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Energy Conservation, Efficiency and Demand Side Management

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Abstract - The efficient use of energy is the key to maintaining our world's resources; indeed our future depends on it. Energy conservation can be achieved through increased efficient energy use, in connection with decreased energy consumption and reduced consumption from conventional energy sources. Energy conservation can result in increased financial capital, environmental quality, national security, personal security, and human comfort. Individuals and organizations that are direct consumers of energy choose to conserve energy to reduce energy costs and promote economic security. In view of the nation's energy security interests, it is important to be increasing alternative fuel capability throughout the fleet. The need to ensure the nation's long-term energy security is of such vital concern that it takes precedent over possible short-term convention energy sources consumption and environmental impacts.

Keywords - Energy conservation, Energy Efficiency, Rebound Effect, Demand side management.

I. INTRODUCTION

Energy being an important element of the infrastructure sector has to be ensured its availability on sustainable basis. On the other hand, the demand for energy is growing day-by-day and the conventional sources are becoming scarce and costlier. Among the various strategies to be evolved for meeting energy demand, efficient use of energy and its conservation emerges out to be the least cost option in any given strategies. The steps to create sustainable energy system begin with the wise use of resources. Energy supply projects are highly capital intensive. They have long gestation period, thereby having a direct bearing on ecology and environment. Inadequate availability of energy resources affects the economic growth, and in fact, the lives of the citizens. Hence, it is imperative that energy resources are consumed rationally and economically, thereby eliminating wastages and losses to the extent possible. The goal of sustainable development, increasing concerns on environmental pollution, global climate change, and the ever-increasing gap between demand and supply has made energy conservation an integral part of power development programme.

II. EFFICIENT ENERGY CONSERVATION- AN OVERVIEW

Using less energy isn't about making drastic lifestyle changes or sacrifices. Conservation and efficiency measures can be as simple as improving the standards for new buildings so that they use less energy

for heating and cooling, replacing an old refrigerator with one that doesn't waste as much power, or adjusting the thermostat before leaving home. Not only do conservation and efficiency ease electricity supply crunches by reducing demand, they also decrease smog and greenhouse gas emissions, lower bills for all customers and create jobs and other economic benefits. It's a win-win situation.

Few Helpful Hints

- Replacing frequently used regular light bulbs with energy-efficient bulbs. Compact fluorescent and LED bulbs also last much longer than standard bulbs.
- Raise air conditioner temperature settings by a few degrees and turn it off when away.
- People with electric water heaters can save energy by fixing leaky taps, insulating their water heater and switching to more efficient showerheads.
- Wash clothes in cold or lukewarm water because upto 90 per cent of the energy consumed in washing is used to heat the water.
- Consider modernizing the electronic gadgets and other appliances.
- Set computer to sleep mode after 5 minutes of inactivity. Turn off computer when away from it for 20 minutes or more.
- Make it a habit to unplug small appliances when not in use.

In a scenario where a nation tries to accelerate its development process and cope with increasing energy demands, conservation and energy efficiency measures are to play a central role in our energy policy. Energy conservation is an objective to which every citizen in the country can contribute.

III. ENERGY EFFICIENCY AND LOSS RATIO

Effective energy is defined as the minimum amount of energy that must be *provided* to accomplish an objective task. Non-effective energy is defined as the energy that is *not used* for the objective task direct, which included energy consumption for accessorial task as well as energy losses.

Energy Efficiency is defined as the proportion of effective energy in the total energy consumed for accomplishing certain objective task. Loss Ratio is defined as the ratio of non-effective energy to effective energy. Energy Efficiency η and Loss Ratio μ may be defined as:

$$\eta = \left[\frac{W_l}{W_\Sigma} \times 100 \right] \% \quad (1)$$

$$\mu = \left[\frac{W_l}{W_e} \times 100 \right] \% = \left[\frac{W_\Sigma - W_e}{W_e} \times 100 \right] \% \quad (2)$$

where, W represents energy and the subscripts 'e', 'l' and ' Σ ' indicate effective energy, energy loss and total energy respectively.

$$\text{Since, } W_\Sigma = W_e + W_l \quad (3)$$

$$\Rightarrow \mu = \frac{1}{\eta} - 1 \text{ and } \eta = \frac{1}{\mu + 1} \quad (4)$$

Since the energy loss occurs in the process of providing effective energy, it is more reasonable to evaluate the energy utilization effect by observing the energy loss corresponding to per unit of effective energy. The concepts of loss ratio and energy efficiency just reflect the idea and are hence practical.

IV. ENERGY EFFICIENCY AND ECONOMIC EFFICIENCY

There exists a symbiotic relationship between energy conservation and the economics of a nation. Energy efficiency encompasses all changes that results in decreasing the amount of energy used to produce one unit of economic activity. Energy efficiency is associated with economic efficiency and includes technical, behavioral and economic changes.

1. Economics of Energy efficiency

Within this framework, energy efficiency is conceived primarily at the disaggregated, product level, rather than at a more aggregated sector level. The economics of energy efficiency is at its heart a question

of balancing of costs and benefits. For the individual energy user, this involves weighing the higher initial cost of purchasing energy-efficient products against the expected benefits of future cost savings when operating the products, among other considerations. For suppliers of energy-using products, decisions regarding energy efficient innovations likewise depend on the expected profits from such technology development. Profits from innovation depend in turn on the expected demand for energy-efficient technologies and the degree to which firms can appropriate the value created by their innovations.

On both the demand and supply side of this market for energy-efficient technology, potential market imperfections can lead to under-investment in energy efficiency. This raises the possibility that corrective government policies could provide economic gains if they are practicable and provide net benefits after inclusion of all public and private implementation costs. Finally, environmental pollution associated with energy production-particularly carbon dioxide emissions from fossil fuels-represents an additional reason why private markets might under-provide energy efficiency if energy users do not face the cost of any resultant environmental harm.

2. Understanding the Energy Efficiency Gap

In energy efficiency contexts, it is frequently stated that there exists an "energy efficiency gap" between current energy use and optimal energy use. An estimate of the magnitude of this gap will be determined mainly by how optimal behavior is defined. Several major conceptual issues surround different approaches to defining an optimal energy-use scenario, with implications for guidance regarding public policy for energy and energy technologies. The standard economic approach defines "good" public policy to be that which maximizes the appropriately weighted sum of the values of goods and services enjoyed by society throughout time (including intangibles such as the environment). From this perspective, energy efficiency is not a goal in itself, but only a means to the end of overall economically efficient (and equitable) resource allocation.

V. THE REBOUND EFFECT OF ENERGY EFFICIENCY

A number of definitions of rebound are found in the literature, with some differences depending on the context. The Oxford Dictionary definition of 'rebound' reads as follows:

The action of rebounding; the springing or bouncing back of an object after impact or release of pressure; an instance of this, Also: the ability to do this; resilience.

By inference, the term ‘rebound effect’ (RE) suggests that improved Energy Efficiency, can result in a release of pressure on energy consumption, an easing of the constraint and consequently enhanced usage of energy services. Additionally, ‘rebound’ can also be interpreted as a resilience of a system to technological interference, and hence describes the response whereby improved technology does not lead to reduced energy consumption by consumers. The RE is also referred to as the *Khazzoom-Brookes Postulate* and sometimes as the ‘*take-back*’ or ‘*snap-back*’ effect. Issues other than price or savings may also contribute to rebound, such as dissatisfaction with the service provided by a new technology, cost barriers to re-purchase, and unwillingness to accept the new technology, changing trends and social factors leading to a shift in the demand for a particular service.

A. Types of rebound

The rebound can be classified in one of the three ways, being take-back or direct rebound, indirect rebound, reversion or substitution.

Take-back/direct rebound

Take-back or direct effects refer to the observation that when the relative cost of an energy (or other) service is cheaper, there is a tendency to consume more of it. This effect is less pronounced if users are satisfied with their prior consumption levels and have no reason to consume more, and if the cost was a prohibitive factor to begin with. The difference in response therefore ties in directly with the developing (elastic) or developed (inelastic) demographic of the consumer. When demand for a particular service is inelastic, the rebound will be low or absent; when it is elastic, rebound will be higher. Where the energy service usage is close to the level of saturation the conservation potential is small and larger for those energy services which are not close to saturation. Therefore Rebound Effect appears more significant for energy services with a significant conservation potential but negligible for services with a minor power savings potential.

Indirect rebound

Indirect rebound is when the savings in energy from an Energy Efficiency intervention result in increased energy consumption in areas other than that related directly to the intervention. Examples of indirect effects are:

- Energy efficient equipment requires energy for its manufacture and distribution, offsetting some of the savings. Another way of referring to this effect is through life cycle impacts, which come into play in two situations:

- when equipment is replaced before the end of its life
- when the emissions associated with providing the energy efficient equipment are higher than non-energy efficient equipment
- Monetary savings from Energy Efficiency are spent on other goods that require energy.
- Producers use energy savings to increase output resulting in an increase in the use of other factors of production (capital, labor and materials) which also require energy.
- Cost-effective Energy Efficiency may lead to economic growth, which if not decoupled from energy demand growth will lead to increased energy use.
- Lower energy prices increase real income, stimulating energy demand.
- Energy services become cheaper reducing the effective cost of energy intensive goods and therefore increasing their usage.

Rebound through reversion

A potentially significant component of the Rebound Effect is termed reversion. For example, if the Energy Efficiency measure involves distributing CFLs to households and subsequently it is found that they give poor quality lighting or fail, then the users may revert back to incandescent since the replacement cost is lower. Factors influencing reversion are replacement costs, availability of the technology, traditions, norms and dissatisfaction with the quality of the service. Lack of awareness, convenience and other social factors may also play a role. Reversion is said to be affected by socio-economic and cultural factors and requires careful consideration when conducting a bottom-up study.

Rebound through substitution

If the cost of one energy service becomes cheaper, consumers who are not concerned about savings in their energy budget may purchase additional energy-consuming devices, so that the savings are reduced through take-back in other services. Substitution may also be more subtle. For example a user who saves on their energy budget, may use the additional funds to save for an overseas holiday, leading to an increase in energy consumed (and emissions produced). Such indirect effects are more difficult to measure.

The size of the rebound from Energy Efficiency improvements affects electricity demand through increasing the service demand. In reality some of this feedback may not lead to a direct increase of the energy service but instead to an ‘upgrading’ thereof to meet unsatisfied demand of another energy service. In other

words, users will increase their consumption of a particular energy service to make up for their inability to increase their consumption of the energy services to the level they desire for those services (due to cost or other constraints).

Economy-wide rebound implications

A price reduction of the energy service may reduce the price of other goods and services throughout the economy, leading to a series of price adjustments in the service chain. Energy efficiency improvements may have the effect of reducing energy prices and increasing economic growth which eventually leads to an increase in energy demand.

B. Calculating Rebound

The Rebound is a behavioral tendency to consume more energy due to the lower cost of energy services derived from an Energy Efficiency improvement. In its simplest form, therefore, the Rebound Effect (RE) can be expressed as:

$$RE = \frac{\text{expected savings} - \text{actual savings}}{\text{expected savings}} \quad (5)$$

A RE of 0% assumes that the expected savings were achieved through reduced consumption, while 100% means that no energy savings were realized and that the Energy Efficiency programme failed. When consumption increases to the extent that the rebound exceeds 100%, it is referred to as the 'backfire effect'. The rebound is generally somewhere between 0% and 100%. It is also possible to have a negative RE, such that the energy savings are greater than originally anticipated, for behavioral or technical reasons, or both.

VI. DEMAND SIDE MANAGEMENT

Energy demand management, also known as demand side management (DSM), is the modification of consumer demand for energy through various methods such as financial incentives and education. Energy conservation and demand-side management (DSM) encompass those activities that influence customer use of electricity to produce both desired changes in a utility's load shape and reduced costs for the customer. Therefore, Demand Side Management is the process of managing the consumption of energy, generally to optimize available and planned generation resources. Figure 1 shows the barriers of DSM and energy saving programs and Figure 2 shows the policy measure to overcome these barriers.

Residential Energy Conservation

Residential energy conservation activities encompass a broad range of utility and customer actions, including almost any type of program involving

residential customers. Some activities involve direct conservation of energy while others reduce peak demand requirements.

Residential energy conservation programs are primarily directed at three areas:

1. Improving energy efficiency of customer appliances
2. Improving energy efficiency of new and existing construction
3. Managing residential load

Fig. 1 : Barriers of DSM

Fig. 2 : Policy Measure to overcome Barriers

Commercial Energy Conservation

Commercial energy conservation activities encompass a broad range of utility/customer interactions including almost any type of utility program involving commercial customers.

Commercial energy conservation technology options have demonstrated the potential to enable

customers to exercise some level of control over their monthly energy bills while simultaneously helping their local utility achieve its load shape modification goals. Six general categories of technology options for commercial customers are:

1. Building envelopes
2. Efficient equipment
 - Lighting
 - Motors
 - Variable speed drives
 - HVAC equipment
3. Thermal storage equipment
4. Subsystems control
5. Load management
6. Community energy systems (district heating and cooling)

Industrial Energy Conservation

The industrial market represents major opportunities for large increments of load growth, conservation, and load management.

Industrial energy conservation activities encompass a broad range of utility and customer actions:

- Load management
- Interruptible rates
- Time-of-use pricing
- End-use applications

Primary end-use applications for industrial electricity can be grouped under four major headings:

- Motor drives and controls
- Process applications
- Lighting
- Space conditioning

The results of industrial energy conservation technology options may include:

- Reduced capital requirements
- Reduced energy consumption
- Reduced spoilage/waste
- Flexibility of raw material base
- Greater control over production
- Improved product quality and yield
- Decoupling of production from fuel supply

- Increased competitiveness
- Increased production at less energy per unit produced

In order to successfully implement the Demand Side Management programs, it needs coordination among implementing and state managing organizations, together with transparent legal framework as well as standards and mechanisms for monitoring, controlling quality of equipment and devices and other technical and training assistance.

VII. CONCLUSION

Adoption of energy conservation measures is necessary to reduce effective demand. This would not only save huge investments but would also help in abatement of greenhouse gasses and other environmental pollutants. Together with development and diversification of power resources, effective management and use of them, especially electricity demand side management, will bring in expected results, and contribute in stabilization of energy supply. The successful Energy Conservation & Energy Efficiency and Demand Side Management programs need support from customers. The Energy Conservation & Energy Efficiency and Demand Side Management programs require careful preparation of implementation strategies in order to involve participation of large number of customers so that maximal effects can be gained in Energy Conservation & Energy Efficiency and peak load reduction. From the customer viewpoint, in order customers to accept, all implementation measures should bring in benefits for them. Therefore, it is necessary to propagate advantages of programs and apply appropriate policies for long term expansion of the programs at large scale. The value to society of saving energy should also include the value of reducing any associated environmental externalities; but again this must be weighed against the costs. There is a growing awareness about the importance of energy conservation and its benefits in reducing the demand-supply gap of energy. This has led the government, utilities, industrial units and consumer forums to set up energy conservation and efficiency improvement cells.

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