6.1. Introduction to DSM

Electricity has a Peculiar characteristic that it cannot be stored in large amounts. Moreover its supply is under the control of the Consumer. Power is drawn by the Consumer to the extent of his requirement and capacity of service mains.

Electric utilities have realized that Consumer demands cannot be met satisfactorily by adding new generating capacity alone. Due to increasing fuel prices and Energy costs, utilities have started thinking of Energy management/Demand side management. In addition to the classical approach of encouraging off peak Energy utilization, penalization for excessive use at peak time has also been considered. Differential charges for Energy used at different times of the day have been given due consideration.

The increased awareness of the potential problems of global Warming has led electric utilities to the thinking that, improved efficiency of Energy utilization is a cost effective method to reduce environmental damage. Demand side management means ***the approaches and actions which aim at augmenting the systems capacity by decreasing the Consumer's demand.*** It is widely recognised that DSM can be of great help in reducing Electricity shortages and increasing reliability of electric supply. DSM concepts, originated in USA, have now spread to almost all the countries of the world.

Energy demand management, also known as Demand side management (DSM), deals with actions that influence the quantity or patterns of use of Energy consumed by end users, such as actions targeting reduction of peak demand during periods when Energy supply systems are constrained. Peak demand management does not necessarily decrease total Energy consumption but could be expected to reduce the need or investments in networks and/or power plants. The term DSM was coined during the time of 1973 Energy crisis.

Demand side management programs consist of the planning, implementing and monitoring the activities of electric utilities that are designed to encourage Consumers to modify their level and pattern of Electricity usage.

In the past, the primary objective of most DSM programs was to provide cost effective Energy and capacity resources to help defer the need for new sources of power, including generating facilities, power purchases and transmission & distribution capacity additions. However, due to changes occurring within the industry, electric utilities are also using DSM to enhance customer service. DSM refers only to Energy and Load shape modifying activities undertaken in response to utility administered programs. It does not refer to Energy and Load shape changes arising from the normal operation of the market place or from government mandated Energy efficiency standards.

6.1.1 What is demand side management?

Demand side management is the process of managing the consumption of Energy, generally to optimize available and planned generation resources. Not all businesses are candidates for cogeneration or regeneration. However, the company may be a great candidate for other Energy saving solutions. One of these is demand side management (DSM). In the context of Power Sector DSM can be defined as "a set of measures to effectively manage the total demand on the integrated grid within its designed capacity to ensure acceptable quality of power supply to all Consumers". Management of voltage, frequency and stability. According to the Department of Energy, Demand side management refers to actions taken on the customer's side of the meter to change the amount or timing of Energy consumption. Utility DSM programs offer a variety of measures that can reduce Energy consumption and Consumer Energy expenses. DSM strategies have the goal of maximizing end use efficiency to avoid or postpone the construction of new generating plants.

6.1.2 Why DSM is required?

- It is an economic necessity; reduces overall cost of installed capacity
- It leads to efficient usage of overall power system
- Ensures quality and equity of supply
- Unlimited demand leads to instability of grid
- Essential during times of power/Energy shortage
- Reduces need for peaking stations (pumped storage Plant)

Reduces 25-35% of global CO_2 emissions to the atmosphere. How ?

- Thinning of ozone layer, green house effect
- Global warming, sea level rise and acid rains
- Should be environmental friendly
- Increase in efficiency of production, transmission and end-use

6.1.3 Scope of demand side management

Demand side management involves all activities which involve actions on the customer's side of the Energy meter. These activities may be undertaken by customers themselves or stimulated by the utility. The scope of DSM includes Load management (shifting Loads form peak to off peak periods), Energy Conservation, increased electrification (replacement of non-electric devices be electric devices). In all the activities with customers for mutual benefit. It leads to the best use of capital and fuel resources.

6.2 Concept of DSM

The oil crises of 1973 had a profound effect on electric utilities and Electricity Consumers. Utilities had to face the problem of increased costs and shortage of fuel supply. The customers were squeezed by higher Electricity bills and shortages of electric supply. The higher prices and the problems associated with increased Energy use created a demand for more efficient technologies and services.

Thus the DSM concepts evolved due to the following.

1. Utility planning was plagued by the uncertainty of future Loads.
2. As Electricity tariffs rose, the Consumers felt greater attraction for Energy conservation

3. Utilities realized that promoting DSM measures is less costly than increasing installed ~~generating capacity.~~
4. Utilities sought methods to alleviate (lessen) customer dissatisfaction by providing service options that offered that opportunity to exercise control over Electricity bills.

It has been reported that between 1977 and 1983, DSM concepts and programs reached 40 million customers in USA and decreased the peak demand by 13,000 MW or 3%. Thus DSM came to be recognized as an important as an tool which can be integrated into long range utility planning.

6.3 Benefits of DSM:

Benefits for Supply Industry

- Reduction in customer's Energy bills.
- Reduction in the need for a new power plant, transmission and distribution network.
- Stimulating economic development.
- Creating long term jobs due to new innovations and technologies.
- Increasing the competitiveness of local enterprises.
- Reduction in air pollution.
- Reduced dependency on foreign Energy sources.
- Reduction in peak power prices for Electricity.
- Improved operating efficiency and flexibility.
- Improved Load factor.
- Increased efficiency of utilization of assets.

Customer benefits.

- Satisfy Electricity demands.
- Reduce / stabilize costs.
- Improve value of service.
- Maintain / improve lifestyle and productivity.

Societal benefits.

- Reduce environmental degradation.
- Conserve resources.
- Protect global environment.
- Maximize customer welfare.

6.3.1 DSM planning and implementation

DSM planning and implementation can be described in steps as shown in figure below. The steps shown are only representative. The actual process is dynamic and would vary from utility to utility.

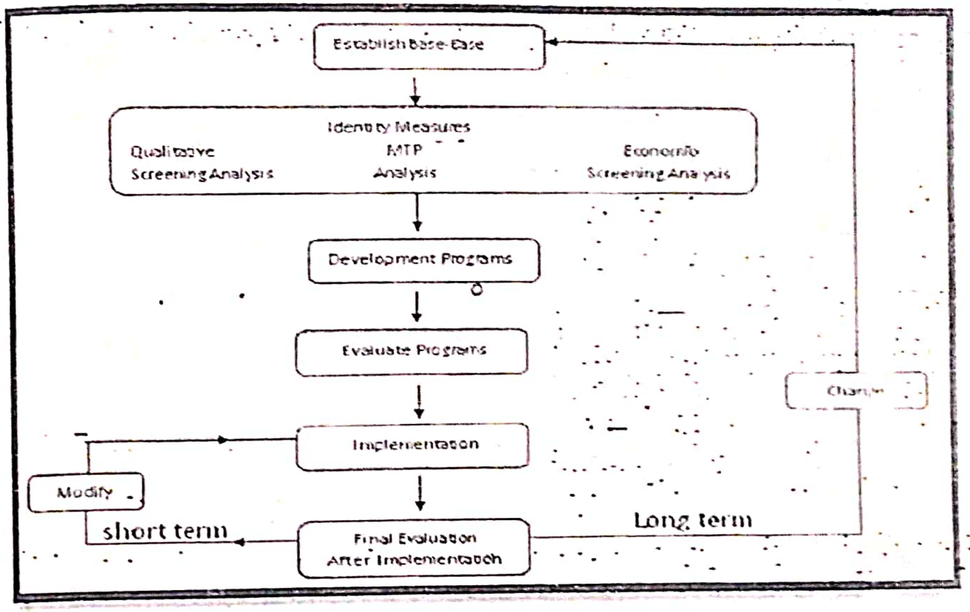


Fig. 6.3.1 (DSM planning stages)

Step 1: Establish base case:

The analyst determines a base case so that impact of DSM may be compared against it. The base case is determined for class of customers. Each segment is characterized using indicators such as total demand and Energy use, number of Consumers, consumption per Consumer. The creation of base case and its calibration with utility's demand and Energy forecasts helps in understanding the customer's usage pattern so that impacts DSM programs can be estimated. This step includes collection of data about end use efficiencies of various technologies.

(a)Domestic Consumer's Base Case:

In this base case domestic end uses of Electricity are found. These end uses include illumination, water heating, refrigeration, fans, cooking, room cooling, room heating etc. The end use Energy consumption is characterized and calibrated to forecast sales data.Domestic end use characteristics can be written as

$$E_{bc,cu} = (HH_{bc})\,(SAT_{bc,cu})\,(AEC_{bc,cu}) \quad \ldots\ldots\ldots\ldots (1)$$

Where, E = Energy consumption, kWh;HH = number of households, SAT = fraction of households owning each end use;AEC = average Energy consumption in kWh per end use.'bc' means building category and 'eu' means end use .

Many utilities and task forces have carried out customer surveys which can be used. However these available data have to be supplemented by utilities own efforts. Figure below shows the various input data which can be used for residential base case analysis. In developed countries lot of national and regional information is available so that quite accurate estimates of average Energy consumption of various appliances can be made. Many organization like electrical power research institute (EPRI), US Department of Energy, manufacturer organizations etc. have collected lot of data. Most of this data can be used as such. However the data about cooling and heating should be used after correlating it with local weather conditions and building construction patterns. This end use data can be calibrated to estimate present and future Energy requirements of this sector. It is ironical that no such data has been collected in developing countries which require to adopt DSM strategies all the more vigorously.

Establish base Case:

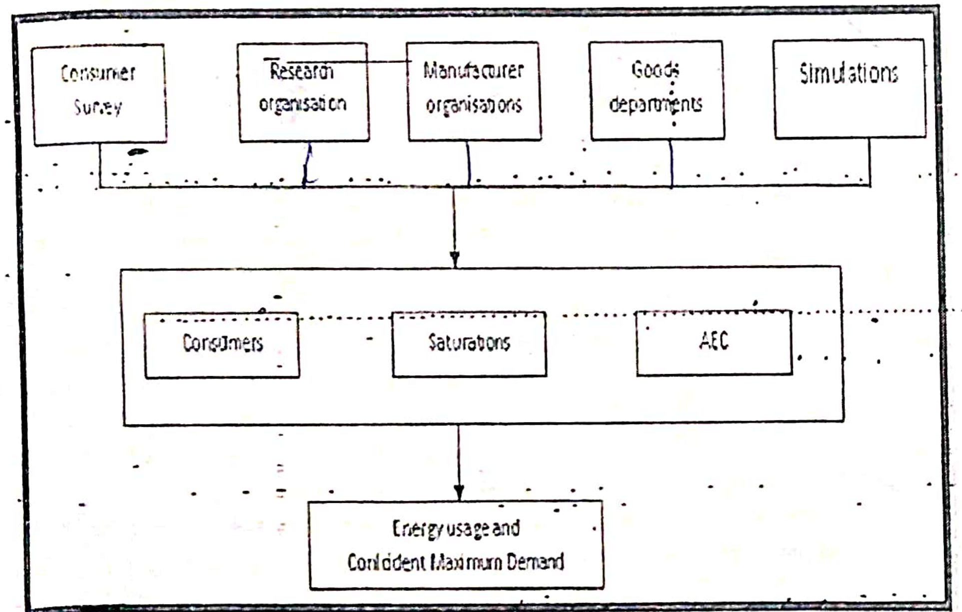


Fig: 6.3.2 (Domestic Consumers base case)

(a) Commercial Consumer's base case: Commercial Consumers include school and other Educational Institutions, Offices, Hotels, Restaurants, Hospitals, Lodging Houses, Shops, Departmental Stores etc. The end use Energy characterization in each year for each commercial building group can be written as $E_{bc.eu} = (SM_{bc})\,(SAT_{bc.eu})\,(EUI_{bc.eu})$ .... (2)

E = Energy consumption in kWh;SM = square metre of area.;SAT = fraction of total square metre of building for each end use.;EUI = average Energy use/m² for end use.'bc' and 'eu' stand for building category and end use respectively.

In USA, electrical power research institute (EPRI) and some other organization have collected

data of Energy use by various commercial organizations. This data can be used with suitable modifications wherever necessary. The commercial end use characterization is used to prepare estimates for total Energy and power demands of this sector.

(b) Industrial Consumers' base case:

Industrial Consumers include small, medium and large scale industries. In addition to the size, the type of industry also determines the Energy consumption. The end use characterization can be written as,

$E_{it.eu} = (TC_{it})\,(SAT_{it.eu})$ ....(3)

Where, E = Energy consumption in kWh

TC = specific total sector Energy consumption.

SAT = fraction of total Energy consumption for each end use.

'it' = industry type. 'eu' = end use.

In USA, the industries are divided into 40 categories. (Denoted by SIC 00 to SIC 39). The end uses are calibrated to prepare present and future power and Energy requirements.

(c) Agricultural Consumers' base case:

For agricultural Consumers, the end use Energy characterization in each year can be written as,

$E_{eu} = (A)\,(SAT_{eu})\,(EU)$ ....(4)

Where,E = Energy consumption, kWh.SAT = fraction of total agricultural area being irrigated through pump Sets, EU = Energy use per unit area, 'eu' = end use.Similar base case characterizations can be prepared for other categories of Consumers.

Step 2. Identify measures:

In this step, a comprehensive list of Energy conservation and demand management measures for each category of Consumers is prepared. The method of analysis available to determine the best measures to be incorporated by the utility into DSM program are,

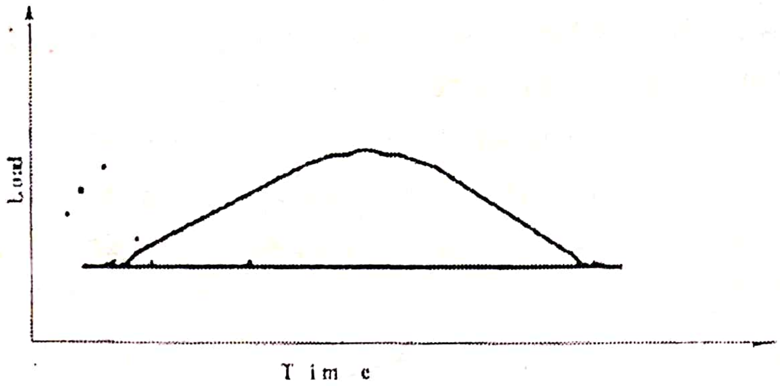
(a) Qualitative screening analysis.

(b) Maximum technical potential (MTP) analysis.

(c) Economic screening analysis.

(a) Qualitative screening analysis:

In this step the best measures suited to the utility for inclusion in DSM option are identified. Simultaneously, the inappropriate measures are eliminated. The criteria to screen out inappropriate measures include poor customer acceptance (equipments which are difficult to install so that the customers would not accept these measures), poor utility match (equipments which have already reached their maximum saving potentials or equipments not suited to the climate of that area or equipments inappropriate to building patterns in that area etc.), Technological maturity (equipments not commercially available), savings variance (equipments or methods whose savings potential can



Flexible Load Shape

Figure 6.4.10

6.4.11 Energy efficiency improvement:

T&D loss reduction is the biggest source of DSM, Efficiency improvement in end use applications Improvement in agricultural pumping sets, Usage of CFLs/LEDs in place of bulbs, BEE's estimation of savings: 10,000 MW, Prayas Energy's study: 30 % savings in households; Corresponds to about 25,000 MW of avoided generating capacity.Education programs to educate Consumers about use of Energy efficient devices have been undertaken in many countries. Many new technologies for Energy saving have been developed in USA, Germany, Japan and some other countries. It has been reported that due to the use of most efficient devices, in USA, the average consumption in refrigerators fell from 950 kWh/year and in deep freezers from 1100 kWh/year to 835 kWh/year. These figures pertain to the period 1990-93.Many end use efficiency programs including cogeneration, promotion and sale of Energy efficient devices, Energy audit, Energy labeling of appliances etc. have been initiated and implemented in Australia. In Germany the electrical Energy consumption has decreased by about 20% for washing machines, 30% for dish washers and 45% for freezers during the past 15years.In Sweden an improvement in the end use efficiency method have resulted in reduction in Energy consumption of refrigerators from 1.4 kWh/litre/year to 0.9 kWh/litre/year. Similar decrease in Energy consumption of various appliances has also been reported from UK, France, Japan and other countries.

6.4.12 Different time zones

Appears to be necessity, India's large spread across longitude; 80 Minute spread, Shifting of peak Load from one to other time zone, Needs adequate transmission capacity, HV DC lines and UHV systems are required for this purpose.

6.4.13 Tariff options for DSM

To discriminate between legitimate use and luxuries/ wastages, Should discourage wastage and encourage efficiency, Very high tariff for higher usage in commercial and domestic usage, much higher demand charges for higher connected Loads, early introduction of feed-in tariff for renewable Energy sources. The function of a tariff structure should be to have an efficient use of resources. To achieve this goal, Consumers should receive correct information about the costs involved in delivering power. Tariff should also lead to a balance between supply and demand so that Load shedding etc., can be avoided.

The ultimate aim of Load management is to reduce the average cost of electric power. To achieve this objective. Load control through proper tariff structure should be applied to improve the system Load factor. This would lead to a reduction in the need for peaking capacity and a higher utilization of the generating units. A proper tariff structure can itself lead to peak clipping and valley filling. This can lead to improved service to Consumers and measures such as Load shedding may not be required.

The guiding principle for tariff design should be that each Consumer category should be charged equitably for its contribution to the total costs for generation, transmission and distribution of electric power. The subsidised Electricity tariff for some sections of economy always leads to wastage of Energy. Tariff structure can be used as a means for achieving DSM objectives because Consumers respond to Electricity bills by changing their level and pattern of usage. It has been found that Consumers respond in a predictable way to alternate rate structure.

Through appropriate price signals, Consumers can be encouraged to recognize that Electricity is not easily stored and that generating costs may vary considerably across the Load curve as increasing demand is met by relatively expensive peak duty generating plant. A properly designed pricing policy can defer investments in new generating capacity be creating incentives for the customers to shift Load from peak hours to off peak hours as well as induce customers to invest in Energy conservation measures.

The cost per unit of Energy varies with time of the day and season. Generally Consumers are charged per unit of Energy at all times of the day at the same flat rate. The variation in the cost of generation over a time period is not reflected in the rate charged for the customer.

Marginal cost based tariffs send the right price signal to Consumers, which helps them to make appropriate decisions when deciding on the purchase and use of Electricity. Marginal cost of power supply is defined as the change in cost of service resulting from small changes in demand. This cost may change according to the place and time of use (TOU). Marginal costs are a reflection of the costs incurred by utility to meet additional demand of Energy. These types of tariffs not only cover the historical costs but also provide a revenue that is high enough to cover the incremental costs arising from new investments (in generation, transmission and distribution) needed to meet the extra demand. Marginal cost based tariffs provide the utility with some leverage to control future Load growth and Load shape and can therefore, be used as a management tool in DSM programs. The tariff structures which can promote DSM activities are as under.

(a) Time of day tariff (TOD tariff): It is also known as time of use (TOU) tariff. The technical development of metering equipment has made it possible to measure Energy consumptions during different times of day, days of week and periods of year, economically. TOD rates make Electricity, more expensive when it costs more to generate additional Electricity during peak hours and cheaper during off peak hours. Such a tariff structure encourages Consumers to shift their Load, whenever possible, from peak to off peak hours thus flattening the Load curve. This would be favorable to the customers who find their bills reduced and also favorable to the electric utility who would gain by a decrease in peak Load.

(b) **Seasonal Tariff:** In this tariff structure, the rates change across the season. This type of tariff is an economical way of managing demand. Since the peak consumption months are more or less fixed, the tariff can be adjusted to reflect seasonal demand variations. Thus, the cost of Electricity is more during certain months of the year than that during other. This tariff system does not require the special Electricity meters needed for (TOD) tariff. Evidently the Electricity billing frequency has to be synchronising with the times when seasonal rates come into effect

(c) **Curtailable / interruptible (C/I) rates:** C/I rates offer incentives to those Consumers who reduce demand to a predetermined level, when they receive a notice to this effect from success of this tariff system depends on reliable communication system.

It is an accepted fact that offering incentives and pricing options to Consumers is the best way to promote DSM. In USA, bill credits range from $1 to $5 per month for water heaters, $1.25 to $12per month for air conditioners and $1.5 to $29 per HP / year for irrigation. In addition 7% to 50% rate reduction per kW demand, 8% to 20% rate reduction per kWh and $0.003 to $0.061 per kWh discounts are offered by many utilities. Some utilities offer inconvenience payments of $25 to $150 per year. In UK, a tariff known as 'Economy' offers Electricity during night time at less than half the day time rate. In Ontario (Canada) DSM programs have resulted in annual savings of $27 to $48 per month. In France a 4 time period per day tariff structure has been proposed for small industrial Consumers. Similar incentives and multiple pricing options exist in a large number of countries in Europe and else where.

6.14 End use Energy Conservation

End use Energy conservation programs form a very important aspect of DSM. These programs reduce the customers' consumption of Energy thereby reducing their Electricity bills. Cost effective conservation options reduce overall requirement of the utility and serve to reduce Electricity tariff for all Consumers. The utilities and governments in all countries have undertaken a number of programs to improve efficiency of various appliances and to promote the use of such Energy efficient appliances. These programs include help to industries in manufacturing high efficiency equipments, information and education programs, Energy audit schemes, subsidies for equipment finance; equipment efficiency programs have limited effect unless supplemented by financial benefits. The various aspects of end use Energy conservation are as under.

6.14.1 Least cost utility planning:

It is an established fact that investments in Energy conservation and Load management activities are less expensive per kW than addition of new generation facilities. In order to decide the best mix between capacity additions, conservation and Load management programs, many utilities in developed countries carry out least cost planning process. In this analysis the costs of new capacity additions, supply side efficiency improvements, end use efficiency measures are all examined critically. The mix of resources which can meet the future power & Energy needs at the lowest cost are selected. This planning process can lead to substantial savings because some expensive new projects can be substituted by low cost efficiency improvement methods.

6.14.2 Promotion of high efficiency technologies:

Many efficiency measures with good saving potential have been implemented in some countries. Examples are, improved efficiency refrigerators, air conditioners, evaporative coolers, fan Motors etc. Similarly electronic ballasts for fluorescent lights, variable speed drives using power electronics devices can also lead to substantial savings. The strategy should include Research and Development and demonstration projects with an emphasis on adopting technologies developed overseas to the Indian context.

1. Technical and financial assistance to the manufacturers so that high efficiency equipments are manufactured.
2. Selective reduction in import duties both for manufacturing equipments (needed to manufacture high efficiency devices indigeneously) as also the actual high efficiency devices.
3. Mandatory efficiency standards for equipments.
4. Preference for high efficiency devices by government and semi-government agencies.

6.14.3. Energy Conservation Opportunities in Agricultural Sector:

Agricultural sector account for about 30% of Electricity consumption in India. The current Energy consumption in this sector is about 93,000 million kWh and the total number of pump sets is 11,850,000. About Two lakh pump sets are added every year. It is evident that improved efficiency of agricultural pump sets can lead to enormous savings. The metering of Electricity to irrigation pump sets is necessary. In many states the agricultural pump sets are charged flatly per kW of the rating of the Motor. This practice leads to a lot of Energy wastage. Use of inefficient Motors and sub-standard accessories is leading to huge wastage of Energy. Use of drip irrigation keeping the pipe fitting losses to the minimum and the operation of pumps & threshers during off peak hours can also lead to saving in Energy and Energy costs.

6.14.4 Energy conservation opportunities in illumination systems:

A conventional incandescent lamp has a luminous efficiency of 12 lumens/watt. Fluorescent lamp has a luminous efficiency of about 60-70 lumens/watt. Compact fluorescent lamps (CFL) are all the more Energy efficient. Moreover CFL has long life and is environment friendly. CFL offer about 5% to 15% increase in efficiency (as compared to conventional fluorescent lamp), and provide good color rendering. Moreover replacement of 40W fluorescent lamps by 36W CFL leads to 10% savings for the same illumination level. A conventional choke consumes about 12-15 watts and operates at a very poor power factor. Electronic ballasts require only about 1-4 watts of power and operate at good power factor. The only inhibiting factor is the higher cost (about Rs 300) of electronic ballast as compared to about Rs 80 for conventional magnetic ballast. High pressure sodium vapor lamps and high pressure mercury vapor lamps should be preferred for street lighting.

6.14.5. Energy conservation opportunities in Fans and Refrigerators:

Fans are used very extensively in summer months. Use of high efficiency fan Motor and use of electronic regulator (in place of conventional resistance regulator) can lead to about 20% saving in Energy. The fans with aerodynamic designs and improved impeller consume about 10% less Energy but are 30% costly as compared to conventional fans. However it is important to note that electronic ballasts introduce harmonics in the system.

The efficiency of refrigerators in India is rather poor. A typical 165 liter Indian refrigerator consumes about 540 kWh/year. On the other hand the 200 liter Korean model consumes about 240 kWh/year. High efficiency refrigerators are not manufactured in India. These refrigerators use a different compressor design which is very sensitive to voltage of electric supply. Unless quality of electric supply is improved these refrigerators cannot be introduced in India. Nevertheless use of better insulation technique can bring about some improvement.

6.14.6. Energy conservation opportunities in cooling and heating systems:

Air conditioners consume lot of Energy. Efficiency of air conditioner is expressed in Energy efficiency ratio (EER) which is BTU of cooling output divided by watts of input power. BIS calls for an EER of 6.6-7 whereas most of the air conditioners used in India have an EER ratio of 5.0 only. Efficiency of central AC systems can be improved by carefully designing the buildings to reduce heat gain into the buildings, improved thermostat and other controls. Slight reduction in thermostat setting can lead to considerable saving without loss of comfort. Reliable door closers can enhance the effectiveness of air conditioning by checking infiltration of outside air into the room. Desert coolers are widely used in India in summer months. A typical cooler consumes 20% more Energy than BIS standard.

The efficiency of a cooler can be increased by an improvement in efficiency of fan Motor and that of water circulating pump. It has been reported that extra cost of Rs 500/cooler can lead to 20% improvement in efficiency. Energy savings in water heating can be achieved by using better insulation techniques. Reduction in Energy use by the water heaters can be achieved by covering the tank with an insulating blanket made of fiber glass and backed with vinyl. These blankets can also be used to cover the sides of water heater.

6.14.7. Energy conservation opportunities in industrial sector:

Electric Motors are very widely used in industry. The most common Motors are squirrel cage induction Motor (up to a few kW rating) and wound rotor induction Motor (for large kW requirements). Use of high efficiency Motors can mean an Energy saving of 2-5%. However high efficiency Motors are about 25-35% more costly than the standard efficiency Motors. Moreover, the use of Motors made by standard manufacturers is also pretty common. These Motors are highly