ML Final Project

Loading the necessary Libraries for project

```
library(dplyr)

##
## Attaching package: 'dplyr'

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

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

library(caret)

## Loading required package: ggplot2

## Loading required package: lattice

library(missForest)

## Warning: package 'missForest' was built under R version 4.2.2

library(corrplot)

## corrplot 0.92 loaded

library(factoextra)

## Warning: package 'factoextra' was built under R version 4.2.2

## Welcome! Want to learn more? See two factoextra-related books at
https://goo.gl/ve3WBa

library(cluster)

## Warning: package 'cluster' was built under R version 4.2.2
```

Reading the CSV File

```
# reading file
Fuel_Receipts_Costs_Data=read.csv("C:/Users/Pavan
Chaitanya/Downloads/fuel_receipts_costs_eia923 (1).csv")

# head part of file
head(Fuel_Receipts_Costs_Data,5)
```

```
##   rowid plant_id_eia report_date contract_type_code
contract_expiration_date
## 1     1            3  2008-01-01                  C               2008-04-
01
## 2     2            3  2008-01-01                  C               2008-04-
01
## 3     3            3  2008-01-01                  C
## 4     4            7  2008-01-01                  C               2015-12-
01
## 5     5            7  2008-01-01                  S               2008-11-
01
##   energy_source_code fuel_type_code_pudl fuel_group_code mine_id_pudl
## 1                BIT                coal            coal            0
## 2                BIT                coal            coal            0
## 3                 NG                 gas     natural_gas           NA
## 4                BIT                coal            coal            1
## 5                BIT                coal            coal            2
##      supplier_name fuel_received_units fuel_mmbtu_per_unit
sulfur_content_pct
## 1  interocean coal              259412              23.100
0.49
## 2  interocean coal               52241              22.800
0.48
## 3 bay gas pipeline             2783619               1.039
0.00
## 4     alabama coal               25397              24.610
1.69
## 5     d & e mining                 764              24.446
0.84
##   ash_content_pct mercury_content_ppm fuel_cost_per_mmbtu
## 1             5.4                  NA               2.135
## 2             5.7                  NA               2.115
## 3             0.0                  NA               8.631
## 4            14.7                  NA               2.776
## 5            15.5                  NA               3.381
##   primary_transportation_mode_code secondary_transportation_mode_code
## 1                               RV
## 2                               RV
## 3                               PL
## 4                               TR
## 5                               TR
##   natural_gas_transport_code natural_gas_delivery_contract_type_code
## 1                       firm
## 2                       firm
## 3                       firm
## 4                       firm
## 5                       firm
##   moisture_content_pct chlorine_content_ppm data_maturity
## 1                   NA                   NA         final
## 2                   NA                   NA         final
```

```
## 3                    NA                    NA          final
## 4                    NA                    NA          final
## 5                    NA                    NA          final
```

```
#Checiking NA's
colMeans(is.na(Fuel_Receipts_Costs_Data))
```

```
##                                  rowid
plant_id_eia
##                              0.0000000
0.0000000
##                            report_date
contract_type_code
##                              0.0000000
0.0000000
##               contract_expiration_date
energy_source_code
##                              0.0000000
0.0000000
##                    fuel_type_code_pudl
fuel_group_code
##                              0.0000000
0.0000000
##                           mine_id_pudl
supplier_name
##                              0.6440512
0.0000000
##                    fuel_received_units
fuel_mmbtu_per_unit
##                              0.0000000
0.0000000
##                     sulfur_content_pct
ash_content_pct
##                              0.0000000
0.0000000
##                    mercury_content_ppm
fuel_cost_per_mmbtu
##                              0.4756797
0.3290363
##         primary_transportation_mode_code
secondary_transportation_mode_code
##                              0.0000000
0.0000000
##              natural_gas_transport_code
natural_gas_delivery_contract_type_code
##                              0.0000000
0.0000000
##                   moisture_content_pct
chlorine_content_ppm
##                              0.8488641
```

```
0.8488641
##                            data_maturity
##                                0.0000000
```

Data Cleaning and Removing the Unnecessary Colums that are present in dataset

```
# Randonmly Assigning the seed value
set.seed(2875)

#checking the NA Values
Fuel_Receipts_Costs_Data[Fuel_Receipts_Costs_Data==""] = NA

#Converting the mean values to the percentage
Filtering_NA  =
Fuel_Receipts_Costs_Data[,(colMeans(is.na(Fuel_Receipts_Costs_Data))*100)<50]

#Sampling the 2 % of the data
Creating_Two_data_Partition =
createDataPartition(Filtering_NA$plant_id_eia,p=0.02,list = FALSE)
Creating_Two_data_Partition1 = Filtering_NA[Creating_Two_data_Partition,]
# Printing the 2% data
head(Creating_Two_data_Partition1,10)

##     rowid plant_id_eia report_date contract_type_code energy_source_code
## 120   120          130  2008-01-01                  C                BIT
## 125   125          136  2008-01-01                  C                BIT
## 142   142          160  2008-01-01                  C                SUB
## 219   219          525  2008-01-01                  C                BIT
## 275   275          535  2008-01-01                  S                 NG
## 309   309          564  2008-01-01                  C                BIT
## 351   351          619  2008-01-01                  C                 NG
## 389   389          666  2008-01-01                  S                 NG
## 486   486          876  2008-01-01                 NC                SUB
## 619   619         1077  2008-01-01                  C                 PC
##     fuel_type_code_pudl fuel_group_code            supplier_name
## 120                coal            coal                     arch
## 125                coal            coal            alliance coal
## 142                coal            coal               rio tinto
## 219                coal            coal              peabody coal
## 275                 gas     natural_gas            suncor energy
## 309                coal            coal                      icg
## 351                 gas     natural_gas florida gas transmission
## 389                 gas     natural_gas florida gas transmission
## 486                coal            coal                rio tinto
## 619                coal  petroleum_coke                  petcoke
##     fuel_received_units fuel_mmbtu_per_unit sulfur_content_pct
ash_content_pct
## 120               21769              24.700               0.79
```

```
10.50
## 125              56274              23.376               2.88
7.10
## 142              13105              20.764               0.40
5.00
## 219             115560              22.512               0.50
10.20
## 275                  7               1.000               0.00
0.00
## 309              11096              22.190               1.18
11.10
## 351             732643               1.026               0.00
0.00
## 389              48274               1.054               0.00
0.00
## 486              31664              17.530               0.29
6.20
## 619               3380              28.000               5.80
0.54
##     mercury_content_ppm fuel_cost_per_mmbtu
primary_transportation_mode_code
## 120                  NA               2.300
RR
## 125                  NA               2.201
RR
## 142                  NA               1.661
RR
## 219                  NA               1.431
RR
## 275                  NA               9.703
<NA>
## 309                  NA               2.761
RR
## 351                  NA               9.386
<NA>
## 389                  NA              10.715
<NA>
## 486                  NA                  NA
RR
## 619                  NA               1.944
TR
##     natural_gas_transport_code data_maturity
## 120                       <NA>         final
## 125                       <NA>         final
## 142                       <NA>         final
## 219                       <NA>         final
## 275                       firm         final
## 309                       <NA>         final
## 351                       firm         final
## 389              interruptible         final
```

```
## 486                        <NA>         final
## 619                        <NA>         final
```

```
colMeans(is.na(Creating_Two_data_Partition1))*100
```

```
##                             rowid                      plant_id_eia
##                        0.00000000                        0.00000000
##                       report_date                contract_type_code
##                        0.00000000                        0.04107451
##                energy_source_code               fuel_type_code_pudl
##                        0.00000000                        0.00000000
##                   fuel_group_code                     supplier_name
##                        0.00000000                        0.00000000
##               fuel_received_units               fuel_mmbtu_per_unit
##                        0.00000000                        0.00000000
##                sulfur_content_pct                   ash_content_pct
##                        0.00000000                        0.00000000
##               mercury_content_ppm               fuel_cost_per_mmbtu
##                       47.96681180                       32.81853282
## primary_transportation_mode_code       natural_gas_transport_code
##                        9.79216298                       43.76899696
##                     data_maturity
##                        0.00000000
```

```
#converting the date to date format
Creating_Two_data_Partition1$report_date <-
as.Date(Creating_Two_data_Partition1$report_date)

Creating_Two_data_Partition1$report_date <-
as.numeric(format(Creating_Two_data_Partition1$report_date, "%Y"))

# removing the unnecessary Colums
Creating_Two_data_Partition1=Creating_Two_data_Partition1[,-c(6,8,17)]

# Printing the data data frame after removing unnecessary columns
head(Creating_Two_data_Partition1,10)
```

```
##     rowid plant_id_eia report_date contract_type_code energy_source_code
## 120   120          130        2008                  C                BIT
## 125   125          136        2008                  C                BIT
## 142   142          160        2008                  C                SUB
## 219   219          525        2008                  C                BIT
## 275   275          535        2008                  S                 NG
## 309   309          564        2008                  C                BIT
## 351   351          619        2008                  C                 NG
## 389   389          666        2008                  S                 NG
## 486   486          876        2008                 NC                SUB
## 619   619         1077        2008                  C                 PC
##     fuel_group_code fuel_received_units fuel_mmbtu_per_unit
sulfur_content_pct
```

```
## 120            coal                21769                24.700
0.79
## 125            coal                56274                23.376
2.88
## 142            coal                13105                20.764
0.40
## 219            coal               115560                22.512
0.50
## 275     natural_gas                    7                 1.000
0.00
## 309            coal                11096                22.190
1.18
## 351     natural_gas               732643                 1.026
0.00
## 389     natural_gas                48274                 1.054
0.00
## 486            coal                31664                17.530
0.29
## 619  petroleum_coke                 3380                28.000
5.80
##     ash_content_pct mercury_content_ppm fuel_cost_per_mmbtu
## 120           10.50                  NA               2.300
## 125            7.10                  NA               2.201
## 142            5.00                  NA               1.661
## 219           10.20                  NA               1.431
## 275            0.00                  NA               9.703
## 309           11.10                  NA               2.761
## 351            0.00                  NA               9.386
## 389            0.00                  NA              10.715
## 486            6.20                  NA                  NA
## 619            0.54                  NA               1.944
##     primary_transportation_mode_code natural_gas_transport_code
## 120                               RR                       <NA>
## 125                               RR                       <NA>
## 142                               RR                       <NA>
## 219                               RR                       <NA>
## 275                             <NA>                       firm
## 309                               RR                       <NA>
## 351                             <NA>                       firm
## 389                             <NA>              interruptible
## 486                               RR                       <NA>
## 619                               TR                       <NA>
```

Data Imputation

```
# Converting the variables of char to factor type for data impuataion
Creating_Two_data_Partition1$report_date =
as.factor(Creating_Two_data_Partition1$report_date)
```

```
Creating_Two_data_Partition1$contract_type_code =
as.factor(Creating_Two_data_Partition1$contract_type_code)

Creating_Two_data_Partition1$energy_source_code =
as.factor(Creating_Two_data_Partition1$energy_source_code)

Creating_Two_data_Partition1$fuel_group_code =
as.factor(Creating_Two_data_Partition1$fuel_group_code)

Creating_Two_data_Partition1$primary_transportation_mode_code =
as.factor(Creating_Two_data_Partition1$primary_transportation_mode_code)

Creating_Two_data_Partition1$natural_gas_transport_code =
as.factor(Creating_Two_data_Partition1$natural_gas_transport_code)

# Computing the Data Imputation
Genertated_Data = missForest(Creating_Two_data_Partition1)

#Taking only the ximp data frame
Imputed = Genertated_Data$ximp

#Printing the data frame after computation of the missing values
head(Imputed,10)

##     rowid plant_id_eia report_date contract_type_code energy_source_code
## 120   120          130        2008                  C                BIT
## 125   125          136        2008                  C                BIT
## 142   142          160        2008                  C                SUB
## 219   219          525        2008                  C                BIT
## 275   275          535        2008                  S                 NG
## 309   309          564        2008                  C                BIT
## 351   351          619        2008                  C                 NG
## 389   389          666        2008                  S                 NG
## 486   486          876        2008                 NC                SUB
## 619   619         1077        2008                  C                 PC
##     fuel_group_code fuel_received_units fuel_mmbtu_per_unit
sulfur_content_pct
## 120            coal               21769              24.700
0.79
## 125            coal               56274              23.376
2.88
## 142            coal               13105              20.764
0.40
## 219            coal              115560              22.512
0.50
## 275     natural_gas                   7               1.000
0.00
## 309            coal               11096              22.190
1.18
```

```
## 351     natural_gas              732643               1.026
0.00
## 389     natural_gas               48274               1.054
0.00
## 486            coal               31664              17.530
0.29
## 619  petroleum_coke                3380              28.000
5.80
##     ash_content_pct mercury_content_ppm fuel_cost_per_mmbtu
## 120           10.50        1.655000e-02            2.300000
## 125            7.10        1.318733e-02            2.201000
## 142            5.00        2.240737e-02            1.661000
## 219           10.20        1.781000e-02            1.431000
## 275            0.00       -2.234844e-16            9.703000
## 309           11.10        1.932000e-02            2.761000
## 351            0.00       -2.314121e-16            9.386000
## 389            0.00       -2.581269e-16           10.715000
## 486            6.20        1.446737e-02            1.634491
## 619            0.54        1.980333e-02            1.944000
##     primary_transportation_mode_code natural_gas_transport_code
## 120                               RR                       firm
## 125                               RR                       firm
## 142                               RR                       firm
## 219                               RR                       firm
## 275                               PL                       firm
## 309                               RR                       firm
## 351                               PL                       firm
## 389                               PL              interruptible
## 486                               RR                       firm
## 619                               TR                       firm
```

Partitioning the 2 % data into 75 % training data.

```
Data_Partition = createDataPartition(Imputed$plant_id_eia,p=0.75,list =
FALSE)

Data_Partition_Trained = Imputed[Data_Partition,]

Data_Partition_Tested = Imputed[-Data_Partition,]
```

As data has Outliers we are making sure that the outlier are removed.

```
# For the fuel received units performing the quartile ranges and IQR
Quartiled_data = quantile(Data_Partition_Trained$fuel_received_units,
probs=c(.25, .75), na.rm = FALSE)
Data_Partition_Quartiled = IQR(Data_Partition_Trained$fuel_received_units)



Fuelunits_Lower = Quartiled_data[1] - 1.5*Data_Partition_Quartiled
```

```
Fuelunits_Upper = Quartiled_data[2] + 1.5*Data_Partition_Quartiled

Data_With_No_Outliers = subset(Data_Partition_Trained,
Data_Partition_Trained$fuel_received_units > Fuelunits_Lower &
Data_Partition_Trained$fuel_received_units < Fuelunits_Upper)

# For the fuel cost per mmbtu performing the quartile ranges and IQR
Range_of_Fuel = quantile(Data_With_No_Outliers$fuel_cost_per_mmbtu,
probs=c(.25, .75), na.rm = FALSE)
Fuelcost_IQR <- IQR(Data_With_No_Outliers$fuel_cost_per_mmbtu)

Fuelcost_Lower = Range_of_Fuel[1] - 1.5*Fuelcost_IQR
Fuelcost_Upper = Range_of_Fuel[2] + 1.5*Fuelcost_IQR

No_Outlier_Data = subset(Data_With_No_Outliers,
Data_With_No_Outliers$fuel_cost_per_mmbtu > Fuelcost_Lower &
Data_With_No_Outliers$fuel_cost_per_mmbtu < Fuelcost_Upper)
```

Choosing and Normalising the selected variables

```
All_Numeric_Variables=No_Outlier_Data[,c(7,8,9,10,11,12)]
head(All_Numeric_Variables,12)

##     fuel_received_units fuel_mmbtu_per_unit sulfur_content_pct
ash_content_pct
## 120               21769              24.700               0.79
10.50
## 125               56274              23.376               2.88
7.10
## 219              115560              22.512               0.50
10.20
## 309               11096              22.190               1.18
11.10
## 389               48274               1.054               0.00
0.00
## 486               31664              17.530               0.29
6.20
## 619                3380              28.000               5.80
0.54
## 685               10905              22.082               3.96
16.20
## 709               40051               1.011               0.00
0.00
## 737               20400              24.790               0.98
10.30
## 747               17889              24.006               1.54
12.70
## 796               33756               1.025               0.00
0.00
```

```
##     mercury_content_ppm fuel_cost_per_mmbtu
## 120        1.655000e-02            2.300000
## 125        1.318733e-02            2.201000
## 219        1.781000e-02            1.431000
## 309        1.932000e-02            2.761000
## 389       -2.581269e-16           10.715000
## 486        1.446737e-02            1.634491
## 619        1.980333e-02            1.944000
## 685        1.850000e-02            1.765000
## 709       -2.546574e-16            8.329000
## 737        1.080000e-02            2.182000
## 747        1.134091e-02            2.425000
## 796       -2.361653e-16            8.633000
```

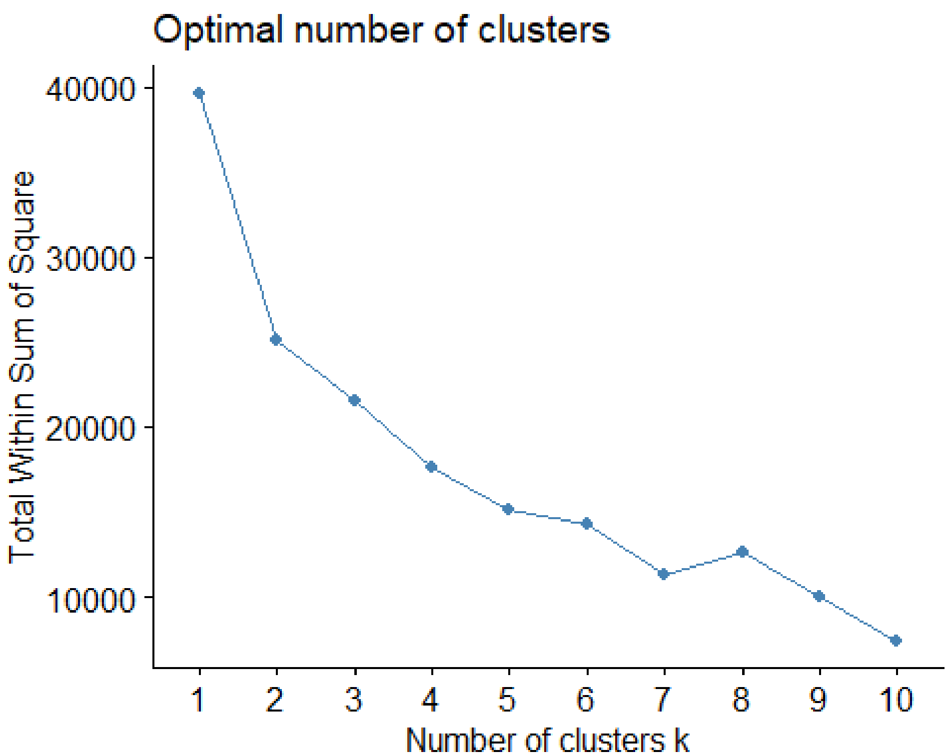
```
Scaled_Data = scale(All_Numeric_Variables)
head(Scaled_Data,12)
```

```
##     fuel_received_units fuel_mmbtu_per_unit sulfur_content_pct
ash_content_pct
## 120        -0.343145722           1.3206695          0.1248810
0.8434456
## 125         0.294744214           1.1942800          2.0336736
0.3548104
## 219         1.390757626           1.1118022         -0.1399754
0.8003308
## 309        -0.540456237           1.0810639          0.4810672
0.9296754
## 389         0.146849141          -0.9365870         -0.5966243      -
0.6655750
## 486        -0.160218004           0.6362185         -0.3317679
0.2254658
## 619        -0.683101034           1.6356888          4.7005035      -
0.5879682
## 685        -0.543987231           1.0707542          3.0200354
1.6626283
## 709        -0.005168507          -0.9406918         -0.5966243      -
0.6655750
## 737        -0.368454267           1.3292610          0.2984076
0.8147024
## 747        -0.414874833           1.2544200          0.8098545
1.1596214
## 796        -0.121543443          -0.9393554         -0.5966243      -
0.6655750
##     mercury_content_ppm fuel_cost_per_mmbtu
## 120         0.076866008          -0.6919802
## 125        -0.007240504          -0.7397989
## 219         0.108380938          -1.1117215
## 309         0.146148830          -0.4693096
## 389        -0.337080099           3.3726032
## 486         0.024775636          -1.0134318
```

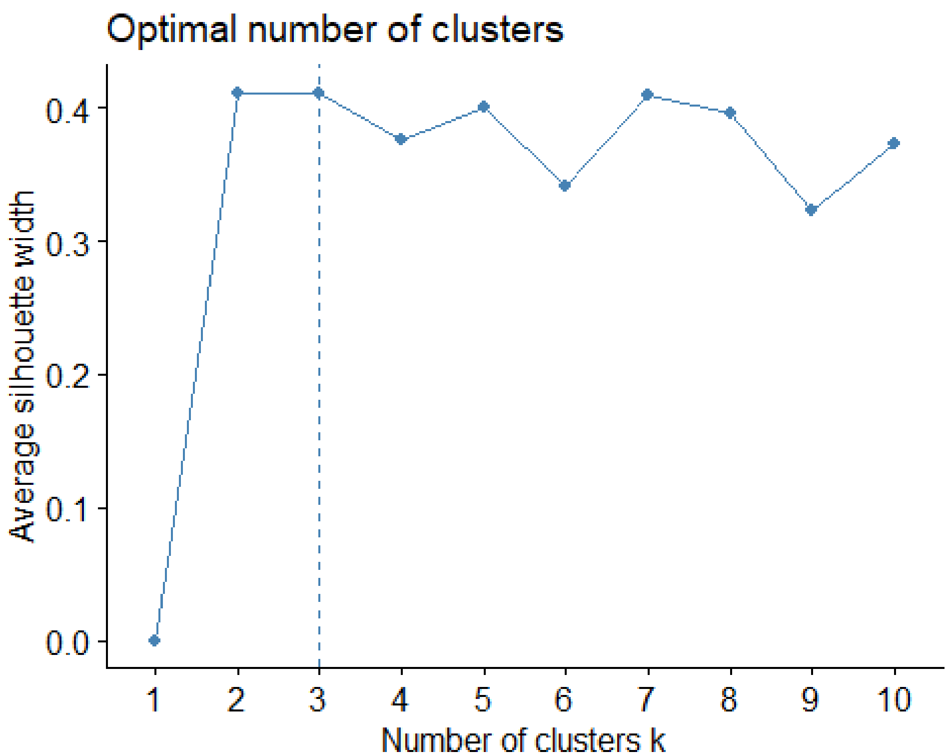
```
## 619          0.158237891          -0.8639341
## 685          0.125639114          -0.9503940
## 709         -0.337080099           2.2201259
## 737         -0.066952126          -0.7489762
## 747         -0.053422989          -0.6316032
## 796         -0.337080099           2.3669629
```

K-Means Clustering

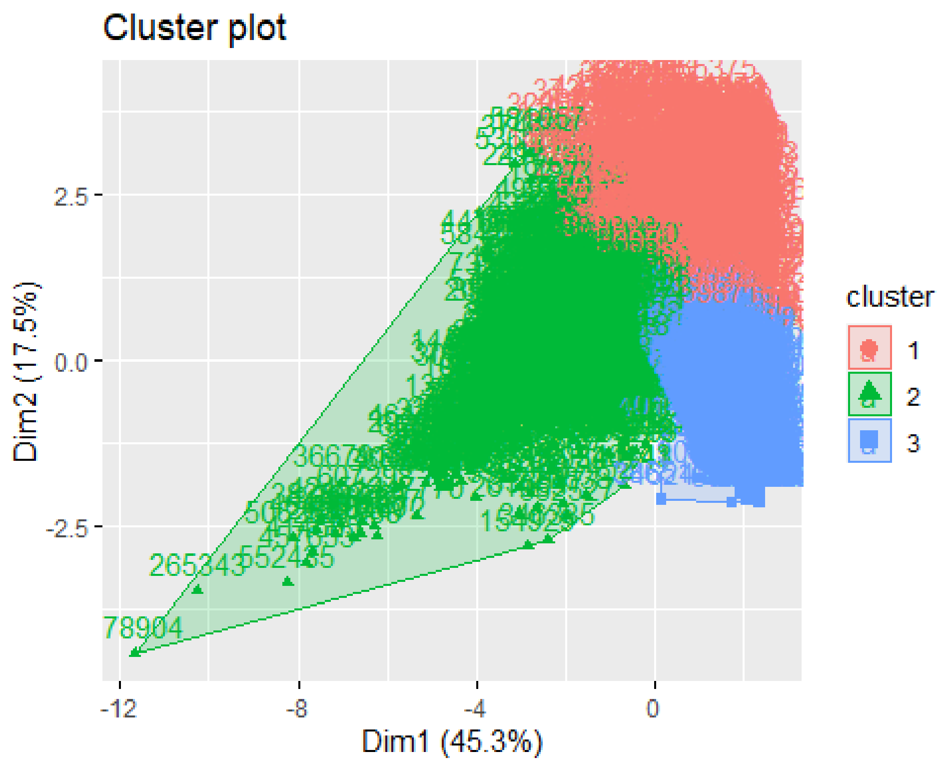
```
#wss
fviz_nbclust(Scaled_Data, kmeans, method = "wss")
```




```
# We feel that k=2 is best.
wss_k2 = kmeans(Scaled_Data, centers=2,nstart=50)
wss_group=wss_k2$cluster
wss_k2$withinss

## [1]  8364.451 16771.092

wss_k2$tot.withinss

## [1] 25135.54

fviz_nbclust(Scaled_Data, kmeans, method = "silhouette")
```




```
# Silhouette shows that k=3 is best.
Sil_k3 = kmeans(Scaled_Data, centers=3,nstart=50)
Silhouette_group=Sil_k3$cluster
Sil_k3$withinss

## [1]  1916.686 15046.584  4047.306

Sil_k3$tot.withinss

## [1] 21010.58

# By comparing the both methods  and by finding the withiness we have come to
an idea that k=3 is the best k for our project.
# ie Sil_k3$tot.withinss is less that of Wss_k2$tot.withinss
# 2101.58 is less than 25135.54

fviz_cluster(Sil_k3,data=Scaled_Data)
```



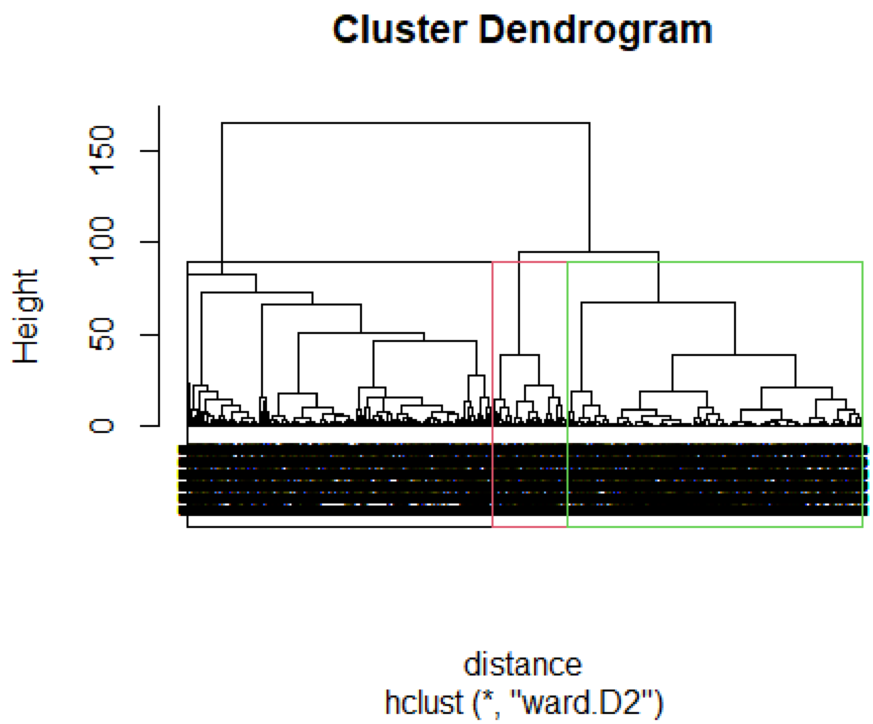
Interpretation

```
Silhouette_group = as.data.frame(Silhouette_group)
Sil_bind=cbind(All_Numeric_Variables,Silhouette_group)
Cluster_mean= Sil_bind %>% group_by(Silhouette_group) %>%
summarise_all("mean")
Cluster_mean

## # A tibble: 3 × 7
##   Silhouette_group fuel_received_units fuel_mm…¹ sulfu…² ash_c…³ mercu…⁴
fuel_…⁵
##              <int>               <dbl>     <dbl>   <dbl>   <dbl>   <dbl>
<dbl>
## 1                1             161116.      5.23 0.111   1.55    3.45e-3
3.70
## 2                2              29500.     21.6  1.42    9.86    2.90e-2
2.64
## 3                3              18050.      1.18 0.00413 0.00863 2.13e-5
4.89
## # … with abbreviated variable names ¹fuel_mmbtu_per_unit, ²
sulfur_content_pct,
## #   ³ash_content_pct, ⁴mercury_content_ppm, ⁵fuel_cost_per_mmbtu

#
# As Sulfer content,ash content,mercury content are less than 0.001 m they
can be neglected for intrepretation.

# Cluster 1
#
```

```
#   The power Plants present in this cluster receives fuel of 161115.82 which
is high than all the 3 clsuters.
#   Their heat content in the fuel is 5.231477 which is very good wrt to the
fuel recieves compared to other 2 clsuters.
#   The fuel cost per mmbtu is also very good(3.704139) wrt to fuel recieved
and the heat content.
#   This Cluster is the preferred one to recommend for the Us Government
beacuse by looking all the factors like (fuel recieved,heat content,fuel cost
per mmbtu).


# Cluster 2
#
#   The power Plants present in this cluster receives fuel of 29500.21 which
is slightly above the Cluster 3 but not cluster 1.
#   Their heat content in the fuel is very very high of 21.607668 comapared
to all the 3 clsuters.
#   The fuel cost per mmbtu is lower(2.635552) than all the 3 clusters
formed.
#   This cluster is also not a preferred one to recommend for us Government
because of fuel mmbtu per unit.


# Cluster 3
#
# The power plants present in this cluster recieves fuel of 18049.93 which is
low compared to other plants.
# As they are receiving low fuel their heat content in fuel(fuel_mmbtu) is
also low (1.183889).
# The fuel cost per mmbtu is higher (4.889421) than all the 3 clusters
formed.
# This Cluster is not a preferred one to recommend for Us Government because
of fuel cost per mmbtu.
```

Hierarchial Clustering for visualizing the data

```
# Getting distance
distance= dist(Scaled_Data,method="euclidean")
# Computing method
hclust_ward=hclust(distance,method = "ward.D2")
#plotting
plot(hclust_ward,cex=0.6,hang=-1);
rect.hclust(hclust_ward,k=3,border=1:4)
```



Cluster Dendrogram
Height
0
50
100
150
distance
hclust (*, "ward.D2")