EPRI Program 201 Back Pocket Insights

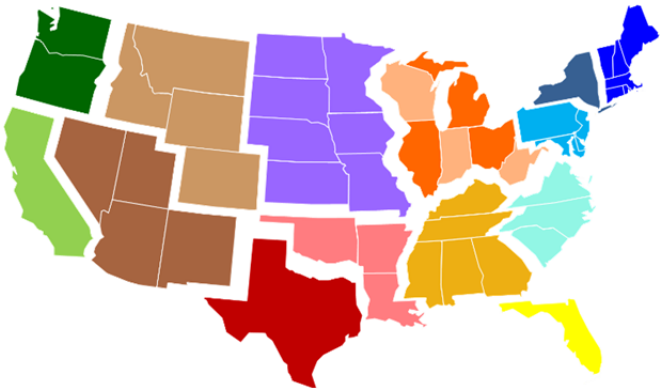
Modeling Storage Investment and Dispatch with US-REGEN

October 2017

EPRI uses the US-REGEN 8760-hour static equilibrium model to represent the arbitrage economics of storage

- **US-REGEN** is a long-horizon economic capacity expansion model, developed and maintained by EPRI, in the same class of models as the IPM model used by the Environmental Protection Agency
- The **static equilibrium version** of US-REGEN solves for the least-cost capacity/dispatch mix for a given year in the future, and represents all 8760 hours in that year
- US-REGEN seeks the **least-cost** capacity/dispatch mix to meet hourly load, taking into account regulatory and resource adequacy constraints

8760-hour Coverage Key to Understanding the Interaction of Storage & Renewables



- US-REGEN static equilibrium model chooses **storage, wind, solar, and gas-fired** technologies to minimize the cost of meeting anticipated load in a future year in 15 regions across the United States.
- This formulation captures both the anticipated drivers of storage (wind and solar) as well as alternatives to storage (gas peaking units)
- Representation of all 8760 hours in a year captures the potential economics for storage charging/discharging cycles as short as **one hour**, or as long as an **entire year**

US-REGEN Includes Multiple Storage Options

Pumped Hydro
Existing facilities only assuming 20 hours storage and a 20% charging penalty; no new facilities considered

Compressed Air Storage (CAES)
Available in all regions; lifetime of 30 years; requires natural gas input of 1.44GJ/MWh; endogenous storage capacity

Batteries
Lifetime of 20 years; 10% charging penalty; model chooses optimal storage capacity (1hr, 2hrs, 4hrs, etc.)

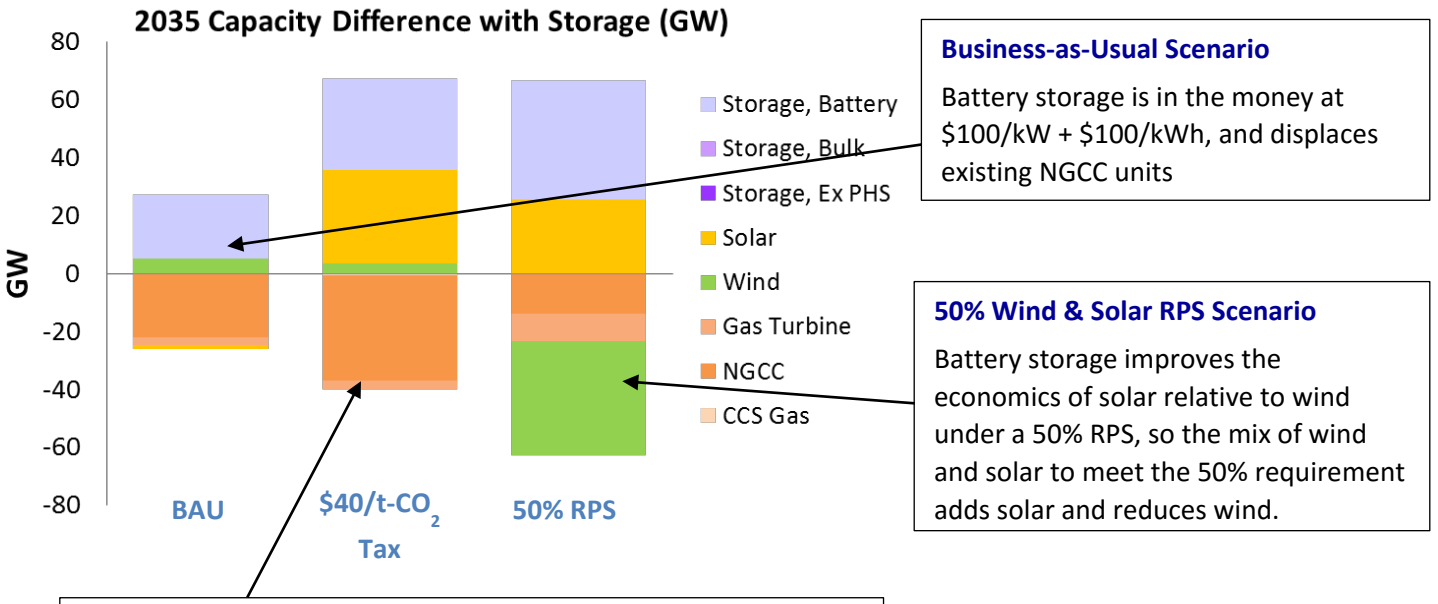
There are many potential ways for storage to pay for itself. This model represents all 8760 hours in a year, enabling the modeler to analyse the value of storage to shift electricity to be used later, including the market value of the energy, the value of backup capacity needed to satisfy peak demands, and the value of operating reserves. Other value streams often considered for storage include frequency response, delaying distribution investments, and alleviating transmission congestion pockets. These require more detailed spatial representation, or sub-hourly chronology to represent, and cannot be captured in the US-REGEN static equilibrium model.

Key Input Parameters for Non-Storage Technologies (as of October 2017)

Technology	Investment Cost*	Fixed Operating Cost*	Variable Operating Cost*	Other information
Onshore Wind	$1320/kW	$36/kW-yr	-	Add $450/kW for new sites for T&D
Solar PV, Single Axis Tracking	$917/kW	$22/kW-yr	-	Add $450/kW for new sites for T&D
Natural Gas Combined Cycle	$1180/kW	$15/kW-yr	$2.4/MWh	Assumed heat-rate of 6.319 mmbtu per MWh
Natural Gas Combustion Turbine	$830/kW	$15/kW-yr	$4.5/MWh	Assumed heat-rate of 10.035 mmbtu per MWh

* All costs are projections for 2035 in real $2010 dollars. These numbers exclude any potential subsidies.

Example Analysis in US-REGEN: What Technologies Could Storage Displace?



Business-as-Usual Scenario

Battery storage is in the money at $100/kW + $100/kWh, and displaces existing NGCC units

50% Wind & Solar RPS Scenario

Battery storage improves the economics of solar relative to wind under a 50% RPS, so the mix of wind and solar to meet the 50% requirement adds solar and reduces wind.

$40/tonne Carbon Tax Scenario

Adding storage technologies on top of a $40 carbon tax enables more solar generation; displacing existing NGCC units

US-REGEN is a long-horizon national model. Due to computational limitations, US-REGEN does not represent:

- Unit commitment constraints, or constraints on power flows within regional borders. For this static equilibrium modeling, inter-region transmission capacity is fixed, but inter-region flows are endogenous.
- Voltage support or other transmission system reliability constraints
- Distribution and other costs of delivering power from the grid to the door
- Natural gas supply and distribution. EPRI is conducting a project to add this capability.
- Technologically detailed end-use demand. Like other models in this class, US-REGEN represents load using historic data plus projected growth rates, with elasticities representing the long-run potential for load to respond to prices. EPRI is conducting a project to add this capability.

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