ENV 790.30 - Time Series Analysis for Energy Data | Spring 2025

Assignment 3 - Due date 02/04/25

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Directions

Then you will start working through the assignment by **creating code and output** that answer each question. Be sure to use this assignment document. Your report should contain the answer to each question and any plots/tables you obtained (when applicable).

Please keep this R code chunk options for the report. It is easier for us to grade when we can see code and output together. And the tidy.opts will make sure that line breaks on your code chunks are automatically added for better visualization.

When you have completed the assignment, **Knit** the text and code into a single PDF file.

Questions

Consider the same data you used for A2 from the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumpti The data comes from the US Energy Information and Administration and corresponds to the December 2024 **Monthly** Energy Review. Once again you will work only with the following columns: Total Renewable Energy Production and Hydroelectric Power Consumption. Create a data frame structure with these two time series only.

R packages needed for this assignment:"forecast","tseries", and "Kendall". Install these packages, if you haven't done yet. Do not forget to load them before running your script, since they are NOT default packages.\

```r
#Load/install required package here
library(tseries)
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```r
library(Kendall)
library(forecast)
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(dplyr)
library(ggplot2)
library(cowplot)
```

```
##
## Attaching package: 'cowplot'
##
## The following object is masked from 'package:lubridate':
##
##     stamp
```

```
library(readxl)
```

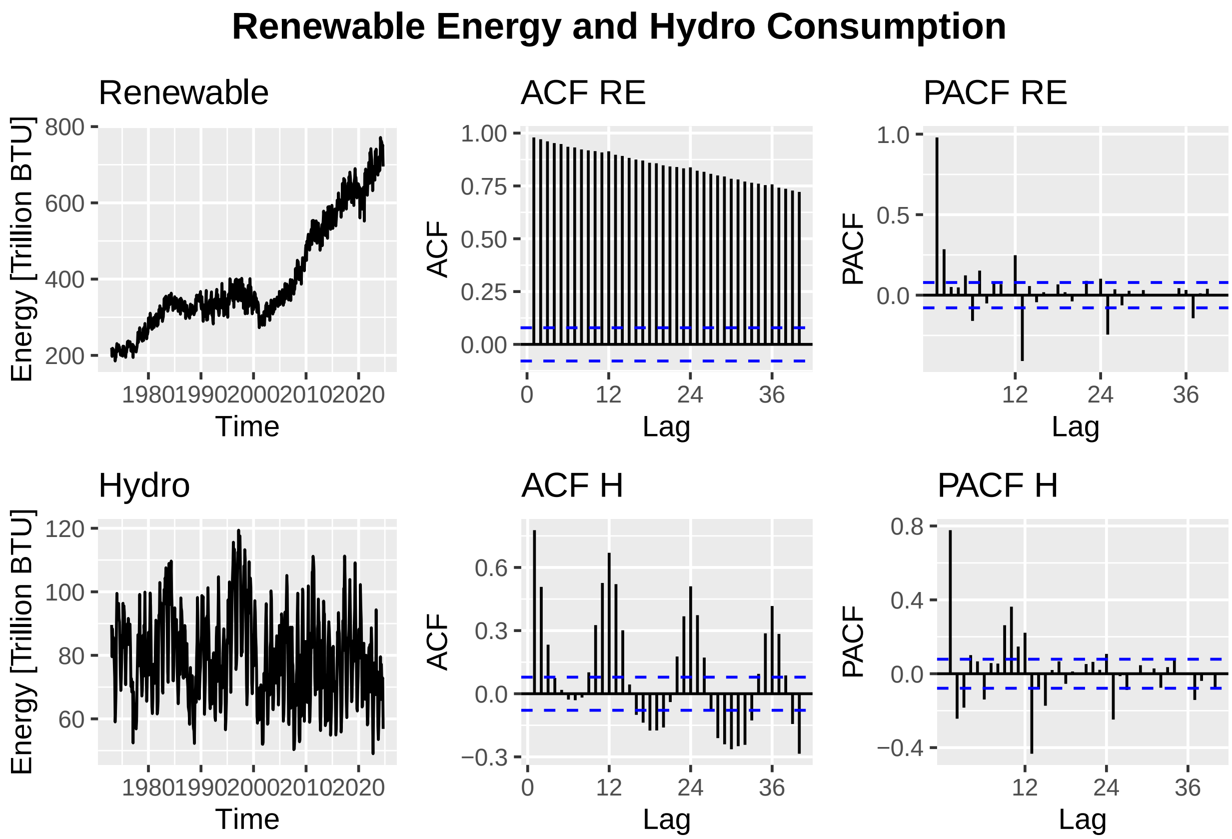
##Trend Component

Q1

For each time series, i.e., Renewable Energy Production and Hydroelectric Consumption create three plots: one with time series, one with the ACF and with the PACF. You may use the some code form A2, but I want all the three plots side by side as in a grid. (Hint: use function `plot_grid()` from the `cowplot` package)

```
# Load the data
Table_10_1_Renewable_Energy_Production_and_Consumption_by_Source <- read_excel(
  "~/ENV797/Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.xlsx",
  skip = 9)
Energy_df <-
  Table_10_1_Renewable_Energy_Production_and_Consumption_by_Source[-1, ]
# Select the relevant columns and convert to numeric
selected_energy <- Energy_df %>%
  select(4,5,6)
selected_energy <- as.data.frame(lapply(selected_energy, as.numeric))
# Create the time series object
energy_ts <- ts(selected_energy[,2:3], start = c(1973, 1), frequency = 12)

#H or Hydro = hydroelectric power consumption
#RE stands for renewable energy production

# Time series plots
ts_renewable <- autoplot(energy_ts[,1], main = "Renewable") +
  ylab("Energy [Trillion BTU]")
ts_hydro <- autoplot(energy_ts[,2], main = "Hydro")+
  ylab("Energy [Trillion BTU]")


# ACF plots
acf_renewable <- Acf(energy_ts[,1], lag.max = 40,
                     main = "ACF of Total Renewable Energy Production",
```

```r
                     plot = FALSE)
acf_hydro <- Acf(energy_ts[,2], lag.max = 40,
                 main = "ACF of Hydroelectric Power Consumption",
                 plot = FALSE)

# PACF plots
pacf_renewable <- Pacf(energy_ts[,1], lag.max = 40,
                       main = "PACF of Total Renewable Energy Production",
                       plot = FALSE)
pacf_hydro <- Pacf(energy_ts[,2], lag.max = 40,
                   main = "PACF of Hydroelectric Power Consumption",
                   plot = FALSE)


#ACTUAL ACF PLOTS
acf_renewable_plot <- autoplot(Acf(energy_ts[,1], lag.max = 40,
                                   main = "ACF of Total Renewable Energy Production",
                                   plot = FALSE))+
  ggtitle("ACF RE")
acf_hydro_plot <- autoplot(Acf(energy_ts[,2], lag.max = 40,
                               main = "ACF of Hydroelectric Power Consumption",
                               plot = FALSE))+
  ggtitle("ACF H")


#ACTUAL PACF PLOTS
pacf_renewable_plot <- autoplot(Pacf(energy_ts[,1], lag.max = 40,
                                     main = "PACF of Total Renewable Energy Production",
                                     plot = FALSE))+
  ggtitle("PACF RE")
pacf_hydro_plot <- autoplot(Pacf(energy_ts[,2], lag.max = 40,
                                 main = "PACF of Hydroelectric Power Consumption",
                                 plot = FALSE))+
  ggtitle("PACF H")




combinedplot<- plot_grid(ts_renewable, acf_renewable_plot,
                         pacf_renewable_plot,
                         ts_hydro, acf_hydro_plot, pacf_hydro_plot,
                         nrow = 2, ncol = 3)
title <- ggdraw() + draw_label ("Renewable Energy and Hydro Consumption",
                                fontface = 'bold')
plot_grid(title, combinedplot, nrow = 2, ncol = 1, rel_heights = c(0.1,1))
```



Q2

From the plot in Q1, do the series Total Renewable Energy Production and Hydroelectric Power Consumption appear to have a trend? If yes, what kind of trend?

<Looking at the Q1 plots, I can tell from the rises and falls of the hydroelectric time series plot and and the acf plot that there is some sort of short-term trend that is represetned in the data. I assume that this may be seasonal data. As for the renewable energy production, there does not seem to be a seasonal trend, but there is a steady rise in energy consumption over time, so there may be just a general upward trend.

Q3

Use the *lm()* function to fit a linear trend to the two time series. Ask R to print the summary of the regression. Interpret the regression output, i.e., slope and intercept. Save the regression coefficients for further analysis.

```
# Create time variable
nobs <- length(energy_ts[,1])
t <- 1:nobs

# Fit linear trend to renewable
linear_model_renewable <- lm(energy_ts[,1] ~ t)
summary(linear_model_renewable)
```

```
##
```

```
## Call:
## lm(formula = energy_ts[, 1] ~ t)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -151.11  -37.84   13.53   41.76  149.42
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 176.87293    4.96189   35.65   <2e-16 ***
## t             0.72393    0.01382   52.37   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 61.75 on 619 degrees of freedom
## Multiple R-squared:  0.8159, Adjusted R-squared:  0.8156
## F-statistic:  2743 on 1 and 619 DF,  p-value: < 2.2e-16
```

```r
beta0_renewable <- as.numeric(linear_model_renewable$coefficients[1])
beta1_renewable <- as.numeric(linear_model_renewable$coefficients[2])

# Fit linear trend to hydro
linear_model_hydro <- lm(energy_ts[,2] ~ t)
summary(linear_model_hydro)
```

```
##
## Call:
## lm(formula = energy_ts[, 2] ~ t)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.995 -10.422  -0.720   9.161  39.624
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 82.96766    1.12339  73.855  < 2e-16 ***
## t           -0.01098    0.00313  -3.508 0.000485 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.98 on 619 degrees of freedom
## Multiple R-squared:  0.01949,    Adjusted R-squared:  0.01791
## F-statistic:  12.3 on 1 and 619 DF,  p-value: 0.0004848
```

```r
beta0_hydro <- as.numeric(linear_model_hydro$coefficients[1])
beta1_hydro <- as.numeric(linear_model_hydro$coefficients[2])


# Print the regression coefficients
print(paste("Renewable Energy Production Intercept:", beta0_renewable))
```

```
## [1] "Renewable Energy Production Intercept: 176.872926383045"
```

```r
print(paste("Renewable Energy Production Slope:", beta1_renewable))
```

```
## [1] "Renewable Energy Production Slope: 0.723934871750931"
```

```r
print(paste("Hydroelectric Power Consumption Intercept:", beta0_hydro))
```

```
## [1] "Hydroelectric Power Consumption Intercept: 82.9676654147837"
```

```r
print(paste("Hydroelectric Power Consumption Slope:", beta1_hydro))
```

```
## [1] "Hydroelectric Power Consumption Slope: -0.0109773377789202"
```

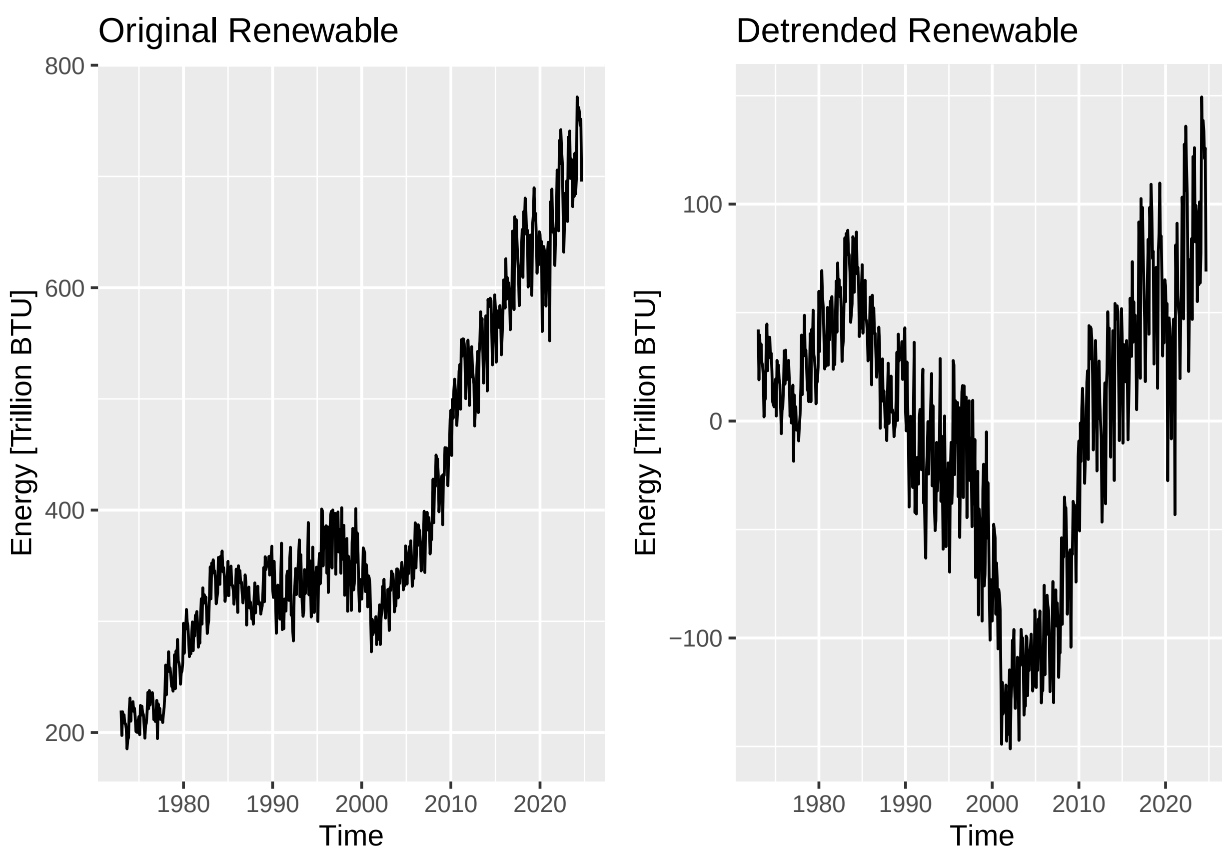
< The intercepts for this data are 177 trillion btu for renewable and 83 trillion btu for hydro, meaning that when time for the plot is just starting (1973), this is where the data starts at these values. < The slope for renewable is 0.72, meaning there is an increase in the renewable energy production over time. There is a -0.01 slope for hydroelectric consumption, meaning there is a very slight decrease over time for hydroelectric power consumption over time.

Q4

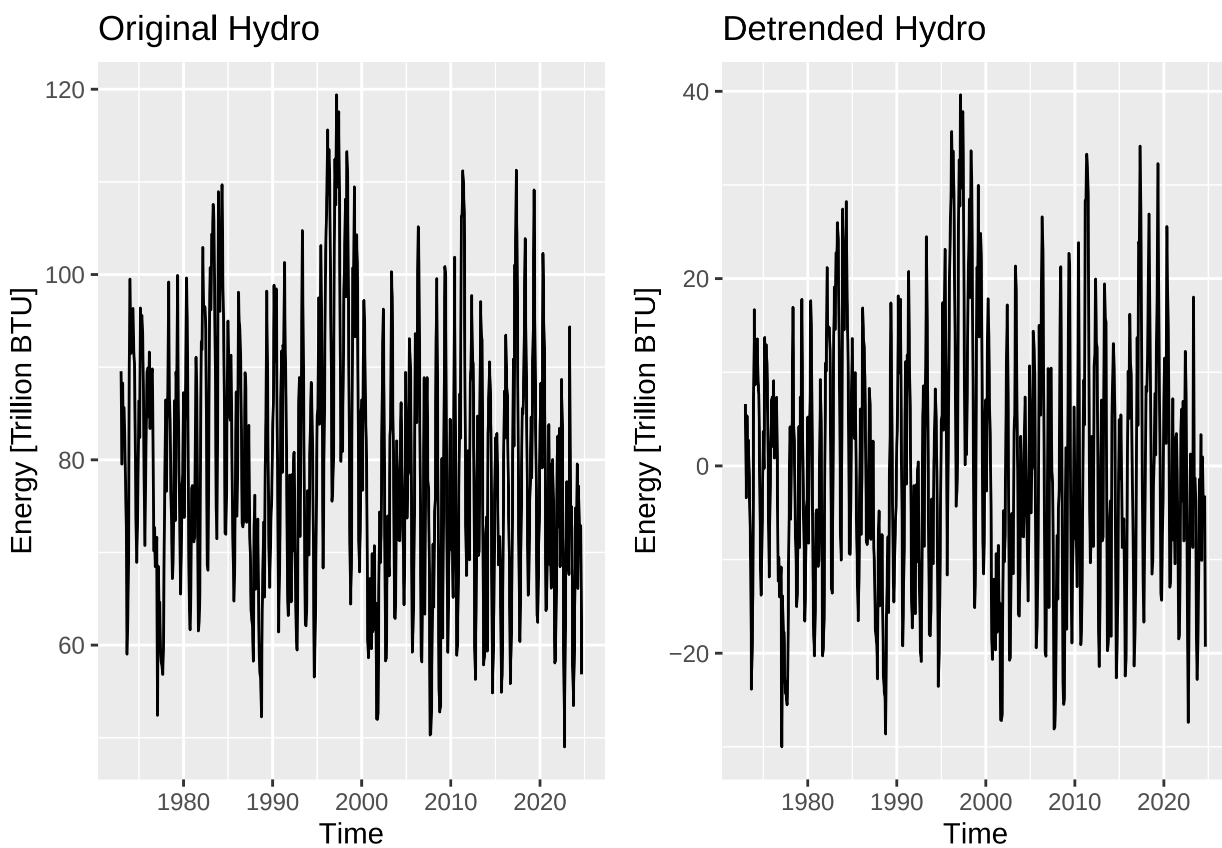
Use the regression coefficients from Q3 to detrend the series. Plot the detrended series and compare with the plots from Q1. What happened? Did anything change?

```r
#H or Hydro = hydroelectric power consumption
#RE stands for renewable energy production

linear_trend_hydro <- beta0_hydro + beta1_hydro * t
detrended_hydro <- energy_ts[,2] - linear_trend_hydro

linear_trend_renewable <- beta0_renewable + beta1_renewable * t
detrended_renewable <- energy_ts[,1] - linear_trend_renewable

ts_detrended_hydro <- ts(detrended_hydro, start = c(1973,1), frequency = 12)
ts_detrended_renewable <- ts(detrended_renewable, start = c(1973,1), frequency = 12)
# Plot original and detrended renewable
 plot_original_renewable <- autoplot(energy_ts[,1], main = "Original Renewable")+
                                      ylab("Energy [Trillion BTU]")

 plot_detrended_renewable <- autoplot(ts_detrended_renewable,
                                      main = "Detrended Renewable")+
                                      ylab("Energy [Trillion BTU]")

 # Plot original and detrended hydro
 plot_original_hydro <- autoplot(energy_ts[,2], main =
                                   "Original Hydro")+
   ylab("Energy [Trillion BTU]")

 plot_detrended_hydro <- autoplot(ts_detrended_hydro, main =
                                    "Detrended Hydro")+
   ylab("Energy [Trillion BTU]")
```

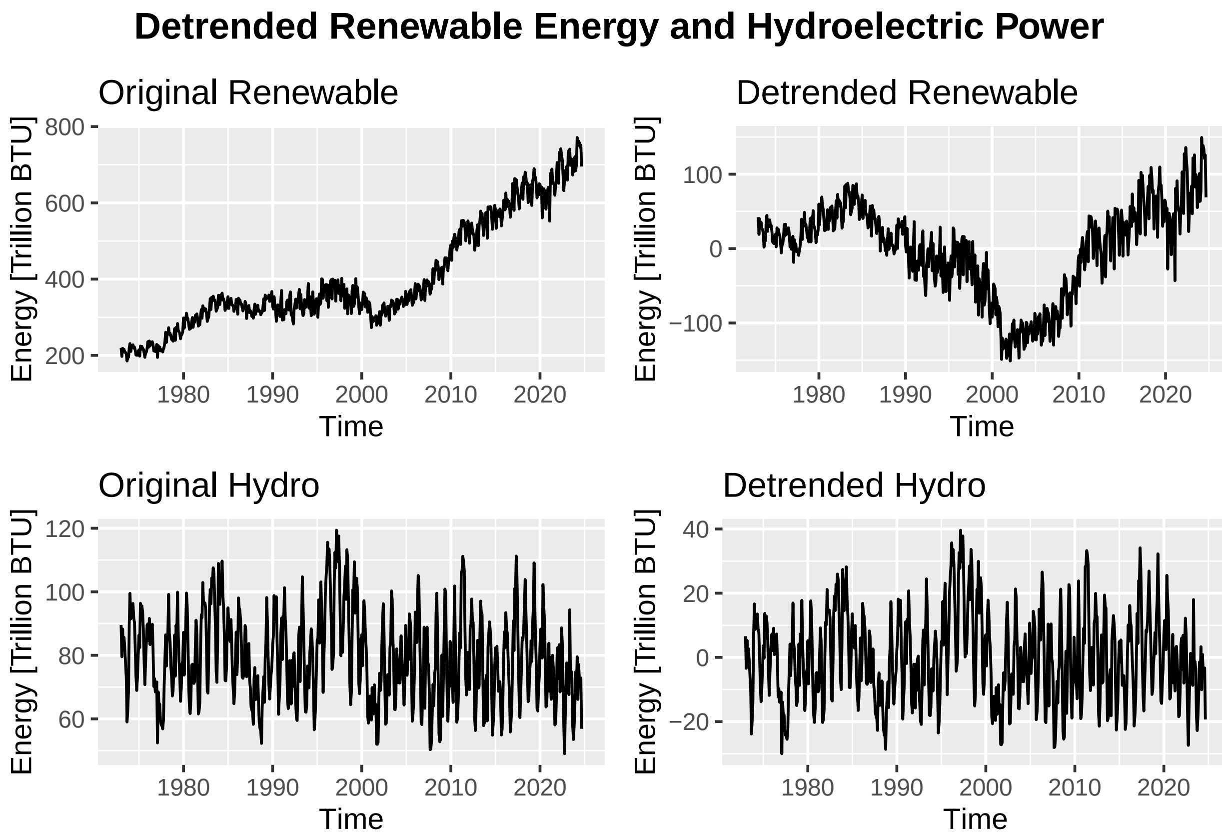
```r
plot_grid(plot_original_renewable, plot_detrended_renewable, ncol = 2)
```




```r
plot_grid(plot_original_hydro, plot_detrended_hydro, ncol = 2)
```




```r
detrended_combined_plot<- plot_grid(plot_original_renewable,
                                    plot_detrended_renewable,
                                    plot_original_hydro,
                                    plot_detrended_hydro,
                                    nrow = 2,
                                    ncol = 2)
title <- ggdraw() + draw_label ("Detrended Renewable Energy and Hydroelectric Power",
                                fontface = 'bold')
plot_grid(title, detrended_combined_plot, nrow = 2, ncol = 1, rel_heights = c(0.1,1))
```

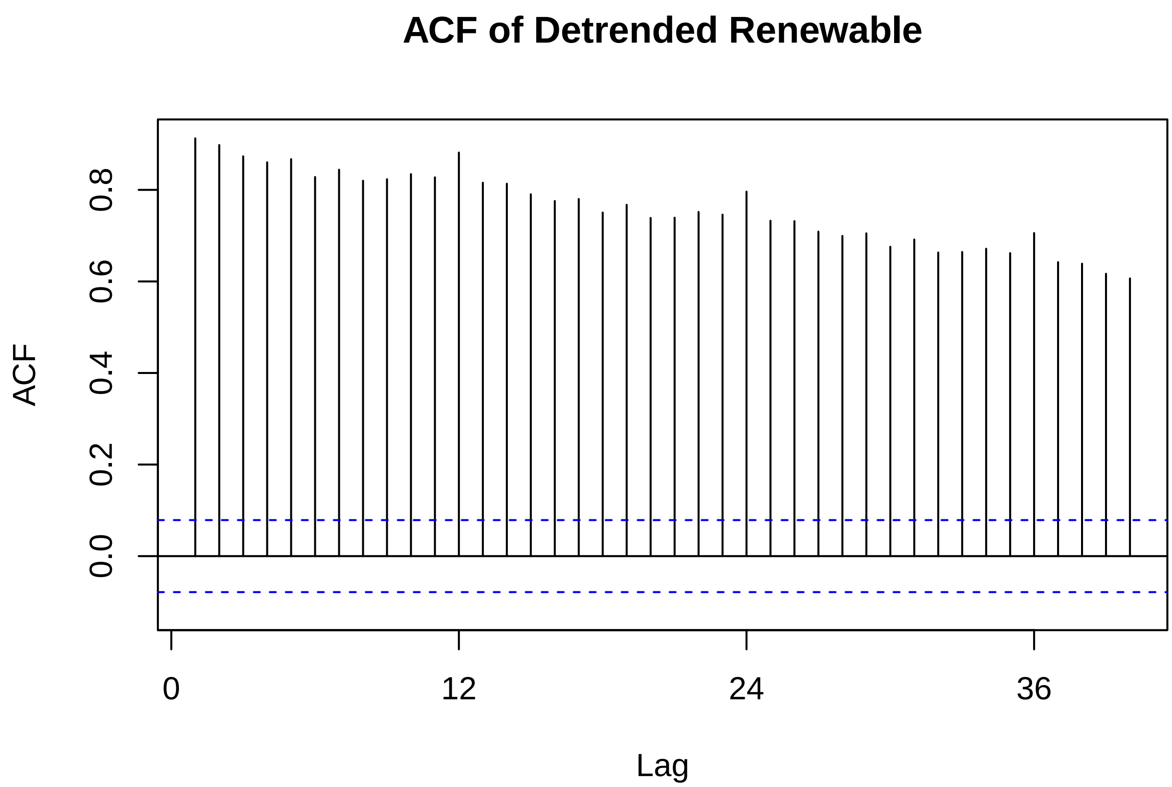


< For the Renewable Energy Plots, there is a clear change in the display of the data. While originally there is a steady increase over time, the detrended plot shows more of a rise and fall over time. Additionally, this rise and fall stays within -150 to 150 Trillion BTU. As for the hydroelectric power, the data is not centered at around 80 anymore but instead it is centered around zero. It does however retain its shape.

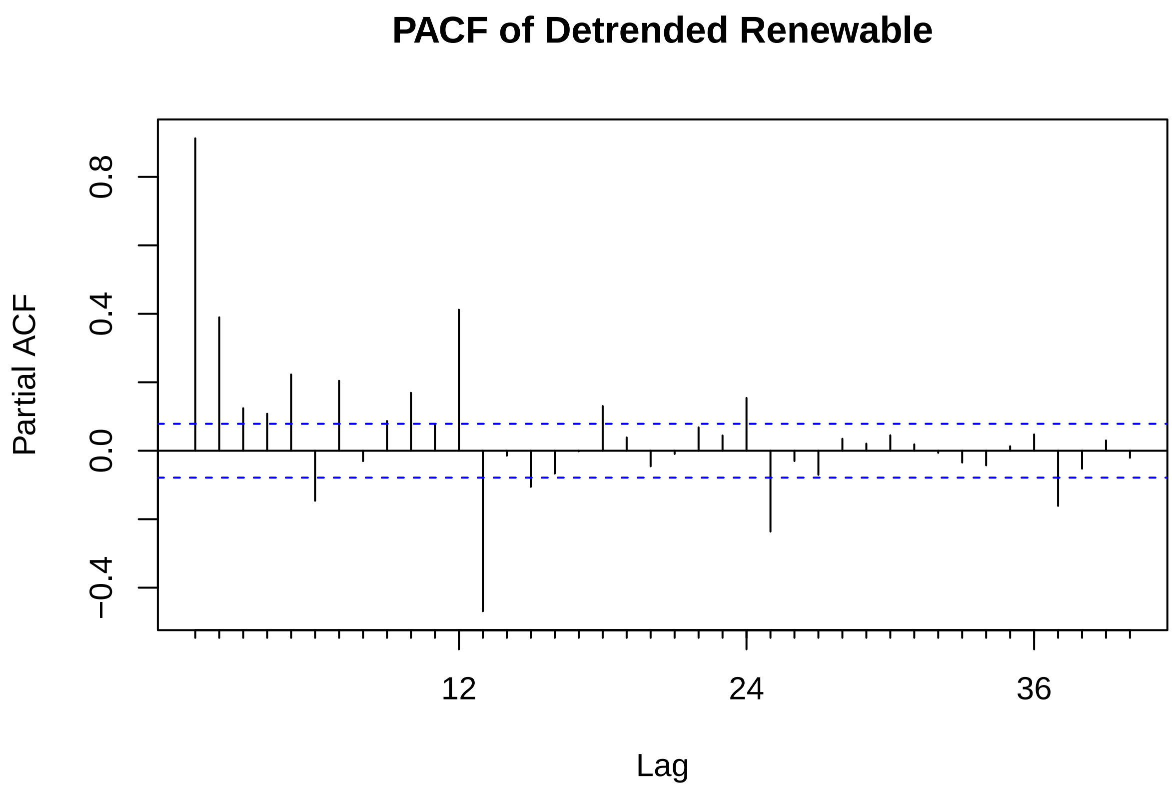
Q5

Plot ACF and PACF for the detrended series and compare with the plots from Q1. You may use plot_grid() again to get them side by side, but not mandatory. Did the plots change? How?

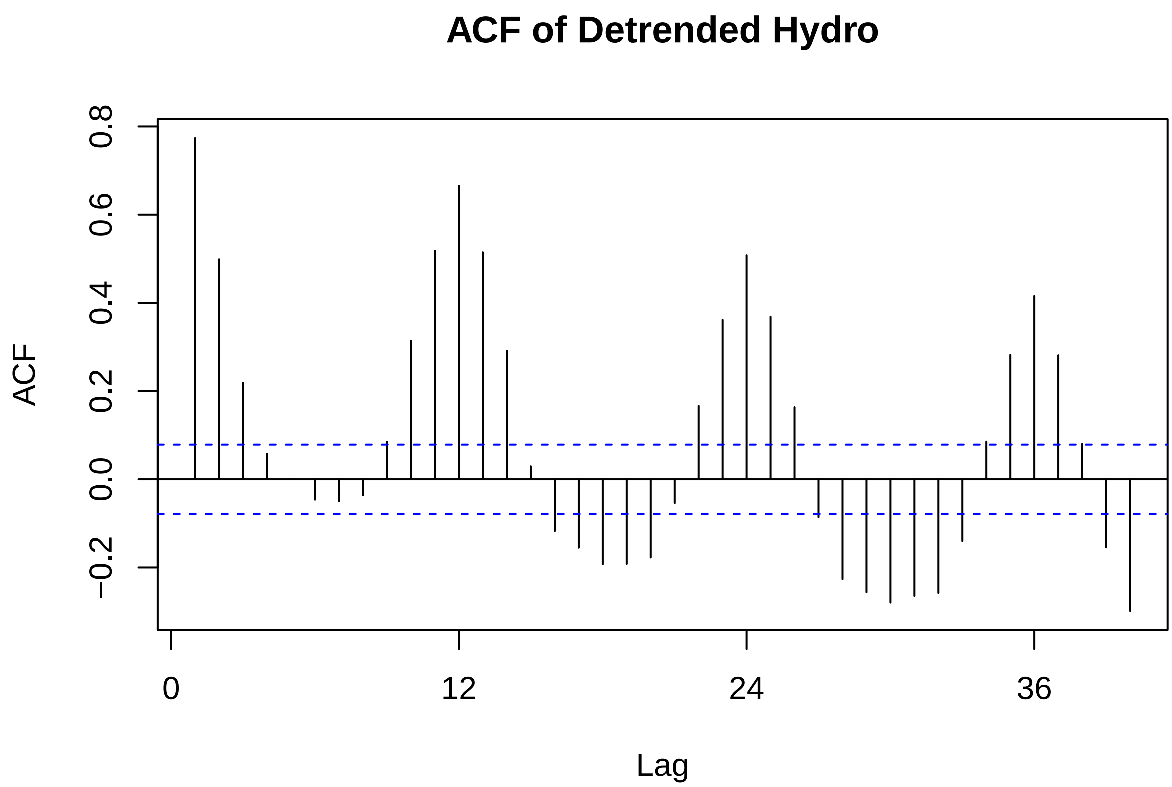
```
# ACF and PACF for detrended Hydroelectric Power
acf_detrended_renewable <- Acf(ts_detrended_renewable, lag.max = 40,
                               main = "ACF of Detrended Renewable")
```



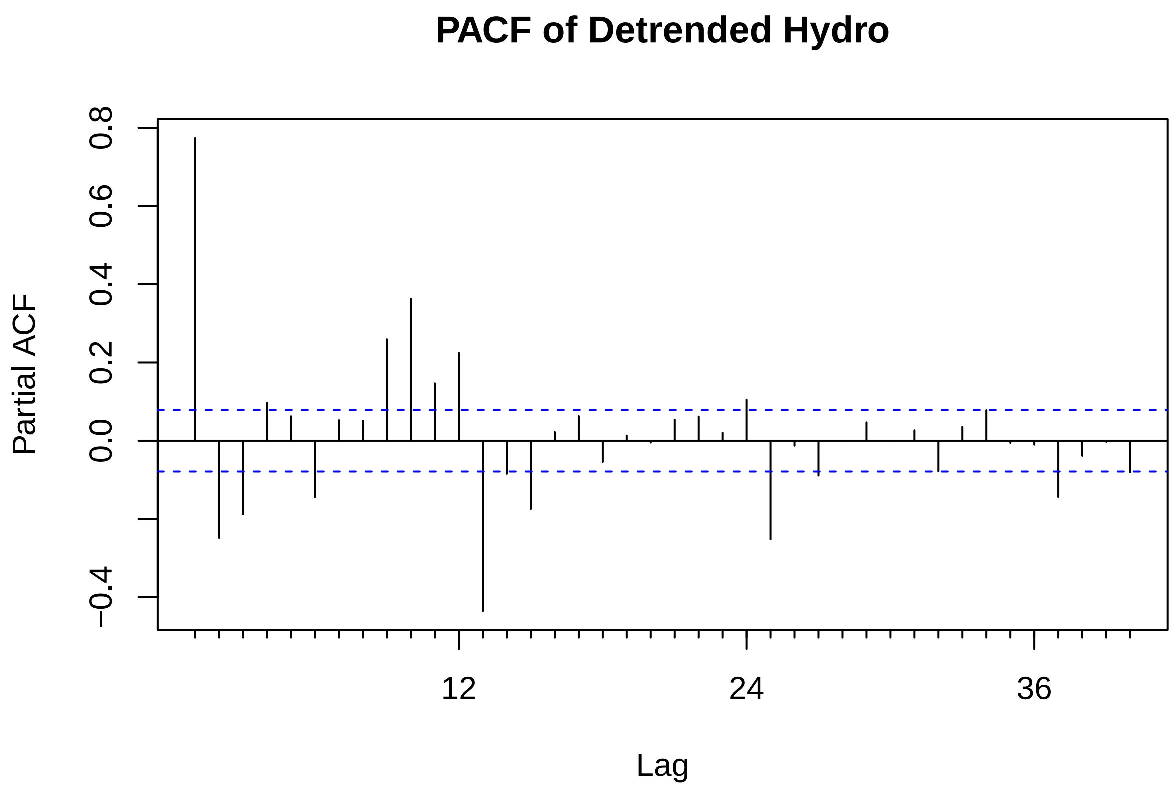

```
pacf_detrended_renewable <- Pacf(ts_detrended_renewable, lag.max = 40,
                                 main = "PACF of Detrended Renewable")
```




```
acf_detrended_hydro <- Acf(ts_detrended_hydro, lag.max = 40,
                           main = "ACF of Detrended Hydro")
```

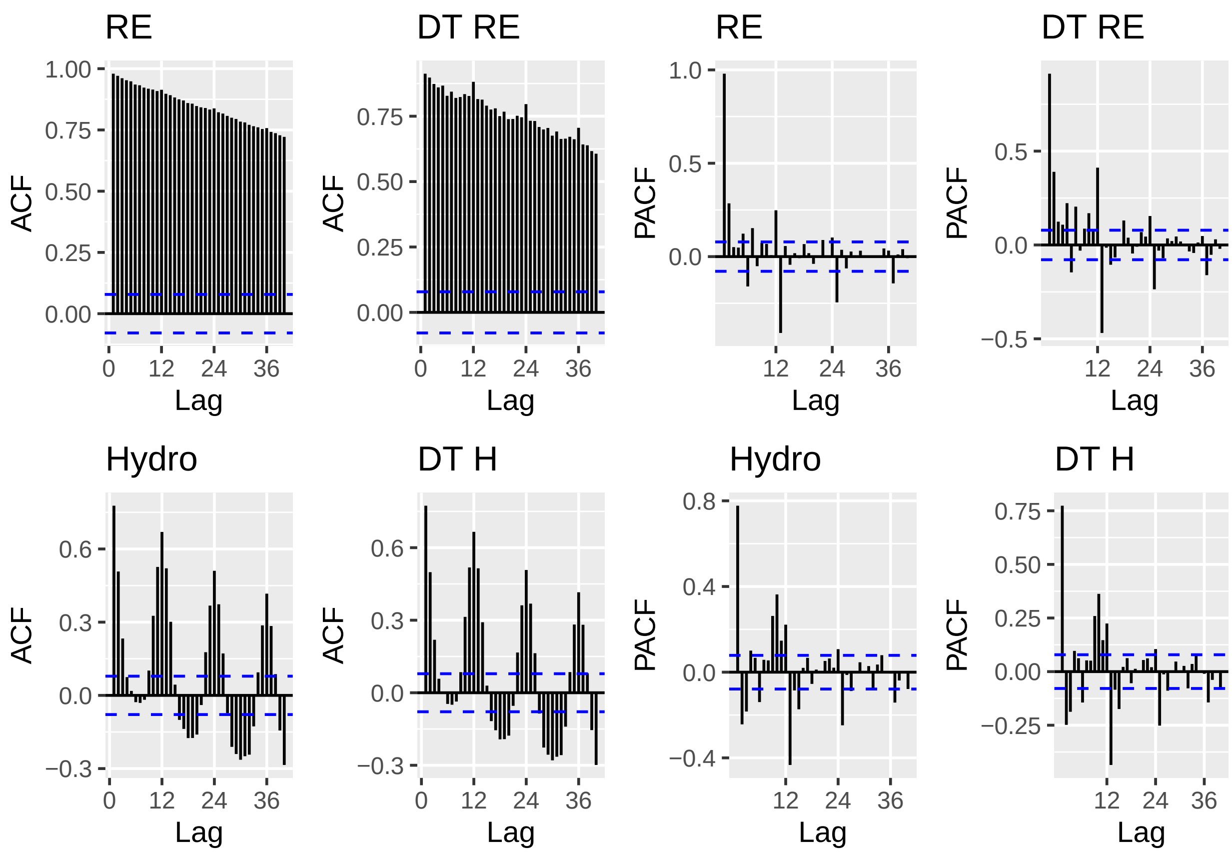



```r
pacf_detrended_hydro <- Pacf(ts_detrended_hydro, lag.max = 40,
                             main = "PACF of Detrended Hydro")
```



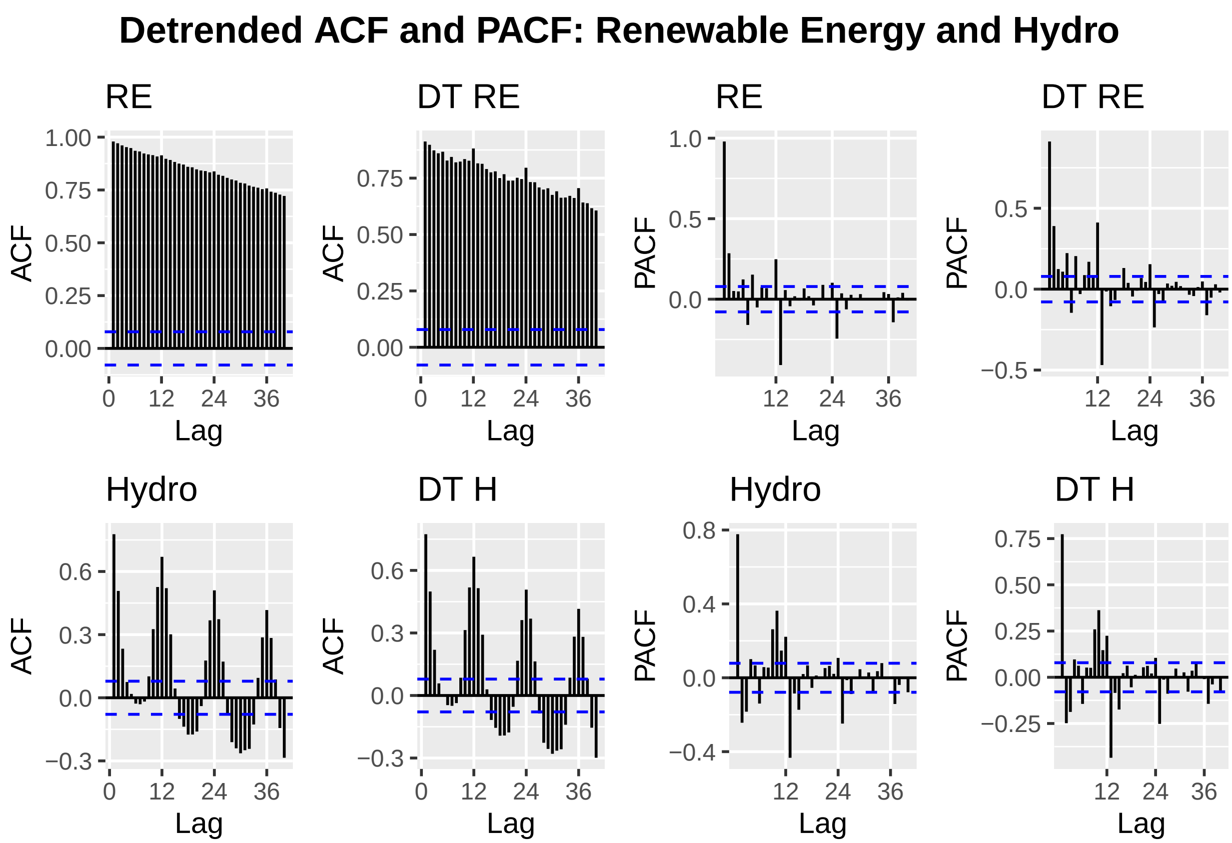

```
#DT stands for detrended,
#H or Hydro = hydroelectric power consumption
#RE stands for renewable energy production


# Create plots for Renewable Energy Production
acf_renewable_plot <- autoplot(Acf(energy_ts[, 1], lag.max = 40, plot = FALSE)) +
  ggtitle("RE")
pacf_renewable_plot <- autoplot(Pacf(energy_ts[, 1], lag.max = 40, plot = FALSE)) +
  ggtitle("RE")

# Create plots for detrended Renewable Energy
acf_detrended_renewable_plot <- autoplot(Acf(ts_detrended_renewable,
                                             lag.max = 40, plot = FALSE)) +
  ggtitle("DT RE")

pacf_detrended_renewable_plot <- autoplot(Pacf(ts_detrended_renewable,
                                               lag.max = 40, plot = FALSE)) +
  ggtitle("DT RE")

# Create plots for Hydroelectric Power Consumption
acf_hydro_plot <- autoplot(Acf(energy_ts[, 2], lag.max = 40, plot = FALSE)) +
  ggtitle("Hydro")
pacf_hydro_plot <- autoplot(Pacf(energy_ts[, 2], lag.max = 40, plot = FALSE)) +
  ggtitle("Hydro")
```

```r
# ACF and PACF for Detrended Hydroelectric Power
acf_detrended_hydro_plot <- autoplot(Acf(ts_detrended_hydro, lag.max = 40,
                                         plot = FALSE)) +
  ggtitle("DT H")

pacf_detrended_hydro_plot <- autoplot(Pacf(ts_detrended_hydro, lag.max = 40,
                                           plot = FALSE)) +
  ggtitle("DT H")

plot_grid(
  plot_grid(acf_renewable_plot, acf_detrended_renewable_plot,
            pacf_renewable_plot, pacf_detrended_renewable_plot,
            ncol = 4),  # 4 plots side by side for Renewable
  plot_grid(acf_hydro_plot, acf_detrended_hydro_plot,
            pacf_hydro_plot, pacf_detrended_hydro_plot,
            ncol = 4),  # 4 plots side by side for Hydro
  ncol = 1
)
```




```r
detrended_acf_pacf_plot<- plot_grid(acf_renewable_plot, acf_detrended_renewable_plot,
                                    pacf_renewable_plot, pacf_detrended_renewable_plot,
                                    acf_hydro_plot, acf_detrended_hydro_plot,
                                    pacf_hydro_plot, pacf_detrended_hydro_plot,
                                    nrow = 2,
                                    ncol = 4)
```

```r
title <- ggdraw() + draw_label ("Detrended ACF and PACF: Renewable Energy and Hydro",
                                fontface = 'bold')
plot_grid(title, detrended_acf_pacf_plot, nrow = 2, ncol = 1, rel_heights = c(0.1,1))
```



<There is very little change in the plots, however, I have noticed that there are a couple small spikes in the renewable ACF plot after being detrended. This leads me to believe there could be a very small seasonal component that could be once-yearly phenomena.

Seasonal Component

Set aside the detrended series and consider the original series again from Q1 to answer Q6 to Q8.

Q6

Just by looking at the time series and the acf plots, do the series seem to have a seasonal trend? No need to run any code to answer your question. Just type in you answer below.

< Looking at the time series, I still have reason to believe that there may be a seasonal component for the hydropower data, as even after detrending, it does not affect the shape of the plotted data much. However, one thing I noticed in the acf plots of renewable energy is that there are spikes at intervals of 12, making me think there may be some sort of yearly or seasonal spike. However, this is not very large of a spike, so it is difficult to determine if there is a trend or not.

Q7

Use function *lm()* to fit a seasonal means model (i.e. using the seasonal dummies) the two time series. Ask R to print the summary of the regression. Interpret the regression output. From the results which series have a seasonal trend? Do the results match you answer to Q6?

```r
# Create seasonal dummies for Renewable Energy
dummies_renewable <- seasonaldummy(energy_ts[,1])

# Create seasonal dummies for Hydroelectric Power
dummies_hydro <- seasonaldummy(energy_ts[,2])

# Fit the seasonal means model for Renewable Energy
seasonal_model_renewable <- lm(energy_ts[,1] ~ dummies_renewable)

# Fit the seasonal means model for Hydroelectric Power
seasonal_model_hydro <- lm(energy_ts[,2] ~ dummies_hydro)

# Print summary of the seasonal model for Renewable Energy
summary(seasonal_model_renewable)
```

```
##
## Call:
## lm(formula = energy_ts[, 1] ~ dummies_renewable)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -205.65  -91.59  -54.59  117.87  356.19
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)           410.598     20.228  20.299   <2e-16 ***
## dummies_renewableJan    1.973     28.468   0.069    0.945
## dummies_renewableFeb  -34.348     28.468  -1.207    0.228
## dummies_renewableMar    4.721     28.468   0.166    0.868
## dummies_renewableApr   -7.896     28.468  -0.277    0.782
## dummies_renewableMay    7.199     28.468   0.253    0.800
## dummies_renewableJun   -3.394     28.468  -0.119    0.905
## dummies_renewableJul    2.850     28.468   0.100    0.920
## dummies_renewableAug   -4.430     28.468  -0.156    0.876
## dummies_renewableSep  -29.037     28.468  -1.020    0.308
## dummies_renewableOct  -20.205     28.606  -0.706    0.480
## dummies_renewableNov  -20.706     28.606  -0.724    0.469
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 144.5 on 609 degrees of freedom
## Multiple R-squared:  0.008696,   Adjusted R-squared:  -0.009209
## F-statistic: 0.4857 on 11 and 609 DF,  p-value: 0.9126
```

```r
# Print summary of the seasonal model for Hydroelectric Power
summary(seasonal_model_hydro)
```

```
##
```

```
## Call:
## lm(formula = energy_ts[, 2] ~ dummies_hydro)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -31.101  -6.241  -0.444   6.410  32.363
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)        79.981      1.452  55.094  < 2e-16 ***
## dummies_hydroJan    4.941      2.043   2.418 0.015880 *
## dummies_hydroFeb   -2.513      2.043  -1.230 0.219219
## dummies_hydroMar    7.053      2.043   3.452 0.000595 ***
## dummies_hydroApr    5.399      2.043   2.642 0.008441 **
## dummies_hydroMay   13.907      2.043   6.807 2.40e-11 ***
## dummies_hydroJun   10.729      2.043   5.251 2.09e-07 ***
## dummies_hydroJul    4.033      2.043   1.974 0.048845 *
## dummies_hydroAug   -5.399      2.043  -2.643 0.008436 **
## dummies_hydroSep  -16.596      2.043  -8.123 2.54e-15 ***
## dummies_hydroOct  -16.370      2.053  -7.973 7.66e-15 ***
## dummies_hydroNov  -10.805      2.053  -5.263 1.97e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.37 on 609 degrees of freedom
## Multiple R-squared:  0.4695, Adjusted R-squared:  0.4599
## F-statistic:    49 on 11 and 609 DF,  p-value: < 2.2e-16
```

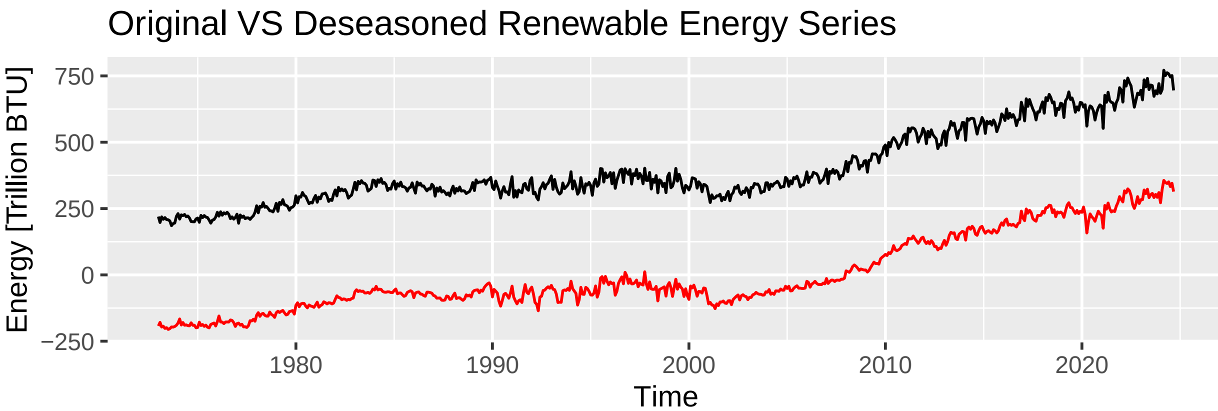
<When I look at the summary, I find that for the renewable energy, the p-value is 0.9126, which is very insignificant. <However, for hydroelectric, the p-value is < 2.2e-16, which is very significant, as it is much smaller than 0.01. This would mean that the hydroelectric does have a seasonal component, which I what I hypothesized earlier.

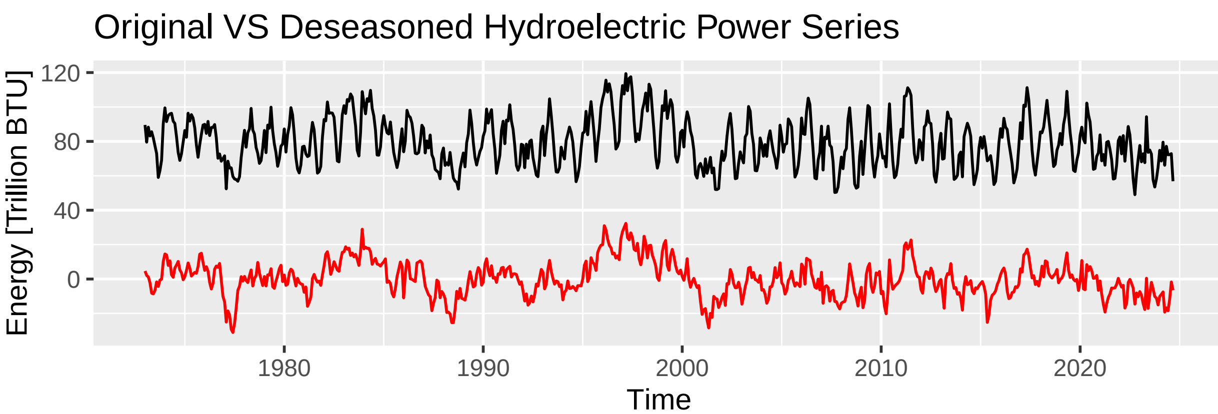
Q8

Use the regression coefficients from Q7 to deseason the series. Plot the deseason series and compare with the plots from part Q1. Did anything change?

```r
# Extract coefficients for Renewable Energy
beta_intercept_renewable <- seasonal_model_renewable$coefficients[1]
beta_coeff_renewable <- seasonal_model_renewable$coefficients[2:12]

# Extract coefficients for Hydroelectric Power
beta_intercept_hydro <- seasonal_model_hydro$coefficients[1]
beta_coeff_hydro <- seasonal_model_hydro$coefficients[2:12]

nobs_renewable <- length(energy_ts[,1])
inflow_seas_comp_renewable <- array(0, nobs_renewable)

for(i in 1:nobs_renewable){
  inflow_seas_comp_renewable[i] <- beta_intercept_renewable +
    beta_coeff_renewable %*% dummies_renewable[i,]
}
```

```r
# Calculate the seasonal component for Hydroelectric Power
nobs_hydro <- length(energy_ts[,2])
inflow_seas_comp_hydro <- array(0, nobs_hydro)

for(i in 1:nobs_hydro){
    inflow_seas_comp_hydro[i] <- beta_intercept_hydro +
      beta_coeff_hydro %*% dummies_hydro[i,]
}
# Deseason the Renewable Energy series
deseason_renewable <- energy_ts[,1] - inflow_seas_comp_renewable

# Deseason the Hydroelectric Power series
deseason_hydro <- energy_ts[,2] - inflow_seas_comp_hydro

#Plotting the original and deseasoned series
ts_deseason_renewable <- ts(deseason_renewable, start = c(1973,1), frequency = 12)
ts_deseason_hydro <- ts(deseason_hydro, start = c(1973,1), frequency = 12)

plot_renewable <- autoplot(energy_ts[,1],
                           main = "Original VS Deseasoned Renewable Energy Series") +
  autolayer(ts_deseason_renewable,
            series = "Deseasoned Series",
            color = "red")+ylab("Energy [Trillion BTU]")

plot_hydro <- autoplot(energy_ts[,2],
                       main = "Original VS Deseasoned Hydroelectric Power Series") +
  autolayer(ts_deseason_hydro, series = "Deseasoned Series", color = "red")+
  ylab("Energy [Trillion BTU]")

cowplot::plot_grid(plot_renewable, plot_hydro, ncol = 1)
```






```
#Note that the original is in black, while the deseasoned data is in red
```

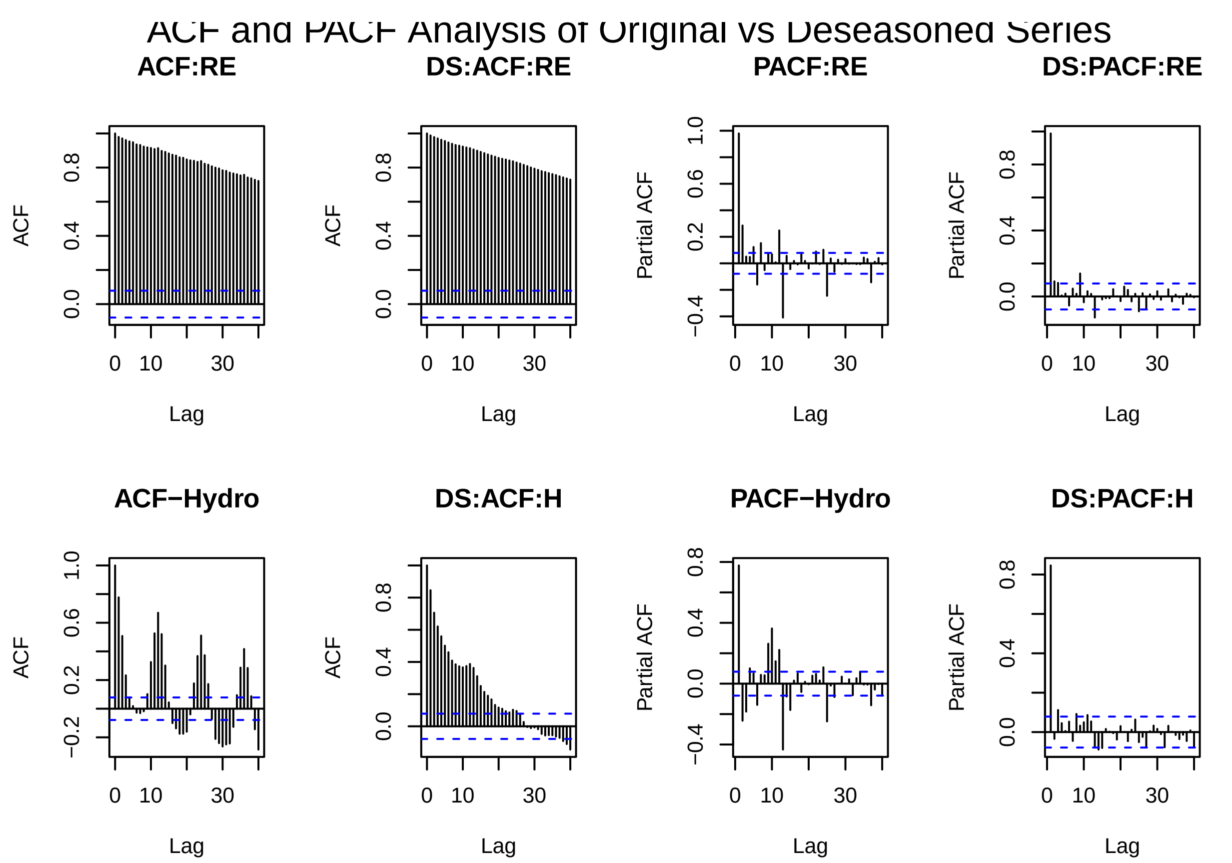
< There is not much change between the original time series and the deseasoned time series in terms of shape. However, for both plots, the data is centered aorund 0 (instead of hydro around 80 and renewable around 375.

Q9

Plot ACF and PACF for the deseason series and compare with the plots from Q1. You may use plot_grid() again to get them side by side, but not mandatory. Did the plots change? How?

```
# DS = Deseasoned



# ACF and PACF for deseasoned Renewable Energy series
acf_deseason_renewable <- Acf(ts_deseason_renewable, lag.max = 40,
                              main = "DS:ACF:RE", plot = FALSE)
pacf_deseason_renewable <- Pacf(ts_deseason_renewable, lag.max = 40,
                                main = "DS:PACF:RE", plot = FALSE)

# ACF and PACF for deseasoned Hydroelectric series
acf_deseason_hydro <- Acf(ts_deseason_hydro, lag.max = 40,
                          main = "DS:ACF:H", plot = FALSE)
pacf_deseason_hydro <- Pacf(ts_deseason_hydro, lag.max = 40,
```

```
                               main = "DS:PACF:H", plot = FALSE)

#+ ggtitle("ACF and PASC of Original vs Deseasoned Series")

# Plotting original and deseasoned ACF and PACF
par(mfrow=c(2,4))

plot(acf_renewable, main = "ACF:RE")
plot(acf_deseason_renewable, main = "DS:ACF:RE")
plot(pacf_renewable, main = "PACF:RE")
plot(pacf_deseason_renewable, main = "DS:PACF:RE")

#par(mfrow=c(2,2))

plot(acf_hydro, main = "ACF-Hydro")
plot(acf_deseason_hydro, main = "DS:ACF:H")
plot(pacf_hydro, main = "PACF-Hydro")
plot(pacf_deseason_hydro, main = "DS:PACF:H")

mtext("ACF and PACF Analysis of Original vs Deseasoned Series",
      side = 3, line = -1, outer = TRUE, cex = 1.2)
```



< After deseasoning, I feel more sure that the hydropower data had a strong seasonal component. It is not super clear in the time series plot, but in the ACF plot, the plots are completely different. Instead of peaks and valleys, there is a more constant, decreasing slope. The deseasoning also supports my claim that the renewable data does not have a major seasonal component, as the plots look quite similar. Additionally, I

may have been correct about the small seasonal spike that I mentioned, as after deseasoning, I no longer see the spikes.