Probabilistic Energy Forecasting: Methodologies, Implementations, and Applications

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Probabilistic Energy Forecasting: Methodologies, Implementations, and Applications

Part 2: Fundamentals of model building for energy forecasting

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Learning objectives

By the end of this course, students should be able to:

Part 1

- Identify, list, and describe the different types of probabilistic forecast

Part 2

- Use a range of metrics and visualizations to evaluate probabilistic forecasts

Part 3

- Describe the processes and data required to produce probabilistic wind and solar power forecasts, electricity price forecasts, and electric load forecasts

Part 4

- List contemporary statistical and machine learning methods used in probabilistic forecasting, their characteristics and available software implementations
- Describe how probabilistic energy forecasting is used in power systems operation, control, and market participation

Fundamentals of model building

Terminology

Terminology

Forecasting vs. planning

Forecasting

- Tell what the future would look like given one or more scenarios.

Planning

- Develop actions in order to reach a desirable stage in the future.

Terminology

Forecasting vs. planning

Background

The planning department of the Big City Power & Light (a distribution company) need to make a 5 year plan for system maintenance and upgrade. The forecasting team developed a 10-year ahead forecast showing an increasing trend of peak demand at about 2% per year. Majority of the load growth was due to the new tax incentives for attracting high tech companies to a technology park near downtown area. The technology park was expected to add 10,000 high tech jobs over the next 5 years. These jobs would help with the local economy growth.

Terminology

Forecasting vs. planning

Case 1

Based on the forecast, the planning team developed a plan to upgrade the existing infrastructure of the areas near the technology park to serve the load growth due to the newly added jobs.

Terminology

Forecasting vs. planning

Case 2

After analyzing the power systems near downtown, the planning team concluded that reasonable system upgrade can support up to 1.5% annual growth. It is not economically justifiable to feed the projected demand at 2% annual growth by only upgrading the system. One possible solution was to launch several demand response (DR) and energy efficiency (EE) programs together with the system upgrade. The planning team need to understand what the load growth would look like given different options of the DR and EE programs. Based on the new scenarios provided by the planning team, the forecasting team then developed several new forecasts with different combinations of DR and EE programs. The new forecasts showed annual load growth at 1-1.5% per year. The planning team then developed a plan that includes both system upgrade and selected DR and EE programs.

Terminology

Forecasting vs. planning

Case 3

One of the high tech companies asked the utility for a new distribution substation to ensure a highly reliable system to serve the data centers. After analyzing the power systems near downtown, the planning team concluded that the annual load growth has to be as high as 3% to justify the addition of the substation. This high tech company lobbied the executives of the utility, who then put a big pressure on the forecasting team. Under the pressure, the forecasting team added two dummy variables to the recent two years with low peak demand to create the 3% annual growth.

Terminology

Model, variable, function, and parameter

Model

- Circuit models
- Data models
- Physical models
- Regression models
- Neural networks

Terminology

Model, variable, function, and parameter

Variable

- Response variable, dependent variable, output variable and regressand
- Explanatory variable, independent variable, input variable and regressor
- Naming by content: weather variables, calendar variables, etc.

Terminology

Model, variable, function, and parameter

Function

- Function of weather and calendar variables
- A cubic function of temperature
- Function at algorithmic level

Terminology

Model, variable, function, and parameter

Parameter

- Coefficient
- To quantify the relationship between the response variable and explanatory variables

Terminology

Hyper parameter

In algorithm design

- When performing outlier detection, there need to be a *threshold* to tell whether an observation is an outlier or not.
- That "threshold" is called a (hyper) parameter for this outlier detection algorithm.

Other examples of hyper parameter

Fundamentals of model building

Error analysis

Error analysis

How accurate is your forecast?

How to define accuracy/goodness/error?

Error analysis

Factors affecting forecast accuracy

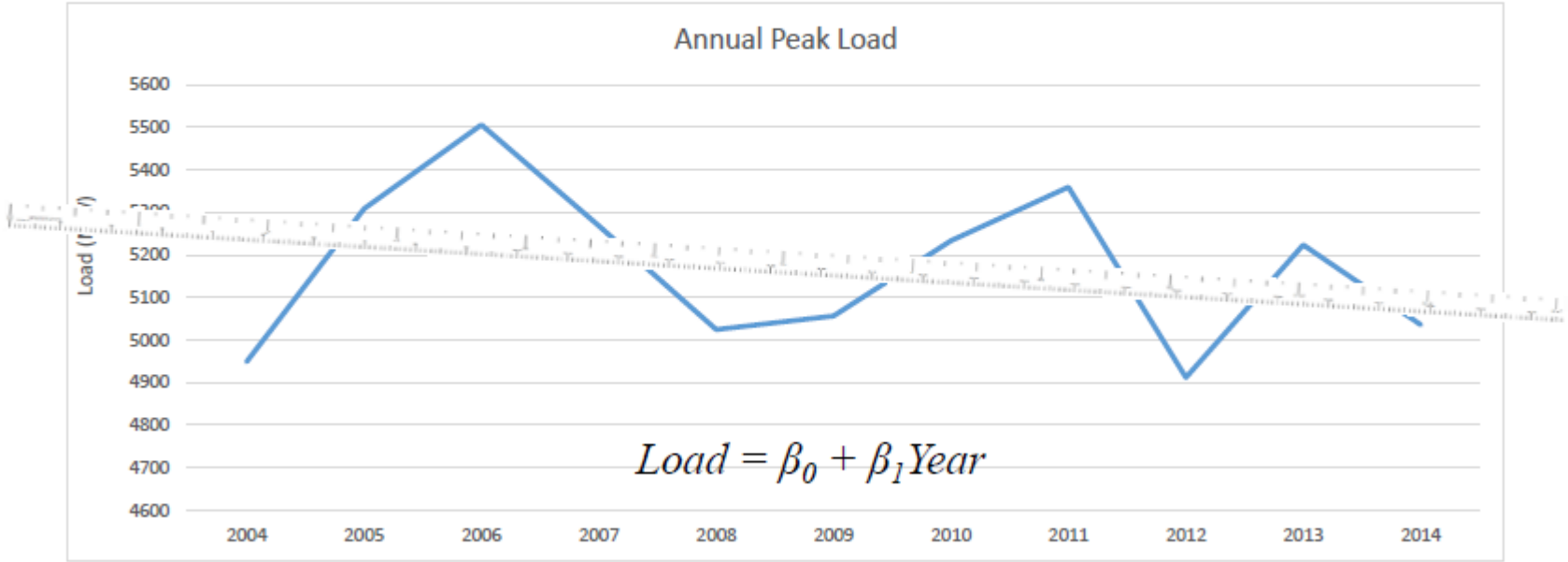
Data quality
Goodness of the model
Subject of interest
Magnitude
Time of day
Season of year
Special days
Weather condition

Weather forecasts
Locations of weather sensor(s)
Size of territory
Hierarchy
Error calculation
Control
Distributed resources
Emerging technologies

Error analysis

Magic ruler

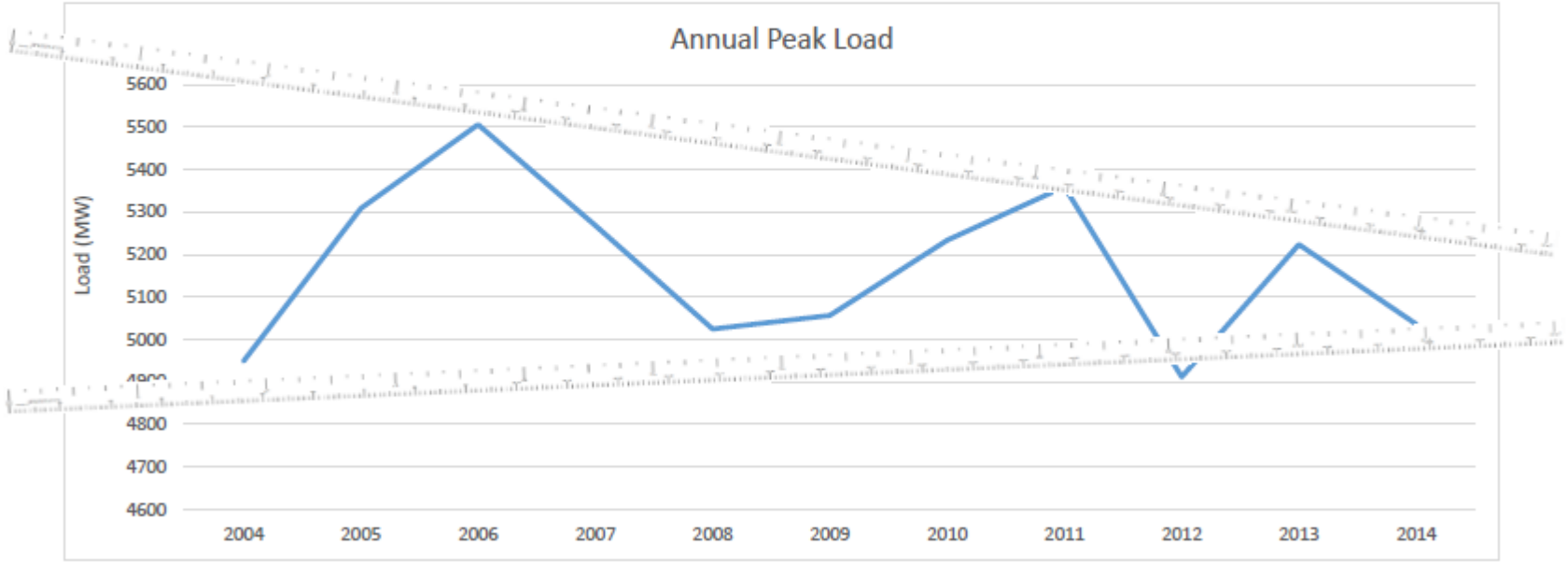
Annual peak load forecasting



Error analysis

Magic ruler

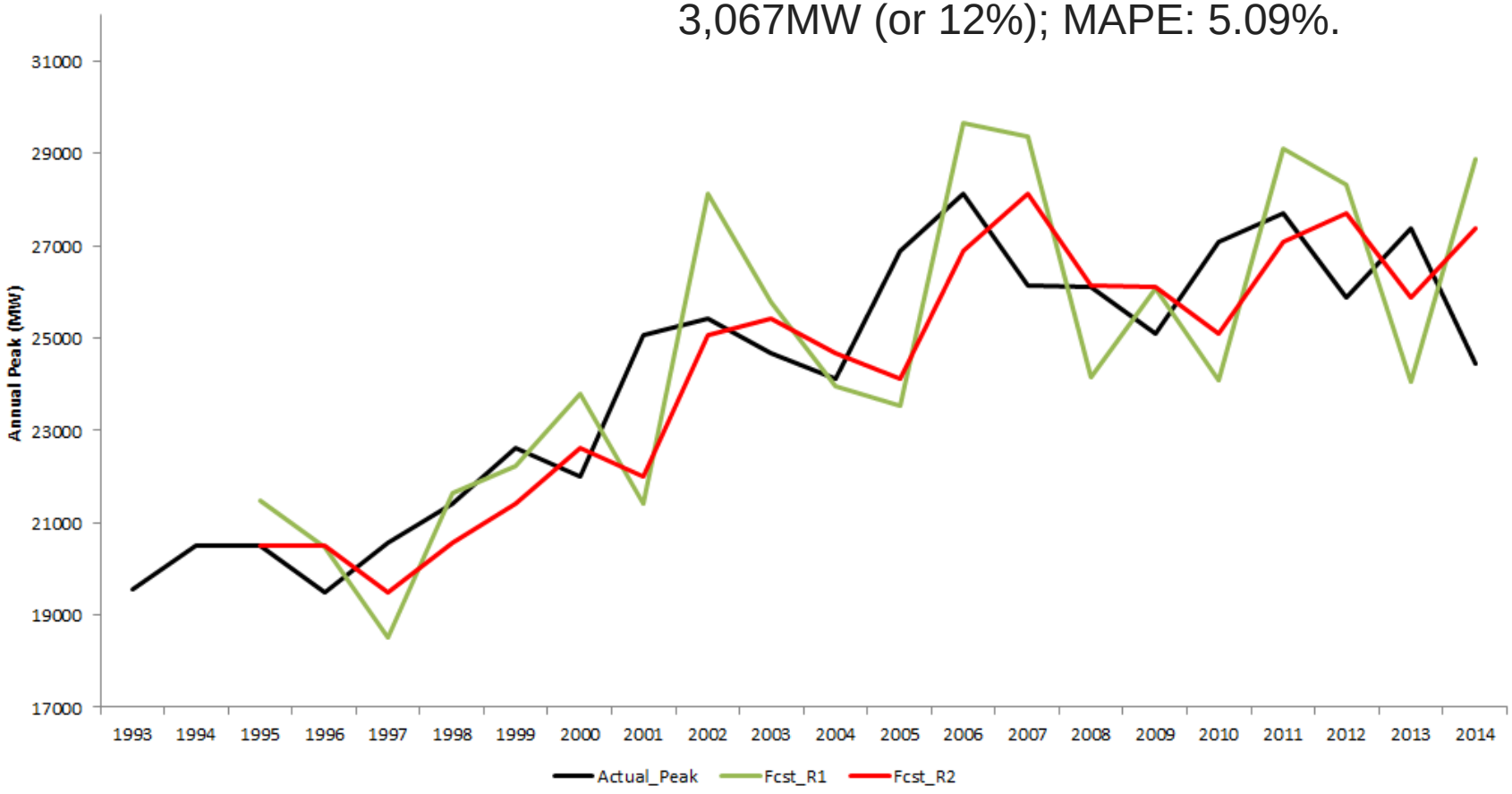
Upper and lower bound



Error analysis

Magic ruler

- The errors from R1 range from -4,435MW (or -18%) to 3,669MW (or 14%); MAPE: 7.92%.
- The errors from R2 range from -2,936MW (or -12%) to 3,067MW (or 12%); MAPE: 5.09%.



Fundamentals of model building

Model selection

Model selection

Running example

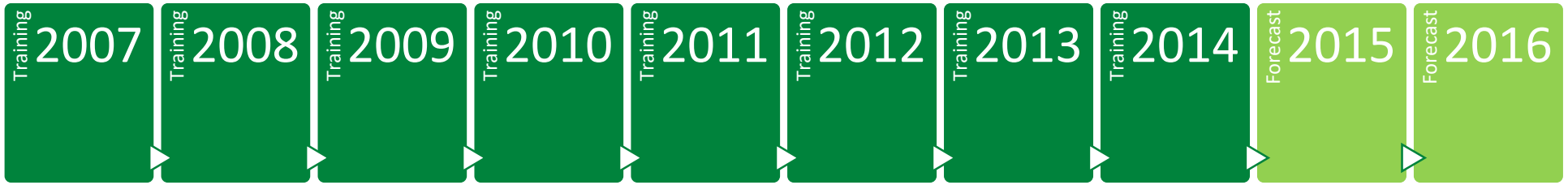
- Given 8 years of history
- How to build the model to forecast the next 2 years

Model selection

In sample fit

Based on training data

1. Estimate multiple models on training data
2. Pick the model with the best in-sample fit

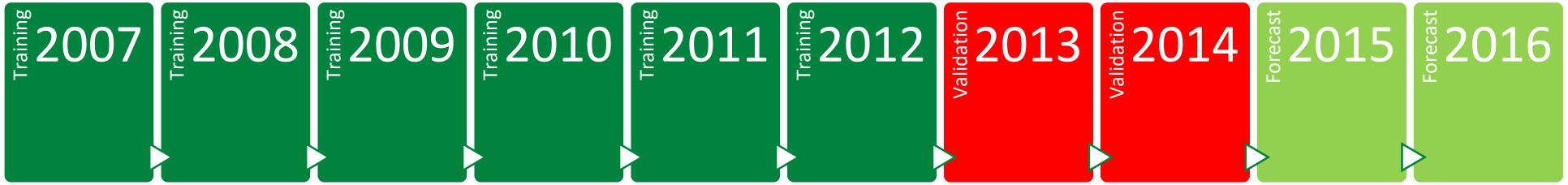


Model selection

Post sample fit

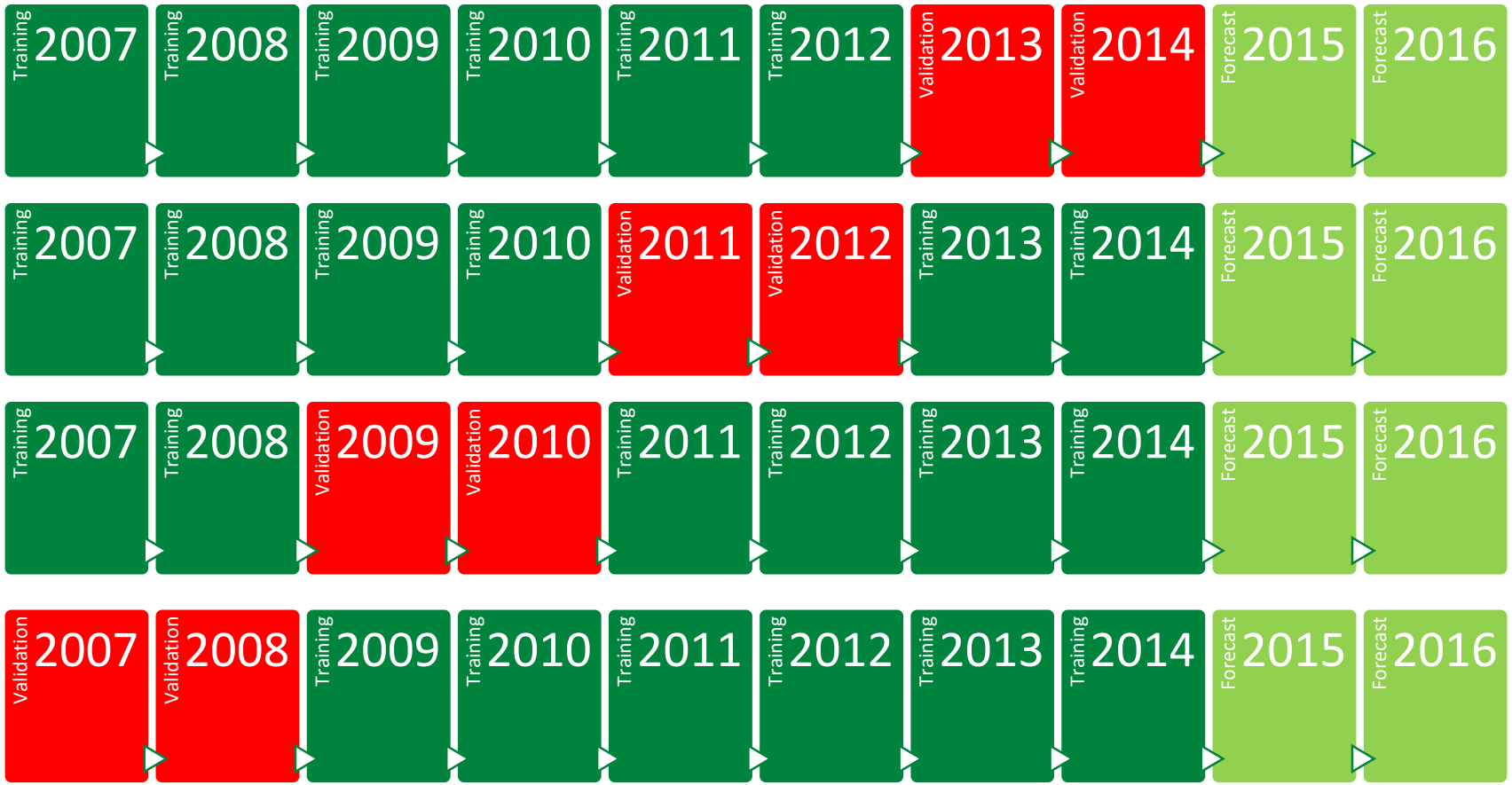
Based on training and validation data

1. Estimate multiple models on training data
2. Apply the models to forecast validation period
3. Pick the model with the best post-sample fit



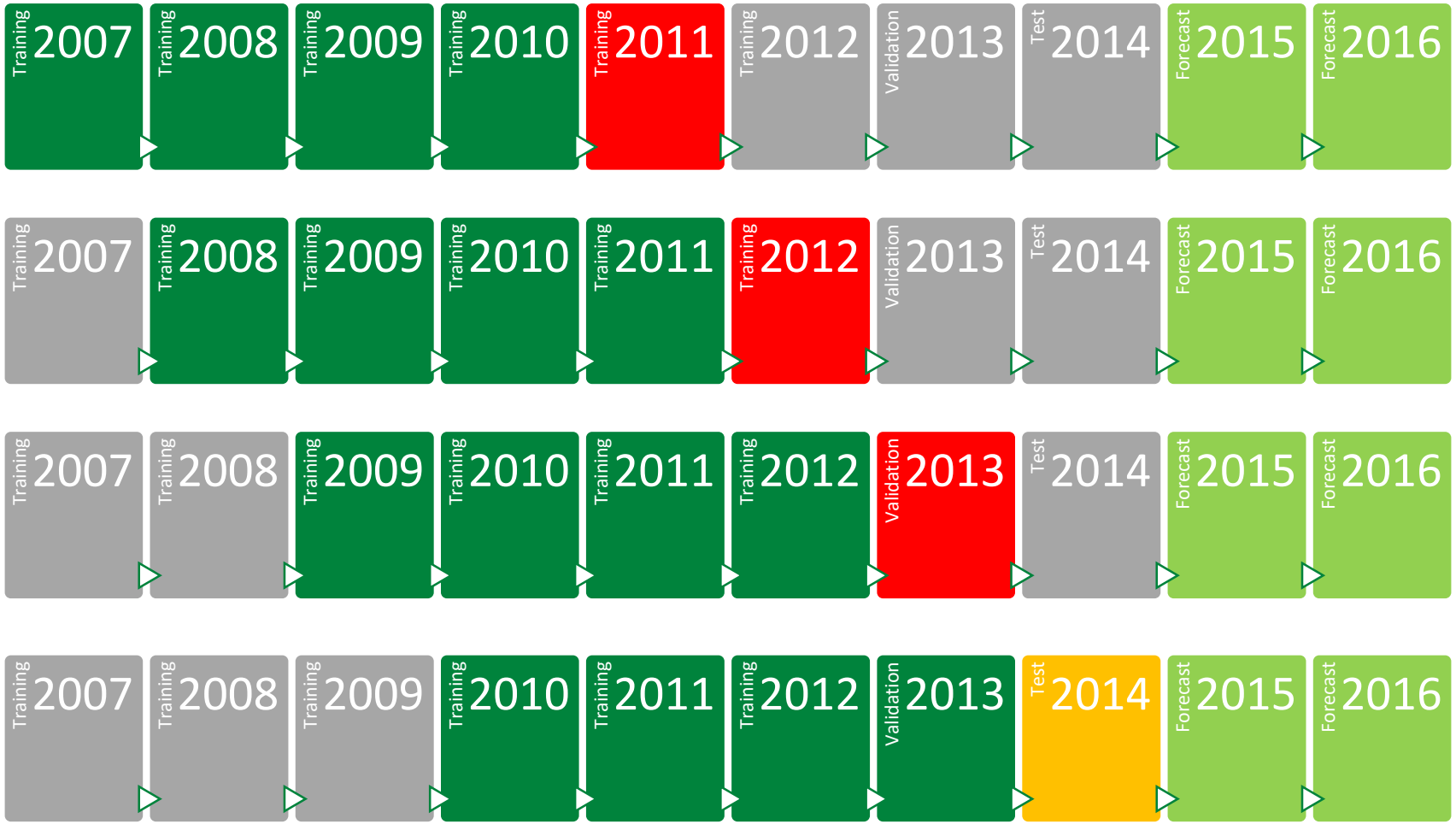
Model selection

Cross validation



Model selection

Sliding simulation

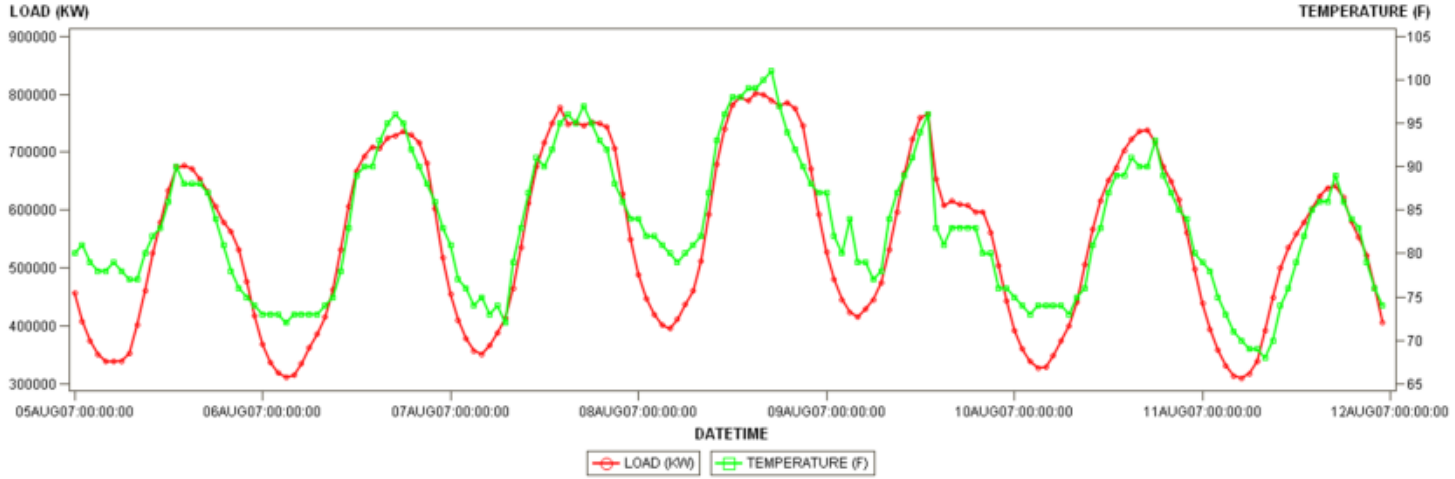


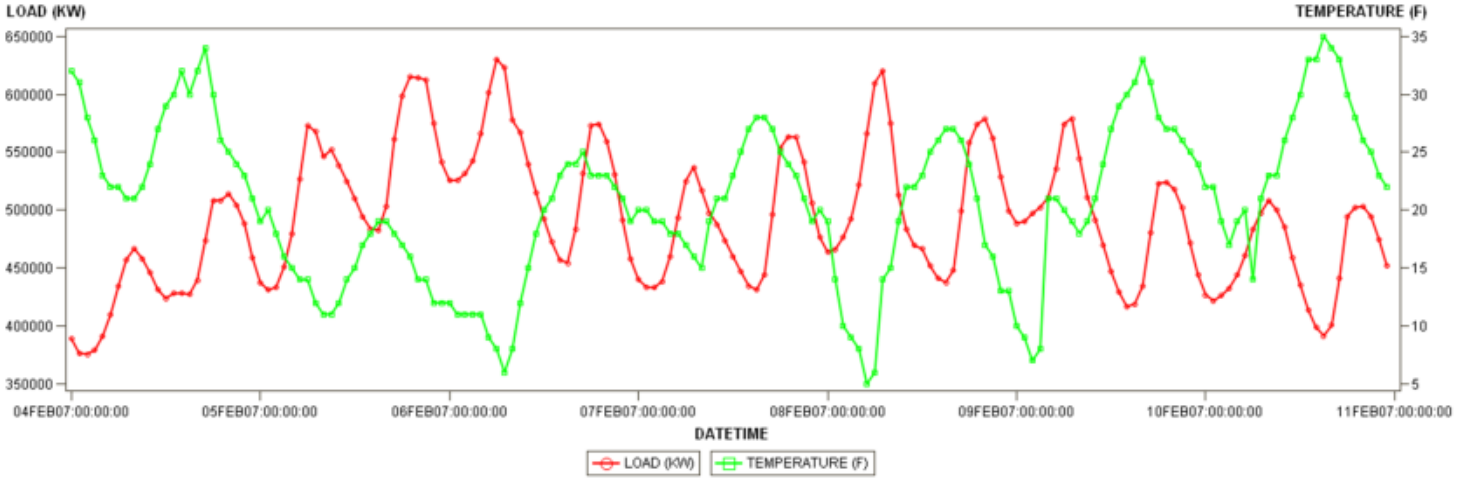
Fundamentals of model building

Driving factors

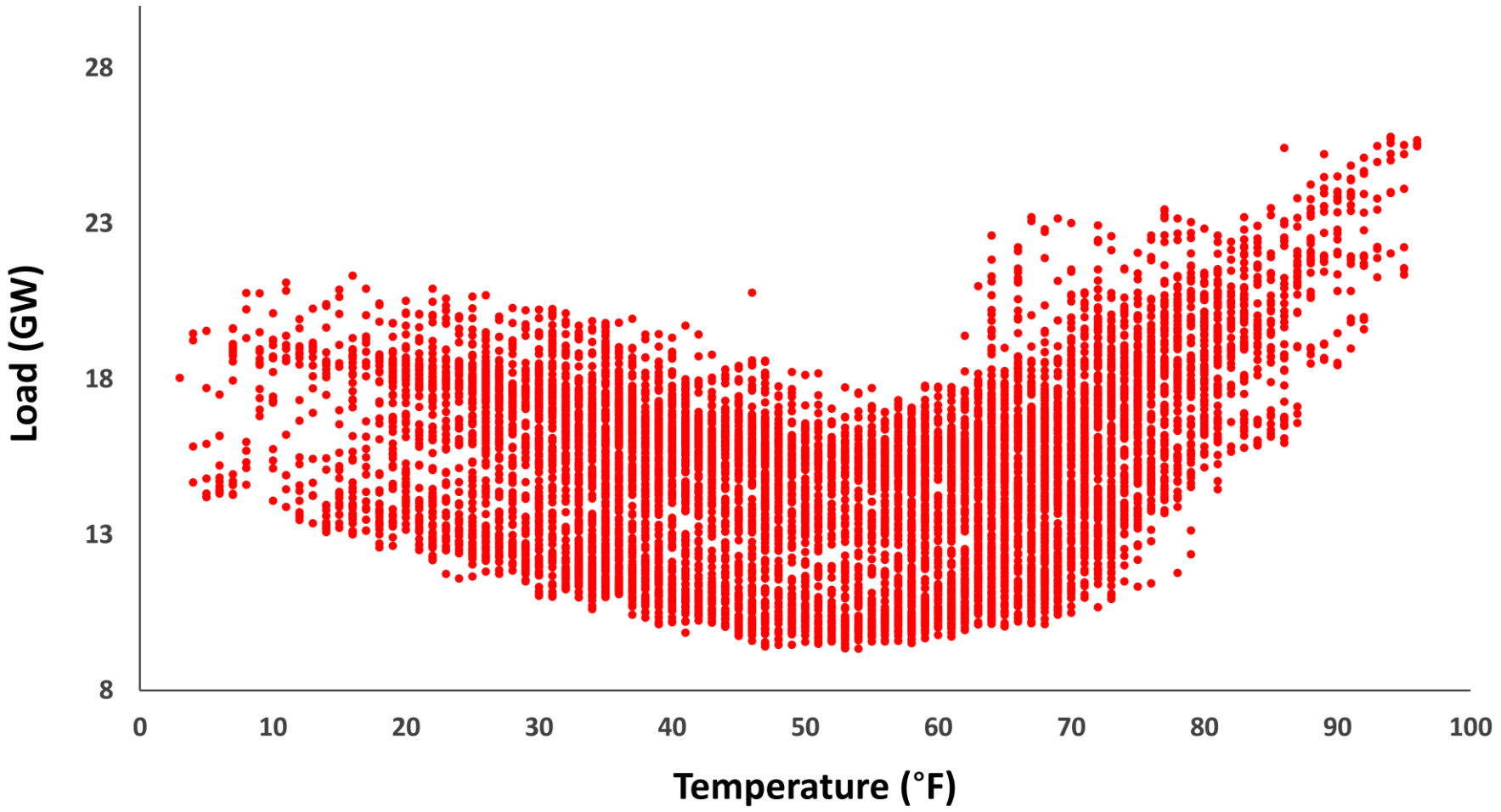
Driving factors

Load and temperature





Driving factors



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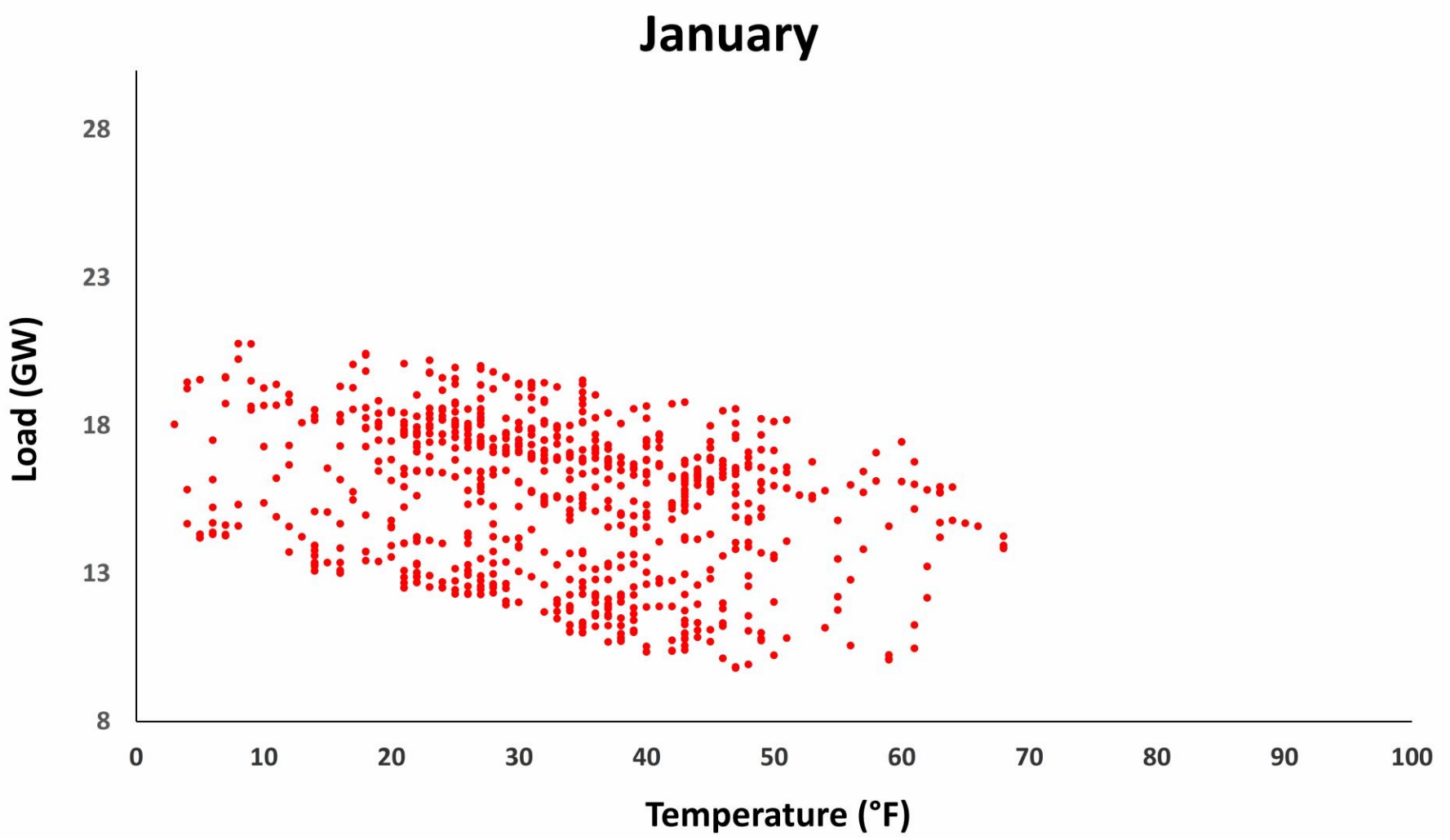

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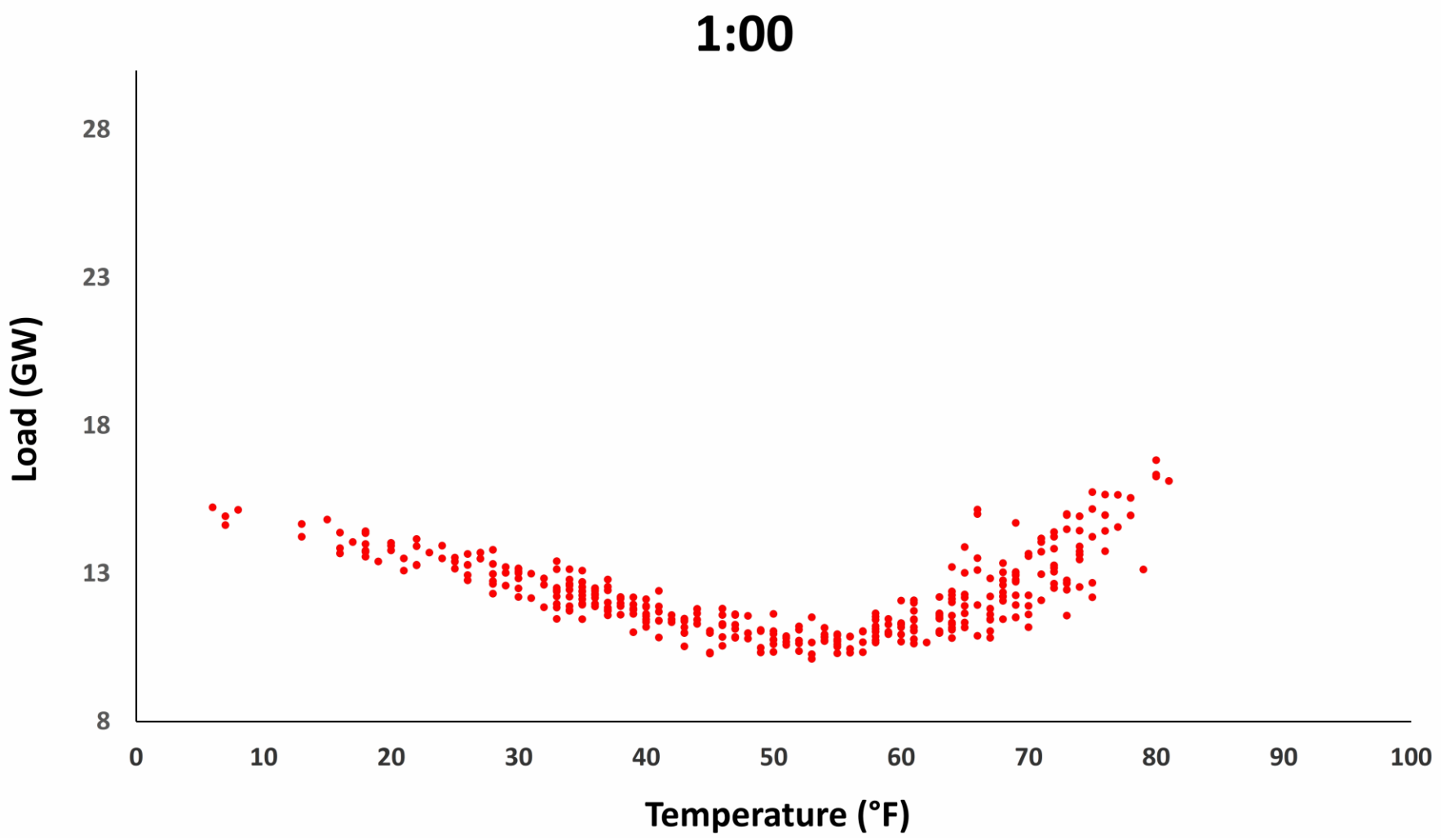
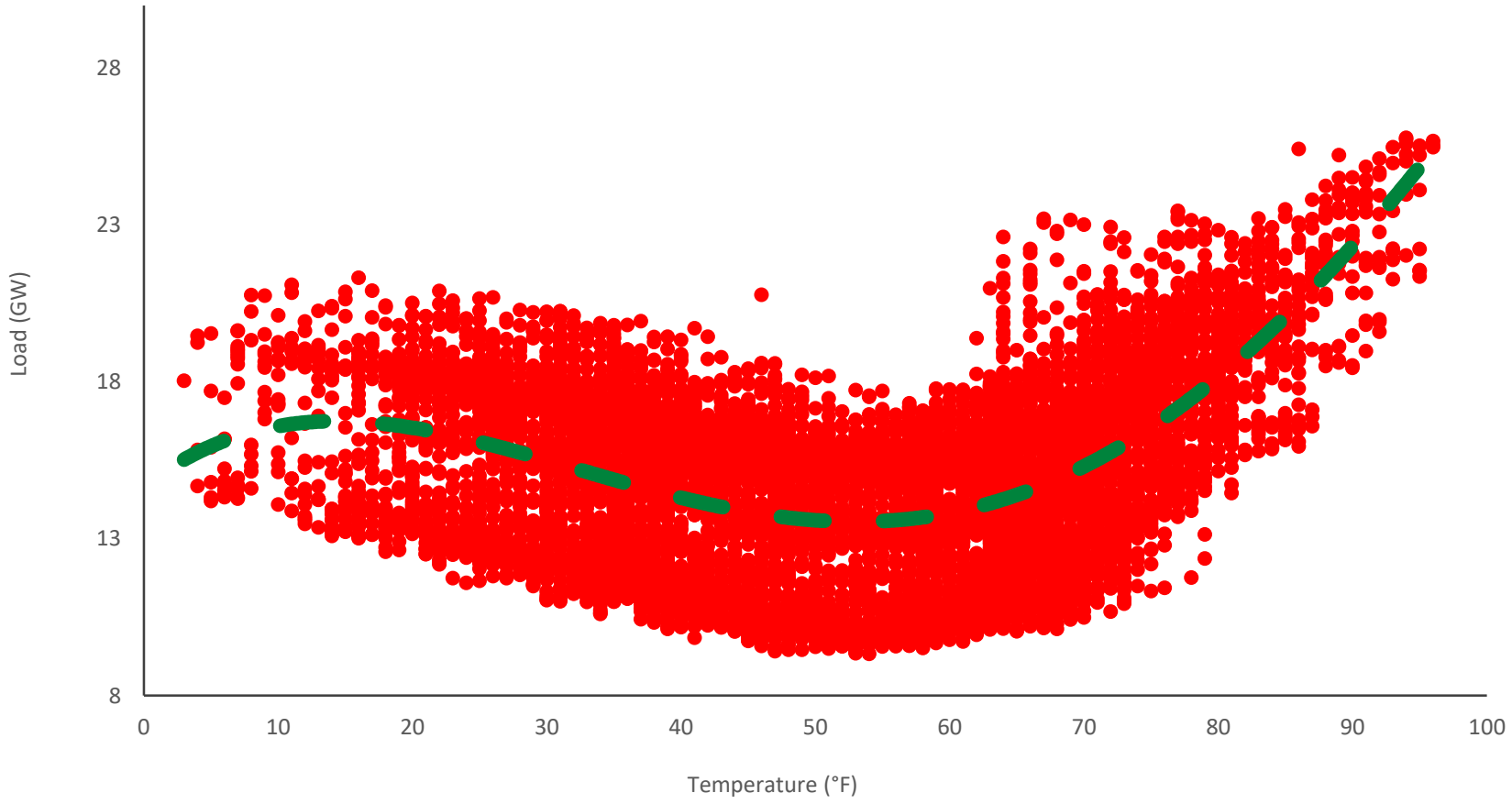


Driving factors



Fundamentals of model building

Ex post vs. ex ante forecasting

Ex post vs. ex ante forecasting

Ex post forecasting

- Given actual values of explanatory variables
- Answer “what-if” questions
- Model analysis

Ex ante forecasting

- Using predicted values of explanatory variables
- Genuine forecast

Things to consider

- Implications of forecast errors of explanatory variables
- The more variables/concepts, the better?
- Does a better ex post forecasting model imply better ex ante forecasts?