ENV 790.30 - Time Series Analysis for Energy Data | Spring 2024

Assignment 5 - Due date 02/19/24

Julia

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 file open on your local machine the first thing you will do is rename the file such that it includes your first and last name (e.g., "LuanaLima_TSA_A05_Sp23.Rmd"). Then change "Student Name" on line 4 with your name.

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

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

R packages needed for this assignment: "readxl", "ggplot2", "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(readxl)
library(stats)
library(tseries)
library(ggplot2)
library(Kendall)
library(lubridate)
```

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

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

```
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr   1.1.3     v stringr 1.5.0
## v forcats 1.0.0     v tibble  3.2.1
## v purrr   1.0.2     v tidyr   1.3.0
```

```
## v readr   2.1.4
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(cowplot)
```

```
##
## Attaching package: 'cowplot'
##
## The following object is masked from 'package:lubridate':
##
##     stamp
```

Decomposing Time Series

Consider the same data you used for A04 from the spreadsheet "Table_10.1_Renewable_Energy_Production_and_Consumptio
The data comes from the US Energy Information and Administration and corresponds to the December 2023 Monthly Energy Review.

```
#Importing data set - using xlsx package
energy_data <- read_excel("~/Julia_Kagiliery_TSA_Sp24/Data/Table_10.1_Renewable_Energy_Production_and_Co
    skip = 9)
energy_data <- energy_data[-1,]
```

```
view(energy_data)
```

start= 1973

Q1

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

```
energy_data <- energy_data |>
  select(c("Solar Energy Consumption", "Wind Energy Consumption", "Month"))

energy_data <- energy_data |>
   filter(
     `Solar Energy Consumption` != "Not Available",
     `Wind Energy Consumption` != "Not Available")

energy_data <- na.omit(energy_data)

energy_data <- energy_data |>
   mutate(
     `Solar Energy Consumption` = as.numeric(`Solar Energy Consumption`),
     `Wind Energy Consumption` = as.numeric(`Wind Energy Consumption`),
     Month = ymd(Month)
   )
```

Chat GPT prompt for ymd(): how to use my() function for date conversions

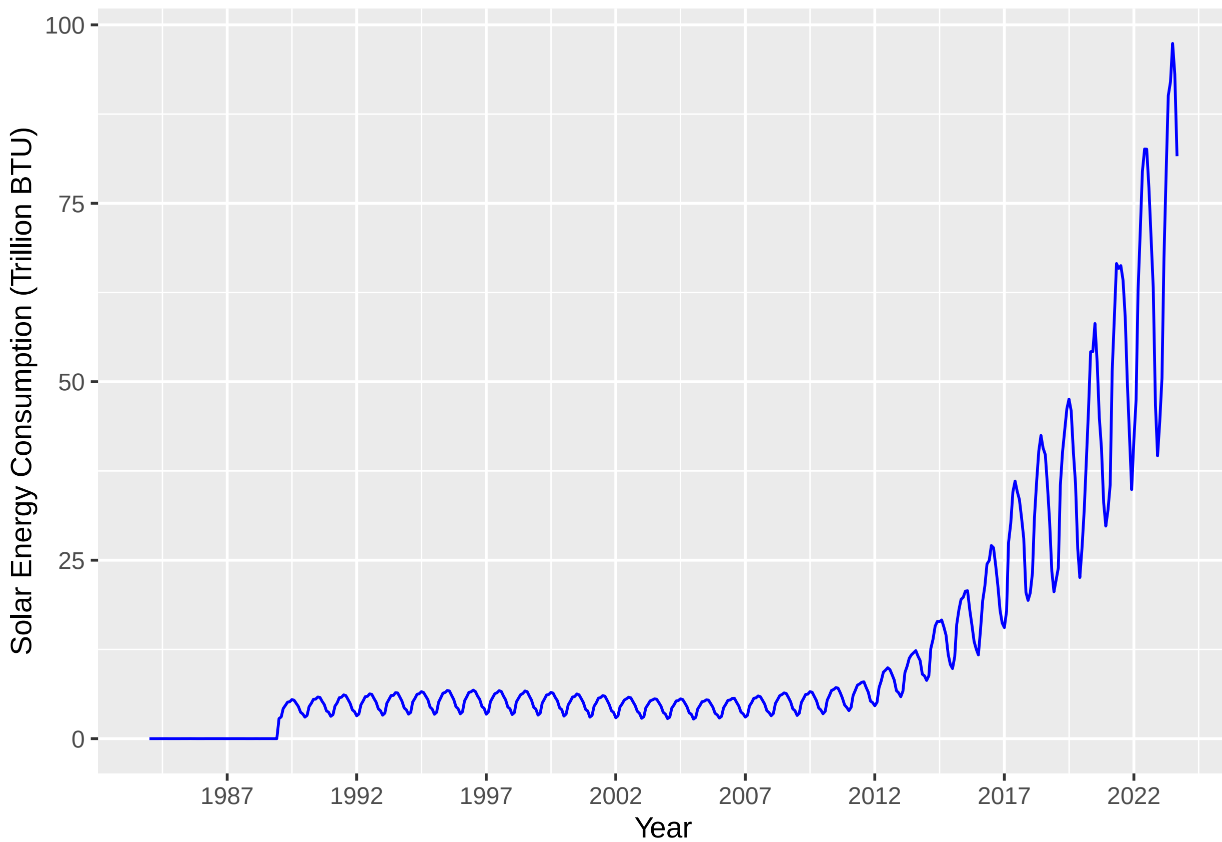
```r
nobs=nrow(energy_data)
nvar=ncol(energy_data)
```

```r
energyTS <- ts(energy_data)
```

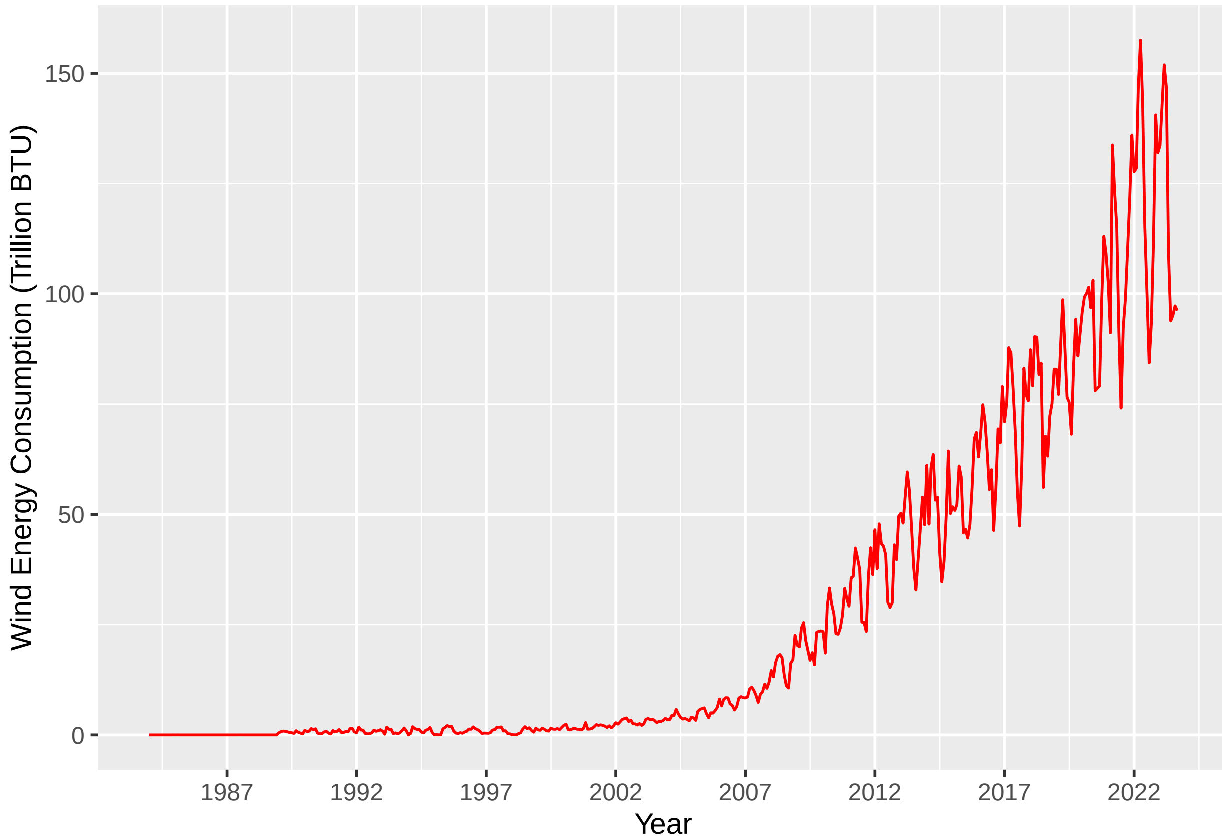
Q2

Plot the Solar and Wind energy consumption over time using ggplot. Plot each series on a separate graph. No need to add legend. Add informative names to the y axis using `ylab()`. 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")")`

```r
energy_data |>
ggplot(aes(x=Month, y= `Solar Energy Consumption`)) +
            geom_line(color="blue") +
  scale_x_date(date_breaks = "5 years", date_labels = "%Y") +
  ylab("Solar Energy Consumption (Trillion BTU)")+
  xlab("Year")
```



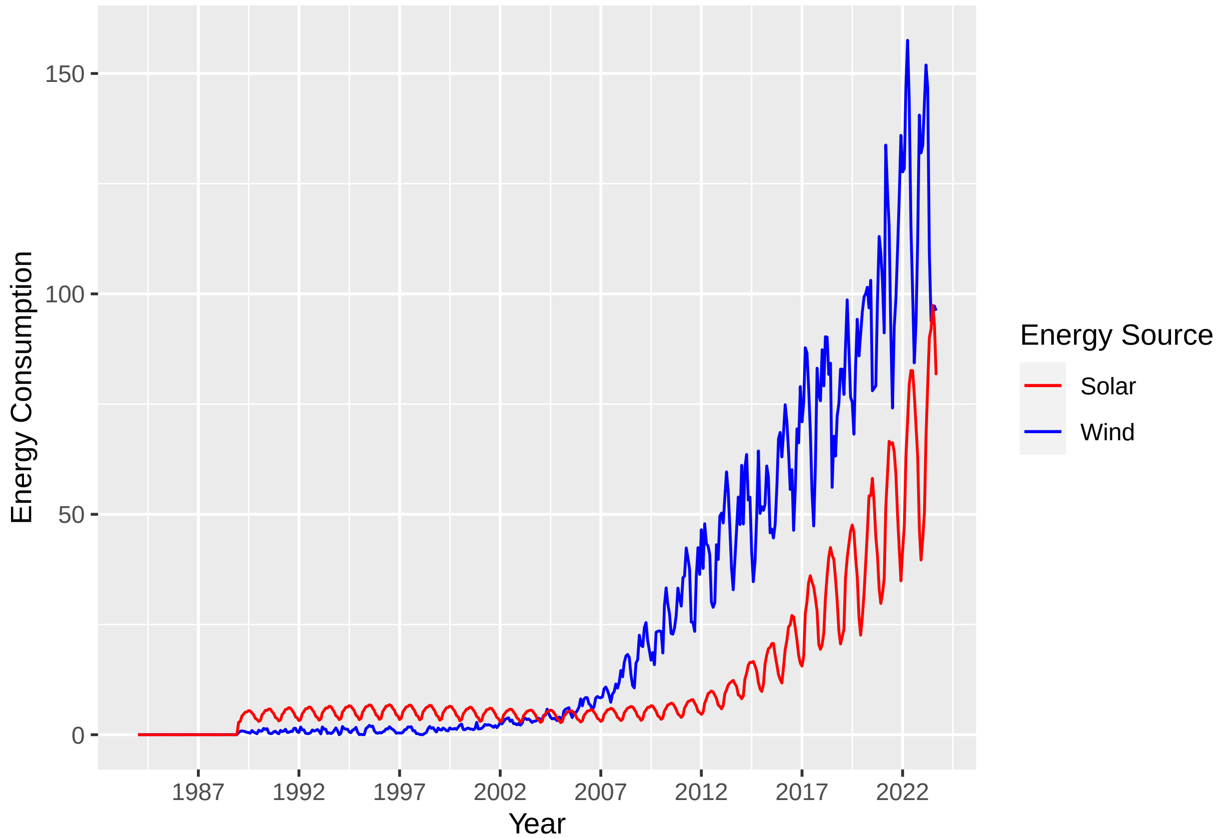

```r
energy_data |>
ggplot(aes(x=Month, y= `Wind Energy Consumption`)) +
            geom_line(color="red") +
  scale_x_date(date_breaks = "5 years", date_labels = "%Y") +
    ylab("Wind Energy Consumption (Trillion BTU)")+
  xlab("Year")
```



Q3

Now plot both series in the same graph, also using ggplot(). Use function `scale_color_manual()` to manually add a legend to ggplot. Make the solar energy consumption red and wind energy consumption blue. Add informative name to the y axis using `ylab("Energy Consumption)`. And use function `scale_x_date()` to set x axis breaks every 5 years.

```
energy_data |>
  ggplot(aes(x = Month, color = factor("Wind"), y = `Wind Energy Consumption`)) +
  geom_line() +
  geom_line(aes(x = Month, color = factor("Solar"), y = `Solar Energy Consumption`)) +
  scale_x_date(date_breaks = "5 years", date_labels = "%Y") +
  ylab("Energy Consumption") +
  xlab("Year") +
  scale_color_manual(name = "Energy Source", values = c("Wind" = "blue", "Solar" = "red"))
```



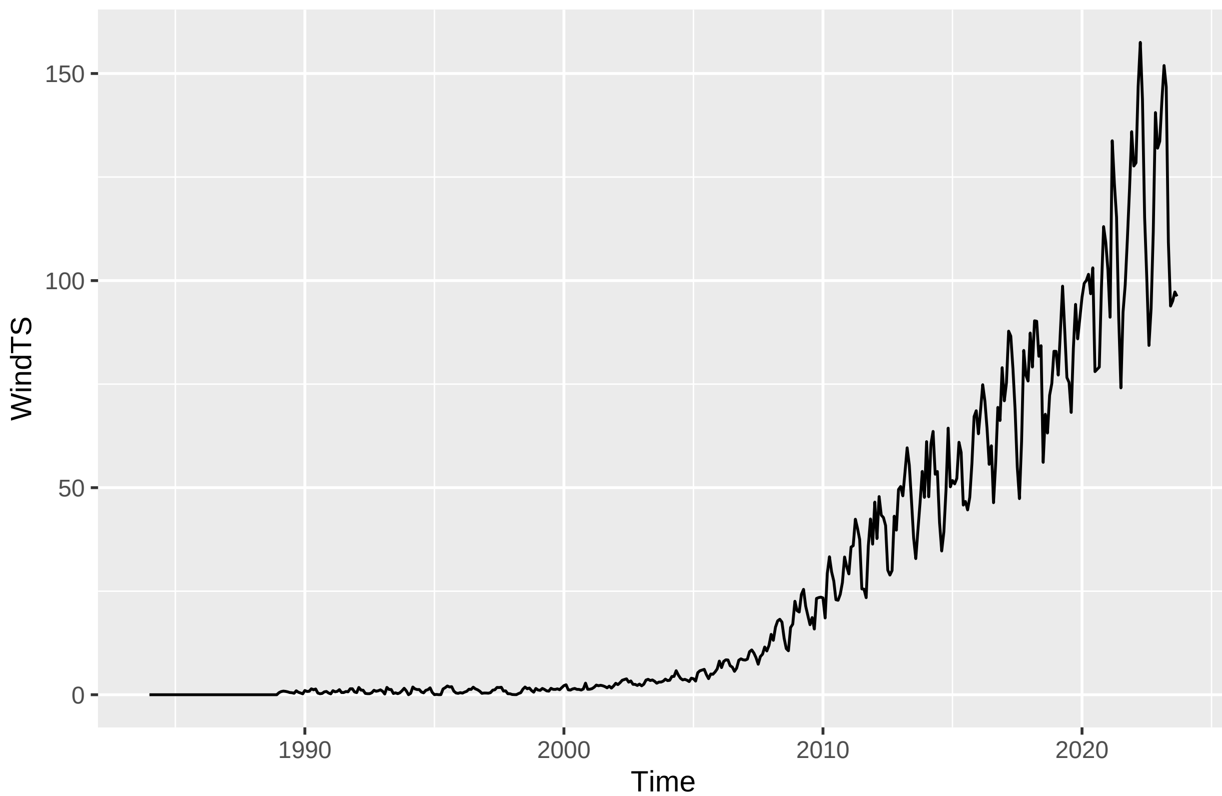
Code inspo: Chat GPT. Prompt: why isn't "scale_color_manual(values = colors)" adding a legend

Decomposing the time series

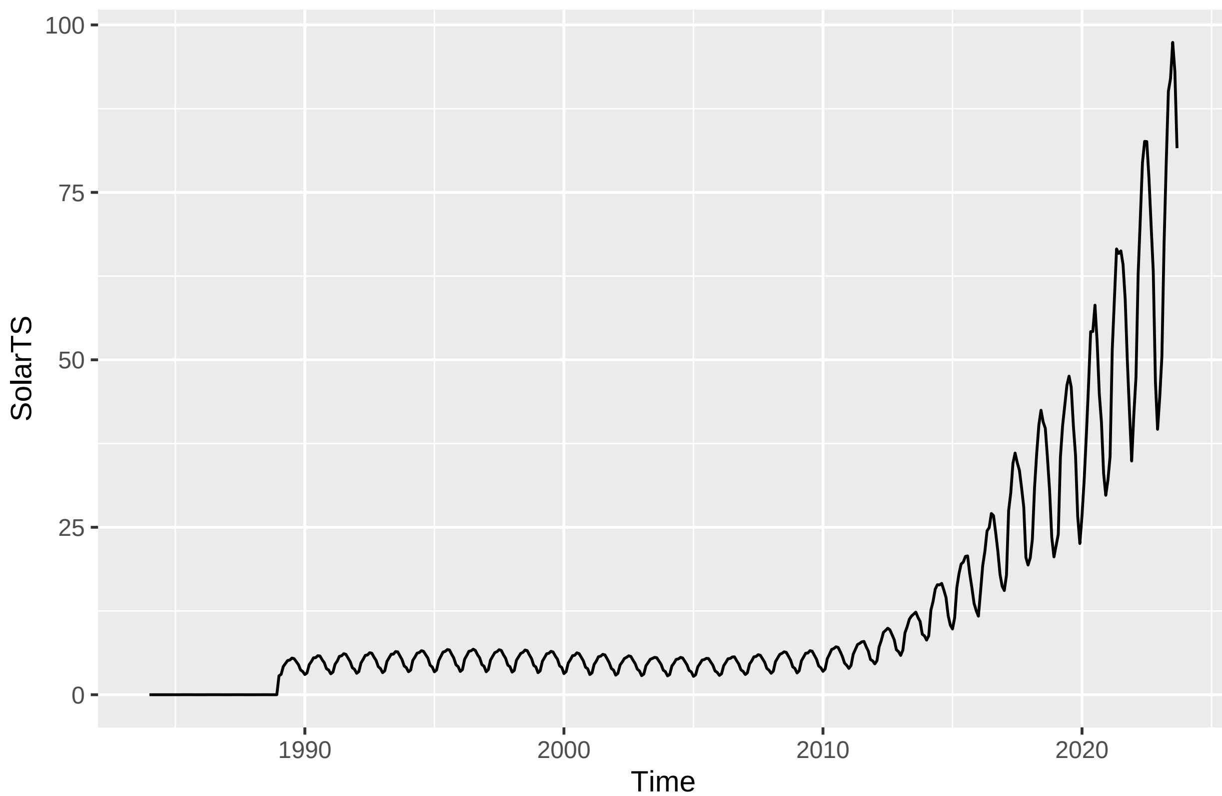
The stats package has a function called decompose(). This function only take time series object. As the name says the decompose function will decompose your time series into three components: trend, seasonal and random. This is similar to what we did in the previous script, but in a more automated way. The random component is the time series without seasonal and trend component.

```
WindTS <- ts(energy_data$`Wind Energy Consumption`, start = c(1984,1), frequency = 12)
SolarTS <- ts(energy_data$`Solar Energy Consumption`, start = c(1984,1), frequency = 12)
```

```
autoplot(WindTS)
```




```
autoplot(SolarTS)
```



Additional info on `decompose()`.

1) You have two options: alternative and multiplicative. Multiplicative models exhibit a change in frequency over time.
2) The trend is not a straight line because it uses a moving average method to detect trend.
3) The seasonal component of the time series is found by subtracting the trend component from the original data then grouping the results by month and averaging them.
4) The random component, also referred to as the noise component, is composed of all the leftover signal which is not explained by the combination of the trend and seasonal component.

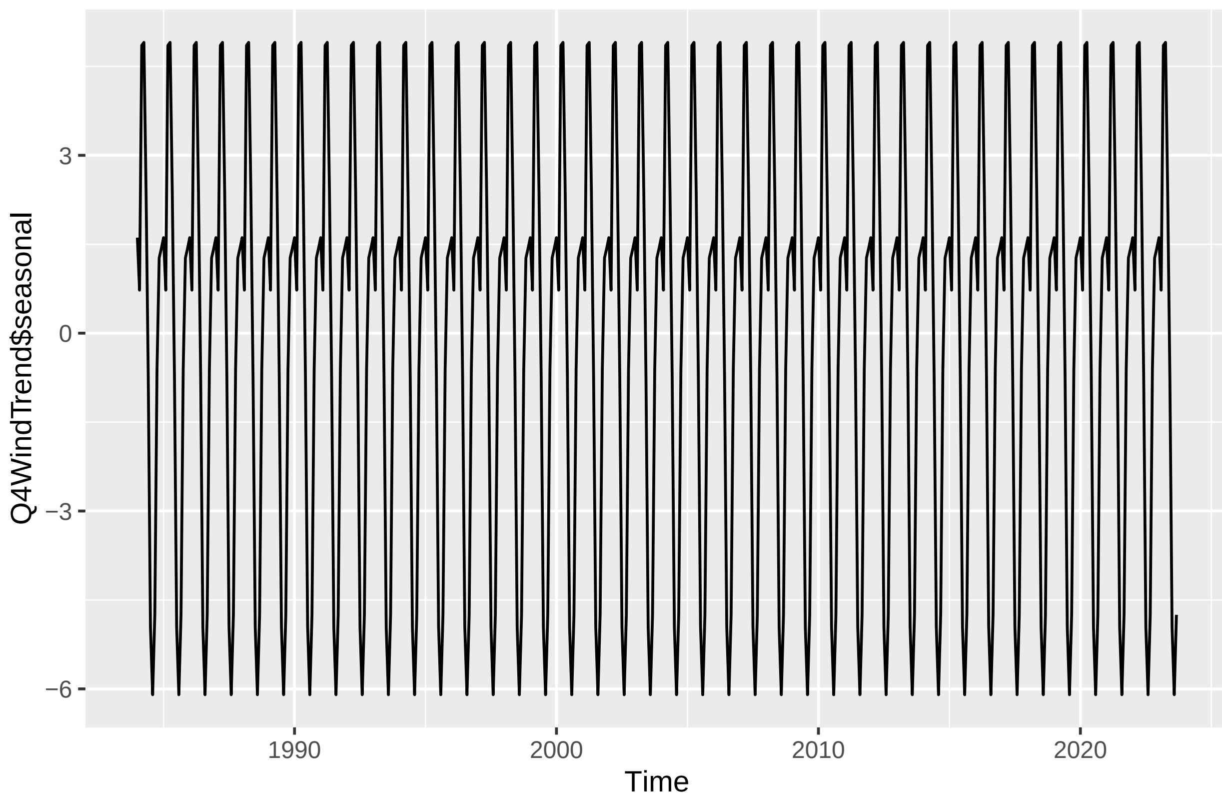
Q4

Transform wind and solar series into a time series object and apply the decompose function on them using the additive option, i.e., `decompose(ts_data, type = "additive")`. 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?

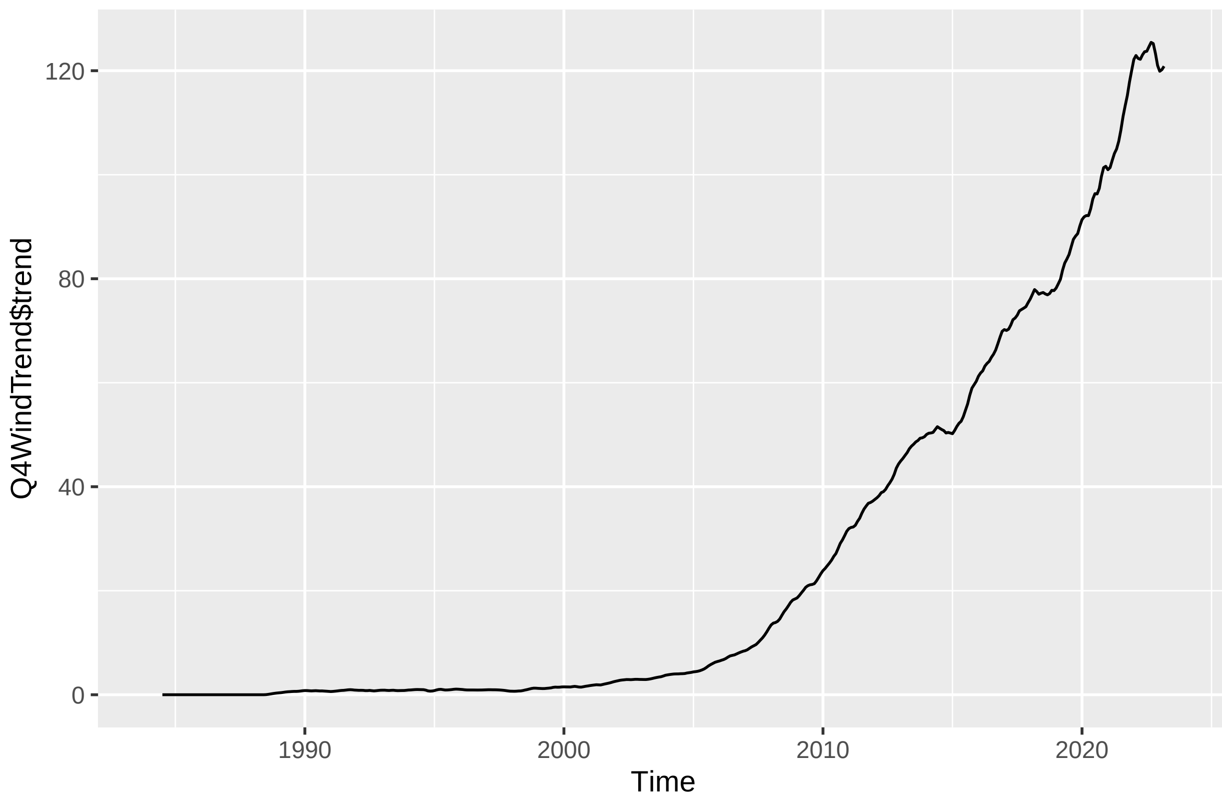
> Answer: The trend componet looks about how I would expect it: increasing. However, the random component does not look random at all; there certainly seems to be some seasonaility left. The random plots almost seem to imply that data before 2012 is one model and data after 2012 is a totally different one.

```r
Q4WindTrend <- decompose(WindTS, type = "additive")
```

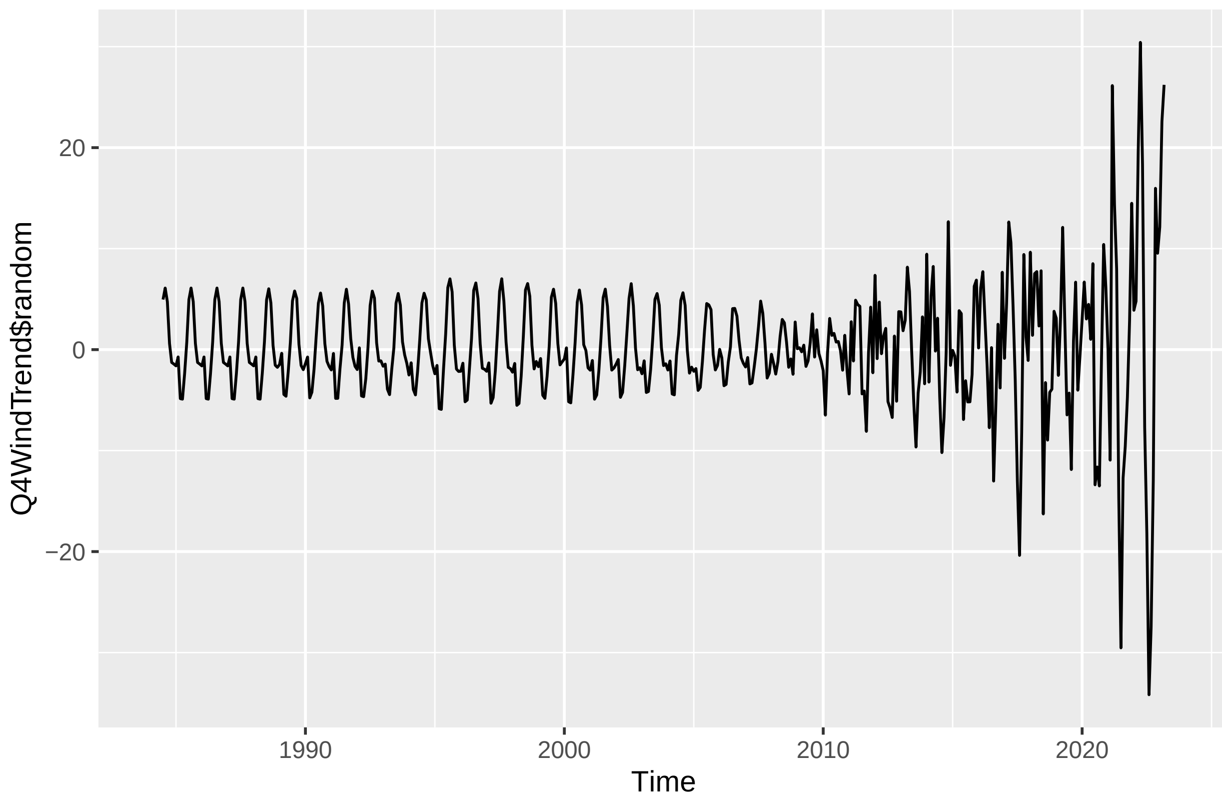
```r
autoplot(Q4WindTrend$seasonal)
```




```r
autoplot(Q4WindTrend$trend)
```




```
autoplot(Q4WindTrend$random)
```




```r
Q4SolarTrend <- print(decompose(SolarTS, type = "additive"))
```

```
## $x
##         Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## 1984  0.000 0.000 0.001 0.001 0.002 0.003 0.001 0.003 0.003 0.002
## 1985  0.002 0.000 0.000 0.004 0.005 0.005 0.004 0.007 0.005 0.003
## 1986  0.002 0.002 0.003 0.005 0.006 0.005 0.006 0.006 0.005 0.004
## 1987  0.000 0.002 0.003 0.004 0.004 0.006 0.006 0.004 0.003 0.002
## 1988  0.002 0.003 0.004 0.002 0.004 0.005 0.004 0.004 0.003 0.000
## 1989  2.821 3.041 4.220 4.660 5.109 5.175 5.476 5.389 4.941 4.501
## 1990  3.015 3.256 4.489 4.946 5.515 5.534 5.832 5.781 5.228 4.782
## 1991  3.125 3.369 4.561 5.026 5.739 5.803 6.133 6.035 5.487 4.935
## 1992  3.196 3.451 4.752 5.284 5.883 5.931 6.274 6.205 5.628 5.115
## 1993  3.288 3.570 4.954 5.515 6.053 6.058 6.445 6.401 5.818 5.243
## 1994  3.432 3.680 5.137 5.640 6.216 6.292 6.584 6.471 5.949 5.458
## 1995  3.415 3.692 5.105 5.735 6.370 6.471 6.750 6.674 6.047 5.471
## 1996  3.472 3.760 5.293 5.865 6.487 6.562 6.804 6.602 5.956 5.494
## 1997  3.422 3.762 5.176 5.748 6.292 6.433 6.721 6.612 5.958 5.437
## 1998  3.375 3.629 5.138 5.664 6.173 6.327 6.679 6.584 5.956 5.395
## 1999  3.294 3.570 4.984 5.536 6.121 6.184 6.482 6.377 5.775 5.311
## 2000  3.155 3.440 4.733 5.239 5.832 5.895 6.261 6.144 5.608 5.056
## 2001  3.008 3.261 4.542 5.020 5.672 5.755 6.029 5.947 5.380 4.773
## 2002  2.923 3.189 4.435 4.877 5.408 5.585 5.812 5.719 5.162 4.647
## 2003  2.848 3.083 4.334 4.795 5.298 5.421 5.579 5.522 5.034 4.535
## 2004  2.809 3.019 4.289 4.722 5.278 5.343 5.575 5.488 4.986 4.470
## 2005  2.742 2.968 4.158 4.638 5.178 5.247 5.438 5.396 4.894 4.399
```

```
## 2006  2.881  3.124  4.327  4.821  5.368  5.410  5.640  5.657  5.085  4.577
## 2007  3.016  3.269  4.579  5.051  5.658  5.707  5.981  5.886  5.367  4.848
## 2008  3.206  3.518  4.933  5.478  6.029  6.181  6.408  6.326  5.758  5.166
## 2009  3.247  3.578  5.053  5.614  6.200  6.229  6.582  6.501  5.892  5.307
## 2010  3.485  3.833  5.386  6.033  6.760  6.895  7.158  7.072  6.433  5.693
## 2011  3.924  4.374  6.043  6.760  7.496  7.667  7.903  7.958  7.178  6.507
## 2012  4.607  5.077  7.148  8.096  9.316  9.605  9.934  9.685  8.960  8.214
## 2013  5.869  6.663  9.260 10.151 11.264 11.745 12.038 12.336 11.551 10.946
## 2014  8.157  8.799 12.624 13.934 15.758 16.428 16.395 16.624 15.631 14.507
## 2015  9.815 11.480 15.989 18.058 19.510 19.804 20.660 20.720 18.026 15.938
## 2016 11.728 15.428 19.297 21.401 24.459 24.955 27.056 26.741 24.199 21.438
## 2017 15.555 17.857 27.472 30.175 34.567 36.083 34.635 33.492 30.881 28.042
## 2018 20.417 23.213 30.918 36.049 40.277 42.476 40.715 39.785 35.355 30.386
## 2019 22.249 23.942 35.490 40.146 43.146 46.198 47.572 45.914 40.157 35.724
## 2020 26.741 32.049 38.731 46.045 54.208 54.219 58.159 52.712 44.933 40.674
## 2021 32.034 35.565 51.477 59.068 66.559 65.882 66.269 64.229 59.026 49.778
## 2022 41.808 47.446 62.806 71.072 79.459 82.611 82.584 77.169 70.105 63.190
## 2023 44.432 50.523 67.312 79.380 90.079 92.024 97.397 93.068 81.595
##         Nov    Dec
## 1984  0.001  0.000
## 1985  0.001  0.001
## 1986  0.003  0.001
## 1987  0.001  0.001
## 1988  0.000  0.000
## 1989  3.697  3.465
## 1990  3.884  3.700
## 1991  4.034  3.792
## 1992  4.187  3.914
## 1993  4.297  4.039
## 1994  4.415  4.136
## 1995  4.473  4.192
## 1996  4.495  4.262
## 1997  4.424  4.187
## 1998  4.389  4.147
## 1999  4.307  4.068
## 2000  4.103  3.882
## 2001  3.905  3.675
## 2002  3.821  3.551
## 2003  3.669  3.452
## 2004  3.625  3.418
## 2005  3.547  3.335
## 2006  3.718  3.487
## 2007  3.922  3.662
## 2008  4.167  3.926
## 2009  4.300  4.023
## 2010  4.721  4.384
## 2011  5.259  5.056
## 2012  6.715  6.439
## 2013  9.028  8.800
## 2014 11.805 10.387
## 2015 13.628 12.547
## 2016 17.985 16.202
## 2017 20.501 19.362
## 2018 23.468 20.576
```

```
## 2019 26.634 22.573
## 2020 33.068 29.778
## 2021 42.082 34.895
## 2022 46.708 39.623
## 2023
##
## $seasonal
##               Jan         Feb         Mar         Apr         May         Jun
## 1984 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1985 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1986 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1987 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1988 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1989 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1990 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1991 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1992 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1993 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1994 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1995 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1996 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1997 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1998 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 1999 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2000 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2001 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2002 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2003 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2004 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2005 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2006 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2007 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2008 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2009 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2010 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2011 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2012 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2013 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2014 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2015 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2016 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2017 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2018 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2019 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2020 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2021 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2022 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
## 2023 -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
##               Jul         Aug         Sep         Oct         Nov         Dec
## 1984  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1985  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1986  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1987  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1988  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
```

```
## 1989  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1990  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1991  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1992  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1993  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1994  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1995  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1996  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1997  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1998  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 1999  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2000  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2001  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2002  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2003  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2004  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2005  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2006  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2007  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2008  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2009  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2010  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2011  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2012  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2013  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2014  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2015  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2016  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2017  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2018  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2019  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2020  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2021  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2022  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
## 2023  3.21594084  2.64254447  1.13678165
##
## $trend
##              Jan         Feb         Mar         Apr         May
## 1984          NA          NA          NA          NA          NA
## 1985 0.002291667 0.002583333 0.002833333 0.002958333 0.003000000
## 1986 0.003750000 0.003791667 0.003750000 0.003791667 0.003916667
## 1987 0.003666667 0.003583333 0.003416667 0.003250000 0.003083333
## 1988 0.003000000 0.002916667 0.002916667 0.002833333 0.002708333
## 1989 2.314416667 2.766791667 3.196916667 3.590208333 3.931791667
## 1990 4.533500000 4.564666667 4.592958333 4.616625000 4.636125000
## 1991 4.748375000 4.771500000 4.792875000 4.810041667 4.822666667
## 1992 4.915291667 4.928250000 4.941208333 4.954583333 4.968458333
## 1993 5.070541667 5.085833333 5.101916667 5.115166667 5.125083333
## 1994 5.225791667 5.234500000 5.242875000 5.257291667 5.271166667
## 1995 5.323666667 5.339041667 5.351583333 5.356208333 5.359166667
## 1996 5.422750000 5.422000000 5.415208333 5.412375000 5.414250000
## 1997 5.367041667 5.364000000 5.364500000 5.362208333 5.356875000
## 1998 5.302000000 5.299083333 5.297833333 5.296000000 5.292791667
## 1999 5.228375000 5.211541667 5.195375000 5.184333333 5.177416667
```

```
## 2000  5.041958333  5.023041667  5.006375000  4.988791667  4.969666667
## 2001  4.849666667  4.831791667  4.814083333  4.792791667  4.772750000
## 2002  4.668125000  4.649583333  4.631000000  4.616666667  4.607916667
## 2003  4.531208333  4.513291667  4.499750000  4.489750000  4.478750000
## 2004  4.437416667  4.435833333  4.432416667  4.427708333  4.423166667
## 2005  4.368708333  4.359166667  4.351500000  4.344708333  4.338500000
## 2006  4.420083333  4.439375000  4.458208333  4.473583333  4.488125000
## 2007  4.634541667  4.658291667  4.679583333  4.702625000  4.722416667
## 2008  4.935375000  4.971500000  5.006125000  5.035666667  5.059125000
## 2009  5.146583333  5.161125000  5.174000000  5.185458333  5.196875000
## 2010  5.440416667  5.488208333  5.534541667  5.573166667  5.606791667
## 2011  6.008125000  6.076083333  6.144041667  6.209000000  6.265333333
## 2012  7.060458333  7.217041667  7.363250000  7.508625000  7.640416667
## 2013  8.829250000  9.027375000  9.245791667  9.467583333  9.677791667
## 2014 11.881458333 12.241666667 12.590333333 12.908708333 13.172791667
## 2015 15.178125000 15.526500000 15.796958333 15.956375000 16.091958333
## 2016 18.498750000 19.016125000 19.524208333 20.010583333 20.421291667
## 2017 24.926625000 25.523708333 26.083416667 26.637000000 27.017000000
## 2018 30.275250000 30.790791667 31.239416667 31.523500000 31.744791667
## 2019 33.740375000 34.281458333 34.736916667 35.159416667 35.513750000
## 2020 39.655041667 40.379416667 40.861666667 41.266916667 41.741250000
## 2021 47.830333333 48.648125000 49.715208333 50.681750000 51.436666667
## 2022 59.136541667 60.355500000 61.356291667 62.376750000 63.128333333
## 2023 67.544625000 68.824291667 69.965500000           NA           NA
##               Jun          Jul          Aug          Sep          Oct
## 1984           NA  0.001500000  0.001583333  0.001541667  0.001625000
## 1985  0.003041667  0.003083333  0.003166667  0.003375000  0.003541667
## 1986  0.004000000  0.003916667  0.003833333  0.003833333  0.003791667
## 1987  0.003000000  0.003083333  0.003208333  0.003291667  0.003250000
## 1988  0.002625000  0.120041667  0.364083333  0.666333333  1.036083333
## 1989  4.230208333  4.382666667  4.399708333  4.419875000  4.443000000
## 1990  4.653708333  4.668083333  4.677375000  4.685083333  4.691416667
## 1991  4.832750000  4.839541667  4.845916667  4.857291667  4.876000000
## 1992  4.979916667  4.988833333  4.997625000  5.011000000  5.029041667
## 1993  5.134875000  5.146083333  5.156666667  5.168875000  5.181708333
## 1994  5.280125000  5.283458333  5.283250000  5.282416667  5.285041667
## 1995  5.363916667  5.368625000  5.373833333  5.384500000  5.397750000
## 1996  5.418083333  5.418916667  5.416916667  5.412125000  5.402375000
## 1997  5.350791667  5.345708333  5.338208333  5.331083333  5.326000000
## 1998  5.289666667  5.284625000  5.278791667  5.269916667  5.258166667
## 1999  5.170708333  5.161625000  5.150416667  5.134541667  5.111708333
## 2000  4.953416667  4.939541667  4.925958333  4.910541667  4.893458333
## 2001  4.755875000  4.743708333  4.737166667  4.729708333  4.719291667
## 2002  4.599250000  4.590958333  4.583416667  4.574791667  4.567166667
## 2003  4.468291667  4.462541667  4.458250000  4.453708333  4.448791667
## 2004  4.419916667  4.415708333  4.410791667  4.403208333  4.394250000
## 2005  4.331791667  4.334125000  4.346416667  4.359958333  4.374625000
## 2006  4.501583333  4.513541667  4.525208333  4.541750000  4.561833333
## 2007  4.738208333  4.753416667  4.771708333  4.796833333  4.829375000
## 2008  5.080333333  5.093041667  5.097250000  5.104750000  5.115416667
## 2009  5.206458333  5.220416667  5.240958333  5.265458333  5.296791667
## 2010  5.639375000  5.672708333  5.713541667  5.763458333  5.821125000
## 2011  6.315750000  6.372208333  6.429958333  6.505291667  6.607000000
## 2012  7.758708333  7.868916667  7.987583333  8.141666667  8.315291667
```

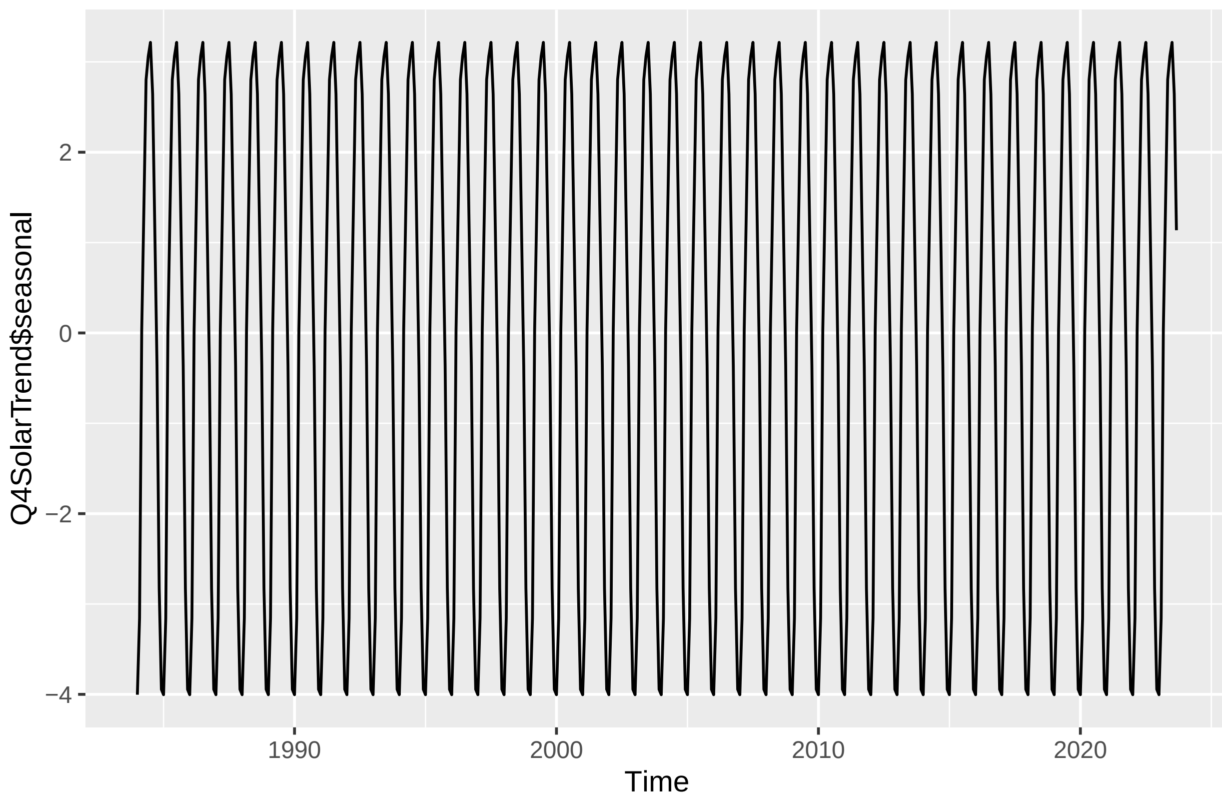
```
## 2013  9.872541667 10.066250000 10.250583333 10.479750000 10.777541667
## 2014 13.354625000 13.489833333 13.670625000 13.922541667 14.234583333
## 2015 16.257916667 16.427625000 16.671833333 16.974166667 17.251291667
## 2016 20.755125000 21.066875000 21.327541667 21.769375000 22.475583333
## 2017 27.253500000 27.587750000 28.013500000 28.380250000 28.768583333
## 2018 31.919000000 32.045916667 32.152625000 32.373500000 32.734708333
## 2019 35.728875000 35.999250000 36.524208333 36.997041667 37.377875000
## 2020 42.309541667 42.830291667 43.197333333 43.874916667 44.948625000
## 2021 52.025458333 52.645916667 53.548208333 54.515291667 55.487500000
## 2022 63.518083333 63.824416667 64.061958333 64.377916667 64.911833333
## 2023           NA           NA           NA           NA
##               Nov          Dec
## 1984  0.001875000  0.002083333
## 1985  0.003625000  0.003666667
## 1986  0.003666667  0.003625000
## 1987  0.003166667  0.003125000
## 1988  1.442875000  1.871000000
## 1989  4.471833333  4.503708333
## 1990  4.704083333  4.724625000
## 1991  4.892750000  4.904083333
## 1992  5.045750000  5.058125000
## 1993  5.193708333  5.210250000
## 1994  5.295416667  5.309291667
## 1995  5.408041667  5.416708333
## 1996  5.389375000  5.375875000
## 1997  5.317541667  5.308166667
## 1998  5.250666667  5.242541667
## 1999  5.087291667  5.063208333
## 2000  4.877666667  4.865166667
## 2001  4.702333333  4.684250000
## 2002  4.559166667  4.547750000
## 2003  4.444916667  4.440833333
## 2004  4.386583333  4.378416667
## 2005  4.390166667  4.404875000
## 2006  4.583500000  4.607958333
## 2007  4.862625000  4.897833333
## 2008  5.128208333  5.137333333
## 2009  5.337583333  5.388666667
## 2010  5.882083333  5.944916667
## 2011  6.738500000  6.895083333
## 2012  8.482083333  8.652416667
## 2013 11.122416667 11.504791667
## 2014 14.562750000 14.859750000
## 2015 17.596791667 18.017625000
## 2016 23.262333333 24.147166667
## 2017 29.251250000 29.755541667
## 2018 33.024958333 33.299583333
## 2019 38.084583333 38.879708333
## 2020 46.005875000 47.006458333
## 2021 56.525166667 57.759708333
## 2022 65.700500000 66.535208333
## 2023
##
## $random
```

```
##               Jan          Feb          Mar          Apr          May
## 1984           NA           NA           NA           NA           NA
## 1985   4.003914933  3.154645702 -0.035158785 -1.401495998 -2.801091393
## 1986   4.002456600  3.155437369 -0.033075452 -1.401329332 -2.801008060
## 1987   4.000539933  3.155645702 -0.032742118 -1.401787665 -2.802174726
## 1988   4.003206600  3.157312369 -0.031242118 -1.403370998 -2.801799726
## 1989   4.510789933  3.431437369  0.990757882 -0.332745998 -1.625883060
## 1990   2.485706600  1.848562369 -0.136283785 -1.073162665 -1.924216393
## 1991   2.380831600  1.754729035 -0.264200452 -1.186579332 -1.886758060
## 1992   2.284914933  1.679979035 -0.221533785 -1.073120998 -1.888549726
## 1993   2.221664933  1.641395702 -0.180242118 -1.002704332 -1.875174726
## 1994   2.210414933  1.602729035 -0.138200452 -1.019829332 -1.858258060
## 1995   2.095539933  1.510187369 -0.278908785 -1.023745998 -1.792258060
## 1996   2.053456600  1.495229035 -0.154533785 -0.949912665 -1.730341393
## 1997   2.059164933  1.555229035 -0.220825452 -1.016745998 -1.867966393
## 1998   2.077206600  1.487145702 -0.192158785 -1.034537665 -1.922883060
## 1999   2.069831600  1.515687369 -0.243700452 -1.050870998 -1.859508060
## 2000   2.117248266  1.574187369 -0.305700452 -1.152329332 -1.940758060
## 2001   2.162539933  1.586437369 -0.304408785 -1.175329332 -1.903841393
## 2002   2.259081600  1.696645702 -0.228325452 -1.142204332 -2.003008060
## 2003   2.320998266  1.726937369 -0.198075452 -1.097287665 -1.983841393
## 2004   2.375789933  1.740395702 -0.175742118 -1.108245998 -1.948258060
## 2005   2.377498266  1.766062369 -0.225825452 -1.109245998 -1.963591393
## 2006   2.465123266  1.841854035 -0.163533785 -1.055120998 -1.923216393
## 2007   2.385664933  1.767937369 -0.132908785 -1.054162665 -1.867508060
## 2008   2.274831600  1.703729035 -0.105450452 -0.960204332 -1.833216393
## 2009   2.104623266  1.574104035 -0.153325452 -0.973995998 -1.799966393
## 2010   2.048789933  1.502020702 -0.180867118 -0.942704332 -1.649883060
## 2011   1.920081600  1.455145702 -0.133367118 -0.851537665 -1.572424726
## 2012   1.550748266  1.017187369 -0.247575452 -0.815162665 -1.127508060
## 2013   1.043956600  0.792854035 -0.018117118 -0.719120998 -1.216883060
## 2014   0.279748266 -0.285437631  0.001341215 -0.377245998 -0.217883060
## 2015  -1.358918400 -0.889270965  0.159716215  0.699087335  0.614950274
## 2016  -2.766543400 -0.430895965 -0.259533785 -0.012120998  1.234616940
## 2017  -5.367418400 -4.509479298  1.356257882  2.135462335  4.746908607
## 2018  -5.854043400 -4.420562631 -0.353742118  3.122962335  5.729116940
## 2019  -7.487168400 -7.182229298  0.720757882  3.584045668  4.829158607
## 2020  -8.909835067 -5.173187631 -2.162992118  3.375545668  9.663658607
## 2021 -11.792126734 -9.925895965  1.729466215  6.983712335 12.319241940
## 2022 -13.324335067 -9.752270965  1.417382882  7.292712335 13.527575274
## 2023 -19.108418400 -15.144062631 -2.685825452           NA           NA
##               Jun          Jul          Aug          Sep          Oct
## 1984           NA -3.216440836 -2.641127802 -1.135323315  0.363774976
## 1985  -3.060551919 -3.215024170 -2.638711135 -1.135156648  0.362858309
## 1986  -3.061510253 -3.213857503 -2.640377802 -1.135614982  0.363608309
## 1987  -3.059510253 -3.213024170 -2.641752802 -1.137073315  0.362149976
## 1988  -3.060135253 -3.331982503 -3.002627802 -1.800114982 -0.672683358
## 1989  -2.117718586 -2.122607503 -1.653252802 -0.615656648  0.421399976
## 1990  -2.182218586 -2.052024170 -1.538919469 -0.593864982  0.453983309
## 1991  -2.092260253 -1.922482503 -1.453461135 -0.507073315  0.422399976
## 1992  -2.111426919 -1.930774170 -1.435169469 -0.519781648  0.449358309
## 1993  -2.139385253 -1.917024170 -1.398211135 -0.487656648  0.424691642
## 1994  -2.050635253 -1.915399170 -1.454794469 -0.470198315  0.536358309
## 1995  -1.955426919 -1.834565836 -1.342377802 -0.474281648  0.436649976
```

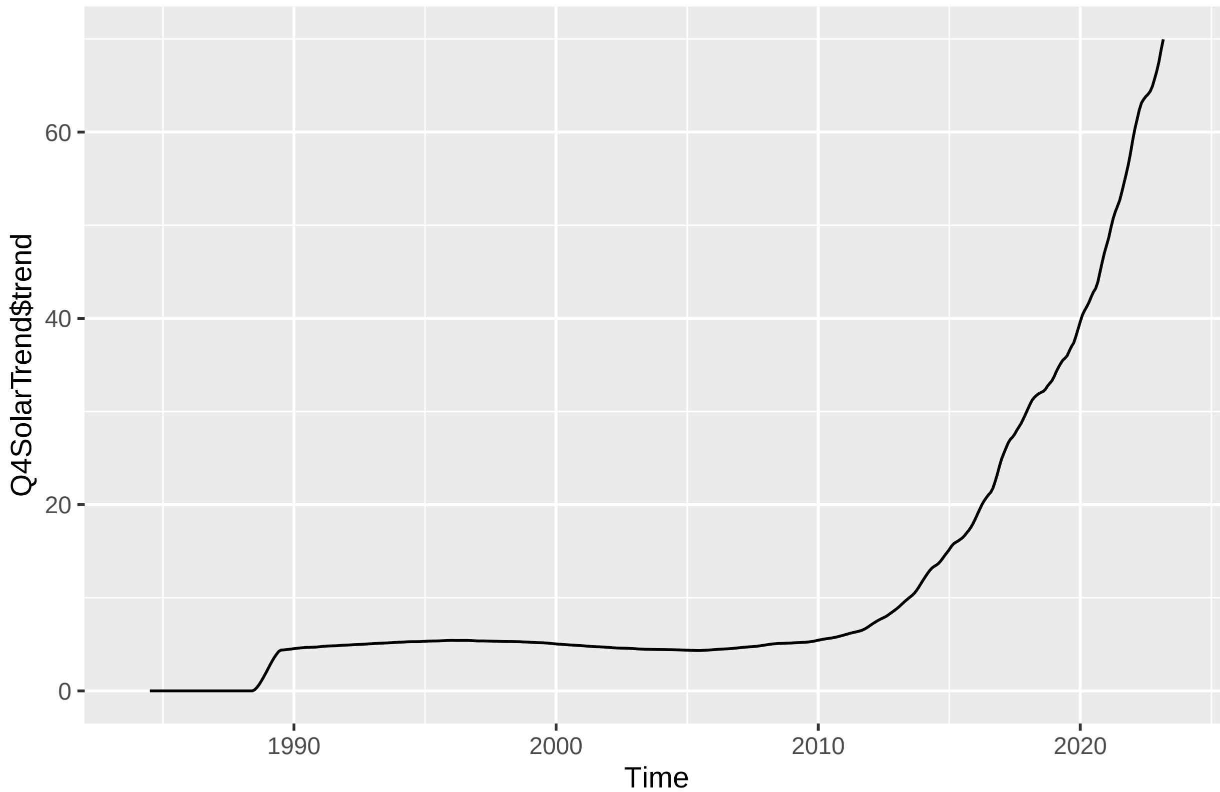
```
## 1996  -1.918593586  -1.830857503  -1.457461135  -0.592906648   0.455024976
## 1997  -1.980301919  -1.840649170  -1.368752802  -0.509864982   0.474399976
## 1998  -2.025176919  -1.821565836  -1.337336135  -0.450698315   0.500233309
## 1999  -2.049218586  -1.895565836  -1.415961135  -0.496323315   0.562691642
## 2000  -2.120926919  -1.894482503  -1.424502802  -0.439323315   0.525941642
## 2001  -2.063385253  -1.930649170  -1.432711135  -0.486489982   0.417108309
## 2002  -2.076760253  -1.994899170  -1.506961135  -0.549573315   0.443233309
## 2003  -2.109801919  -2.099482503  -1.578794469  -0.556489982   0.449608309
## 2004  -2.139426919  -2.056649170  -1.565336135  -0.553989982   0.439149976
## 2005  -2.147301919  -2.112065836  -1.592961135  -0.602739982   0.387774976
## 2006  -2.154093586  -2.089482503  -1.510752802  -0.593531648   0.378566642
## 2007  -2.093718586  -1.988357503  -1.528252802  -0.566614982   0.382024976
## 2008  -1.961843586  -1.900982503  -1.413794469  -0.483531648   0.413983309
## 2009  -2.039968586  -1.854357503  -1.382502802  -0.510239982   0.373608309
## 2010  -1.806885253  -1.730649170  -1.284086135  -0.467239982   0.235274976
## 2011  -1.711260253  -1.685149170  -1.114502802  -0.464073315   0.263399976
## 2012  -1.216218586  -1.150857503  -0.945127802  -0.318448315   0.262108309
## 2013  -1.190051919  -1.244190836  -0.557127802  -0.065531648   0.531858309
## 2014   0.010864747  -0.310774170   0.310830531   0.571676685   0.635816642
## 2015   0.483573081   1.016434164   1.405622198  -0.084948315  -0.949891691
## 2016   1.137364747   2.773184164   2.770913865   1.292843352  -0.674183358
## 2017   5.766989747   3.831309164   2.835955531   1.363968352  -0.363183358
## 2018   7.494489747   5.453142497   4.989830531   1.844718352  -1.985308358
## 2019   7.406614747   8.356809164   6.747247198   2.023176685  -1.290475024
## 2020   8.846948081  12.112767497   6.872122198  -0.078698315  -3.911225024
## 2021  10.794031414  10.407142497   8.038247198   3.373926685  -5.346100024
## 2022  16.030406414  15.543642497  10.464497198   4.590301685  -1.358433358
## 2023            NA            NA            NA            NA
##                Nov           Dec
## 1984   2.825131813   3.942805959
## 1985   2.823381813   3.942222625
## 1986   2.825340147   3.942264292
## 1987   2.823840147   3.942764292
## 1988   1.383131813   2.073889292
## 1989   2.051173480   2.906180959
## 1990   2.005923480   2.920264292
## 1991   1.967256813   2.832805959
## 1992   1.967256813   2.800764292
## 1993   1.929298480   2.773639292
## 1994   1.945590147   2.771597625
## 1995   1.890965147   2.720180959
## 1996   1.931631813   2.831014292
## 1997   1.932465147   2.823722625
## 1998   1.964340147   2.849347625
## 1999   2.045715147   2.949680959
## 2000   2.051340147   2.961722625
## 2001   2.028673480   2.935639292
## 2002   2.087840147   2.948139292
## 2003   2.050090147   2.956055959
## 2004   2.064423480   2.984472625
## 2005   1.982840147   2.875014292
## 2006   1.960506813   2.823930959
## 2007   1.885381813   2.709055959
## 2008   1.864798480   2.733555959
```

```
## 2009   1.788423480   2.579222625
## 2010   1.664923480   2.383972625
## 2011   1.346506813   2.105805959
## 2012   1.058923480   1.731472625
## 2013   0.731590147   1.240097625
## 2014   0.068256813  -0.527860708
## 2015  -1.142784853  -1.525735708
## 2016  -2.451326520  -4.000277375
## 2017  -5.924243187  -6.448652375
## 2018  -6.730951520  -8.778694041
## 2019  -8.624576520 -12.361819041
## 2020 -10.111868187 -13.283569041
## 2021 -11.617159853 -18.919819041
## 2022 -16.166493187 -22.967319041
## 2023
##
## $figure
##  [1] -4.00420660 -3.15722904  0.03232545  1.40253766  2.80309139  3.06251025
##  [7]  3.21594084  2.64254447  1.13678165 -0.36339998 -2.82600681 -3.94488929
##
## $type
## [1] "additive"
##
## attr(,"class")
## [1] "decomposed.ts"
```

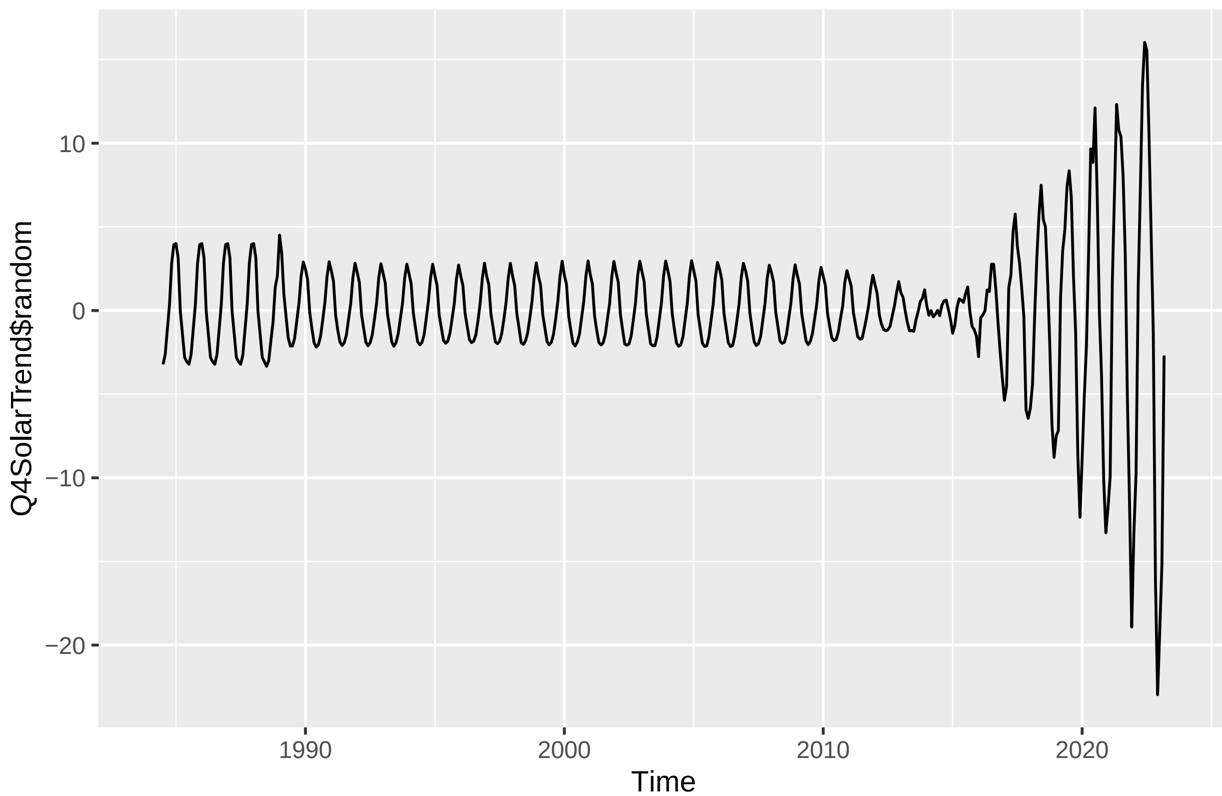
```r
autoplot(Q4SolarTrend$seasonal)
```




```r
autoplot(Q4SolarTrend$trend)
```




```
autoplot(Q4SolarTrend$random)
```



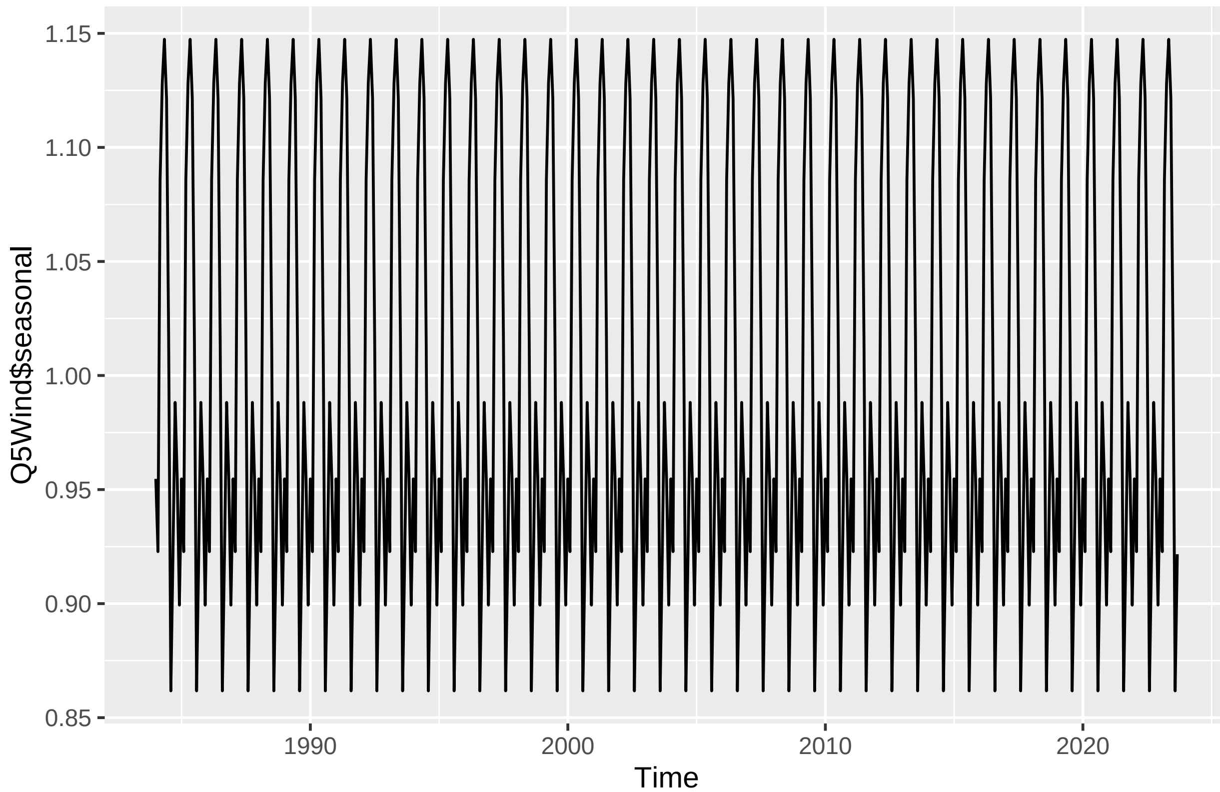
Q5

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?

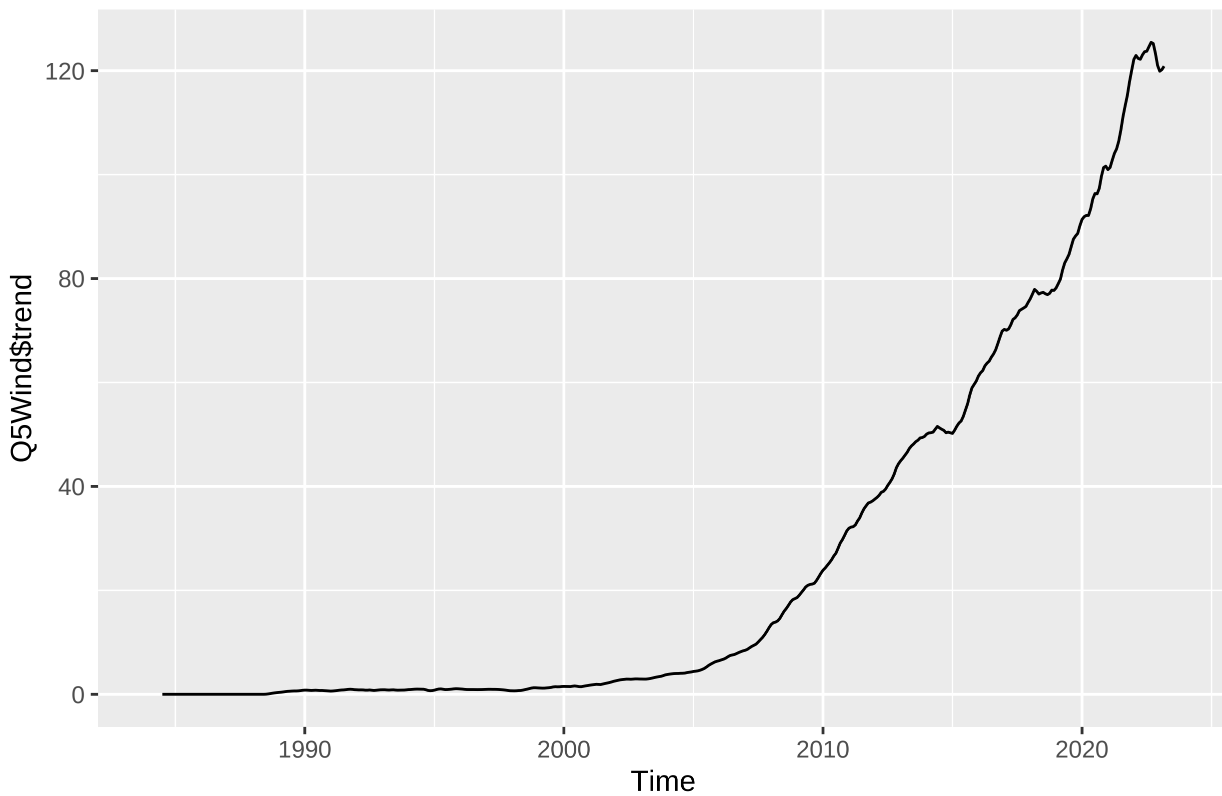
> Answer: The random component looks better this time (expecially for wind) as there is more randomness to the plot and hence less evidence of seasonaility. There is still some indication that the timefram should be fractionated for models.

```
Q5Wind <- decompose(WindTS, type = "multiplicative")
```

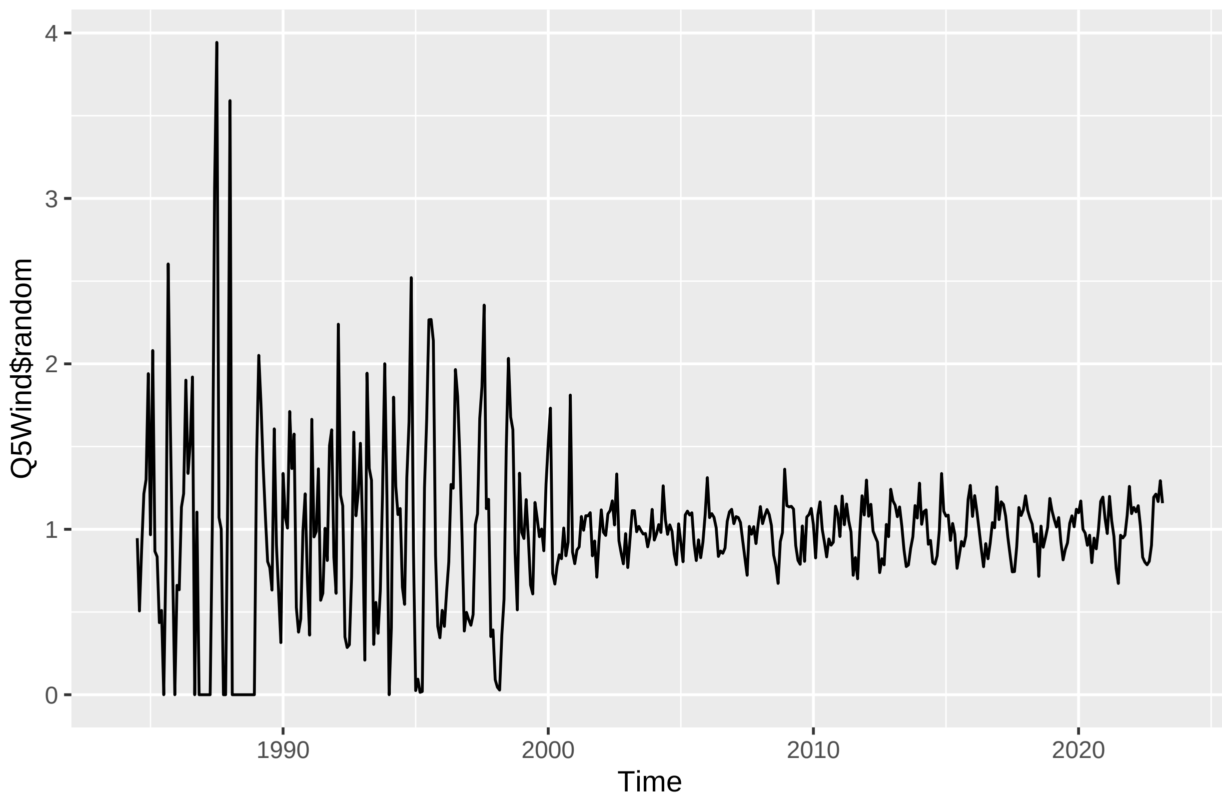
```
autoplot(Q5Wind$seasonal)
```




```r
autoplot(Q5Wind$trend)
```

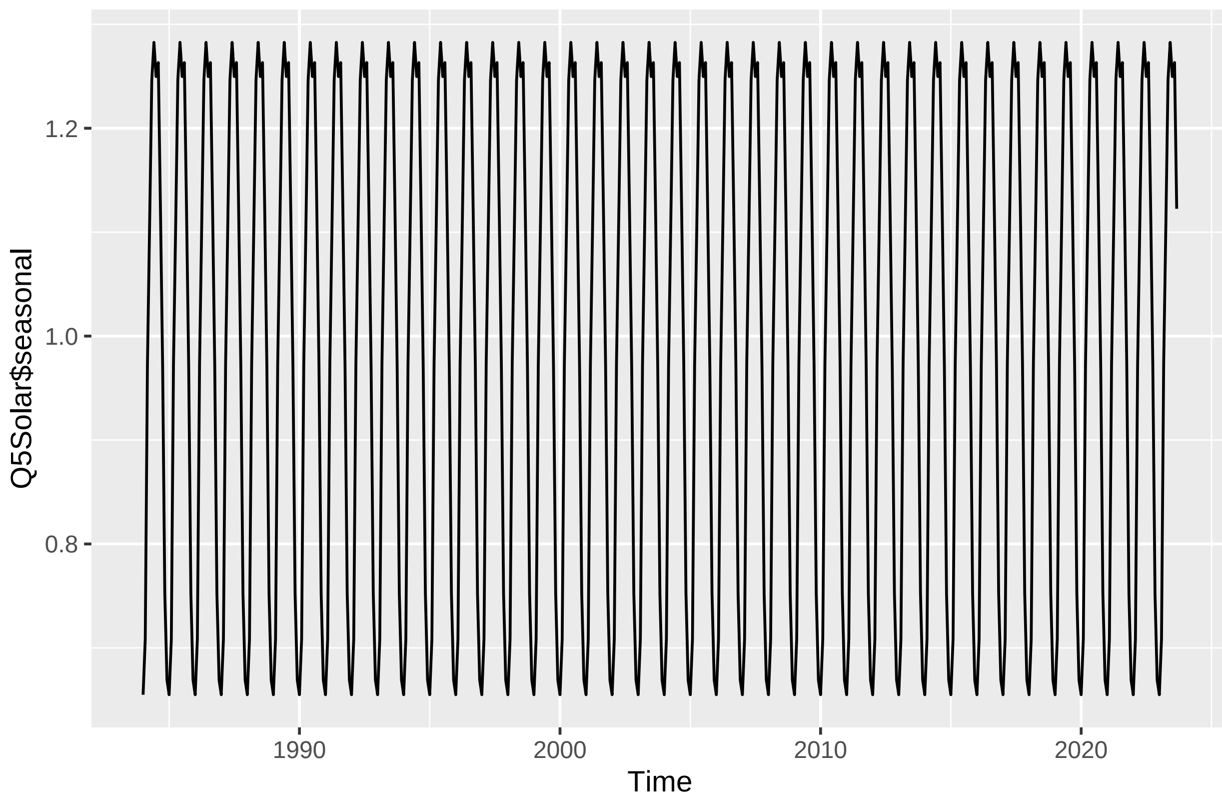



```r
autoplot(Q5Wind$random)
```

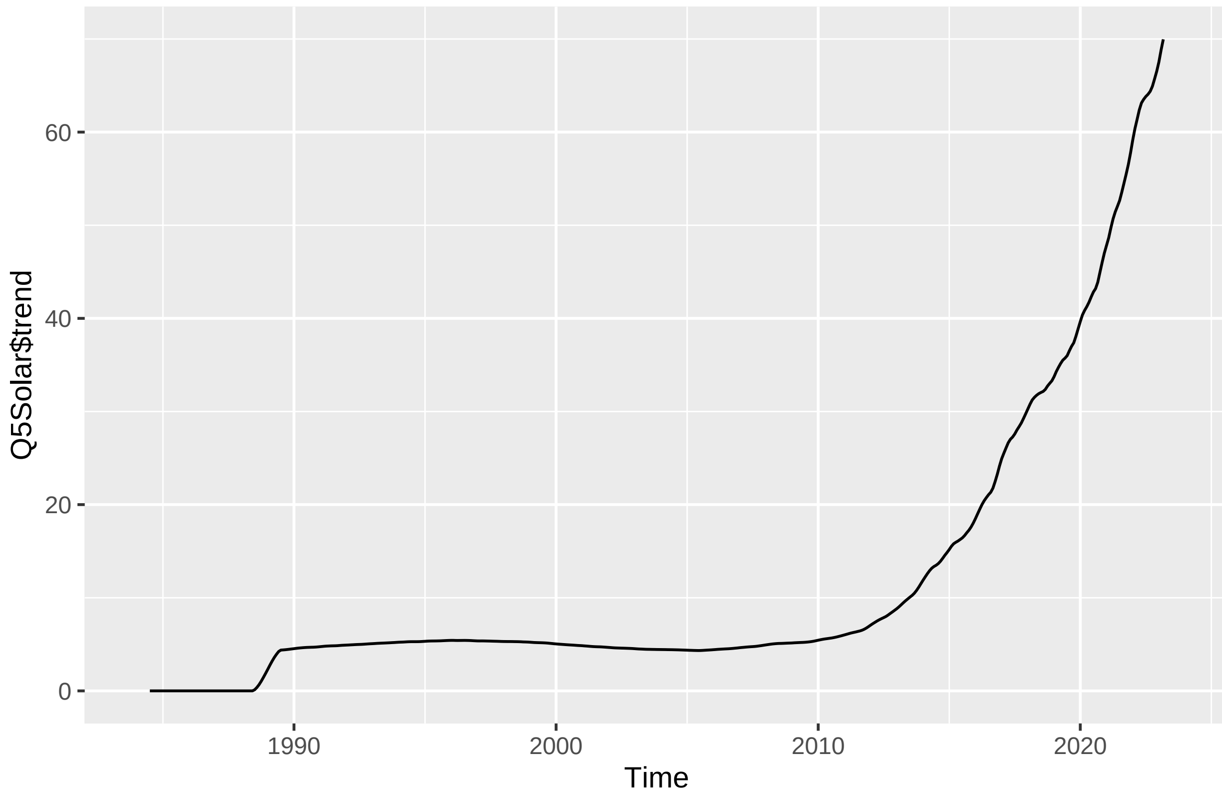



```
Q5Solar <- decompose(SolarTS, type = "multiplicative")
```

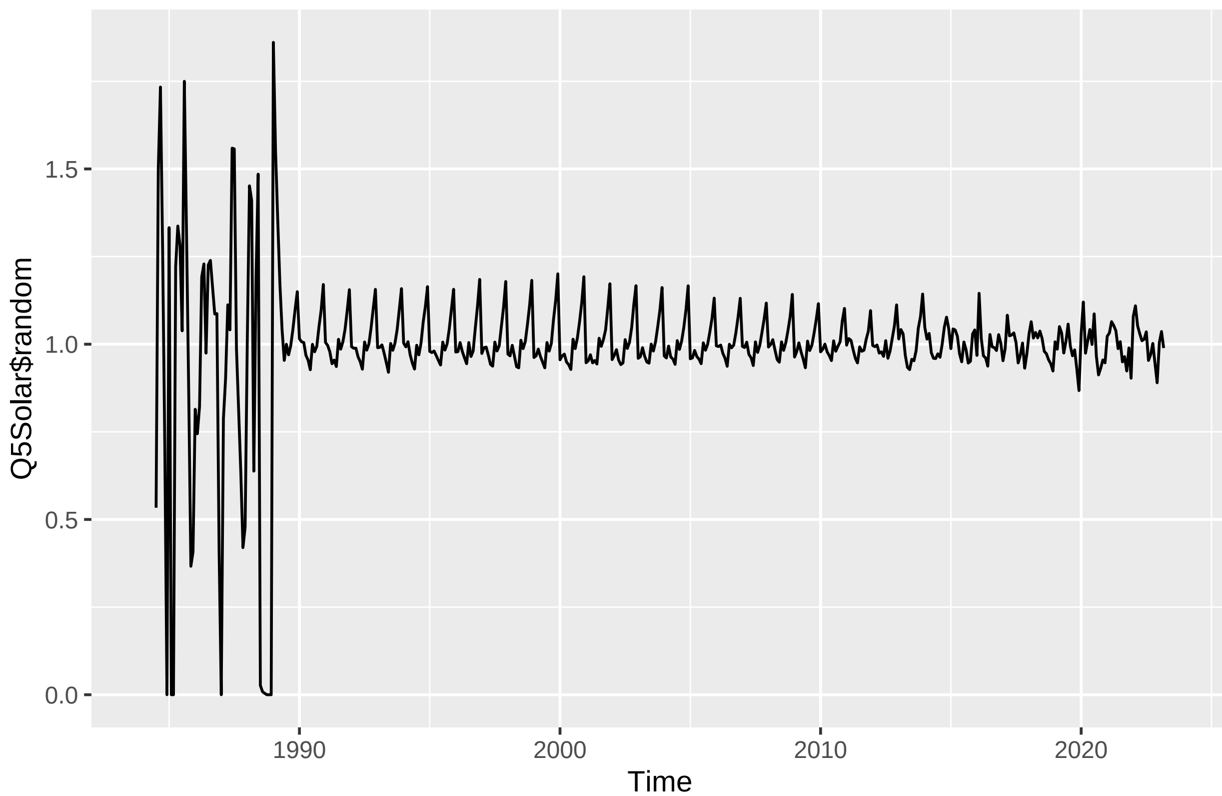
```
autoplot(Q5Solar$seasonal)
```



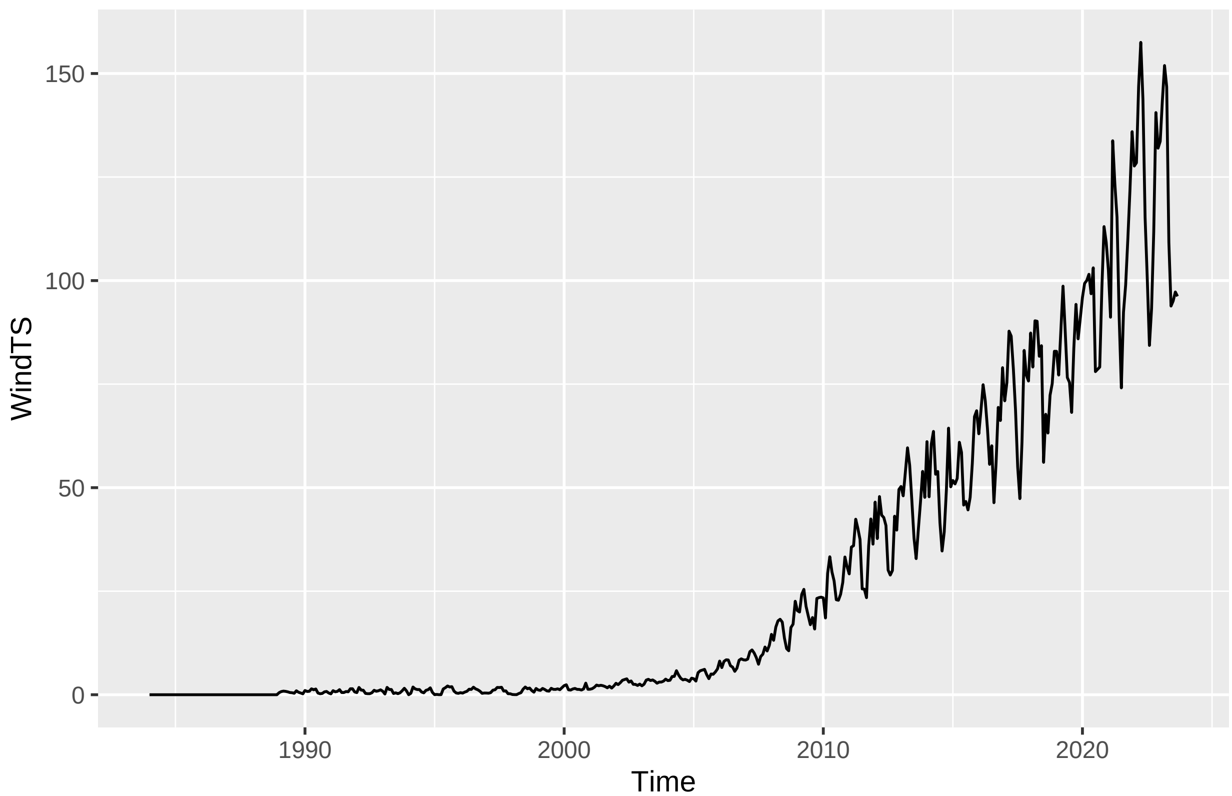

```r
autoplot(Q5Solar$trend)
```



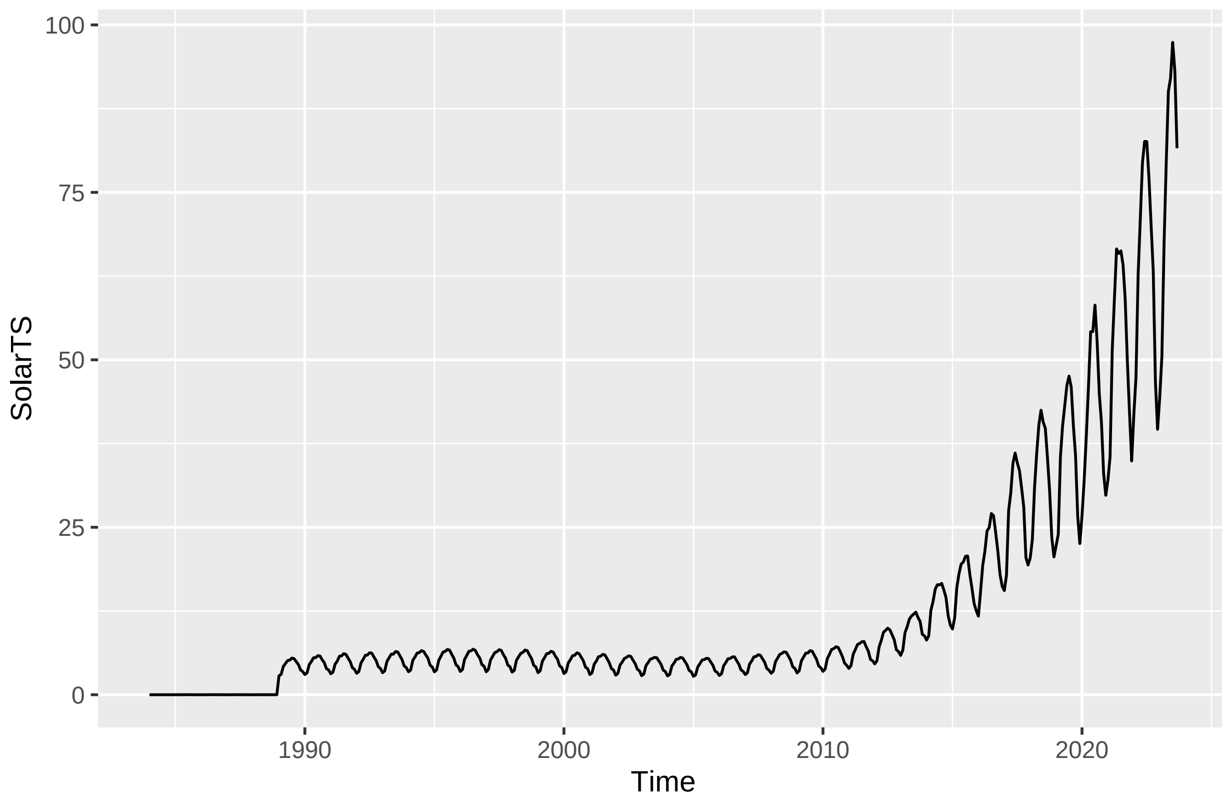

```
autoplot(Q5Solar$random)
```




```
autoplot(WindTS)
```




```
autoplot(SolarTS)
```



Q6

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

> Answer: No, I do not think all of the historic data is neccessary. There have been many factors over time like increased environmental awareness, technology improvemnets as well as cost reductions in solar and wind technology all of whihc have fundamentally changed the way we consumer solar and wind energy. Hence, it is probably better to look at the last year or two to predict the next six months as the technology from 1 or 2 years ago is far similar to the systems we are using today than infomration/technology from 30 years ago.

Q7

Create a new time series object where historical data starts on January 2012. Hint: use `filter()` function so that you don't need to point to row numbers, .i.e, `filter(xxxx, year(Date) >= 2012 )`. Apply the decompose function `type=additive` to this new time series. Comment the results. Does the random component look random? Think about our discussion in class about seasonal components that depends on the level of the series.

```
FilterData <- energy_data|>
  filter(year(as.Date(Month, "%Y")) >= 2012)
```

```
FilterDataTS <- ts(FilterData)
```

```
FilterWind <-FilterData |>
  select(`Wind Energy Consumption`)
```

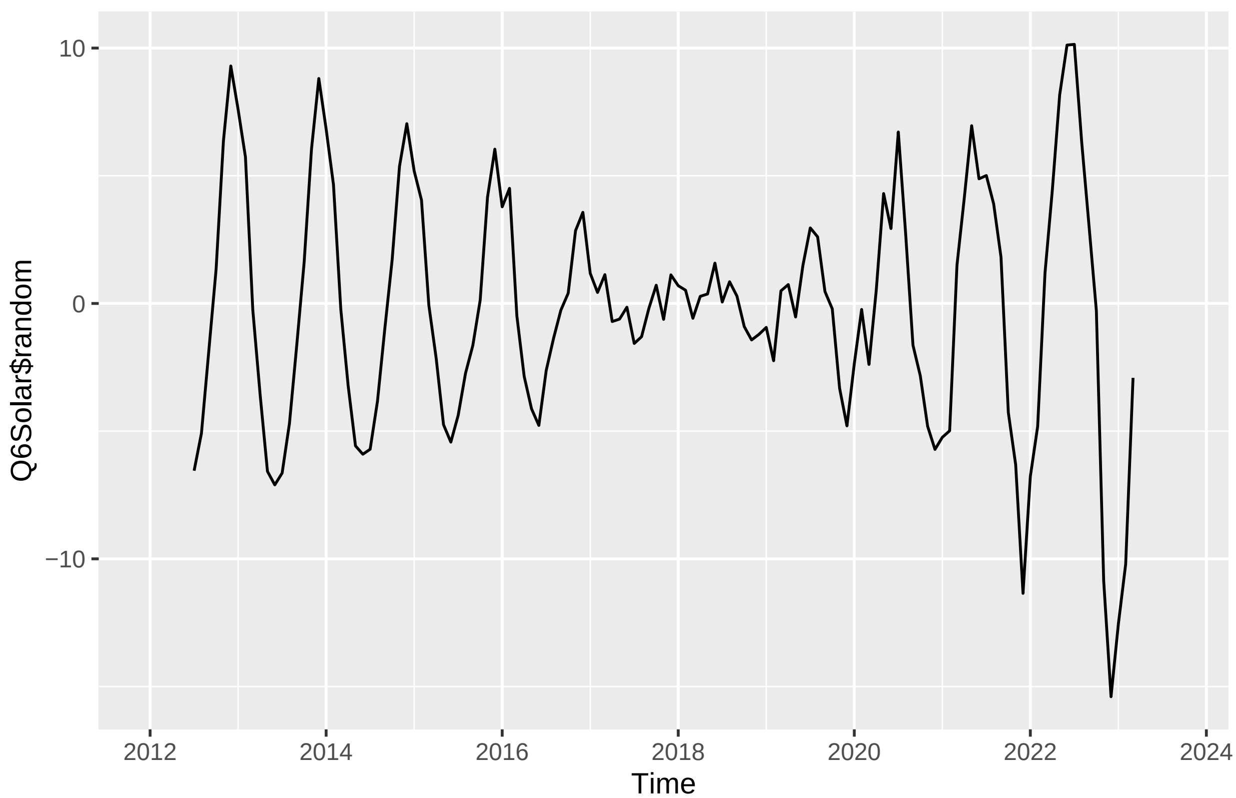
```r
FilterSolar <-FilterData |>
  select(`Solar Energy Consumption`)
```

```r
TSFilterWind <- ts(FilterWind, start = c(2012, 1), frequency = 12)
TSFilterSolar <- ts(FilterSolar, start = c(2012, 1), frequency = 12)
```

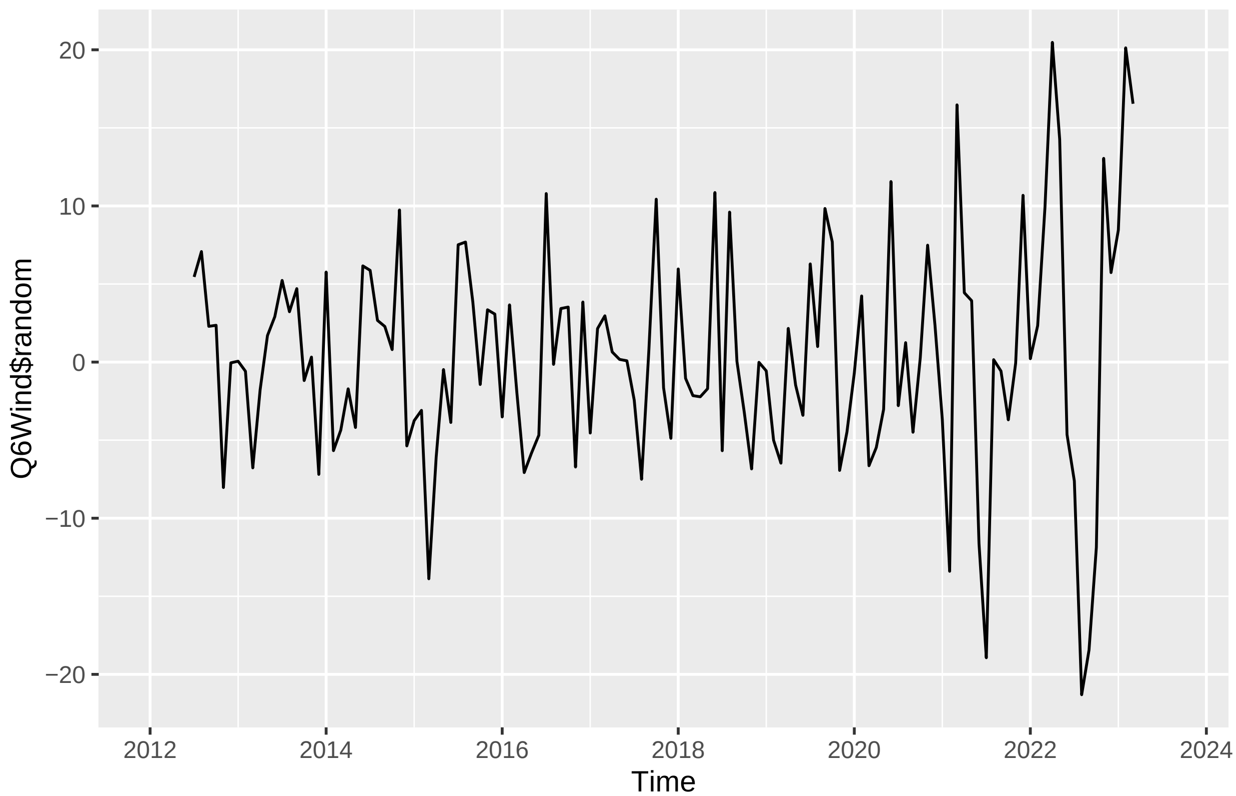
```r
Q6Wind <- decompose(TSFilterWind, type = "additive")
```

```r
Q6Solar <- decompose(TSFilterSolar, type = "additive")
```

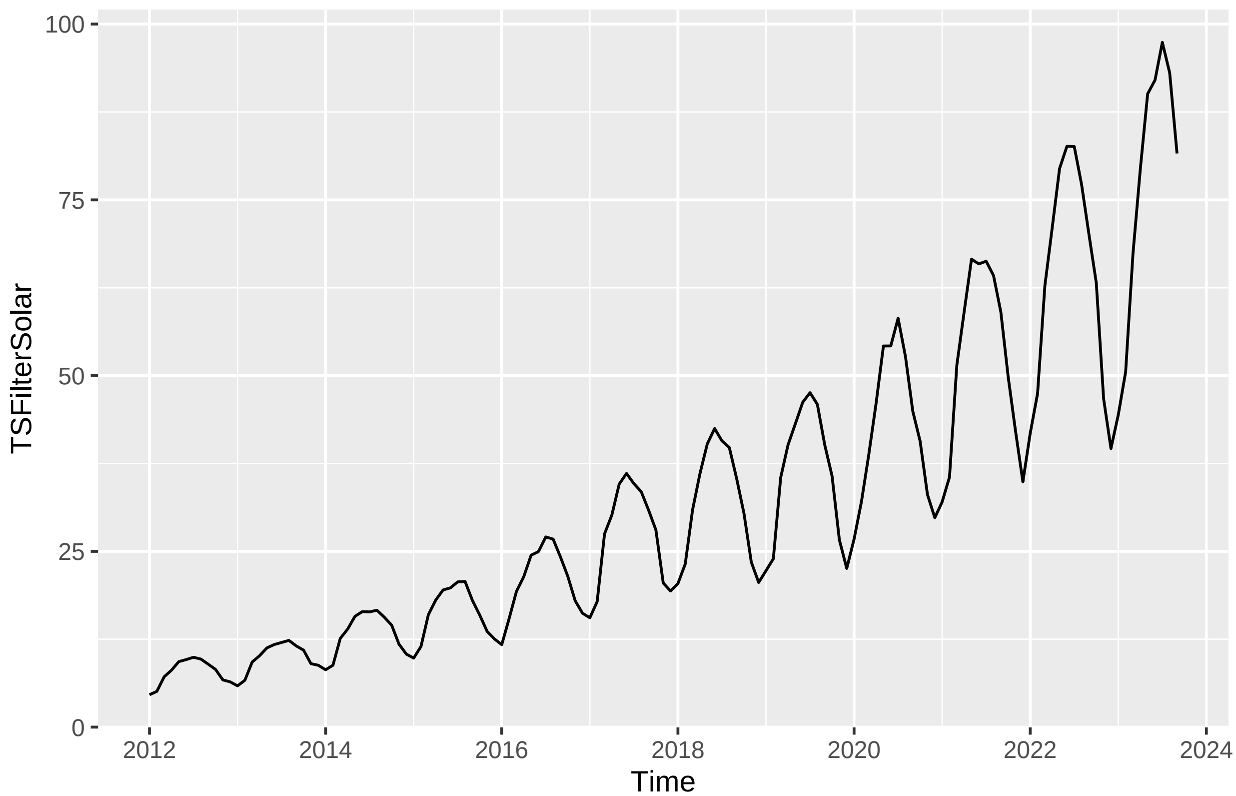
```r
autoplot(Q6Solar$random)
```



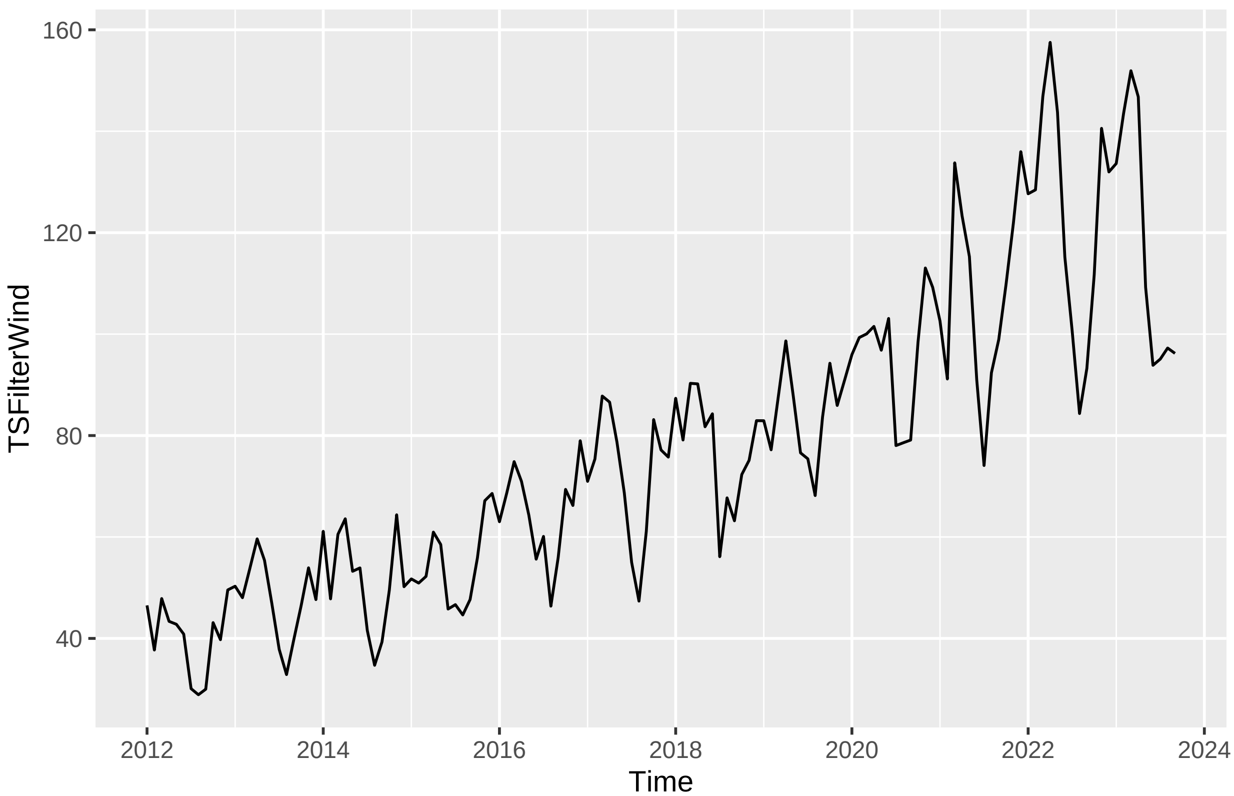

```r
autoplot(Q6Wind$random)
```




```r
autoplot(TSFilterSolar)
```




```
autoplot(TSFilterWind)
```



Answer: The random components do look much better here and are far more random; there are no distinguishable patterns that emerge year to year. Of course, this will never be completely ranomd as we expect some noise in everydata set but this version of the data is the best explained by the model so far.

Identify and Remove outliers

Q8

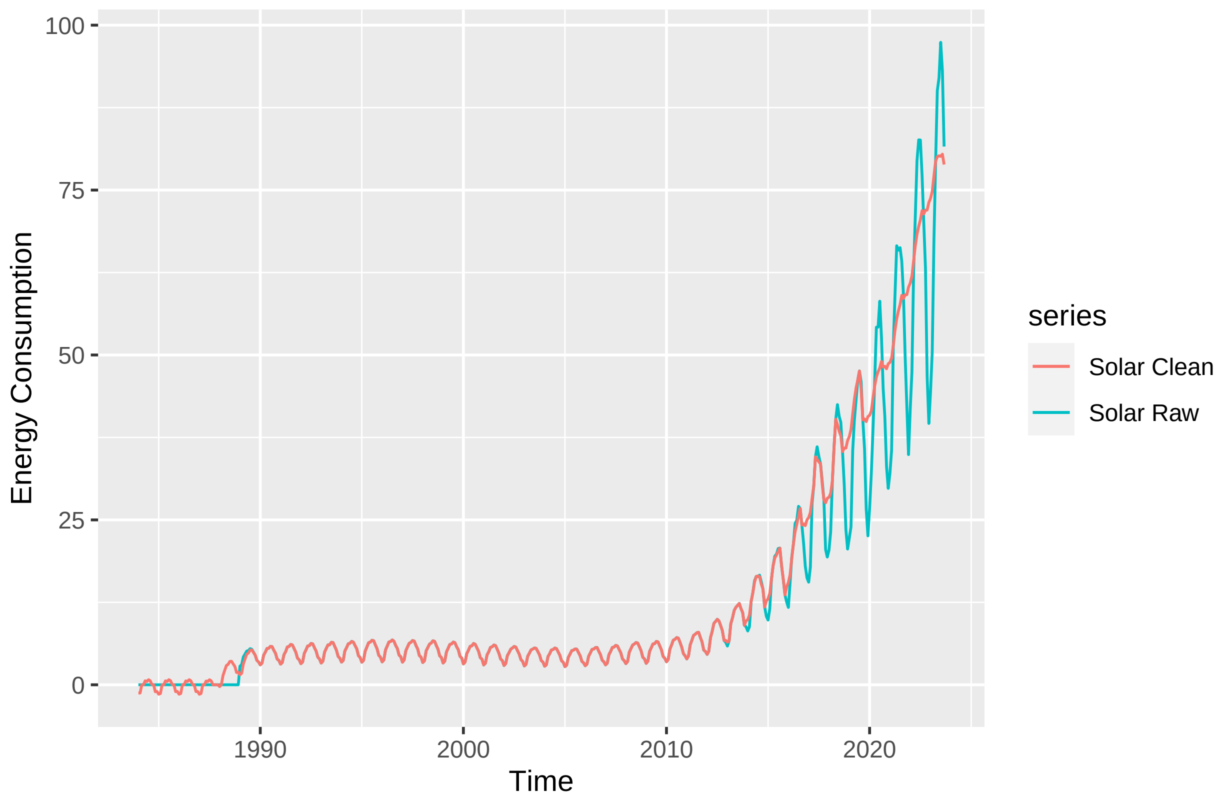
Apply the `tsclean()` to both series from Q7. Did the function removed any outliers from the series? Hint: Use `autoplot()` to check if there is difference between cleaned series and original series.

Answer:When considering substantial historical data in the data set, a ton of outliers are removed for solar and wind (you know this because the two trends are nit super imposed). There seem to be a variety of factors (like new technology and increased environmnetal awareness) that have changed the energy consumption in these two categories. The variability across time tells us that historic data may not be the best predictor of current and future uses.

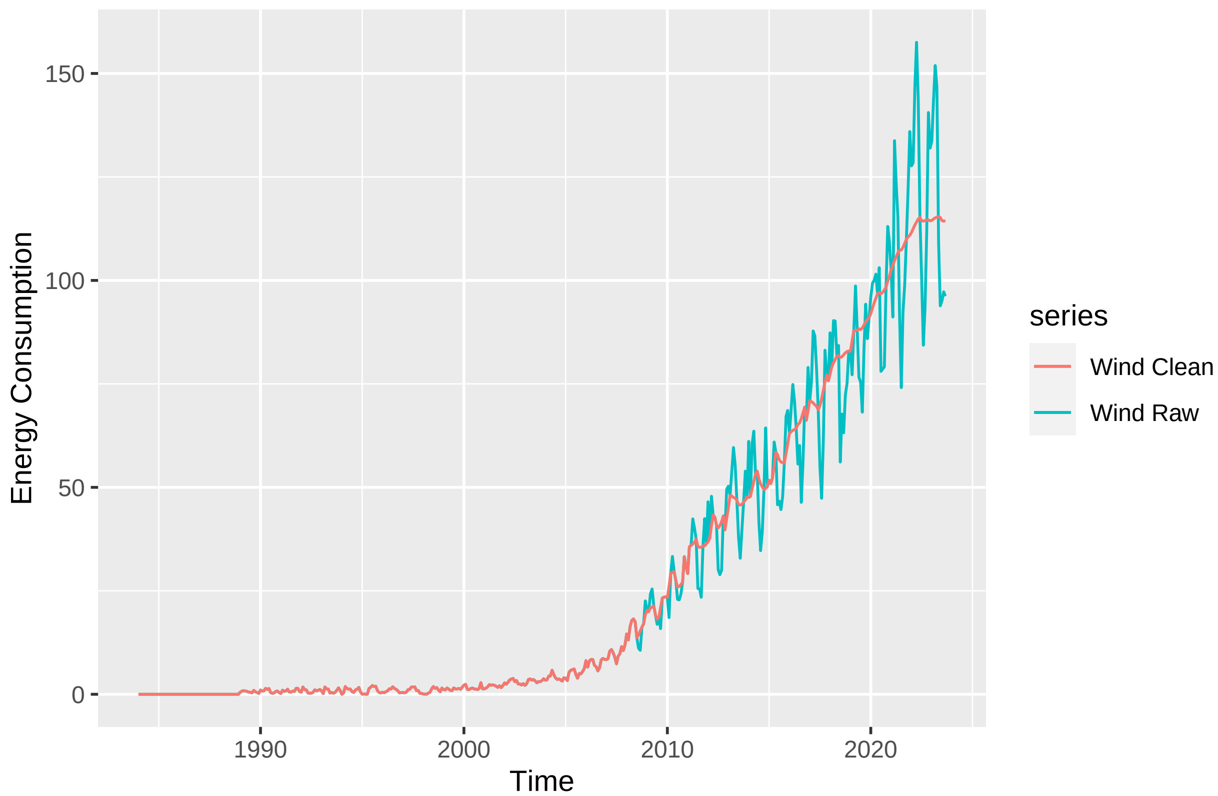
```
CleanWindTS <-tsclean(WindTS)
```

```
CleanSolarTS <- tsclean(SolarTS)
```

```
autoplot(SolarTS, series="Solar Raw") +
  autolayer(CleanSolarTS, series="Solar Clean") +
  ylab("Energy Consumption")
```




```r
autoplot(WindTS, series="Wind Raw") +
  autolayer(CleanWindTS, series="Wind Clean") +
  ylab("Energy Consumption")
```



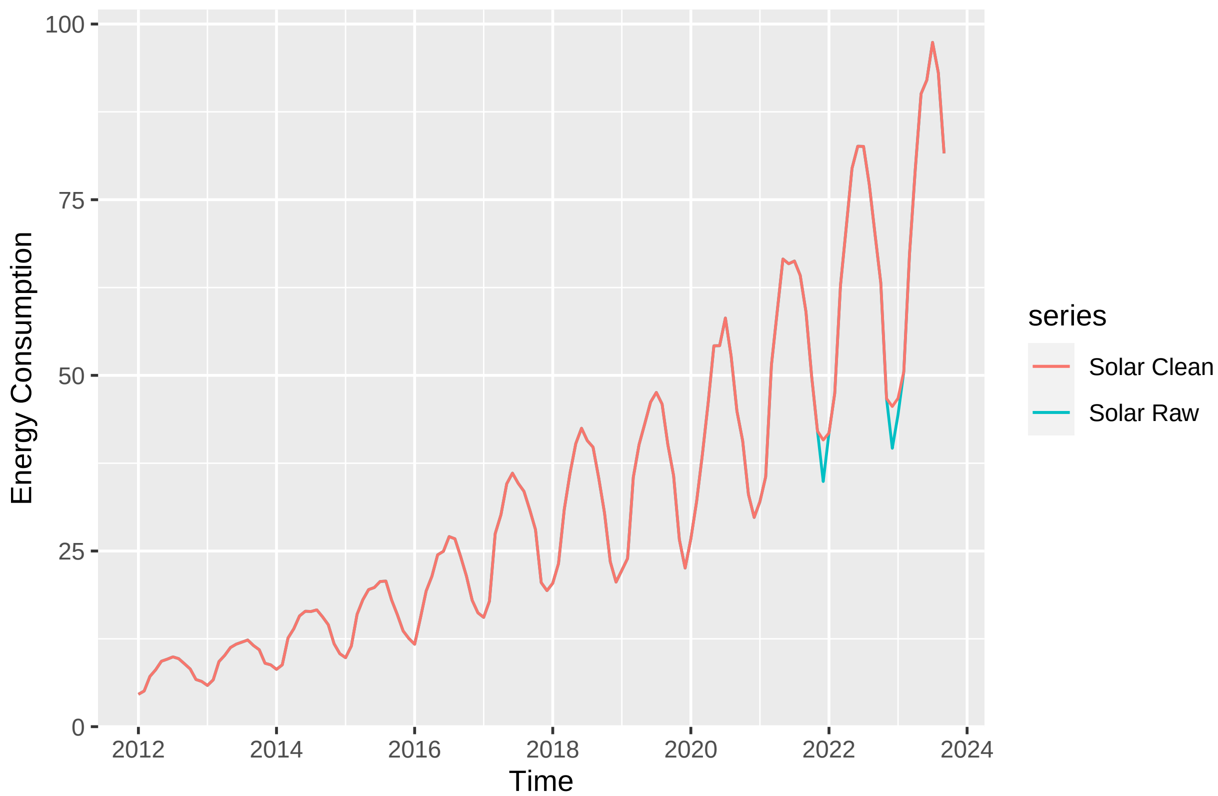
Q9

Redo number Q8 but now with the time series you created on Q7, i.e., the series starting in 2014. Using what `autoplot()` again what happened now?Did the function removed any outliers from the series? After 2012

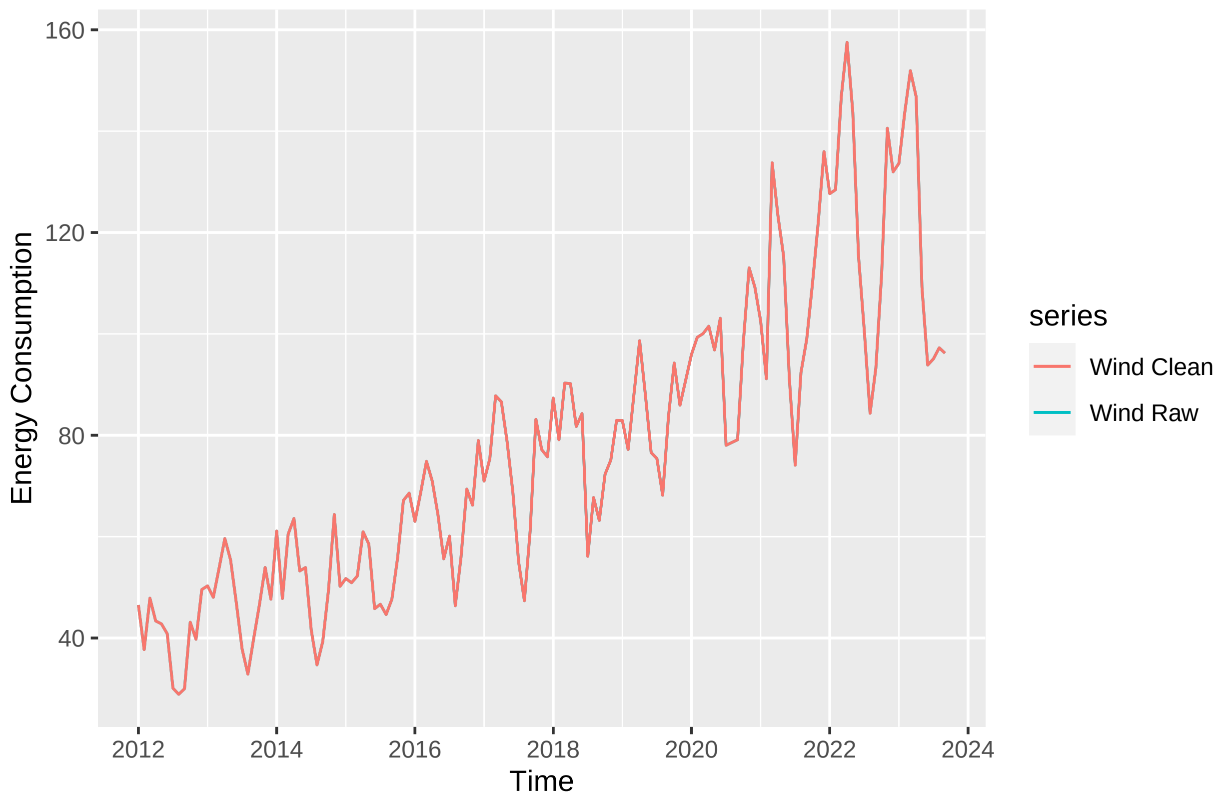
> Answer: With the series including data only from 2012 on, there were very few outliers removed in the solar data (right around Janurary of 2022 and 2023) but otherwise no data was removed (the two series are almost completely superimposed). This seems to show that it is better/ more predicatble to look at data around the same time rather than using largerly historic data.

```
TSCWind <- tsclean(TSFilterWind)
TSCSolar <- tsclean(TSFilterSolar)
```

```
autoplot(TSFilterSolar, series="Solar Raw") +
  autolayer(TSCSolar, series="Solar Clean") +
  ylab("Energy Consumption")
```




```
autoplot(TSFilterWind, series="Wind Raw") +
  autolayer(TSCWind, series="Wind Clean") +
  ylab("Energy Consumption")
```


Energy Consumption
160
120
80
40
2012
2014
2016
2018
2020
2022
2024
Time
series
Wind Clean
Wind Raw