



Time Series Analysis

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Overview

Our client is interested in understanding their residential power usage and would like some insight into where most of their power usage is coming from and how it can be reduced in order for the client to conserve energy and be more eco-friendly.

Given the client's residential power usage data for 3 submeters from the years 2007 to 2010, we performed a visual analysis and time series forecasting in order to provide a general picture of the client's power usage and to provide energy savings suggestions to the client.





Data Breakdown

- Data consists of power usage information from 3 submeters in the residence, measured in watt- hours (W/h).
 - ◆ Submeter 1 = Dishwasher, oven (stovetop is gas powered), and microwave
 - ◆ Submeter 2 = Washing machine, dryer, refrigerator
 - ◆ Submeter 3 = Electric water heater, air conditioner
- Data covers the time period from December 2006 - November 2010 (47 months)
- We will be closely analyzing the month of September 2008
- Power measurements are taken every 30 minutes



Data Visualizations



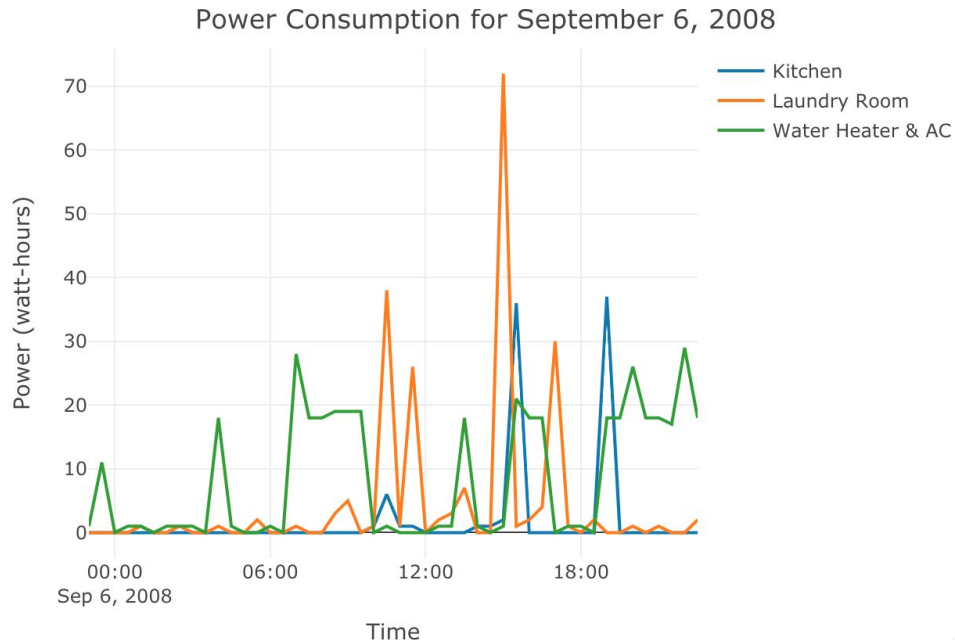
September 2008

Day

Power consumption over a 24 hour period on September 6, 2008. This is one of the more active power usage days for the week.

Client Implications:

Activity in the laundry room produces the highest wattage at one given time -- likely the dryer. AC and water heater are using power more steadily over time. Power in the kitchen is also relatively high but over a short period.



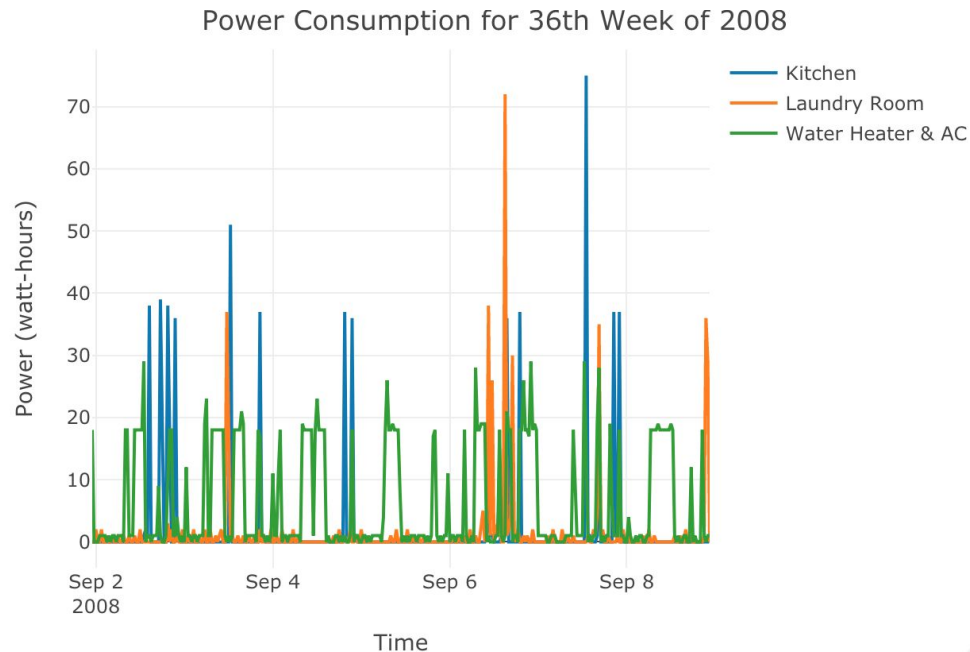


September 2008 Week

Power consumption over a week period during the 2nd week of September 2008 (the 36th week of the year)

Client Implications:

Again, the kitchen and laundry room produce the highest spikes of power usage, while the AC and water heater use power over longer periods.



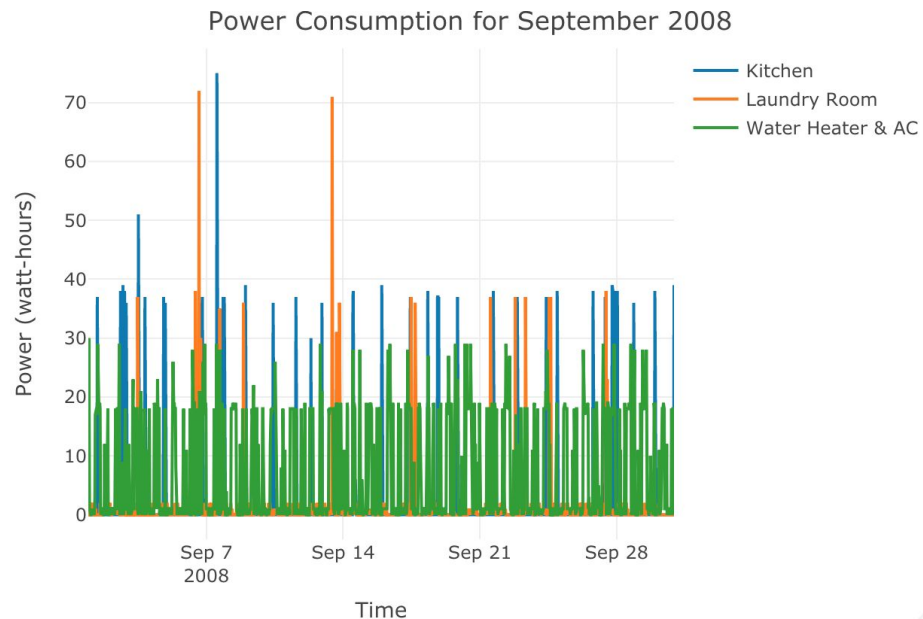
September 2008

Month

Power consumption over the full month of September 2008.

Client Implications:

There is more activity towards the first half of the month. High spikes include the laundry room and kitchen. AC and water heater usage remain rather constant.

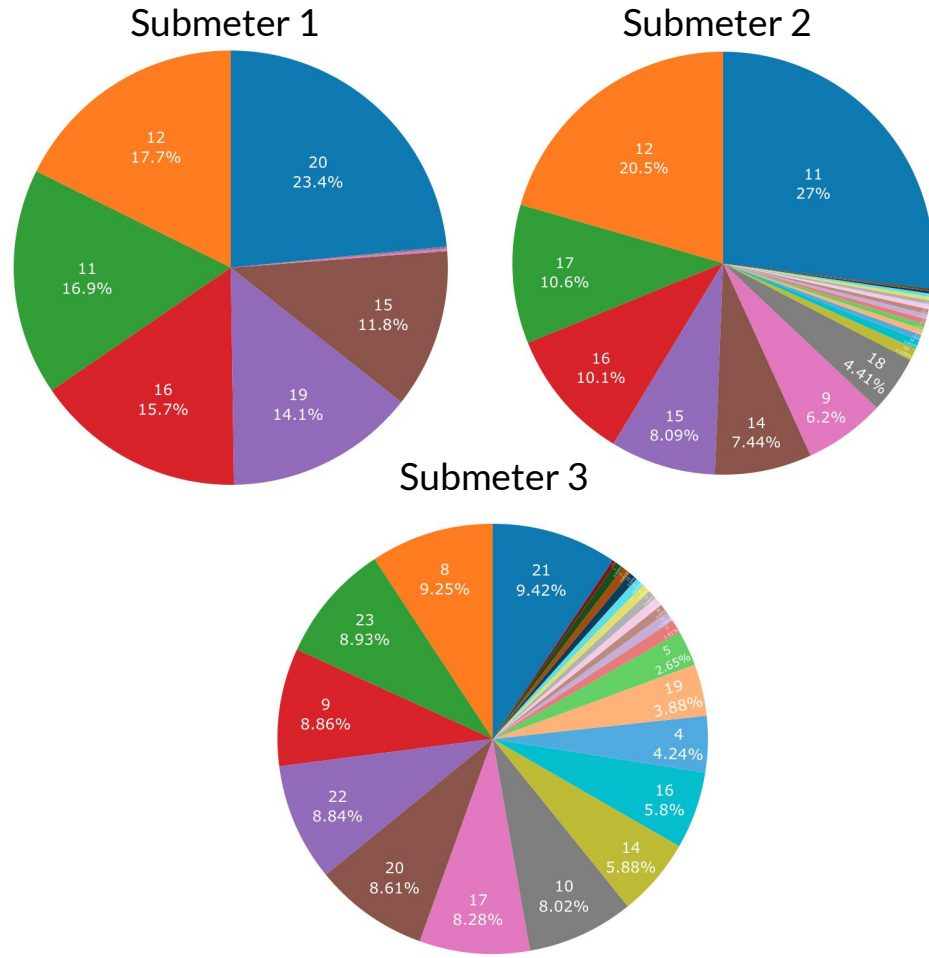


Percentage of Power Usage Day

Percentage of power usage over a 24 hour period on September 6, 2008 for each submeter.

Client Implications:

Submeter 1 (kitchen) uses the most power at 8:00pm, 12:00pm, and 11:00am. Submeter 2 (laundry) uses the most power at 11:00am, 12:00pm, and 5:00pm. Submeter 3 (AC/water heater) uses the most power at 9:00pm, 8:00am, and 11:00pm, although power usage is fairly constant throughout the hours of the day.





Percentage of Power Usage Month

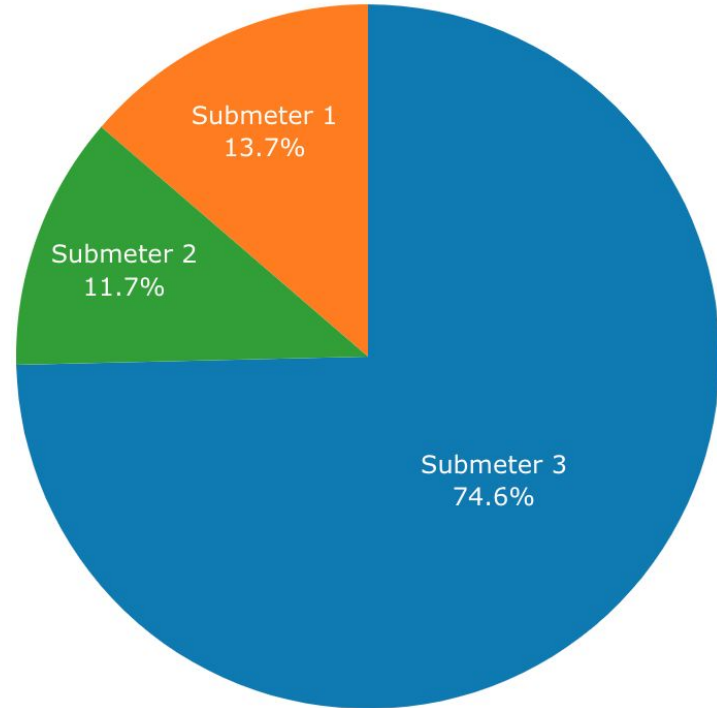
Percentage of power usage over the month of September 2008 by each submeter.

Client Implications:

While submeters 1 and 2 (kitchen and laundry) exhibit higher power usage spikes, submeter 3 uses the majority of the power, nearly 75%, for the month of September.

The proportion of power usage for each submeter is also similar for the entire year of 2008.

September 2008 Power Usage



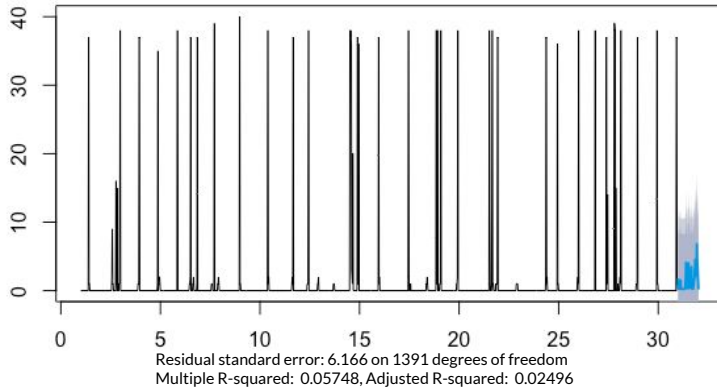


Linear Regression Forecasting

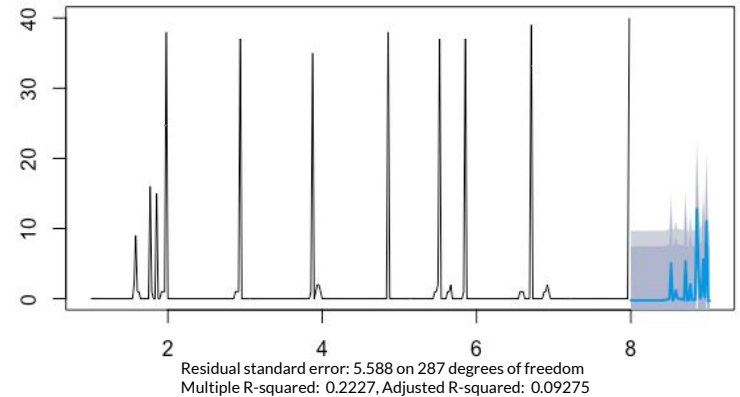
Submeter 1

Depicted here is a linear regression forecast for Submeter 1 for both the entire month of September and for a week in September. Forecasting for Submeter 1 is more difficult due to the sparsity of observations. The forecast is similar for both the month and week time periods.

Power Usage in September 2008
Submeter 1



Power Usage in 2nd week of September 2008
Submeter 1





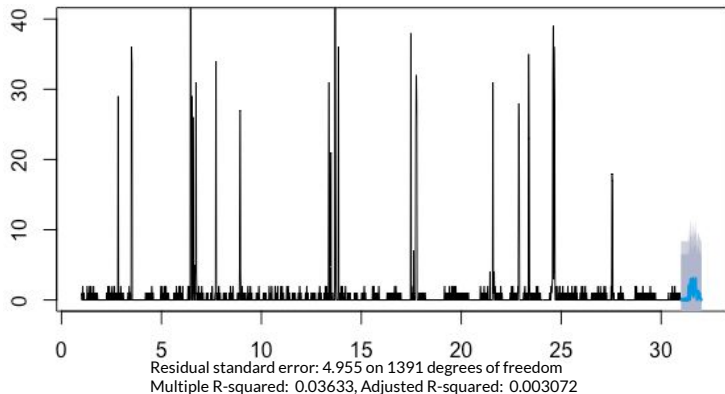
Linear Regression Forecasting

Submeter 2

Depicted here is a linear regression forecast for Submeter 2 over both a month and week period. Again, the forecast is difficult to make due to sparsity of observations.

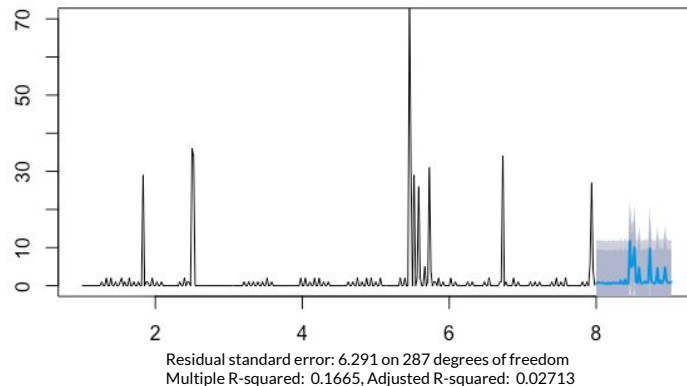
Power Usage in September 2008

Submeter 2



Power Usage in 2nd week of September 2008

Submeter 2



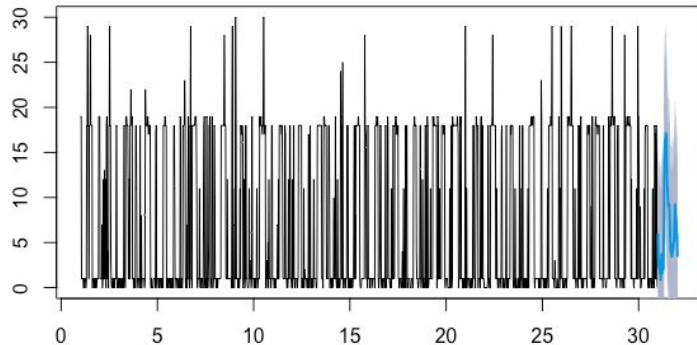


Linear Regression Forecasting

Submeter 3

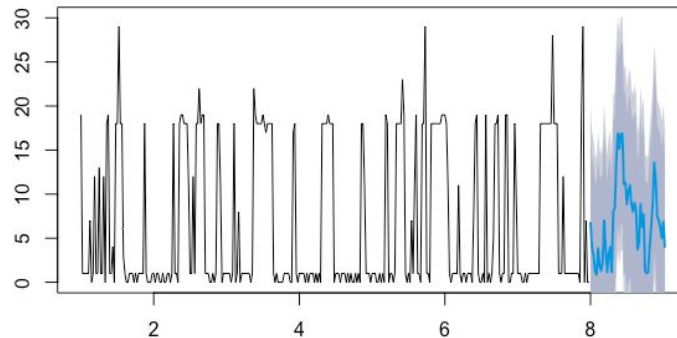
Depicted here is the linear regression forecast for Submeter 3 over the month and week period. Because Submeter 3 contains more peaks in energy usage, the forecast appears to be more revealing.

Power Usage in September 2008
Submeter 3



Residual standard error: 7.048 on 1391 degrees of freedom
Multiple R-squared: 0.3065, Adjusted R-squared: 0.2826

Power Usage in 2nd week of September 2008
Submeter 3



Residual standard error: 7.048 on 1391 degrees of freedom
Multiple R-squared: 0.3065, Adjusted R-squared: 0.2826

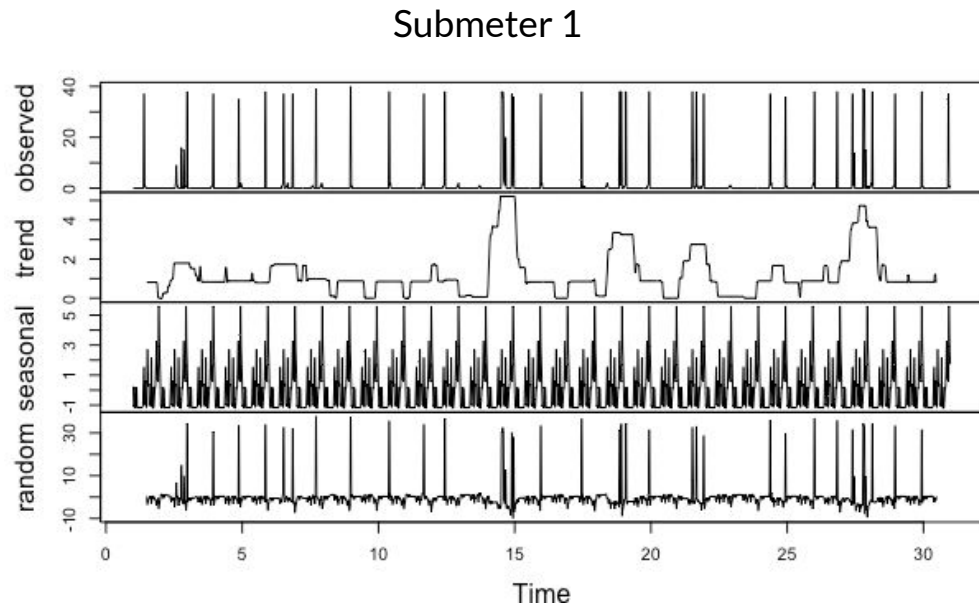


Decomposition Month

Decomposition of the time series for submeter 1 during the month of September 2008.

Client Implications:

We can see a trend of higher usage during the second half of the month. We can also see that there is a definite seasonality to the time series.



Decomposition

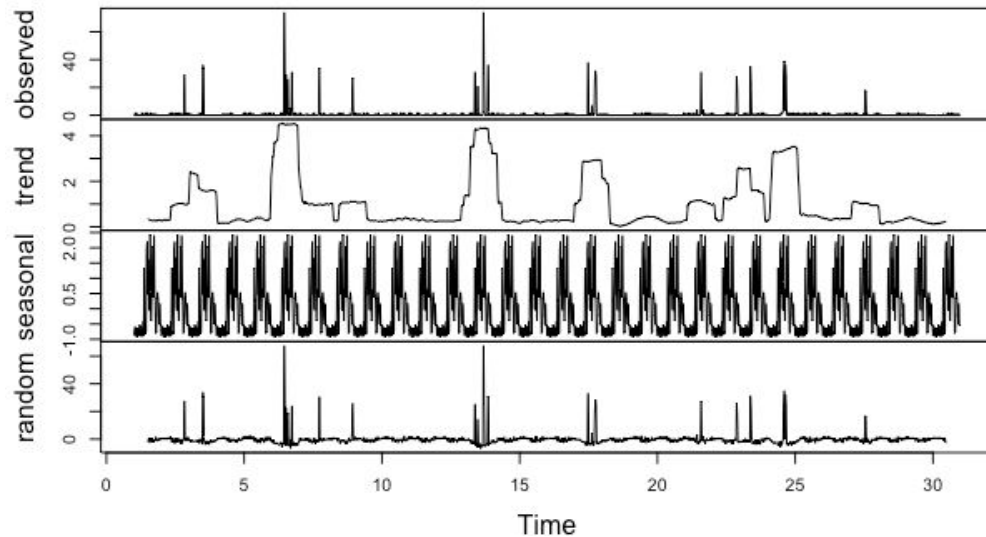
Month

Decomposition of the time series for submeter 2 during the month of September 2008.

Client Implications:

Peaks in power usage occur every 4-6 days. There is a seasonality to the time series as well.

Submeter 2





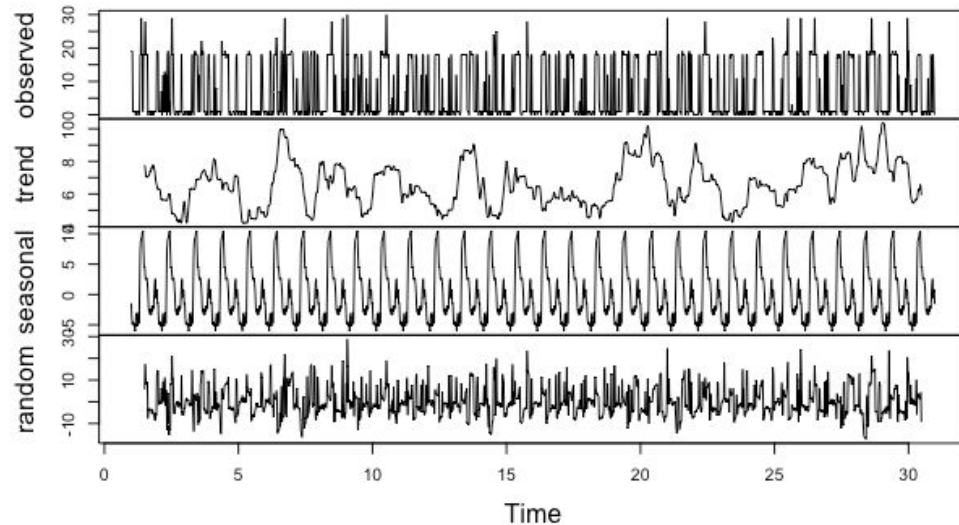
Decomposition Month

Decomposition of the time series for submeter 3 during the month of September 2008.

Client Implications:

Peaks in power usage seem to stretch over several days at a time. There is also a seasonality to the time series.

Submeter 3



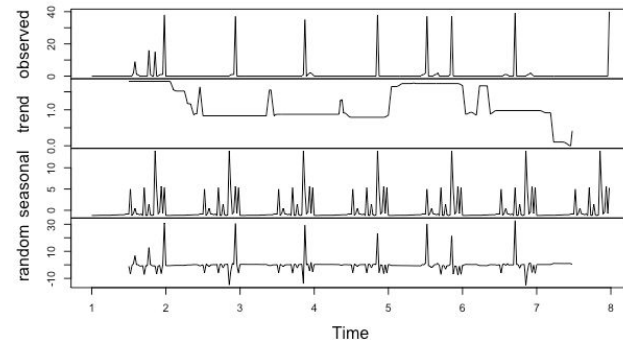


Decomposition Week

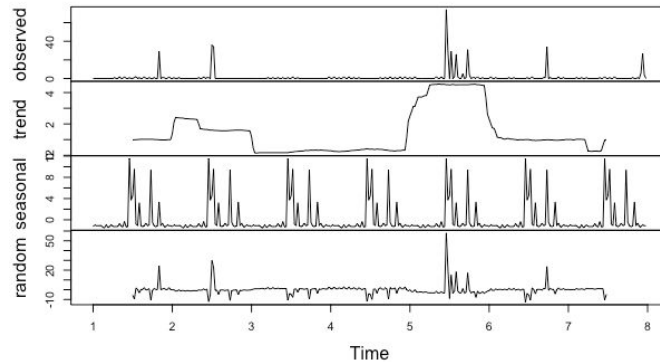
Decomposition of the time series for submeters 1 and 2 during the second week of September 2008.

Client Implications:

Submeter 1



Submeter 2

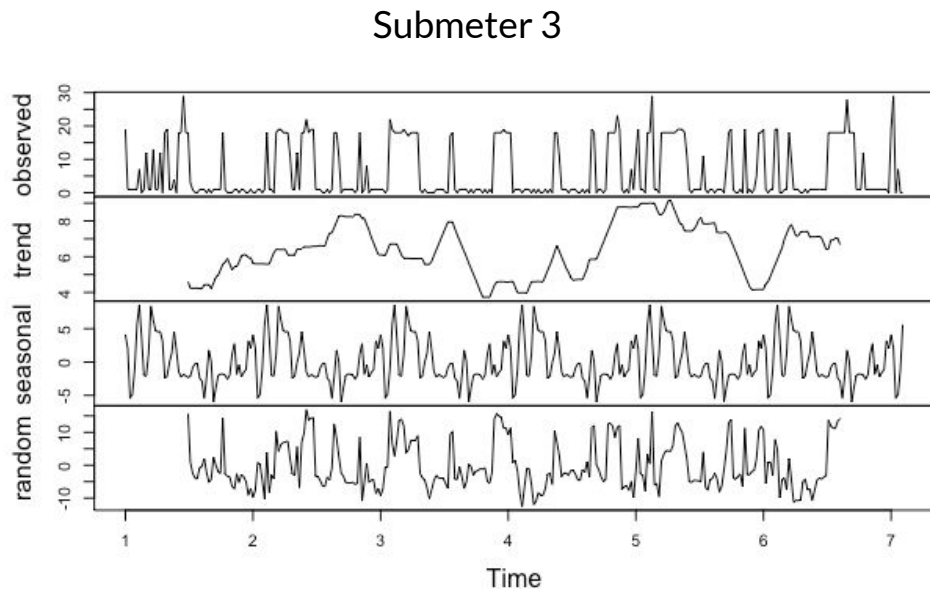




Decomposition Week

Decomposition of the time series for submeter 3 during the second week of September 2008.

Client Implications:



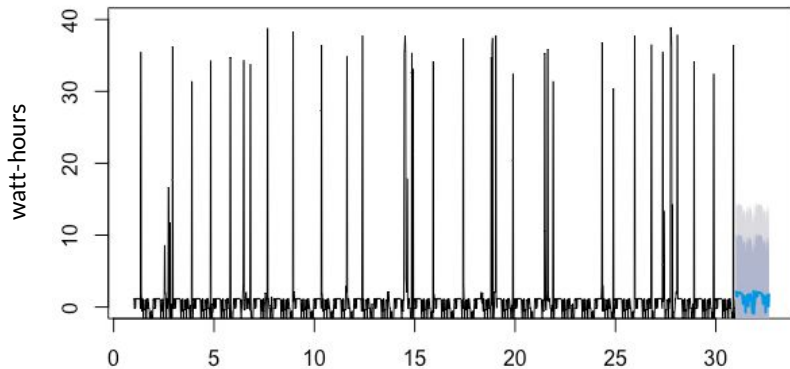


Holt-Winters Forecasting

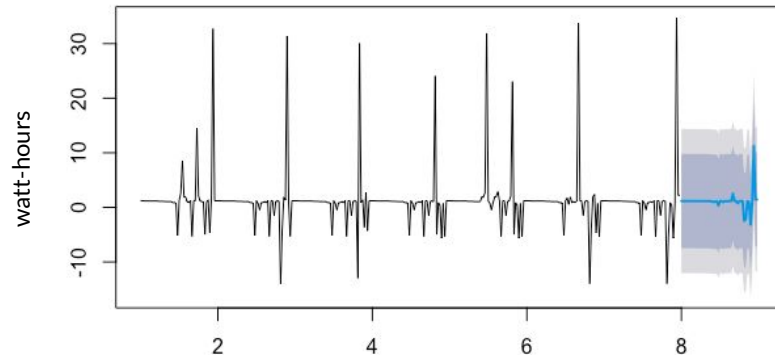
Submeter 1

Depicted here is a Holt-Winters forecast for both the entire month of September and for the second week of September for Submeter 1. Forecasts with Submeter 1 are more difficult due to the general sparsity of readings. The forecasts depict the energy readings over the next 2 days. In this case, the week forecast is more useful than the month forecast, as it was able to predict a peak of energy usage.

Power Usage in September 2008
Submeter 1 - Month



Power Usage in 2nd week of September 2008
Submeter 1 - Week





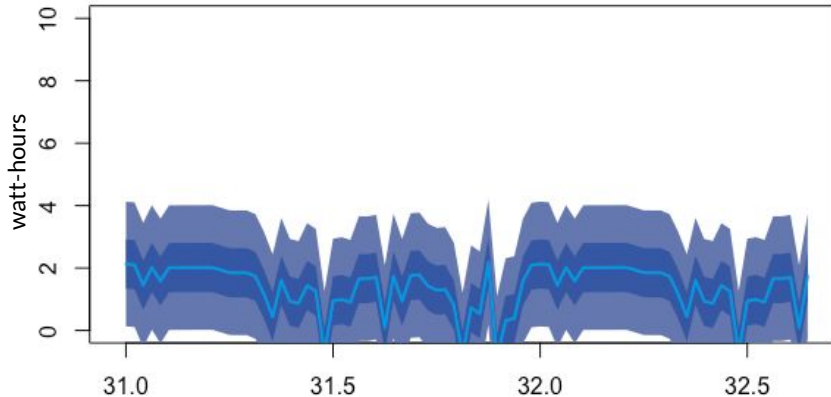
Holt-Winters Forecasting

Submeter 1

This is a closeup view of forecasts for Submeter 1. Note the difference in the scale of the graphs -- for the month of September, only basal level power usage was predicted for the next 2 days. However, for the week forecast, a peak at around 15 watt-hours is predicted.

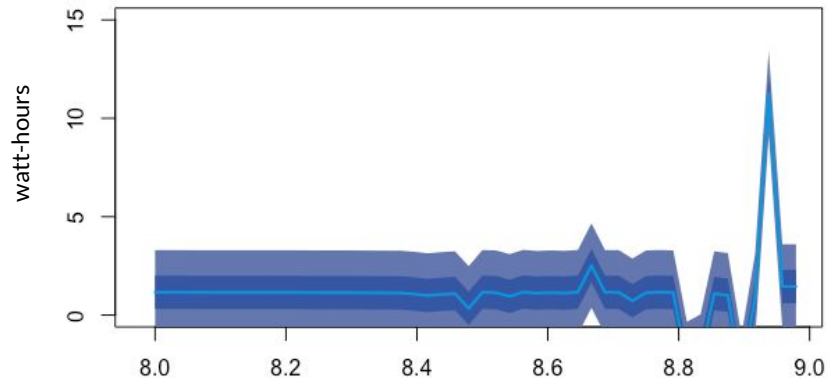
Power Usage in September 2008

Submeter 1 - Month



Power Usage in 2nd week of September 2008

Submeter 1 - Week





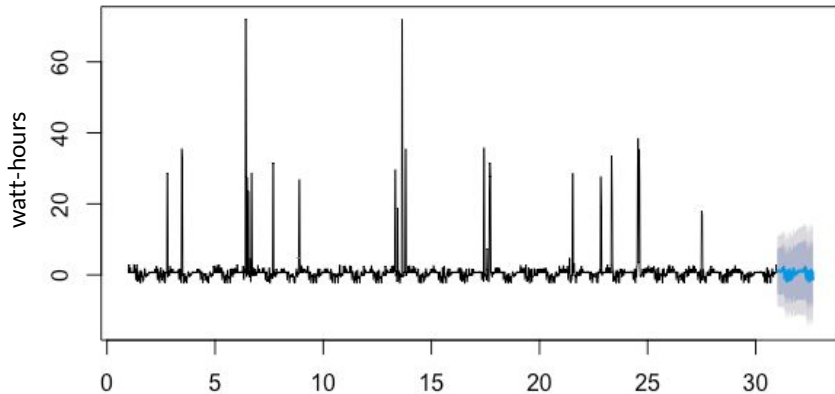
Holt-Winters Forecasting

Submeter 2

Depicted here are Holt-Winters forecasts for Submeter 2 over both a month and week period. Much like Submeter 1, these forecasts proved difficult due to sparsity of power usage. Again, the week forecast did a better job of capturing the spikes in power usage.

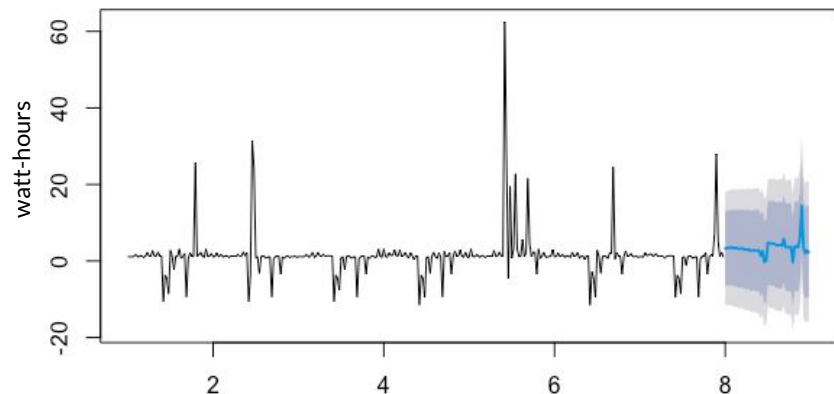
Power Usage in September 2008

Submeter 2 - Month



Power Usage in 2nd week of September 2008

Submeter 2 - Week





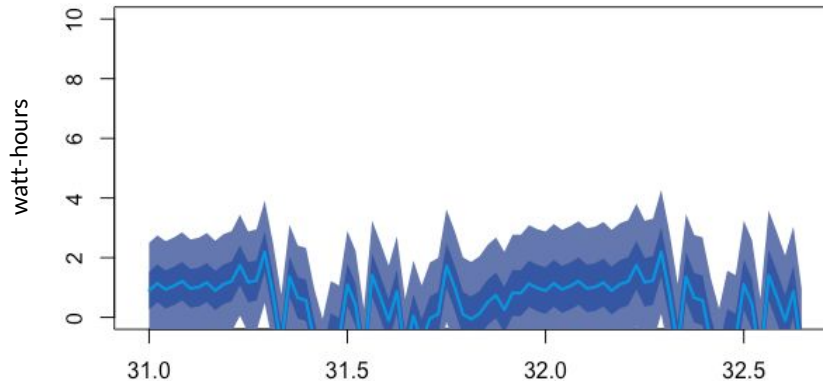
Holt-Winters Forecasting

Submeter 2

This is a closeup view of the forecasts for Submeter 2. Again, note the difference in scale between the graphs. The forecast for the week has higher variation in its forecast.

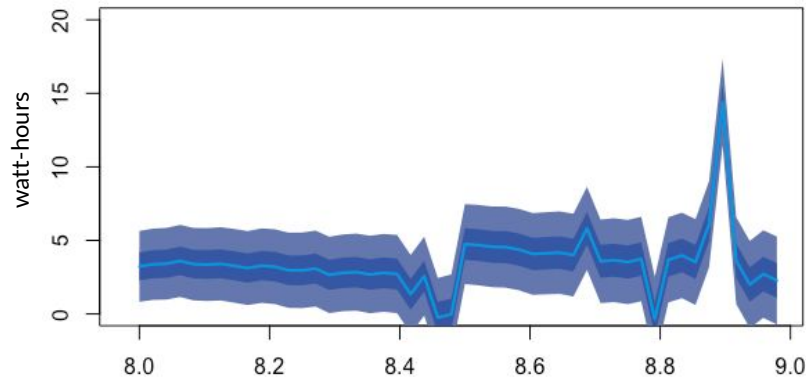
Power Usage in September 2008

Submeter 2 - Month



Power Usage in 2nd week of September 2008

Submeter 2 - Week





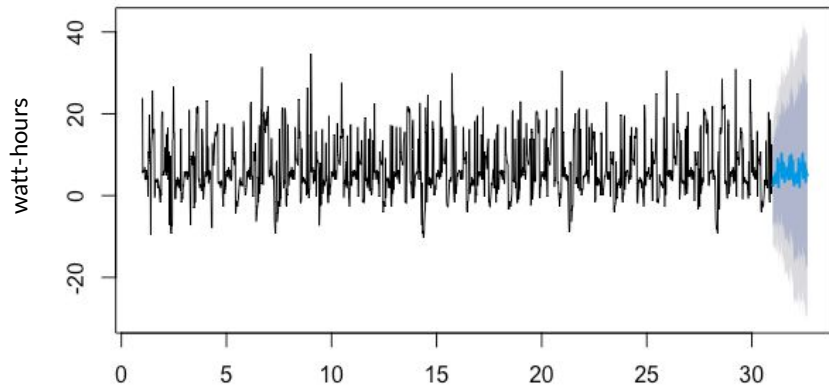
Holt-Winters Forecasting

Submeter 3

Depicted here are the Holt-Winters forecasts for Submeter 3 over both the month and week period. Because there is more variation in power usage, Holt-Winters did a better job of forecasting for this Submeter than the others.

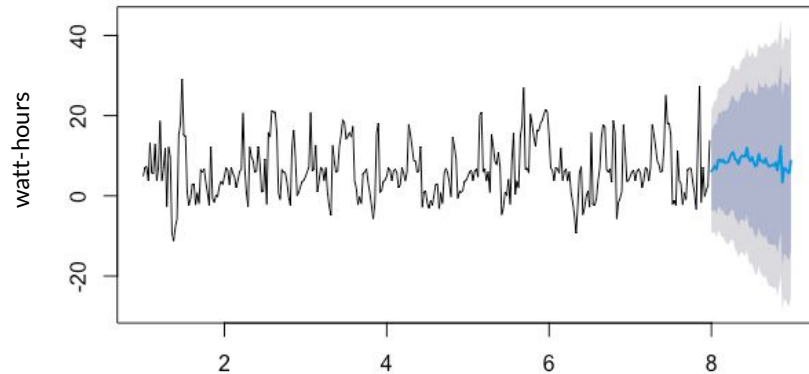
Power Usage in September 2008

Submeter 3 - Month



Power Usage in 2nd week of September 2008

Submeter 3 - Week



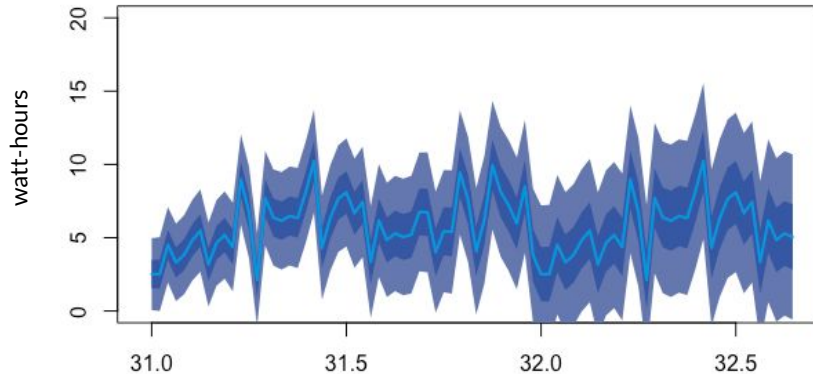


Holt-Winters Forecasting

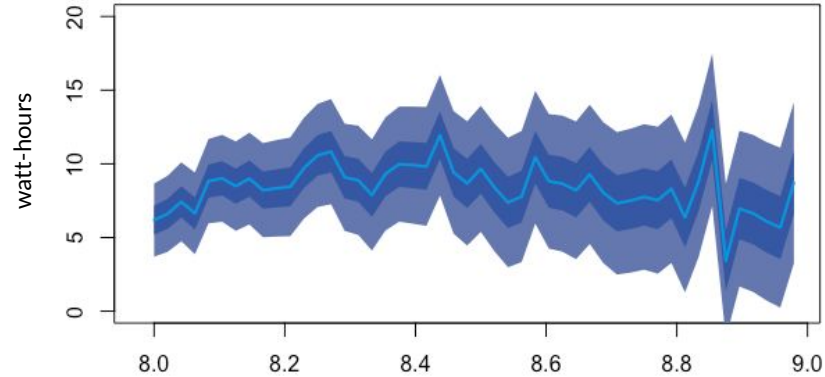
Submeter 3

A closeup of the power usage forecast over a period of 2 days for both a month and week forecast for Submeter 3.

Power Usage in September 2008
Submeter 3 - Month



Power Usage in 2nd week of September 2008
Submeter 3 - Week





Recommendations

After thoroughly analyzing the data, we have come up with several energy-saving recommendations based on our findings.

Most of the energy-savings will come from reducing both the usage of AC and hot water (which together make up at least 75% of power usage for the year).

We recommend that the client reduces power usage of AC by putting the AC unit on a timer so that it is not on as much when they are out for the day. They can also set the AC unit to a higher temperature (as high as is tolerable) or, during cooler months, turn off the AC and open windows to allow a more natural cooling of the home.

The client should also try to reduce the length of hot showers, or even take luke-warm or cold showers from now on. Washing clothes on the “cold” setting can also help reduce power usage caused by the hot water heater.



Recommendations

The kitchen and laundry room each make up around 12% of the energy usage in the home (totaling around 25% together). While this is much less than the power used by the AC/water heater, it is still significant.

Power usage in the kitchen can be reduced by handwashing dishes (especially with cold water) instead of using the dishwasher. Otherwise, it appears that power usage in the kitchen is limited to once or twice daily, which is reasonable. However, power usage can be reduced by making meals that don't require the oven or stove (such as salads and sandwiches).

Power usage in the laundry room could be greatly reduced. As of now, we see that the washer/dryer is used several times weekly. We recommend combining laundry loads and to do laundry less often (once weekly or every other week). Also, instead of using the dryer, the client should consider hanging their clothes to dry.



Lessons Learned

1

Submeters 1 and 2 had huge variation (lots of around zero readings, then sudden very large peaks, which were outliers). This made making forecasts difficult, as the peaks we were most interested in were considered “outliers”.

2


Submeter 3 was easier to make forecasts with because power readings were more frequent and less sparse.

3

Determining frequency of a time-series object can be challenging. It's important that time series graph displays the amount of time you're trying to study -- ie. 30 days or 7 days.

4

Holt-Winters can also be tricky. It's important to test out graphs with different beta/gamma values in order to get a good forecast. Also, forecasts may be different depending on the time period studied and frequency of observations.



After analyzing submetering data for a period of both a month and a week, we were able to make several power-saving recommendations to the client in order for them to effectively reduce their carbon footprint.



Thank you.

