Incorporating BTM Solar PV into a Load Forecast

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Advanced Statistical Model Specifications for Incorporating On-Premise Solar PV Generation into a Short-Term Load Forecast Model

EPC-17-003 Task 5 Report

California Energy Commission
Edmund G. Brown Jr., Governor

December 2018 | EPC-17-003

THE PROBLEM OF LOAD MASKING

In July 2017, the California Public Utility Commission issued a Scoping Memo and Ruling that is intended to address several issues around Electric Rule 21, one of which is:

> "As the penetration levels of distributed energy resources increase, what changes to telemetry requirements should the Commission adopt to ensure adequate visibility while minimizing costs?"

To address this issue a working group was established. The findings of the working are contained in *Interconnection Rulemaking (R.17-07-007) Working Group One Final Report*, pages 70-87. In this report, the working group describes the challenge of deep penetration of Distributed Energy Resources as:

> "Without the use of telemetry, the IOUs *[PG&E, SCE, and SDG&E]* have no real-time visibility or operational awareness of projects connected to the utility grid. With increased levels of
> nected to the distribution grid, this
> the safe operation of the distribution system
> s and DERs. In particular, telemetry
> h describes a situation in which the lack of
> perators and engineers from determining the
> he ability to plan and operate the
> ion is caused equally by both exporting and
> point of view of the grid operator, the DER
> even if the DER does not export power into
> the grid."

…"load masking", which describes a situation in which the lack of generation output visibility prevents system operators and engineers from determining the real system load conditions which can inhibit the ability to plan and operate the distribution system."

IMPACT OF LOAD MASKING ON LOAD FORECASTING

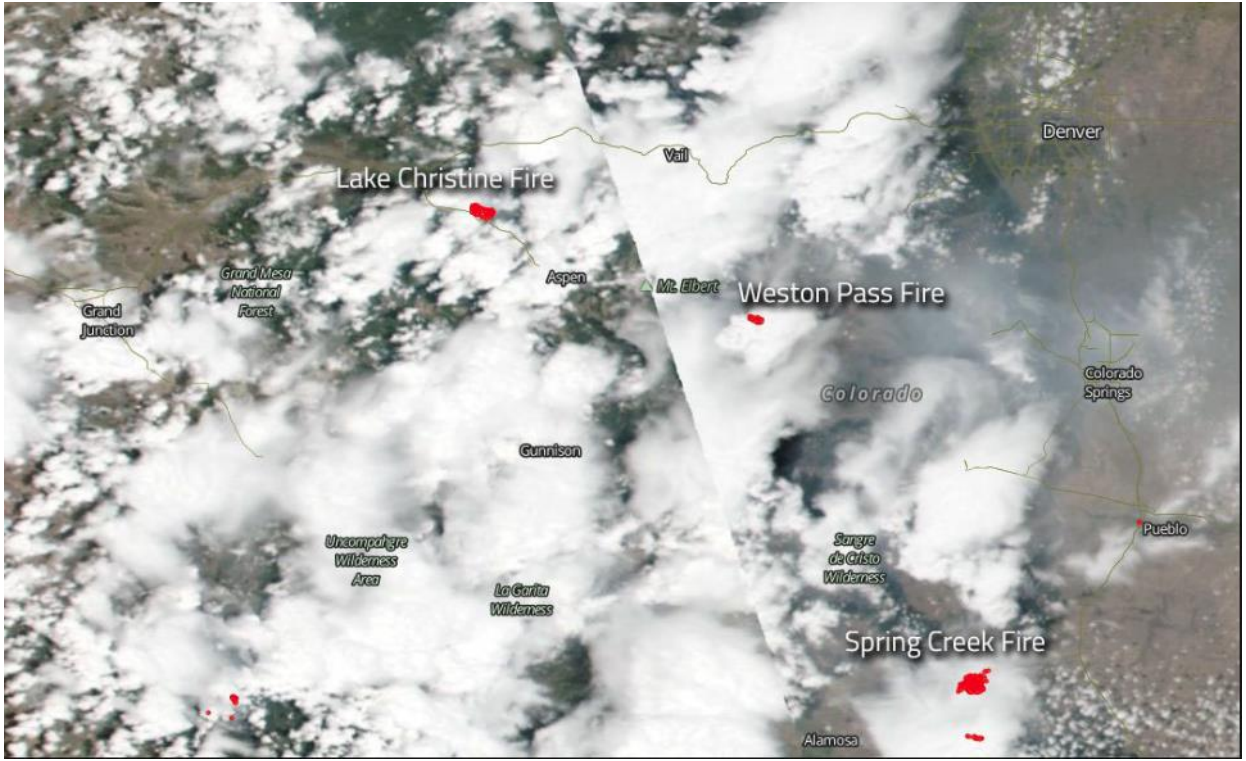
» Today's Load Forecast Models are based on a deep understanding of the factors that drive energy consumption.

- This understanding is based on years of analysis of metered consumption patterns and their correlation with prevailing weather, calendar, and operating conditions.

» Load Masking changes the data that load forecast models are constructed upon from measurement of energy consumption to measurement of energy imbalance.

- As a result, the correlation of prevailing weather, calendar, and operating conditions to what is measured is evolving.
- This leads to eroding performance of traditional load forecast models.

"LOAD MASKING" FROM A SOLAR PV FORECASTING PERSPECTIVE



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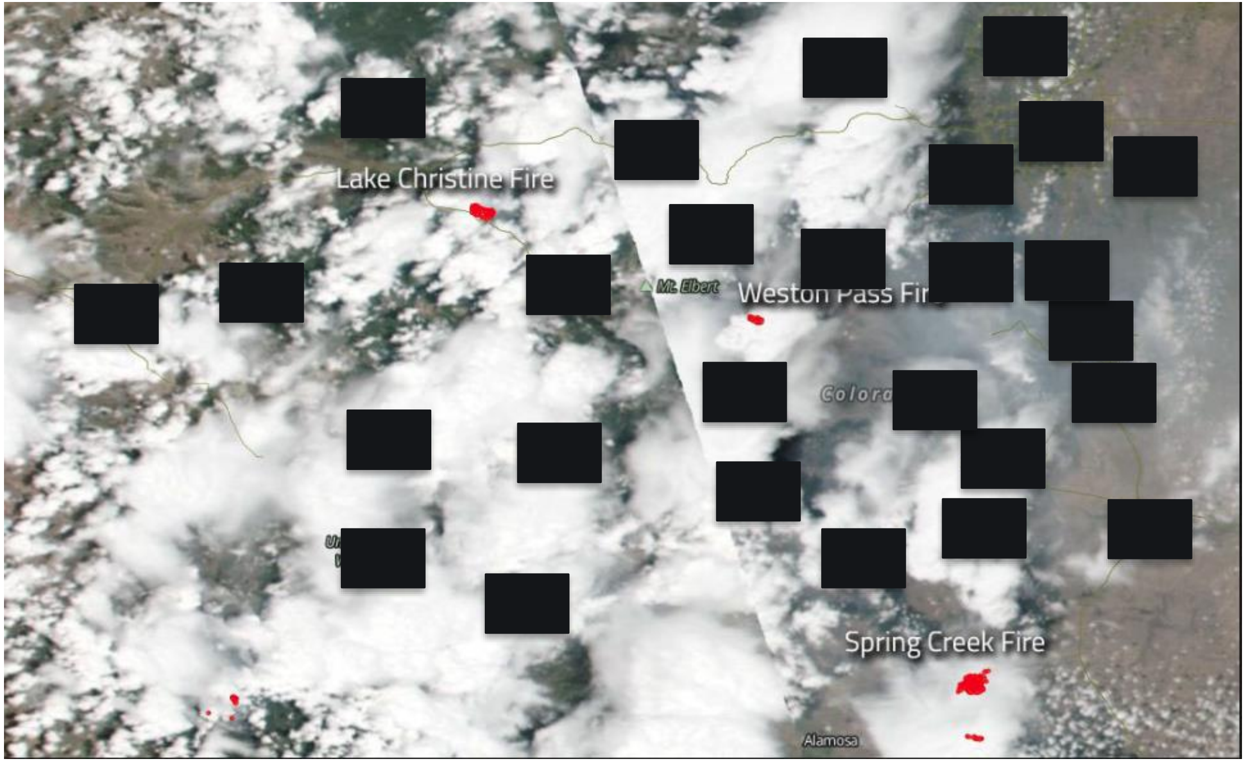

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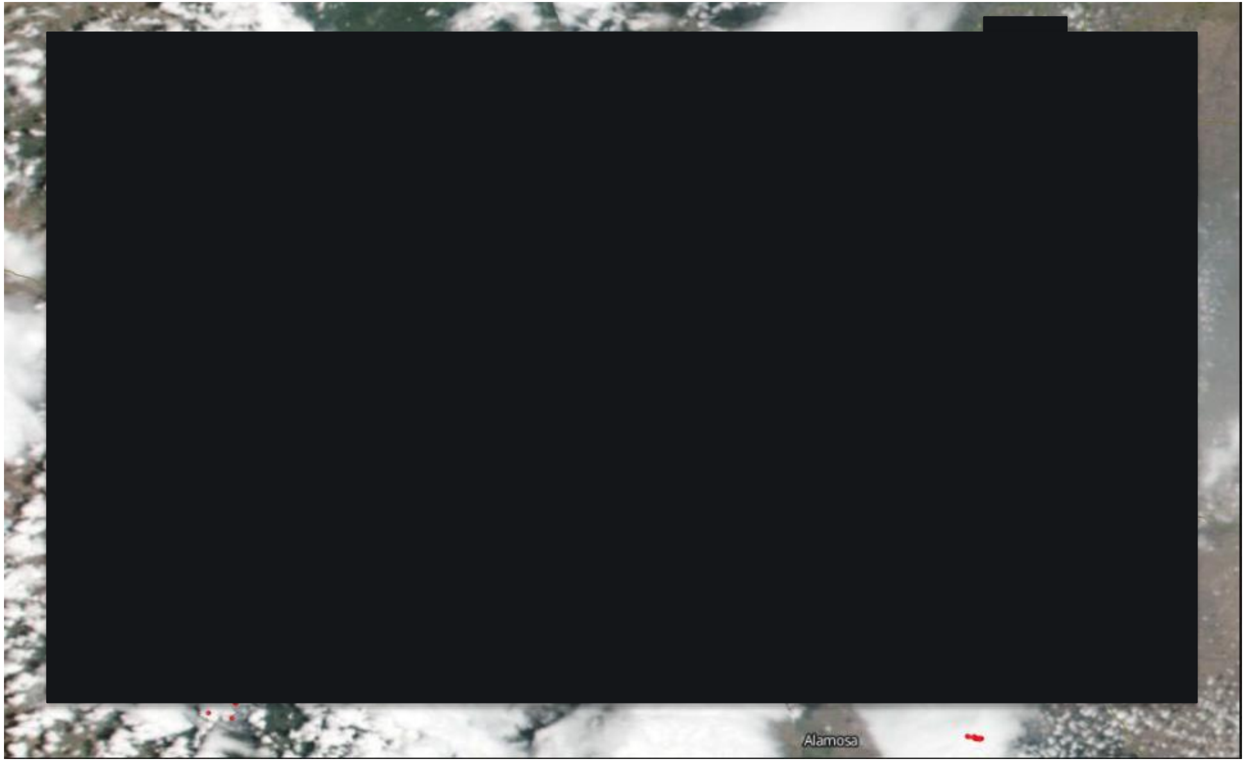
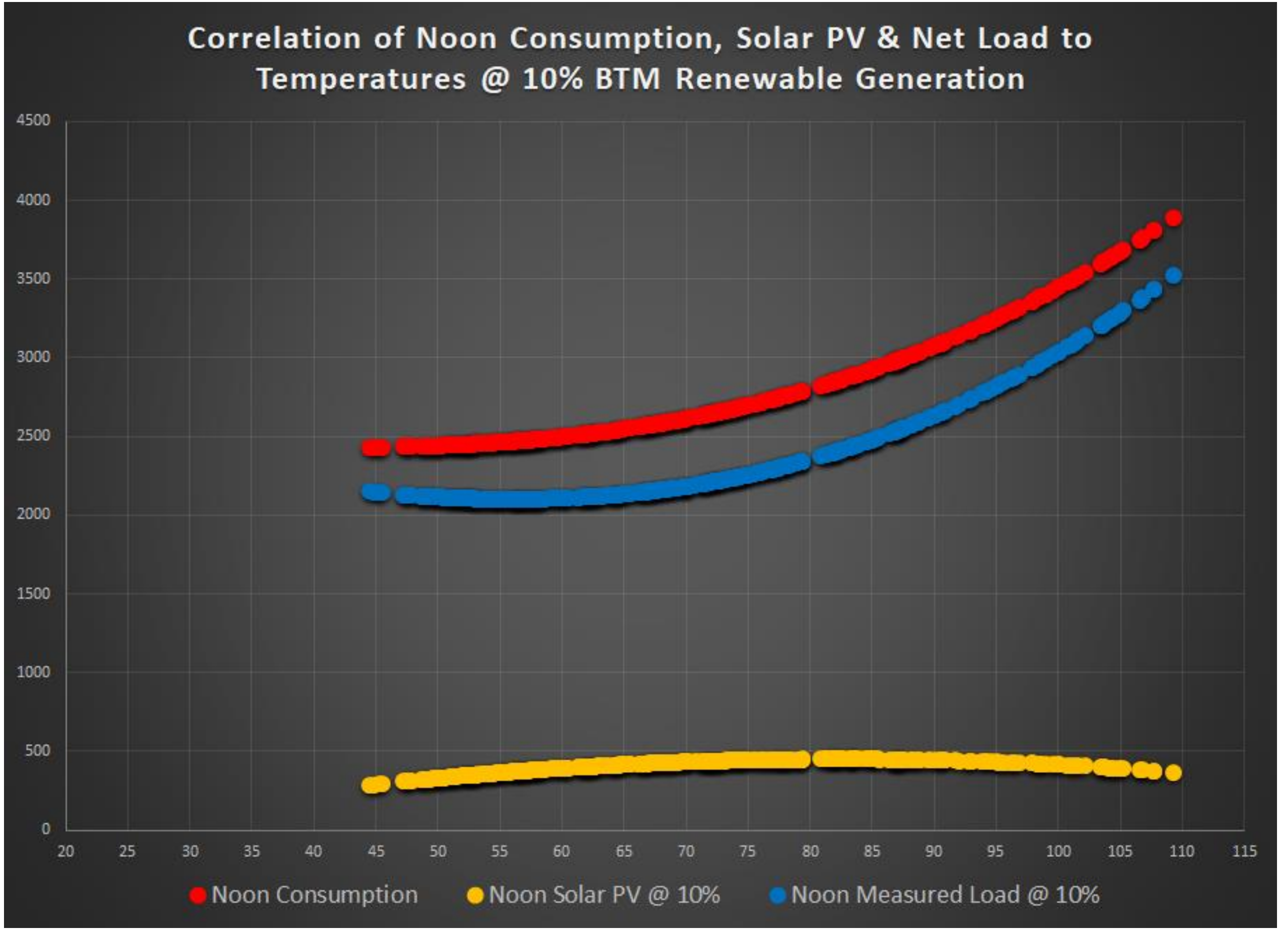


LOAD MASKING IS A TRANSITIONAL PROBLEM

$$\text{Consumption}_d = \beta_0 + \beta_1 T_d + \beta_2 T_d^2 + \beta_3 T_d^3$$

$$\text{MeasuredLoad}_d^{10\%} = \beta_0^{10\%} + \beta_1^{10\%} T_d + \beta_2^{10\%} T_d^2 + \beta_3^{10\%} T_d^3$$



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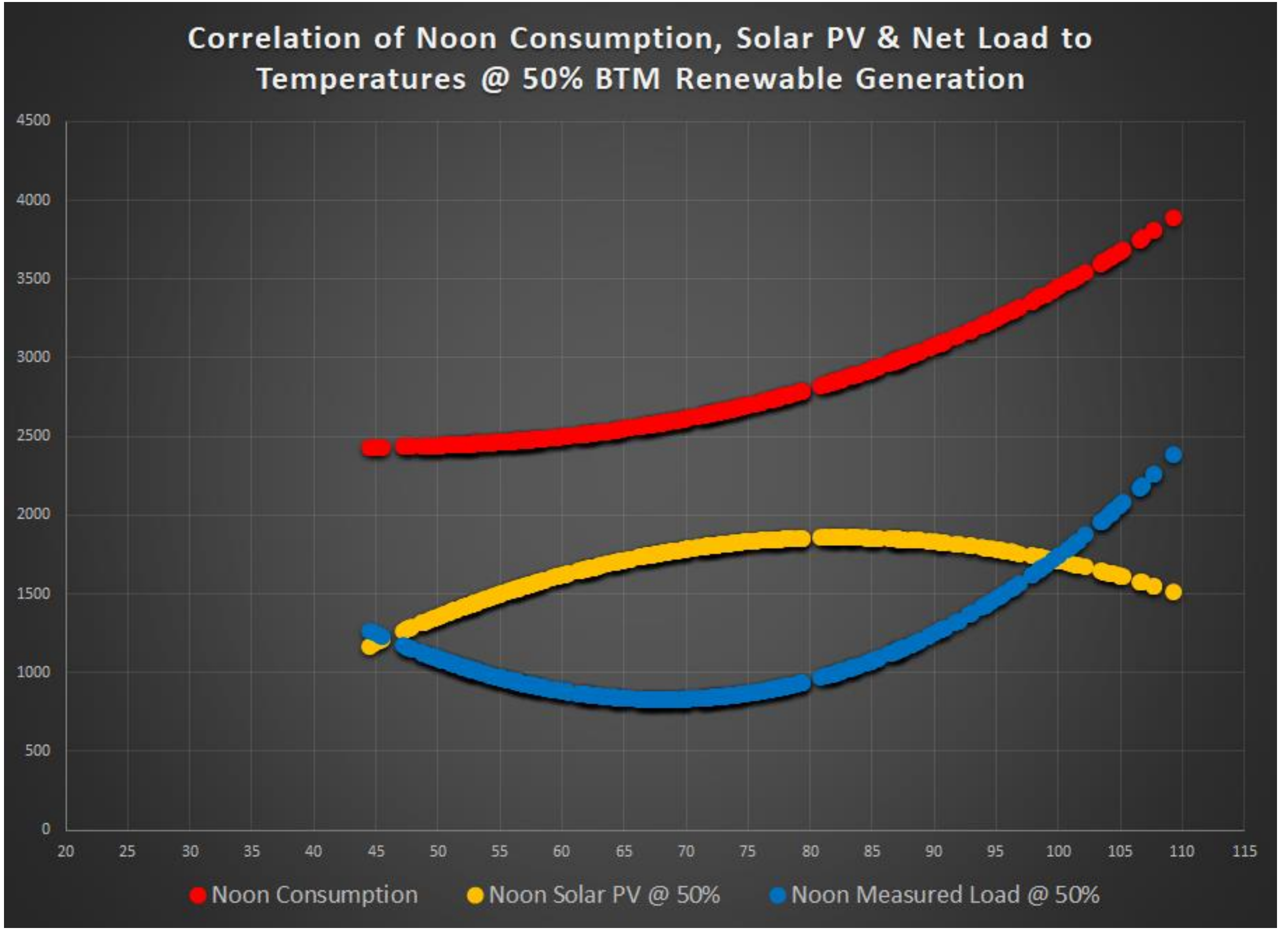

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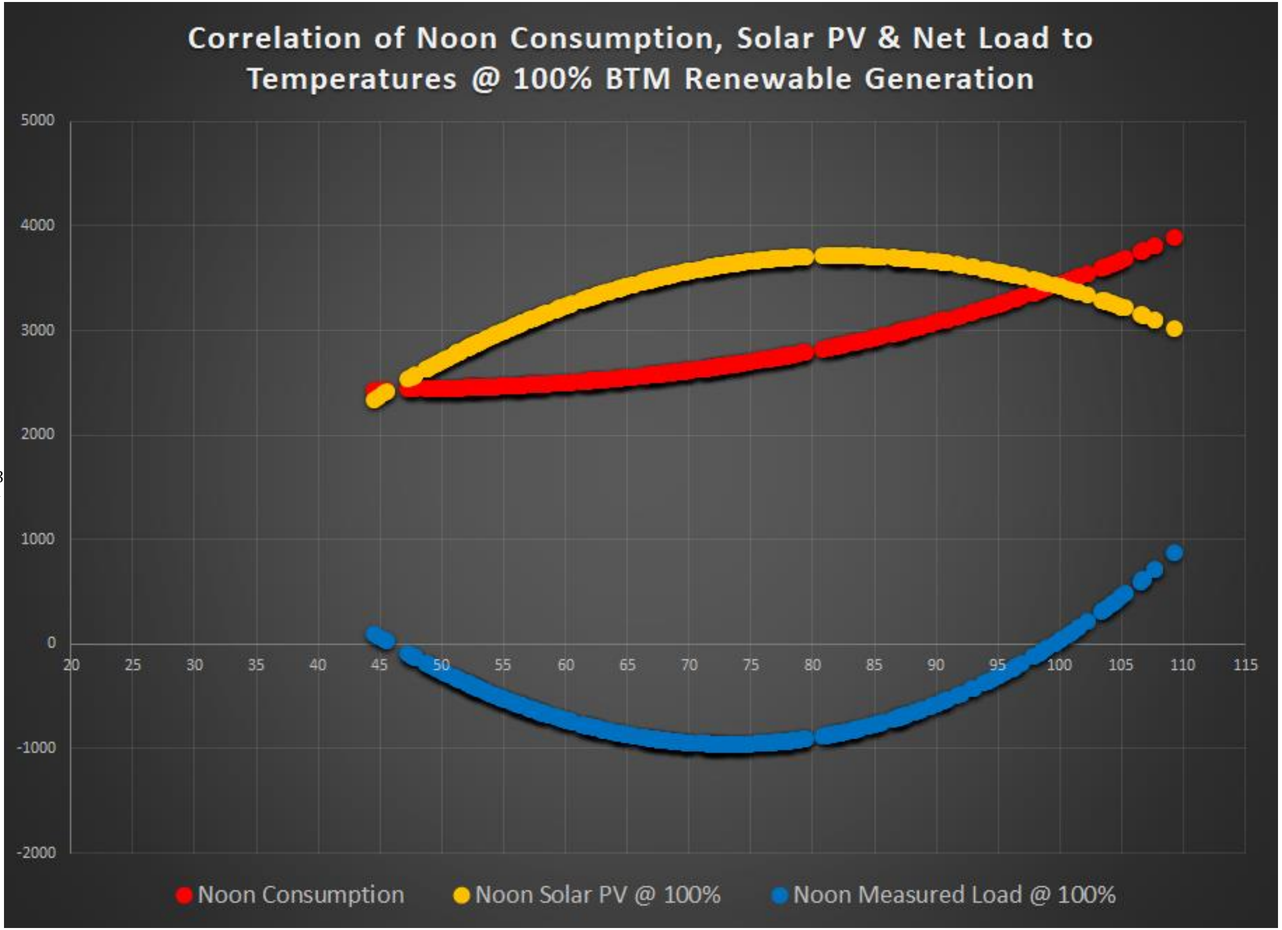

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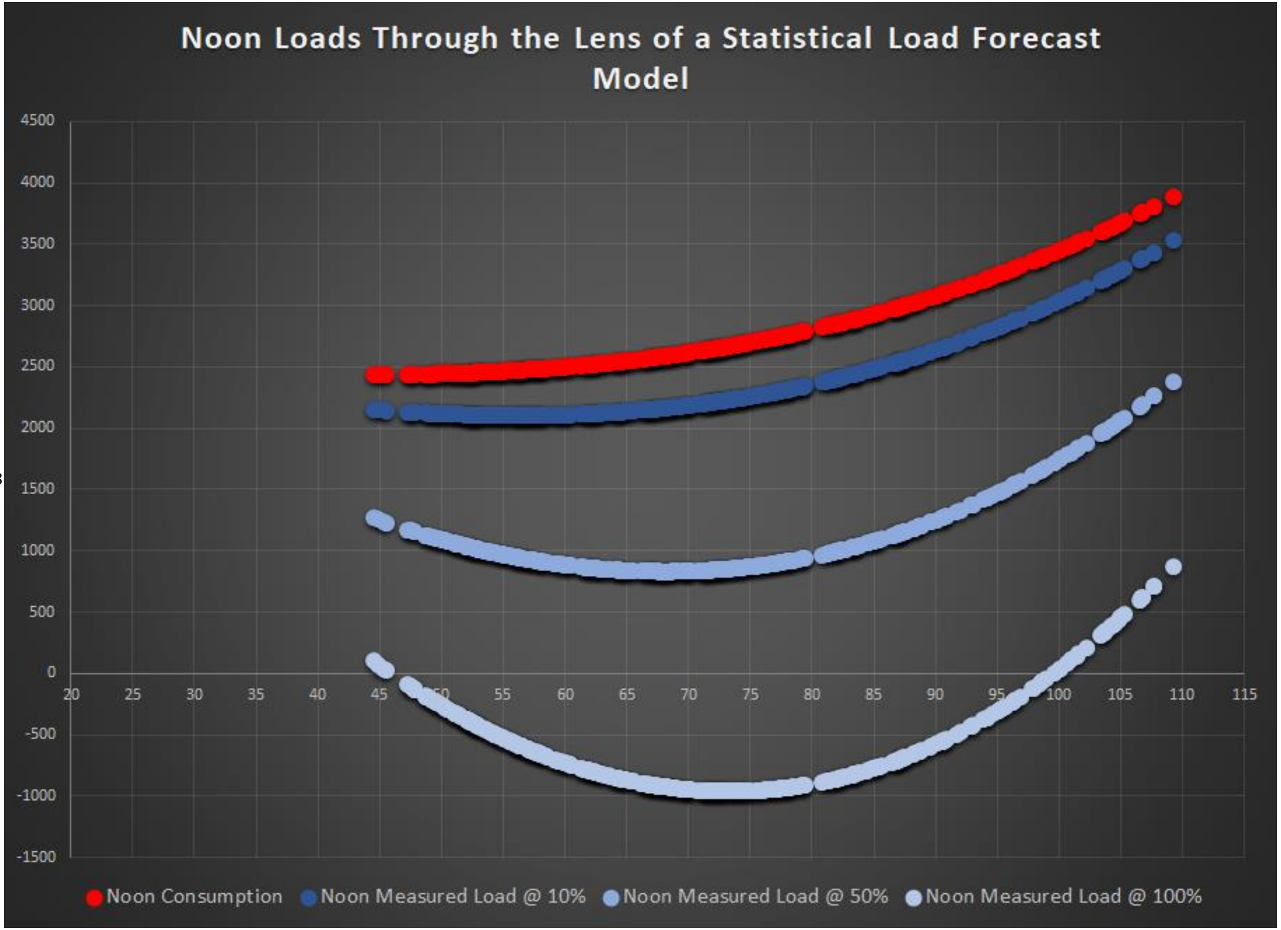

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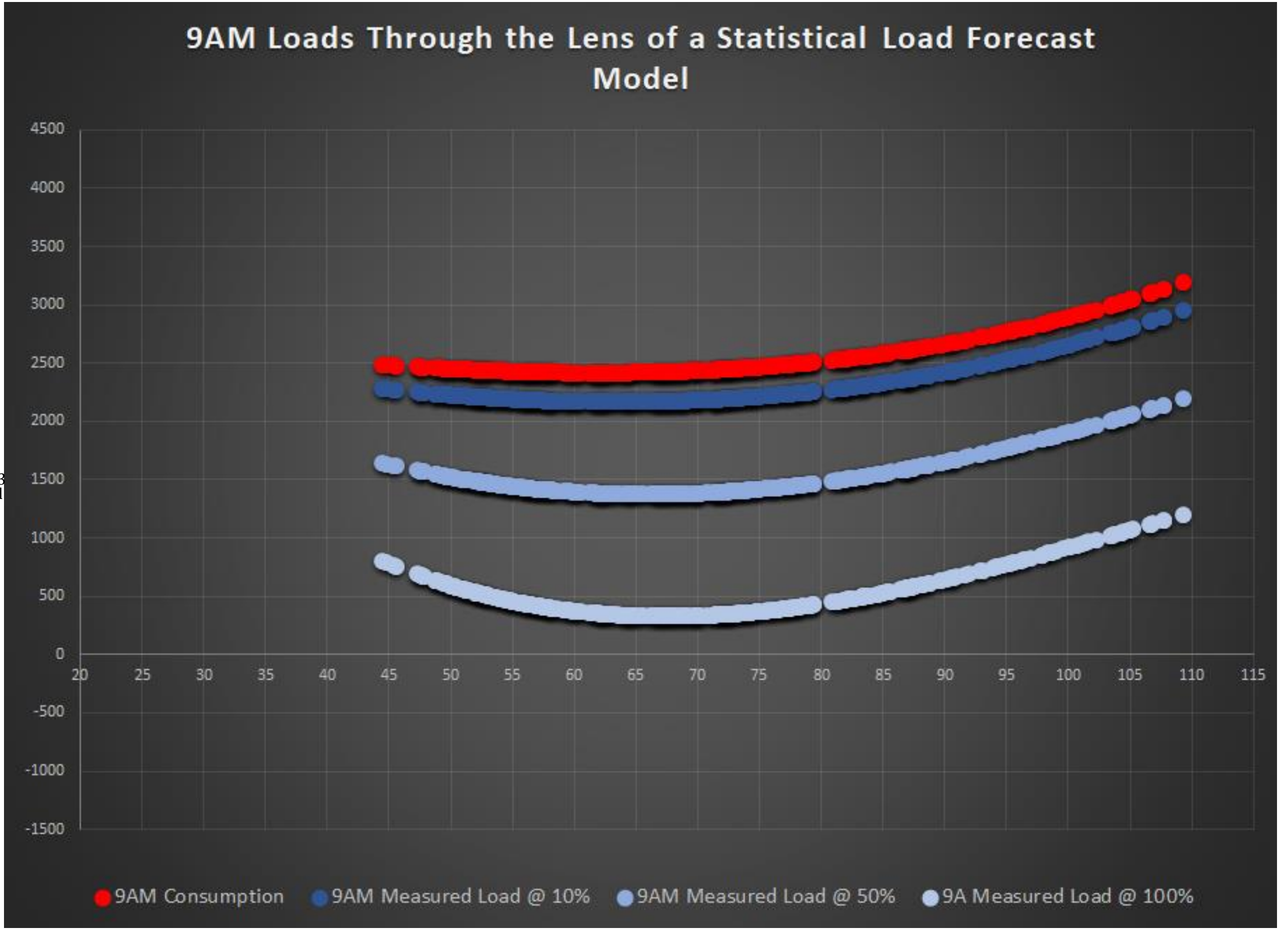

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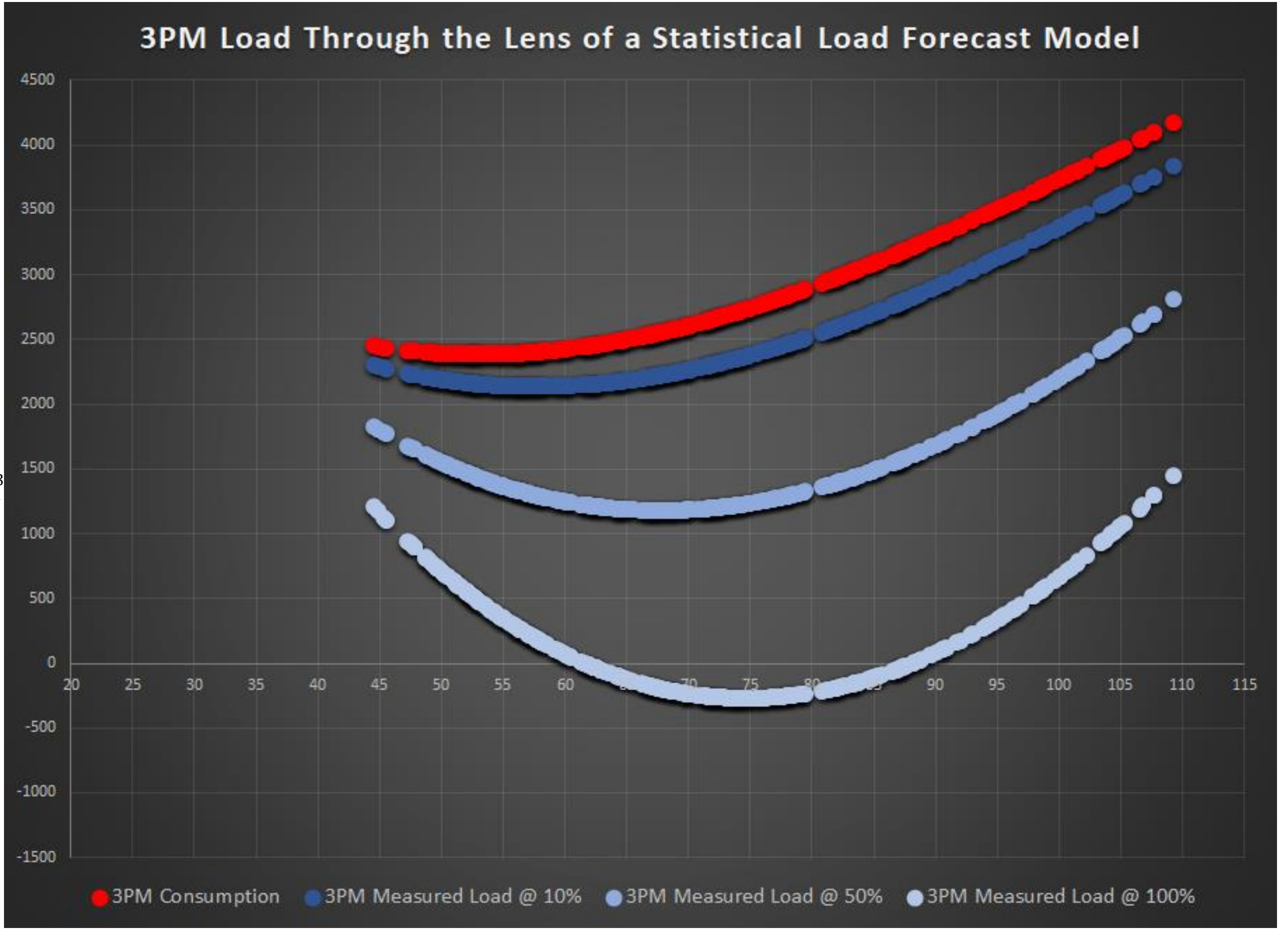

THE LOAD FORECAST STRATEGY FOR THE TRANSITION PERIOD

» Incorporate an externally sourced solar PV generation estimates/forecasts into an existing load forecast model.

» Available approaches include:

- **Error Correction.** Make *ex post* adjustments of the base load forecast to account for forecasted values of embedded solar generation.
- **Reconstituted Loads.** Reconstitute the historical load data by adding back estimates of embedded solar generation. Model the reconstituted loads using the existing load model specifications. The resulting reconstituted load forecast is then adjusted downward by subtracting off forecasts of embedded solar generation.
- **Model Directly.** Include Embedded Solar Generation as an Explanatory Variable in the existing Short-term Load Forecasting Models.

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POSSIBLE TELEMETRY SOURCES FOR SOLAR PV GENERATION

» Add a separate meter on all (big and small) solar PV installations

- Install a second meter when solar PV is installed
- Used primarily for billing purposes and are not read in real time
- Requires a forecast value from another source

» Upscale Real-time Telemetry on big solar PV installations

- Upscaling assumes small solar PV systems perform like the big systems
- Upscaling requires managing a database of all solar PV databases
- No guarantee that a big solar PV system is located near every cluster of small solar PV installations
- Requires a forecast value from another source

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ESTIMATION SOURCES FOR SOLAR PV GENERATION

» Estimation Approaches based on Weather Measurement/Forecast
  - Ingest weather data/forecasts, satellite images, and/or ground-based measurements and use algorithms to back into estimates/forecasts of solar PV generation for either a representative sample of solar PV installations (which are then upscaled) or the population of solar PV installations
  - Requires managing a database of all solar PV installations & modeling horsepower
  - If a representative sample is used then upscaling is required which assumes the population installations are similar to the sample installations
  - Ongoing effort is required to maintain a representative sample and the population database
  - Ongoing effort to refine forecast performance

THE CASE FOR THE RECONSTITUTED LOAD APPROACH

» At low solar PV saturations it is difficult for a statistical model to isolate the solar PV load impact from over all load variation driven by calendar and weather conditions.

Consumption	Solar PV Generation	Solar Saturation	Estimated Coefficient
1000	0	0%	0.00
1000	7	0.7%	-0.02
1000	14	1.4%	-0.06
1000	30	3.0%	-0.18
1000	60	6.0%	-0.44
1000	119	11.9%	-0.73
1000	239	23.9%	-0.90
1000	477	47.7%	-0.97
1000	954	95.4%	-0.99
1000	1000	100.0%	-0.99

CEC STUDY MOTIVATION

» Over the past three years, several ISOs in North America and Australia have implemented the Reconstituted Load approach.

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$$\mathrm{ReconstitutedLoad}_{d,i}^{h} = \mathrm{MeasuredLoad}_{d,i}^{h} + \boxed{\beta_1}\,\mathrm{SolarPVGeneration}_{d,i}^{h} = \mathrm{Consumption}_{d,i}^{h}$$

» Observations from the ISOs suggest that the assumption of $\beta_1 = 1.0$ is too restrictive.

WHY RECONSTITUTED APPROACH MAY BE TOO RESTRICTIVE

» Inaccuracies in the Solar PV population estimates arising from:
  - Population Tilt and Azimuth Uncertainty
  - Shading Uncertainty
  - Soiling Uncertainty
  - Population Capacity Uncertainty
  - Solar Irradiance Uncertainty

» Other reasons:
  - Behavioral Uncertainty
  - Day-of-the-Week load variation swamps solar PV generation variation
  - Close collinearity between solar PV generation and HVAC

ANALYSIS FRAMEWORK

- Use the Direct Model approach to estimate a series of alternative model specifications
  - BTMSG
  - BTMSG x Temperature Bin Interactions
  - BTMSG x Temperature Bin & Week Day/Weekend Interactions
  - BTMSG x Temperature Bin, Week Day/Weekend & Pre/Post 2016 Interactions

- Compare the forecast performance of the alternative Direct Model Regression and Neural Network specifications to the in-kind Regression and Neural Network Reconstituted Load Model specifications.

HIGH LEVEL RESULTS

Neural Network Model	Dawn Reconstituted	Dawn Direct	Morning Reconstituted	Morning Direct	Mid-Day Reconstituted	Mid-Day Direct	Afternoon Reconstituted	Afternoon Direct	Evening Reconstituted	Evening Direct
No SolarPVGen Treatment		3.28%		4.07%		4.34%		4.39%		4.19%
Reconstituted Load with 100% SolarPVGen	3.12%		3.45%		3.29%		3.39%		3.76%	
Single Variable	3.05%	3.04%	3.44%	3.44%	3.18%	3.17%	3.15%	3.15%	3.20%	3.19%
Week Day/Weekend	3.05%	3.03%	3.44%	3.46%	3.18%	3.17%	3.14%	3.14%	3.20%	3.19%
Pre-2016/Post 2015	3.05%	3.03%	3.43%	3.43%	3.17%	3.17%	3.16%	3.15%	3.05%	3.05%
Week Day/Weekend, Pre-2016/Post-2015	3.04%	3.02%	3.43%	3.43%	3.18%	3.17%	3.15%	3.14%	3.04%	3.04%
Temperature Bin	3.03%	3.01%	3.43%	3.44%	3.18%	3.17%	3.14%	3.14%	3.20%	3.19%
Temperature Bin, Week Day/Weekend	3.01%	3.00%	3.43%	3.43%	3.18%	3.17%	3.14%	3.13%	3.19%	3.17%
Temperature Bin, Pre-2016/Post-2015	3.01%	3.00%	3.42%	3.41%	3.17%	3.16%	3.15%	3.15%	2.97%	2.95%
Temperature Bin, Pre-2016/Post-2015, Week Day/Weekend	3.13%	2.98%	3.54%	3.40%	3.36%	3.16%	3.19%	3.12%	3.17%	2.94%
Best MAPE	**2.98%**		**3.40%**		**3.16%**		**3.12%**		**2.94%**	

Regression Model	Dawn Reconstituted	Dawn Direct	Morning Reconstituted	Morning Direct	Mid-Day Reconstituted	Mid-Day Direct	Afternoon Reconstituted	Afternoon Direct	Evening Reconstituted	Evening Direct
No SolarPVGen Treatment		3.46%		4.18%		5.02%		5.22%		4.82%
Reconstituted Load with 100% SolarPVGen	3.28%		3.57%		4.11%		4.40%		4.55%	
Single Variable	3.22%	3.21%	3.56%	3.55%	4.02%	4.00%	4.21%	4.19%	4.13%	4.11%
Week Day/Weekend	3.73%	3.06%	3.56%	3.55%	4.02%	4.00%	4.20%	4.18%	4.13%	4.11%
Pre-2016/Post 2015	3.21%	3.21%	3.55%	3.54%	4.02%	4.00%	4.21%	4.19%	3.92%	3.90%
Week Day/Weekend, Pre-2016/Post-2015	3.20%	3.20%	3.55%	3.54%	4.02%	4.00%	4.20%	4.18%	3.91%	3.89%
Temperature Bin	3.16%	3.15%	3.53%	3.52%	3.87%	3.85%	4.10%	4.08%	4.10%	4.08%
Temperature Bin, Week Day/Weekend	3.15%	3.15%	3.53%	3.52%	3.87%	3.85%	4.09%	4.07%	4.09%	4.08%
Temperature Bin, Pre-2016/Post-2015	3.14%	3.13%	3.52%	3.51%	3.84%	3.82%	4.06%	4.04%	3.88%	3.86%
Temperature Bin, Pre-2016/Post-2015, Week Day/Weekend	3.12%	3.12%	3.57%	3.50%	3.90%	3.81%	4.04%	4.03%	4.02%	3.85%
Best MAPE	**3.06%**		**3.50%**		**3.81%**		**4.03%**		**3.85%**	

CONCLUSIONS

- The analysis demonstrates that the assumption of $\beta_{SGPV} = 1.0$ in the Reconstituted Load approach is too restrictive.

- To improve upon the existing Reconstituted Load approach there is value to interacting the solar PV generation data with Temperature Bins, Day-of-the-Week, and Time Trends.

- As solar PV generation saturations grow there will be added benefit to the Direct Model approach to account for solar PV generation estimation/forecast errors, as well as underlying behavioral changes.

SOMETHING TO PONDER

- In the 100% renewables world the greatest source of forecast error will be renewable generation forecast error.
  - Question: In this world will the *Law of Large Numbers* help neutralize the impact of solar PV generation forecast errors.
    - e.g. Temperature forecasts for large geographic regions handle space heating and cooling loads today. Will cloud cover for a large geographic region with 100% saturation of solar PV generation be sufficient too?

- What does 100% renewable mean? Is it 100% renewable meets average load over the course of a year? Is it an hour-by-hour target?

- How will storage, EV charging, TOU rate migration, strategic load control impact the load forecasts?

THANK YOU

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