National Renewable Energy Laboratory
Innovation for Our Energy Future

Estimating the Costs and Benefits of Avoided Generation Capacity

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Estimating Capacity Value Involves 2 Steps

1) Determine *capacity credit*, i.e., the fraction of a DET's capacity that adds to system reliability.
2) Translate capacity credit into a monetary value, i.e., *capacity value*.

Note: In the literature *capacity credit* and *capacity value* are often used interchangeably. Here following Mills and Wiser (2012) we use capacity credit to refer to physical capacity and capacity value to refer to economic value (measured in $ or $/MW).

1) Methods to Calculate Capacity Credit

Name	Description	Tools Required
Capacity factor approximation using net load	Examines output during periods of highest net demand	Spreadsheet
Capacity factor approximation using loss of load probability (LOLP)	Examines output during periods of highest LOLP	Spreadsheet
Effective load-carrying capacity (ELCC) approximation (Garver's Method)	Calculates an approximate ELCC using LOLPs in each period	Spreadsheet
Full Effective load-carrying capacity (ELCC) calculation	Performs full ELCC calculation using iterative LOLPs in each period	Dedicated tool

Capacity Factor Approximation Methods

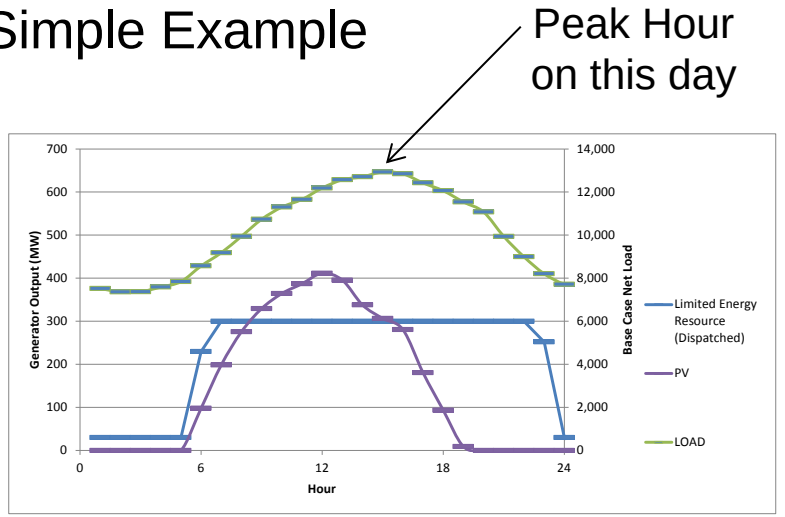
Basic Method:

- Examine generator output/ capacity factor during periods of high net load or periods of highest risk
- Choice of peak period (top 100 hours, top 1% etc) can significantly influence results

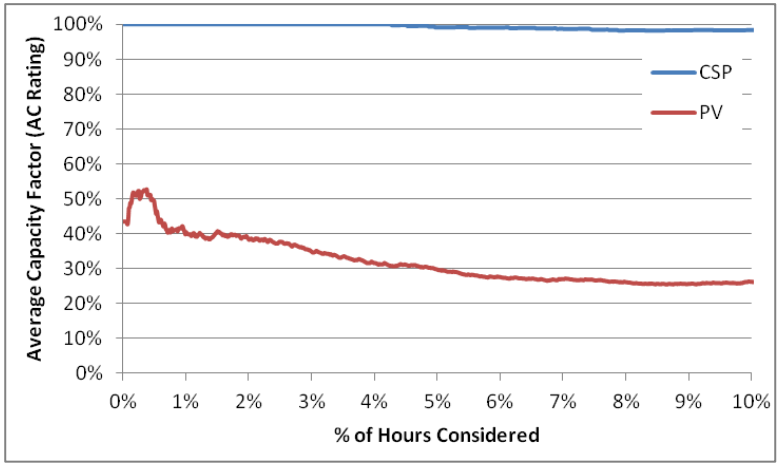
Pros/Cons

- Very easy, useful for rough estimates
- Requirements are only load, DET profiles and a spreadsheet
- Still somewhat common although decreasingly so…

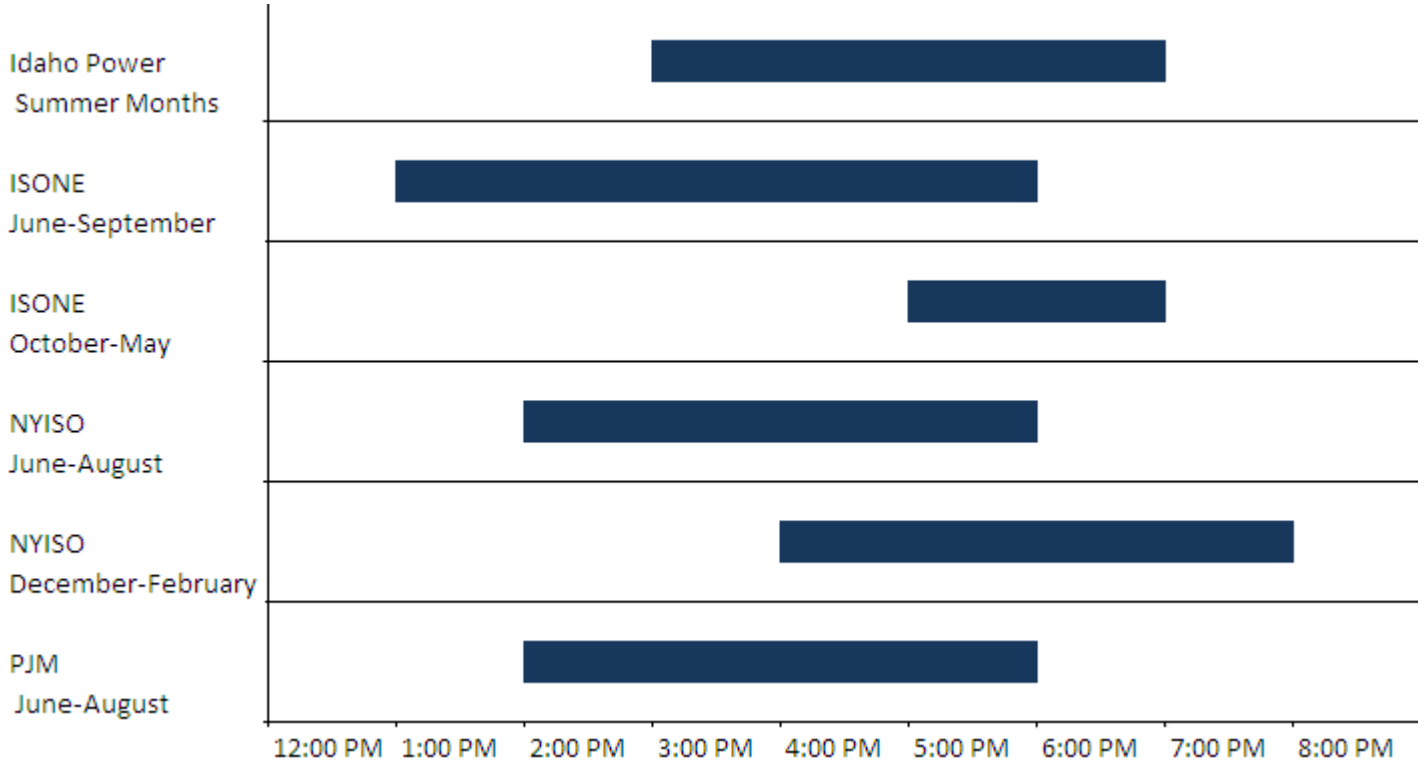
Simple Example



But period examined is important



Examples of Peak Periods used for Capacity Value Approximation Methods in the United States

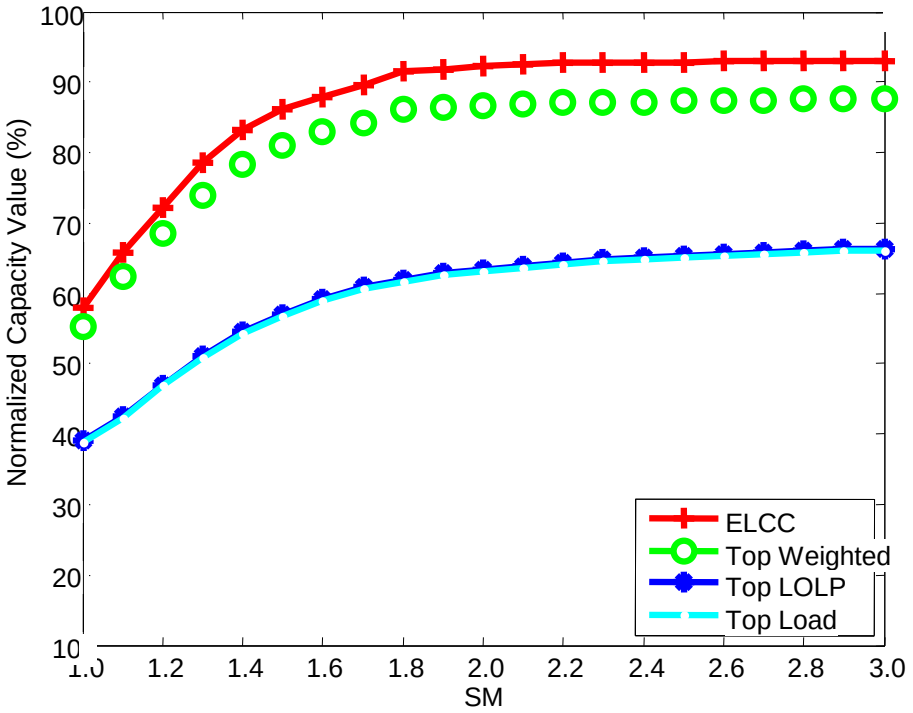


Rogers and Porter (2012), “Summary of Time Period-Based and Other Approximation Methods for Determining the Capacity Value of Wind and Solar in the United States.” NREL Subcontract report. Available at http://www.nrel.gov/docs/fy12osti/54338.pdf

CF Approximation Methods may not Fully Measure Contribution to Resource Adequacy

- DET generation-load relationship is only part of the equation
- Capacity factor, even during peak periods, won't capture annual risk profile
- Improvement is to use CF during period of high risk (high LOLP periods)
- All CF based approaches are inherently limited

Comparison of Capacity Factor Methods for CSP with Increasing Levels of Storage



Reliability (ELCC) Based Approach

How does ELCC work?

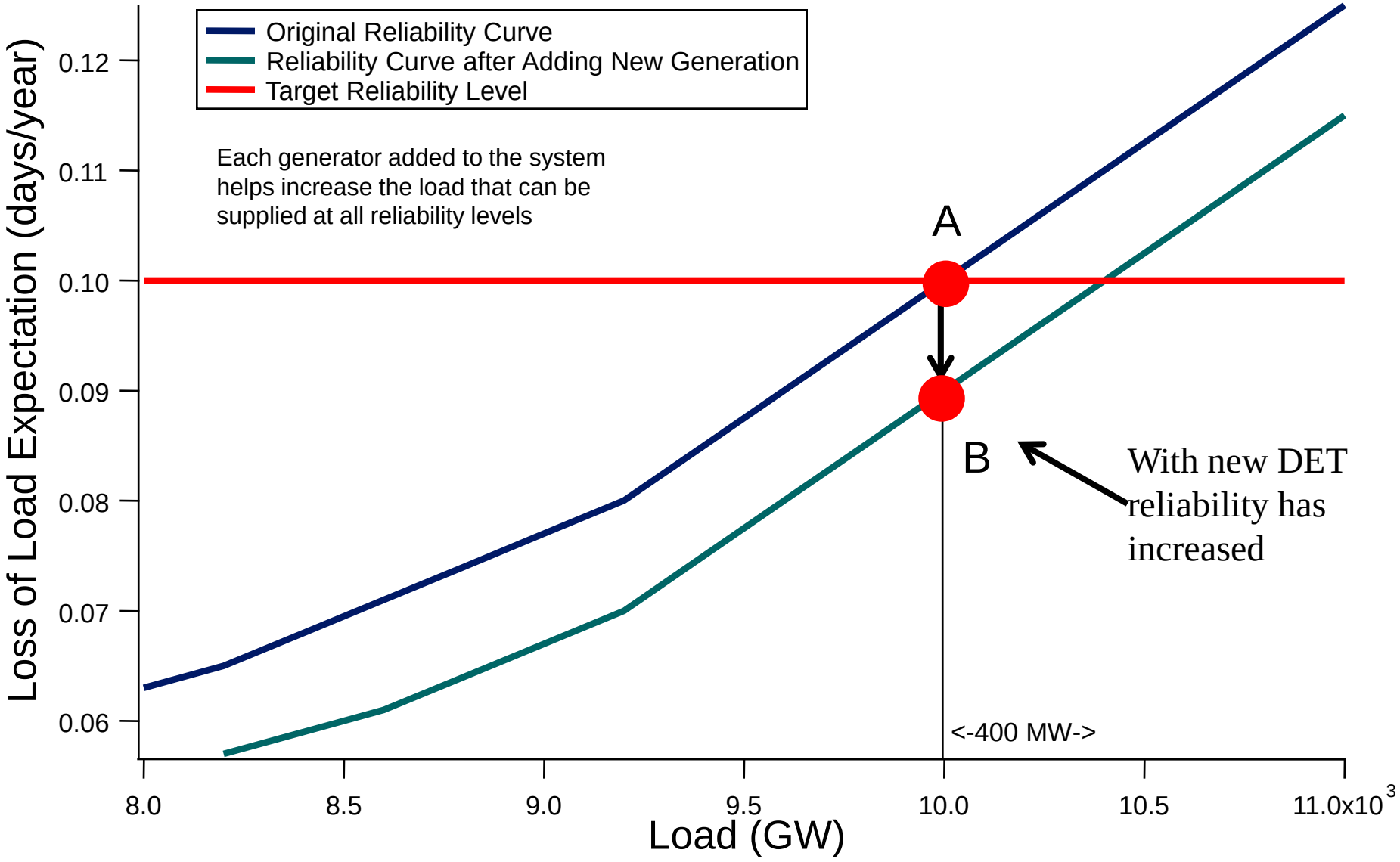
- Holds the system at constant annual risk level with/without the generator of interest (wind, solar, etc.)
- Utilizes reliability/production simulation model
  - Hourly loads
  - Generator characteristics
  - DET generation pattern (hourly for >= 1 year) time-synchronized with load
  - Calculates hourly LOLP (loss of load probability)
- The hourly LOLP calculation finds high-risk hours: risk can be caused by
  - Peak loads
  - Unit unavailability (planned maintenance)
  - Interchange and hydro schedules/availability
- Most hours/days have LOLP=0 so are discarded: only high-risk/peak hours remain in the calculation of ELCC
- Conventional units ELCC is function of FOR (forced outage rate)

Steps to Calculating ELCC

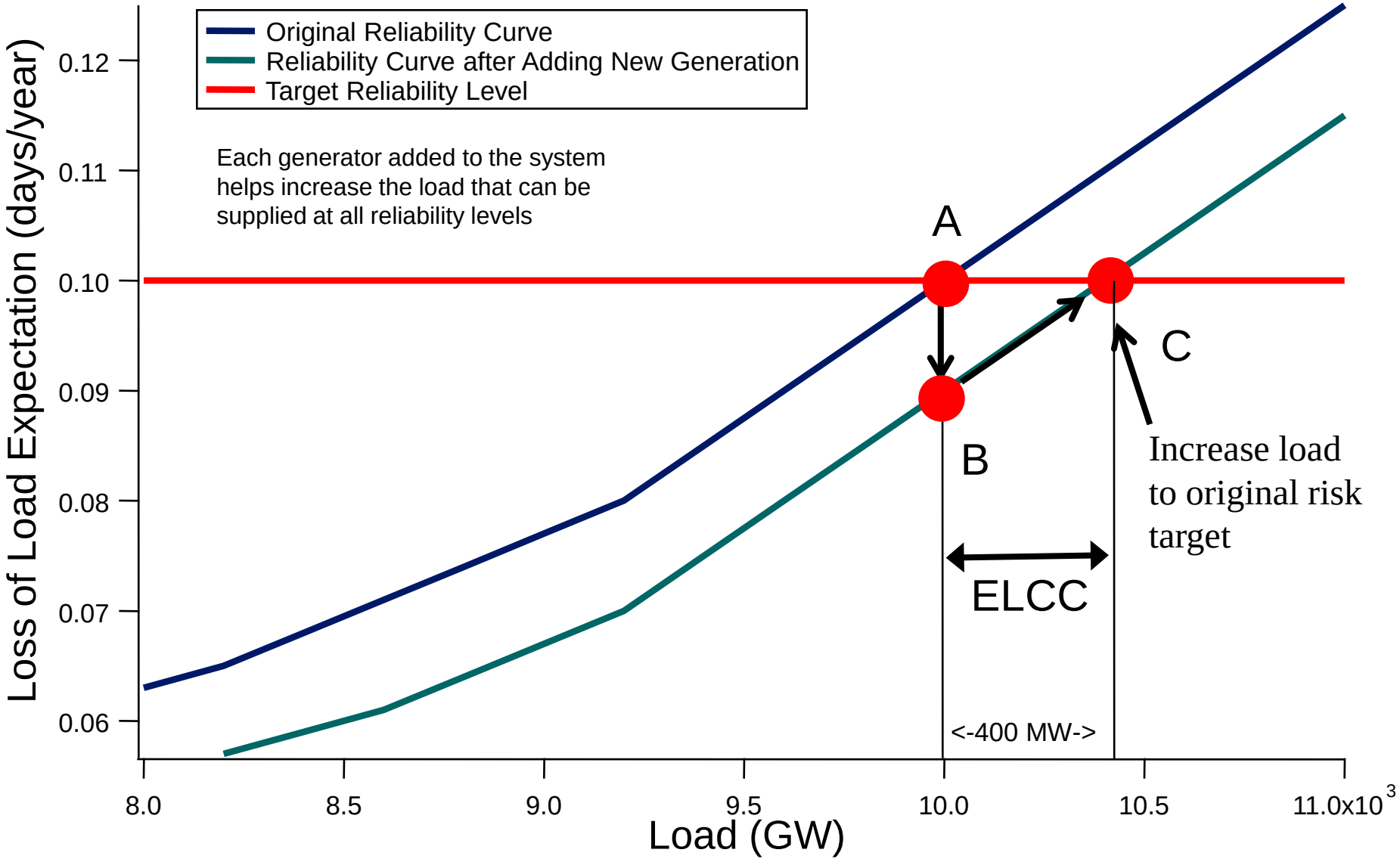
A. Develop benchmark system excluding DET that meets the target reliability level (1 day in 10 years is a common target)
B. Add DET and rerun model, noting annual reliability (this is the DET case)
C. Incrementally increase load until annual reliability matches the benchmark system case

The capacity of the added load is the ELCC of the DET

A) Benchmark System ➔ B) with DET



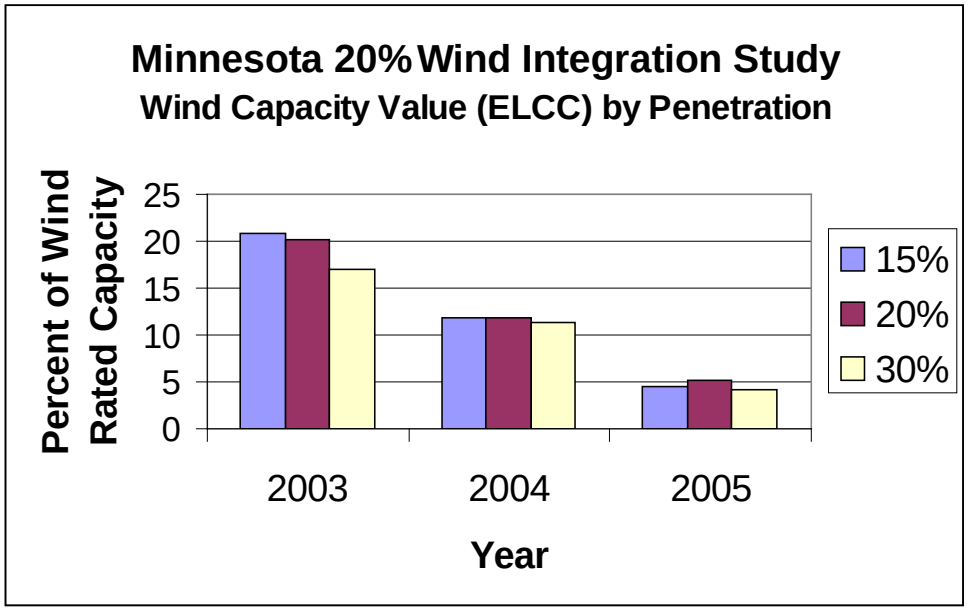
C) Return to Target Reliability Level



ELCC Data Requirements

- Hourly DET generation and load data must be from the same year
- State of the art is to use meso-scale weather models or actual DET production data (same as integration studies)
- Want to preserve underlying correlations between DETs and load with weather, etc.

➢ *Should use multiple years of data*

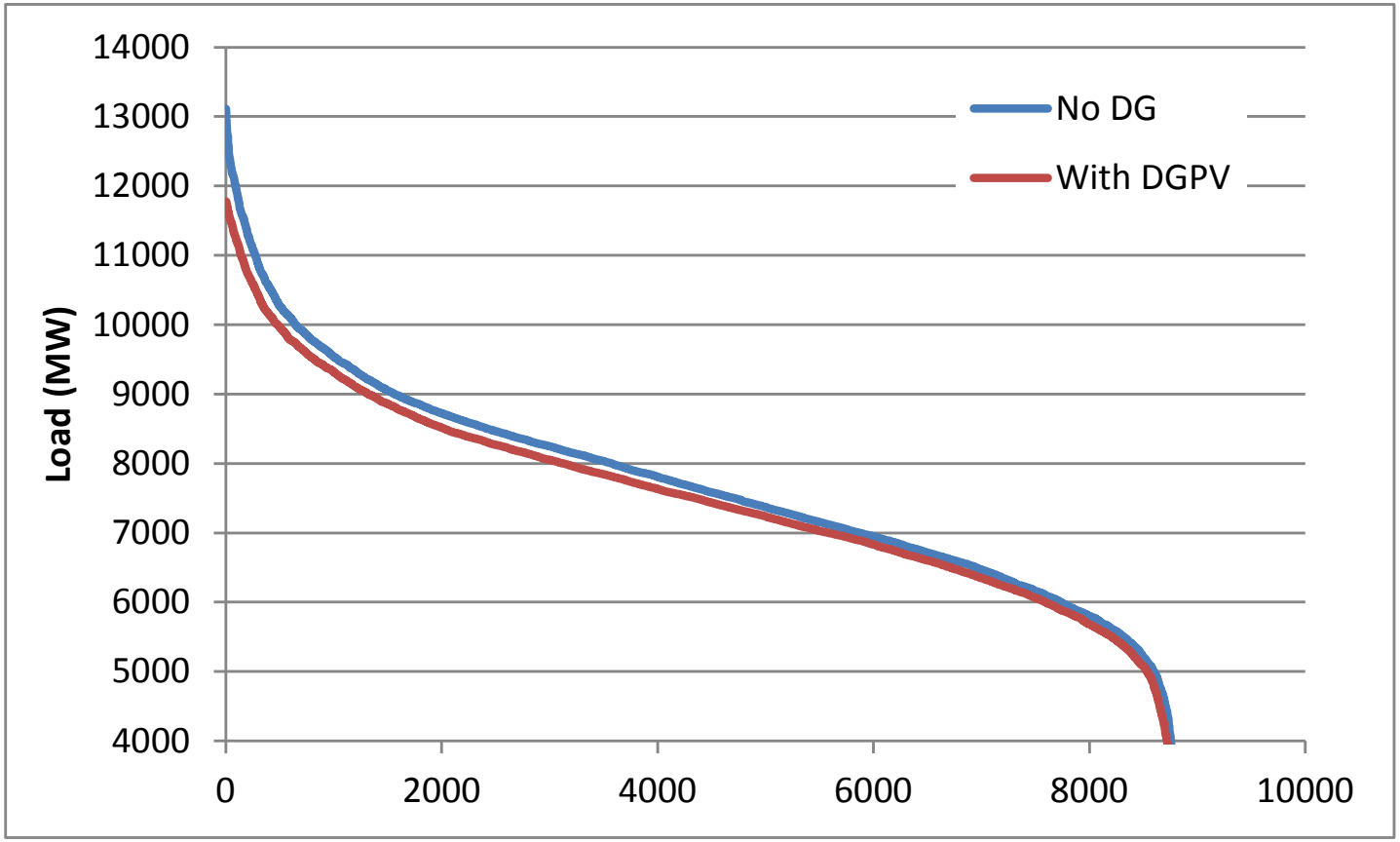


- Generator capacity, forced outage rates
- Maintenance schedules
- Hydro schedules
- Transaction schedules
- Transmission limits
- Calculation over large part of the interconnection with transmission
- ***All of these will have some influence on LOLP and therefore VG ELCC***

2) Translating Capacity Credit to $ Value

Name	Description	Tools Required
Simple avoided generator (CT)	Assumes DG avoids construction of a new CT	None
Weighted avoided generator	Assumes DG avoids a mix of generators based on avoided fuel	None
Capacity market value	Uses cost of capacity in restructured markets	None
Screening curve	Uses system load and generation data to estimate avoided generation mix based on capacity factor	Spreadsheet
Complete valuation of DET versus alternative technologies	Estimates the type or mix of generators avoided in subsequent years using a capacity-expansion model	Detailed capacity-expansion model

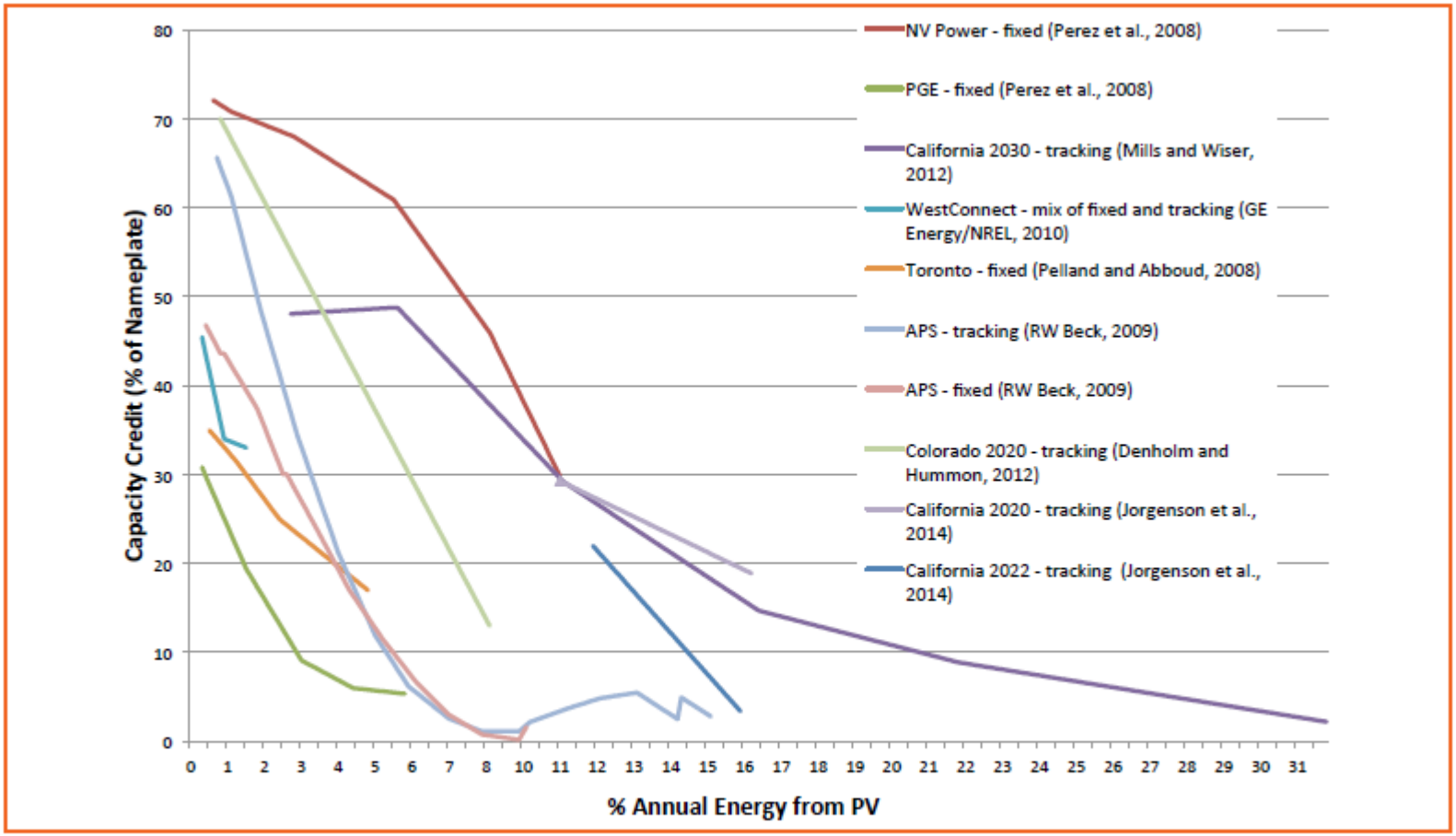
DETs May Avoid a Mix of Generation Types



Bottom line….

- Lower Bound Value – DET avoids only CTs
- Upper Bound Value– DET avoids CCs

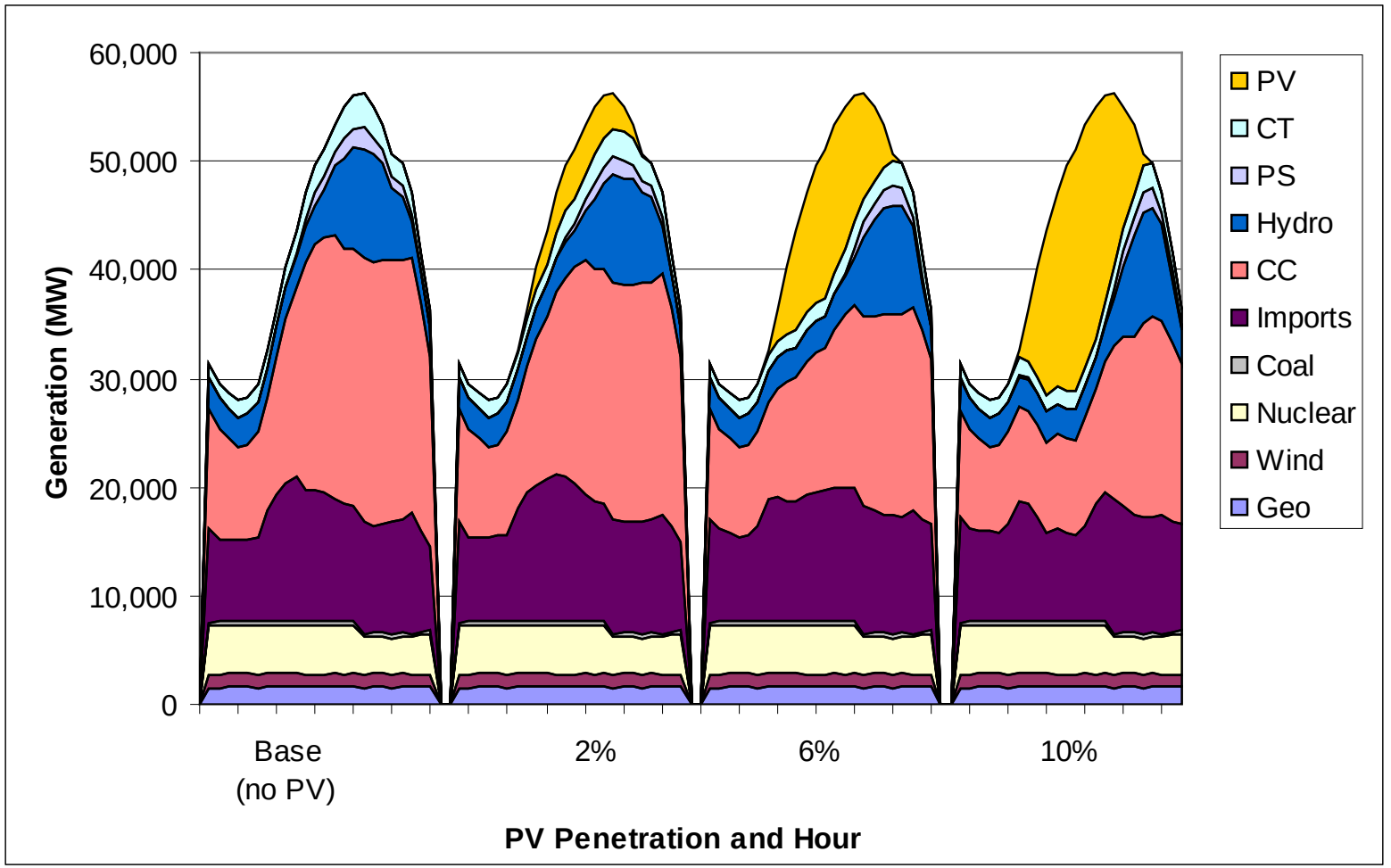
Capacity Value Depends on Level of Penetration



Source: Mills and Wiser (2012); adapted with additional results in Helman (2014).

Most studies indicate that by 10% energy penetration capacity credit and capacity value of DG PV is very low

Could see Interactions between DETs



Here PV narrows the peak, which could ease the ability of demand response, hydro, storage, etc. to provide capacity

Additional Issues

- Fundamental relationship between weather and solar/wind profiles means need for multiple years of data/analysis
- Transmission – capacity sharing would impact DET capacity value
- As penetration of DETs increases, could see interactions between technologies.
- ELCC addresses the issue of sufficient planning reserves—is there a need for a flexibility assessment?
  - Consider ramping needs over relevant time scales
  - Contribution of various sources of flexibility (including DET control)
  - Probabilistic assessment of system ramping capability (effective ramping capability)