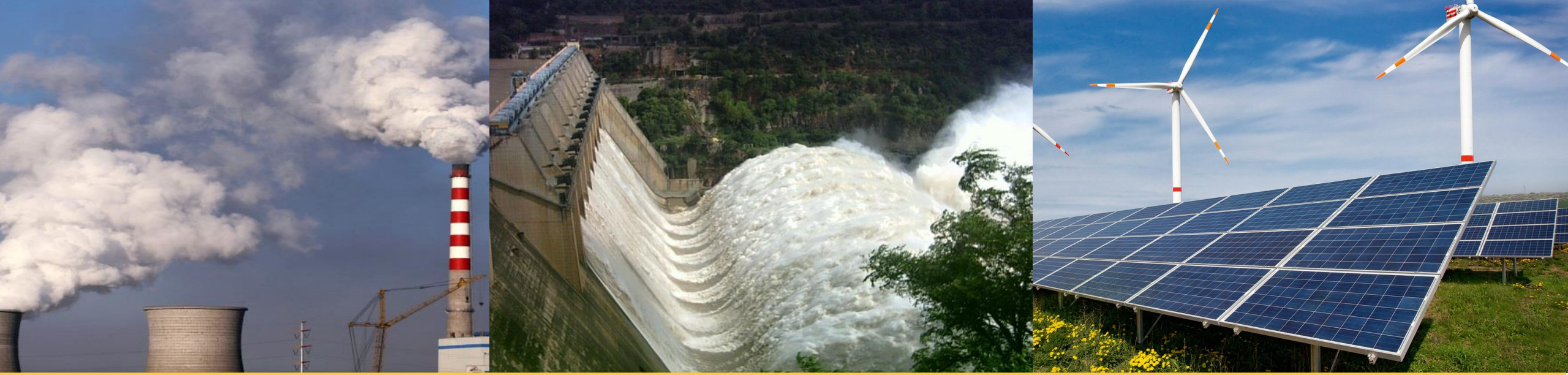




# Application of Forecasting Tools

Dr. Chandrasekhar Reddy Atla



# Regression Analysis

Regression analysis is a statistical tool for the investigation of relationships between variables.

Usually, the causal effect of one variable upon another is investigated.

To explore such issues, data on the underlying variables of interest is assembled and regression is performed to estimate the quantitative effect of the causal variables upon the variable that they influence.

“statistical significance” of the estimated relationships, that is, the degree of confidence that the true relationship is close to the estimated relationship is also computed.

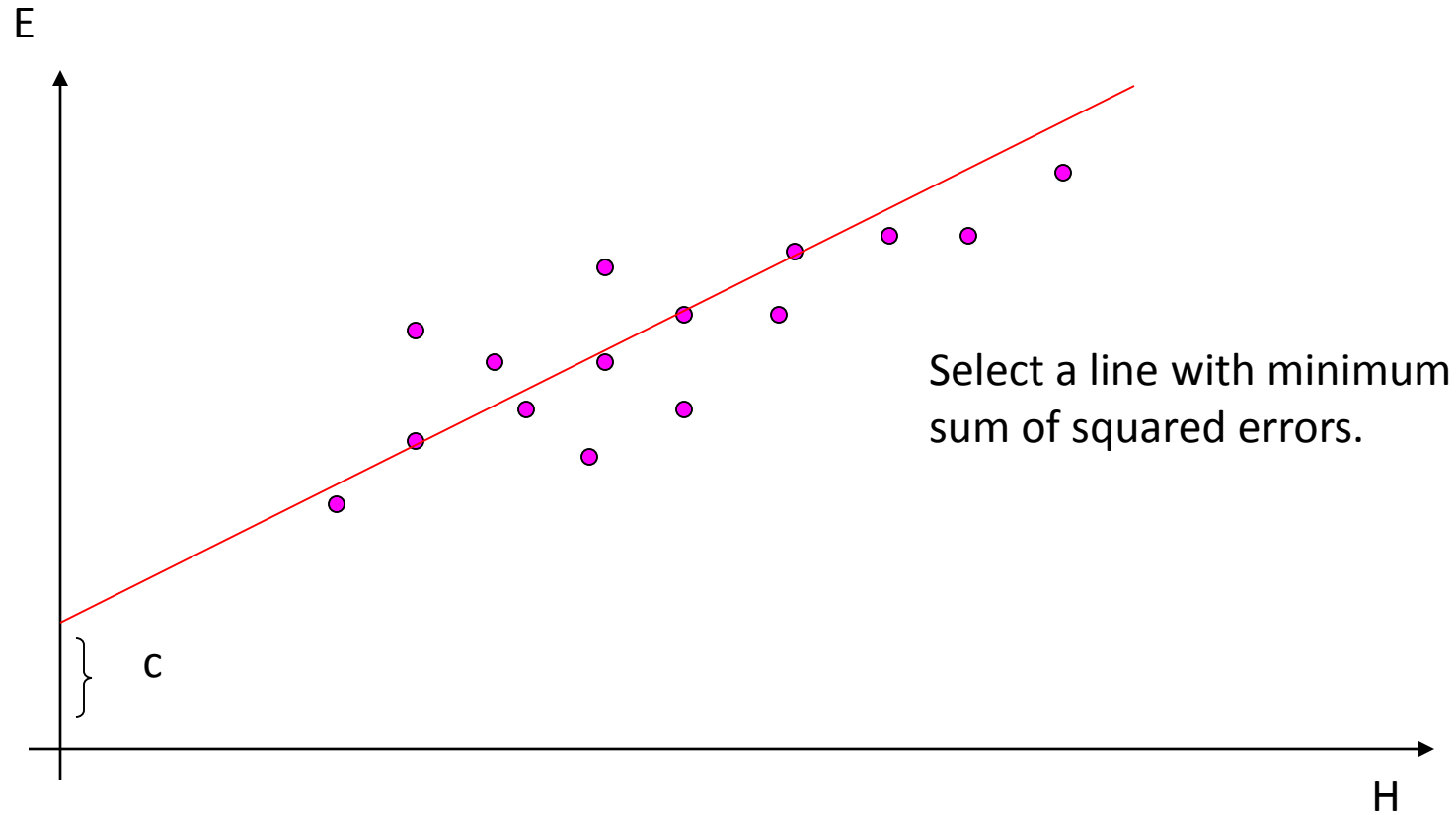
# Regression Analysis

If we have the energy consumption  $E$  and the house holds  $H$ , then, the hypothesized relationship between  $E$  and  $H$  may be written as

$$E = c + aH + n$$

- where
  - $c$  = a constant amount ;
  - $a$  = the effect in energy consumption with house holds.
  - $n$  = the “noise” term reflecting other factors that influence energy consumption

# Regression Analysis



# Multiple Regression Analysis

If we have the energy consumption  $E$ , the house holds  $H$ , income  $I$ , then, the hypothesized relationship between  $E$ ,  $H$  and  $I$  may be written as

$$E = c + aH + bI + n$$

- Where
- $c$  = a constant amount ;
- $a$  = the effect in energy consumption with house holds.
- $b$  = the effect in energy consumption with income
- $n$  = the “noise” term reflecting other factors that influence energy consumption

Once again, here the sum of the squared errors is minimized.

# Regression Analysis – two samples

| Year | reading | Munits |       |           |                             |     |    |
|------|---------|--------|-------|-----------|-----------------------------|-----|----|
| 1990 | 1       | 1000   | slope | m         | $(y_2 - y_1) / (x_2 - x_1)$ | 200 |    |
| 1991 | 2       | 1200   |       | c         | y-mx                        | 800 |    |
|      |         |        |       | c - check |                             | 800 | ok |



# Regression Analysis – three samples

| Year | reading | Munits |       |           |                             |      |    |
|------|---------|--------|-------|-----------|-----------------------------|------|----|
| 1990 | 1       | 1000   | slope | m         | $(y_2 - y_1) / (x_2 - x_1)$ | 200  |    |
| 1991 | 2       | 1200   |       | c         | y-mx                        | 800  |    |
| 1992 | 3       | 1300   |       | c - check |                             | 800  | ok |
|      |         |        |       |           |                             |      |    |
|      |         |        |       | m         | $(y_2 - y_1) / (x_2 - x_1)$ | 100  |    |
|      |         |        |       | c         | y-mx                        | 1000 |    |
|      |         |        |       | c - check |                             | 1000 | ok |
|      |         |        |       |           |                             |      |    |
|      |         |        |       | m         | $(y_2 - y_1) / (x_2 - x_1)$ | 150  |    |
|      |         |        |       | c         | y-mx                        | 850  |    |
|      |         |        |       | c - check |                             | 850  | ok |

# Regression Analysis – three samples

- ✓ Equation form  $y = m \cdot x + c$ 
  - $y_1 = m \cdot x_1 + c$
  - $y_2 = m \cdot x_2 + c$
  - $y_3 = m \cdot x_3 + c$
- ✓ Error is  $(y_i - c - m \cdot x_i)$
- ✓ Sum of error square =  $\sum((y_i - c - m \cdot x_i)^2) = 0$
- ✓ Derivative with respect to  $c$  is given by
$$-2 \cdot \sum(y_i - c - m \cdot x_i) = 0$$
- ✓ Derivative with respect to  $m$  is given by
$$-2 \cdot \sum(y_i - c - m \cdot x_i) \cdot (x_i) = 0$$



# Regression Analysis – three samples

$$y_1 - c - m x_1 + y_2 - c - m x_2 + y_3 - c - m x_3 = 0$$

$$3c + m(x_1 + x_2 + x_3) = y_1 + y_2 + y_3$$

$$y_1 x_1 - c x_1 - m x_1^2 + y_2 x_2 - c x_2 - m x_2^2 \\ + y_3 x_3 - c x_3 - m x_3^2 = 0$$

$$c(x_1 + x_2 + x_3) + m(x_1^2 + x_2^2 + x_3^2) = x_1 y_1 + x_2 y_2 + x_3 y_3$$

$$\begin{bmatrix} 3 & x_1 + x_2 + x_3 \\ x_1 + x_2 + x_3 & x_1^2 + x_2^2 + x_3^2 \end{bmatrix} \begin{bmatrix} c \\ m \end{bmatrix} = \begin{bmatrix} y_1 + y_2 + y_3 \\ x_1 y_1 + x_2 y_2 + x_3 y_3 \end{bmatrix}$$

# Regression Analysis – three samples

$$\begin{bmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix} \begin{bmatrix} c \\ m \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \end{bmatrix}$$

$$\begin{bmatrix} c \\ m \end{bmatrix} = \begin{bmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix}^{-1} \begin{bmatrix} \sum y_i \\ \sum x_i y_i \end{bmatrix}$$

# Regression Analysis – three samples

| Year         | reading (xi) | Munits (yi) | xi*yi    | xi*xi | observations |
|--------------|--------------|-------------|----------|-------|--------------|
| 1990         | 1            | 1000        | 1000     | 1     | 3            |
| 1991         | 2            | 1200        | 2400     | 4     |              |
| 1992         | 3            | 1300        | 3900     | 9     |              |
| sigma        | 6            | 3500        | 7300     | 14    |              |
| Matrix       | A            | B           | 3        | 6     |              |
|              | C            | D           | 6        | 14    |              |
| Inverse      |              |             | 2.333333 | -1    | 3500         |
|              |              |             | -1       | 0.5   | 7300         |
|              |              |             |          |       |              |
| Check        |              |             | 1        | 0     |              |
|              |              |             | 0        | 1     |              |
| Slope        | 150          | Error       |          | c     | 866.6666667  |
| Constant     | 866.66667    |             |          | m     | 150          |
| y1 estimated | 1016.6667    | -16.6666667 |          |       |              |
| y2 estimated | 1166.6667    | 33.3333333  |          |       |              |
| y3 estimated | 1316.6667    | -16.6666667 |          |       |              |
| Sum of error |              | 0.00        |          |       |              |

# Load Forecasting : Input Data

**Historical Category wise Energy Sales/consumption**

**Historical load factor, T&D losses and future projection if any**

**Historical Unserved energy, unmet demand**

**Existing and proposed Bulk load details**

**Historical and Future Econometric data**

**Historical peak demand, energy sales and area for division wise forecasting for cities**

**No of customers, connected load for each category**

# Long term Load Forecasting : Tool

**LFC - Configure Data Variables**

| VariableName       | VariableUnit |
|--------------------|--------------|
| Year               | Year         |
| Domestic           | MUnits       |
| Commercial         | MUnits       |
| Industrial         | MUnits       |
| Agricultu.         | MUnits       |
| Public_Water_Works | MUnits       |
| Industries_H.T.    | MUnits       |
| Misc_Municipality  | MUnits       |

Ok Cancel

**LFC-Study Case**

| Case Number | Case Name |
|-------------|-----------|
| 13          | LFC_1     |

Add  
Delete  
Clear

Execute After Input File Creation

Configure Forecast Options >>

View Graph

View Report

Execute

Close

17:00:27:709 :: CASE [13] :: LFC\_1  
17:00:27:725 :: Independent Variables [1], Dependent Variables [1]  
17:00:27:725 :: IN-[E:\RAPDRP\_DLL\JUNE\_2011\29JUNE\_Test1\appfolder\lfc\_13\_29\_06\_2011\_17\_00\_27.dat]  
17:00:27:725 :: OUT-[E:\RAPDRP\_DLL\JUNE\_2011\29JUNE\_Test1\appfolder\lfc\_13\_29\_06\_2011\_17\_00\_27.out]  
17:00:27:850 :: LFC Data File Preparation Status [1]  
17:00:27:928 :: LFC Application Execution Status [1] Error [-1] Reason [SUCCESS]  
17:00:27:928 :: CASE [13] :: ..... End of Execution .....

# Long term Load F

## Load Forecast Data

Study Number 50

Study Description Load ForeCasting From LFC Manual

Add Variable

Insert Variable

Delete Variables

| Ref No. | 1           | 2             | 3          | 4          | 5           | 6           |
|---------|-------------|---------------|------------|------------|-------------|-------------|
| Name    | population  | Dom.Prod      | Commercial | Domestic   | Industry    | Agriculture |
| Units   | lakhs       | lakhs         | MUnits     | MUnits     | MUnits      | MUnits      |
| Type    | Independent | Independent   | Dependent  | Dependent  | Dependent   | Dependent   |
| 1       | 407         | 242072.000000 | 411.000000 | 336.000000 | 2681.000000 | 1275.000000 |
| 2       | 415         | 254538.000000 | 434.000000 | 358.000000 | 2850.000000 | 1403.000000 |
| 3       | 421         | 255659.000000 | 410.000000 | 360.000000 | 2655.000000 | 1489.000000 |
| 4       | 427         | 267510.000000 | 478.000000 | 390.000000 | 2498.000000 | 1605.000000 |
| 5       | 434         | 232490.000000 | 417.000000 | 425.000000 | 2442.000000 | 1850.000000 |
| 6       | 440         | 261170.000000 | 457.000000 | 501.000000 | 3098.000000 | 1694.000000 |
| 7       | 446         | 261462.000000 | 523.000000 | 541.000000 | 3076.000000 | 1694.000000 |
| 8       | 453         | 291183.000000 | 571.000000 | 591.000000 | 3468.000000 | 1740.000000 |
| 9       | 459         | 322398.000000 | 670.000000 | 670.000000 | 4160.000000 | 2118.000000 |
| 10      | 470         | 322400.000000 |            |            |             |             |
| 11      | 480         | 332400.000000 |            |            |             |             |
| 12      | 490         | 341200.000000 |            |            |             |             |
| 13      | 500         | 345200.000000 |            |            |             |             |

## Demand Forecast Data

Case Number 50

Study Number 50

Data ---> Dependent

Independent

| Select                              | Name            | Log                      | nObservati... |
|-------------------------------------|-----------------|--------------------------|---------------|
| <input type="checkbox"/>            | 3 [Commercial]  | <input type="checkbox"/> | 9             |
| <input checked="" type="checkbox"/> | 4 [Domestic]    | <input type="checkbox"/> | 9             |
| <input type="checkbox"/>            | 5 [Industry]    | <input type="checkbox"/> | 9             |
| <input type="checkbox"/>            | 6 [Agriculture] | <input type="checkbox"/> | 9             |

| Select                              | Name           | Log                      |
|-------------------------------------|----------------|--------------------------|
| <input checked="" type="checkbox"/> | 1 [population] | <input type="checkbox"/> |
| <input checked="" type="checkbox"/> | 2 [Dom.Prod]   | <input type="checkbox"/> |

Base Year 1980

Start Year 1980

Observation 9

No. of forecasting years

5

Bar graph option

- ☒ Input, Results and Estimated
- ☐ Results only
- ☐ Input and Results

Curve option

- ☒ Best suitable curve for regression analysis
- ☐ Linear regression,  $y = a + bx$
- ☐ Power equation,  $y = ax^b$
- ☐ Power series of the form,  $y = ab^x$
- ☐ Exponential equation of the form,  $y = ae^{(bx)}$
- ☐ Exponential series of the form,  $y = e^{(a+bx)}$
- ☐ Non-linear equation of the form,  $y = a + bx + cx^2$
- ☐ Logarithmic equation,  $y = a + b_1 \log x_1 + b_2 \log x_2$
- ☐ Multiple regression

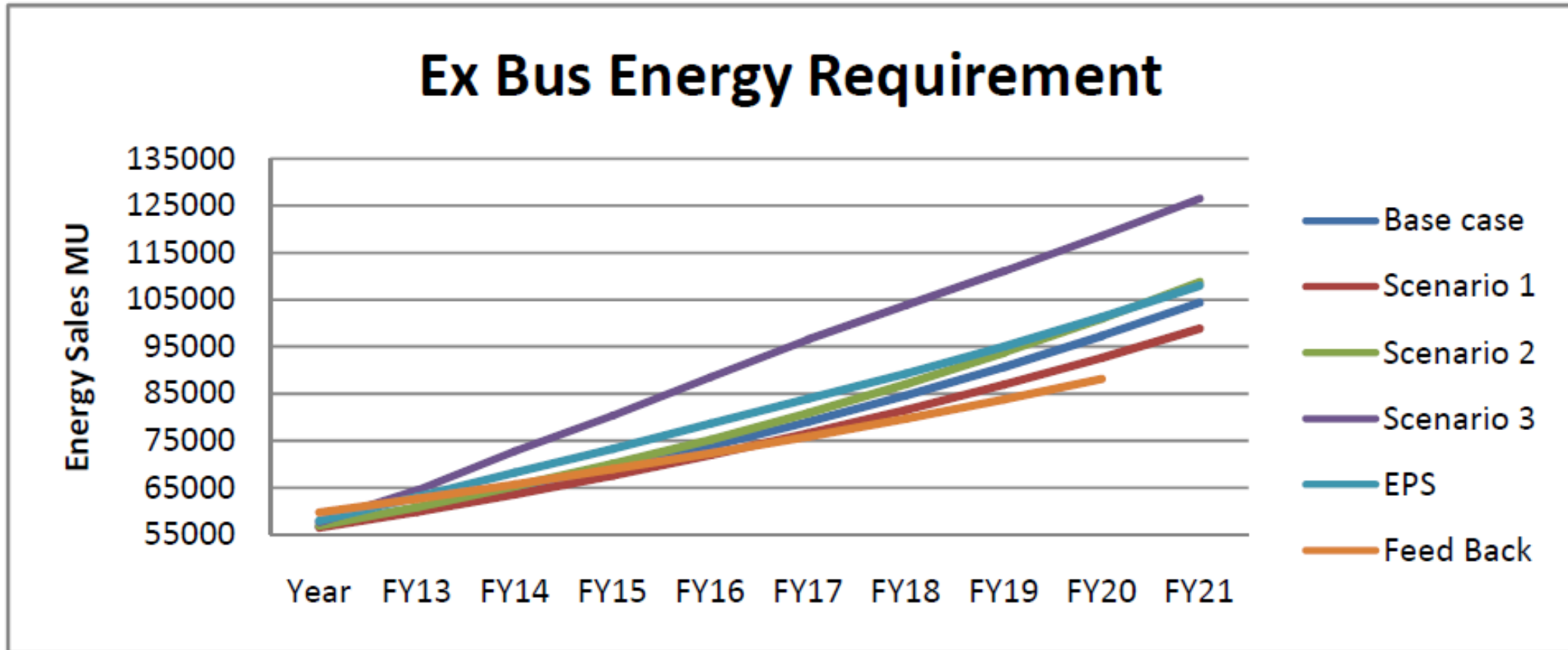
OK

Cancel

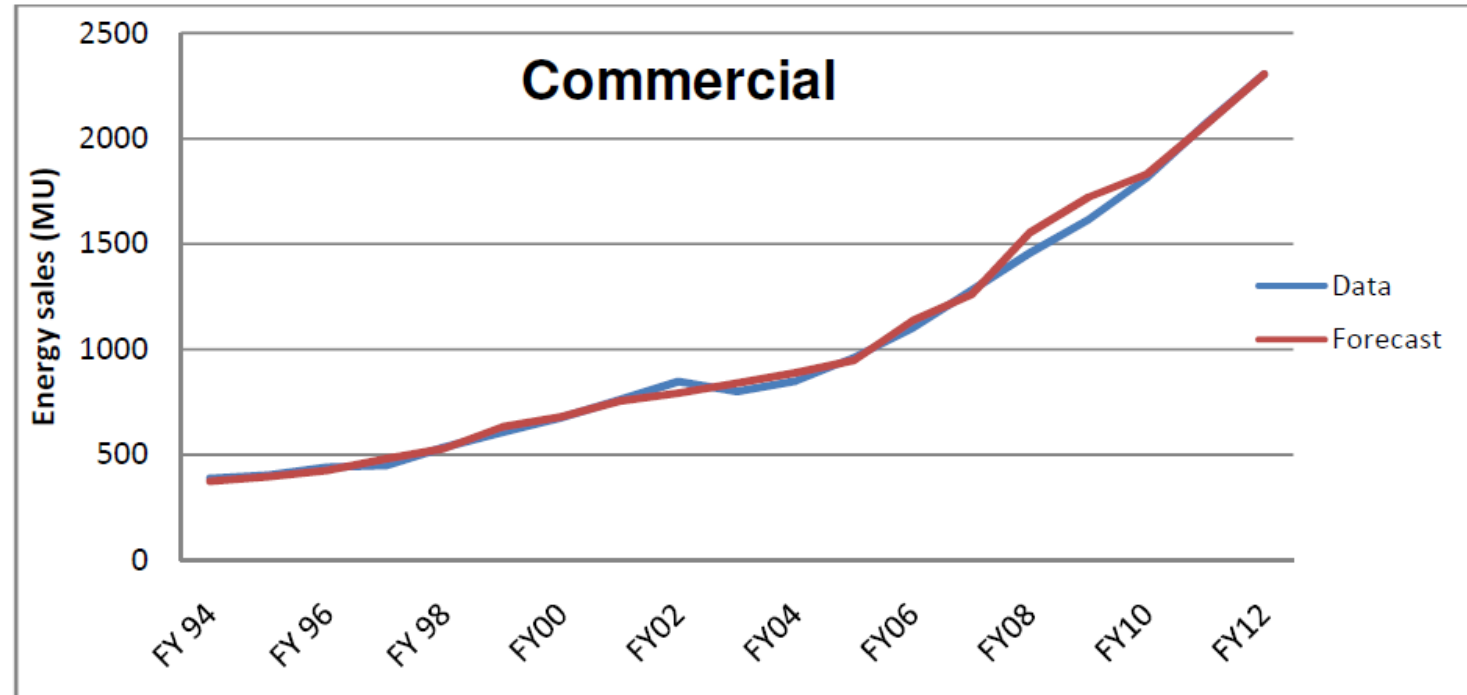
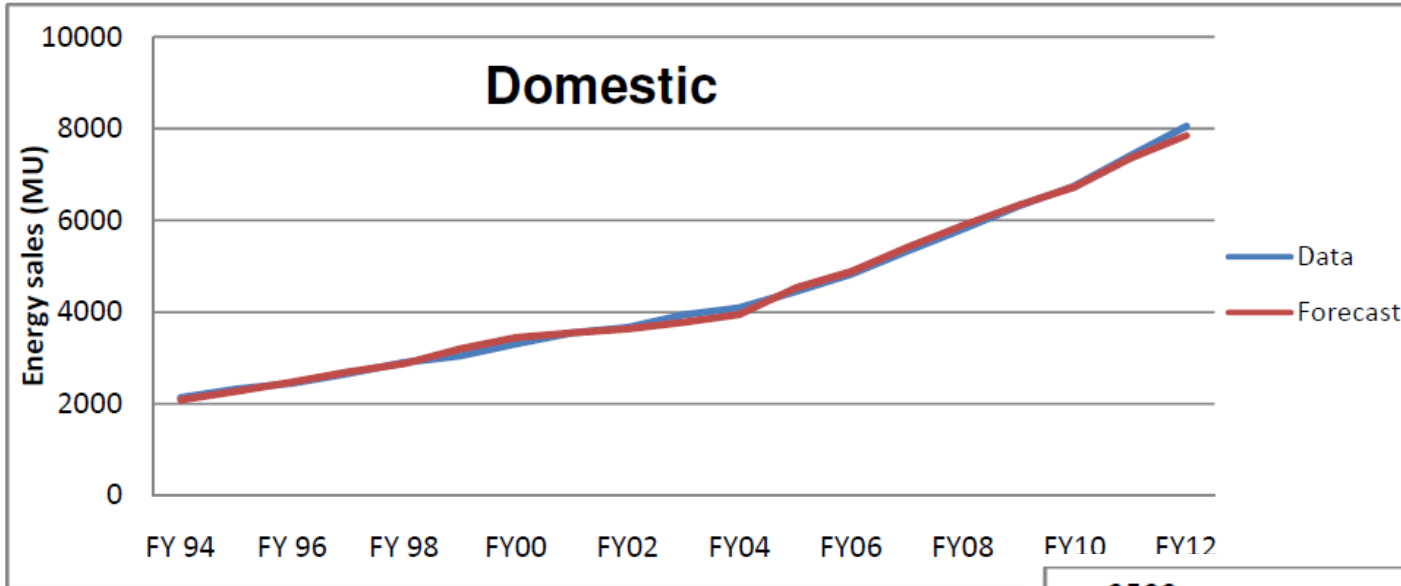
# Forecast Models – Some samples



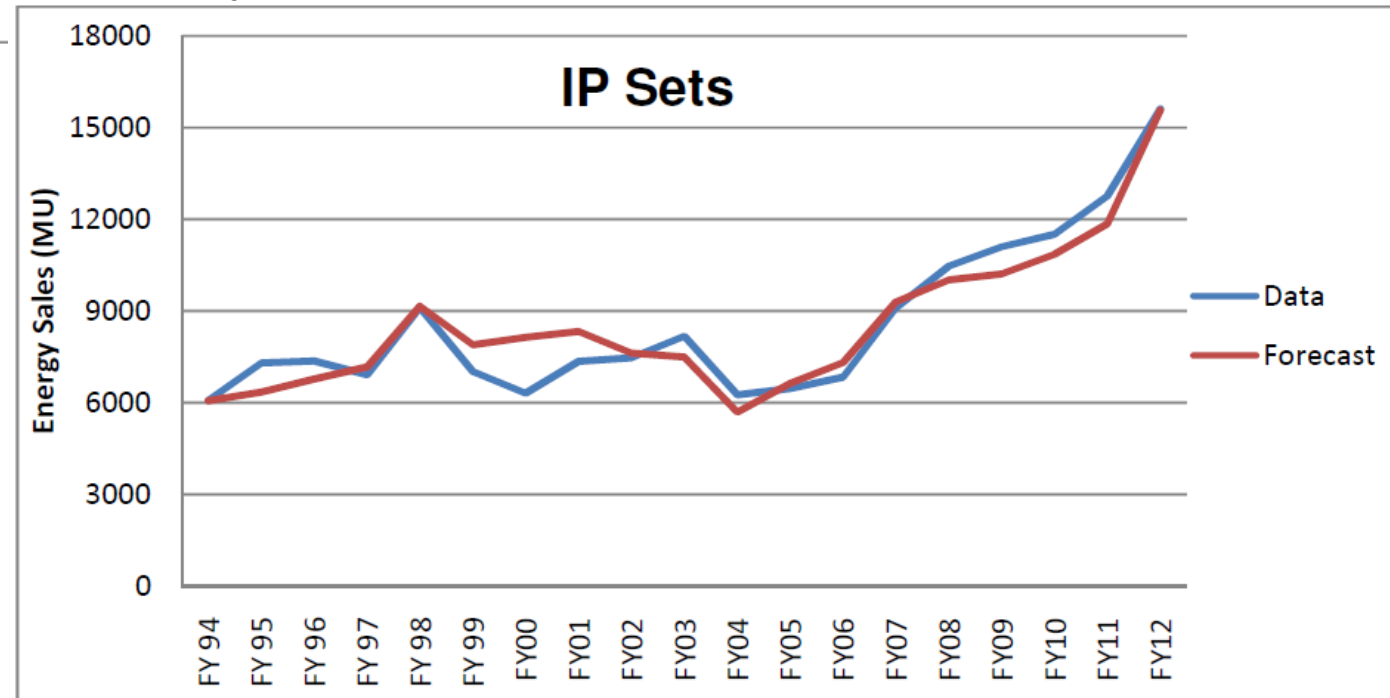
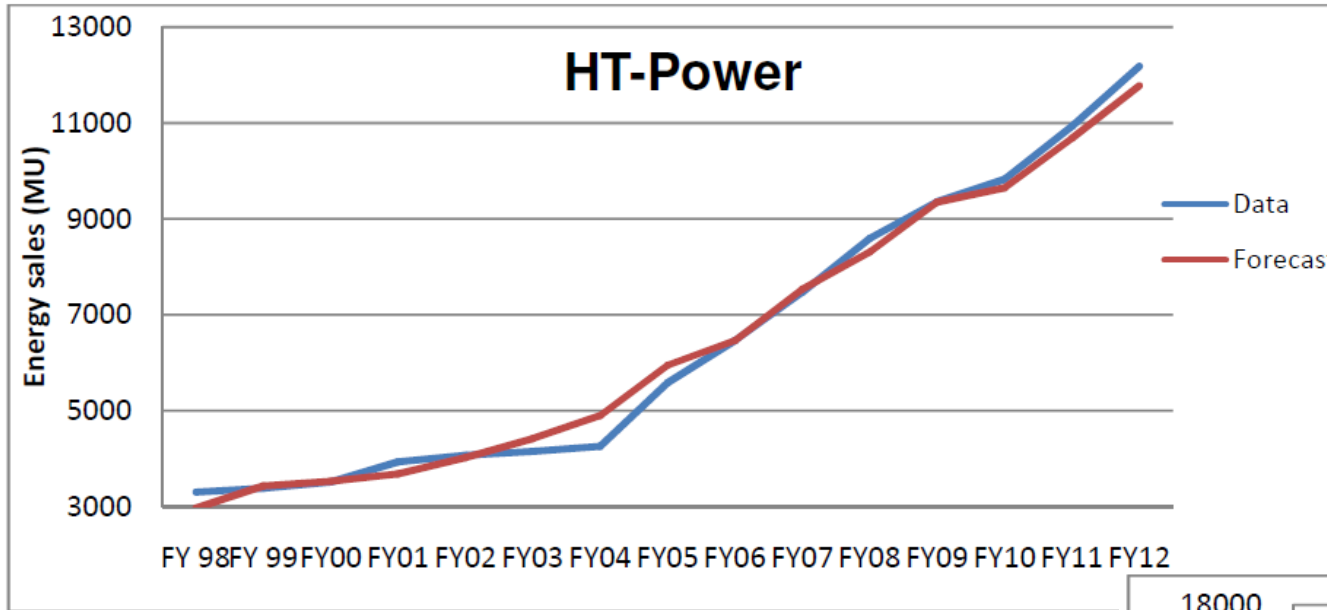
# Energy Requirement: State Level



# Category wise Energy Forecast



# Category wise Energy Forecast



# System Level Energy Forecast

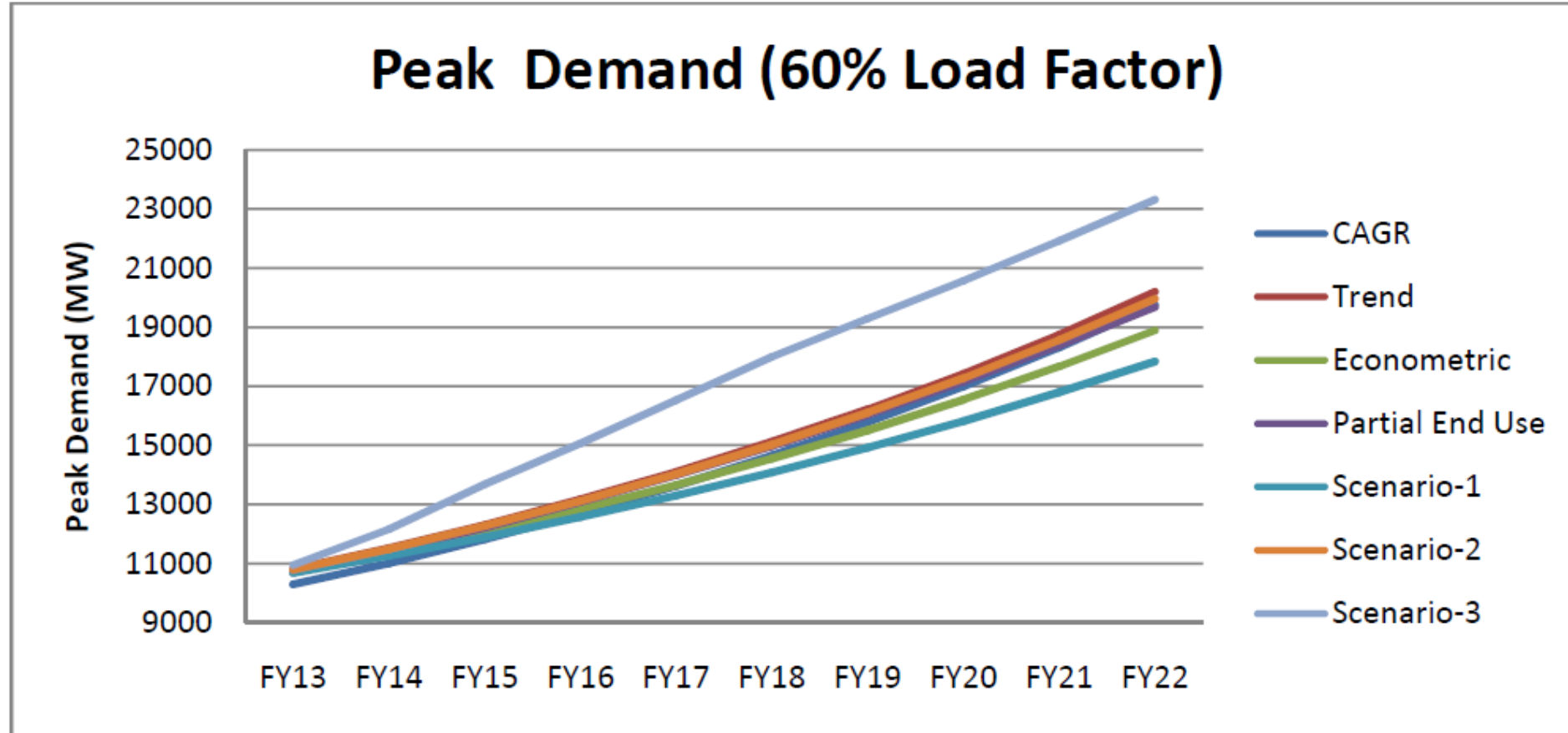
| SUMMARY OF YEAR WISE ENERGY SALES (MU) BASED ON MULTI REGRESSION ANALYSIS |       |              |               |          |             |         |          |                 |       |
|---------------------------------------------------------------------------|-------|--------------|---------------|----------|-------------|---------|----------|-----------------|-------|
| YEAR                                                                      | BJ/KJ | DOM Lighting | Commercial LT | LT Power | Water Works | IP SETS | HT Power | Street Lighting | Total |
| 2012-13                                                                   | 579   | 8669         | 2549          | 1842     | 1134        | 16227   | 13253    | 833             | 45087 |
| 2013-14                                                                   | 608   | 9332         | 2820          | 1908     | 1275        | 16873   | 14421    | 870             | 48107 |
| 2014-15                                                                   | 638   | 10046        | 3120          | 1978     | 1435        | 17542   | 15691    | 907             | 51357 |
| 2015-16                                                                   | 670   | 10816        | 3451          | 2049     | 1614        | 18239   | 17072    | 945             | 54857 |
| 2016-17                                                                   | 703   | 11644        | 3817          | 2124     | 1816        | 18963   | 18576    | 983             | 58627 |
| 2017-18                                                                   | 738   | 12535        | 4223          | 2201     | 2043        | 19717   | 20212    | 1022            | 62692 |
| 2018-19                                                                   | 775   | 13494        | 4671          | 2281     | 2299        | 20501   | 21992    | 1061            | 67075 |
| 2019-20                                                                   | 814   | 14527        | 5167          | 2364     | 2586        | 21316   | 23929    | 1101            | 71805 |
| 2020-21                                                                   | 854   | 15639        | 5715          | 2449     | 2909        | 22162   | 26037    | 1141            | 76907 |
| 2021-22                                                                   | 897   | 16836        | 6322          | 2538     | 3273        | 23042   | 28329    | 1181            | 82414 |

# Category wise Energy Forecast

| EX-BUS ENERGY REQUIREMENT FOR THE STATE IN MILLION UNITS |        |        |             |        |            |            |            |
|----------------------------------------------------------|--------|--------|-------------|--------|------------|------------|------------|
| Year                                                     | CAGR   | Trend  | Econometric | PEUM   | Scenario-1 | Scenario-2 | Scenario-3 |
| <b>FY13</b>                                              | 54059  | 56796  | 56429       | 56170  | 56148      | 56712      | 57514      |
| <b>FY14</b>                                              | 57842  | 60507  | 59760       | 59993  | 59158      | 60369      | 63912      |
| <b>FY15</b>                                              | 62072  | 64673  | 63483       | 64225  | 62507      | 64464      | 71914      |
| <b>FY16</b>                                              | 66640  | 69174  | 67475       | 68734  | 66074      | 68887      | 79168      |
| <b>FY17</b>                                              | 71575  | 74049  | 71759       | 73523  | 69871      | 73658      | 86897      |
| <b>FY18</b>                                              | 77003  | 79421  | 76453       | 78723  | 74010      | 78908      | 94545      |
| <b>FY19</b>                                              | 82877  | 85247  | 81500       | 84271  | 78424      | 84594      | 101374     |
| <b>FY20</b>                                              | 89236  | 91571  | 86931       | 90176  | 83139      | 90746      | 108088     |
| <b>FY21</b>                                              | 96240  | 98558  | 92883       | 96572  | 88273      | 97525      | 115199     |
| <b>FY22</b>                                              | 103837 | 106157 | 99294       | 103381 | 93767      | 104881     | 122512     |

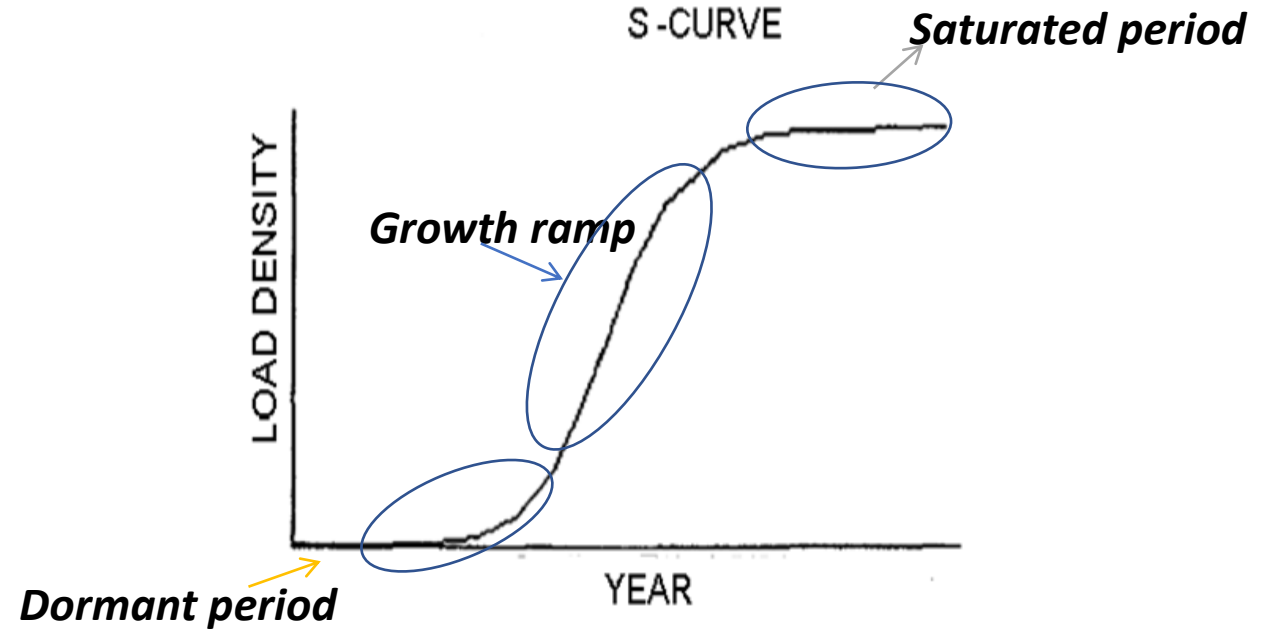
# State wise Energy Forecast

| LOAD FACTORS |                  |
|--------------|------------------|
| YEAR         | Load Factor in % |
| 2003-04      | 71.85            |
| 2004-05      | 68.12            |
| 2005-06      | 69.81            |
| 2006-07      | 67.75            |
| 2007-08      | 69.90            |
| 2008-09      | 71.32            |
| 2009-10      | 68.54            |
| 2010-11      | 70.44            |
| 2011-12      | 68.38            |



# Energy Requirement: City Level

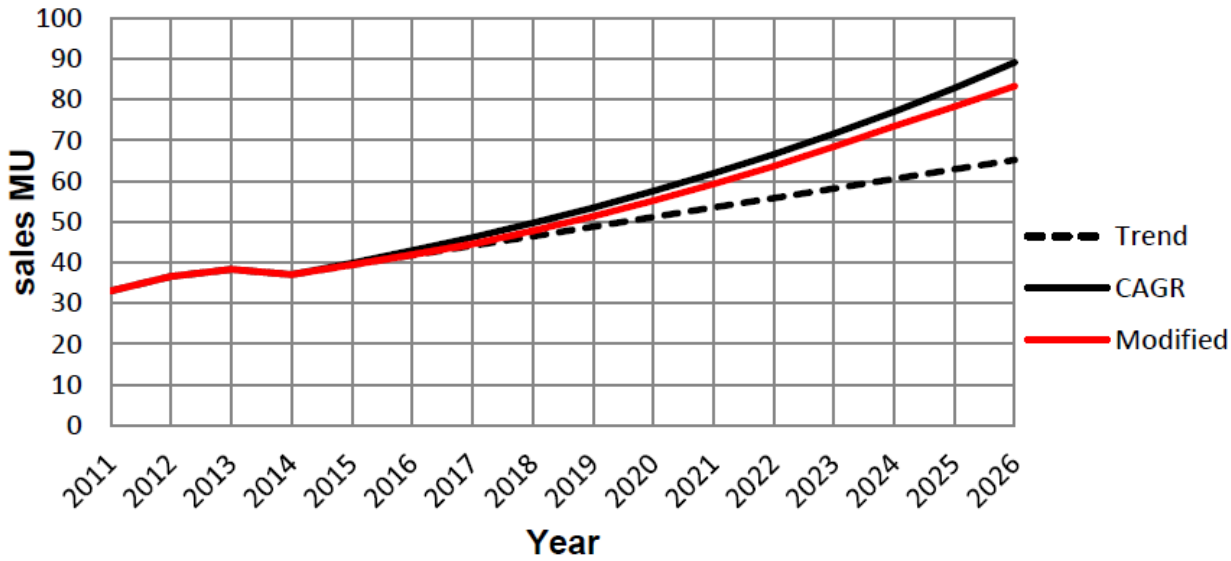
## SPATIAL LOAD FORECASTING



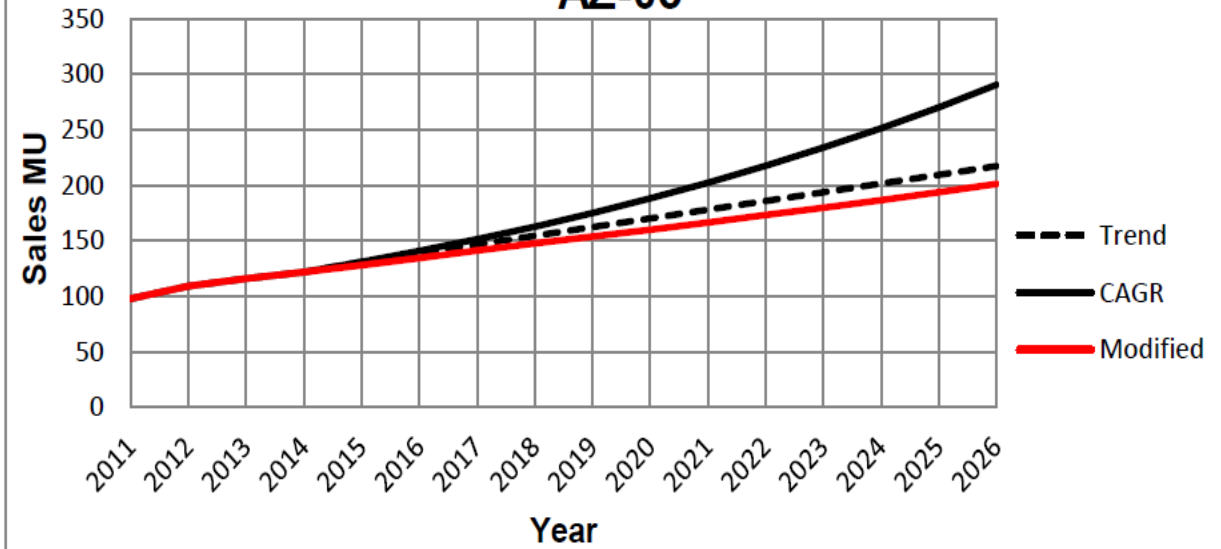
| SL no | ZONE number | Load density (MU/sq.km) | % Growth |
|-------|-------------|-------------------------|----------|
| 1     | AZ-02       | 3.507                   | 8.93     |
| 2     | AZ-02       | 3.820                   | 14.21    |
| 3     | AZ-02       | 4.363                   | 34.99    |
| 4     | NZ-19       | 4.351                   | 8.84     |
| 5     | NZ-19       | 4.736                   | 3.27     |
| 6     | NZ-19       | 4.891                   | 39.52    |
| ...   | ....        | ....                    | ....     |

# Energy Requirement: City Level

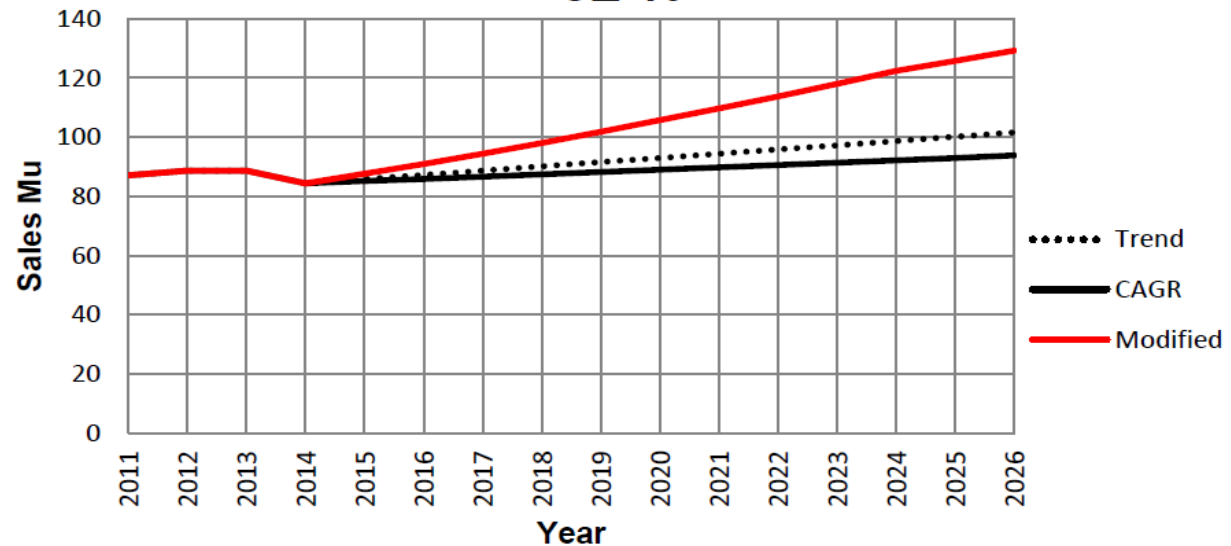
## AZ-01



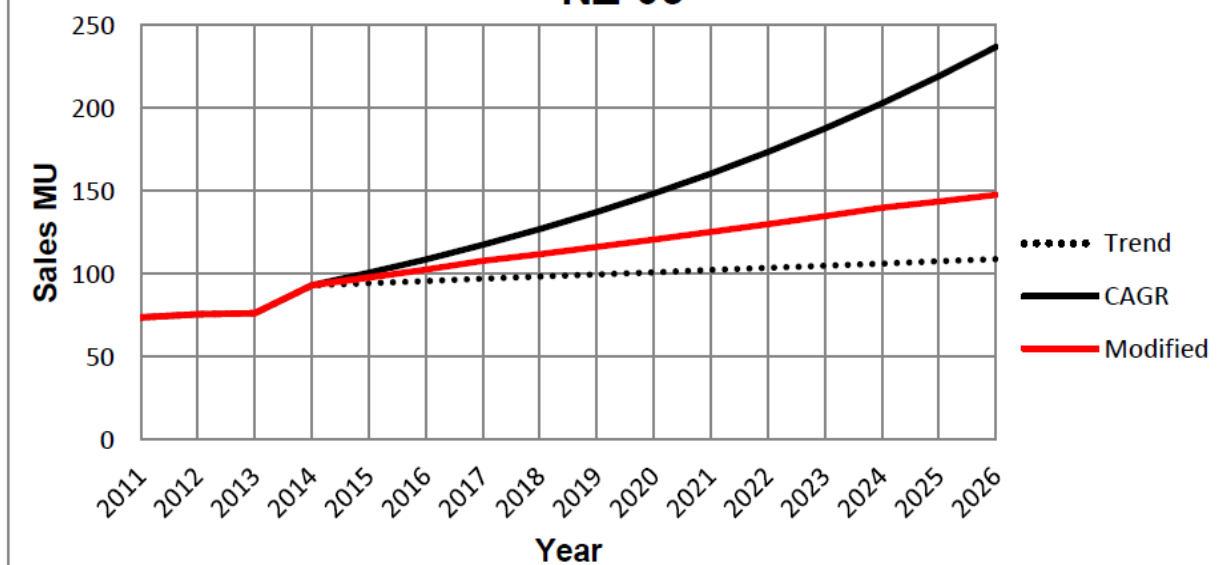
## AZ-03



## CZ-19



## NZ-03





# Energy Requirement: City Level

## Comparison of Group wise and System level forecasts

| Year | Sales (in MU)                            |                             | % Error |
|------|------------------------------------------|-----------------------------|---------|
|      | Total sales based on Group wise forecast | System level Trend Analysis |         |
| 2015 | 7212.90                                  | 7211.99                     | 0.01    |
| 2016 | 7594.756                                 | 7554.56                     | 0.53    |
| 2017 | 7987.508                                 | 7897.13                     | 1.14    |
| 2018 | 8333.379                                 | 8239.70                     | 1.14    |
| 2019 | 8681.89                                  | 8582.27                     | 1.16    |
| 2020 | 9034.989                                 | 8924.84                     | 1.23    |
| 2021 | 9394.19                                  | 9267.41                     | 1.37    |
| 2022 | 9752.463                                 | 9609.98                     | 1.48    |
| 2023 | 10118.62                                 | 9952.55                     | 1.67    |
| 2024 | 10486.5                                  | 10295.12                    | 1.86    |
| 2025 | 10860.52                                 | 10637.69                    | 2.09    |
| 2026 | 11244.55                                 | 10980.26                    | 2.41    |

**THANK YOU**