METHODS FOR FORECAS ELECTRICITY DEMAND

Douglas J. Gotham, SUFG Director

Presented to Indiana Society of Professional Engineers Annual Conference

June 10, 2022

PURDUE UNIVERSITY | State Utility Forecasting Group

Using the Past to Predict the Future

What is the next number in the following sequences?

0, 2, 4, 6, 8, 10, ….

0, 1, 4, 9, 16, 25, 36, ...

0, 1, 2, 3, 5, 7, 11, 13, ...

1, 3, 7, 15, 31, ...

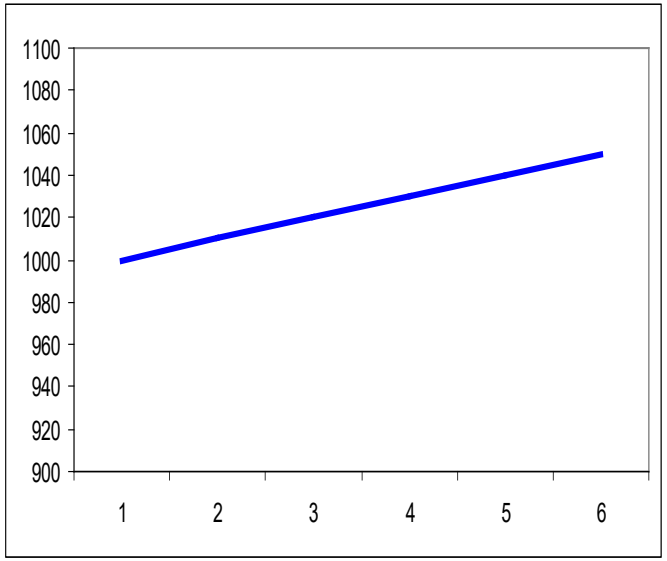
0, 1, 1, 2, 3, 5, 8, 13, ...

8, 6, 7, 5, 3, 0, ….

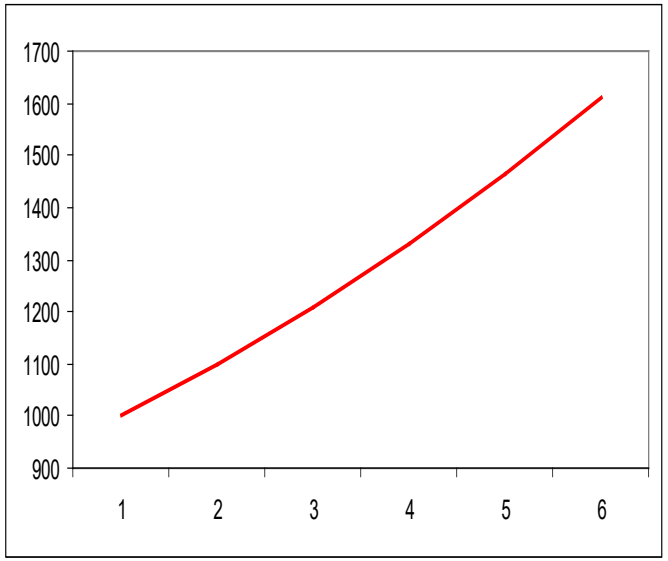
8, 5, 4, 9, 1, 7, ….

Simple Examples

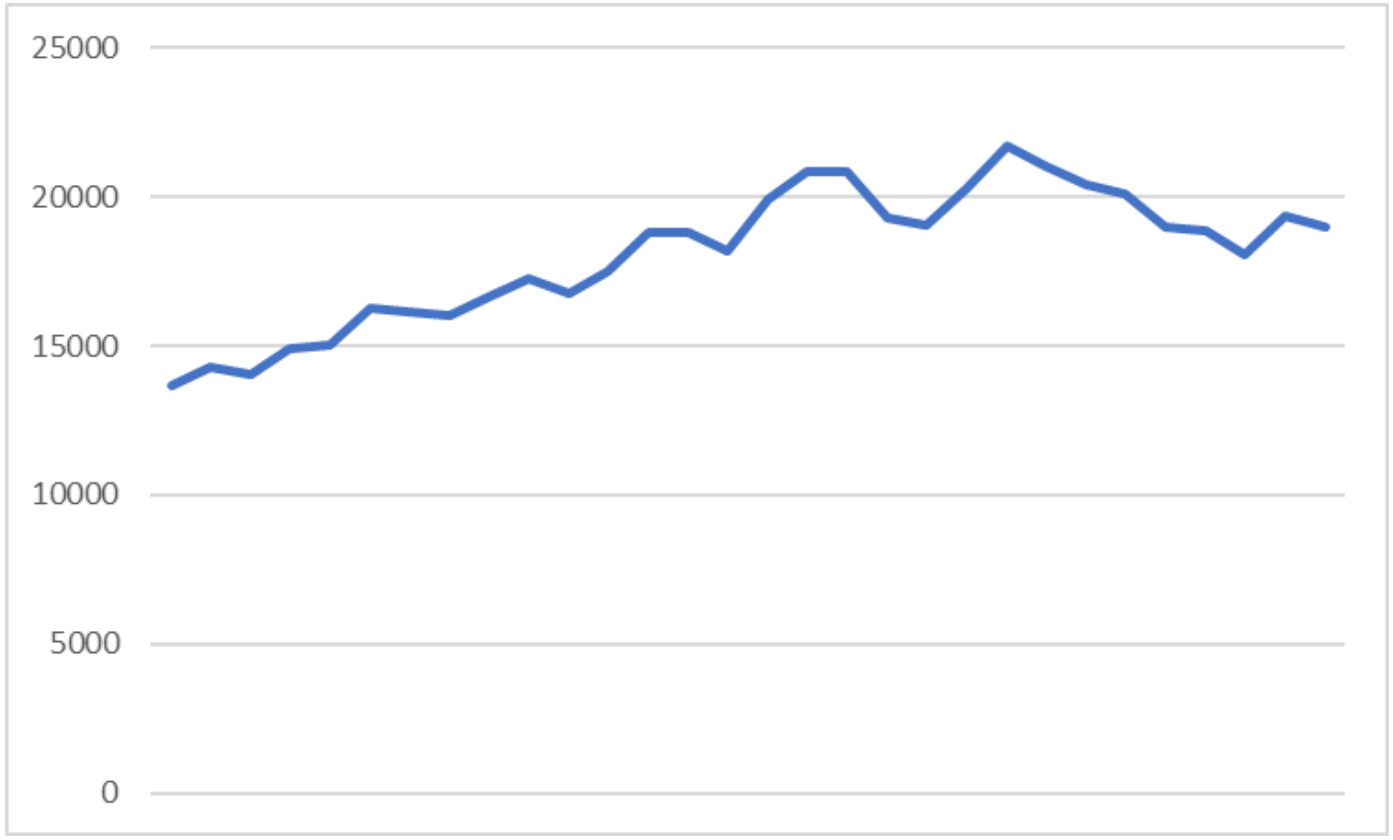
1000
1010
1020
1030
1040
1050
?
?
?



1000
1100
1210
1331
1464
1610
?
?
?



Much More Difficult



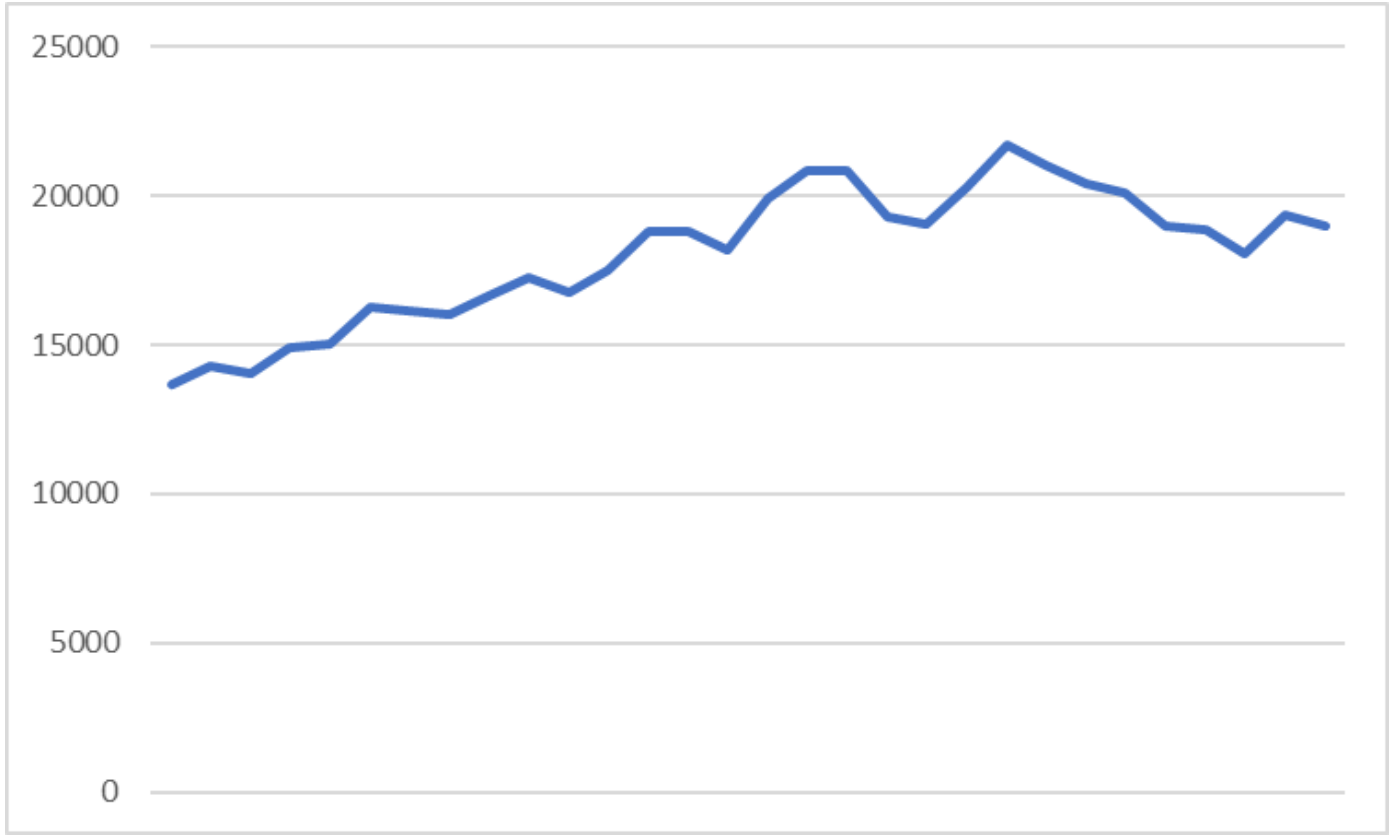
Much More Difficult

The numbers on the previous slide were the summer peak demands for Indiana from 1990 to 2019

- They are affected by a number of factors
  - Weather
  - Economic activity
  - Price (both electricity and competing fuels)
  - Interruptible customers called upon
  - Energy efficiency programs

Question

How do we find a pattern in these peak demand numbers to predict the future?



Methods of Forecasting

- Palm reading
- Tea leaves
- Tarot cards
- Ouija board
- Crystal ball
- Polling
- Astrology
- Dart board
- Sheep entrails
- Hire a consultant
- Wishful thinking

Alternative Methods of Forecasting

- Top-down
  - trend analysis (aka time series)
  - econometric
- Bottom-up
  - survey-based
  - end-use
- Hybrid
  - statistically-adjusted end-use

Time Series Forecasting

Linear Trend

- Fit the best straight line to the historical data and assume that the future will follow that line
  - works perfectly in the 1st example

- Many methods exist for finding the best fitting line; the most common is the least squares method

$$Y = \beta + \alpha X$$

Time Series Forecasting

Polynomial Trend

- Fit the polynomial curve to the historical data and assume that the future will follow that line

- Can be done to any order of polynomial (square, cube, etc.) but higher orders are usually needlessly complex

$$Y = \beta + \alpha_1 X + \alpha_2 X^2 + \ldots$$

Time Series Forecasting

Logarithmic Trend

- Fit an exponential curve to the historical data and assume that the future will follow that line
  - works perfectly for the 2nd example

$$Y = \beta\alpha^{X}$$

Time Series Forecasting

Advantages

- Relatively easy
- The statistical functions in most commercial spreadsheet software packages will calculate many of these for you
- Requires little data

Disadvantages

- Does not account for changing circumstances
- Choice of historical observations can impact results
- May not work well when there is a lot of variability in the historical data
  - If the time series curve does not perfectly fit the historical data, there is model error

Acceptability

- Trend analysis was a popular forecasting methodology until the 1970s
- The inability to handle changing conditions led to considerably inaccurate forecasts
- They have been largely discredited
  - MISO's forecasting whitepaper lists it as an "unacceptable" method

Econometric Forecasting

- Econometric models attempt to quantify the relationship between the parameter of interest (output variable) and a number of factors that affect the output variable
- Example
  - Output variable
  - Explanatory variable
    - Economic activity
    - Weather (HDD/CDD)
    - Electricity price
    - Natural gas price
    - Fuel oil price

Econometric Forecasting

Estimating Relationships

- Each explanatory variable affects the output variable in a different way. The relationships (or sensitivities) can be calculated via any of the methods used in time series forecasting
  - Can be linear, polynomial, logarithmic, moving averages, …

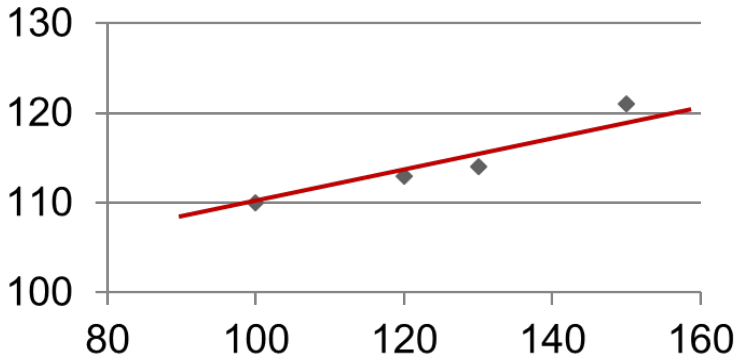
$$Y = \beta + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \ldots$$

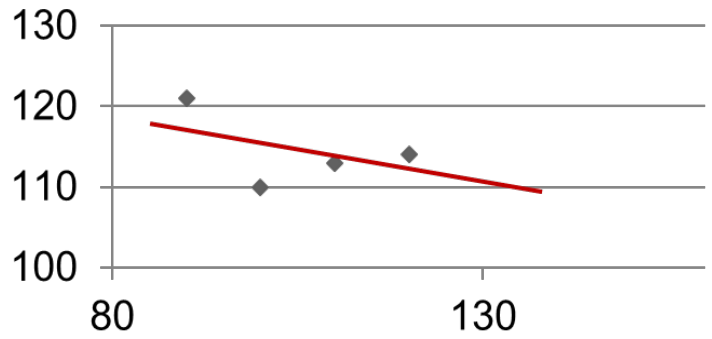
- Relationships are determined simultaneously to find overall best fit

Econometric Model Simple Example

Suppose we have 4 sets of observations with 2 possible explanatory variables

Output Y	Variable X_1	Variable X_2
110	100	100
113	120	110
114	130	90
121	150	120





Econometric Model Simple Example

- Including both variables provides a perfect fit
  - Perfect fits are not usually achievable in complex systems

$$Y = 0.2X_1 - 0.1X_2 + 100$$

Econometric Forecasting

Advantages

- Improved accuracy over trend analysis
- Ability to analyze different scenarios
- Greater understanding of the factors affecting forecast uncertainty

Disadvantages

- More time and resource intensive than trend analysis
- Difficult to account for factors that will change the future relationship between the drivers and the output variable
  - utility DSM programs
  - government codes and standards

Acceptability

- Econometric methods became popular as trend analysis died out in the 1970s and 1980s
- They continue to be used today
- MISO's forecasting whitepaper lists it as an "acceptable" method

Survey Based Forecasting

- Also referred to as “informed opinion” forecasts
- Use information from a select group of customers regarding their future production and expansion plans as the basis for a forecast
- Commonly done with large users

Survey-Based Forecasting

Advantages

- Simplicity
- The ability to account for expected fundamental changes in customer demand for large users, especially in the near-term
  - new major user or customer closing a facility

Disadvantages

- Tend to be inaccurate beyond first few years
  - most customers do not know what their production levels will be five or ten years in the future
  - few customers expect to close shop
  - new customers after first couple years are unknown
- Lack of transparency

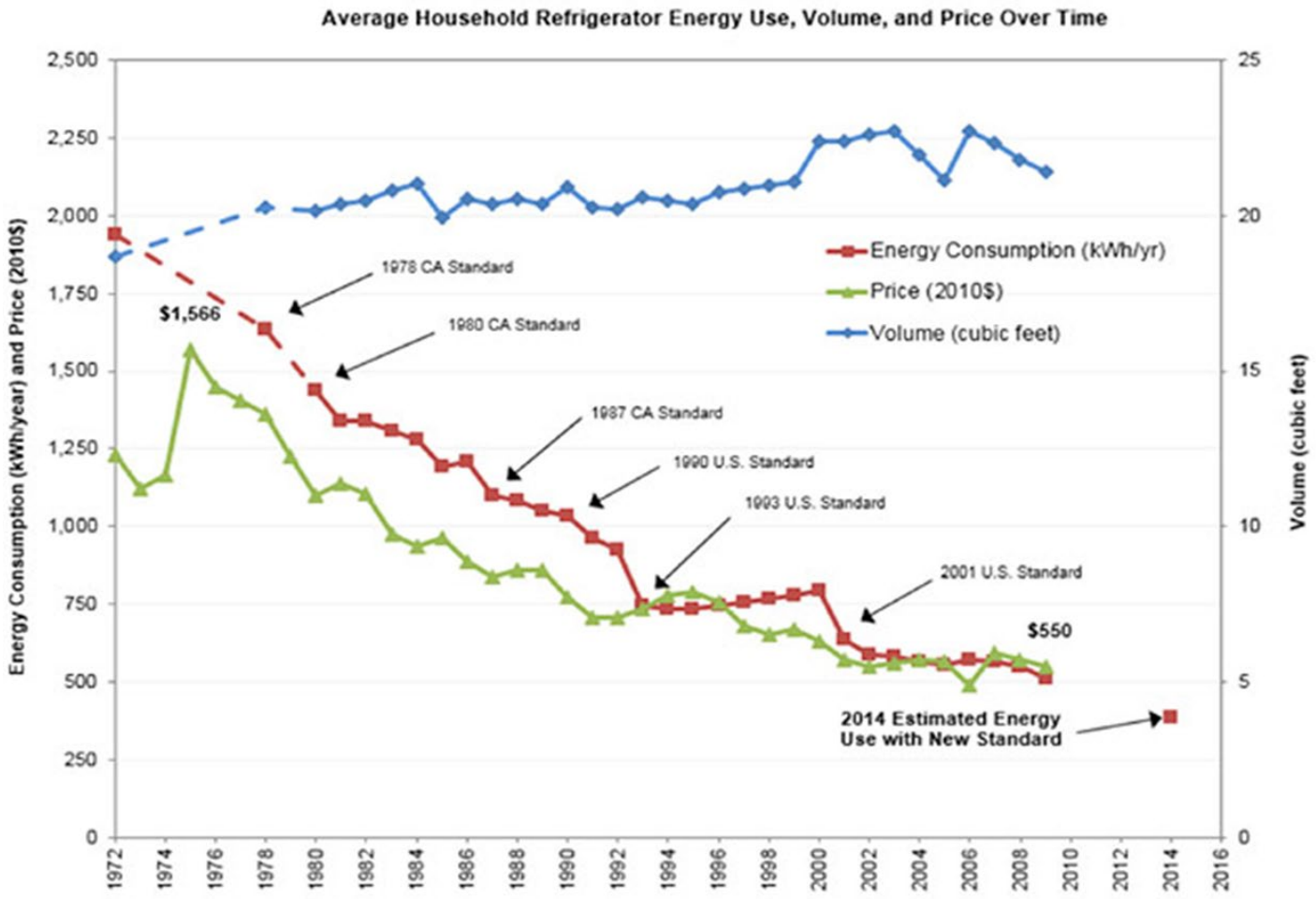
Acceptability

- Survey-based forecasts may be acceptable for short-term applications or if used in conjunction with another method in the longer term
- MISO's forecasting whitepaper lists it as an "unacceptable" method

End Use Forecasting

- End use forecasting looks at individual devices, aka end uses (e.g., refrigerators)
- How many refrigerators are out there?
- How much electricity does a refrigerator use?
- How will the number of refrigerators change in the future?
- How will the amount of use per refrigerator change in the future?
- Repeat for other end uses

End Use Forecasting



Source: ACEEE

Survey-Based Forecasting

Advantages

- Account for changes in efficiency levels both for new uses and for replacement of old equipment
- Allow for impact of competing fuels (natural gas vs. electricity for heating) or for competing technologies (electric resistance heating vs. heat pump)
- Incorporate and evaluate the impact of demand-side management (DSM) and conservation programs

Disadvantages

- Tremendously data intensive
- Primarily limited to forecasting energy usage, unlike other forecasting methods
  - Most long-term planning electricity forecasting models forecast energy and then derive peak demand from the energy forecast

Acceptability

- End-use modeling was first developed in the 1970s but started to gain popularity with the increase in DSM in the 1990s
- MISO's forecasting whitepaper lists it as an "acceptable" method

Hybrid Forecasting

- Hybrid models employ facets of both top-down and bottom-up models
- Most common is called the statistically-adjusted end-use (SAE) model
- In reality, most end-use models are hybrid to some degree in that they rely on top-down approaches to determine the growth in new devices

Hybrid Forecasting

SAE Models

- SAE models incorporate features of both econometric and end-use models
- Adjust the end-use estimated loads using a statistical regression to match observed loads

Hybrid Forecasting

Advantages

- In general, hybrid approaches attempt to combine the relative advantages and disadvantages of both model types
- Can better capture externalities that affect customer decisions when compared to end-use models
  - green options

Disadvantages

- Increased model complexity
  - More time and resource intensive
- Generally have less end use detail
  - cooling, space heating, and other

Acceptability

- Hybrid models have been gaining in popularity in recent years
- MISO's forecasting whitepaper lists it as an "acceptable" method

Forecasting Example

- SUFG has electrical energy models for each of 8 utilities in Indiana
- Utility energy forecasts are built up from sectoral forecasting models
  - residential (end-use & econometric)
  - commercial (end-use & econometric)
  - industrial (econometric)

Another Example

- SUFG has developed independent forecasting models for MISO
  - econometric
  - individual state level (15 states)

Yet Another Example

- The Energy Information Administration's National Energy Modeling System (NEMS) projects energy and fuel prices for 9 census regions
- Energy demand (end-use)
  - residential
  - commercial
  - industrial
  - transportation

THANK YOU

Doug Gotham
gotham@purdue.edu
765-494-0851
https://www.purdue.edu/discoverypark/sufg/

MISO Forecasting Methodology White Paper
https://cdn.misoenergy.org/Peak%20Forecasting%20Methodology%20Review%20Whitepaper173766.pdf