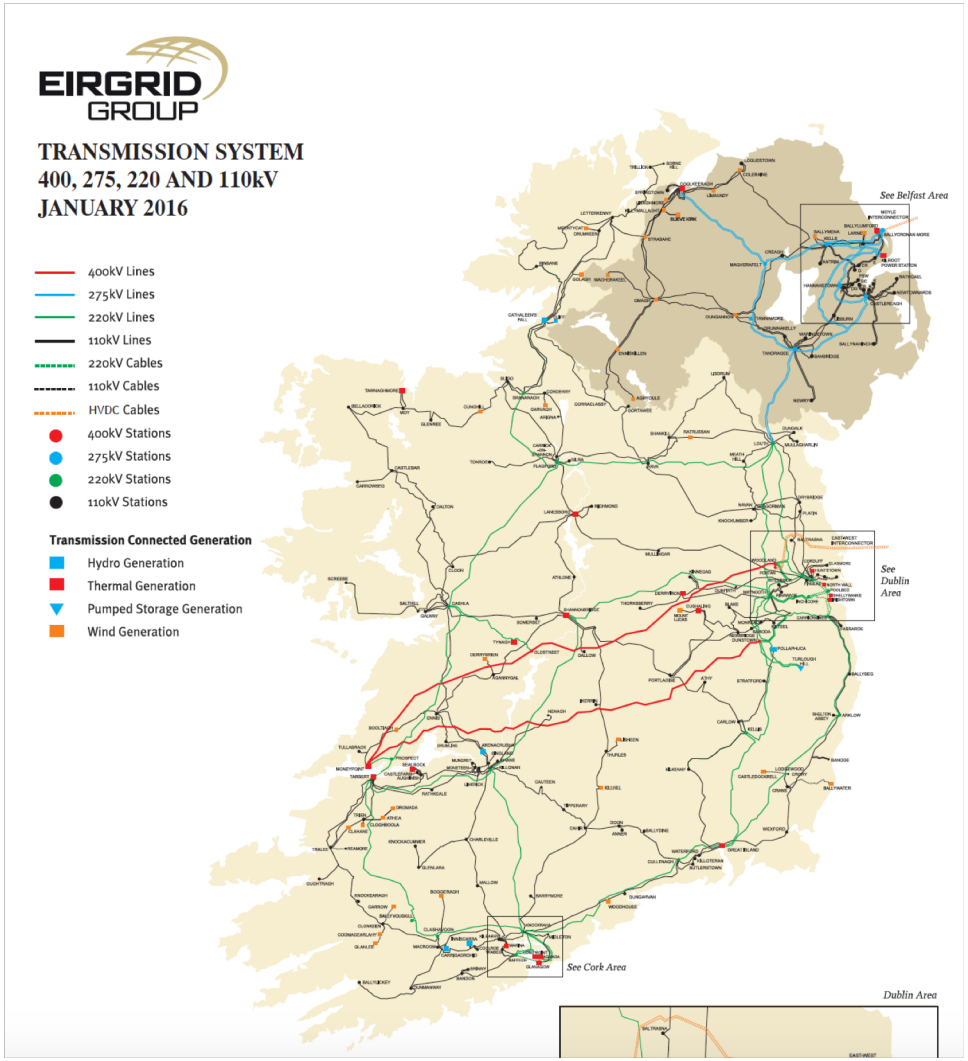
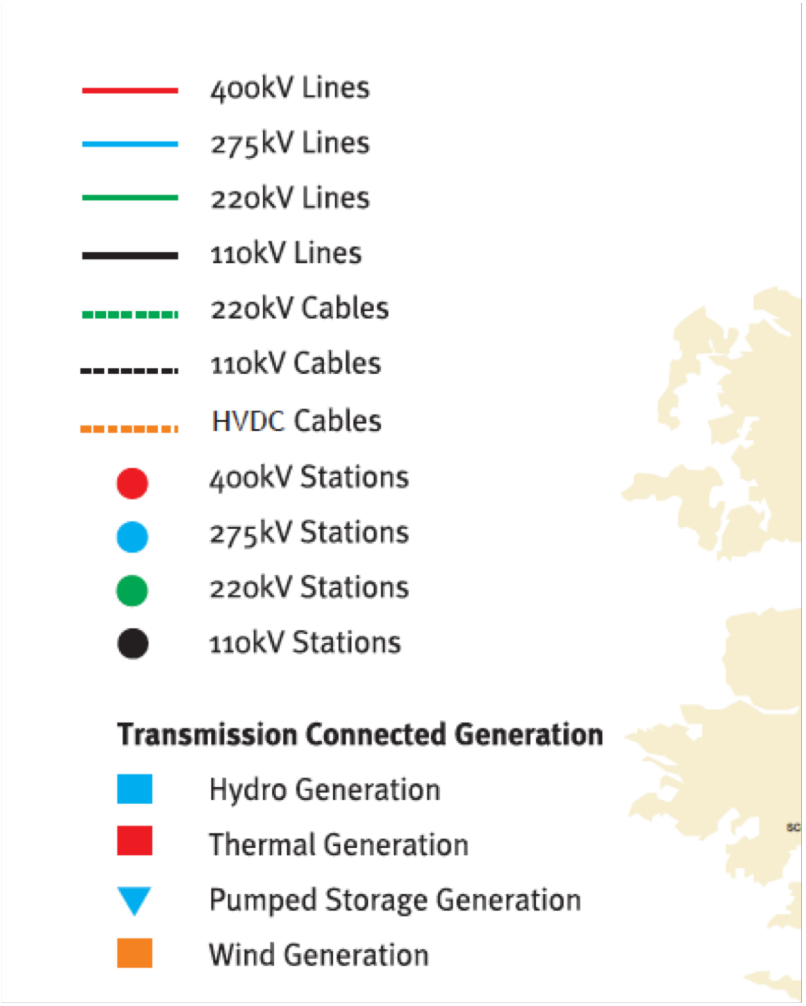
# CT474: Smart Grid

# Lecture 3: Analysing Energy Data

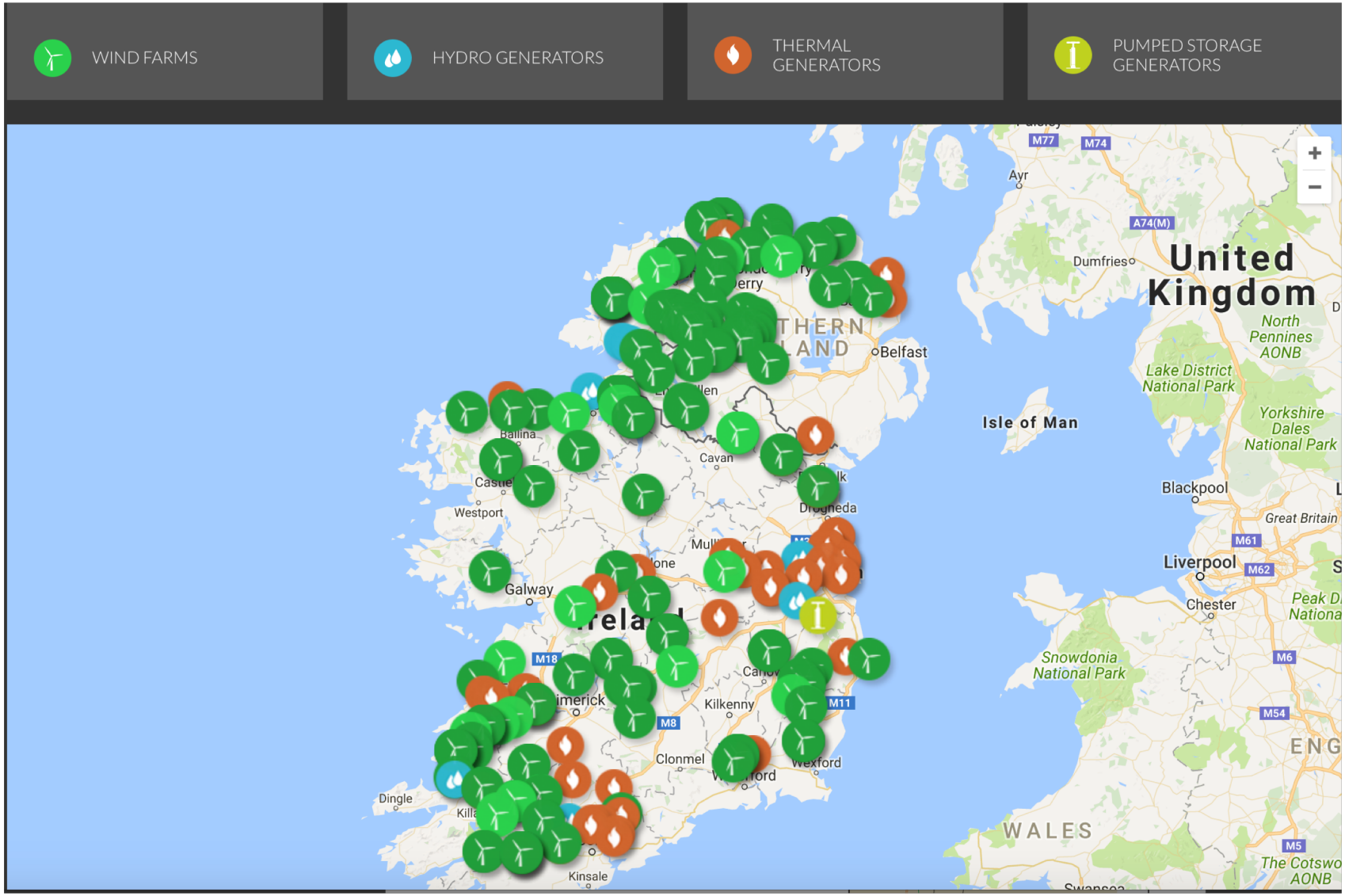
Dr. Jim Duggan,
School of Engineering & Informatics
National University of Ireland Galway.

# Transmission System

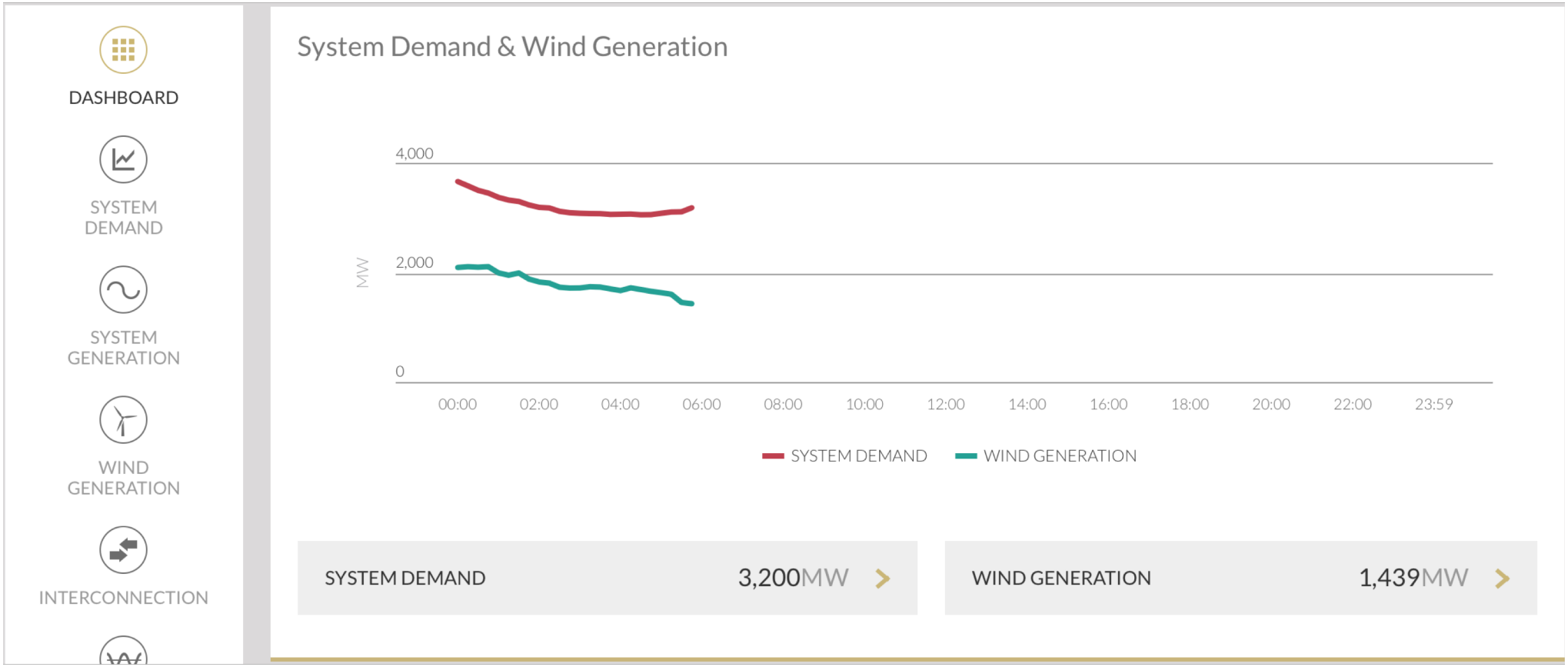


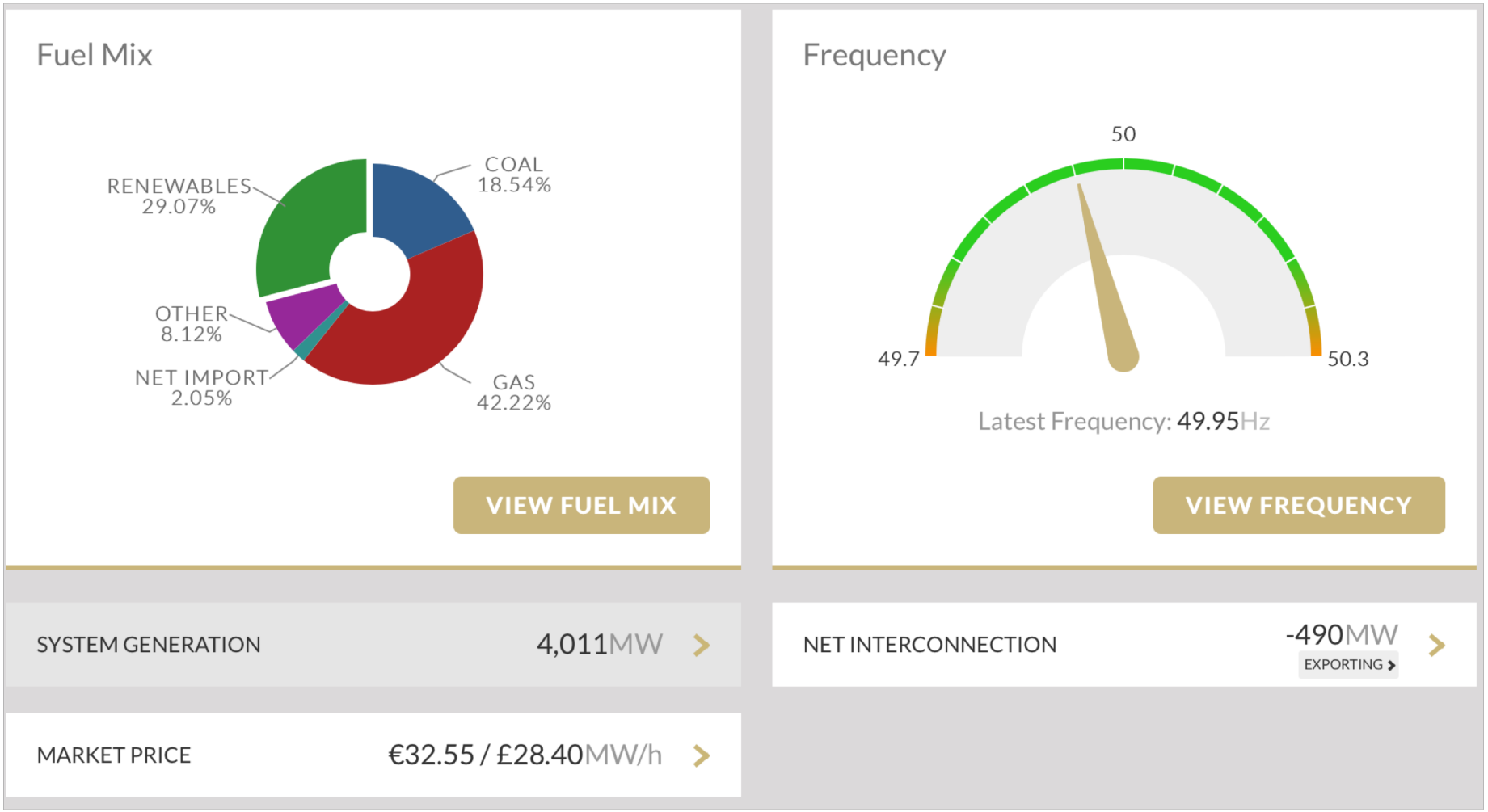
# Generation Information



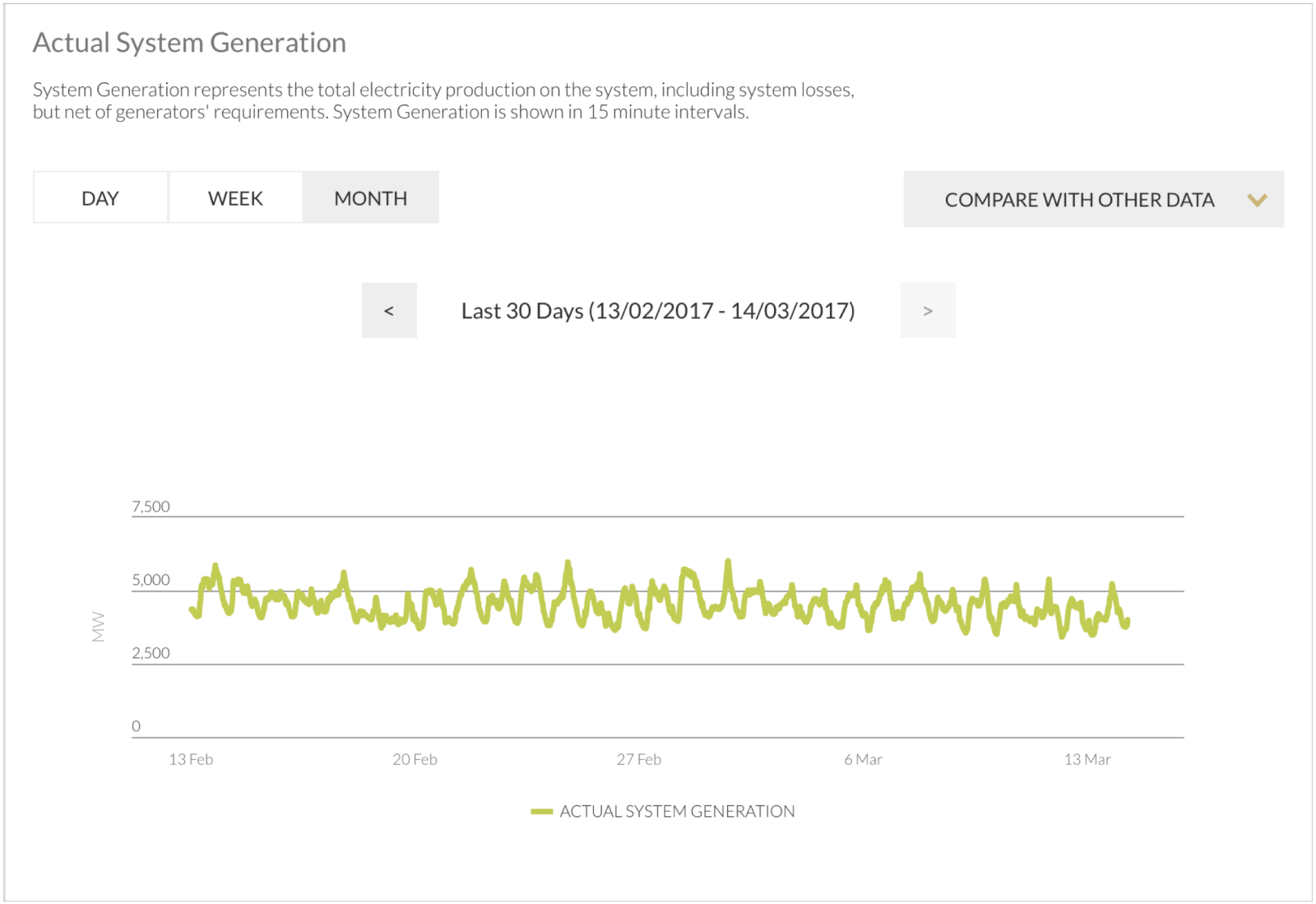
# http://smartgriddashboard.eirgrid.com



# Fuel Mix, Frequency & Net Flows



# Generation over time



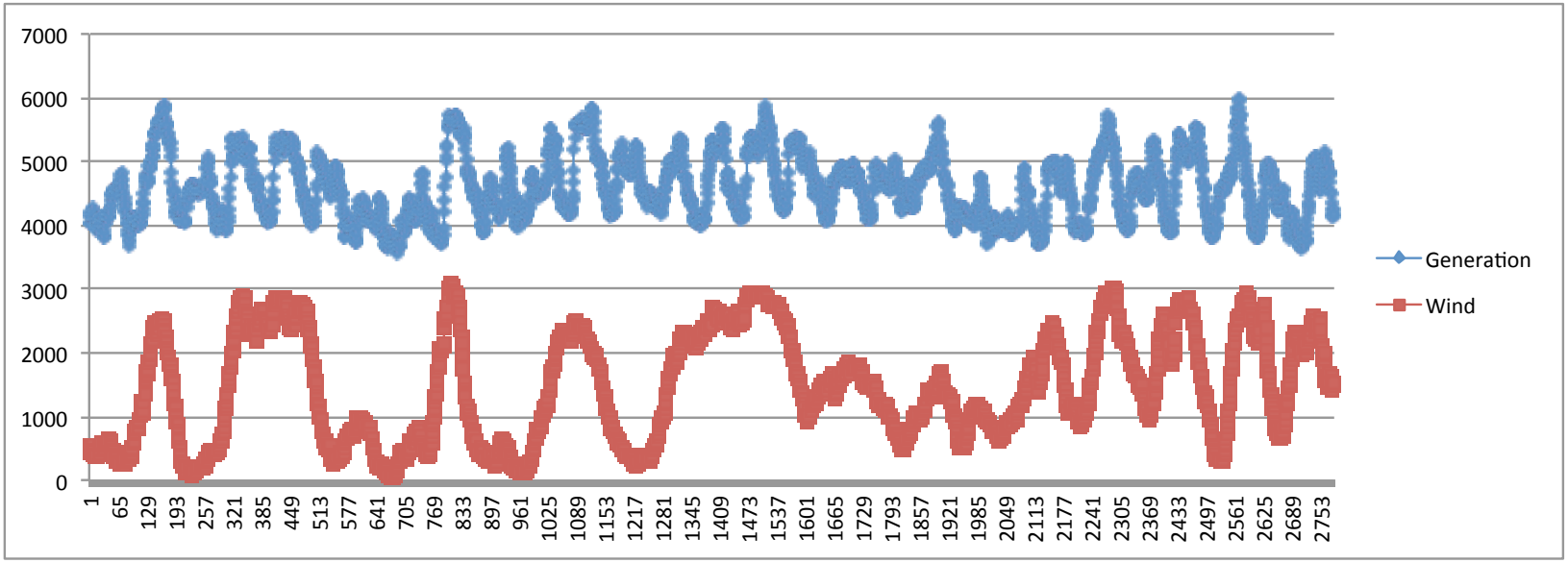
# Extracting the data (download csv)

VIEW FULL BREAKDOWN IN TABLE

| TIME | GENERATION (MW) |
|---|---|
| 14 March 2017, 00:00 | 4,301 |
| 14 March 2017, 00:15 | 4,294 |
| 14 March 2017, 00:30 | 4,213 |
| 14 March 2017, 00:45 | 4,161 |
| 14 March 2017, 01:00 | 4,078 |
| 14 March 2017, 01:15 | 4,027 |
| 14 March 2017, 01:30 | 4,005 |

# Combine individual downloads

| DateTime | Demand | Generation | Wind | CO2 | NetImports | EWIC | Moyle |
|---|---|---|---|---|---|---|---|
| 29/01/17 00:00 | 3834 | 4041 | 449 | 552 | -145 | -33 | -112 |
| 29/01/17 00:15 | 3785 | 4041 | 505 | 548 | -200 | -108 | -92 |
| 29/01/17 00:30 | 3708 | 4130 | 521 | 544 | -294 | -183 | -111 |
| 29/01/17 00:45 | 3634 | 4181 | 492 | 543 | -419 | -258 | -161 |
| 29/01/17 01:00 | 3581 | 4211 | 538 | 555 | -503 | -333 | -170 |
| 29/01/17 01:15 | 3552 | 4278 | 561 | 531 | -598 | -379 | -219 |
| 29/01/17 01:30 | 3491 | 4133 | 484 | 545 | -516 | -374 | -142 |
| 29/01/17 01:45 | 3435 | 4143 | 474 | 551 | -581 | -365 | -216 |
| 29/01/17 02:00 | 3374 | 4158 | 442 | 550 | -653 | -373 | -280 |
| 29/01/17 02:15 | 3329 | 4135 | 421 | 550 | -676 | -377 | -299 |
| 29/01/17 02:30 | 3299 | 4122 | 415 | 553 | -693 | -394 | -299 |
| 29/01/17 02:45 | 3256 | 4146 | 401 | 558 | -761 | -469 | -292 |



# Additional R Packages

| Package | Purpose |
|---|---|
| gdata | Read excel files into R |
| lubridate | Process times and dates |
| tidyr | Split column information, and restructure tibbles |

# Get and Prepare Data for Analysis

```
library(gdata)

ener <- as_data_frame(read.xls("data/energy/data/IrelandData January 2017.xlsx"),
                      stringsAsFactors=F)
```

```
> ener
# A tibble: 2,784 x 8
                 DateTime Demand Generation  Wind   CO2 NetImports  EWIC Moyle
                   <fctr>  <int>      <int> <int> <int>      <int> <int> <int>
1  2017-01-29 00:00:00.00   3834       4041   449   552       -145   -33  -112
2  2017-01-29 00:15:00.00   3785       4041   505   548       -200  -108   -92
3  2017-01-29 00:30:00.00   3708       4130   521   544       -294  -183  -111
4  2017-01-29 00:45:00.00   3634       4181   492   543       -419  -258  -161
5  2017-01-29 01:00:00.00   3581       4211   538   555       -503  -333  -170
6  2017-01-29 01:15:00.00   3552       4278   561   531       -598  -379  -219
7  2017-01-29 01:30:00.00   3491       4133   484   545       -516  -374  -142
8  2017-01-29 01:45:00.00   3435       4143   474   551       -581  -365  -216
9  2017-01-29 02:00:00.00   3374       4158   442   550       -653  -373  -280
10 2017-01-29 02:15:00.00   3329       4135   421   550       -676  -377  -299
# ... with 2,774 more rows
```

# Parsing functions

| Order of elements in date-time | Parse function |
|---|---|
| year, month, day | `ymd()` |
| year, day, month | `ydm()` |
| month, day, year | `mdy()` |
| day, month, year | `dmy()` |
| hour, minute | `hm()` |
| hour, minute, second | `hms()` |
| year, month, day, hour, minute, second | `ymd_hms()` |

```
> dmy("12-01-2010")
[1] "2010-01-12"
>
> ymd("2010-01-12")
[1] "2010-01-12"
```

# Manipulating date-times

- Each element of a date-time object can be extracted
- Accessor functions allow this

| Date component | Accessor |
|---|---|
| Year | `year()` |
| Month | `month()` |
| Week | `week()` |
| Day of year | `yday()` |
| Day of month | `mday()` |
| Day of week | `wday()` |
| Hour | `hour()` |
| Minute | `minute()` |
| Second | `second()` |
| Time zone | `tz()` |

# Reminder: dplyr key functions

| Function | Purpose |
|---|---|
| **filter()** | Pick observations by their values |
| **arrange()** | Reorder the rows |
| **select()** | Pick variables by their names |
| **mutate()** | Create new variables with functions of existing variables |
| **summarise()** | Collapse many values down to a single summary |

# Extracting useful date info.

```
> ener
# A tibble: 2,784 × 8
                 DateTime D
                   <fctr>
1  2017-01-29 00:00:00.00
2  2017-01-29 00:15:00.00
3  2017-01-29 00:30:00.00
4  2017-01-29 00:45:00.00
5  2017-01-29 01:00:00.00
6  2017-01-29 01:15:00.00
7  2017-01-29 01:30:00.00
8  2017-01-29 01:45:00.00
9  2017-01-29 02:00:00.00
10 2017-01-29 02:15:00.00
# ... with 2,774 more rows
```

- Convert factor into date object
- Create new features:
  - Hour of day
  - Minute of day
  - Day of Week

# mutate() – Creates new features (new features can be used)

```
ener <- mutate(ener, DateTime    = ymd_hms(DateTime),
                     HourOfDay   = hour(DateTime),
                     MinuteOfDay = minute(DateTime),
                     DayOfWeek   = wday(DateTime,label=T))
```

```
> ener
# A tibble: 2,784 × 11
             DateTime Demand Generation  Wind   CO2 NetImports  EWIC Moyle HourOfDay MinuteOfDay DayOfWeek
               <dttm>  <int>      <int> <int> <int>      <int> <int> <int>     <int>       <int>     <ord>
1  2017-01-29 00:00:00   3834       4041   449   552       -145   -33  -112         0           0       Sun
2  2017-01-29 00:15:00   3785       4041   505   548       -200  -108   -92         0          15       Sun
3  2017-01-29 00:30:00   3708       4130   521   544       -294  -183  -111         0          30       Sun
4  2017-01-29 00:45:00   3634       4181   492   543       -419  -258  -161         0          45       Sun
5  2017-01-29 01:00:00   3581       4211   538   555       -503  -333  -170         1           0       Sun
6  2017-01-29 01:15:00   3552       4278   561   531       -598  -379  -219         1          15       Sun
7  2017-01-29 01:30:00   3491       4133   484   545       -516  -374  -142         1          30       Sun
8  2017-01-29 01:45:00   3435       4143   474   551       -581  -365  -216         1          45       Sun
9  2017-01-29 02:00:00   3374       4158   442   550       -653  -373  -280         2           0       Sun
10 2017-01-29 02:15:00   3329       4135   421   550       -676  -377  -299         2          15       Sun
# ... with 2,774 more rows
```

# separate()

https://rpubs.com/bradleyboehmke/data_wrangling

```
Function:       separate(data, col, into, sep = " ", remove = TRUE, convert = FALSE)
Same as:        data %>% separate(col, into, sep = " ", remove = TRUE, convert = FALSE)

Arguments:
        data:           data frame
        col:            column name representing current variable
        into:           names of variables representing new variables
        sep:            how to separate current variable (char, num, or symbol)
        remove:         if TRUE, remove input column from output data frame
        convert:        if TRUE will automatically convert values to logical, integer, numeric, complex or
                        factor as appropriate
```

```
> unsep
      Date Product Sales
1 Jan_2005     ABC  1000
2 Jan_2006     DEF  2000
3 Jan_2007     ABC  3000
```

```
> separate(unsep,Date,c("Year","Month"))
  Year Month Product Sales
1  Jan  2005     ABC  1000
2  Jan  2006     DEF  2000
3  Jan  2007     ABC  3000
```

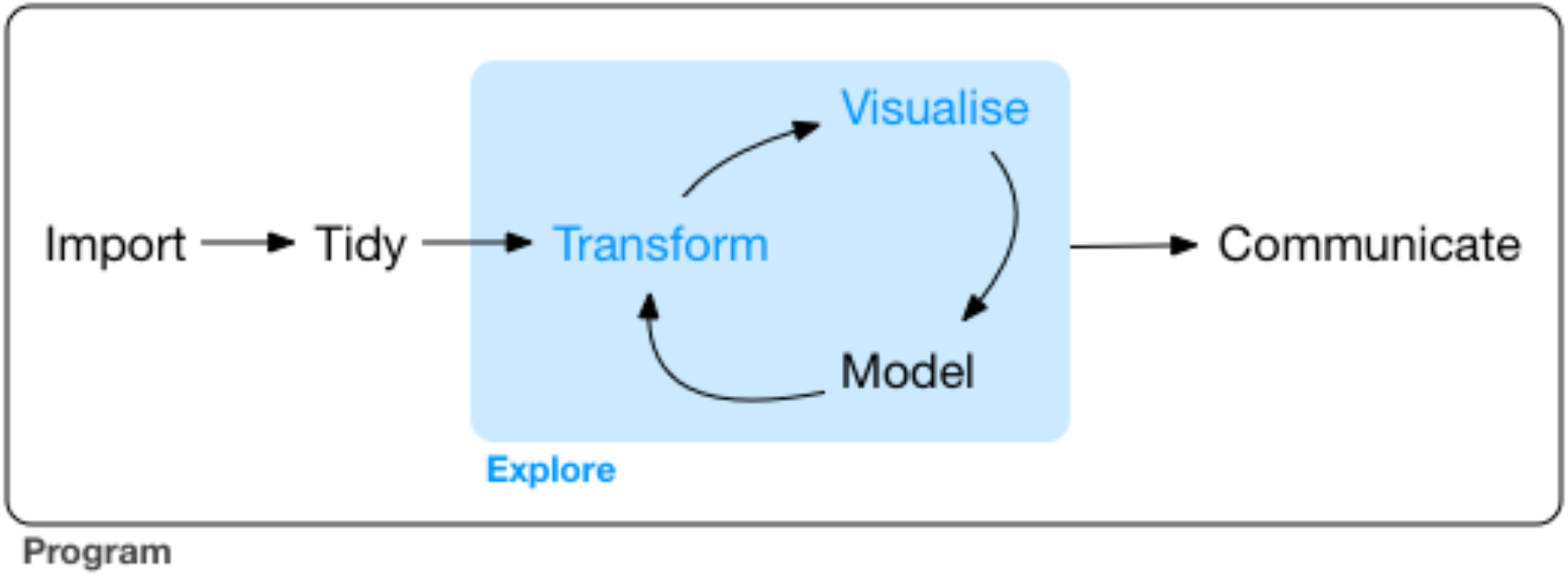
# Split date/time column

```
ener <- separate(ener,DateTime,c("Date","Time"),sep=" ",remove=F)
```

```
> ener
# A tibble: 2,784 × 13
              DateTime       Date     Time Demand Generation  Wind   CO2 NetImports  EWIC
*                <dttm>      <chr>    <chr>  <int>      <int> <int> <int>      <int> <int>
1  2017-01-29 00:00:00 2017-01-29 00:00:00   3834       4041   449   552       -145   -33
2  2017-01-29 00:15:00 2017-01-29 00:15:00   3785       4041   505   548       -200  -108
3  2017-01-29 00:30:00 2017-01-29 00:30:00   3708       4130   521   544       -294  -183
4  2017-01-29 00:45:00 2017-01-29 00:45:00   3634       4181   492   543       -419  -258
5  2017-01-29 01:00:00 2017-01-29 01:00:00   3581       4211   538   555       -503  -333
6  2017-01-29 01:15:00 2017-01-29 01:15:00   3552       4278   561   531       -598  -379
7  2017-01-29 01:30:00 2017-01-29 01:30:00   3491       4133   484   545       -516  -374
8  2017-01-29 01:45:00 2017-01-29 01:45:00   3435       4143   474   551       -581  -365
9  2017-01-29 02:00:00 2017-01-29 02:00:00   3374       4158   442   550       -653  -373
10 2017-01-29 02:15:00 2017-01-29 02:15:00   3329       4135   421   550       -676  -377
# ... with 2,774 more rows, and 4 more variables: Moyle <int>, HourOfDay <int>,
#   MinuteOfDay <int>, DayOfWeek <ord>
```

# Data Exploration

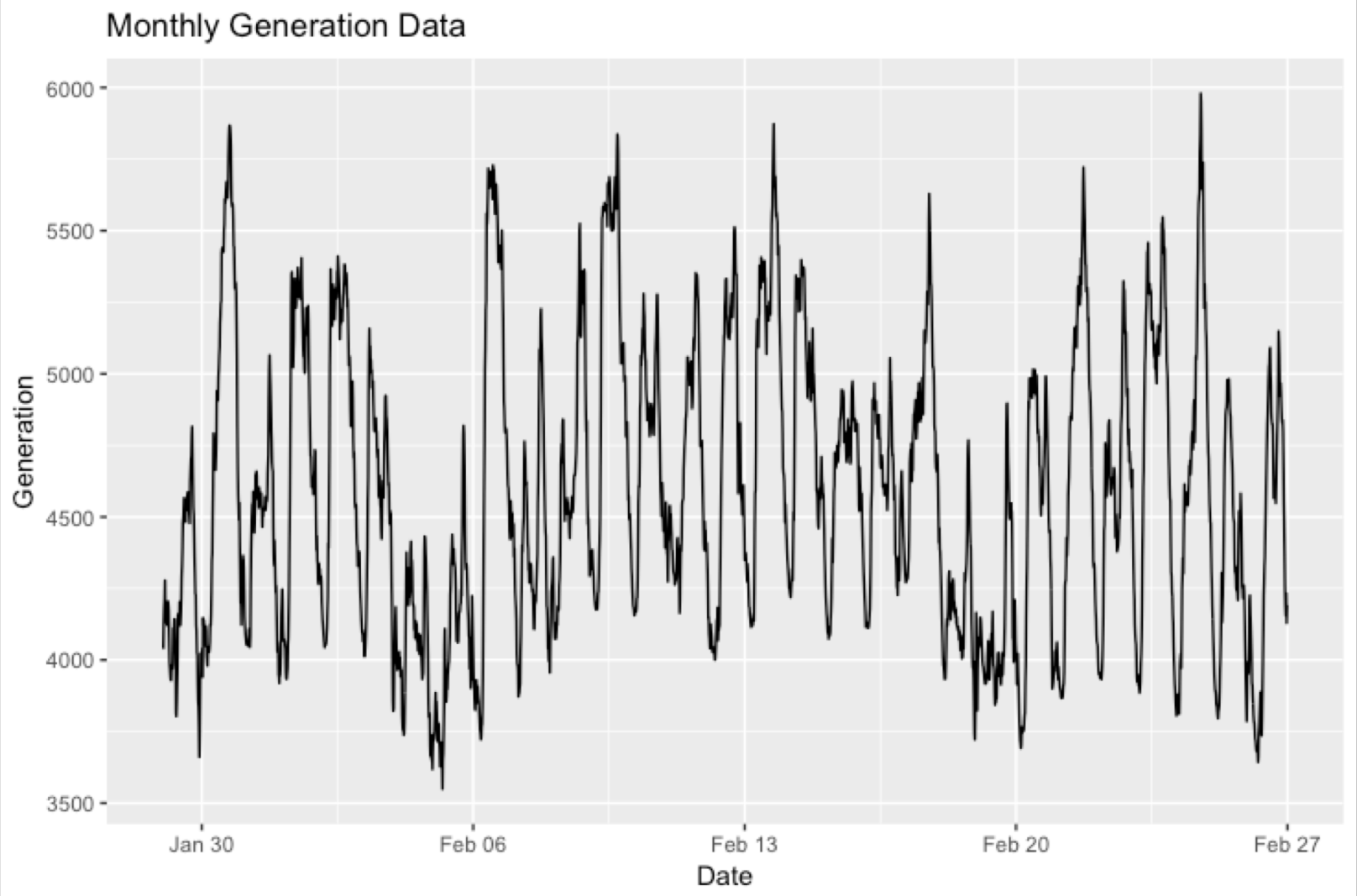
"Data exploration is the art of looking at your data, rapidly generating hypotheses, quickly testing them, then repeating again and again and again." (Wickham and Grolemund 2017).



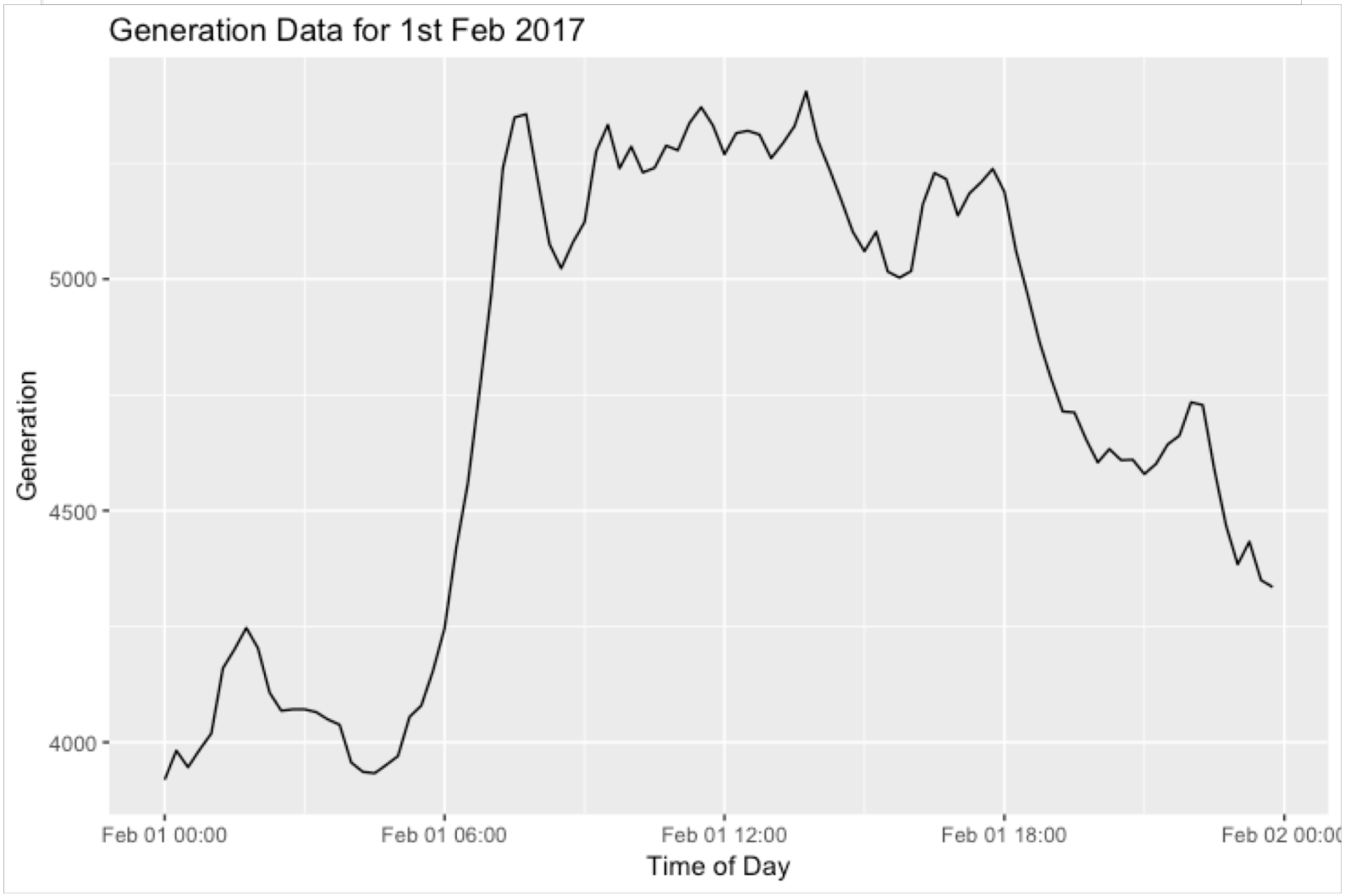
# Exploring Data Relationships

- Time series:
  - Generation data over the entire month
  - Generation data over a day
- Time of Day v Net Imports
- Demand v Net Imports
- Wind Generation v CO2 Emissions
- Comparing Wind Generation with Overall Generation

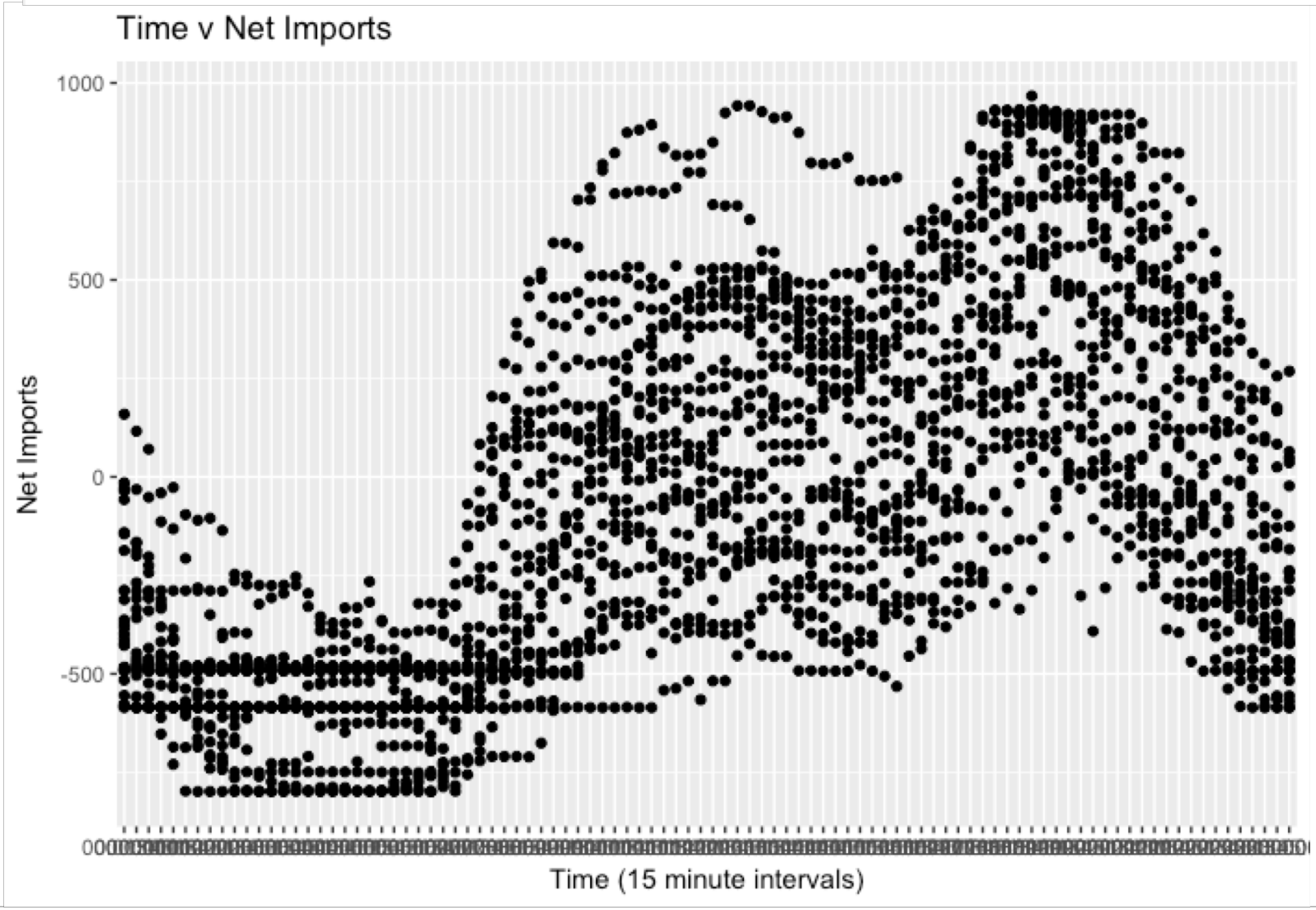
```
ggplot(data = ener) +
  geom_line(mapping = aes(x=DateTime,y=Generation)) +
  xlab("Date") + ylab("Generation") + ggtitle("Monthly Generation Data")
```



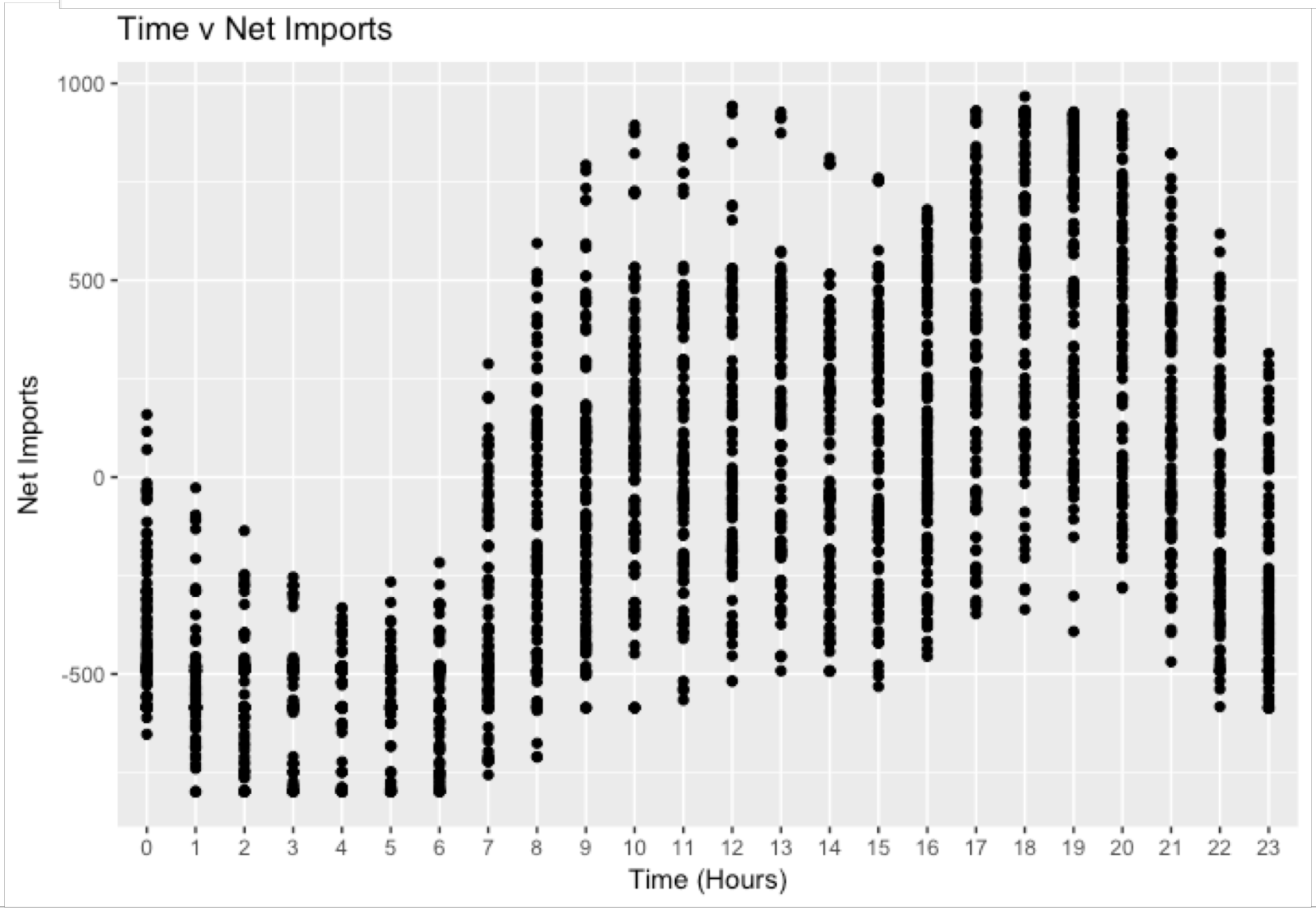
```
ggplot(data = filter(ener,Date=="2017-02-01")) +
  geom_line(mapping = aes(x=DateTime,y=Generation)) +
  xlab("Time of Day") + ylab("Generation")+
  ggtitle("Generation Data for 1st Feb 2017")
```



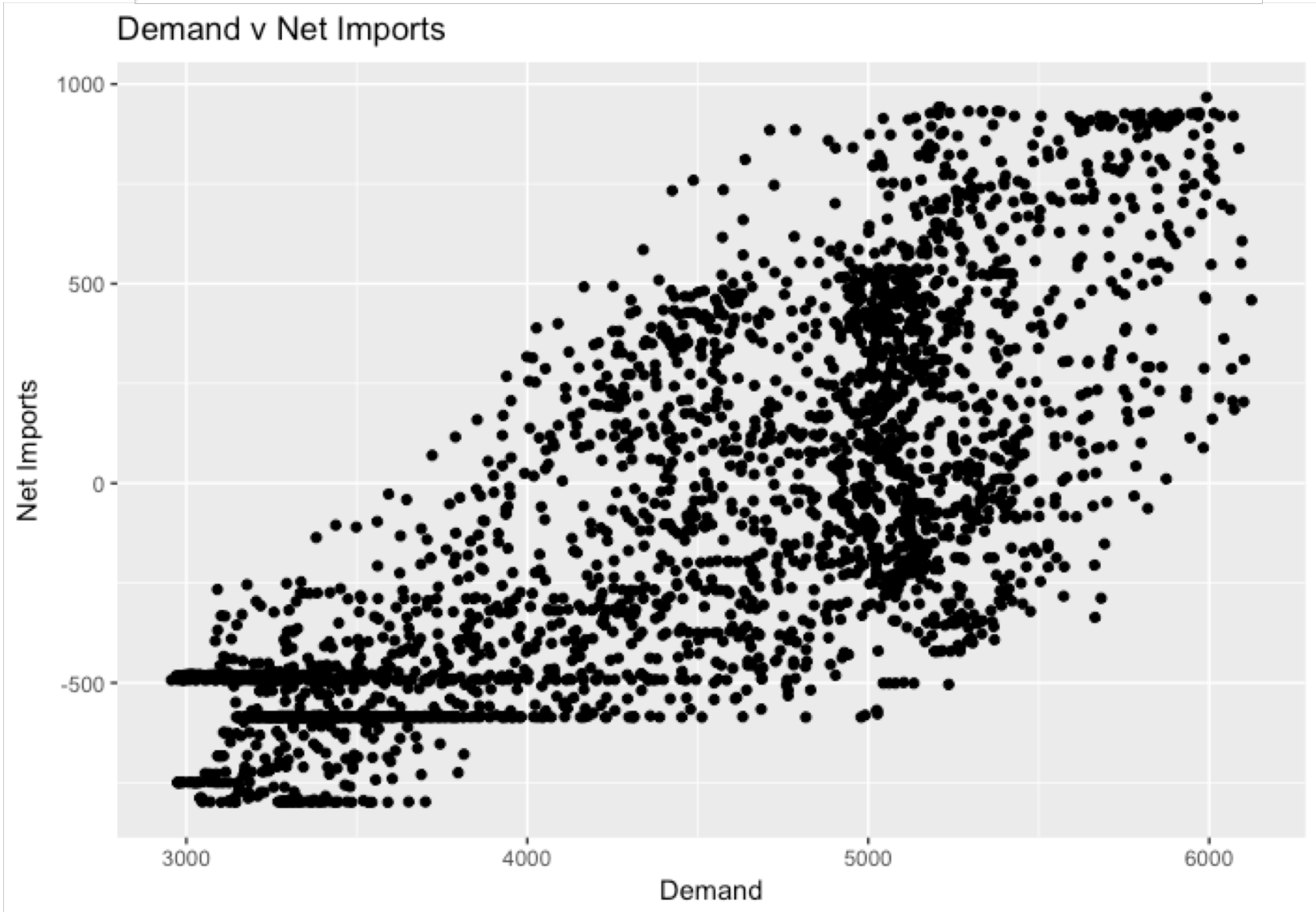
```
ggplot(data = ener) +
  geom_point(mapping = aes(x=as.factor(Time),y=NetImports)) +
  xlab("Time (15 minute intervals)") + ylab("Net Imports") +
  ggtitle("Time v Net Imports")
```



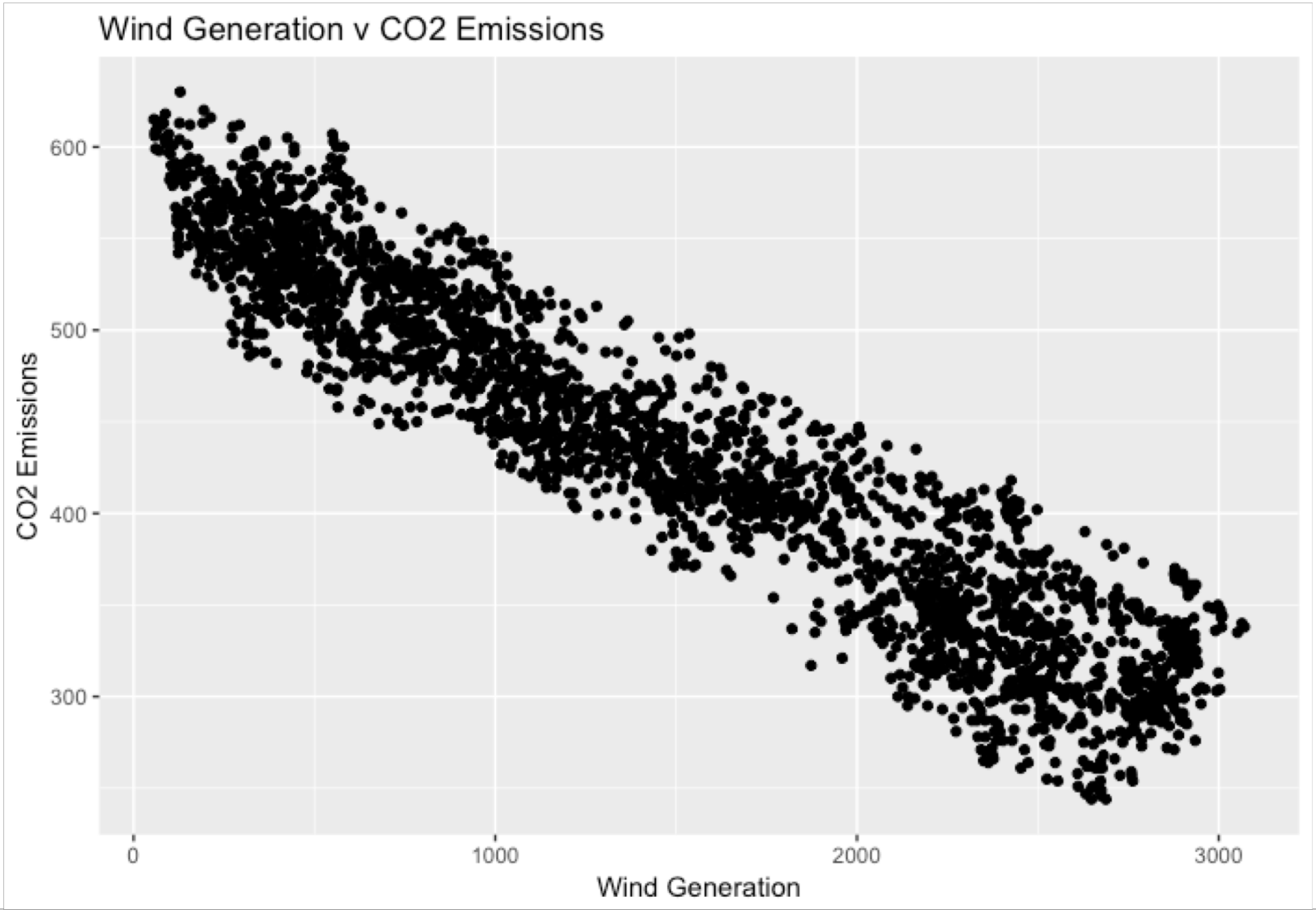
```
ggplot(data = ener) +
  geom_point(mapping = aes(x=as.factor(HourOfDay),y=NetImports)) +
  xlab("Time (Hours)") + ylab("Net Imports") +
  ggtitle("Time v Net Imports")
```



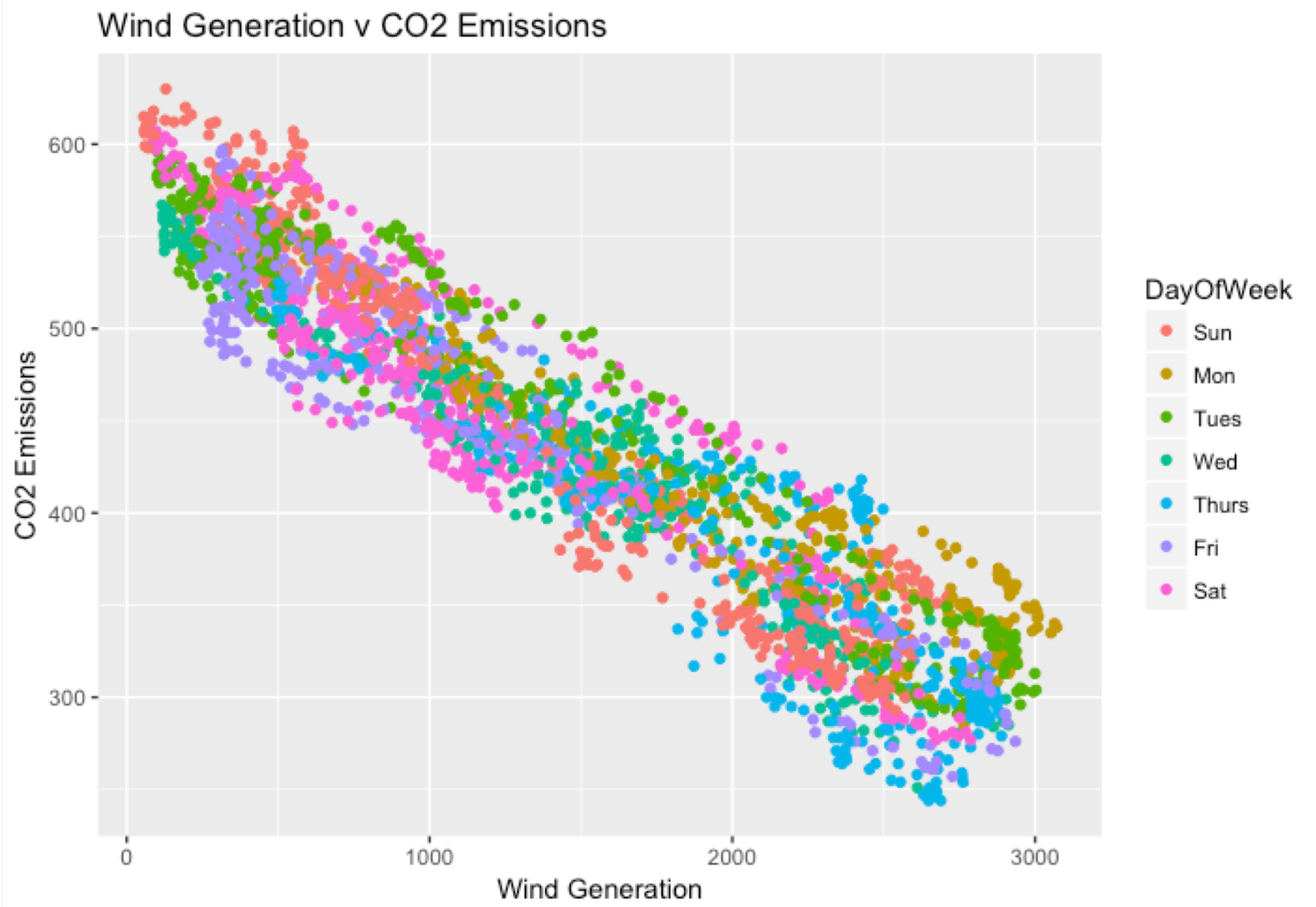
```
ggplot(data = ener) +
  geom_point(mapping = aes(x=Demand,y=NetImports)) +
  xlab("Demand") + ylab("Net Imports") +
  ggtitle("Demand v Net Imports")
```



```
ggplot(data = ener) +
  geom_point(mapping = aes(x=Wind,y=CO2)) +
  xlab("Wind Generation") + ylab("CO2 Emissions") +
  ggtitle("Wind Generation v CO2 Emissions")
```



```
ggplot(data = ener) +
  geom_point(mapping = aes(x=Wind,y=CO2,colour=DayOfWeek)) +
  xlab("Wind Generation") + ylab("CO2 Emissions") +
  ggtitle("Wind Generation v CO2 Emissions")
```



# Summary

- Identify data source
- Import data and prepare for analysis
- Using ggplot to explore hyptheses
- Next steps
  - dplyr
  - Integrate weather data