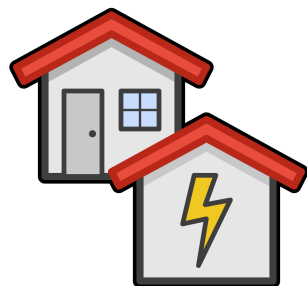


Energy Twin

M&V adherence



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1 M&V guidelines adherence

SkySpark itself provides various features that are useful for M&V. Details can be found on the SkyFoundry website ¹.

On top of the standard SkySpark functionality, ET adds ready-to-use modeling capabilities that are in adherence with to the *International Performance Measurement and Verification Protocol – IPMVP, ASHRAE Guideline 14, Measurement of Energy, Demand and Water Savings* and other M&V guidelines.

1.1 Model uncertainty quantification

For each model, the following three metrics are calculated and evaluated against the guidelines targets (see Figure 1.1)

Metric	Target value
R^2 - Coefficient of Determination	> 0.75 ^a
CV(RMSE) - Coefficient of Variation of RMSE	$< 25\%$ ^b
NDBE - Normalized Mean Bias Error	$ NDBE < 0.005\%$ ^c

^asuggested in IPMVP - Uncertainty assessment chapter 1.7.1

^bASHRAE Guideline 14-2014, chapter 4.3.2.1 (12 - 60 months of data)

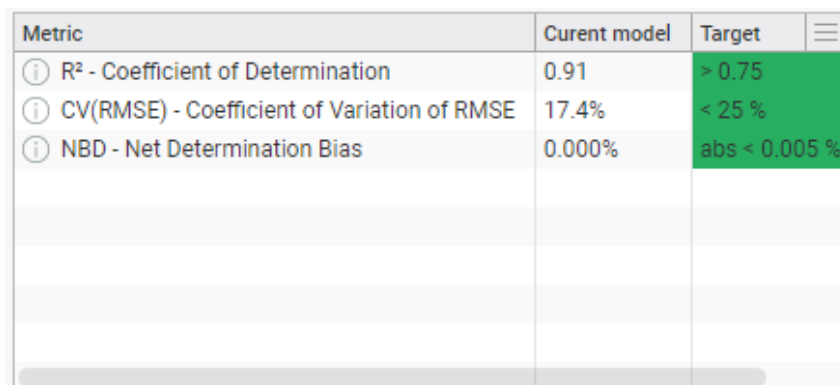
^cASHRAE Guideline 14-2014, chapter 4.2.10

The evaluation of aforementioned metrics is done using full model prediction. The average day substitution is not applied. Note that the prediction provided by ET in SkySpark uses the average day substitution and one can obtain slightly different metrics when evaluating ET prediction data against measurement.

1.2 Identification period selection

In ASHRAE Guideline 14-2014, chapter 4.2.2 the baseline period selection is discussed: *"The baseline period is typically the period immediately before the retrofit is analyzed or proposed and should represent one or more complete operating cycles to minimize bias. For example, a facility that operates on an annual cycle in response to weather should have a baseline period of a full year, or several complete years. If data cannot be obtained for less than a full cycle of operation (e.g., 12 months for a facility with weather-dependent*

¹<https://skyfoundry.com/verticals/services>



Metric	Current model	Target	⋮
① R^2 - Coefficient of Determination	0.91	> 0.75	
① CV(RMSE) - Coefficient of Variation of RMSE	17.4%	$< 25\%$	
① NBD - Net Determination Bias	0.000%	$abs < 0.005\%$	

Figure 1.1: Model uncertainty quantification in ET - Load Profile view

loads), shorter periods that are representative of each operating mode (e.g., one month in each season) may be acceptable if the data collection interval is reduced (e.g., from monthly to hourly)."

ET allows for selection of multiple shorter periods by means of **Additional Training Periods** definition, see Figure 1.2.

Selection of convenient identification period is also important with respect to the uncertainty quantification. The importance is highlighted in ASHRAE Guideline 14-2014, chapter 4.2.11.3:

"This guideline uses the following three indices to represent how well a mathematical model describes the variability in measured data. These indices shall be computed for the single mathematical model used to describe the baseline data from all operating conditions (i.e., both summer and winter shall be consolidated in one model for evaluating these indices)."

ET will allow to identify model using just e.g. summer data, however, such model shall not be used in long-term M&V project even if it satisfies model uncertainty targets.

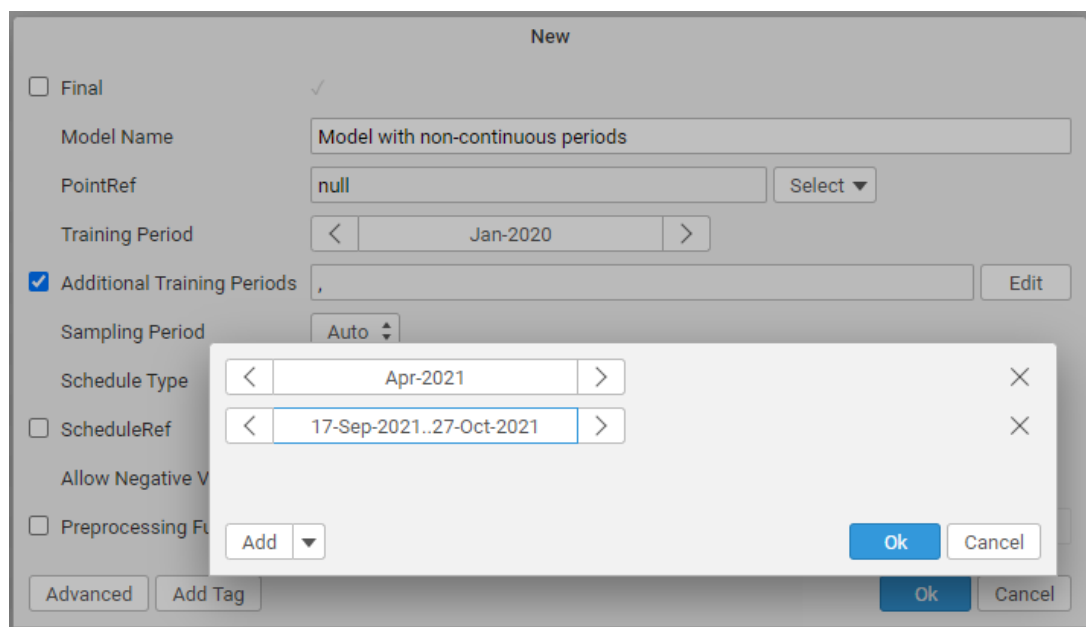


Figure 1.2: Additional periods definition for less than a full cycle of operation data