SMART HOME ENERGY USAGE

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Objectives

- The main objectives identified for this analysis are to provide data analytics and visualizations that will:
  - Detect surges or spikes in usage in the smart home by sub-meter
  - Prevent damage to electronics by consistent monitoring of usage over time
  - Identify cost saving opportunities for the consumer

- The following slides review some of the visualizations that have been created to meet the above objectives

Data

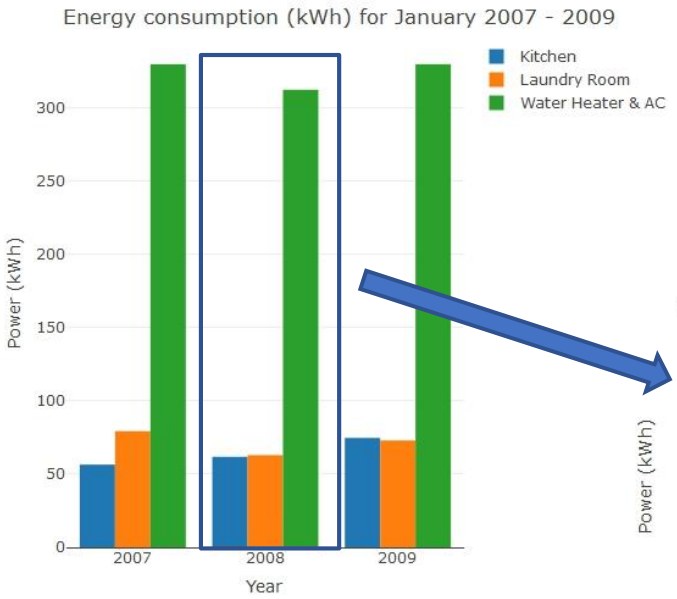
- The dataset consists of over 2 million rows of power consumption data, with a data point collected once per minute
- The time period spans from December 2006 to November 2010
  - Because 2006 is significantly less than a full year, this data will be excluded from subsequent analysis
  - Full year analysis will also exclude 2010 as it is an incomplete year
- Less than 2% of the data is missing
  - Since this accounts for a small amount of data, this will not impact the analysis

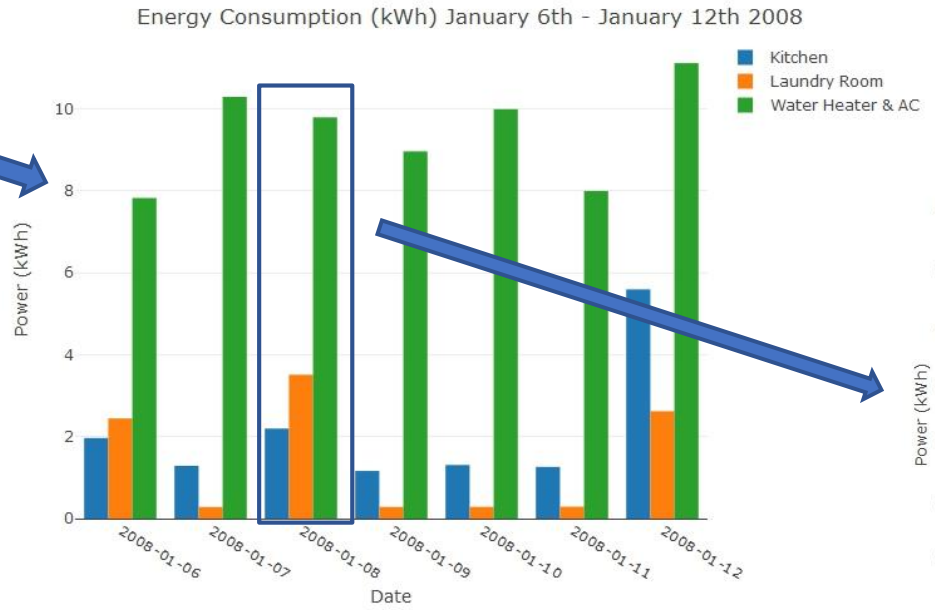
Sub-meters

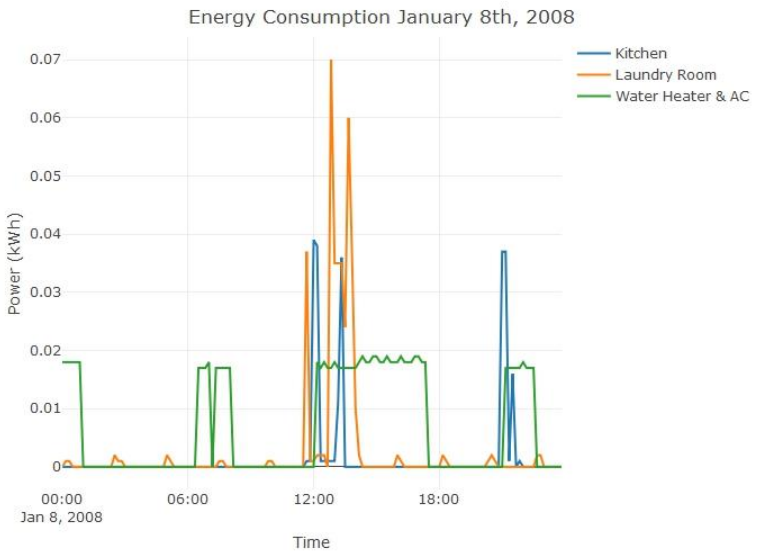
- Data is divided by sub-meters into three separate groups
  - Sub-meter 1: Kitchen, which includes a dishwasher, an oven, and a microwave
  - Sub-meter 2: Laundry Room, which includes washer, dryer, refrigerator, and a light
  - Sub-meter 3: Electric water heater and air conditioner

Visualizing Energy Data

- We can look at the total energy consumption values for several different time frames to glean insights on energy usage

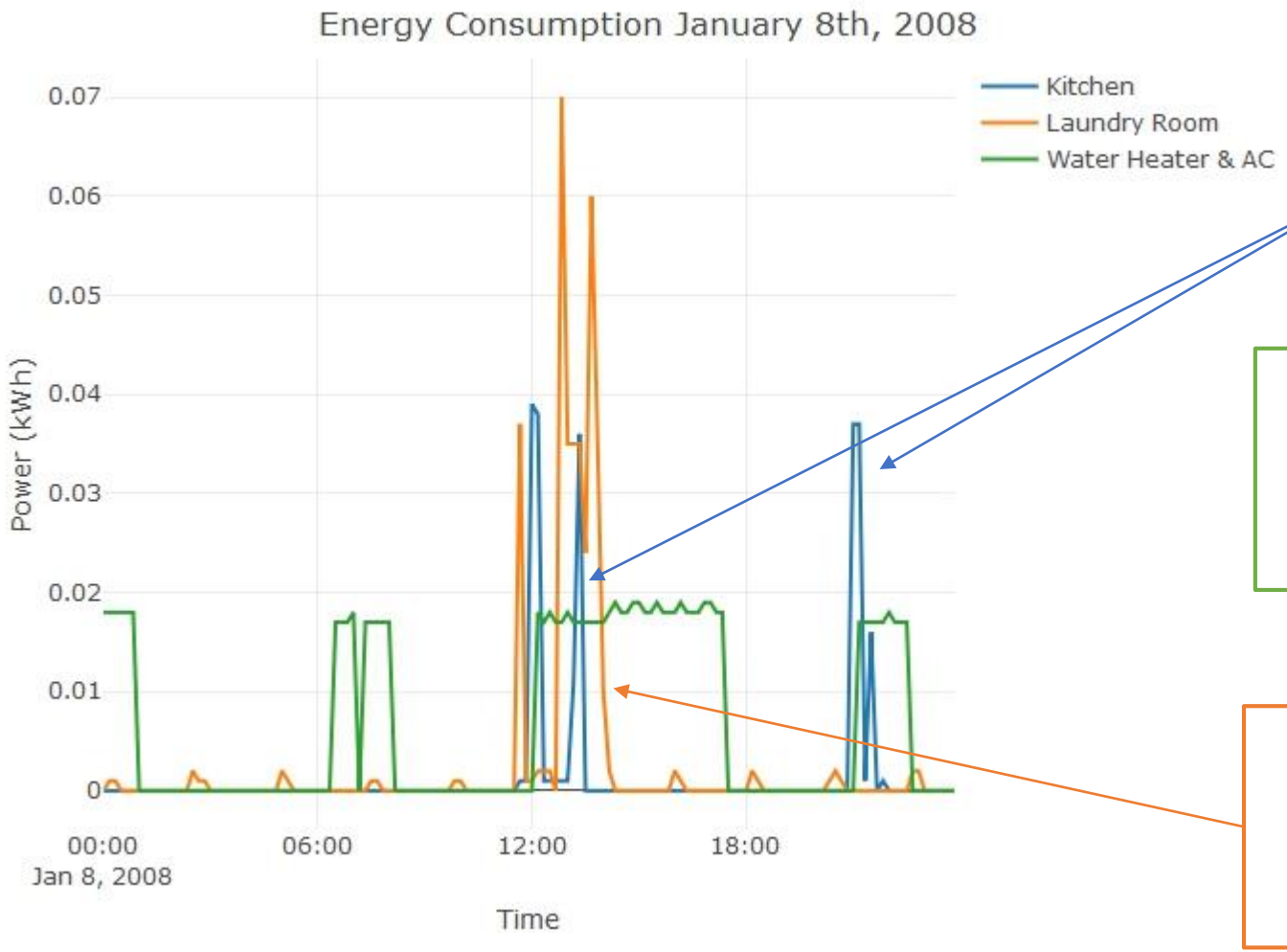






- For example, we can look at the total usage for January in 2007 thru 2009, then zoom into a specific week in January 2008, then just a single day of January 9th, 2008

Analyzing the Data for January 8th, 2008



The kitchen only shows energy usage during dinner and lunch time

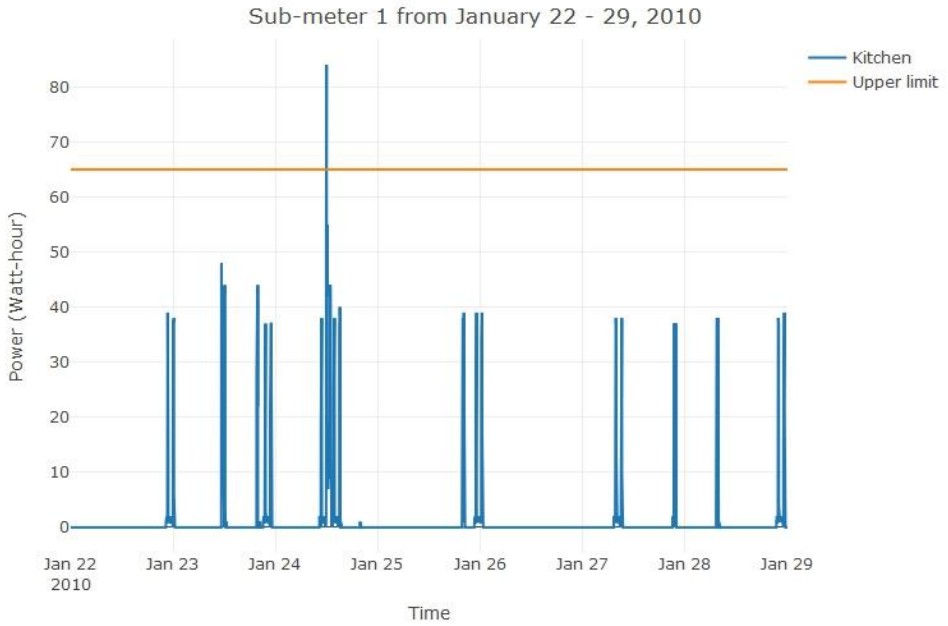
The water heater and A/C spike when hot water is demanded (hot shower, dishwasher cycle) or when occupants are at home and using A/C

Laundry room energy usage is cyclical (likely from refrigerator cycles) and shows spikes when appliances are used

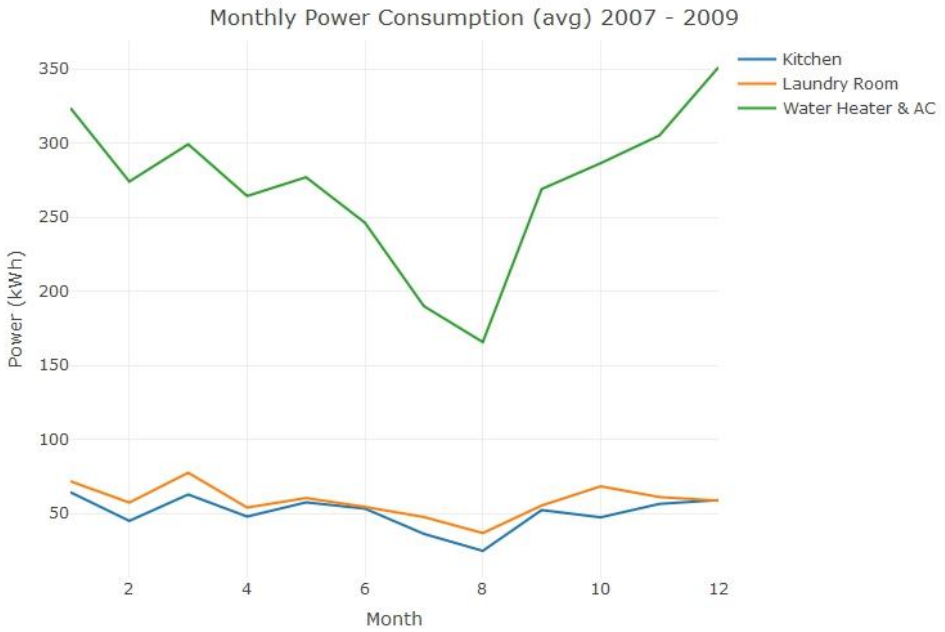
DETECTING SPIKES AND SURGES

Spikes In Usage

- One of the items the visualizations can show is if there are any abnormal spikes in usage for each submeter
- Limits can be set for each submeter based on normal usage plus a buffer to alert for any abnormal usage
- In the example to the right, the spike to about 80 watt-hours would trigger an alert for a spike in energy usage for the kitchen (sub-meter 1)



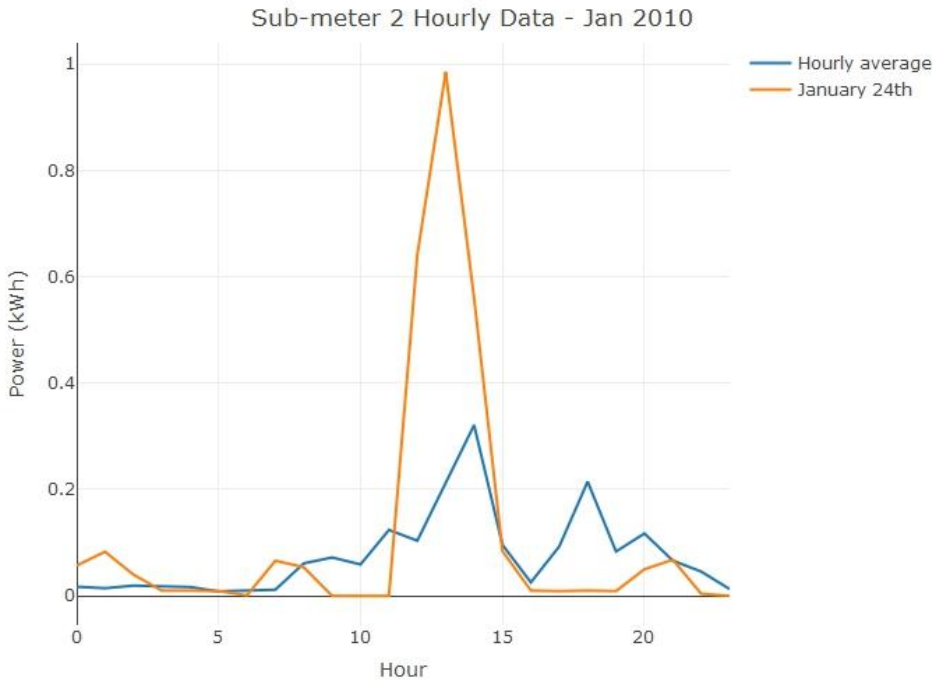
Monitoring Trends



- The monthly average power consumption by sub-meter can be shown to get an idea of what is "normal" usage
- As seen on the left, for 2007 thru 2009, there has been lower energy consumption for the water heater and A/C together during the summer months and dipping the lowest in August

Additional Trends

- Furthermore, we can drill down to a single day average consumption
- This data can then be compared to a single day to determine if there are any abnormalities in the trend that does not qualify as a spike
- In the chart on the right, January 24th laundry room (sub-meter 2) usage was a bit higher than normal for this month
- Continuous monitoring of these values can help pinpoint extra usage on sub-meters that is not expected



PREVENTING DAMAGE

Breaking Down the Trend

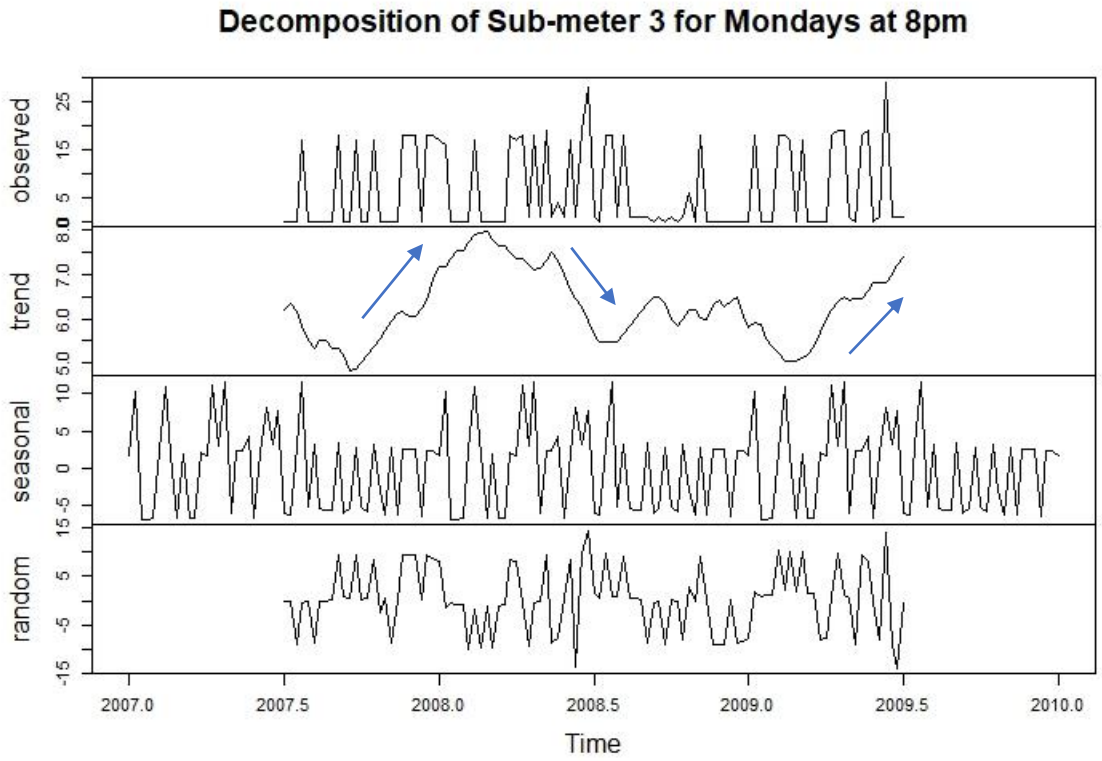
- The energy consumption levels also have a seasonal component, as shown earlier with the monthly data, and other factors that can be broken down (or decomposed)
- We can separate out the trend (whether usage is increasing or decreasing), the seasonality (where the usage is cyclical or repetitive) and any other random contributions to the data
- This helps to isolate any increase in random behavior that can lead to damage to electronics

Actual data

Trend component

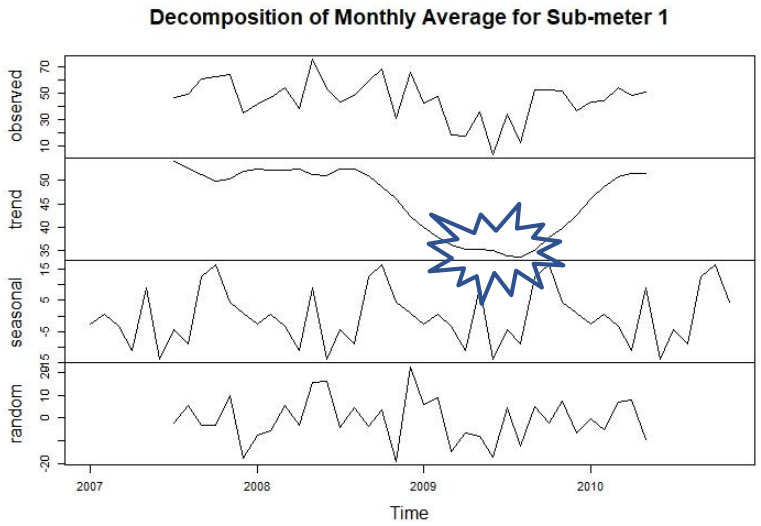
Seasonal component

Random component

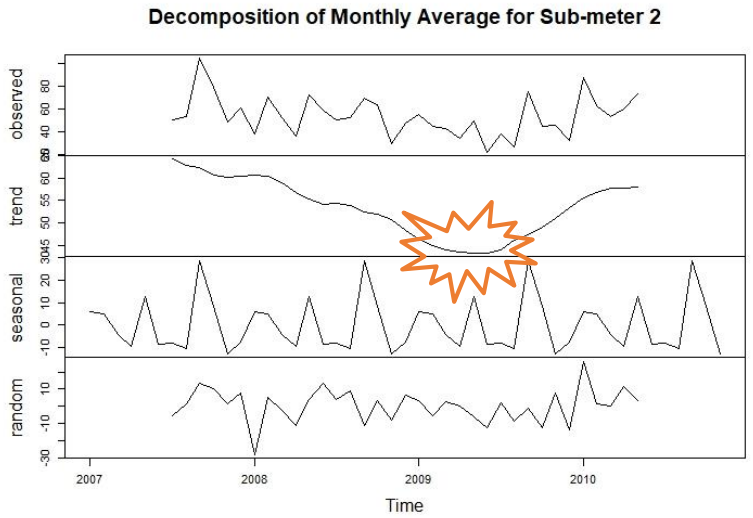


The example above shows the water heater and A/C (sub-meter 3) for every Monday at 8pm for 2007 – 2009.

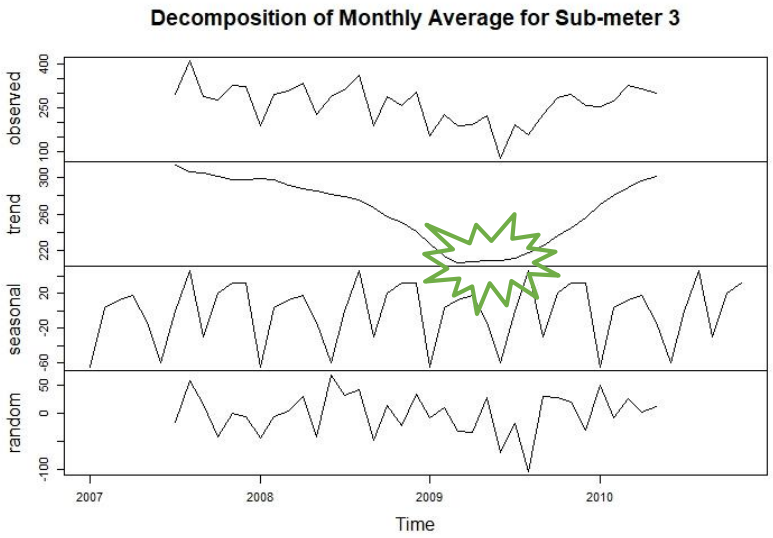
Breakdown By Sub-meter



Kitchen



Laundry Room



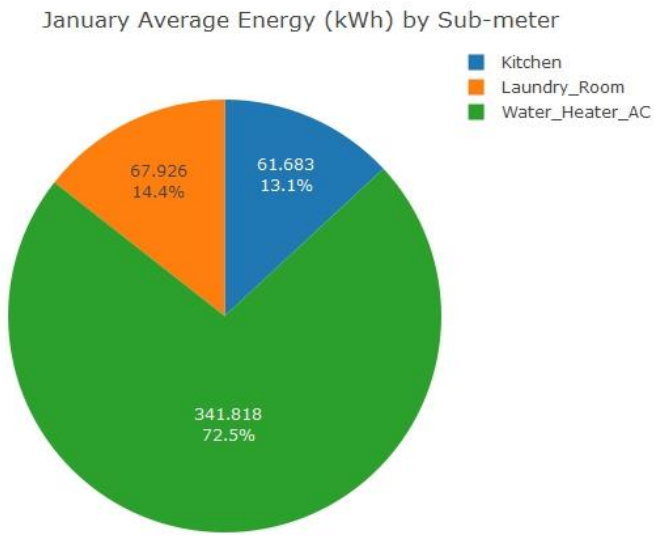
Water Heater & A/C

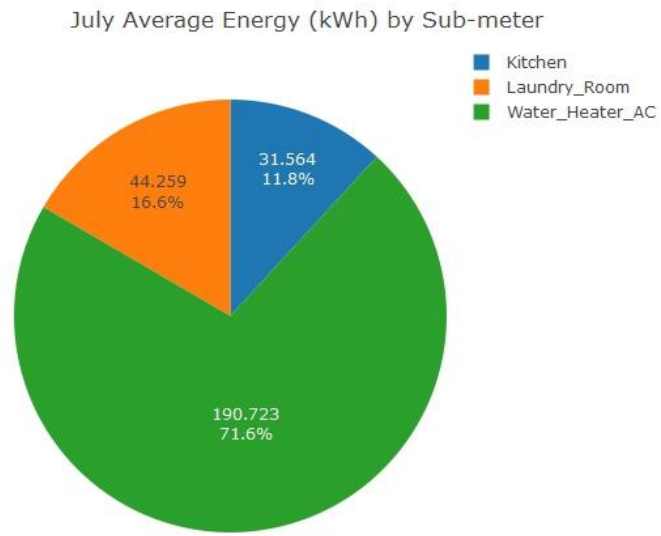
- Each sub-meter shows similar trending – starting out with higher usage in 2007 and reaching a dip mid-2009 before increasing again
- Sub-meter 1 shows slight seasonality with higher usage towards the end of the year (Nov./Dec.)
- Sub-meter 2 shows some seasonality with higher usage around Sep./Oct.
- Sub-meter 3 seasonality appears very cyclical throughout the year
- The random component for each is small but accounts for what cannot be explained by trends or seasonality

IDENTIFYING COST SAVINGS OPPORTUNITIES

Seasonal Energy Usage

- Energy consumption can also be compared by month by each sub-meter. This can show any seasonal dependencies for certain appliances. For example, the water heater and AC unit consume more of the total energy in July than they do in January. Additionally, total energy consumption is higher in January than in July



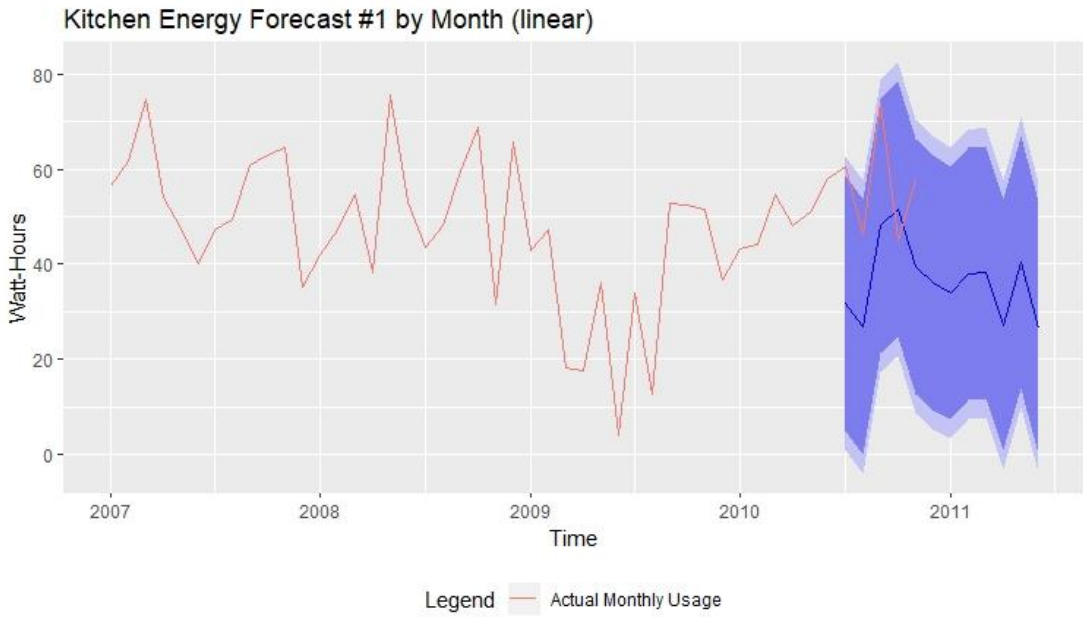


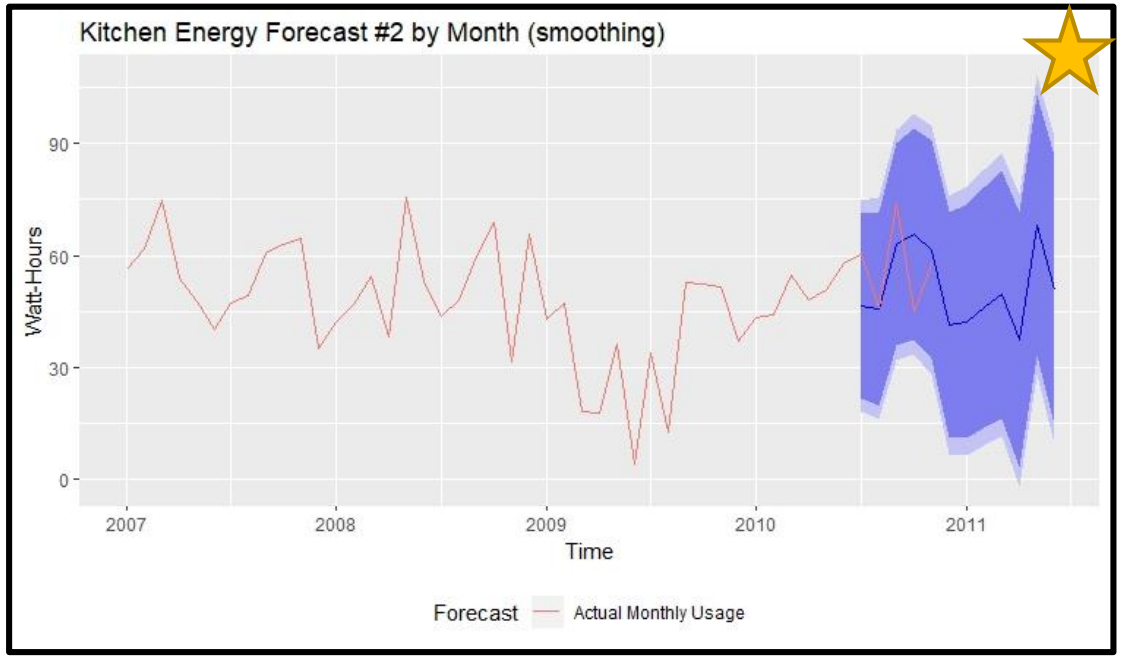
Forecasting

- There are two primary methods to forecast future energy usage so that the consumer can anticipate any possible billing increases or decreases based on the forecast
  - One method is based on historic usage and takes into account seasonality and trend
  - The second method "smooths" out the trend and uses this data to forecast future usage
    - In general, this method is the preferred method for forecasting based on historic usage accuracy
- This can serve to forewarn customers if their usage looks to be increasing and will continue to increase, or to confirm to customers their usage is decreasing and they are looking to stay at a lower consumption level
- The more data collected, the better the forecasts become

Kitchen Forecasts

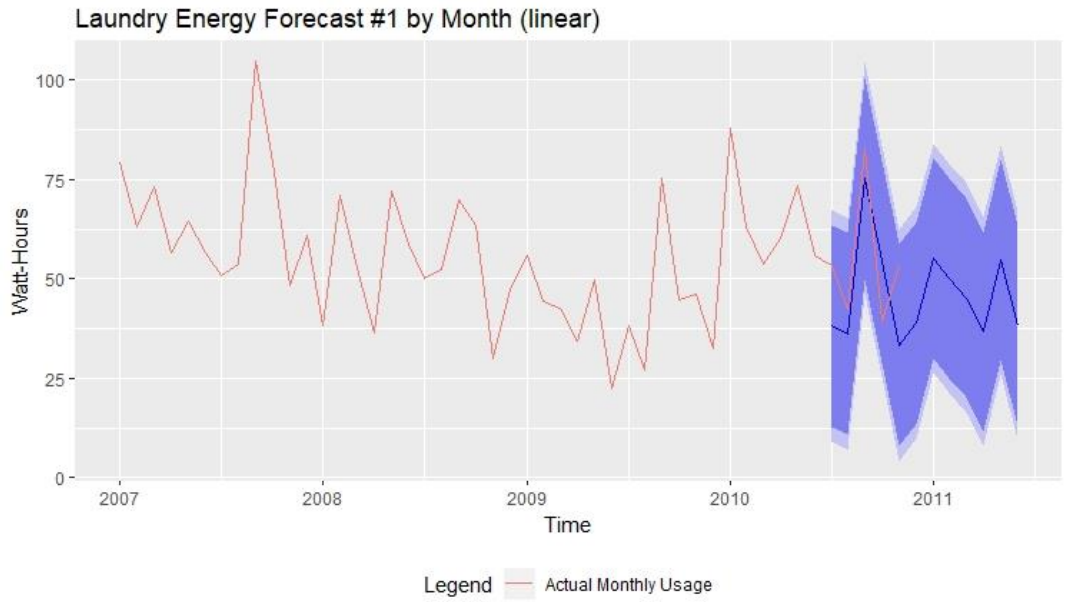
- For each graph, the line in blue is the forecasted value, and the blue shading indicates the forecast margin with high confidence levels
- For sub-meter 1, the smoothing method of forecasting (forecast #2) shows higher accuracy in comparison to the actual usage for the end of 2010

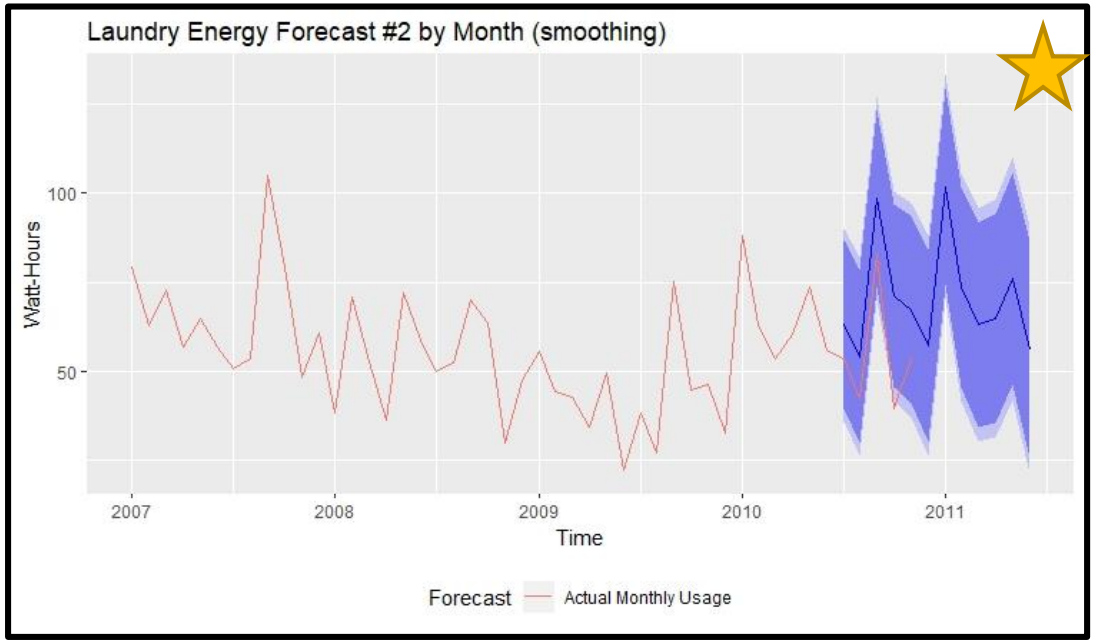




Laundry Room Forecasts

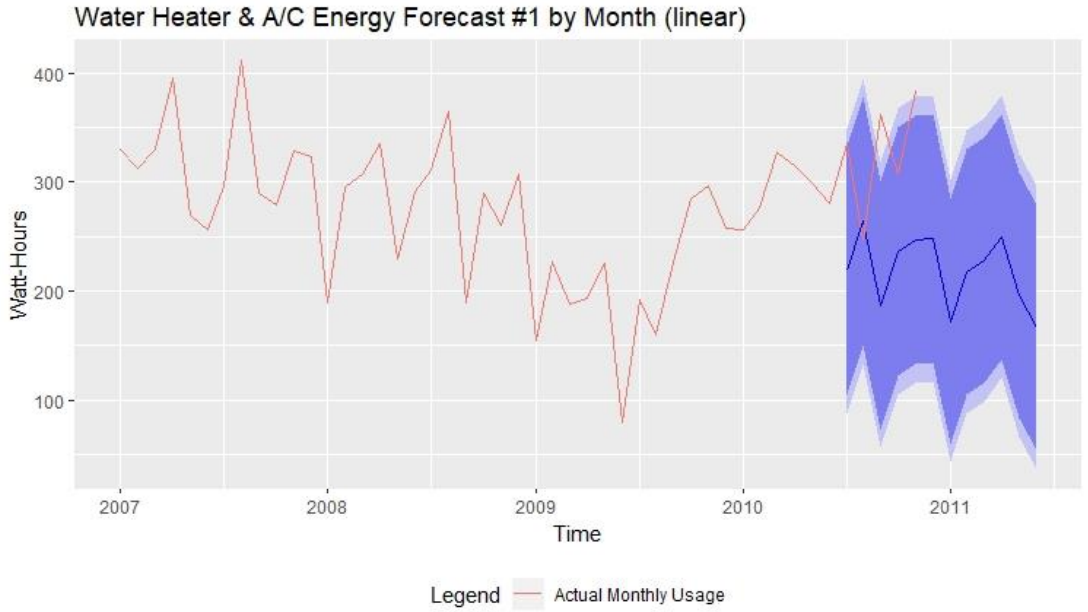
- For sub-meter 2, the linear forecast (forecast #1) looks to more accurately reflect the actual usage for November and December 2010
- However, forecast #2 also captures the Nov – Dec 2010 data within the forecast margin and can still be considered a valid forecast

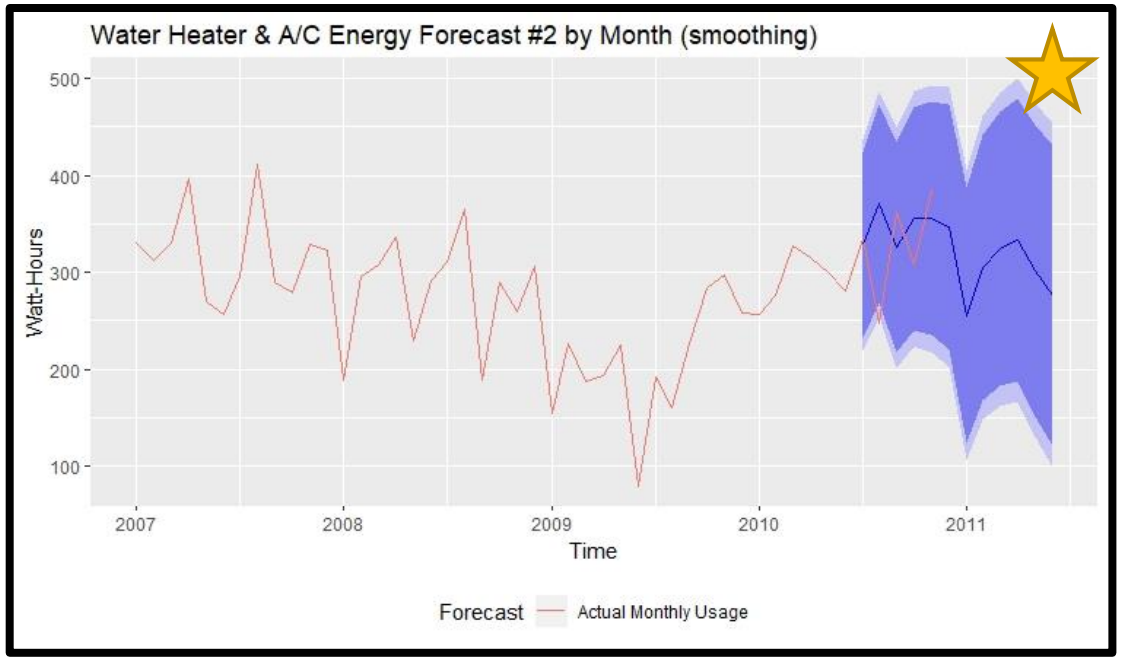




Water Heater & A/C Forecasts

- Again, the smoothing forecast method reflects better accuracy for sub-meter 3 historical usage which indicates a better forecast for future usage





Conclusions

- Overall, all objectives earlier listed can be met based on the data set provided and the analysis completed
- Spikes and surges can be detected by using any time subset for the data, but can be most useful when looking at hourly data (see slide 7)
- Breaking down the trends can show any excess random or trend contribution to the data that cannot be attributed to normal seasonal variations (see slide 12)
  - This can pinpoint appliances drawing extra energy to address before damage occurs
- Seasonal comparisons can identify periods of higher usage for the consumer to work on energy optimization
- Forecasts using the smoothing method can also provide estimated future usages which the consumers can use to plan for budgeting purposes or to identify opportunities for improvement on energy usage

Recommendations

- In order to produce more accurate data to assist the consumer, it would be helpful to re-assign the refrigerator currently listed under sub-meter 2 (the laundry room) to sub-meter 1 (the kitchen)
- Breaking out the water heater and A/C unit into two separate sub-meters would also help pinpoint which is using more energy
  - Sub-meter 3 is the highest consuming sub-meter in the house which offers best opportunity for cost saving measures
- Recommend implementing hourly energy usage monitoring for spike/surge detection
- Recommend adding in historic annual energy usage so consumer can review differences from year-to-year
- Recommend using the smoothing method to provide the consumer with accurate forecasts, including margins for future usage