CONNECTIONS SUMMIT

Distribution Circuit Load Forecasting Using AMI Data

Bradley Lawson – SAS
Mark Konya - SAS

ELECTRICITIES of NORTH CAROLINA, INC.

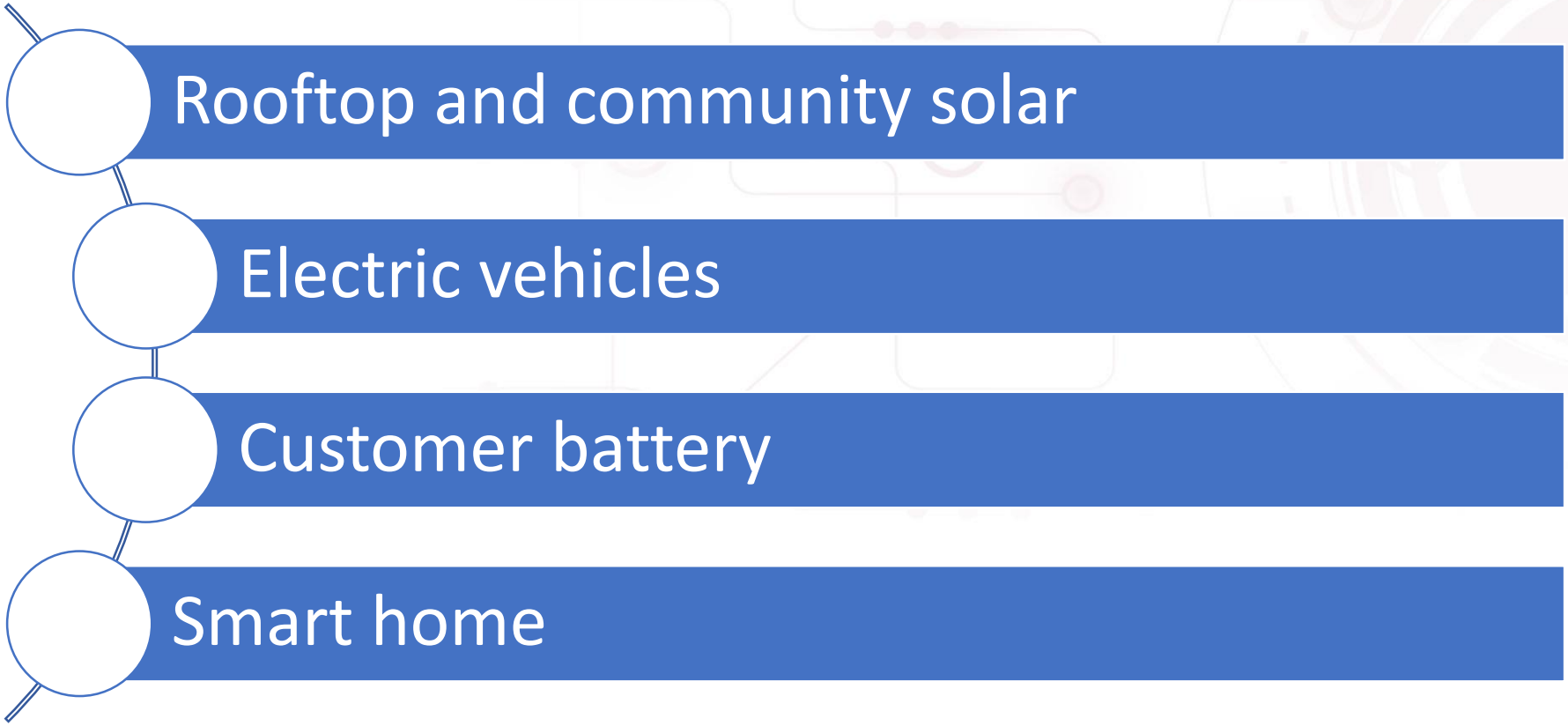
What is Distribution Circuit Load Forecasting?

- **Very short to very long-term forecasts of distribution circuit loads**
  - at intermediate distribution circuit locations between customer meters and substation feeder buses
  - using AMI (Advanced Metering Infrastructure) data
- **Provides significant advantages to distribution system planners and operators in a number of areas**
  - anticipation of device overloads
  - facilitation of switching operations

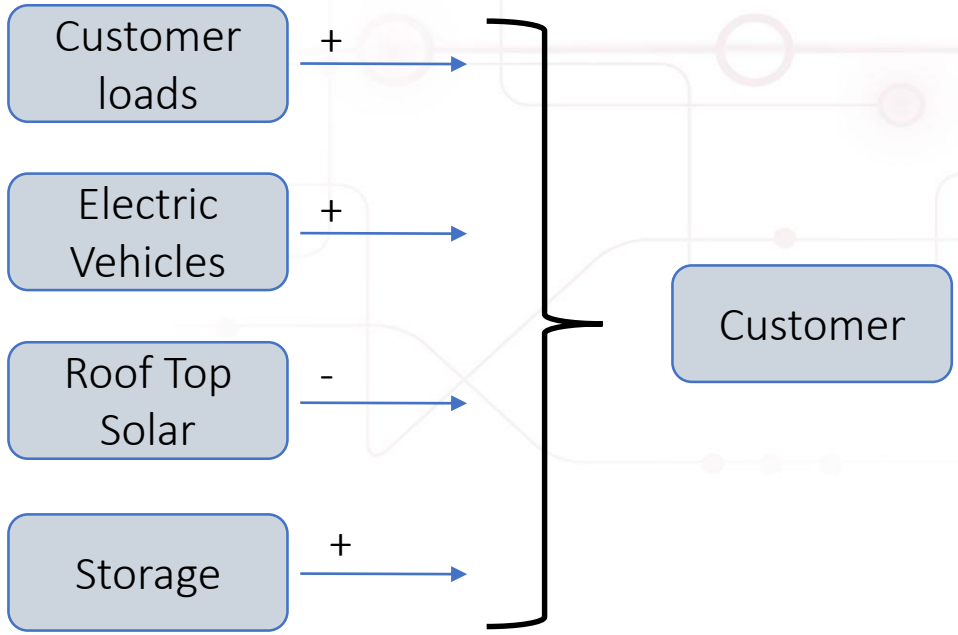
Why Hourly Distribution Circuit Load Forecasting?

- **Now have AMI (Advanced Metering Infrastructure) data**
- **The pattern of customer loads matter when changes are taking place**
  - Knowing customer's peak load is not enough, need to know how it fits with all the other customers on the distribution feeder.
  - More chance for localized problems. (Know the feeder pattern, but problems could arise on the local/transformer.)
  - More chance for localized opportunities. (DR)
- **Hourly modeling helps anticipate localized loads from severe weather**

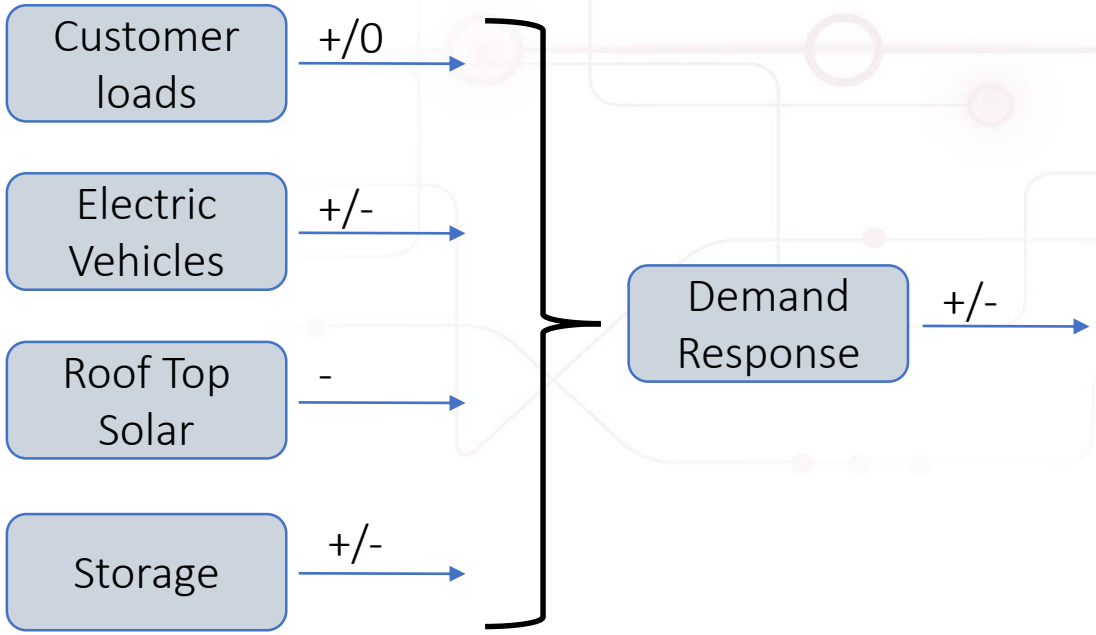
Grid Disruption Will Continue



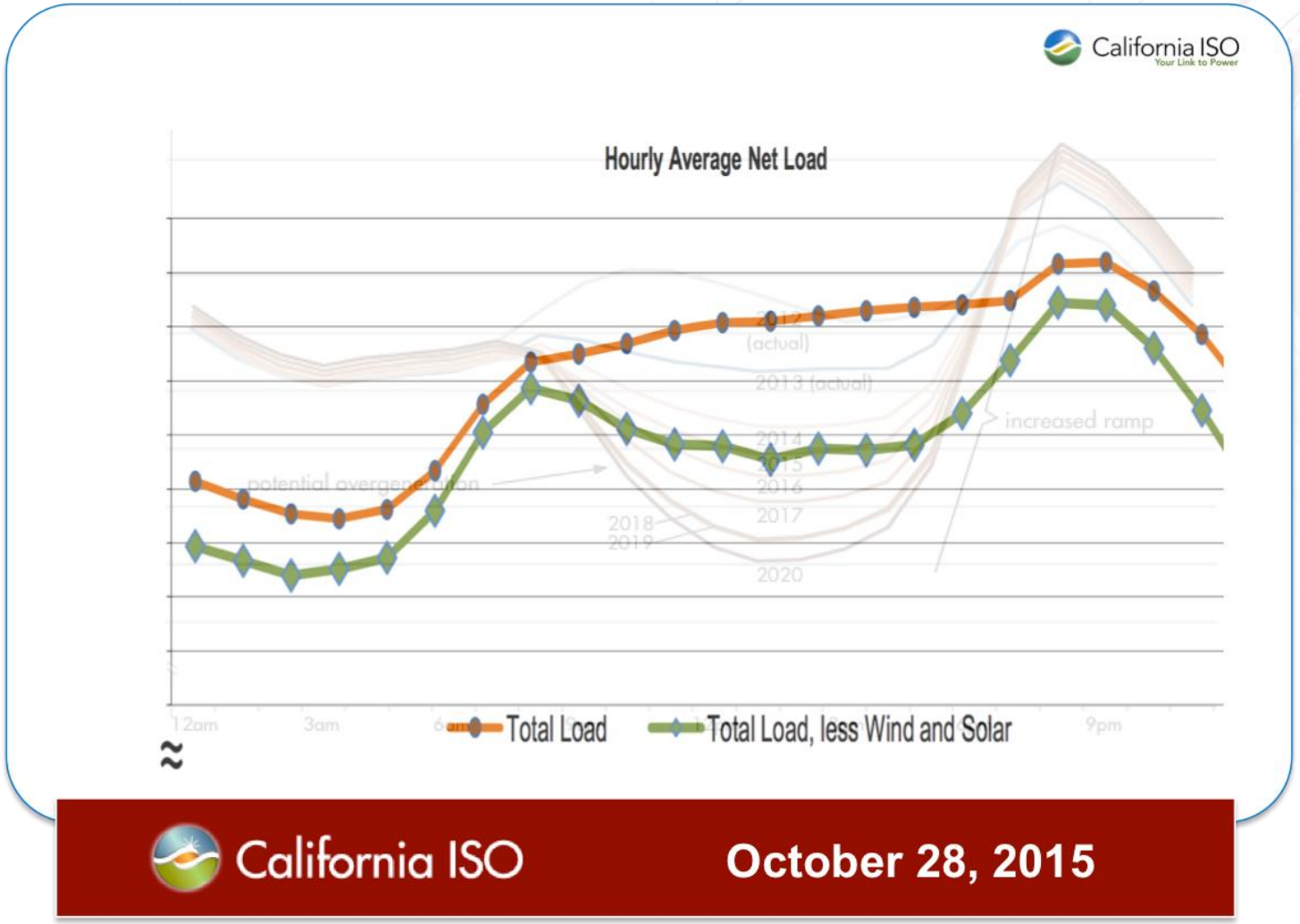
The Residential Customer



The New Residential Customer



Effect of Solar and Wind Generation

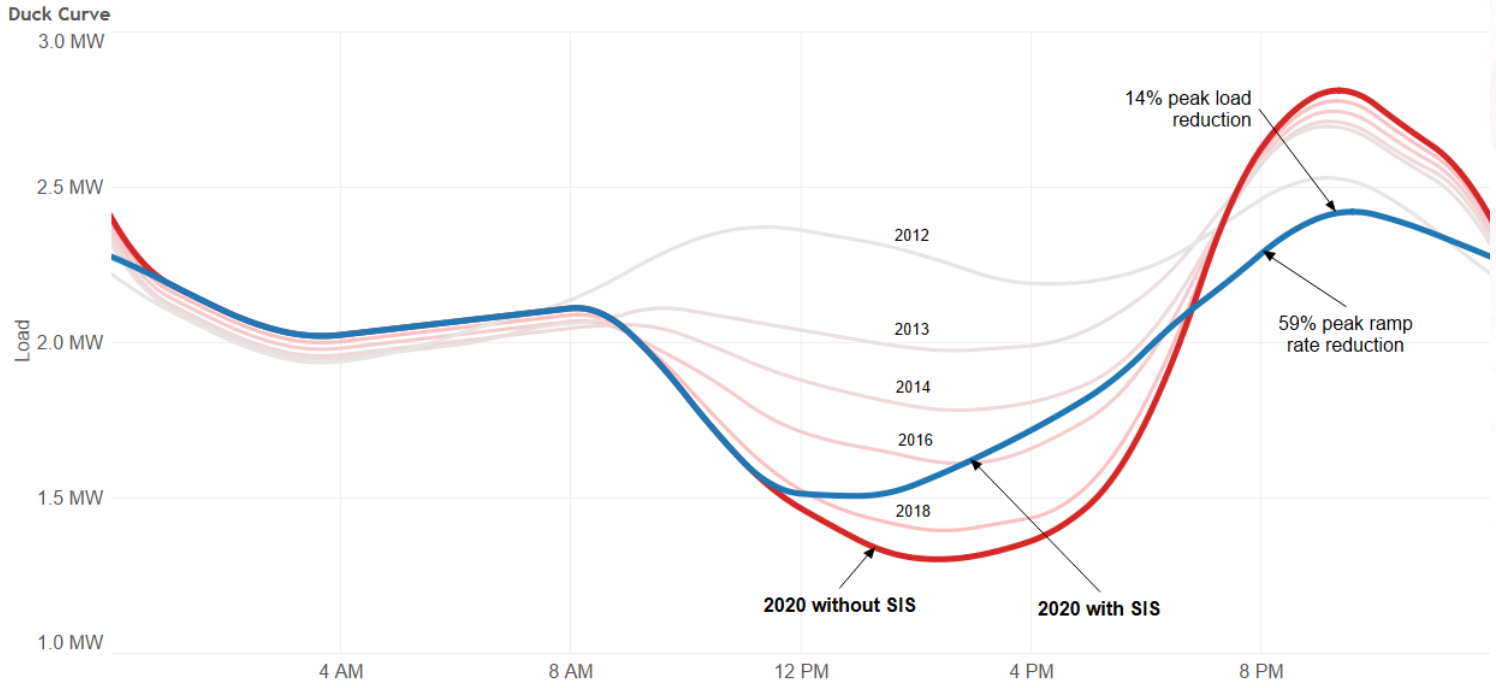


North Carolina Solar

Data Current Through:Q3 2018
Installed (MW): 4,671
National Ranking: 2nd (2nd in 2017)
State Homes Powered by Solar: 533,796
Percentage of State's Electricity from Solar: 5.44%
Solar Jobs: 7,622
Prices have fallen 43% over the last 5 years
Growth Projection and Ranking:
3,671 MW over the next 5 years (ranks 4th)

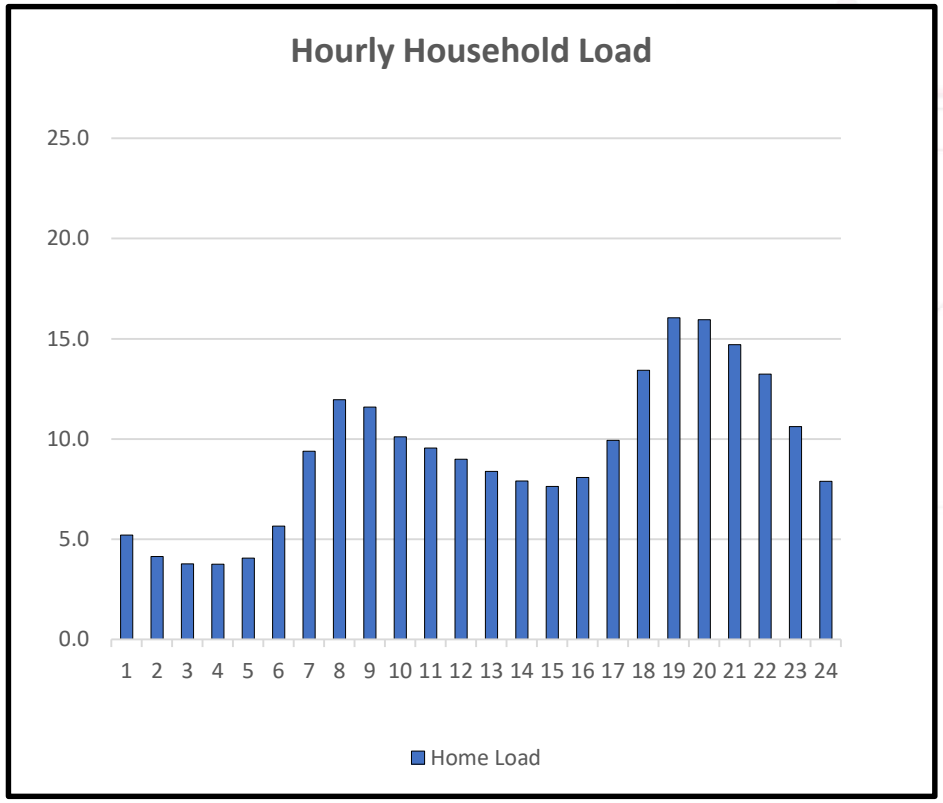
https://www.seia.org/state-solar-policy/north-carolina-solar

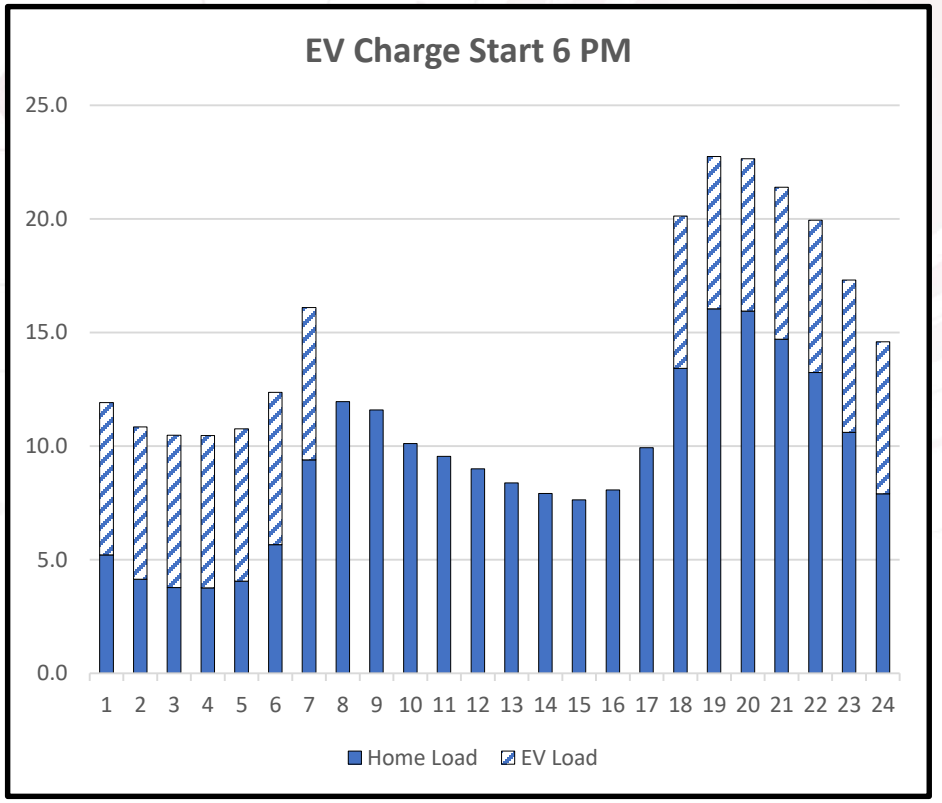
Mitigating the duck curve with storage



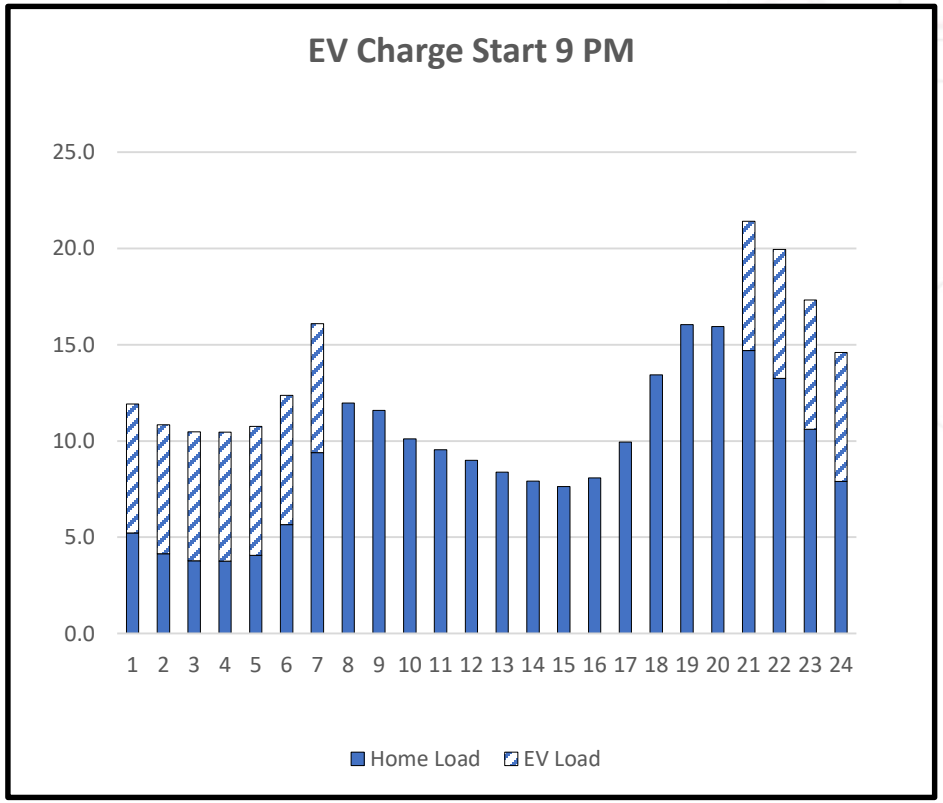
Electric vehicles

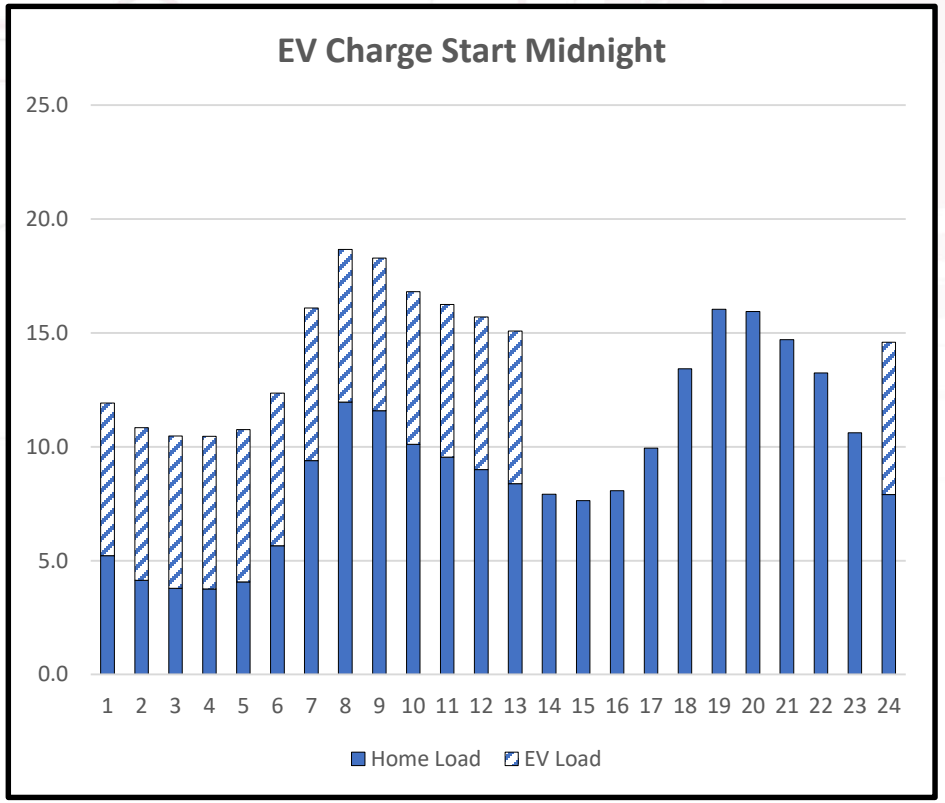
Electric Vehicles





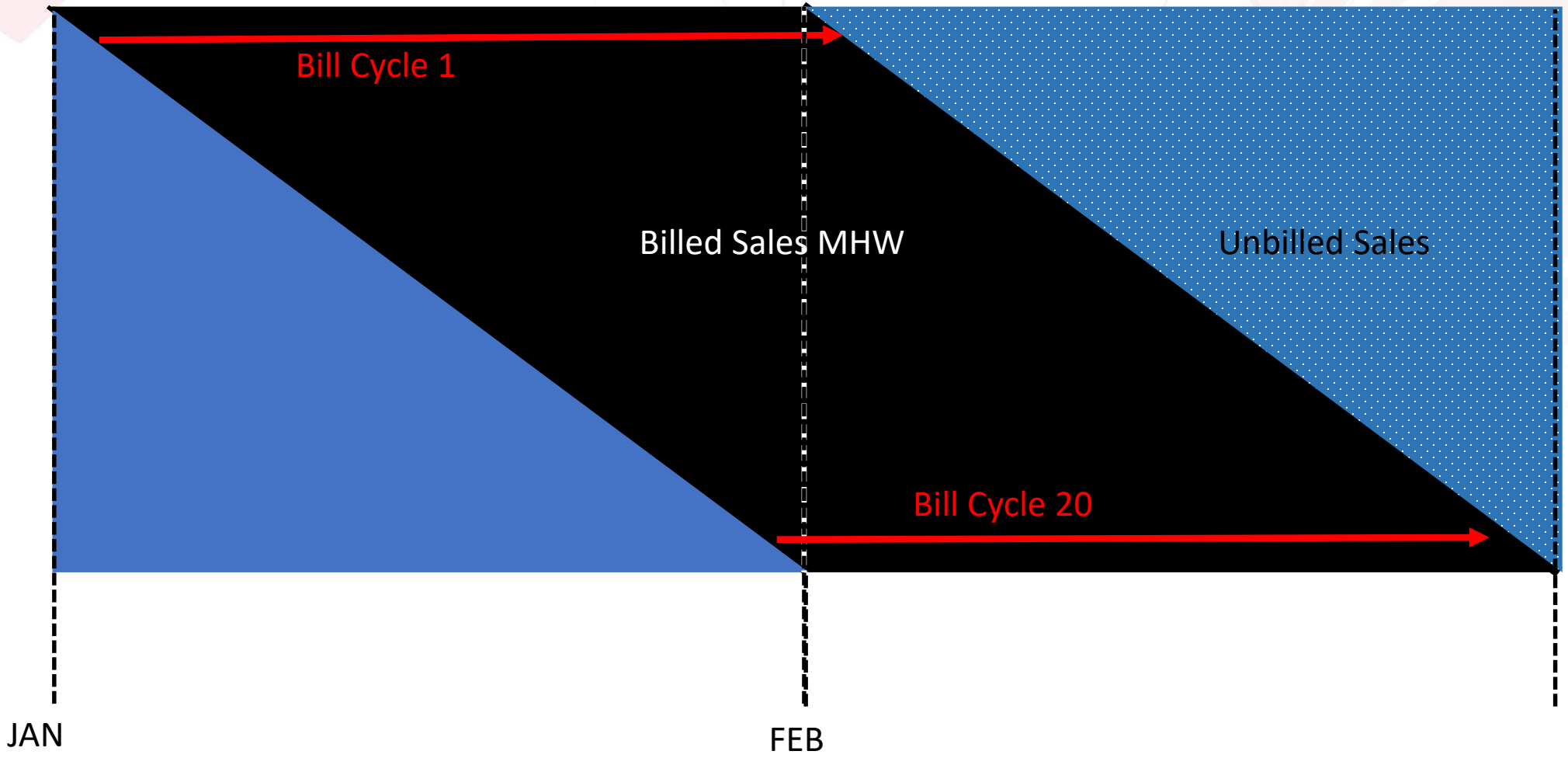
Electric Vehicles





METERING ADVANCES

Billed and unbilled sales



Metering

AMR - Automated Meter reading

Reads meter once per month

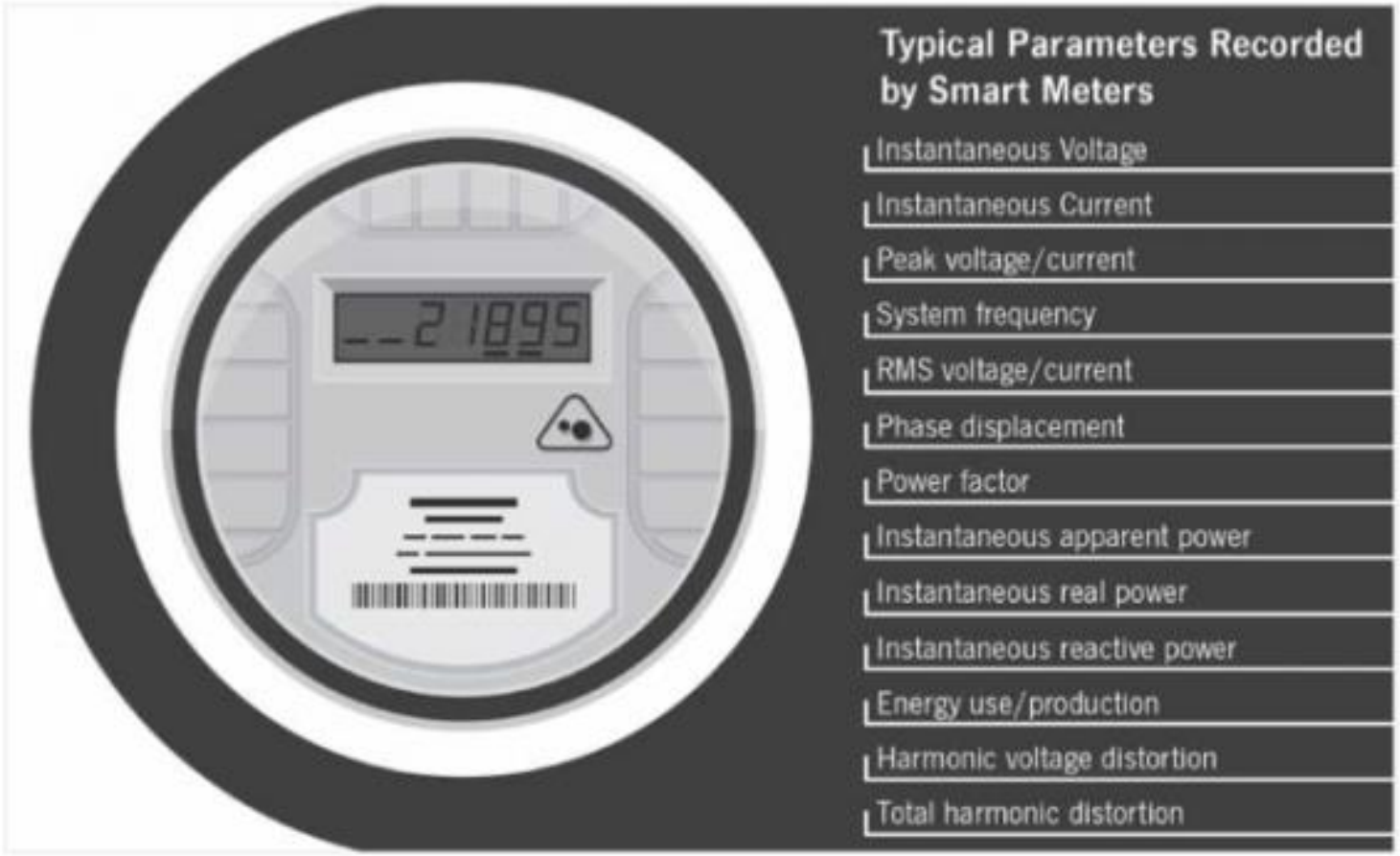
- **No hourly Data**
- **Read in cycle – never a calendar month**
- **Data no different from traditional meter**

AMI - Automated Metering Infrastructure

Read meter continuously

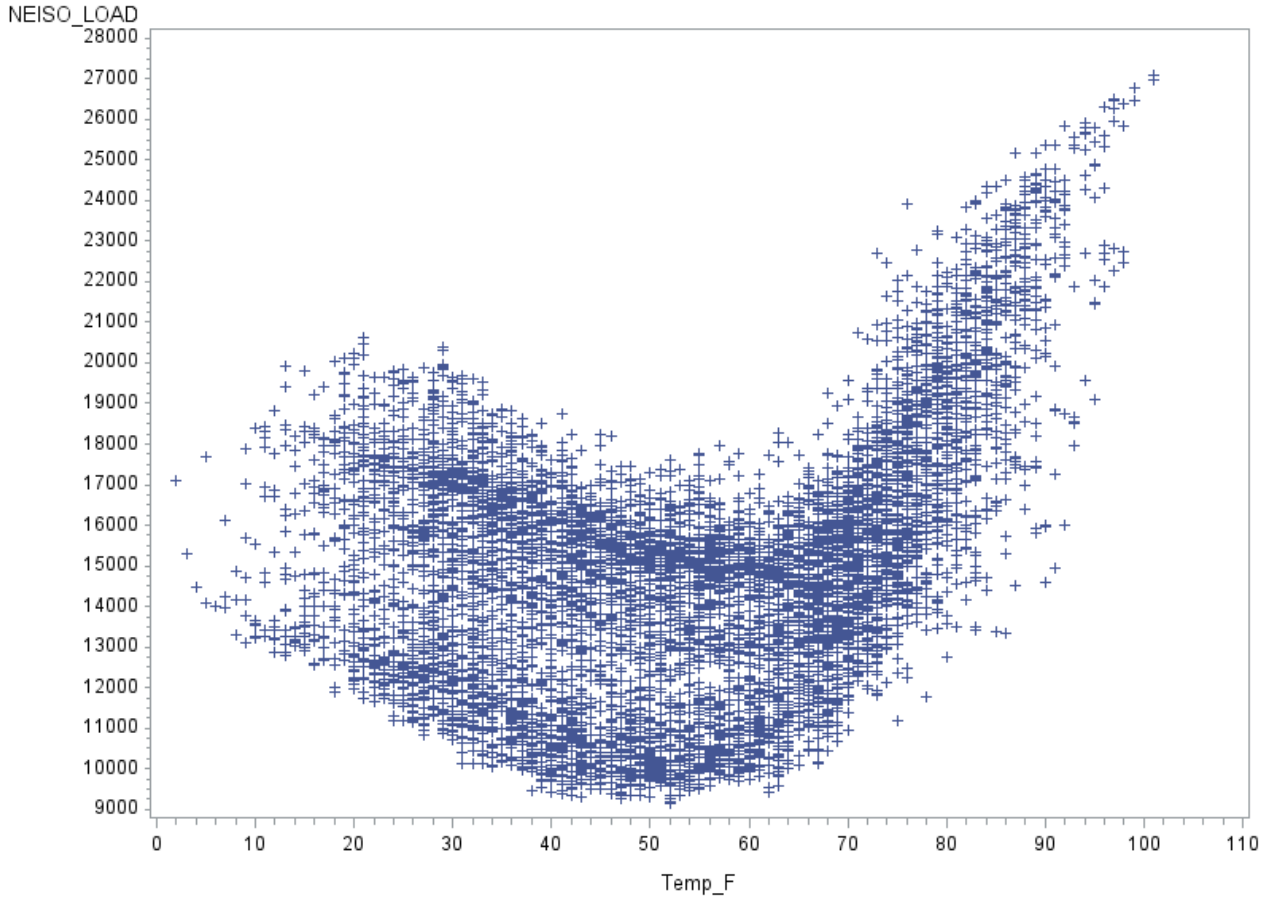
- **Hourly data……Big Data**

AMI Meters

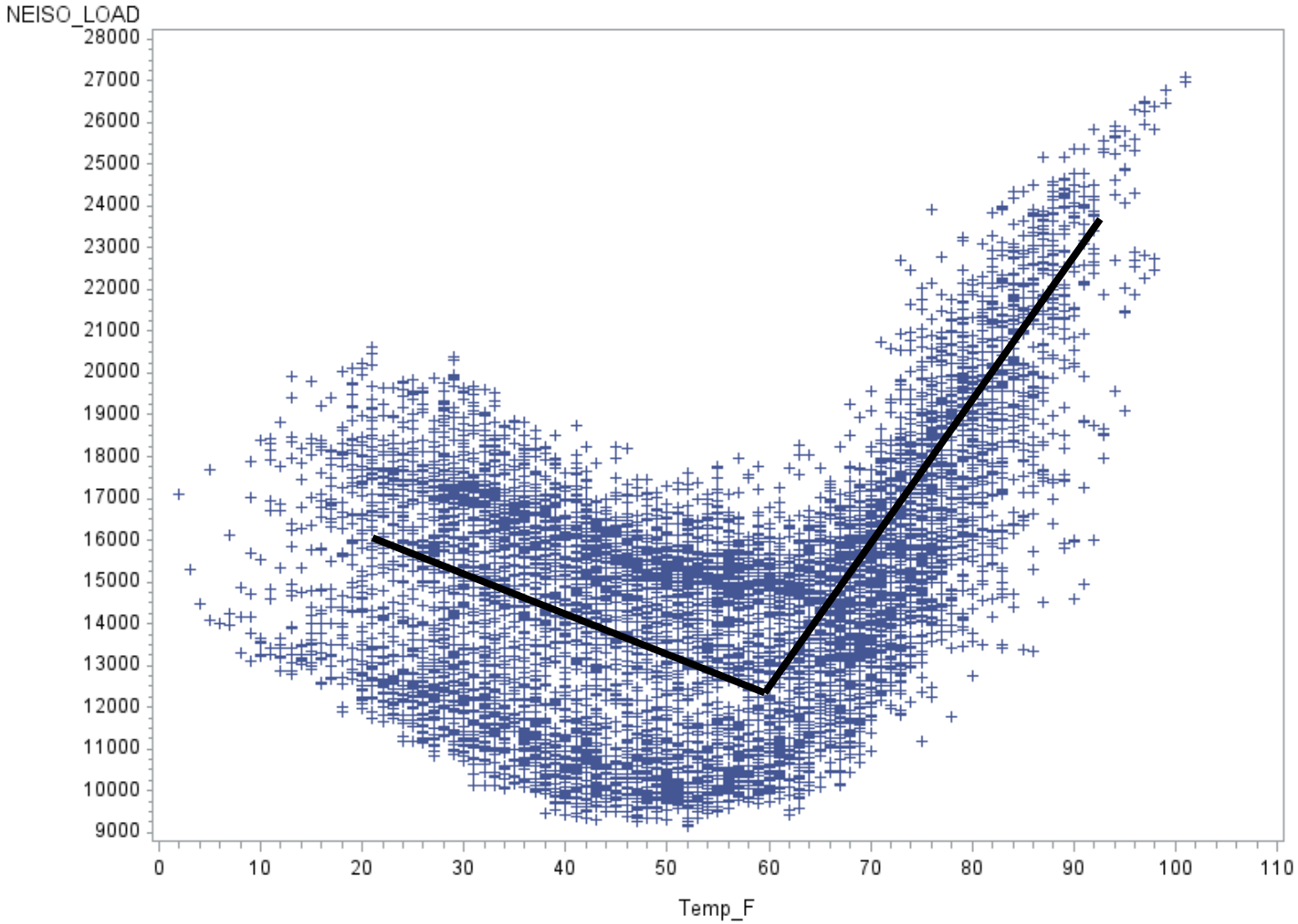

Typical Parameters Recorded by Smart Meters
Instantaneous Voltage
Instantaneous Current
Peak voltage/current
System frequency
RMS voltage/current
Phase displacement
Power factor
Instantaneous apparent power
Instantaneous real power
Instantaneous reactive power
Energy use/production
Harmonic voltage distortion
Total harmonic distortion

How is hourly forecasting different from monthly or daily?

What is the Challenge of Hourly Forecasting?



What is the Challenge of Hourly Forecasting?



Simple Load Forecast Model

$$Load = Intercept + \beta 1 * (Temperature < 60) + \beta 2 * (Temperature > 60)$$

Degree Days

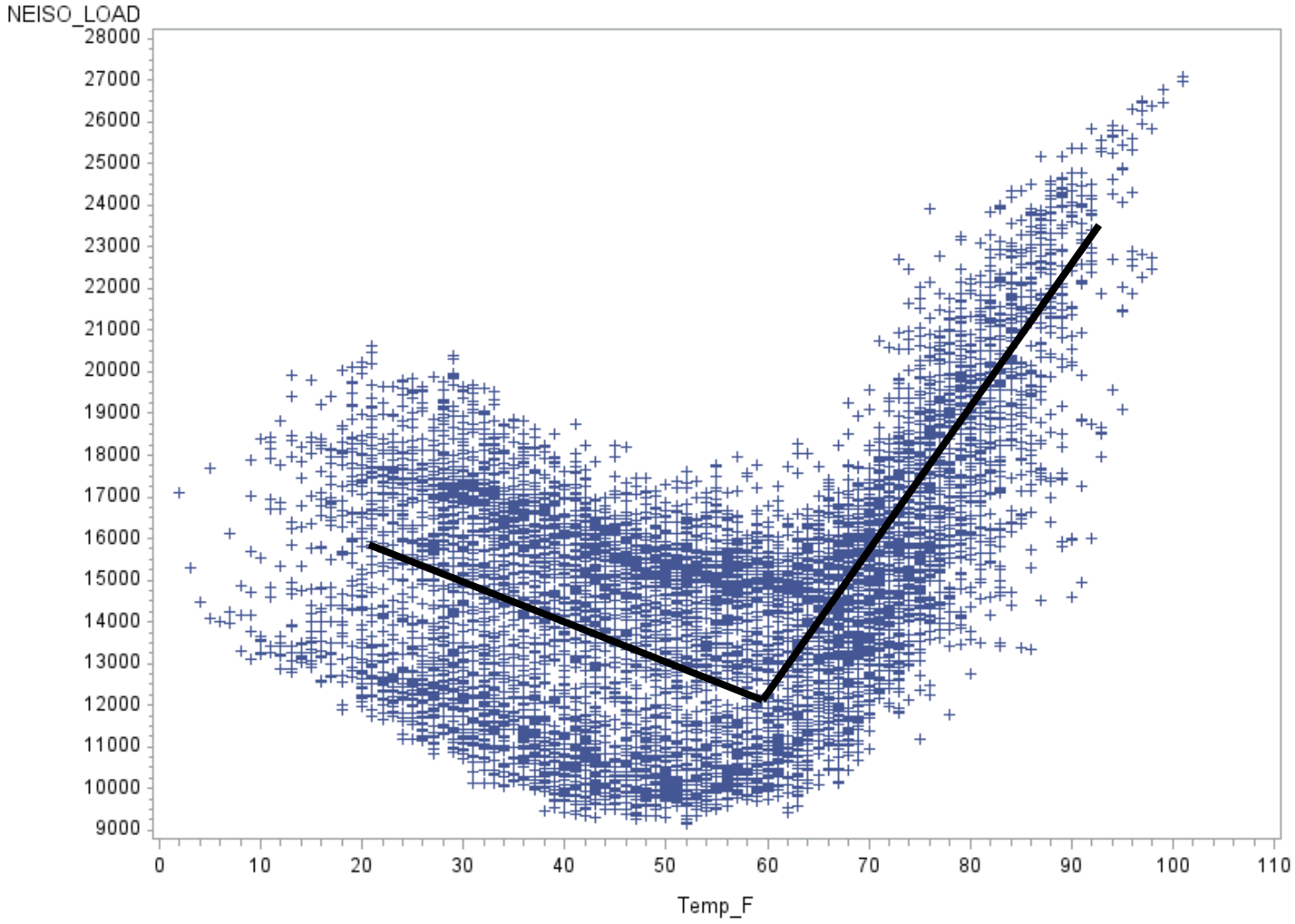
Daily Average Temperature (DAT) = (maximum + minimum)/2

Heating Degree Days = 65 degrees F – DAT
Where temperatures are below 65

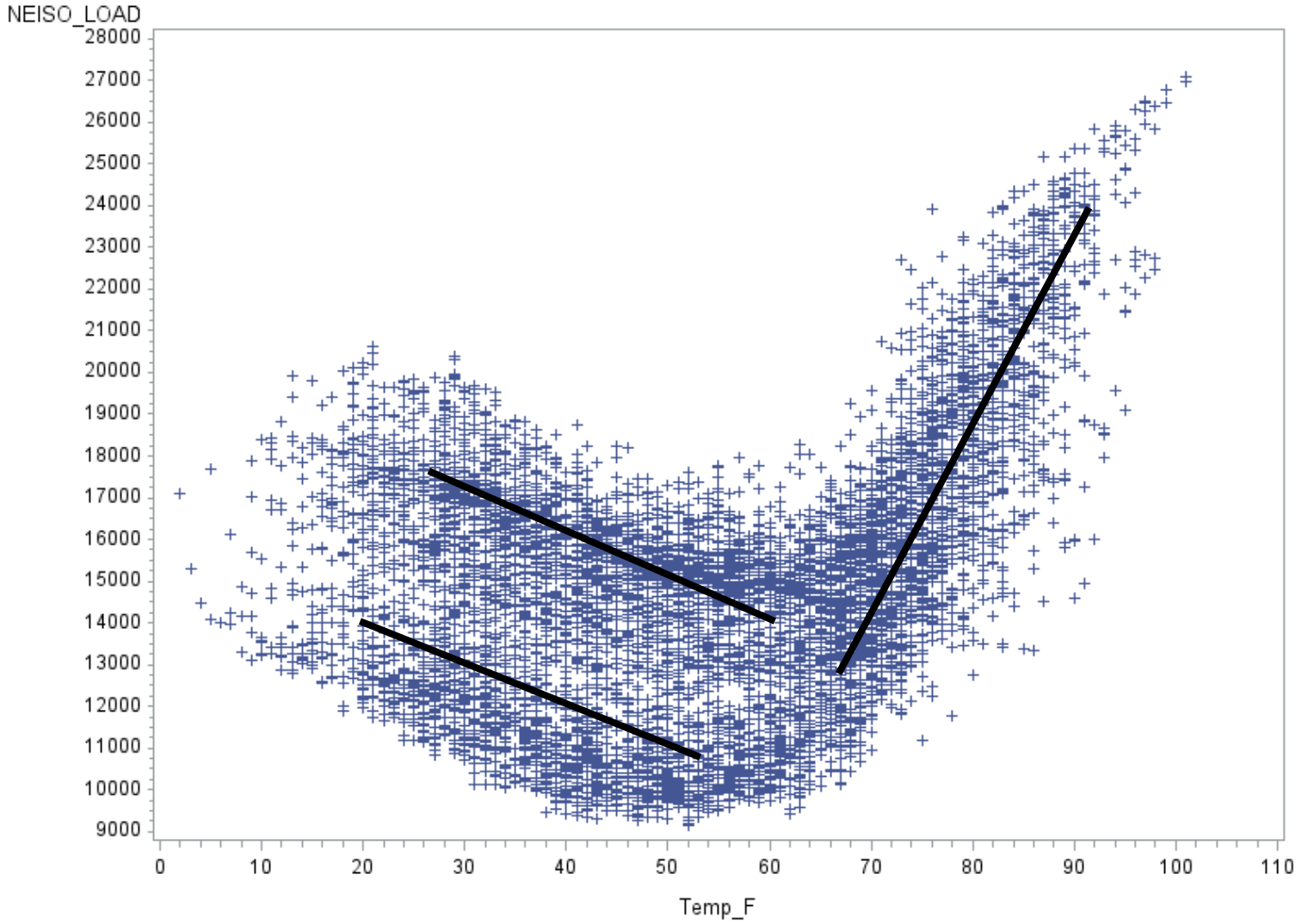
Cooling Degree Days = DAT- 65 degrees F
Where temperatures are above 65

$$Load = Intercept + \beta 1 * (HDD65) + \beta 2 * (CDD65)$$

What is the Challenge of Hourly Forecasting?



What is the Challenge of Hourly Forecasting?



What causes the differences

Season or Month	• Heating/Cooling • Schools • Pool pumps
Day of Week	• Lower loads on Saturdays and Sundays • Drop off of Industrial load on Friday • Schools
Hour of Day	• Family life patterns • Businesses open and close • Industrial Plants – 1/2/3 shifts

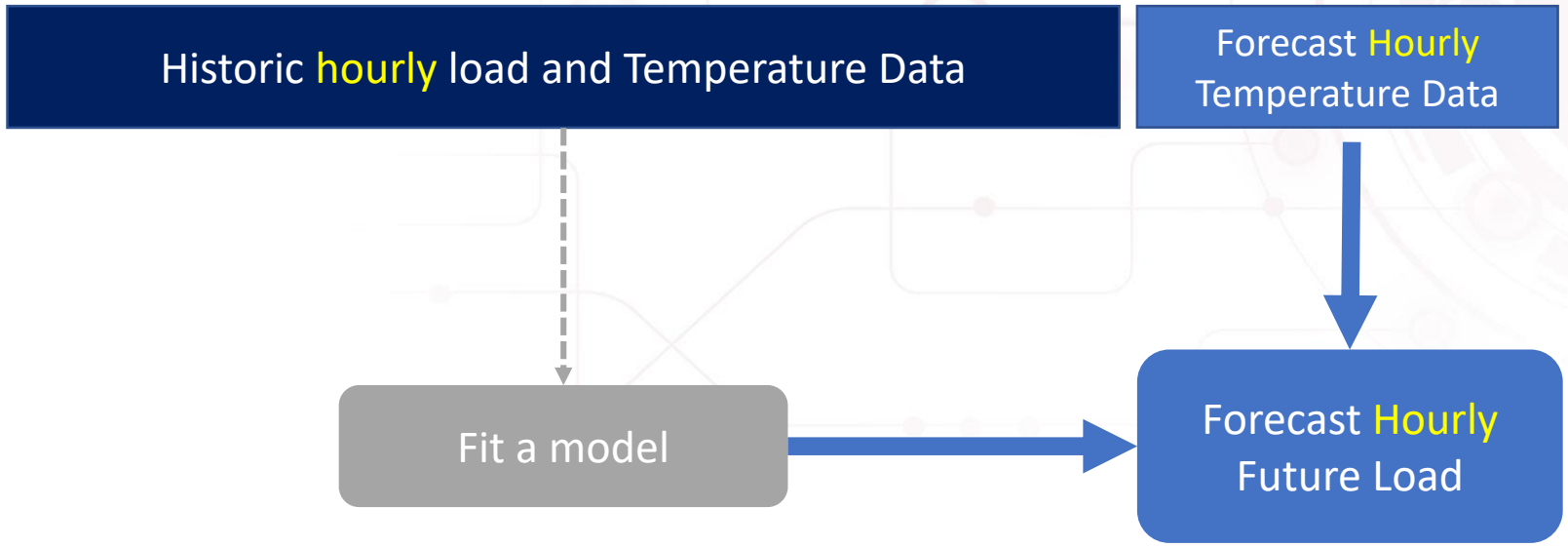
What should a hourly load forecast model consider?

- Temperature
- Season or Month
- Day of Week
- Hour of Day

DATA

“Before (adopting analytics), we spent 80 percent of our time processing data and just 20 percent analyzing it. Those percentages have now flip-flopped, freeing up more time for us to plan and launch data-driven operational activities.”

Forecast process



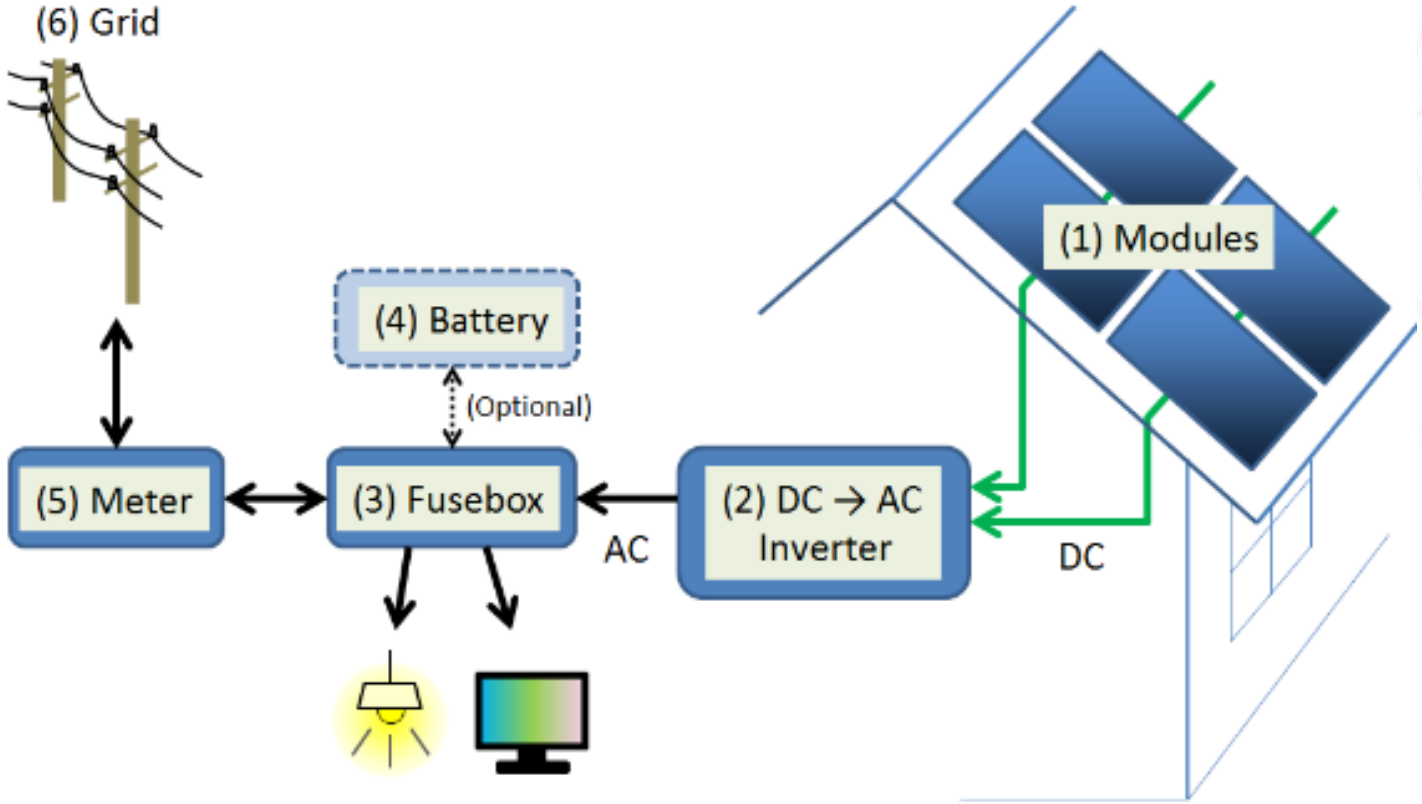
Data for hourly forecasting

- Need at least a year of data to build models/Two or three years are better
  - Hourly (AMI) load data
  - Temperature

Data needs to be cleaned

- Data problems
  - AMI - missing
  - Temperature – missing & incorrect
  - Demand response & solar reduced load

Residential behind the meter solar



Distribution Circuit Load Forecasting

Levels of the power system

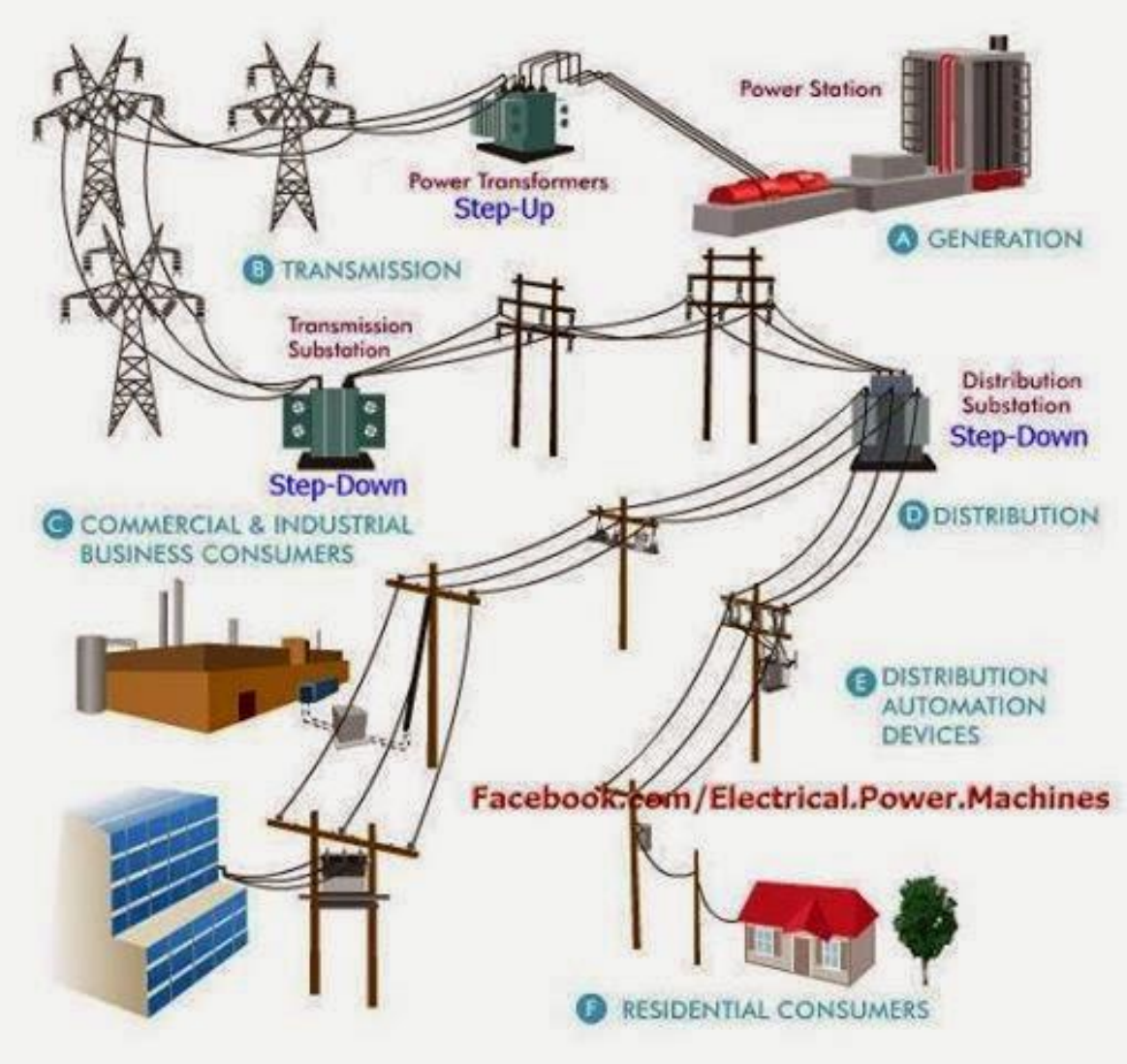
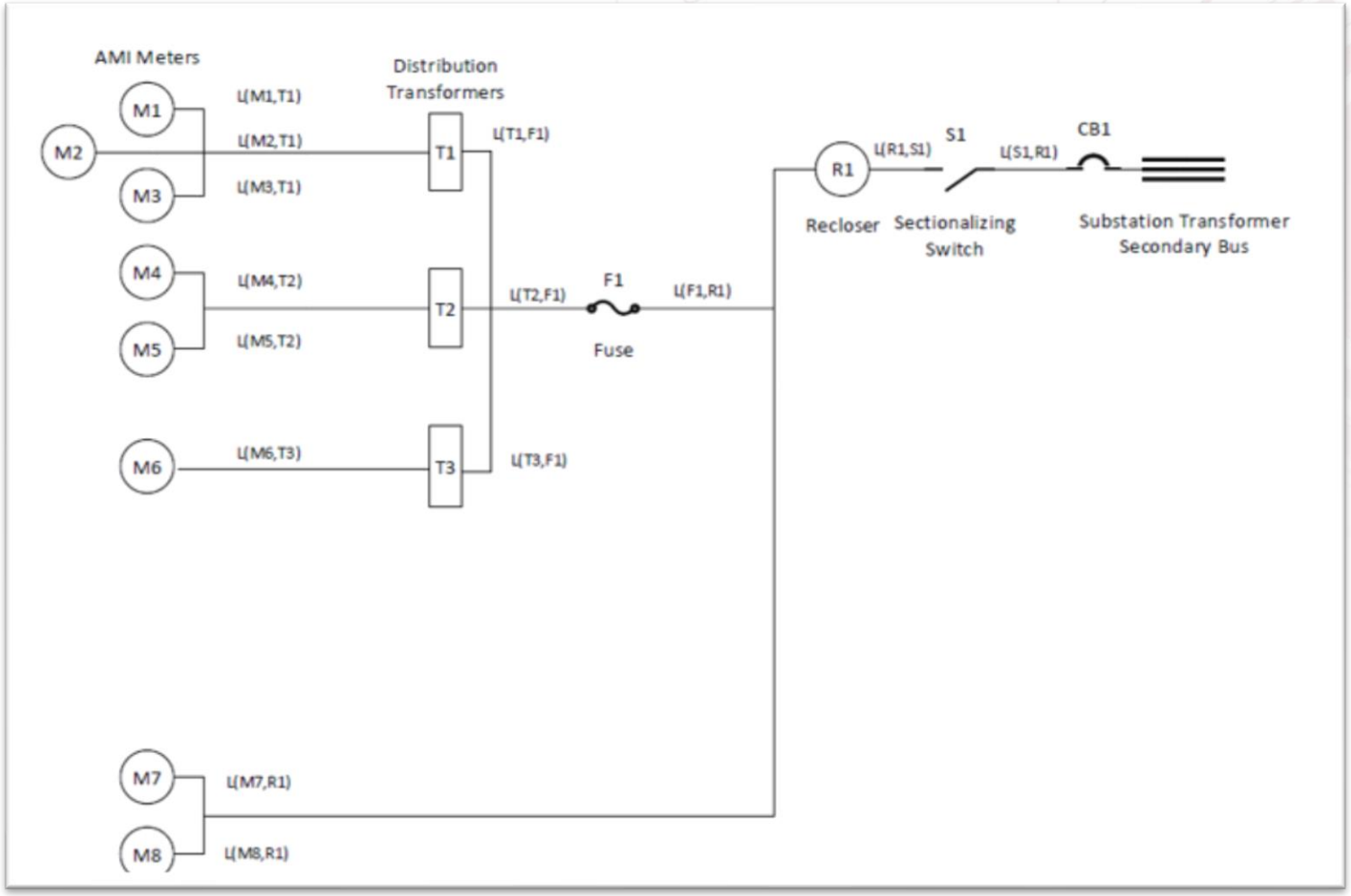
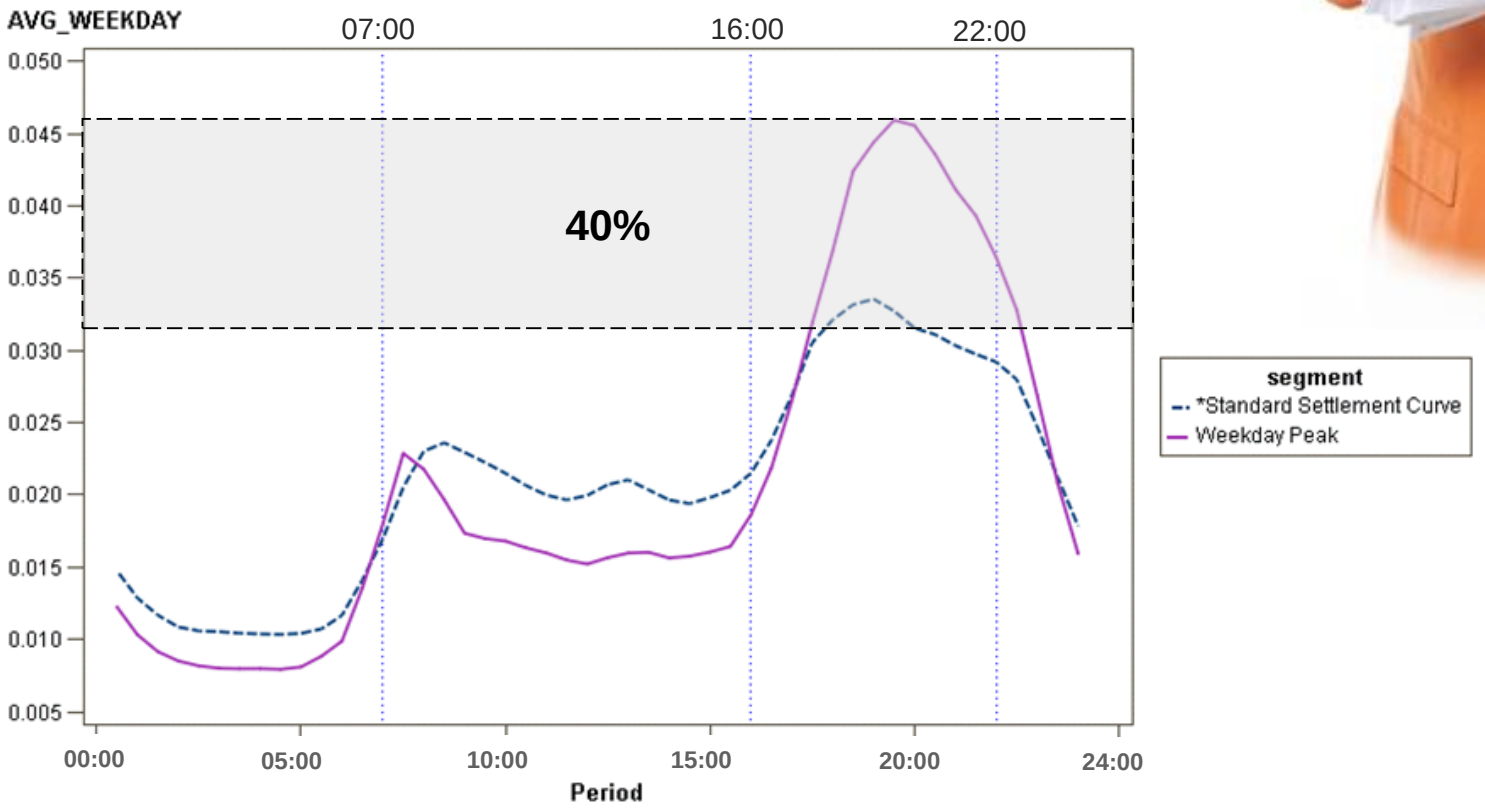


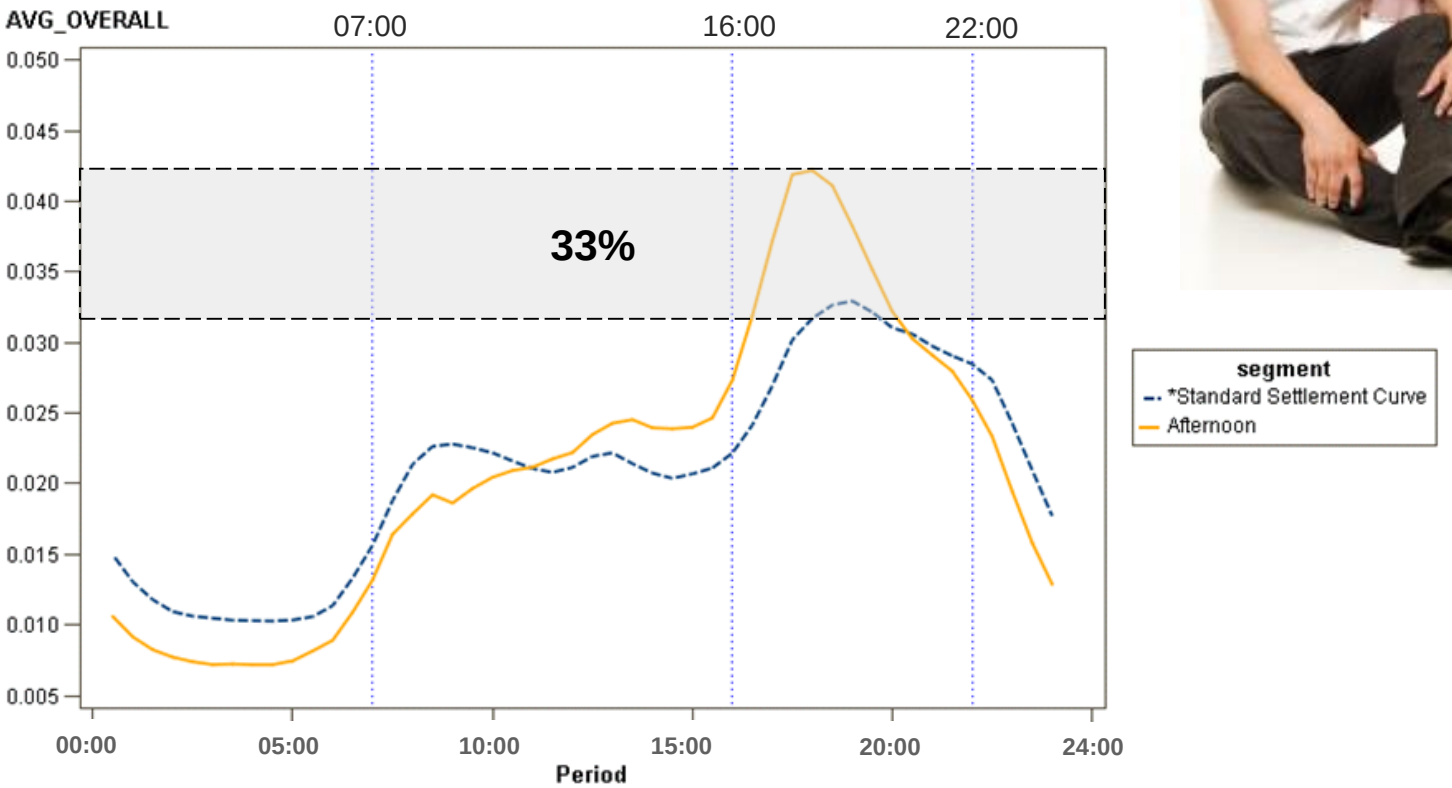
Illustration of Feeder Circuit

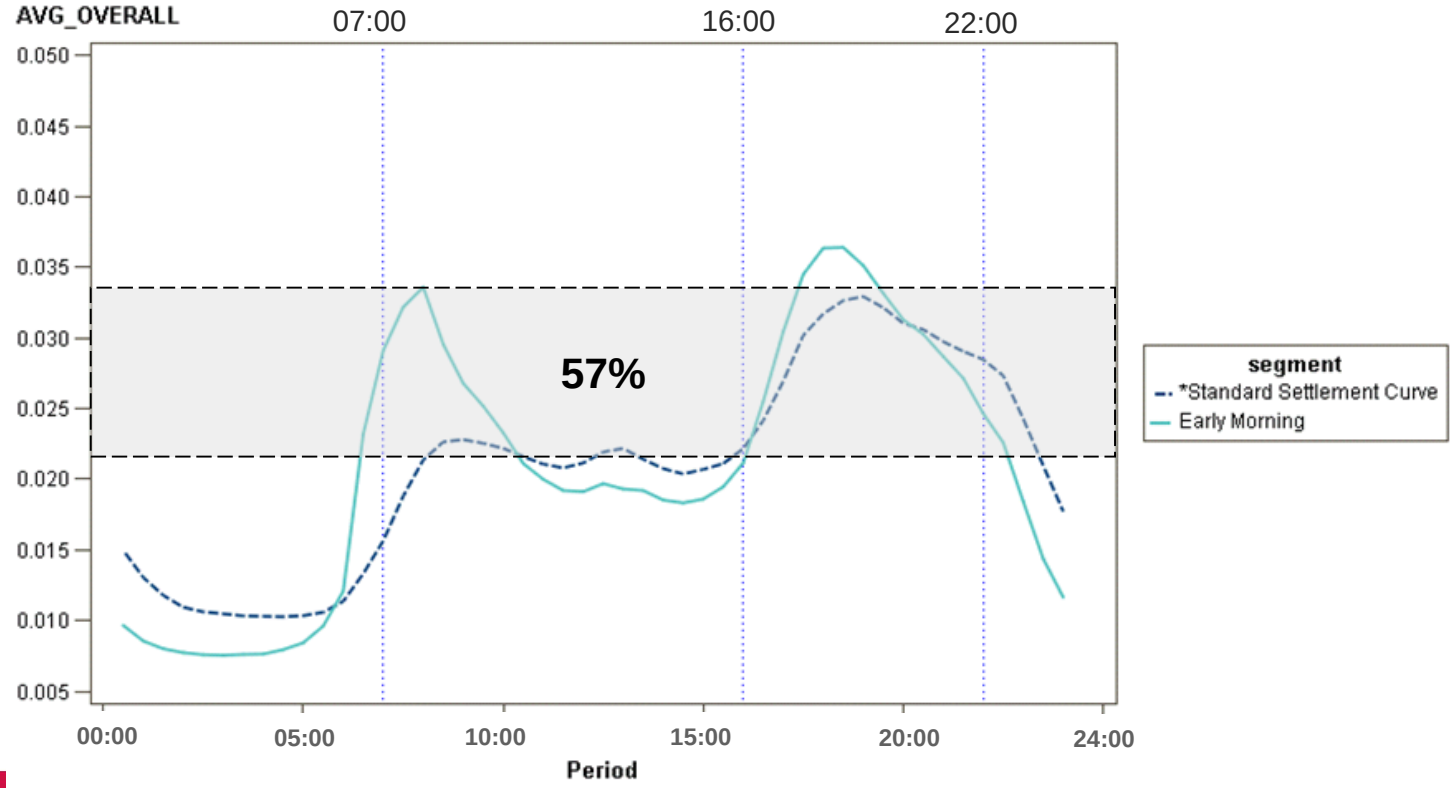


Customer Segmentation

- **May want to forecast individual customers as a segment of the population rather than from their individual data.**


AVG_WEEKDAY
07:00
16:00
22:00
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
40%
00:00
05:00
10:00
15:00
20:00
24:00
Period
segment
*Standard Settlement Curve
Weekday Peak


AVG_OVERALL
07:00
16:00
22:00
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
33%
00:00
05:00
10:00
15:00
20:00
24:00
Period
segment
*Standard Settlement Curve
Afternoon


AVG_OVERALL
07:00
16:00
22:00
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
57%
segment
*Standard Settlement Curve
Early Morning
00:00
05:00
10:00
15:00
20:00
24:00
Period

Lingering issues

- **Behind the meter solar reductions**
  - Identify customers with solar
- **Customers with EVs**
- **Phase identification**
- **Forecast by customer type**

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