PG&E's Renewable Integration Calculator

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(Western Interconnection Regional Advisory Body and the Committee on Regional Electric Power Cooperation)

Increased use of intermittent resources changes resource need

PG&E and The Brattle Group jointly developed the Calculator to understand the operational impacts of higher levels of intermittent resources

- Variability and uncertainty of intermittent resources increase need for regulation, load following, day-ahead commitment, ramping resources
- Resource need is currently set by reliability target (expected peak + planning reserve margin or PRM)
- Resources available to meet reliability requirements may not be adequate to satisfy operating requirements of additional intermittent resources
- PRM evaluation is based on loss of load estimation which does not account for forecast uncertainty or operating needs of load or intermittent resources

Renewable Integration Calculator is a learning tool

- Learn how to integrate new intermittent resources – rather than another integration study
- Evaluate operating requirements of different intermittent resource portfolios (regulation, load following, day-ahead commitment)
- Estimate fixed and variable integration cost
- Multiple intermittent portfolios in CAISO or a LSE's areas
- Easy change inputs for portfolio and service area being analyzed
  - Intermittent resource amounts
  - Hourly load and generation profiles
  - Standard deviation of forecast uncertainty for both load and intermittent generation for day-ahead, hour-ahead and real-time dispatch timeframes
  - Correlation among uncertainties
  - Fixed and variable costs of integration resources

The Calculator's focus is renewable integration

Aspects of renewable generation addressed by Calculator	Addressed	Not Addressed
Ancillary services needed for incremental intermittent generation	X	
Need for resources to integrate intermittent resources	X	
Fixed cost of integration (only to the extent additional resources above reliability need are needed for integration)	X	
Variable cost of integration	X	
Cost premium of renewable generation compared to conventional resources		X
Transmission costs		X
Cost of buying additional ancillary services in the market for intermittent resources		X
Cost of over-generation created by renewable generation		X
CO2 emission benefits or costs		X

Renewable Integration Calculator – Learning opportunities

Inputs to Calculator	*Learning opportunities*
The Calculator assumes the system has just enough resources to cover existing reliability and operating needs	CAISO's integration work should inform how much new intermittent generation can be integrated with resources available to meet reliability need.
Wind variability and forecast errors are based on historic performance of wind in PG&E's and CAISO's areas	Update inputs to the Calculator as better information, or improvements in intermittent generation forecast become available
Solar variability is derived from typical PV and thermal solar generation profiles; forecast errors are assumed as 1/3 of historic wind's forecast errors	Improve solar inputs to the Calculator based on actual weather-specific (vs. typical) generation profiles and actual forecast experience
Load variability and uncertainty due to dynamic pricing not incorporated	Reflect experience with use dynamic pricing in inputs to load in the Calculator
Integration costs are based on cost rather than market prices of ancillary services	Calculator estimates ancillary services required for intermittent resources; market prices can be used to calculate ancillary service cost of intermittent resources

Example: Assuming 95% coverage (2 std. deviations)

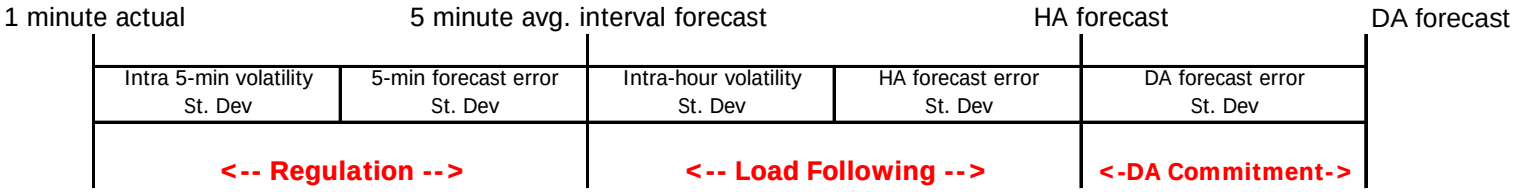
Calculate operating needs for:

- Baseline: CAISO 2020 load + 2648 MW of existing wind (2006 weather)
- Incremental intermittent resource needs:

  + 1000 to 8000 MW of wind (use Tehachapi 2006 weather)

Renewable Integration Operating Requirements (2 std. deviations)

- Regulation: captures 95% of deviations (forecast error) between the 1-minute actual net load and the forecast of the 5-minute average net load* (done approximately 10-minutes ahead)
- Load following: captures 95% of forecast error between the 5-minute and the HA forecasts of net load
- Unit commitment: captures 95% of forecast error between DA and HA forecasts of net load



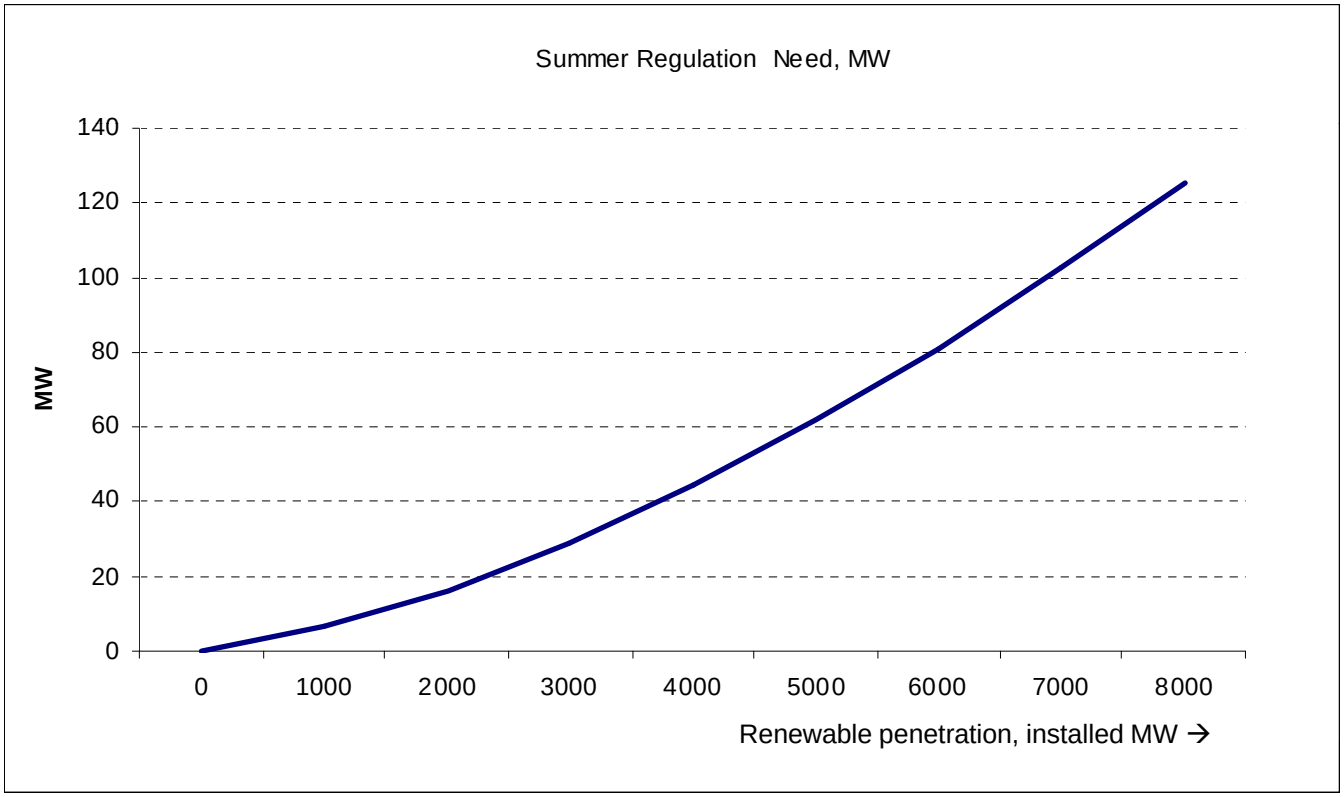
- Ramping: MW/minute needed to meet maximum morning and afternoon net load change

* Net load is the residual load left after subtracting intermittent resource generation (wind and solar).

Example: Incremental regulation

- Regulation requirements in Summer for incremental intermittent resource *
  - New wind: 1-2% of installed capacity

Tehachapi Wind Additions

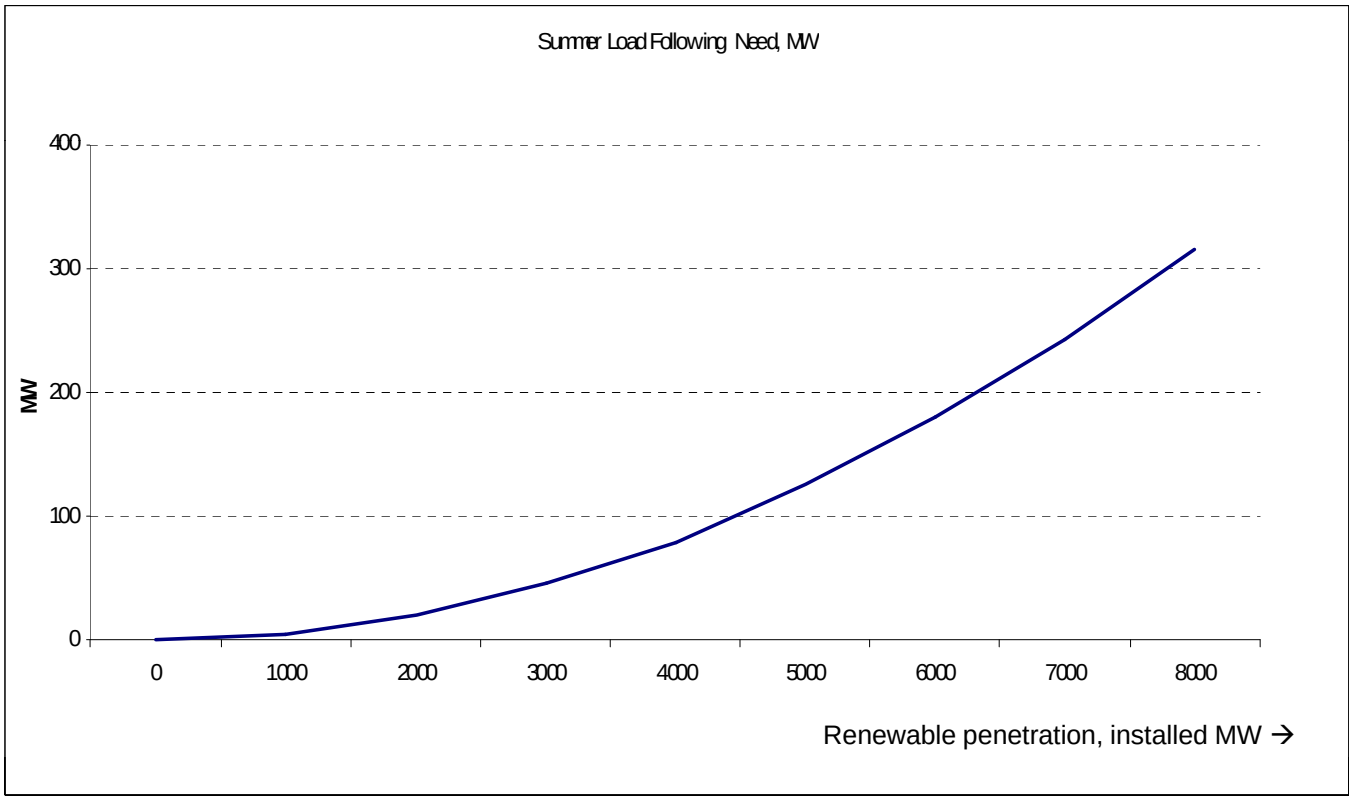


* Based on assumed forecast errors, and expressed as a percentage of incremental installed capacity of intermittent resource (ie, the slope of the curve, or incremental MW of regulation divided by incremental installed MW of new intermittent resource).

Example: Incremental load following

- Load following requirements in Summer*:
  - New wind: 1-8% of installed capacity

Tehachapi Wind Additions

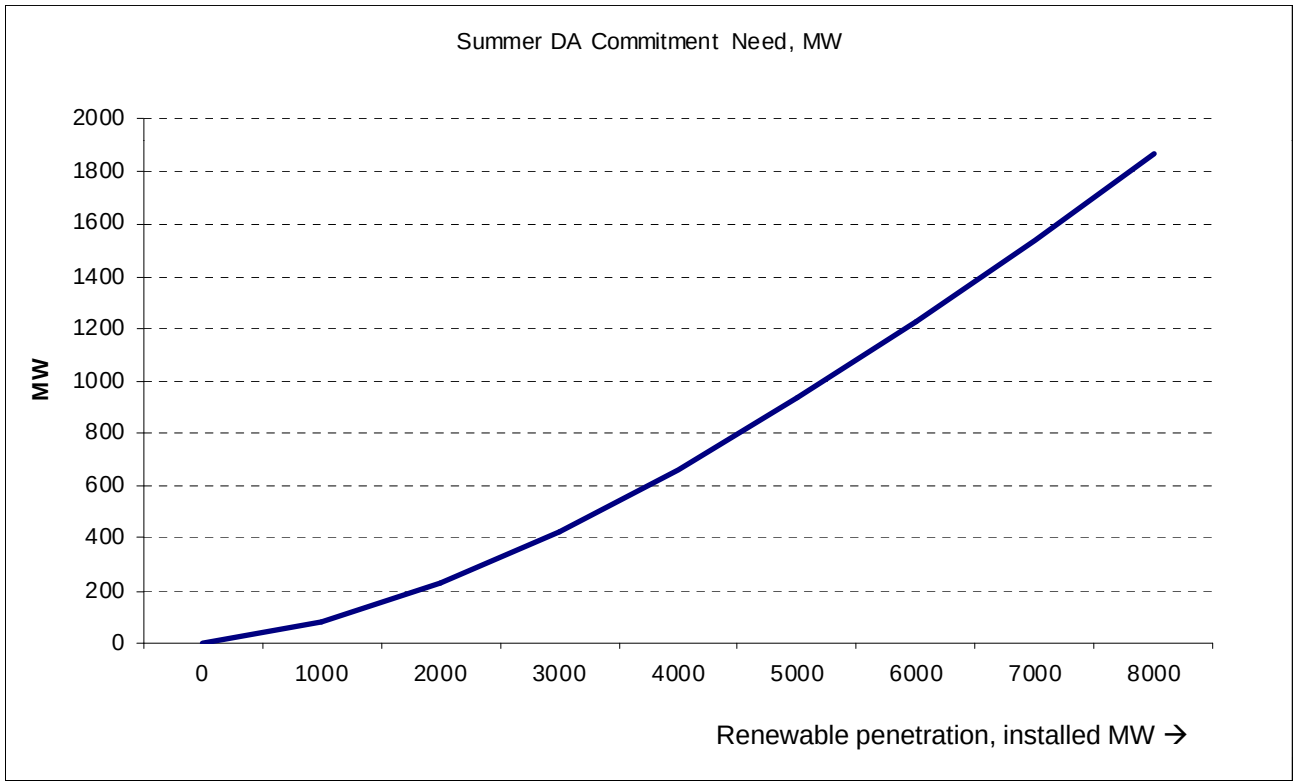


* Based on assumed forecast errors, and expressed as a percentage of incremental installed capacity of intermittent resource (ie, the slope of the curve, or incremental MW of regulation divided by incremental installed MW of new intermittent resource).

Example: Incremental day-ahead commitment

- Day-ahead commitment requirements in Summer*:
  - New wind: 8-30% of installed capacity

Tehachapi Wind Additions



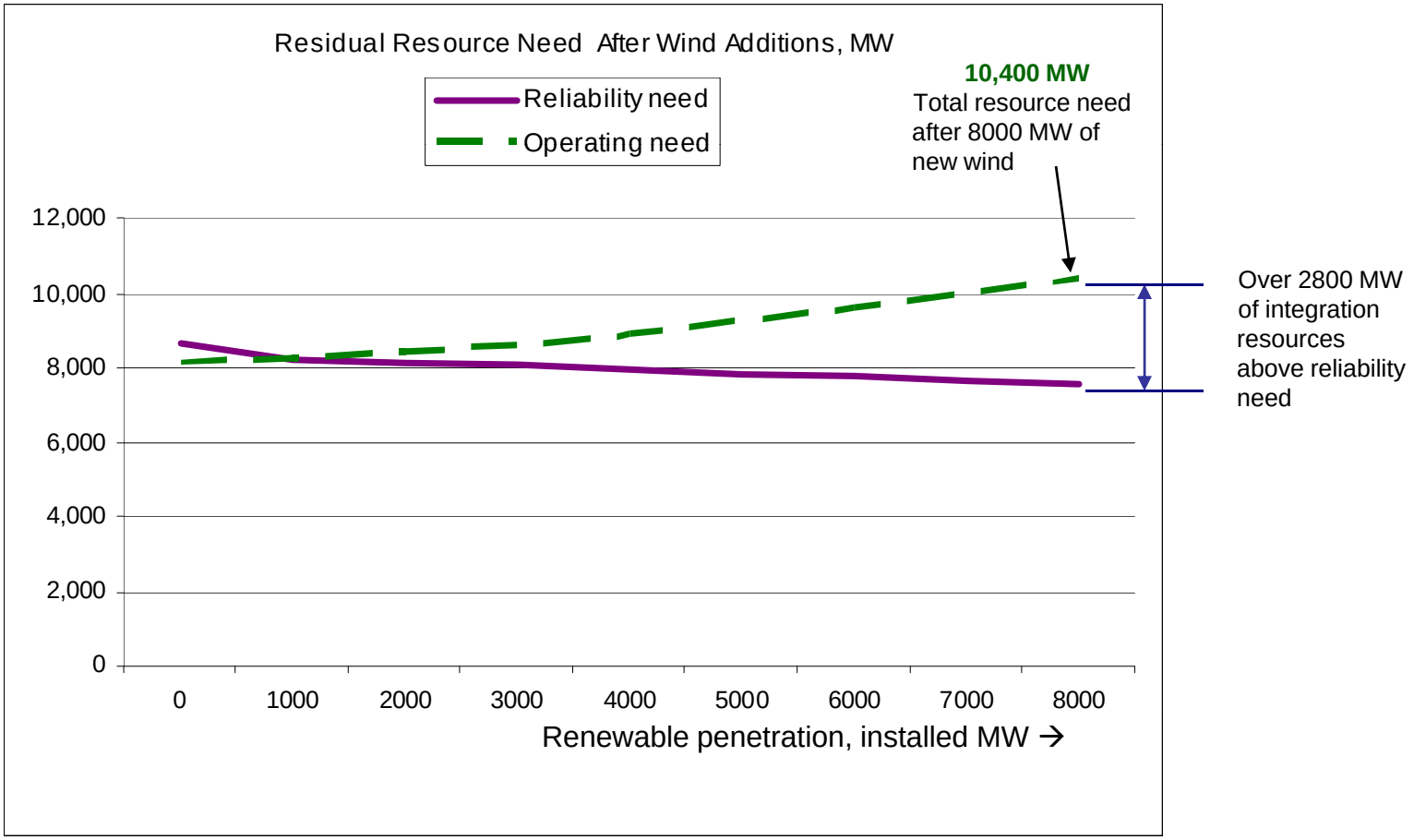
* Based on assumed forecast errors, and expressed as a percentage of incremental installed capacity of intermittent resource (ie, the slope of the curve, or incremental MW of regulation divided by incremental installed MW of new intermittent resource).

Example: Reliability need decreases assuming 10% wind RA credit; Operating need increases due to uncertainty in wind generation; Total resource need is the higher of the two needs

Operating Requirement: DA Incremental Load – DA Wind Generation + A/S

Reliability Requirement: Expected Peak + PRM – Wind RA credit

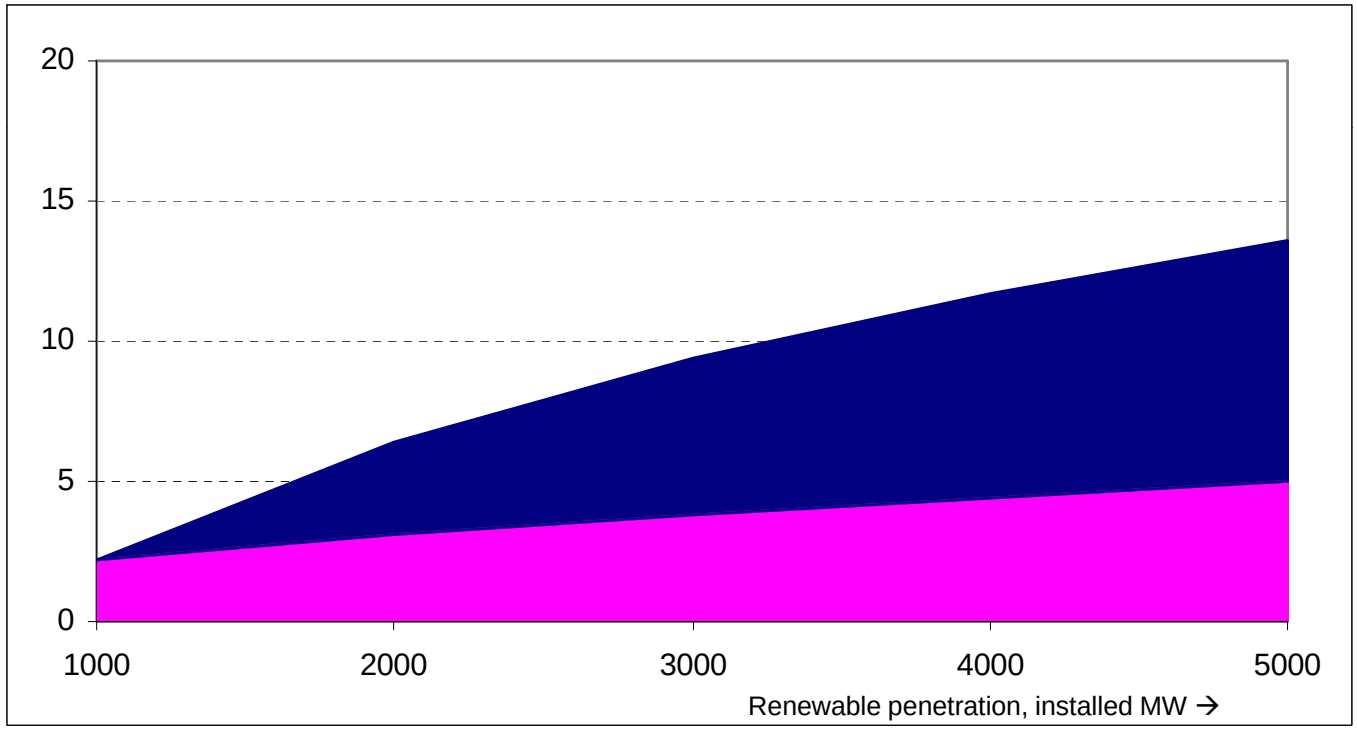
Tehachapi Wind Additions



Sample wind variable and fixed integration costs

- Sample calculation of integration cost based on input assumptions being calibrated as part of the CAISO 33% renewable integration study.

Average Integration Cost for Tehachapi Wind at Different Penetration Levels*, $/MWh



* Per MWh cost assumes Tehachapi has 39% capacity factor, about twice the capacity factor of existing CAISO wind.