RE Futures Modeling Framework

Only currently commercial technologies were modeled, with incremental and evolutionary improvements.

ITI Projection (by Black & Veatch)
ETI Projections (by Tech Teams)
Flexible Resources
End-Use Electricity
System Operations
Transmission

Technology cost & performance
Resource availability
Demand projection
Demand-side technologies
Grid operations
Transmission costs

SolarPV (rooftop PV market penetration)
GridView (by ABB Inc.) (hourly production cost)
rooftop PV penetration
2050 mix of generators
does it balance hourly?
High resolution modeling using 134 nodes & hourly time steps

Implications
GHG Emissions
Water Use
Land Use
Direct Costs

Capacity & Generation 2010-2050

- A U.S. DOE sponsored collaboration among more than 110 individuals from about 35 organizations.
Regional Energy Deployment Systems Model (ReEDS)

- **Capacity expansion & dispatch** for the continental U.S. electricity sector, including transmission and all major generator types.
- **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.
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

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.

Does the system operate (hourly)?
Scenarios and Assumptions

- **Renewable Technology Improvements**: NTI, ITI, ETI
- **Exploratory Scenarios**: 30%, 40%, 50%, 60%, 70%, 80%, 90%
- **System Constraints**: Transmission, Flexibility, Resources
- **Sensitivities**: Demand—High/Low, Fossil Fuel Costs—High/Low, Fossil Technology

**Energy Efficiency**: Most scenarios assumed significant energy efficiency measures in the residential, commercial, industrial sectors.

**Transportation**: Most scenarios assumed a shift toward plug-in hybrid or electric vehicles, partially offsetting the electricity efficiency advances that were considered.

**Grid Flexibility**: Most scenarios assumed improved electric system operations to enhance flexibility in both electricity generation and end-use demand, helping to enable more efficient integration of variable-output renewable electricity generation.

**Transmission**: Most scenarios expanded transmission infrastructure and access to support renewable energy deployment. Distribution-level upgrades were not considered.

**Siting and Permitting**: Most scenarios assumed project siting/permitting that allows RE development and transmission expansion with standard land-use practices.
Renewable Resources and Technologies

Biopower ~100 GW
- Stand-alone
- Cofired with coal

Hydropower ~200 GW
- Run-of-river

CSP ~37,000 GW
- Trough
- Tower
  With thermal storage

PV ~80,000 GW
  (rooftop ~700 GW)
- Residential
- Commercial
- Utility-scale

Geothermal ~36 GW
- Hydrothermal

Wind ~10,000 GW
- Onshore
- Offshore fixed-bottom

- Only currently commercial technologies were modeled (no EGS, ocean, floating wind) with incremental and evolutionary improvements.
- RE characteristics, including location (exclusions), technical resource potential, and grid output (dispatchability), were considered
- Technical resource potential shown, not economic potential