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_3

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
```

```
## Warning: NAs introduced by coercion
```

```
Renewable_altered.df$`Total Renewable Energy Production`<-as.numeric(Renewable_altered.df$`Total Renewal
```

```
## Warning: NAs introduced by coercion
```

```
Renewable_altered.df$`Hydroelectric Power Consumption`<-as.numeric(Renewable_altered.df$`Hydroelectric
```

```
## 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
```

```r
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]), co
  #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("Coumn",i,"PACF",sep=""))
}
```

Time Series Plot
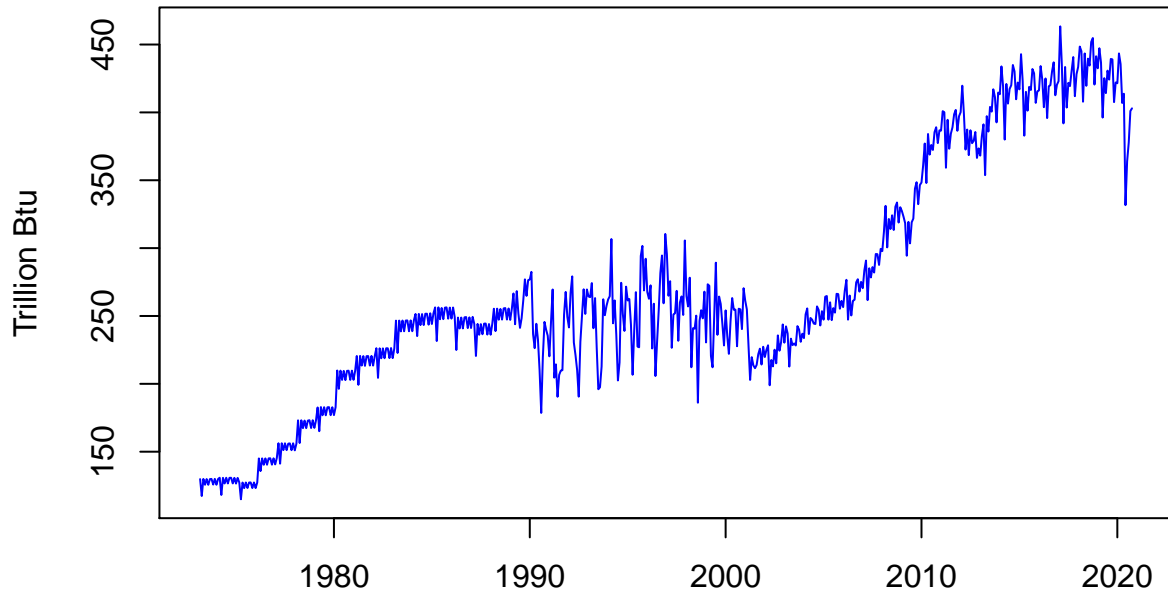
Time Series Plot
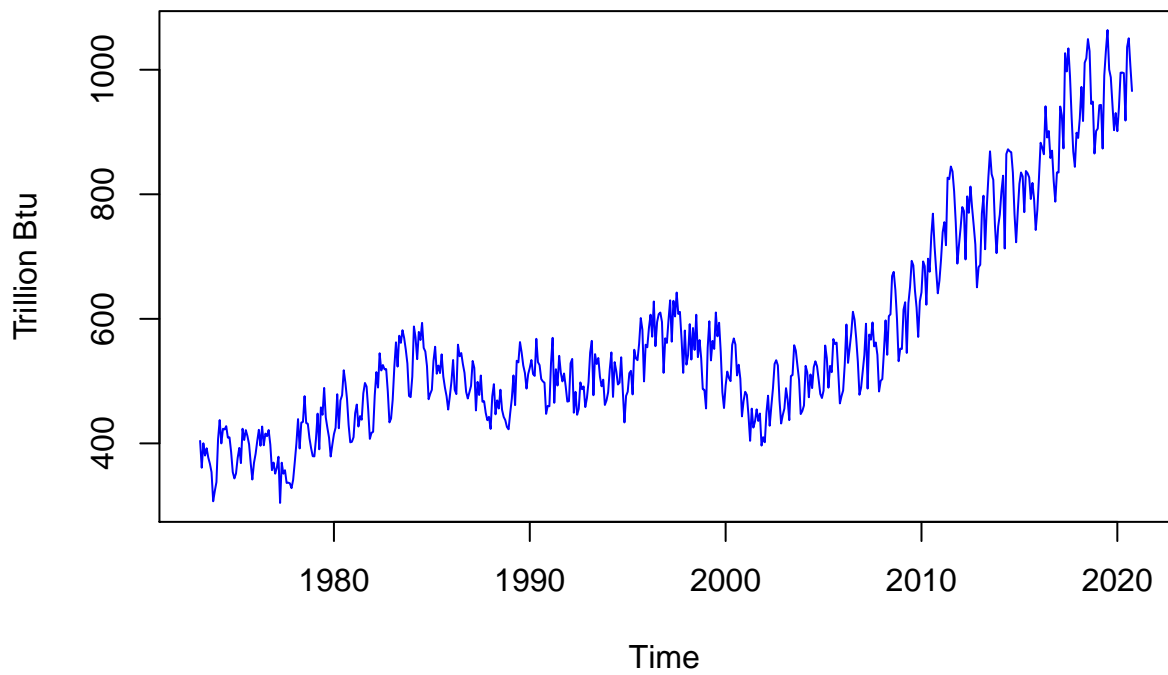
Time Series Plot
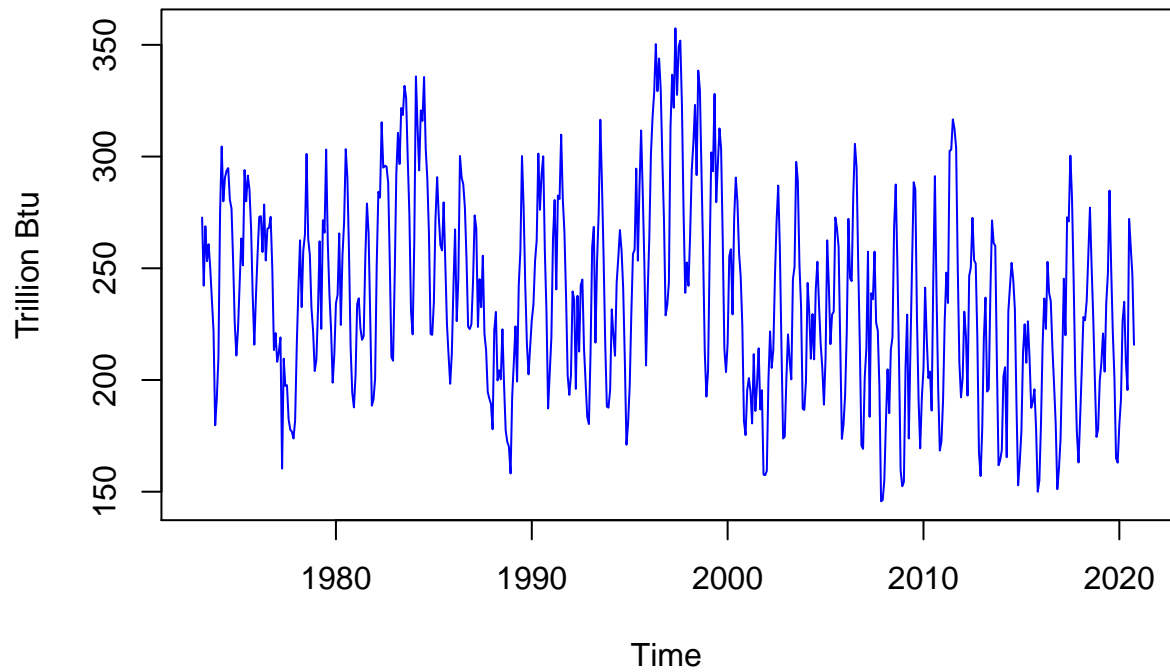

```r
for(i in 2:4){
  #par(mfrow=c(1,3))  #place plot side by side
  plot(Renewable_diff.df[,i], ylab="Difference",  col=c("blue"))+abline(h=mean(Renewable_diff.df[,i]),
  #Acf(Renewable_diff.df[,i],lag.max=40,main=paste("Column",i,"ACF",sep=""))
  # because I am not storing Acf() into any object, I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

Difference Plot
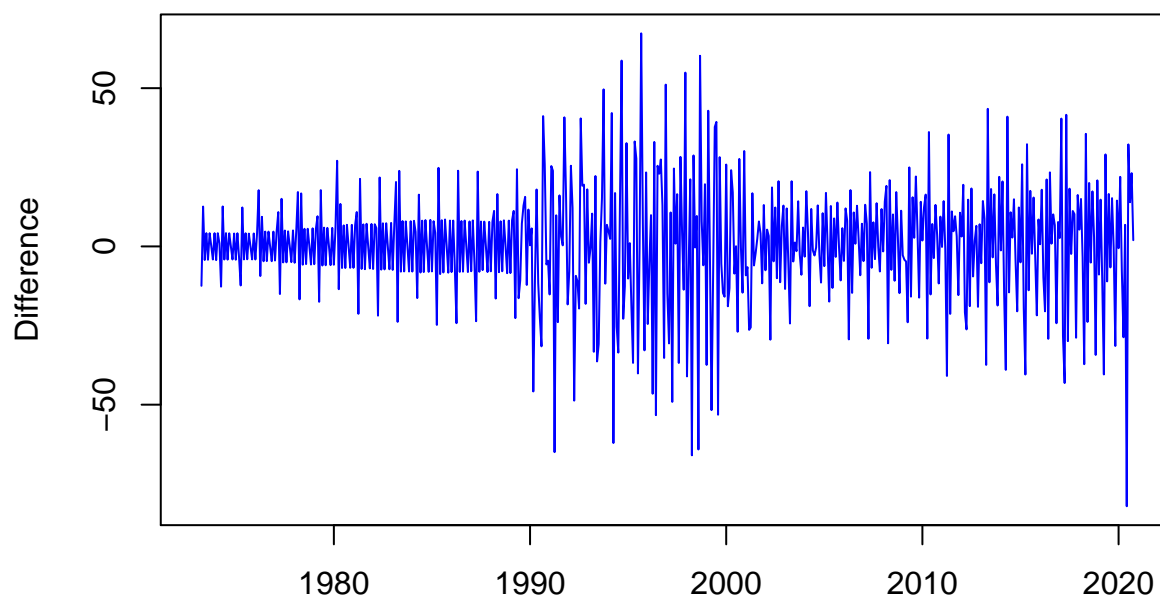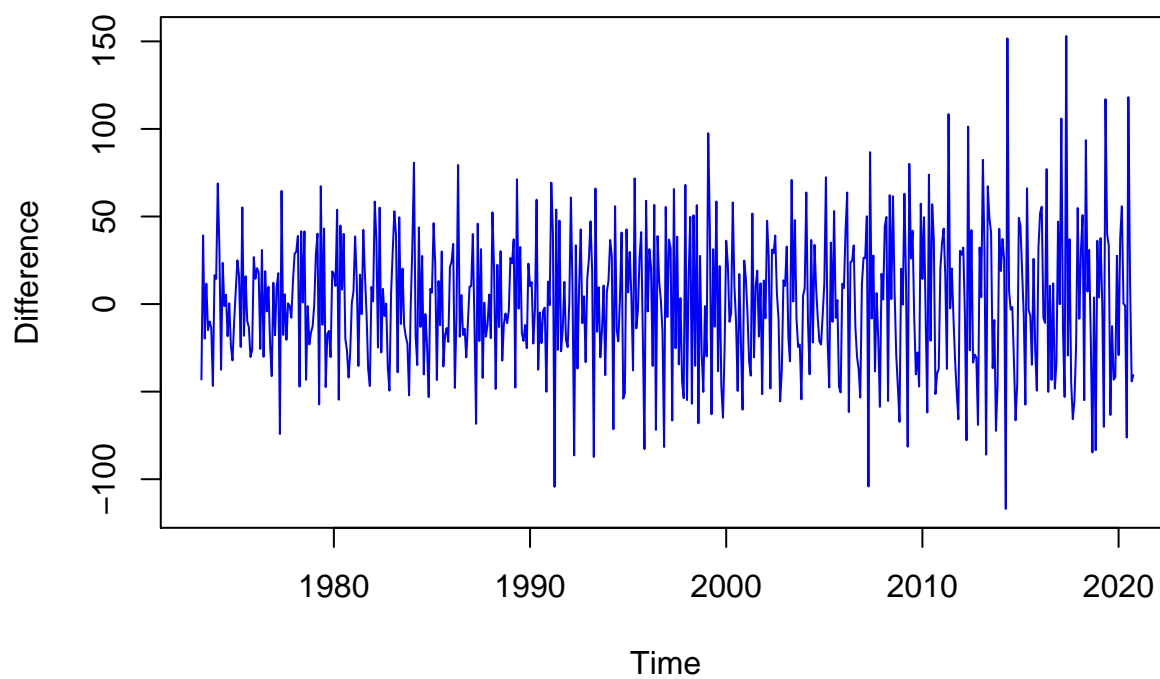
Difference Plot
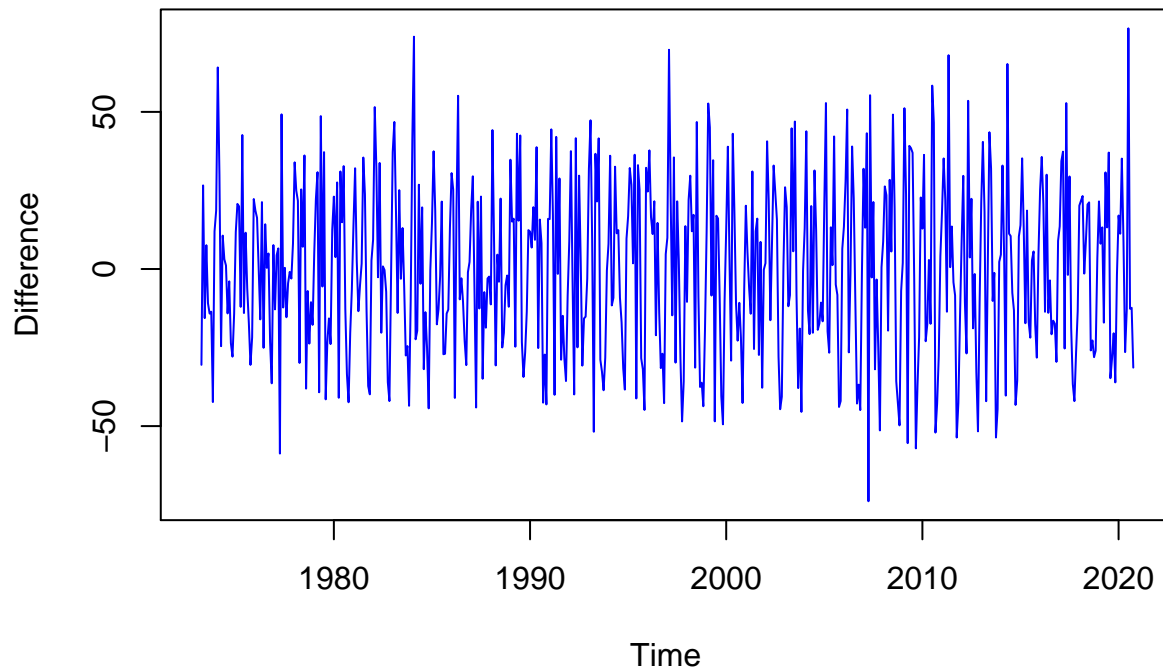
Difference Plot

After differencing these plots with a lag of 1, all three time series seem to have lost their series. 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 conver 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"
```

```r
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 Consu
```

```
## Warning: NAs introduced by coercion
```

```r
Renewable_SolarWind.df$`Wind Energy Consumption`<-as.numeric(Renewable_SolarWind.df$`Wind Energy Consump
```

```
## Warning: NAs introduced by coercion
```

```r
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"*

```r
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.
```
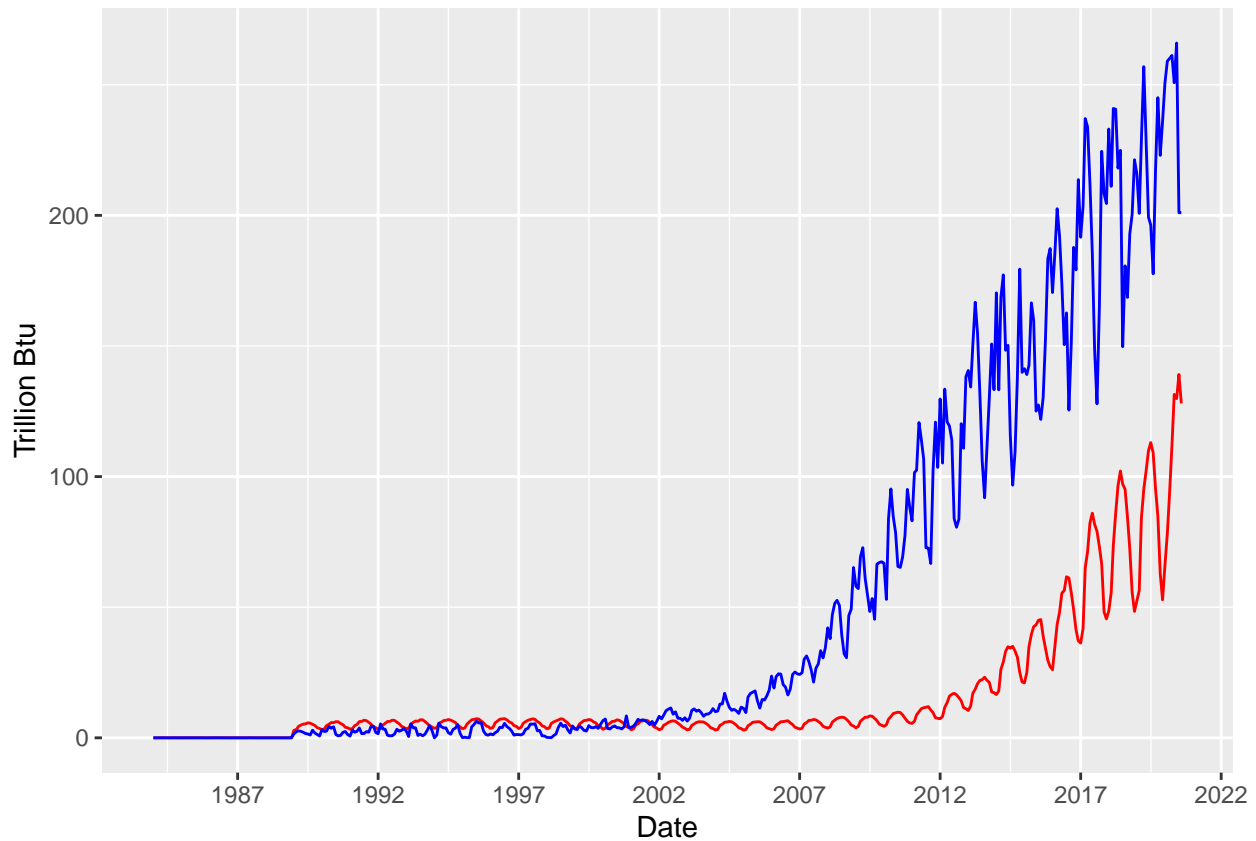
Q5

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
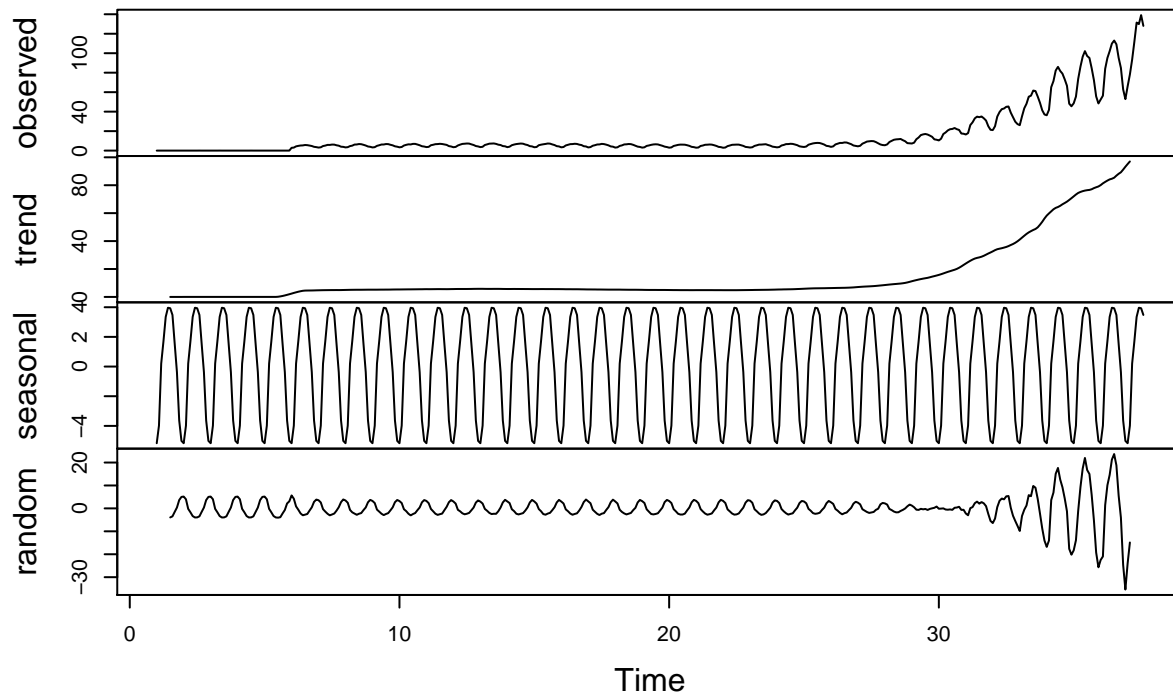

```
#Inspect random component
Solar_random <- decompose_Solar$random    #this would just be the random component then
mean_Solar <- mean(Solar_random)
sd_Solar <- sd(Solar_random)

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
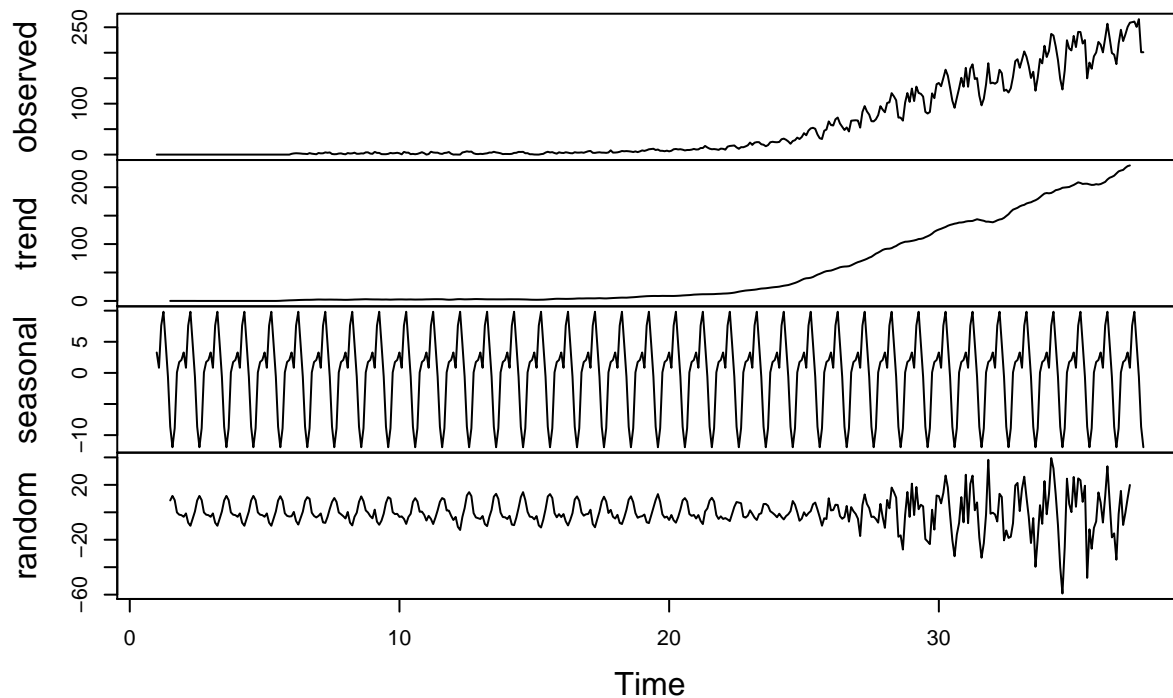

```
#Inspect random component
Wind_random <- decompose_Wind$random    #this would just be the random component then
mean_Wind <- mean(Wind_random)
sd_Wind <- sd(Wind_random)

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?

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

Decomposition of multiplicative time series
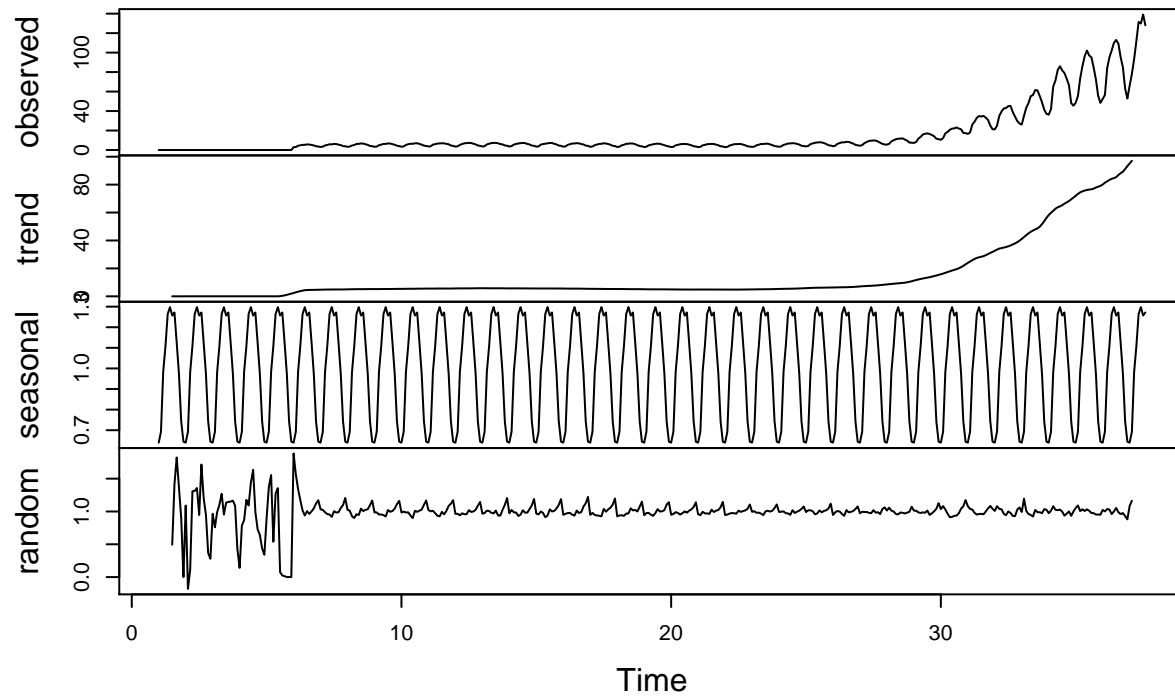

```r
decompose_Wind_m=decompose(Renewable_SolarWind_ts[,3], "multiplicative")
plot(decompose_Wind_m)
```

Decomposition of multiplicative time series
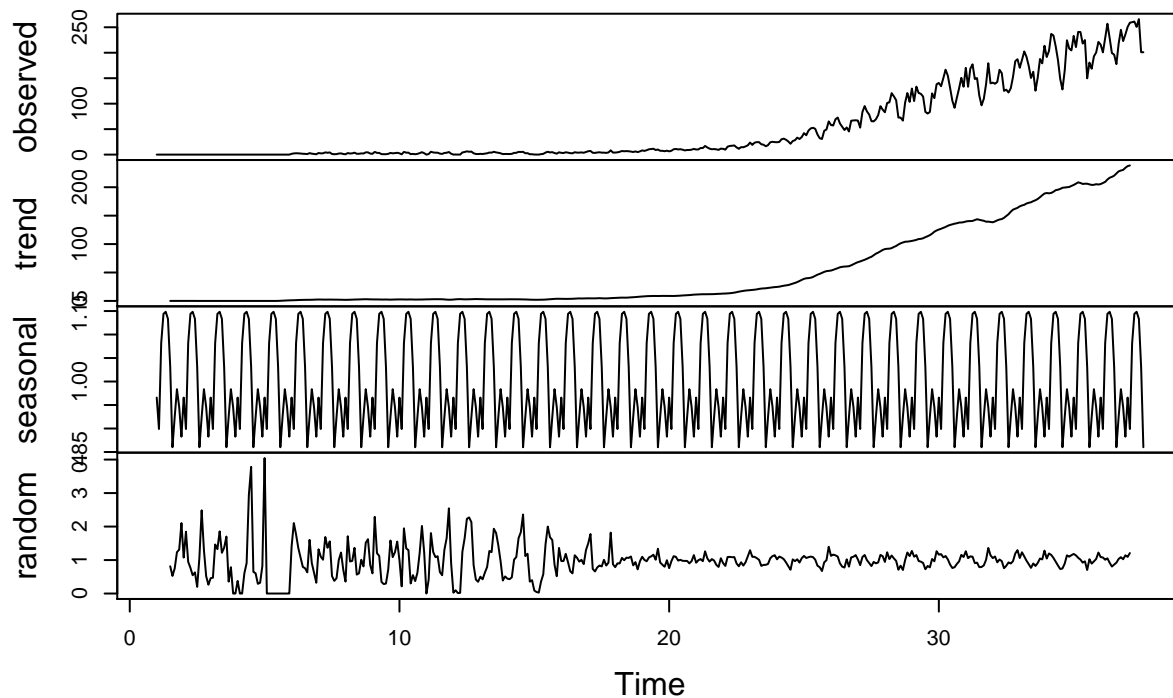
After decomposing both the series using the multiplicative seasonal component, the random component changes significantly. What previously appeared to be a seasonally varying component has become more erratic and less seasonal. The random component is particularly more erratic at earlier times (when 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.