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

Assignment 2 - Ayoung Kim

Ayoung Kim

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
#install.packages("forecast")
#install.packages("tseries")
#install.packages("dplyr")

#Addtional Package (For Plot)
#install.packages("ggplot2")
#install.packages("formatR")

library(forecast)
```

```
## Warning: package 'forecast' was built under R version 4.3.3
```

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

```
library(tseries)
```

```
## Warning: package 'tseries' was built under R version 4.3.3
```

```r
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
#Loading packages
#install.packages("readxl")
#install.packages("openxlsx")

library(readxl)
library(openxlsx)
```

```
## Warning: package 'openxlsx' was built under R version 4.3.3
```

```r
#Setting a working directory again
setwd("/Users/ayoungkim/TSA_Sp25")

renewable_data2 <- read.xlsx(xlsxFile="./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_

read_col_names2  <- read.xlsx(xlsxFile="./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by

#Assign the column names to the data set
colnames(renewable_data2) <- read_col_names2

#Visualize the first rows of the data set
head(renewable_data2)
```

```
##   Month Wood Energy Production Biofuels Production
## 1 26665                129.630       Not Available
## 2 26696                117.194       Not Available
```

```
## 3 26724                129.763       Not Available
## 4 26755                125.462       Not Available
## 5 26785                129.624       Not Available
## 6 26816                125.435       Not Available
##   Total Biomass Energy Production Total Renewable Energy Production
## 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 Geothermal Energy Consumption
## 1                          89.562                          0.490
## 2                          79.544                          0.448
## 3                          88.284                          0.464
## 4                          83.152                          0.542
## 5                          85.643                          0.505
## 6                          82.060                          0.579
##   Solar Energy Consumption Wind Energy Consumption Wood Energy Consumption
## 1           Not Available          Not Available                 129.630
## 2           Not Available          Not Available                 117.194
## 3           Not Available          Not Available                 129.763
## 4           Not Available          Not Available                 125.462
## 5           Not Available          Not Available                 129.624
## 6           Not Available          Not Available                 125.435
##   Waste Energy Consumption Biofuels Consumption
## 1                    0.157        Not Available
## 2                    0.144        Not Available
## 3                    0.176        Not Available
## 4                    0.174        Not Available
## 5                    0.210        Not Available
## 6                    0.176        Not Available
##   Total Biomass Energy Consumption 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
```

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.

```
#Using "select" function, selected only Total Biomass Energy Production, Total Renewable Energy Product
renewable_data2_filtered <- select(renewable_data2,`Total Biomass Energy Production`,`Total Renewable E

df_renewable_data2_filtered<-as.data.frame(renewable_data2_filtered)

head(df_renewable_data2_filtered)
```

```
##   Total Biomass Energy Production Total Renewable Energy Production
## 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().

```
#Transform into a time series object + Starting point and frequency
#1 Time Series of Total Biomass Energy Production
ts1_renewable_data2_filtered <- ts(df_renewable_data2_filtered$`Total Biomass Energy Production`,start =

ts1_renewable_data2_filtered
```

```
##         Jan     Feb     Mar     Apr     May     Jun     Jul     Aug     Sep
## 1   129.787 117.338 129.938 125.636 129.834 125.611 129.787 129.918 125.782
## 2   130.807 118.091 130.727 126.583 130.789 126.611 130.756 130.763 126.637
## 3   127.269 114.942 127.251 123.139 127.303 123.241 127.288 127.321 123.210
## 4   145.049 135.695 145.051 140.363 145.047 140.405 145.088 145.110 140.436
## 5   156.220 141.176 156.217 151.161 156.186 151.153 155.920 156.081 151.110
## 6   173.128 156.387 173.136 167.349 172.923 167.340 172.912 173.189 167.455
## 7   182.600 165.096 182.881 176.844 182.782 176.833 182.700 182.808 176.891
## 8   209.829 196.310 209.727 202.894 209.548 202.723 209.554 209.675 202.905
## 9   220.544 199.248 220.595 213.467 220.433 213.237 220.392 220.428 213.480
## 10 226.251 204.375 226.157 218.821 226.135 218.866 226.202 226.168 218.947
## 11 246.575 222.738 246.610 238.625 246.647 238.736 246.651 246.695 238.755
## 12 251.483 235.169 251.529 243.277 251.408 243.303 251.632 251.638 243.596
## 13 256.315 231.512 256.336 247.599 255.881 247.643 256.159 256.301 247.997
## 14 249.178 224.922 248.837 240.788 248.822 240.837 249.011 249.176 241.074
## 15 244.137 220.511 244.157 236.139 244.007 236.522 244.359 244.396 236.298
## 16 255.331 238.853 255.385 247.241 255.188 247.340 255.582 255.815 247.357
## 17 266.572 243.927 268.315 251.946 241.235 248.447 261.318 276.985 264.811
## 18 236.692 226.266 244.248 232.640 210.108 178.544 219.713 245.632 239.932
## 19 269.531 204.535 214.374 190.452 206.579 209.721 210.055 250.834 267.735
## 20 279.197 230.468 221.177 210.172 190.537 230.985 250.150 269.662 251.511
## 21 274.257 240.964 263.204 226.859 196.012 197.445 212.707 262.322 250.551
## 22 306.708 244.594 261.461 236.035 202.480 215.744 274.451 251.577 238.967
## 23 243.462 206.657 239.820 267.571 227.439 226.934 294.251 301.628 268.791
## 24 272.584 226.038 259.039 205.729 231.211 254.182 281.656 294.581 259.345
## 25 275.641 226.521 251.136 252.010 268.515 231.690 259.985 264.422 250.744
## 26 278.211 212.209 240.963 240.612 250.239 186.089 246.326 254.237 248.270
```

```
## 27 272.260 220.539 212.177 249.920 289.264 236.090 264.292 258.854 244.140
## 28 222.067 246.169 263.209 254.609 254.678 227.712 255.348 254.942 240.331
## 29 228.434 202.849 219.649 213.628 211.506 213.950 221.842 225.897 214.229
## 30 228.396 198.932 217.568 212.852 225.155 215.107 235.713 224.400 230.855
## 31 237.044 212.693 233.288 228.516 229.756 228.254 242.533 239.928 230.968
## 32 255.574 236.689 248.532 247.253 244.383 244.075 257.042 254.446 243.019
## 33 264.707 247.271 260.043 246.929 255.790 252.466 266.332 266.097 255.348
## 34 276.647 247.274 265.069 250.384 261.125 261.960 274.809 277.063 267.952
## 35 290.845 261.666 285.146 278.386 286.010 281.995 295.653 295.523 287.603
## 36 331.138 300.535 321.487 314.073 324.185 313.335 330.507 333.607 318.840
## 37 318.353 294.389 319.356 303.489 319.032 321.739 343.841 348.551 332.374
## 38 377.071 347.952 384.094 368.922 376.012 372.328 385.443 389.064 377.355
## 39 400.710 359.327 394.959 373.481 385.273 389.673 399.454 402.931 387.218
## 40 399.385 373.028 388.074 368.981 387.318 377.793 379.862 386.269 366.955
## 41 391.713 354.251 397.835 386.469 404.782 401.893 419.452 413.684 395.313
## 42 420.974 382.165 423.586 408.886 420.035 422.748 437.471 431.020 411.083
## 43 426.511 385.395 418.058 404.120 421.760 419.237 434.897 431.663 409.666
## 44 427.096 405.894 428.603 399.665 423.333 424.295 434.044 441.530 416.425
## 45 439.505 396.448 437.424 408.163 426.858 423.548 435.021 446.019 416.699
## 46 449.046 412.743 448.952 424.993 444.580 438.066 455.270 459.141 426.893
## 47 444.763 404.542 433.330 422.589 439.614 432.664 448.899 446.231 416.083
## 48 432.686 403.222 411.076 323.946 354.840 374.660 395.536 397.879 386.097
## 49 408.145 347.470 409.925 392.199 417.354 409.532 424.652 412.133 394.091
## 50 434.269 393.379 429.548 404.987 429.290 428.681 435.460 428.012 400.695
## 51 433.513 389.710 436.050 404.830 435.219 428.283 437.718 441.412 427.094
## 52 427.243 414.326 443.242 415.784 431.972 427.619 449.261 453.456 430.045
##        Oct     Nov     Dec
## 1  129.970 125.643 129.824
## 2  130.718 126.506 130.674
## 3  127.312 123.180 127.277
## 4  145.114 140.651 145.364
## 5  156.172 151.000 155.935
## 6  173.169 167.557 173.060
## 7  182.752 176.949 182.770
## 8  209.717 202.945 209.671
## 9  220.581 213.437 220.440
## 10 226.373 218.948 226.210
## 11 246.732 238.780 246.871
## 12 251.974 244.068 252.042
## 13 256.175 248.070 256.246
## 14 248.974 241.122 249.352
## 15 244.059 236.197 244.104
## 16 255.517 247.096 255.345
## 17 276.462 276.819 282.520
## 18 235.437 220.256 245.644
## 19 249.408 241.541 267.033
## 20 269.545 264.383 263.891
## 21 257.383 262.183 264.559
## 22 271.599 261.436 262.482
## 23 292.175 267.659 262.694
## 24 310.461 295.562 264.912
## 25 305.656 264.591 256.998
## 26 267.922 230.488 273.362
## 27 228.256 254.125 235.215
```

```
## 28 270.472 261.335 254.788
## 29 227.319 219.773 225.088
## 30 243.767 230.328 242.334
## 31 236.938 233.698 251.160
## 32 253.520 247.286 264.199
## 33 261.121 256.532 268.550
## 34 275.120 270.475 283.636
## 35 299.416 297.828 312.007
## 36 330.125 327.317 323.102
## 37 346.472 348.333 360.689
## 38 386.771 386.602 400.917
## 39 397.994 400.892 420.525
## 40 373.975 368.902 383.017
## 41 417.493 415.796 436.115
## 42 424.674 419.845 446.730
## 43 418.147 418.730 436.774
## 44 424.366 427.930 468.507
## 45 433.481 438.539 453.938
## 46 448.699 439.958 455.737
## 47 431.685 430.407 454.125
## 48 398.927 402.541 418.294
## 49 421.241 422.748 444.056
## 50 424.580 426.665 427.775
## 51 433.043 432.608 465.432
## 52
```

```
#2 Time series of Total Renewable Energy Production
ts2_renewable_data2_filtered<-ts(df_renewable_data2_filtered$`Total Renewable Energy Production`, start

ts2_renewable_data2_filtered
```

```
##        Jan     Feb     Mar     Apr     May     Jun     Jul     Aug     Sep
## 1  219.839 197.330 218.686 209.330 215.982 208.249 207.800 203.432 185.300
## 2  231.010 210.188 226.384 223.218 227.793 218.976 221.909 214.197 200.900
## 3  214.319 198.008 224.384 215.679 223.695 217.798 216.202 206.312 194.934
## 4  236.073 221.374 237.807 224.756 234.082 229.595 235.984 228.336 211.665
## 5  228.907 194.523 225.781 216.602 221.823 211.752 215.097 214.871 208.974
## 6  260.677 233.933 258.863 255.285 272.691 254.703 258.056 250.652 241.494
## 7  270.000 239.377 273.485 265.526 283.727 264.118 262.394 257.423 243.468
## 8  298.221 271.194 294.931 293.043 310.682 299.633 295.537 281.831 268.204
## 9  299.483 273.604 293.454 286.764 305.297 305.860 308.821 296.678 276.720
## 10 320.311 297.475 330.131 316.183 323.939 316.816 321.854 310.059 289.054
## 11 348.969 320.213 352.422 343.331 355.330 346.012 345.359 338.025 315.758
## 12 355.607 333.238 358.566 348.756 363.212 344.623 348.366 340.669 317.887
## 13 353.933 323.067 344.083 334.259 349.644 332.457 332.393 328.026 315.367
## 14 326.552 307.952 349.995 338.487 345.587 334.442 335.334 325.501 316.539
## 15 334.890 296.606 327.541 315.231 330.797 311.957 317.495 311.395 302.090
## 16 334.583 307.533 326.015 316.232 331.539 315.603 317.391 315.766 306.500
## 17 348.321 317.572 358.115 346.511 350.304 349.753 351.720 358.320 341.553
## 18 329.327 321.465 353.956 334.136 317.791 289.276 315.872 332.580 311.965
## 19 370.278 292.511 317.683 293.309 320.120 313.437 309.257 340.813 345.122
## 20 366.577 305.537 311.299 292.073 282.361 323.546 333.005 347.510 324.027
## 21 373.255 322.185 359.855 330.605 313.546 304.450 309.916 346.577 324.882
## 22 388.854 323.751 354.509 332.955 303.865 313.708 366.741 333.540 307.933
```

```
## 23 336.872 299.810 346.752 361.046 333.643 342.092 400.977 399.583 349.815
## 24 385.971 343.243 385.026 325.915 356.221 375.816 395.278 398.870 347.920
## 25 397.124 342.279 381.623 374.093 398.347 362.325 382.540 370.673 343.197
## 26 386.269 323.378 360.492 348.763 374.487 309.019 358.537 354.150 332.989
## 27 383.582 328.183 334.062 355.198 401.370 353.158 379.433 360.215 328.356
## 28 319.978 334.369 366.040 364.110 361.267 326.724 351.077 343.214 312.937
## 29 303.197 272.585 301.844 288.028 290.338 298.272 297.654 304.239 279.069
## 30 314.861 279.136 302.856 309.709 331.378 326.674 337.792 311.593 302.858
## 31 318.956 291.767 330.201 327.749 345.099 341.209 342.647 333.101 308.470
## 32 347.154 321.055 342.168 334.068 344.066 346.968 353.034 344.004 328.252
## 33 361.269 333.479 354.763 342.863 367.186 362.264 372.396 356.107 331.447
## 34 388.583 348.049 368.883 367.940 386.890 383.011 381.340 370.019 345.317
## 35 399.004 343.865 390.167 383.102 398.044 382.096 393.450 386.428 360.587
## 36 427.860 388.671 424.851 421.184 449.522 444.695 446.062 431.761 398.411
## 37 431.011 386.812 432.104 431.059 456.231 455.356 455.962 449.335 421.927
## 38 489.844 449.090 499.560 482.552 507.544 517.750 508.593 497.073 476.105
## 39 530.909 490.715 553.169 538.506 554.011 553.885 549.374 534.036 500.175
## 40 539.030 494.125 541.241 519.625 546.973 528.767 520.173 513.269 475.611
## 41 542.692 487.697 541.012 551.448 578.378 563.561 572.289 542.610 514.219
## 42 574.074 507.104 589.448 582.906 589.532 590.551 588.452 559.856 530.545
## 43 580.459 532.998 579.274 569.372 578.595 564.148 583.940 572.235 539.599
## 44 599.152 581.670 626.078 589.659 609.017 593.636 604.272 591.306 562.170
## 45 627.073 580.264 663.855 635.068 661.222 642.277 625.487 612.088 583.803
## 46 652.294 609.263 668.458 656.425 680.571 668.645 647.806 651.821 600.580
## 47 644.675 593.023 656.855 665.815 689.814 661.001 666.840 647.495 612.975
## 48 648.257 632.086 641.509 560.555 618.177 637.050 632.878 618.503 583.472
## 49 636.532 552.157 677.204 650.405 688.670 656.020 650.413 648.043 619.939
## 50 696.686 651.094 732.321 711.645 742.103 724.756 712.392 671.642 631.913
## 51 696.038 659.518 735.318 708.522 740.890 698.192 715.729 713.484 672.812
## 52 684.313 698.914 771.513 750.907 762.088 757.944 746.007 751.485 695.378
##        Oct     Nov     Dec
## 1  193.514 195.326 220.755
## 2  200.312 200.068 211.046
## 3  206.489 208.436 217.911
## 4  218.818 209.968 216.239
## 5  216.727 222.663 235.754
## 6  241.095 237.214 250.285
## 7  253.559 255.317 262.637
## 8  273.058 270.913 288.131
## 9  284.684 280.364 304.193
## 10 296.056 300.864 323.054
## 11 320.524 325.785 357.437
## 12 326.373 323.172 343.652
## 13 327.776 330.222 346.947
## 14 325.125 323.172 341.787
## 15 309.095 297.439 319.908
## 16 310.737 313.792 326.992
## 17 356.682 359.731 367.555
## 18 312.873 301.883 341.584
## 19 324.454 318.757 355.690
## 20 340.565 345.048 360.200
## 21 331.480 338.485 352.074
## 22 343.569 338.304 348.732
## 23 384.663 366.200 373.129
```

```
## 24 400.155 387.043 378.537
## 25 402.188 355.868 355.807
## 26 345.379 309.809 370.867
## 27 308.985 337.650 332.407
## 28 341.025 339.223 333.069
## 29 292.015 283.668 302.843
## 30 315.739 309.716 328.629
## 31 313.818 314.096 347.074
## 32 332.739 332.106 367.856
## 33 339.018 338.541 360.826
## 34 353.690 359.164 376.761
## 35 374.075 373.327 397.970
## 36 412.573 409.976 428.996
## 37 450.940 456.527 481.882
## 38 489.125 500.488 524.855
## 39 517.691 528.710 552.823
## 40 491.520 489.081 527.555
## 41 543.689 548.475 574.712
## 42 557.212 569.440 593.582
## 43 556.624 575.262 607.029
## 44 584.344 586.159 650.886
## 45 614.591 613.732 635.064
## 46 627.834 623.070 647.358
## 47 633.410 620.528 650.319
## 48 611.896 629.909 640.842
## 49 649.287 662.792 705.767
## 50 658.345 684.997 679.561
## 51 693.952 682.056 720.952
## 52
```

```
#3 Time series of Hydroelectricc Power Consumption
ts3_renewable_data2_filtered <-ts(df_renewable_data2_filtered$`Hydroelectric Power Consumption`,start =

ts3_renewable_data2_filtered
```

```
##        Jan     Feb     Mar     Apr     May     Jun     Jul     Aug     Sep
## 1   89.562  79.544  88.284  83.152  85.643  82.060  77.400  72.936  59.029
## 2   99.500  91.476  94.950  95.969  96.337  91.719  90.437  82.727  73.610
## 3   86.356  82.404  96.386  91.791  95.581  93.550  87.900  77.892  70.756
## 4   89.904  84.626  91.629  83.378  88.065  88.182  89.807  82.153  70.186
## 5   71.630  52.424  68.518  64.508  64.629  59.609  58.130  57.830  56.835
## 6   86.454  76.606  84.951  87.281  99.185  86.645  84.339  76.518  73.042
## 7   86.378  73.446  89.483  87.645  99.903  86.230  78.573  73.393  65.516
## 8   87.244  73.781  83.978  88.865  99.622  95.451  84.448  70.517  63.819
## 9   77.214  72.830  71.150  71.718  83.301  91.061  86.714  74.556  61.534
## 10  92.763  91.907 102.924  96.303  96.572  96.463  94.087  82.333  68.612
## 11 100.743  96.206 104.348 103.334 107.568 105.810  96.883  88.929  74.808
## 12 102.459  96.034 104.801 103.270 109.683  99.261  94.772  86.573  72.076
## 13  94.973  89.219  85.029  84.276  91.284  82.425  73.612  68.980  64.761
## 14  73.934  80.075  98.081  94.922  93.958  90.562  83.094  73.104  72.767
## 15  87.702  73.264  80.279  76.163  83.712  72.271  69.864  63.744  62.756
## 16  76.171  66.029  67.539  66.195  73.601  65.346  58.636  56.923  56.241
## 17  73.277  65.188  79.268  84.295  98.200  90.614  79.373  70.675  66.237
## 18  83.078  86.122  98.841  90.589  95.753  98.444  84.490  75.559  61.422
```

```
## 19  91.732  78.638  92.384  91.874 101.296  91.854  86.984  77.658  65.997
## 20  77.844  64.670  78.408  70.180  79.980  80.819  70.671  65.474  60.474
## 21  88.873  71.730  83.868  90.980 104.743  95.182  84.360  71.587  62.245
## 22  72.773  69.738  80.508  84.264  88.353  85.343  79.712  69.257  56.561
## 23  84.852  85.447  97.479  83.847  94.791 103.128  93.729  83.175  68.333
## 24 104.821 108.488 115.603 108.647 113.485 108.928  98.519  89.620  75.536
## 25 112.458 107.528 119.397 109.441 116.635 117.564 108.011  91.802  79.836
## 26  98.328 102.347 108.119  97.610 113.264 110.348  97.785  85.678  71.060
## 27 100.724  97.902 109.456  93.280  98.936 104.294 101.288  87.778  71.283
## 28  86.468  76.714  91.110  97.207  93.560  85.931  82.333  74.999  60.736
## 29  64.323  59.617  69.868  61.460  65.427  70.723  61.686  64.534  52.054
## 30  74.364  68.894  71.682  82.729  90.973  96.262  86.906  71.938  58.300
## 31  70.287  67.489  82.578  84.478 100.297  97.536  84.765  78.381  63.055
## 32  78.419  71.357  78.184  71.270  81.955  86.161  79.562  73.672  70.032
## 33  82.817  73.722  78.258  78.675  93.074  91.384  88.565  73.582  59.245
## 34  93.614  84.487  84.019  97.432 105.153 101.532  86.799  74.137  58.691
## 35  88.865  63.349  82.446  81.515  88.872  77.850  76.694  68.037  50.302
## 36  70.898  64.108  73.934  75.862  92.879  99.553  87.194  72.434  55.200
## 37  80.149  60.775  74.475  87.927 100.858  99.744  79.789  66.808  59.228
## 38  76.371  70.252  71.262  65.158  85.570 101.861  83.651  68.647  58.909
## 39  87.112  82.336 106.231 106.435 111.187 109.700 106.743  87.905  72.940
## 40  78.842  69.209  88.393  89.720  97.724  90.956  90.387  78.591  60.065
## 41  84.715  69.668  70.063  85.631  97.072  93.434  92.993  73.813  57.871
## 42  73.815  59.356  82.765  86.801  90.568  87.838  83.107  67.582  54.846
## 43  82.360  76.040  82.846  76.671  68.668  69.653  71.701  65.245  54.913
## 44  87.397  82.362  93.454  88.296  86.960  79.284  73.206  66.771  55.847
## 45  90.854  81.485 101.040 100.345 111.255 104.323  90.753  75.180  65.346
## 46  85.519  84.967  88.236  95.929 103.876  94.163  85.640  75.122  65.393
## 47  84.610  78.068  89.852  94.922 109.123  95.801  84.875  77.038  63.210
## 48  83.587  88.262  81.284  79.139 102.279  95.534  91.243  79.443  63.732
## 49  83.799  68.706  72.404  66.155  79.530  80.025  75.397  69.360  58.080
## 50  82.562  72.746  83.377  68.465  79.700  88.670  83.824  72.106  58.093
## 51  77.637  68.107  72.783  67.625  94.346  73.604  74.988  72.652  57.716
## 52  74.805  68.583  79.551  66.116  77.156  72.234  72.288  72.875  56.844
##        Oct     Nov     Dec
## 1   62.967  69.063  90.131
## 2   68.931  72.773  79.542
## 3   78.060  84.171  89.510
## 4   72.690  68.463  69.900
## 5   59.480  70.583  78.744
## 6   67.184  68.818  76.162
## 7   69.619  77.213  78.457
## 8   61.661  66.325  76.858
## 9   62.420  65.459  82.279
## 10  68.091  80.245  95.522
## 11  71.491  84.956 108.936
## 12  71.968  76.704  88.949
## 13  69.105  79.075  87.328
## 14  73.498  79.755  89.397
## 15  61.964  58.272  72.753
## 16  52.265  63.762  68.748
## 17  70.285  74.172  76.402
## 18  66.657  71.863  86.440
## 19  63.197  66.085  78.349
```

```
## 20  59.474  69.964  85.579
## 21  62.087  64.729  76.662
## 22  59.757  65.325  75.959
## 23  78.993  87.148  99.640
## 24  77.094  80.374 103.400
## 25  84.394  80.900  88.252
## 26  64.434  68.310  85.937
## 27  67.908  72.210  85.198
## 28  58.639  65.377  67.181
## 29  51.980  52.589  66.010
## 30  58.589  67.319  73.933
## 31  62.878  67.268  82.039
## 32  64.360  71.437  89.431
## 33  61.438  66.031  75.546
## 34  58.192  69.167  73.685
## 35  50.485  53.507  62.582
## 36  52.783  53.459  71.179
## 37  67.186  71.678  84.378
## 38  60.334  66.744  79.053
## 39  67.515  70.562  80.973
## 40  56.304  63.918  78.423
## 41  58.682  60.313  72.090
## 42  58.547  63.548  76.186
## 43  56.743  65.981  79.041
## 44  59.160  64.174  76.865
## 45  60.386  67.859  75.910
## 46  66.698  74.766  77.784
## 47  62.459  68.982  73.284
## 48  64.181  71.286  73.385
## 49  58.458  66.102  80.393
## 50  49.022  61.068  69.706
## 51  53.475  58.092  64.922
## 52
```

Question 3

Compute mean and standard deviation for these three series.

```
#1 Mean and standard deviation of Time Series of Total Biomass Energy Production
mean(ts1_renewable_data2_filtered)
```

```
## [1] 282.6779
```

```
sd(ts1_renewable_data2_filtered)
```

```
## [1] 94.05815
```

```
#2 Mean and standard deviation of Time Series of Total Renewable Enerfy Production
mean(ts2_renewable_data2_filtered)
```

```
## [1] 402.0167
```

```r
sd(ts2_renewable_data2_filtered)
```

```
## [1] 143.7927
```

```r
#3 Mean and standard deviation of Time Series of Hydroelectric Power Consumption
mean(ts3_renewable_data2_filtered)
```

```
## [1] 79.55371
```

```r
sd(ts3_renewable_data2_filtered)
```

```
## [1] 14.10737
```

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.

Plot 1, which represents the time series of total biomass energy production, shows the increasing trend. The mean is around 282 with the standard deviation of 94.1. It has high inflow because the time series gradually increase.

Plot 2 displaying time series of total renewable energy produciton shows the increasing trend as well. The mean is around 402 with the standard deviation of 143.9. It has high inflow because the time series gradually increase.

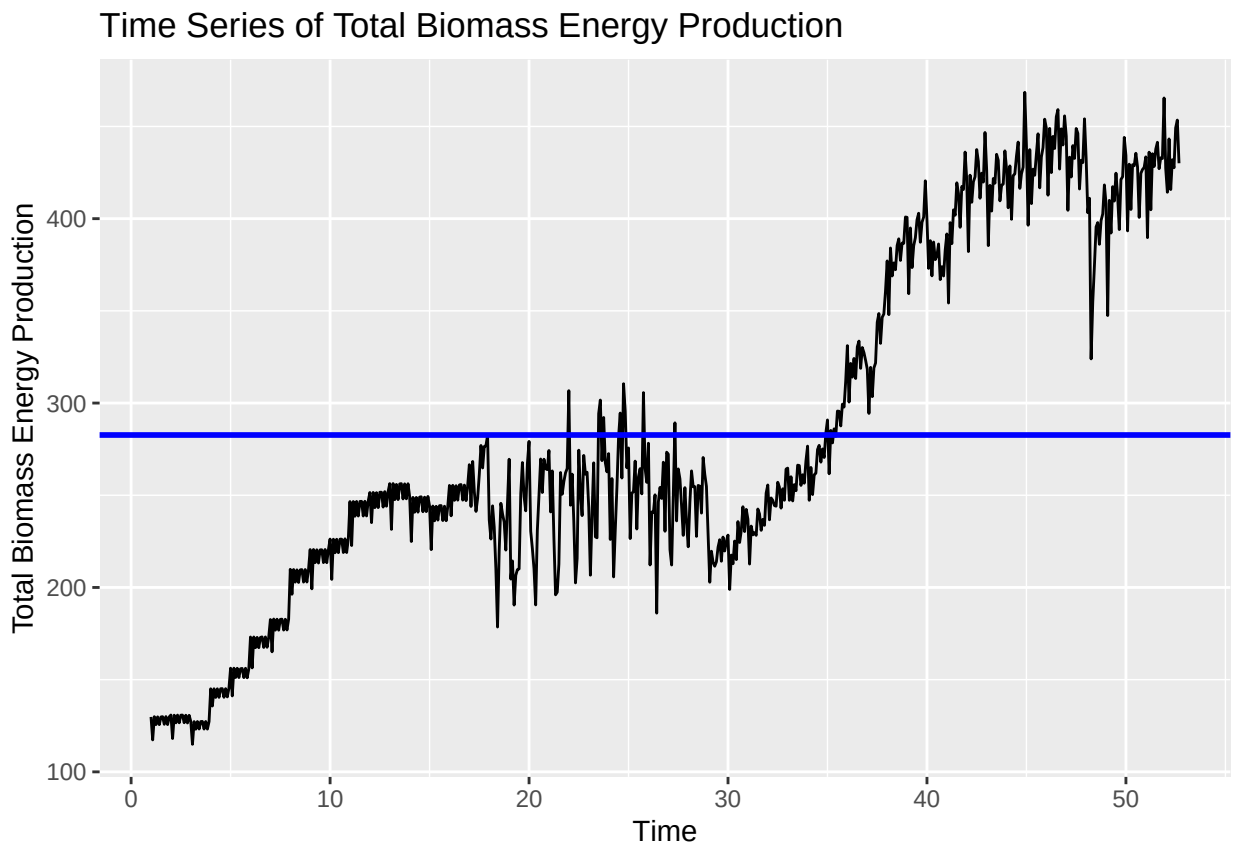
In the Plot 3 representing the time series of hydroelectric power consumption, I could find the seasonal pattern. The mean is around 79 and it has lower standard deviation with 14.11 than other 2 time series, which are 94.1 and 143. 9 each. IT has low inflow because the time series fluctuate with certain pattern.

Checked my code using AI.

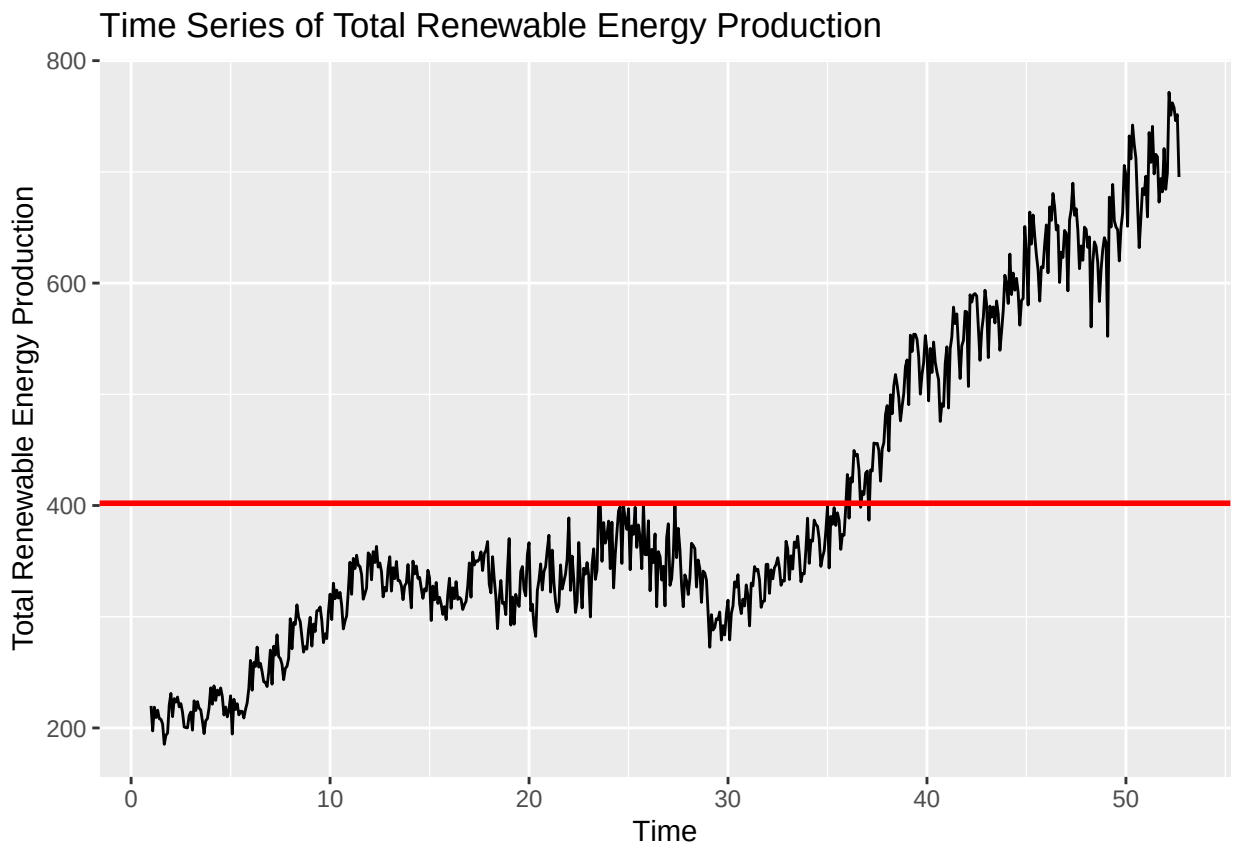
```r
## Titles, labels, horizontal line at the mean
## Plot, interpretation

#Plot 1 - Time series of total biomass energy production
autoplot(ts1_renewable_data2_filtered) +
  labs(title = "Time Series of Total Biomass Energy Production",
       y = "Total Biomass Energy Production",
       x = "Time") +
  geom_hline(yintercept = mean(ts1_renewable_data2_filtered, na.rm = TRUE),
             color = "blue", linetype = "solid", size = 1)
```

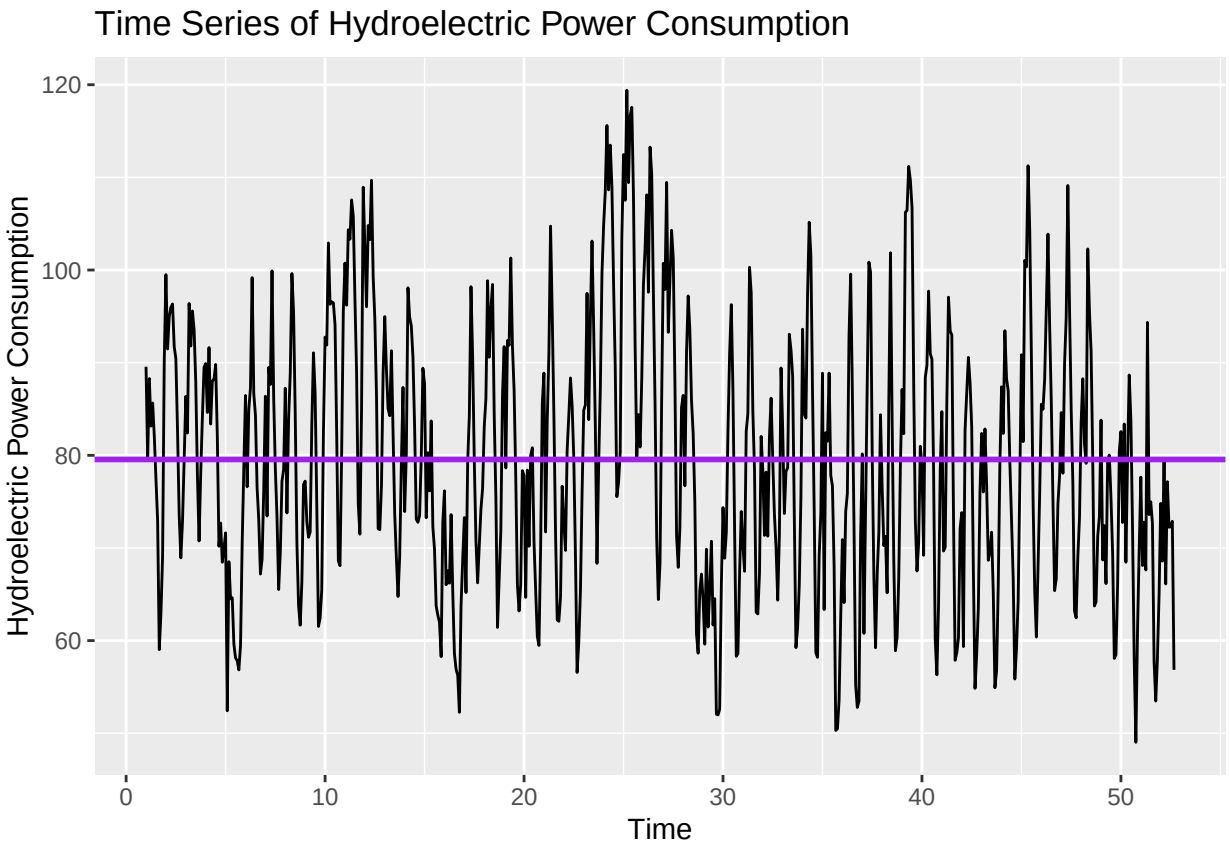
```
## Warning: Using ‘size‘ aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use ‘linewidth‘ instead.
## This warning is displayed once every 8 hours.
## Call ‘lifecycle::last_lifecycle_warnings()‘ to see where this warning was
## generated.
```




```
#Plot 2 - Time Series of Total Renewable Energy Production
autoplot(ts2_renewable_data2_filtered) +
  labs(title = "Time Series of Total Renewable Energy Production",
       y = "Total Renewable Energy Production",
       x = "Time") +
  geom_hline(yintercept = mean(ts2_renewable_data2_filtered, na.rm = TRUE),
             color = "red", linetype = "solid", size = 1)
```




```
#Plot 3 - Time Series of Hydroelectric Power Consumption
autoplot(ts3_renewable_data2_filtered) +
  labs(title = "Time Series of Hydroelectric Power Consumption",
       y = "Hydroelectric Power Consumption",
       x = "Time") +
  geom_hline(yintercept = mean(ts3_renewable_data2_filtered, na.rm = TRUE),
             color = "purple", linetype = "solid", size = 1)
```



Question 5

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

ts1 - Total Biomass Energy Production ts2 - Total Renewable Energy Production ts3 - Hydroelectric Power Consumption

Answer: ts1 and ts2 are significantly correlated seeing that the result of correlation computation is 0.9678. However, ts2 & ts3 and ts 1 &3 are not correlated significantly wit the result of -0.02916103 and -0.1142927 each.

```
#Making as one df to find the correlation between three timeseries in matrix
df_ts_correlation <-data.frame(ts1_renewable_data2_filtered,ts2_renewable_data2_filtered,ts3_renewable_

correlation_ts<-cor(df_ts_correlation)
correlation_ts
```

```
##                               ts1_renewable_data2_filtered
## ts1_renewable_data2_filtered                    1.0000000
## ts2_renewable_data2_filtered                    0.9678137
## ts3_renewable_data2_filtered                   -0.1142927
##                               ts2_renewable_data2_filtered
## ts1_renewable_data2_filtered                   0.96781371
## ts2_renewable_data2_filtered                   1.00000000
## ts3_renewable_data2_filtered                  -0.02916103
##                               ts3_renewable_data2_filtered
```

```
## ts1_renewable_data2_filtered                  -0.11429266
## ts2_renewable_data2_filtered                  -0.02916103
## ts3_renewable_data2_filtered                   1.00000000
```

```
#OR

#1 ts1+ts2
cor(ts1_renewable_data2_filtered,ts2_renewable_data2_filtered)
```

```
## [1] 0.9678137
```

```
#2 ts2+ts3
cor(ts2_renewable_data2_filtered,ts3_renewable_data2_filtered)
```

```
## [1] -0.02916103
```

```
# ts1+ts3
cor(ts1_renewable_data2_filtered,ts3_renewable_data2_filtered)
```

```
## [1] -0.1142927
```

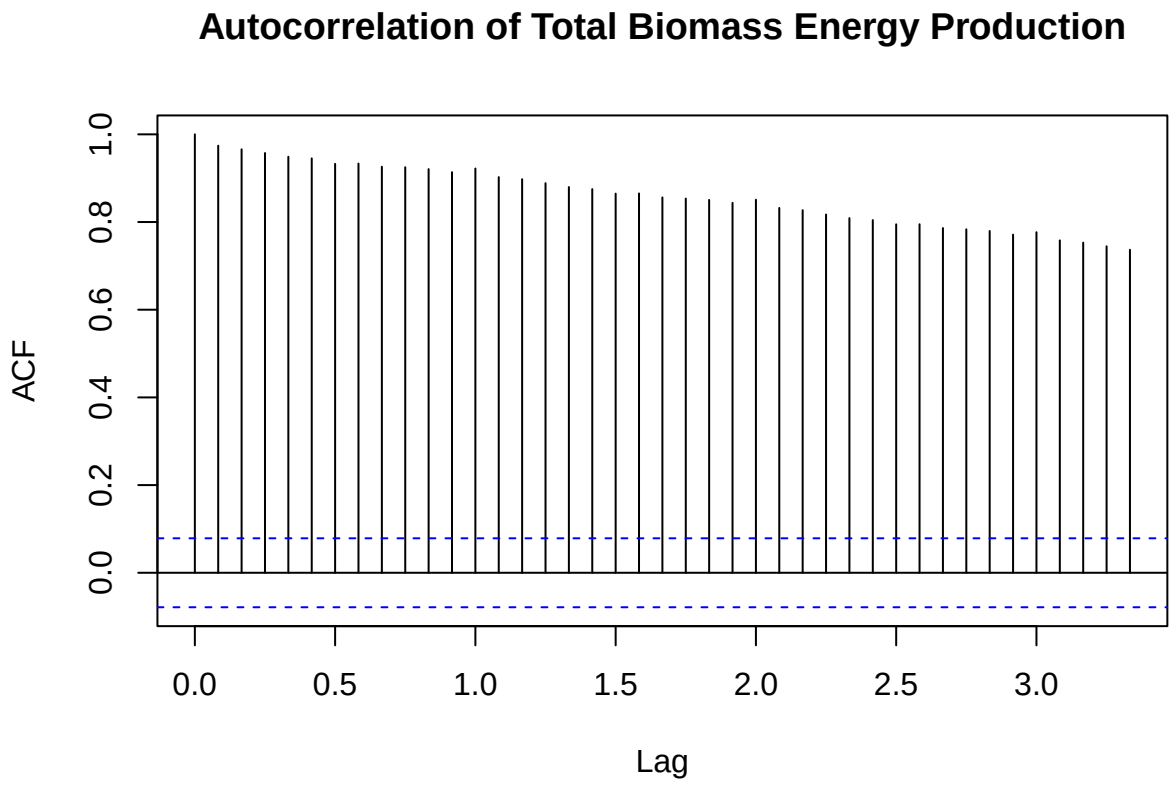
Question 6

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?

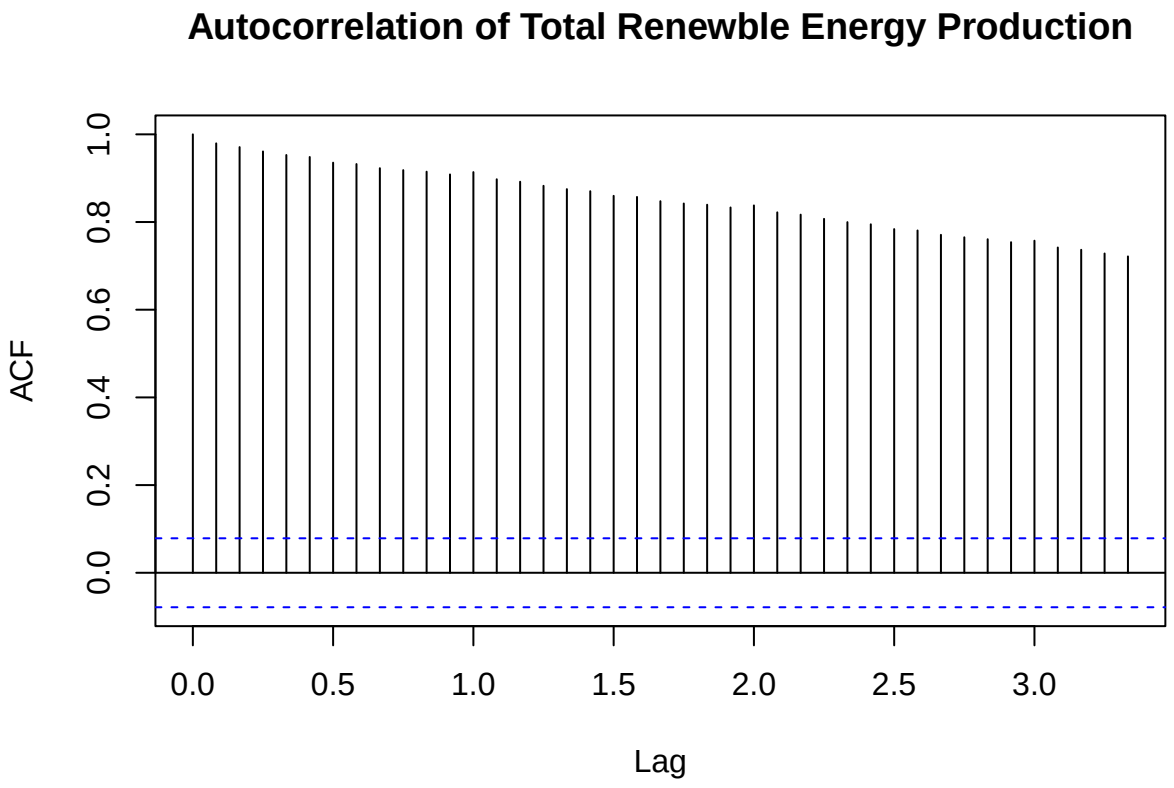
Answer: The autocorrelation of ts1 and ts2 shows a similar behavior with a downward trend. The ACF values decrease as the lag increases in both cases. However, the autocorrelation of ts3 (Hydroelectric Power Consumption) exhibits a different behavior. It shows a seasonal pattern with regular fluctuations, rising and falling as the lag increases.

##Each of the bar represents of the p

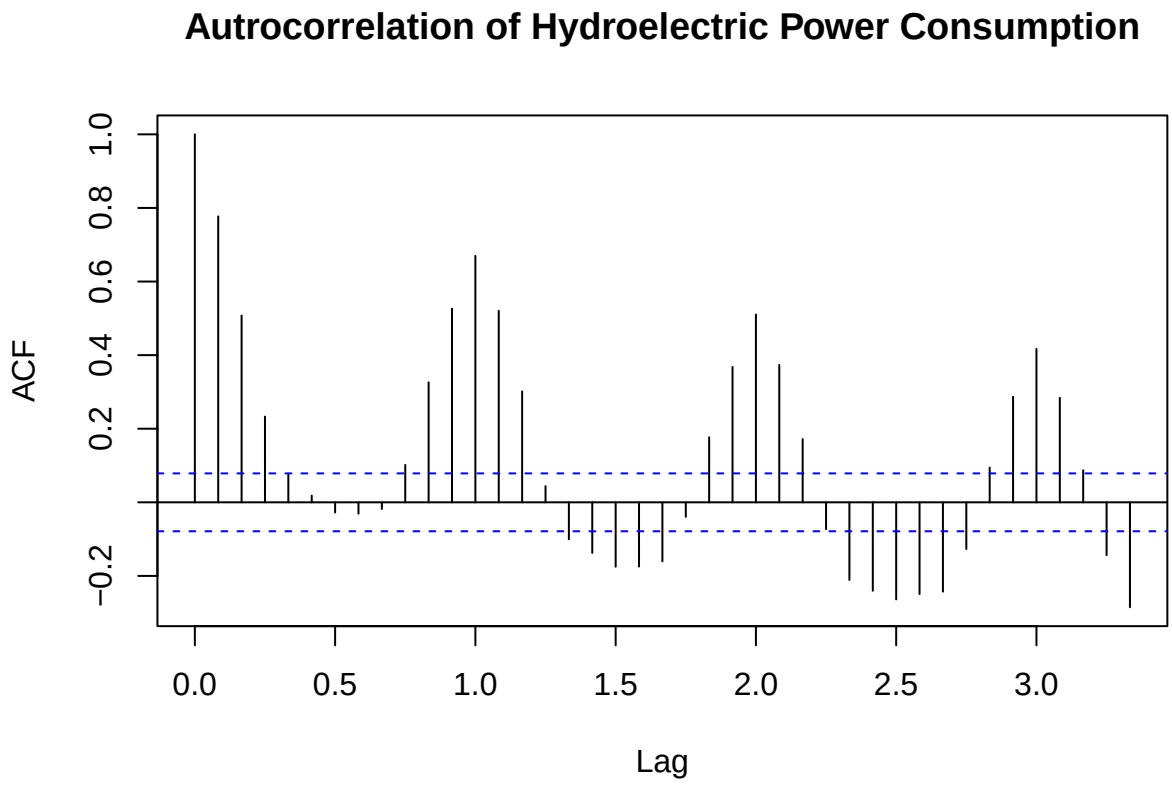
```
#1 Autocorrelation of ts1
acf_ts1 <-acf(ts1_renewable_data2_filtered,lag.max = 40,main="Autocorrelation of Total Biomass Energy P
```




```
#2 Autocorrelation of ts2
acf_ts2<-acf(ts2_renewable_data2_filtered,lag.max = 40, main="Autocorrelation of Total Renewble Energy
```




```
#3 Autocorrelation of ts3
acf_ts3<-acf(ts3_renewable_data2_filtered,lag.max = 40, main="Autrocorrelation of Hydroelectric Power C
```

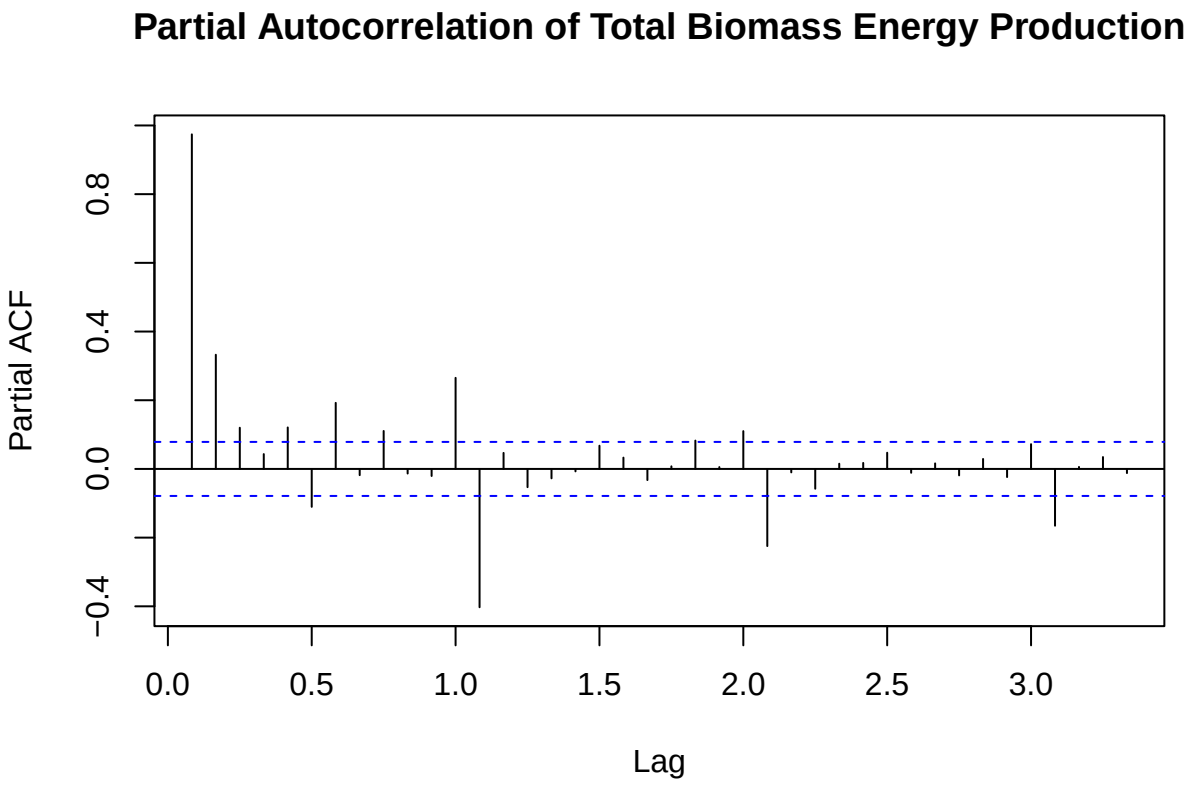


Question 7

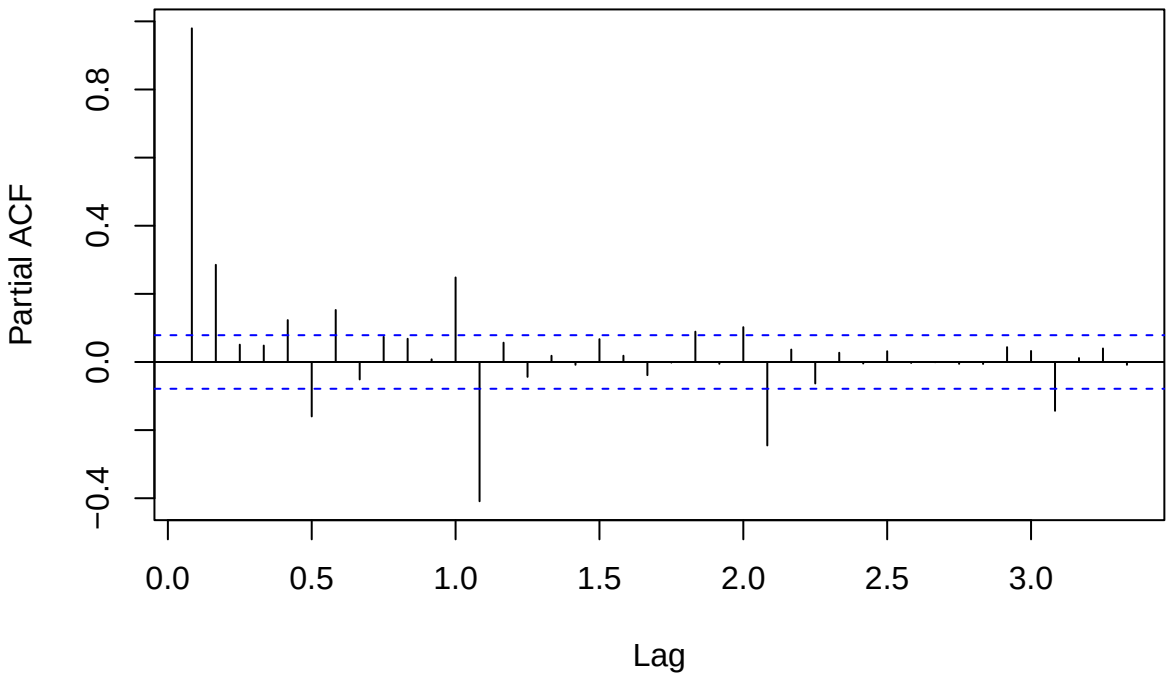
Compute the partial autocorrelation function from lag 1 to lag 40 for these three variables. How these plots differ from the ones in Q6?

Answer: In Q6, the autocorrelation (ACF) values for ts1 and ts2 were all positive, but in the partial autocorrelation (PACF) plots, the values turned out to be negative. The PACF plots in Q7 show the direct correlations, excluding the influence of previous lags. The PACF plot for Hydroelectric Power Consumption in Q7 has a similar pattern to the one in Q6, but the distribution is less fluctuating compared to Q6.

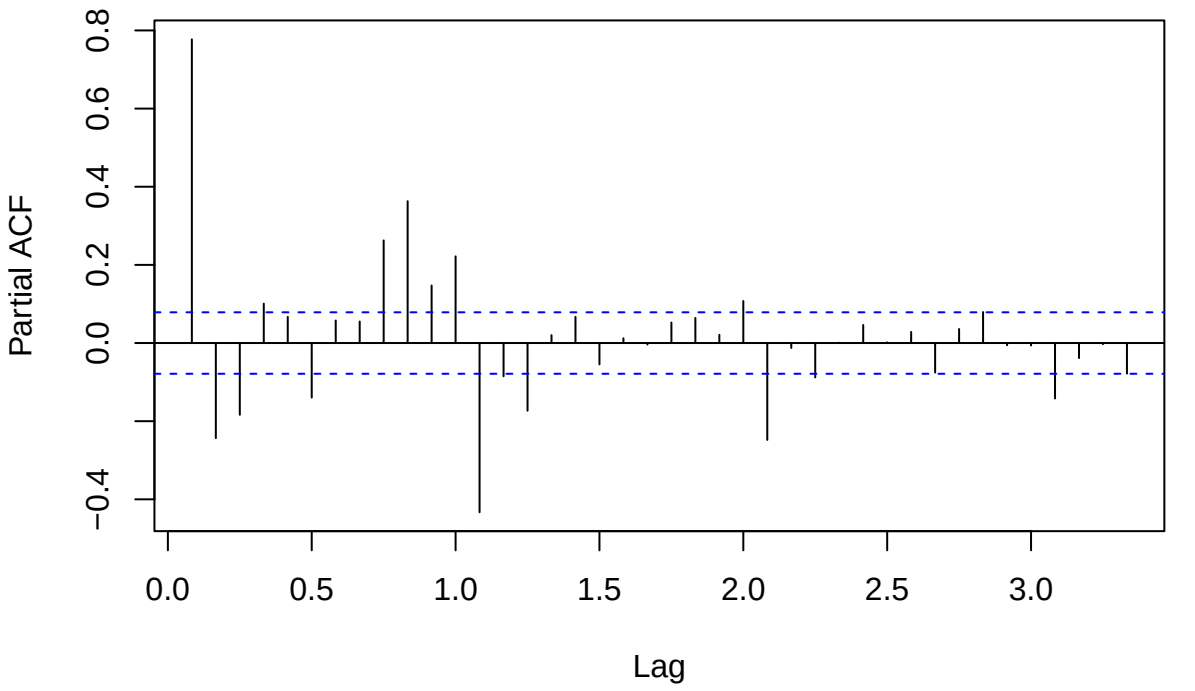
```
#1 Partial Autocorrelation of ts1
pacf_ts1 <-pacf(ts1_renewable_data2_filtered,lag.max = 40,main="Partial Autocorrelation of Total Biomas
```




```
#2 Partial Autocorrelation of ts2
pacf_ts2<-pacf(ts2_renewable_data2_filtered,lag.max = 40, main="Partial Autocorrelation of Total Renewbl
```




```
#3 Partial Autocorrelation of ts3
pacf_ts3<-pacf(ts3_renewable_data2_filtered,lag.max = 40, main="Partial Autocorrelation of Hydroelectri
```


Partial Autocorrelation of Hydroelectric Power Consumption
Partial ACF
0.8
0.6
0.4
0.2
0.0
−0.4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Lag