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

Assignment 2 - Due date 01/27/26

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Submission Instructions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github.

Once you have the file open on your local machine the first thing you will do is rename the file such that it includes your first and last name (e.g., "LuanaLima_TSA_A02_Sp26.Rmd"). Then change "Student Name" on line 4 with your name.

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).

When you have completed the assignment, **Knit** the text and code into a single PDF file. Submit this pdf using Sakai.

R packages

R packages needed for this assignment:"forecast","tseries", and "dplyr". 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.\

```
#Load/install required package here
knitr::opts_chunk$set(echo = TRUE,tidy.opts=list(width.cutoff=60), tidy=TRUE)
library(forecast)
```

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

```
library(tseries)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(ggplot2)
```

Data set information

Consider the data provided in the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source on our **Data** folder. The data comes from the US Energy Information and Administration and corresponds to the December 2025 Monthly Energy Review. The spreadsheet is ready to be used. Refer to the file "M2_ImportingData_XLSX.Rmd" in our Lessons folder for instructions on how to read *.xlsx* files.

```r
# Importing data set
library(readxl)
library(openxlsx)
getwd()
```

```
## [1] "/home/guest/ZZhang727"
```

```r
# Importing data set without change the original file using
# read.xlsx
energy_data1 <- read_excel(path = "./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Sou
    skip = 12, sheet = "Monthly Data", col_names = FALSE)
```

```
## New names:
## * `` -> `...1`
## * `` -> `...2`
## * `` -> `...3`
## * `` -> `...4`
## * `` -> `...5`
## * `` -> `...6`
## * `` -> `...7`
## * `` -> `...8`
## * `` -> `...9`
## * `` -> `...10`
## * `` -> `...11`
## * `` -> `...12`
## * `` -> `...13`
## * `` -> `...14`
```

```r
# Now let's extract the column names from row 11
read_col_names <- read_excel(path = "./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_S
    skip = 10, n_max = 1, sheet = "Monthly Data", col_names = FALSE)
```

```
## New names:
## * `` -> `...1`
## * `` -> `...2`
## * `` -> `...3`
## * `` -> `...4`
## * `` -> `...5`
## * `` -> `...6`
## * `` -> `...7`
## * `` -> `...8`
```

```
## * `` -> `...9`
## * `` -> `...10`
## * `` -> `...11`
## * `` -> `...12`
## * `` -> `...13`
## * `` -> `...14`
```

```
# Assign the column names to the data set
colnames(energy_data1) <- read_col_names

# Visualize the first rows of the data set
head(energy_data1)
```

```
## # A tibble: 6 x 14
##   Month               `Wood Energy Production` `Biofuels Production`
##   <dttm>                                 <dbl> <chr>
## 1 1973-01-01 00:00:00                     130. Not Available
## 2 1973-02-01 00:00:00                     117. Not Available
## 3 1973-03-01 00:00:00                     130. Not Available
## 4 1973-04-01 00:00:00                     125. Not Available
## 5 1973-05-01 00:00:00                     130. Not Available
## 6 1973-06-01 00:00:00                     125. Not Available
## # i 11 more variables: `Total Biomass Energy Production` <dbl>,
## #   `Total Renewable Energy Production` <dbl>,
## #   `Hydroelectric Power Consumption` <dbl>,
## #   `Geothermal Energy Consumption` <dbl>, `Solar Energy Consumption` <chr>,
## #   `Wind Energy Consumption` <chr>, `Wood Energy Consumption` <dbl>,
## #   `Waste Energy Consumption` <dbl>, `Biofuels Consumption` <chr>,
## #   `Total Biomass Energy Consumption` <dbl>, ...
```

Question 1

You will work only with the following columns: Total Biomass Energy Production, Total Renewable Energy Production, Hydroelectric Power Consumption. Create a data frame structure with these three time series only. Use the command head() to verify your data.

```
energy_data_new <- energy_data1[, c(1, 4, 5, 6)]

head(energy_data_new)
```

```
## # A tibble: 6 x 4
##   Month               `Total Biomass Energy Production` Total Renewable Energy~1
##   <dttm>                                          <dbl>                    <dbl>
## 1 1973-01-01 00:00:00                              130.                     220.
## 2 1973-02-01 00:00:00                              117.                     197.
## 3 1973-03-01 00:00:00                              130.                     219.
## 4 1973-04-01 00:00:00                              126.                     209.
## 5 1973-05-01 00:00:00                              130.                     216.
## 6 1973-06-01 00:00:00                              126.                     208.
## # i abbreviated name: 1: `Total Renewable Energy Production`
## # i 1 more variable: `Hydroelectric Power Consumption` <dbl>
```

Question 2

Transform your data frame in a time series object and specify the starting point and frequency of the time series using the function ts().

```
energy_data_tsa <- ts(energy_data_new[, 2:4], start = c(1973,
    1), frequency = 12)
energy_data_tsa
```

```
##          Total Biomass Energy Production Total Renewable Energy Production
## Jan 1973                         129.787                              219.839
## Feb 1973                         117.338                              197.330
## Mar 1973                         129.938                              218.686
## Apr 1973                         125.636                              209.330
## May 1973                         129.834                              215.982
## Jun 1973                         125.611                              208.249
## Jul 1973                         129.787                              207.800
## Aug 1973                         129.918                              203.432
## Sep 1973                         125.782                              185.300
## Oct 1973                         129.970                              193.514
## Nov 1973                         125.643                              195.326
## Dec 1973                         129.824                              220.755
## Jan 1974                         130.807                              231.010
## Feb 1974                         118.091                              210.188
## Mar 1974                         130.727                              226.384
## Apr 1974                         126.583                              223.218
## May 1974                         130.789                              227.793
## Jun 1974                         126.611                              218.976
## Jul 1974                         130.756                              221.909
## Aug 1974                         130.763                              214.197
## Sep 1974                         126.637                              200.900
## Oct 1974                         130.718                              200.312
## Nov 1974                         126.506                              200.068
## Dec 1974                         130.674                              211.046
## Jan 1975                         127.269                              214.319
## Feb 1975                         114.942                              198.008
## Mar 1975                         127.251                              224.384
## Apr 1975                         123.139                              215.679
## May 1975                         127.303                              223.695
## Jun 1975                         123.241                              217.798
## Jul 1975                         127.288                              216.202
## Aug 1975                         127.321                              206.312
## Sep 1975                         123.210                              194.934
## Oct 1975                         127.312                              206.489
## Nov 1975                         123.180                              208.436
## Dec 1975                         127.277                              217.911
## Jan 1976                         145.049                              236.073
## Feb 1976                         135.695                              221.374
## Mar 1976                         145.051                              237.807
## Apr 1976                         140.363                              224.756
## May 1976                         145.047                              234.082
## Jun 1976                         140.405                              229.595
## Jul 1976                         145.088                              235.984
## Aug 1976                         145.110                              228.336
```

```
## Sep 1976 140.436 211.665
## Oct 1976 145.114 218.818
## Nov 1976 140.651 209.968
## Dec 1976 145.364 216.239
## Jan 1977 156.220 228.907
## Feb 1977 141.176 194.523
## Mar 1977 156.217 225.781
## Apr 1977 151.161 216.602
## May 1977 156.186 221.823
## Jun 1977 151.153 211.752
## Jul 1977 155.920 215.097
## Aug 1977 156.081 214.871
## Sep 1977 151.110 208.974
## Oct 1977 156.172 216.727
## Nov 1977 151.000 222.663
## Dec 1977 155.935 235.754
## Jan 1978 173.128 260.677
## Feb 1978 156.387 233.933
## Mar 1978 173.136 258.863
## Apr 1978 167.349 255.285
## May 1978 172.923 272.691
## Jun 1978 167.340 254.703
## Jul 1978 172.912 258.056
## Aug 1978 173.189 250.652
## Sep 1978 167.455 241.494
## Oct 1978 173.169 241.095
## Nov 1978 167.557 237.214
## Dec 1978 173.060 250.285
## Jan 1979 182.600 270.000
## Feb 1979 165.096 239.377
## Mar 1979 182.881 273.485
## Apr 1979 176.844 265.526
## May 1979 182.782 283.727
## Jun 1979 176.833 264.118
## Jul 1979 182.700 262.394
## Aug 1979 182.808 257.423
## Sep 1979 176.891 243.468
## Oct 1979 182.752 253.559
## Nov 1979 176.949 255.317
## Dec 1979 182.770 262.637
## Jan 1980 209.829 298.221
## Feb 1980 196.310 271.194
## Mar 1980 209.727 294.931
## Apr 1980 202.894 293.043
## May 1980 209.548 310.682
## Jun 1980 202.723 299.633
## Jul 1980 209.554 295.537
## Aug 1980 209.675 281.831
## Sep 1980 202.905 268.204
## Oct 1980 209.717 273.058
## Nov 1980 202.945 270.913
## Dec 1980 209.671 288.131
## Jan 1981 220.544 299.483
## Feb 1981 199.248 273.604
```

```
## Mar 1981 220.595 293.454
## Apr 1981 213.467 286.764
## May 1981 220.433 305.297
## Jun 1981 213.237 305.860
## Jul 1981 220.392 308.821
## Aug 1981 220.428 296.678
## Sep 1981 213.480 276.720
## Oct 1981 220.581 284.684
## Nov 1981 213.437 280.364
## Dec 1981 220.440 304.193
## Jan 1982 226.251 320.311
## Feb 1982 204.375 297.475
## Mar 1982 226.157 330.131
## Apr 1982 218.821 316.183
## May 1982 226.135 323.939
## Jun 1982 218.866 316.816
## Jul 1982 226.202 321.854
## Aug 1982 226.168 310.059
## Sep 1982 218.947 289.054
## Oct 1982 226.373 296.056
## Nov 1982 218.948 300.864
## Dec 1982 226.210 323.054
## Jan 1983 246.575 348.969
## Feb 1983 222.738 320.213
## Mar 1983 246.610 352.422
## Apr 1983 238.625 343.331
## May 1983 246.647 355.330
## Jun 1983 238.736 346.012
## Jul 1983 246.651 345.359
## Aug 1983 246.695 338.025
## Sep 1983 238.755 315.758
## Oct 1983 246.732 320.524
## Nov 1983 238.780 325.785
## Dec 1983 246.871 357.437
## Jan 1984 251.483 355.607
## Feb 1984 235.169 333.238
## Mar 1984 251.529 358.566
## Apr 1984 243.277 348.756
## May 1984 251.408 363.212
## Jun 1984 243.303 344.623
## Jul 1984 251.632 348.366
## Aug 1984 251.638 340.669
## Sep 1984 243.596 317.887
## Oct 1984 251.974 326.373
## Nov 1984 244.068 323.172
## Dec 1984 252.042 343.652
## Jan 1985 256.315 353.933
## Feb 1985 231.512 323.067
## Mar 1985 256.336 344.083
## Apr 1985 247.599 334.259
## May 1985 255.881 349.644
## Jun 1985 247.643 332.457
## Jul 1985 256.159 332.393
## Aug 1985 256.301 328.026
```

```
## Sep 1985 247.997 315.367
## Oct 1985 256.175 327.776
## Nov 1985 248.070 330.222
## Dec 1985 256.246 346.947
## Jan 1986 249.178 326.552
## Feb 1986 224.922 307.952
## Mar 1986 248.837 349.995
## Apr 1986 240.788 338.487
## May 1986 248.822 345.587
## Jun 1986 240.837 334.442
## Jul 1986 249.011 335.334
## Aug 1986 249.176 325.501
## Sep 1986 241.074 316.539
## Oct 1986 248.974 325.125
## Nov 1986 241.122 323.172
## Dec 1986 249.352 341.787
## Jan 1987 244.137 334.890
## Feb 1987 220.511 296.606
## Mar 1987 244.157 327.541
## Apr 1987 236.139 315.231
## May 1987 244.007 330.797
## Jun 1987 236.522 311.957
## Jul 1987 244.359 317.495
## Aug 1987 244.396 311.395
## Sep 1987 236.298 302.090
## Oct 1987 244.059 309.095
## Nov 1987 236.197 297.439
## Dec 1987 244.104 319.908
## Jan 1988 255.331 334.583
## Feb 1988 238.853 307.533
## Mar 1988 255.385 326.015
## Apr 1988 247.241 316.232
## May 1988 255.188 331.539
## Jun 1988 247.340 315.603
## Jul 1988 255.582 317.391
## Aug 1988 255.815 315.766
## Sep 1988 247.357 306.500
## Oct 1988 255.517 310.737
## Nov 1988 247.096 313.792
## Dec 1988 255.345 326.992
## Jan 1989 266.572 348.321
## Feb 1989 243.927 317.572
## Mar 1989 268.315 358.115
## Apr 1989 251.946 346.511
## May 1989 241.235 350.304
## Jun 1989 248.447 349.753
## Jul 1989 261.318 351.720
## Aug 1989 276.985 358.320
## Sep 1989 264.811 341.553
## Oct 1989 276.462 356.682
## Nov 1989 276.819 359.731
## Dec 1989 282.520 367.555
## Jan 1990 236.692 329.327
## Feb 1990 226.266 321.465
```

```
## Mar 1990                244.248                353.956
## Apr 1990                232.640                334.136
## May 1990                210.108                317.791
## Jun 1990                178.544                289.276
## Jul 1990                219.713                315.872
## Aug 1990                245.632                332.580
## Sep 1990                239.932                311.965
## Oct 1990                235.437                312.873
## Nov 1990                220.256                301.883
## Dec 1990                245.644                341.584
## Jan 1991                269.531                370.278
## Feb 1991                204.535                292.511
## Mar 1991                214.374                317.683
## Apr 1991                190.452                293.309
## May 1991                206.579                320.120
## Jun 1991                209.721                313.437
## Jul 1991                210.055                309.257
## Aug 1991                250.834                340.813
## Sep 1991                267.735                345.122
## Oct 1991                249.408                324.454
## Nov 1991                241.541                318.757
## Dec 1991                267.033                355.690
## Jan 1992                279.197                366.577
## Feb 1992                230.468                305.537
## Mar 1992                221.177                311.299
## Apr 1992                210.172                292.073
## May 1992                190.537                282.361
## Jun 1992                230.985                323.546
## Jul 1992                250.150                333.005
## Aug 1992                269.662                347.510
## Sep 1992                251.511                324.027
## Oct 1992                269.545                340.565
## Nov 1992                264.383                345.048
## Dec 1992                263.891                360.200
## Jan 1993                274.257                373.255
## Feb 1993                240.964                322.185
## Mar 1993                263.204                359.855
## Apr 1993                226.859                330.605
## May 1993                196.012                313.546
## Jun 1993                197.445                304.450
## Jul 1993                212.707                309.916
## Aug 1993                262.322                346.577
## Sep 1993                250.551                324.882
## Oct 1993                257.383                331.480
## Nov 1993                262.183                338.485
## Dec 1993                264.559                352.074
## Jan 1994                306.708                388.854
## Feb 1994                244.594                323.751
## Mar 1994                261.461                354.509
## Apr 1994                236.035                332.955
## May 1994                202.480                303.865
## Jun 1994                215.744                313.708
## Jul 1994                274.451                366.741
## Aug 1994                251.577                333.540
```

```
## Sep 1994 238.967 307.933
## Oct 1994 271.599 343.569
## Nov 1994 261.436 338.304
## Dec 1994 262.482 348.732
## Jan 1995 243.462 336.872
## Feb 1995 206.657 299.810
## Mar 1995 239.820 346.752
## Apr 1995 267.571 361.046
## May 1995 227.439 333.643
## Jun 1995 226.934 342.092
## Jul 1995 294.251 400.977
## Aug 1995 301.628 399.583
## Sep 1995 268.791 349.815
## Oct 1995 292.175 384.663
## Nov 1995 267.659 366.200
## Dec 1995 262.694 373.129
## Jan 1996 272.584 385.971
## Feb 1996 226.038 343.243
## Mar 1996 259.039 385.026
## Apr 1996 205.729 325.915
## May 1996 231.211 356.221
## Jun 1996 254.182 375.816
## Jul 1996 281.656 395.278
## Aug 1996 294.581 398.870
## Sep 1996 259.345 347.920
## Oct 1996 310.461 400.155
## Nov 1996 295.562 387.043
## Dec 1996 264.912 378.537
## Jan 1997 275.641 397.124
## Feb 1997 226.521 342.279
## Mar 1997 251.136 381.623
## Apr 1997 252.010 374.093
## May 1997 268.515 398.347
## Jun 1997 231.690 362.325
## Jul 1997 259.985 382.540
## Aug 1997 264.422 370.673
## Sep 1997 250.744 343.197
## Oct 1997 305.656 402.188
## Nov 1997 264.591 355.868
## Dec 1997 256.998 355.807
## Jan 1998 278.211 386.269
## Feb 1998 212.209 323.378
## Mar 1998 240.963 360.492
## Apr 1998 240.612 348.763
## May 1998 250.239 374.487
## Jun 1998 186.089 309.019
## Jul 1998 246.326 358.537
## Aug 1998 254.237 354.150
## Sep 1998 248.270 332.989
## Oct 1998 267.922 345.379
## Nov 1998 230.488 309.809
## Dec 1998 273.362 370.867
## Jan 1999 272.260 383.582
## Feb 1999 220.539 328.183
```

```
## Mar 1999                212.177                334.062
## Apr 1999                249.920                355.198
## May 1999                289.264                401.370
## Jun 1999                236.090                353.158
## Jul 1999                264.292                379.433
## Aug 1999                258.854                360.215
## Sep 1999                244.140                328.356
## Oct 1999                228.256                308.985
## Nov 1999                254.125                337.650
## Dec 1999                235.215                332.407
## Jan 2000                222.067                319.978
## Feb 2000                246.169                334.369
## Mar 2000                263.209                366.040
## Apr 2000                254.609                364.110
## May 2000                254.678                361.267
## Jun 2000                227.712                326.724
## Jul 2000                255.348                351.077
## Aug 2000                254.942                343.214
## Sep 2000                240.331                312.937
## Oct 2000                270.472                341.025
## Nov 2000                261.335                339.223
## Dec 2000                254.788                333.069
## Jan 2001                228.434                303.197
## Feb 2001                202.849                272.585
## Mar 2001                219.649                301.844
## Apr 2001                213.628                288.028
## May 2001                211.506                290.338
## Jun 2001                213.950                298.272
## Jul 2001                221.842                297.654
## Aug 2001                225.897                304.239
## Sep 2001                214.229                279.069
## Oct 2001                227.319                292.015
## Nov 2001                219.773                283.668
## Dec 2001                225.088                302.843
## Jan 2002                228.396                314.861
## Feb 2002                198.932                279.136
## Mar 2002                217.568                302.856
## Apr 2002                212.852                309.709
## May 2002                225.155                331.378
## Jun 2002                215.107                326.674
## Jul 2002                235.713                337.792
## Aug 2002                224.400                311.593
## Sep 2002                230.855                302.858
## Oct 2002                243.767                315.739
## Nov 2002                230.328                309.716
## Dec 2002                242.334                328.629
## Jan 2003                237.044                318.956
## Feb 2003                212.693                291.767
## Mar 2003                233.288                330.201
## Apr 2003                228.516                327.749
## May 2003                229.756                345.099
## Jun 2003                228.254                341.209
## Jul 2003                242.533                342.647
## Aug 2003                239.928                333.101
```

```
## Sep 2003 230.968 308.470
## Oct 2003 236.938 313.818
## Nov 2003 233.698 314.096
## Dec 2003 251.160 347.074
## Jan 2004 255.574 347.154
## Feb 2004 236.689 321.055
## Mar 2004 248.532 342.168
## Apr 2004 247.253 334.068
## May 2004 244.383 344.066
## Jun 2004 244.075 346.968
## Jul 2004 257.042 353.034
## Aug 2004 254.446 344.004
## Sep 2004 243.019 328.252
## Oct 2004 253.520 332.739
## Nov 2004 247.286 332.106
## Dec 2004 264.199 367.856
## Jan 2005 264.707 361.269
## Feb 2005 247.271 333.479
## Mar 2005 260.043 354.763
## Apr 2005 246.929 342.863
## May 2005 255.790 367.186
## Jun 2005 252.466 362.264
## Jul 2005 266.332 372.396
## Aug 2005 266.097 356.107
## Sep 2005 255.348 331.447
## Oct 2005 261.121 339.018
## Nov 2005 256.532 338.541
## Dec 2005 268.550 360.826
## Jan 2006 276.647 388.583
## Feb 2006 247.274 348.049
## Mar 2006 265.069 368.883
## Apr 2006 250.384 367.940
## May 2006 261.125 386.890
## Jun 2006 261.960 383.011
## Jul 2006 274.809 381.340
## Aug 2006 277.063 370.019
## Sep 2006 267.952 345.317
## Oct 2006 275.120 353.690
## Nov 2006 270.475 359.164
## Dec 2006 283.636 376.761
## Jan 2007 290.845 399.004
## Feb 2007 261.666 343.865
## Mar 2007 285.146 390.167
## Apr 2007 278.386 383.102
## May 2007 286.010 398.044
## Jun 2007 281.995 382.096
## Jul 2007 295.653 393.450
## Aug 2007 295.523 386.428
## Sep 2007 287.603 360.587
## Oct 2007 299.416 374.075
## Nov 2007 297.828 373.327
## Dec 2007 312.007 397.970
## Jan 2008 331.138 427.860
## Feb 2008 300.535 388.671
```

```
## Mar 2008  321.487  424.851
## Apr 2008  314.073  421.184
## May 2008  324.185  449.522
## Jun 2008  313.335  444.695
## Jul 2008  330.507  446.062
## Aug 2008  333.607  431.761
## Sep 2008  318.840  398.411
## Oct 2008  330.125  412.573
## Nov 2008  327.317  409.976
## Dec 2008  323.102  428.996
## Jan 2009  318.353  431.011
## Feb 2009  294.389  386.812
## Mar 2009  319.356  432.104
## Apr 2009  303.489  431.059
## May 2009  319.032  456.231
## Jun 2009  321.739  455.356
## Jul 2009  343.841  455.962
## Aug 2009  348.551  449.335
## Sep 2009  332.374  421.927
## Oct 2009  346.472  450.940
## Nov 2009  348.333  456.527
## Dec 2009  360.689  481.882
## Jan 2010  377.071  489.844
## Feb 2010  347.952  449.090
## Mar 2010  384.094  499.560
## Apr 2010  368.922  482.552
## May 2010  376.012  507.544
## Jun 2010  372.328  517.750
## Jul 2010  385.443  508.593
## Aug 2010  389.064  497.073
## Sep 2010  377.355  476.105
## Oct 2010  386.771  489.125
## Nov 2010  386.602  500.488
## Dec 2010  400.917  524.855
## Jan 2011  400.710  530.909
## Feb 2011  359.327  490.715
## Mar 2011  394.959  553.169
## Apr 2011  373.481  538.506
## May 2011  385.273  554.011
## Jun 2011  389.673  553.885
## Jul 2011  399.454  549.374
## Aug 2011  402.931  534.036
## Sep 2011  387.218  500.175
## Oct 2011  397.994  517.691
## Nov 2011  400.892  528.710
## Dec 2011  420.525  552.823
## Jan 2012  399.385  539.030
## Feb 2012  373.028  494.125
## Mar 2012  388.074  541.241
## Apr 2012  368.981  519.625
## May 2012  387.318  546.973
## Jun 2012  377.793  528.767
## Jul 2012  379.862  520.173
## Aug 2012  386.269  513.269
```

```
## Sep 2012                366.955                 475.611
## Oct 2012                373.975                 491.520
## Nov 2012                368.902                 489.081
## Dec 2012                383.017                 527.555
## Jan 2013                391.713                 542.692
## Feb 2013                354.251                 487.697
## Mar 2013                397.835                 541.012
## Apr 2013                386.469                 551.448
## May 2013                404.782                 578.378
## Jun 2013                401.893                 563.561
## Jul 2013                419.452                 572.289
## Aug 2013                413.684                 542.610
## Sep 2013                395.313                 514.219
## Oct 2013                417.493                 543.689
## Nov 2013                415.796                 548.475
## Dec 2013                436.115                 574.712
## Jan 2014                420.974                 574.074
## Feb 2014                382.165                 507.104
## Mar 2014                423.586                 589.448
## Apr 2014                408.886                 582.906
## May 2014                420.035                 589.532
## Jun 2014                422.748                 590.551
## Jul 2014                437.471                 588.452
## Aug 2014                431.020                 559.856
## Sep 2014                411.083                 530.545
## Oct 2014                424.674                 557.212
## Nov 2014                419.845                 569.440
## Dec 2014                446.730                 593.582
## Jan 2015                426.511                 580.459
## Feb 2015                385.395                 532.998
## Mar 2015                418.058                 579.274
## Apr 2015                404.120                 569.372
## May 2015                421.760                 578.595
## Jun 2015                419.237                 564.148
## Jul 2015                434.897                 583.940
## Aug 2015                431.663                 572.235
## Sep 2015                409.666                 539.599
## Oct 2015                418.147                 556.624
## Nov 2015                418.730                 575.262
## Dec 2015                436.774                 607.029
## Jan 2016                427.135                 599.191
## Feb 2016                405.931                 581.707
## Mar 2016                428.642                 626.117
## Apr 2016                399.703                 589.697
## May 2016                423.372                 609.056
## Jun 2016                424.332                 593.674
## Jul 2016                434.083                 604.311
## Aug 2016                441.570                 591.345
## Sep 2016                416.462                 562.208
## Oct 2016                424.405                 584.383
## Nov 2016                427.968                 586.197
## Dec 2016                468.546                 650.925
## Jan 2017                439.571                 627.139
## Feb 2017                396.508                 580.323
```

```
## Mar 2017 437.490 663.921
## Apr 2017 408.227 635.132
## May 2017 426.923 661.288
## Jun 2017 423.612 642.341
## Jul 2017 435.087 625.553
## Aug 2017 446.085 612.154
## Sep 2017 416.763 583.867
## Oct 2017 433.547 614.657
## Nov 2017 438.603 613.796
## Dec 2017 454.004 635.130
## Jan 2018 449.180 652.428
## Feb 2018 412.864 609.384
## Mar 2018 449.086 668.591
## Apr 2018 425.122 656.554
## May 2018 444.714 680.705
## Jun 2018 438.195 668.774
## Jul 2018 455.403 647.940
## Aug 2018 459.274 651.954
## Sep 2018 427.023 600.710
## Oct 2018 448.833 627.968
## Nov 2018 440.087 623.200
## Dec 2018 455.871 647.491
## Jan 2019 444.926 644.838
## Feb 2019 404.689 593.170
## Mar 2019 433.493 657.018
## Apr 2019 422.747 665.972
## May 2019 439.777 689.977
## Jun 2019 432.822 661.158
## Jul 2019 449.062 667.002
## Aug 2019 446.394 647.658
## Sep 2019 416.241 613.133
## Oct 2019 431.848 633.573
## Nov 2019 430.565 620.685
## Dec 2019 454.288 650.482
## Jan 2020 432.686 648.215
## Feb 2020 403.222 632.039
## Mar 2020 411.076 641.447
## Apr 2020 323.946 560.486
## May 2020 354.840 618.100
## Jun 2020 374.660 636.973
## Jul 2020 395.536 632.799
## Aug 2020 397.879 618.428
## Sep 2020 386.097 583.405
## Oct 2020 398.927 611.837
## Nov 2020 402.541 629.861
## Dec 2020 418.294 640.797
## Jan 2021 409.222 637.522
## Feb 2021 348.443 553.037
## Mar 2021 411.001 678.149
## Apr 2021 393.241 651.301
## May 2021 418.431 689.586
## Jun 2021 410.574 656.900
## Jul 2021 425.729 651.325
## Aug 2021 413.209 648.963
```

```
## Sep 2021                        395.132                        620.842
## Oct 2021                        422.318                        650.243
## Nov 2021                        423.789                        663.731
## Dec 2021                        445.133                        706.750
## Jan 2022                        445.593                        707.979
## Feb 2022                        403.607                        661.288
## Mar 2022                        440.872                        743.597
## Apr 2022                        415.946                        722.551
## May 2022                        440.614                        753.369
## Jun 2022                        439.639                        735.657
## Jul 2022                        446.783                        723.656
## Aug 2022                        439.336                        682.908
## Sep 2022                        411.653                        642.820
## Oct 2022                        435.904                        669.622
## Nov 2022                        437.624                        695.918
## Dec 2022                        439.099                        690.850
## Jan 2023                        436.791                        699.219
## Feb 2023                        392.663                        662.356
## Mar 2023                        439.248                        738.376
## Apr 2023                        407.991                        711.502
## May 2023                        438.492                        743.971
## Jun 2023                        431.448                        701.163
## Jul 2023                        440.978                        718.784
## Aug 2023                        444.676                        716.526
## Sep 2023                        430.249                        675.796
## Oct 2023                        436.250                        697.000
## Nov 2023                        435.762                        685.076
## Dec 2023                        468.477                        723.896
## Jan 2024                        434.799                        689.644
## Feb 2024                        426.280                        711.645
## Mar 2024                        449.238                        777.166
## Apr 2024                        421.256                        761.186
## May 2024                        436.085                        775.130
## Jun 2024                        438.369                        775.144
## Jul 2024                        457.471                        756.708
## Aug 2024                        458.855                        756.385
## Sep 2024                        435.823                        700.397
## Oct 2024                        442.432                        735.345
## Nov 2024                        452.505                        725.928
## Dec 2024                        466.293                        741.701
## Jan 2025                        444.383                        750.981
## Feb 2025                        403.385                        693.266
## Mar 2025                        442.050                        812.838
## Apr 2025                        412.690                        783.482
## May 2025                        435.814                        793.521
## Jun 2025                        435.904                        789.933
## Jul 2025                        454.480                        794.256
## Aug 2025                        446.279                        763.036
## Sep 2025                        435.735                        715.006
##          Hydroelectric Power Consumption
## Jan 1973                          89.562
## Feb 1973                          79.544
## Mar 1973                          88.284
## Apr 1973                          83.152
```

```
## May 1973                    85.643
## Jun 1973                    82.060
## Jul 1973                    77.400
## Aug 1973                    72.936
## Sep 1973                    59.029
## Oct 1973                    62.967
## Nov 1973                    69.063
## Dec 1973                    90.131
## Jan 1974                    99.500
## Feb 1974                    91.476
## Mar 1974                    94.950
## Apr 1974                    95.969
## May 1974                    96.337
## Jun 1974                    91.719
## Jul 1974                    90.437
## Aug 1974                    82.727
## Sep 1974                    73.610
## Oct 1974                    68.931
## Nov 1974                    72.773
## Dec 1974                    79.542
## Jan 1975                    86.356
## Feb 1975                    82.404
## Mar 1975                    96.386
## Apr 1975                    91.791
## May 1975                    95.581
## Jun 1975                    93.550
## Jul 1975                    87.900
## Aug 1975                    77.892
## Sep 1975                    70.756
## Oct 1975                    78.060
## Nov 1975                    84.171
## Dec 1975                    89.510
## Jan 1976                    89.904
## Feb 1976                    84.626
## Mar 1976                    91.629
## Apr 1976                    83.378
## May 1976                    88.065
## Jun 1976                    88.182
## Jul 1976                    89.807
## Aug 1976                    82.153
## Sep 1976                    70.186
## Oct 1976                    72.690
## Nov 1976                    68.463
## Dec 1976                    69.900
## Jan 1977                    71.630
## Feb 1977                    52.424
## Mar 1977                    68.518
## Apr 1977                    64.508
## May 1977                    64.629
## Jun 1977                    59.609
## Jul 1977                    58.130
## Aug 1977                    57.830
## Sep 1977                    56.835
## Oct 1977                    59.480
```

```
## Nov 1977                    70.583
## Dec 1977                    78.744
## Jan 1978                    86.454
## Feb 1978                    76.606
## Mar 1978                    84.951
## Apr 1978                    87.281
## May 1978                    99.185
## Jun 1978                    86.645
## Jul 1978                    84.339
## Aug 1978                    76.518
## Sep 1978                    73.042
## Oct 1978                    67.184
## Nov 1978                    68.818
## Dec 1978                    76.162
## Jan 1979                    86.378
## Feb 1979                    73.446
## Mar 1979                    89.483
## Apr 1979                    87.645
## May 1979                    99.903
## Jun 1979                    86.230
## Jul 1979                    78.573
## Aug 1979                    73.393
## Sep 1979                    65.516
## Oct 1979                    69.619
## Nov 1979                    77.213
## Dec 1979                    78.457
## Jan 1980                    87.244
## Feb 1980                    73.781
## Mar 1980                    83.978
## Apr 1980                    88.865
## May 1980                    99.622
## Jun 1980                    95.451
## Jul 1980                    84.448
## Aug 1980                    70.517
## Sep 1980                    63.819
## Oct 1980                    61.661
## Nov 1980                    66.325
## Dec 1980                    76.858
## Jan 1981                    77.214
## Feb 1981                    72.830
## Mar 1981                    71.150
## Apr 1981                    71.718
## May 1981                    83.301
## Jun 1981                    91.061
## Jul 1981                    86.714
## Aug 1981                    74.556
## Sep 1981                    61.534
## Oct 1981                    62.420
## Nov 1981                    65.459
## Dec 1981                    82.279
## Jan 1982                    92.763
## Feb 1982                    91.907
## Mar 1982                   102.924
## Apr 1982                    96.303
```

```
## May 1982                    96.572
## Jun 1982                    96.463
## Jul 1982                    94.087
## Aug 1982                    82.333
## Sep 1982                    68.612
## Oct 1982                    68.091
## Nov 1982                    80.245
## Dec 1982                    95.522
## Jan 1983                   100.743
## Feb 1983                    96.206
## Mar 1983                   104.348
## Apr 1983                   103.334
## May 1983                   107.568
## Jun 1983                   105.810
## Jul 1983                    96.883
## Aug 1983                    88.929
## Sep 1983                    74.808
## Oct 1983                    71.491
## Nov 1983                    84.956
## Dec 1983                   108.936
## Jan 1984                   102.459
## Feb 1984                    96.034
## Mar 1984                   104.801
## Apr 1984                   103.270
## May 1984                   109.683
## Jun 1984                    99.261
## Jul 1984                    94.772
## Aug 1984                    86.573
## Sep 1984                    72.076
## Oct 1984                    71.968
## Nov 1984                    76.704
## Dec 1984                    88.949
## Jan 1985                    94.973
## Feb 1985                    89.219
## Mar 1985                    85.029
## Apr 1985                    84.276
## May 1985                    91.284
## Jun 1985                    82.425
## Jul 1985                    73.612
## Aug 1985                    68.980
## Sep 1985                    64.761
## Oct 1985                    69.105
## Nov 1985                    79.075
## Dec 1985                    87.328
## Jan 1986                    73.934
## Feb 1986                    80.075
## Mar 1986                    98.081
## Apr 1986                    94.922
## May 1986                    93.958
## Jun 1986                    90.562
## Jul 1986                    83.094
## Aug 1986                    73.104
## Sep 1986                    72.767
## Oct 1986                    73.498
```

```
## Nov 1986                    79.755
## Dec 1986                    89.397
## Jan 1987                    87.702
## Feb 1987                    73.264
## Mar 1987                    80.279
## Apr 1987                    76.163
## May 1987                    83.712
## Jun 1987                    72.271
## Jul 1987                    69.864
## Aug 1987                    63.744
## Sep 1987                    62.756
## Oct 1987                    61.964
## Nov 1987                    58.272
## Dec 1987                    72.753
## Jan 1988                    76.171
## Feb 1988                    66.029
## Mar 1988                    67.539
## Apr 1988                    66.195
## May 1988                    73.601
## Jun 1988                    65.346
## Jul 1988                    58.636
## Aug 1988                    56.923
## Sep 1988                    56.241
## Oct 1988                    52.265
## Nov 1988                    63.762
## Dec 1988                    68.748
## Jan 1989                    73.277
## Feb 1989                    65.188
## Mar 1989                    79.268
## Apr 1989                    84.295
## May 1989                    98.200
## Jun 1989                    90.614
## Jul 1989                    79.373
## Aug 1989                    70.675
## Sep 1989                    66.237
## Oct 1989                    70.285
## Nov 1989                    74.172
## Dec 1989                    76.402
## Jan 1990                    83.078
## Feb 1990                    86.122
## Mar 1990                    98.841
## Apr 1990                    90.589
## May 1990                    95.753
## Jun 1990                    98.444
## Jul 1990                    84.490
## Aug 1990                    75.559
## Sep 1990                    61.422
## Oct 1990                    66.657
## Nov 1990                    71.863
## Dec 1990                    86.440
## Jan 1991                    91.732
## Feb 1991                    78.638
## Mar 1991                    92.384
## Apr 1991                    91.874
```

```
## May 1991                    101.296
## Jun 1991                     91.854
## Jul 1991                     86.984
## Aug 1991                     77.658
## Sep 1991                     65.997
## Oct 1991                     63.197
## Nov 1991                     66.085
## Dec 1991                     78.349
## Jan 1992                     77.844
## Feb 1992                     64.670
## Mar 1992                     78.408
## Apr 1992                     70.180
## May 1992                     79.980
## Jun 1992                     80.819
## Jul 1992                     70.671
## Aug 1992                     65.474
## Sep 1992                     60.474
## Oct 1992                     59.474
## Nov 1992                     69.964
## Dec 1992                     85.579
## Jan 1993                     88.873
## Feb 1993                     71.730
## Mar 1993                     83.868
## Apr 1993                     90.980
## May 1993                    104.743
## Jun 1993                     95.182
## Jul 1993                     84.360
## Aug 1993                     71.587
## Sep 1993                     62.245
## Oct 1993                     62.087
## Nov 1993                     64.729
## Dec 1993                     76.662
## Jan 1994                     72.773
## Feb 1994                     69.738
## Mar 1994                     80.508
## Apr 1994                     84.264
## May 1994                     88.353
## Jun 1994                     85.343
## Jul 1994                     79.712
## Aug 1994                     69.257
## Sep 1994                     56.561
## Oct 1994                     59.757
## Nov 1994                     65.325
## Dec 1994                     75.959
## Jan 1995                     84.852
## Feb 1995                     85.447
## Mar 1995                     97.479
## Apr 1995                     83.847
## May 1995                     94.791
## Jun 1995                    103.128
## Jul 1995                     93.729
## Aug 1995                     83.175
## Sep 1995                     68.333
## Oct 1995                     78.993
```

```
## Nov 1995  87.148
## Dec 1995  99.640
## Jan 1996 104.821
## Feb 1996 108.488
## Mar 1996 115.603
## Apr 1996 108.647
## May 1996 113.485
## Jun 1996 108.928
## Jul 1996  98.519
## Aug 1996  89.620
## Sep 1996  75.536
## Oct 1996  77.094
## Nov 1996  80.374
## Dec 1996 103.400
## Jan 1997 112.458
## Feb 1997 107.528
## Mar 1997 119.397
## Apr 1997 109.441
## May 1997 116.635
## Jun 1997 117.564
## Jul 1997 108.011
## Aug 1997  91.802
## Sep 1997  79.836
## Oct 1997  84.394
## Nov 1997  80.900
## Dec 1997  88.252
## Jan 1998  98.328
## Feb 1998 102.347
## Mar 1998 108.119
## Apr 1998  97.610
## May 1998 113.264
## Jun 1998 110.348
## Jul 1998  97.785
## Aug 1998  85.678
## Sep 1998  71.060
## Oct 1998  64.434
## Nov 1998  68.310
## Dec 1998  85.937
## Jan 1999 100.724
## Feb 1999  97.902
## Mar 1999 109.456
## Apr 1999  93.280
## May 1999  98.936
## Jun 1999 104.294
## Jul 1999 101.288
## Aug 1999  87.778
## Sep 1999  71.283
## Oct 1999  67.908
## Nov 1999  72.210
## Dec 1999  85.198
## Jan 2000  86.468
## Feb 2000  76.714
## Mar 2000  91.110
## Apr 2000  97.207
```

```
## May 2000                    93.560
## Jun 2000                    85.931
## Jul 2000                    82.333
## Aug 2000                    74.999
## Sep 2000                    60.736
## Oct 2000                    58.639
## Nov 2000                    65.377
## Dec 2000                    67.181
## Jan 2001                    64.323
## Feb 2001                    59.617
## Mar 2001                    69.868
## Apr 2001                    61.460
## May 2001                    65.427
## Jun 2001                    70.723
## Jul 2001                    61.686
## Aug 2001                    64.534
## Sep 2001                    52.054
## Oct 2001                    51.980
## Nov 2001                    52.589
## Dec 2001                    66.010
## Jan 2002                    74.364
## Feb 2002                    68.894
## Mar 2002                    71.682
## Apr 2002                    82.729
## May 2002                    90.973
## Jun 2002                    96.262
## Jul 2002                    86.906
## Aug 2002                    71.938
## Sep 2002                    58.300
## Oct 2002                    58.589
## Nov 2002                    67.319
## Dec 2002                    73.933
## Jan 2003                    70.287
## Feb 2003                    67.489
## Mar 2003                    82.578
## Apr 2003                    84.478
## May 2003                   100.297
## Jun 2003                    97.536
## Jul 2003                    84.765
## Aug 2003                    78.381
## Sep 2003                    63.055
## Oct 2003                    62.878
## Nov 2003                    67.268
## Dec 2003                    82.039
## Jan 2004                    78.419
## Feb 2004                    71.357
## Mar 2004                    78.184
## Apr 2004                    71.270
## May 2004                    81.955
## Jun 2004                    86.161
## Jul 2004                    79.562
## Aug 2004                    73.672
## Sep 2004                    70.032
## Oct 2004                    64.360
```

```
## Nov 2004  71.437
## Dec 2004  89.431
## Jan 2005  82.817
## Feb 2005  73.722
## Mar 2005  78.258
## Apr 2005  78.675
## May 2005  93.074
## Jun 2005  91.384
## Jul 2005  88.565
## Aug 2005  73.582
## Sep 2005  59.245
## Oct 2005  61.438
## Nov 2005  66.031
## Dec 2005  75.546
## Jan 2006  93.614
## Feb 2006  84.487
## Mar 2006  84.019
## Apr 2006  97.432
## May 2006 105.153
## Jun 2006 101.532
## Jul 2006  86.799
## Aug 2006  74.137
## Sep 2006  58.691
## Oct 2006  58.192
## Nov 2006  69.167
## Dec 2006  73.685
## Jan 2007  88.865
## Feb 2007  63.349
## Mar 2007  82.446
## Apr 2007  81.515
## May 2007  88.872
## Jun 2007  77.850
## Jul 2007  76.694
## Aug 2007  68.037
## Sep 2007  50.302
## Oct 2007  50.485
## Nov 2007  53.507
## Dec 2007  62.582
## Jan 2008  70.898
## Feb 2008  64.108
## Mar 2008  73.934
## Apr 2008  75.862
## May 2008  92.879
## Jun 2008  99.553
## Jul 2008  87.194
## Aug 2008  72.434
## Sep 2008  55.200
## Oct 2008  52.783
## Nov 2008  53.459
## Dec 2008  71.179
## Jan 2009  80.149
## Feb 2009  60.775
## Mar 2009  74.475
## Apr 2009  87.927
```

```
## May 2009                    100.858
## Jun 2009                     99.744
## Jul 2009                     79.789
## Aug 2009                     66.808
## Sep 2009                     59.228
## Oct 2009                     67.186
## Nov 2009                     71.678
## Dec 2009                     84.378
## Jan 2010                     76.371
## Feb 2010                     70.252
## Mar 2010                     71.262
## Apr 2010                     65.158
## May 2010                     85.570
## Jun 2010                    101.861
## Jul 2010                     83.651
## Aug 2010                     68.647
## Sep 2010                     58.909
## Oct 2010                     60.334
## Nov 2010                     66.744
## Dec 2010                     79.053
## Jan 2011                     87.112
## Feb 2011                     82.336
## Mar 2011                    106.231
## Apr 2011                    106.435
## May 2011                    111.187
## Jun 2011                    109.700
## Jul 2011                    106.743
## Aug 2011                     87.905
## Sep 2011                     72.940
## Oct 2011                     67.515
## Nov 2011                     70.562
## Dec 2011                     80.973
## Jan 2012                     78.842
## Feb 2012                     69.209
## Mar 2012                     88.393
## Apr 2012                     89.720
## May 2012                     97.724
## Jun 2012                     90.956
## Jul 2012                     90.387
## Aug 2012                     78.591
## Sep 2012                     60.065
## Oct 2012                     56.304
## Nov 2012                     63.918
## Dec 2012                     78.423
## Jan 2013                     84.715
## Feb 2013                     69.668
## Mar 2013                     70.063
## Apr 2013                     85.631
## May 2013                     97.072
## Jun 2013                     93.434
## Jul 2013                     92.993
## Aug 2013                     73.813
## Sep 2013                     57.871
## Oct 2013                     58.682
```

```
## Nov 2013  60.313
## Dec 2013  72.090
## Jan 2014  73.815
## Feb 2014  59.356
## Mar 2014  82.765
## Apr 2014  86.801
## May 2014  90.568
## Jun 2014  87.838
## Jul 2014  83.107
## Aug 2014  67.582
## Sep 2014  54.846
## Oct 2014  58.547
## Nov 2014  63.548
## Dec 2014  76.186
## Jan 2015  82.360
## Feb 2015  76.040
## Mar 2015  82.846
## Apr 2015  76.671
## May 2015  68.668
## Jun 2015  69.653
## Jul 2015  71.701
## Aug 2015  65.245
## Sep 2015  54.913
## Oct 2015  56.743
## Nov 2015  65.981
## Dec 2015  79.041
## Jan 2016  87.397
## Feb 2016  82.362
## Mar 2016  93.454
## Apr 2016  88.296
## May 2016  86.960
## Jun 2016  79.284
## Jul 2016  73.206
## Aug 2016  66.771
## Sep 2016  55.847
## Oct 2016  59.160
## Nov 2016  64.174
## Dec 2016  76.865
## Jan 2017  90.854
## Feb 2017  81.485
## Mar 2017 101.040
## Apr 2017 100.345
## May 2017 111.255
## Jun 2017 104.323
## Jul 2017  90.753
## Aug 2017  75.180
## Sep 2017  65.346
## Oct 2017  60.386
## Nov 2017  67.859
## Dec 2017  75.910
## Jan 2018  85.519
## Feb 2018  84.967
## Mar 2018  88.236
## Apr 2018  95.929
```

```
## May 2018                    103.876
## Jun 2018                     94.163
## Jul 2018                     85.640
## Aug 2018                     75.122
## Sep 2018                     65.393
## Oct 2018                     66.698
## Nov 2018                     74.766
## Dec 2018                     77.784
## Jan 2019                     84.610
## Feb 2019                     78.068
## Mar 2019                     89.852
## Apr 2019                     94.922
## May 2019                    109.123
## Jun 2019                     95.801
## Jul 2019                     84.875
## Aug 2019                     77.038
## Sep 2019                     63.210
## Oct 2019                     62.459
## Nov 2019                     68.982
## Dec 2019                     73.284
## Jan 2020                     83.587
## Feb 2020                     88.262
## Mar 2020                     81.284
## Apr 2020                     79.139
## May 2020                    102.279
## Jun 2020                     95.534
## Jul 2020                     91.243
## Aug 2020                     79.443
## Sep 2020                     63.732
## Oct 2020                     64.181
## Nov 2020                     71.286
## Dec 2020                     73.385
## Jan 2021                     83.799
## Feb 2021                     68.706
## Mar 2021                     72.404
## Apr 2021                     66.155
## May 2021                     79.530
## Jun 2021                     80.025
## Jul 2021                     75.397
## Aug 2021                     69.360
## Sep 2021                     58.080
## Oct 2021                     58.458
## Nov 2021                     66.102
## Dec 2021                     80.393
## Jan 2022                     82.562
## Feb 2022                     72.746
## Mar 2022                     83.377
## Apr 2022                     68.465
## May 2022                     79.700
## Jun 2022                     88.670
## Jul 2022                     83.824
## Aug 2022                     72.106
## Sep 2022                     58.093
## Oct 2022                     49.022
```

```
## Nov 2022                          61.068
## Dec 2022                          69.706
## Jan 2023                          77.637
## Feb 2023                          68.107
## Mar 2023                          72.783
## Apr 2023                          67.625
## May 2023                          94.346
## Jun 2023                          73.604
## Jul 2023                          74.988
## Aug 2023                          72.652
## Sep 2023                          57.716
## Oct 2023                          53.475
## Nov 2023                          58.092
## Dec 2023                          64.922
## Jan 2024                          73.542
## Feb 2024                          70.954
## Mar 2024                          79.713
## Apr 2024                          71.365
## May 2024                          83.516
## Jun 2024                          76.417
## Jul 2024                          72.962
## Aug 2024                          69.914
## Sep 2024                          54.289
## Oct 2024                          52.382
## Nov 2024                          57.060
## Dec 2024                          66.647
## Jan 2025                          73.116
## Feb 2025                          66.674
## Mar 2025                          76.613
## Apr 2025                          77.930
## May 2025                          83.111
## Jun 2025                          75.615
## Jul 2025                          68.186
## Aug 2025                          68.181
## Sep 2025                          52.277
```

Question 3

Compute mean and standard deviation for these three series.

```
data_threeseries <- energy_data_new[, 2:4]
Mean <- colMeans(data_threeseries, na.rm = TRUE)
SD <- sapply(data_threeseries, sd, na.rm = TRUE)
Mean  #Showing mean of the three series
```

```
##   Total Biomass Energy Production Total Renewable Energy Production
##                         286.04893                          409.19521
##   Hydroelectric Power Consumption
##                          79.35682
```

```
SD  #Showing standard deviation of the three series
```

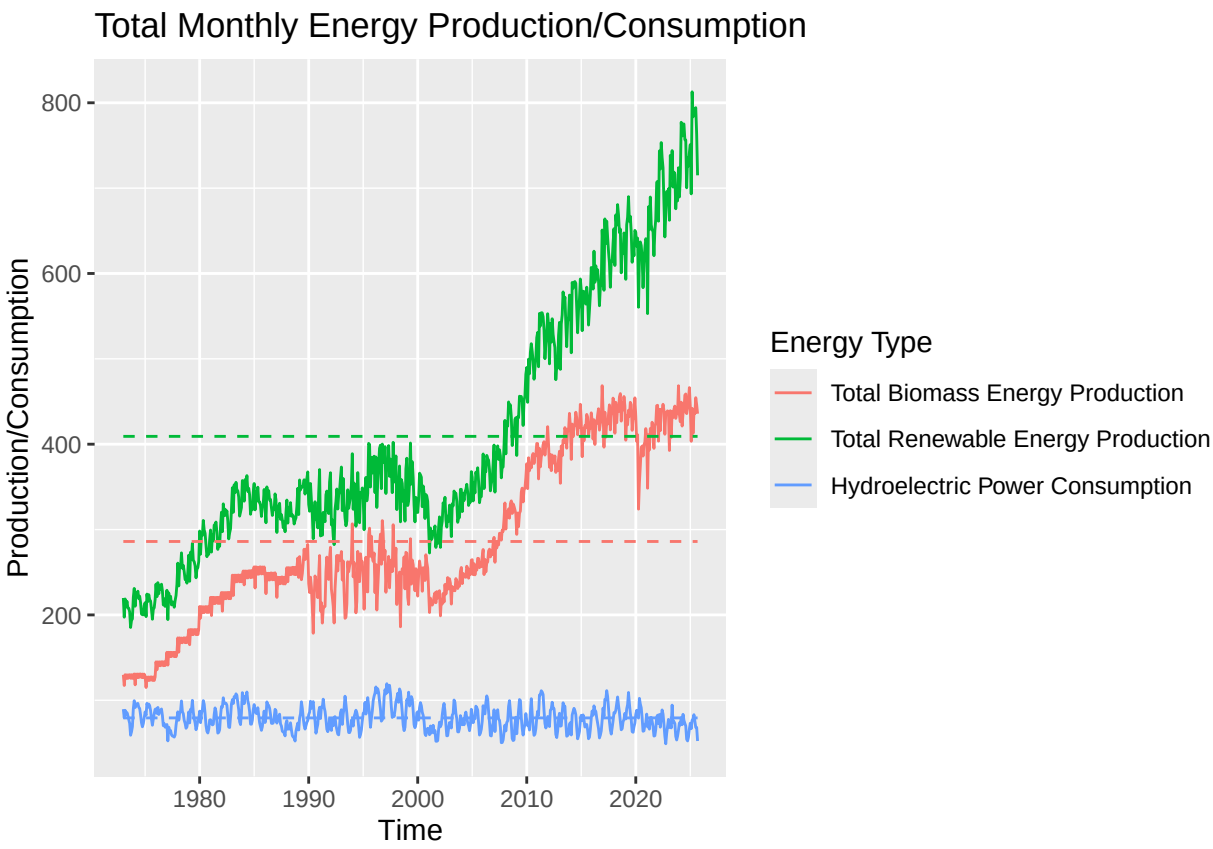
```
##   Total Biomass Energy Production Total Renewable Energy Production
##                          96.21209                          151.42232
##   Hydroelectric Power Consumption
##                          14.12020
```

Question 4

Display and interpret the time series plot for each of these variables. Try to make your plot as informative as possible by writing titles, labels, etc. For each plot add a horizontal line at the mean of each series in a different color.

```
# Mean
Mean <- colMeans(energy_data_tsa, na.rm = TRUE)
mean_tsa <- energy_data_tsa
mean_tsa[, ] <- matrix(rep(Mean, each = nrow(energy_data_tsa)),
    nrow = nrow(energy_data_tsa), byrow = FALSE)
autoplot(energy_data_tsa) + autolayer(mean_tsa, linetype = "dashed",
    alpha = 1.5, show.legend = FALSE) + ggtitle("Total Monthly Energy Production/Consumption") +
    xlab("Time") + ylab("Production/Consumption") + labs(color = "Energy Type")
```

```
## For a multivariate time series, specify a seriesname for each time series. Defaulting to column names
```



The Hydroelectric Power Consumption shows a releative constant and slow growth during the decades, while the biomass production and renewable energy production have similar trends. The biomass and renewable energy production have grown fast and fluctuated through years, which may due to the change of public policies and technology of renewable energy.

Question 5

Compute the correlation between these three series. Are they significantly correlated? Explain your answer.

```
correlation <- cor(energy_data_tsa, use = "complete.obs")
correlation
```

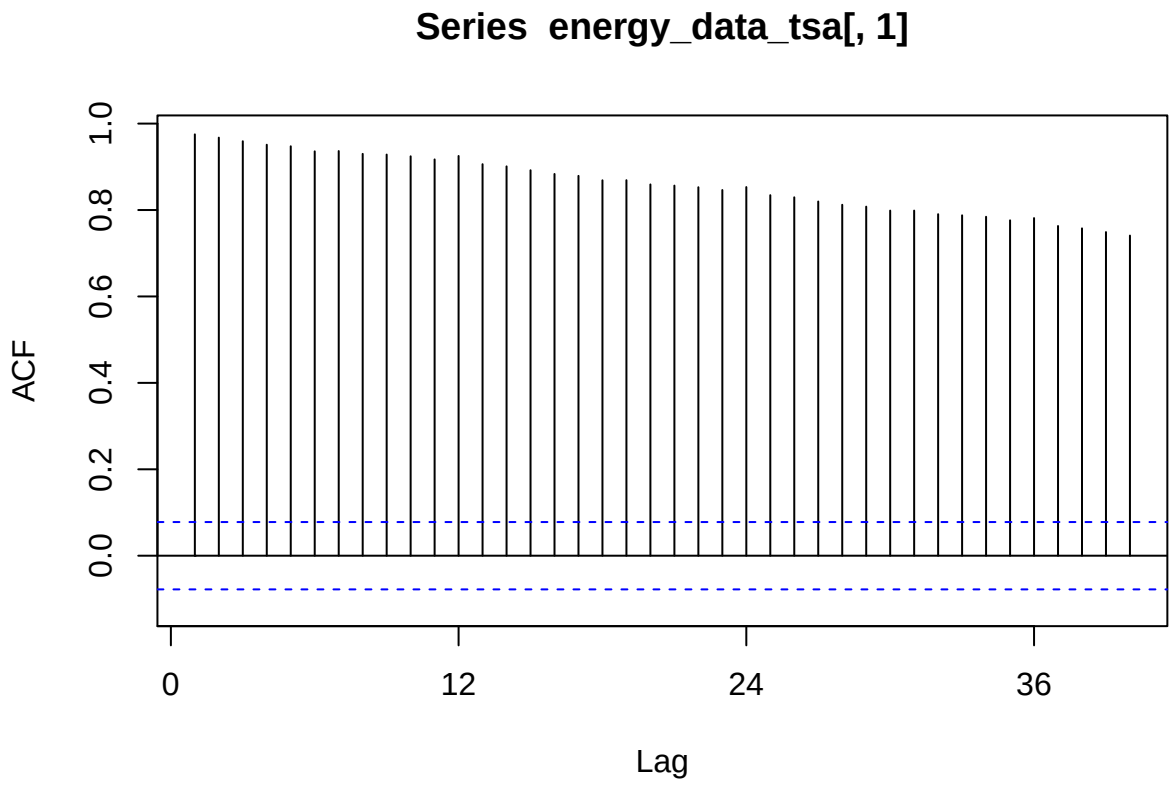
```
##                                    Total Biomass Energy Production
## Total Biomass Energy Production                          1.0000000
## Total Renewable Energy Production                        0.9652985
## Hydroelectric Power Consumption                         -0.1347374
##                                    Total Renewable Energy Production
## Total Biomass Energy Production                           0.96529851
## Total Renewable Energy Production                         1.00000000
## Hydroelectric Power Consumption                          -0.05842436
##                                    Hydroelectric Power Consumption
## Total Biomass Energy Production                        -0.13473742
## Total Renewable Energy Production                      -0.05842436
## Hydroelectric Power Consumption                         1.00000000
```

Total Biomass Production and Total Renewable Energy Production have a correlation of 0.96529851, showing that they are significantly correlated. Total Biomass Energy Production and Hydroelectric Power Consumption have a correlation of -0.13473742, which is weak and not significant. Total Renewable Energy Production and Hydroelectric Power Consumption have a correlation of -0.05842436, which also shows a weak and insignificant correlation.

Question 6

Compute the autocorrelation function from lag 1 up to lag 40 for these three variables. What can you say about these plots? Do the three of them have the same behavior?

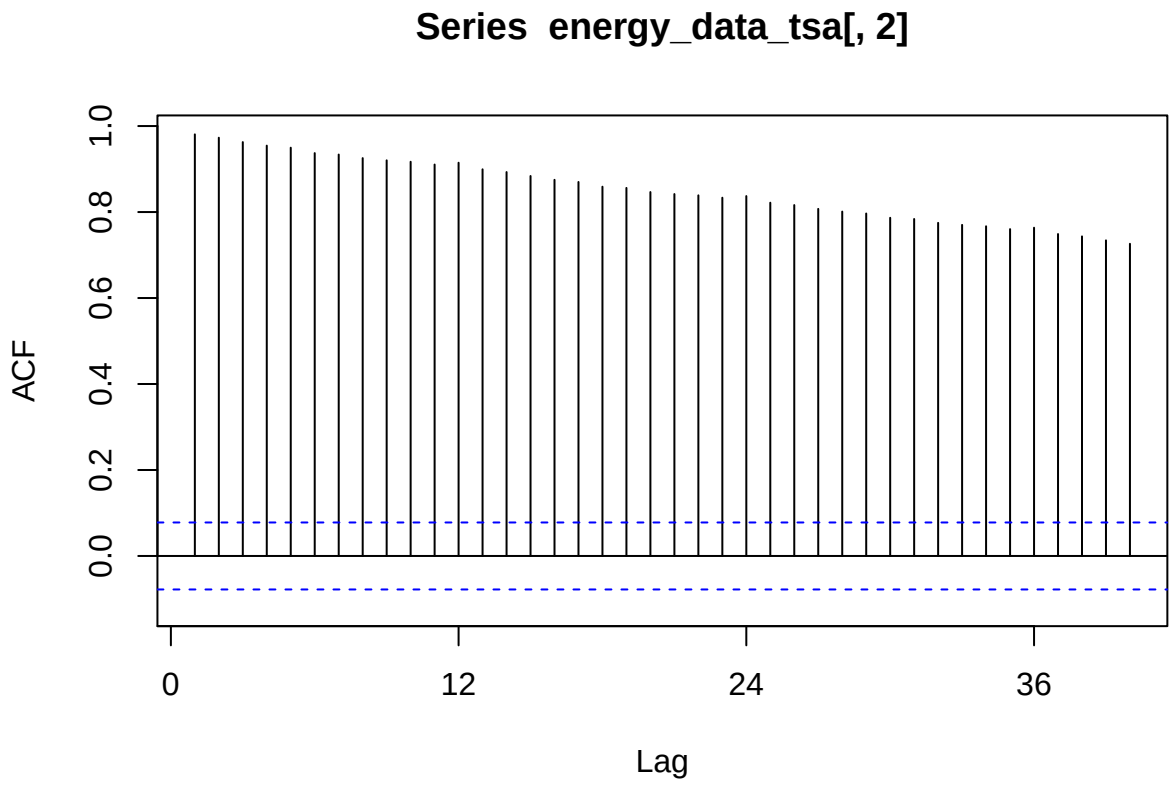
```
Biomass_acf = Acf(energy_data_tsa[, 1], lag.max = 40, plot = TRUE)
```




```
Biomass_acf
```

```
##
## Autocorrelations of series 'energy_data_tsa[, 1]', by lag
##
##     0     1     2     3     4     5     6     7     8     9    10    11    12
## 1.000 0.975 0.968 0.959 0.951 0.948 0.936 0.937 0.930 0.928 0.924 0.917 0.925
##    13    14    15    16    17    18    19    20    21    22    23    24    25
## 0.906 0.901 0.892 0.883 0.879 0.869 0.869 0.859 0.857 0.853 0.846 0.853 0.834
##    26    27    28    29    30    31    32    33    34    35    36    37    38
## 0.829 0.820 0.812 0.808 0.799 0.799 0.790 0.788 0.784 0.776 0.781 0.763 0.758
##    39    40
## 0.749 0.741
```

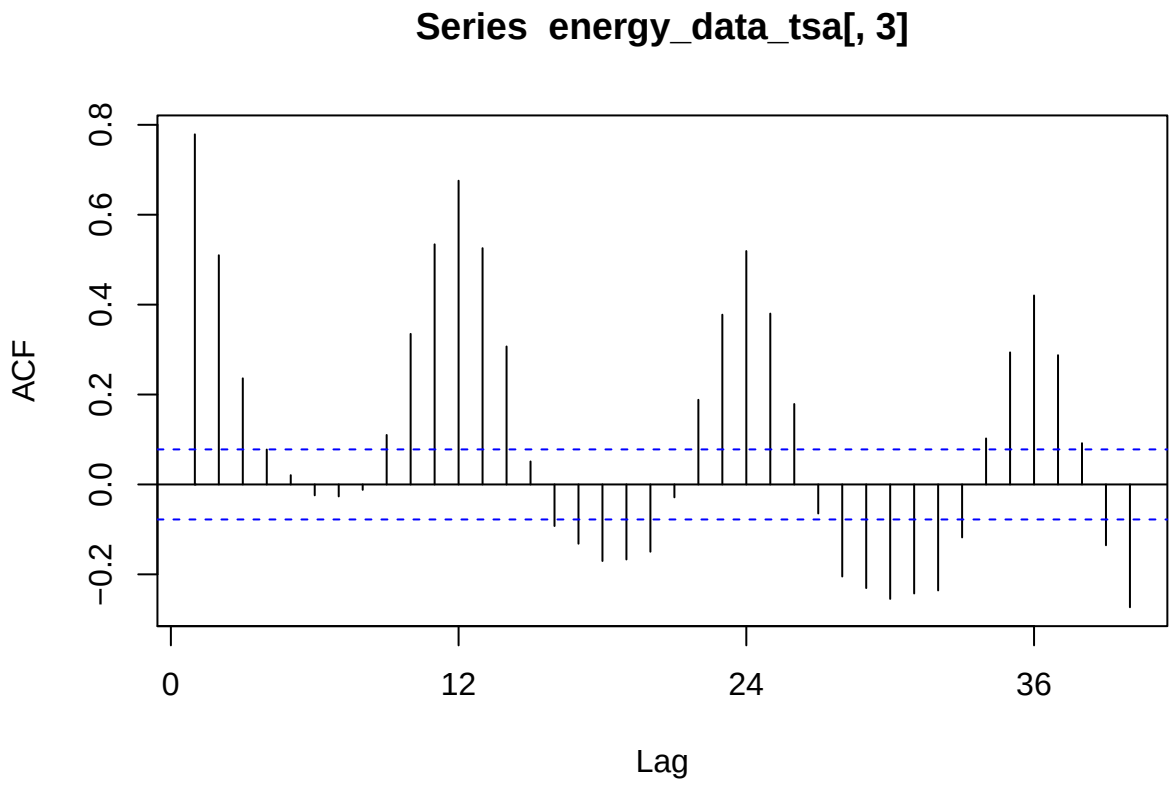
```
Renewable_acf = Acf(energy_data_tsa[, 2], lag.max = 40, plot = TRUE)
```




```
Renewable_acf
```

```
##
## Autocorrelations of series 'energy_data_tsa[, 2]', by lag
##
##     0     1     2     3     4     5     6     7     8     9    10    11    12
## 1.000 0.981 0.973 0.963 0.955 0.950 0.937 0.934 0.925 0.920 0.917 0.910 0.915
##    13    14    15    16    17    18    19    20    21    22    23    24    25
## 0.899 0.893 0.884 0.875 0.870 0.859 0.856 0.847 0.842 0.839 0.833 0.837 0.822
##    26    27    28    29    30    31    32    33    34    35    36    37    38
## 0.816 0.807 0.801 0.797 0.787 0.784 0.775 0.770 0.767 0.760 0.764 0.749 0.743
##    39    40
## 0.734 0.726
```

```
Hydro_acf = Acf(energy_data_tsa[, 3], lag.max = 40, plot = TRUE)
```




```
Hydro_acf
```

```
##
## Autocorrelations of series 'energy_data_tsa[, 3]', by lag
##
##      0      1      2      3      4      5      6      7      8      9     10
##  1.000  0.779  0.510  0.236  0.078  0.021 -0.024 -0.027 -0.012  0.110  0.335
##     11     12     13     14     15     16     17     18     19     20     21
##  0.534  0.676  0.526  0.307  0.051 -0.092 -0.132 -0.170 -0.167 -0.150 -0.029
##     22     23     24     25     26     27     28     29     30     31     32
##  0.188  0.378  0.519  0.380  0.179 -0.065 -0.205 -0.230 -0.255 -0.243 -0.236
##     33     34     35     36     37     38     39     40
## -0.118  0.102  0.294  0.420  0.288  0.092 -0.135 -0.273
```

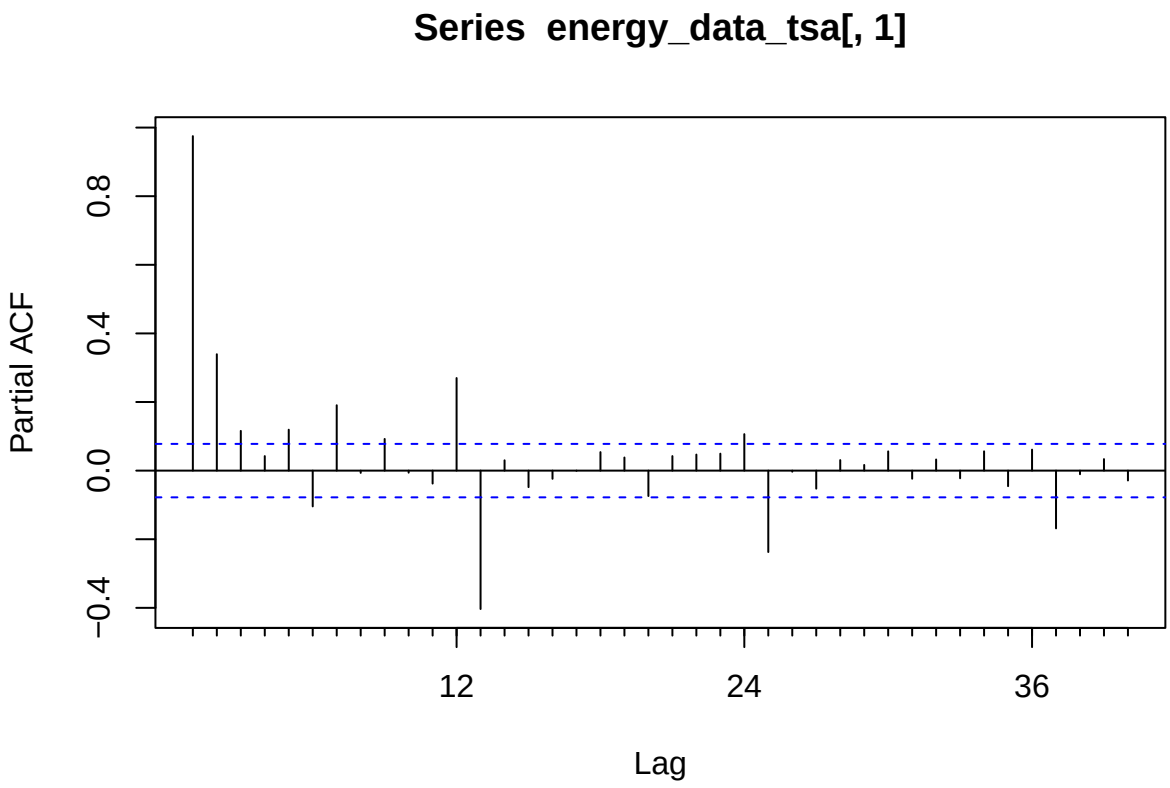
The total biomass production and renewable energy production trends have the similar behavior. Both total biomass production and renewable energy production show positive and significant autocorrelation from lag 1 up to lag 40, indicating that they have strong high persistence and are correlated with their past values over time.

The hydroelectric power consumption has a fluctuating trend: the autocorrelation moves up and down between positive and negative values, indicating a seasonal trend instead of a persistent trend.

Question 7

Compute the partial autocorrelation function from lag 1 to lag 40 for these three variables. How these plots differ from the ones in Q6?

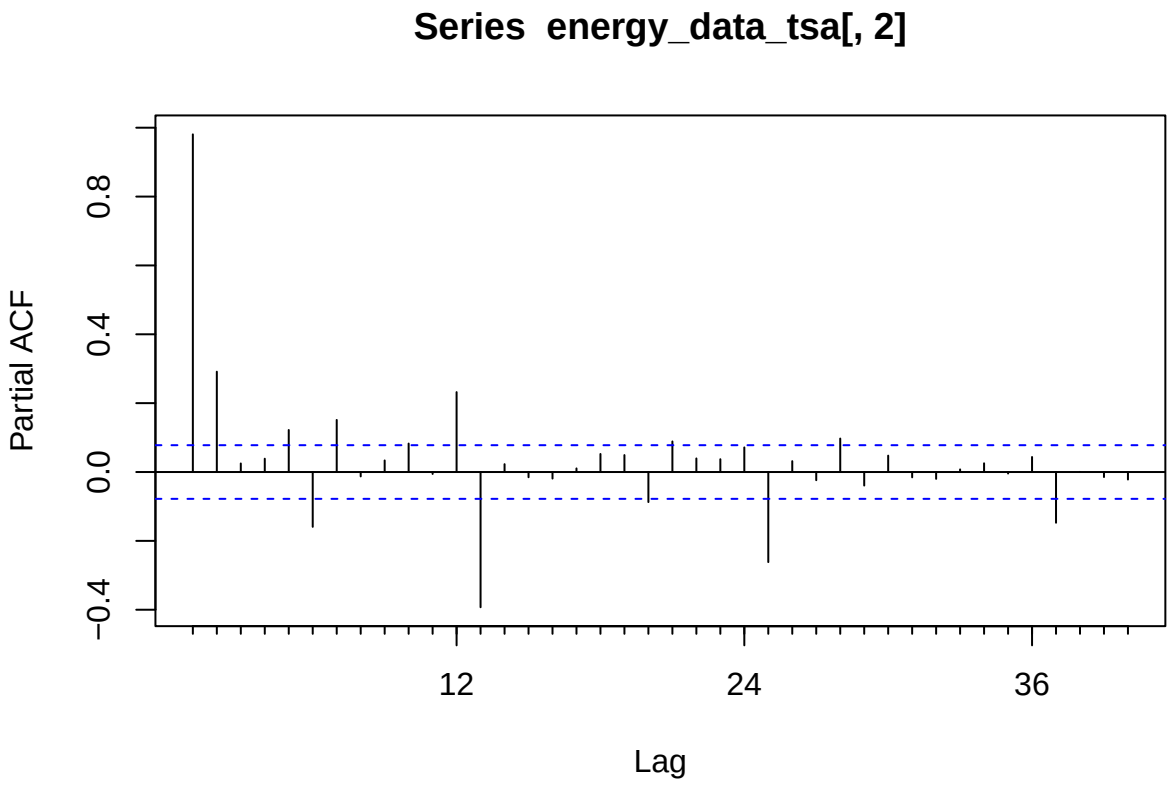
```r
Biomass_pacf = Pacf(energy_data_tsa[, 1], lag.max = 40, plot = TRUE)
```




```r
Biomass_pacf
```

```
##
## Partial autocorrelations of series 'energy_data_tsa[, 1]', by lag
##
##      1      2      3      4      5      6      7      8      9     10     11
##  0.975  0.339  0.116  0.042  0.119 -0.104  0.191 -0.007  0.092 -0.006 -0.038
##     12     13     14     15     16     17     18     19     20     21     22
##  0.270 -0.403  0.030 -0.048 -0.024 -0.001  0.054  0.038 -0.074  0.042  0.047
##     23     24     25     26     27     28     29     30     31     32     33
##  0.049  0.106 -0.237 -0.003 -0.053  0.031  0.017  0.056 -0.024  0.032 -0.022
##     34     35     36     37     38     39     40
##  0.056 -0.045  0.061 -0.168 -0.010  0.034 -0.029
```

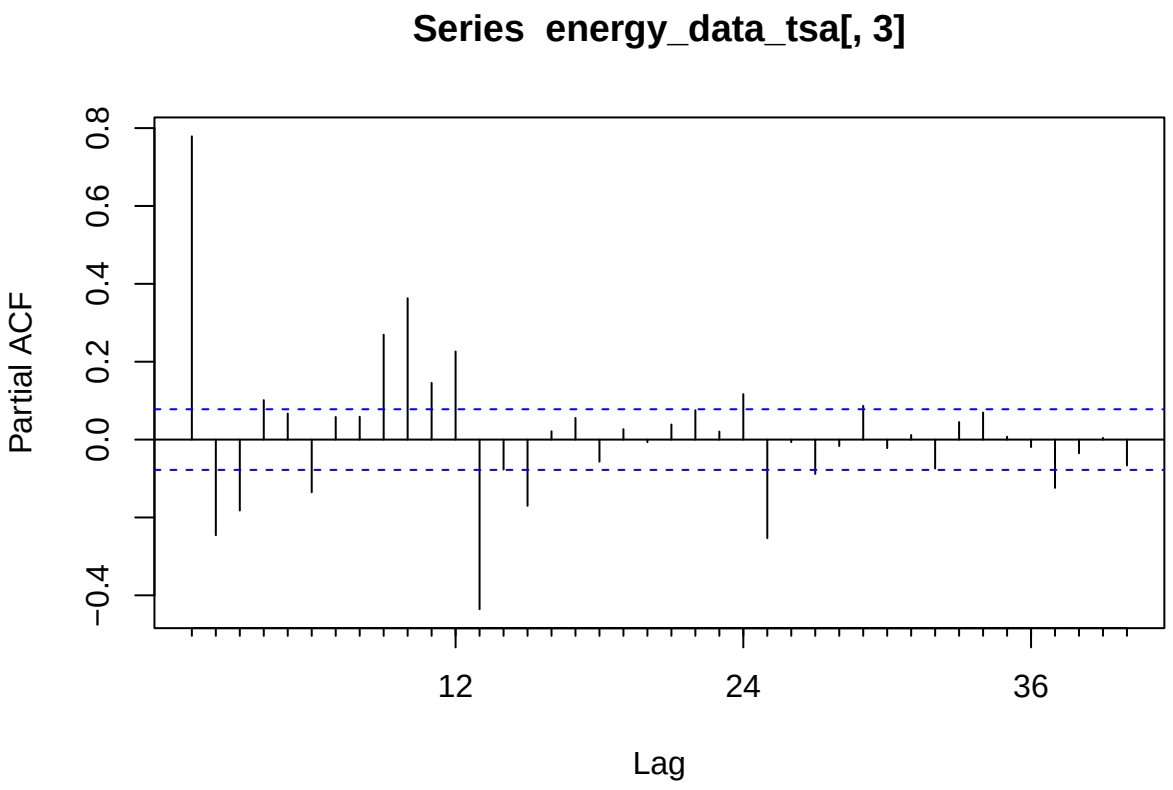
```r
Renewable_pacf = Pacf(energy_data_tsa[, 2], lag.max = 40, plot = TRUE)
```




```
Renewable_pacf
```

```
##
## Partial autocorrelations of series 'energy_data_tsa[, 2]', by lag
##
##      1      2      3      4      5      6      7      8      9     10     11
##  0.981  0.291  0.025  0.039  0.122 -0.159  0.151 -0.013  0.034  0.083 -0.006
##     12     13     14     15     16     17     18     19     20     21     22
##  0.232 -0.393  0.023 -0.015 -0.019  0.010  0.052  0.049 -0.087  0.089  0.039
##     23     24     25     26     27     28     29     30     31     32     33
##  0.037  0.071 -0.262  0.032 -0.024  0.097 -0.039  0.048 -0.016 -0.020  0.008
##     34     35     36     37     38     39     40
##  0.025 -0.004  0.044 -0.147  0.000 -0.015 -0.022
```

```
Hydro_pacf = Pacf(energy_data_tsa[, 3], lag.max = 40, plot = TRUE)
```




```
Hydro_pacf
```

```
##
## Partial autocorrelations of series 'energy_data_tsa[, 3]', by lag
##
##      1      2      3      4      5      6      7      8      9     10     11
##  0.779 -0.246 -0.182  0.101  0.067 -0.135  0.058  0.059  0.269  0.363  0.146
##     12     13     14     15     16     17     18     19     20     21     22
##  0.226 -0.436 -0.077 -0.170  0.021  0.056 -0.057  0.027 -0.007  0.039  0.076
##     23     24     25     26     27     28     29     30     31     32     33
##  0.021  0.117 -0.253 -0.007 -0.088 -0.017  0.087 -0.022  0.012 -0.074  0.045
##     34     35     36     37     38     39     40
##  0.069  0.007 -0.019 -0.124 -0.035  0.004 -0.066
```

All of the three variables show fluctuating trends between positive and negative values, and most of the lines show weak correlations. After removing the influence of all these intermediate variables, the trends of biomass production and renewable production have changed from what we saw in Q6. The biomass production and renewable energy production trends are very similar, indicating that they have similar seasonality. The hydroelectric consumption trend also show seasonality, while it has a more complex and fluctuating change through 12 months.