

ENV 790.30 - Time Series Analysis for Energy Data | Spring 2021

Assignment 4 - Due date 02/25/21

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Directions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github. And to do so you will need to fork our repository and link it to your RStudio.

Once you have the project open the first thing you will do is change “Student Name” on line 3 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. Rename the pdf file such that it includes your first and last name (e.g., “LuanaLima_TSA_A04_Sp21.Rmd”). Submit this pdf using Sakai.

Questions

Consider the same data you used for A2 from the spreadsheet “Table_10.1_Renewable_Energy_Production_and_Consumption”. The data comes from the US Energy Information and Administration and corresponds to the January 2021 Monthly Energy Review.

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

```
#Load/install required package here  
library(forecast)
```

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

```
library(tseries)  
library(Kendall)  
library(readxl)  
library(readr)  
library(lubridate)
```

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

```
library(outliers)  
library(tidyverse)
```

```
## -- Attaching packages ----- tidyverse 1.3.0 --
## v ggplot2 3.3.3      v dplyr 1.0.3
## v tibble 3.0.5       v stringr 1.4.0
## v tidyr 1.1.2        v forcats 0.5.0
## v purrr 0.3.4

## -- Conflicts ----- tidyverse_conflicts() --
## x lubridate::as.difftime() masks base::as.difftime()
## x lubridate::date() masks base::date()
## x dplyr::filter() masks stats::filter()
## x lubridate::intersect() masks base::intersect()
## x dplyr::lag() masks stats::lag()
## x lubridate::setdiff() masks base::setdiff()
## x lubridate::union() masks base::union()
```

Stochastic Trend and Stationarity Test

For this part you will once again 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 and the Date column. Don't forget to format the date object.

```
Renewable.df <- read.csv("/Users/benculberson/Documents/Duke /Spring 2021/Time Series Analysis/ENV790_30/
Renewable_data.csv")
Renewable_date<-Renewable.df[12:585,1]
Renewable_altered.df<-Renewable.df[12:585,4:6]

colnames(Renewable_altered.df)=c("Total Biomass Energy Production", "Total Renewable Energy Production",
Renewable_altered.df$Date<-Renewable_date

Renewable_altered.df$`Total Biomass Energy Production`<-as.numeric(Renewable_altered.df$`Total Biomass Energy Production`)

## Warning: NAs introduced by coercion
Renewable_altered.df$`Total Renewable Energy Production`<-as.numeric(Renewable_altered.df$`Total Renewable Energy Production`)

## Warning: NAs introduced by coercion
Renewable_altered.df$`Hydroelectric Power Consumption`<-as.numeric(Renewable_altered.df$`Hydroelectric Power Consumption`)

## Warning: NAs introduced by coercion
#using package lubridate
my_date <- paste(Renewable_altered.df[,4])
my_date <- ym(my_date) #function my from package lubridate, my is short for month, year

## Warning: 2 failed to parse.
head(my_date)

## [1] NA NA "1973-01-01" "1973-02-01" "1973-03-01"
## [6] "1973-04-01"

#add that to inflow_data and store in a new data frame
Renewable_altered.df <- cbind(my_date, Renewable_altered.df[,1:3])
```

```
head(Renewable_altered.df)
```

```
##      my_date Total Biomass Energy Production Total Renewable Energy Production
## 12      <NA>                        NA                        NA
## 13      <NA>                        NA                        NA
## 14 1973-01-01                    129.787                    403.981
## 15 1973-02-01                    117.338                    360.900
## 16 1973-03-01                    129.938                    400.161
## 17 1973-04-01                    125.636                    380.470
##      Hydroelectric Power Consumption
## 12                        NA
## 13                        NA
## 14                    272.703
## 15                    242.199
## 16                    268.810
## 17                    253.185
```

```
ncolumns <- ncol(Renewable_altered.df)
```

```
nmonths <- nrow(Renewable_altered.df)
```

```
Renewable_ts.df<-ts(Renewable_altered.df[,2:4], start=c(1973, 1), end=c(2020,10), frequency=12)
Renewable_ts.df<-cbind(my_date, Renewable_ts.df)
```

Q1

Now let's try to difference these three series using function `diff()`. Start with the original data from part (b). Try differencing first at lag 1 and plot the remaining series. Did anything change? Do the series still seem to have trend?

```
Renewable_ts.df
```

```
##      my_date Renewable_ts.df.Total Biomass Energy Production
## Jan 1973      NA                        NA
## Feb 1973      NA                        NA
## Mar 1973    1096                    129.787
## Apr 1973    1127                    117.338
## May 1973    1155                    129.938
## Jun 1973    1186                    125.636
## Jul 1973    1216                    129.834
## Aug 1973    1247                    125.611
## Sep 1973    1277                    129.787
## Oct 1973    1308                    129.918
## Nov 1973    1339                    125.782
## Dec 1973    1369                    129.970
## Jan 1974    1400                    125.643
## Feb 1974    1430                    129.824
## Mar 1974    1461                    130.807
## Apr 1974    1492                    118.091
## May 1974    1520                    130.727
## Jun 1974    1551                    126.583
## Jul 1974    1581                    130.789
## Aug 1974    1612                    126.611
## Sep 1974    1642                    130.756
## Oct 1974    1673                    130.763
```

## Nov 1974	1704	126.637
## Dec 1974	1734	130.718
## Jan 1975	1765	126.506
## Feb 1975	1795	130.674
## Mar 1975	1826	127.269
## Apr 1975	1857	114.942
## May 1975	1885	127.251
## Jun 1975	1916	123.139
## Jul 1975	1946	127.303
## Aug 1975	1977	123.241
## Sep 1975	2007	127.288
## Oct 1975	2038	127.321
## Nov 1975	2069	123.210
## Dec 1975	2099	127.312
## Jan 1976	2130	123.180
## Feb 1976	2160	127.277
## Mar 1976	2191	145.049
## Apr 1976	2222	135.695
## May 1976	2251	145.051
## Jun 1976	2282	140.363
## Jul 1976	2312	145.047
## Aug 1976	2343	140.405
## Sep 1976	2373	145.088
## Oct 1976	2404	145.110
## Nov 1976	2435	140.436
## Dec 1976	2465	145.114
## Jan 1977	2496	140.651
## Feb 1977	2526	145.364
## Mar 1977	2557	156.220
## Apr 1977	2588	141.176
## May 1977	2616	156.217
## Jun 1977	2647	151.161
## Jul 1977	2677	156.186
## Aug 1977	2708	151.153
## Sep 1977	2738	155.920
## Oct 1977	2769	156.081
## Nov 1977	2800	151.110
## Dec 1977	2830	156.172
## Jan 1978	2861	151.000
## Feb 1978	2891	155.935
## Mar 1978	2922	173.128
## Apr 1978	2953	156.387
## May 1978	2981	173.136
## Jun 1978	3012	167.349
## Jul 1978	3042	172.923
## Aug 1978	3073	167.340
## Sep 1978	3103	172.912
## Oct 1978	3134	173.189
## Nov 1978	3165	167.455
## Dec 1978	3195	173.169
## Jan 1979	3226	167.557
## Feb 1979	3256	173.060
## Mar 1979	3287	182.600
## Apr 1979	3318	165.096

## May 1979	3346	182.881
## Jun 1979	3377	176.844
## Jul 1979	3407	182.782
## Aug 1979	3438	176.833
## Sep 1979	3468	182.700
## Oct 1979	3499	182.808
## Nov 1979	3530	176.891
## Dec 1979	3560	182.752
## Jan 1980	3591	176.949
## Feb 1980	3621	182.770
## Mar 1980	3652	209.829
## Apr 1980	3683	196.310
## May 1980	3712	209.727
## Jun 1980	3743	202.894
## Jul 1980	3773	209.548
## Aug 1980	3804	202.723
## Sep 1980	3834	209.554
## Oct 1980	3865	209.675
## Nov 1980	3896	202.905
## Dec 1980	3926	209.717
## Jan 1981	3957	202.945
## Feb 1981	3987	209.671
## Mar 1981	4018	220.544
## Apr 1981	4049	199.248
## May 1981	4077	220.595
## Jun 1981	4108	213.467
## Jul 1981	4138	220.433
## Aug 1981	4169	213.237
## Sep 1981	4199	220.392
## Oct 1981	4230	220.428
## Nov 1981	4261	213.480
## Dec 1981	4291	220.581
## Jan 1982	4322	213.437
## Feb 1982	4352	220.440
## Mar 1982	4383	226.251
## Apr 1982	4414	204.375
## May 1982	4442	226.157
## Jun 1982	4473	218.821
## Jul 1982	4503	226.135
## Aug 1982	4534	218.866
## Sep 1982	4564	226.202
## Oct 1982	4595	226.168
## Nov 1982	4626	218.947
## Dec 1982	4656	226.373
## Jan 1983	4687	218.948
## Feb 1983	4717	226.210
## Mar 1983	4748	246.575
## Apr 1983	4779	222.738
## May 1983	4807	246.610
## Jun 1983	4838	238.625
## Jul 1983	4868	246.647
## Aug 1983	4899	238.736
## Sep 1983	4929	246.651
## Oct 1983	4960	246.695

## Nov 1983	4991	238.755
## Dec 1983	5021	246.732
## Jan 1984	5052	238.780
## Feb 1984	5082	246.871
## Mar 1984	5113	251.483
## Apr 1984	5144	235.169
## May 1984	5173	251.529
## Jun 1984	5204	243.277
## Jul 1984	5234	251.408
## Aug 1984	5265	243.303
## Sep 1984	5295	251.632
## Oct 1984	5326	251.638
## Nov 1984	5357	243.596
## Dec 1984	5387	251.974
## Jan 1985	5418	244.068
## Feb 1985	5448	252.042
## Mar 1985	5479	256.315
## Apr 1985	5510	231.512
## May 1985	5538	256.336
## Jun 1985	5569	247.599
## Jul 1985	5599	255.881
## Aug 1985	5630	247.643
## Sep 1985	5660	256.159
## Oct 1985	5691	256.301
## Nov 1985	5722	247.997
## Dec 1985	5752	256.175
## Jan 1986	5783	248.070
## Feb 1986	5813	256.246
## Mar 1986	5844	249.178
## Apr 1986	5875	224.922
## May 1986	5903	248.837
## Jun 1986	5934	240.788
## Jul 1986	5964	248.822
## Aug 1986	5995	240.837
## Sep 1986	6025	249.011
## Oct 1986	6056	249.176
## Nov 1986	6087	241.074
## Dec 1986	6117	248.974
## Jan 1987	6148	241.122
## Feb 1987	6178	249.352
## Mar 1987	6209	244.137
## Apr 1987	6240	220.511
## May 1987	6268	244.157
## Jun 1987	6299	236.139
## Jul 1987	6329	244.007
## Aug 1987	6360	236.522
## Sep 1987	6390	244.359
## Oct 1987	6421	244.396
## Nov 1987	6452	236.298
## Dec 1987	6482	244.059
## Jan 1988	6513	236.197
## Feb 1988	6543	244.104
## Mar 1988	6574	255.331
## Apr 1988	6605	238.853

## May 1988	6634	255.385
## Jun 1988	6665	247.241
## Jul 1988	6695	255.188
## Aug 1988	6726	247.340
## Sep 1988	6756	255.582
## Oct 1988	6787	255.815
## Nov 1988	6818	247.357
## Dec 1988	6848	255.517
## Jan 1989	6879	247.096
## Feb 1989	6909	255.345
## Mar 1989	6940	266.572
## Apr 1989	6971	243.927
## May 1989	6999	268.315
## Jun 1989	7030	251.946
## Jul 1989	7060	241.235
## Aug 1989	7091	248.447
## Sep 1989	7121	261.318
## Oct 1989	7152	276.985
## Nov 1989	7183	264.811
## Dec 1989	7213	276.462
## Jan 1990	7244	276.819
## Feb 1990	7274	282.520
## Mar 1990	7305	236.692
## Apr 1990	7336	226.266
## May 1990	7364	244.248
## Jun 1990	7395	232.640
## Jul 1990	7425	210.108
## Aug 1990	7456	178.544
## Sep 1990	7486	219.713
## Oct 1990	7517	245.632
## Nov 1990	7548	239.932
## Dec 1990	7578	235.437
## Jan 1991	7609	220.256
## Feb 1991	7639	245.644
## Mar 1991	7670	269.531
## Apr 1991	7701	204.535
## May 1991	7729	214.374
## Jun 1991	7760	190.452
## Jul 1991	7790	206.579
## Aug 1991	7821	209.721
## Sep 1991	7851	210.055
## Oct 1991	7882	250.834
## Nov 1991	7913	267.735
## Dec 1991	7943	249.408
## Jan 1992	7974	241.541
## Feb 1992	8004	267.033
## Mar 1992	8035	279.197
## Apr 1992	8066	230.468
## May 1992	8095	221.177
## Jun 1992	8126	210.172
## Jul 1992	8156	190.537
## Aug 1992	8187	230.985
## Sep 1992	8217	250.150
## Oct 1992	8248	269.662

## Nov 1992	8279	251.511
## Dec 1992	8309	269.545
## Jan 1993	8340	264.383
## Feb 1993	8370	263.891
## Mar 1993	8401	274.257
## Apr 1993	8432	240.964
## May 1993	8460	263.204
## Jun 1993	8491	226.859
## Jul 1993	8521	196.012
## Aug 1993	8552	197.445
## Sep 1993	8582	212.707
## Oct 1993	8613	262.322
## Nov 1993	8644	250.551
## Dec 1993	8674	257.383
## Jan 1994	8705	262.183
## Feb 1994	8735	264.559
## Mar 1994	8766	306.708
## Apr 1994	8797	244.594
## May 1994	8825	261.461
## Jun 1994	8856	236.035
## Jul 1994	8886	202.480
## Aug 1994	8917	215.744
## Sep 1994	8947	274.451
## Oct 1994	8978	251.577
## Nov 1994	9009	238.967
## Dec 1994	9039	271.599
## Jan 1995	9070	261.436
## Feb 1995	9100	262.482
## Mar 1995	9131	243.462
## Apr 1995	9162	206.657
## May 1995	9190	239.820
## Jun 1995	9221	267.571
## Jul 1995	9251	227.439
## Aug 1995	9282	226.934
## Sep 1995	9312	294.251
## Oct 1995	9343	301.628
## Nov 1995	9374	268.791
## Dec 1995	9404	292.175
## Jan 1996	9435	267.659
## Feb 1996	9465	262.694
## Mar 1996	9496	272.584
## Apr 1996	9527	226.038
## May 1996	9556	259.039
## Jun 1996	9587	205.729
## Jul 1996	9617	231.211
## Aug 1996	9648	254.182
## Sep 1996	9678	281.656
## Oct 1996	9709	294.581
## Nov 1996	9740	259.345
## Dec 1996	9770	310.461
## Jan 1997	9801	295.562
## Feb 1997	9831	264.912
## Mar 1997	9862	275.641
## Apr 1997	9893	226.521

## May 1997	9921	251.136
## Jun 1997	9952	252.010
## Jul 1997	9982	268.515
## Aug 1997	10013	231.690
## Sep 1997	10043	259.985
## Oct 1997	10074	264.422
## Nov 1997	10105	250.744
## Dec 1997	10135	305.656
## Jan 1998	10166	264.591
## Feb 1998	10196	256.998
## Mar 1998	10227	278.211
## Apr 1998	10258	212.209
## May 1998	10286	240.963
## Jun 1998	10317	240.612
## Jul 1998	10347	250.239
## Aug 1998	10378	186.089
## Sep 1998	10408	246.326
## Oct 1998	10439	254.237
## Nov 1998	10470	248.270
## Dec 1998	10500	267.922
## Jan 1999	10531	230.488
## Feb 1999	10561	273.362
## Mar 1999	10592	272.260
## Apr 1999	10623	220.539
## May 1999	10651	212.177
## Jun 1999	10682	249.920
## Jul 1999	10712	289.264
## Aug 1999	10743	236.090
## Sep 1999	10773	264.292
## Oct 1999	10804	258.854
## Nov 1999	10835	244.140
## Dec 1999	10865	228.256
## Jan 2000	10896	254.125
## Feb 2000	10926	235.215
## Mar 2000	10957	222.067
## Apr 2000	10988	246.169
## May 2000	11017	263.209
## Jun 2000	11048	254.609
## Jul 2000	11078	254.678
## Aug 2000	11109	227.712
## Sep 2000	11139	255.348
## Oct 2000	11170	254.942
## Nov 2000	11201	240.331
## Dec 2000	11231	270.472
## Jan 2001	11262	261.335
## Feb 2001	11292	254.788
## Mar 2001	11323	228.434
## Apr 2001	11354	202.849
## May 2001	11382	219.649
## Jun 2001	11413	213.628
## Jul 2001	11443	211.506
## Aug 2001	11474	213.950
## Sep 2001	11504	221.842
## Oct 2001	11535	225.897

## Nov 2001	11566	214.229
## Dec 2001	11596	227.319
## Jan 2002	11627	219.773
## Feb 2002	11657	225.088
## Mar 2002	11688	228.396
## Apr 2002	11719	198.932
## May 2002	11747	217.568
## Jun 2002	11778	212.852
## Jul 2002	11808	225.155
## Aug 2002	11839	215.107
## Sep 2002	11869	235.713
## Oct 2002	11900	224.400
## Nov 2002	11931	230.855
## Dec 2002	11961	243.767
## Jan 2003	11992	230.328
## Feb 2003	12022	242.334
## Mar 2003	12053	237.044
## Apr 2003	12084	212.693
## May 2003	12112	233.288
## Jun 2003	12143	228.516
## Jul 2003	12173	229.756
## Aug 2003	12204	228.254
## Sep 2003	12234	242.533
## Oct 2003	12265	239.928
## Nov 2003	12296	230.968
## Dec 2003	12326	236.938
## Jan 2004	12357	233.698
## Feb 2004	12387	251.160
## Mar 2004	12418	255.574
## Apr 2004	12449	236.689
## May 2004	12478	248.532
## Jun 2004	12509	247.253
## Jul 2004	12539	244.383
## Aug 2004	12570	244.075
## Sep 2004	12600	257.042
## Oct 2004	12631	254.446
## Nov 2004	12662	243.019
## Dec 2004	12692	253.520
## Jan 2005	12723	247.286
## Feb 2005	12753	264.199
## Mar 2005	12784	264.707
## Apr 2005	12815	247.271
## May 2005	12843	260.043
## Jun 2005	12874	246.929
## Jul 2005	12904	255.790
## Aug 2005	12935	252.466
## Sep 2005	12965	266.332
## Oct 2005	12996	266.097
## Nov 2005	13027	255.348
## Dec 2005	13057	261.121
## Jan 2006	13088	256.532
## Feb 2006	13118	268.550
## Mar 2006	13149	276.647
## Apr 2006	13180	247.274

## May 2006	13208	265.069
## Jun 2006	13239	250.384
## Jul 2006	13269	261.125
## Aug 2006	13300	261.960
## Sep 2006	13330	274.809
## Oct 2006	13361	277.063
## Nov 2006	13392	267.952
## Dec 2006	13422	275.120
## Jan 2007	13453	270.475
## Feb 2007	13483	283.636
## Mar 2007	13514	290.845
## Apr 2007	13545	261.666
## May 2007	13573	285.146
## Jun 2007	13604	278.386
## Jul 2007	13634	286.010
## Aug 2007	13665	281.995
## Sep 2007	13695	295.653
## Oct 2007	13726	295.523
## Nov 2007	13757	287.603
## Dec 2007	13787	299.416
## Jan 2008	13818	297.828
## Feb 2008	13848	312.007
## Mar 2008	13879	331.138
## Apr 2008	13910	300.535
## May 2008	13939	321.487
## Jun 2008	13970	314.073
## Jul 2008	14000	324.185
## Aug 2008	14031	313.335
## Sep 2008	14061	330.507
## Oct 2008	14092	333.607
## Nov 2008	14123	318.840
## Dec 2008	14153	330.125
## Jan 2009	14184	327.317
## Feb 2009	14214	323.102
## Mar 2009	14245	318.353
## Apr 2009	14276	294.389
## May 2009	14304	319.356
## Jun 2009	14335	303.489
## Jul 2009	14365	319.032
## Aug 2009	14396	321.739
## Sep 2009	14426	343.841
## Oct 2009	14457	348.551
## Nov 2009	14488	332.374
## Dec 2009	14518	346.472
## Jan 2010	14549	348.333
## Feb 2010	14579	360.689
## Mar 2010	14610	377.071
## Apr 2010	14641	347.952
## May 2010	14669	384.094
## Jun 2010	14700	368.922
## Jul 2010	14730	376.012
## Aug 2010	14761	372.328
## Sep 2010	14791	385.443
## Oct 2010	14822	389.064

## Nov 2010	14853	377.355
## Dec 2010	14883	386.771
## Jan 2011	14914	386.602
## Feb 2011	14944	400.917
## Mar 2011	14975	400.130
## Apr 2011	15006	359.201
## May 2011	15034	394.547
## Jun 2011	15065	373.224
## Jul 2011	15095	384.288
## Aug 2011	15126	389.076
## Sep 2011	15156	398.608
## Oct 2011	15187	401.827
## Nov 2011	15218	386.447
## Dec 2011	15248	397.089
## Jan 2012	15279	400.207
## Feb 2012	15309	419.677
## Mar 2012	15340	398.833
## Apr 2012	15371	372.611
## May 2012	15400	387.374
## Jun 2012	15431	368.516
## Jul 2012	15461	386.825
## Aug 2012	15492	377.323
## Sep 2012	15522	379.041
## Oct 2012	15553	385.552
## Nov 2012	15584	366.465
## Dec 2012	15614	373.472
## Jan 2013	15645	368.172
## Feb 2013	15675	382.521
## Mar 2013	15706	391.206
## Apr 2013	15737	353.773
## May 2013	15765	397.238
## Jun 2013	15796	385.899
## Jul 2013	15826	404.043
## Aug 2013	15857	400.577
## Sep 2013	15887	417.027
## Oct 2013	15918	411.328
## Nov 2013	15949	392.654
## Dec 2013	15979	414.632
## Jan 2014	16010	413.361
## Feb 2014	16040	433.893
## Mar 2014	16071	418.976
## Apr 2014	16102	379.971
## May 2014	16130	420.974
## Jun 2014	16161	406.459
## Jul 2014	16191	417.246
## Aug 2014	16222	420.030
## Sep 2014	16252	434.940
## Oct 2014	16283	430.195
## Nov 2014	16314	409.688
## Dec 2014	16344	422.001
## Jan 2015	16375	416.969
## Feb 2015	16405	442.916
## Mar 2015	16436	423.312
## Apr 2015	16467	382.846

## May 2015	16495	415.134
## Jun 2015	16526	401.278
## Jul 2015	16556	418.828
## Aug 2015	16587	416.506
## Sep 2015	16617	431.961
## Oct 2015	16648	428.805
## Nov 2015	16679	407.021
## Dec 2015	16709	415.534
## Jan 2016	16740	416.219
## Feb 2016	16770	434.134
## Mar 2016	16801	424.372
## Apr 2016	16832	403.858
## May 2016	16861	425.011
## Jun 2016	16892	395.813
## Jul 2016	16922	419.210
## Aug 2016	16953	420.069
## Sep 2016	16983	430.196
## Oct 2016	17014	436.909
## Nov 2016	17045	412.641
## Dec 2016	17075	420.363
## Jan 2017	17106	423.015
## Feb 2017	17136	463.404
## Mar 2017	17167	435.062
## Apr 2017	17198	391.897
## May 2017	17226	433.480
## Jun 2017	17257	403.555
## Jul 2017	17287	421.799
## Aug 2017	17318	419.407
## Sep 2017	17348	430.602
## Oct 2017	17379	440.802
## Nov 2017	17410	411.947
## Dec 2017	17440	428.203
## Jan 2018	17471	433.495
## Feb 2018	17501	448.499
## Mar 2018	17532	445.080
## Apr 2018	17563	407.868
## May 2018	17591	443.437
## Jun 2018	17622	419.576
## Jul 2018	17652	439.621
## Aug 2018	17683	434.512
## Sep 2018	17713	451.901
## Oct 2018	17744	454.811
## Nov 2018	17775	420.524
## Dec 2018	17805	441.384
## Jan 2019	17836	432.494
## Feb 2019	17866	447.277
## Mar 2019	17897	436.639
## Apr 2019	17928	396.188
## May 2019	17956	425.258
## Jun 2019	17987	414.210
## Jul 2019	18017	430.776
## Aug 2019	18048	424.141
## Sep 2019	18078	439.406
## Oct 2019	18109	439.032

## Nov 2019	18140	407.577
## Dec 2019	18170	422.058
## Jan 2020	18201	421.487
## Feb 2020	18231	443.469
## Mar 2020	18262	435.632
## Apr 2020	18293	406.933
## May 2020	18322	413.749
## Jun 2020	18353	331.662
## Jul 2020	18383	363.894
## Aug 2020	18414	377.859
## Sep 2020	18444	401.014
## Oct 2020	18475	402.983
##	Renewable_ts.df.Total Renewable Energy Production	
## Jan 1973		NA
## Feb 1973		NA
## Mar 1973		403.981
## Apr 1973		360.900
## May 1973		400.161
## Jun 1973		380.470
## Jul 1973		392.141
## Aug 1973		377.232
## Sep 1973		367.325
## Oct 1973		353.757
## Nov 1973		307.006
## Dec 1973		323.453
## Jan 1974		337.817
## Feb 1974		406.694
## Mar 1974		437.467
## Apr 1974		399.942
## May 1974		423.474
## Jun 1974		422.323
## Jul 1974		427.657
## Aug 1974		409.281
## Sep 1974		409.719
## Oct 1974		386.101
## Nov 1974		353.910
## Dec 1974		343.703
## Jan 1975		351.633
## Feb 1975		376.642
## Mar 1975		392.756
## Apr 1975		368.278
## May 1975		423.490
## Jun 1975		405.368
## Jul 1975		421.283
## Aug 1975		411.622
## Sep 1975		398.459
## Oct 1975		368.230
## Nov 1975		341.957
## Dec 1975		368.786
## Jan 1976		383.196
## Feb 1976		403.696
## Mar 1976		421.775
## Apr 1976		396.173
## May 1976		427.044

## Jun 1976	396.931
## Jul 1976	415.728
## Aug 1976	411.555
## Sep 1976	421.425
## Oct 1976	398.129
## Nov 1976	356.984
## Dec 1976	369.186
## Jan 1977	351.386
## Feb 1977	360.834
## Mar 1977	378.521
## Apr 1977	304.328
## May 1977	368.966
## Jun 1977	351.301
## Jul 1977	356.923
## Aug 1977	336.485
## Sep 1977	336.903
## Oct 1977	335.881
## Nov 1977	328.075
## Dec 1977	341.368
## Jan 1978	370.168
## Feb 1978	400.048
## Mar 1978	438.983
## Apr 1978	391.866
## May 1978	433.459
## Jun 1978	434.379
## Jul 1978	475.883
## Aug 1978	432.628
## Sep 1978	431.461
## Oct 1978	408.417
## Nov 1978	392.287
## Dec 1978	379.436
## Jan 1979	379.078
## Feb 1979	407.564
## Mar 1979	447.796
## Apr 1979	390.487
## May 1979	457.799
## Jun 1979	445.932
## Jul 1979	489.080
## Aug 1979	441.683
## Sep 1979	424.513
## Oct 1979	409.210
## Nov 1979	378.903
## Dec 1979	397.602
## Jan 1980	414.740
## Feb 1980	425.109
## Mar 1980	478.943
## Apr 1980	424.298
## May 1980	469.134
## Jun 1980	477.356
## Jul 1980	517.456
## Aug 1980	497.768
## Sep 1980	471.331
## Oct 1980	429.358
## Nov 1980	401.712

## Dec 1980	402.564
## Jan 1981	409.876
## Feb 1981	448.546
## Mar 1981	462.381
## Apr 1981	427.043
## May 1981	443.808
## Jun 1981	438.020
## Jul 1981	480.423
## Aug 1981	496.995
## Sep 1981	491.304
## Oct 1981	454.028
## Nov 1981	407.220
## Dec 1981	416.966
## Jan 1982	418.476
## Feb 1982	477.024
## Mar 1982	514.440
## Apr 1982	489.624
## May 1982	544.724
## Jun 1982	517.128
## Jul 1982	525.795
## Aug 1982	518.974
## Sep 1982	519.267
## Oct 1982	483.203
## Nov 1982	433.748
## Dec 1982	439.874
## Jan 1983	469.930
## Feb 1983	522.930
## Mar 1983	562.279
## Apr 1983	523.276
## May 1983	572.853
## Jun 1983	561.458
## Jul 1983	581.741
## Aug 1983	569.493
## Sep 1983	550.993
## Oct 1983	528.288
## Nov 1983	476.173
## Dec 1983	474.251
## Jan 1984	507.035
## Feb 1984	587.773
## Mar 1984	570.081
## Apr 1984	535.239
## May 1984	579.040
## Jun 1984	566.019
## Jul 1984	593.504
## Aug 1984	553.321
## Sep 1984	547.618
## Oct 1984	524.053
## Nov 1984	470.910
## Dec 1984	479.620
## Jan 1985	486.110
## Feb 1985	532.347
## Mar 1985	555.205
## Apr 1985	511.838
## May 1985	525.002

## Jun 1985	512.937
## Jul 1985	542.968
## Aug 1985	507.330
## Sep 1985	489.577
## Oct 1985	475.912
## Nov 1985	454.274
## Dec 1985	475.406
## Jan 1986	499.606
## Feb 1986	533.960
## Mar 1986	486.064
## Apr 1986	479.122
## May 1986	558.538
## Jun 1986	539.897
## Jul 1986	545.072
## Aug 1986	527.412
## Sep 1986	513.292
## Oct 1986	482.847
## Nov 1986	472.114
## Dec 1986	482.113
## Jan 1987	492.321
## Feb 1987	532.346
## Mar 1987	521.265
## Apr 1987	452.878
## May 1987	498.782
## Jun 1987	477.656
## Jul 1987	509.032
## Aug 1987	466.873
## Sep 1987	467.691
## Oct 1987	448.986
## Nov 1987	437.201
## Dec 1987	442.655
## Jan 1988	423.208
## Feb 1988	475.580
## Mar 1988	495.132
## Apr 1988	446.663
## May 1988	469.098
## Jun 1988	455.993
## Jul 1988	486.212
## Aug 1988	453.891
## Sep 1988	442.602
## Oct 1988	437.214
## Nov 1988	426.312
## Dec 1988	422.602
## Jan 1989	448.903
## Feb 1989	472.132
## Mar 1989	509.147
## Apr 1989	461.435
## May 1989	532.715
## Jun 1989	530.097
## Jul 1989	562.701
## Aug 1989	546.136
## Sep 1989	525.098
## Oct 1989	513.154
## Nov 1989	487.949

## Dec 1989	511.060
## Jan 1990	521.324
## Feb 1990	533.841
## Mar 1990	511.272
## Apr 1990	508.361
## May 1990	567.935
## Jun 1990	530.430
## Jul 1990	525.673
## Aug 1990	503.363
## Sep 1990	499.495
## Oct 1990	497.455
## Nov 1990	447.349
## Dec 1990	460.199
## Jan 1991	459.565
## Feb 1991	528.927
## Mar 1991	569.477
## Apr 1991	465.116
## May 1991	519.109
## Jun 1991	492.912
## Jul 1991	540.589
## Aug 1991	513.638
## Sep 1991	499.535
## Oct 1991	512.229
## Nov 1991	491.722
## Dec 1991	467.135
## Jan 1992	467.743
## Feb 1992	528.581
## Mar 1992	535.605
## Apr 1992	449.194
## May 1992	482.783
## Jun 1992	445.954
## Jul 1992	455.238
## Aug 1992	497.881
## Sep 1992	486.977
## Oct 1992	491.440
## Nov 1992	458.262
## Dec 1992	472.679
## Jan 1993	498.631
## Feb 1993	545.912
## Mar 1993	564.643
## Apr 1993	477.337
## May 1993	543.313
## Jun 1993	527.476
## Jul 1993	537.102
## Aug 1993	506.688
## Sep 1993	491.684
## Oct 1993	502.290
## Nov 1993	461.700
## Dec 1993	468.760
## Jan 1994	482.149
## Feb 1994	518.766
## Mar 1994	546.055
## Apr 1994	474.597
## May 1994	530.492

## Jun 1994	515.824
## Jul 1994	494.547
## Aug 1994	497.431
## Sep 1994	538.297
## Oct 1994	484.333
## Nov 1994	433.624
## Dec 1994	476.301
## Jan 1995	482.931
## Feb 1995	512.711
## Mar 1995	516.505
## Apr 1995	478.622
## May 1995	550.407
## Jun 1995	536.526
## Jul 1995	533.621
## Aug 1995	560.146
## Sep 1995	601.277
## Oct 1995	582.282
## Nov 1995	499.493
## Dec 1995	558.496
## Jan 1996	554.287
## Feb 1996	585.644
## Mar 1996	606.652
## Apr 1996	571.304
## May 1996	627.925
## Jun 1996	556.068
## Jul 1996	594.906
## Aug 1996	607.617
## Sep 1996	610.096
## Oct 1996	594.878
## Nov 1996	513.259
## Dec 1996	568.744
## Jan 1997	561.307
## Feb 1997	598.134
## Mar 1997	629.798
## Apr 1997	563.285
## May 1997	628.987
## Jun 1997	603.776
## Jul 1997	642.247
## Aug 1997	607.803
## Sep 1997	611.214
## Oct 1997	566.984
## Nov 1997	513.212
## Dec 1997	581.272
## Jan 1998	526.466
## Feb 1998	541.767
## Mar 1998	591.525
## Apr 1998	534.593
## May 1998	585.345
## Jun 1998	550.085
## Jul 1998	606.593
## Aug 1998	538.492
## Sep 1998	565.999
## Oct 1998	537.288
## Nov 1998	487.111

## Dec 1998	485.978
## Jan 1999	456.086
## Feb 1999	553.640
## Mar 1999	596.138
## Apr 1999	533.206
## May 1999	564.564
## Jun 1999	551.655
## Jul 1999	610.254
## Aug 1999	571.951
## Sep 1999	593.682
## Oct 1999	547.076
## Nov 1999	482.163
## Dec 1999	456.717
## Jan 2000	492.906
## Feb 2000	515.277
## Mar 2000	505.150
## Apr 2000	499.959
## May 2000	558.005
## Jun 2000	568.524
## Jul 2000	558.724
## Aug 2000	509.114
## Sep 2000	526.262
## Oct 2000	503.686
## Nov 2000	443.376
## Dec 2000	468.215
## Jan 2001	482.866
## Feb 2001	477.785
## Mar 2001	444.970
## Apr 2001	404.069
## May 2001	455.780
## Jun 2001	425.366
## Jul 2001	435.516
## Aug 2001	454.616
## Sep 2001	436.066
## Oct 2001	447.902
## Nov 2001	396.469
## Dec 2001	409.918
## Jan 2002	401.771
## Feb 2002	449.328
## Mar 2002	476.543
## Apr 2002	428.357
## May 2002	459.464
## Jun 2002	488.511
## Jul 2002	527.649
## Aug 2002	533.572
## Sep 2002	525.246
## Oct 2002	469.661
## Nov 2002	431.895
## Dec 2002	445.453
## Jan 2003	455.854
## Feb 2003	488.697
## Mar 2003	470.089
## Apr 2003	437.335
## May 2003	508.207

## Jun 2003	509.640
## Jul 2003	557.612
## Aug 2003	549.082
## Sep 2003	524.613
## Oct 2003	501.519
## Nov 2003	447.111
## Dec 2003	451.922
## Jan 2004	460.811
## Feb 2004	524.525
## Mar 2004	514.255
## Apr 2004	474.095
## May 2004	510.691
## Jun 2004	488.747
## Jul 2004	522.597
## Aug 2004	531.784
## Sep 2004	523.858
## Oct 2004	502.480
## Nov 2004	479.391
## Dec 2004	472.887
## Jan 2005	484.745
## Feb 2005	557.141
## Mar 2005	537.035
## Apr 2005	489.393
## May 2005	524.494
## Jun 2005	514.339
## Jul 2005	567.464
## Aug 2005	559.554
## Sep 2005	561.835
## Oct 2005	514.654
## Nov 2005	464.168
## Dec 2005	475.814
## Jan 2006	484.901
## Feb 2006	527.161
## Mar 2006	590.884
## Apr 2006	529.231
## May 2006	553.158
## Jun 2006	577.819
## Jul 2006	611.342
## Aug 2006	598.581
## Sep 2006	568.553
## Oct 2006	531.447
## Nov 2006	478.075
## Dec 2006	489.353
## Jan 2007	515.797
## Feb 2007	542.004
## Mar 2007	592.160
## Apr 2007	488.001
## May 2007	574.760
## Jun 2007	566.514
## Jul 2007	594.208
## Aug 2007	555.751
## Sep 2007	562.032
## Oct 2007	542.044
## Nov 2007	483.318

## Dec 2007	500.596
## Jan 2008	503.177
## Feb 2008	547.807
## Mar 2008	597.548
## Apr 2008	542.194
## May 2008	604.394
## Jun 2008	607.199
## Jul 2008	668.768
## Aug 2008	675.460
## Sep 2008	646.244
## Oct 2008	599.201
## Nov 2008	531.925
## Dec 2008	552.128
## Jan 2009	551.737
## Feb 2009	614.750
## Mar 2009	626.672
## Apr 2009	545.223
## May 2009	625.284
## Jun 2009	651.263
## Jul 2009	693.147
## Aug 2009	685.792
## Sep 2009	645.637
## Oct 2009	618.027
## Nov 2009	570.906
## Dec 2009	628.228
## Jan 2010	642.567
## Feb 2010	692.188
## Mar 2010	684.564
## Apr 2010	622.652
## May 2010	696.585
## Jun 2010	675.623
## Jul 2010	732.650
## Aug 2010	768.894
## Sep 2010	717.520
## Oct 2010	677.960
## Nov 2010	641.005
## Dec 2010	661.275
## Jan 2011	695.959
## Feb 2011	739.075
## Mar 2011	755.268
## Apr 2011	718.247
## May 2011	826.703
## Jun 2011	824.252
## Jul 2011	844.606
## Aug 2011	836.734
## Sep 2011	804.736
## Oct 2011	754.488
## Nov 2011	688.692
## Dec 2011	719.072
## Jan 2012	747.237
## Feb 2012	779.516
## Mar 2012	773.134
## Apr 2012	695.351
## May 2012	796.681

## Jun 2012	770.234
## Jul 2012	812.443
## Aug 2012	778.948
## Sep 2012	750.086
## Oct 2012	719.598
## Nov 2012	650.584
## Dec 2012	682.912
## Jan 2013	686.847
## Feb 2013	769.199
## Mar 2013	797.741
## Apr 2013	711.752
## May 2013	779.063
## Jun 2013	828.095
## Jul 2013	869.011
## Aug 2013	832.404
## Sep 2013	823.306
## Oct 2013	750.860
## Nov 2013	705.477
## Dec 2013	748.438
## Jan 2014	767.298
## Feb 2014	804.457
## Mar 2014	829.877
## Apr 2014	712.919
## May 2014	864.639
## Jun 2014	872.368
## Jul 2014	869.210
## Aug 2014	867.499
## Sep 2014	834.735
## Oct 2014	768.361
## Nov 2014	722.957
## Dec 2014	772.211
## Jan 2015	816.747
## Feb 2015	834.995
## Mar 2015	828.694
## Apr 2015	771.267
## May 2015	837.382
## Jun 2015	833.853
## Jul 2015	827.107
## Aug 2015	792.408
## Sep 2015	818.244
## Oct 2015	792.096
## Nov 2015	742.621
## Dec 2015	775.185
## Jan 2016	827.144
## Feb 2016	882.764
## Mar 2016	875.088
## Apr 2016	864.281
## May 2016	941.359
## Jun 2016	891.190
## Jul 2016	901.615
## Aug 2016	858.269
## Sep 2016	870.081
## Oct 2016	821.794
## Nov 2016	788.108

## Dec 2016	835.099
## Jan 2017	835.016
## Feb 2017	940.971
## Mar 2017	926.632
## Apr 2017	873.587
## May 2017	1026.651
## Jun 2017	997.275
## Jul 2017	1034.318
## Aug 2017	989.713
## Sep 2017	923.984
## Oct 2017	868.653
## Nov 2017	844.056
## Dec 2017	898.917
## Jan 2018	890.499
## Feb 2018	921.636
## Mar 2018	972.470
## Apr 2018	917.637
## May 2018	1011.223
## Jun 2018	1018.357
## Jul 2018	1049.282
## Aug 2018	1029.846
## Sep 2018	945.119
## Oct 2018	948.886
## Nov 2018	865.466
## Dec 2018	901.608
## Jan 2019	905.400
## Feb 2019	943.070
## Mar 2019	943.541
## Apr 2019	873.434
## May 2019	990.413
## Jun 2019	1030.384
## Jul 2019	1063.768
## Aug 2019	1000.405
## Sep 2019	987.828
## Oct 2019	944.649
## Nov 2019	902.923
## Dec 2019	930.498
## Jan 2020	901.364
## Feb 2020	939.392
## Mar 2020	995.264
## Apr 2020	995.532
## May 2020	994.615
## Jun 2020	918.395
## Jul 2020	1036.515
## Aug 2020	1050.542
## Sep 2020	1006.388
## Oct 2020	965.785
##	Renewable_ts.df.Hydroelectric Power Consumption
## Jan 1973	NA
## Feb 1973	NA
## Mar 1973	272.703
## Apr 1973	242.199
## May 1973	268.810
## Jun 1973	253.185

## Jul 1973	260.770
## Aug 1973	249.859
## Sep 1973	235.670
## Oct 1973	222.077
## Nov 1973	179.733
## Dec 1973	191.723
## Jan 1974	210.285
## Feb 1974	274.435
## Mar 1974	304.506
## Apr 1974	279.950
## May 1974	290.582
## Jun 1974	293.702
## Jul 1974	294.828
## Aug 1974	280.695
## Sep 1974	276.772
## Oct 1974	253.175
## Nov 1974	225.274
## Dec 1974	210.955
## Jan 1975	222.713
## Feb 1975	243.428
## Mar 1975	263.371
## Apr 1975	251.317
## May 1975	293.961
## Jun 1975	279.947
## Jul 1975	291.504
## Aug 1975	285.310
## Sep 1975	268.081
## Oct 1975	237.557
## Nov 1975	215.793
## Dec 1975	238.068
## Jan 1976	256.706
## Feb 1976	272.990
## Mar 1976	273.323
## Apr 1976	257.277
## May 1976	278.567
## Jun 1976	253.482
## Jul 1976	267.732
## Aug 1976	268.088
## Sep 1976	273.026
## Oct 1976	249.759
## Nov 1976	213.376
## Dec 1976	220.990
## Jan 1977	208.138
## Feb 1977	212.507
## Mar 1977	219.069
## Apr 1977	160.329
## May 1977	209.549
## Jun 1977	197.287
## Jul 1977	197.656
## Aug 1977	182.303
## Sep 1977	177.779
## Oct 1977	176.863
## Nov 1977	173.821
## Dec 1977	181.908

## Jan 1978	215.864
## Feb 1978	240.826
## Mar 1978	262.529
## Apr 1978	232.625
## May 1978	257.965
## Jun 1978	265.041
## Jul 1978	301.188
## Aug 1978	263.109
## Sep 1978	256.107
## Oct 1978	232.357
## Nov 1978	221.801
## Dec 1978	204.012
## Jan 1979	208.974
## Feb 1979	231.275
## Mar 1979	262.096
## Apr 1979	222.855
## May 1979	271.516
## Jun 1979	265.941
## Jul 1979	303.134
## Aug 1979	261.646
## Sep 1979	238.414
## Oct 1979	222.695
## Nov 1979	198.794
## Dec 1979	211.243
## Jan 1980	234.286
## Feb 1980	238.063
## Mar 1980	265.618
## Apr 1980	224.631
## May 1980	255.676
## Jun 1980	270.552
## Jul 1980	303.305
## Aug 1980	290.604
## Sep 1980	257.106
## Oct 1980	214.693
## Nov 1980	194.301
## Dec 1980	187.730
## Jan 1981	201.929
## Feb 1981	233.998
## Mar 1981	236.553
## Apr 1981	223.123
## May 1981	217.976
## Jun 1981	219.717
## Jul 1981	255.200
## Aug 1981	278.976
## Sep 1981	265.656
## Oct 1981	228.409
## Nov 1981	188.516
## Dec 1981	191.231
## Jan 1982	200.541
## Feb 1982	252.071
## Mar 1982	284.215
## Apr 1982	281.593
## May 1982	315.347
## Jun 1982	295.061

## Jul 1982	295.887
## Aug 1982	295.552
## Sep 1982	288.273
## Oct 1982	252.259
## Nov 1982	210.219
## Dec 1982	208.623
## Jan 1983	245.861
## Feb 1983	292.668
## Mar 1983	310.615
## Apr 1983	296.625
## May 1983	321.730
## Jun 1983	318.603
## Jul 1983	331.656
## Aug 1983	326.237
## Sep 1983	298.715
## Oct 1983	274.189
## Nov 1983	230.650
## Dec 1983	220.423
## Jan 1984	261.940
## Feb 1984	335.876
## Mar 1984	313.504
## Apr 1984	293.845
## May 1984	320.670
## Jun 1984	315.985
## Jul 1984	335.607
## Aug 1984	303.719
## Sep 1984	289.982
## Oct 1984	264.894
## Nov 1984	220.536
## Dec 1984	220.205
## Jan 1985	234.699
## Feb 1985	272.166
## Mar 1985	290.793
## Apr 1985	273.175
## May 1985	260.344
## Jun 1985	258.039
## Jul 1985	279.498
## Aug 1985	252.373
## Sep 1985	225.387
## Oct 1985	211.206
## Nov 1985	198.288
## Dec 1985	211.589
## Jan 1986	242.115
## Feb 1986	267.386
## Mar 1986	226.352
## Apr 1986	245.152
## May 1986	300.280
## Jun 1986	290.609
## Jul 1986	287.656
## Aug 1986	277.260
## Sep 1986	254.396
## Oct 1986	223.810
## Nov 1986	222.779
## Dec 1986	225.018

## Jan 1987	244.175
## Feb 1987	273.692
## Mar 1987	267.809
## Apr 1987	223.722
## May 1987	245.143
## Jun 1987	232.573
## Jul 1987	255.627
## Aug 1987	220.689
## Sep 1987	213.340
## Oct 1987	194.652
## Nov 1987	191.635
## Dec 1987	189.215
## Jan 1988	177.943
## Feb 1988	222.161
## Mar 1988	230.477
## Apr 1988	199.789
## May 1988	204.359
## Jun 1988	200.293
## Jul 1988	222.701
## Aug 1988	197.723
## Sep 1988	177.420
## Oct 1988	172.238
## Nov 1988	170.174
## Dec 1988	158.144
## Jan 1989	192.932
## Feb 1989	208.016
## Mar 1989	224.040
## Apr 1989	199.310
## May 1989	242.358
## Jun 1989	257.728
## Jul 1989	300.240
## Aug 1989	277.046
## Sep 1989	242.678
## Oct 1989	216.086
## Nov 1989	202.515
## Dec 1989	214.892
## Jan 1990	226.777
## Feb 1990	233.595
## Mar 1990	253.277
## Apr 1990	262.555
## May 1990	301.333
## Jun 1990	276.175
## Jul 1990	291.917
## Aug 1990	300.121
## Sep 1990	257.581
## Oct 1990	230.354
## Nov 1990	187.254
## Dec 1990	203.213
## Jan 1991	219.084
## Feb 1991	263.525
## Mar 1991	280.572
## Apr 1991	240.524
## May 1991	282.566
## Jun 1991	281.008

## Jul 1991	309.826
## Aug 1991	280.947
## Sep 1991	266.050
## Oct 1991	237.525
## Nov 1991	201.861
## Dec 1991	193.296
## Jan 1992	202.130
## Feb 1992	239.639
## Mar 1992	235.950
## Apr 1992	196.021
## May 1992	237.660
## Jun 1992	212.719
## Jul 1992	242.426
## Aug 1992	244.966
## Sep 1992	214.207
## Oct 1992	198.457
## Nov 1992	183.300
## Dec 1992	180.270
## Jan 1993	212.065
## Feb 1993	259.394
## Mar 1993	268.521
## Apr 1993	216.725
## May 1993	253.399
## Jun 1993	274.886
## Jul 1993	316.469
## Aug 1993	287.581
## Sep 1993	254.885
## Oct 1993	216.292
## Nov 1993	188.068
## Dec 1993	187.590
## Jan 1994	195.571
## Feb 1994	231.625
## Mar 1994	220.026
## Apr 1994	210.850
## May 1994	243.412
## Jun 1994	254.767
## Jul 1994	267.130
## Aug 1994	258.029
## Sep 1994	241.004
## Oct 1994	209.396
## Nov 1994	171.008
## Dec 1994	180.671
## Jan 1995	197.506
## Feb 1995	229.658
## Mar 1995	256.445
## Apr 1995	258.244
## May 1995	294.609
## Jun 1995	253.408
## Jul 1995	286.483
## Aug 1995	311.683
## Sep 1995	283.275
## Oct 1995	251.378
## Nov 1995	206.520
## Dec 1995	238.738

## Jan 1996	263.386
## Feb 1996	301.139
## Mar 1996	317.658
## Apr 1996	328.772
## May 1996	350.334
## Jun 1996	329.254
## Jul 1996	343.915
## Aug 1996	330.103
## Sep 1996	298.560
## Oct 1996	271.592
## Nov 1996	228.911
## Dec 1996	233.632
## Jan 1997	243.572
## Feb 1997	313.353
## Mar 1997	336.616
## Apr 1997	321.859
## May 1997	357.387
## Jun 1997	327.586
## Jul 1997	349.120
## Aug 1997	351.899
## Sep 1997	323.304
## Oct 1997	274.788
## Nov 1997	238.970
## Dec 1997	252.613
## Jan 1998	242.156
## Feb 1998	264.160
## Mar 1998	293.860
## Apr 1998	305.870
## May 1998	323.122
## Jun 1998	291.715
## Jul 1998	338.499
## Aug 1998	329.782
## Sep 1998	292.237
## Oct 1998	256.055
## Nov 1998	212.368
## Dec 1998	192.567
## Jan 1999	204.150
## Feb 1999	256.829
## Mar 1999	301.877
## Apr 1999	293.419
## May 1999	328.047
## Jun 1999	279.566
## Jul 1999	296.517
## Aug 1999	312.577
## Sep 1999	303.567
## Oct 1999	263.077
## Nov 1999	213.640
## Dec 1999	203.526
## Jan 2000	216.417
## Feb 2000	255.344
## Mar 2000	258.518
## Apr 2000	229.354
## May 2000	272.397
## Jun 2000	290.623

## Jul 2000	279.719
## Aug 2000	256.913
## Sep 2000	246.155
## Oct 2000	224.228
## Nov 2000	181.584
## Dec 2000	175.315
## Jan 2001	195.459
## Feb 2001	200.852
## Mar 2001	194.798
## Apr 2001	180.547
## May 2001	211.591
## Jun 2001	186.128
## Jul 2001	198.142
## Aug 2001	214.179
## Sep 2001	186.812
## Oct 2001	195.436
## Nov 2001	157.641
## Dec 2001	157.418
## Jan 2002	159.262
## Feb 2002	199.905
## Mar 2002	221.720
## Apr 2002	205.410
## May 2002	213.723
## Jun 2002	246.661
## Jul 2002	271.240
## Aug 2002	287.009
## Sep 2002	259.113
## Oct 2002	214.487
## Nov 2002	173.824
## Dec 2002	174.684
## Jan 2003	200.714
## Feb 2003	220.434
## Mar 2003	208.576
## Apr 2003	200.271
## May 2003	245.048
## Jun 2003	250.685
## Jul 2003	297.627
## Aug 2003	289.436
## Sep 2003	251.536
## Oct 2003	232.592
## Nov 2003	187.115
## Dec 2003	186.588
## Jan 2004	199.617
## Feb 2004	243.449
## Mar 2004	230.201
## Apr 2004	209.471
## May 2004	229.509
## Jun 2004	209.214
## Jul 2004	240.581
## Aug 2004	252.927
## Sep 2004	233.556
## Oct 2004	216.265
## Nov 2004	205.581
## Dec 2004	188.930

## Jan 2005	209.705
## Feb 2005	262.527
## Mar 2005	242.697
## Apr 2005	216.046
## May 2005	229.338
## Jun 2005	230.561
## Jul 2005	272.758
## Aug 2005	267.803
## Sep 2005	259.542
## Oct 2005	215.635
## Nov 2005	173.619
## Dec 2005	180.046
## Jan 2006	193.507
## Feb 2006	221.389
## Mar 2006	272.144
## Apr 2006	245.611
## May 2006	244.251
## Jun 2006	283.244
## Jul 2006	305.688
## Aug 2006	295.163
## Sep 2006	252.333
## Oct 2006	215.524
## Nov 2006	170.621
## Dec 2006	169.170
## Jan 2007	201.075
## Feb 2007	214.210
## Mar 2007	257.426
## Apr 2007	183.513
## May 2007	238.832
## Jun 2007	236.135
## Jul 2007	257.448
## Aug 2007	225.519
## Sep 2007	222.170
## Oct 2007	197.092
## Nov 2007	145.715
## Dec 2007	146.248
## Jan 2008	155.001
## Feb 2008	181.289
## Mar 2008	204.758
## Apr 2008	185.146
## May 2008	213.526
## Jun 2008	219.093
## Jul 2008	268.237
## Aug 2008	287.514
## Sep 2008	251.820
## Oct 2008	209.193
## Nov 2008	159.420
## Dec 2008	152.441
## Jan 2009	154.392
## Feb 2009	205.569
## Mar 2009	229.265
## Apr 2009	173.845
## May 2009	213.036
## Jun 2009	251.513

## Jul 2009	288.502
## Aug 2009	285.318
## Sep 2009	228.235
## Oct 2009	191.105
## Nov 2009	169.421
## Dec 2009	192.185
## Jan 2010	205.035
## Feb 2010	241.363
## Mar 2010	218.369
## Apr 2010	200.874
## May 2010	203.761
## Jun 2010	186.307
## Jul 2010	244.673
## Aug 2010	291.254
## Sep 2010	239.186
## Oct 2010	196.283
## Nov 2010	168.439
## Dec 2010	172.515
## Jan 2011	190.842
## Feb 2011	226.037
## Mar 2011	248.060
## Apr 2011	234.459
## May 2011	302.503
## Jun 2011	303.084
## Jul 2011	316.615
## Aug 2011	312.381
## Sep 2011	303.962
## Oct 2011	250.319
## Nov 2011	207.705
## Dec 2011	192.254
## Jan 2012	200.932
## Feb 2012	230.580
## Mar 2012	219.888
## Apr 2012	193.017
## May 2012	246.546
## Jun 2012	250.215
## Jul 2012	272.562
## Aug 2012	253.685
## Sep 2012	252.091
## Oct 2012	219.192
## Nov 2012	167.517
## Dec 2012	157.020
## Jan 2013	178.257
## Feb 2013	218.713
## Mar 2013	236.889
## Apr 2013	194.813
## May 2013	195.918
## Jun 2013	239.451
## Jul 2013	271.442
## Aug 2013	261.271
## Sep 2013	260.036
## Oct 2013	206.403
## Nov 2013	161.826
## Dec 2013	164.092

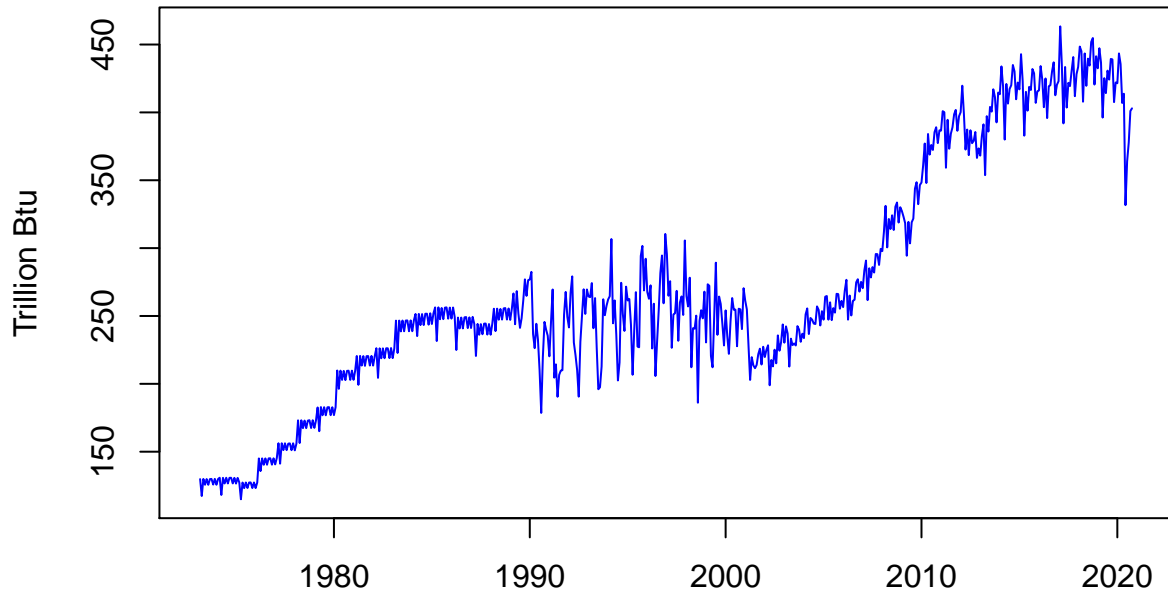
## Jan 2014	168.655
## Feb 2014	201.585
## Mar 2014	205.737
## Apr 2014	165.437
## May 2014	230.685
## Jun 2014	241.934
## Jul 2014	252.432
## Aug 2014	244.824
## Sep 2014	231.639
## Oct 2014	188.367
## Nov 2014	152.867
## Dec 2014	163.184
## Jan 2015	177.123
## Feb 2015	212.347
## Mar 2015	224.946
## Apr 2015	207.684
## May 2015	226.274
## Jun 2015	209.407
## Jul 2015	187.549
## Aug 2015	190.239
## Sep 2015	195.832
## Oct 2015	178.199
## Nov 2015	149.981
## Dec 2015	154.979
## Jan 2016	180.209
## Feb 2016	215.880
## Mar 2016	236.473
## Apr 2016	222.851
## May 2016	252.863
## Jun 2016	238.906
## Jul 2016	235.290
## Aug 2016	214.523
## Sep 2016	198.076
## Oct 2016	180.666
## Nov 2016	151.106
## Dec 2016	160.072
## Jan 2017	173.638
## Feb 2017	207.976
## Mar 2017	245.323
## Apr 2017	220.023
## May 2017	272.826
## Jun 2017	270.949
## Jul 2017	300.409
## Aug 2017	281.690
## Sep 2017	245.050
## Oct 2017	202.998
## Nov 2017	176.445
## Dec 2017	163.053
## Jan 2018	183.231
## Feb 2018	204.969
## Mar 2018	228.183
## Apr 2018	226.710
## May 2018	235.435
## Jun 2018	255.960

```
## Jul 2018 277.165
## Aug 2018 251.248
## Sep 2018 228.506
## Oct 2018 200.442
## Nov 2018 174.484
## Dec 2018 177.967
## Jan 2019 199.493
## Feb 2019 207.545
## Mar 2019 220.800
## Apr 2019 203.728
## May 2019 234.478
## Jun 2019 247.711
## Jul 2019 284.768
## Aug 2019 250.004
## Sep 2019 221.491
## Oct 2019 201.040
## Nov 2019 164.953
## Dec 2019 162.995
## Jan 2020 180.017
## Feb 2020 191.242
## Mar 2020 226.383
## Apr 2020 235.003
## May 2020 208.559
## Jun 2020 195.508
## Jul 2020 272.098
## Aug 2020 259.445
## Sep 2020 247.114
## Oct 2020 215.725
```

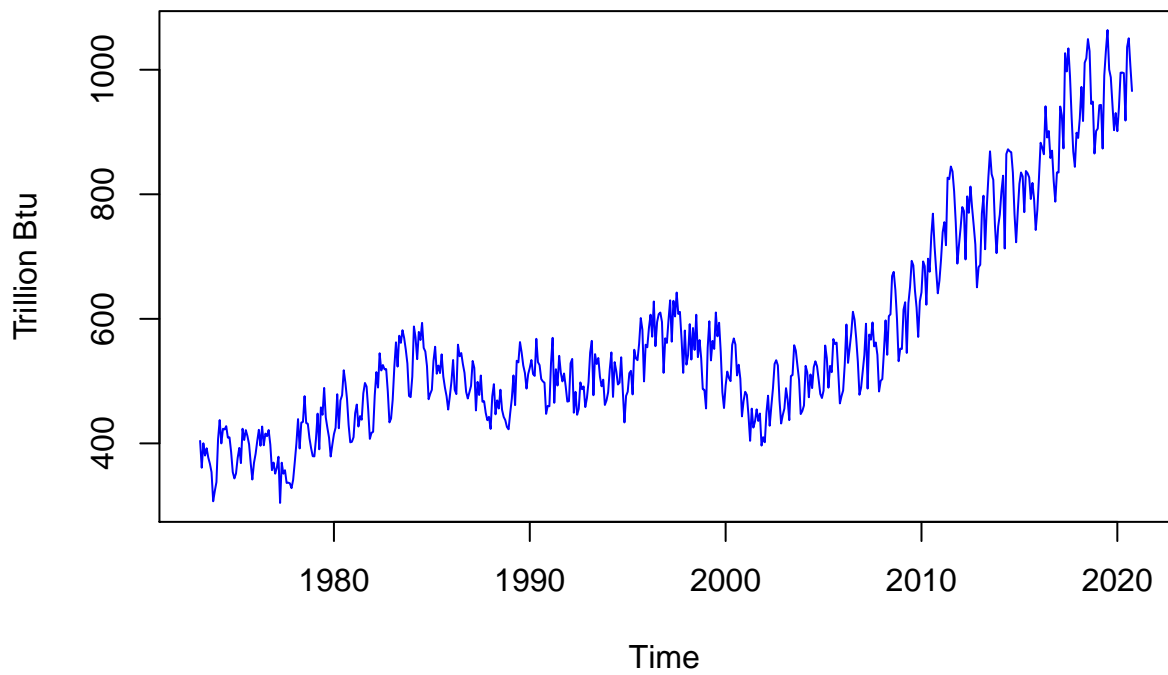
```
Renewable_diff.df<-diff(Renewable_ts.df, lag=1)
```

```
for(i in 2:4){
  #par(mfrow=c(1,3)) #place plot side by side
  plot(Renewable_ts.df[,i], ylab="Trillion Btu", col=c("blue"))+abline(h=mean(Renewable_ts.df[,i]), col="red")
  #Acf(Renewable_ts.df[,i], lag.max=40, main=paste("Column", i, "ACF", sep=""))
  # because I am not storing Acf() into any object, I don't need to specify plot=TRUE
  #Pacf(Renewable_ts.df[,i], lag.max=40, main=paste("Column", i, "PACF", sep=""))
}
```

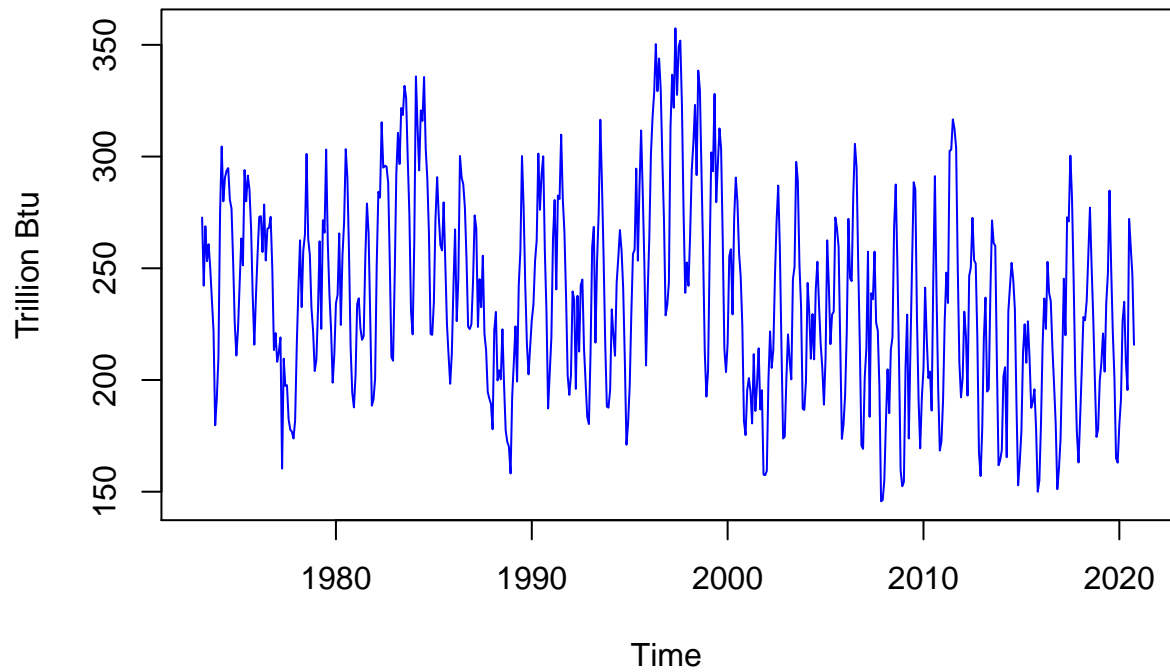
Time Series Plot



Time
Time Series Plot

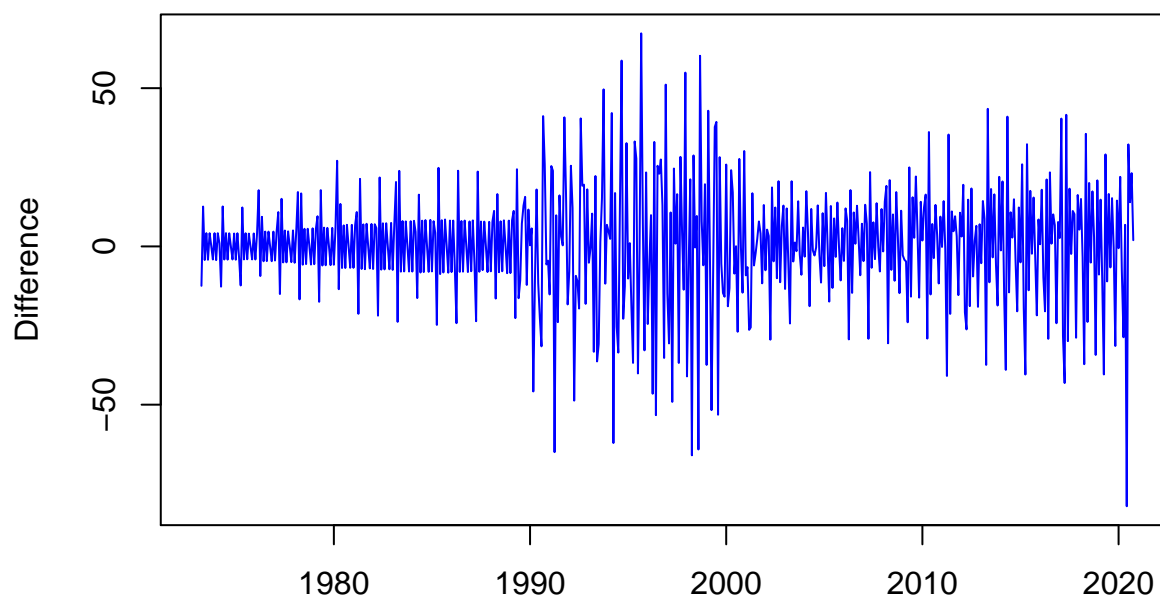


Time Series Plot

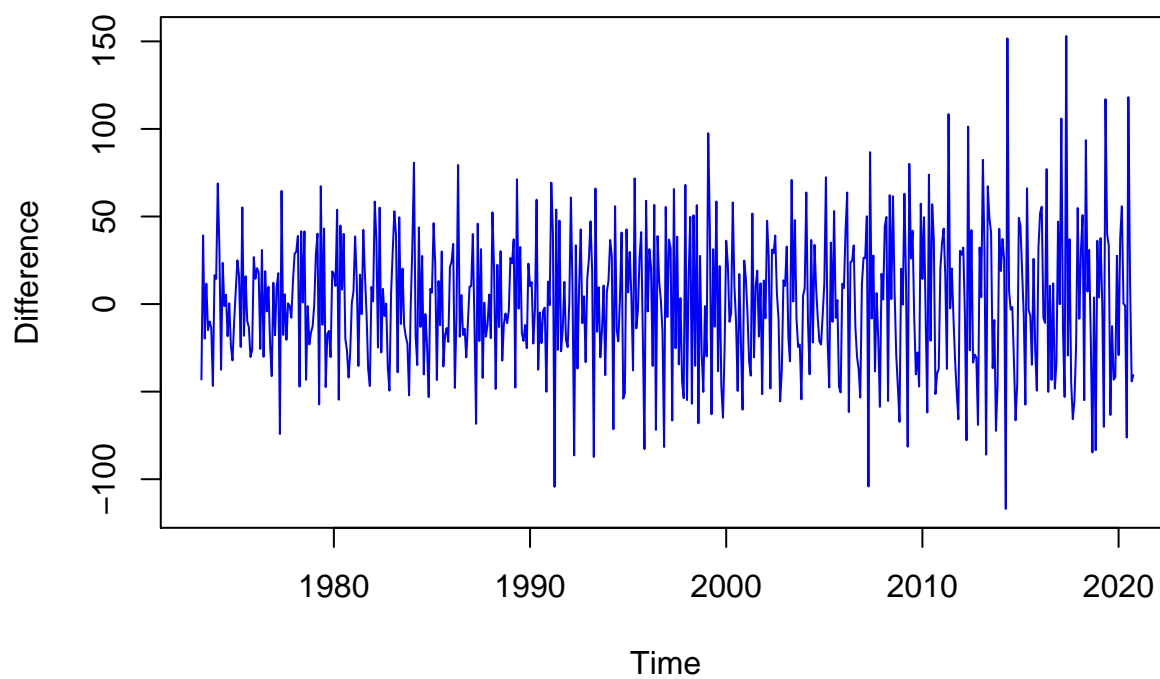


```
for(i in 2:4){  
  #par(mfrow=c(1,3)) #place plot side by side  
  plot(Renewable_diff.df[,i], ylab="Difference", col=c("blue"))+abline(h=mean(Renewable_diff.df[,i]), col="red")  
  #Acf(Renewable_diff.df[,i], lag.max=40, main=paste("Column", i, "ACF", sep=""))  
  # because I am not storing Acf() into any object, I don't need to specify plot=TRUE  
  #Pacf(Renewable_diff.df[,i], lag.max=40, main=paste("Column", i, "PACF", sep=""))  
}
```

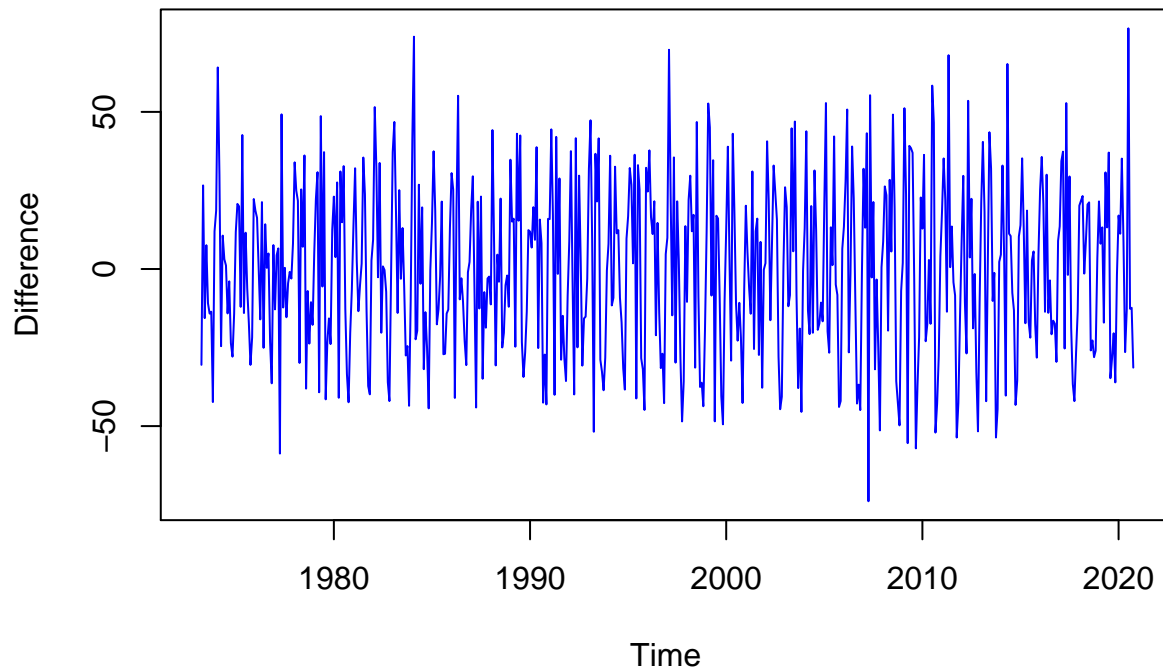
Difference Plot



Time
Difference Plot



Difference Plot



After differencing these plots with a lag of 1, all three time series seem to have lost their series. They now seem to be stationary plots. However, all three series continue to have a seasonal trend (as we did not difference at lag=12). Still, this differencing does drastically alter our time series plots from their non-differenced plots.

Q2

Compute Mann-Kendall and Spearman's Correlation Rank Test for each time series. Ask R to print the results. Interpret the results.

```
MannKendall(Renewable_ts.df[,2])

## tau = 0.71, 2-sided pvalue =< 2.22e-16
MannKendall(Renewable_ts.df[,3])

## tau = 0.652, 2-sided pvalue =< 2.22e-16
MannKendall(Renewable_ts.df[,4])

## tau = -0.182, 2-sided pvalue =7.6024e-11
cor.test(Renewable_ts.df[,2], Renewable_ts.df[,1],
         method = "pearson")

##
## Pearson's product-moment correlation
##
## data: Renewable_ts.df[, 2] and Renewable_ts.df[, 1]
## t = 47.027, df = 570, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.8735456 0.9073260
## sample estimates:
##      cor
```

```
## 0.8916705
cor.test(Renewable_ts.df[,3], Renewable_ts.df[,1],
         method = "pearson")

##
## Pearson's product-moment correlation
##
## data: Renewable_ts.df[, 3] and Renewable_ts.df[, 1]
## t = 35.248, df = 570, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## 0.8002917 0.8520960
## sample estimates:
## cor
## 0.827952

cor.test(Renewable_ts.df[,4], Renewable_ts.df[,1],
         method = "pearson")

##
## Pearson's product-moment correlation
##
## data: Renewable_ts.df[, 4] and Renewable_ts.df[, 1]
## t = -6.7038, df = 570, p-value = 4.892e-11
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.3446805 -0.1926255
## sample estimates:
## cor
## -0.270338
```

Each of the Mann-Kendall tests have a null hypothesis of series stationarity and an alternate hypothesis of a series trend. In each of the three series, Total Biomass Energy Production, Total Renewable Energy Production, and Hydroelectric Power Consumption we reject the null hypothesis of stationarity with p values of very close to 0. In all three series, I am confident that each series has a trend: the first two are positive, Hydro is negative.

The Spearman's Rank Correlation test has a null hypothesis that says the two tested variables do not covary and an alternate hypothesis that says they do. In all three of my tests, which compare my three series of note to the date, we reject the null hypothesis with p-values very close to zero. I am confident all three of my series: Total Biomass Energy Production, Total Renewable Energy Production, and Hydroelectric Power Consumption covary with time.

Decomposing the series

For this part you will work only with the following columns: Solar Energy Consumption and Wind Energy Consumption.

Q3

Create a data frame structure with these two time series only and the Date column. Drop the rows with *Not Available* and convert the columns to numeric. You can use filtering to eliminate the initial rows or convert to numeric and then use the `drop_na()` function. If you are familiar with pipes for data wrangling, try using it!

```
Renewable.df <- read.csv("../Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.csv")
```



```

Renewable_date<-Renewable.df[14:585,1]
Renewable_SolarWind.df<-Renewable.df[14:585,8:9]

colnames(Renewable_SolarWind.df)=c("Solar Energy Consumption","Wind Energy Consumption")
Renewable_SolarWind.df$Date<-Renewable_date

Renewable_SolarWind.df$`Solar Energy Consumption`<-as.numeric(Renewable_SolarWind.df$`Solar Energy Consumption`)

## Warning: NAs introduced by coercion
Renewable_SolarWind.df$`Wind Energy Consumption`<-as.numeric(Renewable_SolarWind.df$`Wind Energy Consumption`)

## Warning: NAs introduced by coercion
Renewable_SolarWind.df<-drop_na(Renewable_SolarWind.df)

my_date <- paste(Renewable_SolarWind.df[,3])
my_date <- ym(my_date) #function my from package lubridate, my is short for month, year

Renewable_SolarWind.df <- cbind(my_date,Renewable_SolarWind.df[,1:2])
#head(Renewable_SolarWind.df)

```

Q4

Plot the Solar and Wind energy consumption over time using ggplot. Explore the function `scale_x_date()` on ggplot and see if you can change the x axis to improve your plot. Hint: use `scale_x_date(date_breaks = "5 years", date_labels = "%Y")`

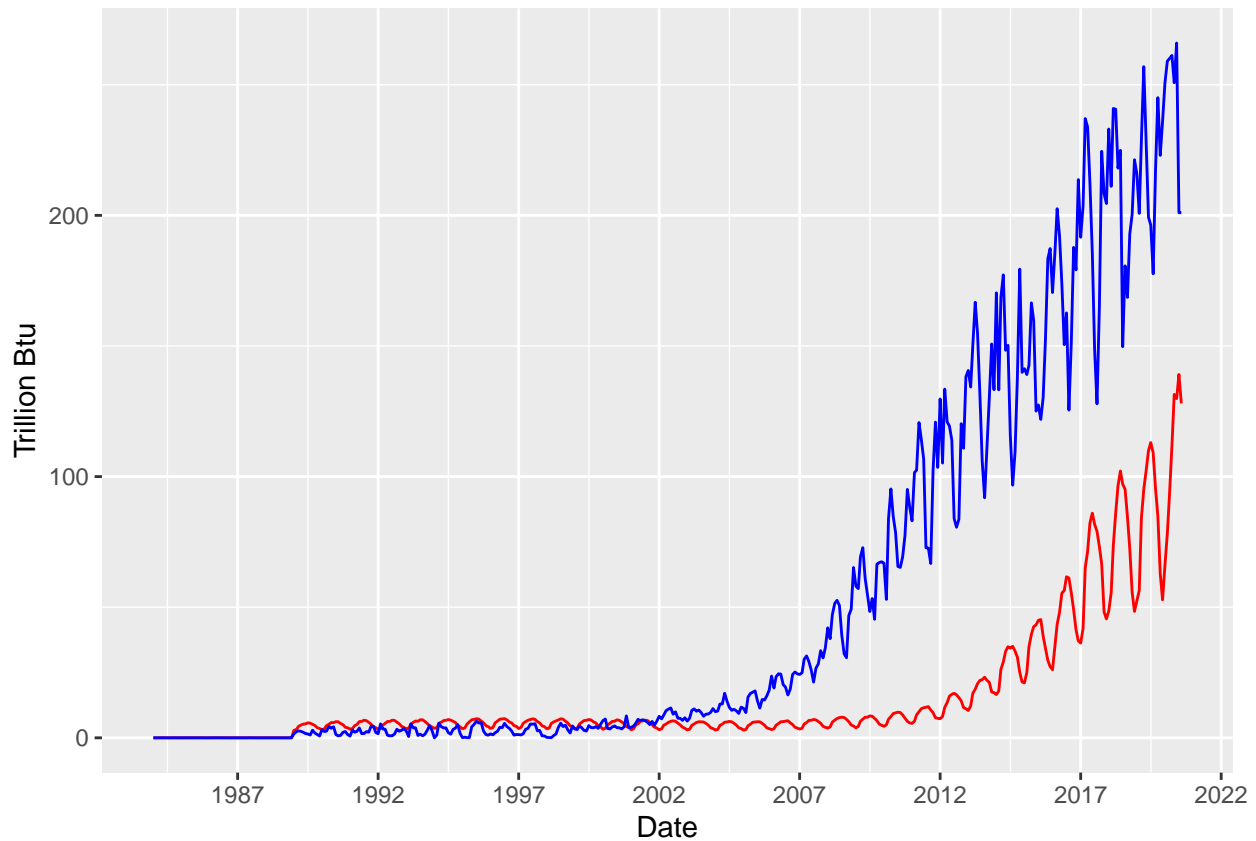
Try changing the color of the wind series to blue. Hint: use `color = "blue"`

```

ggplot(Renewable_SolarWind.df) +
  geom_line(aes(x = Renewable_SolarWind.df$my_date, y = Renewable_SolarWind.df$`Solar Energy Consumption`)) +
  geom_line(aes(x = Renewable_SolarWind.df$my_date, y = Renewable_SolarWind.df$`Wind Energy Consumption`)) +
  ylab("Trillion Btu") +
  xlab("Date") +
  scale_x_date(date_breaks = "5 years", date_labels = "%Y")

## Warning: Use of `Renewable_SolarWind.df$my_date` is discouraged. Use `my_date` instead.
## Warning: Use of `Renewable_SolarWind.df$`Solar Energy Consumption`` is discouraged. Use `Solar Energy Consumption` instead.
## Warning: Use of `Renewable_SolarWind.df$my_date` is discouraged. Use `my_date` instead.
## Warning: Use of `Renewable_SolarWind.df$`Wind Energy Consumption`` is discouraged. Use `Wind Energy Consumption` instead.

```



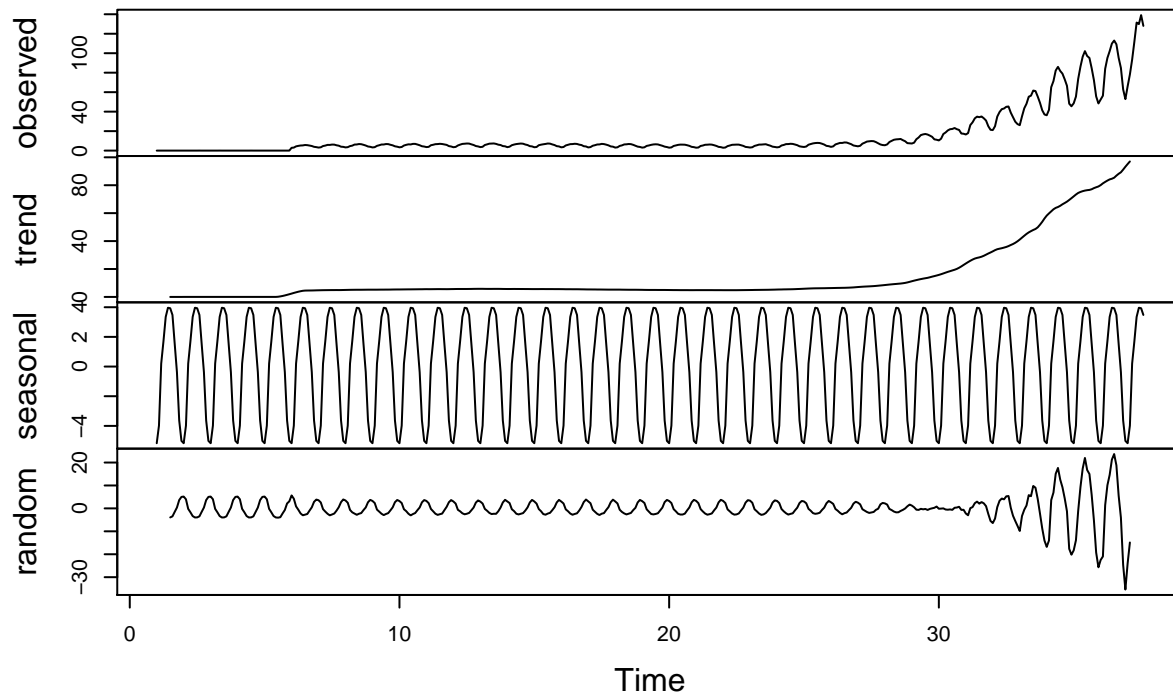
Q5

Transform wind and solar series into a time series object and apply the `decompose` function on them using the additive option. What can you say about the trend component? What about the random component? Does the random component look random? Or does it appear to still have some seasonality on it?

```
Renewable_SolarWind_ts<-ts(Renewable_SolarWind.df, frequency=12)
#SOLAR PLOT

#Using R decompose function
decompose_Solar=decompose(Renewable_SolarWind_ts[,2], "additive")
plot(decompose_Solar)
```

Decomposition of additive time series



```
#Inspect random component
Solar_random <- decompose_Solar$random #this would just be the random component then
mean_Solar <- mean(Solar_random)
sd_Solar <- sd(Solar_random)

cat(mean_Solar,sd_Solar)
```

```
## NA NA
```

```
#Note random series has some missing values, that is why we got NAs
```

```
#Compute mean and standard deviation without missing values
```

```
mean_Solar <- mean(na.exclude(Solar_random)) #exclude NA or missing observation to compute mean and st
sd_Solar <- sd(na.exclude(Solar_random))
```

```
cat(mean_Solar,sd_Solar)
```

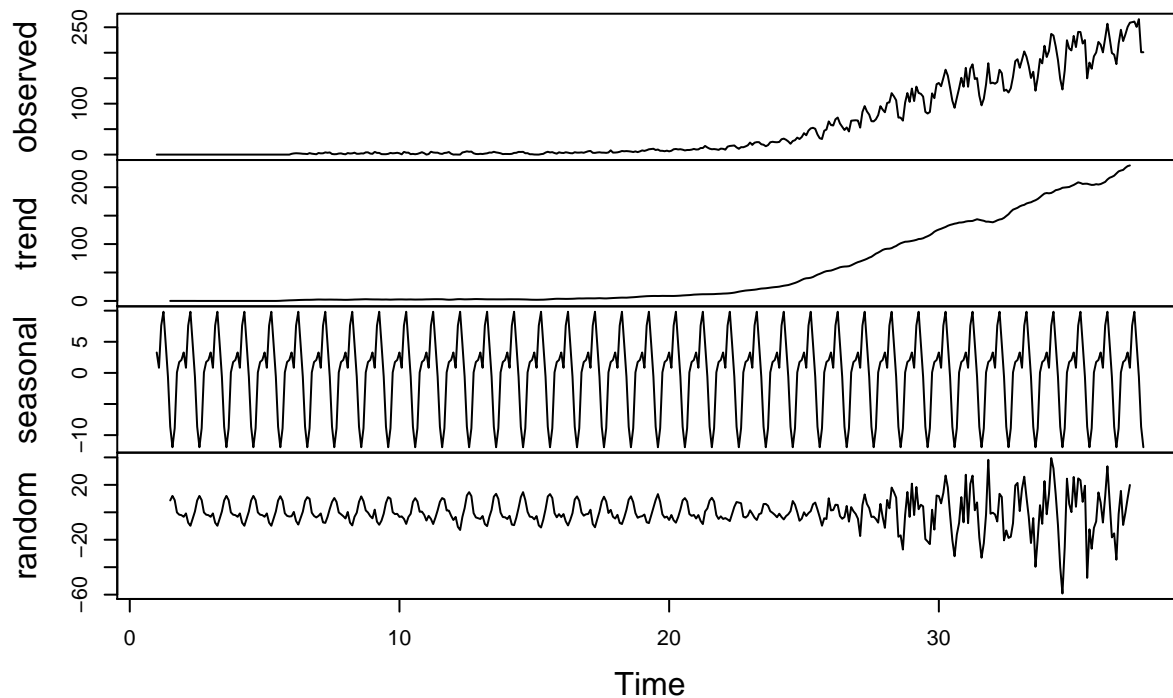
```
## -0.1401871 5.59249
```

```
#WIND PLOT
```

```
#Using R decompose function
```

```
decompose_Wind=decompose(Renewable_SolarWind_ts[,3], "additive")
plot(decompose_Wind)
```

Decomposition of additive time series



```
#Inspect random component
Wind_random <- decompose_Wind$random #this would just be the random component then
mean_Wind <- mean(Wind_random)
sd_Wind <- sd(Wind_random)

cat(mean_Wind,sd_Wind)
```

```
## NA NA
```

```
#Note random series has some missing values, that is why we got NAs
```

```
#Compute mean and standard deviation without missing values
```

```
mean_Wind <- mean(na.exclude(Wind_random)) #exclude NA or missing observation to compute mean and std
sd_Wind <- sd(na.exclude(Wind_random))
```

```
cat(mean_Wind,sd_Wind)
```

```
## 0.02325102 11.03871
```

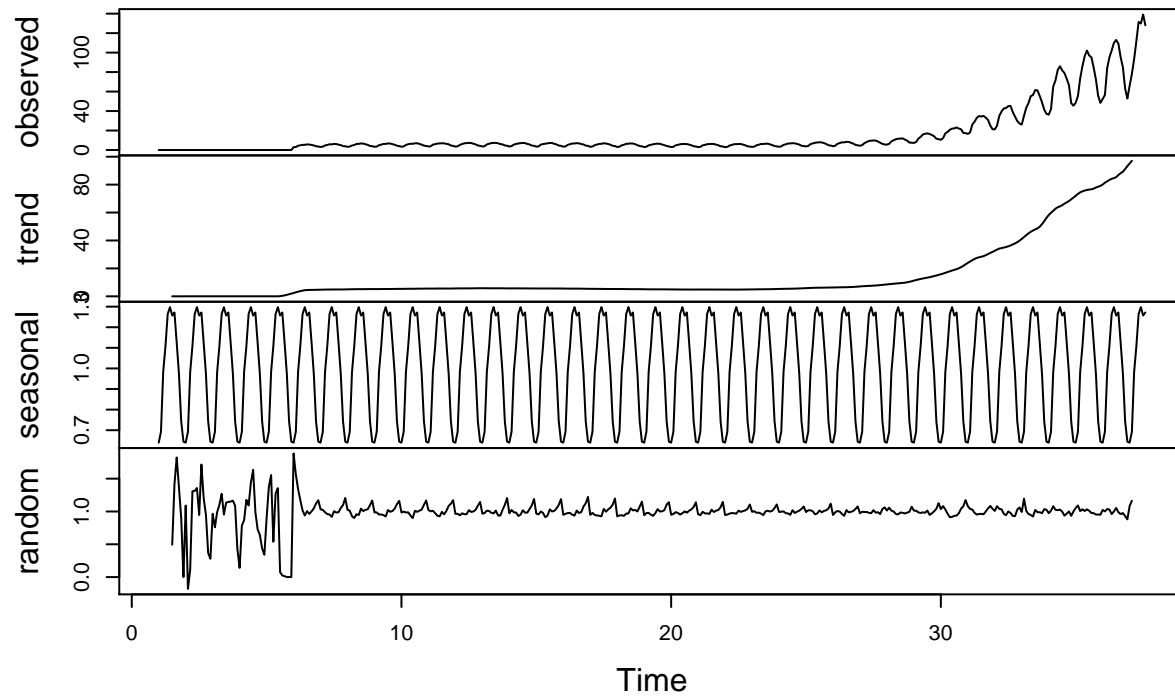
The trend component of the Solar (1st plot) and Wind (2nd plot) energy consumption both appear to be steady close to 0 and then linearly increasing at around 2005 for wind energy and 2012 for solar energy. The random components appear to be rather seasonal for both series for the entire plot, however it does seem that the magnitude of the random component increases at the same time their respective trends begin increasing linearly.

Q6

Use the decompose function again but now change the type of the seasonal component from additive to multiplicative. What happened to the random component this time?

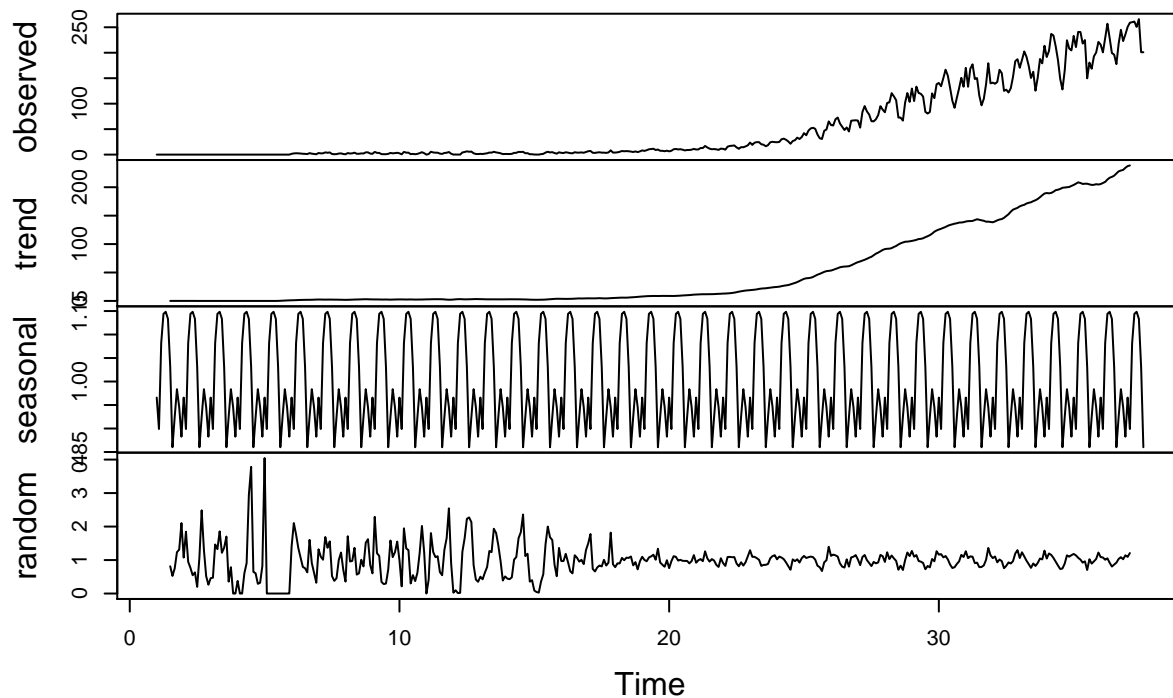
```
decompose_Solar_m=decompose(Renewable_SolarWind_ts[,2], "multiplicative")
plot(decompose_Solar_m)
```

Decomposition of multiplicative time series



```
decompose_Wind_m=decompose(Renewable_SolarWind_ts[,3], "multiplicative")
plot(decompose_Wind_m)
```

Decomposition of multiplicative time series



After decomposing both the series using the multiplicative seasonal component, the random component changes significantly. What previously appeared to be a seasonally varying component has become more erratic and less seasonal. The random component is particularly more erratic at earlier times (when the data had smaller observed values). As the observed values increase, the random values diminish in variability significantly and become somewhat seasonally varying. ### Q7

When fitting a model to this data, do you think you need all the historical data? Think about the date from 90s and early 20s. Are there any information from those year we might need to forecast the next six months of Solar and/or Wind consumption. Explain your response.

When fitting a model to this data, it appears that we only need data starting at around 2000 for the Wind Power Consumption and around 2010 for Solar Power Consumption. Prior to those dates, the trends for these two energy sources remain constant and close to 0. Any more information prior to those dates is not very useful if we were to fit a model to the data.