CHAPTER 7

CONCLUSIONS AND FUTURE SCOPE OF THE WORK

This chapter discusses the conclusion drawn from the present research work and incorporates the possibility for the future scope of the work.

7.1 Conclusions

In this research, India's energy security problem is thoroughly analyzed and discussed. It is observed that efficiently managing demand at the consumer end has huge potential for overall savings.

Demand-side management strategies are based on the principle that by efficient utilization of electricity at the consumer end, significant savings from electricity generation's overall life cycle costs can be achieved. Multiple national and international studies in the subject of DSM have been published in the form of research articles and reports. The literature relevant to the scope of this research has been summarized in chapter 2. A thorough understanding of the current state and statistical estimates regarding future projections for power generation and consumption is developed is discussed in Chapter 1. The threat to the environment and sustainability concerns are discussed in a separate section. This understanding is then used to establish the need and application of Demand-Side Management options in India. After understanding the load pattern of different categories of consumers four high potential DSM interventions are suggested in this report, that would help in bringing down the overall energy requirement.

Residential end-use appliances (particularly heating and cooling appliances), agricultural irrigation pumping, and rooftop solar photovoltaic systems offer tremendous potential for Utility DSM in India. These four DSM interventions are studied and analyzed.

The methodological framework to analyze the feasibility of these DSM options is discussed in chapter 3. Techno-economic, and environmental costs of electricity generation and distribution are calculated in this chapter, which is then used to analyze the feasibility of suggested DSM options. However, the developed analysis framework is a generalist and can be applied to any other DSM intervention as well.

Based on these costs, critical cost efficiency levels have been identified and discussed in chapter 6. Total energy and emission saving potential have also been discussed in the same chapter. In this chapter, recommendations are made for policymakers and public based on the inferences collected from the study.

India is at the crossroads for adopting the right policy approach that can ensure that the promise of DSM is delivered to Indian stakeholders. We hope this research becomes a valuable resource for the executive stakeholders in this matter.

7.2 Rooftop Solar, Jalgaon MIDC Case Study:

The load pattern in the industrial sector of Jalgaon, Maharashtra, has been considered for the case studies assessing the potential for rooftop solar installations. Based on the developed models, customized MATLAB subroutines have been written for data analysis. The impact of rooftop solar on the consumption schedule is studied considering the TOD tariff in place. Further, a storage system's importance is studied by comparing the daily savings for cases with and without storage availability. For the case when battery storage is available, a linear programming-based optimization model is used to estimate the maximum possible savings from the installation. Total energy savings that can be achieved from the DSM options suggested have been calculated along with the reduction in CO_2 emissions.

Results show that the utilization of PV generation per day is 172.307 units compared to the total generation of 179.901 units, i.e., almost 95.78% utilization. This is mainly because the concerned industrial building load is concentrated in the PV generation duration, contrary to any household consumption. The load is concentrated in the morning and the evening with lower consumption during the daytime. Thus, high utilization of the PV panels is achieved even without having a storage system in place. A linear programming problem has been set, for a grid-connected household, having a PV generation system and battery storage. Two cases are considered for a better understanding of the advantages of the proposed system. In the first case, PV grid-connected installation without storage option is explored. In this case, during the non-sunshine hours, the load required is satisfied from grid electricity. During the sunshine hours, some portion of the load is provided by the power generated from the PV panels. The generation from the PV panels starts at around 7:00 am in the morning and ends at around 6:00 pm in the evening with peak generation at noon. Because of the PV panels' installation, the average monthly savings in the electricity bill is INR 1359.7. For the second case, the storage system is considered, which gives the total reduced cost incurred by the electricity customer. The monthly savings, in this case, is INR 1587.8, which is 16.77% higher. The PV utilization, in this case, is of 179.901 units, which implies 100% utilization of PV power generated. These observations are caused by two main factors, availability of storage system and Time of Day tariff being in place. Electrical energy from the PV panels is stored in the battery when the PV generation exceeds the load, and the energy is stored in the battery when the cost of purchasing electricity from the grid is low and is utilized when the grid electricity cost is high.

7.3. Solar Pumps, PM KUSUM Scheme, Component C

Optimum cost efficiency levels for DSM options that all the DSM options suggested in this research are cost-efficient for the consumers, as well as from the economic and environmental perspectives. If the COE of the DSM option or any other energy-efficient technology is below the critical levels, the technology is feasible. The distribution among State government, Central government, and Farmers (collectively) is done in the ratio 3:3:4 (Except Himachal Pradesh) under PM KUSUM Scheme. From the calculations, it is established that the central government would be spending about INR 445.3 Crore, and a similar amount would be spent by all the state governments combined. This highlights the importance given by the government to uplift the farmers out of economic plights (by providing them an additional source of income- the energy generated by solar pumps can be transferred to the grid when not in use) and promoting renewable energy in the country. Therefore, we recommend that on the policy front, there is a need to explicitly recognize 'demand-side resources' as an alternative resource option in the energy resource basket of electric utilities. Based on the overall cost-effectiveness, more efficient devices should be promoted by market pull as well as push strategies. For Component-B of the scheme (stand-alone systems), the system should include batteries so that excess energy can be stored and used later. As of now, no such provision is there.

India is at the crossroads for adopting the right policy approach that can ensure that the promise of DSM is delivered to Indian stakeholders. We hope this research becomes a valuable resource for the executive stakeholders in this matter.

7.4. Room Air Conditioners

We have generated scenario for Star rated Air conditioners as energy-efficient appliances, and projected results are as given below:

Consider Scenario for 50%, 5 star rated Air Conditioners for calculating future cost savings, its electricity-saving till the year 2030 will be 1914 GWh, and till the year 2040 will be 7243 GWh. CO_2 emissions saving will be 1569291 tonnes till the year 2030, and till the year 2040 it will be 5938916 tonnes. Because of this activity money saved in crores till the year 2030 INR 290 Crores and till the year 2040 it will be INR 1099 Crores.

Consider Scenario for 75%, 5 star rated Air Conditioners, for calculating future cost savings, it's electricity saving till the year 2030 will be 6697 GWh, and till the year 2040 will be 25337 GWh. CO_2 emissions saving will be 5491655 tonnes by the year 2030, and by the year 2040 it will be 20776242 tonnes. Because of this activity money saved in Crores till the year 2030 INR 1016 and till year 2040 it will be INR 3844 Crores.

The scenario for 100%, 5 star rated Air Conditioners, for calculating future cost savings, it's electricity saving till the year 2030 will be 11480 GWh, and till the year 2040 will be 43432 GWh. CO_2 emissions saving will be 9414018 tonnes till the year 2030, and by the year 2040 it will be 35614437 tonnes. Because of this activity money saved in Crores till the year 2030 INR 1742 and till the year 2040 it will be INR 6589 Crores.

7.5 Rooftop Solar PV System with Batteries

Total Energy Saved (124 GW capacity) = 42050 GWh

CO_2 Emissions Saving (tonnes) = 34,481,000 tonnes

Economic Benefit in (Crore INR) = 6379 Crores

7.6. Solar Pumps

Farmers took benefit of PM KUSUM Scheme under Component C and ran their solar pumps for irrigation of their fields and used solar power for their own consumption for lighting and

other appliances. They export electrical energy to grid and received payment from Utility at the predecided cost of energy by SERC (State Electricity Regulatory Commission)

Total Electricity Saved by the implementation of PM KUSUM Component-C = 42.85 GWh

CO_2 Emissions Saving (tonnes) = 35,137 tonnes

Economic Benefit in (Crore INR) = 6.5 Crores

7.7 Household Appliances, A Case Study of Energy Conservation, ToU and Improvement in Energy Efficiency

In Maharashtra State, Jalgaon city is situated in Jalgaon District. A study for a sample of 16000 residential premises of Jalgaon city is carried out, and studied load profiles of all these household appliances and their average use in hours are calculated as a weighted average method. Calculated average hours used of these appliances for winter and summer seasons considering heating and cooling load in view of ToU and ToD tariff. The appliances television, washing machine, air conditioner, air cooler, fan, refrigerator, electric water heater (geyser), electric oven, electric toaster, microwave, computer, DVD player, Radio, CD /DVD Player have been considered, and their consumption calculated with respect to their ratings and conclusion are drawn. The same is discussed in Chapter 6.

The average usage in hours per day of widely used residential appliances is calculated. These average usages have been used to calculate the total consumption over the year. It is discussed in chapter 6. Appliance wise average consumption per month Actual and after energy conservation is considered and calculated energy saved per month in MJ. It also discusses Appliance-wise average consumption per month in Summer and Winter season in MJ.

Results are encouraging and found 15 to 20 % savings in electricity bills with energy conservation. It is concluded that if all appliances and lighting load are replaced with energy-efficient lighting system with LEDs and other all appliances replaced with energy-efficient appliances, the energy savings go up to 62%, i.e., effective reduction of consumers energy bills. The details are given in Appendix C.

7.8. Inferences and Recommendations

7.8.1. *Policy Related*

- *Key to Keeping International Commitments*: DSM is an important strategy to meet India's low carbon development commitments in the newly emerging global framework for combating climate change (UN Paris Agreement signed by 175 countries). The significance of DSM in achieving these commitments must be realized and clearly formulated, and integrated with other sustainability actions, plans, and policies.
- *Acknowledging Demand-Side Management***:** DSM needs to be explicitly recognized as an alternative resource option in the energy resource basket of electric Utilities. The DSM options can be recognized as a qualifying resource under the definition of renewable energy sources in the existing legal and policy framework. The potential of DSM and its implementation by Utilities must be clearly emphasized in the government policies by allowing it to directly compete with supply-side options within the principles of equity, reliability, and cost-effectiveness.
- *Environment-Friendly Economic Zones (EFEZ***):** Based on the overall cost of electricity generation, including environmental costs, critical, cost-effective efficiencies in household appliances can be identified. Critical efficiency would mean efficiency, which can be achieved cost-effectively. Efficiency such that COE

of the machine is equal to the overall cost of electricity generation and distribution. Manufacturing of Efficient devices should be promoted by the market-pull method by the creation of special Environment-Friendly Economic Zones (EFEZ), with tax benefits.

7.8.2. *Air Conditioning*

- As part of DSM of cooling energy use, Minimum Energy Performance Standards (MEPS) and star-rating scheme for room air conditioners are already in place in the country, and MEPS for room air conditioners are systematically ratcheted up. These positive actions need to be further strengthened in line with the increase in energy use for addressing the cooling demand.
- To keep up with the revised standards, the manufacturers also have the challenge to increase air conditioning efficiency through other means. Thus, new innovative technologies are urgently needed in this field. The Space Cooling sector presents unique opportunities for optimization of cooling demand, including through energy efficiency, since a large portion of the cooling demand is yet to come.
- Innovative technologies in air conditioning should be promoted. Integrated efforts are required in this area. Technology options like centralized air conditioning and district cooling are some of the promising available options.
- Natural refrigerants and cooling with minimum HFC refrigerants should be emphasized through policies. More research is required in the new technology areas which do not use refrigerants like desiccant, vapor absorption type systems.
- The critical cost efficiency levels of all kinds of residential appliances and efficient technologies can be calculated in a similar fashion as done for air conditioners in this

study. Based on the overall cost-effectiveness, more efficient devices should be promoted by market pull as well as push strategies.

- Manufacturing of efficient devices can be promoted through (EFEZ) Push strategies would include setting minimum efficiency standards as are already being done by BEE's standard and labeling program.

7.8.3. *PM KUSUM Scheme*

- The distribution among State government, Central government, and Farmers (collectively) is done in the ratio 3:3:4 (Except Himachal Pradesh), From the calculations, it is established that the central government would be spending about INR 445.3 Crore, and a similar amount would be spent by all the state governments combined. This highlights the importance given by the government to uplift the farmers out of economic plights (by providing them an additional source of income- the energy generated by solar pumps can be transferred to the grid when not in use) and promoting renewable energy in the country.
- For Component-B of the scheme (stand-alone systems), the system should include batteries so that excess energy can be stored and used later. As of now, no such provision is there.

7.8.4 *Household Appliances, Jalgaon City case study*

- With this study, it is found that consumer's electricity bills are reduced to 15 to 20 % with energy conservation and with the shifting of use from peak hours to non-peak hours. The result shows that if lighting load is replaced with energy-efficient lighting system having LEDs and all other appliances replaced with energy-efficient appliances, the energy savings go up to 62% i.e. effective reduction of consumer's energy bills. The details are placed in Appendix C.

Authorities have to take cognizance of the above benefits and create awareness among society members, Institutions, and the general public.

7.9. Future Scope of the Work

The major outcomes of the present research work are as follows:

- Customers can enjoy profits on the implementation of Grid-connected load with PV-Battery hybrid system.
- Profits are higher when policies such as feed-in tariff and TOD tariff are available.
- The utilization of solar energy through PV generation system is higher when such a hybrid system is available compared to stand-alone systems without battery storage.

Future prospects

- Analysis based on actual data for an average Indian scenario is needed to be done.
- Some modifications will be required in the existing model to incorporate the inverter and some other factors. Also, changes are needed based on the nature of the data available.
- The capital cost associated with an investment in PV-Battery hybrid system is to be considered. Based on this, the payback period for system installation is to be evaluated.
- The benefits associated with the relief on demand from the grid side to distribution companies and savings on the elimination of the need for an additional power plant or some reduced generation capacity of newly proposed power plants are needed to be considered.
- The reduced carbon footprint of the newly introduced conventional power plants is an important aspect. Incentives for reduced carbon footprint are also an important part of future work.

- If the COE of the DSM options or any other energy-efficient technology is below the critical levels, the technology is feasible. The technology used for 5 star rated inverter type air conditioners shall be widely used to save electrical energy and reduce carbon emissions. Energy-efficient technology used for lighting and heating purpose shall be widely used in the coming future for saving electrical energy and reducing carbon emissions. Execution of PM KUSUM scheme for installation of Solar Pump for farmers shall be monitored closely and to be completed in a time bound manner.