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8760-Based Method for Representing Variable Generation Capacity Value in Capacity Expansion Models

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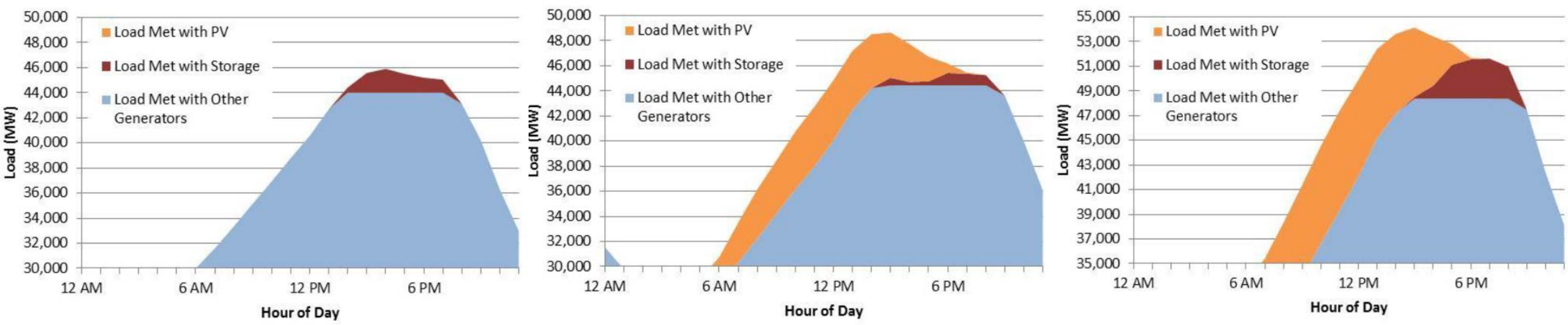
What is the “8760 method”?

- Alternate method to calculate annual **capacity value** (CV) and (eventually) timeslice **curtailment** using **8760-hourly** load and variable generation (VG) data
- “8760” but only use top 100 hours for CV
- Curtailment based only on hours when net load < mingen
- Within ReEDS, CV is implemented in planning reserve (capacity) constraint; curtailment in surplus (energy) constraint

See Eurek et al. (2016) for description of ReEDS model

Why are we doing this?

- CV matters for resource adequacy via planning reserve constraint → **reliability**
- Curtailment (specifically impact from storage/DR, "mingen" level, and transmission) is increasingly important (and complicated) with higher VG penetration levels → **flexibility**



a) Zero PV (October 12)

b) 5% PV (June 30)

c) 10% PV (September 9)

Impact of PV on netload profile and 4-hour storage effective market potential in California in 2015

Source: Paul Denholm

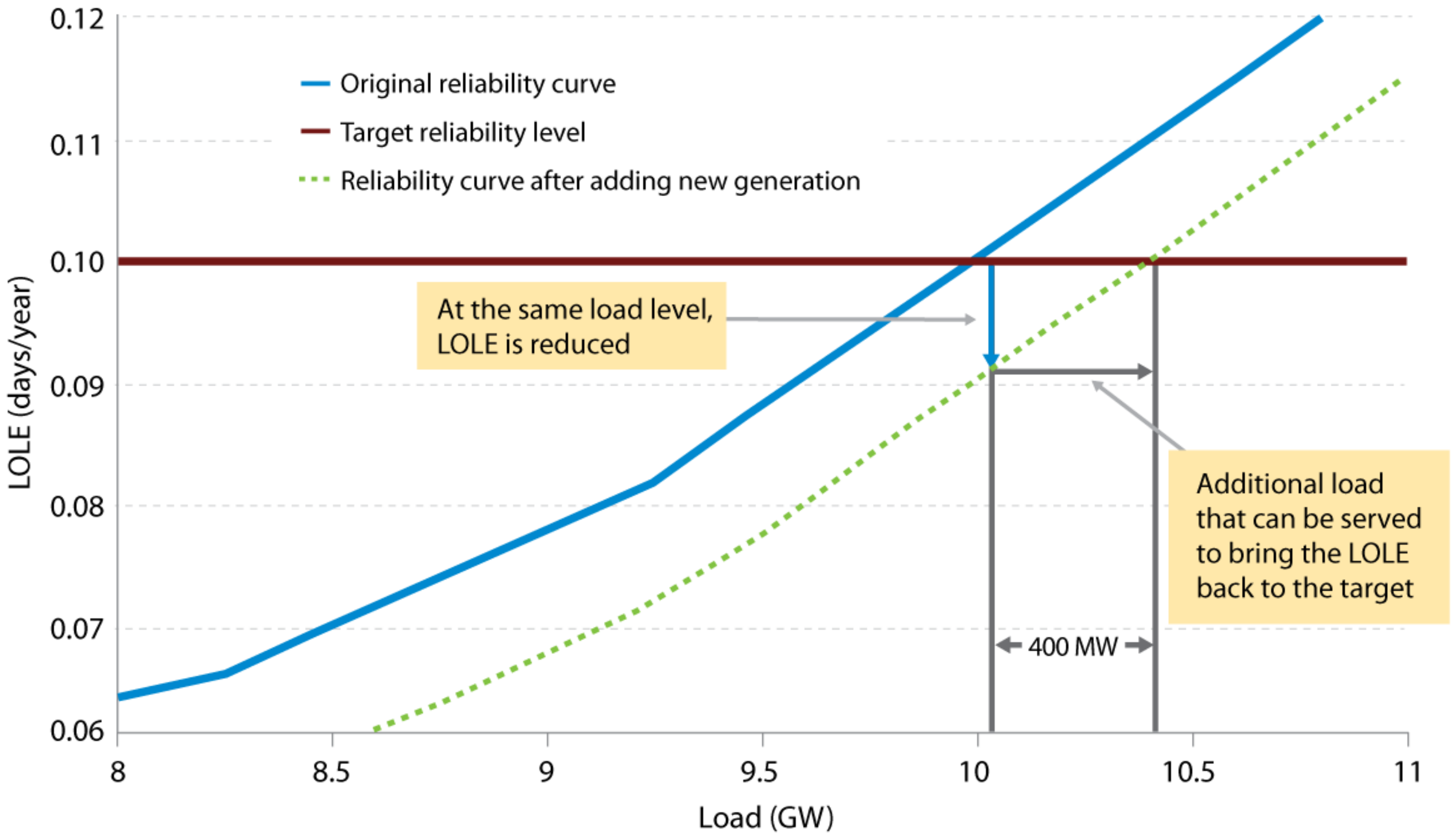
Current status

- **CV**
  - Validated and implemented in v.2017 of ReEDS
  - Increases run time by < 10% (adds 40min to 7.25hr)

Focus of this slide deck is CV, but also includes progress on related curtailment capability

- **Curtailment**
  - Functioning script (mostly) but need to finalize transmission treatment

CV is ideally calculated as the ELCC



- We care about Effective Load Carrying Capability (**ELCC**) in highest Loss of Load Probability (**LOLP**) hours
- See Hasche et al. (2011) for inter-annual variability

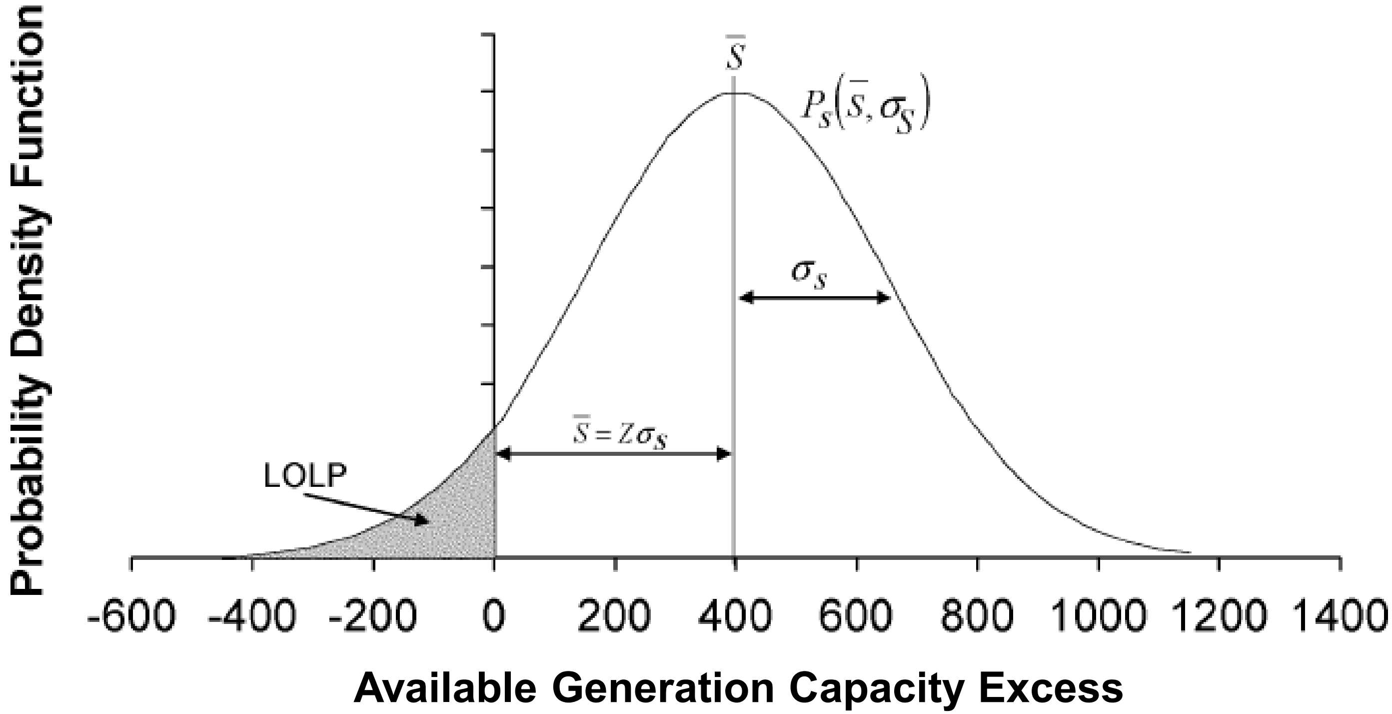
Modeling CV in CEMs: Simplifications

- **ELCC estimations**
  - Approximate the relationship between capacity additions and LOLP
  - e.g., Z-method (Dragoon and Dvortsov 2006), Garver's method (Garver 1966), and Garver's method extended to multistate generators (D'Annunzio and Santoso 2008)

- **Capacity factor proxy**
  - Applied to "high risk" hours (e.g., Milligan and Parsons 1999 for wind, Madaeni et al. 2013 for solar)
  - Applied to top load hours in load duration curve (LDC) (Hale et al. 2016)

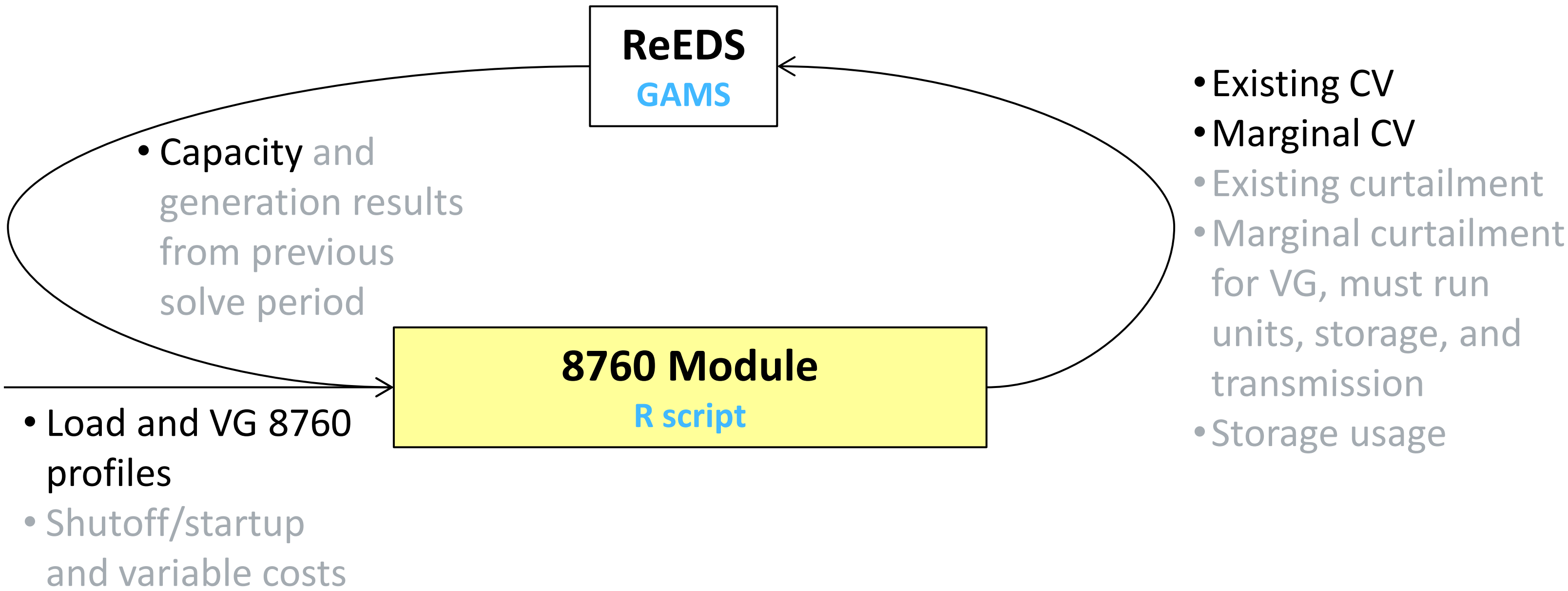
ReEDS: 8760 method is replacing statistical method

- **CV**: additional load that can be served (ELCC) by an additional unit of capacity (e.g., VG) while maintaining the same level of reliability (LOLP) – see curve below
- **Curtailment**: similar concept, but uses different "surplus" curve to calculate the difference in area under curve with-VG and without-VG



Source: Dragoon and Dvortsov (2006)

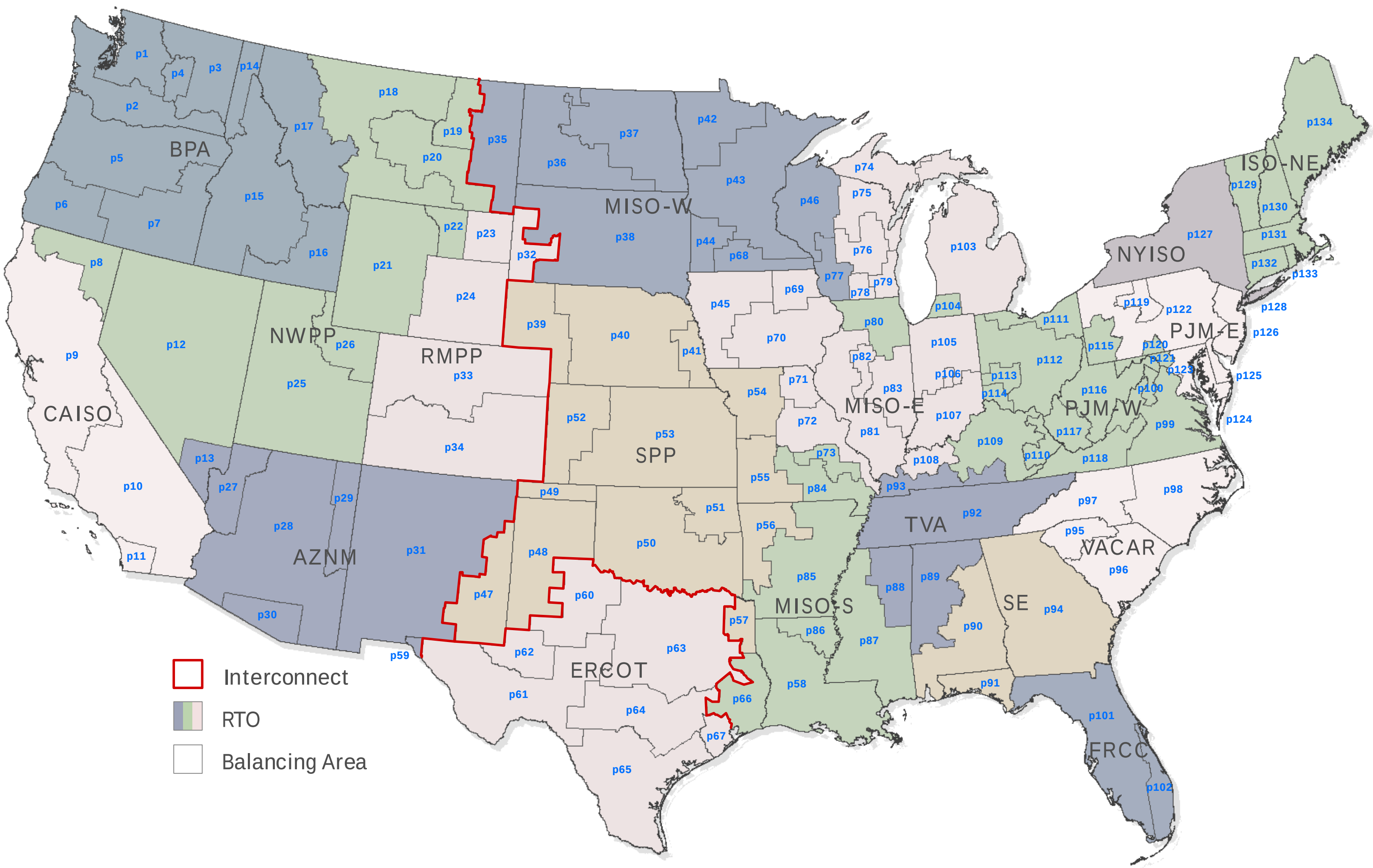
8760 method runs outside of GAMS between 2-yr solve periods



Gray text indicates future model development related to curtailment

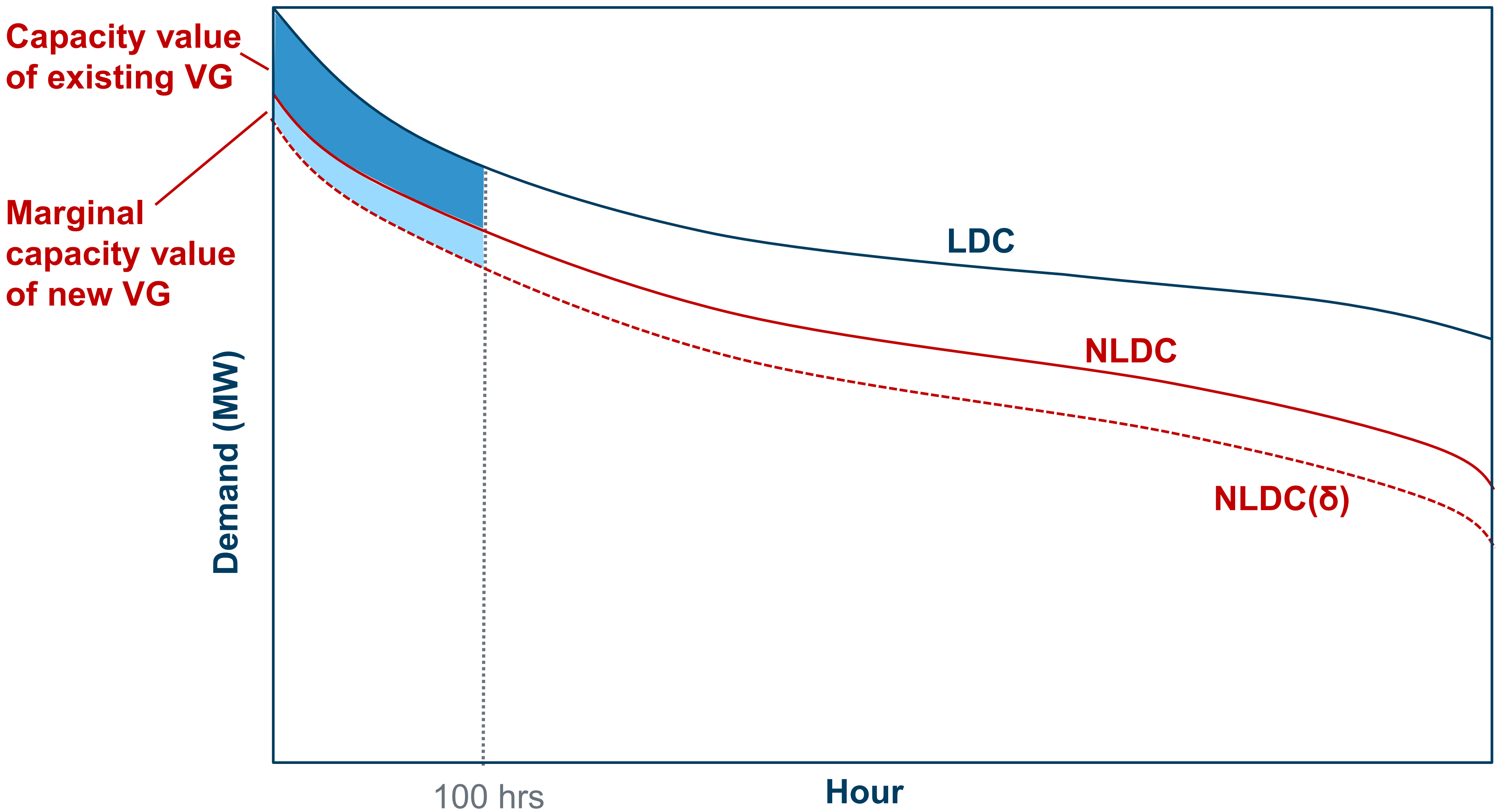
CV calculated at RTO-level, curtailment at BA-level

Map of ReEDS 134 "Balancing Area" regions and 18 “RTOs”



CV estimated as capacity factor during top hours in LDC

LDC = load duration curve; NLDC = net load duration curve

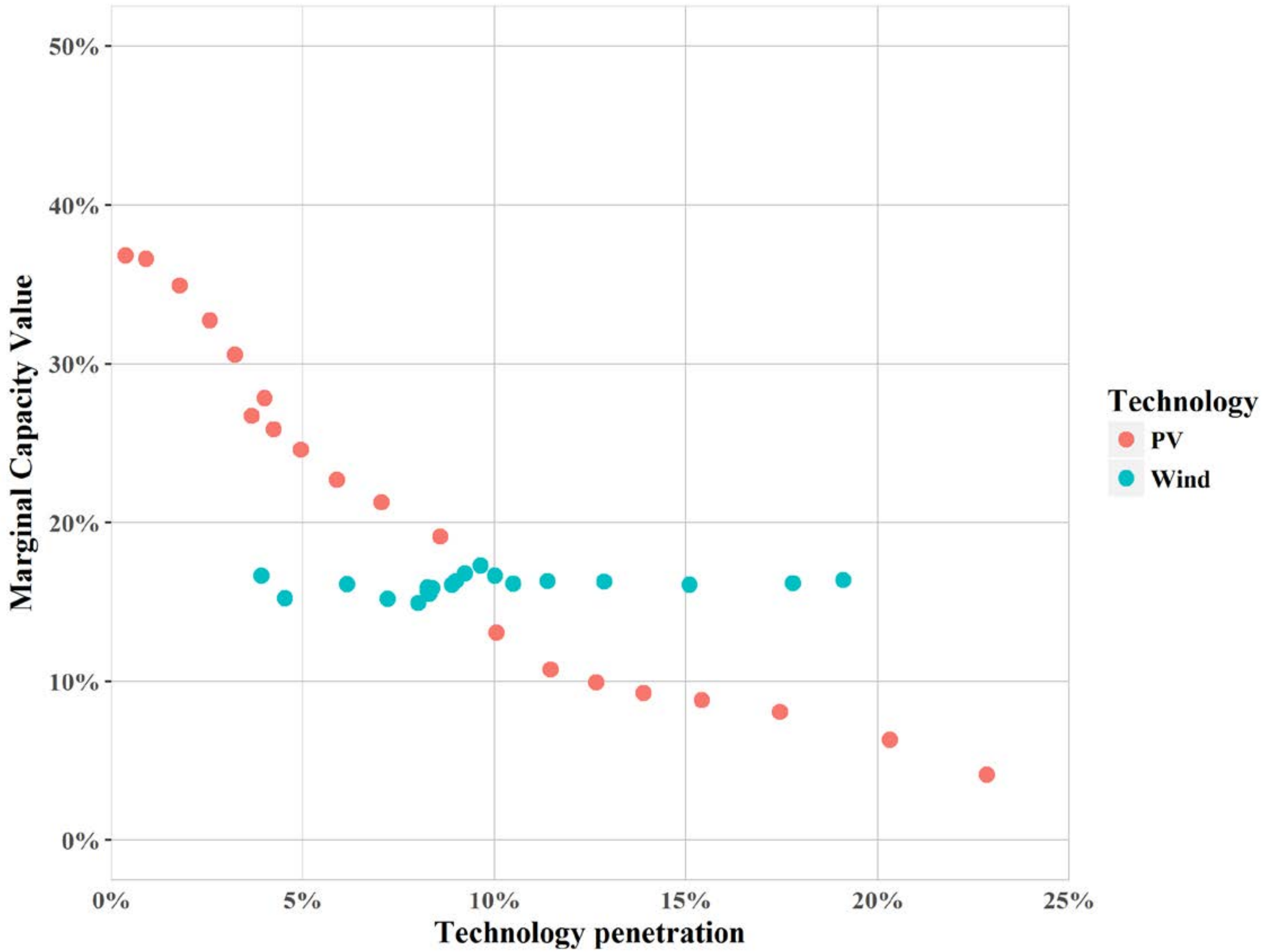


Consistent methodology with NREL's RPM model (Hale et al. 2016)

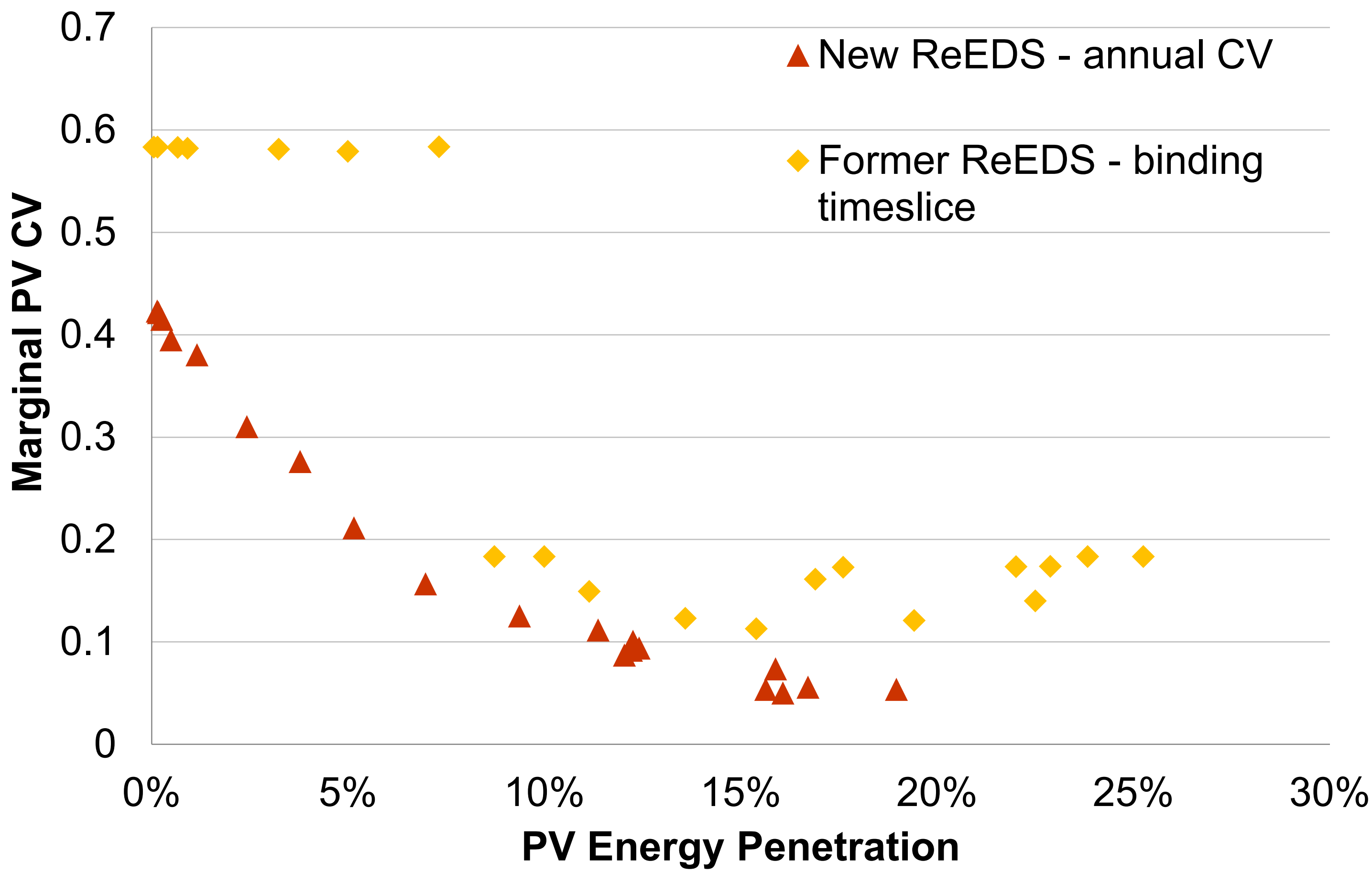
PV CV declines because of shift in peak *net load* hours

National median marginal CV for PV and wind with new ReEDS CV method

Results vary by individual regions; wind CVs remain flat because of placement of windy hours in peak net load hours



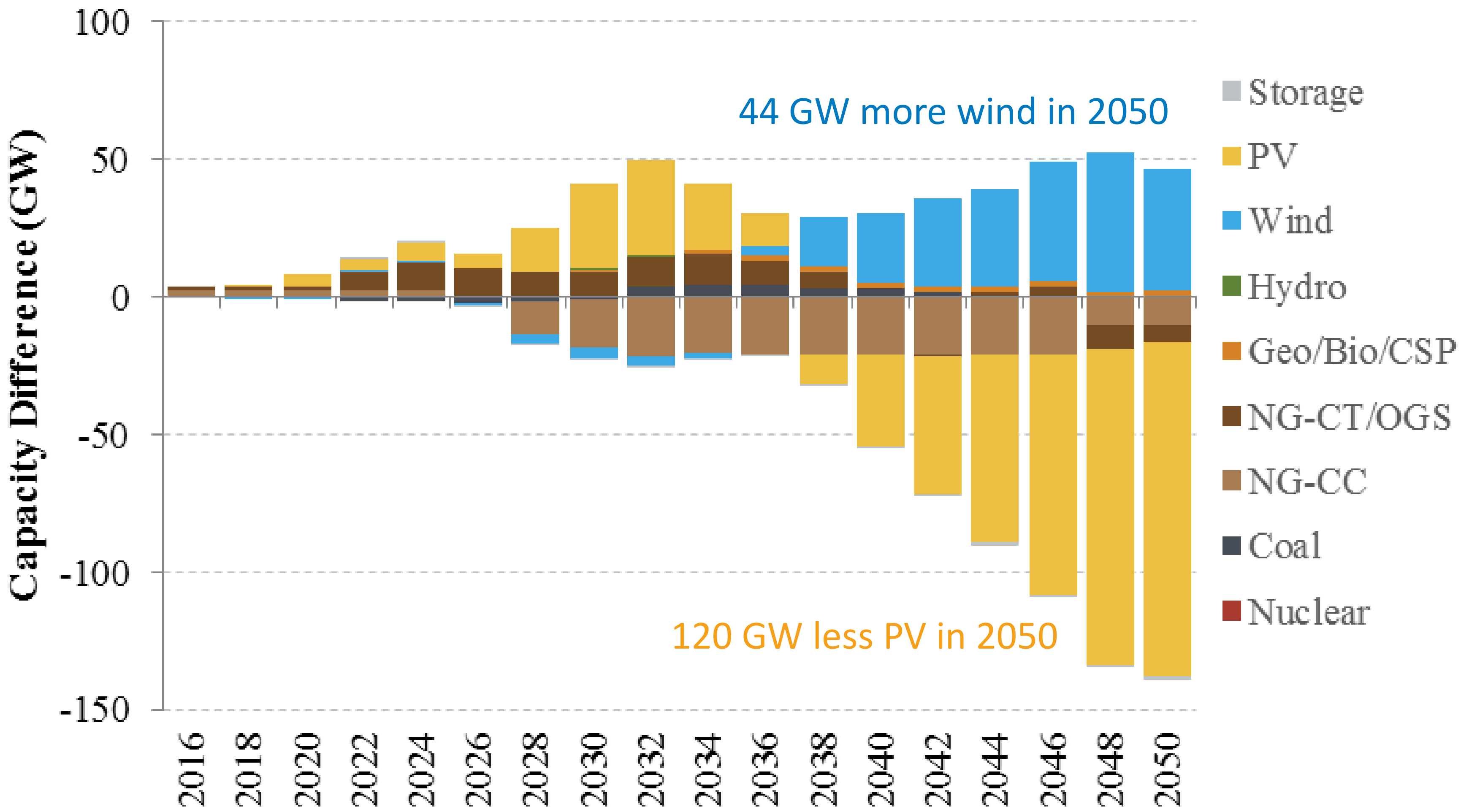
8760 method better captures declining CV



Incremental PV CV in the Austin, Texas region (p64)
"New ReEDS" is 8760 method; "Former ReEDS" is statistical method

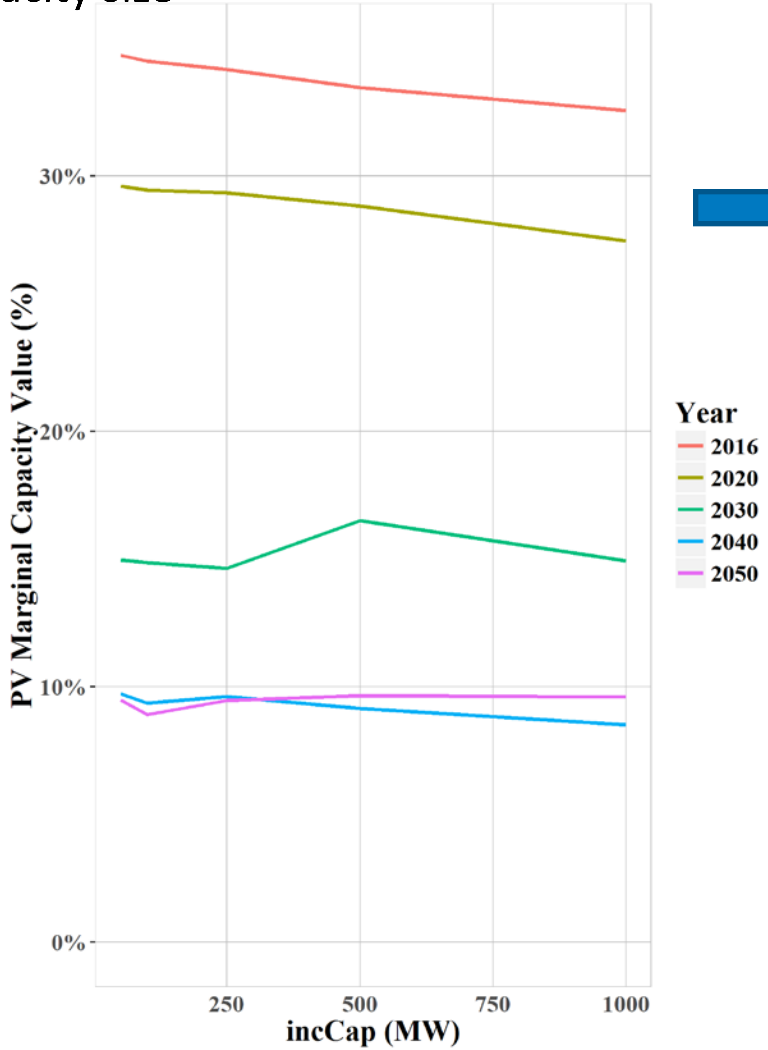
8760 CV method yields more PV early on, less in later years

8760 method minus old ReEDS method nationwide installed capacity

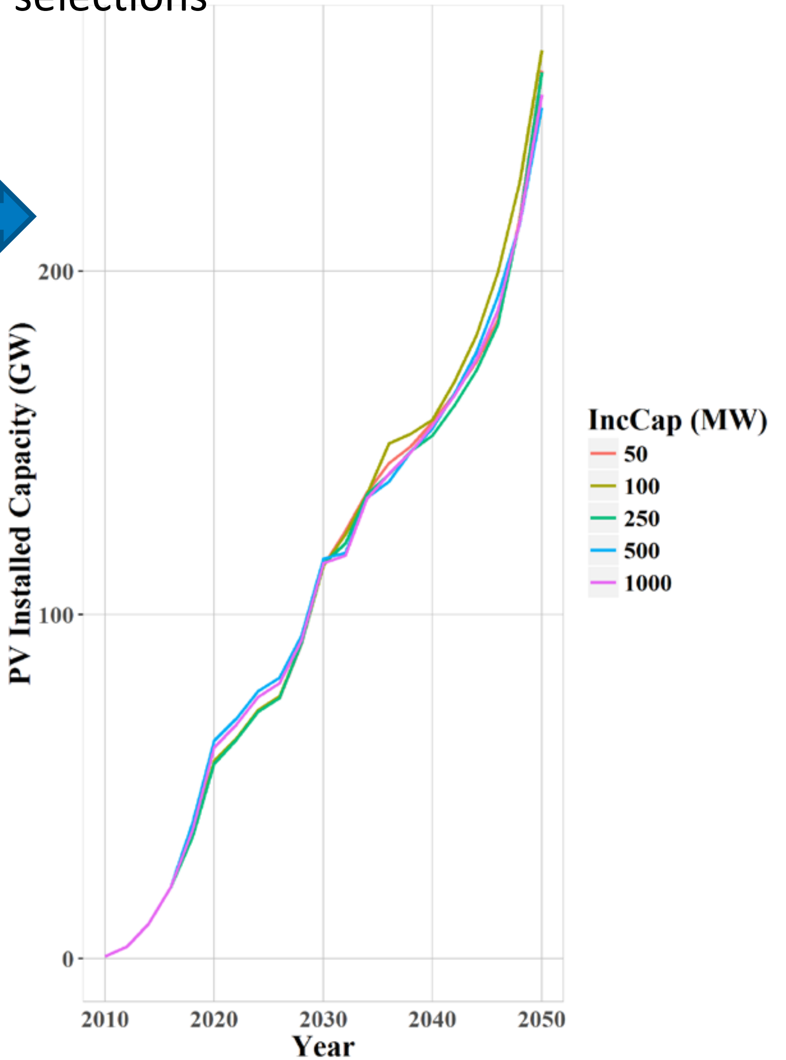


Deployment insensitive to marginal CV increment size

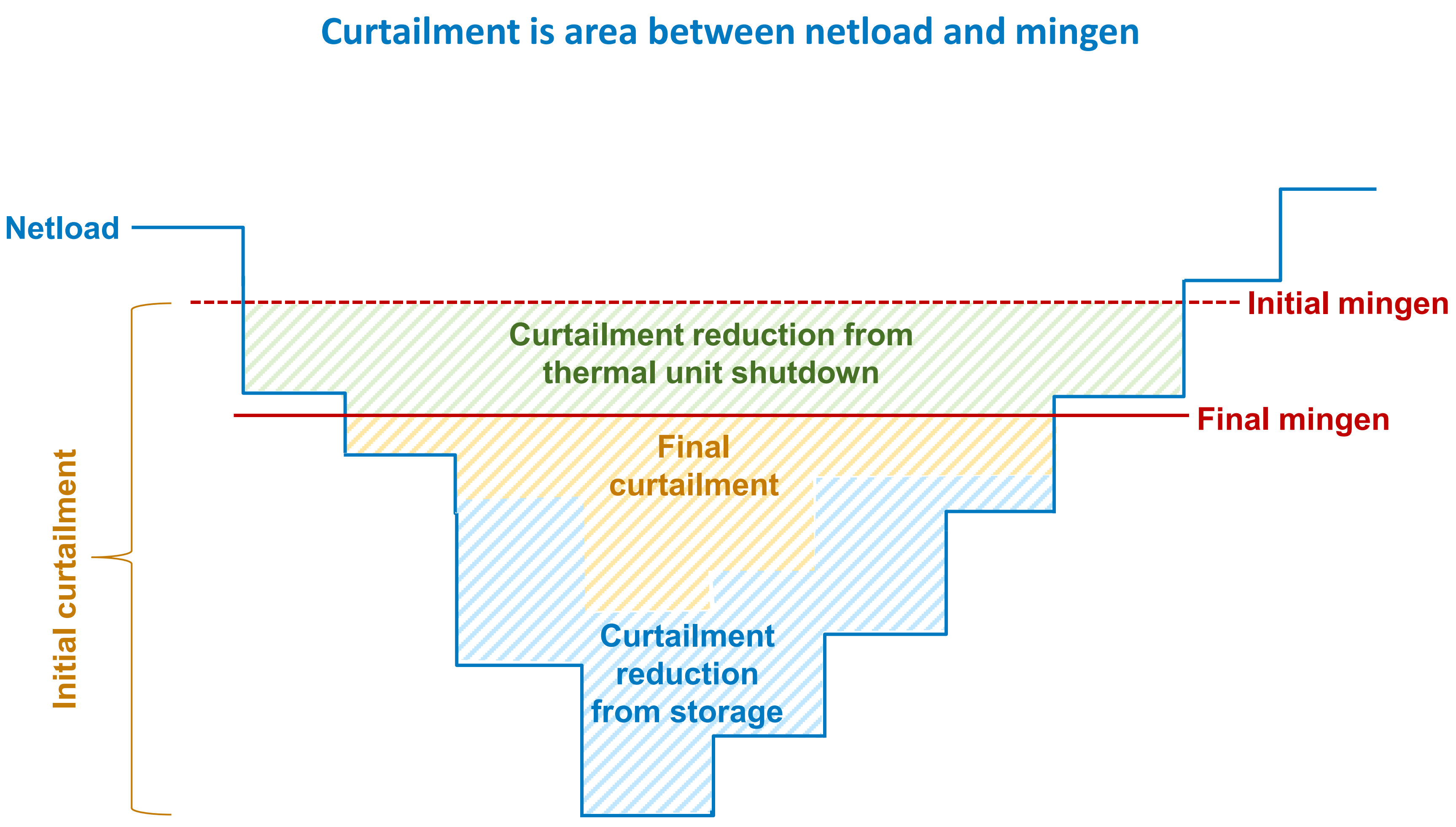
PV marginal capacity value (median value across resource regions) by incremental capacity size



National installed PV capacity by year for different incremental capacity value selections



Up next: Curtailment and related metrics



8760 curtailment method faces "Goldilocks" problem

- **Spatial treatment**: RTO-level yields too little curtailment, but BA-level yields too much
- **Proposed solution**: calculate at the BA-level and then apply BA-level marginal reduction/increase in curtailment due to potential BA-to-BA transmission flows (export/import)

Benefits of 8760-based method

- **Flexible platform** to incorporate additional 8760-based features, including **chronological** operation (e.g., storage, mingen, DR, transmission)
- Captures **interaction of different technologies** on both existing and potential new VG, including the impact of coincident VG
- **VG parameters updated** after each solve year to capture system evolution
- **Resolved** by VG technology, resource class, and region

Next steps

- Finalize curtailment spatial treatment
- Add estimation of storage CV
- Incorporate additional years of 8760 data
- Continue to test/tune assumptions
    - How many top hours in CV? Would individual hours be better than annual CV?
- Continue to improve run time and memory usage

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