NZ Electricity Generation Trends 1998-2017

Ben Anderson (b.anderson@soton.ac.uk `@dataknut`)

Last run at: 2018-06-18 15:15:26

Contents

1 Citation

If you wish to use any of the material from this report please cite as:

- Anderson, B. (2018) *NZ Electricity Generation Trends 1998-2017*, Centre for Sustainability, University of Otago: Dunedin.

2 About

2.1 Circulation

Report circulation:

- Restricted to: NZ GREEN Grid project partners and contractors.

2.2 Purpose

This report is intended to:

- load and test NZ electricity generation data from https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/ from 1998 to 2017.

2.3 Requirements:

- pre-downloaded NZ wholesale generation datasets

2.4 History

Generally tracked via our git.soton repo:

- history
- issues

Specific history of this code:

- https://git.soton.ac.uk/ba1e12/nzGREENGrid/commits/master/analysis/generation/nzGenerationHistory.Rmd

2.5 Support

This work was supported by:

- The University of Otago;
- The University of Southampton;
- The New Zealand Ministry of Business, Innovation and Employment (MBIE) through the NZ GREEN Grid project;
- SPATIALEC - a Marie Skłodowska-Curie Global Fellowship based at the University of Otago's Centre for Sustainability (2017-2019) & the University of Southampton's Sustainable Energy Research Group (2019-202).

We do not 'support' the code but if you have a problem check the issues on our repo and if it doesn't already exist, open one. We might be able to fix it :-)

3 Introduction

Inspired by Steffel (2018) which analyses trends in the type and timing of generation in the UK over the same time period. Intended to build on Kahn et al's 2018 CO2 intensity of peak demand paper - how have thngs changed over time?

Uses https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/ from 1998 to 2017. Note that this does not appear to include Solar (too low or in a seperate data set?) nor does it appear to include domestic/small-scale generation? It is possible that these are to be found in https://www.emi.ea.govt.nz/Wholesale/Datasets/Metered_data/Embedded_generation and should be combined with this data?

Data is kWh - so energy not power.

4 Load data

Load the generation data from files stored in:

- /Volumes/hum-csafe/Research Projects/GREEN Grid/_RAW DATA/EA_Generation_Data/

These have been pre-downloaded and cleaned but could be pulled on the fly to be refreshed for other dates…

```
## Warning in `[.data.table`(filesToDateDT, , `:=`(c("year", "month",
## "stub"), : Supplied 3 columns to be assigned a list (length 5) of values (2
## unused)
```

```
## [1] "Files loaded"
```

```
## [1] "Loaded 352,250 rows of data"
```

```
## sampleGenDT
##
##  14  Variables      352250  Observations
## ---------------------------------------------------------------------------
## Site_Code
##        n  missing distinct
##   352250        0       69
##
## lowest : ANI ARA ARG ARI ATI, highest: WPA WPI WRK WTK WWD
## ---------------------------------------------------------------------------
## POC_Code
##        n  missing distinct
##   352250        0       68
##
## lowest : ARA2201 ARG1101 ARI1101 ARI1102 ASB0661
## highest: WRK0331 WRK2201 WTK0111 WWD1102 WWD1103
## ---------------------------------------------------------------------------
## Nwk_Code
##        n  missing distinct
##   352250        0       27
##
## lowest : ALNT BOPD CHHE CTCT EASH, highest: TRPG TRUS TUAR WAIK WATA
## ---------------------------------------------------------------------------
## Gen_Code
##        n  missing distinct
##   352250        0       68
##
## lowest : aniwhenua     arapuni       aratiatia     argyle_wairau atiamuri
## highest: whakamaru     whareroa      wheao_flaxy   whirinaki     white_hill
## ---------------------------------------------------------------------------
## Fuel_Code
##        n  missing distinct
##   352250        0        8
```

```
##
## Value         Coal  Diesel     Gas Gas&Oil     Geo   Hydro    Wind    Wood
## Frequency     6100    6100   44300    6100   42700  213500   27350    6100
## Proportion   0.017   0.017   0.126   0.017   0.121   0.606   0.078   0.017
## ---------------------------------------------------------------------------
## Tech_Code
##        n  missing distinct
##   352250        0        5
##
## Value       Cogen    Geo  Hydro  Thrml   Wind
## Frequency   27500  42700 213500  41200  27350
## Proportion  0.078  0.121  0.606  0.117  0.078
## ---------------------------------------------------------------------------
## Trading_date
##        n  missing distinct
##   352250        0      122
##
## lowest : 1998-06-01 1998-06-02 1998-06-03 1998-06-04 1998-06-05
## highest: 2017-12-27 2017-12-28 2017-12-29 2017-12-30 2017-12-31
## ---------------------------------------------------------------------------
## Time_Period
##        n  missing distinct
##   352250        0       50
##
## lowest : TP1  TP10 TP11 TP12 TP13, highest: TP50 TP6  TP7  TP8  TP9
## ---------------------------------------------------------------------------
## kWh
##        n  missing distinct     Info     Mean      Gmd      .05      .10
##   338160    14090   116836    0.997    37186    45162        0        0
##      .25      .50      .75      .90      .95
##     6563    19715    48640    82910   150714
##
## lowest : 0.0000e+00 4.5000e-03 8.7000e-03 1.0000e-02 1.0200e-02
## highest: 4.9213e+05 4.9239e+05 4.9246e+05 4.9266e+05 4.9302e+05
## ---------------------------------------------------------------------------
## rTime [secs]
##        n  missing distinct
##   338160    14090       48
##
## lowest : 00:15:00 00:45:00 01:15:00 01:45:00 02:15:00
## highest: 21:45:00 22:15:00 22:45:00 23:15:00 23:45:00
## ---------------------------------------------------------------------------
## rDate
##        n  missing distinct
##   352250        0      122
##
## lowest : 1998-06-01 1998-06-02 1998-06-03 1998-06-04 1998-06-05
## highest: 2017-12-27 2017-12-28 2017-12-29 2017-12-30 2017-12-31
## ---------------------------------------------------------------------------
## rDateTime
##                   n             missing            distinct
##              338160               14090                5856
##                Info                Mean                 Gmd
##                   1 2010-03-23 19:23:45 1979-03-18 16:00:26
```

```
##                  .05                 .10                 .25
## 1998-06-09 00:15:00 1998-06-17 00:15:00 1998-12-10 09:15:00
##                  .50                 .75                 .90
## 2017-06-11 15:45:00 2017-12-06 19:15:00 2017-12-21 22:15:00
##                  .95
## 2017-12-26 23:15:00
##
## Value      8.950e+08 9.000e+08 9.100e+08 9.150e+08 1.495e+09 1.500e+09
## Frequency      20548     42812       752     69184     47600     53200
## Proportion     0.061     0.127     0.002     0.205     0.141     0.157
##
## Value      1.510e+09 1.515e+09
## Frequency      16100     87964
## Proportion     0.048     0.260
## ---------------------------------------------------------------------------
## month
##        n  missing distinct     Info     Mean      Gmd
##   352250        0        2    0.749    9.087    2.997
##
## Value           6     12
## Frequency  171000 181250
## Proportion  0.485  0.515
## ---------------------------------------------------------------------------
## year
##        n  missing distinct     Info     Mean      Gmd
##   352250        0        2    0.716     2010    9.075
##
## Value        1998   2017
## Frequency  138850 213400
## Proportion  0.394  0.606
## ---------------------------------------------------------------------------
```

Table **??** sumarises the data. Notice that there are missing (NA) values in the kWh column. These are caused by periods 49 and 50:

> "The data is presented by trading period, TP1, TP2, ... TP48. Trading period 1 starts at midnight, trading period 2 starts at 12:30am, trading period 3 starts at 1:00am, etc. Users of this data should be aware of daylight saving in New Zealand. On the day daylight saving commences there are only 46 trading periods and on the day it ends, there are 50." (https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/)

So on 2 days of the year TP47 & TP48 do not exist and on the following days they are back and we also have TP49 & TP50. There are only two things in life worse than death & taxes: daylight saving time and time-zones.

Daylight saving begins/ends in October and March so we carefully avoid this problem in this section by using June and December. However these TP are still present as labels in the Time_Period variable and so give NA kWh in the data as the following table (Table 1) and plot (Figure 1) of NA observations (only) by Fuel Type and month show.

In order to avoid future confusion and to save a lot of error checking we therefore remove NA kWh (i.e. TP49 & TP 50) from the dataset.

```r
# N rows before:
nrow(sampleGenDT)
```

```
## [1] 352250
```

Table 1: Mean kWh by Time Period

Time_Period	mean
TP1	32193.95
TP10	28197.44
TP11	29102.29
TP12	30355.92
TP13	32589.18
TP14	35307.47
TP15	38153.58
TP16	40611.99
TP17	41846.03
TP18	42344.12
TP19	42572.59
TP2	31058.35
TP20	42364.31
TP21	41953.33
TP22	41580.21
TP23	41157.60
TP24	40811.56
TP25	40331.06
TP26	39886.99
TP27	39653.17
TP28	39227.72
TP29	38878.22
TP3	30111.71
TP30	38668.61
TP31	38707.44
TP32	39144.56
TP33	39847.08
TP34	41145.00
TP35	42903.35
TP36	44126.06
TP37	43686.30
TP38	43162.35
TP39	42323.73
TP4	29313.75
TP40	41477.26
TP41	40763.28
TP42	40360.00
TP43	39752.14
TP44	38615.70
TP45	36913.02
TP46	35083.01
TP47	34647.09
TP48	33234.67
TP49	NA
TP5	28734.70
TP50	NA
TP6	28278.83
TP7	28020.79
TP8	27830.14
TP9	27905.97

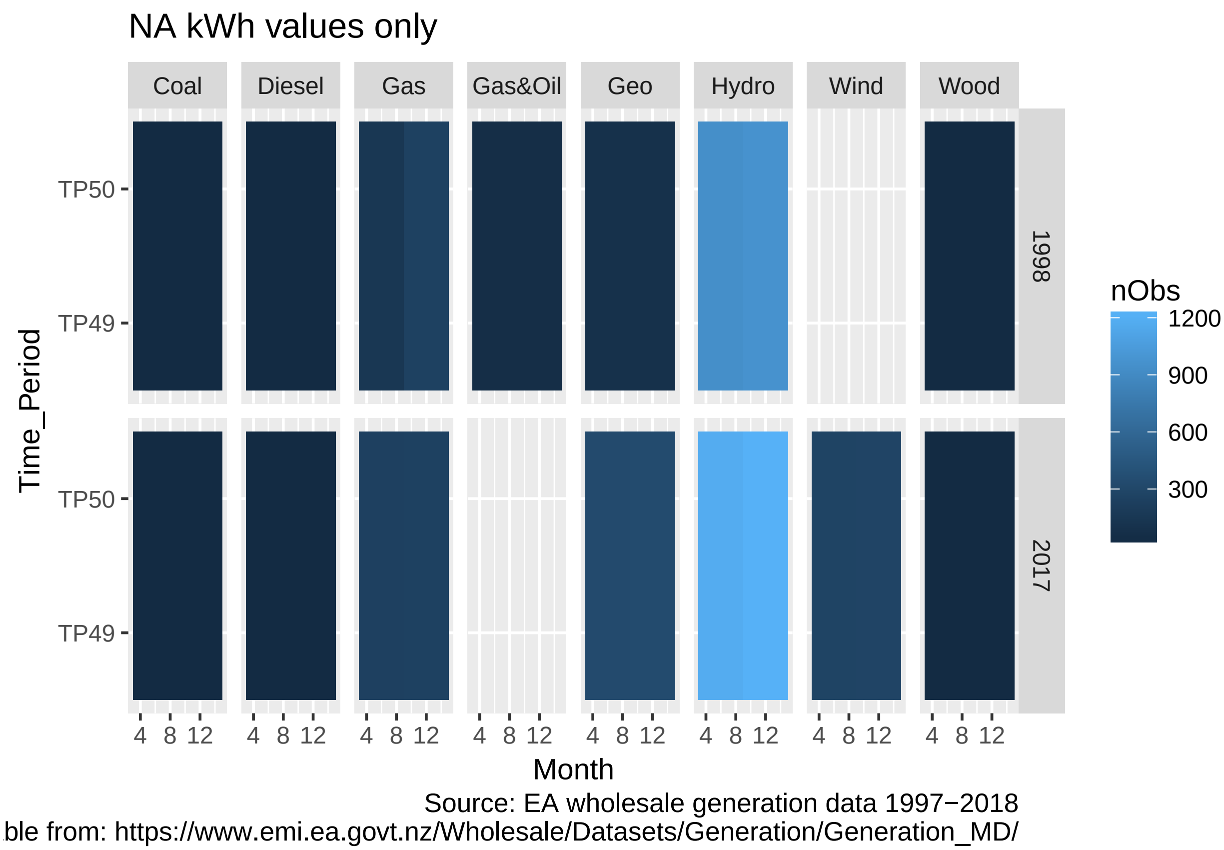


Figure 1: Plot showing presence of NA observations by time period and Fuel Type

Table 2: Summary of energy produced by all fuels

year	Fuel_Code	sumMWh	meanMWh	medianMWh	minMWh	maxMWh	sdMWh
1998	Coal	379460.72	129.60	40.99	0	493.02	159.50
1998	Diesel	322.77	0.11	0.00	0	84.86	2.97
1998	Gas	537031.60	28.11	10.27	0	267.10	45.45
1998	Gas&Oil	514797.99	87.91	91.95	0	173.73	43.46
1998	Geo	340786.48	38.80	25.60	0	81.87	28.90
1998	Hydro	3870532.38	42.64	26.49	0	294.98	53.53
1998	Wood	29067.50	9.93	14.10	0	19.50	7.41
2017	Coal	426606.86	145.70	140.41	0	241.88	64.98
2017	Diesel	941.40	0.32	0.00	0	45.39	2.49
2017	Gas	1367101.27	58.36	22.78	0	290.87	75.67
2017	Geo	1222782.96	37.97	38.87	0	84.75	23.46
2017	Hydro	3586485.42	31.41	19.57	0	291.82	39.68
2017	Wind	255368.77	9.73	6.30	0	44.27	9.90
2017	Wood	43571.23	14.88	16.64	0	19.51	4.91

```r
# N time periods before:
uniqueN(sampleGenDT$Time_Period)
```

```
## [1] 50
```

```r
# remove NA
sampleGenDT <- sampleGenDT[!is.na(kWh)]
# N rows after
nrow(sampleGenDT)
```

```
## [1] 338160
```

```r
# N time periods after:
uniqueN(sampleGenDT$Time_Period)
```

```
## [1] 48
```

5 Analysis: 1998 & 2017 Comparison

5.1 Distribution tests

Table 2 shows summary statistics for each fuel source by year. Hydro contributes the majority of energy in each year but coal has the highest half-hourly mean in each year suggesting that is makes large contributions at specific times. Comparing the mean and median for coal shows how skewed this distirbution was in 1998 although far less so in 2017. This is also supported by the maximum values which show coal as the 'peaked' energy producer in 1998 although this has faded by 2017 where it shows similar maxima to gas and hydro. Note that 2 of the 4 the Huntly coal-fired units were mothballed/retired during this period.

Figure 2 shows the distribution of half-hourly observations by month and year. It clearly shows the use of coal in June 1998, non-use in December 1998 but re-use in December 2017 where there appears little differnece between winter & summer use for most fuels. We also see the emergence of wind by 2017.

Figure 3 visualises the distribution of MWh values within fuel sources. Note that the vertical axis has been allowed to vary by fuel source so that smaller counts are visible. The y axis is constant which enables the higher unit output of coal to be clearly visible. The histogram for coal shows the use of multiple units in

Figure 2: Box plot of energy produced by all fuels

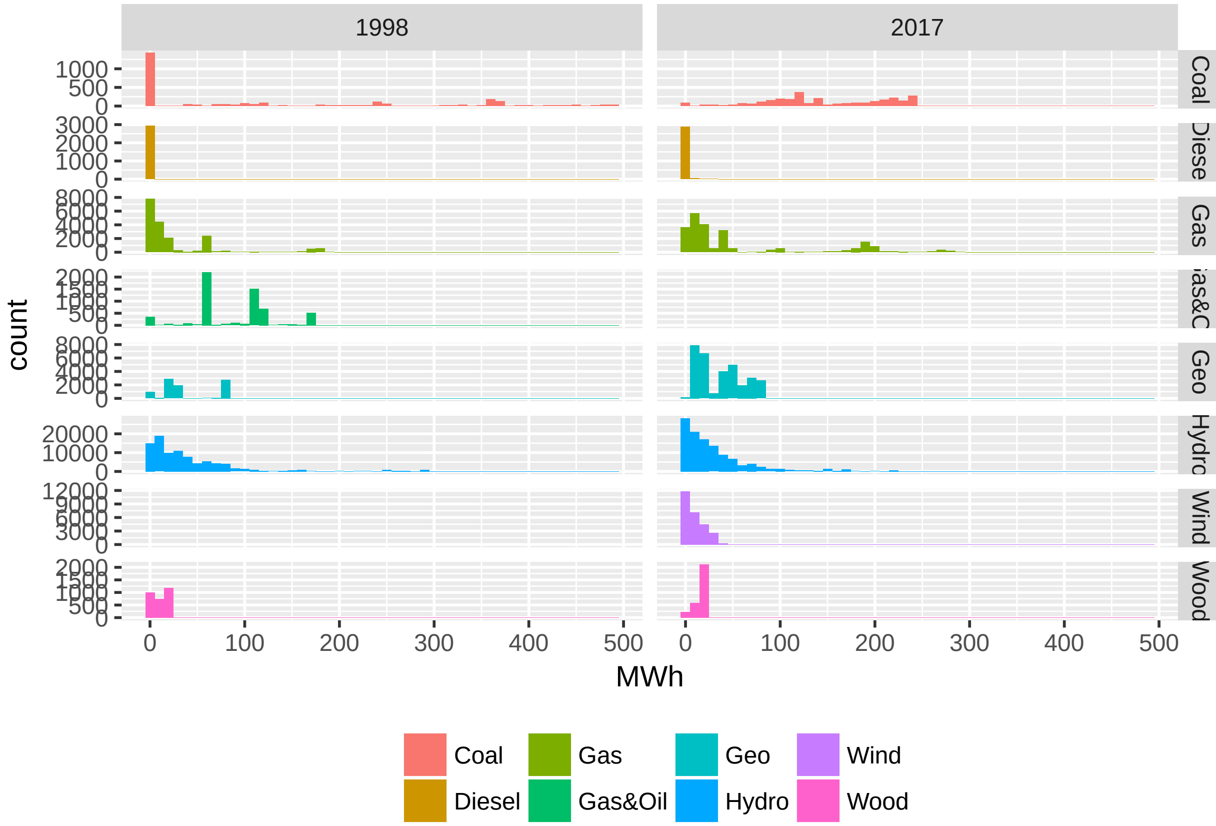


Figure 3: Overall energy production histrograms by fuel type

June 1998 but not 2017 for example where the output is clearly truncated. It also shows that coal was almost constantly generating in 2017 (very few zero values). Hydro on the other hand shows a large number of zero or low values as does wind and back-up diesel which is to be expected.

5.2 Monthly generation

The following plots shows the total, mean, s.d. and coefficient of variation plots of half-hourly GWh produced by each fuel source each month and to some extent relfects the previous box plots.

The total is simply the sum of all half-hourly values and Figure 4 shows the dominance of hydro followed by coal in June 1998; the non-use of coal in December 1998; the growth of gas & geo by 2017 but the relative stasis in at-capacity hydro (?).

Figure **??** shows the mean of half-hourly values for each month and indicates that the Coal generation may be skewed, especially for June 1998 by a few very large values (ref the histograms above).

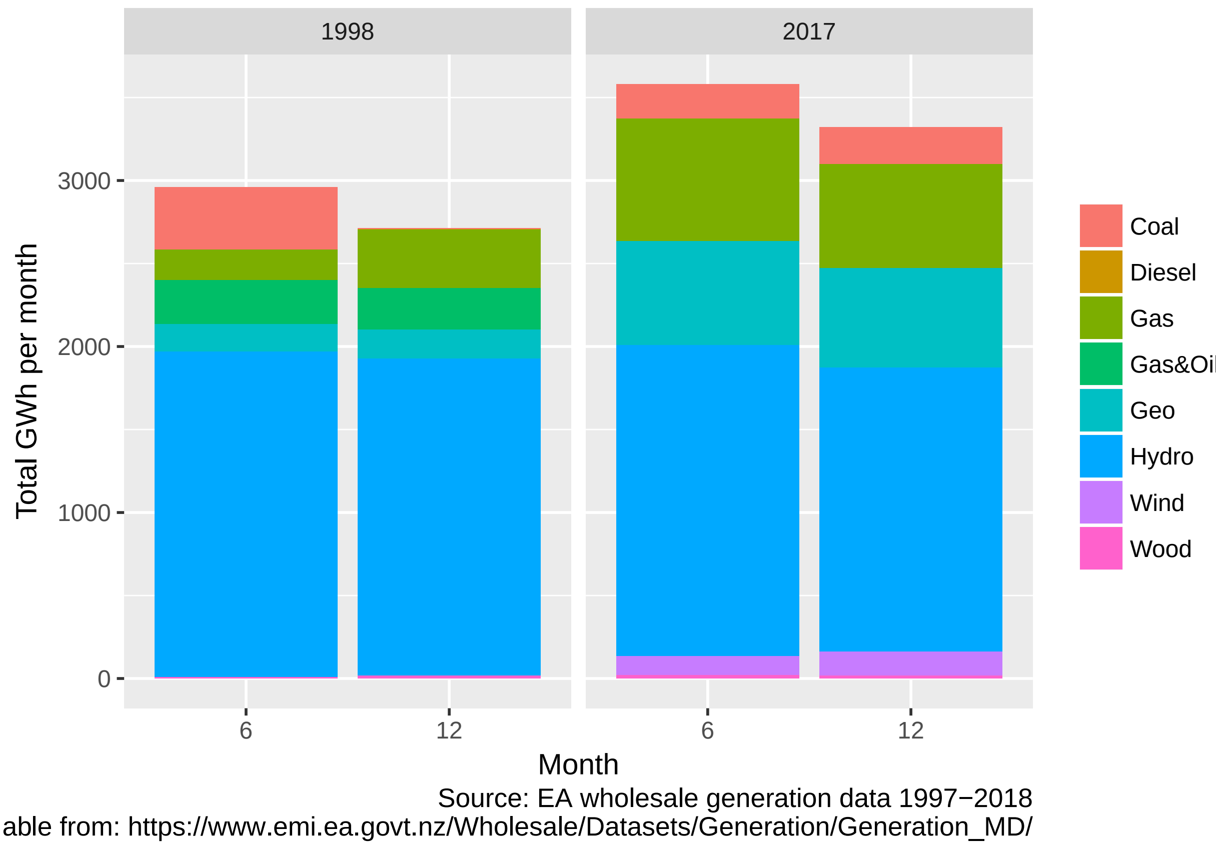


Figure 4: Monthly total plot by fuel type

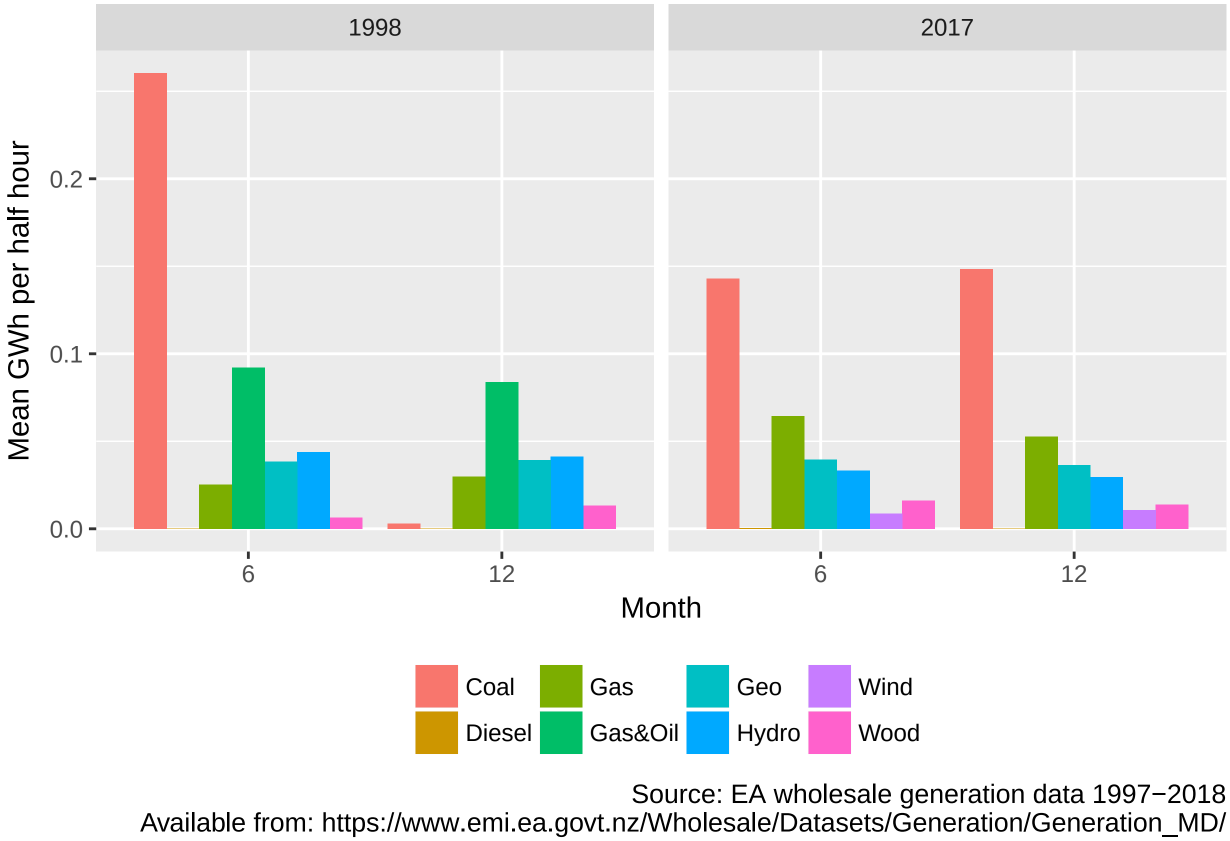


Figure 5 shows the standard deviation of the half-hourly generation data and suggests that coal has the highest absolute variation in June 1998 which may correspond to a particular spike and/or a period of very heavy use. Coal is less variable in 2017 perhaps due to the increased use of Gas.

Finally, Figure **??** shows the coefficient of variation across the half-hourly values (mean/s.d). We take the CoV to indicate *relative* variability (i.e. relative volatility) in generation load between the different fuels and use it in preference to the standard deviation (shown above) which, as an absolute measure, is affected by the underlying magnitude of each fuel's use. The plots suggest that Coal and Wood tend to see greatest relative variability although Gas & Oil in 1998 also stand out.

```
# coefficient of variation https://en.wikipedia.org/wiki/Coefficient_of_variation
plotDT <- plotDT[, cov := 1000000 * (meankWh/sdkWh)] # corrct for GW conversion in plot function (doh!)

makeMonthlyDodgedPlot(plotDT, "cov", "CoV half-hourly GWh") + geom_col(position = "dodge")
```

```
## Warning: Removed 1 rows containing missing values (geom_col).

## Warning: Removed 1 rows containing missing values (geom_col).
```

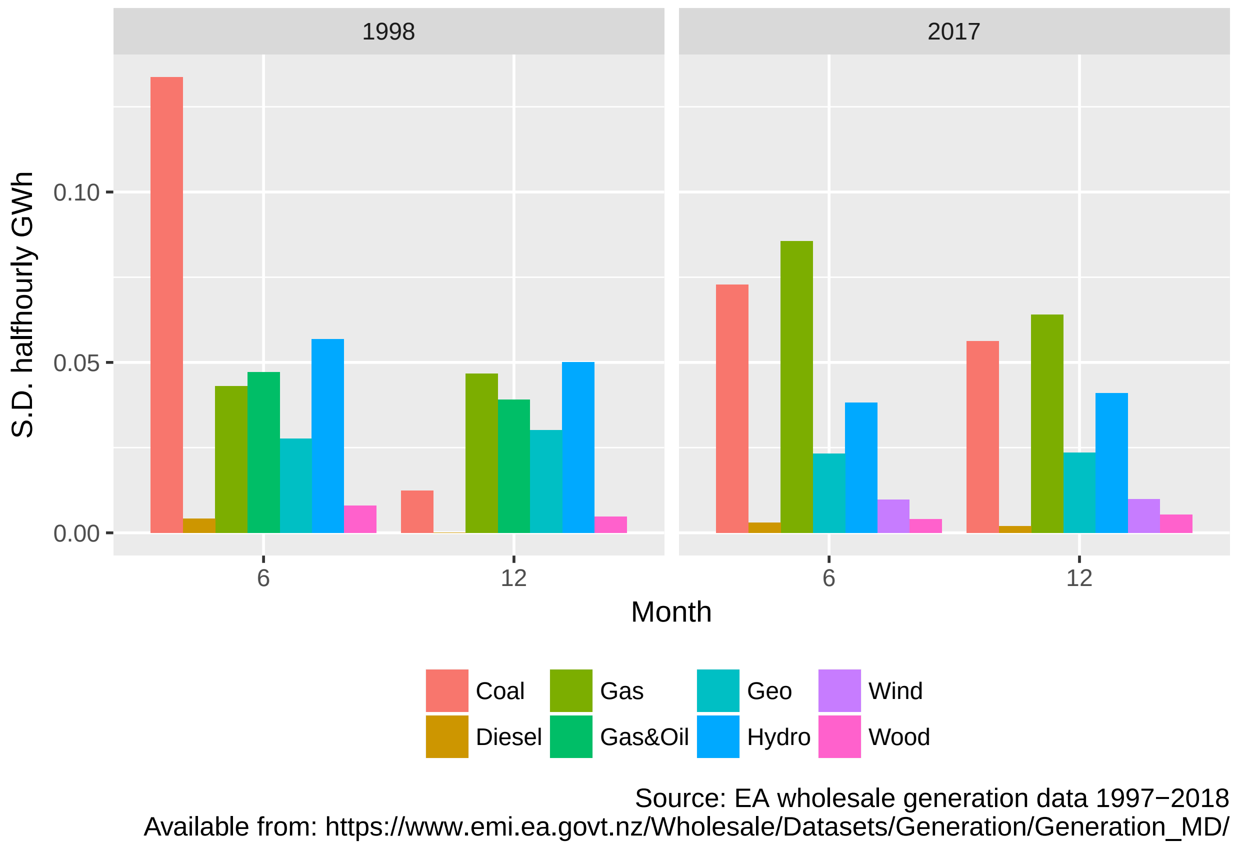
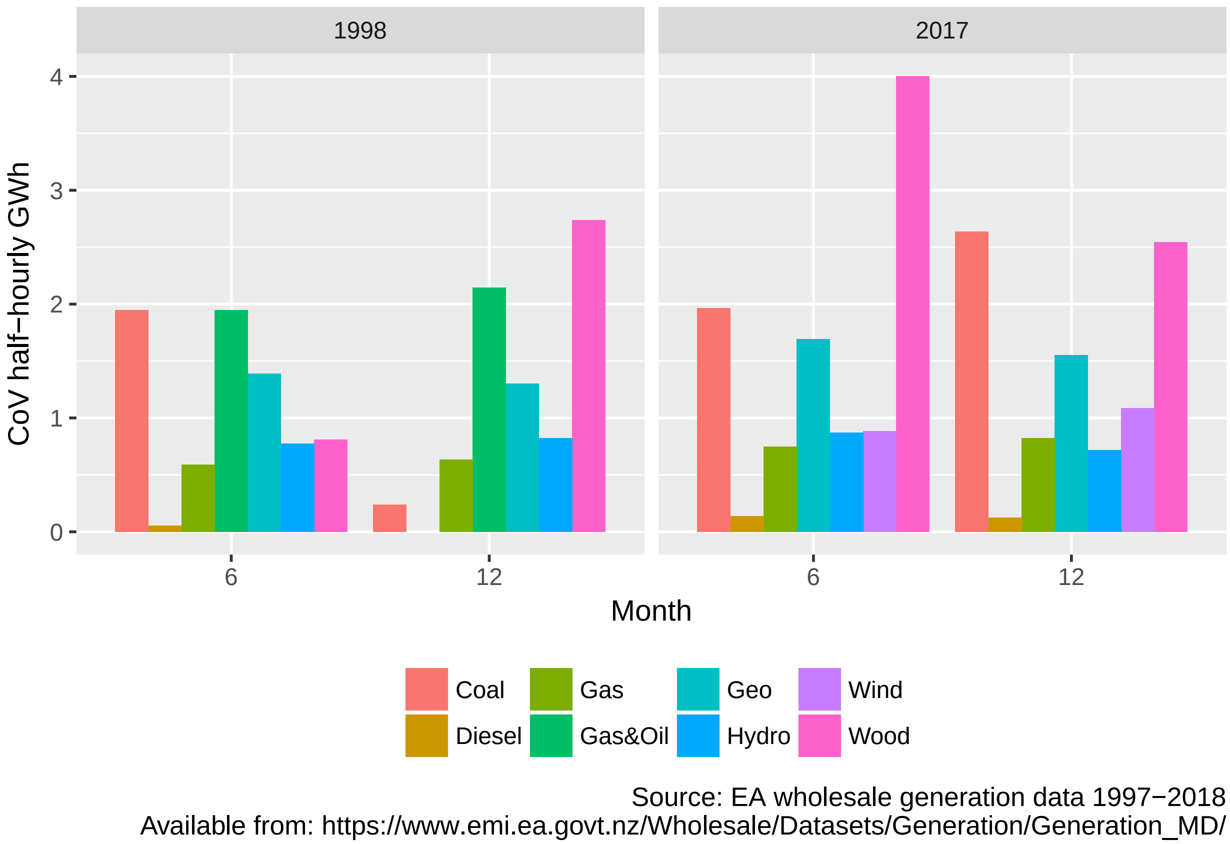


Figure 5: Monthly s.d. plot by fuel type



5.3 Half hourly profiles by month

However the monthly plots do not tell us about the use of different generation sources by time of day which has clear implications for how peaks in demand have been met over time.

To do this, the following plots partially replicate one of those found in Staffel, 2018 for the UK to show how the different components of generation have changed over time.

Figure 6 shows the total half-hourly generation for each month summed over all days whilst Figure 7 shows the same data but as a point plot to more clearly show the absolute contribution of each fuel. Note that the half-hours are plotted at mid-points (00:15, 00:45, 01:15 etc…).

Figures 8 and 9 repeat this analysis but shows the mean, again suggesting that the values for coal are skewed by some extremely large values in December 1998 and by high generation values when used in 2017.

5.4 Half hourly profiles by day of the month

The following plots show the profiles for each day of the month. Unfortunately due to the lack of wind generation in 1998 the colour scheme changes from 1998 to 2017.

To be fixed

Nevertheless the differences between the compositions of each half-hour can be seen.

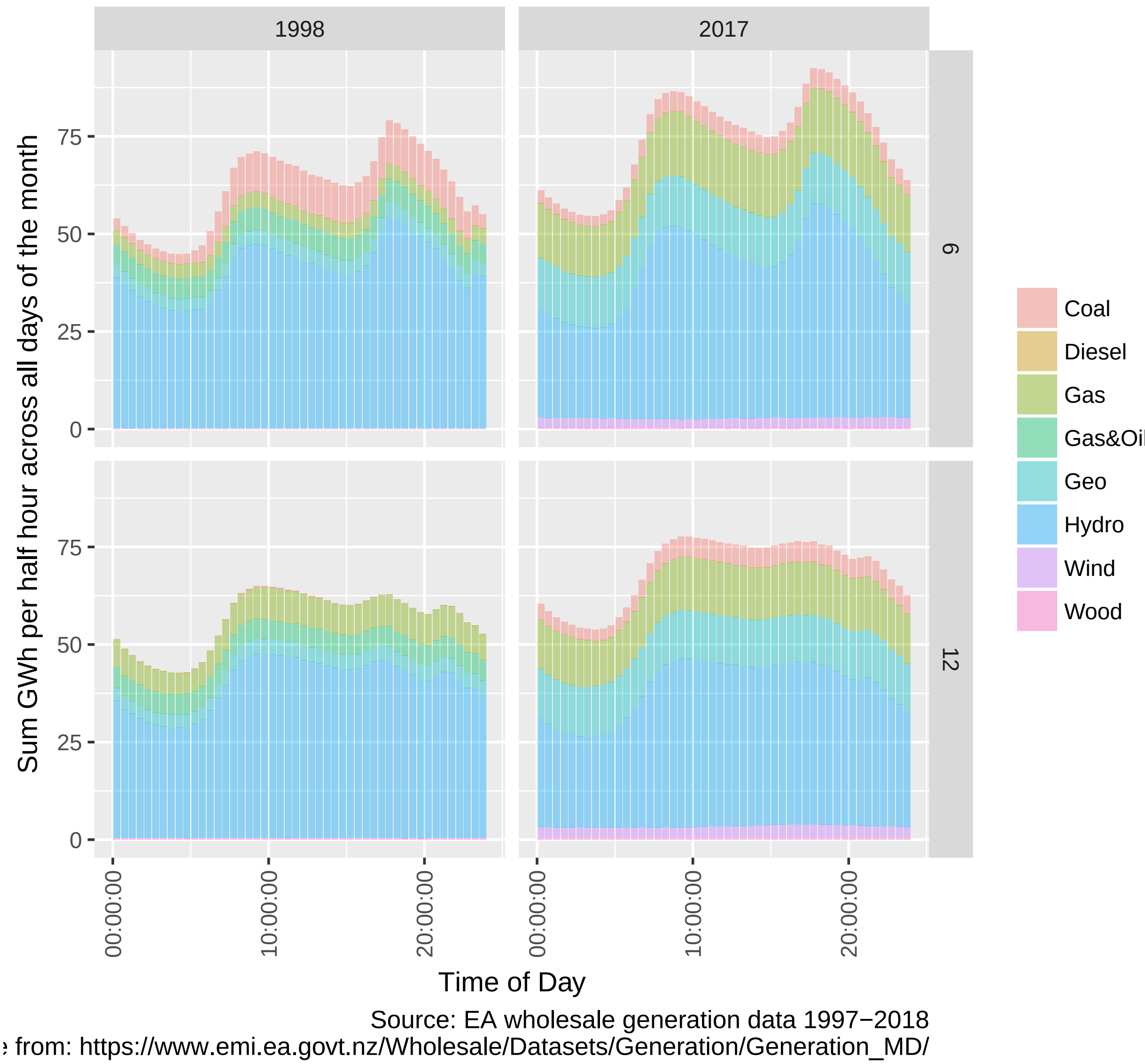


Figure 6: Half-hourly profile plot by fuel type (sum)

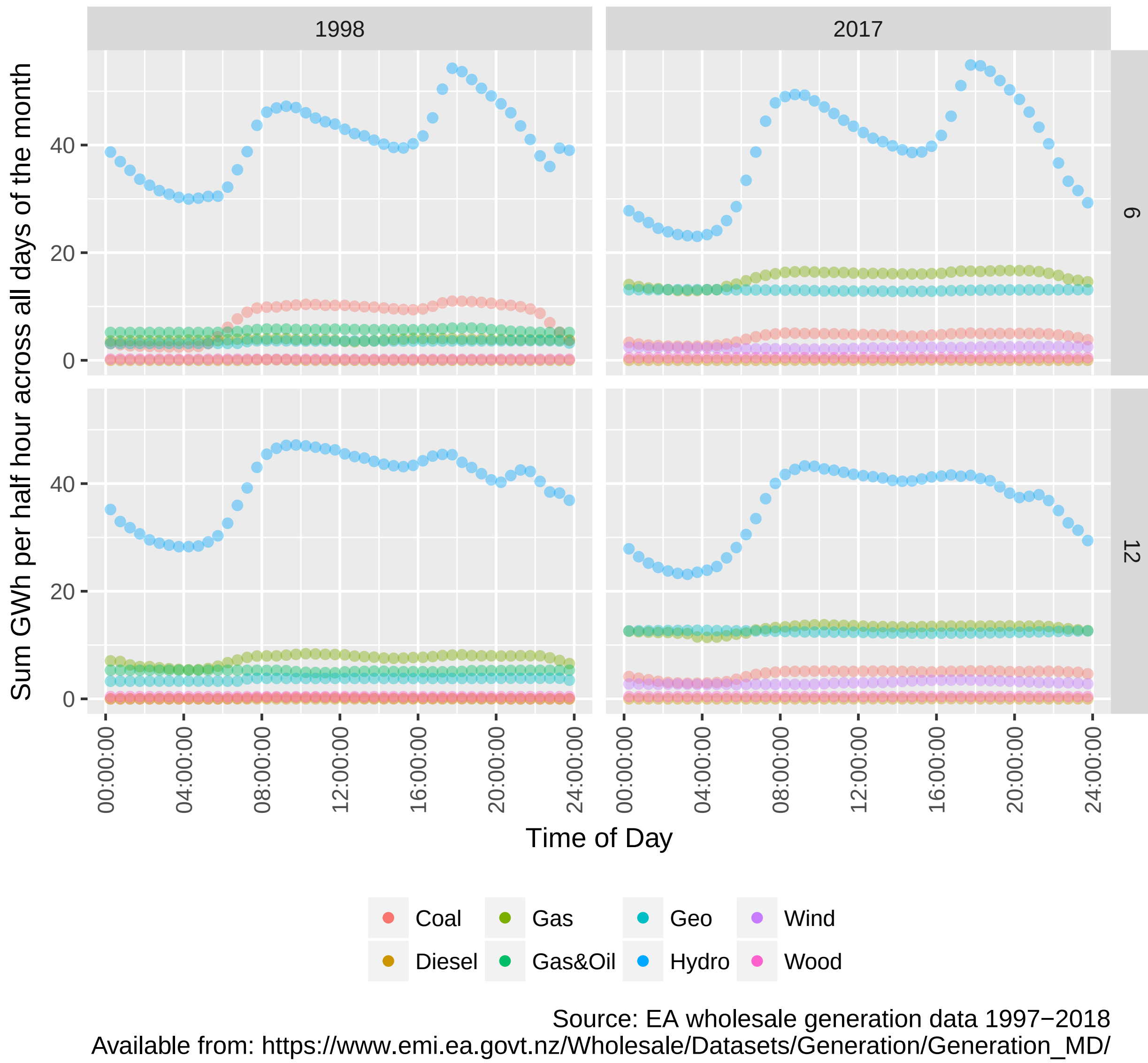


Figure 7: Half-hourly profile plot by fuel type (sum)

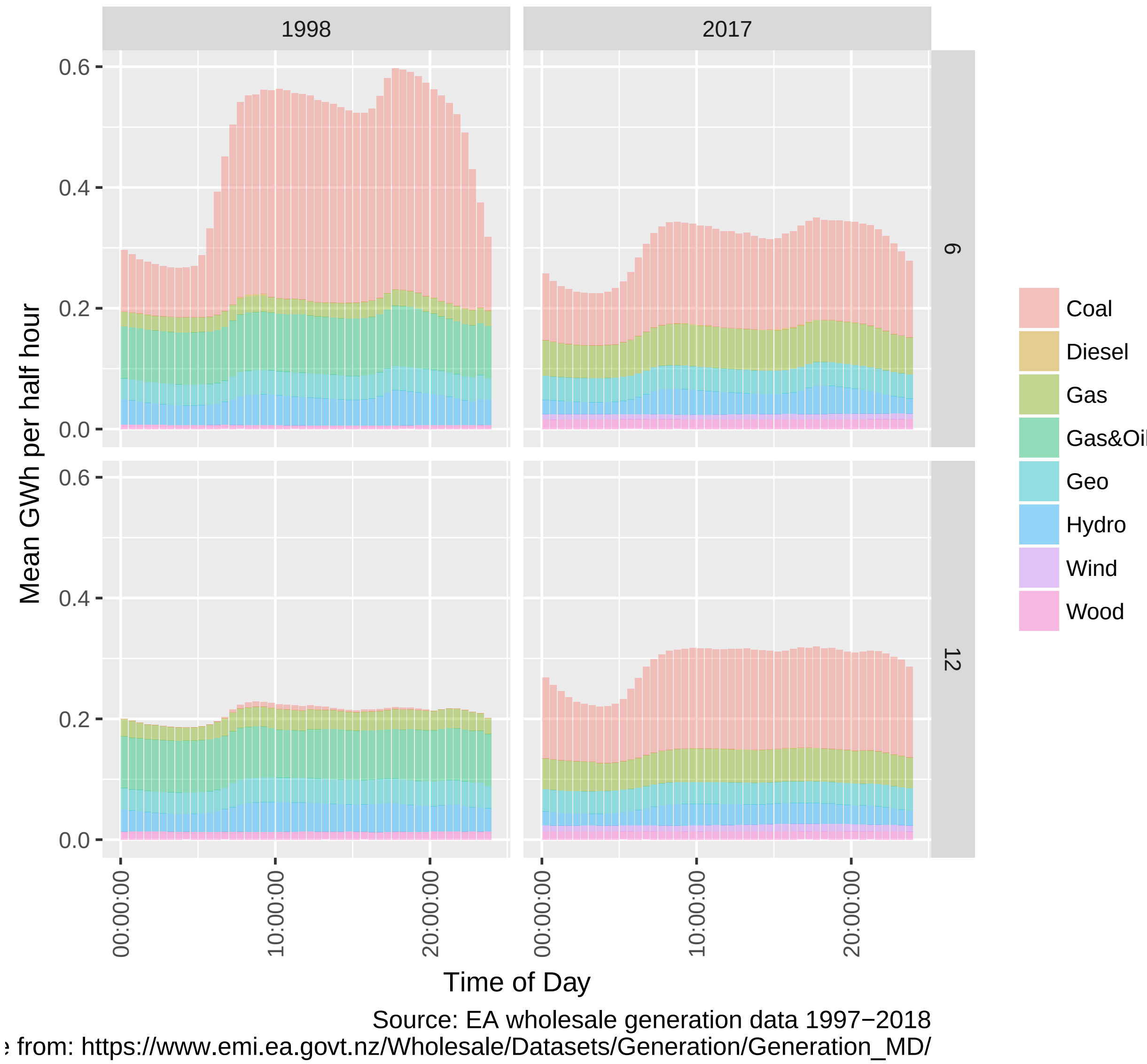


Figure 8: Half-hourly profile plot by fuel type (mean)

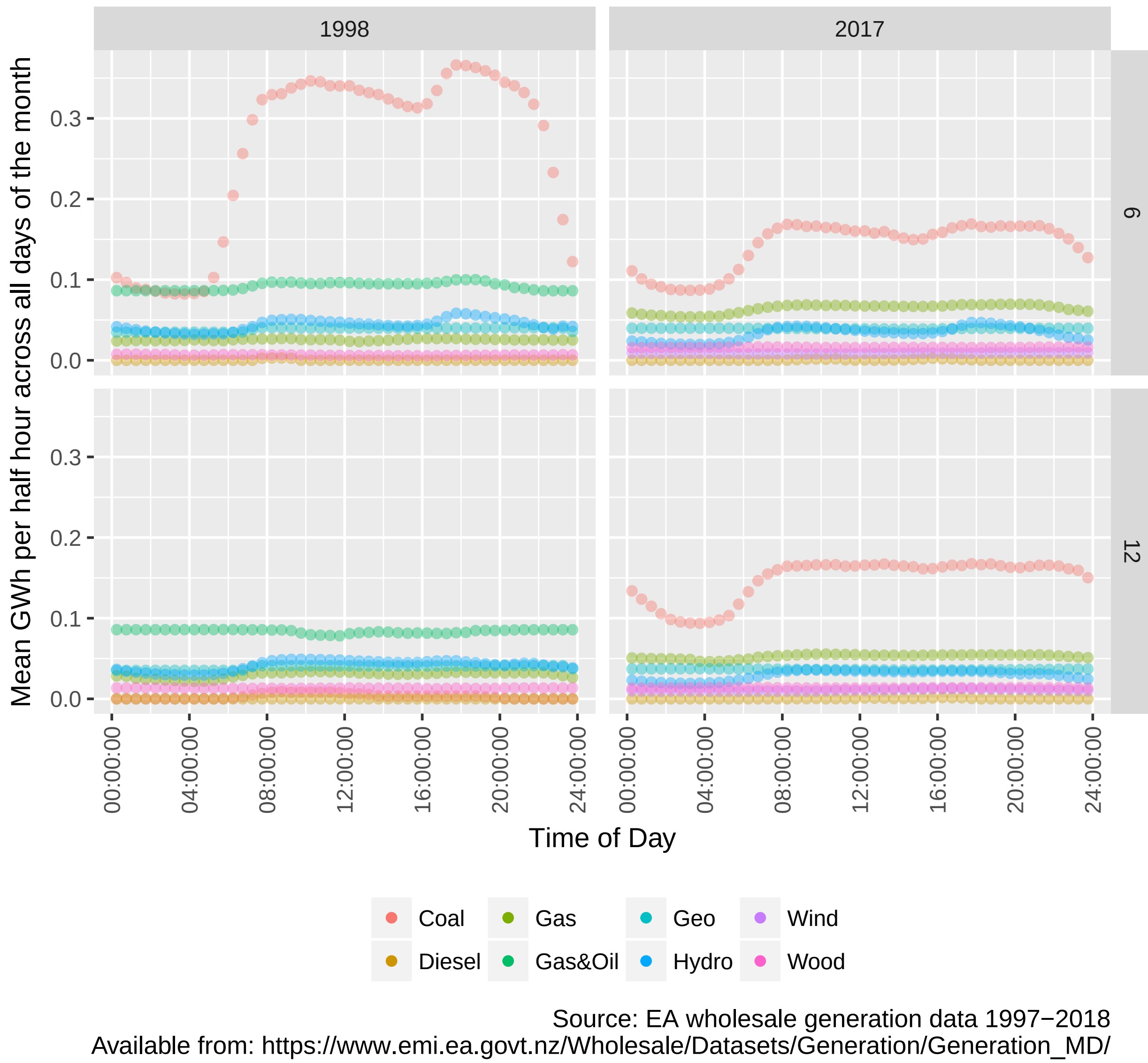
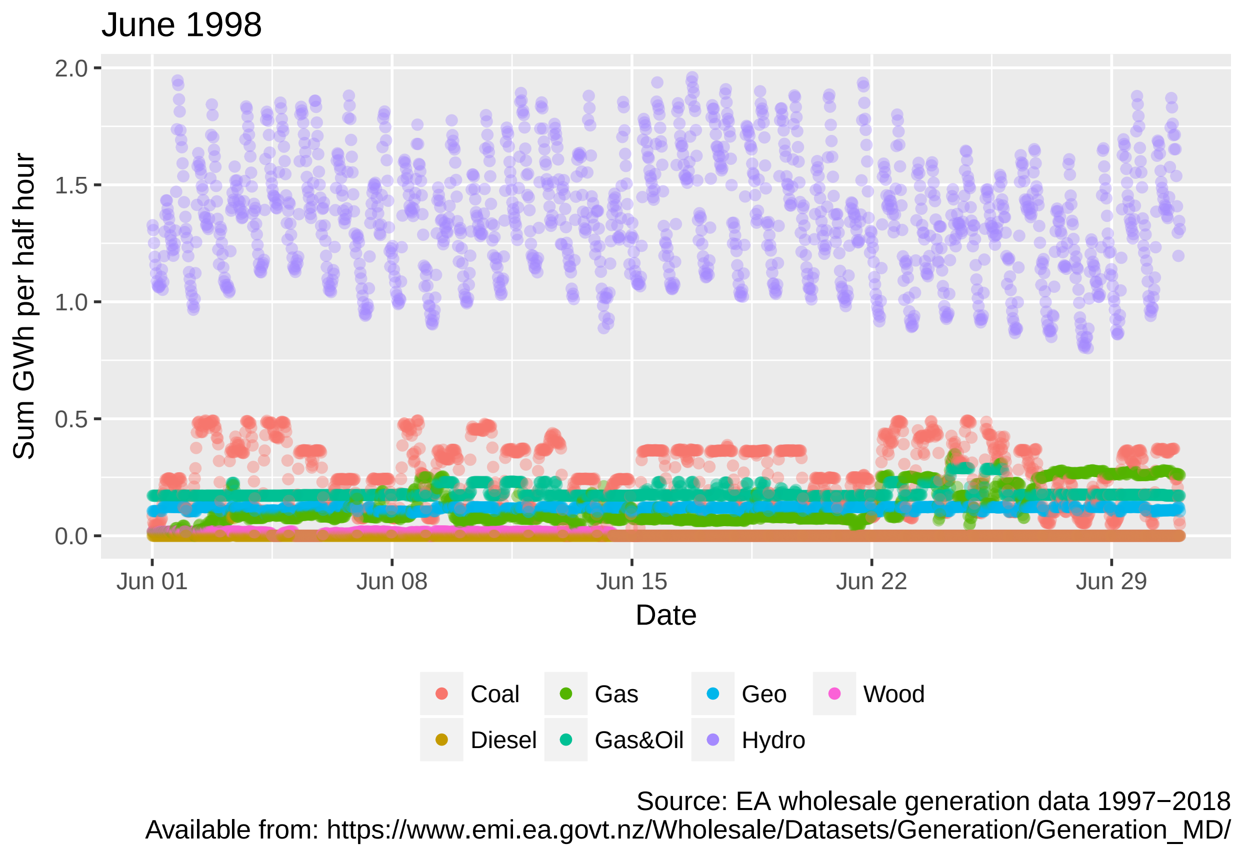
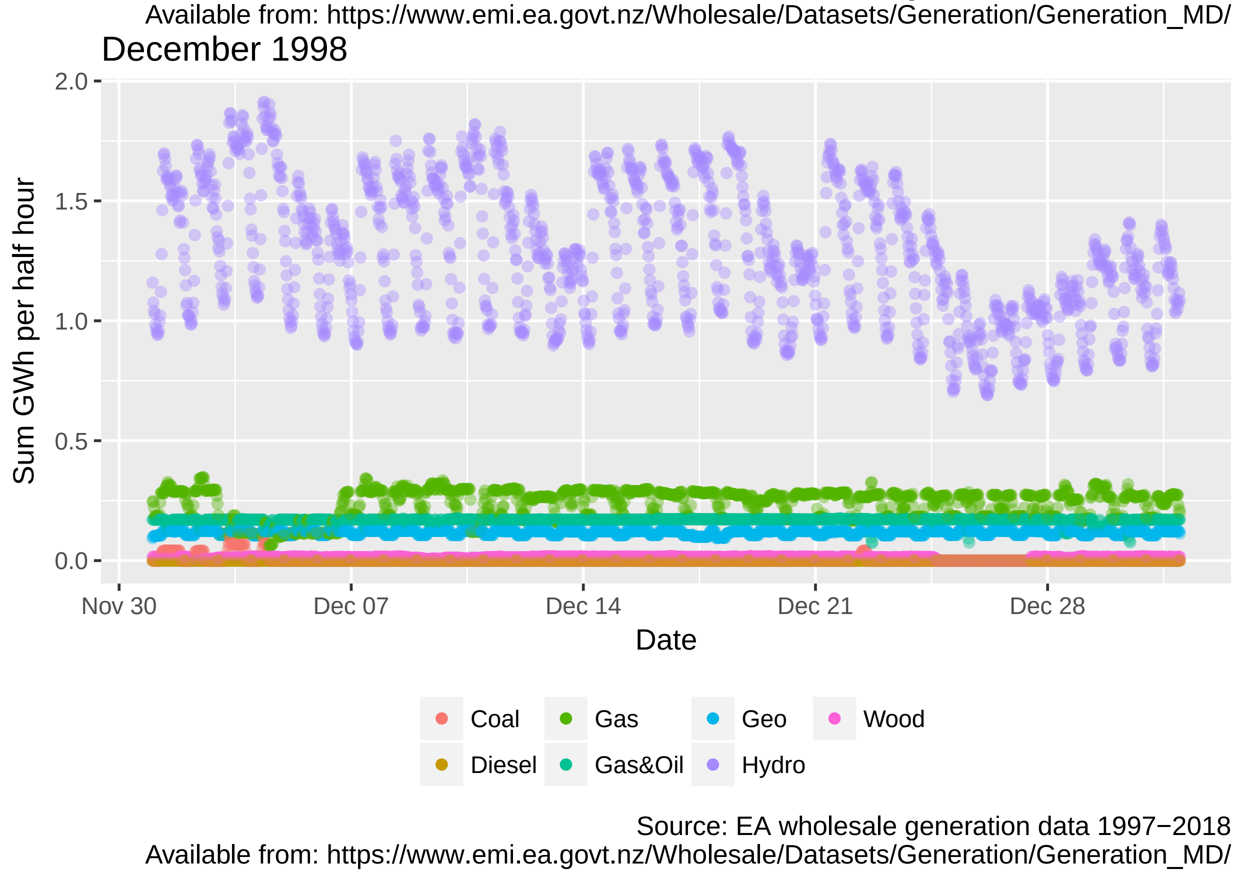
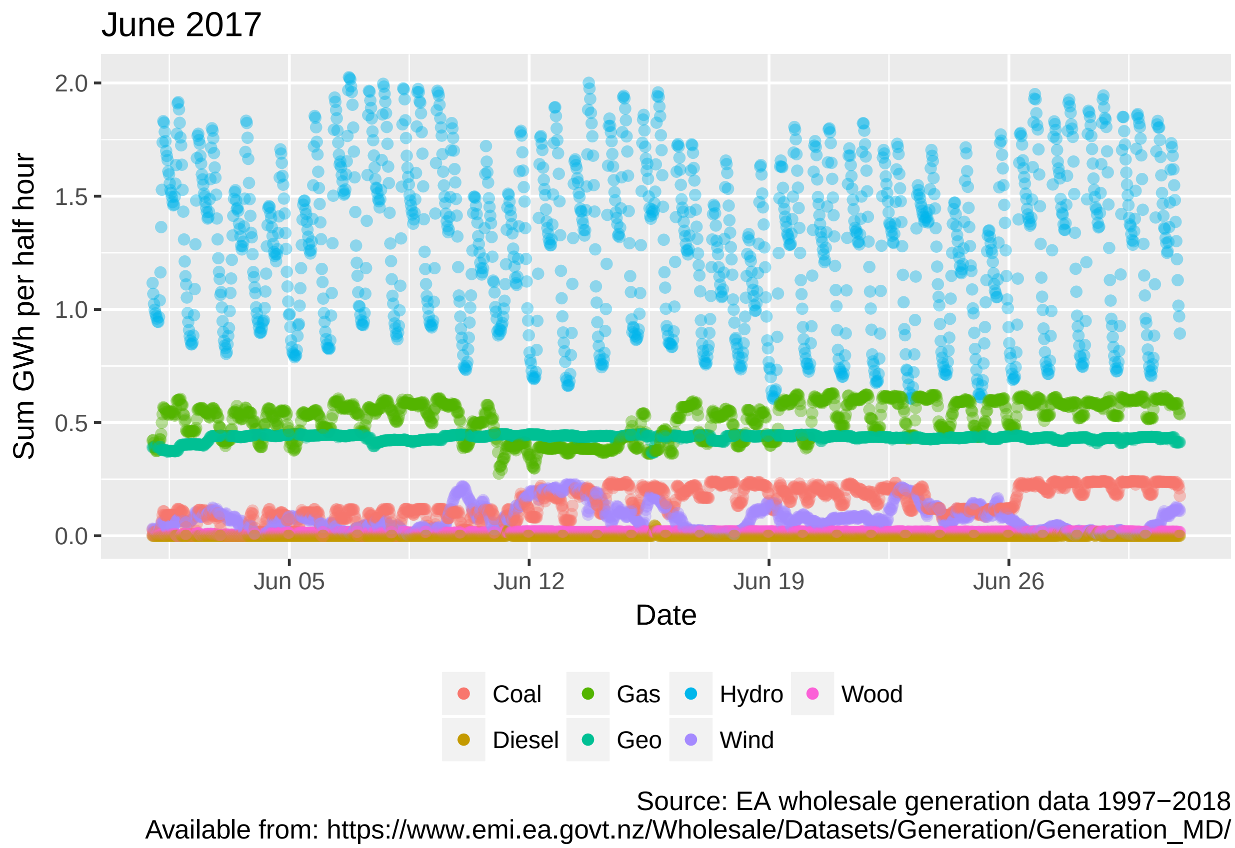


Figure 9: Half-hourly profile plot by fuel type (mean)


June 1998
Sum GWh per half hour
2.0
1.5
1.0
0.5
0.0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Date
Coal
Gas
Geo
Wood
Diesel
Gas&Oil
Hydro
Source: EA wholesale generation data 1997−2018
Available from: https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/


December 1998
Sum GWh per half hour
2.0
1.5
1.0
0.5
0.0
Nov 30
Dec 07
Dec 14
Dec 21
Dec 28
Date
Coal
Gas
Geo
Wood
Diesel
Gas&Oil
Hydro
Source: EA wholesale generation data 1997−2018
Available from: https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/



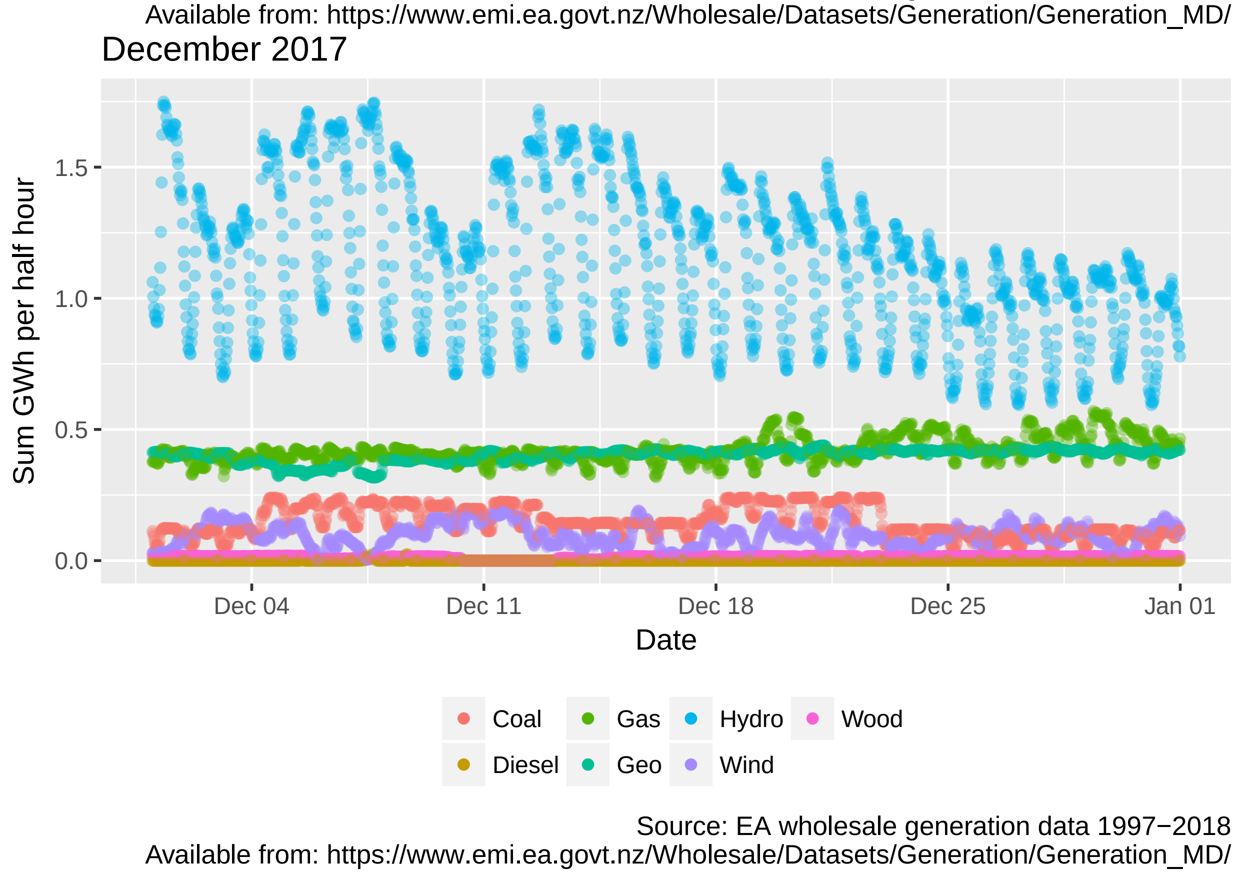
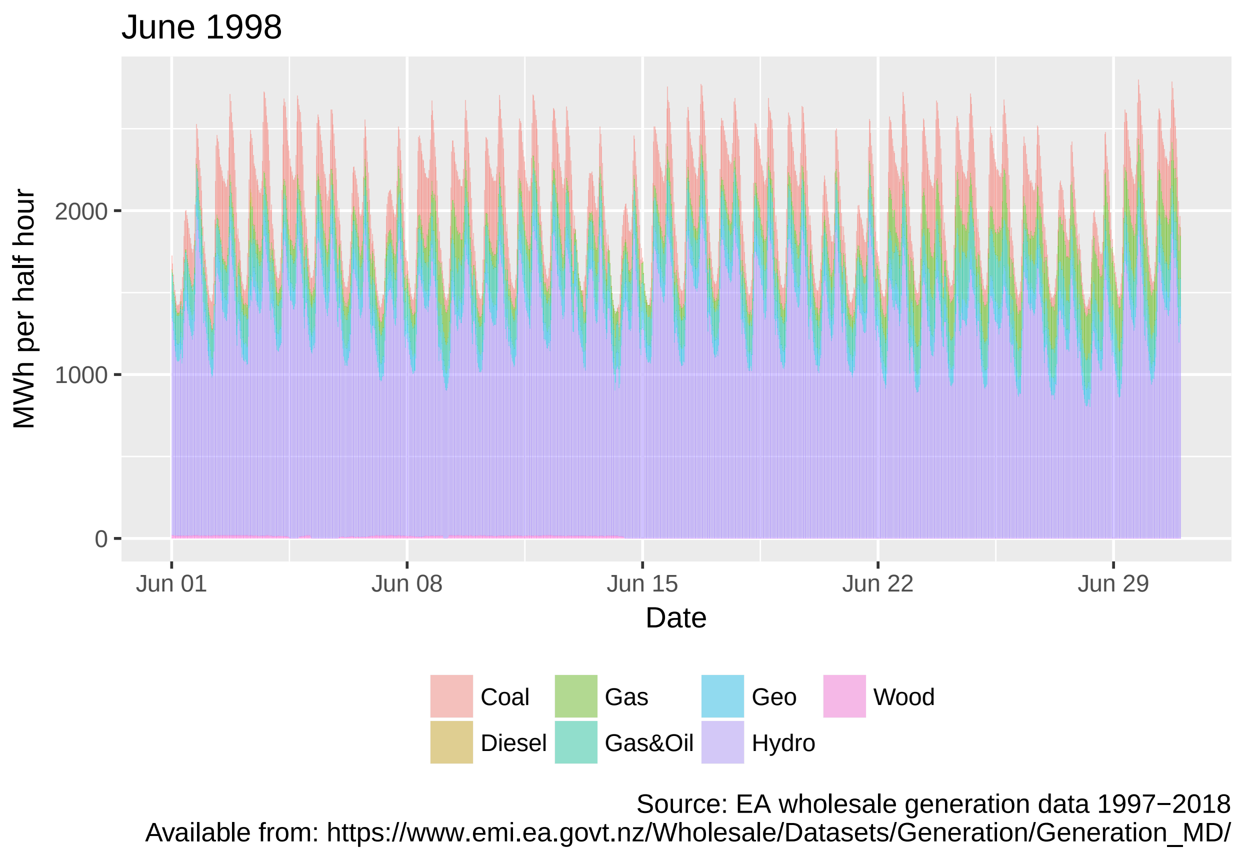
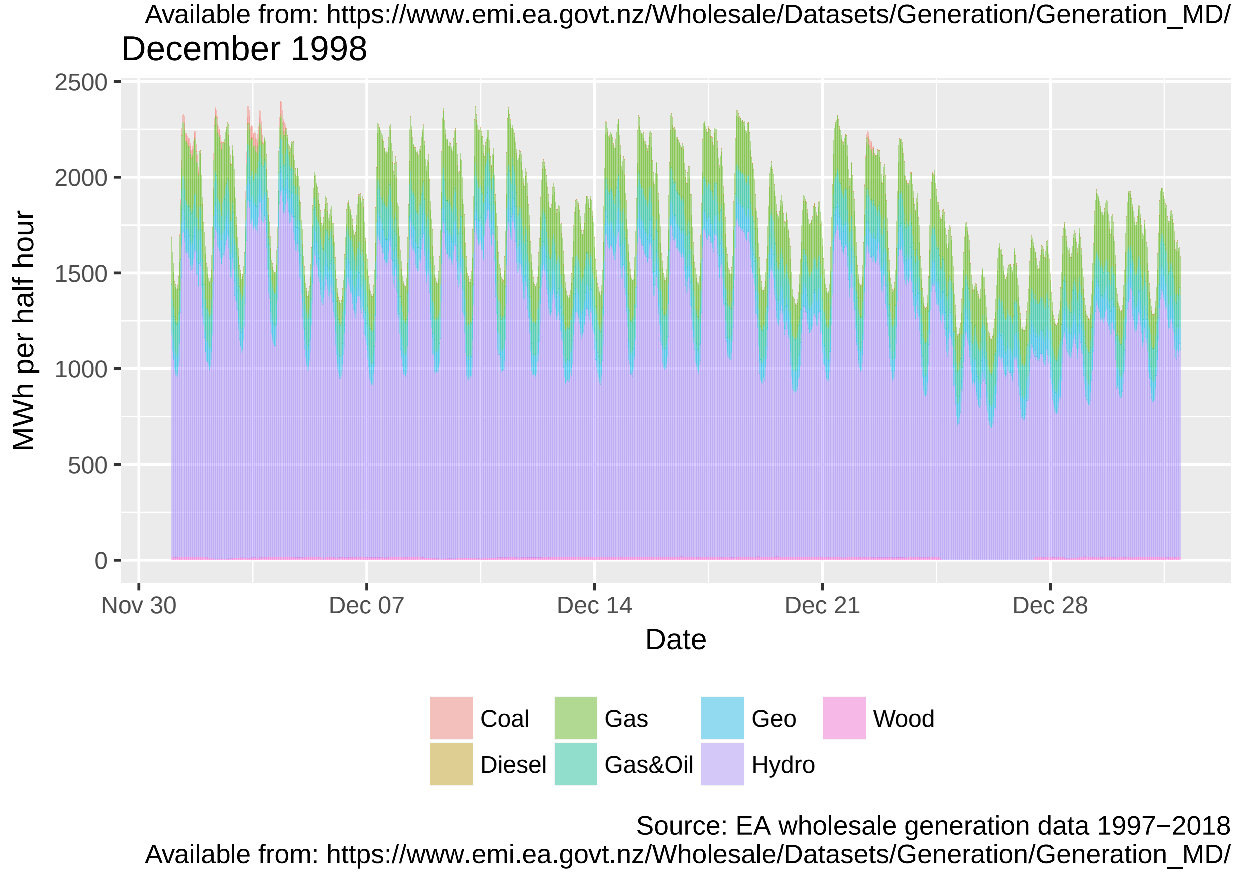
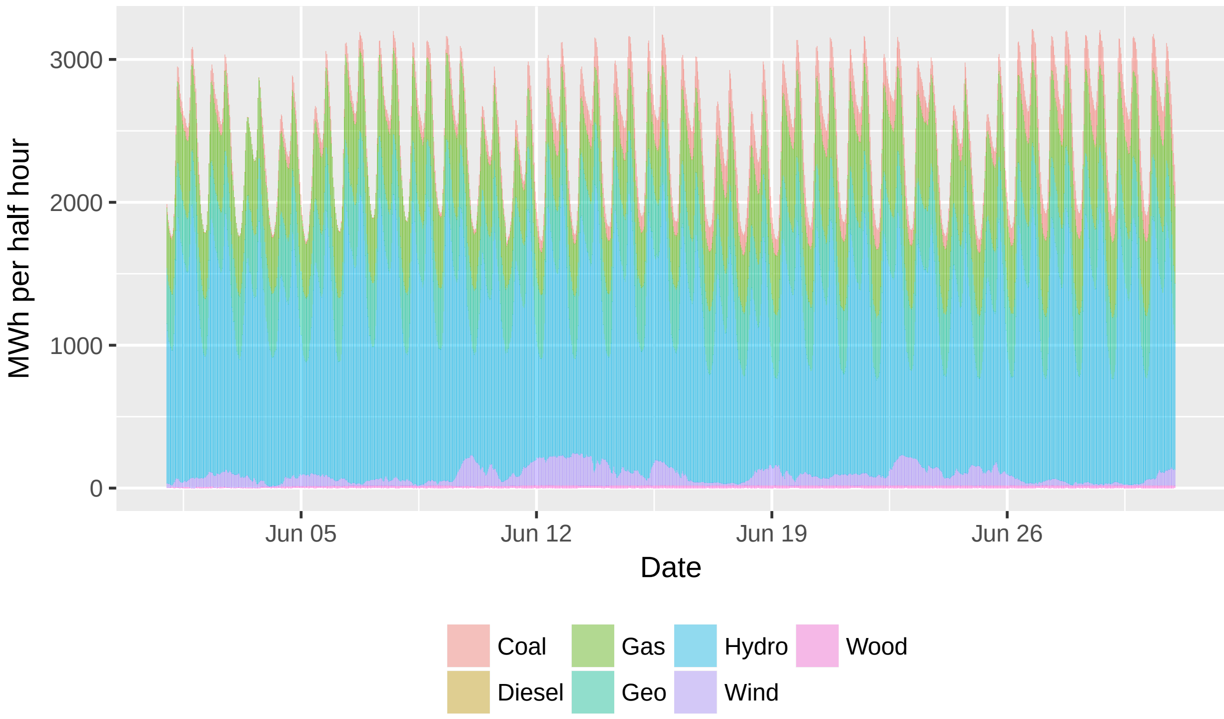


Figure **??** shows the total as a point plot while Figure **??** shows the total as stacked column plots to show the proportion of energy generation produced by each fuel.



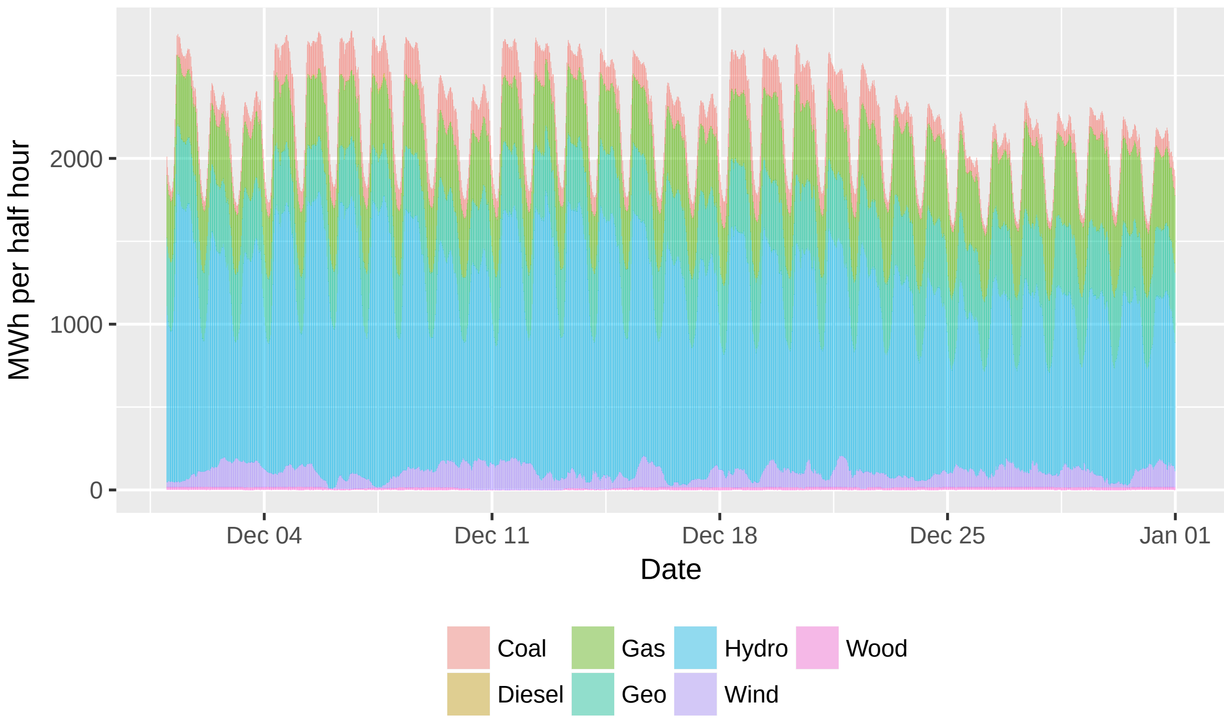


June 2017



Source: EA wholesale generation data 1997−2018
Available from: https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/

December 2017



Source: EA wholesale generation data 1997−2018
Available from: https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/

6 Analysis: Trends 1998 - 2017

Using full dataset for each day, month & year.

```
## [1] "Files loaded"
```

```
## [1] "Loaded 22,503,700 rows of data"
```

As above, in order to avoid future confusion and to save a lot of error checking we again remove NA kWh (i.e. TP49 & TP 50) from the dataset.

```
# N rows before:
nrow(allGenDT)
```

```
## [1] 22503700
```

```
# N time periods before:
uniqueN(allGenDT$Time_Period)
```

```
## [1] 50
```

```
# remove NA
allGenDT <- allGenDT[!is.na(kWh)]
# N rows after
nrow(allGenDT)
```

```
## [1] 21600076
```

```
# N time periods after:
uniqueN(allGenDT$Time_Period)
```

```
## [1] 50
```

6.1 Trends over years

Figures 10 and 11 show the dominance of hydro and decrease in coal use.

Adding annotations with information from:

- https://www.niwa.co.nz/climate/summaries/seasonal
- https://en.wikipedia.org/wiki/Huntly_Power_Station

6.2 Trends by day

Figures 12 and 13 show the same trends but using daily data to highlight seasonal patterns over time. Annotations use information from:

- https://www.niwa.co.nz/climate/summaries/seasonal
- https://en.wikipedia.org/wiki/Huntly_Power_Station

```
## Warning: Removed 217 rows containing missing values (geom_point).
```

```
## Warning: Removed 217 rows containing missing values (position_stack).
```

7 Discussion

here

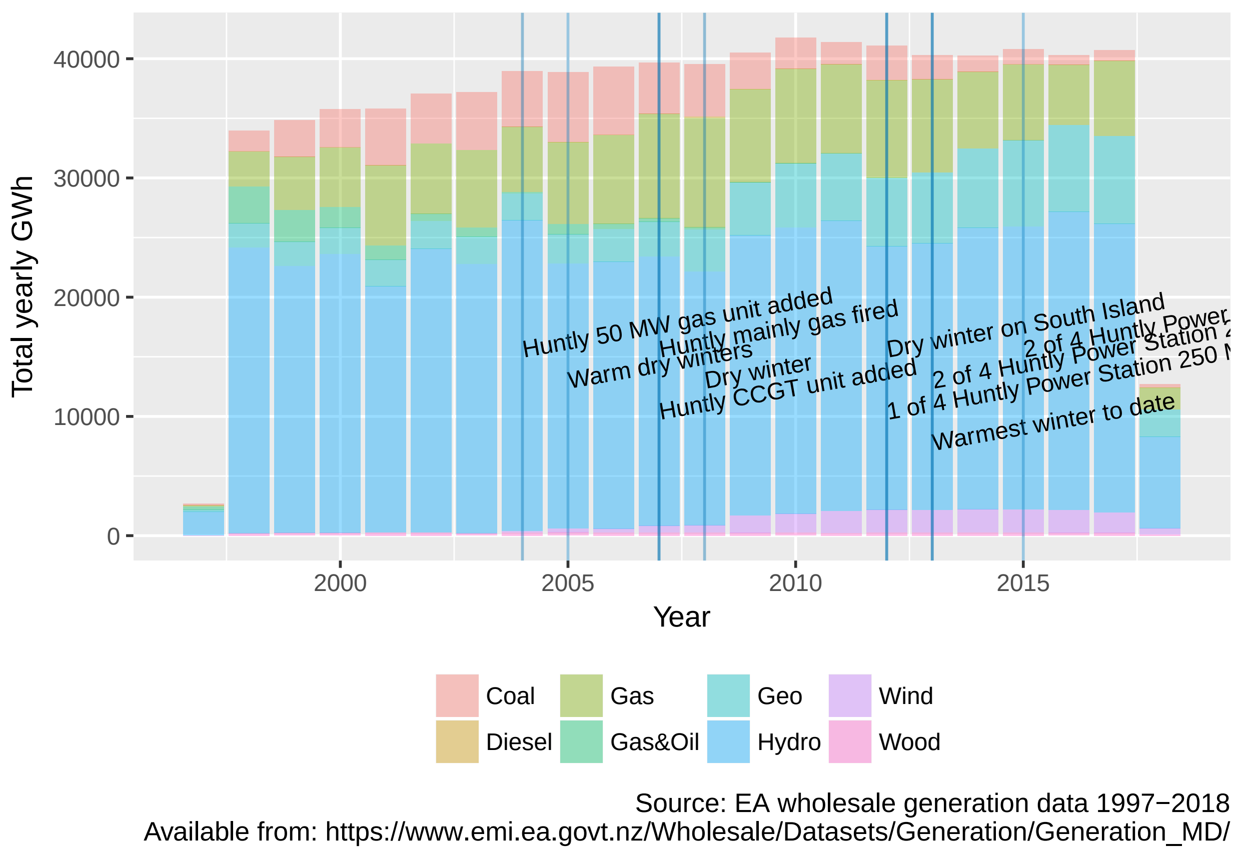
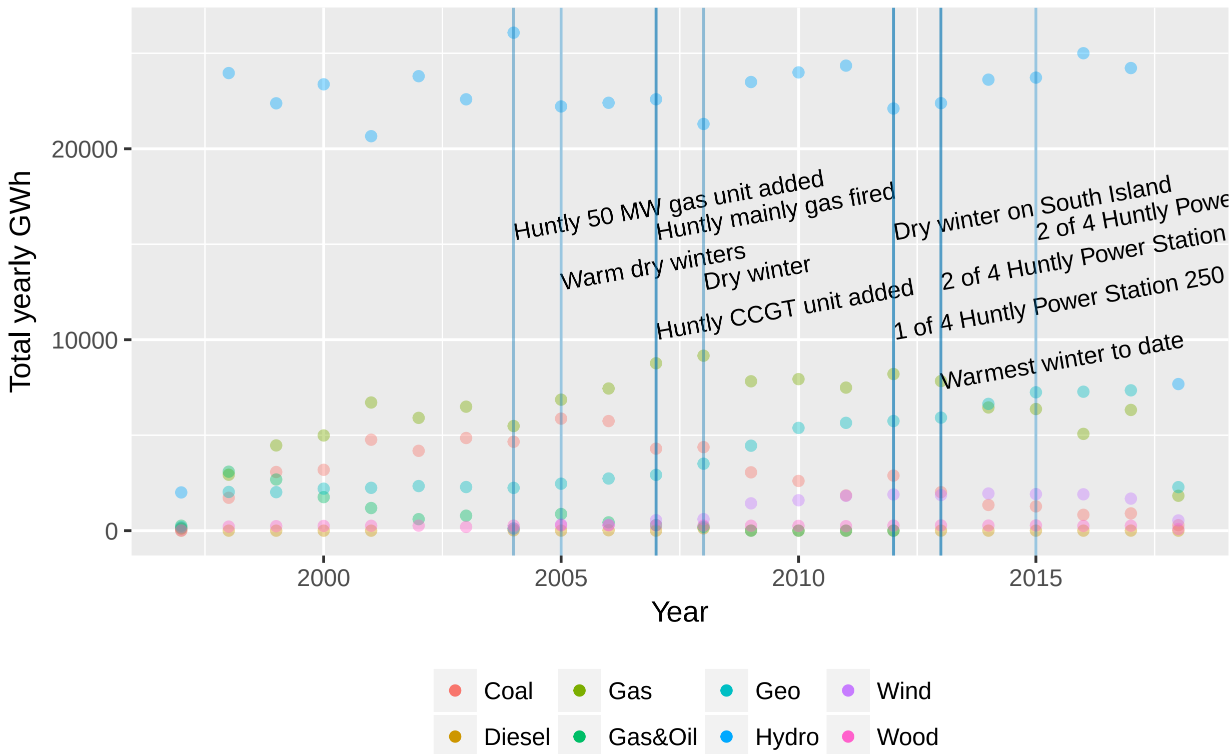


Figure 10: Yearly total plot by fuel type



Source: EA wholesale generation data 1997−2018
Available from: https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_MD/

Figure 11: Yearly total plot by fuel type

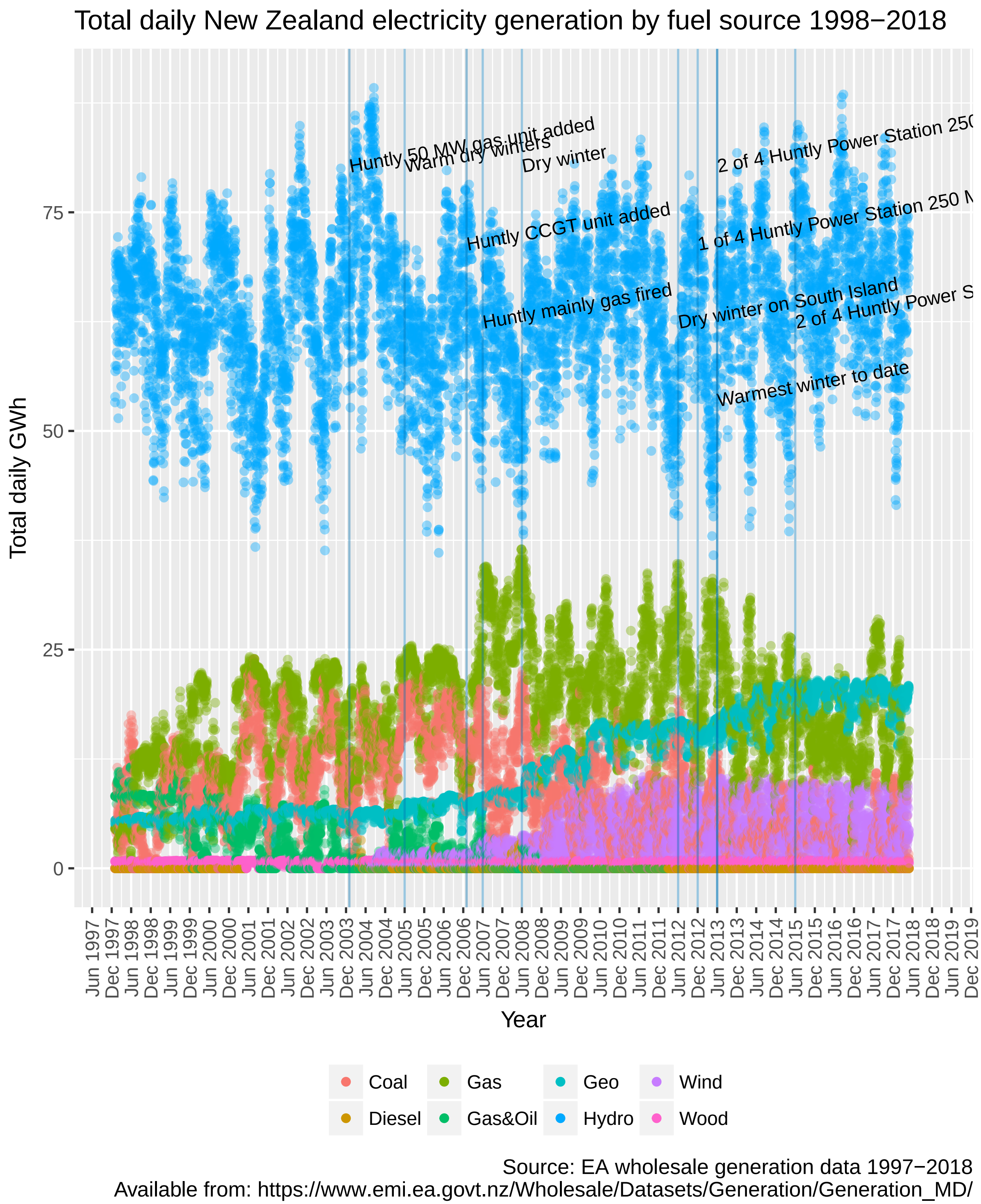


Figure 12: Yearly total plot by fuel type

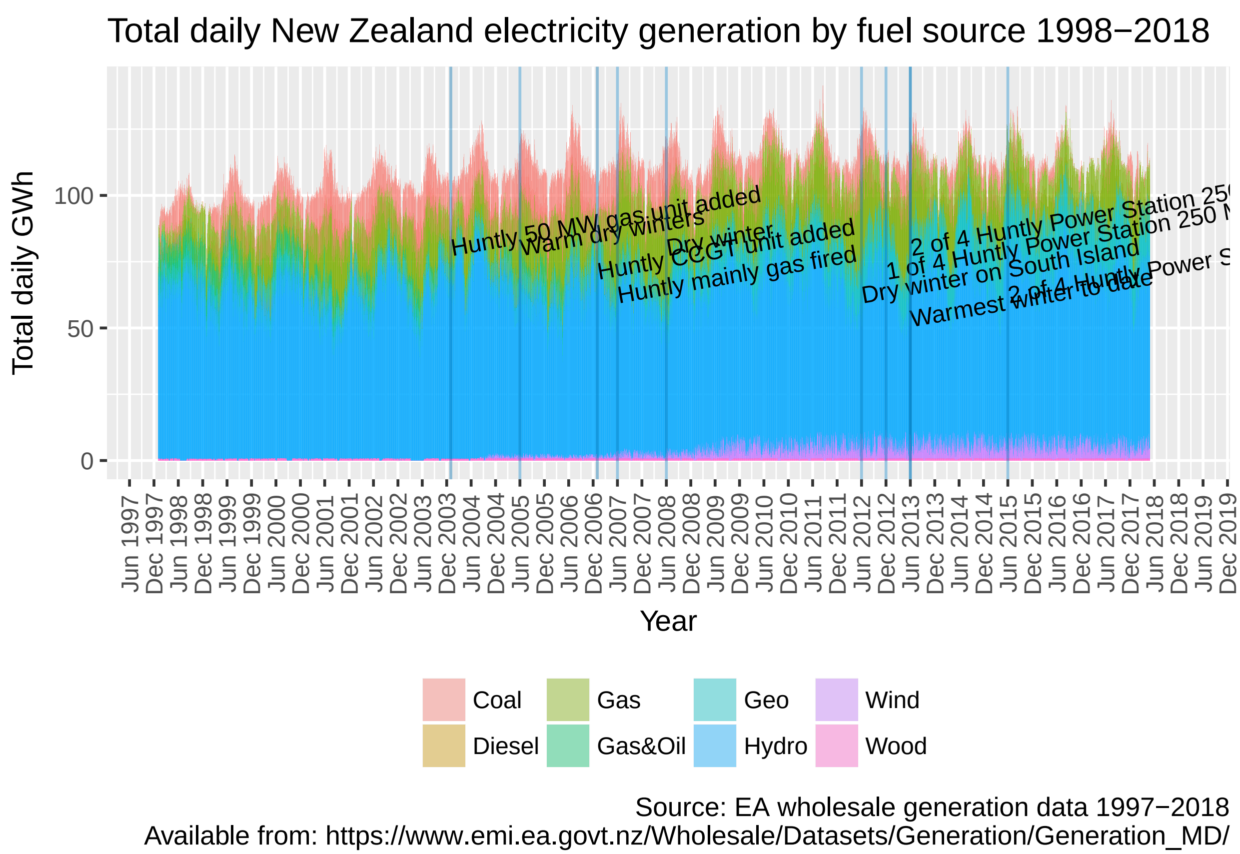


Figure 13: Yearly total plot by fuel type

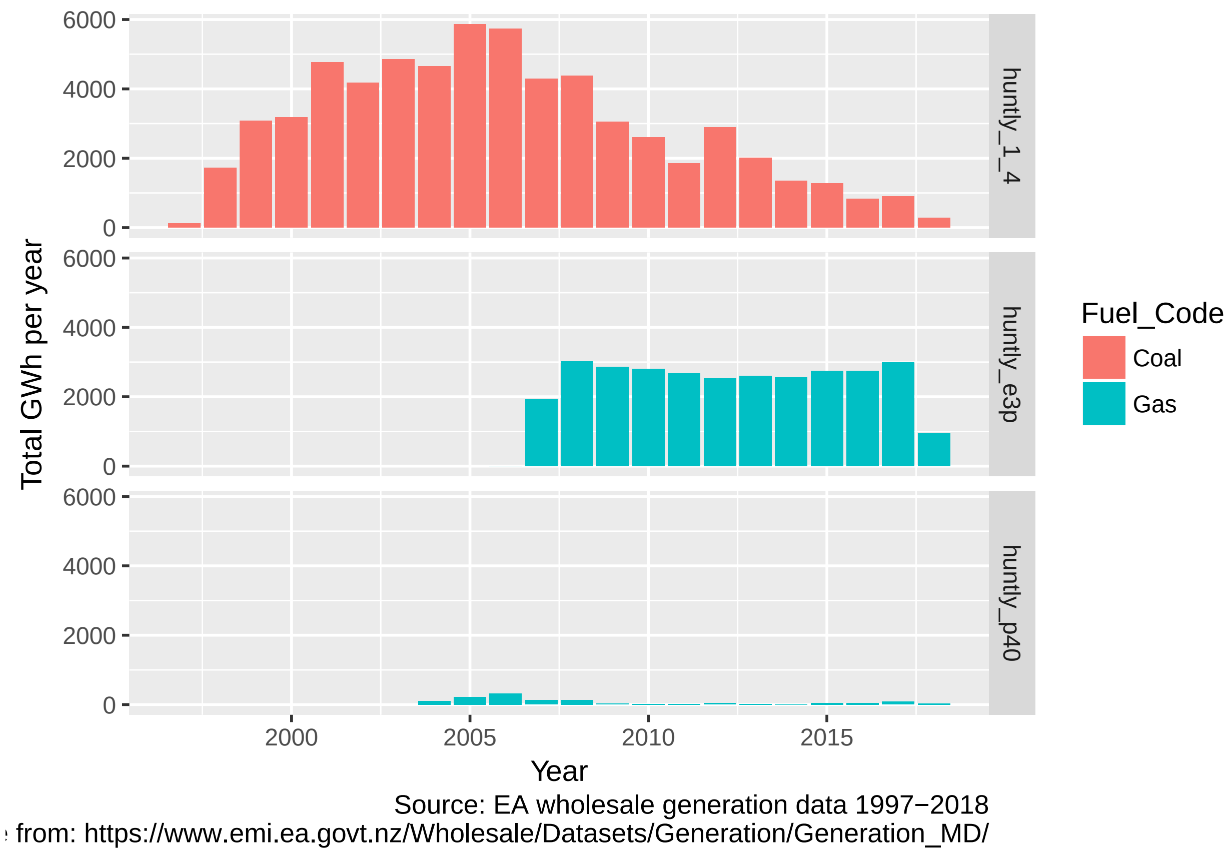


Figure 14: Huntly fuel sources

8 Conclusions

go here

8.1 Data issues

8.1.1 Huntly 1-4 Fuel source

Figure 14 shows the fuel use by each of the Huntly units over time. It appears to show that huntly_1_4 always burns coal although the units are able to also burn gas. It is not clear if this data is correct.

8.1.2 What to do about TP49 & TP50?

8.1.3 Solar & embedded generation

Should we be adding embedded generation from https://www.emi.ea.govt.nz/Wholesale/Datasets/Metered_data/Embedded_generation ?

9 Runtime

Analysis completed in 469.32 seconds (7.82 minutes) using knitr in RStudio with R version 3.5.0 (2018-04-23) running on x86_64-apple-darwin15.6.0.

10 R environment

R packages used:

- base R - for the basics (R Core Team 2016)
- data.table - for fast (big) data handling (Dowle et al. 2015)
- lubridate - date manipulation (Grolemund and Wickham 2011)
- ggplot2 - for slick graphics (Wickham 2009)
- readr - for csv reading/writing (Wickham, Hester, and Francois 2016)
- Hmisc - for describe (Harrell Jr, Charles Dupont, and others. 2016)
- knitr - to create this document & neat tables (Xie 2016b)
- bookdown - for additional markdown (Xie 2016a)
- nzGREENGrid - for local NZ GREEN Grid project utilities

Session info:

```
## R version 3.5.0 (2018-04-23)
## Platform: x86_64-apple-darwin15.6.0 (64-bit)
## Running under: macOS High Sierra 10.13.5
##
## Matrix products: default
## BLAS: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_GB.UTF-8/en_GB.UTF-8/en_GB.UTF-8/C/en_GB.UTF-8/en_GB.UTF-8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] knitr_1.20        Hmisc_4.1-1       Formula_1.2-3
##  [4] survival_2.42-3   lattice_0.20-35   skimr_1.0.3
##  [7] readr_1.1.1       ggplot2_2.2.1     dplyr_0.7.5
## [10] data.table_1.11.4 nzGREENGrid_0.1.0
##
## loaded via a namespace (and not attached):
##  [1] progress_1.2.0      tidyselect_0.2.4    xfun_0.1
##  [4] reshape2_1.4.3      purrr_0.2.5         splines_3.5.0
##  [7] colorspace_1.3-2    htmltools_0.3.6     yaml_2.1.19
## [10] base64enc_0.1-3     utf8_1.1.4          rlang_0.2.1
## [13] pillar_1.2.3        foreign_0.8-70      glue_1.2.0
## [16] RColorBrewer_1.1-2  bindrcpp_0.2.2      bindr_0.1.1
## [19] plyr_1.8.4          stringr_1.3.1       munsell_0.5.0
## [22] gtable_0.2.0        htmlwidgets_1.2     evaluate_0.10.1
## [25] labeling_0.3        latticeExtra_0.6-28 highr_0.7
## [28] htmlTable_1.12      Rcpp_0.12.17        acepack_1.4.1
## [31] checkmate_1.8.5     backports_1.1.2     scales_0.5.0
## [34] gridExtra_2.3       hms_0.4.2           digest_0.6.15
```

```
## [37] stringi_1.2.3      bookdown_0.7       grid_3.5.0
## [40] rprojroot_1.3-2    cli_1.0.0          tools_3.5.0
## [43] magrittr_1.5       lazyeval_0.2.1     tibble_1.4.2
## [46] cluster_2.0.7-1    crayon_1.3.4       pkgconfig_2.0.1
## [49] Matrix_1.2-14      prettyunits_1.0.2  lubridate_1.7.4
## [52] assertthat_0.2.0   rmarkdown_1.10     rstudioapi_0.7
## [55] R6_2.2.2           rpart_4.1-13       nnet_7.3-12
## [58] compiler_3.5.0
```

References

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