NREL’s Resource Planning Model

Elaine T. Hale, Ph.D.
Senior Engineer
Strategic Energy Analysis Center

Contents

Resource Planning Model (RPM)

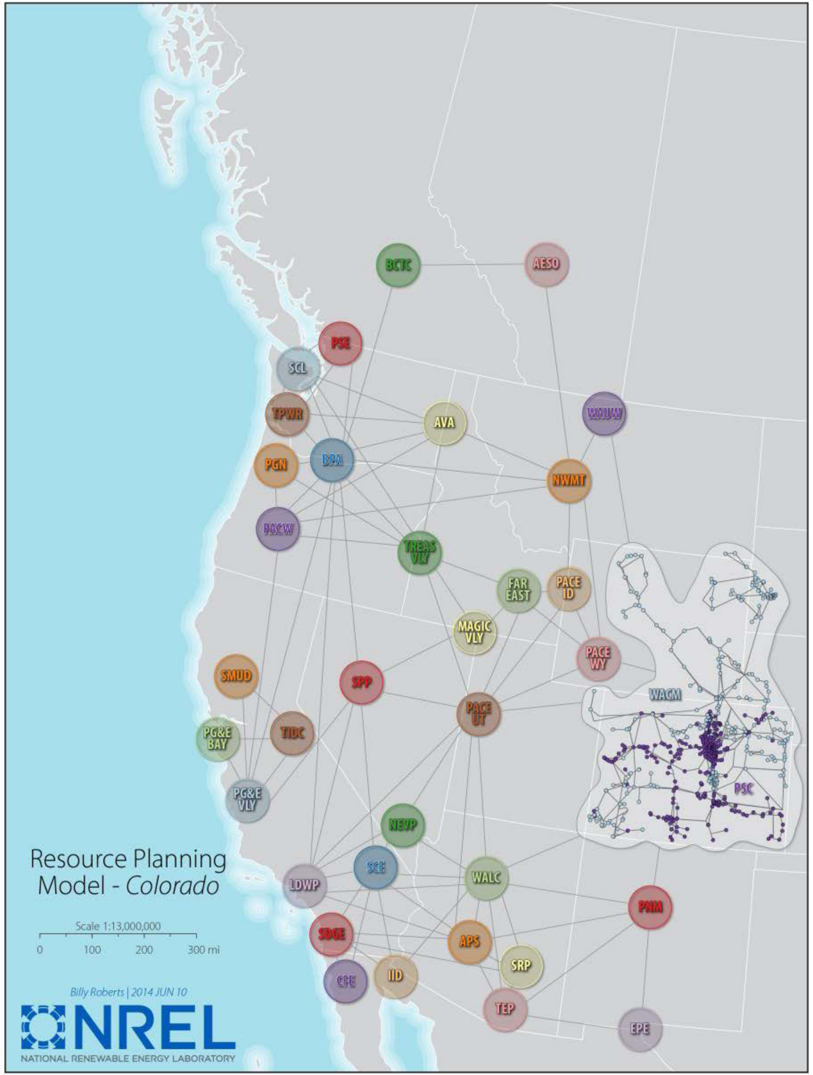
Capacity expansion model for a *regional* electric system over a utility planning horizon (through 2035).

Key features:

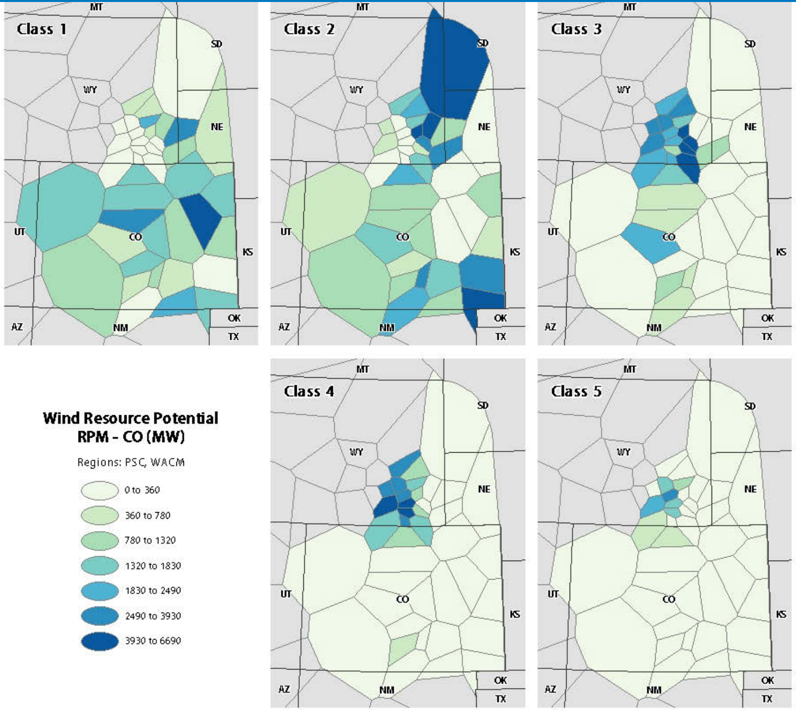
- Individual generation unit and transmission line representation
- Hourly chronological dispatch and detailed system operation representation
- High spatial resolution informs generator siting options, particularly for renewable resources
- Flexible data structure to develop models for customized regions
- *New*: Models the cost and value of storage and other enabling technologies

https://www.nrel.gov/analysis/models-rpm.html

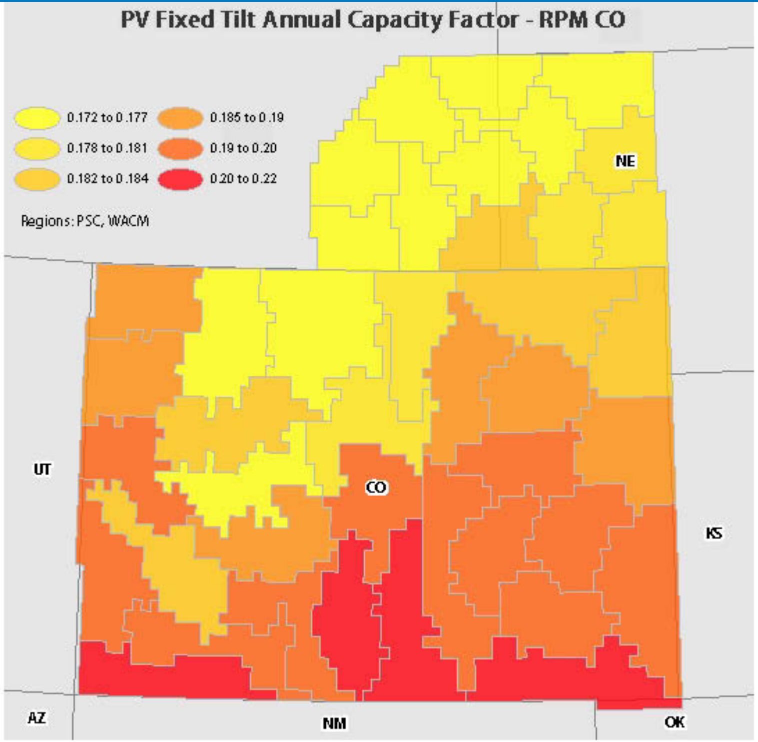
RPM is a Mixed Nodal / Zonal Model



High spatial resolution modeling to accurately represent renewable resource potential and quality



Examples from Colorado model

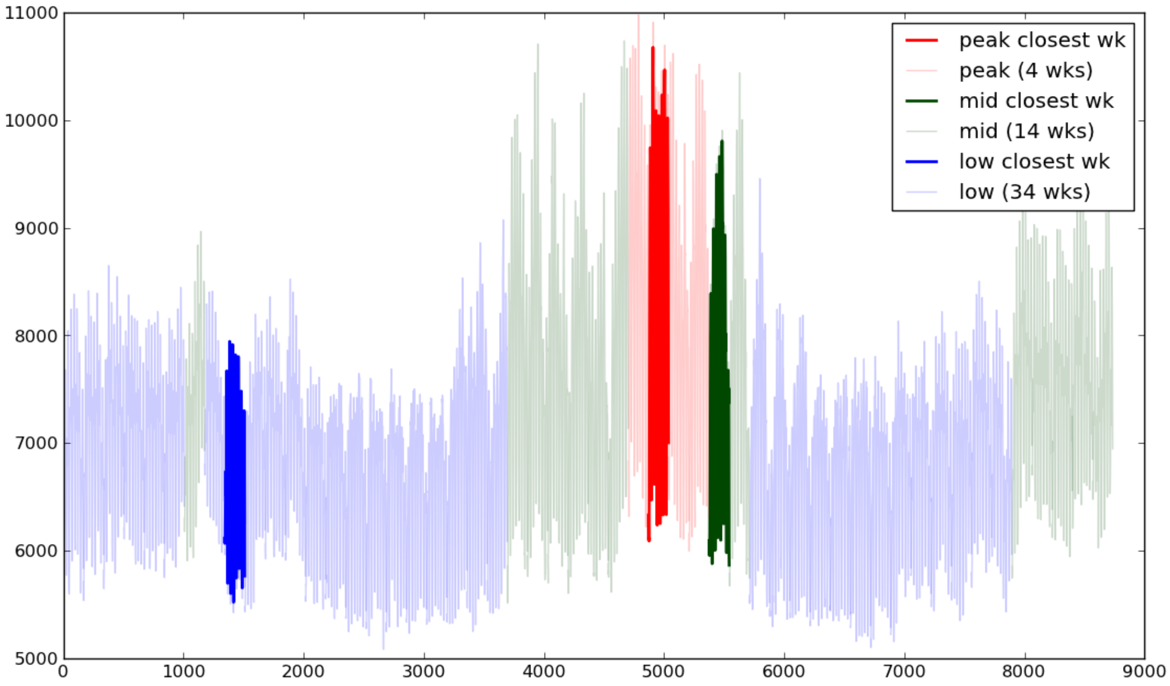


Clustering techniques are applied to develop renewable resource zones that have similar output characteristics. Each zone is characterized by:

(1) resource potential, (2) hourly profiles, and (3) grid interconnection costs

Temporal resolution and sampled dispatch

- Clustering used to select representative weeks
- Can model up to 3 weeks + peak day at hourly resolution
- Typical models include 4 separate chronological 24-hour periods, i.e. 96 hours of the year



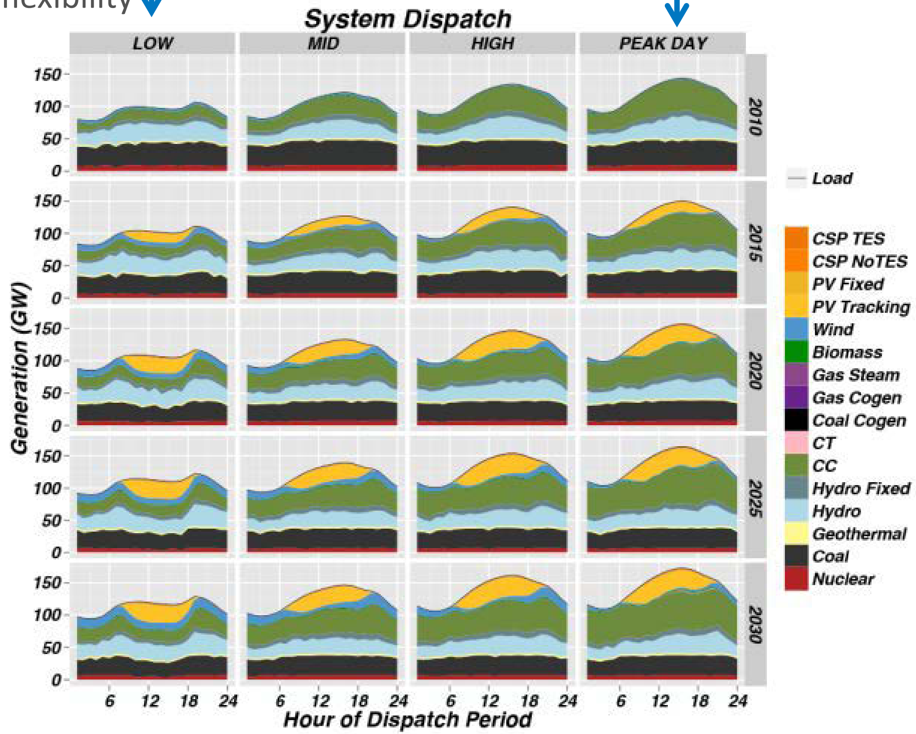
(Getman et al. 2015)

Reduced Order Dispatch Does Not Fully Address the Variability Seen Throughout the Year

96 dispatch hours per year

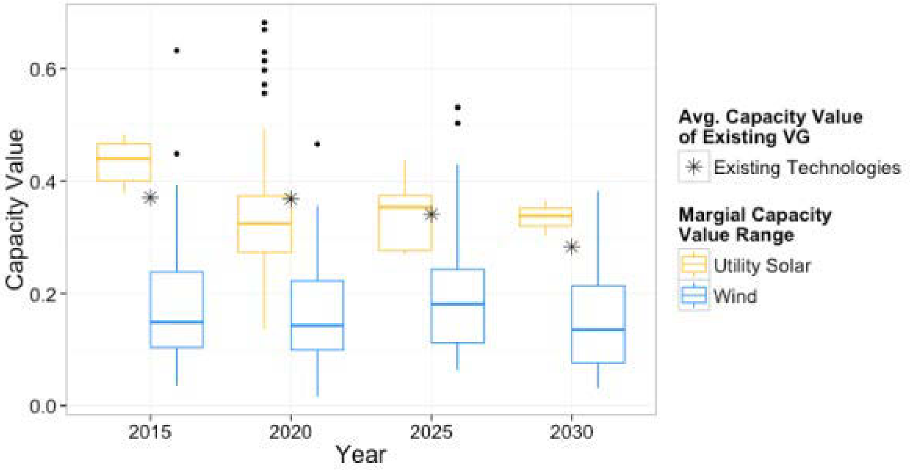
Low period does not fully capture conflict between wind, solar, and thermal fleet inflexibility

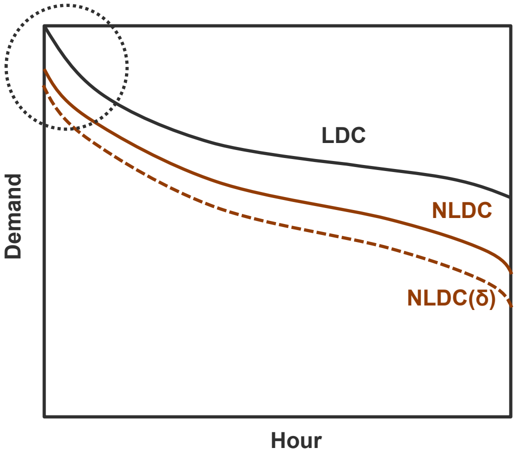
Peak day does not fully capture capacity value



We therefore estimate some parameters using a full year's worth of data ...

Variable Generation (Wind and Solar) Capacity Value

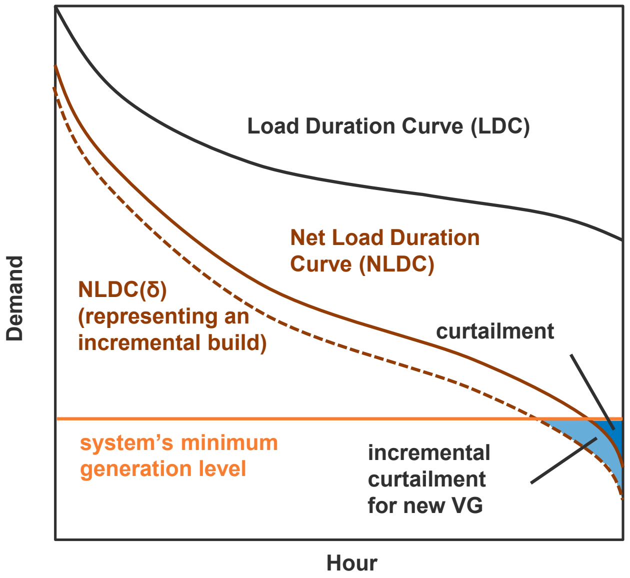


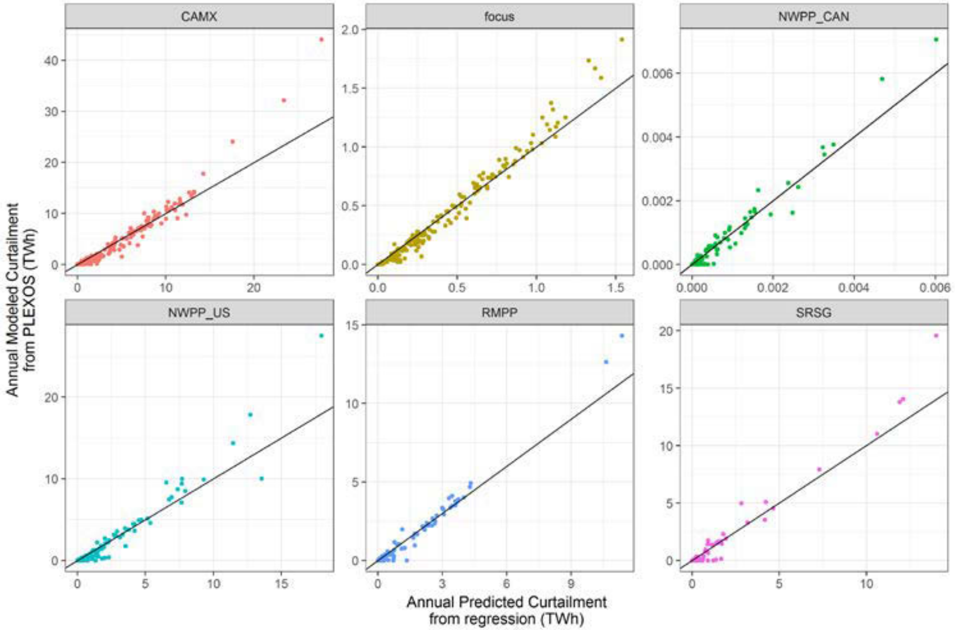


- Capture shift in net peak load based on top 100 hours
- Values geospatial and technology diversity
- For each NERC region:
  - Capacity value of existing VG = <LDC – NLDC>$_{\text{top 100}}$ / (existing VG capacity · 100)
- For each VG resource region:
  - Marginal capacity value of new VG = <NLDC(δ) – NLDC>$_{\text{top 100}}$ / (δ · 100)

Fractional capacity values used in planning reserve constraints

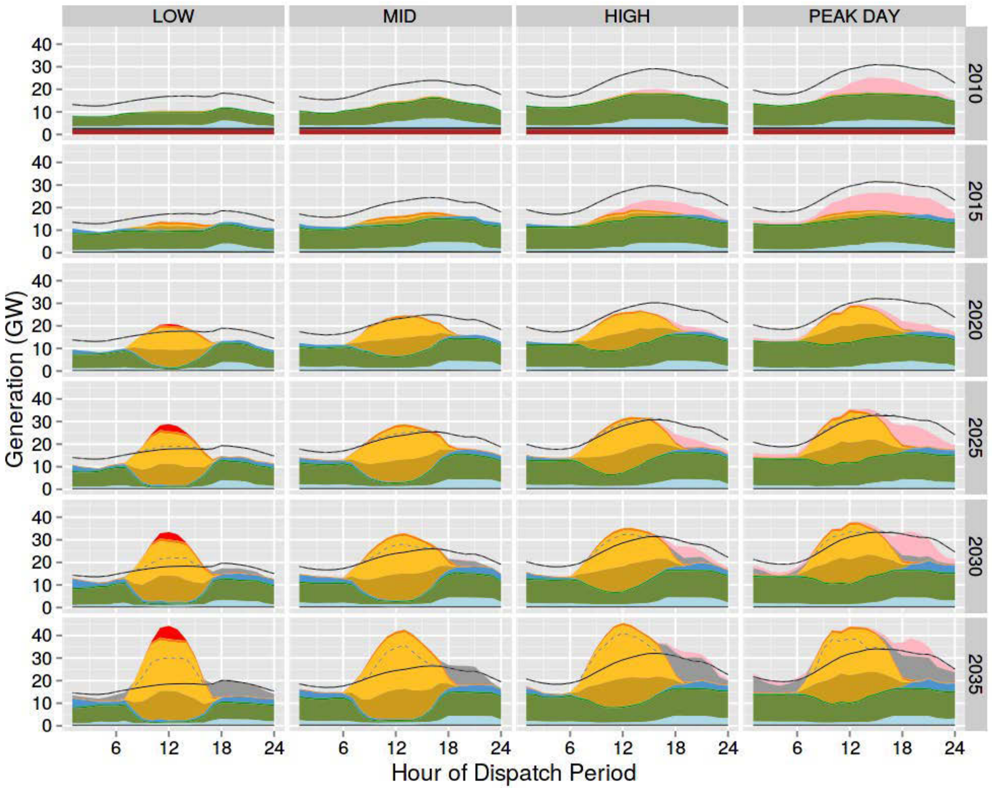
Minimum Curtailment of Variable Generation

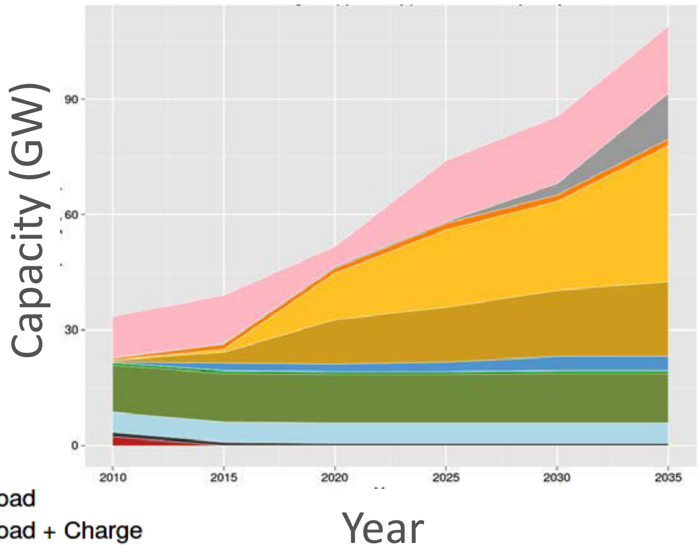




- Curtailment of wind and solar arises when load, net of renewable generation (i.e., "net-load"), is below the system's minimum generation level. This occurs because committed thermal generators can only be turned down to a specific minimum level.
- RPM estimates curtailment rates based on regression analysis of curtailment observed in numerous production cost model runs

Primary outcomes are capacity expansion and generation dispatch



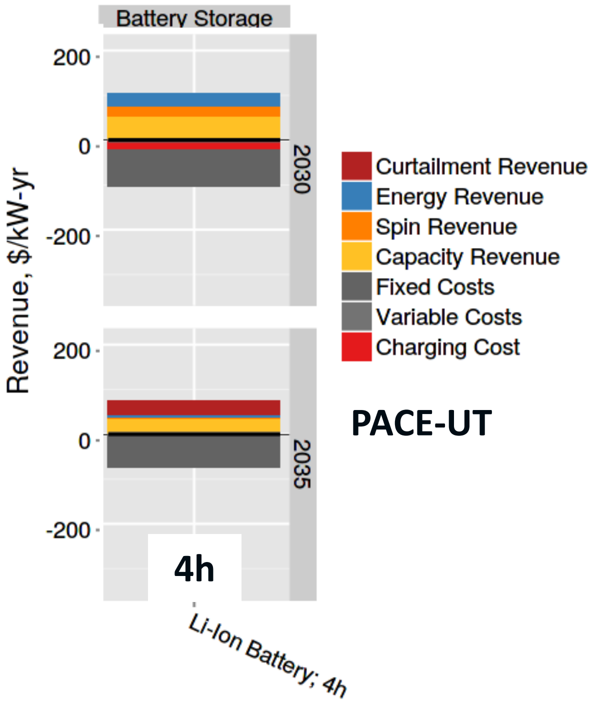


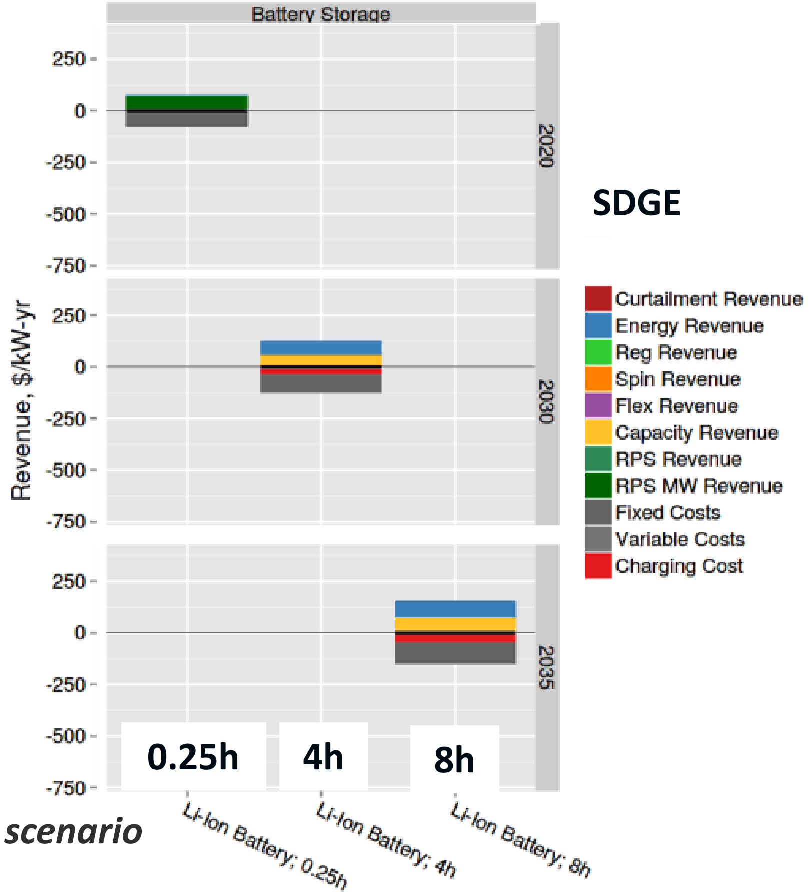
Load
Load + Charge

Curtailment
CT
Storage
CSP
Utility PV
Dist. PV
Wind
Other Renewable
CC
Hydro
Coal
Nuclear

Illustrative high-solar scenario; Results for a focus region

Model revenues show why resources are built



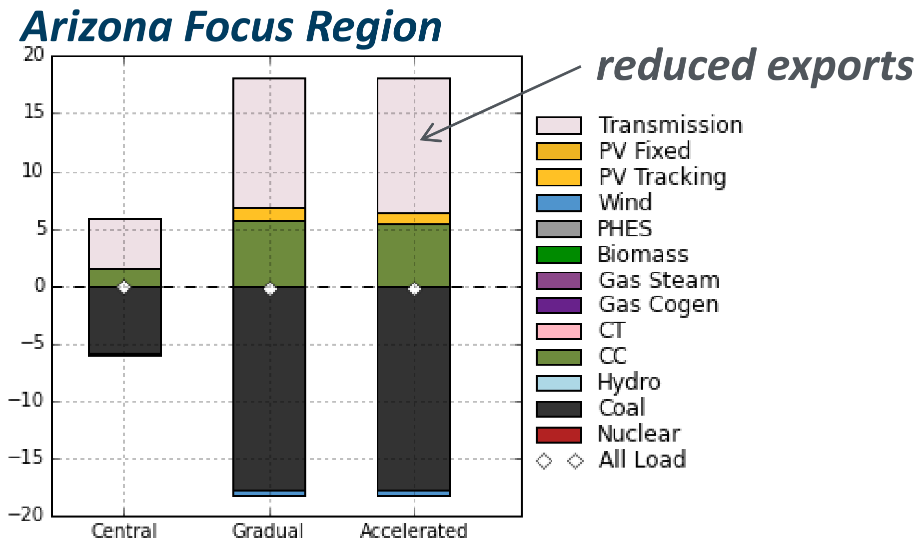


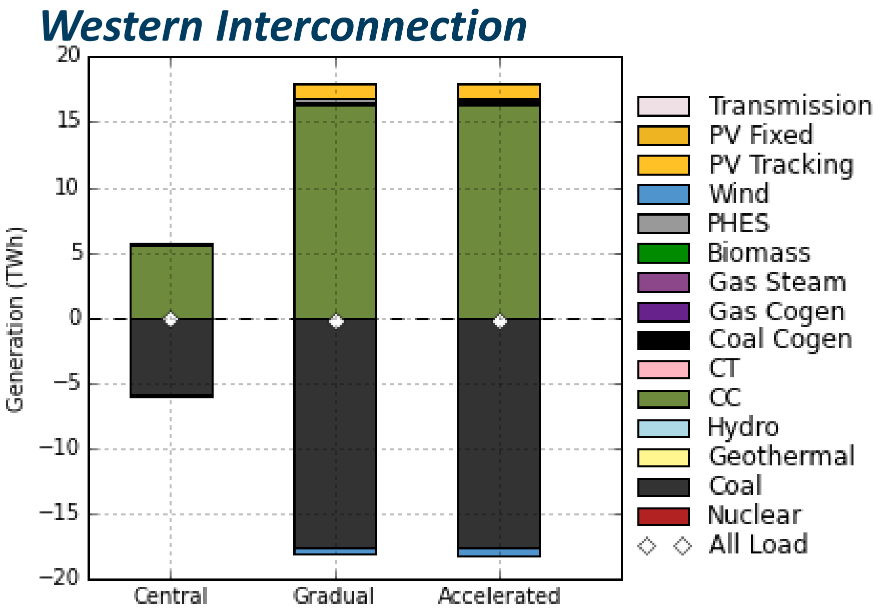
Model revenues from a low tech cost scenario

Contents

Navajo Generating Study, Phase 2

2030 Generation Differences with Reference

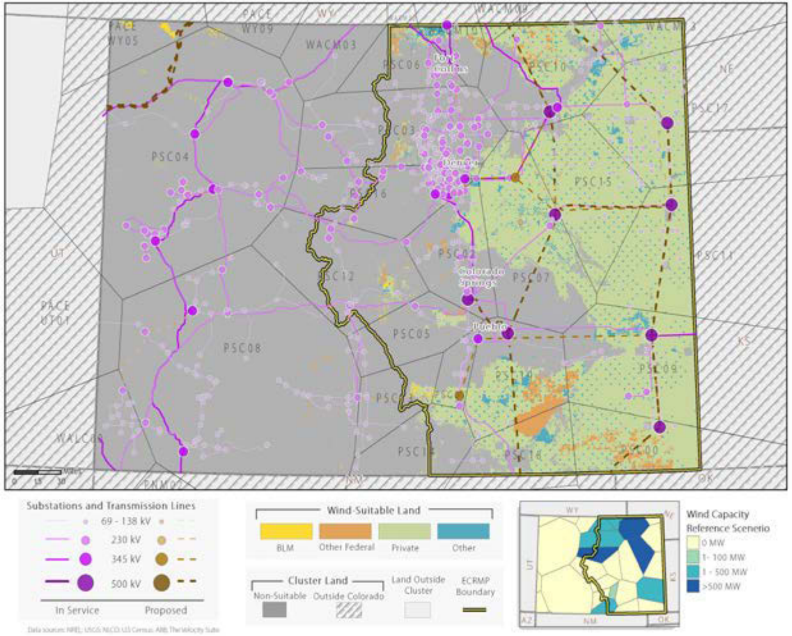




Related to (Hurlbut et al. 2016)

Ownership of Lands Suitable for RE Development

Lands suitable for wind development



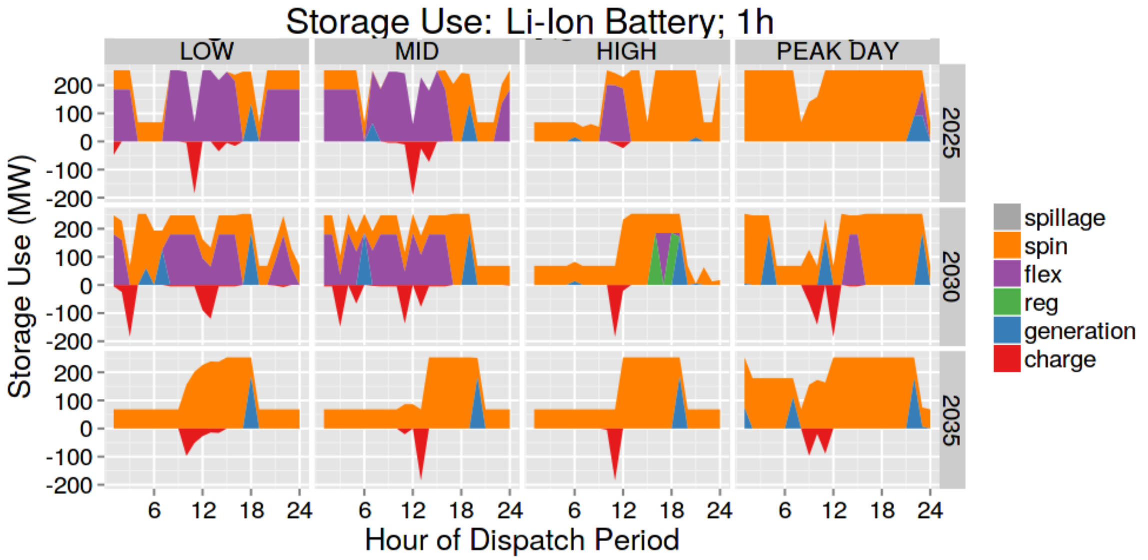
Wind

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	676	8	10,742	130	35,485	431	85,689	1,040
Federal	286	3	35,028	425	152,692	1,854	747,768	9,078
Other	14,855	180	286,770	3,482	403,691	4,901	630,510	7,655
Private	170,090	2,065	3,482,771	42,283	5,609,683	68,105	8,660,317	105,141

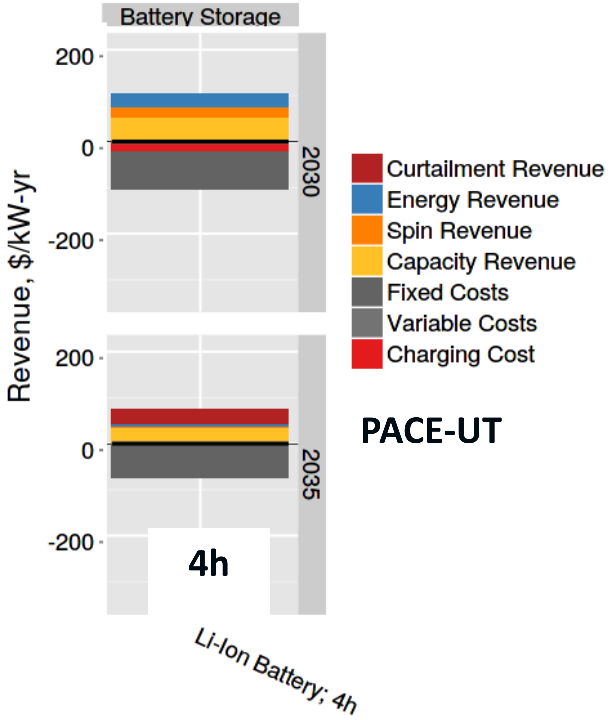
(Barrows et al. 2016)

Value of Storage

value-stacking dispatch

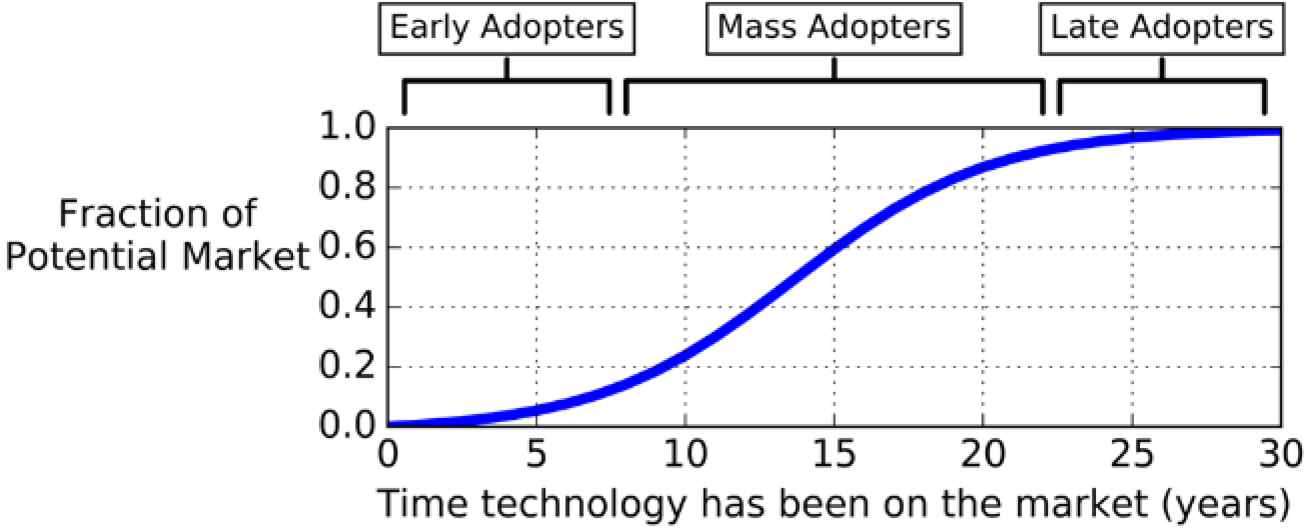


revenue outputs clarify why a resource was built



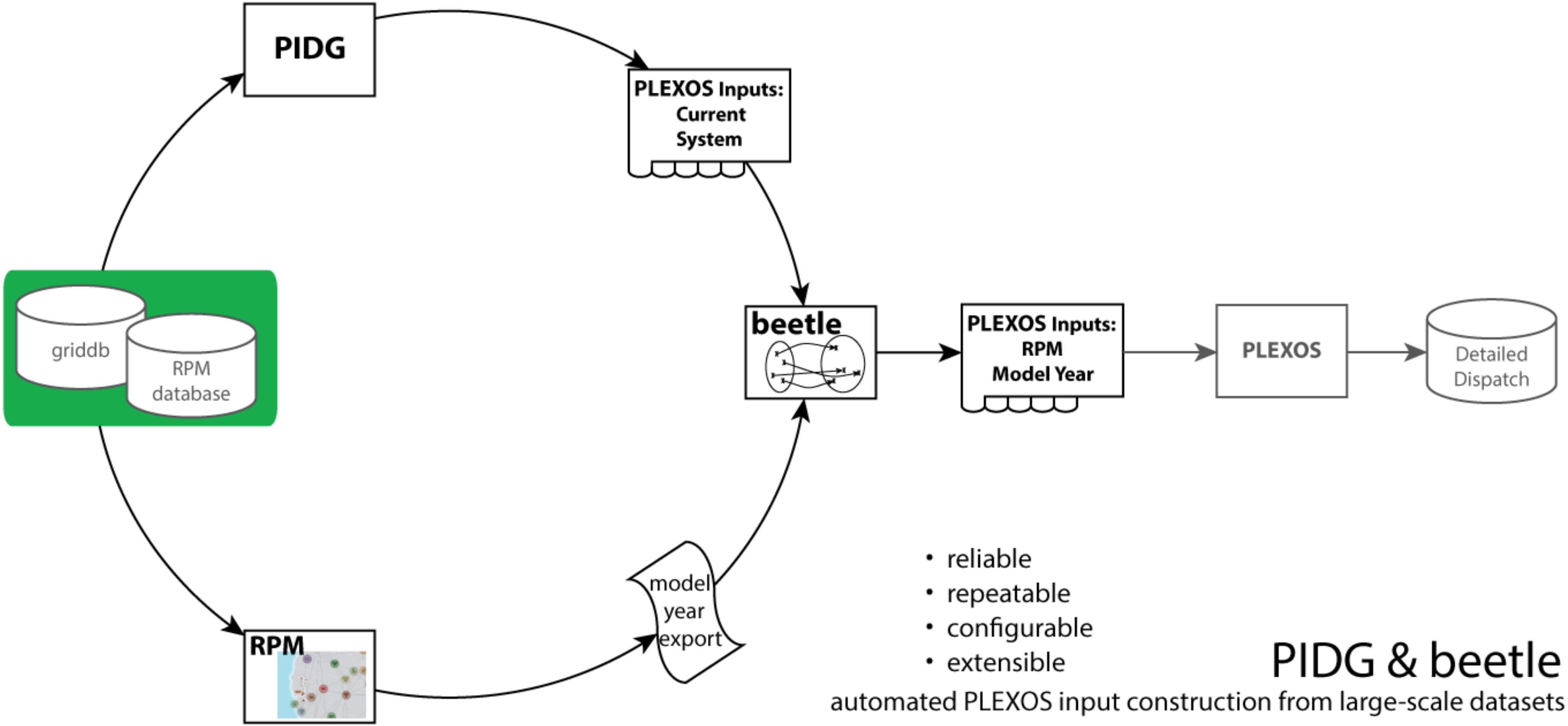
Contents

Integration with Distributed Generation Market Demand Model (dGen)



Calculate financial performance → Estimate maximum market share → Estimate rate of adoption

Automated toolchain enables production cost modeling (PCM) of expansion plans



- reliable
- repeatable
- configurable
- extensible

PIDG & beetle

automated PLEXOS input construction from large-scale datasets

References

Gagnon, Pieter, Brady Stoll, Ali Ehlen, Trieu Mai, Galen Barbose, Andrew Mills and Jarrett Zuboy. *Estimating the Value of Improved Distributed Photovoltaic Adoption Forecasts for Utility Resource Planning*, NREL Technical Report (2018)

Hurlbut, David et al. *Navajo Generating Station & Federal Resource Planning. Volume 1: Sectoral, Technical, and Economic Trends*, NREL Technical Report (2016)

Barrows, Clayton, Trieu Mai, Scott Haase, Jennifer Melius, and Meghan Mooney. *Renewable Energy Deployment in Colorado and the West: A Modeling Sensitivity and GIS Analysis*, NREL Technical Report (2016)

Hale, Elaine, Brady Stoll and Trieu Mai. *Capturing the Impact of Storage and Other Flexible Technologies on Electric System Planning*, NREL Technical Report (2016)

Getman, Dan, Anthony Lopez, Trieu Mai and Mark Dyson. *Methodology for Clustering High-Resolution Spatiotemporal Solar Resource Data*, NREL Technical Report (2015)

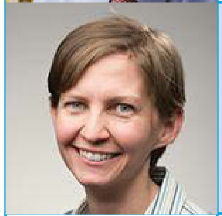
Mai, Trieu, Clayton Barrows, Anthony Lopez, Elaine Hale, Mark Dyson and Kelly Eurek. *Implications of Model Structure and Detail for Utility Planning: Scenario Case Studies Using the Resource Planning Model*, NREL Technical Report (2015)

Mai, Trieu, Easan Drury, Kelly Eurek, Natalie Bodington, Anthony Lopez, and Andrew Perry. *Resource Planning Model: An Integrated Resource Planning and Dispatch Tool for Regional Electric Systems*, NREL Technical Report (2013)

Who are we?

Clayton Barrows
Ph.D. Energy and Mineral Engineering
Pennsylvania State University

Anthony Lopez
M.S. Geographic Information Science
University of Denver



Elaine Hale
Ph.D. Chemical Engineering
University of Texas, Austin

Trieu Mai
Ph.D. Theoretical Physics
University of California, Santa Cruz

Dylan Hettinger
B.S. Geography
Appalachian State University

Daniel Steinberg
M.E.Sc Environmental Economics and Energy Analysis
Yale School of Forestry and Environmental Studies

Jennie Jorgenson
M.S. Mechanical Engineering
University of Colorado, Boulder

Brady Stoll
Ph.D. Mechanical Engineering
University of Texas, Austin

Thank you

www.nrel.gov

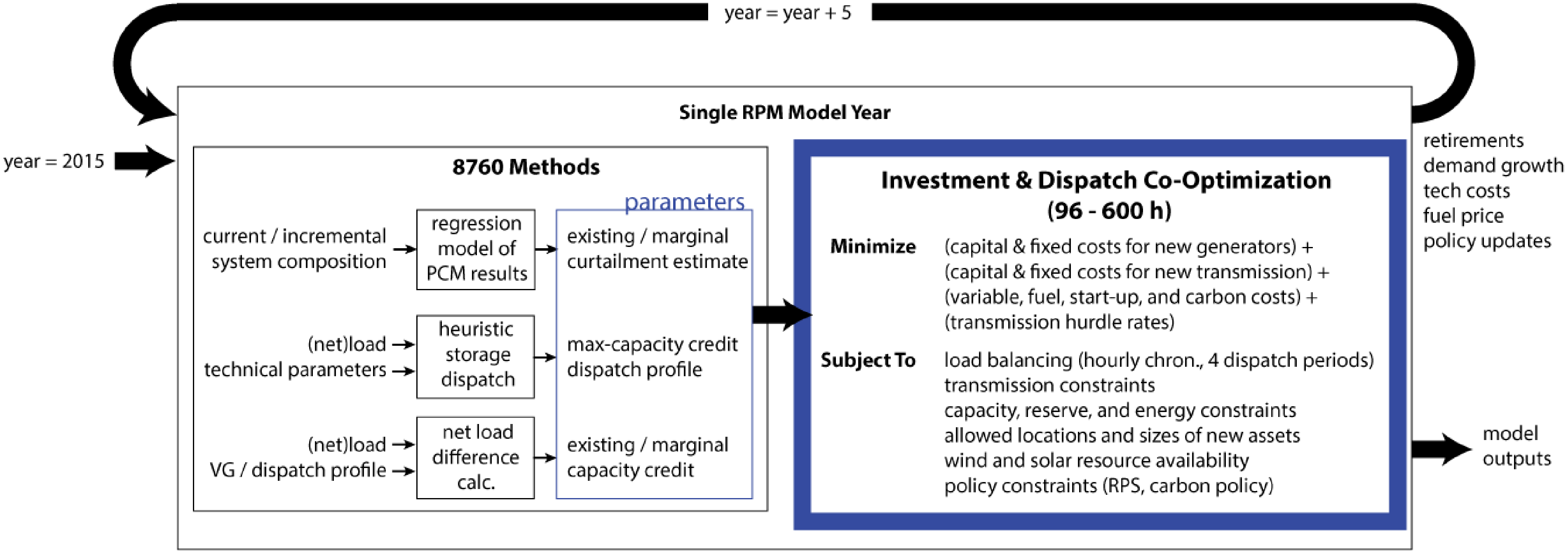
NREL/PR-6A20-71664

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Backmatter

Algorithmic Structure

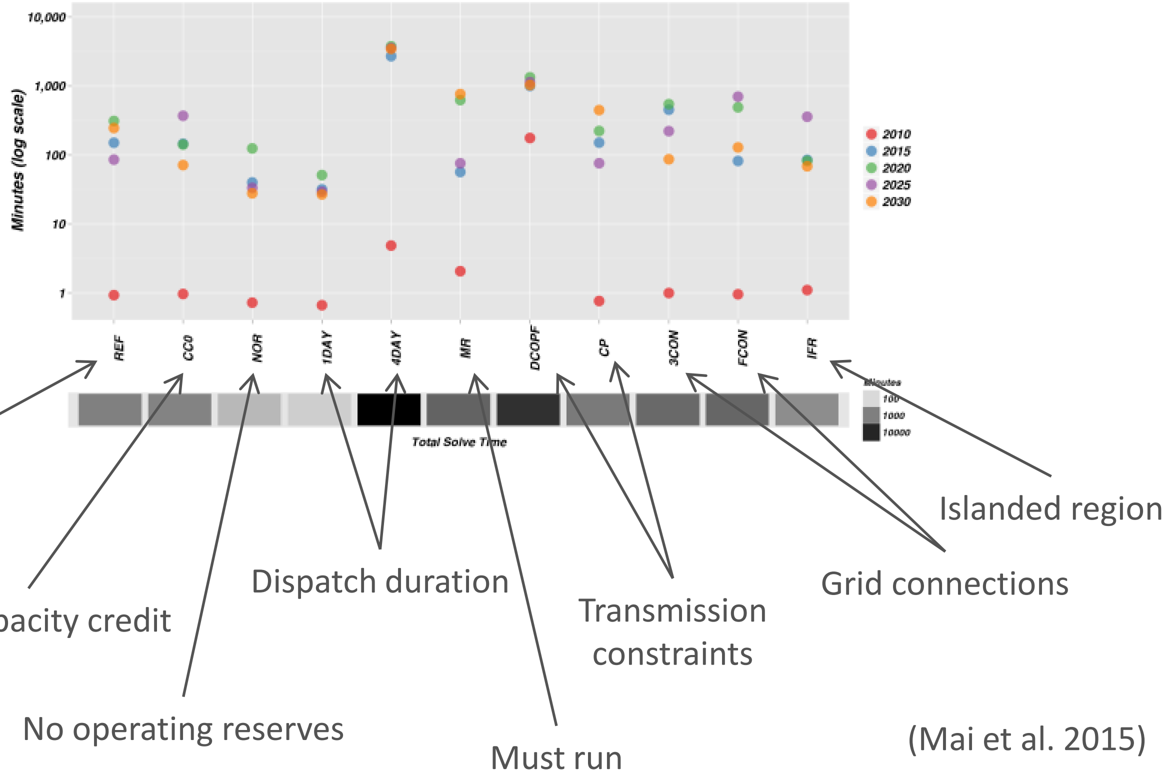


- Sequentially solves for resources that meet system needs at least cost
- 8760 methods adjust reduced-order co-optimization to dynamically account for VG & storage technology capacity value and curtailment impacts

Capacity Expansion Models Have to Balance Operational Detail with Computational Complexity

Computation Time as a Function of Model Configuration

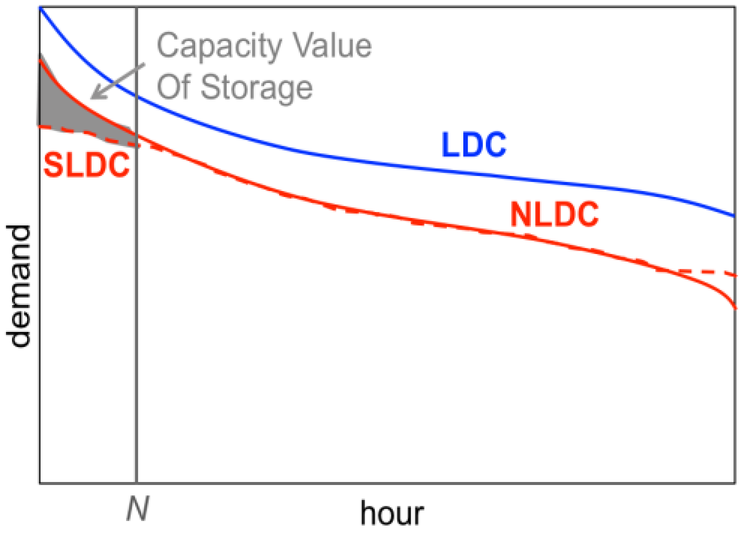
These have generally been improved, but the relative times are still illustrative.



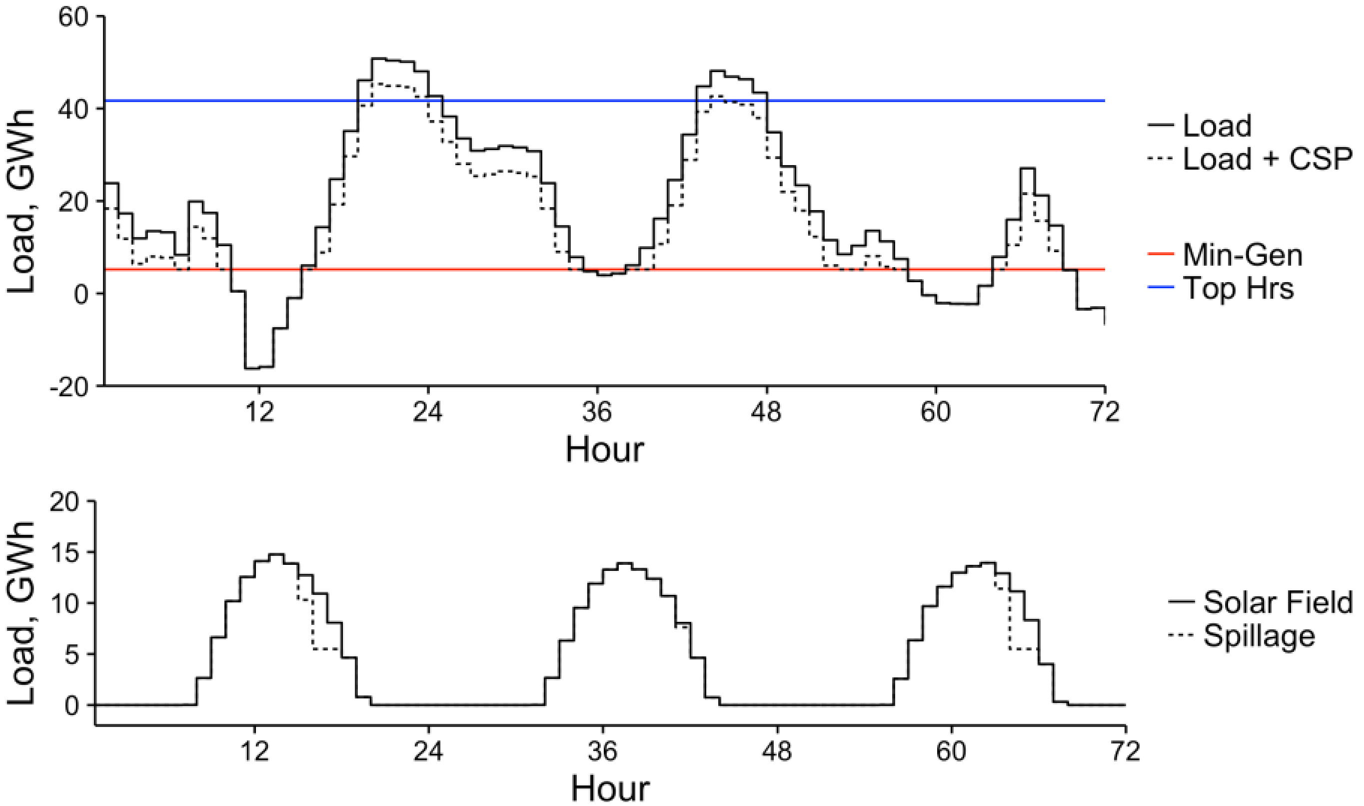
(Mai et al. 2015)

Storage Capacity Value

- Capture shift in net peak load based on top 100 hours
- Values geospatial and technology diversity
- At the NERC level and by storage technology:
  - capacity value of existing storage =
    $\langle NLDC - SLDC \rangle_{top\ 100}$ / existing capacity
  - marginal capacity value of new storage =
    $\langle SLDC(\delta) \rangle_{top\ 100} / \delta$

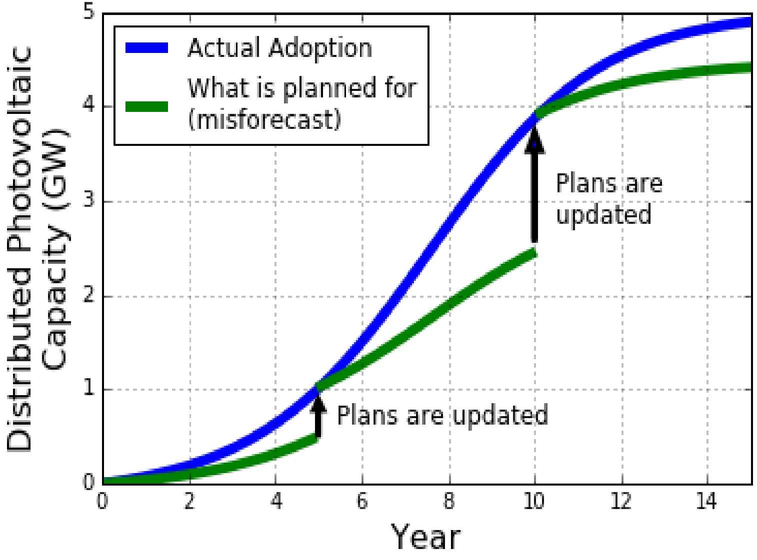


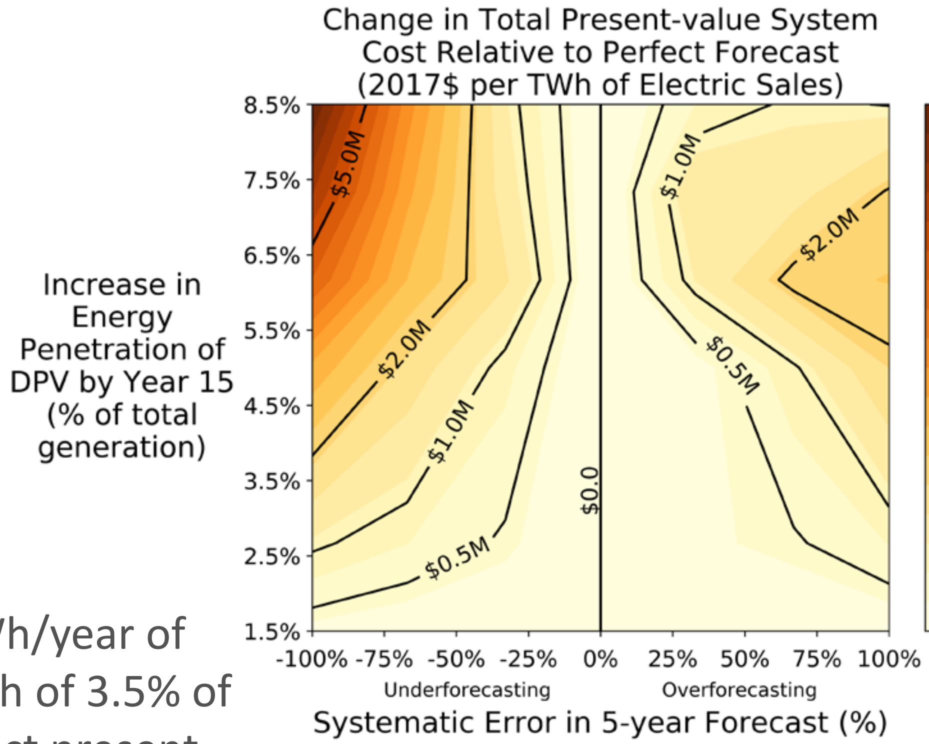
Capacity value of storage resource and required spillage (CSP with TES) is estimated using a heuristic dispatch algorithm applied to the NERC sub-region net load curve



Concentrating Solar Power with Thermal Energy Storage (CSP with TES) Example

What is the cost of misforecasting distributed PV adoption (and what is the value of improving it)?





Example result: A large utility with 10 TWh/year of retail sales that is planning for DPV growth of 3.5% of total generation over 15 years could expect present-value savings of $4.0 million by reducing its DPV forecast uncertainty from roughly +75%/-55% to ±25%.

(Gagnon et al. 2018)