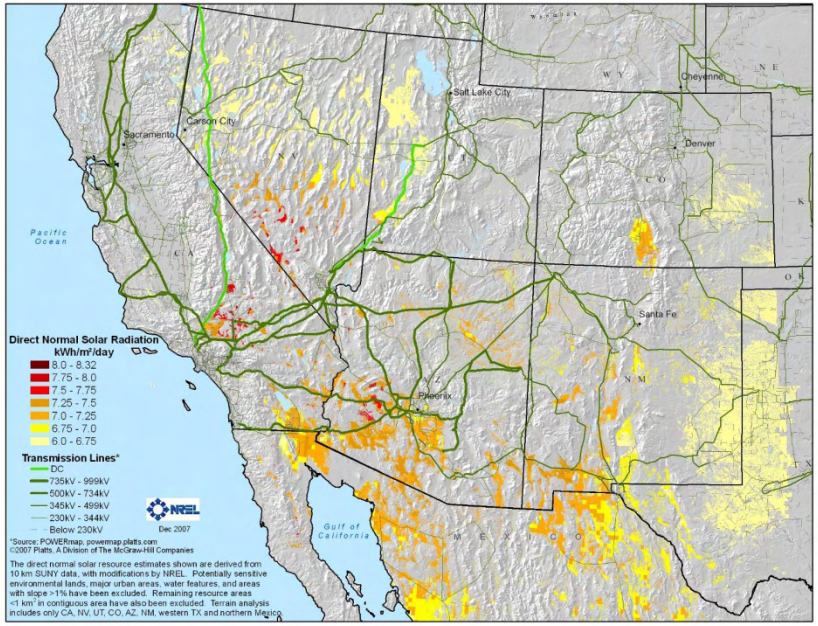


Previous plus slope < 1%



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

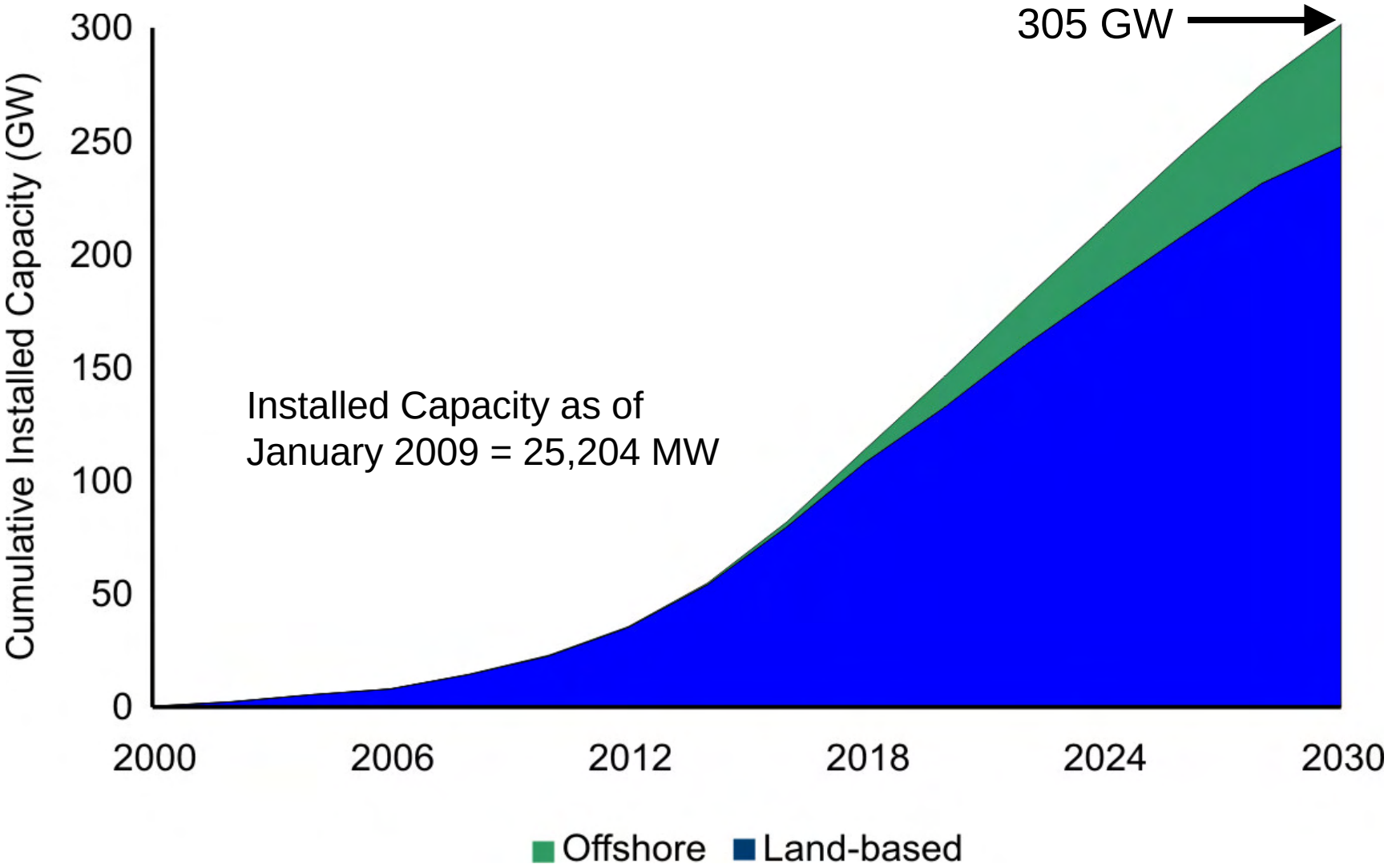


The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands.

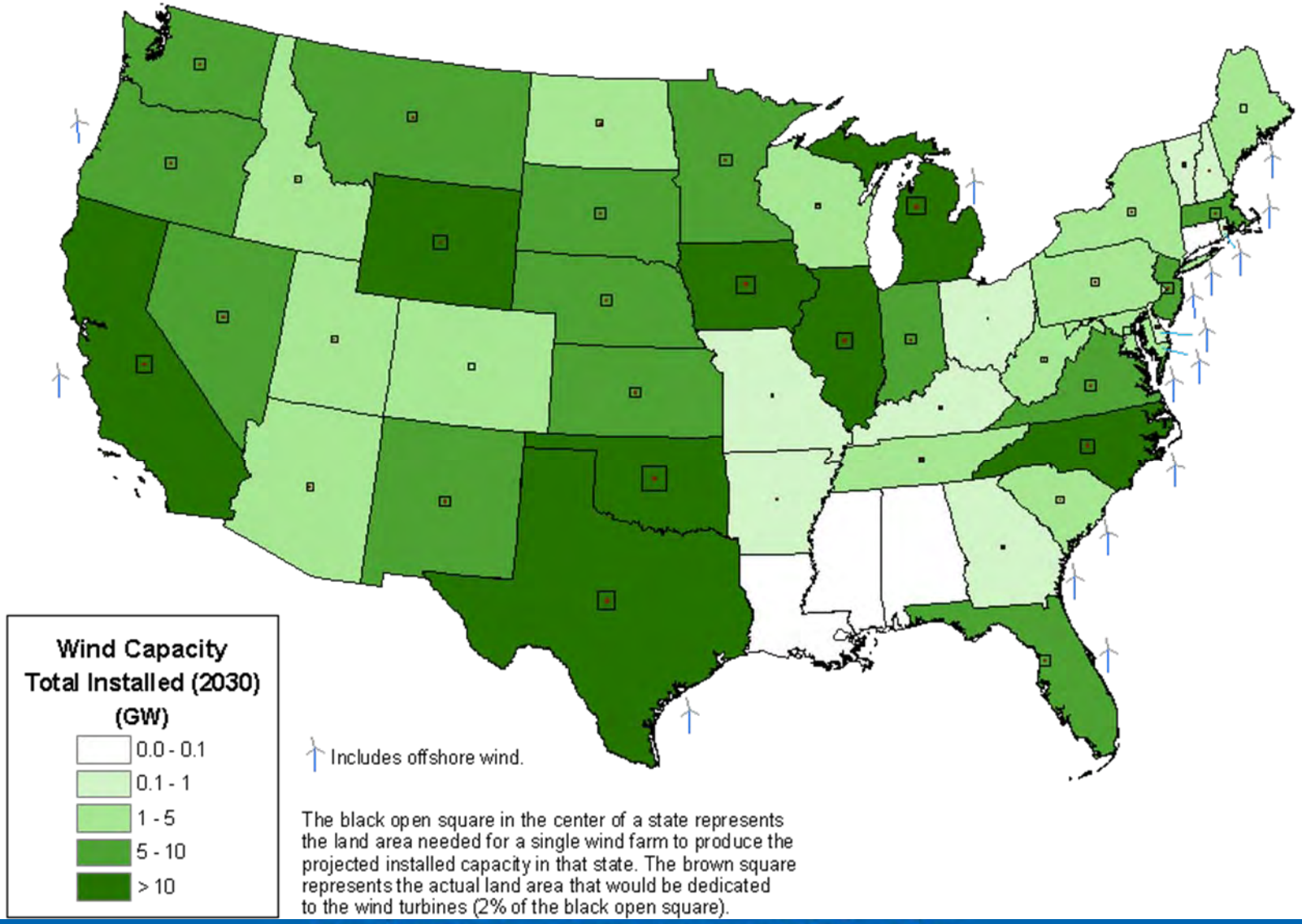
Solar Energy Resource ≥ 6.0
Capacity assumes 5 acres/MW
Generation assumes 27% annual capacity factor

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

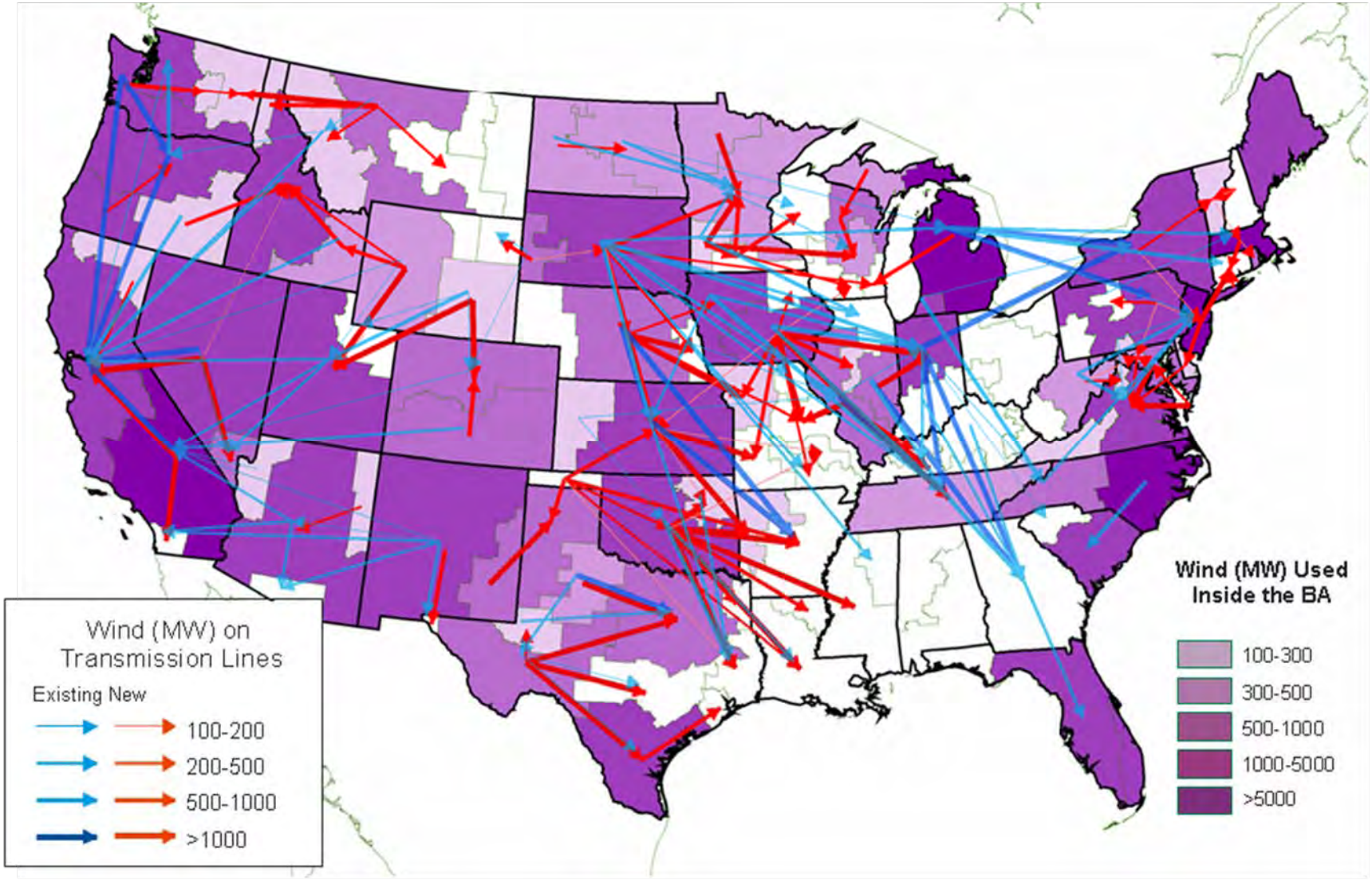
20% Wind Scenario



20% Wind Scenario – Wind in 46 States



Transmission Requirements in 2030



Example Issue
High Penetration PV

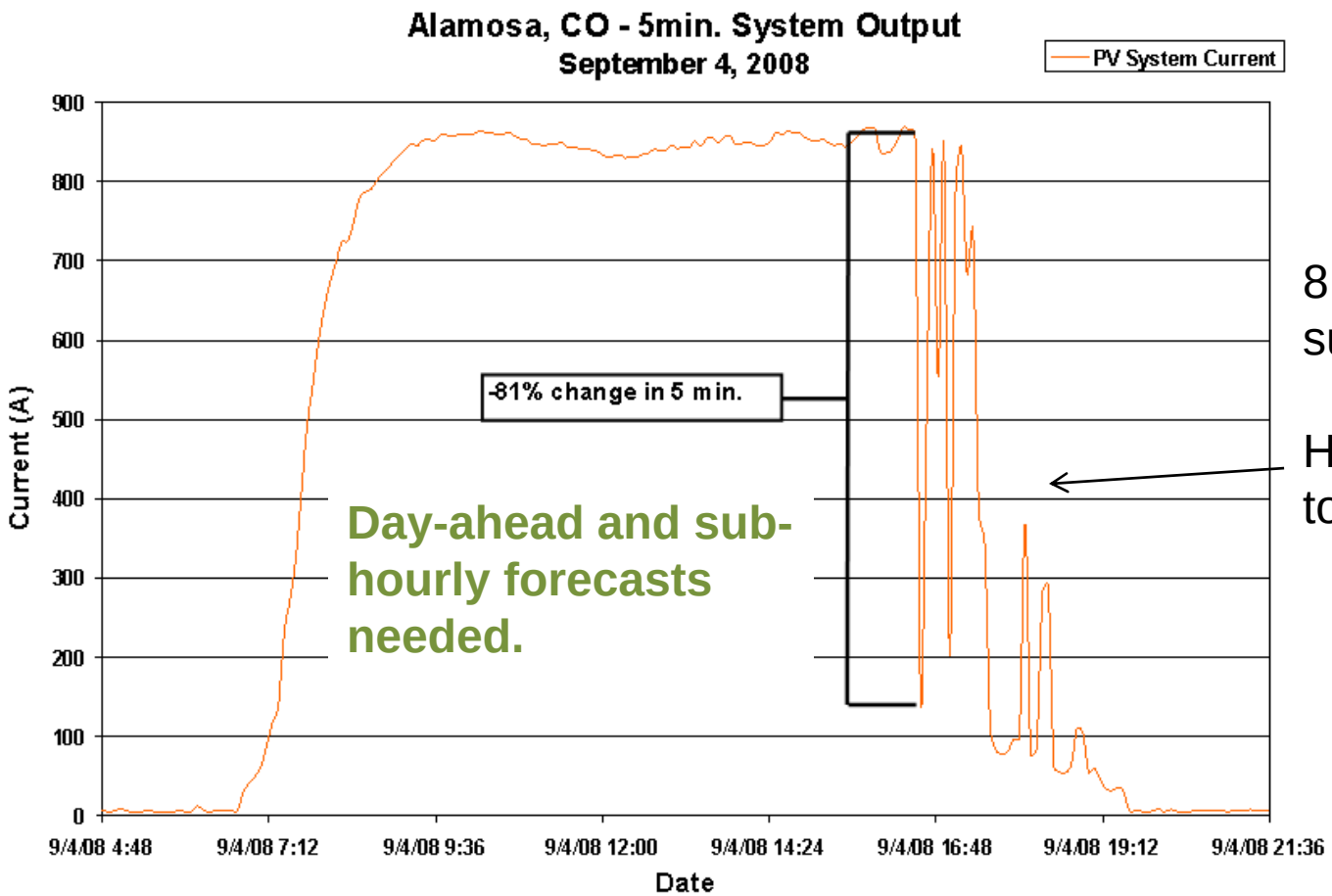
Current Situation – Low Penetration

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

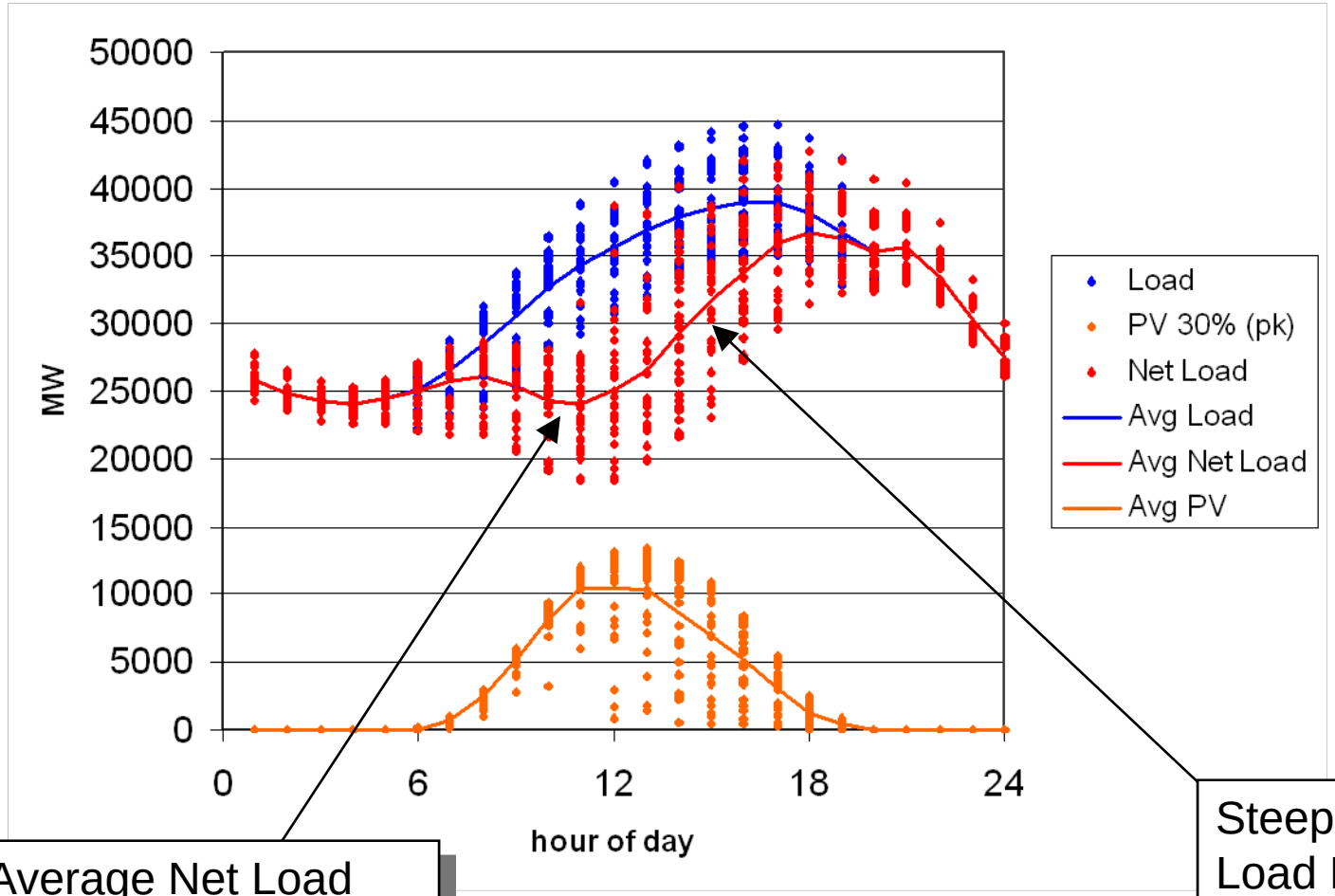
Xcel Energy – Alamosa System



8MW connected to substation

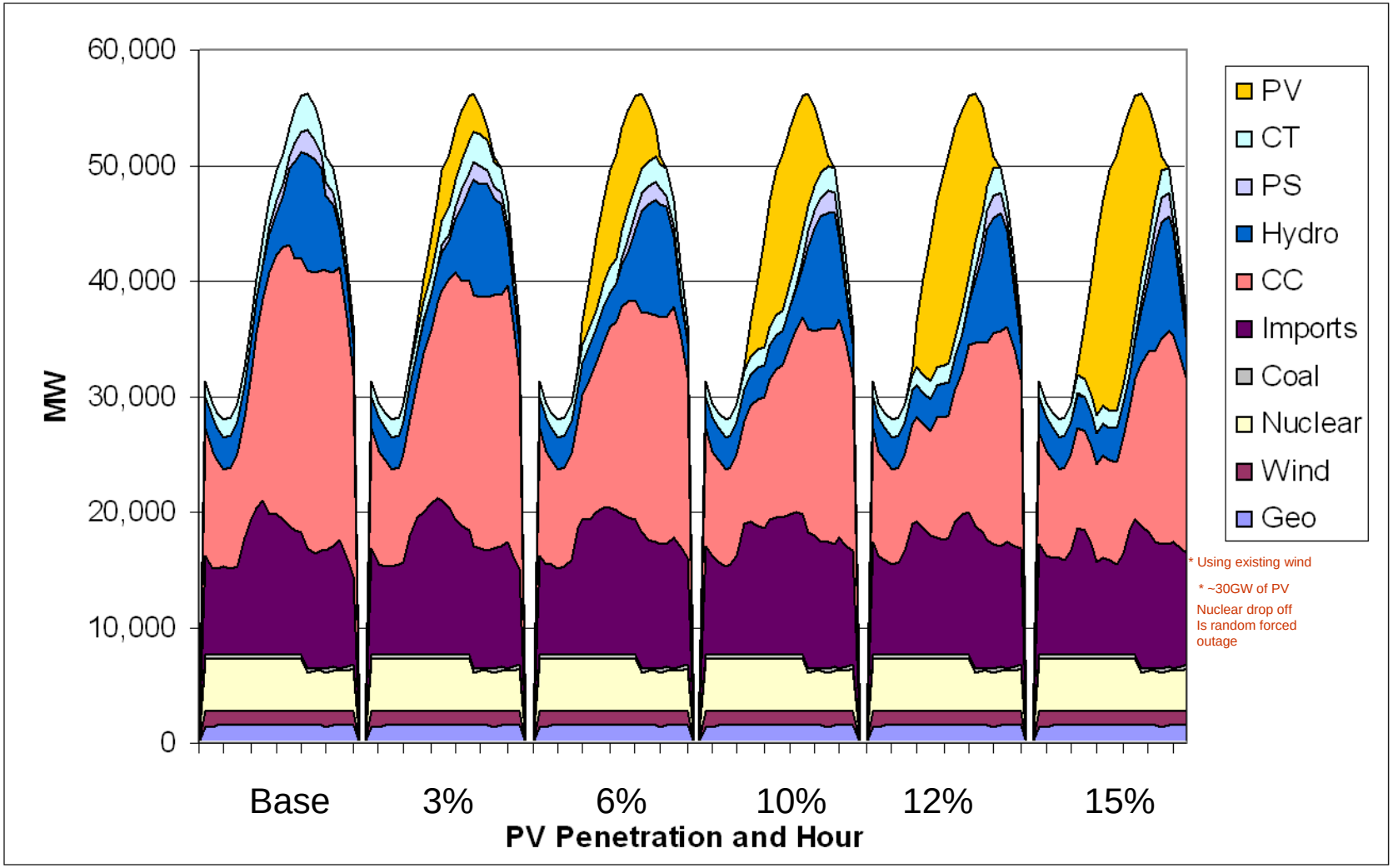
High Variability due to clouds

Evaluating High Penetration of PV

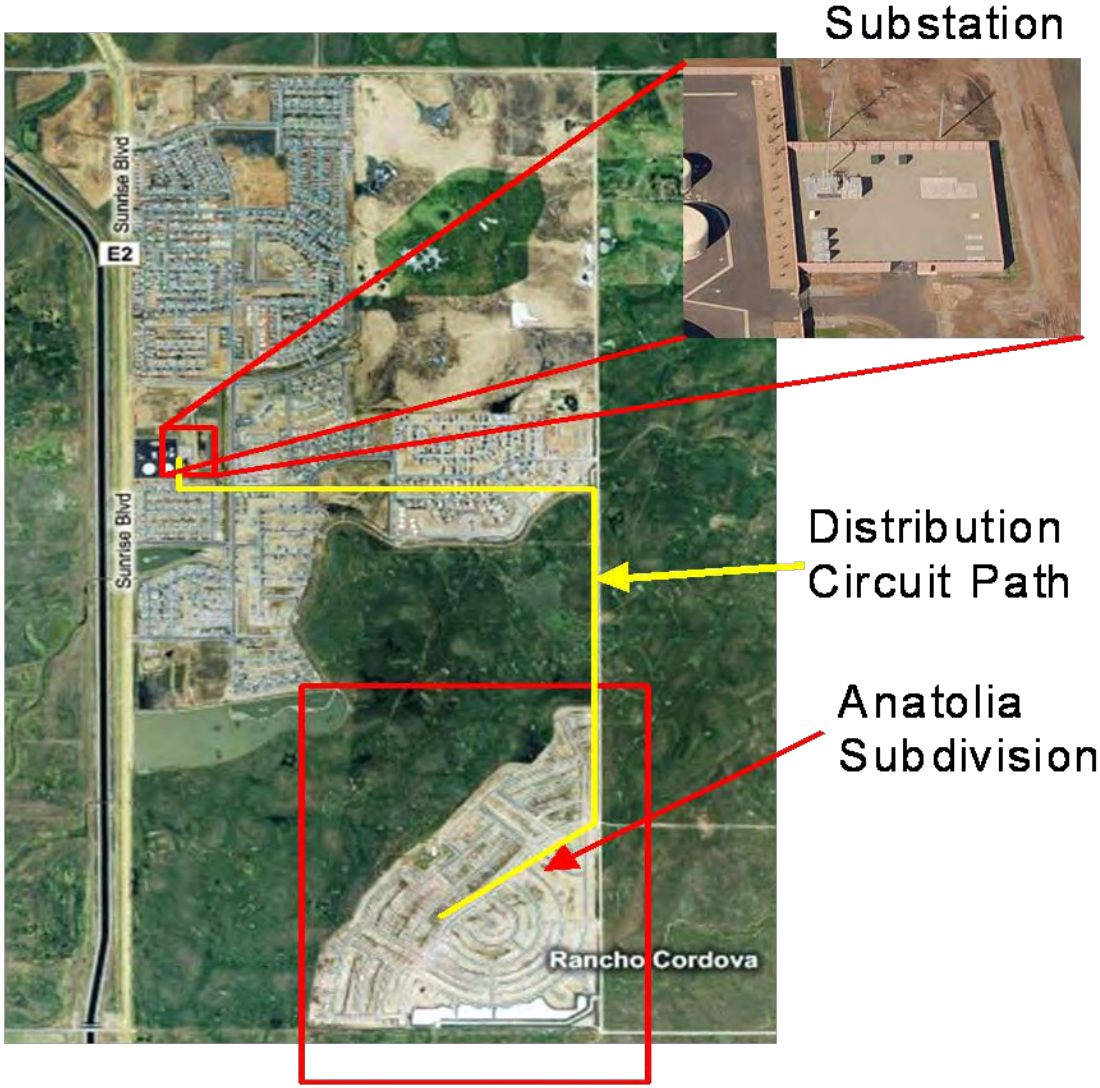


Average Net Load Min @ ~11AM

Steeper Load Rise

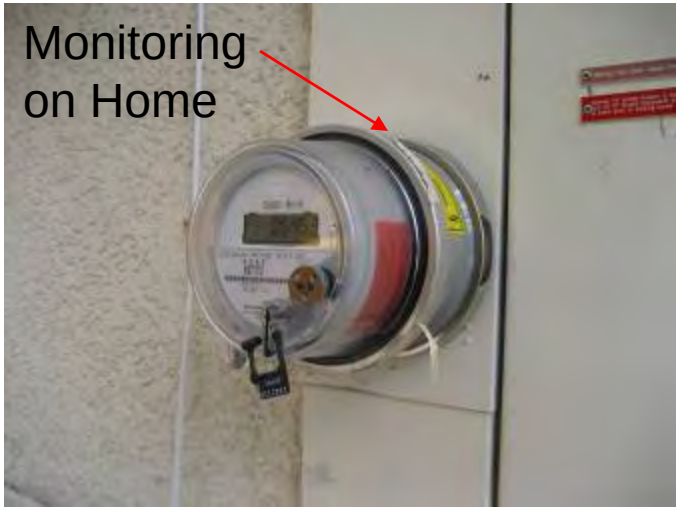

60,000
50,000
40,000
30,000
20,000
10,000
0
MW
Base
3%
6%
10%
12%
15%
PV Penetration and Hour
PV
CT
PS
Hydro
CC
Imports
Coal
Nuclear
Wind
Geo
* Using existing wind
* ~30GW of PV
Nuclear drop off
Is random forced
outage

Sacramento Municipal Utility District

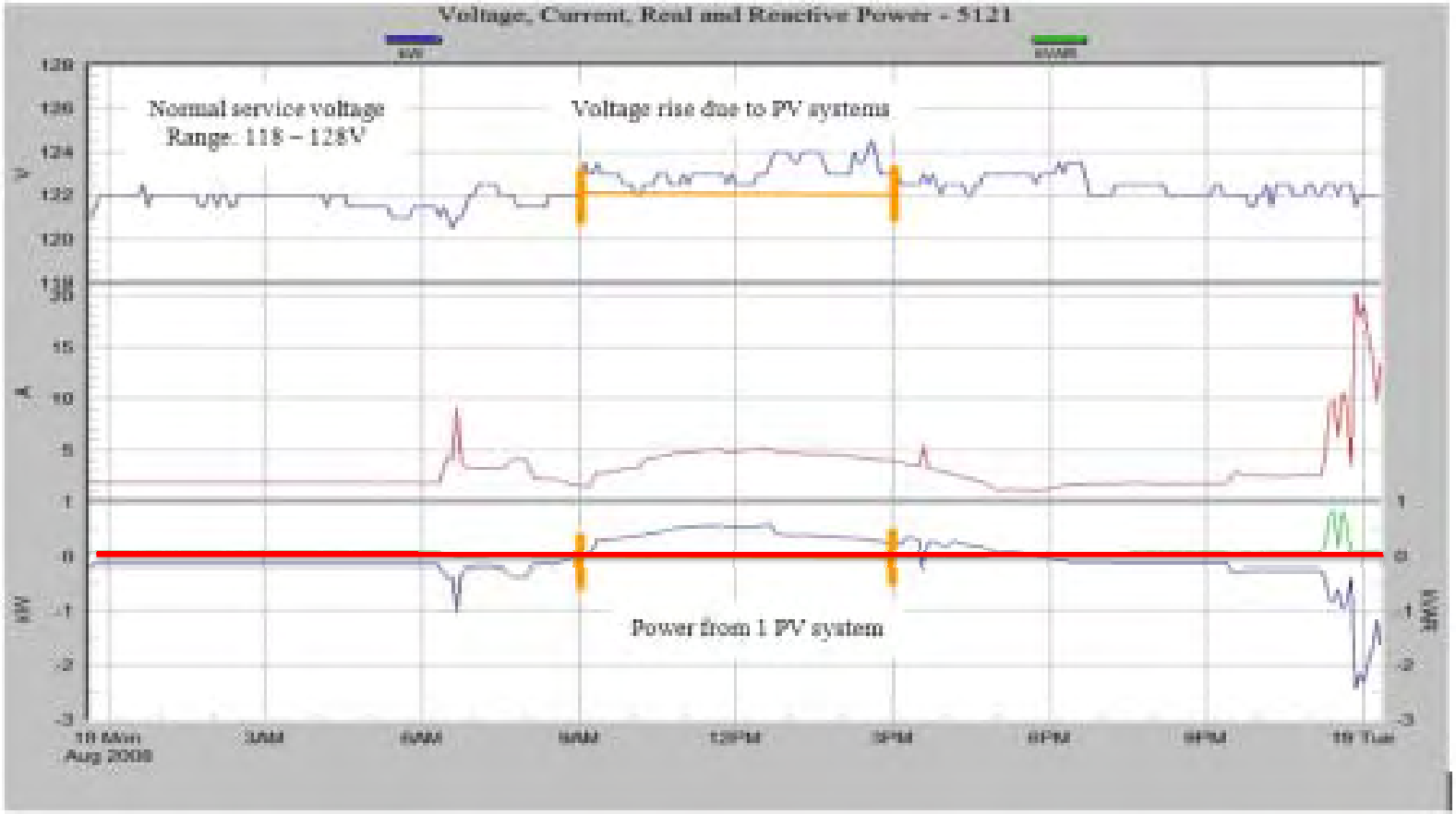


SMUD

Monitoring on Distribution Transformer

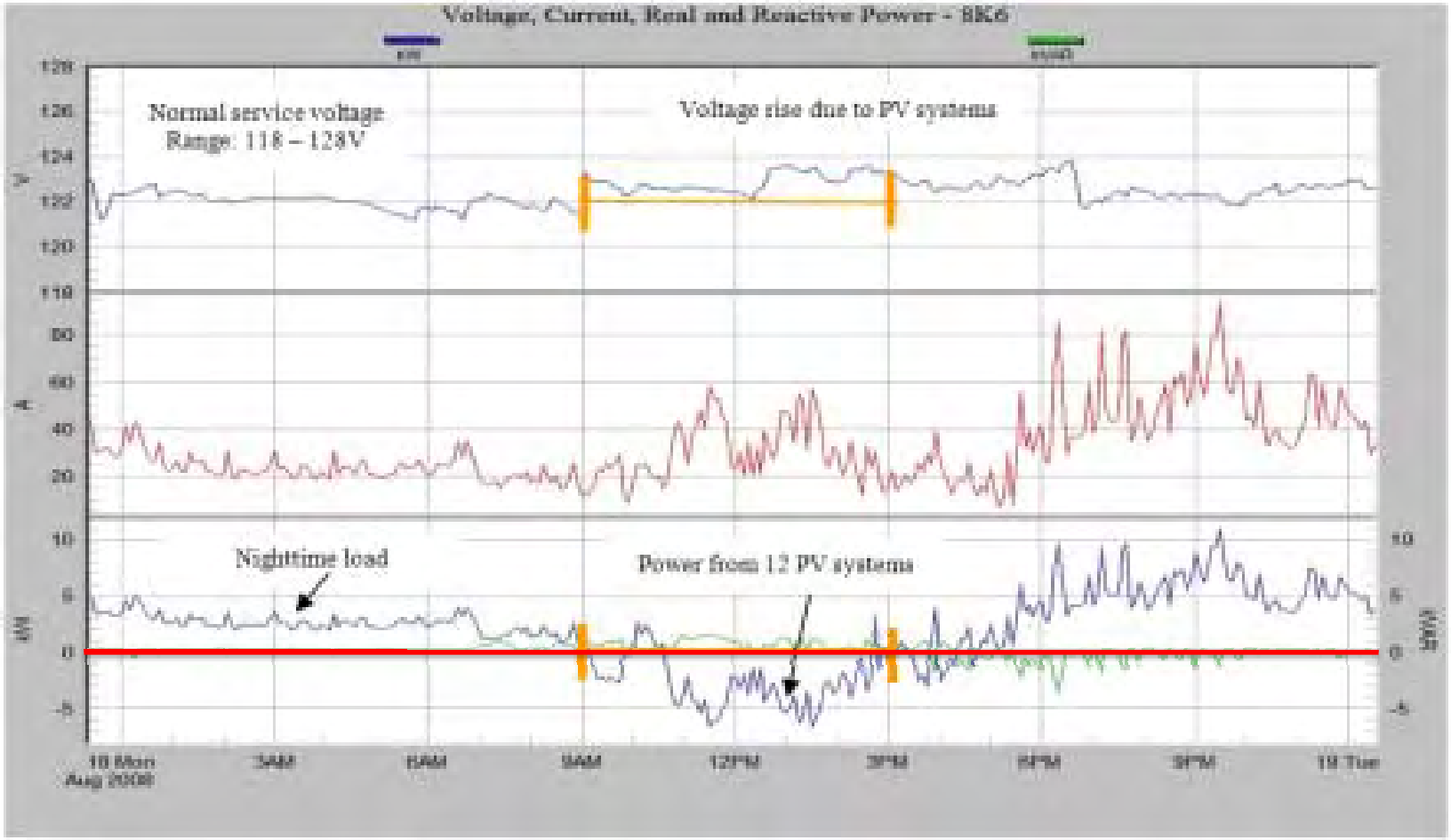


SMUD



Individual Home

SMUD



Distribution Transformer

Thank You

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