



# **Renewable Electricity Futures Activities & Status**

## **Electricity Advisory Committee**

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# Objectives for Today

- Provide a high-level overview of the Renewable Electricity Futures study,
  - current status
  - modeling approach
  - key questions.



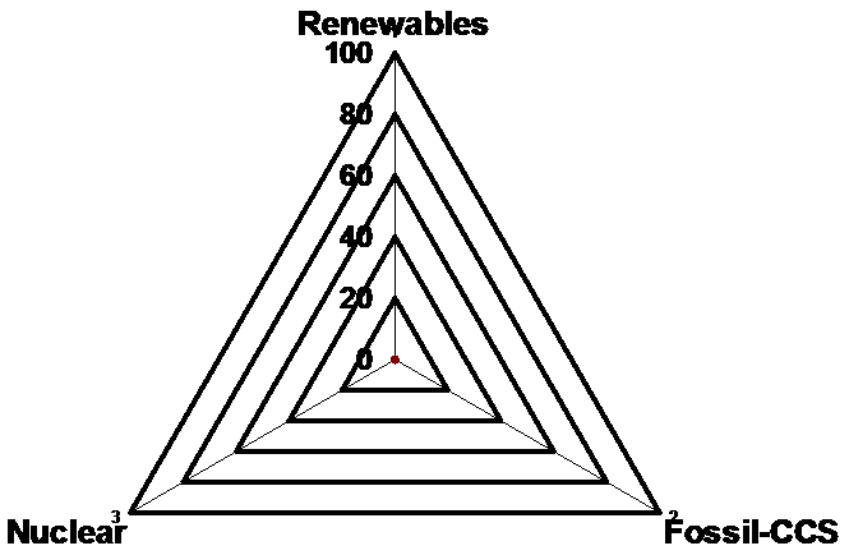
# REF Context

- **Energy-linked challenges:**
  - Energy price volatility
  - Dependence on and cost of imported fossil fuels
  - Potential fossil fuel supply constraints
  - Health & environmental impacts
  - Climate change impacts
  - Water and land impacts
- **Potential Responses**
  - More efficient use of energy
  - Shift from distributed fossil to low-carbon electricity sources
  - Low-carbon electricity generation



# Electricity Sector Options

Electric Sector Options.



Renewables are one pathway – ultimately, all pathways will have important roles.

**Options face related challenges of:**

- meeting public concerns of safety and environmental protection;
  - siting new facilities in publicly acceptable areas with adequate power transmission while meeting their other constraints;
  - reducing capital and operating costs as much as possible, preferably at or below the cost of current power generation;
  - managing electricity generation characteristics.
- 
- The REF study is solely focused on the feasibility (generation adequacy) and impacts of high levels of renewable energy generated electricity. If this could be achieved, it would help address these energy challenges, help the United States take a global leadership role in these technologies and markets, and provide a stable energy foundation for our economy.



# Opportunity

- **Renewable Energy:** Abundant, diverse, distributed.
- **Vision:** Develop a detailed bottom-up evaluation of what can be achieved and at what cost, what constraints need to be addressed, and what RD<sup>3</sup> and policy pathways are needed to approach it.
- **Flexible:** Analysis of a high renewable penetration grid requires conceptualization of an electric system designed to be highly flexible both in supply and demand. This system will utilize a variety of renewable generation, demand response, and storage technologies, and goes well beyond current analyses of renewables integration into the electric system.
- **Possible Synergies:** Large-scale use of renewables may benefit from synergies, possibly including daily/seasonal correlations in different resources, sharing energy storage systems; linking supply with active load shifting; smart grid benefits... etc.

# Challenge

- Use of renewable energy requires technical, economic, environmental, & institutional solutions designed to reflect the **unique characteristics** of renewable energy.
  - Site specificity;
  - Resource intensity;
  - Variability;
  - Energy storage;
  - Fuel costs.



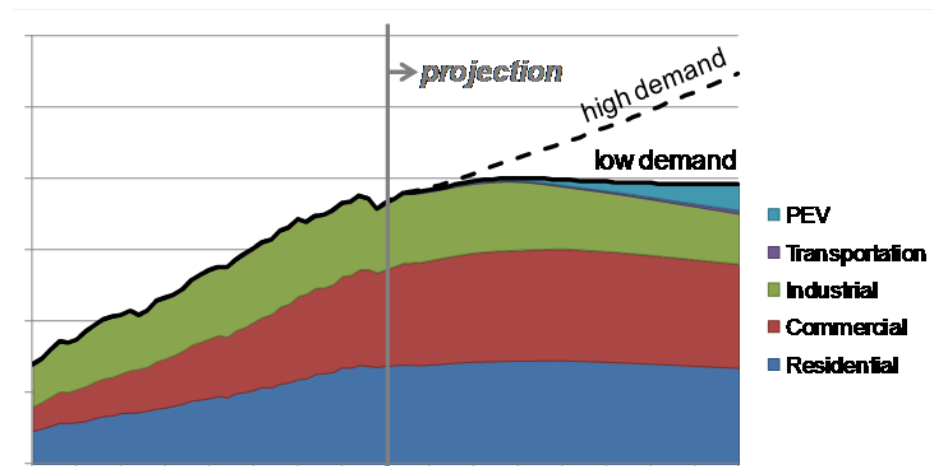
# The Renewable Electricity Futures Study

- **Goals of the REF Study:**
  - Explore large-scale renewable technology deployment in the continental US electric sector and its implications:
    - Renewable resource potential and geographic distribution;
    - RE technology RD<sup>3</sup> pathways and expansion to achieve these options;
    - Seasonal to hourly generation adequacy
    - Economic costs, secondary impacts/benefits
    - Electric system operation and expansion challenges
    - Sensitivities: Impacts of constraints on transmission, grid flexibility, resources, etc.
- **REF is NOT:**
  - A detailed transmission and integration study
    - Typically focused on specific geographic region with high-resolution time series representation of system—frequency response, stability, etc..
  - An integrated model of carbon mitigation pathways or other specific environmental issues
    - Typically regional/global energy sector focus to assess policy
  - A renewable energy vision
    - Typically conceptual, using high-level heuristic tools
  - A projection of response to particular policy efforts
    - Typically sector response to specific legislation or policy
  - **The last word or final study** on high RE generation
    - Need economic and policy analysis
    - Need optimization analysis; analysis of robust, no-regrets pathways, etc.
    - Need subhourly response analysis
    - And much more....



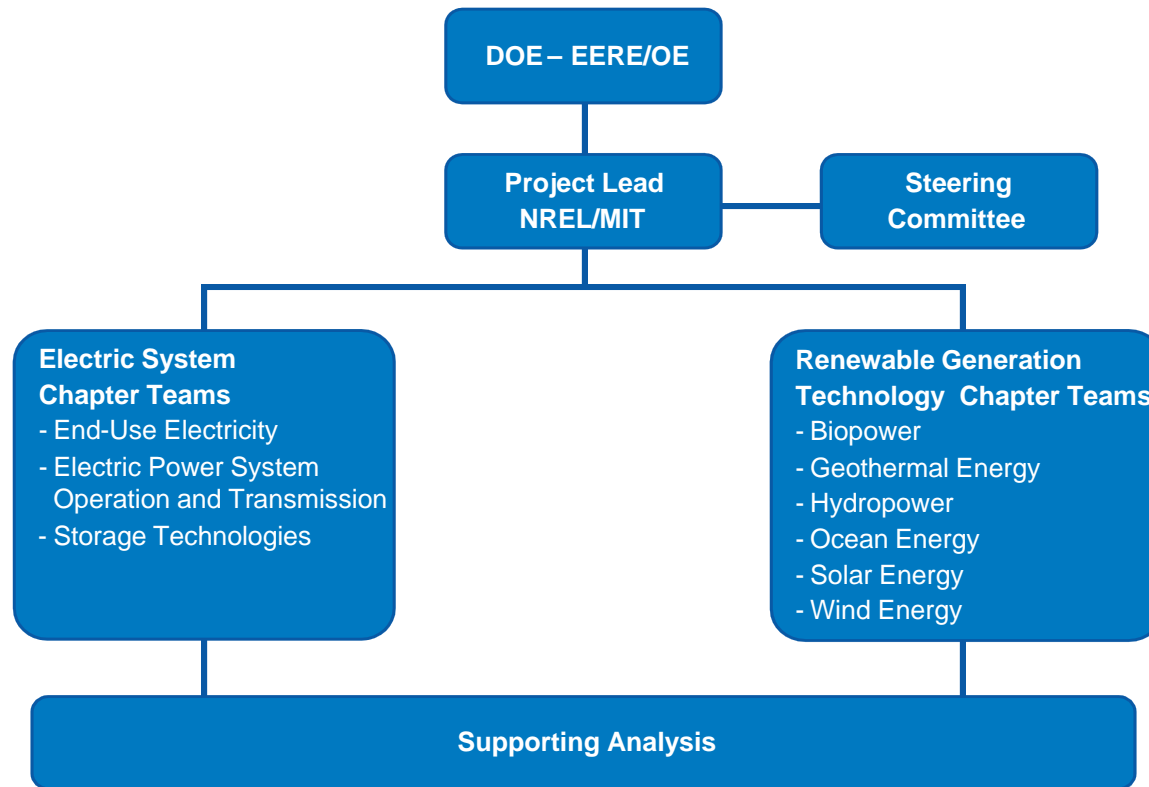
# General Assumptions for REF

- Large-scale deployment is based on RE technologies available today with expected evolutionary development; no technology breakthroughs are required. Some future anticipated technologies (EGS, ocean) are examined in one case; many possible options are not considered in scenarios.
- Electricity demand can be reduced through aggressive energy efficiency measures.
- Some transportation energy requirements shifted to electricity such that overall electricity demand exceeds that achieved through EE demand reduction, but less than demand projections at historical growth rates.
- Biomass contribution to fuel sector carbon mitigation is not quantified
- Electric system operation strategies and markets enhance their flexibility both in electricity end-use and supply.
- Transmission infrastructure in place today largely remains in 2050.
- No specific carbon policies are considered.
- Today's policies continue or end per current statute.





# RE Futures Study Organization



- Over 140 Individuals from over 50 Organizations (Selected List):
  - **National Laboratories:** INL, LBNL, NREL, ORNL, PNNL, SNL
  - **Industry:** Midwest Independent System Operator, Western Interstate Energy Board, Deutsche Bank, Xcel Energy, Vestas Wind Systems, RES Americas, Black and Veatch
  - **Universities:** Massachusetts Institute of Technology, University College Dublin, University of Colorado, Virginia Polytechnic Institute and University, Texas Tech
  - **NGOs:** Electric Power Research Institute, Environmental Defense Fund, American Council for an Energy-Efficient Economy, Energy Foundation



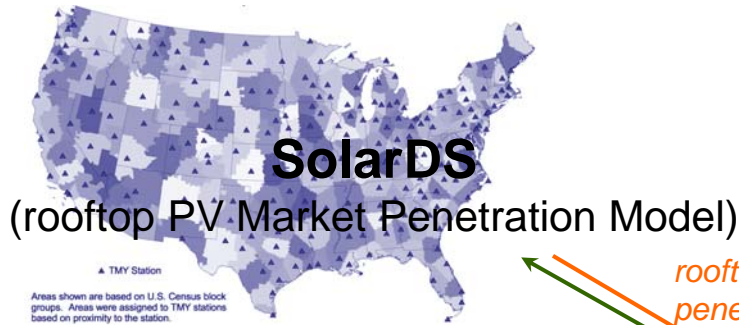


# REF Scenario Matrix

- **Demand:** Low, High
- **RE Penetration:** Business-as-usual to very high
- **Constraints:** Transmission, Flexibility, Resources
- **Technology Advance:** Limited, Current R&D, New Techs
- **Fuel Prices:** Low, Medium, High
- **Conventional Technology Cost:** Low, Medium, High



# Modeling Framework



rooftop PV penetration  
electricity prices

2050 mix of generators  
does it work hourly?

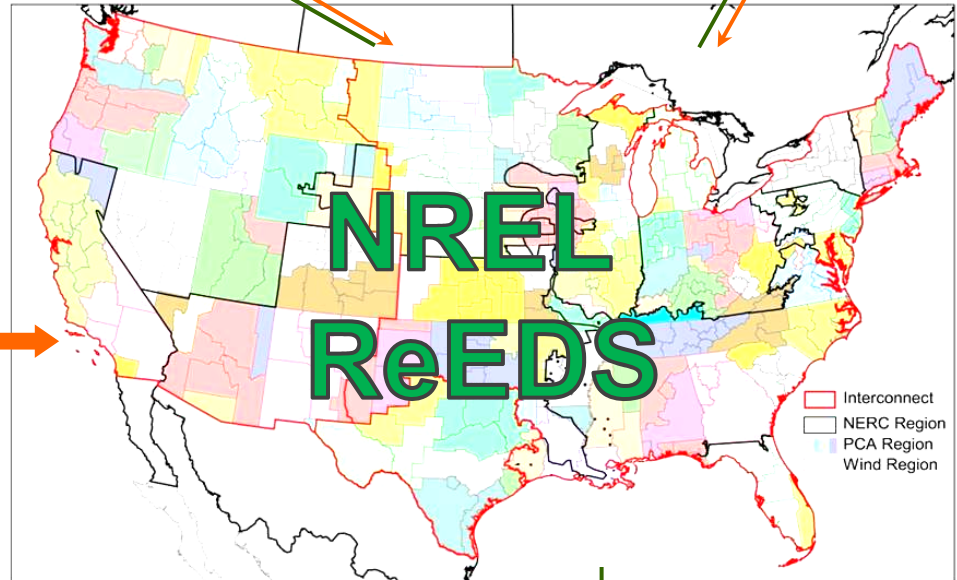
- Black & Veatch
- RE technologies
- Flexible Resources
- End-Use Electricity
- System Operations
- Transmission

REF Core Cost

REF Advanced Cost

Performance  
Resource availability  
Demand Projection

Grid Operations  
Transmission costs / characterizations



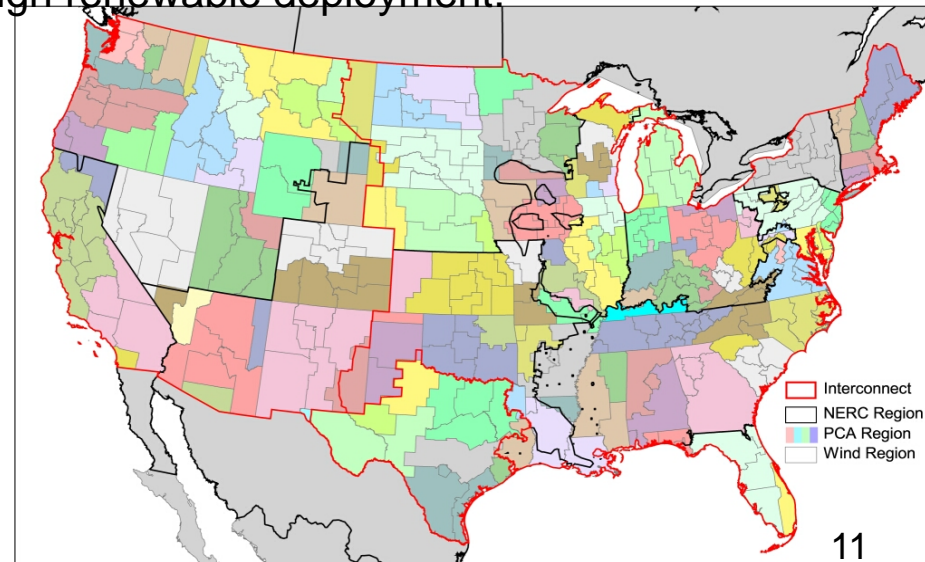
Impacts  
GHG Emissions  
Water Usage  
Land Use

Capacity & Generation  
2010-2050



# Regional Energy Deployment Systems Model

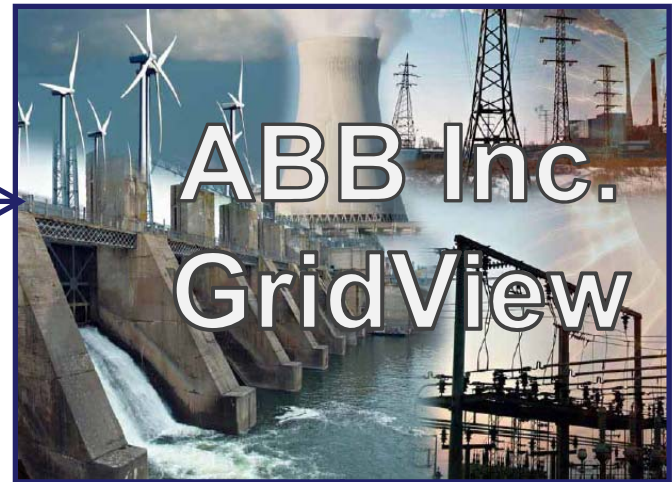
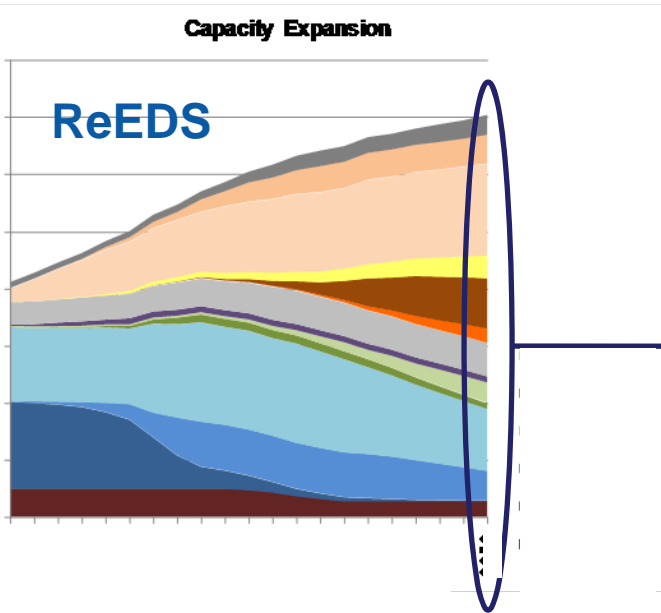
- **Capacity expansion & dispatch** for the continental U.S. electricity sector, including transmission and all major generator types:
  - hydro, gas CT/CC, coal (w/wo CCS), gas/oil steam, nuclear, wind, CSP, biopower (wo CCS), geothermal, storage, central station PV.
- **Minimize total system cost** in each 2-year investment period until 2050. All constraints (e.g. balance load, planning & operating reserves, etc.) must be satisfied. Linear program without inter-temporal optimization (nonlinear calcs between periods)
- **Multi-regional**: 356 regions in continental US; 134 power control areas; RTOs; States; NERC areas; Interconnection areas.
- **Temporal Resolution**: 17 time slices in each year: 4 daily x 4 seasons, 1 super-peak
- **Linked with GridView** hourly unit commitment/economic dispatch model
  - Examines amount of “unserved load”, curtailment, congestion, etc.
  - Identify potential operational issues with high renewable deployment.
- Input future electric demands and fuel prices by region.
- Simple elasticities provide *demand* and fossil fuel price response.
- Expands transmission capacity as needed.
- Does not yet directly include distributed PV; imports SolarDS





# Operating the Electricity System

- Commercial production cost model
- Hourly chronological model, 8760 hours
- Realistic plant flexibility parameters
- Directly simulates plant outages and forecast error events, unserved load
- Transmission: DC power flow

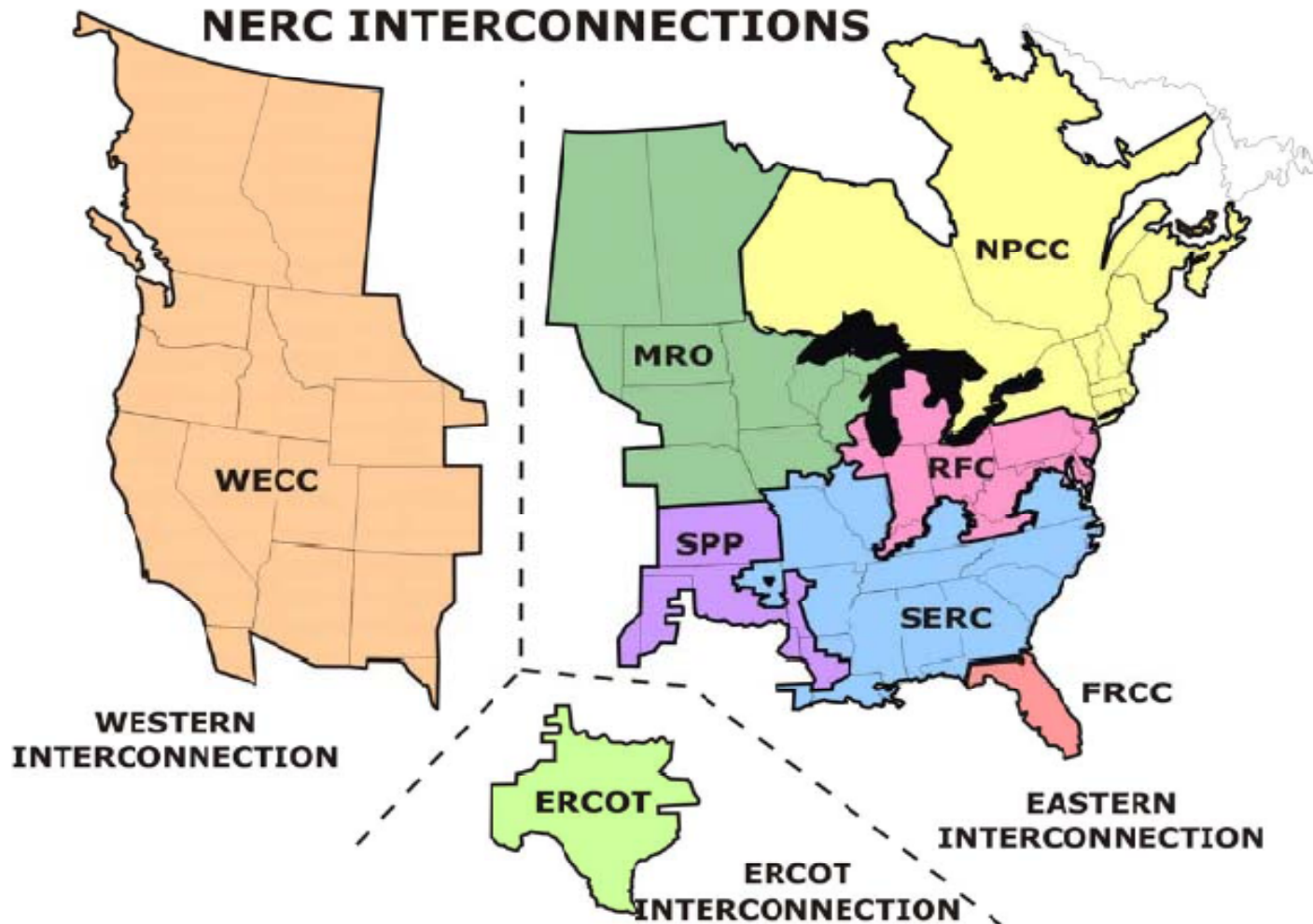


**Does the system operate (hourly)?**

- Used by ISOs, utilities, others for planning—transmission/generation expansion; total production cost, prices, congestion, etc.
- 11,000 Generators; 85,000 Transmission lines; 34,000 Buses with load; 65,000 nodes; 136 transmission zones
- Commits/Dispatches generating units based on electricity demand, operating characteristics of generators, transmission grid parameters.



# Database considerations

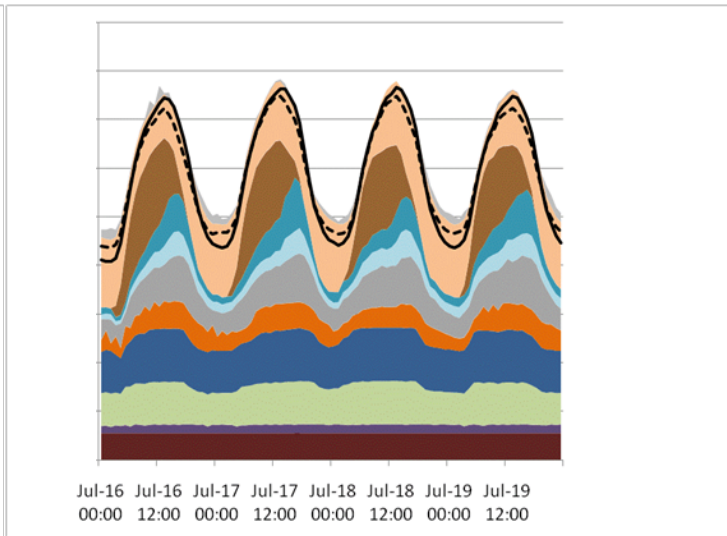
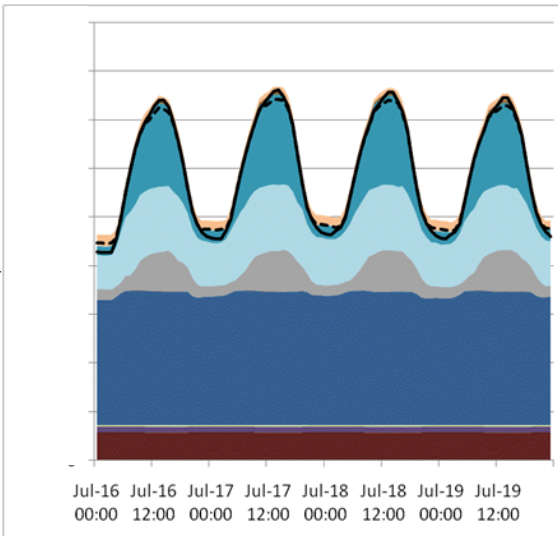


- 3 interconnections optimized simultaneously (with significant DC connections)
- Spatial resolution of the ReEDS outputs limits the resolution of the GridView modeling for the study

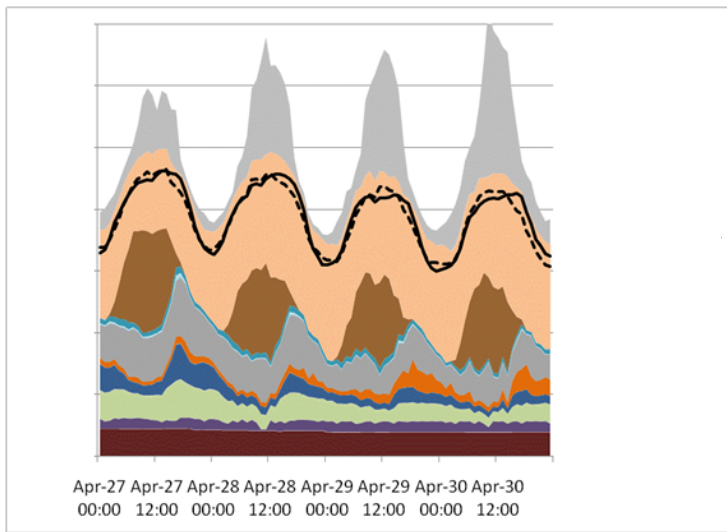
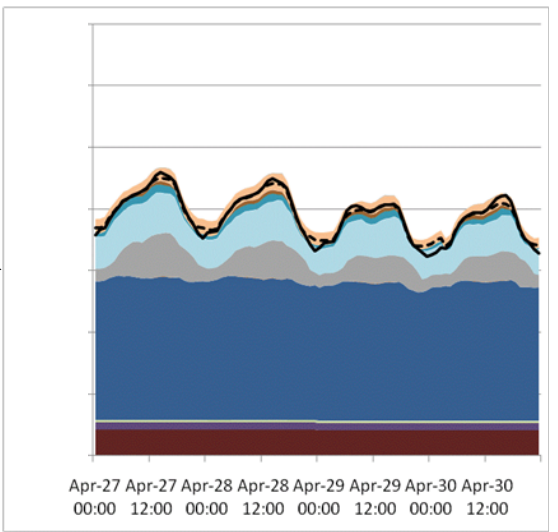


# Representative GridView Outputs

Summer Peak



Spring Off-Peak

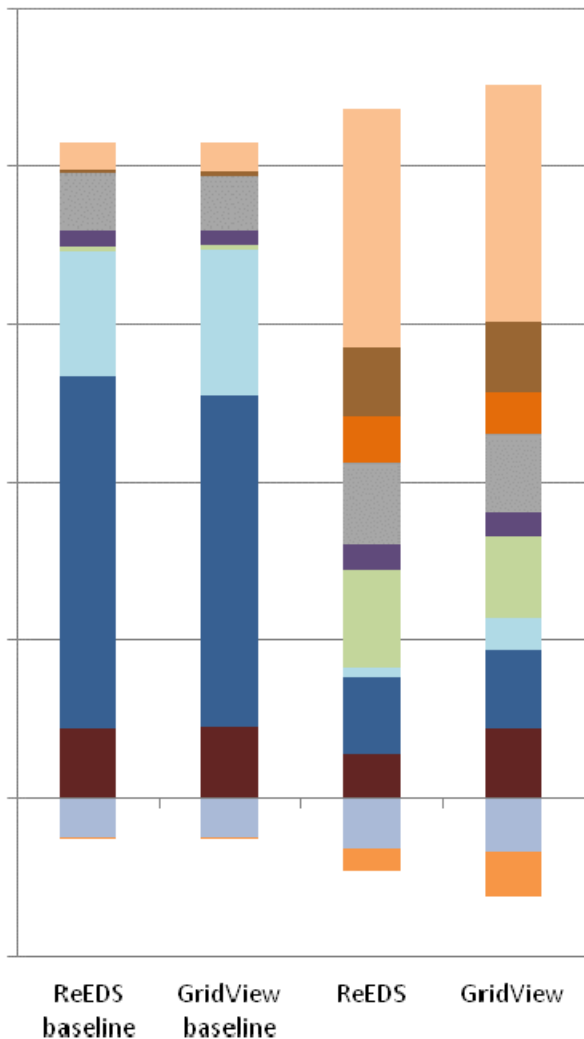


↑  
**Baseline**

↑  
**REF Case**



# GridView & ReEDS *mostly* agree

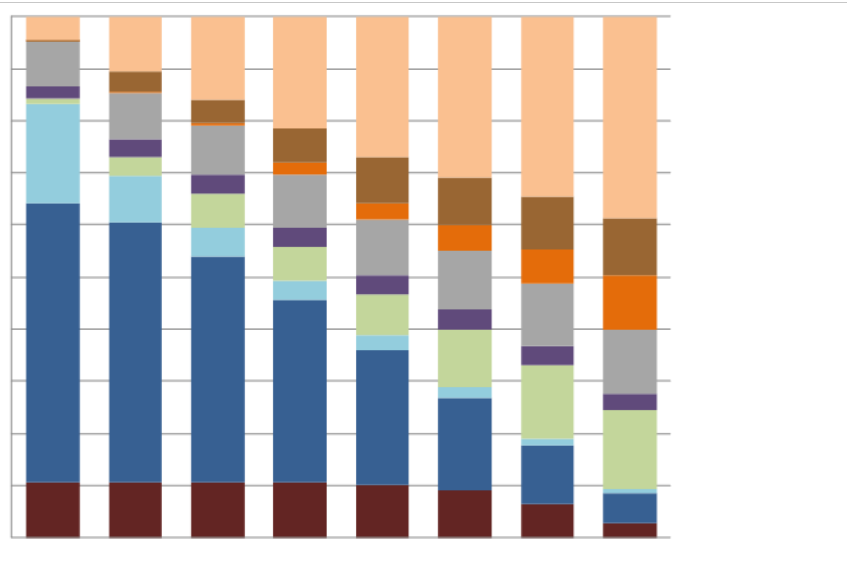


- **Curtailed energy** in Gridview is more than the amount in ReEDS
- **Biopower plants operate less** in GridView
- Greater nuclear and natural gas generation in GridView
- Differences are primarily due to more detailed representation of **transmission** and plant flexibility in GridView
- Due to the above, GridView shows slightly less RE than in ReEDS
- But...no renewable requirement in GridView
- However...intra-zonal congestion and subhourly events not considered
- More detailed studies needed.



# Exploratory Scenarios

Generation Mix



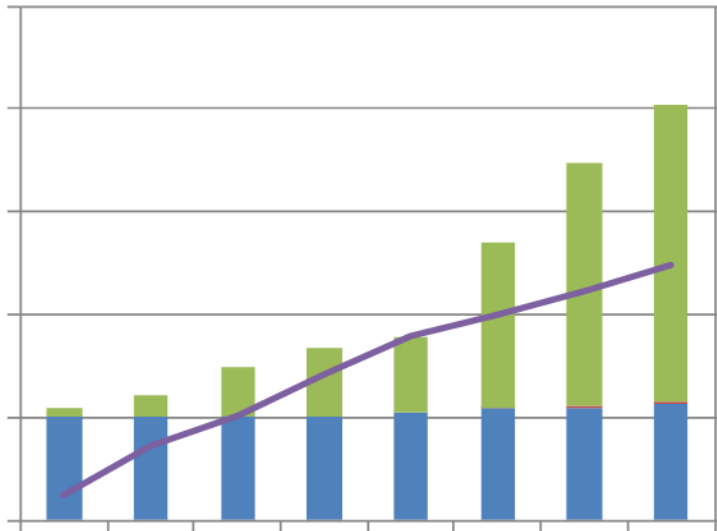
- **Deployment** significant for all major renewables
- **Operational** challenges (curtailment, forecast, reserves) grow with increasing deployment variable generation
- **Transmission** expansion significant with high RE targets (though reduced because of the low demand assumption and reduced conventional generation)
- **Storage** deployment grows with increasing RE targets
- **Costs** rise non-linearly with RE deployment (but not exponentially)





# Exploratory Scenarios

**2050 Storage Capacity**

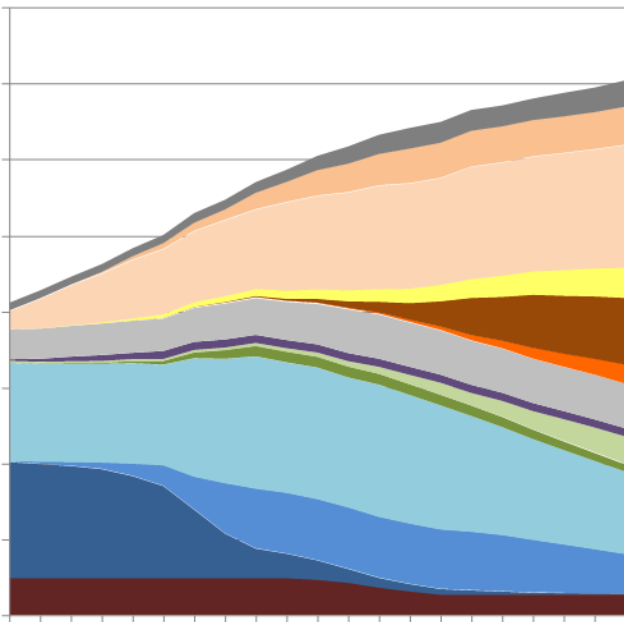


- Variable generation increases with RE targets
- Storage deployment increases with variable generation
- Storage helps mitigate curtailment and provide ancillary services

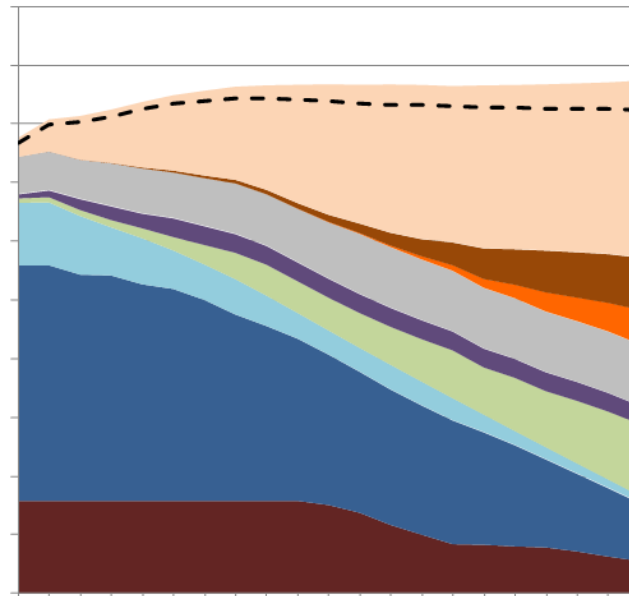


# REF Scenarios

Capacity Expansion



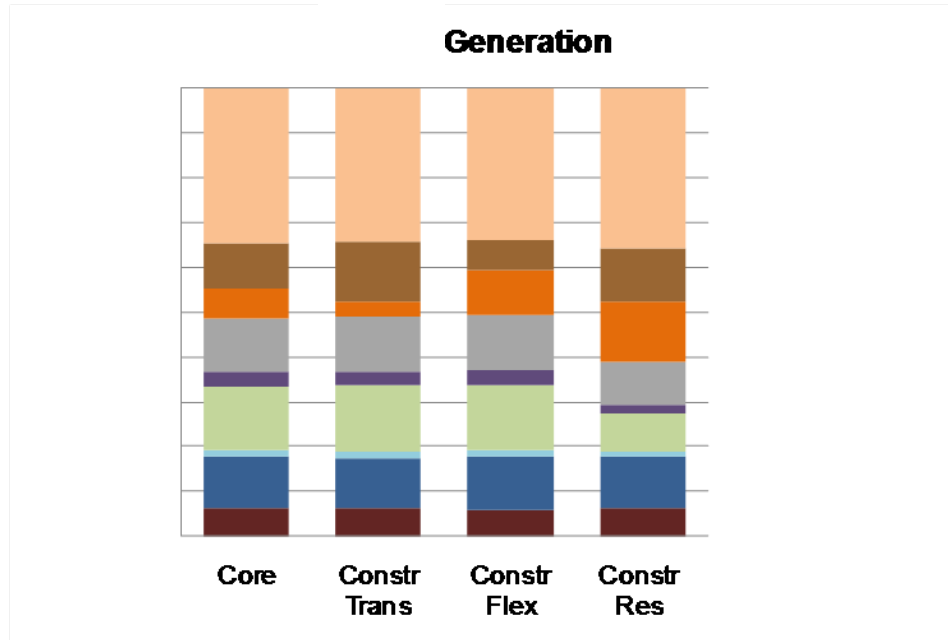
Generation Expansion



- Onshore wind & geothermal penetration
- Offshore wind, rooftop PV, & hydropower; coal retrofits to cofire biomass
- Utility PV, dedicated biomass, & storage
- CSP growth, continued PV & dedicated biomass expansion



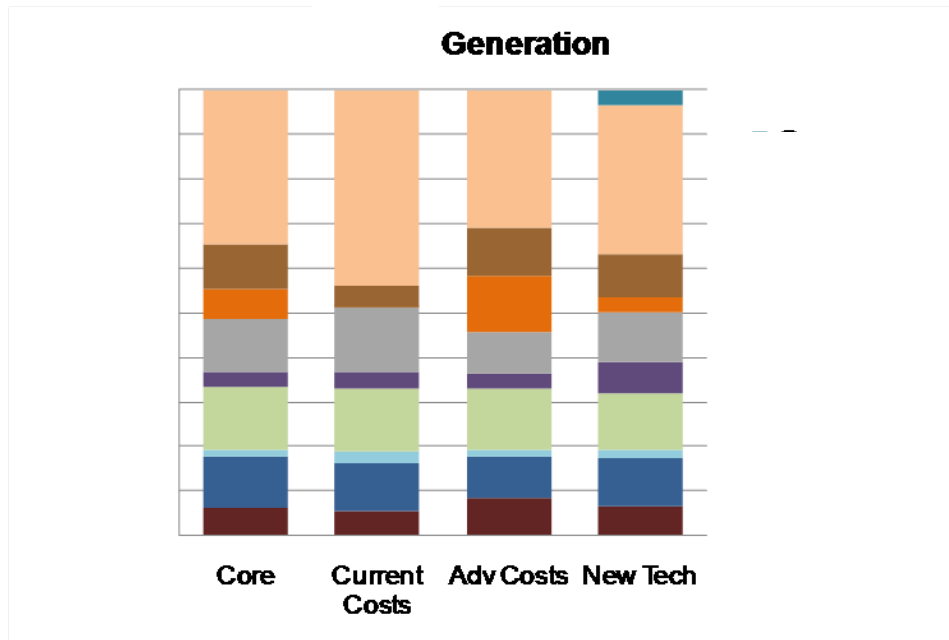
# Constrained REF Scenarios



- **Constrained Transmission:** Increased cost of & limitations on new transmission leads to greater reliance on local resources
- **Constrained Flexibility:** Institutional concerns about managing variability and uncertainty lead to greater reliance on CSP & storage technologies
- **Constrained Resources:** Environmental issues, siting, and resource competition from other sectors decrease deployment of limited renewable resources and increase CSP, PV, & onshore wind



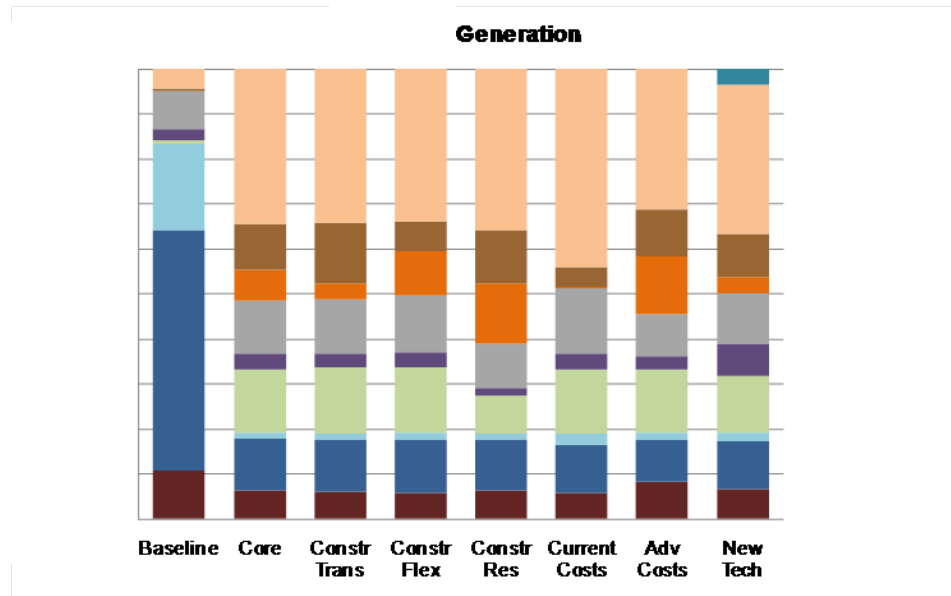
# RE Cost & Deployment Sensitivities



- **Current Costs:** Assuming no cost or performance improvement leads to greater reliance on “mature” technologies
- **Advanced Costs:** With continued cost & performance improvements (e.g. through R&D), technologies with greater improvement potential see greater deployment
- **New RE Technologies:** Deploying fixed amounts of currently non-commercial technologies diversifies the overall portfolio
- ***These scenarios provide a range of costs for achieving xx% RE and show the value of R&D***



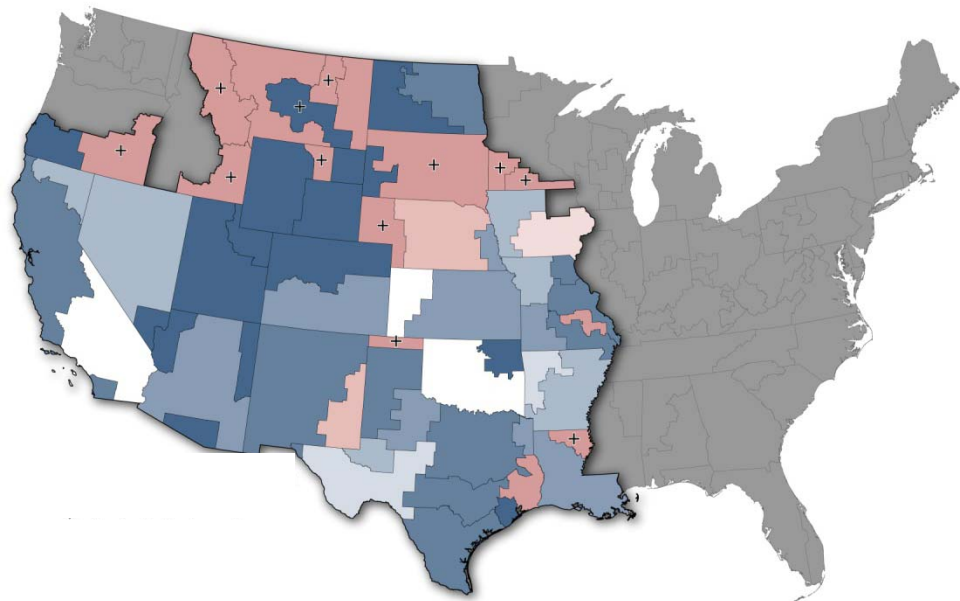
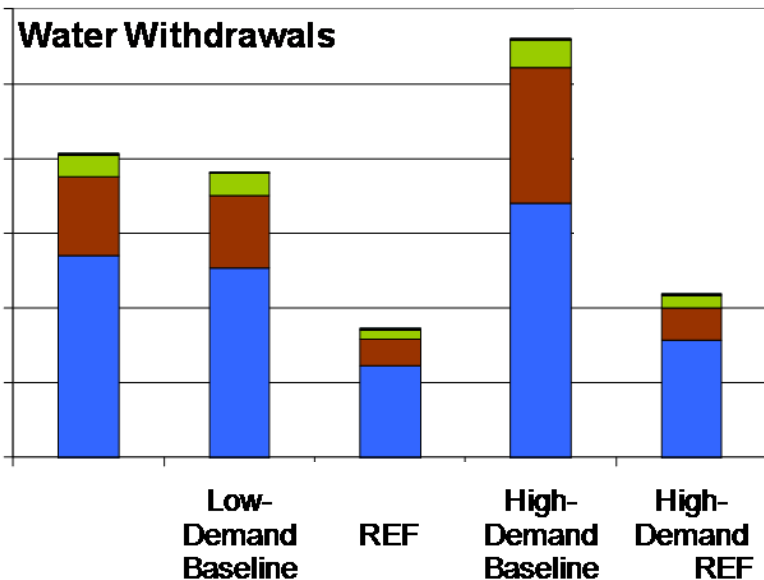
# Alternate RE Futures



- Explore the effects that **constraints to renewable electricity deployment** (limited transmission, limited system flexibility, limited RE resources) may have on deployed RE technologies and electricity supply costs
- Explore renewable technology cost sensitivities to deployment and system cost



# Impacts of achieving xx% RE by 2050



- Water use reduction
- Public health impacts
- Reduced risk due to fossil fuel price volatility
- Land use implications
- Scale up challenges



# Key Questions

- RE capacity/generation over time?
- Sensitivity to transmission costs, utility flexibility, resource availability?
- RE curtailments?
- System cost?
- Unserved load?
- Regional variations?
- Other key questions?