

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

Assignment 2 - Due date 01/27/26

Trudy

Submission Instructions

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

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

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

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

R packages

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

```
knitr::opts_chunk$set(echo = TRUE, tidy.opts=list(width.cutoff=60), tidy=TRUE)
#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
```

```
library(readxl)
library(openxlsx)
```

Data set information

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

```
# Importing data set Importing data set without change the
# original file using read.xlsx
file_path <- "./Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.xlsx"

energy_data1 <- read_excel(path = file_path, skip = 12, sheet = "Monthly Data",
  col_names = FALSE)
```

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

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

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

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

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

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

Question 1

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

```
q1_data <- energy_data1 %>%
  dplyr::select(`Total Biomass Energy Production`, `Total Renewable Energy Production`,
    `Hydroelectric Power Consumption`)

head(q1_data)
```

```
## # A tibble: 6 x 3
##   Total Biomass Energy Productio~1 Total Renewable Ener~2 Hydroelectric Power ~3
##   <dbl>                <dbl>                <dbl>
## 1          130.          220.          89.6
## 2          117.          197.          79.5
## 3          130.          219.          88.3
## 4          126.          209.          83.2
## 5          130.          216.          85.6
## 6          126.          208.          82.1
## # i abbreviated names: 1: 'Total Biomass Energy Production',
## #   2: 'Total Renewable Energy Production',
## #   3: 'Hydroelectric Power Consumption'
```

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()`.

```

# Convert data frame to time series object
q1_ts <- ts(q1_data, start = c(1973, 1), frequency = 12)

# Check the time series object
q1_ts

```

##	Total Biomass Energy Production	Total Renewable Energy Production
## Jan 1973	129.787	219.839
## Feb 1973	117.338	197.330
## Mar 1973	129.938	218.686
## Apr 1973	125.636	209.330
## May 1973	129.834	215.982
## Jun 1973	125.611	208.249
## Jul 1973	129.787	207.800
## Aug 1973	129.918	203.432
## Sep 1973	125.782	185.300
## Oct 1973	129.970	193.514
## Nov 1973	125.643	195.326
## Dec 1973	129.824	220.755
## Jan 1974	130.807	231.010
## Feb 1974	118.091	210.188
## Mar 1974	130.727	226.384
## Apr 1974	126.583	223.218
## May 1974	130.789	227.793
## Jun 1974	126.611	218.976
## Jul 1974	130.756	221.909
## Aug 1974	130.763	214.197
## Sep 1974	126.637	200.900
## Oct 1974	130.718	200.312
## Nov 1974	126.506	200.068
## Dec 1974	130.674	211.046
## Jan 1975	127.269	214.319
## Feb 1975	114.942	198.008
## Mar 1975	127.251	224.384
## Apr 1975	123.139	215.679
## May 1975	127.303	223.695
## Jun 1975	123.241	217.798
## Jul 1975	127.288	216.202
## Aug 1975	127.321	206.312
## Sep 1975	123.210	194.934
## Oct 1975	127.312	206.489
## Nov 1975	123.180	208.436
## Dec 1975	127.277	217.911
## Jan 1976	145.049	236.073
## Feb 1976	135.695	221.374
## Mar 1976	145.051	237.807
## Apr 1976	140.363	224.756
## May 1976	145.047	234.082
## Jun 1976	140.405	229.595
## Jul 1976	145.088	235.984
## Aug 1976	145.110	228.336
## Sep 1976	140.436	211.665
## Oct 1976	145.114	218.818

## Nov 1976	140.651	209.968
## Dec 1976	145.364	216.239
## Jan 1977	156.220	228.907
## Feb 1977	141.176	194.523
## Mar 1977	156.217	225.781
## Apr 1977	151.161	216.602
## May 1977	156.186	221.823
## Jun 1977	151.153	211.752
## Jul 1977	155.920	215.097
## Aug 1977	156.081	214.871
## Sep 1977	151.110	208.974
## Oct 1977	156.172	216.727
## Nov 1977	151.000	222.663
## Dec 1977	155.935	235.754
## Jan 1978	173.128	260.677
## Feb 1978	156.387	233.933
## Mar 1978	173.136	258.863
## Apr 1978	167.349	255.285
## May 1978	172.923	272.691
## Jun 1978	167.340	254.703
## Jul 1978	172.912	258.056
## Aug 1978	173.189	250.652
## Sep 1978	167.455	241.494
## Oct 1978	173.169	241.095
## Nov 1978	167.557	237.214
## Dec 1978	173.060	250.285
## Jan 1979	182.600	270.000
## Feb 1979	165.096	239.377
## Mar 1979	182.881	273.485
## Apr 1979	176.844	265.526
## May 1979	182.782	283.727
## Jun 1979	176.833	264.118
## Jul 1979	182.700	262.394
## Aug 1979	182.808	257.423
## Sep 1979	176.891	243.468
## Oct 1979	182.752	253.559
## Nov 1979	176.949	255.317
## Dec 1979	182.770	262.637
## Jan 1980	209.829	298.221
## Feb 1980	196.310	271.194
## Mar 1980	209.727	294.931
## Apr 1980	202.894	293.043
## May 1980	209.548	310.682
## Jun 1980	202.723	299.633
## Jul 1980	209.554	295.537
## Aug 1980	209.675	281.831
## Sep 1980	202.905	268.204
## Oct 1980	209.717	273.058
## Nov 1980	202.945	270.913
## Dec 1980	209.671	288.131
## Jan 1981	220.544	299.483
## Feb 1981	199.248	273.604
## Mar 1981	220.595	293.454
## Apr 1981	213.467	286.764

## May 1981	220.433	305.297
## Jun 1981	213.237	305.860
## Jul 1981	220.392	308.821
## Aug 1981	220.428	296.678
## Sep 1981	213.480	276.720
## Oct 1981	220.581	284.684
## Nov 1981	213.437	280.364
## Dec 1981	220.440	304.193
## Jan 1982	226.251	320.311
## Feb 1982	204.375	297.475
## Mar 1982	226.157	330.131
## Apr 1982	218.821	316.183
## May 1982	226.135	323.939
## Jun 1982	218.866	316.816
## Jul 1982	226.202	321.854
## Aug 1982	226.168	310.059
## Sep 1982	218.947	289.054
## Oct 1982	226.373	296.056
## Nov 1982	218.948	300.864
## Dec 1982	226.210	323.054
## Jan 1983	246.575	348.969
## Feb 1983	222.738	320.213
## Mar 1983	246.610	352.422
## Apr 1983	238.625	343.331
## May 1983	246.647	355.330
## Jun 1983	238.736	346.012
## Jul 1983	246.651	345.359
## Aug 1983	246.695	338.025
## Sep 1983	238.755	315.758
## Oct 1983	246.732	320.524
## Nov 1983	238.780	325.785
## Dec 1983	246.871	357.437
## Jan 1984	251.483	355.607
## Feb 1984	235.169	333.238
## Mar 1984	251.529	358.566
## Apr 1984	243.277	348.756
## May 1984	251.408	363.212
## Jun 1984	243.303	344.623
## Jul 1984	251.632	348.366
## Aug 1984	251.638	340.669
## Sep 1984	243.596	317.887
## Oct 1984	251.974	326.373
## Nov 1984	244.068	323.172
## Dec 1984	252.042	343.652
## Jan 1985	256.315	353.933
## Feb 1985	231.512	323.067
## Mar 1985	256.336	344.083
## Apr 1985	247.599	334.259
## May 1985	255.881	349.644
## Jun 1985	247.643	332.457
## Jul 1985	256.159	332.393
## Aug 1985	256.301	328.026
## Sep 1985	247.997	315.367
## Oct 1985	256.175	327.776

## Nov 1985	248.070	330.222
## Dec 1985	256.246	346.947
## Jan 1986	249.178	326.552
## Feb 1986	224.922	307.952
## Mar 1986	248.837	349.995
## Apr 1986	240.788	338.487
## May 1986	248.822	345.587
## Jun 1986	240.837	334.442
## Jul 1986	249.011	335.334
## Aug 1986	249.176	325.501
## Sep 1986	241.074	316.539
## Oct 1986	248.974	325.125
## Nov 1986	241.122	323.172
## Dec 1986	249.352	341.787
## Jan 1987	244.137	334.890
## Feb 1987	220.511	296.606
## Mar 1987	244.157	327.541
## Apr 1987	236.139	315.231
## May 1987	244.007	330.797
## Jun 1987	236.522	311.957
## Jul 1987	244.359	317.495
## Aug 1987	244.396	311.395
## Sep 1987	236.298	302.090
## Oct 1987	244.059	309.095
## Nov 1987	236.197	297.439
## Dec 1987	244.104	319.908
## Jan 1988	255.331	334.583
## Feb 1988	238.853	307.533
## Mar 1988	255.385	326.015
## Apr 1988	247.241	316.232
## May 1988	255.188	331.539
## Jun 1988	247.340	315.603
## Jul 1988	255.582	317.391
## Aug 1988	255.815	315.766
## Sep 1988	247.357	306.500
## Oct 1988	255.517	310.737
## Nov 1988	247.096	313.792
## Dec 1988	255.345	326.992
## Jan 1989	266.572	348.321
## Feb 1989	243.927	317.572
## Mar 1989	268.315	358.115
## Apr 1989	251.946	346.511
## May 1989	241.235	350.304
## Jun 1989	248.447	349.753
## Jul 1989	261.318	351.720
## Aug 1989	276.985	358.320
## Sep 1989	264.811	341.553
## Oct 1989	276.462	356.682
## Nov 1989	276.819	359.731
## Dec 1989	282.520	367.555
## Jan 1990	236.692	329.327
## Feb 1990	226.266	321.465
## Mar 1990	244.248	353.956
## Apr 1990	232.640	334.136

## May 1990	210.108	317.791
## Jun 1990	178.544	289.276
## Jul 1990	219.713	315.872
## Aug 1990	245.632	332.580
## Sep 1990	239.932	311.965
## Oct 1990	235.437	312.873
## Nov 1990	220.256	301.883
## Dec 1990	245.644	341.584
## Jan 1991	269.531	370.278
## Feb 1991	204.535	292.511
## Mar 1991	214.374	317.683
## Apr 1991	190.452	293.309
## May 1991	206.579	320.120
## Jun 1991	209.721	313.437
## Jul 1991	210.055	309.257
## Aug 1991	250.834	340.813
## Sep 1991	267.735	345.122
## Oct 1991	249.408	324.454
## Nov 1991	241.541	318.757
## Dec 1991	267.033	355.690
## Jan 1992	279.197	366.577
## Feb 1992	230.468	305.537
## Mar 1992	221.177	311.299
## Apr 1992	210.172	292.073
## May 1992	190.537	282.361
## Jun 1992	230.985	323.546
## Jul 1992	250.150	333.005
## Aug 1992	269.662	347.510
## Sep 1992	251.511	324.027
## Oct 1992	269.545	340.565
## Nov 1992	264.383	345.048
## Dec 1992	263.891	360.200
## Jan 1993	274.257	373.255
## Feb 1993	240.964	322.185
## Mar 1993	263.204	359.855
## Apr 1993	226.859	330.605
## May 1993	196.012	313.546
## Jun 1993	197.445	304.450
## Jul 1993	212.707	309.916
## Aug 1993	262.322	346.577
## Sep 1993	250.551	324.882
## Oct 1993	257.383	331.480
## Nov 1993	262.183	338.485
## Dec 1993	264.559	352.074
## Jan 1994	306.708	388.854
## Feb 1994	244.594	323.751
## Mar 1994	261.461	354.509
## Apr 1994	236.035	332.955
## May 1994	202.480	303.865
## Jun 1994	215.744	313.708
## Jul 1994	274.451	366.741
## Aug 1994	251.577	333.540
## Sep 1994	238.967	307.933
## Oct 1994	271.599	343.569

## Nov 1994	261.436	338.304
## Dec 1994	262.482	348.732
## Jan 1995	243.462	336.872
## Feb 1995	206.657	299.810
## Mar 1995	239.820	346.752
## Apr 1995	267.571	361.046
## May 1995	227.439	333.643
## Jun 1995	226.934	342.092
## Jul 1995	294.251	400.977
## Aug 1995	301.628	399.583
## Sep 1995	268.791	349.815
## Oct 1995	292.175	384.663
## Nov 1995	267.659	366.200
## Dec 1995	262.694	373.129
## Jan 1996	272.584	385.971
## Feb 1996	226.038	343.243
## Mar 1996	259.039	385.026
## Apr 1996	205.729	325.915
## May 1996	231.211	356.221
## Jun 1996	254.182	375.816
## Jul 1996	281.656	395.278
## Aug 1996	294.581	398.870
## Sep 1996	259.345	347.920
## Oct 1996	310.461	400.155
## Nov 1996	295.562	387.043
## Dec 1996	264.912	378.537
## Jan 1997	275.641	397.124
## Feb 1997	226.521	342.279
## Mar 1997	251.136	381.623
## Apr 1997	252.010	374.093
## May 1997	268.515	398.347
## Jun 1997	231.690	362.325
## Jul 1997	259.985	382.540
## Aug 1997	264.422	370.673
## Sep 1997	250.744	343.197
## Oct 1997	305.656	402.188
## Nov 1997	264.591	355.868
## Dec 1997	256.998	355.807
## Jan 1998	278.211	386.269
## Feb 1998	212.209	323.378
## Mar 1998	240.963	360.492
## Apr 1998	240.612	348.763
## May 1998	250.239	374.487
## Jun 1998	186.089	309.019
## Jul 1998	246.326	358.537
## Aug 1998	254.237	354.150
## Sep 1998	248.270	332.989
## Oct 1998	267.922	345.379
## Nov 1998	230.488	309.809
## Dec 1998	273.362	370.867
## Jan 1999	272.260	383.582
## Feb 1999	220.539	328.183
## Mar 1999	212.177	334.062
## Apr 1999	249.920	355.198

## May 1999	289.264	401.370
## Jun 1999	236.090	353.158
## Jul 1999	264.292	379.433
## Aug 1999	258.854	360.215
## Sep 1999	244.140	328.356
## Oct 1999	228.256	308.985
## Nov 1999	254.125	337.650
## Dec 1999	235.215	332.407
## Jan 2000	222.067	319.978
## Feb 2000	246.169	334.369
## Mar 2000	263.209	366.040
## Apr 2000	254.609	364.110
## May 2000	254.678	361.267
## Jun 2000	227.712	326.724
## Jul 2000	255.348	351.077
## Aug 2000	254.942	343.214
## Sep 2000	240.331	312.937
## Oct 2000	270.472	341.025
## Nov 2000	261.335	339.223
## Dec 2000	254.788	333.069
## Jan 2001	228.434	303.197
## Feb 2001	202.849	272.585
## Mar 2001	219.649	301.844
## Apr 2001	213.628	288.028
## May 2001	211.506	290.338
## Jun 2001	213.950	298.272
## Jul 2001	221.842	297.654
## Aug 2001	225.897	304.239
## Sep 2001	214.229	279.069
## Oct 2001	227.319	292.015
## Nov 2001	219.773	283.668
## Dec 2001	225.088	302.843
## Jan 2002	228.396	314.861
## Feb 2002	198.932	279.136
## Mar 2002	217.568	302.856
## Apr 2002	212.852	309.709
## May 2002	225.155	331.378
## Jun 2002	215.107	326.674
## Jul 2002	235.713	337.792
## Aug 2002	224.400	311.593
## Sep 2002	230.855	302.858
## Oct 2002	243.767	315.739
## Nov 2002	230.328	309.716
## Dec 2002	242.334	328.629
## Jan 2003	237.044	318.956
## Feb 2003	212.693	291.767
## Mar 2003	233.288	330.201
## Apr 2003	228.516	327.749
## May 2003	229.756	345.099
## Jun 2003	228.254	341.209
## Jul 2003	242.533	342.647
## Aug 2003	239.928	333.101
## Sep 2003	230.968	308.470
## Oct 2003	236.938	313.818

## Nov 2003	233.698	314.096
## Dec 2003	251.160	347.074
## Jan 2004	255.574	347.154
## Feb 2004	236.689	321.055
## Mar 2004	248.532	342.168
## Apr 2004	247.253	334.068
## May 2004	244.383	344.066
## Jun 2004	244.075	346.968
## Jul 2004	257.042	353.034
## Aug 2004	254.446	344.004
## Sep 2004	243.019	328.252
## Oct 2004	253.520	332.739
## Nov 2004	247.286	332.106
## Dec 2004	264.199	367.856
## Jan 2005	264.707	361.269
## Feb 2005	247.271	333.479
## Mar 2005	260.043	354.763
## Apr 2005	246.929	342.863
## May 2005	255.790	367.186
## Jun 2005	252.466	362.264
## Jul 2005	266.332	372.396
## Aug 2005	266.097	356.107
## Sep 2005	255.348	331.447
## Oct 2005	261.121	339.018
## Nov 2005	256.532	338.541
## Dec 2005	268.550	360.826
## Jan 2006	276.647	388.583
## Feb 2006	247.274	348.049
## Mar 2006	265.069	368.883
## Apr 2006	250.384	367.940
## May 2006	261.125	386.890
## Jun 2006	261.960	383.011
## Jul 2006	274.809	381.340
## Aug 2006	277.063	370.019
## Sep 2006	267.952	345.317
## Oct 2006	275.120	353.690
## Nov 2006	270.475	359.164
## Dec 2006	283.636	376.761
## Jan 2007	290.845	399.004
## Feb 2007	261.666	343.865
## Mar 2007	285.146	390.167
## Apr 2007	278.386	383.102
## May 2007	286.010	398.044
## Jun 2007	281.995	382.096
## Jul 2007	295.653	393.450
## Aug 2007	295.523	386.428
## Sep 2007	287.603	360.587
## Oct 2007	299.416	374.075
## Nov 2007	297.828	373.327
## Dec 2007	312.007	397.970
## Jan 2008	331.138	427.860
## Feb 2008	300.535	388.671
## Mar 2008	321.487	424.851
## Apr 2008	314.073	421.184

## May 2008	324.185	449.522
## Jun 2008	313.335	444.695
## Jul 2008	330.507	446.062
## Aug 2008	333.607	431.761
## Sep 2008	318.840	398.411
## Oct 2008	330.125	412.573
## Nov 2008	327.317	409.976
## Dec 2008	323.102	428.996
## Jan 2009	318.353	431.011
## Feb 2009	294.389	386.812
## Mar 2009	319.356	432.104
## Apr 2009	303.489	431.059
## May 2009	319.032	456.231
## Jun 2009	321.739	455.356
## Jul 2009	343.841	455.962
## Aug 2009	348.551	449.335
## Sep 2009	332.374	421.927
## Oct 2009	346.472	450.940
## Nov 2009	348.333	456.527
## Dec 2009	360.689	481.882
## Jan 2010	377.071	489.844
## Feb 2010	347.952	449.090
## Mar 2010	384.094	499.560
## Apr 2010	368.922	482.552
## May 2010	376.012	507.544
## Jun 2010	372.328	517.750
## Jul 2010	385.443	508.593
## Aug 2010	389.064	497.073
## Sep 2010	377.355	476.105
## Oct 2010	386.771	489.125
## Nov 2010	386.602	500.488
## Dec 2010	400.917	524.855
## Jan 2011	400.710	530.909
## Feb 2011	359.327	490.715
## Mar 2011	394.959	553.169
## Apr 2011	373.481	538.506
## May 2011	385.273	554.011
## Jun 2011	389.673	553.885
## Jul 2011	399.454	549.374
## Aug 2011	402.931	534.036
## Sep 2011	387.218	500.175
## Oct 2011	397.994	517.691
## Nov 2011	400.892	528.710
## Dec 2011	420.525	552.823
## Jan 2012	399.385	539.030
## Feb 2012	373.028	494.125
## Mar 2012	388.074	541.241
## Apr 2012	368.981	519.625
## May 2012	387.318	546.973
## Jun 2012	377.793	528.767
## Jul 2012	379.862	520.173
## Aug 2012	386.269	513.269
## Sep 2012	366.955	475.611
## Oct 2012	373.975	491.520

## Nov 2012	368.902	489.081
## Dec 2012	383.017	527.555
## Jan 2013	391.713	542.692
## Feb 2013	354.251	487.697
## Mar 2013	397.835	541.012
## Apr 2013	386.469	551.448
## May 2013	404.782	578.378
## Jun 2013	401.893	563.561
## Jul 2013	419.452	572.289
## Aug 2013	413.684	542.610
## Sep 2013	395.313	514.219
## Oct 2013	417.493	543.689
## Nov 2013	415.796	548.475
## Dec 2013	436.115	574.712
## Jan 2014	420.974	574.074
## Feb 2014	382.165	507.104
## Mar 2014	423.586	589.448
## Apr 2014	408.886	582.906
## May 2014	420.035	589.532
## Jun 2014	422.748	590.551
## Jul 2014	437.471	588.452
## Aug 2014	431.020	559.856
## Sep 2014	411.083	530.545
## Oct 2014	424.674	557.212
## Nov 2014	419.845	569.440
## Dec 2014	446.730	593.582
## Jan 2015	426.511	580.459
## Feb 2015	385.395	532.998
## Mar 2015	418.058	579.274
## Apr 2015	404.120	569.372
## May 2015	421.760	578.595
## Jun 2015	419.237	564.148
## Jul 2015	434.897	583.940
## Aug 2015	431.663	572.235
## Sep 2015	409.666	539.599
## Oct 2015	418.147	556.624
## Nov 2015	418.730	575.262
## Dec 2015	436.774	607.029
## Jan 2016	427.135	599.191
## Feb 2016	405.931	581.707
## Mar 2016	428.642	626.117
## Apr 2016	399.703	589.697
## May 2016	423.372	609.056
## Jun 2016	424.332	593.674
## Jul 2016	434.083	604.311
## Aug 2016	441.570	591.345
## Sep 2016	416.462	562.208
## Oct 2016	424.405	584.383
## Nov 2016	427.968	586.197
## Dec 2016	468.546	650.925
## Jan 2017	439.571	627.139
## Feb 2017	396.508	580.323
## Mar 2017	437.490	663.921
## Apr 2017	408.227	635.132

## May 2017	426.923	661.288
## Jun 2017	423.612	642.341
## Jul 2017	435.087	625.553
## Aug 2017	446.085	612.154
## Sep 2017	416.763	583.867
## Oct 2017	433.547	614.657
## Nov 2017	438.603	613.796
## Dec 2017	454.004	635.130
## Jan 2018	449.180	652.428
## Feb 2018	412.864	609.384
## Mar 2018	449.086	668.591
## Apr 2018	425.122	656.554
## May 2018	444.714	680.705
## Jun 2018	438.195	668.774
## Jul 2018	455.403	647.940
## Aug 2018	459.274	651.954
## Sep 2018	427.023	600.710
## Oct 2018	448.833	627.968
## Nov 2018	440.087	623.200
## Dec 2018	455.871	647.491
## Jan 2019	444.926	644.838
## Feb 2019	404.689	593.170
## Mar 2019	433.493	657.018
## Apr 2019	422.747	665.972
## May 2019	439.777	689.977
## Jun 2019	432.822	661.158
## Jul 2019	449.062	667.002
## Aug 2019	446.394	647.658
## Sep 2019	416.241	613.133
## Oct 2019	431.848	633.573
## Nov 2019	430.565	620.685
## Dec 2019	454.288	650.482
## Jan 2020	432.686	648.215
## Feb 2020	403.222	632.039
## Mar 2020	411.076	641.447
## Apr 2020	323.946	560.486
## May 2020	354.840	618.100
## Jun 2020	374.660	636.973
## Jul 2020	395.536	632.799
## Aug 2020	397.879	618.428
## Sep 2020	386.097	583.405
## Oct 2020	398.927	611.837
## Nov 2020	402.541	629.861
## Dec 2020	418.294	640.797
## Jan 2021	409.222	637.522
## Feb 2021	348.443	553.037
## Mar 2021	411.001	678.149
## Apr 2021	393.241	651.301
## May 2021	418.431	689.586
## Jun 2021	410.574	656.900
## Jul 2021	425.729	651.325
## Aug 2021	413.209	648.963
## Sep 2021	395.132	620.842
## Oct 2021	422.318	650.243

## Nov 2021	423.789	663.731
## Dec 2021	445.133	706.750
## Jan 2022	445.593	707.979
## Feb 2022	403.607	661.288
## Mar 2022	440.872	743.597
## Apr 2022	415.946	722.551
## May 2022	440.614	753.369
## Jun 2022	439.639	735.657
## Jul 2022	446.783	723.656
## Aug 2022	439.336	682.908
## Sep 2022	411.653	642.820
## Oct 2022	435.904	669.622
## Nov 2022	437.624	695.918
## Dec 2022	439.099	690.850
## Jan 2023	436.791	699.219
## Feb 2023	392.663	662.356
## Mar 2023	439.248	738.376
## Apr 2023	407.991	711.502
## May 2023	438.492	743.971
## Jun 2023	431.448	701.163
## Jul 2023	440.978	718.784
## Aug 2023	444.676	716.526
## Sep 2023	430.249	675.796
## Oct 2023	436.250	697.000
## Nov 2023	435.762	685.076
## Dec 2023	468.477	723.896
## Jan 2024	434.799	689.644
## Feb 2024	426.280	711.645
## Mar 2024	449.238	777.166
## Apr 2024	421.256	761.186
## May 2024	436.085	775.130
## Jun 2024	438.369	775.144
## Jul 2024	457.471	756.708
## Aug 2024	458.855	756.385
## Sep 2024	435.823	700.397
## Oct 2024	442.432	735.345
## Nov 2024	452.505	725.928
## Dec 2024	466.293	741.701
## Jan 2025	444.383	750.981
## Feb 2025	403.385	693.266
## Mar 2025	442.050	812.838
## Apr 2025	412.690	783.482
## May 2025	435.814	793.521
## Jun 2025	435.904	789.933
## Jul 2025	454.480	794.256
## Aug 2025	446.279	763.036
## Sep 2025	435.735	715.006
##	Hydroelectric Power Consumption	
## Jan 1973	89.562	
## Feb 1973	79.544	
## Mar 1973	88.284	
## Apr 1973	83.152	
## May 1973	85.643	
## Jun 1973	82.060	

## Jul 1973	77.400
## Aug 1973	72.936
## Sep 1973	59.029
## Oct 1973	62.967
## Nov 1973	69.063
## Dec 1973	90.131
## Jan 1974	99.500
## Feb 1974	91.476
## Mar 1974	94.950
## Apr 1974	95.969
## May 1974	96.337
## Jun 1974	91.719
## Jul 1974	90.437
## Aug 1974	82.727
## Sep 1974	73.610
## Oct 1974	68.931
## Nov 1974	72.773
## Dec 1974	79.542
## Jan 1975	86.356
## Feb 1975	82.404
## Mar 1975	96.386
## Apr 1975	91.791
## May 1975	95.581
## Jun 1975	93.550
## Jul 1975	87.900
## Aug 1975	77.892
## Sep 1975	70.756
## Oct 1975	78.060
## Nov 1975	84.171
## Dec 1975	89.510
## Jan 1976	89.904
## Feb 1976	84.626
## Mar 1976	91.629
## Apr 1976	83.378
## May 1976	88.065
## Jun 1976	88.182
## Jul 1976	89.807
## Aug 1976	82.153
## Sep 1976	70.186
## Oct 1976	72.690
## Nov 1976	68.463
## Dec 1976	69.900
## Jan 1977	71.630
## Feb 1977	52.424
## Mar 1977	68.518
## Apr 1977	64.508
## May 1977	64.629
## Jun 1977	59.609
## Jul 1977	58.130
## Aug 1977	57.830
## Sep 1977	56.835
## Oct 1977	59.480
## Nov 1977	70.583
## Dec 1977	78.744

## Jan 1978	86.454
## Feb 1978	76.606
## Mar 1978	84.951
## Apr 1978	87.281
## May 1978	99.185
## Jun 1978	86.645
## Jul 1978	84.339
## Aug 1978	76.518
## Sep 1978	73.042
## Oct 1978	67.184
## Nov 1978	68.818
## Dec 1978	76.162
## Jan 1979	86.378
## Feb 1979	73.446
## Mar 1979	89.483
## Apr 1979	87.645
## May 1979	99.903
## Jun 1979	86.230
## Jul 1979	78.573
## Aug 1979	73.393
## Sep 1979	65.516
## Oct 1979	69.619
## Nov 1979	77.213
## Dec 1979	78.457
## Jan 1980	87.244
## Feb 1980	73.781
## Mar 1980	83.978
## Apr 1980	88.865
## May 1980	99.622
## Jun 1980	95.451
## Jul 1980	84.448
## Aug 1980	70.517
## Sep 1980	63.819
## Oct 1980	61.661
## Nov 1980	66.325
## Dec 1980	76.858
## Jan 1981	77.214
## Feb 1981	72.830
## Mar 1981	71.150
## Apr 1981	71.718
## May 1981	83.301
## Jun 1981	91.061
## Jul 1981	86.714
## Aug 1981	74.556
## Sep 1981	61.534
## Oct 1981	62.420
## Nov 1981	65.459
## Dec 1981	82.279
## Jan 1982	92.763
## Feb 1982	91.907
## Mar 1982	102.924
## Apr 1982	96.303
## May 1982	96.572
## Jun 1982	96.463

## Jul 1982	94.087
## Aug 1982	82.333
## Sep 1982	68.612
## Oct 1982	68.091
## Nov 1982	80.245
## Dec 1982	95.522
## Jan 1983	100.743
## Feb 1983	96.206
## Mar 1983	104.348
## Apr 1983	103.334
## May 1983	107.568
## Jun 1983	105.810
## Jul 1983	96.883
## Aug 1983	88.929
## Sep 1983	74.808
## Oct 1983	71.491
## Nov 1983	84.956
## Dec 1983	108.936
## Jan 1984	102.459
## Feb 1984	96.034
## Mar 1984	104.801
## Apr 1984	103.270
## May 1984	109.683
## Jun 1984	99.261
## Jul 1984	94.772
## Aug 1984	86.573
## Sep 1984	72.076
## Oct 1984	71.968
## Nov 1984	76.704
## Dec 1984	88.949
## Jan 1985	94.973
## Feb 1985	89.219
## Mar 1985	85.029
## Apr 1985	84.276
## May 1985	91.284
## Jun 1985	82.425
## Jul 1985	73.612
## Aug 1985	68.980
## Sep 1985	64.761
## Oct 1985	69.105
## Nov 1985	79.075
## Dec 1985	87.328
## Jan 1986	73.934
## Feb 1986	80.075
## Mar 1986	98.081
## Apr 1986	94.922
## May 1986	93.958
## Jun 1986	90.562
## Jul 1986	83.094
## Aug 1986	73.104
## Sep 1986	72.767
## Oct 1986	73.498
## Nov 1986	79.755
## Dec 1986	89.397

## Jan 1987	87.702
## Feb 1987	73.264
## Mar 1987	80.279
## Apr 1987	76.163
## May 1987	83.712
## Jun 1987	72.271
## Jul 1987	69.864
## Aug 1987	63.744
## Sep 1987	62.756
## Oct 1987	61.964
## Nov 1987	58.272
## Dec 1987	72.753
## Jan 1988	76.171
## Feb 1988	66.029
## Mar 1988	67.539
## Apr 1988	66.195
## May 1988	73.601
## Jun 1988	65.346
## Jul 1988	58.636
## Aug 1988	56.923
## Sep 1988	56.241
## Oct 1988	52.265
## Nov 1988	63.762
## Dec 1988	68.748
## Jan 1989	73.277
## Feb 1989	65.188
## Mar 1989	79.268
## Apr 1989	84.295
## May 1989	98.200
## Jun 1989	90.614
## Jul 1989	79.373
## Aug 1989	70.675
## Sep 1989	66.237
## Oct 1989	70.285
## Nov 1989	74.172
## Dec 1989	76.402
## Jan 1990	83.078
## Feb 1990	86.122
## Mar 1990	98.841
## Apr 1990	90.589
## May 1990	95.753
## Jun 1990	98.444
## Jul 1990	84.490
## Aug 1990	75.559
## Sep 1990	61.422
## Oct 1990	66.657
## Nov 1990	71.863
## Dec 1990	86.440
## Jan 1991	91.732
## Feb 1991	78.638
## Mar 1991	92.384
## Apr 1991	91.874
## May 1991	101.296
## Jun 1991	91.854

## Jul 1991	86.984
## Aug 1991	77.658
## Sep 1991	65.997
## Oct 1991	63.197
## Nov 1991	66.085
## Dec 1991	78.349
## Jan 1992	77.844
## Feb 1992	64.670
## Mar 1992	78.408
## Apr 1992	70.180
## May 1992	79.980
## Jun 1992	80.819
## Jul 1992	70.671
## Aug 1992	65.474
## Sep 1992	60.474
## Oct 1992	59.474
## Nov 1992	69.964
## Dec 1992	85.579
## Jan 1993	88.873
## Feb 1993	71.730
## Mar 1993	83.868
## Apr 1993	90.980
## May 1993	104.743
## Jun 1993	95.182
## Jul 1993	84.360
## Aug 1993	71.587
## Sep 1993	62.245
## Oct 1993	62.087
## Nov 1993	64.729
## Dec 1993	76.662
## Jan 1994	72.773
## Feb 1994	69.738
## Mar 1994	80.508
## Apr 1994	84.264
## May 1994	88.353
## Jun 1994	85.343
## Jul 1994	79.712
## Aug 1994	69.257
## Sep 1994	56.561
## Oct 1994	59.757
## Nov 1994	65.325
## Dec 1994	75.959
## Jan 1995	84.852
## Feb 1995	85.447
## Mar 1995	97.479
## Apr 1995	83.847
## May 1995	94.791
## Jun 1995	103.128
## Jul 1995	93.729
## Aug 1995	83.175
## Sep 1995	68.333
## Oct 1995	78.993
## Nov 1995	87.148
## Dec 1995	99.640

## Jan 1996	104.821
## Feb 1996	108.488
## Mar 1996	115.603
## Apr 1996	108.647
## May 1996	113.485
## Jun 1996	108.928
## Jul 1996	98.519
## Aug 1996	89.620
## Sep 1996	75.536
## Oct 1996	77.094
## Nov 1996	80.374
## Dec 1996	103.400
## Jan 1997	112.458
## Feb 1997	107.528
## Mar 1997	119.397
## Apr 1997	109.441
## May 1997	116.635
## Jun 1997	117.564
## Jul 1997	108.011
## Aug 1997	91.802
## Sep 1997	79.836
## Oct 1997	84.394
## Nov 1997	80.900
## Dec 1997	88.252
## Jan 1998	98.328
## Feb 1998	102.347
## Mar 1998	108.119
## Apr 1998	97.610
## May 1998	113.264
## Jun 1998	110.348
## Jul 1998	97.785
## Aug 1998	85.678
## Sep 1998	71.060
## Oct 1998	64.434
## Nov 1998	68.310
## Dec 1998	85.937
## Jan 1999	100.724
## Feb 1999	97.902
## Mar 1999	109.456
## Apr 1999	93.280
## May 1999	98.936
## Jun 1999	104.294
## Jul 1999	101.288
## Aug 1999	87.778
## Sep 1999	71.283
## Oct 1999	67.908
## Nov 1999	72.210
## Dec 1999	85.198
## Jan 2000	86.468
## Feb 2000	76.714
## Mar 2000	91.110
## Apr 2000	97.207
## May 2000	93.560
## Jun 2000	85.931

## Jul 2000	82.333
## Aug 2000	74.999
## Sep 2000	60.736
## Oct 2000	58.639
## Nov 2000	65.377
## Dec 2000	67.181
## Jan 2001	64.323
## Feb 2001	59.617
## Mar 2001	69.868
## Apr 2001	61.460
## May 2001	65.427
## Jun 2001	70.723
## Jul 2001	61.686
## Aug 2001	64.534
## Sep 2001	52.054
## Oct 2001	51.980
## Nov 2001	52.589
## Dec 2001	66.010
## Jan 2002	74.364
## Feb 2002	68.894
## Mar 2002	71.682
## Apr 2002	82.729
## May 2002	90.973
## Jun 2002	96.262
## Jul 2002	86.906
## Aug 2002	71.938
## Sep 2002	58.300
## Oct 2002	58.589
## Nov 2002	67.319
## Dec 2002	73.933
## Jan 2003	70.287
## Feb 2003	67.489
## Mar 2003	82.578
## Apr 2003	84.478
## May 2003	100.297
## Jun 2003	97.536
## Jul 2003	84.765
## Aug 2003	78.381
## Sep 2003	63.055
## Oct 2003	62.878
## Nov 2003	67.268
## Dec 2003	82.039
## Jan 2004	78.419
## Feb 2004	71.357
## Mar 2004	78.184
## Apr 2004	71.270
## May 2004	81.955
## Jun 2004	86.161
## Jul 2004	79.562
## Aug 2004	73.672
## Sep 2004	70.032
## Oct 2004	64.360
## Nov 2004	71.437
## Dec 2004	89.431

## Jan 2005	82.817
## Feb 2005	73.722
## Mar 2005	78.258
## Apr 2005	78.675
## May 2005	93.074
## Jun 2005	91.384
## Jul 2005	88.565
## Aug 2005	73.582
## Sep 2005	59.245
## Oct 2005	61.438
## Nov 2005	66.031
## Dec 2005	75.546
## Jan 2006	93.614
## Feb 2006	84.487
## Mar 2006	84.019
## Apr 2006	97.432
## May 2006	105.153
## Jun 2006	101.532
## Jul 2006	86.799
## Aug 2006	74.137
## Sep 2006	58.691
## Oct 2006	58.192
## Nov 2006	69.167
## Dec 2006	73.685
## Jan 2007	88.865
## Feb 2007	63.349
## Mar 2007	82.446
## Apr 2007	81.515
## May 2007	88.872
## Jun 2007	77.850
## Jul 2007	76.694
## Aug 2007	68.037
## Sep 2007	50.302
## Oct 2007	50.485
## Nov 2007	53.507
## Dec 2007	62.582
## Jan 2008	70.898
## Feb 2008	64.108
## Mar 2008	73.934
## Apr 2008	75.862
## May 2008	92.879
## Jun 2008	99.553
## Jul 2008	87.194
## Aug 2008	72.434
## Sep 2008	55.200
## Oct 2008	52.783
## Nov 2008	53.459
## Dec 2008	71.179
## Jan 2009	80.149
## Feb 2009	60.775
## Mar 2009	74.475
## Apr 2009	87.927
## May 2009	100.858
## Jun 2009	99.744

## Jul 2009	79.789
## Aug 2009	66.808
## Sep 2009	59.228
## Oct 2009	67.186
## Nov 2009	71.678
## Dec 2009	84.378
## Jan 2010	76.371
## Feb 2010	70.252
## Mar 2010	71.262
## Apr 2010	65.158
## May 2010	85.570
## Jun 2010	101.861
## Jul 2010	83.651
## Aug 2010	68.647
## Sep 2010	58.909
## Oct 2010	60.334
## Nov 2010	66.744
## Dec 2010	79.053
## Jan 2011	87.112
## Feb 2011	82.336
## Mar 2011	106.231
## Apr 2011	106.435
## May 2011	111.187
## Jun 2011	109.700
## Jul 2011	106.743
## Aug 2011	87.905
## Sep 2011	72.940
## Oct 2011	67.515
## Nov 2011	70.562
## Dec 2011	80.973
## Jan 2012	78.842
## Feb 2012	69.209
## Mar 2012	88.393
## Apr 2012	89.720
## May 2012	97.724
## Jun 2012	90.956
## Jul 2012	90.387
## Aug 2012	78.591
## Sep 2012	60.065
## Oct 2012	56.304
## Nov 2012	63.918
## Dec 2012	78.423
## Jan 2013	84.715
## Feb 2013	69.668
## Mar 2013	70.063
## Apr 2013	85.631
## May 2013	97.072
## Jun 2013	93.434
## Jul 2013	92.993
## Aug 2013	73.813
## Sep 2013	57.871
## Oct 2013	58.682
## Nov 2013	60.313
## Dec 2013	72.090

## Jan 2014	73.815
## Feb 2014	59.356
## Mar 2014	82.765
## Apr 2014	86.801
## May 2014	90.568
## Jun 2014	87.838
## Jul 2014	83.107
## Aug 2014	67.582
## Sep 2014	54.846
## Oct 2014	58.547
## Nov 2014	63.548
## Dec 2014	76.186
## Jan 2015	82.360
## Feb 2015	76.040
## Mar 2015	82.846
## Apr 2015	76.671
## May 2015	68.668
## Jun 2015	69.653
## Jul 2015	71.701
## Aug 2015	65.245
## Sep 2015	54.913
## Oct 2015	56.743
## Nov 2015	65.981
## Dec 2015	79.041
## Jan 2016	87.397
## Feb 2016	82.362
## Mar 2016	93.454
## Apr 2016	88.296
## May 2016	86.960
## Jun 2016	79.284
## Jul 2016	73.206
## Aug 2016	66.771
## Sep 2016	55.847
## Oct 2016	59.160
## Nov 2016	64.174
## Dec 2016	76.865
## Jan 2017	90.854
## Feb 2017	81.485
## Mar 2017	101.040
## Apr 2017	100.345
## May 2017	111.255
## Jun 2017	104.323
## Jul 2017	90.753
## Aug 2017	75.180
## Sep 2017	65.346
## Oct 2017	60.386
## Nov 2017	67.859
## Dec 2017	75.910
## Jan 2018	85.519
## Feb 2018	84.967
## Mar 2018	88.236
## Apr 2018	95.929
## May 2018	103.876
## Jun 2018	94.163

## Jul 2018	85.640
## Aug 2018	75.122
## Sep 2018	65.393
## Oct 2018	66.698
## Nov 2018	74.766
## Dec 2018	77.784
## Jan 2019	84.610
## Feb 2019	78.068
## Mar 2019	89.852
## Apr 2019	94.922
## May 2019	109.123
## Jun 2019	95.801
## Jul 2019	84.875
## Aug 2019	77.038
## Sep 2019	63.210
## Oct 2019	62.459
## Nov 2019	68.982
## Dec 2019	73.284
## Jan 2020	83.587
## Feb 2020	88.262
## Mar 2020	81.284
## Apr 2020	79.139
## May 2020	102.279
## Jun 2020	95.534
## Jul 2020	91.243
## Aug 2020	79.443
## Sep 2020	63.732
## Oct 2020	64.181
## Nov 2020	71.286
## Dec 2020	73.385
## Jan 2021	83.799
## Feb 2021	68.706
## Mar 2021	72.404
## Apr 2021	66.155
## May 2021	79.530
## Jun 2021	80.025
## Jul 2021	75.397
## Aug 2021	69.360
## Sep 2021	58.080
## Oct 2021	58.458
## Nov 2021	66.102
## Dec 2021	80.393
## Jan 2022	82.562
## Feb 2022	72.746
## Mar 2022	83.377
## Apr 2022	68.465
## May 2022	79.700
## Jun 2022	88.670
## Jul 2022	83.824
## Aug 2022	72.106
## Sep 2022	58.093
## Oct 2022	49.022
## Nov 2022	61.068
## Dec 2022	69.706

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

Question 3

Compute mean and standard deviation for these three series.

```
q3_stats <- data.frame(Mean = colMeans(q1_ts), Std_Dev = apply(q1_ts,
  2, sd))

q3_stats
```

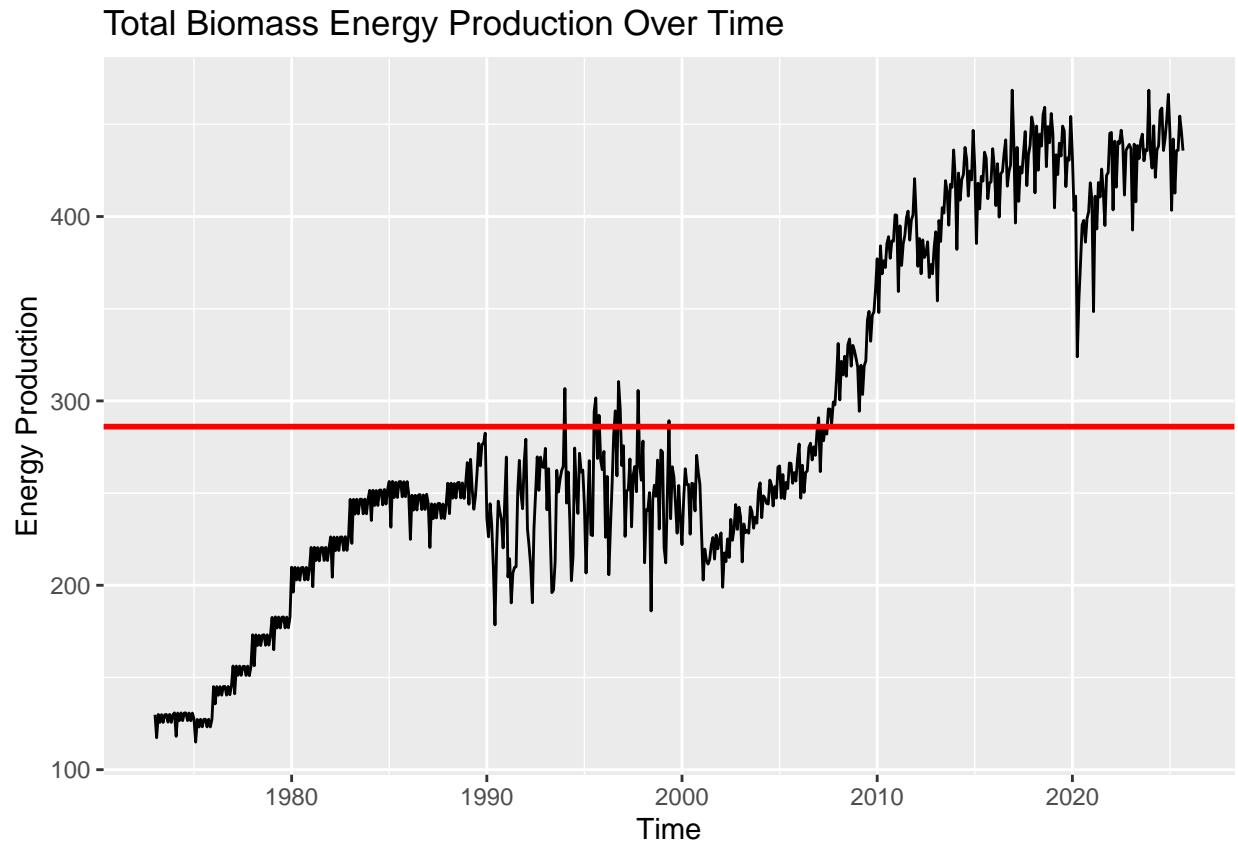
```
##              Mean  Std_Dev
## Total Biomass Energy Production  286.04893  96.21209
## Total Renewable Energy Production 409.19521 151.42232
## Hydroelectric Power Consumption   79.35682  14.12020
```

Question 4

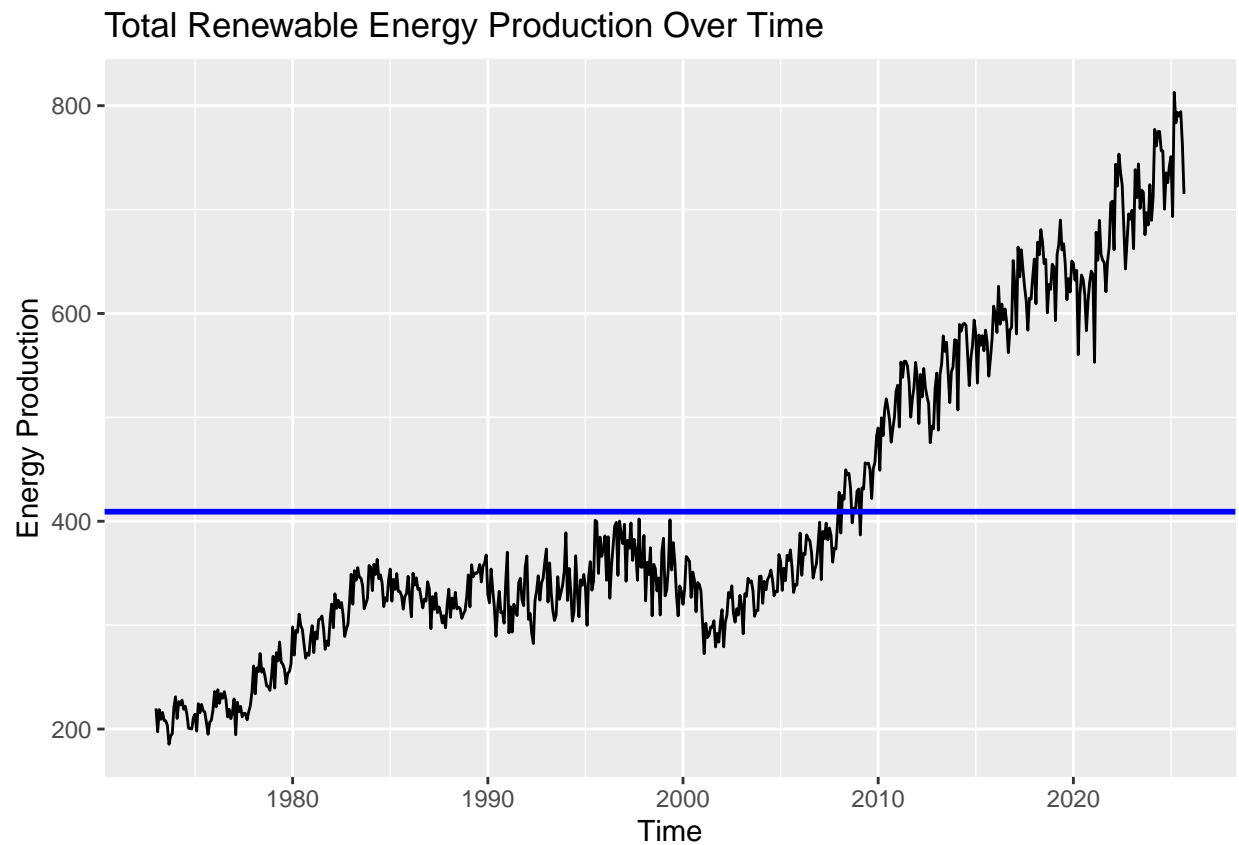
Display and interpret the time series plot for each of these variables. Try to make your plot as informative as possible by writing titles, labels, etc. For each plot add a horizontal line at the mean of each series in a different color.

```
library(ggplot2)
library(forecast)

# 1. Total Biomass Energy Production
p1 <- autoplot(q1_ts[, "Total Biomass Energy Production"]) +
  geom_hline(yintercept = mean(q1_ts[, "Total Biomass Energy Production"]),
    color = "red", linewidth = 1) + labs(title = "Total Biomass Energy Production Over Time",
    x = "Time", y = "Energy Production")
print(p1)
```

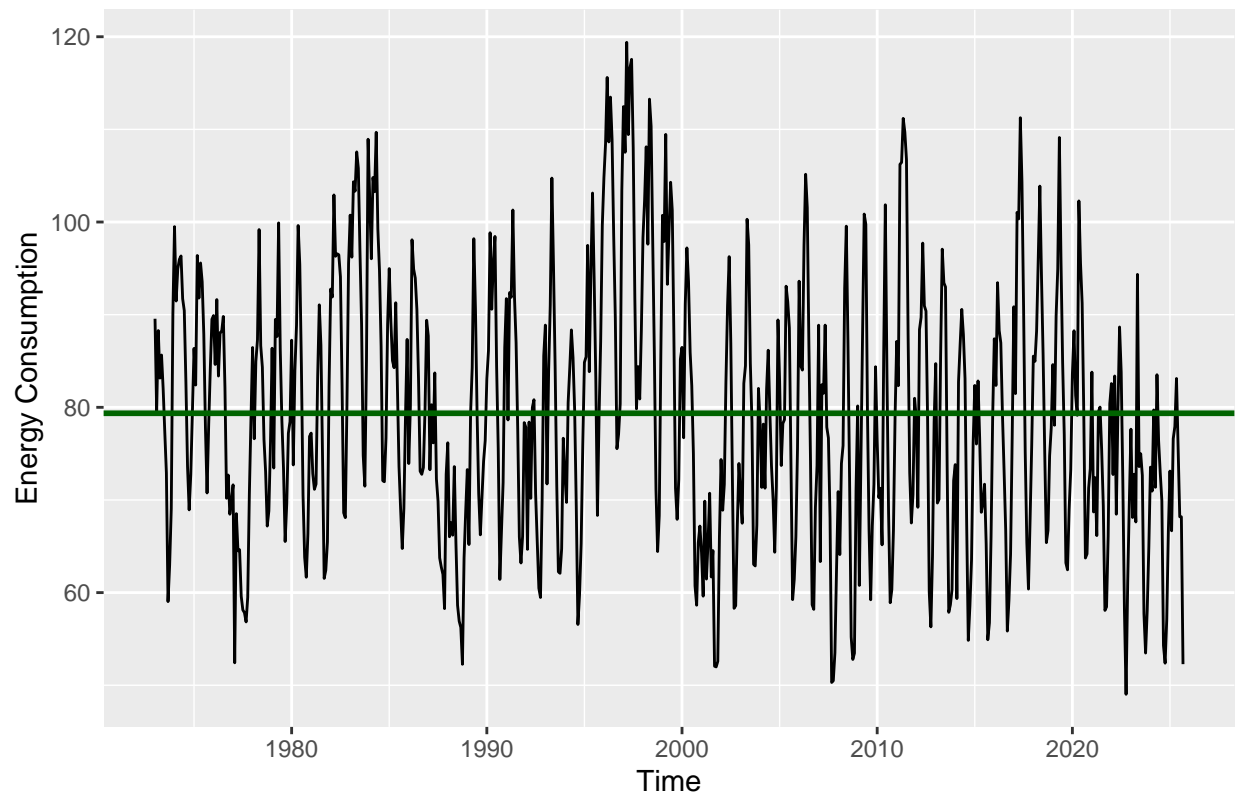


```
# 2. Total Renewable Energy Production
p2 <- autoplot(q1_ts[, "Total Renewable Energy Production"]) +
  geom_hline(yintercept = mean(q1_ts[, "Total Renewable Energy Production"]),
    color = "blue", linewidth = 1) + labs(title = "Total Renewable Energy Production Over Time",
    x = "Time", y = "Energy Production")
print(p2)
```



```
# 3. Hydroelectric Power Consumption
p3 <- autoplot(q1_ts[, "Hydroelectric Power Consumption"]) +
  geom_hline(yintercept = mean(q1_ts[, "Hydroelectric Power Consumption"]),
    color = "darkgreen", linewidth = 1) + labs(title = "Hydroelectric Power Consumption Over Time",
    x = "Time", y = "Energy Consumption")
print(p3)
```

Hydroelectric Power Consumption Over Time



Question 5

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

```
q5_cor <- cor(q1_ts)
```

```
q5_cor
```

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

The correlation matrix shows a very strong positive correlation between total biomass energy production and total renewable energy production (around 0.97), indicating that these two series move closely together over time. This result is expected since biomass energy constitutes a substantial component of total renewable energy production.

In contrast, hydroelectric power consumption exhibits very weak correlations with both biomass energy production and total renewable energy production, suggesting that hydropower dynamics are largely independent of biomass-related and overall renewable energy trends.

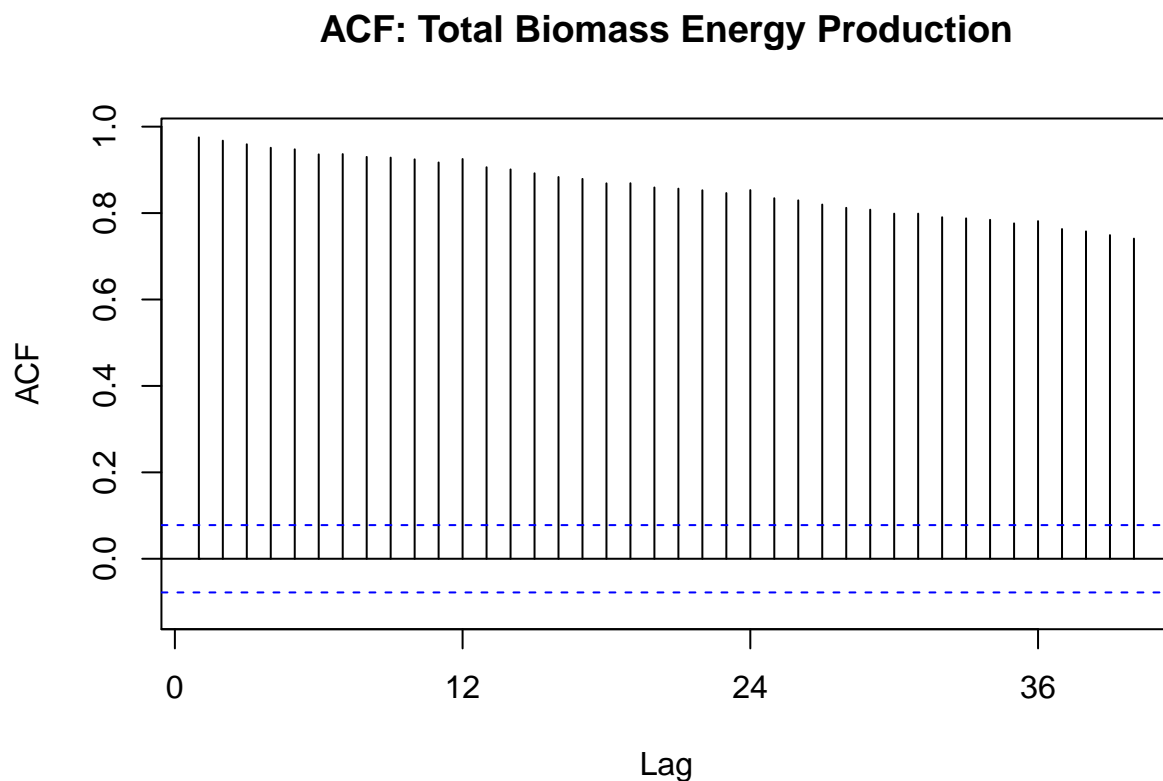
Overall, only biomass energy production and total renewable energy production are strongly and significantly correlated, while hydroelectric power consumption is not meaningfully correlated with the other two series.

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?

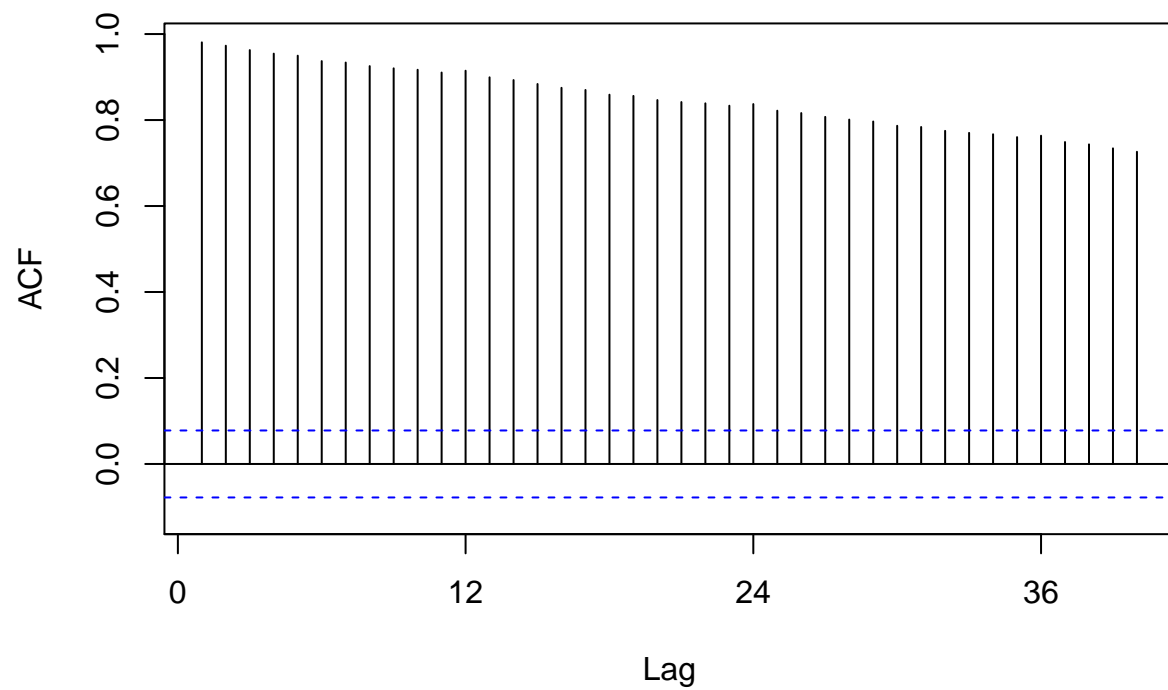
```
library(forecast)

# ACF: Total Biomass Energy Production
Acf(q1_ts[, "Total Biomass Energy Production"], lag.max = 40,
    main = "ACF: Total Biomass Energy Production")
```

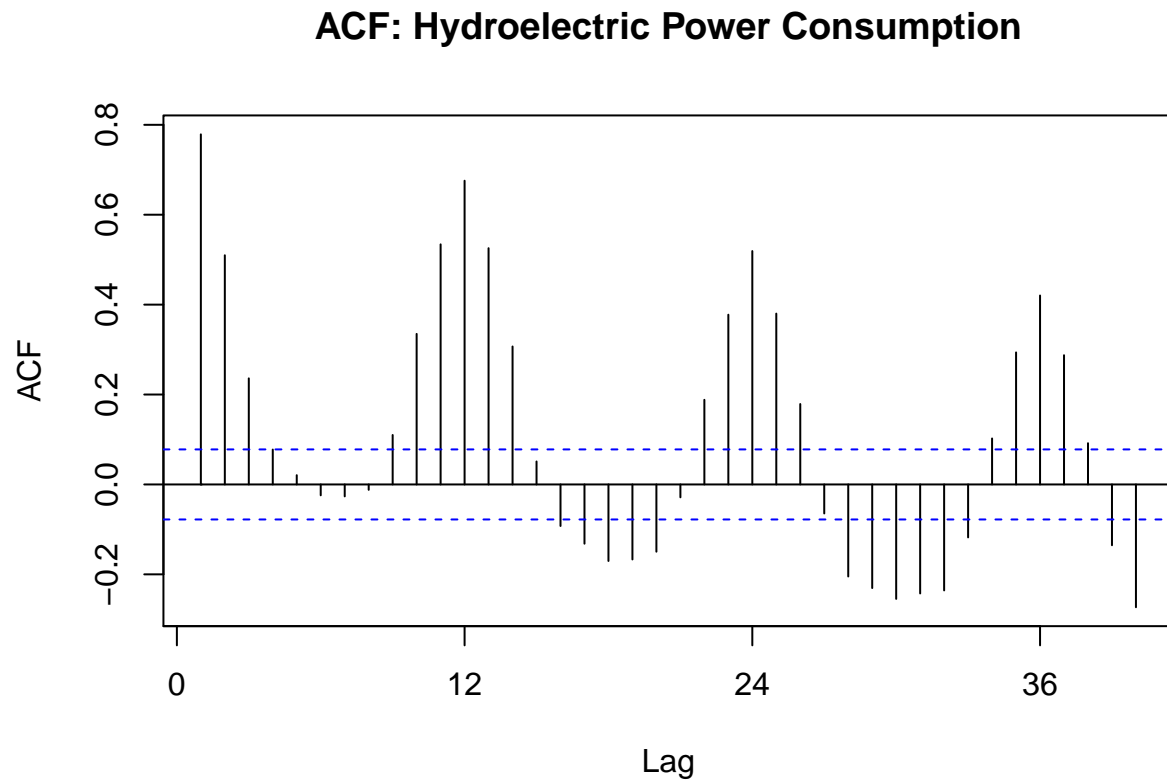


```
# ACF: Total Renewable Energy Production
Acf(q1_ts[, "Total Renewable Energy Production"], lag.max = 40,
    main = "ACF: Total Renewable Energy Production")
```

ACF: Total Renewable Energy Production



```
# ACF: Hydroelectric Power Consumption
Acf(q1_ts[, "Hydroelectric Power Consumption"], lag.max = 40,
    main = "ACF: Hydroelectric Power Consumption")
```

The three time series do not exhibit the same autocorrelation behavior.

Total Biomass Energy Production and Total Renewable Energy Production show very strong and slowly decaying positive autocorrelations across many lags, indicating strong persistence and trend-dominated, non-stationary behavior.

In contrast, Hydroelectric Power Consumption displays an oscillating autocorrelation pattern with alternating positive and negative values and clear peaks at seasonal lags (around 12, 24, and 36), suggesting strong seasonal dynamics rather than a long-term trend.

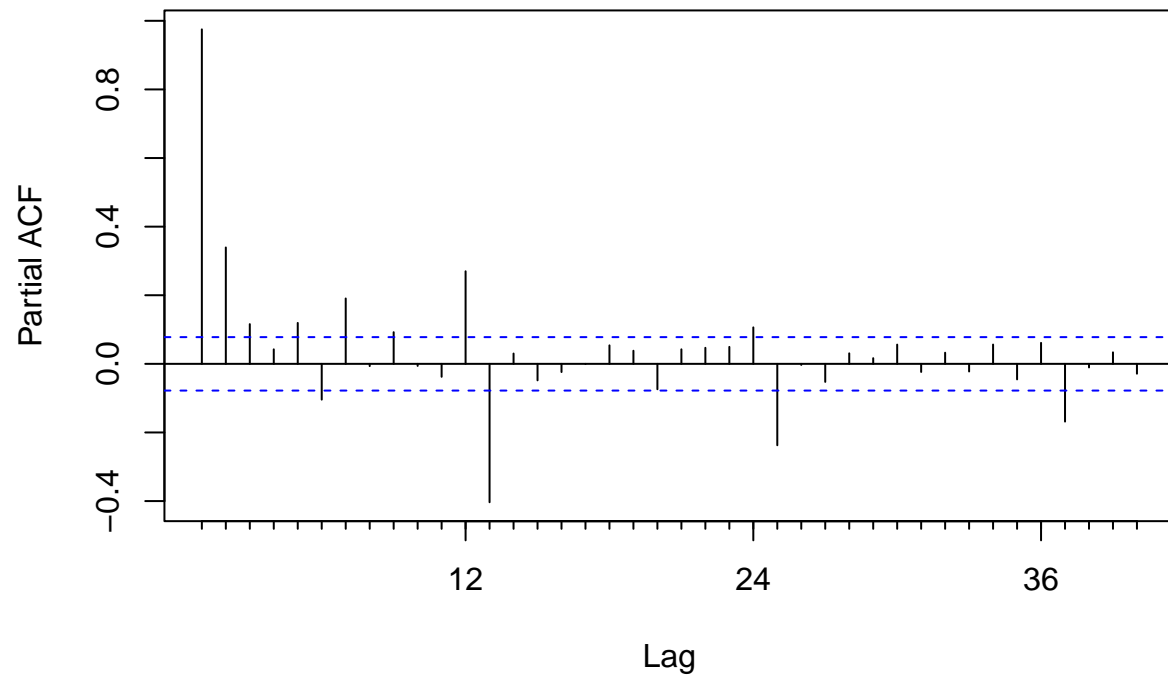
Question 7

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

```
library(forecast)

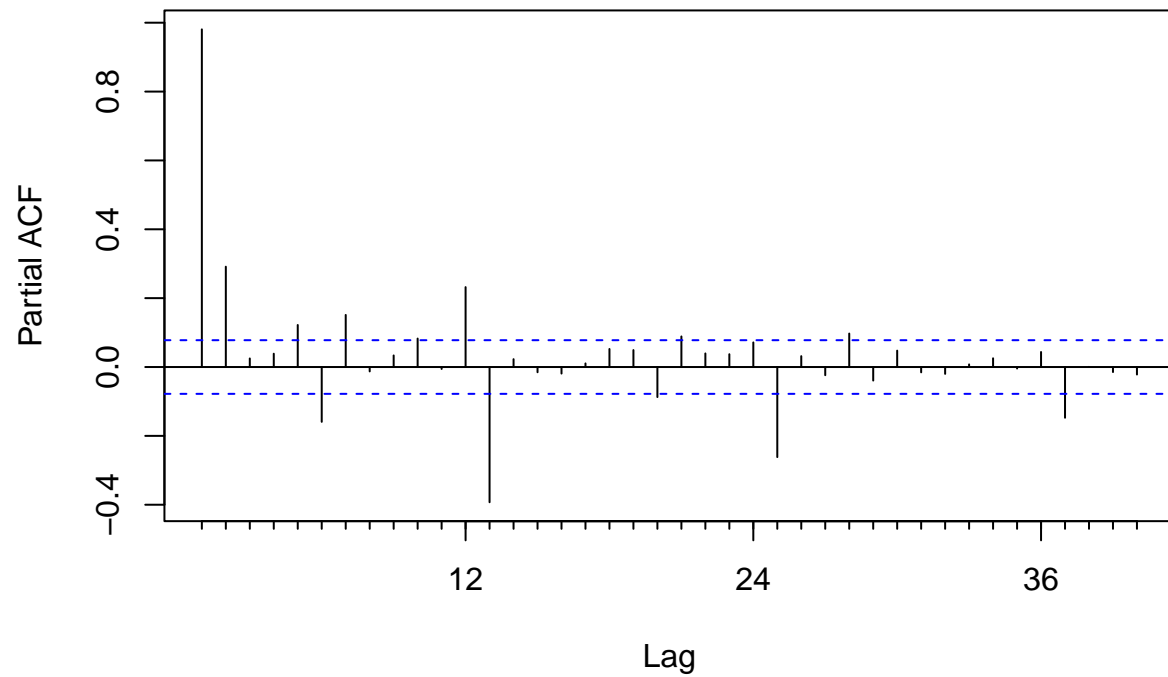
Pacf(q1_ts[, "Total Biomass Energy Production"], lag.max = 40,
     main = "PACF: Total Biomass Energy Production (Lag 1-40)")
```

PACF: Total Biomass Energy Production (Lag 1–40)



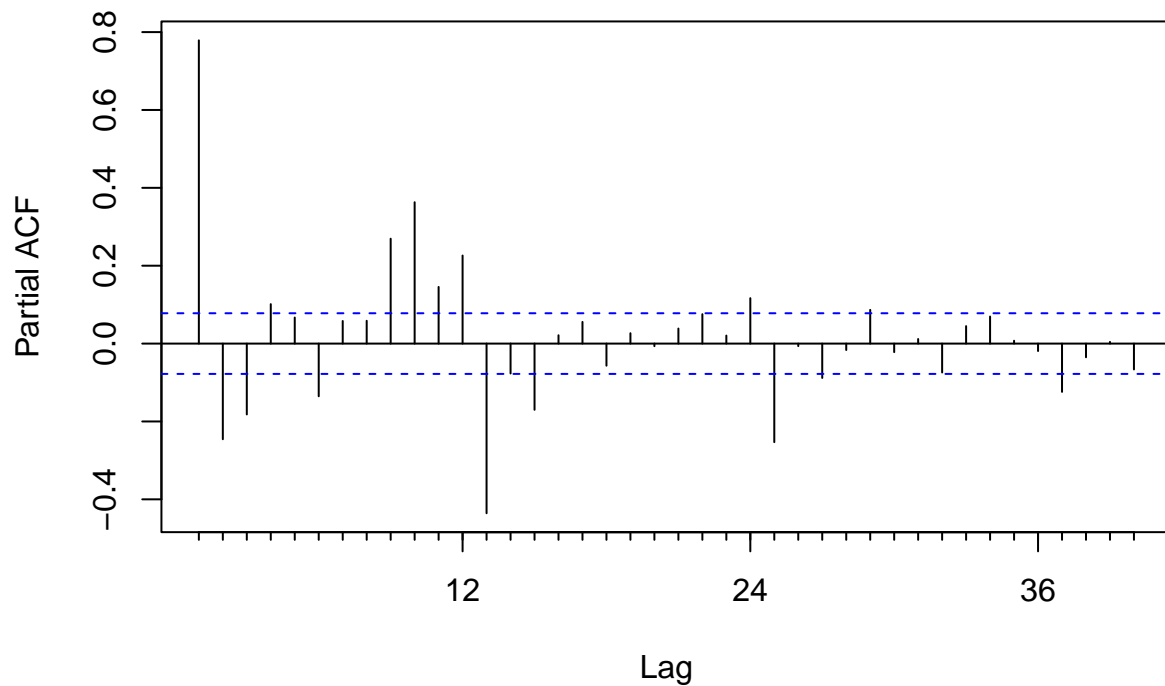
```
Pacf(q1_ts[, "Total Renewable Energy Production"], lag.max = 40,  
     main = "PACF: Total Renewable Energy Production (Lag 1-40)")
```

PACF: Total Renewable Energy Production (Lag 1–40)



```
Pacf(q1_ts[, "Hydroelectric Power Consumption"], lag.max = 40,  
     main = "PACF: Hydroelectric Power Consumption (Lag 1-40)")
```

PACF: Hydroelectric Power Consumption (Lag 1–40)



Compared to the ACF plots in Question 6, the PACF plots show a much clearer structure. While the ACF decays slowly over many lags due to strong persistence and trend, the PACF exhibits a dominant spike at lag 1 and significant seasonal spikes around lag 12. This indicates that most of the serial dependence can be explained by short-term (AR(1)) and seasonal effects, rather than long-range direct dependence.

The three series do not exhibit exactly the same behavior. Total Biomass Energy Production and Total Renewable Energy Production show very similar PACF patterns, characterized by strong first-order dependence and seasonal effects. In contrast, Hydroelectric Power Consumption displays stronger seasonal dependence and weaker long-term persistence, reflecting its sensitivity to hydrological cycles rather than long-term growth trends.