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

Assignment 2 - Due date 01/26/22

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Submission Instructions

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

Once you have the file open on your local machine the first thing you will do is change "Student Name" on line 4 with your name. Then you will start working through the assignment by **creating code and output** that answer each question. Be sure to use this assignment document. Your report should contain the answer to each question and any plots/tables you obtained (when applicable).

When you have completed the assignment, **Knit** the text and code into a single PDF file. Rename the pdf file such that it includes your first and last name (e.g., "LuanaLima_TSA_A02_Sp22.Rmd"). Submit this pdf using Sakai.

R packages

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

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

```
## Warning: package 'forecast' was built under R version 4.0.5
```

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

```
library(tseries)
```

```
## Warning: package 'tseries' was built under R version 4.0.5
```

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 4.0.5
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

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

```
library(lubridate)
```

```
## Warning: package 'lubridate' was built under R version 4.0.5
```

```
##
## Attaching package: 'lubridate'
```

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

```
library(readxl)
```

```
## Warning: package 'readxl' was built under R version 4.0.5
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.0.5
```

Data set information

Consider the data provided in the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source on our **Data** folder. The data comes from the US Energy Information and Administration and corresponds to the January 2022 Monthly Energy Review. The spreadsheet is ready to be used. Use the command *read.table*() to import the data in R or *panda.read_excel*() in Python (note that you will need to import pandas package). }

```
#Importing data set
data <- read_excel("../Data/Table_10.1_Renewable_Energy_Production_and_Consumption_by_Source.xlsx")
```

```
## New names:
## * `` -> ...2
## * `` -> ...3
## * `` -> ...4
## * `` -> ...5
## * `` -> ...6
## * ...
```

```
View(data)
```

Question 1

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

```
data_of_interest = data[12:596, 4:6]
colnames(data_of_interest) = c("Total Biomass Energy Production", "Total Renewable Energy Production",
head(data_of_interest)
```

```
## # A tibble: 6 x 3
##   `Total Biomass Energy Production` `Total Renewable Ener~ `Hydroelectric Power~
##   <chr>                             <chr>                  <chr>
## 1 129.787                           403.981                272.703
## 2 117.338                           360.9                  242.199
## 3 129.938                           400.161                268.81
## 4 125.636                           380.47                 253.185
## 5 129.834                           392.141                260.77
## 6 125.611                           377.232                249.859
```

Question 2

Transform your data frame in a time series object and specify the starting point and frequency of the time series using the function ts().

```
ts_data = ts(data=data_of_interest, start=1, frequency = 12)
ts_data
```

```
##        Total Biomass Energy Production Total Renewable Energy Production
## Jan  1                              23                                 73
## Feb  1                               2                                 38
## Mar  1                              27                                 68
## Apr  1                               9                                 52
## May  1                              25                                 57
## Jun  1                               8                                 47
## Jul  1                              23                                 39
## Aug  1                              26                                 33
## Sep  1                              11                                 20
## Oct  1                              28                                 21
## Nov  1                              10                                 26
## Dec  1                              24                                 76
## Jan  2                              35                                121
## Feb  2                               3                                 66
## Mar  2                              31                                 97
## Apr  2                              13                                 94
## May  2                              34                                106
## Jun  2                              14                                 81
## Jul  2                              32                                 82
## Aug  2                              33                                 54
## Sep  2                              15                                 34
## Oct  2                              30                                 29
## Nov  2                              12                                 32
## Dec  2                              29                                 46
## Jan  3                              17                                 59
## Feb  3                               1                                 41
## Mar  3                              16                                 98
## Apr  3                               4                                 75
## May  3                              20                                 91
```

```
## Jun  3   7  86
## Jul  3  19  65
## Aug  3  22  40
## Sep  3   6  28
## Oct  3  21  42
## Nov  3   5  53
## Dec  3  18  72
## Jan  4  43  93
## Feb  4  36  60
## Mar  4  44 105
## Apr  4  37  62
## May  4  42  88
## Jun  4  38  85
## Jul  4  45  92
## Aug  4  46  64
## Sep  4  39  36
## Oct  4  47  44
## Nov  4  40  31
## Dec  4  48  37
## Jan  5  59  48
## Feb  5  41  19
## Mar  5  58  43
## Apr  5  52  30
## May  5  57  35
## Jun  5  51  24
## Jul  5  53  25
## Aug  5  55  23
## Sep  5  50  22
## Oct  5  56  27
## Nov  5  49  45
## Dec  5  54  67
## Jan  6  69 123
## Feb  6  60  56
## Mar  6  70 112
## Apr  6  63 115
## May  6  67 190
## Jun  6  62 111
## Jul  6  66 109
## Aug  6  72  79
## Sep  6  64  58
## Oct  6  71  51
## Nov  6  65  50
## Dec  6  68  78
## Jan  7  78 137
## Feb  7  61  55
## Mar  7  84 156
## Apr  7  74 132
## May  7  82 230
## Jun  7  73 125
## Jul  7  79 100
## Aug  7  83  80
## Sep  7  75  49
## Oct  7  80  63
## Nov  7  76  87
```

```
## Dec  7  81 101
## Jan  8 111 202
## Feb  8  89  99
## Mar  8 110 174
## Apr  8  96 197
## May  8 104 294
## Jun  8  94 247
## Jul  8 105 179
## Aug  8 107 108
## Sep  8  97  69
## Oct  8 108  71
## Nov  8  98  83
## Dec  8 106 139
## Jan  9 146 164
## Feb  9  92 104
## Mar  9 148 129
## Apr  9 123 122
## May  9 142 206
## Jun  9 121 244
## Jul  9 140 235
## Aug  9 141 147
## Sep  9 124  77
## Oct  9 147  89
## Nov  9 122  90
## Dec  9 143 195
## Jan 10 164 287
## Feb 10  99 234
## Mar 10 160 355
## Apr 10 132 293
## May 10 159 313
## Jun 10 133 296
## Jul 10 162 298
## Aug 10 161 214
## Sep 10 134 114
## Oct 10 166 124
## Nov 10 135 176
## Dec 10 163 302
## Jan 11 250 390
## Feb 11 152 303
## Mar 11 251 410
## Apr 11 205 387
## May 11 252 415
## Jun 11 206 405
## Jul 11 253 367
## Aug 11 254 320
## Sep 11 207 192
## Oct 11 255 185
## Nov 11 208 265
## Dec 11 256 419
## Jan 12 291 406
## Feb 12 191 339
## Mar 12 293 413
## Apr 12 227 396
## May 12 290 423
```

```
## Jun 12  228  372
## Jul 12  295  362
## Aug 12  296  305
## Sep 12  230  178
## Oct 12  298  205
## Nov 12  235  221
## Dec 12  300  331
## Jan 13  326  375
## Feb 13  186  276
## Mar 13  327  309
## Apr 13  266  279
## May 13  321  353
## Jun 13  267  266
## Jul 13  322  233
## Aug 13  325  191
## Sep 13  268  148
## Oct 13  323  187
## Nov 13  269  254
## Dec 13  324  337
## Jan 14  278  220
## Feb 14  154  203
## Mar 14  274  382
## Apr 14  216  347
## May 14  273  356
## Jun 14  217  317
## Jul 14  276  283
## Aug 14  277  211
## Sep 14  220  180
## Oct 14  275  207
## Nov 14  221  239
## Dec 14  279  330
## Jan 15  238  299
## Feb 15  144  145
## Mar 15  240  250
## Apr 15  197  198
## May 15  233  269
## Jun 15  200  167
## Jul 15  242  169
## Aug 15  244  141
## Sep 15  199  118
## Oct 15  234  127
## Nov 15  198   96
## Dec 15  237  188
## Jan 16  312  243
## Feb 16  209  134
## Mar 16  315  173
## Apr 16  259  153
## May 16  311  222
## Jun 16  264  146
## Jul 16  318  126
## Aug 16  320  119
## Sep 16  265  103
## Oct 16  316   95
## Nov 16  258  140
```

```
## Dec 16 313 181
## Jan 17 364 271
## Feb 17 232 162
## Mar 17 371 332
## Apr 17 297 324
## May 17 222 391
## Jun 17 271 360
## Jul 17 339 310
## Aug 17 392 280
## Sep 17 359 225
## Oct 17 389 274
## Nov 17 391 300
## Dec 17 399 336
## Jan 18 202 275
## Feb 18 165 268
## Mar 18 241 400
## Apr 18 188 325
## May 18 113 312
## Jun 18  77 261
## Jul 18 137 252
## Aug 18 246 246
## Sep 18 213 136
## Oct 18 193 160
## Nov 18 139 159
## Dec 18 247 322
## Jan 19 375 404
## Feb 19 100 166
## Mar 19 128 297
## Apr 19  86 241
## May 19 102 348
## Jun 19 109 284
## Jul 19 112 253
## Aug 19 287 277
## Sep 19 368 238
## Oct 19 280 168
## Nov 19 223 170
## Dec 19 365 321
## Jan 20 396 340
## Feb 20 180 142
## Mar 20 149 210
## Apr 20 114 133
## May 20  87 150
## Jun 20 184 248
## Jul 20 282 223
## Aug 20 377 236
## Sep 20 292 157
## Oct 20 376 182
## Nov 20 354 249
## Dec 20 351 358
## Jan 21 384 394
## Feb 21 219 196
## Mar 21 349 354
## Apr 21 168 318
## May 21  88 343
```

```
## Jun 21  90 264
## Jul 21 119 237
## Aug 21 346 258
## Sep 21 285 163
## Oct 21 331 172
## Nov 21 345 208
## Dec 21 356 295
## Jan 22 419 359
## Feb 22 245 186
## Mar 22 342 326
## Apr 22 195 291
## May 22  93 242
## Jun 22 130 245
## Jul 22 385 345
## Aug 22 294 216
## Sep 22 210 113
## Oct 22 380 193
## Nov 22 341 213
## Dec 22 347 278
## Jan 23 229 292
## Feb 23 103 201
## Mar 23 211 366
## Apr 23 366 341
## May 23 171 335
## Jun 23 169 385
## Jul 23 407 433
## Aug 23 416 416
## Sep 23 374 251
## Oct 23 406 381
## Nov 23 367 374
## Dec 23 348 418
## Jan 24 382 437
## Feb 24 158 408
## Mar 24 333 450
## Apr 24 101 377
## May 24 185 427
## Jun 24 304 439
## Jul 24 397 441
## Aug 24 409 426
## Sep 24 334 282
## Oct 24 420 403
## Nov 24 411 386
## Dec 24 360 430
## Jan 25 388 453
## Feb 25 167 392
## Mar 25 288 452
## Apr 25 299 434
## May 25 372 455
## Jun 25 187 440
## Jul 25 335 443
## Aug 25 355 398
## Sep 25 286 281
## Oct 25 418 414
## Nov 25 357 315
```

Dec 25	329	349
Jan 26	394	421
Feb 26	117	338
Mar 26	218	417
Apr 26	215	365
May 26	283	436
Jun 26	85	346
Jul 26	249	395
Aug 26	305	344
Sep 26	270	224
Oct 26	369	219
Nov 26	181	154
Dec 26	383	373
Jan 27	381	428
Feb 27	145	333
Mar 27	116	393
Apr 27	281	368
May 27	404	442
Jun 27	196	409
Jul 27	353	424
Aug 27	332	361
Sep 27	239	209
Oct 27	174	155
Nov 27	303	240
Dec 27	192	289
Jan 28	151	263
Feb 28	248	255
Mar 28	350	380
Apr 28	307	401
May 28	308	383
Jun 28	172	270
Jul 28	314	314
Aug 28	310	262
Sep 28	214	128
Oct 28	378	171
Nov 28	340	212
Dec 28	309	199
Jan 29	176	130
Feb 29	95	74
Mar 29	136	151
Apr 29	125	102
May 29	115	116
Jun 29	126	149
Jul 29	150	117
Aug 29	157	138
Sep 29	127	61
Oct 29	170	84
Nov 29	138	70
Dec 29	155	143
Jan 30	175	194
Feb 30	91	107
Mar 30	131	158
Apr 30	120	227
May 30	156	319

```
## Jun 30  129  334
## Jul 30  194  311
## Aug 30  153  175
## Sep 30  182  110
## Oct 30  231  131
## Nov 30  179  152
## Dec 30  224  228
## Jan 31  204  177
## Feb 31  118  120
## Mar 31  189  267
## Apr 31  177  272
## May 31  178  379
## Jun 31  173  364
## Jul 31  225  308
## Aug 31  212  257
## Sep 31  183  135
## Oct 31  203  144
## Nov 31  190  161
## Dec 31  289  307
## Jan 32  317  285
## Feb 32  201  184
## Mar 32  272  273
## Apr 32  260  229
## May 32  243  301
## Jun 32  236  328
## Jul 32  330  304
## Aug 32  306  259
## Sep 32  226  204
## Oct 32  302  183
## Nov 32  263  217
## Dec 32  352  378
## Jan 33  358  342
## Feb 33  261  232
## Mar 33  336  306
## Apr 33  257  286
## May 33  319  399
## Jun 33  301  384
## Jul 33  363  388
## Aug 33  362  288
## Sep 33  314  165
## Oct 33  337  189
## Nov 33  328  218
## Dec 33  373  316
## Jan 34  390  420
## Feb 34  262  323
## Mar 34  361  371
## Apr 34  284  412
## May 34  338  444
## Jun 34  344  431
## Jul 34  386  402
## Aug 34  393  327
## Sep 34  370  200
## Oct 34  387  231
## Nov 34  379  290
```

```
## Dec 34                400                350
## Jan 35                405                422
## Feb 35                343                226
## Mar 35                401                411
## Apr 35                395                397
## May 35                402                425
## Jun 35                398                376
## Jul 35                412                389
## Aug 35                410                351
## Sep 35                403                215
## Oct 35                414                256
## Nov 35                413                260
## Dec 35                421                363
## Jan 36                435                429
## Feb 36                415                352
## Mar 36                428                435
## Apr 36                423                438
## May 36                431                462
## Jun 36                422                463
## Jul 36                434                458
## Aug 36                438                432
## Sep 36                425                329
## Oct 36                433                370
## Nov 36                432                369
## Dec 36                430                445
## Jan 37                424                449
## Feb 37                408                357
## Mar 37                427                448
## Apr 37                417                460
## May 37                426                472
## Jun 37                429                468
## Jul 37                439                457
## Aug 37                443                446
## Sep 37                437                407
## Oct 37                440                451
## Nov 37                442                456
## Dec 37                447                471
## Jan 38                458                467
## Feb 38                441                447
## Mar 38                465                475
## Apr 38                451                464
## May 38                457                484
## Jun 38                453                494
## Jul 38                468                479
## Aug 38                476                465
## Sep 38                459                454
## Oct 38                472                461
## Nov 38                471                474
## Dec 38                492                485
## Jan 39                490                492
## Feb 39                446                480
## Mar 39                481                518
## Apr 39                455                515
## May 39                467                532
```

```
## Jun 39  477  527
## Jul 39  489  510
## Aug 39  496  491
## Sep 39  473  470
## Oct 39  486  481
## Nov 39  491  487
## Dec 39  529  504
## Jan 40  488  499
## Feb 40  454  473
## Mar 40  475  508
## Apr 40  452  497
## May 40  474  512
## Jun 40  460  503
## Jul 40  461  488
## Aug 40  470  482
## Sep 40  449  459
## Oct 40  456  466
## Nov 40  450  469
## Dec 40  464  496
## Jan 41  478  509
## Feb 41  445  477
## Mar 41  485  502
## Apr 41  469  519
## May 41  498  537
## Jun 41  493  524
## Jul 41  524  516
## Aug 41  510  490
## Sep 41  482  476
## Oct 41  518  489
## Nov 41  515  495
## Dec 41  558  511
## Jan 42  528  523
## Feb 42  462  478
## Mar 42  534  536
## Apr 42  503  543
## May 42  526  540
## Jun 42  531  538
## Jul 42  562  526
## Aug 42  551  493
## Sep 42  507  483
## Oct 42  538  500
## Nov 42  525  513
## Dec 42  573  528
## Jan 43  542  522
## Feb 43  466  498
## Mar 43  519  531
## Apr 43  497  525
## May 43  530  521
## Jun 43  523  507
## Jul 43  557  514
## Aug 43  552  506
## Sep 43  504  486
## Oct 43  520  501
## Nov 43  521  520
```

```
## Dec 43  559  549
## Jan 44  544  545
## Feb 44  499  535
## Mar 44  546  565
## Apr 44  487  551
## May 44  533  553
## Jun 44  536  534
## Jul 44  555  542
## Aug 44  568  517
## Sep 44  517  505
## Oct 44  537  529
## Nov 44  545  530
## Dec 44  583  566
## Jan 45  565  562
## Feb 45  483  544
## Mar 45  560    8
## Apr 45  502    1
## May 45  541   14
## Jun 45  532  581
## Jul 45  556  561
## Aug 45  572  541
## Sep 45  516  533
## Oct 45  554  552
## Nov 45  563  550
## Dec 45  579  560
## Jan 46  577  575
## Feb 46  508  558
## Mar 46  576    5
## Apr 46  535    7
## May 46  570   15
## Jun 46  561    9
## Jul 46  580  567
## Aug 46  582  572
## Sep 46  539  539
## Oct 46  575  554
## Nov 46  566  557
## Dec 46  581  569
## Jan 47  569  571
## Feb 47  494  547
## Mar 47  553  585
## Apr 47  527   12
## May 47  564   16
## Jun 47  550    4
## Jul 47  574  584
## Aug 47  571  570
## Sep 47  512  556
## Oct 47  549  564
## Nov 47  547  555
## Dec 47  578  568
## Jan 48  567  577
## Feb 48  506  579
## Mar 48  522  583
## Apr 48  436  559
## May 48  448    6
```

```
## Jun 48                          463                          13
## Jul 48                          495                         582
## Aug 48                          500                         573
## Sep 48                          479                         548
## Oct 48                          501                         563
## Nov 48                          505                         576
## Dec 48                          540                         578
## Jan 49                          509                           2
## Feb 49                          444                         546
## Mar 49                          511                          17
## Apr 49                          480                          11
## May 49                          543                          18
## Jun 49                          514                          10
## Jul 49                          548                         580
## Aug 49                          513                           3
## Sep 49                          484                         574
##        Hydroelectric Power Consumption
## Jan  1                          460
## Feb  1                          334
## Mar  1                          449
## Apr  1                          383
## May  1                          419
## Jun  1                          362
## Jul  1                          307
## Aug  1                          245
## Sep  1                           56
## Oct  1                           97
## Nov  1                          185
## Dec  1                          469
## Jan  2                          548
## Feb  2                          483
## Mar  2                          506
## Apr  2                          518
## May  2                          523
## Jun  2                          485
## Jul  2                          473
## Aug  2                          382
## Sep  2                          262
## Oct  2                          187
## Nov  2                          250
## Dec  2                          340
## Jan  3                          430
## Feb  3                          368
## Mar  3                          521
## Apr  3                          482
## May  3                          512
## Jun  3                          495
## Jul  3                          445
## Aug  3                          314
## Sep  3                          214
## Oct  3                          317
## Nov  3                          400
## Dec  3                          463
## Jan  4                          466
```

```
## Feb  4                          404
## Mar  4                          477
## Apr  4                          387
## May  4                          442
## Jun  4                          446
## Jul  4                          464
## Aug  4                          361
## Sep  4                          200
## Oct  4                          240
## Nov  4                          172
## Dec  4                          196
## Jan  5                          226
## Feb  5                           18
## Mar  5                          182
## Apr  5                          118
## May  5                          120
## Jun  5                           67
## Jul  5                           51
## Aug  5                           48
## Sep  5                           41
## Oct  5                           66
## Nov  5                          215
## Dec  5                          328
## Jan  6                          425
## Feb  6                          295
## Mar  6                          409
## Apr  6                          435
## May  6                          538
## Jun  6                          429
## Jul  6                          398
## Aug  6                          292
## Sep  6                          244
## Oct  6                          154
## Nov  6                          175
## Dec  6                          289
## Jan  7                          423
## Feb  7                          253
## Mar  7                          454
## Apr  7                          438
## May  7                          543
## Jun  7                          421
## Jul  7                          318
## Aug  7                          248
## Sep  7                          126
## Oct  7                          190
## Nov  7                          300
## Dec  7                          316
## Jan  8                          436
## Feb  8                          259
## Mar  8                          395
## Apr  8                          450
## May  8                          544
## Jun  8                          507
## Jul  8                          403
```

```
## Aug  8                    209
## Sep  8                    106
## Oct  8                     82
## Nov  8                    145
## Dec  8                    299
## Jan  9                    311
## Feb  9                    254
## Mar  9                    223
## Apr  9                    230
## May  9                    392
## Jun  9                    478
## Jul  9                    437
## Aug  9                    274
## Sep  9                     85
## Oct  9                     94
## Nov  9                    136
## Dec  9                    373
## Jan 10                    493
## Feb 10                    488
## Mar 10                    558
## Apr 10                    524
## May 10                    527
## Jun 10                    526
## Jul 10                    502
## Aug 10                    375
## Sep 10                    184
## Oct 10                    174
## Nov 10                    355
## Dec 10                    516
## Jan 11                    552
## Feb 11                    529
## Mar 11                    565
## Apr 11                    563
## May 11                    576
## Jun 11                    569
## Jul 11                    532
## Aug 11                    468
## Sep 11                    287
## Oct 11                    235
## Nov 11                    422
## Dec 11                    578
## Jan 12                    557
## Feb 12                    519
## Mar 12                    564
## Apr 12                    559
## May 12                    577
## Jun 12                    546
## Jul 12                    505
## Aug 12                    434
## Sep 12                    237
## Oct 12                    234
## Nov 12                    304
## Dec 12                    457
## Jan 13                    510
```

```
## Feb 13 465
## Mar 13 418
## Apr 13 411
## May 13 479
## Jun 13 377
## Jul 13 263
## Aug 13 188
## Sep 13 124
## Oct 13 191
## Nov 13 332
## Dec 13 441
## Jan 14 267
## Feb 14 351
## Mar 14 535
## Apr 14 508
## May 14 501
## Jun 14 476
## Jul 14 389
## Aug 14 256
## Sep 14 251
## Oct 14 261
## Nov 14 343
## Dec 14 467
## Jan 15 444
## Feb 15 255
## Mar 15 350
## Apr 15 293
## May 15 394
## Jun 15 238
## Jul 15 199
## Aug 15 107
## Sep 15  96
## Oct 15  88
## Nov 15  52
## Dec 15 246
## Jan 16 284
## Feb 16 130
## Mar 16 157
## Apr 16 134
## May 16 249
## Jun 16 121
## Jul 16  50
## Aug 16  37
## Sep 16  34
## Oct 16  14
## Nov 16 101
## Dec 16 171
## Jan 17 257
## Feb 17 127
## Mar 17 335
## Apr 17 408
## May 17 534
## Jun 17 474
## Jul 17 337
```

```
## Aug 17 218
## Sep 17 147
## Oct 17 210
## Nov 17 270
## Dec 17 297
## Jan 18 384
## Feb 18 426
## Mar 18 539
## Apr 18 472
## May 18 514
## Jun 18 533
## Jul 18 407
## Aug 18 283
## Sep 18  79
## Oct 18 149
## Nov 18 227
## Dec 18 432
## Jan 19 484
## Feb 19 326
## Mar 19 490
## Apr 19 487
## May 19 551
## Jun 19 486
## Jul 19 439
## Aug 19 313
## Sep 19 144
## Oct 19 103
## Nov 19 146
## Dec 19 325
## Jan 20 308
## Feb 20 115
## Mar 20 315
## Apr 20 197
## May 20 336
## Jun 20 347
## Jul 20 205
## Aug 20 125
## Sep 20  70
## Oct 20  60
## Nov 20 193
## Dec 20 415
## Jan 21 448
## Feb 21 222
## Mar 21 385
## Apr 21 471
## May 21 560
## Jun 21 500
## Jul 21 391
## Aug 21 220
## Sep 21  83
## Oct 21  81
## Nov 21 112
## Dec 21 290
## Jan 22 233
```

```
## Feb 22                    186
## Mar 22                    339
## Apr 22                    390
## May 22                    440
## Jun 22                    410
## Jul 22                    329
## Aug 22                    179
## Sep 22                     36
## Oct 22                     63
## Nov 22                    119
## Dec 22                    281
## Jan 23                    399
## Feb 23                    412
## Mar 23                    522
## Apr 23                    386
## May 23                    497
## Jun 23                    553
## Jul 23                    492
## Aug 23                    369
## Sep 23                    166
## Oct 23                    319
## Nov 23                    431
## Dec 23                    537
## Jan 24                    562
## Feb 24                    572
## Mar 24                    583
## Apr 24                    573
## May 24                    581
## Jun 24                    575
## Jul 24                    531
## Aug 24                    455
## Sep 24                    276
## Oct 24                    298
## Nov 24                    342
## Dec 24                    556
## Jan 25                    579
## Feb 25                    566
## Mar 25                    585
## Apr 25                    570
## May 25                    582
## Jun 25                    584
## Jul 25                    568
## Aug 25                    470
## Sep 25                    322
## Oct 25                    379
## Nov 25                    333
## Dec 25                    433
## Jan 26                    520
## Feb 26                    550
## Mar 26                    567
## Apr 26                    513
## May 26                    580
## Jun 26                    574
## Jul 26                    515
```

```
## Aug 26 397
## Sep 26 195
## Oct 26 100
## Nov 26 155
## Dec 26 401
## Jan 27 540
## Feb 27 517
## Mar 27 571
## Apr 27 480
## May 27 528
## Jun 27 555
## Jul 27 545
## Aug 27 428
## Sep 27 202
## Oct 27 151
## Nov 27 221
## Dec 27 393
## Jan 28 413
## Feb 28 279
## Mar 28 458
## Apr 28 509
## May 28 481
## Jun 28 402
## Jul 28 356
## Aug 28 258
## Sep 28  65
## Oct 28  46
## Nov 28 111
## Dec 28 138
## Jan 29 108
## Feb 29  61
## Mar 29 192
## Apr 29  74
## May 29 123
## Jun 29 204
## Jul 29  77
## Aug 29 110
## Sep 29  13
## Oct 29  11
## Nov 29  15
## Dec 29 131
## Jan 30 243
## Feb 30 161
## Mar 30 203
## Apr 30 358
## May 30 452
## Jun 30 498
## Jul 30 414
## Aug 30 207
## Sep 30  42
## Oct 30  45
## Nov 30 137
## Dec 30 236
## Jan 31 173
```

```
## Feb 31                    133
## Mar 31                    348
## Apr 31                    366
## May 31                    530
## Jun 31                    504
## Jul 31                    371
## Aug 31                    294
## Sep 31                     78
## Oct 31                     76
## Nov 31                    129
## Dec 31                    341
## Jan 32                    282
## Feb 32                    181
## Mar 32                    280
## Apr 32                    178
## May 32                    327
## Jun 32                    381
## Jul 32                    296
## Aug 32                    219
## Sep 32                    163
## Oct 32                     87
## Nov 32                    183
## Dec 32                    424
## Jan 33                    338
## Feb 33                    217
## Mar 33                    278
## Apr 33                    285
## May 33                    461
## Jun 33                    443
## Jul 33                    416
## Aug 33                    213
## Sep 33                     39
## Oct 33                     58
## Nov 33                    104
## Dec 33                    241
## Jan 34                    456
## Feb 34                    353
## Mar 34                    344
## Apr 34                    491
## May 34                    549
## Jun 34                    525
## Jul 34                    376
## Aug 34                    212
## Sep 34                     35
## Oct 34                     32
## Nov 34                    142
## Dec 34                    206
## Jan 35                    405
## Feb 35                     71
## Mar 35                    320
## Apr 35                    309
## May 35                    406
## Jun 35                    264
## Jul 35                    247
```

```
## Aug 35 117
## Sep 35   1
## Oct 35   2
## Nov 35   9
## Dec 35  64
## Jan 36 158
## Feb 36  73
## Mar 36 201
## Apr 36 228
## May 36 447
## Jun 36 499
## Jul 36 372
## Aug 36 177
## Sep 36  16
## Oct 36   5
## Nov 36   7
## Dec 36 162
## Jan 37 277
## Feb 37  43
## Mar 37 198
## Apr 37 370
## May 37 503
## Jun 37 496
## Jul 37 273
## Aug 37  93
## Sep 37  33
## Oct 37  98
## Nov 37 160
## Dec 37 330
## Jan 38 224
## Feb 38 139
## Mar 38 153
## Apr 38  75
## May 38 345
## Jun 38 511
## Jul 38 323
## Aug 38 116
## Sep 38  29
## Oct 38  38
## Nov 38  92
## Dec 38 265
## Jan 39 360
## Feb 39 301
## Mar 39 541
## Apr 39 542
## May 39 561
## Jun 39 554
## Jul 39 547
## Aug 39 365
## Sep 39 169
## Oct 39  99
## Nov 39 140
## Dec 39 286
## Jan 40 231
```

```
## Feb 40                    102
## Mar 40                    357
## Apr 40                    364
## May 40                    459
## Jun 40                    388
## Jul 40                    374
## Aug 40                    229
## Sep 40                     28
## Oct 40                     10
## Nov 40                     55
## Dec 40                    225
## Jan 41                    312
## Feb 41                    109
## Mar 41                    114
## Apr 41                    324
## May 41                    453
## Jun 41                    420
## Jul 41                    417
## Aug 41                    165
## Sep 41                     19
## Oct 41                     24
## Nov 41                     31
## Dec 41                    143
## Jan 42                    164
## Feb 42                     27
## Mar 42                    288
## Apr 42                    331
## May 42                    378
## Jun 42                    346
## Jul 42                    291
## Aug 42                     84
## Sep 42                      6
## Oct 42                     22
## Nov 42                     49
## Dec 42                    194
## Jan 43                    260
## Feb 43                    168
## Mar 43                    266
## Apr 43                    180
## May 43                     80
## Jun 43                     91
## Jul 43                    113
## Aug 43                     54
## Sep 43                      3
## Oct 43                      8
## Nov 43                     59
## Dec 43                    216
## Jan 44                    310
## Feb 44                    252
## Mar 44                    380
## Apr 44                    321
## May 44                    305
## Jun 44                    208
## Jul 44                    122
```

```
## Aug 44  62
## Sep 44   4
## Oct 44  17
## Nov 44  40
## Dec 44 170
## Jan 45 352
## Feb 45 232
## Mar 45 462
## Apr 45 451
## May 45 536
## Jun 45 489
## Jul 45 349
## Aug 45 148
## Sep 45  47
## Oct 45  21
## Nov 45  68
## Dec 45 159
## Jan 46 272
## Feb 46 269
## Mar 46 306
## Apr 46 396
## May 46 475
## Jun 46 367
## Jul 46 275
## Aug 46 135
## Sep 46  44
## Oct 46  53
## Nov 46 128
## Dec 46 167
## Jan 47 239
## Feb 47 152
## Mar 47 302
## Apr 47 359
## May 47 494
## Jun 47 363
## Jul 47 242
## Aug 47 141
## Sep 47  25
## Oct 47  20
## Nov 47  57
## Dec 47  95
## Jan 48 211
## Feb 48 271
## Mar 48 176
## Apr 48 150
## May 48 427
## Jun 48 354
## Jul 48 303
## Aug 48 156
## Sep 48  23
## Oct 48  26
## Nov 48  69
## Dec 48  86
## Jan 49 268
```

```
## Feb 49                                90
## Mar 49                                89
## Apr 49                                30
## May 49                               132
## Jun 49                               189
## Jul 49                               105
## Aug 49                                72
## Sep 49                                12
```

Question 3

Compute mean and standard deviation for these three series.

```
print('Biomass: Mean =')
```

```
## [1] "Biomass: Mean ="
```

```
mean_bio = mean(ts_data[, 1])
mean_bio
```

```
## [1] 291.5778
```

```
print('Total Renewables: Mean =')
```

```
## [1] "Total Renewables: Mean ="
```

```
mean_rene = mean(ts_data[, 2])
mean_rene
```

```
## [1] 293
```

```
print('Hydro: Mean =')
```

```
## [1] "Hydro: Mean ="
```

```
mean_hydro = mean(ts_data[, 3])
mean_hydro
```

```
## [1] 293
```

```
print('Biomass: Standard deviation =')
```

```
## [1] "Biomass: Standard deviation ="
```

```
std_bio = sd(ts_data[, 1])
std_bio
```

```
## [1] 168.5232
```

```
print('Total Renewables: Standard deviation =')
```

```
## [1] "Total Renewables: Standard deviation ="
```

```
std_rene = sd(ts_data[, 2])
std_rene
```

```
## [1] 169.0192
```

```
print('Hydro: Standard deviation =')
```

```
## [1] "Hydro: Standard deviation ="
```

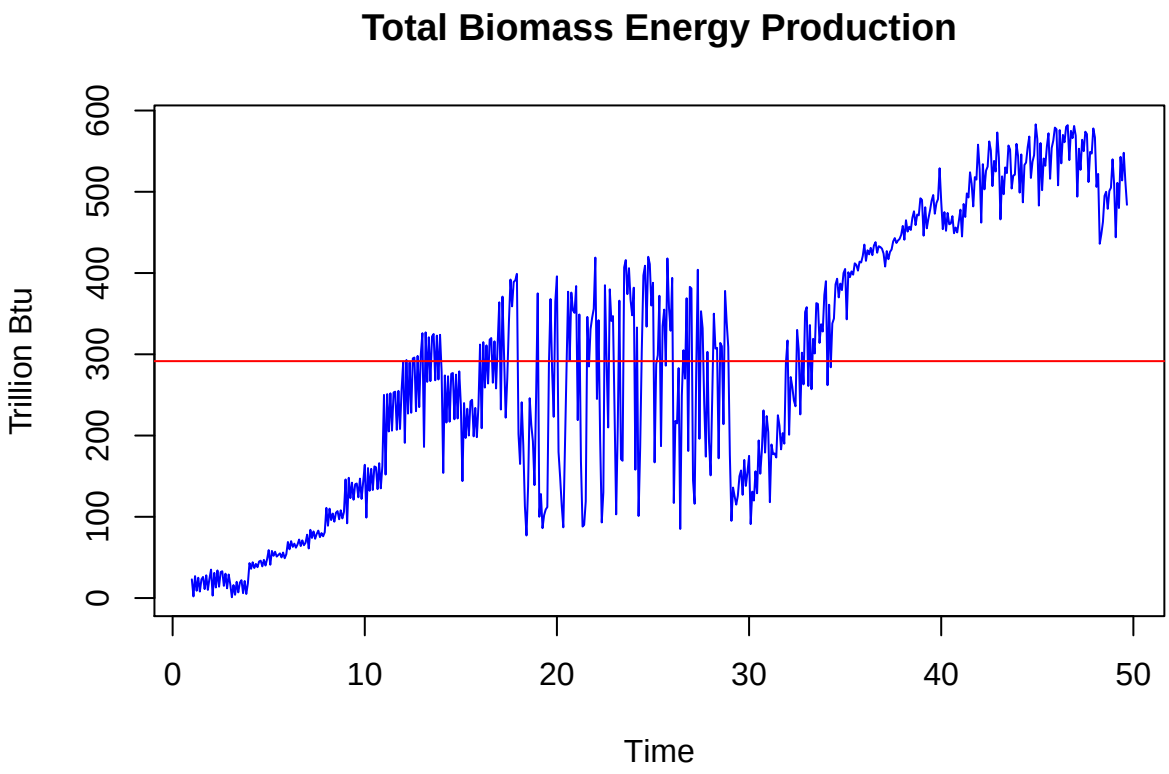
```
std_hydro = sd(ts_data[, 3])
std_hydro
```

```
## [1] 169.0192
```

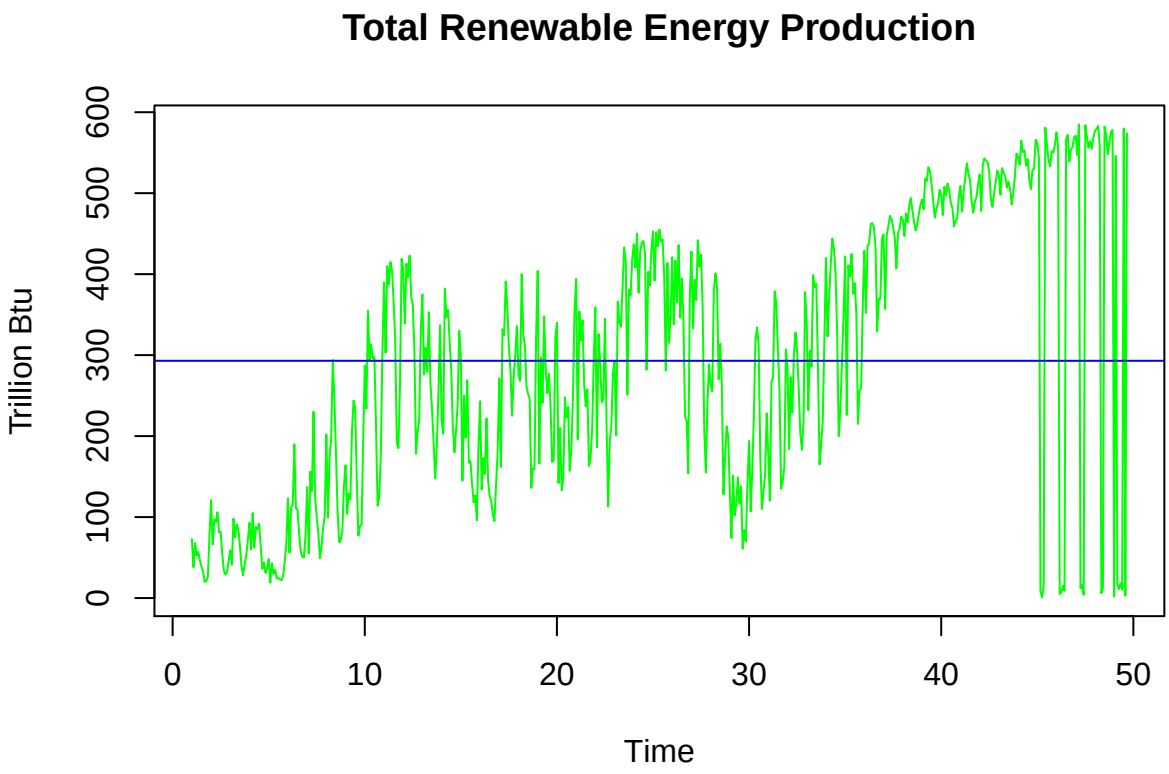
Question 4

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

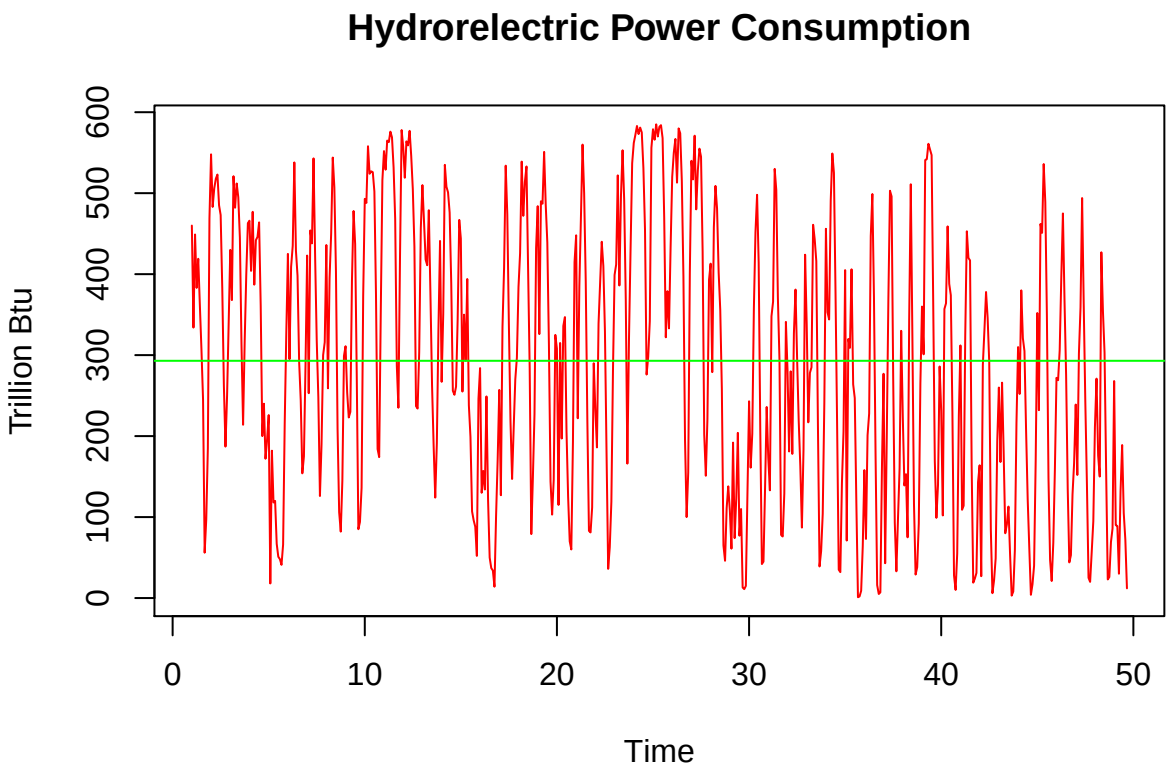
```
plot(ts_data[,1],type="l",col="blue",ylab="Trillion Btu",main="Total Biomass Energy Production")
abline(h=mean_bio, col="red")
```




```
plot(ts_data[,2],type="l",col="green",ylab="Trillion Btu",main="Total Renewable Energy Production")
abline(h=mean_rene, col="blue")
```




```
plot(ts_data[,3],type="l",col="red",ylab="Trillion Btu",main="Hydrorelectric Power Consumption")
abline(h=mean_hydro, col="green")
```



Question 5

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

```
cor(ts_data)
```

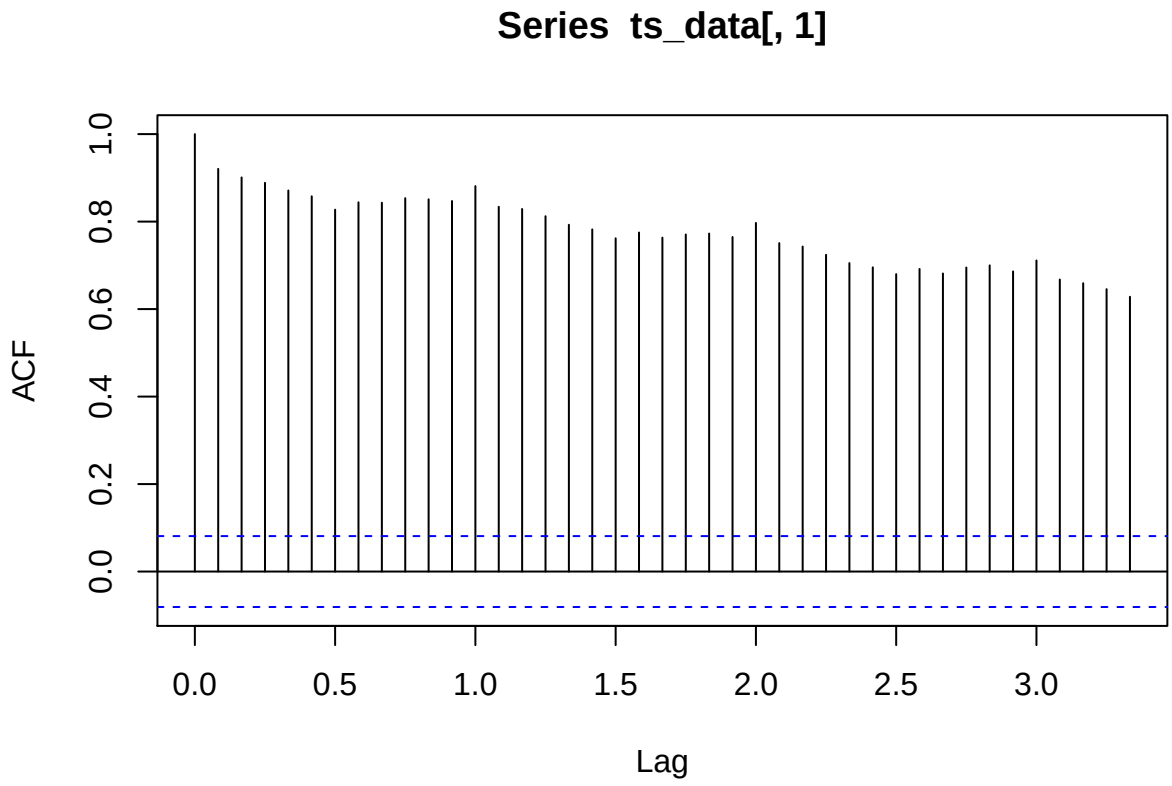
```
##                                    Total Biomass Energy Production
## Total Biomass Energy Production                          1.0000000
## Total Renewable Energy Production                        0.7325836
## Hydroelectric Power Consumption                         -0.2724661
##                                    Total Renewable Energy Production
## Total Biomass Energy Production                           0.73258363
## Total Renewable Energy Production                         1.00000000
## Hydroelectric Power Consumption                           0.06868406
##                                    Hydroelectric Power Consumption
## Total Biomass Energy Production                         -0.27246610
## Total Renewable Energy Production                        0.06868406
## Hydroelectric Power Consumption                          1.00000000
```

The correlation between Total Biomass Energy Production and Total Renewable Energy Production is a strong positive correlation, the coeffecient being 0.732. The correlation between Hydroelectric Power Consumption and Total Biomass Energy Production is a moderately strong negative correlation, the coefficient being -0.272. The correlation between Hydroelectric Power Consumption and Total Renewable Energy Production is a weak positive correlation, the coefficient being 0.0686.

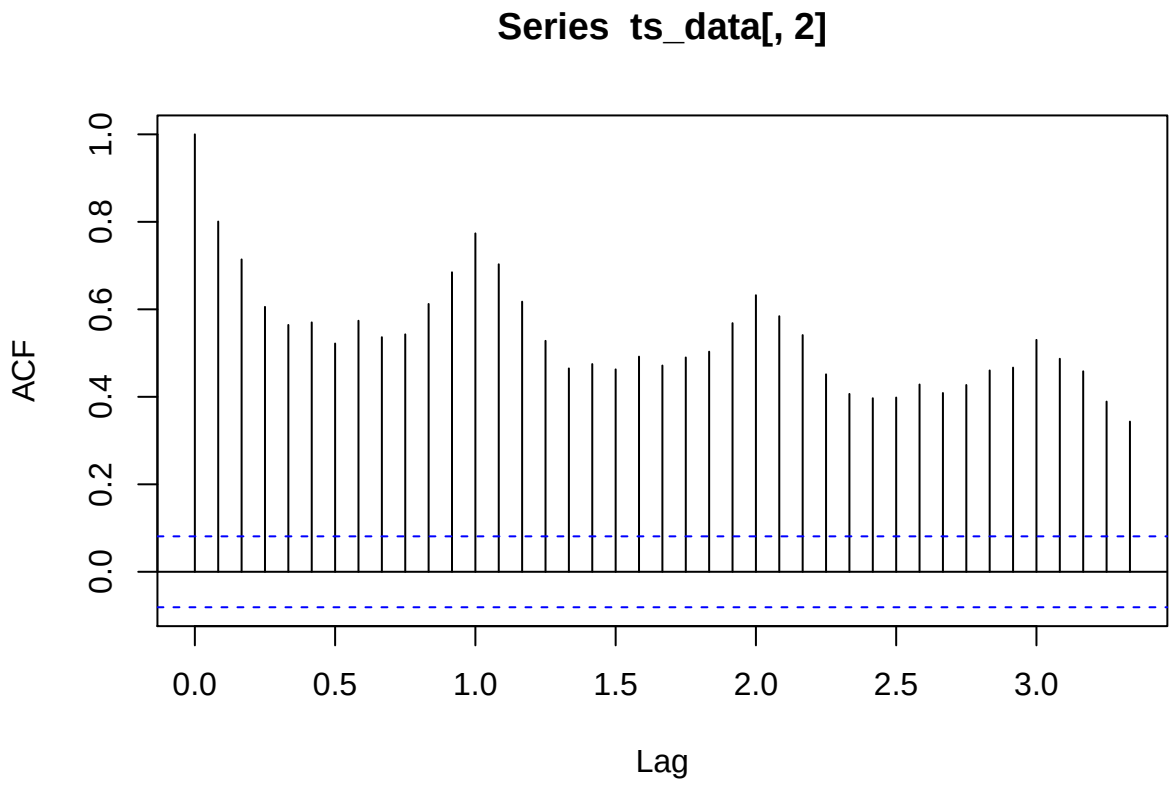
Question 6

Compute the autocorrelation function from lag 1 up to lag 40 for these three variables. What can you say about these plots? Do the three of them have the same behavior?

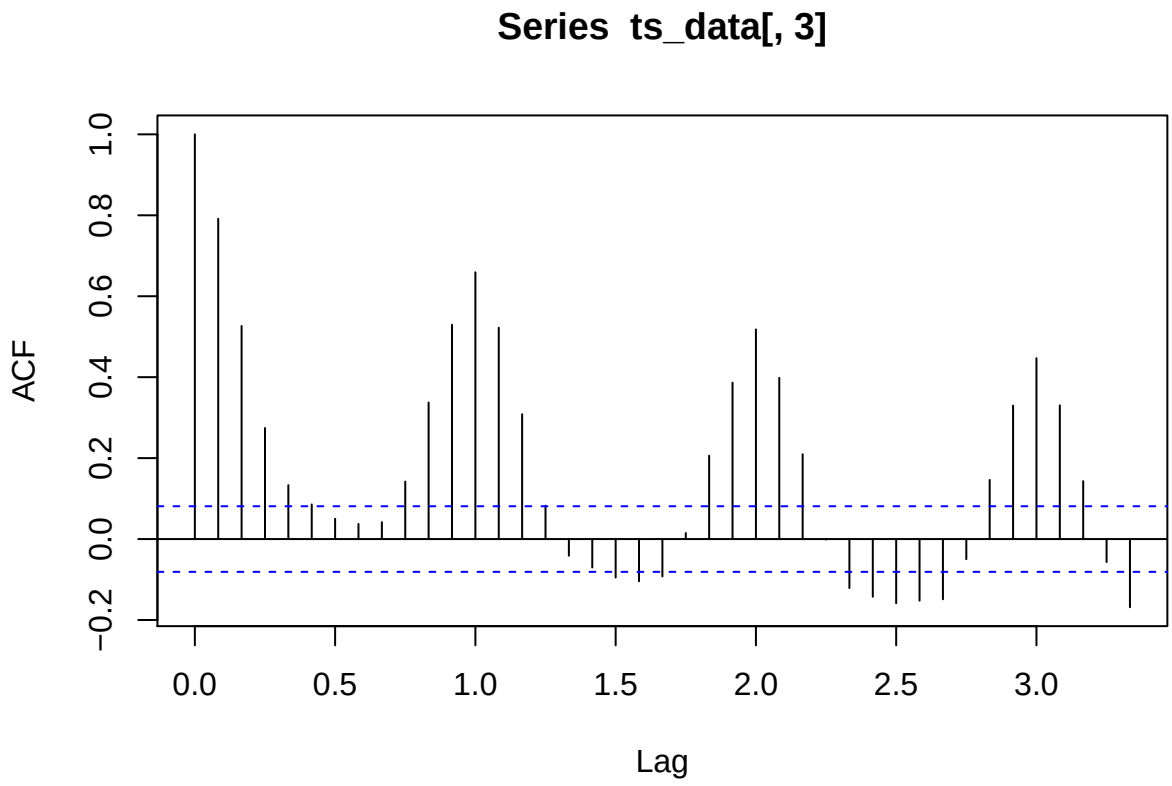
```
acf(x=ts_data[, 1], lag.max = 40)
```




```
acf(x=ts_data[, 2], lag.max = 40)
```




```
acf(x=ts_data[, 3], lag.max = 40)
```

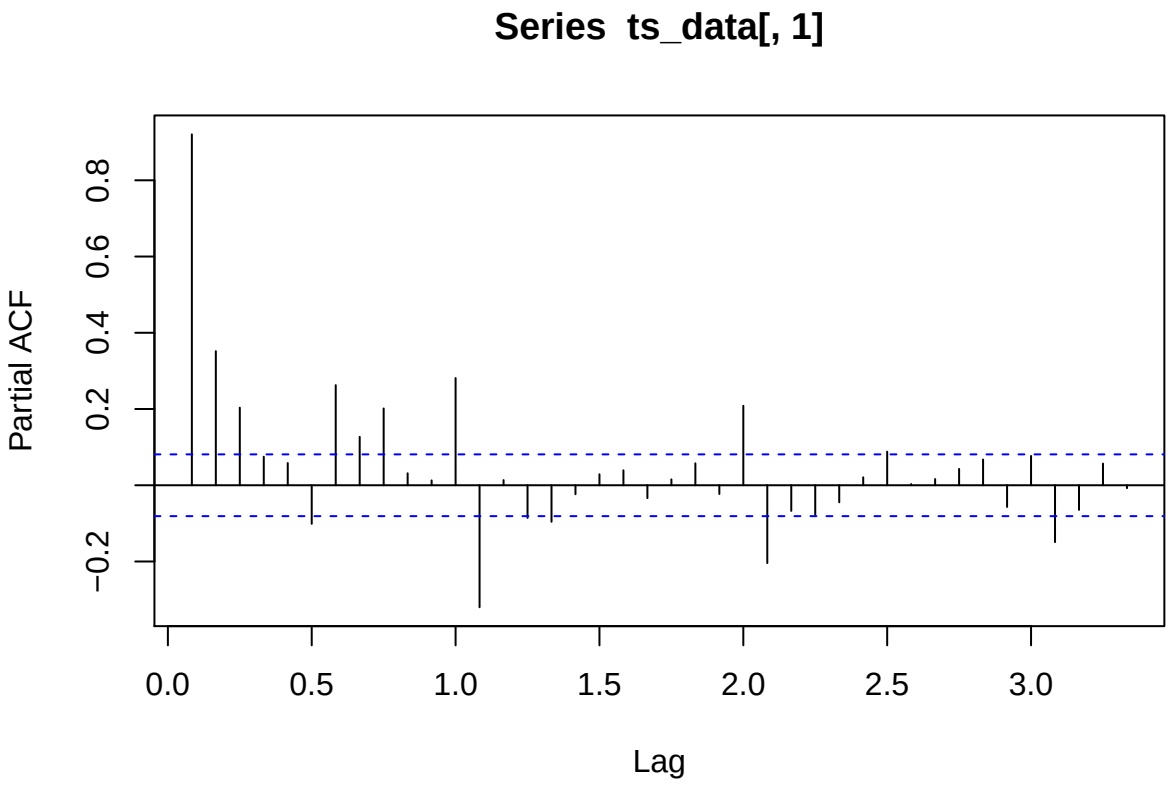


The ACF plot for Total Biomass Energy Production shows a decrease with increase in lag. The ACF plot for Total Renewable Energy Production shows a declining trend as well, for the most part, but there seems to be some sort of seasonality in the data, although not clearly observed. The ACF plot for Hydroelectric Power Consumption shows rapid increases and decreases, with increase in lag from 1 to 40, suggesting the unequivocal presence of seasonality.

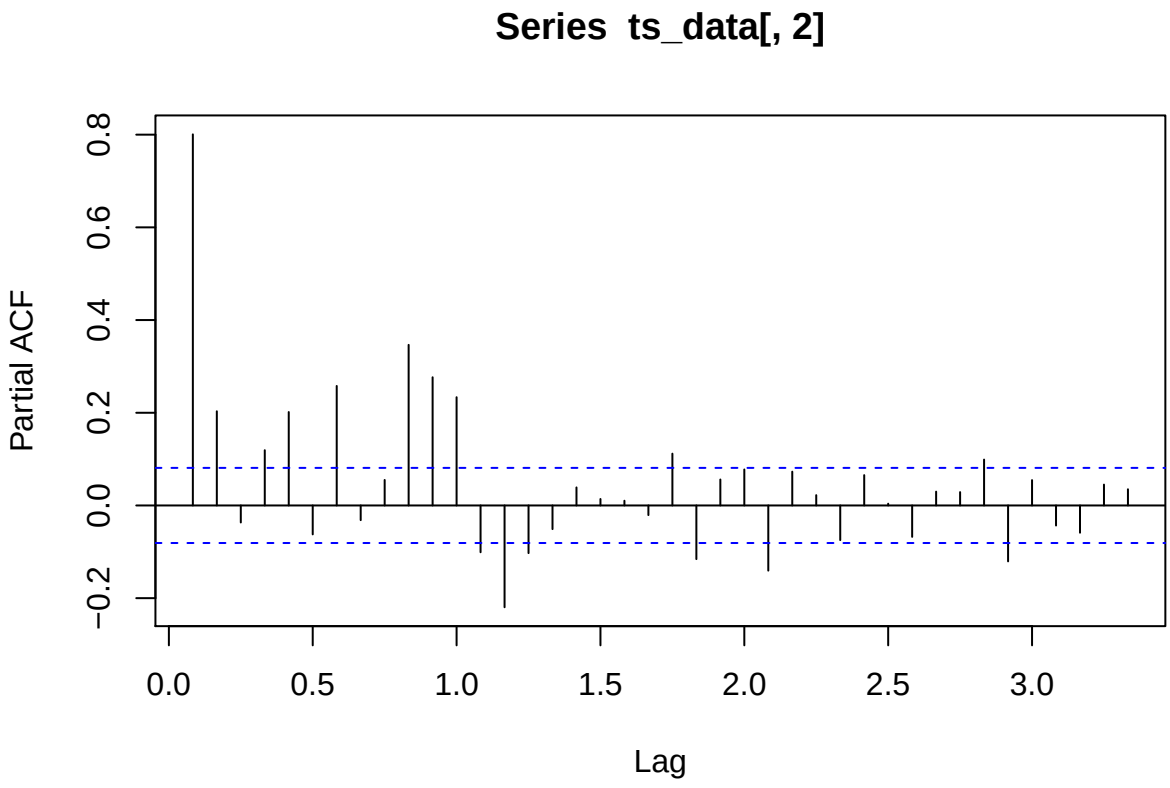
Question 7

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

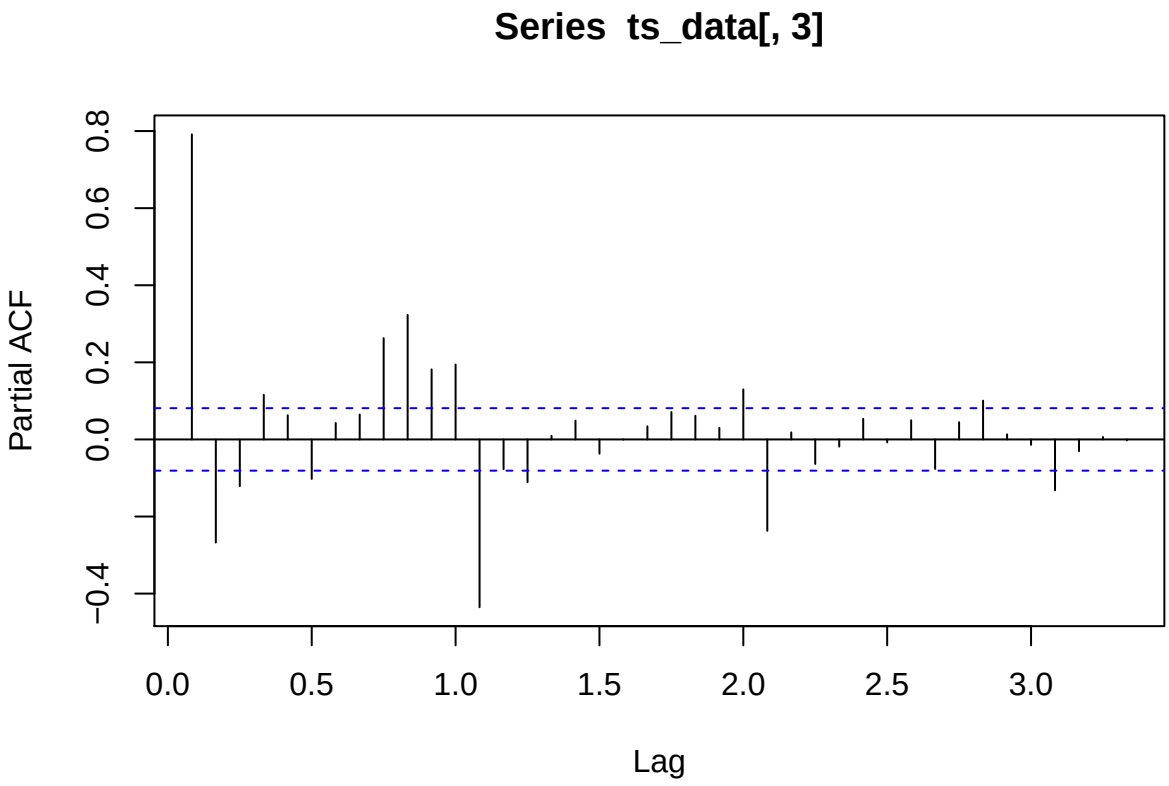
```
pacf(x=ts_data[, 1], lag.max = 40)
```




```
pacf(x=ts_data[, 2], lag.max = 40)
```




```
pacf(x=ts_data[, 3], lag.max = 40)
```



The PACF plots basically removes the influence of intermediary correlations, something that the ACF does not. All three PACF plots - Total Biomass Energy Production, Total Renewable Energy Production, and Hydroelectric Power Consumption suggests the presence of seasonality (although minimal for Total Biomass Energy Production & Total Renewable Energy Production). The ACF plots, obtained from Question 6, do not show this unequivocal presence of seasonality. Therefore, if we were to move forward building our ARIMA models by just plotting ACF to check for seasonality, we would be incorrect because, we'll arrive at the conclusion that the models are non-seasonal, meaning stationary - which is clearly wrong. Therefore, PACF plots are crucial to examine the presence of seasonality.