ENV 790.30 - Time Series Analysis for Energy Data | Spring 2024

Assignment 2 - Due date 02/25/24

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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_Sp24.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
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 2023 Monthly Energy Review. The spreadsheet is ready to be used. You will also find a *.csv* version of the data "Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source-Edit.csv". You may use the function *read.table*() to import the *.csv* data in R. Or refer to the file "M2_ImportingData_CSV_XLSX.Rmd" in our Lessons folder for functions that are better suited for importing the *.xlsx*.

```r
#Importing data set
getwd()
```

```
## [1] "/Users/lzh/Desktop/TSA_Sp24"
```

```r
energy_data <- read.table(file="./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source
```

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.

```r
#New data frame
energy_data <- energy_data %>% select("Total.Biomass.Energy.Production", "Total.Renewable.Energy.Consump

#Verification
head(energy_data)
```

```
##   Total.Biomass.Energy.Production Total.Renewable.Energy.Consumption
## 1                         129.787                             219.839
## 2                         117.338                             197.330
## 3                         129.938                             218.686
## 4                         125.636                             209.330
## 5                         129.834                             215.982
## 6                         125.611                             208.249
##   Hydroelectric.Power.Consumption
## 1                          89.562
## 2                          79.544
## 3                          88.284
## 4                          83.152
## 5                          85.643
## 6                          82.060
```

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().

```r
ts_energy <- ts(energy_data[,1:3], start = c(1973, 1), frequency = 12)
ts_energy
```

```
##          Total.Biomass.Energy.Production Total.Renewable.Energy.Consumption
## 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  372.485
## Feb 1993  240.964  322.577
## Mar 1993  263.204  360.077
## Apr 1993  226.859  329.831
## May 1993  196.012  312.544
## Jun 1993  197.445  303.968
## Jul 1993  212.707  309.725
## Aug 1993  262.322  345.762
## Sep 1993  250.551  325.416
## Oct 1993  257.383  331.637
## Nov 1993  262.183  340.132
## Dec 1993  264.559  352.882
## Jan 1994  306.708  389.790
## Feb 1994  244.594  324.355
## Mar 1994  261.461  354.797
## Apr 1994  236.035  333.618
## May 1994  202.480  303.702
## Jun 1994  215.744  313.104
## Jul 1994  274.451  366.408
## Aug 1994  251.577  333.782
## Sep 1994  238.967  304.919
## Oct 1994  271.599  345.071
## Nov 1994  261.436  337.957
## Dec 1994  262.482  348.958
## Jan 1995  243.462  335.783
```

```
## Feb 1995                206.657                 298.846
## Mar 1995                239.820                 346.954
## Apr 1995                267.571                 360.765
## May 1995                227.439                 332.030
## Jun 1995                226.934                 343.116
## Jul 1995                294.251                 399.964
## Aug 1995                301.628                 397.631
## Sep 1995                268.791                 349.856
## Oct 1995                292.175                 387.053
## Nov 1995                267.659                 371.034
## Dec 1995                262.694                 373.611
## Jan 1996                272.584                 386.973
## Feb 1996                226.038                 344.842
## Mar 1996                259.039                 385.713
## Apr 1996                205.729                 325.967
## May 1996                231.211                 357.092
## Jun 1996                254.182                 376.357
## Jul 1996                281.656                 395.184
## Aug 1996                294.581                 398.950
## Sep 1996                259.345                 347.223
## Oct 1996                310.461                 398.629
## Nov 1996                295.562                 386.949
## Dec 1996                264.912                 377.621
## Jan 1997                275.641                 396.451
## Feb 1997                226.521                 342.432
## Mar 1997                251.136                 381.349
## Apr 1997                252.010                 373.961
## May 1997                268.515                 396.319
## Jun 1997                231.690                 361.596
## Jul 1997                259.985                 382.384
## Aug 1997                264.422                 370.753
## Sep 1997                250.744                 342.452
## Oct 1997                305.656                 403.225
## Nov 1997                264.591                 356.111
## Dec 1997                256.998                 356.344
## Jan 1998                278.211                 385.839
## Feb 1998                212.209                 323.992
## Mar 1998                240.963                 361.643
## Apr 1998                240.612                 347.366
## May 1998                250.239                 373.713
## Jun 1998                186.089                 308.120
## Jul 1998                246.326                 358.273
## Aug 1998                254.237                 354.102
## Sep 1998                248.270                 332.635
## Oct 1998                267.922                 346.208
## Nov 1998                230.488                 309.366
## Dec 1998                273.362                 371.443
## Jan 1999                272.260                 383.010
## Feb 1999                220.539                 328.079
## Mar 1999                212.177                 333.234
## Apr 1999                249.920                 352.815
## May 1999                289.264                 400.059
## Jun 1999                236.090                 354.459
## Jul 1999                264.292                 379.388
```

```
## Aug 1999  258.854  359.730
## Sep 1999  244.140  327.451
## Oct 1999  228.256  309.520
## Nov 1999  254.125  339.200
## Dec 1999  235.215  333.816
## Jan 2000  222.067  320.353
## Feb 2000  246.169  333.404
## Mar 2000  263.209  366.512
## Apr 2000  254.609  362.737
## May 2000  254.678  361.371
## Jun 2000  227.712  325.357
## Jul 2000  255.348  350.411
## Aug 2000  254.942  344.955
## Sep 2000  240.331  313.113
## Oct 2000  270.472  342.246
## Nov 2000  261.335  340.787
## Dec 2000  254.788  334.352
## Jan 2001  228.434  305.297
## Feb 2001  202.849  272.999
## Mar 2001  219.649  302.202
## Apr 2001  213.628  287.200
## May 2001  211.506  289.692
## Jun 2001  213.950  294.920
## Jul 2001  221.842  300.029
## Aug 2001  225.897  301.895
## Sep 2001  214.229  278.433
## Oct 2001  227.319  294.372
## Nov 2001  219.773  282.914
## Dec 2001  225.088  301.994
## Jan 2002  228.396  313.316
## Feb 2002  198.932  279.574
## Mar 2002  217.568  299.890
## Apr 2002  212.852  309.223
## May 2002  225.155  330.978
## Jun 2002  215.107  326.107
## Jul 2002  235.713  338.340
## Aug 2002  224.400  311.155
## Sep 2002  230.855  301.973
## Oct 2002  243.767  315.646
## Nov 2002  230.328  311.921
## Dec 2002  242.334  328.033
## Jan 2003  237.044  316.629
## Feb 2003  212.693  295.192
## Mar 2003  233.288  328.108
## Apr 2003  228.516  327.968
## May 2003  229.756  345.168
## Jun 2003  228.254  340.349
## Jul 2003  242.533  341.879
## Aug 2003  239.928  333.952
## Sep 2003  230.968  306.776
## Oct 2003  236.938  314.009
## Nov 2003  233.698  317.080
## Dec 2003  251.160  348.768
## Jan 2004  255.574  348.075
```

```
## Feb 2004  236.689  322.908
## Mar 2004  248.532  342.267
## Apr 2004  247.253  335.227
## May 2004  244.383  344.647
## Jun 2004  244.075  349.647
## Jul 2004  257.042  353.184
## Aug 2004  254.446  343.947
## Sep 2004  243.019  329.085
## Oct 2004  253.520  333.981
## Nov 2004  247.286  333.005
## Dec 2004  264.199  369.554
## Jan 2005  264.707  362.181
## Feb 2005  247.271  333.249
## Mar 2005  260.043  354.219
## Apr 2005  246.929  342.257
## May 2005  255.790  368.082
## Jun 2005  252.466  364.912
## Jul 2005  266.332  373.092
## Aug 2005  266.097  358.740
## Sep 2005  255.348  331.935
## Oct 2005  261.121  340.286
## Nov 2005  256.532  340.586
## Dec 2005  268.550  363.365
## Jan 2006  276.647  387.157
## Feb 2006  247.274  345.819
## Mar 2006  265.069  367.428
## Apr 2006  250.384  369.820
## May 2006  261.125  393.615
## Jun 2006  261.960  392.691
## Jul 2006  274.809  386.734
## Aug 2006  277.063  375.697
## Sep 2006  267.952  351.261
## Oct 2006  275.120  361.028
## Nov 2006  270.475  365.938
## Dec 2006  283.636  383.083
## Jan 2007  290.845  403.846
## Feb 2007  261.666  346.849
## Mar 2007  285.146  392.456
## Apr 2007  278.386  382.355
## May 2007  286.010  397.397
## Jun 2007  281.995  384.285
## Jul 2007  295.653  392.889
## Aug 2007  295.523  386.651
## Sep 2007  287.603  359.623
## Oct 2007  299.416  377.047
## Nov 2007  297.828  371.505
## Dec 2007  312.007  399.957
## Jan 2008  331.138  423.909
## Feb 2008  300.535  388.128
## Mar 2008  321.487  417.287
## Apr 2008  314.073  420.361
## May 2008  324.185  445.634
## Jun 2008  313.335  443.148
## Jul 2008  330.507  445.735
```

```
## Aug 2008    333.607    429.994
## Sep 2008    318.840    399.306
## Oct 2008    330.125    414.393
## Nov 2008    327.317    407.538
## Dec 2008    323.102    432.271
## Jan 2009    318.353    426.373
## Feb 2009    294.389    378.565
## Mar 2009    319.356    430.087
## Apr 2009    303.489    435.012
## May 2009    319.032    460.473
## Jun 2009    321.739    457.323
## Jul 2009    343.841    455.899
## Aug 2009    348.551    449.686
## Sep 2009    332.374    420.236
## Oct 2009    346.472    451.477
## Nov 2009    348.333    451.441
## Dec 2009    360.689    475.975
## Jan 2010    377.071    480.067
## Feb 2010    347.952    443.254
## Mar 2010    384.094    490.357
## Apr 2010    368.922    479.212
## May 2010    376.012    505.945
## Jun 2010    372.328    519.901
## Jul 2010    385.443    509.025
## Aug 2010    389.064    495.511
## Sep 2010    377.355    472.836
## Oct 2010    386.771    486.337
## Nov 2010    386.602    493.982
## Dec 2010    400.917    519.257
## Jan 2011    400.710    515.053
## Feb 2011    359.327    483.761
## Mar 2011    394.959    542.539
## Apr 2011    373.481    529.311
## May 2011    385.273    547.848
## Jun 2011    389.673    553.298
## Jul 2011    399.454    539.749
## Aug 2011    402.931    533.537
## Sep 2011    387.218    493.388
## Oct 2011    397.994    508.749
## Nov 2011    400.892    517.794
## Dec 2011    420.525    543.031
## Jan 2012    399.385    517.861
## Feb 2012    373.028    482.433
## Mar 2012    388.074    534.186
## Apr 2012    368.981    515.898
## May 2012    387.318    544.283
## Jun 2012    377.792    528.939
## Jul 2012    379.862    521.059
## Aug 2012    386.269    518.634
## Sep 2012    366.955    474.573
## Oct 2012    373.976    497.275
## Nov 2012    368.902    489.543
## Dec 2012    383.017    525.662
## Jan 2013    391.713    541.722
```

```
## Feb 2013                354.251                 489.703
## Mar 2013                397.835                 542.829
## Apr 2013                386.469                 553.445
## May 2013                404.782                 578.839
## Jun 2013                401.893                 568.941
## Jul 2013                419.452                 572.609
## Aug 2013                413.684                 545.940
## Sep 2013                395.313                 521.977
## Oct 2013                417.493                 548.917
## Nov 2013                415.796                 547.426
## Dec 2013                436.115                 574.669
## Jan 2014                421.219                 567.339
## Feb 2014                382.387                 504.187
## Mar 2014                423.831                 584.354
## Apr 2014                409.123                 580.934
## May 2014                420.280                 587.999
## Jun 2014                422.985                 586.665
## Jul 2014                437.716                 585.151
## Aug 2014                431.265                 562.820
## Sep 2014                411.320                 529.542
## Oct 2014                424.919                 558.405
## Nov 2014                420.082                 566.067
## Dec 2014                446.975                 585.563
## Jan 2015                427.054                 566.212
## Feb 2015                385.885                 529.192
## Mar 2015                418.601                 575.700
## Apr 2015                404.645                 567.987
## May 2015                422.303                 580.929
## Jun 2015                419.763                 566.693
## Jul 2015                435.439                 585.911
## Aug 2015                432.205                 577.011
## Sep 2015                410.191                 547.077
## Oct 2015                418.690                 557.857
## Nov 2015                419.255                 572.632
## Dec 2015                437.317                 602.293
## Jan 2016                427.949                 581.193
## Feb 2016                406.692                 573.285
## Mar 2016                429.456                 617.896
## Apr 2016                400.491                 583.988
## May 2016                424.186                 606.997
## Jun 2016                425.120                 588.654
## Jul 2016                434.897                 605.704
## Aug 2016                442.383                 591.730
## Sep 2016                417.250                 562.391
## Oct 2016                425.218                 580.043
## Nov 2016                428.755                 584.705
## Dec 2016                469.360                 643.136
## Jan 2017                440.361                 605.491
## Feb 2017                397.221                 564.936
## Mar 2017                438.279                 651.877
## Apr 2017                408.991                 631.253
## May 2017                427.713                 660.715
## Jun 2017                424.376                 643.404
## Jul 2017                435.876                 621.282
```

```
## Aug 2017    446.874    608.199
## Sep 2017    417.527    575.243
## Oct 2017    434.336    605.173
## Nov 2017    439.367    598.341
## Dec 2017    454.794    617.570
## Jan 2018    449.901    634.306
## Feb 2018    413.516    584.663
## Mar 2018    449.807    650.944
## Apr 2018    425.820    638.792
## May 2018    445.435    675.219
## Jun 2018    438.894    654.596
## Jul 2018    456.125    632.779
## Aug 2018    459.996    638.726
## Sep 2018    427.721    582.054
## Oct 2018    449.554    610.084
## Nov 2018    440.785    604.744
## Dec 2018    456.593    627.650
## Jan 2019    445.618    621.459
## Feb 2019    405.314    580.478
## Mar 2019    434.186    646.819
## Apr 2019    423.416    650.823
## May 2019    440.470    682.371
## Jun 2019    433.492    649.664
## Jul 2019    449.754    654.643
## Aug 2019    447.086    635.174
## Sep 2019    416.911    602.462
## Oct 2019    432.540    625.912
## Nov 2019    431.235    609.519
## Dec 2019    454.980    634.502
## Jan 2020    433.538    626.996
## Feb 2020    404.020    615.107
## Mar 2020    411.929    611.100
## Apr 2020    324.772    553.731
## May 2020    355.693    619.881
## Jun 2020    375.486    636.990
## Jul 2020    396.389    624.469
## Aug 2020    398.732    607.820
## Sep 2020    386.923    573.790
## Oct 2020    399.780    592.810
## Nov 2020    403.366    612.464
## Dec 2020    419.147    625.360
## Jan 2021    409.000    607.049
## Feb 2021    348.243    546.565
## Mar 2021    410.780    666.529
## Apr 2021    393.027    641.570
## May 2021    418.210    681.811
## Jun 2021    410.360    644.786
## Jul 2021    425.507    638.611
## Aug 2021    412.988    642.608
## Sep 2021    394.918    610.537
## Oct 2021    422.097    641.215
## Nov 2021    423.575    643.254
## Dec 2021    444.912    679.717
## Jan 2022    435.124    666.207
```

```
## Feb 2022                        394.151                        627.784
## Mar 2022                        430.403                        715.101
## Apr 2022                        405.815                        699.901
## May 2022                        429.947                        724.706
## Jun 2022                        429.508                        710.218
## Jul 2022                        436.315                        691.801
## Aug 2022                        428.868                        664.491
## Sep 2022                        401.522                        617.973
## Oct 2022                        425.435                        646.526
## Nov 2022                        427.493                        665.046
## Dec 2022                        428.630                        661.098
## Jan 2023                        436.916                        684.522
## Feb 2023                        392.661                        643.267
## Mar 2023                        436.299                        718.440
## Apr 2023                        404.131                        686.994
## May 2023                        437.506                        735.066
## Jun 2023                        429.839                        681.330
## Jul 2023                        437.109                        693.048
## Aug 2023                        439.521                        703.012
## Sep 2023                        422.351                        651.798
##          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                    69.207
## Mar 2012                    88.400
## Apr 2012                    89.716
## May 2012                    97.728
## Jun 2012                    90.960
## Jul 2012                    90.388
## Aug 2012                    78.592
## Sep 2012                    60.064
## Oct 2012                    56.300
## Nov 2012                    63.915
## Dec 2012                    78.420
## 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                        76.048
## Feb 2023                        63.745
## Mar 2023                        69.017
## Apr 2023                        59.646
## May 2023                        93.759
## Jun 2023                        66.434
## Jul 2023                        72.463
## Aug 2023                        72.150
## Sep 2023                        56.284
```

Question 3

Compute mean and standard deviation for these three series.

```
#Mean and standard deviation for total biomass energy production
biomass_total_mean <- mean(ts_energy[,1])
biomass_total_mean
```

```
## [1] 279.8046
```

```
biomass_total_stdv <- sd(ts_energy[,1])
biomass_total_stdv
```

```
## [1] 92.66504
```

```r
#Mean and standard deviation for total renewable energy production
renewable_total_mean <- mean(ts_energy[,2])
renewable_total_mean
```

```
## [1] 393.4552
```

```r
renewable_total_stdv <- sd(ts_energy[,2])
renewable_total_stdv
```

```
## [1] 133.7188
```

```r
#Mean and standard deviation for hydroelectric power consumption
hydro_mean <- mean(ts_energy[,3])
hydro_mean
```

```
## [1] 79.73071
```

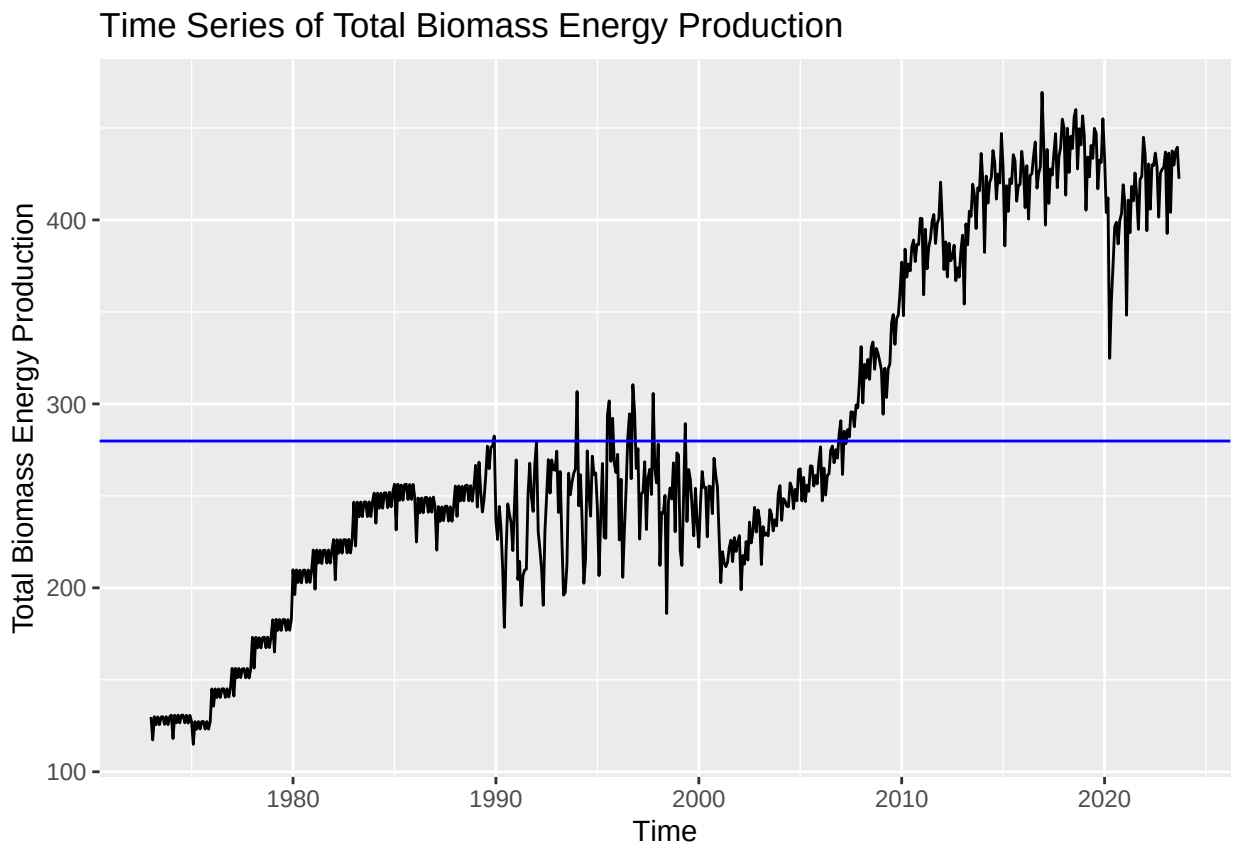
```r
hydro_stdv <- sd(ts_energy[,3])
hydro_stdv
```

```
## [1] 14.14734
```

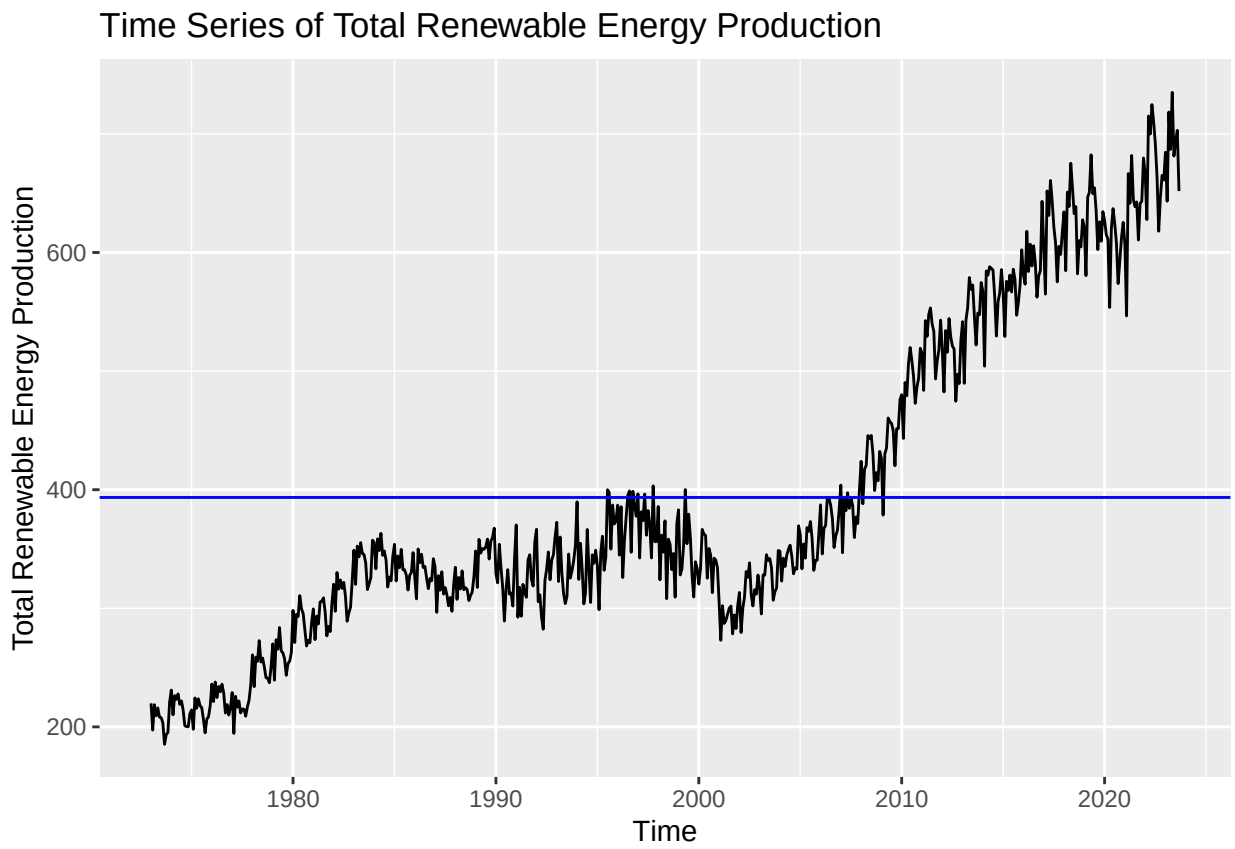
Question 4

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.

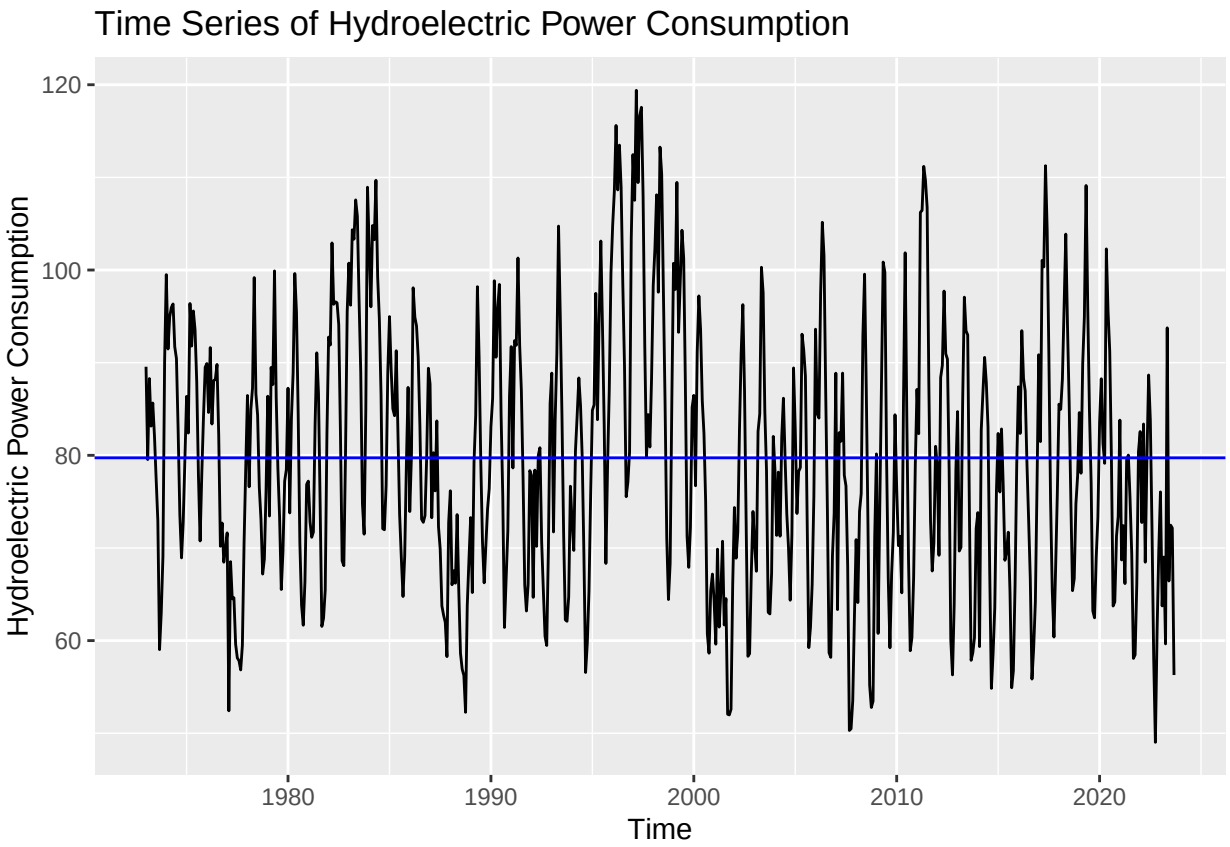
```r
autoplot(ts_energy[,1]) +
  geom_hline(yintercept = biomass_total_mean, color = "blue") +
  xlab("Time") +
  ylab("Total Biomass Energy Production") +
  labs(color="Total.Biomass.Energy.Production") +
   ggtitle("Time Series of Total Biomass Energy Production")
```




```
autoplot(ts_energy[,2]) +
  geom_hline(yintercept = renewable_total_mean, color = "blue") +
  xlab("Time") +
  ylab("Total Renewable Energy Production") +
  labs(color="Total.Renewable.Energy.Production") +
   ggtitle("Time Series of Total Renewable Energy Production")
```




```
autoplot(ts_energy[,3]) +
  geom_hline(yintercept = hydro_mean, color = "blue") +
  xlab("Time") +
  ylab("Hydroelectric Power Consumption") +
  labs(color="Hydroelectric.Power.Consumption") +
   ggtitle("Time Series of Hydroelectric Power Consumption")
```



Question 5

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

```
cor(ts_energy[,1:3])
```

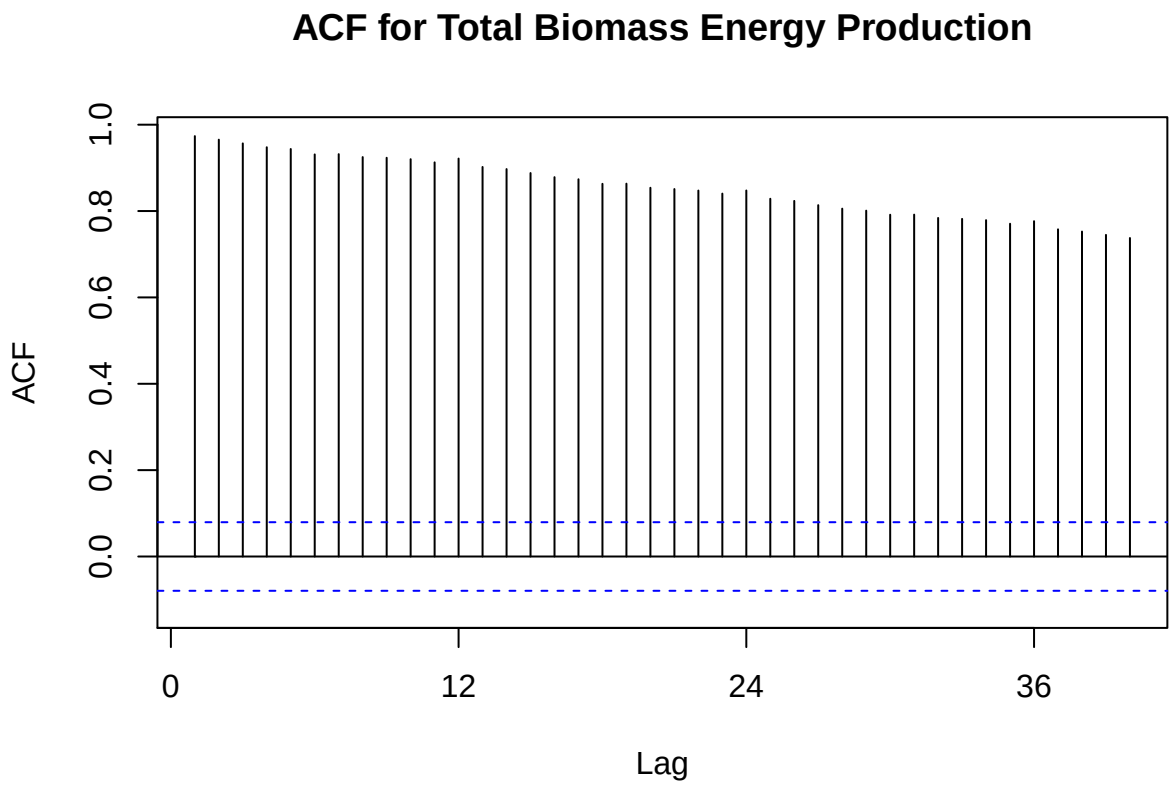
```
##                                    Total.Biomass.Energy.Production
## Total.Biomass.Energy.Production                         1.00000000
## Total.Renewable.Energy.Consumption                      0.97315510
## Hydroelectric.Power.Consumption                        -0.09656318
##                                    Total.Renewable.Energy.Consumption
## Total.Biomass.Energy.Production                           0.9731551043
## Total.Renewable.Energy.Consumption                        1.0000000000
## Hydroelectric.Power.Consumption                          -0.0002494076
##                                    Hydroelectric.Power.Consumption
## Total.Biomass.Energy.Production                      -0.0965631773
## Total.Renewable.Energy.Consumption                   -0.0002494076
## Hydroelectric.Power.Consumption                       1.0000000000
```

The total biomass energy production is highly postive-correlated to total renewable energy consumption. Hydroelectric power consumption, however, is slightly negatively correlated to total biomass energy production and barely has any correlation with total renewable energy consumption.

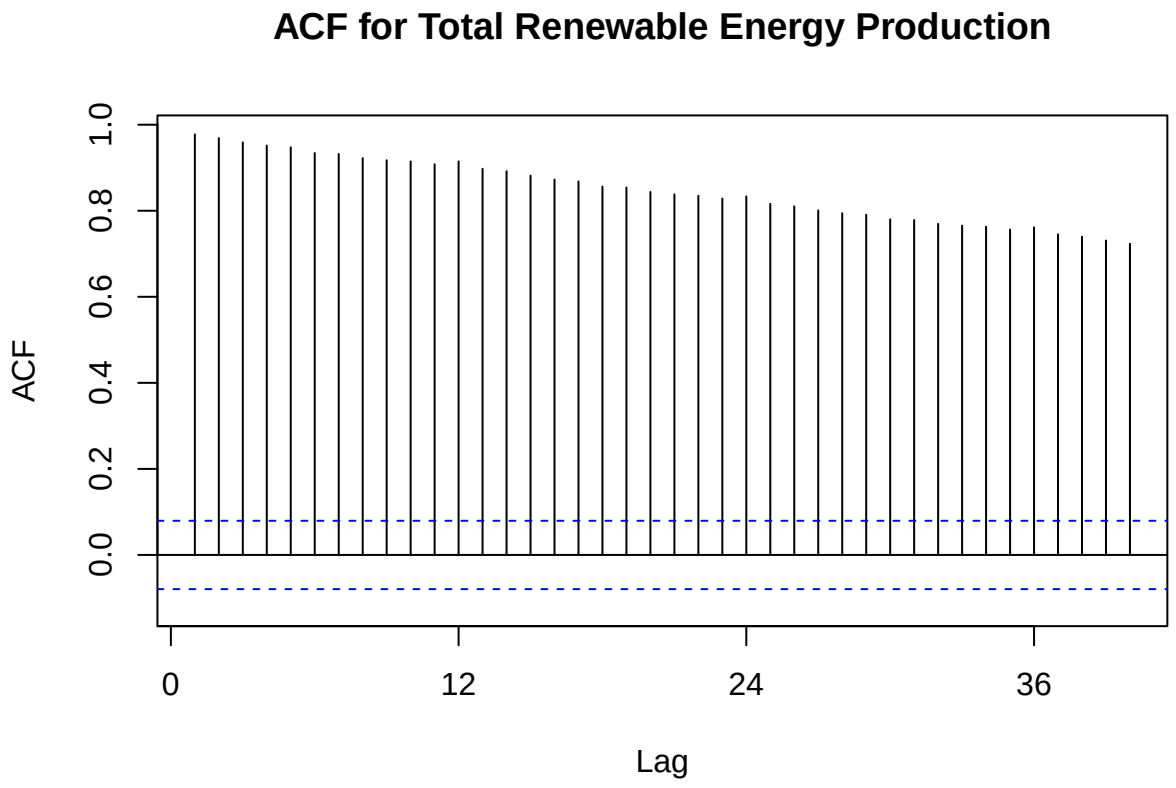
Question 6

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?

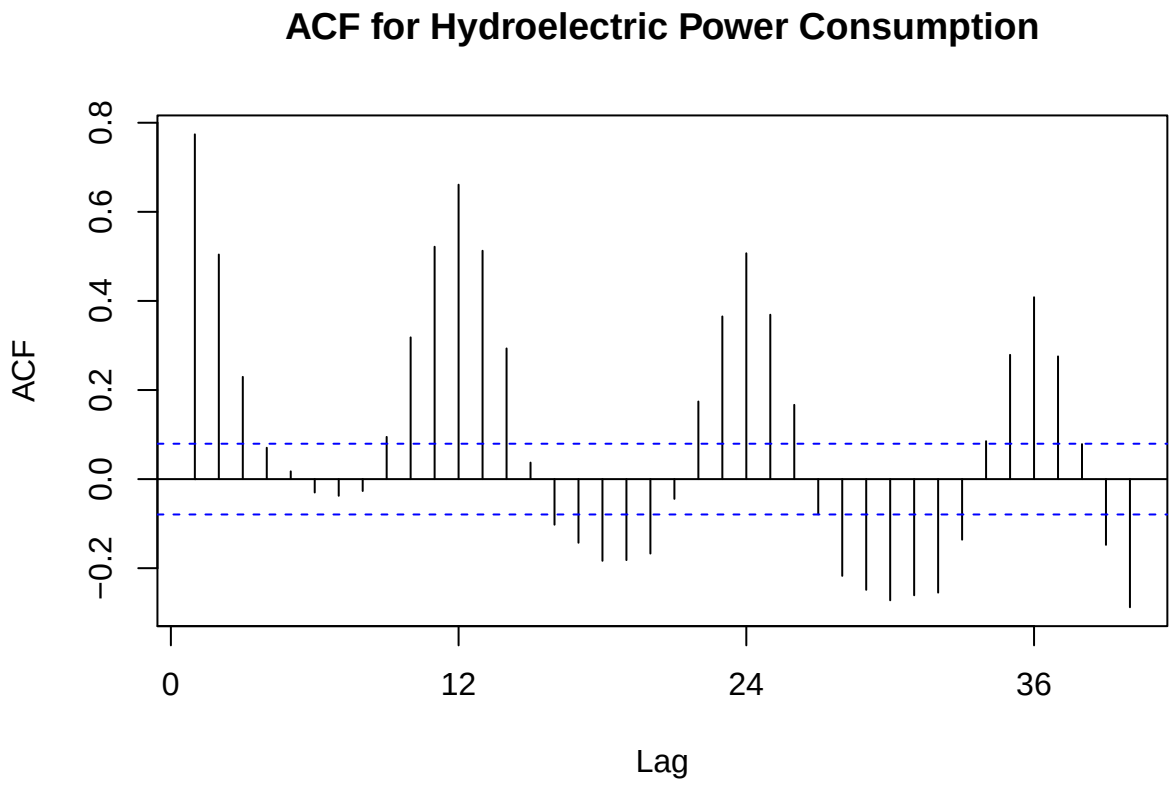
```
Acf(ts_energy[,1], lag.max = 40, main = "ACF for Total Biomass Energy Production")
```




```
Acf(ts_energy[,2], lag.max = 40, main = "ACF for Total Renewable Energy Production")
```




```
Acf(ts_energy[,3], lag.max = 40, main = "ACF for Hydroelectric Power Consumption")
```

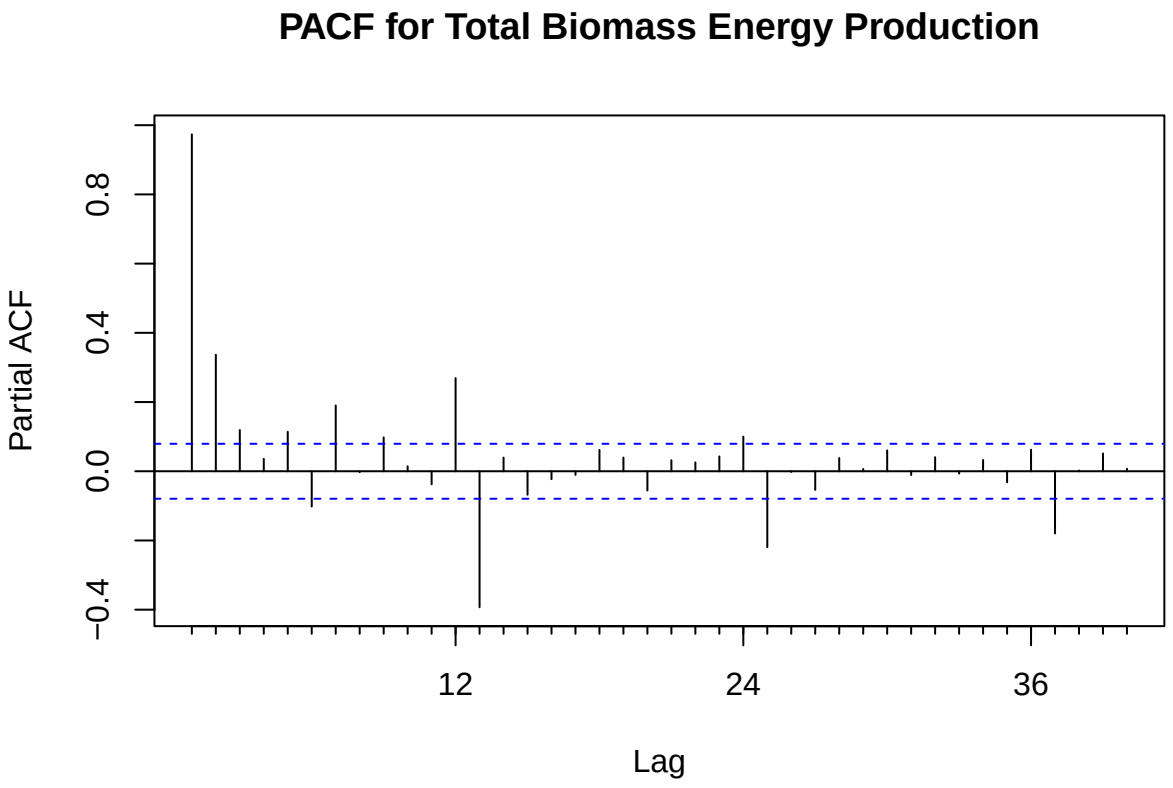


For total biomass energy production and total renewable energy consumption, within 40 lags, the graph displays a slowly-decaying trend, indicating that there exists a trend in its time series data. For hydroelectric power consumption, within 40 lags, not only can we observe a slowly-decaying trend from the graph, but we can also discover an obvious seasonality from the graph of this time series, indicating that such time series data has both trend and seasonality.

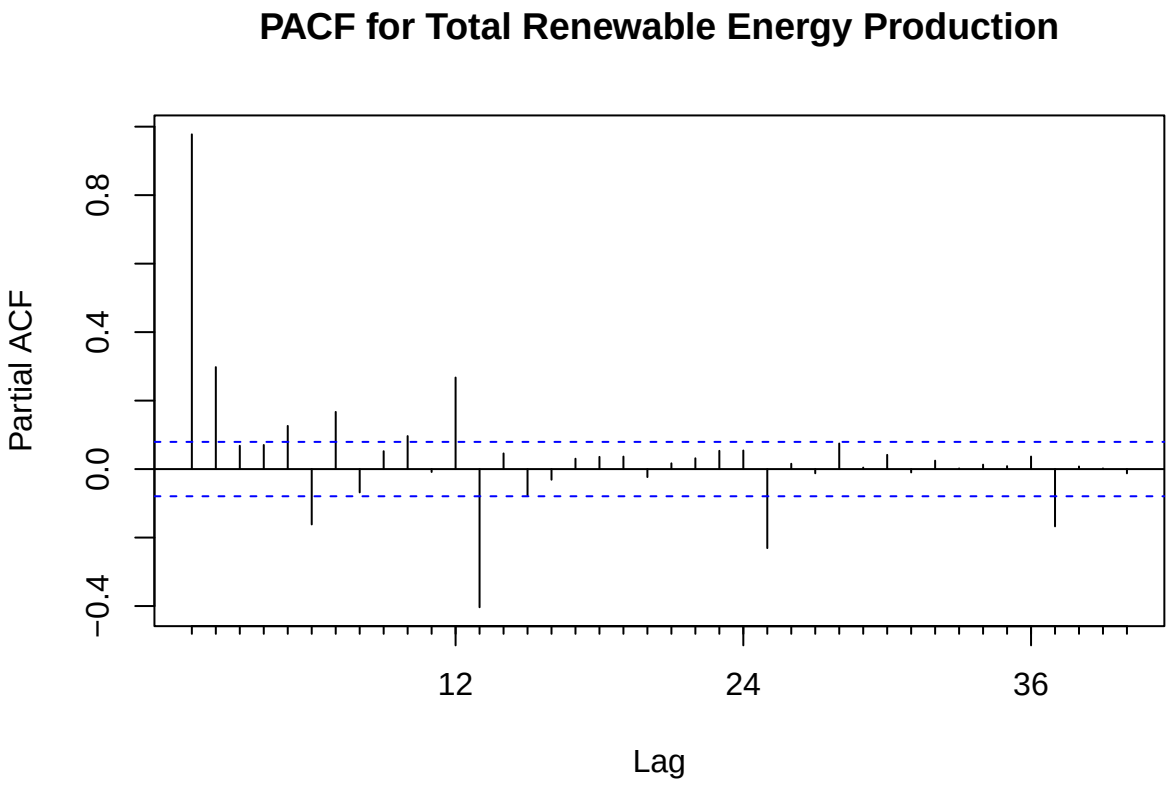
Question 7

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

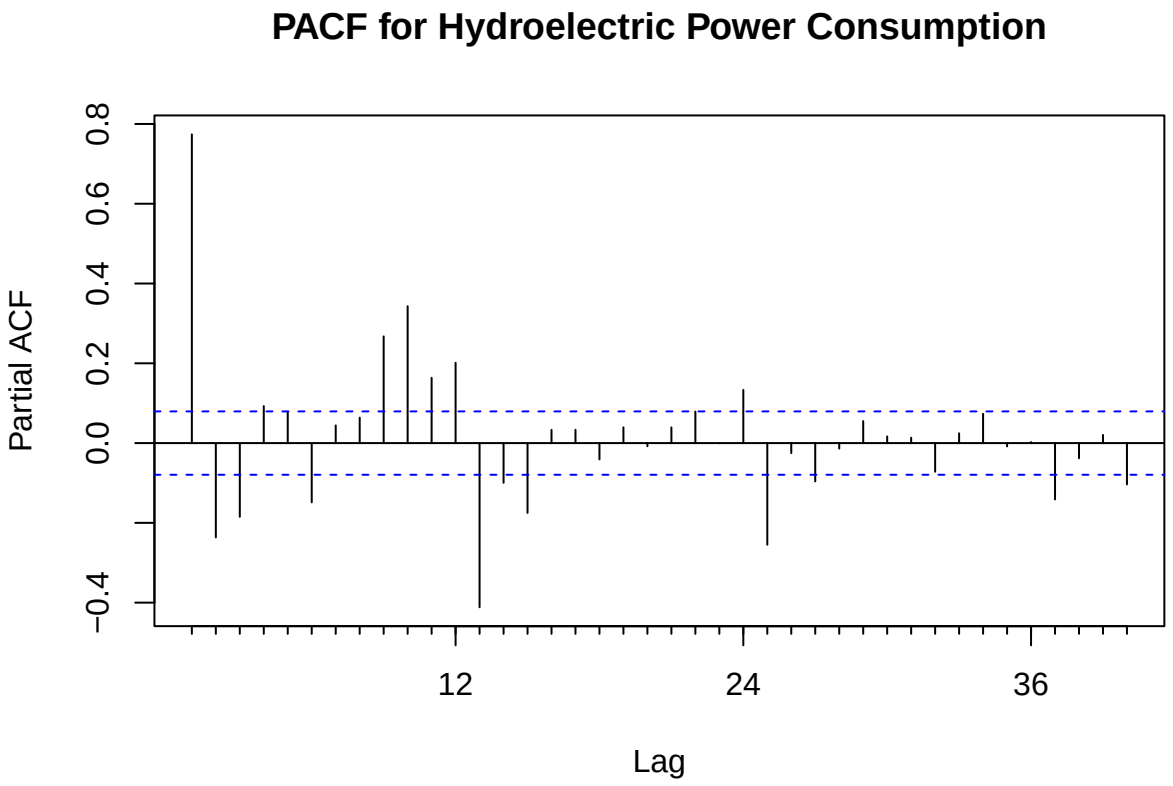
```
Pacf(ts_energy[,1], lag.max = 40, main = "PACF for Total Biomass Energy Production")
```




```
Pacf(ts_energy[,2], lag.max = 40, main = "PACF for Total Renewable Energy Production")
```




```
Pacf(ts_energy[,3], lag.max = 40, main = "PACF for Hydroelectric Power Consumption")
```



Unlike the ACFs, in PACFs of the three time series data, all three graphs seem to cut off at certain lag after several significant lags.