# Individual Household Electric Power Consumption *Sceaux, France*

## DEEP ANALYTICS AND FORECAST

# INTRODUCTION

- IOT Analytics have been asked to perform deep analytics and forecast for the residential electrical power usage in the individual household in Sceaux, France based on the energy consumption data for the period from 2007 to 2009.

- The data consists of the active energy readings from 3 submeters in the following areas:

  - Submeter 1 – major kitchen appliances, containing mainly a dishwasher, an oven and a microwave (hot plates are not electric, but gas powered).
  - Submeter 2 – a laundry room, containing a washing-machine, a tumble-drier, a refrigerator and a light.
  - Submeter 3 - an electric water-heater and an air-conditioner (AC).

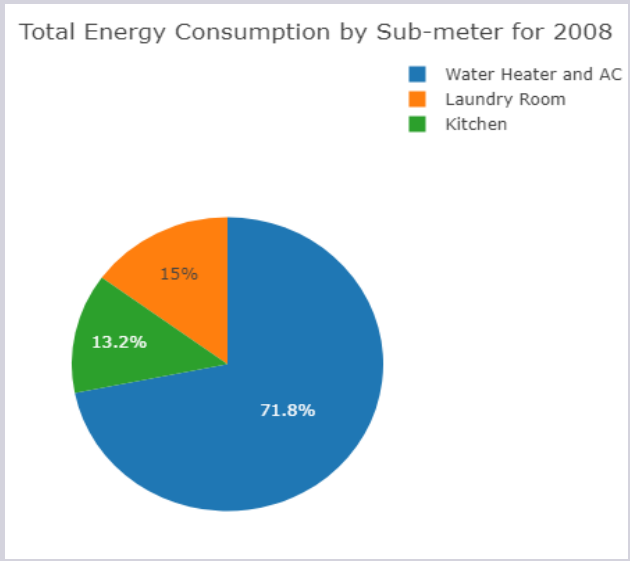
# ANALYSIS PLAN

The analysis and forecast will be performed for 3 sub-meters and include the following:

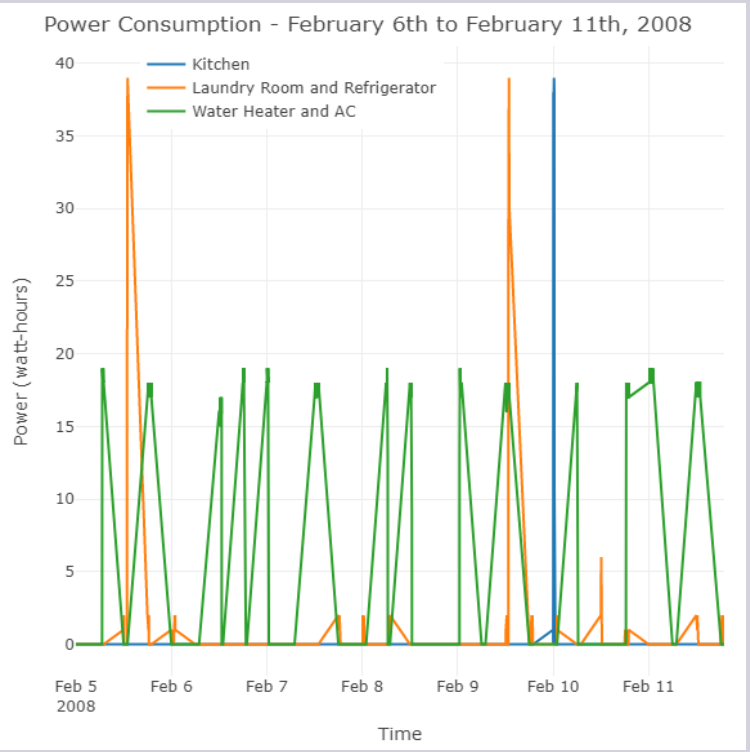
- Investigation of energy consumption patterns for different  time periods (months, weeks, workdays vs weekend, summer days vs fall days, etc.)
- Time series analysis for different periods of time (time series - series of data points ordered in time)
- Exploration of the energy consumption seasonal, trend, and random (remainder) components for different time periods
- Generation of the forecast based on different models for different time periods

# ENERGY CONSUMPTION PATTERNS

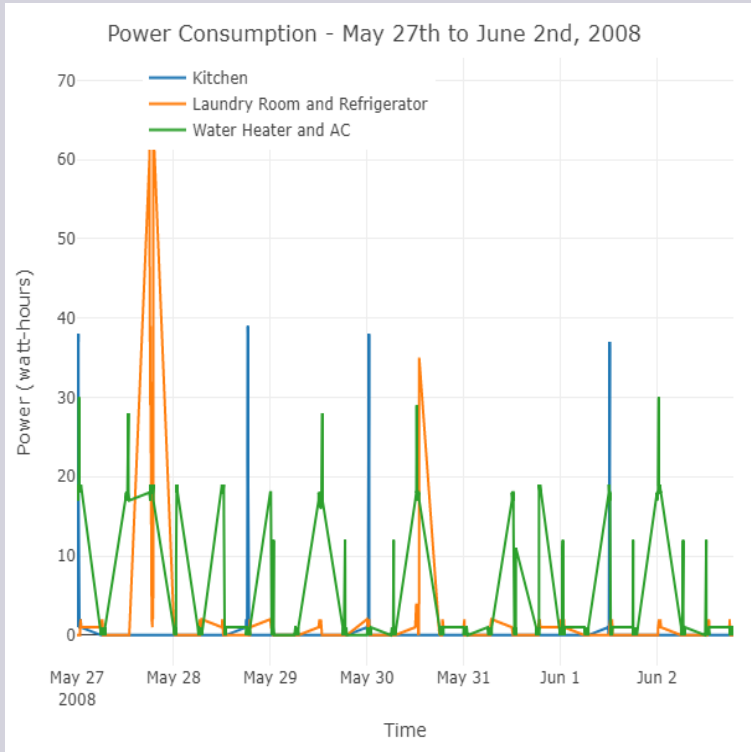
In 2008, the AC and the water heater used significant amount of energy – 71.8% of total usage, while the laundry room/refrigerator and the kitchen appliances consumed 15.0% and 13.2%, respectively.



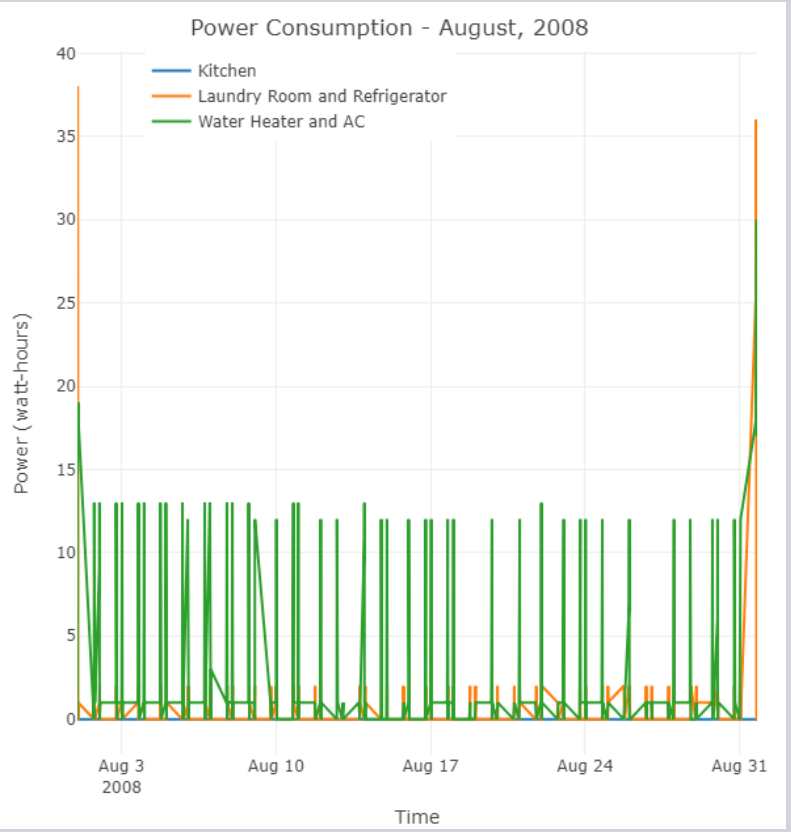

The week of May 27th to June 2nd, 2008 showed the consistent usage of the AC and the water heater, mainly at the rate of 30 and below watt-hours. The laundry room was used twice with the refrigerator working in the background. The kitchen appliances were used 4 times during the week at the rate of approx. 37-39 watt-hours.



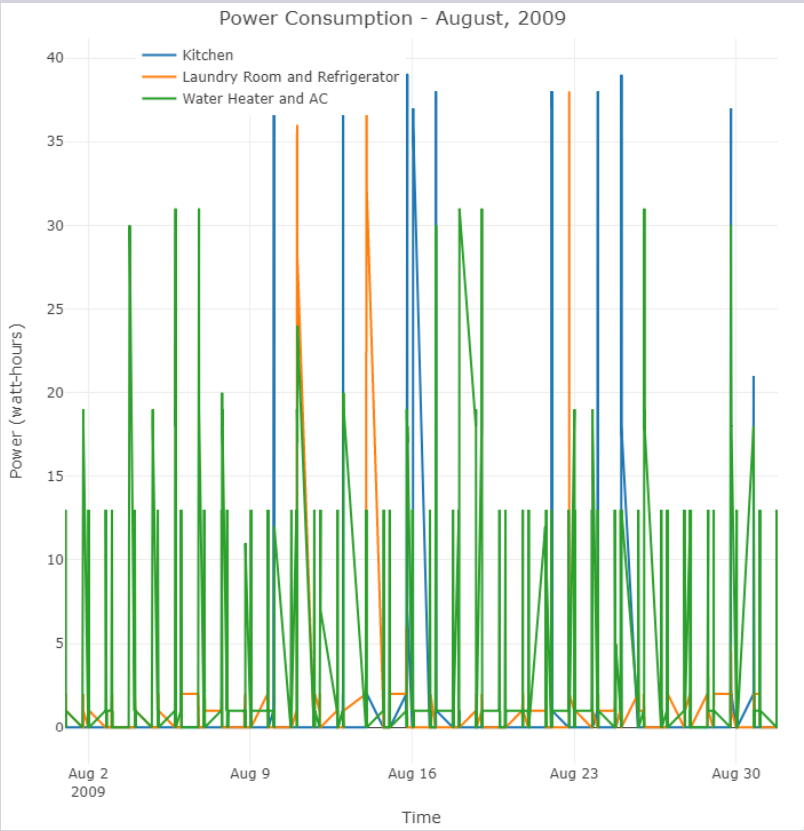

Second week of February of 2008 showed the consistent usage of the AC and the water heater at the rate of approx. 16-19 watt-hours, while the laundry room was used twice during the week with the refrigerator working in the background. The kitchen appliances were used only once on February 10th.



# ENERGY CONSUMPTION PATTERNS – AUGUST 2008 AND 2009

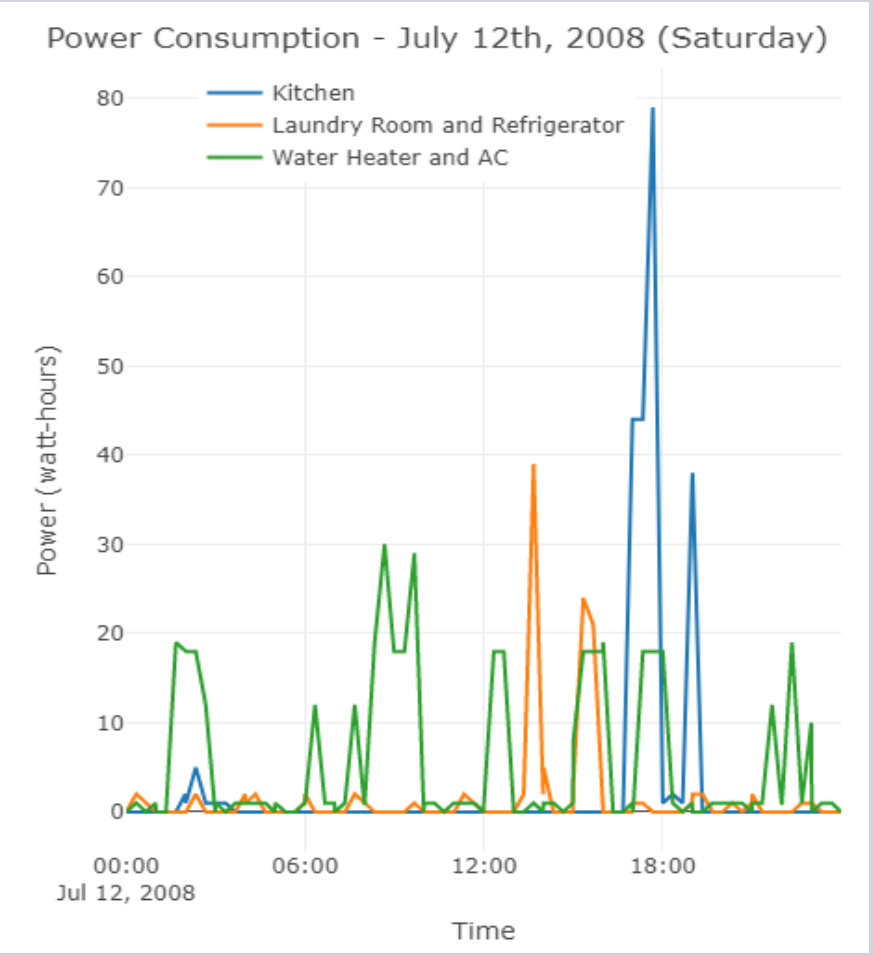



August of 2009 showed that the laundry room was used 3 times. The kitchen appliances were used multiple times. The AC and the water heater were heavily used.



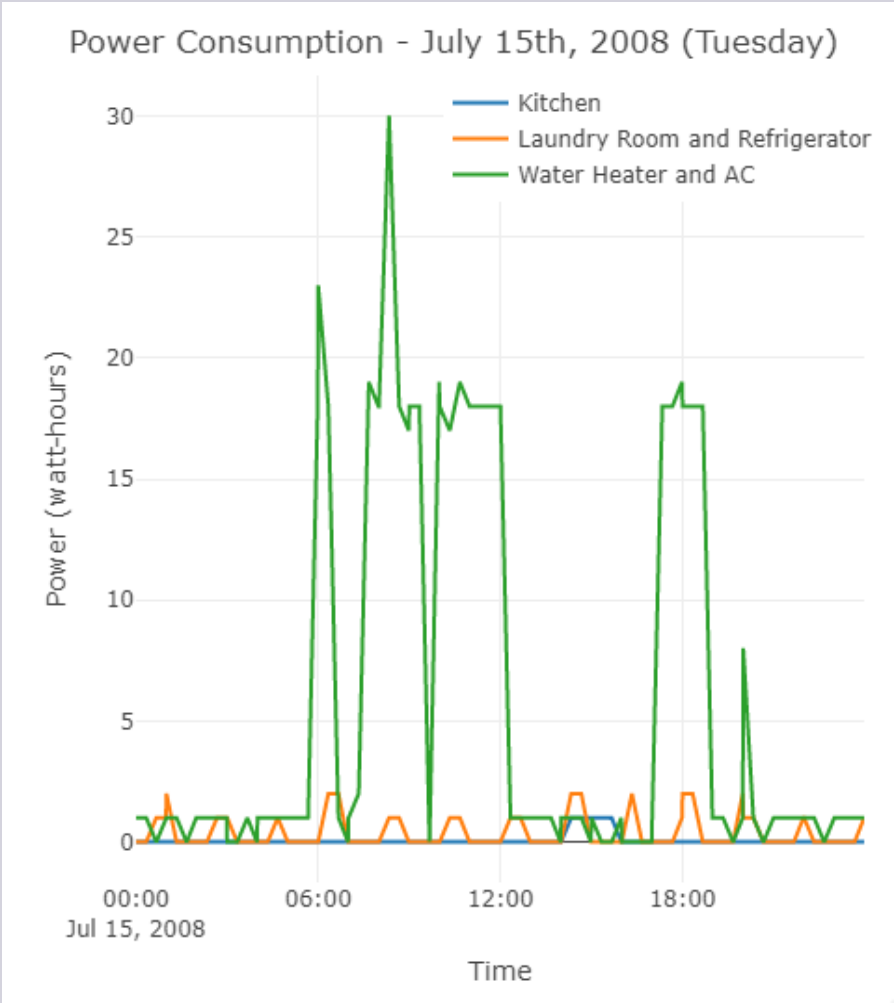

Most of August of 2008 had no activity in the kitchen and the laundry room. The refrigerator was working in the background. The AC and the water heater were consuming only approx. 13-14 watt-hours (combined).

# ENERGY CONSUMPTION PATTERNS – JULY 12th AND 15th, 2008

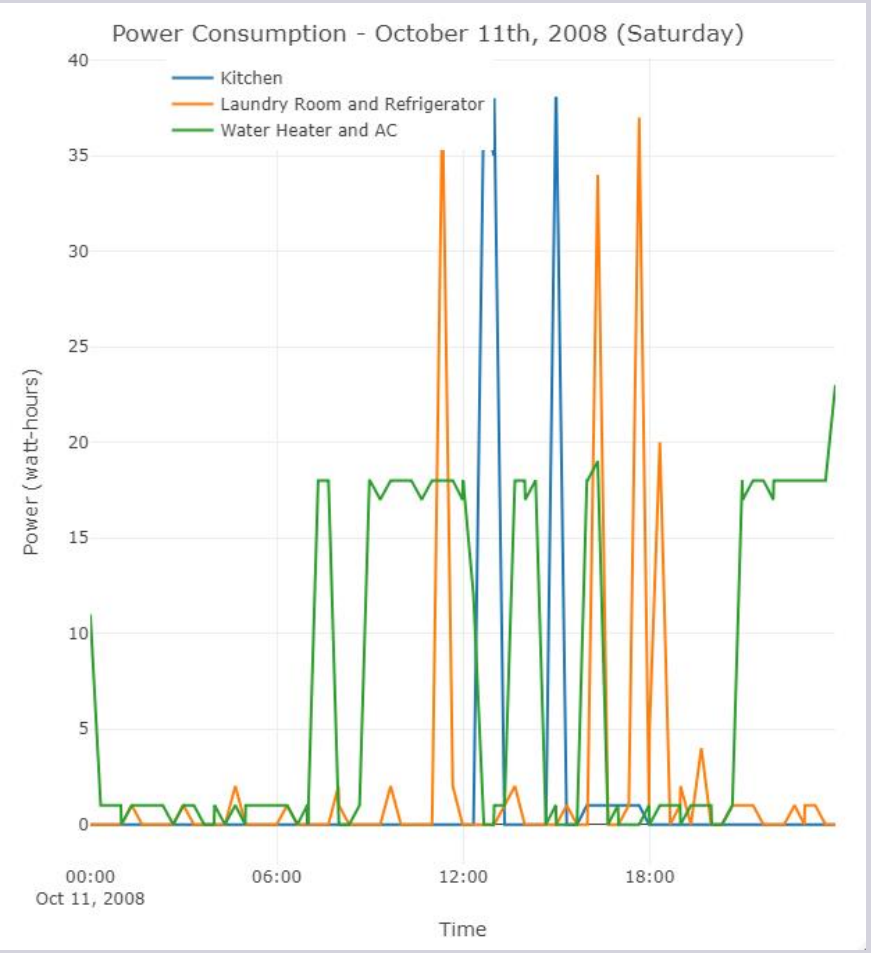



On July 12 , 2008 (Saturday) the kitchen appliances were heavily used around dinner time. The laundry room was used in the afternoon. The refrigerator was working in the background. The AC and the water heater showed the sporadic usage through the day peaking 30 watt-hours in the morning.

On July 15th, 2008 (Tuesday) the kitchen appliances were not used. No activity in the laundry room. The refrigerator continued working in the background. The AC and the water heater showed the sporadic usage through the day peaking 30 watt-hours in the morning.

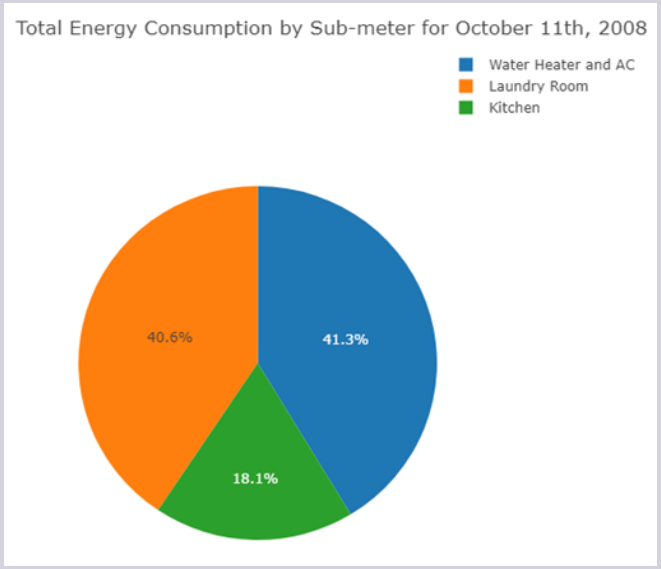


# ENERGY CONSUMPTION PATTERNS – OCTOBER 11th, 2008



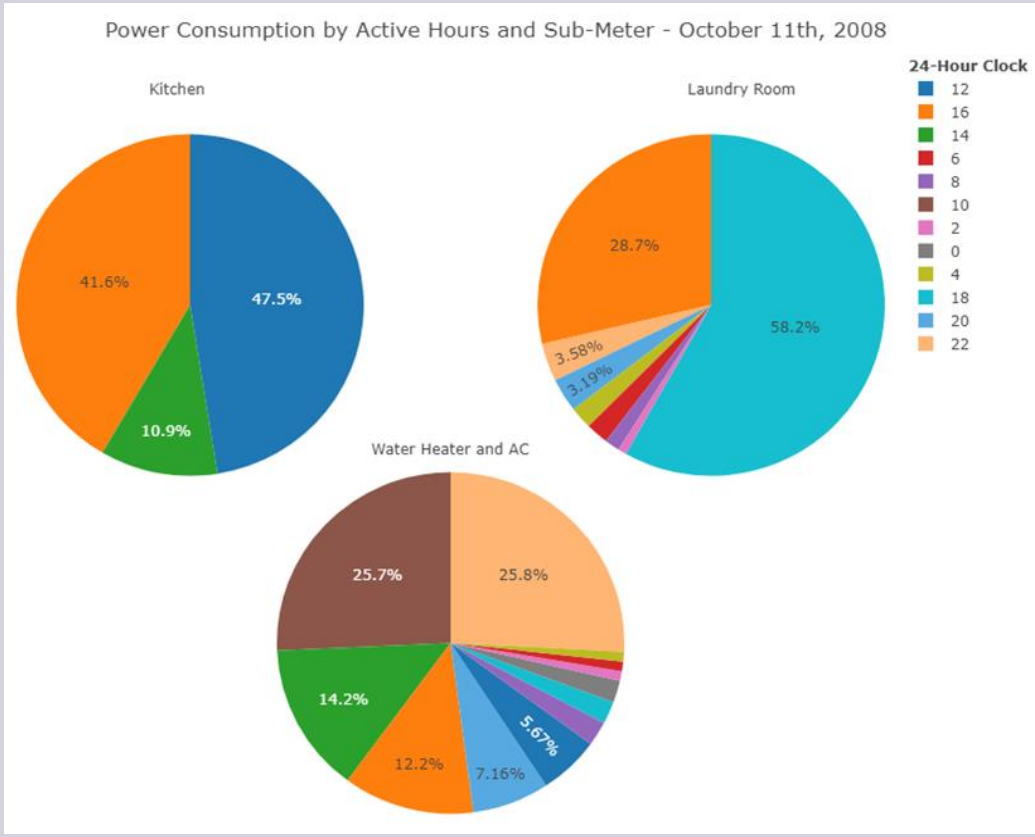

The kitchen appliances consumed only 18.1% of the total daily usage. The active hours were:

1. 12:00
2. 16:00
3. 14:00




The AC and the water heater consumed 41.3% of the total daily usage. The active hours were:

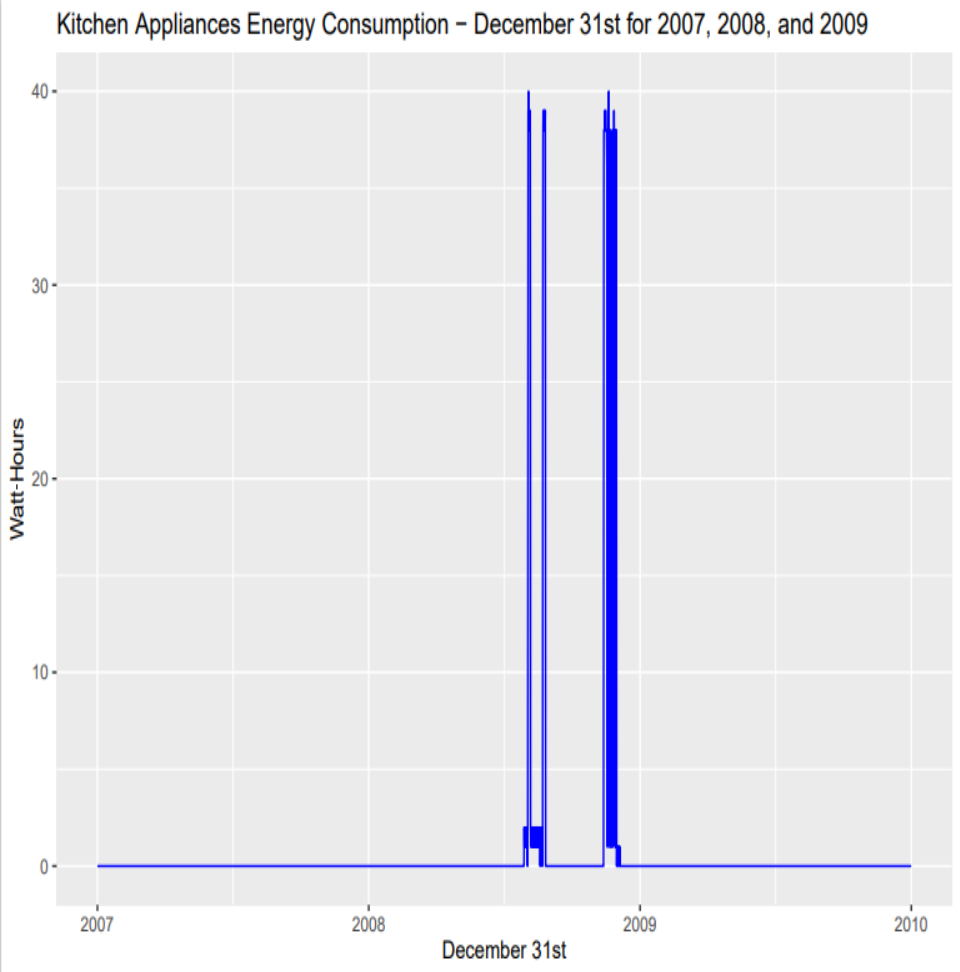
1. 22:00
2. 10:00
3. 14:00
4. 16:00
5. 20:00



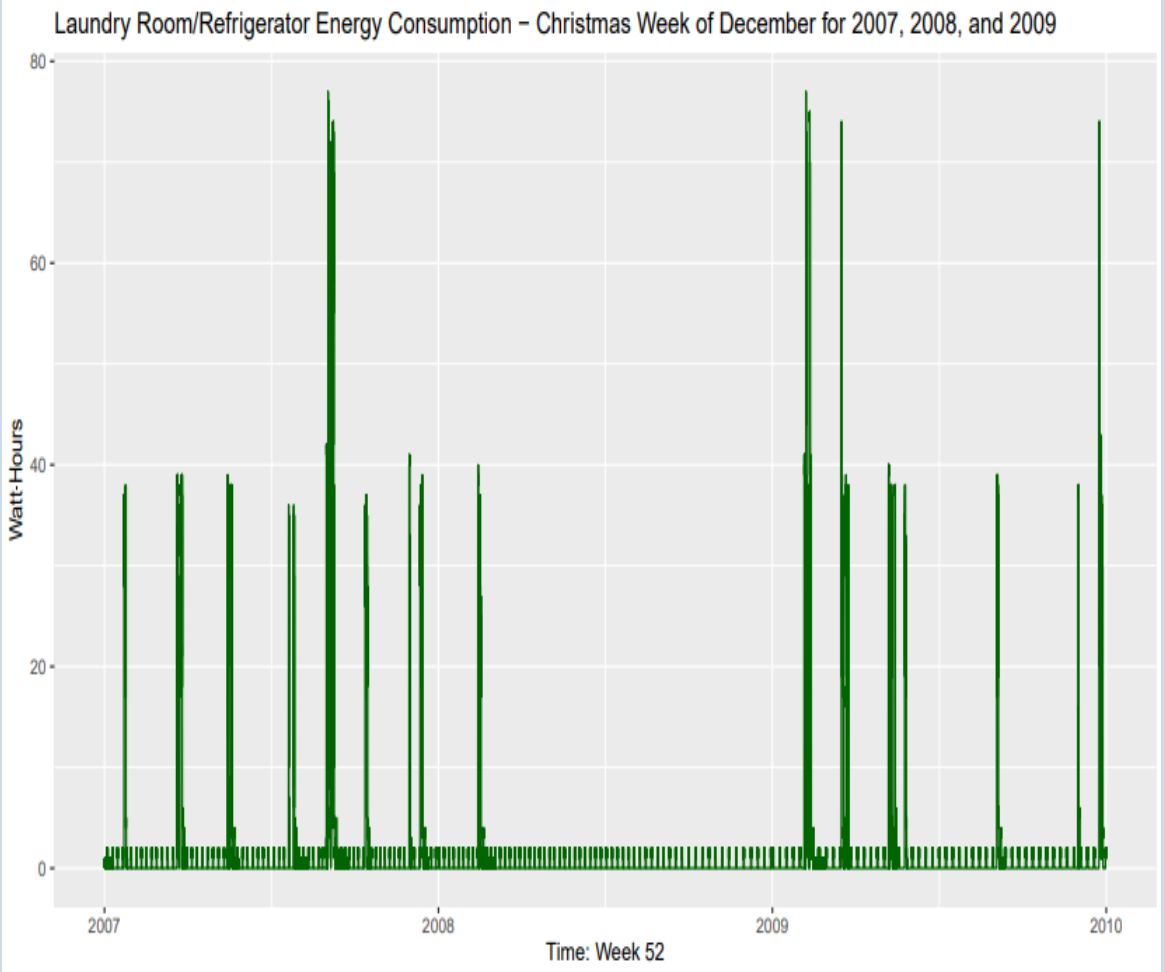

The laundry room/refrigerator consumed 40.6% of the total daily usage. The active hours were:

1. 18:00
2. 16:00
3. 22:00
4. 20:00

# TIME SERIES ANALYSIS



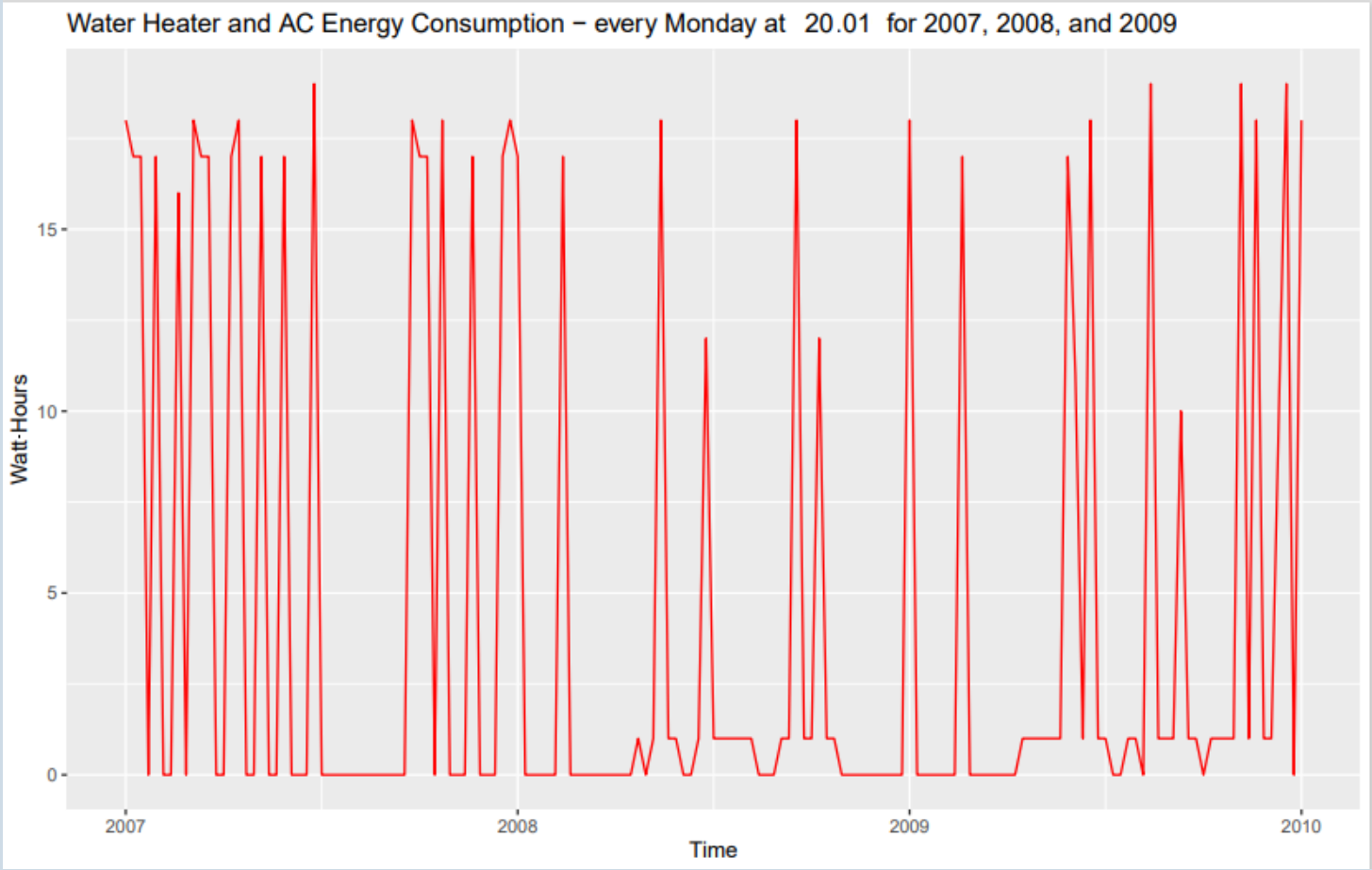

The kitchen appliances were used only on December 31st of 2008, while December 31st of 2007 or 2009 had no activity.



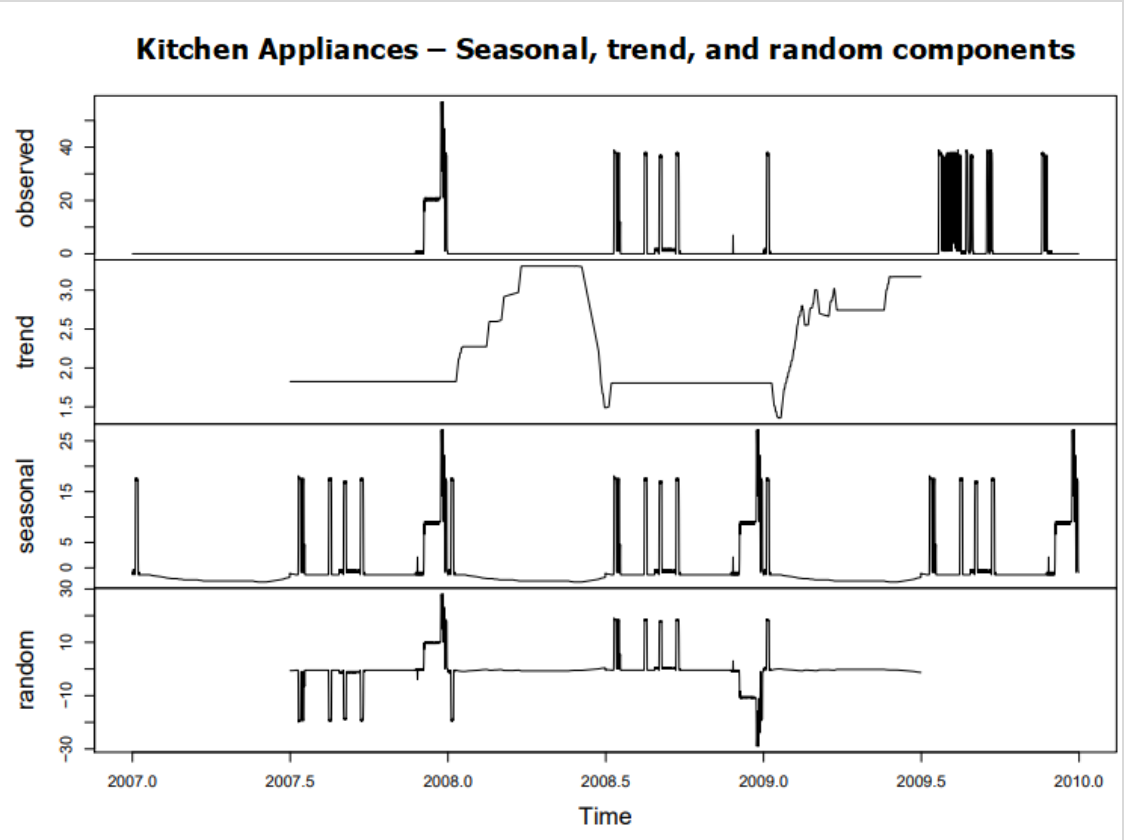

The laundry room was consistently used during Christmas week of 2007 and 2009, while most of the Christmas week of 2008 had no activity. The refrigerator continued to work in the background.

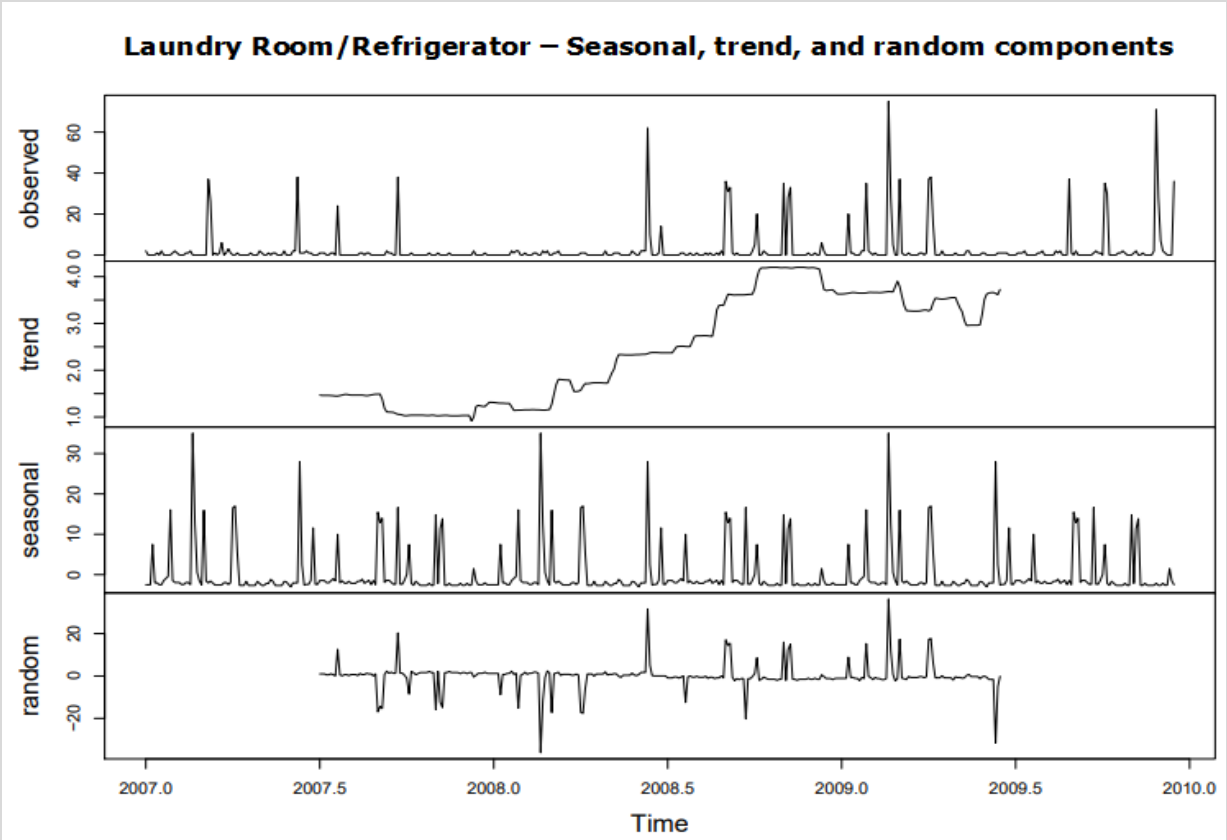
# TIME SERIES ANALYSIS (continued)

The AC and the water heater usage shows a seasonal pattern for Mondays at 20:01. During 2008 and the first half of 2009 the usage appears to be more sporadic.



# ENERGY CONSUMPTION SEASONAL, TREND, AND RANDOM COMPONENTS



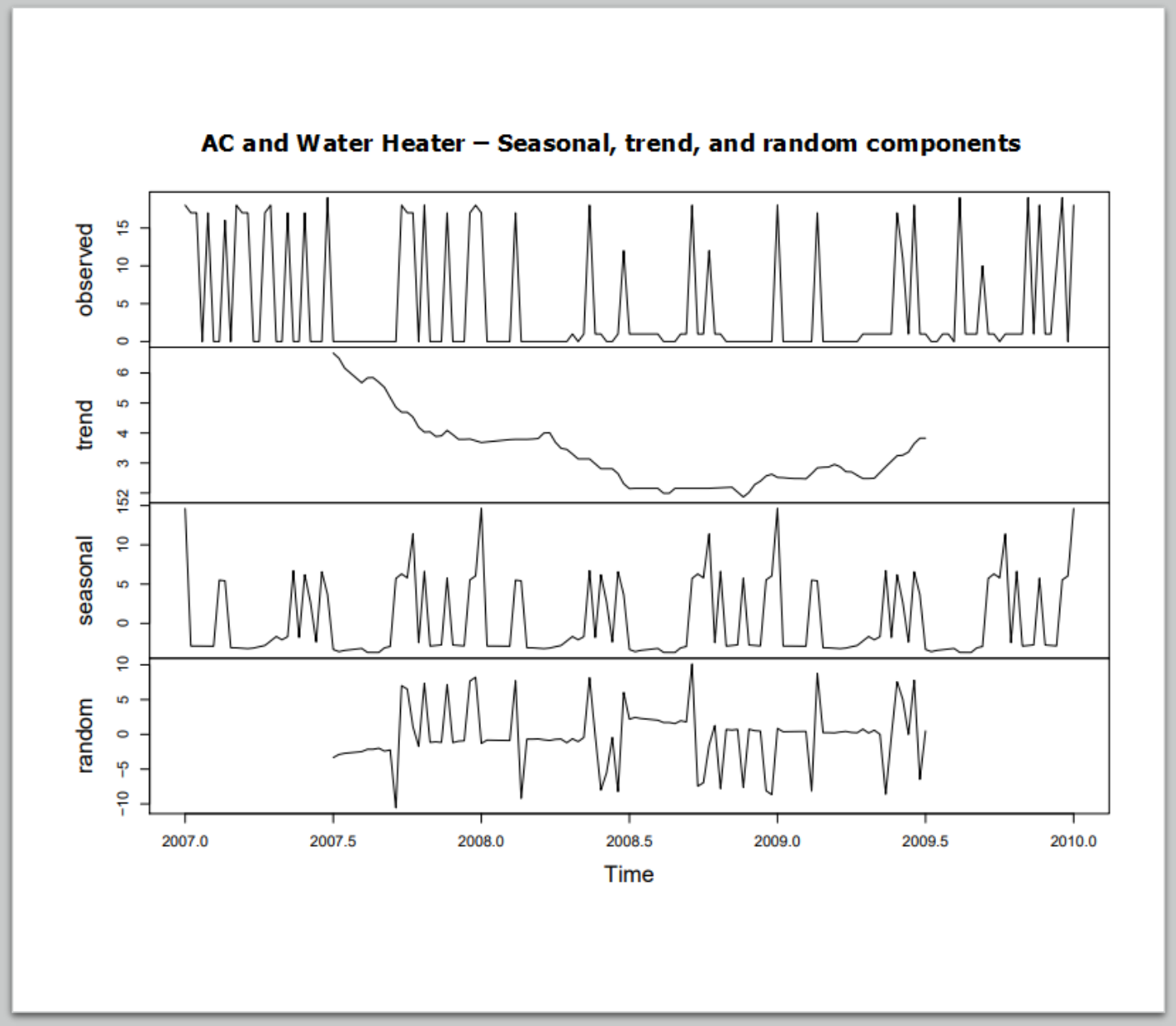




On October 11th of 2007, 2008, and 2009 the kitchen appliances usage had a sporadic pattern.

Every Saturday of 2007, 2008, and 2009 between 18:00 and 19:00 the laundry room/refrigerator usage had a consistent seasonal pattern.

# ENERGY CONSUMPTION SEASONAL, TREND, AND RANDOM COMPONENTS (CONTINUED)

Every Monday for 2007, 2008, and 2009 at 20:01 the AC and the water heater usage had a consistent seasonal pattern.



# ENERGY CONSUMPTION SEASONAL, TREND, AND RANDOM COMPONENTS - STATISTICS

## KITCHEN APPLIANCES

The analysis was performed for October 11th of 2007, 2008, and 2009.

The seasonal component has a zero mean, while the maximum value was 27 watt-hours confirming the sporadic pattern. The trend component based on a moving average has a mean of 2 watt-hours, minimum of 1 watt-hour and the maximum of 3 watt-hours. The random component has a zero mean and median, and a symmetrical pattern confirming that no underlying pattern exists.

## LAUNDRY ROOM/REFRIGERATOR

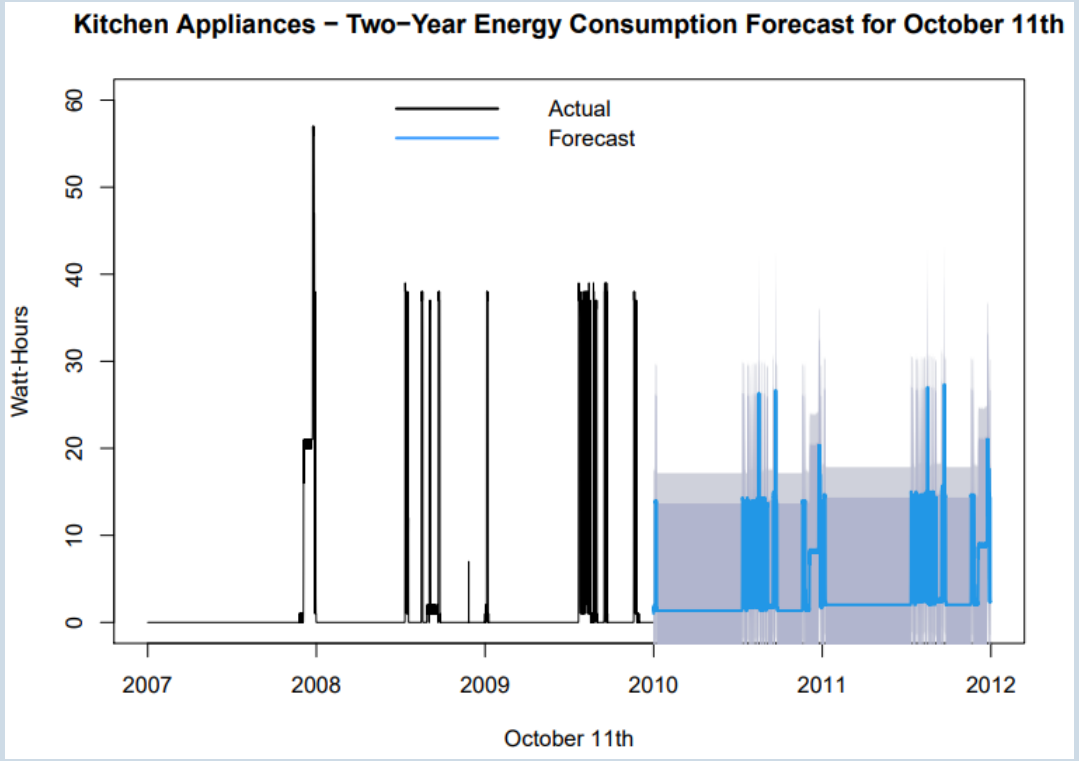
The analysis was performed for every Saturday for hours between 18:00 and 19:00 for years 2007, 2008, and 2009.

The seasonal component has a zero mean, while the maximum value was 35 watt-hours confirming the seasonal pattern. The trend component based on a moving average has a mean of 2 watt-hours, minimum of 1 watt-hour and the maximum of 4 watt-hours. The random component has a slightly above zero (0.04 watt-hours) mean and median, and a symmetrical pattern confirming that the underlying pattern exists (working at the constant rate refrigerator).

## AC AND WATER HEATER

The analysis was performed for every Monday at 20:01 for years 2007, 2008, and 2009.

The seasonal component has a slightly above zero (0.09 watt-hours) mean, while the maximum value was 14 watt-hours confirming the seasonal pattern. The trend component based on a moving average has a mean of 3 watt-hours, minimum of 2 watt-hours and the maximum of 7 watt-hours. The random component has a zero mean and median, and a symmetrical pattern. The different means for seasonal and random components indicate the existence of the underlying pattern (idle water heater consumes energy).

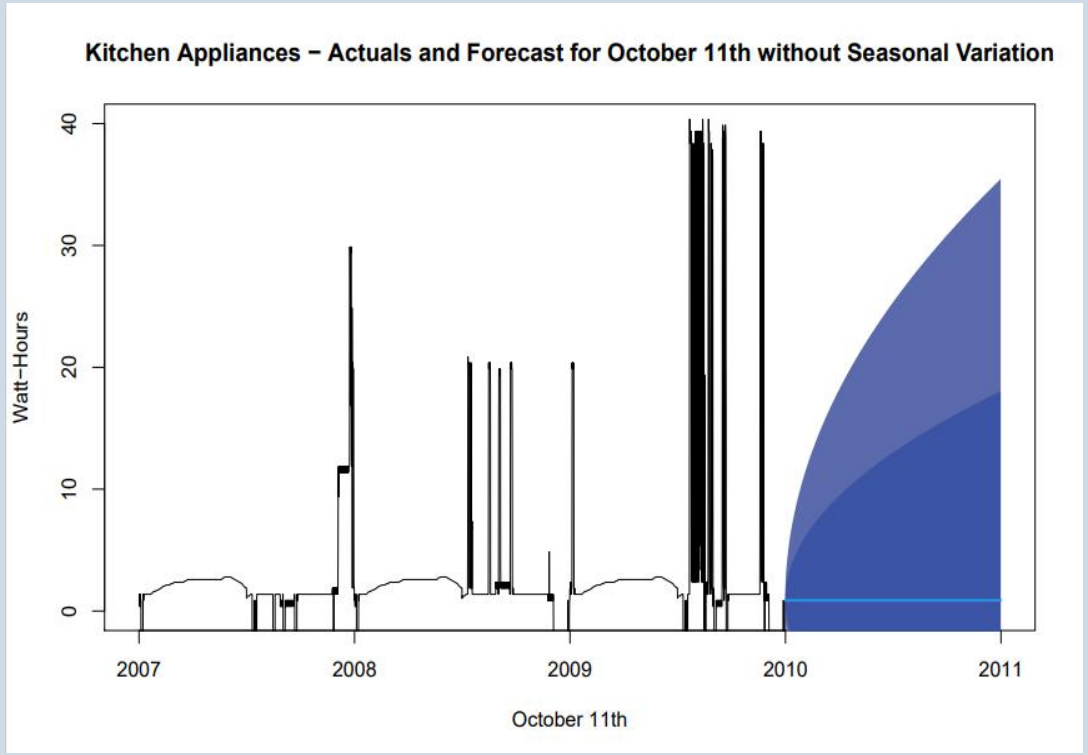


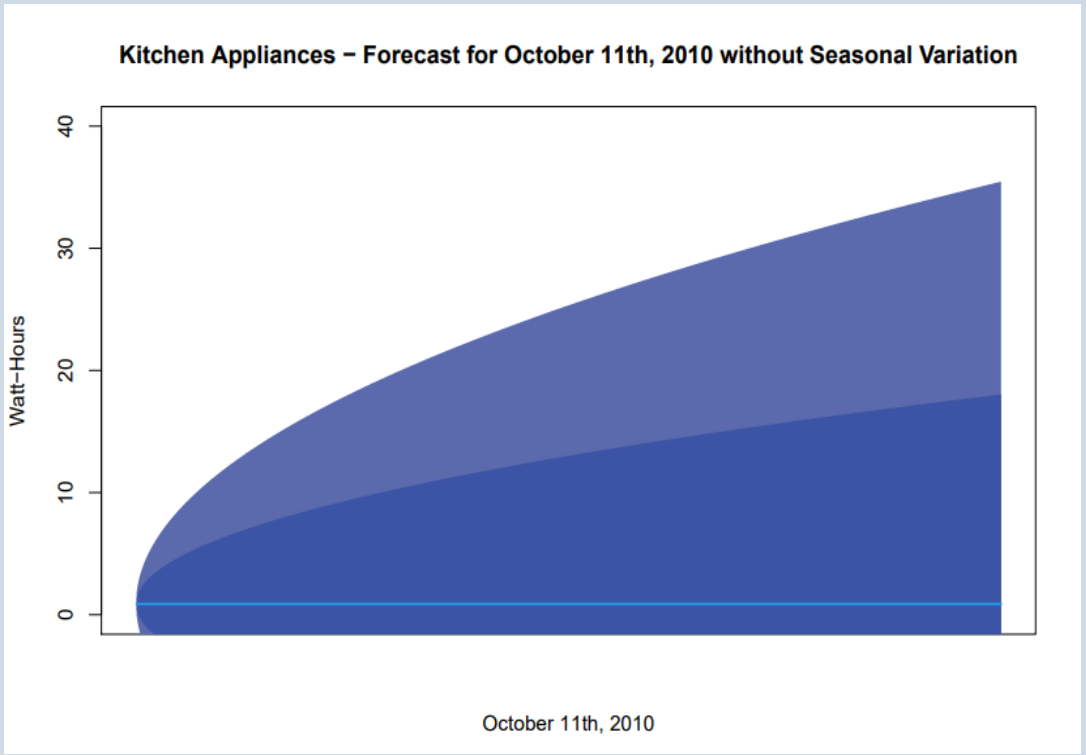

| | STATISTICS | |
|---|---|---|
| | Coefficient of determination* | Residual Standard Error** |
| Linear Regression Model | -0.03651 | 8.313 |

*shows how well data points fit a line (value closed to 1 is preferred)
** measures the variability of the residuals from a linear model (value closed to 0 is preferred)

# *LINEAR FORECAST*

Energy consumption linear forecast for the kitchen appliances for October 11$^{th}$ , 2010 and 2011 showed the sporadic pattern with the increased energy consumption around dinner hours and at the end of the day. The statistical coefficients presented in the table above confirm the non-linear relationship.

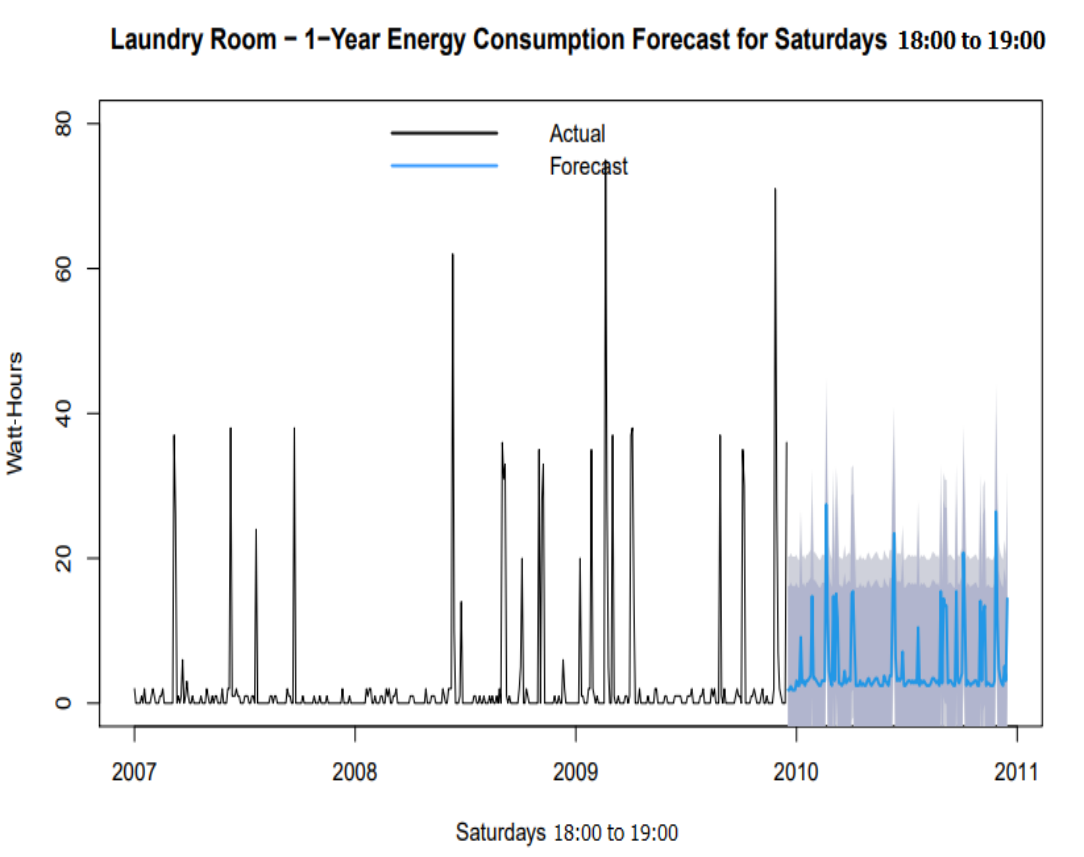



# *EXPONENTIAL SMOOTHING FORECAST **

Energy consumption exponential smoothing forecast for the kitchen appliances for October 11$^{th}$ , 2010 without seasonal variation showed the increased energy consumption around dinner hours and at the end of the day. This pattern could be consistently observed in prior years.

*exponential smoothing forecast smooths out minor deviations in past data trends by detecting seasonality patterns and confidence

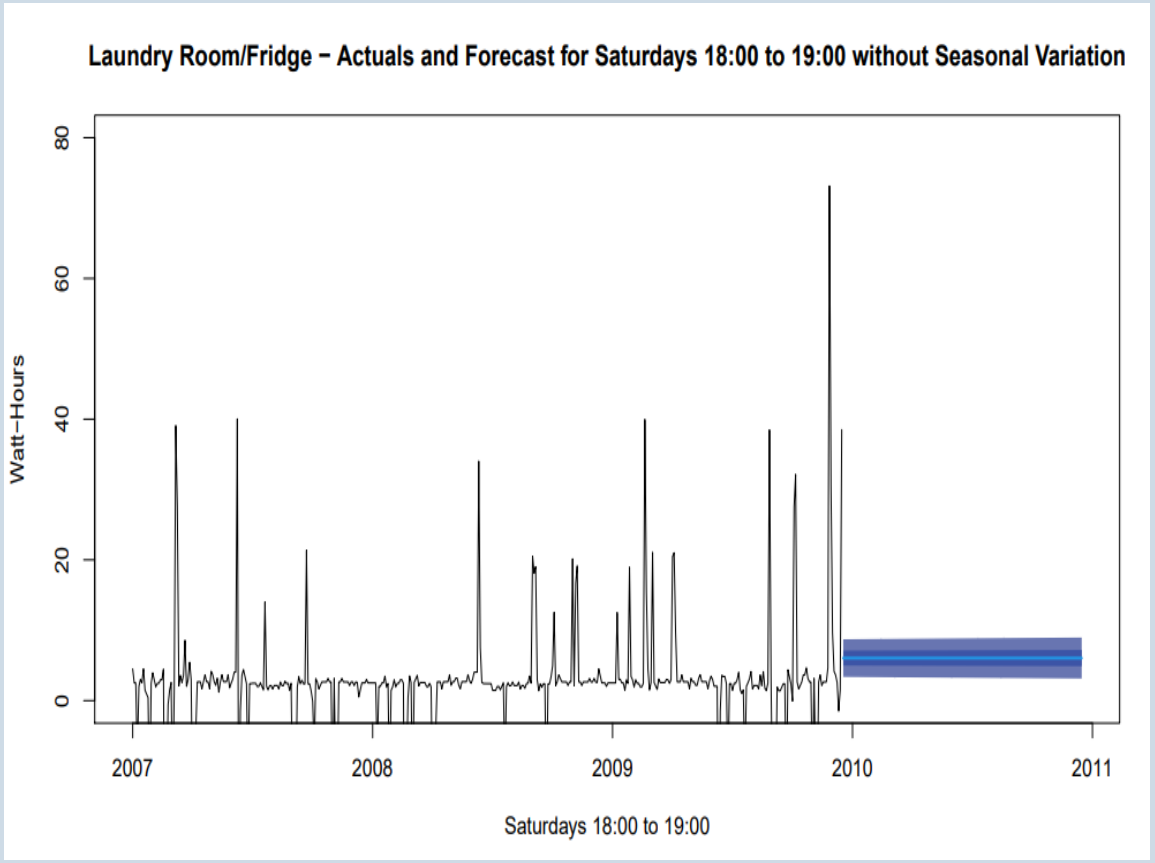


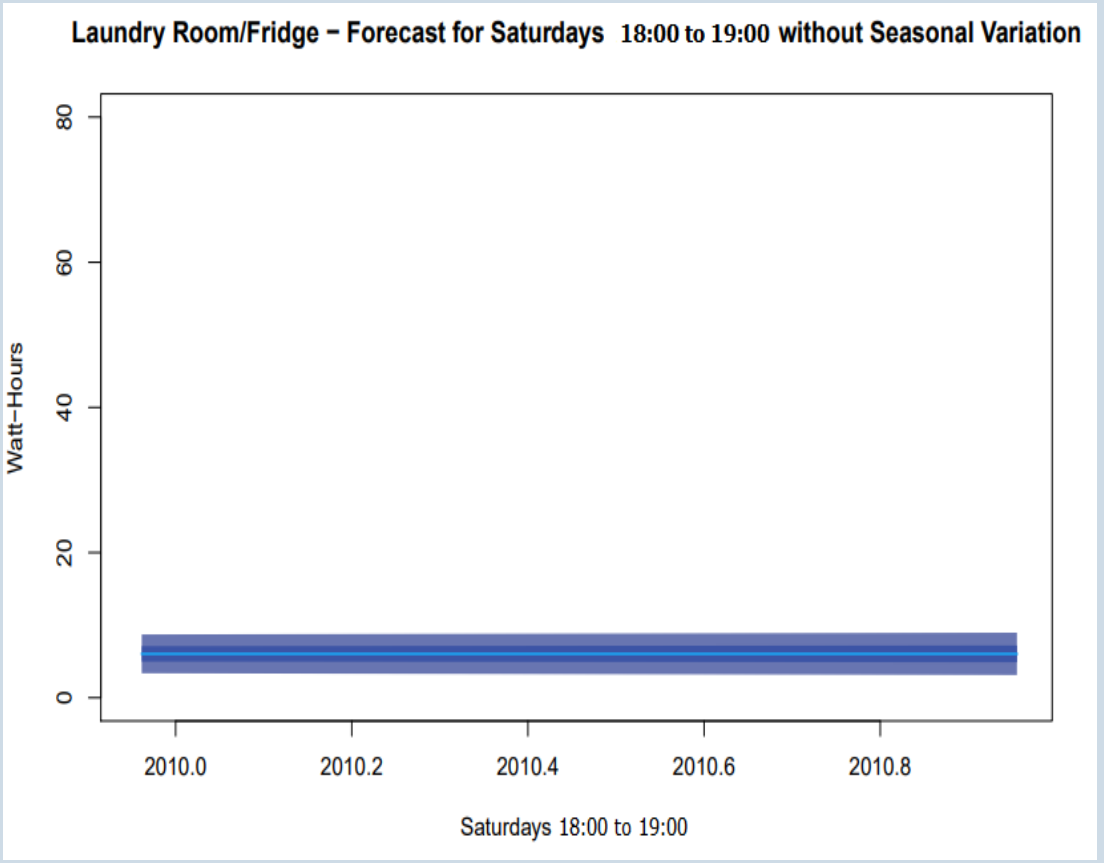

| | STATISTICS | |
|---|---|---|
| | Coefficient of determination* | Residual Standard Error** |
| Linear Regression Model | -0.03078 | 9.081 |

*shows how well data points fit a line (value closed to 1 is preferred)
** measures the variability of the residuals from a linear model (value closed to 0 is preferred)

# *LINEAR FORECAST*

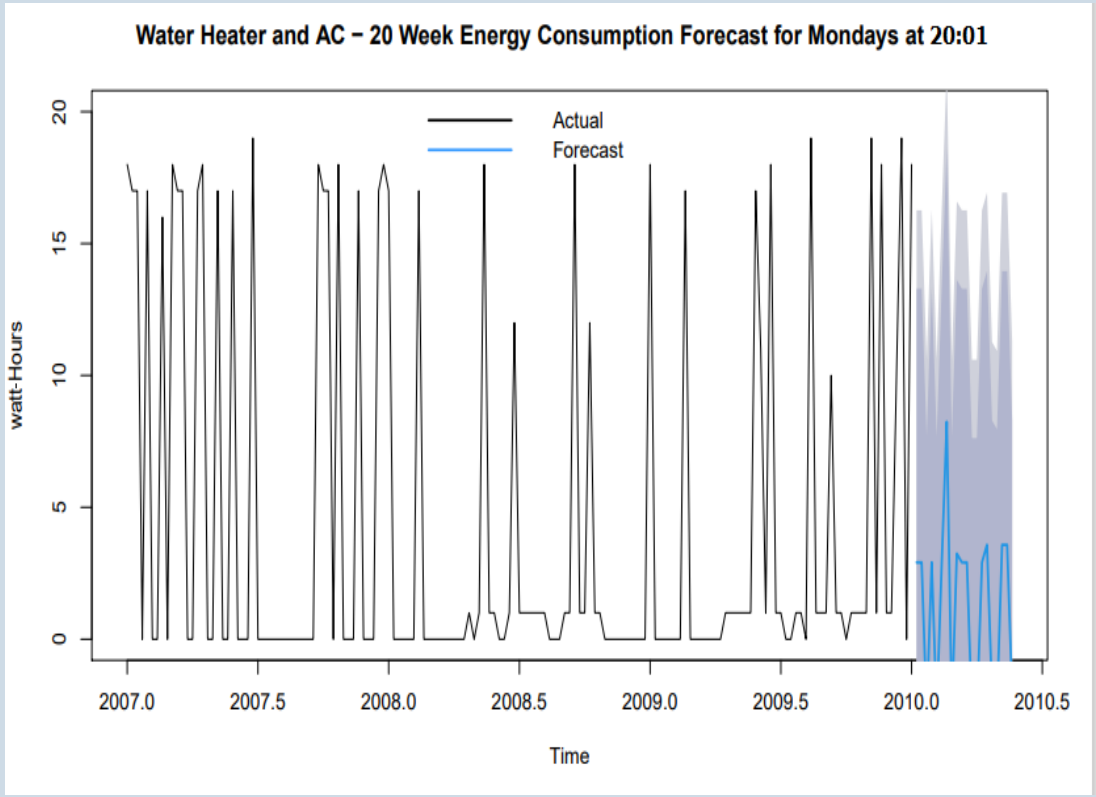
Energy consumption linear forecast for the laundry room/refrigerator for Saturdays between 18:00 and 19:00 showed the seasonal pattern. The statistical coefficients presented in the table above confirm the non-linear relationship.




# *EXPONENTIAL SMOOTHING FORECAST*

Energy consumption exponential smoothing forecast for the laundry room/refrigerator for Saturdays between 18:00 and 19:00 without seasonal variation showed the underlying linear pattern at the constant rate (working refrigerator).

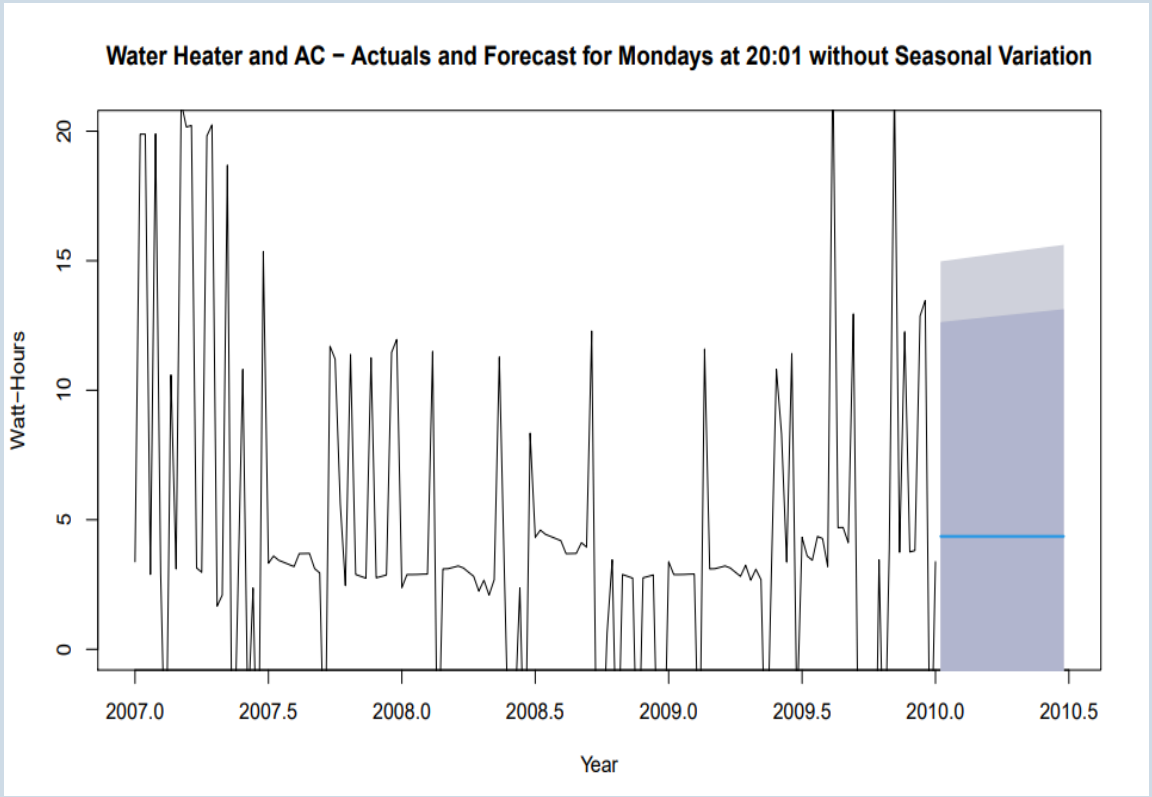


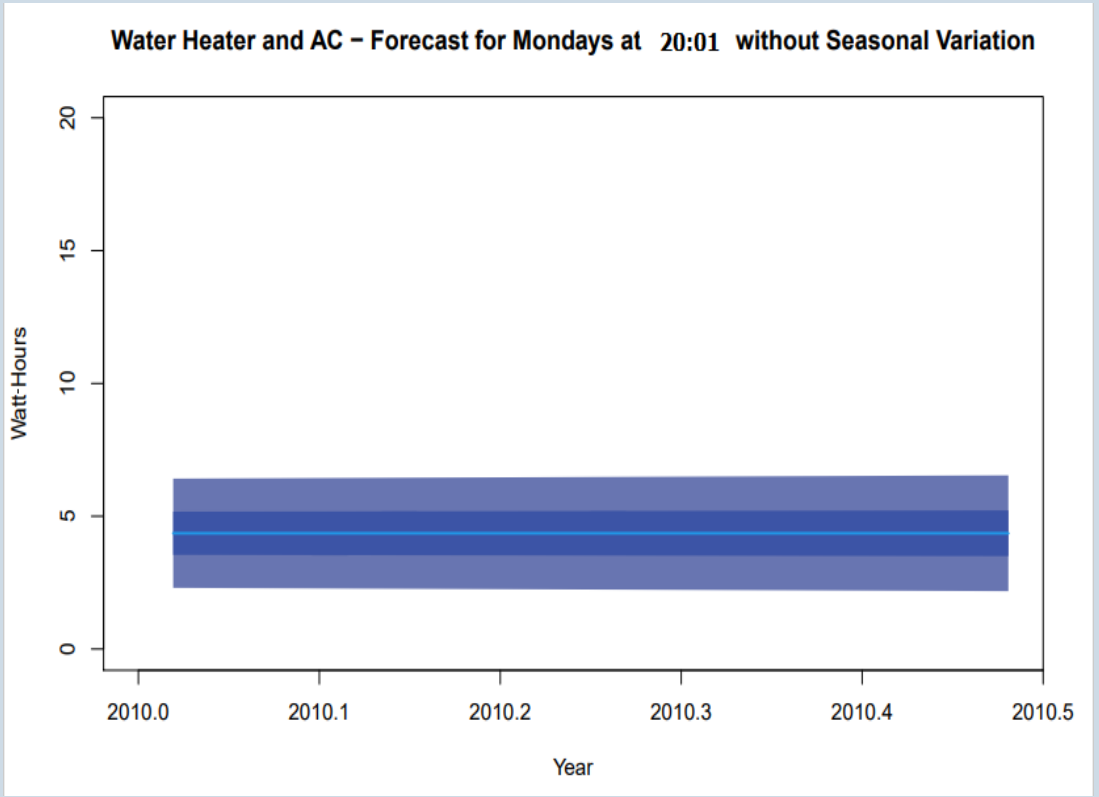

| | STATISTICS | |
|---|---|---|
| | Coefficient of determination* | Residual Standard Error** |
| Linear Regression Model | 0.07461 | 6.871 |

*shows how well data points fit a line (value closed to 1 is preferred)
** measures the variability of the residuals from a linear model (value closed to 0 is preferred)

# *LINEAR FORECAST*

Energy consumption linear forecast for the AC and the water heater for Mondays at 20:01 showed the seasonal pattern. The statistical coefficients presented in the table above confirm the non-linear relationship.




# *EXPONENTIAL SMOOTHING FORECAST*

Energy consumption exponential smoothing forecast for the AC and the water heater for Mondays at 20:01 without seasonal variation showed the underlying linear pattern at the constant rate (idle water heater).

# SUMMARY

1. The AC and the water heater as well as the laundry room/refrigerator have overall seasonal energy consumption patterns. The refrigerator and the idle water heater have the underlying linear energy consumption patterns.
2. The kitchen appliances have the sporadic energy consumption patterns.
3. The AC and the water heater are the most energy consuming electric equipment.
4. The major kitchen appliances are rarely used.
5. There are long periods of time when the electric equipment in the idle mode continues to consume energy.

# RECOMMENDATION

1. Shut off all electric equipment/appliances in apartments unoccupied long-term.
2. Use “smart” thermostats which will learn habits of residents. “Away” mode during workdays will save energy.
3. Switch the electric water heater to gas water heater. Upfront costs for gas water heaters are higher depending on the model, but they are recovered during a couple of years.
4. Make sure all windows and doorways are insulated not to let the hot air in during summer months.
5. Ask residents to avoid placing lamps or TV sets near the room air-conditioning thermostat. The thermostat senses heat from these appliances, which can cause the air conditioner to run longer than necessary.

# *LESSONS LEARNED*

1. Large time series need to be broken into smaller periods to observe meaningful patterns.
2. Different filters need to be applied to the analysis – weekday vs weekend, the same month different years, different times of the day, etc.
3. Trend shows the long-term tendencies in the data.
4. Time series need to be broke down into seasonal, trend, and random (remainder) components to explore seasonal and underlying patterns.
5. Different forecast models need to be used to generate forecast for seasonal and underlying patterns.

# Q & A