Low Carbon London Notebook

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Introduction

We explore the Low Carbon London dataset. This project sampled 5,567 London households between November 2011 and Feburary 2014, with reading taken at half-hourly intervals. The dataset contains: - energy consumption (kWh/hh), - unique household identifier, - date and time, and - CACI Acorn group. The dataset below contains sample data representing a single household.

It can be a good idea to have a look at the first few rows of the data to get a sense of what we're dealing with.

```
url = paste0("https://files.datapress.com/london/dataset/",
             "smartmeter-energy-use-data-in-london-households/",
             "UKPN-LCL-smartmeter-sample.csv")
scan(url, what = "", sep = ",", n = 12)
```

```
##  [1] "LCLid"                  "stdorToU"
##  [3] "DateTime"               "KWH/hh (per half hour) "
##  [5] "Acorn"                  "Acorn_grouped"
##  [7] "MAC003718"              "Std"
##  [9] "17/10/2012 13:00:00"    "0.09"
## [11] "ACORN-A"                "Affluent"
```

We can now read in the data.

```
col_names = c("id", "time_of_use", "datetime", "kwh_hh", "acorn", "acorn_group")
col_types = cols(id = col_character(),
                 time_of_use = col_character(),
                 datetime = col_datetime("%d/%m/%Y %H:%M:%S"),
                 kwh_hh = col_double(),
                 acorn = col_character(),
                 acorn_group = col_character())
lcl = read_csv(url, col_names = col_names, col_types = col_types, skip = 1)
```

Sampling rate

First we ensure that all the readings are in fact half-hourly. This is to allow the use of time series analysis methods later, most of which assume equally- spaced time intervals in the series.

```
dates = select(lcl, datetime)

## Wipe duplicated and missing dates.
lcl2 = lcl %>%
  filter(!duplicated(datetime), !is.na(datetime))
```

```
## Compute time differences between rows. We also store row numbers to see
## which rows are dropped later on.
lcl_diffs = lcl2 %>%
  mutate(ind = row_number()) %>%
  select(datetime, ind) %>%
  distinct() %>%
  mutate(diff = datetime - lag(datetime)) %>%
  slice(-1)
```

Observe that the sum of the time difference between rows 2981 and 2982 is in fact 30 minutes, so removing row 2981 should do the trick for 2 out of the 4 problematic rows.

```
## Which households have non-hh readings?
lcl_diffs %>%
  filter(diff != 30)
```

```
## # A tibble: 4 x 3
##              datetime   ind           diff
##                <dttm> <int>         <time>
## 1 2012-12-09 07:30:00  2533 60.000000 mins
## 2 2012-12-18 15:24:01  2981 24.016667 mins
## 3 2012-12-18 15:30:00  2982  5.983333 mins
## 4 2013-02-19 20:00:00  6014 60.000000 mins
```

```
lcl_diffs %>%
  slice(2979:2982)
```

```
## # A tibble: 4 x 3
##              datetime   ind           diff
##                <dttm> <int>         <time>
## 1 2012-12-18 15:00:00  2980 30.000000 mins
## 2 2012-12-18 15:24:01  2981 24.016667 mins
## 3 2012-12-18 15:30:00  2982  5.983333 mins
## 4 2012-12-18 16:00:00  2983 30.000000 mins
```

```
lcl_diffs2 = lcl2 %>%
  slice(-2981) %>%
  mutate(ind = row_number()) %>%
  select(datetime, ind) %>%
  distinct() %>%
  mutate(diff = datetime - lag(datetime)) %>%
  slice(-1)
```

This seems to have had the desired effect. We now have to tackle two other rows.

```
lcl_diffs2 %>%
  filter(diff != 30)
```

```
## # A tibble: 2 x 3
##              datetime   ind    diff
##                <dttm> <int>  <time>
## 1 2012-12-09 07:30:00  2533 60 mins
## 2 2013-02-19 20:00:00  6013 60 mins
```

Since the gaps in time are both 2 half-hour units, we can simply take the average of the surrounding values.

```
slice(lcl_diffs2, 2531:2533)
```

```
## # A tibble: 3 x 3
##              datetime   ind    diff
##                <dttm> <int>  <time>
## 1 2012-12-09 06:30:00  2532 30 mins
## 2 2012-12-09 07:30:00  2533 60 mins
## 3 2012-12-09 08:00:00  2534 30 mins
```

```
slice(lcl_diffs, 6014:6016)
```

```
## # A tibble: 3 x 3
##              datetime   ind    diff
##                <dttm> <int>  <time>
## 1 2013-02-19 20:30:00  6015 30 mins
## 2 2013-02-19 21:00:00  6016 30 mins
## 3 2013-02-19 21:30:00  6017 30 mins
```

```
## Simple function for linear interpolation of equally-spaced series.
insert_row = function(data, ind) {
  sub = ind:(ind + 1)
  new_kwh = mean(data$kwh_hh[sub])
  new_time = mean(data$datetime[sub])
  new_row = data %>%
    slice(ind) %>%
    mutate(kwh_hh = new_kwh, datetime = new_time)
  data %>%
    head(ind) %>%
    rbind(new_row, slice(data, ind + 1:nrow(data)))
}
```

```
lcl2 %>%
  insert_row(2532) %>%
  slice(2532:2534)
```

```
## # A tibble: 3 x 6
##          id time_of_use            datetime kwh_hh   acorn acorn_group
##       <chr>       <chr>              <dttm>  <dbl>   <chr>       <chr>
## 1 MAC003718         Std 2012-12-09 06:30:00  0.112 ACORN-A    Affluent
## 2 MAC003718         Std 2012-12-09 07:00:00  0.142 ACORN-A    Affluent
## 3 MAC003718         Std 2012-12-09 07:30:00  0.172 ACORN-A    Affluent
```

```
lcl2 %>%
  insert_row(6013) %>%
  slice(6013:6015)
```

```
## # A tibble: 3 x 6
##          id time_of_use            datetime kwh_hh   acorn acorn_group
##       <chr>       <chr>              <dttm>  <dbl>   <chr>       <chr>
## 1 MAC003718         Std 2013-02-19 19:00:00 0.4010 ACORN-A    Affluent
## 2 MAC003718         Std 2013-02-19 19:30:00 0.3225 ACORN-A    Affluent
## 3 MAC003718         Std 2013-02-19 20:00:00 0.2440 ACORN-A    Affluent
```

Check that the series is equidistant:

```
lcl3 = lcl2 %>%
  insert_row(2532) %>%
  insert_row(6014) %>%
  slice(-2982)

lcl_diffs3 = lcl3 %>%
  select(datetime) %>%
  distinct() %>%
  mutate(diff = datetime - lag(datetime)) %>%
  slice(-1)

all(lcl_diffs3$diff == 30)
```

```
## [1] TRUE
```

Time

We augment our dataset with useful time information: year, month, day, hour, minute, and weekday.

```
lcl4 = lcl3 %>%
  mutate(wday = wday(datetime, lab = TRUE),
         year = year(datetime),
         month = month(datetime),
         day = day(datetime),
         hour = hour(datetime),
         minute = minute(datetime)) %>%
  arrange(datetime)
```

Add 2012 UK Seasons. Recall that: - Spring: March to June - Summer: July to September - Autumn: October to December - Winter: January to March

```
brks = ymd(c("20120922", "20121221", "20130320", "20130621", "20130922", "20131221"))
labs = c("Autumn 12", "Winter 12-13", "Spring 13", "Summer 13", "Autumn 13")
lcl_seas = lcl4 %>%
  mutate(date = as.Date(datetime),
         seas = cut(date, breaks = brks, labels = labs))

lcl_seas %>%
  select(seas, datetime, kwh_hh) %>%
  head()
```

```
## # A tibble: 6 x 3
##        seas            datetime kwh_hh
##      <fctr>              <dttm>  <dbl>
## 1 Autumn 12 2012-10-17 13:00:00  0.090
## 2 Autumn 12 2012-10-17 13:30:00  0.160
## 3 Autumn 12 2012-10-17 14:00:00  0.212
## 4 Autumn 12 2012-10-17 14:30:00  0.145
## 5 Autumn 12 2012-10-17 15:00:00  0.104
## 6 Autumn 12 2012-10-17 15:30:00  0.122
```

If we were to plot this, we need a "change-of-season" dates. But since we have 48 rows of each day, there will be many matching cut-off dates (in fact $48 \times 4 = 192$ matches). To overcome this issue, we could just take the first match.

```
matches = lcl_seas %>%
  mutate(n = row_number()) %>%
  filter(date %in% brks) %>%
  select(n)

matches
```

```
## # A tibble: 192 x 1
##        n
##    <int>
##  1  3095
##  2  3096
##  3  3097
##  4  3098
```

```
##  5  3099
##  6  3100
##  7  3101
##  8  3102
##  9  3103
## 10  3104
## # ... with 182 more rows
```

```
## Get the first match.
n = matches$n
i = c(0, which(diff(n) > 1)) + 1
j = n[i]
```

Missing readings

Let's move on to missing readings. Fortunately there doesn't seem to be any for this household.

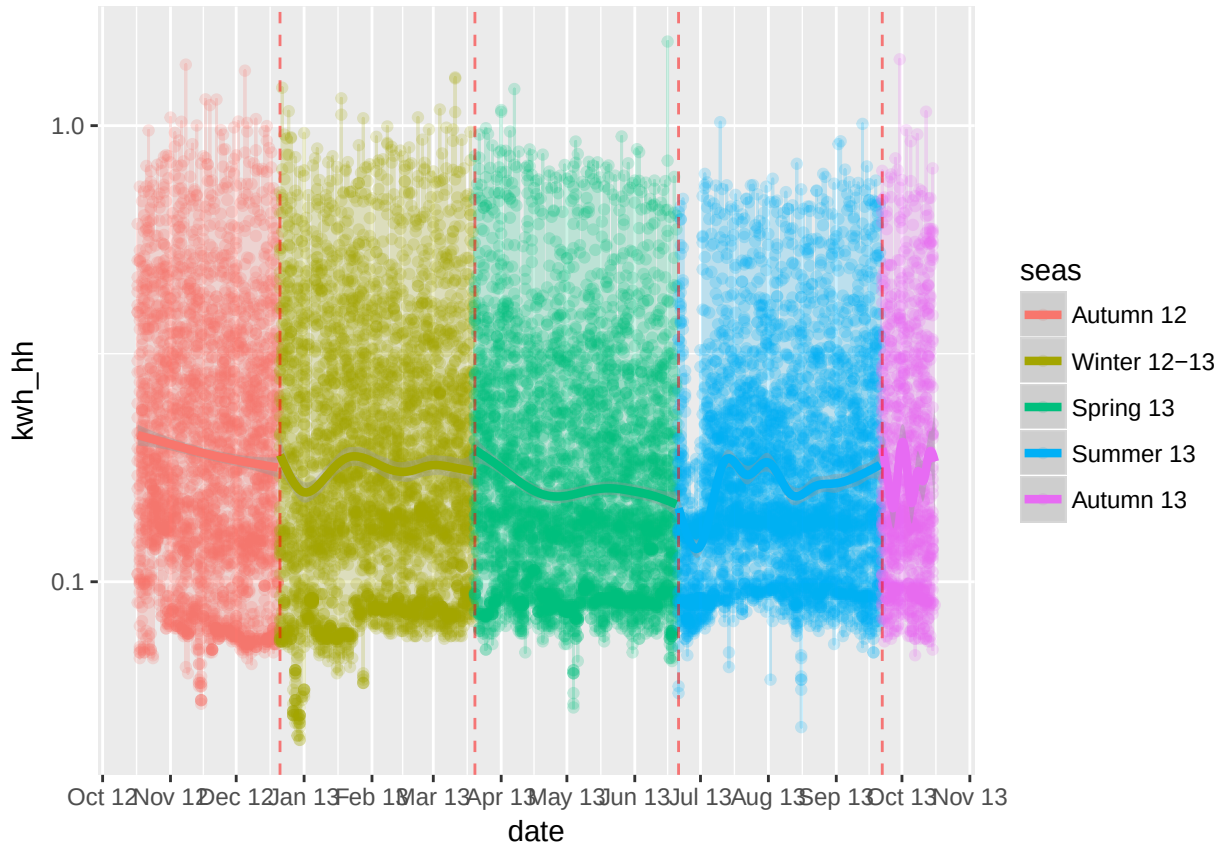
```
lcl_seas %>%
  filter(is.na(kwh_hh))
```

```
## # A tibble: 0 x 14
## # ... with 14 variables: id <chr>, time_of_use <chr>, datetime <dttm>,
## #   kwh_hh <dbl>, acorn <chr>, acorn_group <chr>, wday <ord>, year <dbl>,
## #   month <dbl>, day <int>, hour <int>, minute <int>, date <date>,
## #   seas <fctr>
```

Plots

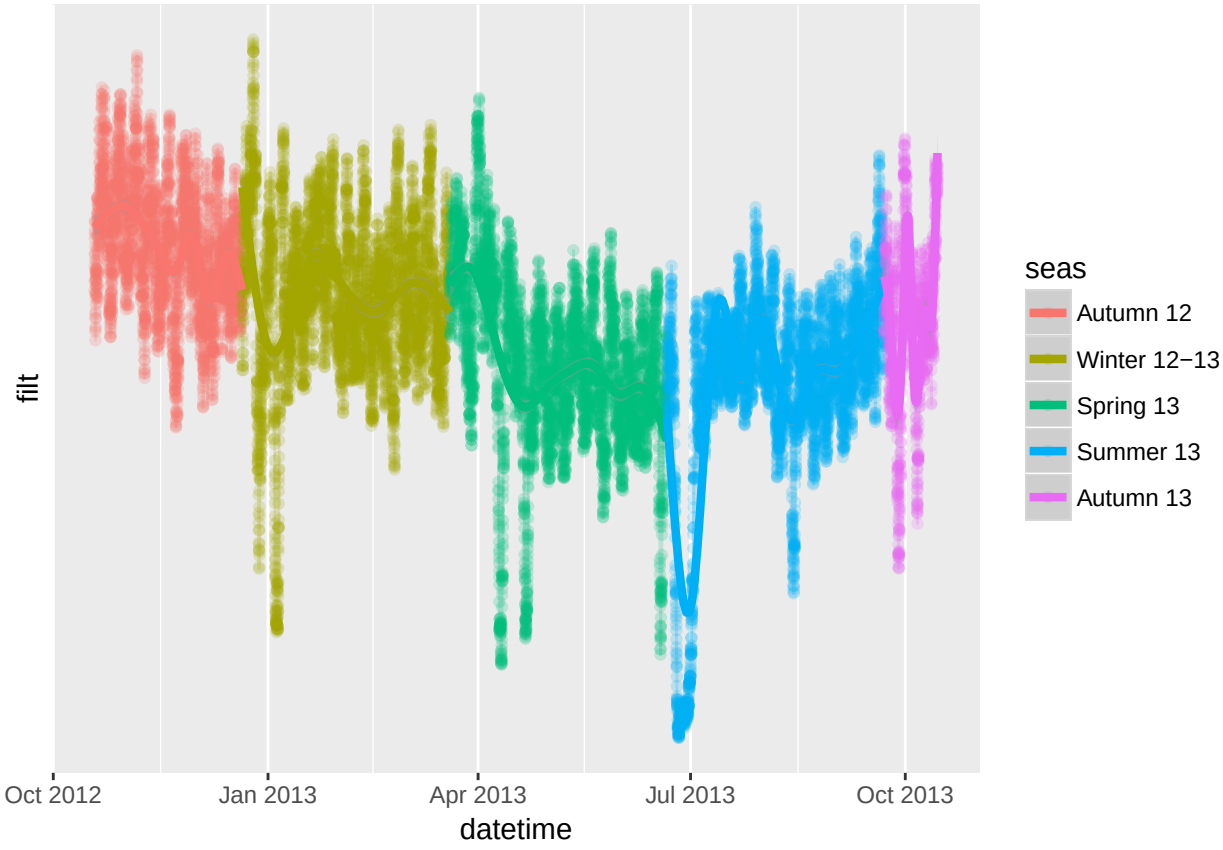
```
lcl_seas %>%
  ggplot(aes(date, kwh_hh, col = seas)) +
  geom_line(alpha = 0.2) +
  geom_point(alpha = 0.2) +
  geom_smooth(span = 1, lwd = 1.5) +
  scale_y_log10() +
  scale_x_date(date_labels = "%b %y",
               date_breaks = "1 month") +
  geom_vline(xintercept = as.numeric(lcl_seas$date[j]),
             linetype = 2, colour = 2, alpha = 0.5)
```

```
## `geom_smooth()` using method = 'gam'
```




```
## Smooth with a 2-sided 115-pt weighted moving average.
wgts = 1 / c(rep(16, 31), rep(8, 21), rep(4, 11), rep(8, 21), rep(16, 31))
lcl_seas %>%
  mutate(filt = stats::filter(kwh_hh, filter = wgts, sides = 2)) %>%
  filter(!is.na(filt)) %>%
  ggplot(aes(datetime, filt, col = seas)) +
  geom_line(alpha = 0.2) +
  geom_point(alpha = 0.2) +
  geom_smooth(span = 0.75, lwd = 1.5) +
  scale_y_log10() +
  geom_vline(xintercept = as.numeric(lcl_seas$date[j]),
             linetype = 2, colour = 2, alpha = 0.5)
```

```
## `geom_smooth()` using method = 'gam'
```

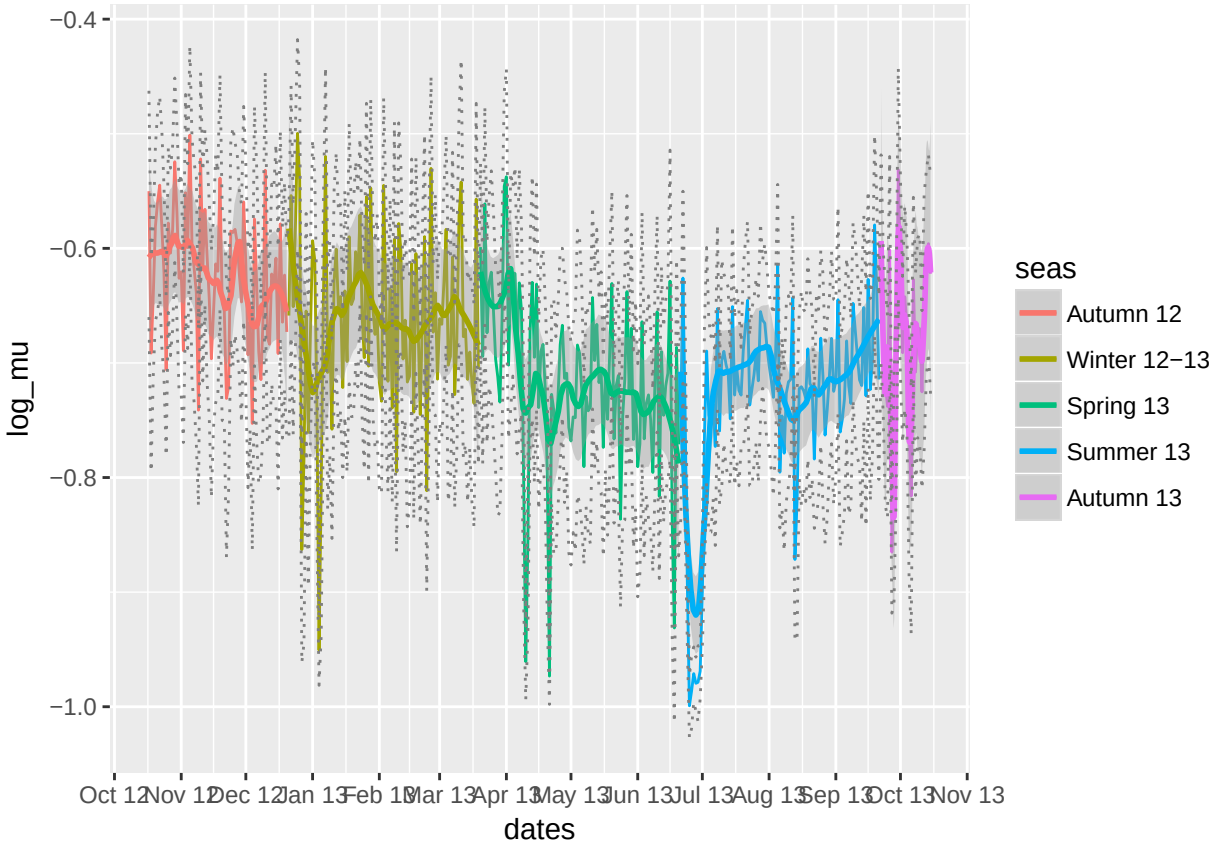



```
## Statistical summaries.
lcl_seas2 = lcl_seas %>%
  group_by(year, month, day) %>%
  summarize(mu = mean(kwh_hh),
            log_mu = log10(mu),
            sd = sd(kwh_hh),
            n = n(),
            seas = unique(seas),
            wday = unique(wday),
            ci_low = mu - 1.96 * sd / sqrt(n),
            ci_high = mu + 1.96 * sd / sqrt(n),
            log_low = log10(ci_low),
            log_high = log10(ci_high)) %>%
  filter(!is.na(log_low), !is.na(log_high))
```

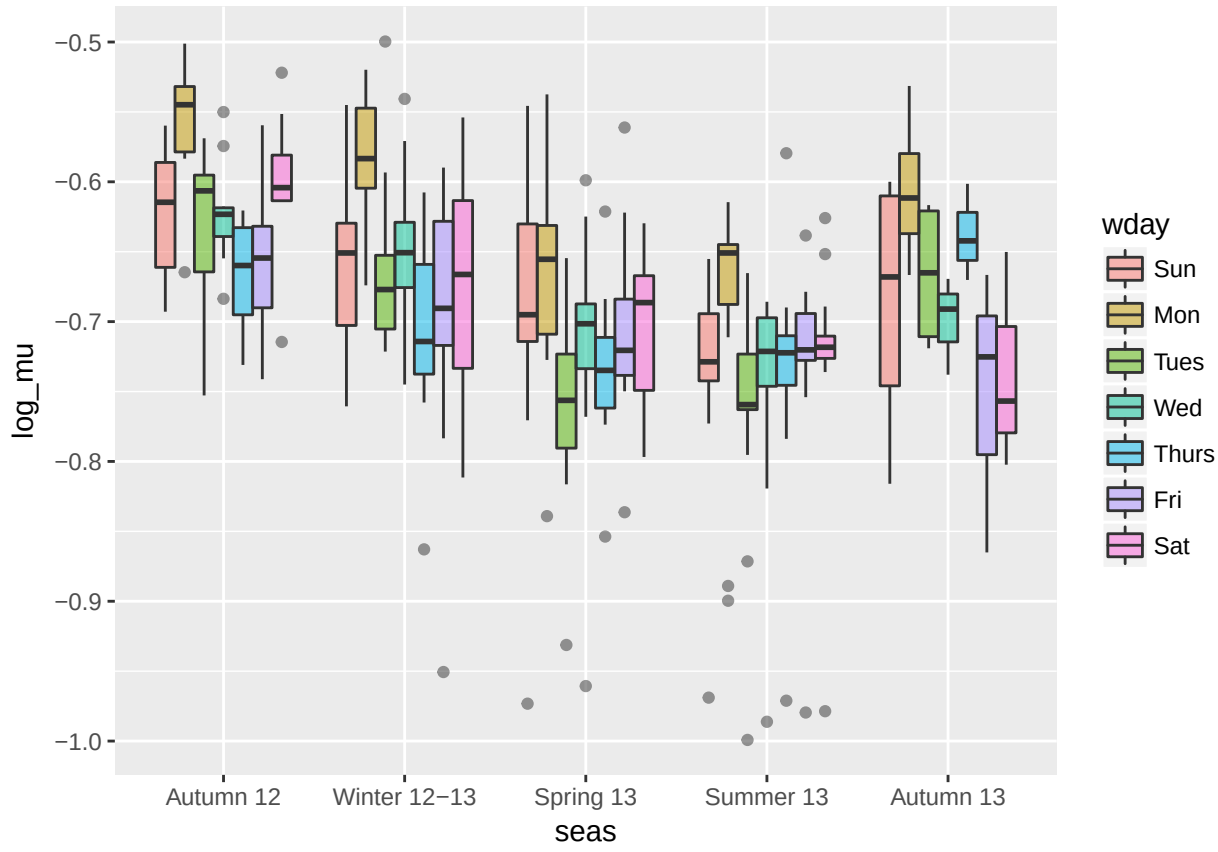
```
dates = with(lcl_seas2, ymd(paste0(year,
                                   sprintf("%02d", month),
                                   sprintf("%02d", day))))

lcl_seas2 %>%
  ggplot(aes(dates, log_mu, col = seas)) +
  geom_line() +
  geom_smooth(span = 0.25) +
  geom_line(aes(dates, log10(ci_low)), col = "gray50", linetype = "dotted") +
  geom_line(aes(dates, log10(ci_high)), col = "gray50", linetype = "dotted") +
  scale_x_date(date_labels = "%b %y", date_breaks = "1 month")
```

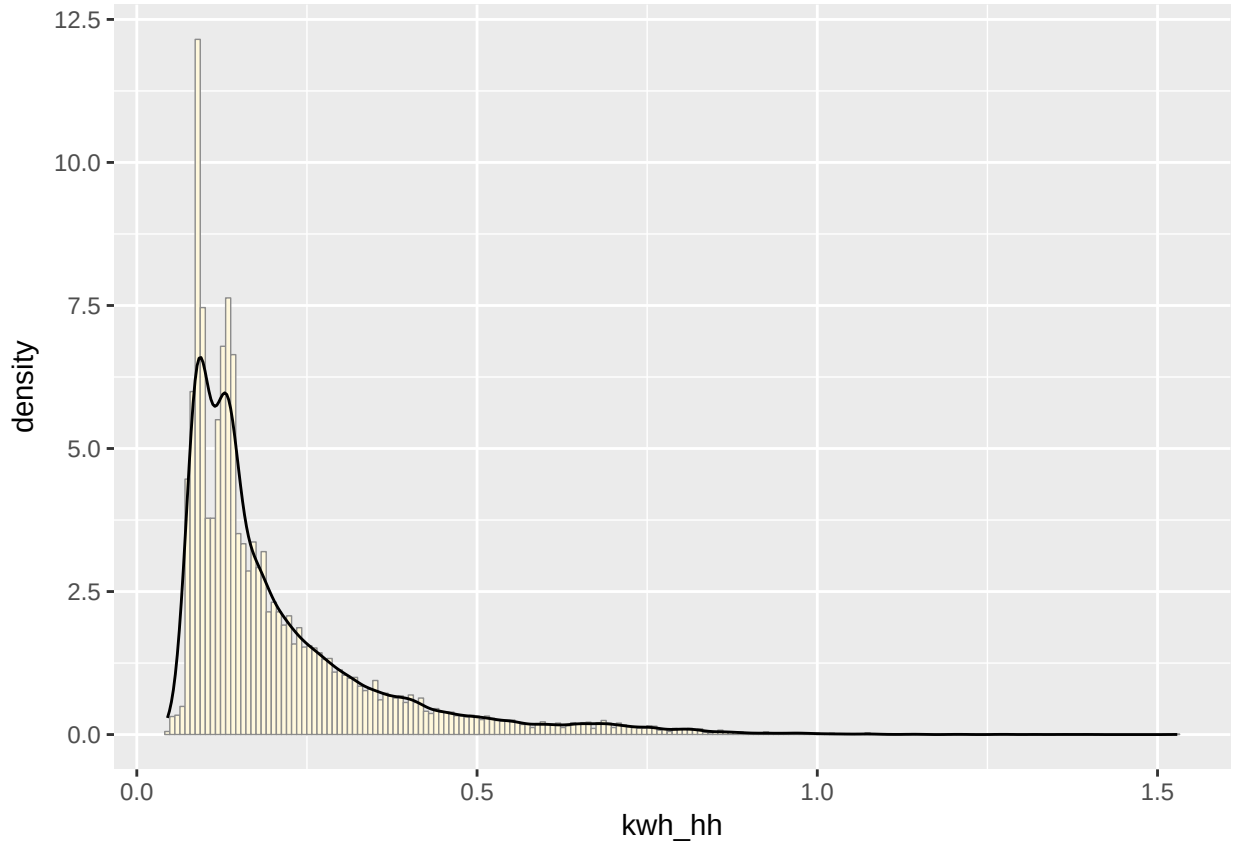
```
## `geom_smooth()` using method = 'loess'
```



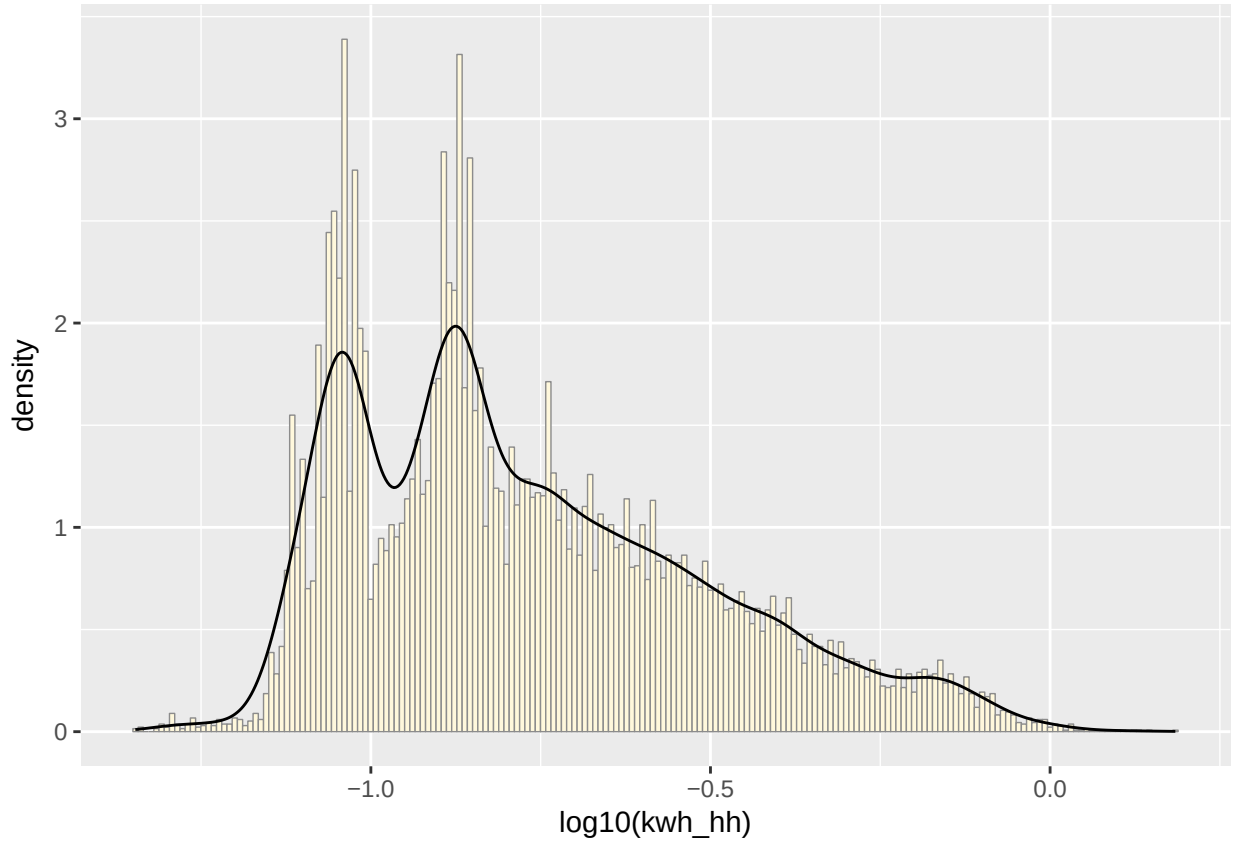

```
## Weekdays
lcl_seas2 %>%
  ggplot(aes(seas, log_mu, bg = wday)) +
  geom_boxplot(alpha = .5)
```



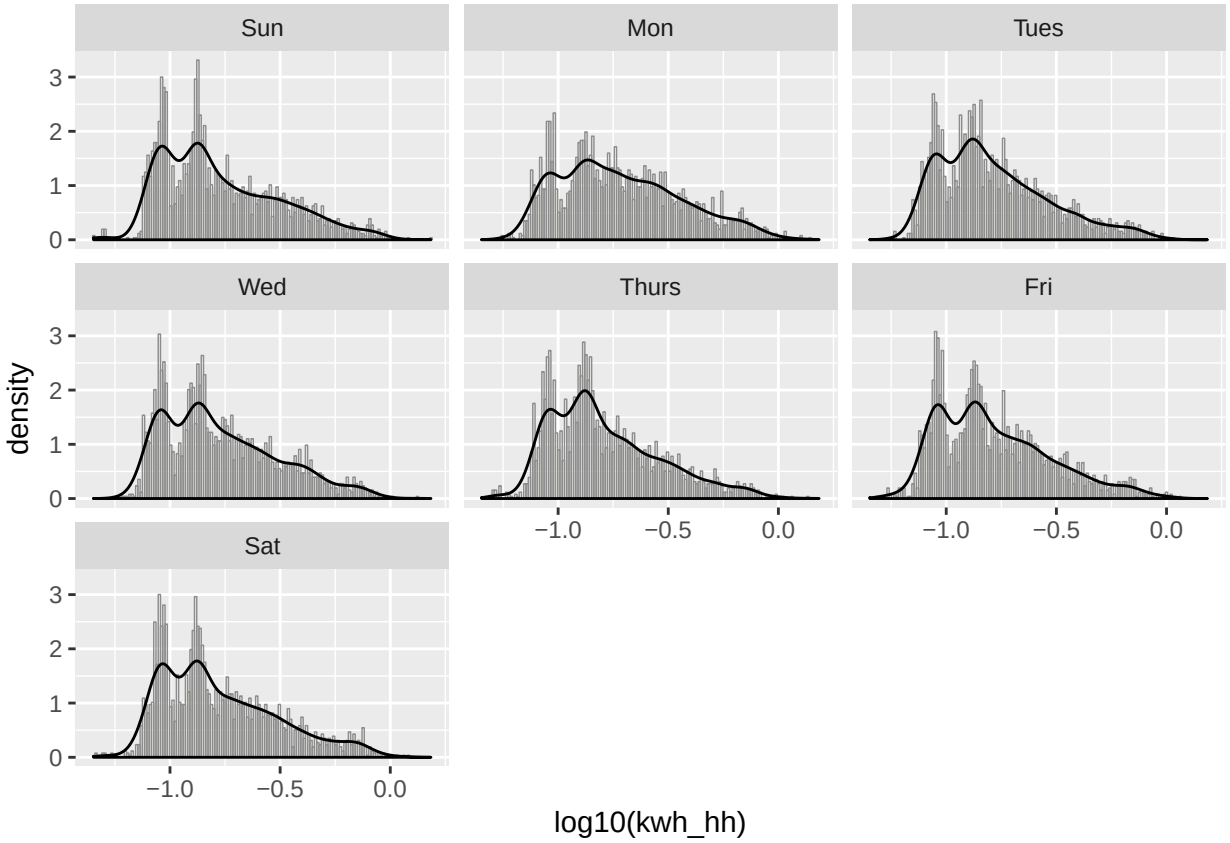

```
lcl_seas %>%
  ggplot(aes(kwh_hh, ..density..)) +
  geom_histogram(fill = "cornsilk",
                 colour = "grey55",
                 size = .25,
                 bins = 200) +
  geom_line(stat = "density")
```



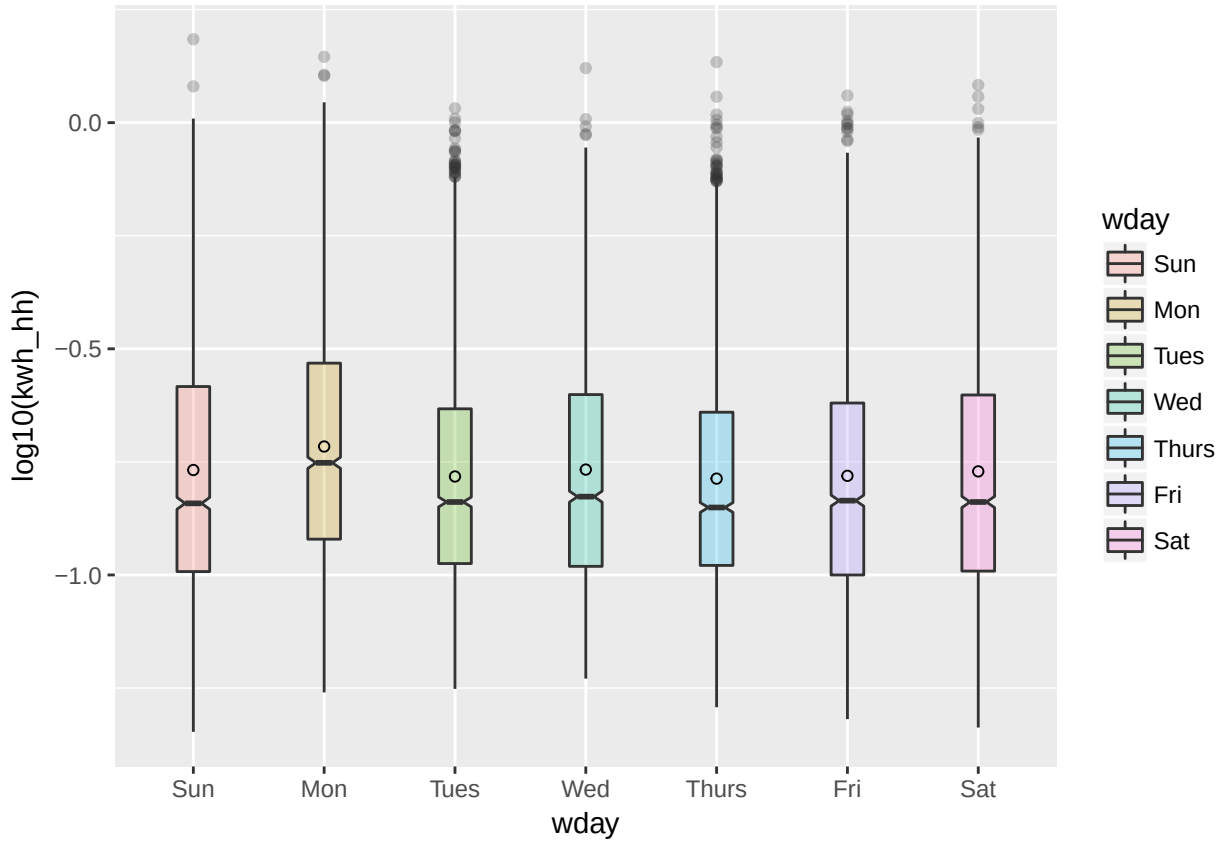

```
lcl_seas %>%
  ggplot(aes(log10(kwh_hh), ..density..)) +
  geom_histogram(fill = "cornsilk",
                 colour = "grey55",
                 size = .25,
                 bins = 200) +
  geom_line(stat = "density")
```



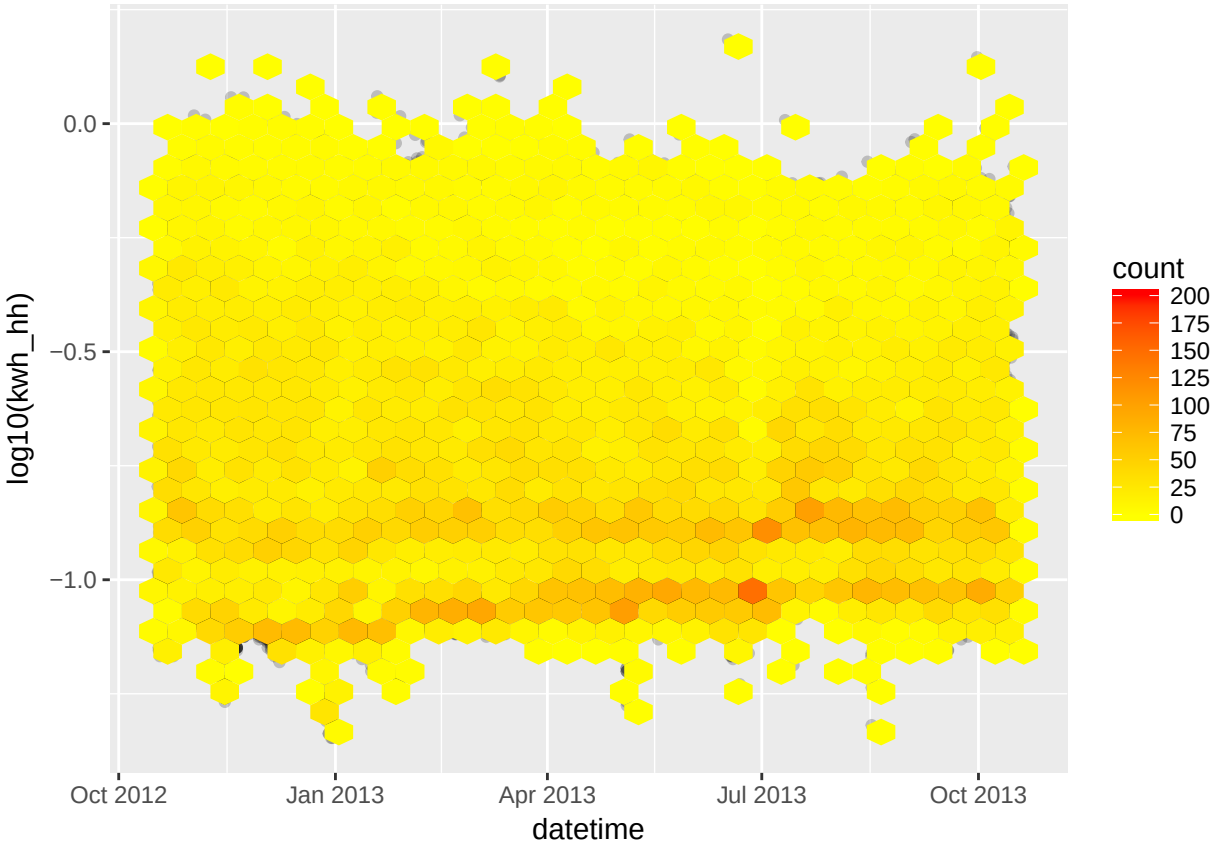

```
lcl_seas %>%
  ggplot(aes(log10(kwh_hh), ..density..)) +
  geom_histogram(fill = "cornsilk",
                 colour = "grey55",
                 alpha = 0.1,
                 size = .25,
                 bins = 150) +
  geom_density(alpha = .1) +
  facet_wrap(~ wday)
```




```
lcl_seas %>%
  ggplot(aes(wday, log10(kwh_hh), fill = wday)) +
  geom_boxplot(width = .25, alpha = .25, notch = TRUE) +
  stat_summary(fun.y = "mean", geom = "point", shape = 1, fill = "white")
```




```
## Ignore time for a second.
lcl_seas %>%
  ggplot(aes(datetime, log10(kwh_hh))) +
  geom_point(alpha = 0.2) +
  stat_binhex() +
  scale_fill_gradient(low = "yellow", high = "red",
                      breaks = seq(0, 200, length = 9),
                      limits = c(0, 200))
```


0.0
−0.5
−1.0
log10(kwh_hh)
Oct 2012
Jan 2013
Apr 2013
Jul 2013
Oct 2013
datetime
count
200
175
150
125
100
75
50
25
0