U.S. Department of Energy

Office of Electricity Delivery and Energy Reliability

Maximizing Renewable Energy in the US Electric Grid

Presented at:

2011 Workshop -- The Road to a 100% Renewable Energy System

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Why Clean Electricity Generation

Economy—
economic development and growth

Security and Reliability
diversified generation and storage

Environment—
Air and water

President Obama's clean energy initiatives to reach:

- ***80% of electricity from clean energy sources by 2035***
- ***1 million electric vehicles on the road by 2015***

Impacts

Benefit Category	Benefit Sub-category	Specific Outcomes
Economic	Improved Asset Utilization	Optimized Generator Operation (utility/ratepayer) Deferred Generation Capacity Investments (utility/ratepayer) Reduced Ancillary Service Cost (utility/ratepayer) Reduced Congestion Cost (utility/ratepayer)
	T&D Capital Savings	Deferred Transmission Capacity Investments (utility/ratepayer) Deferred Distribution Capacity Investments (utility/ratepayer) Reduced Equipment Failures (utility/ratepayer)
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost (utility/ratepayer) Reduced Distribution Operations Cost (utility/ratepayer) Reduced Meter Reading Cost (utility/ratepayer)
	Theft Reduction	Reduced Electricity Theft (utility/ratepayer)
	Energy Efficiency	Reduced Electricity Losses (utility/ratepayer)
	Electricity Cost Savings	Reduced Electricity Cost (consumer)
Reliability (and Risk)	Power Interruptions	Reduced Sustained Outages (consumer) Reduced Major Outages (consumer) Reduced Restoration Cost (utility/ratepayer)
	Power Quality	Reduced Momentary Outages (consumer) Reduced Sags and Swells (consumer)
Environmental	Air Emissions	Reduced Carbon Dioxide Emissions (society) Reduced SO_X, NO_X, and PM-10 Emissions (society)
Energy Diversity	Energy "Security"	Reduced Oil Usage (society) Reduced Wide-scale Blackouts (society)
Economics	Market Operations Policy - Incentives	Reduced volatility Minimize Electricity Cost (consumer)

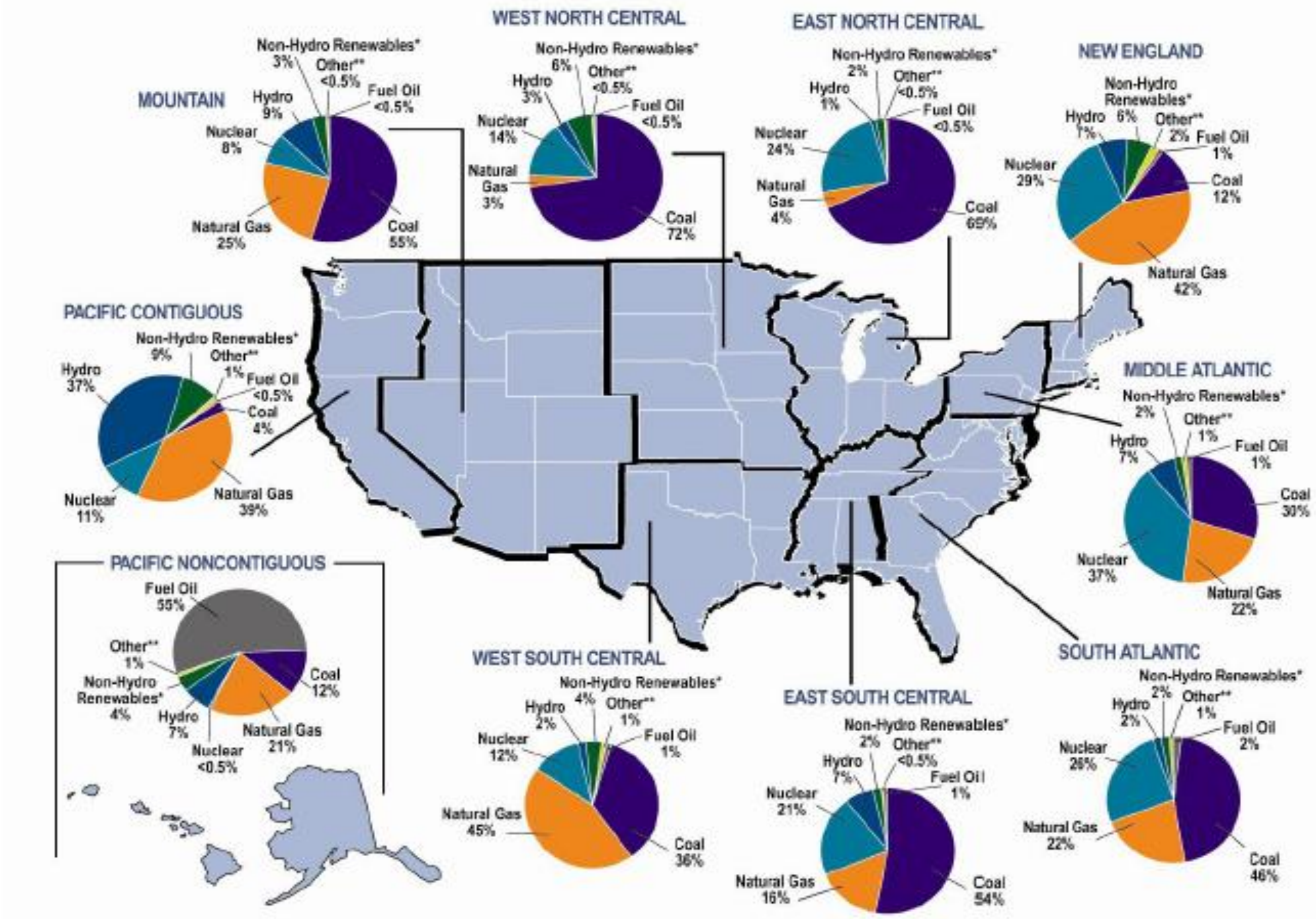
Adapted from *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects, EPRI, January 2010.

Strategy

- Advance Grid Functionality/flexibility - technologies, markets and policies
- Build in security and resiliency

Systems	Now	Near-term	Long-Term
Generation	Coal, Natural Gas, Nuclear, Central	Optimized Generation	Balance central/distributed
Transmission	System monitoring by based on limited parameters	Sensor-based monitoring by operators	Automatic switchable network Expanded Contingency Analysis
Distribution	Utilities perform operations manually (high latency)	Real-time tools to improve reliability and system efficiency	Integration of PEVs, real-time operations and dynamic reconfiguration and protection- Ability to Microgrid
Customer	Some demand-response programs, especially among commercial and industrial customers; most residential customers on fixed rates	All customers being offered a variety of technologies and pricing policies to better establish demand-side management practices	Customers are partners with utilities in the management of electricity. Utility business model: neutral arbitrator of the grid or an energy service company?

Different Regions of the Country Use Different Fuel Mixes to Generate Electricity



*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

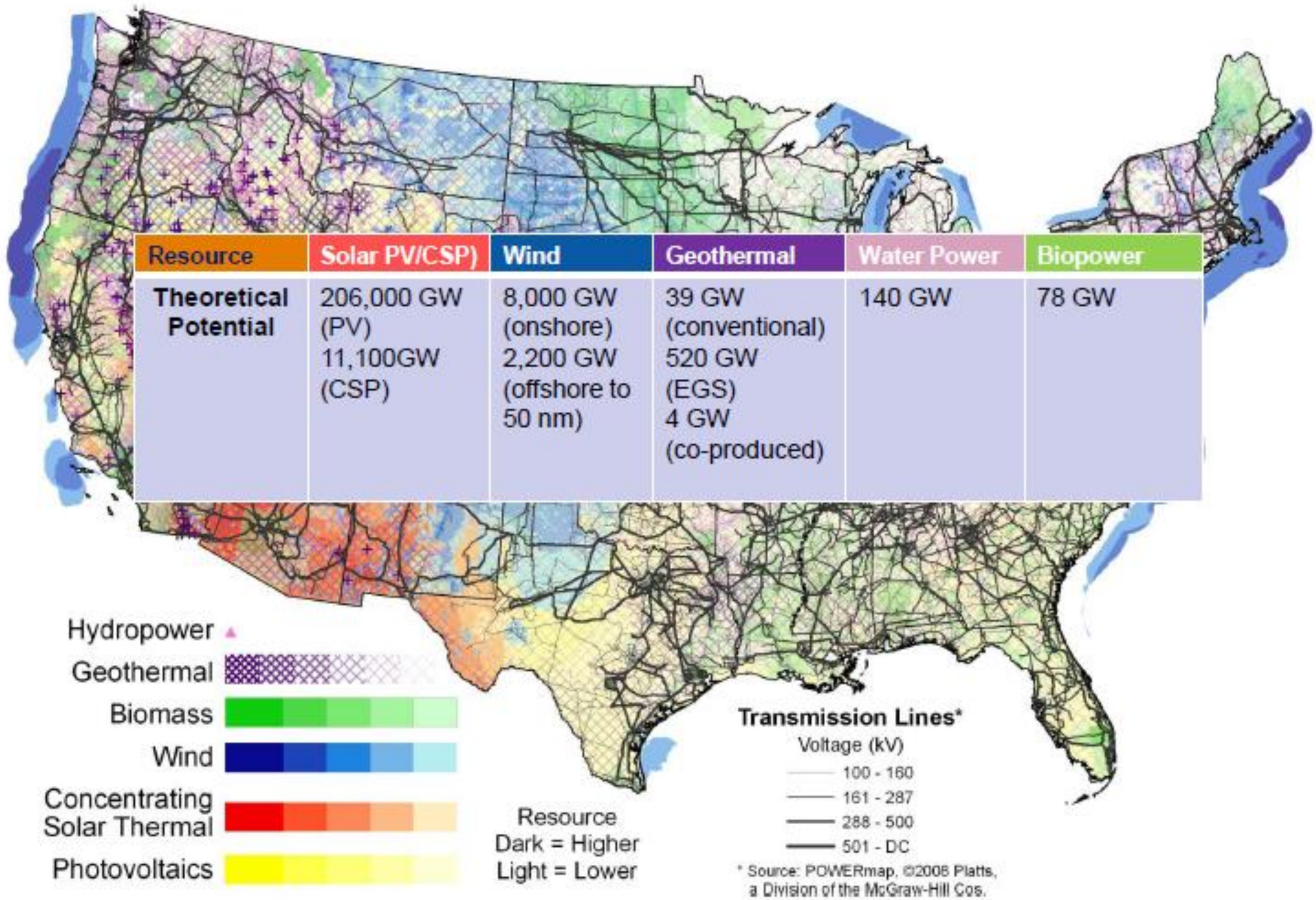
** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Sum of components may not add to 100% due to independent rounding.

Source: U.S. Department of Energy, Energy Information Administration, Power Plant Operations Report (EIA-923); 2009 preliminary generation data.

May 2010

U.S. Renewable Resources



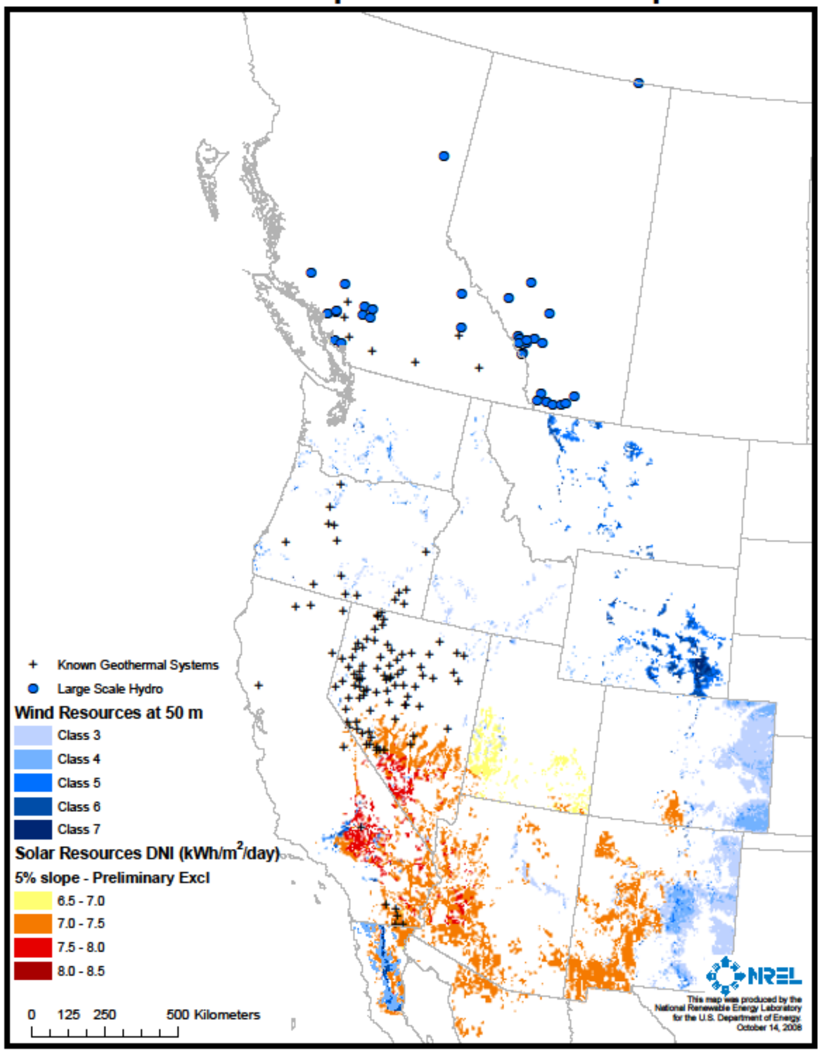
Resource	Solar PV/CSP)	Wind	Geothermal	Water Power	Biopower
Theoretical Potential	206,000 GW (PV) 11,100GW (CSP)	8,000 GW (onshore) 2,200 GW (offshore to 50 nm)	39 GW (conventional) 520 GW (EGS) 4 GW (co-produced)	140 GW	78 GW

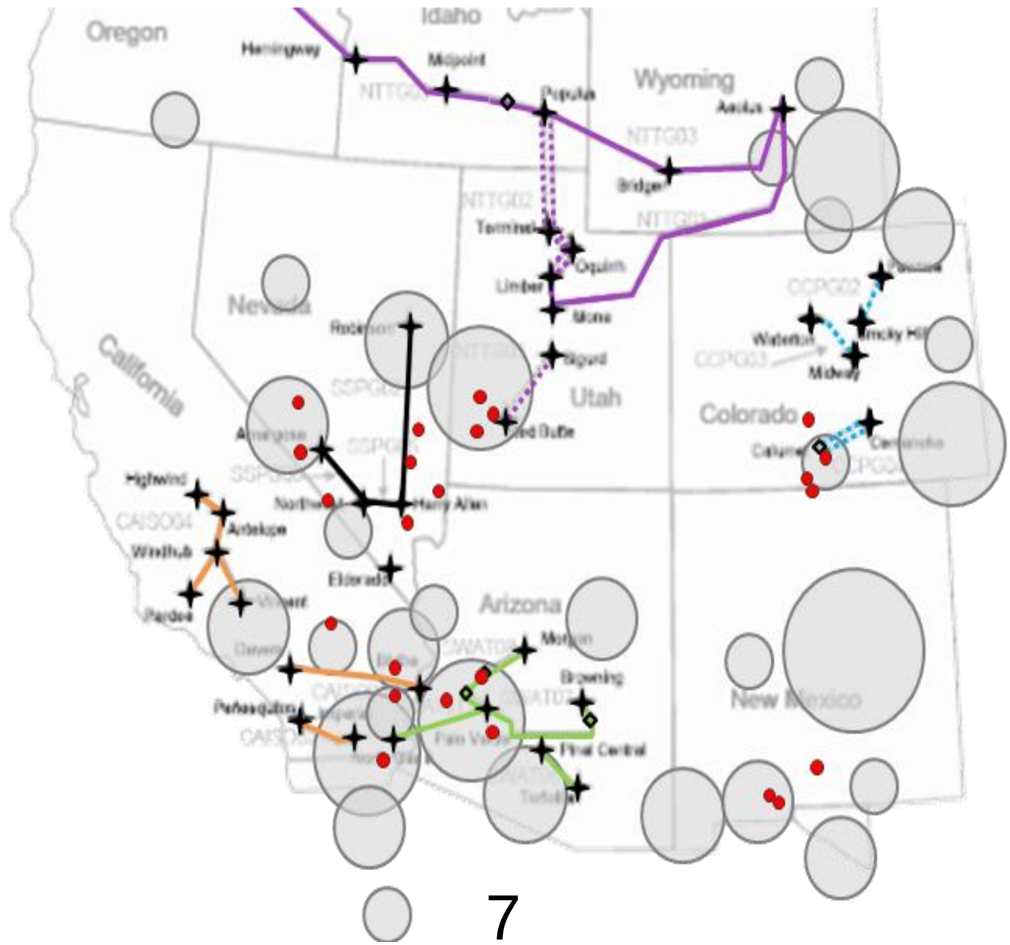
Source: NREL

Transmission and Clean Energy

Clean Diversified Generation Fleet

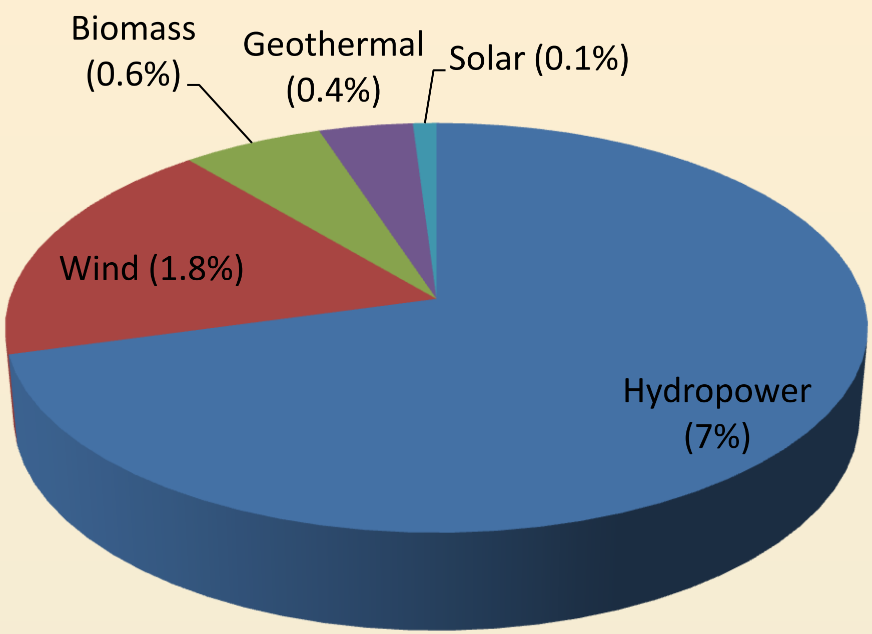
WREZ Composite Resource Map



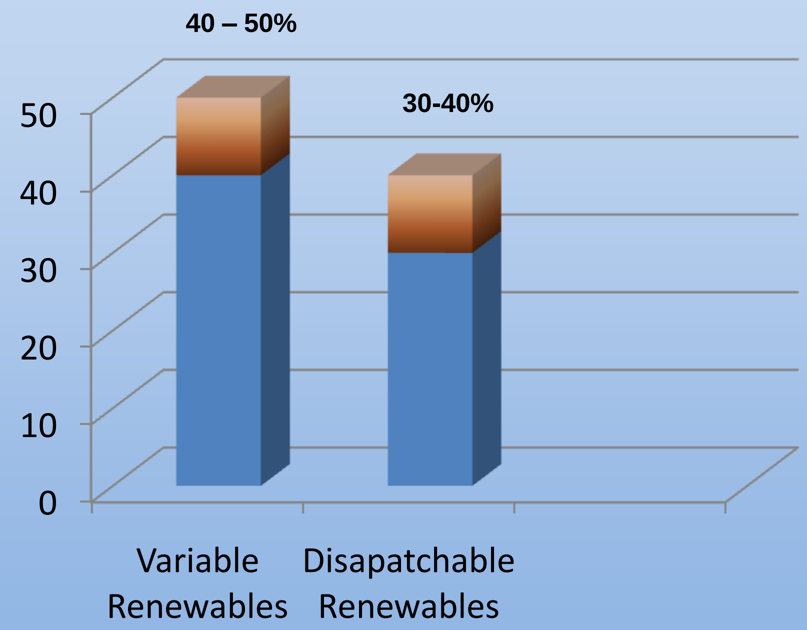


Renewable Electricity Futures Study

Renewable Electricity Generation Today: 10% of Total U.S. Electricity Supply



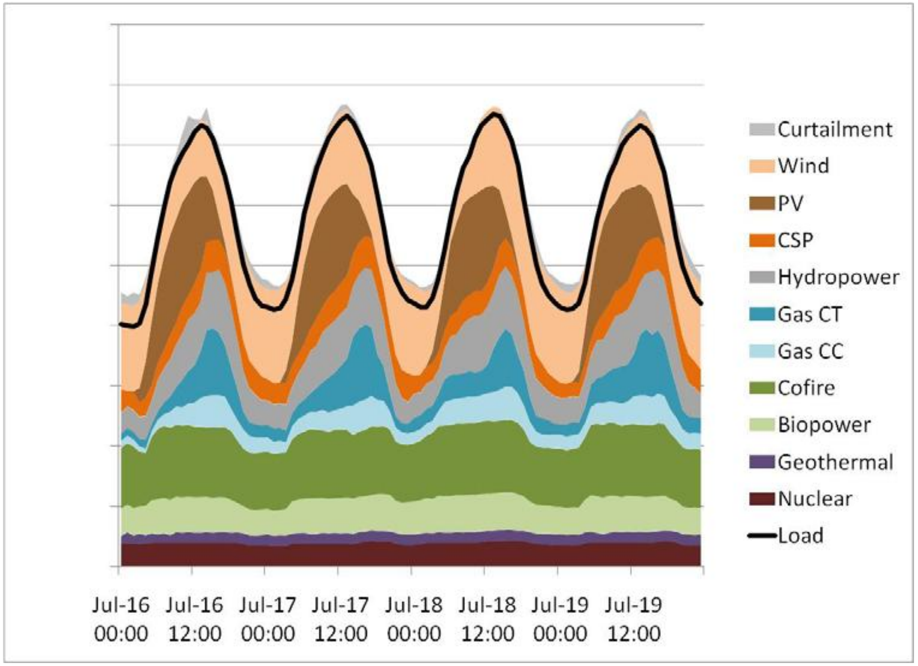
Renewable Electricity Generation by 2050: 80% Scenarios



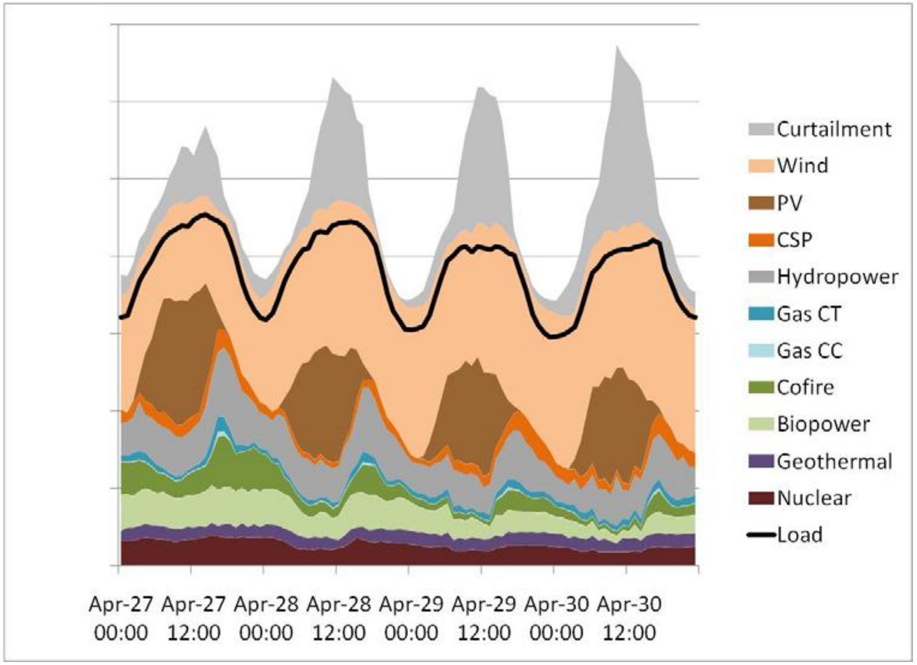
Emerging Technologies
Potential to displace commercial tech up to 4% each

Core 80% Renewable Electricity Scenario

Dispatch stack:
summer peak in 2050

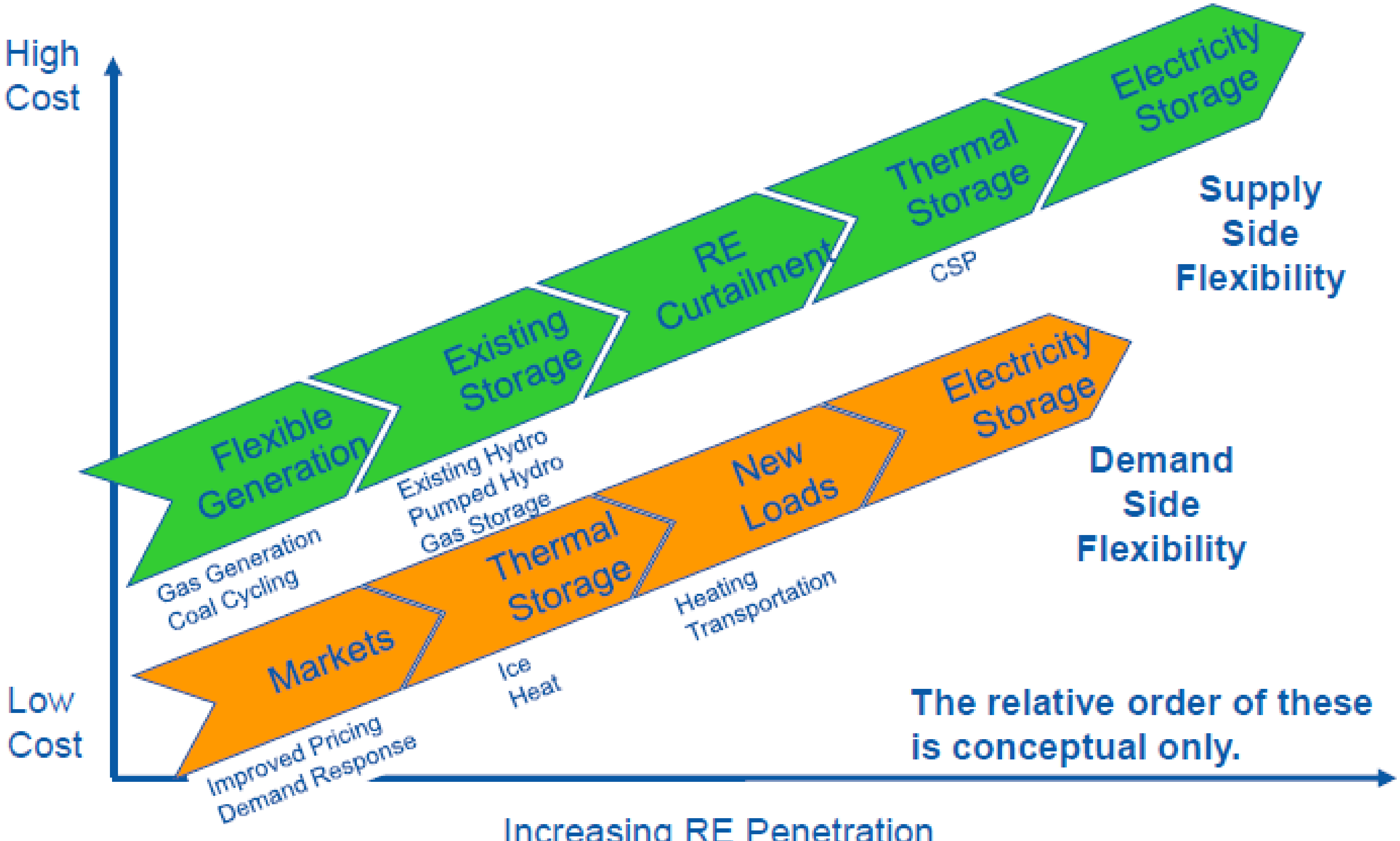


Dispatch stack:
spring (off-peak) in 2050



Source: Renewable Electricity Futures Study: Executive Summary, October 2010

Enhanced Flexibility Needed for Electric Grid with Increasing RE Penetration



Source: NREL

Simulation, Modeling, and Control

Integration of forecasting and renewable energy production tools into grid resource planning and operation tools

- Forecasting generation capacity and ramp ranges needed to balance the system (orange bands)
- Incorporating all sources of uncertainty/variability: wind and solar generation and demand
- Example Outcome: predicting generation deficiency above the available range (gray band)
- Tool is installed at the CAISO Control Center to help real-time dispatchers anticipate and address ramping needs.; Planned deployment to other ISOs

Energy Storage Technologies

Energy

- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Batteries
  - Sodium Sulfur (NaS)
  - Flow Batteries
  - Lead Acid, Lead Carbon
  - Lithium Ion
  - NiMH
  - NiCad
- Flywheels
- Electrochemical Capacitors

Power

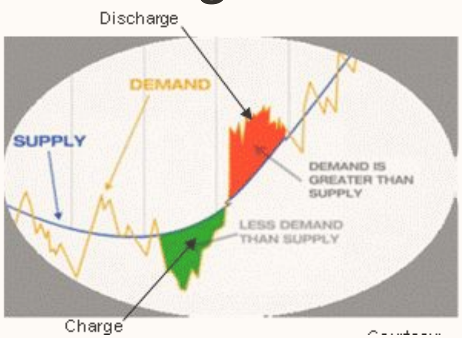
Pumped Hydro
(Taum Sauk)
400 MW

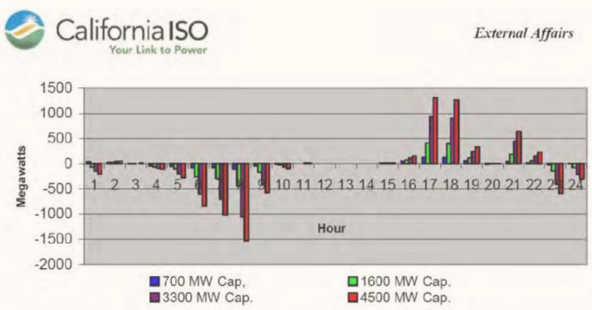
Sodium Sulfur
Battery
2 MW

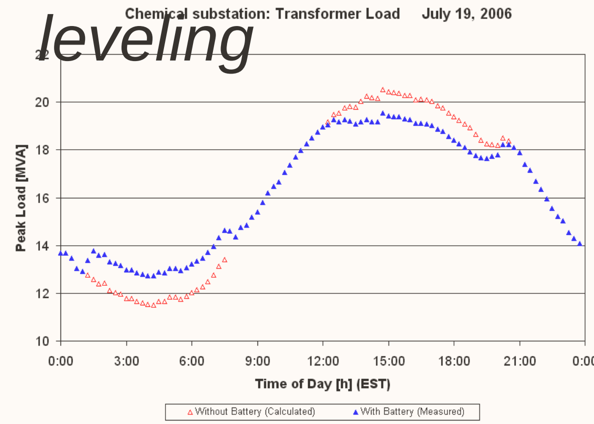
Flywheels
1 – 20 MW

Basics: Energy Storage Time Scales

Seconds to Minutes	Minutes - one Hour	Several Hours - one Day
Regulation	*Ramping*	*Peak shaving, load leveling*







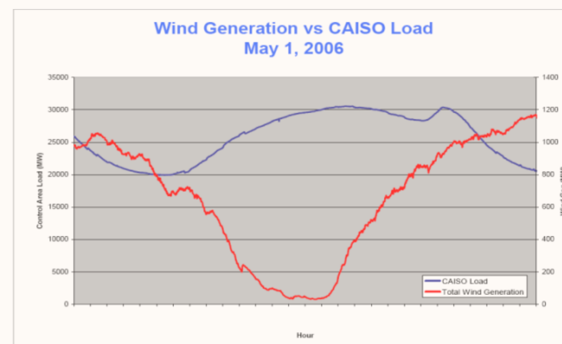


Figure 11: Total Wind vs. CAISO Load

Different Time Regimes
will Require
Different Storage Solutions

Frequency Regulation

100kW/15 min Flywheel system Demos
CEC / DOE and NYSERDA / DOE

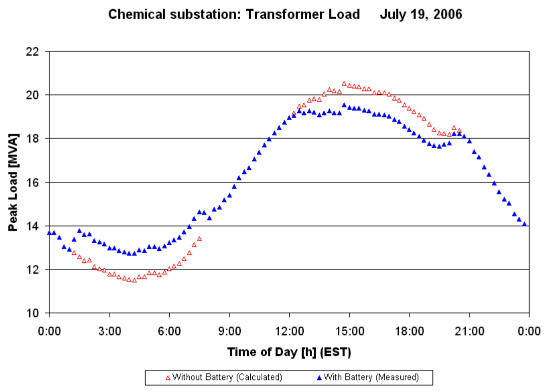
2 x 1MW / 15 min Flywheels in NE-ISO

4 x 1MW / 15min Li-Ion in PJM.

- Potentially twice as effective as gas turbines (Y. Makarov, PNNL,)

- Potentially a 70-80% Reduction in CO_2 emission over present methods (Fioravanti, KEMA, 2007)

Utility-Scale Storage on the Grid



3x2MW/6hr
In 2009

Concept

Storage defers upgrade;
Opens possibility for regional islanding, renewables

First 1MW/6hr in 2007, 3 in 2009
+ Duke, First Energy, PG&E

NaS, Flow Batteries, Lead Carbon

3 ARRA Projects -- 53MW

Community Energy Storage

25 kW / 2 hrs
15 year life time

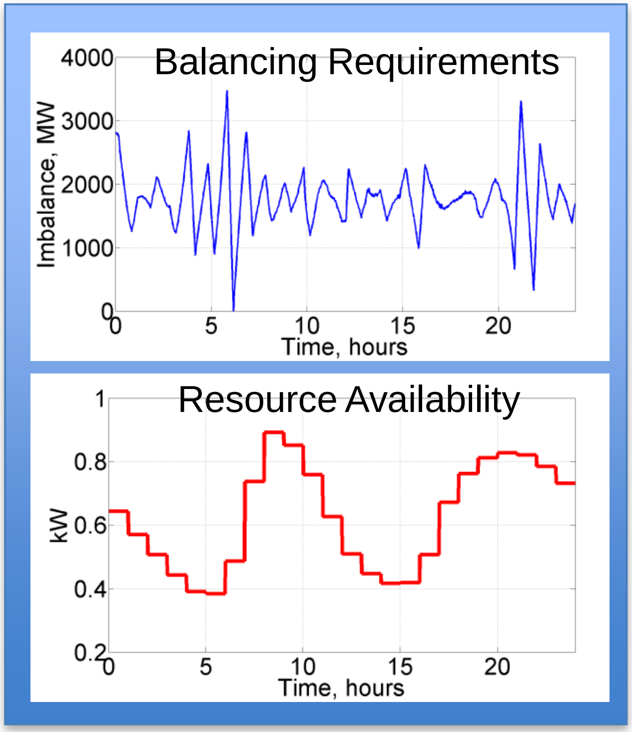
Backup, Platform for Solar, Utility Dispatchable

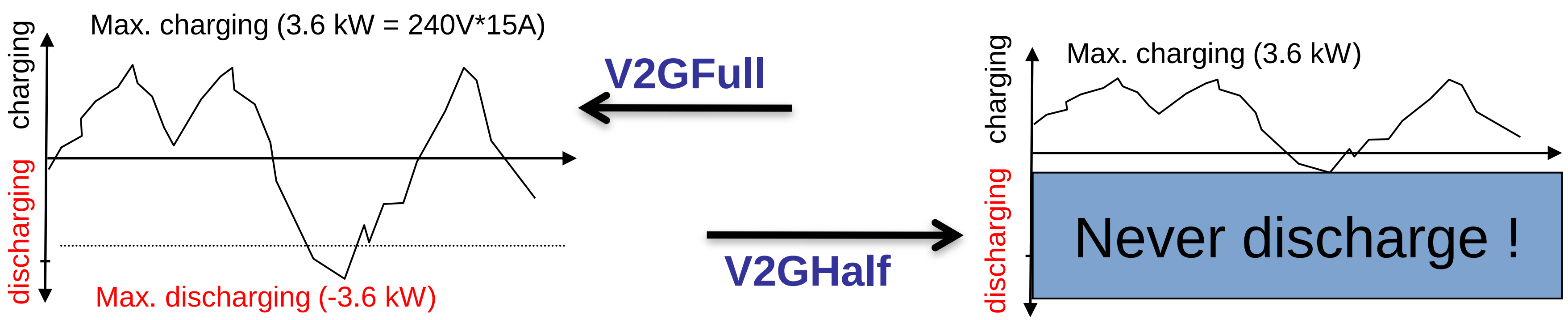
ARRA Project: 20 Li-Ion CES Units on Detroit Edison Grid

New Electric Vehicle Load as a Grid Resource

Use plug-in hybrid electric vehicles to aid in renewable generation source integration

- Determine balancing requirements for 10 GW of additional wind
  - NWPP oriented
  - Represents 12% RPS requirement
- Determine resource availability
  - Use 2001 NHTS Data for driving habits and population information
  - Use V2GHalf and V2GFull charging





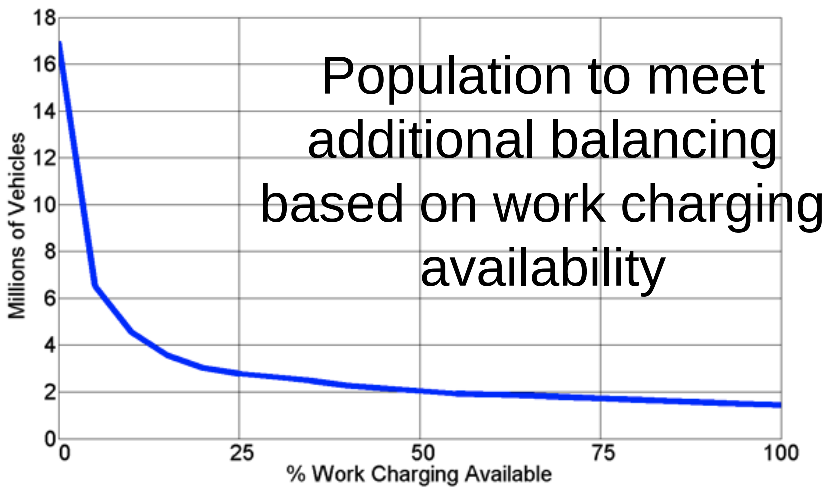
New Electric Vehicle Load as a Grid Resource

Completed report with the following key insights

- All new balancing requirements for 10GW of new wind capacity in NWPP by 2020 could be furnished by electric vehicles
- Solution insensitive to battery size
- Availability of infrastructure during day is essential

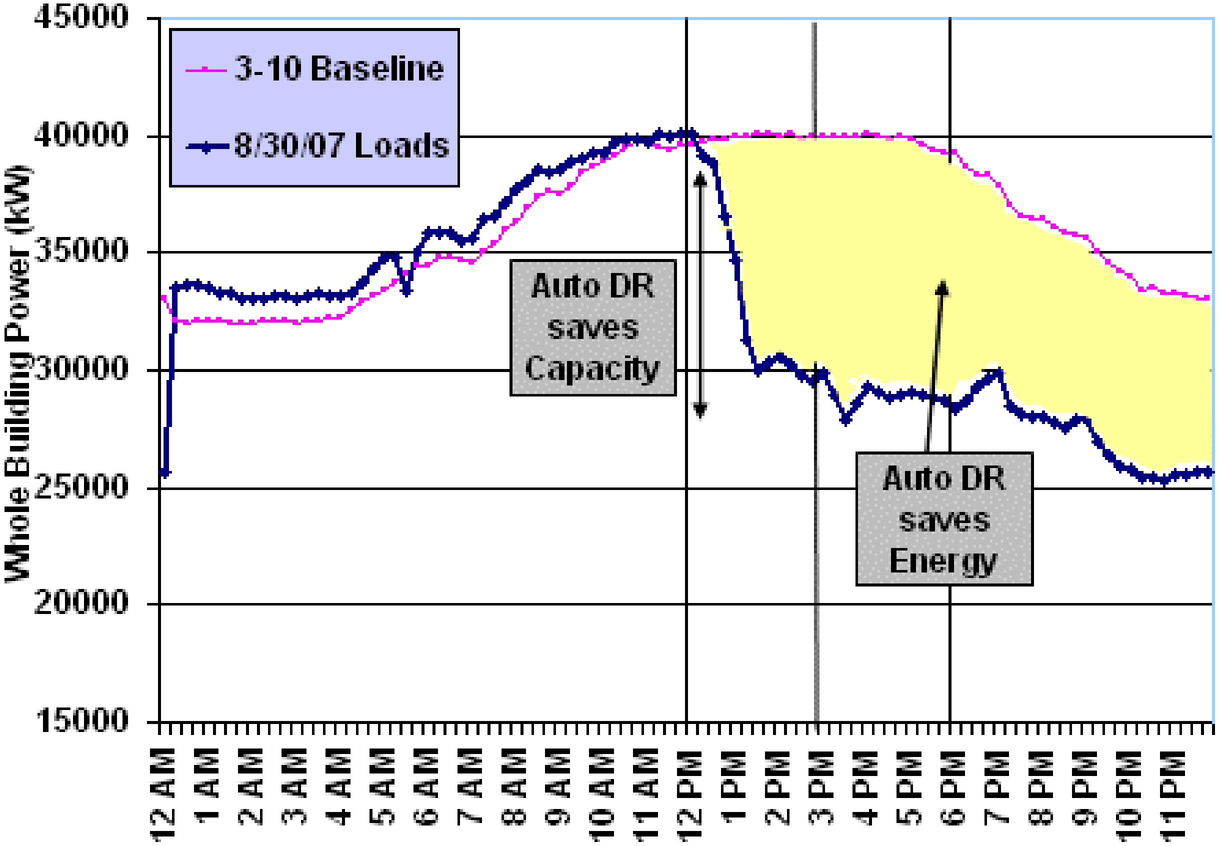
% of NWPP vehicle fleet to meet new balancing requirements

Charging type	Battery Size Scenario			
	PHEV 33		BEV 110	
	Home only	Home and Work	Home only	Home and Work
V2GHalf	180%	13%	126%	12%
V2GHalf and V2GFull	132%	10%	103%	8%
V2GFull	113%	8%	94%	8%



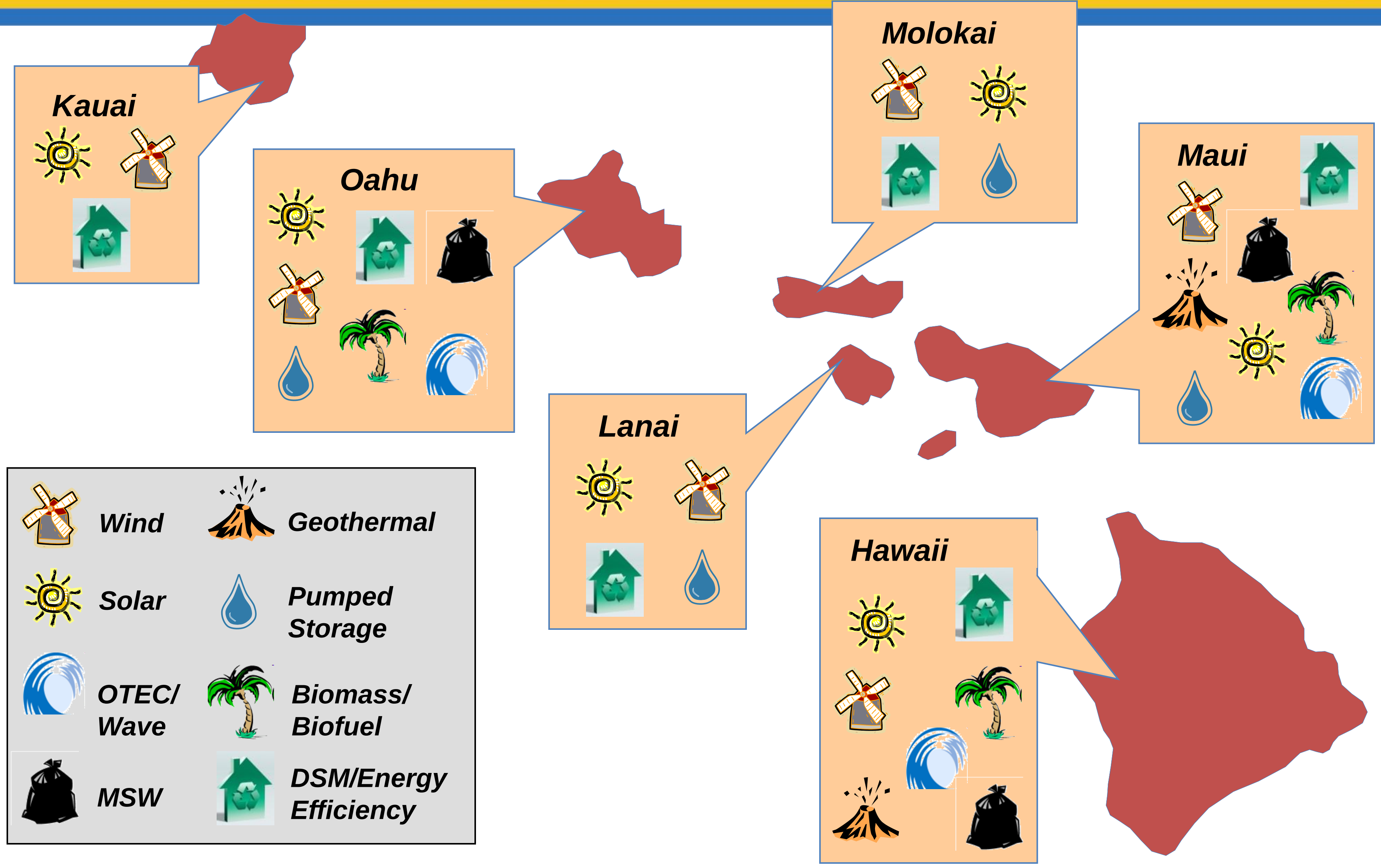
Automated Demand Response and Energy Efficiency -Saves Capacity and Energy

Electric Load Profile of Auto DR Participants on 8/30/2007



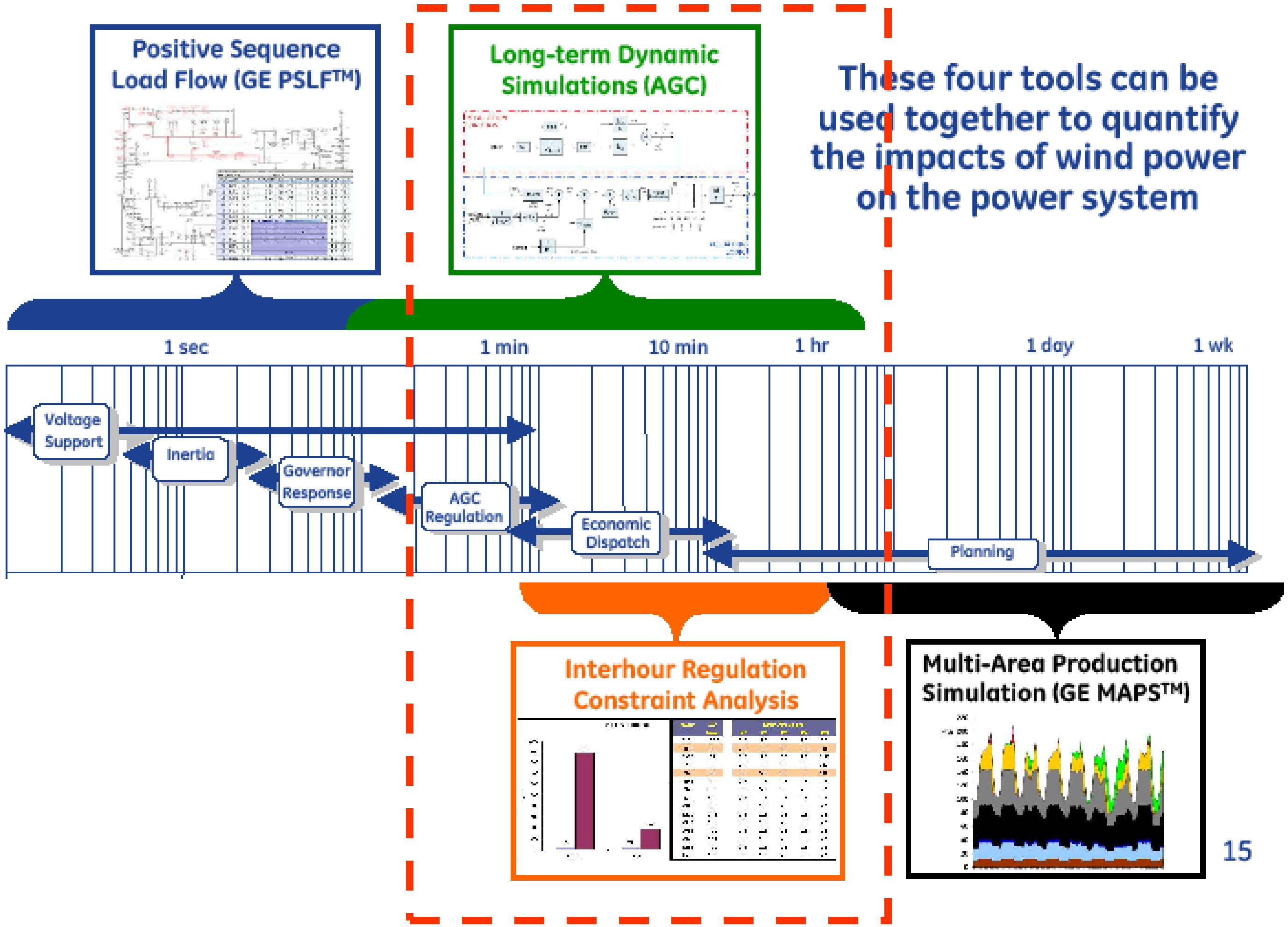
Source: PG&E

Hawaii's Wealth of Renewable Potential



Grid Modeling/Planning

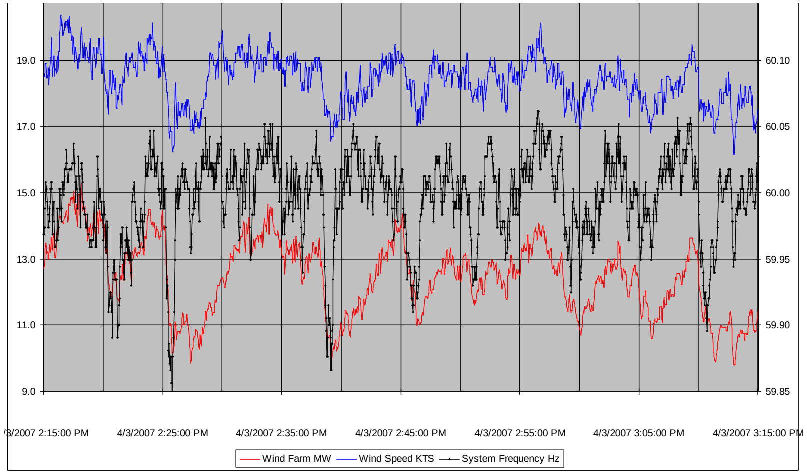
A Tool for each timescale of HECO's system

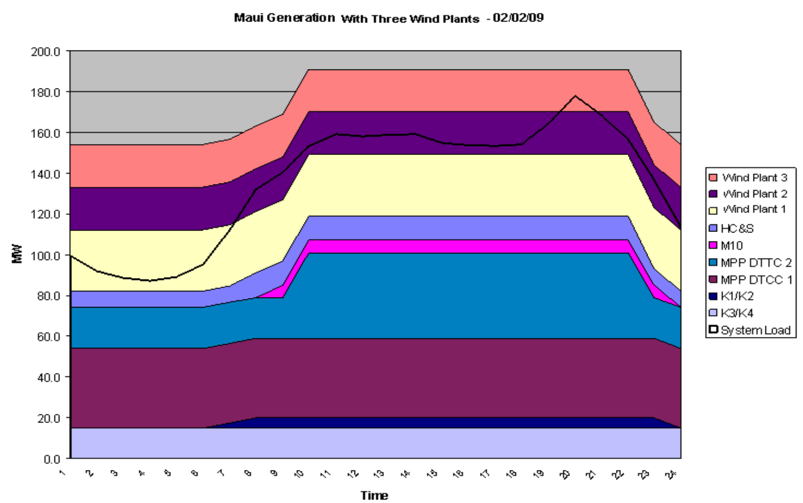


Hawaii Case Study

Issues Facing Hawaii Grids

- Balancing and Frequency Regulation
- Ride-Through
- Anti-Islanding
- Reserve Requirements
- Excess Energy





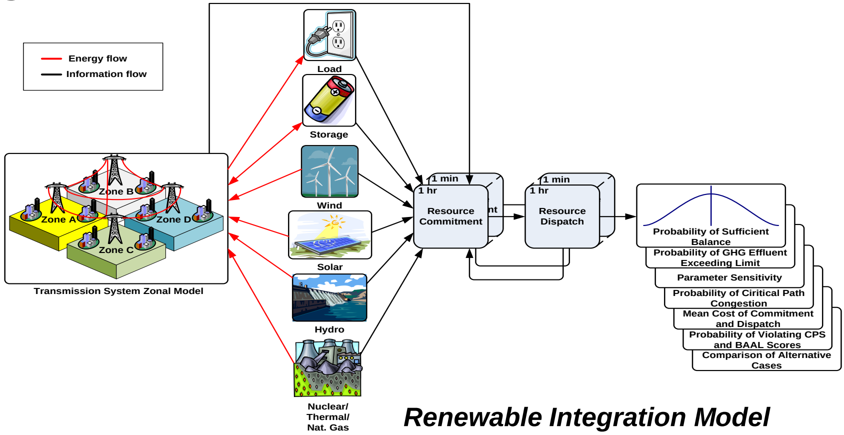
Cyber Security

Measure and Assess Security Posture	Develop and Integrate Protective Measures	Detect Intrusion & Implement Response Strategies	Sustain Security Improvements
Energy asset owners are able to perform fully automated security state monitoring and control systems networks with real-time remediation	Next-generation control systems components and architectures produced with built-in, end-to-end security will replace older	Control systems networks will inform operator response to provide contingency and remedial actions in response to attempted	Implement effective incentives through Federal and state governments to accelerate investment in secure control system technologies and practices

Planned R&D to Address High RE Penetration

OE/EERE collaboration areas on system integration of RE

- **Better forecasting to ensure reserves and manage uncertainty**
- **Developing comprehensive sub-hourly and real-time models for simulation of grid operations and for planning**
- **Improving scheduling, dispatch and control systems for managing uncertainty**
- **Developing coordinated wide-area control approaches and algorithms**
- **Increasing flexibility of existing grid assets, DR, and storage to facilitate RE integration**
- **Examination of multi-terminal HVDC/AC for offshore wind development**
- **Adapting foreign RE integration and grid operations experience to the U.S. where prudent**



Renewable Integration Model

- **TECHNOLOGIES- MARKETS- POLICIES**