Chapter 6

RESULTS AND DISCUSSION

This chapter discusses the result and discussion. In this chapter results obtained from various Demand-side options have been discussed. Inferences and Recommendations are also discussed.

6.1. RESULTS AND DISCUSSION

DSM is a key strategy to meet India's low carbon development commitments (viz. to reduce the emissions intensity of GDP by 33% to 35% by 2030 and to achieve about 40% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030) in the newly emerging global framework for combating climate change (UN Paris Agreement signed by 175 countries). The role and significance of DSM in achieving these commitments must be clearly formulated and integrated with other sustainability actions, plans, and policies.

Therefore, 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. The perception about DSM and its treatment by Utilities must be clearly emphasized in the policy framework by allowing it to directly compete with supply-side options within the principles of equity, reliability, and cost-effectiveness.

The 'demand-side resources' can be explicitly defined and emphasized as stand-alone independent resources apart from conventional and renewable energy sources. This however, requires legislative action to empower the state regulatory commissions for effective enforcement and consideration of DSM by the Utilities and central /state governments. The 'demand-side resources' can be recognized as a qualifying resource under the definition of renewable energy sources in the existing legal and policy framework.

Another important aspect of refrigerant-based cooling is energy use, resulting in a much larger portion of the emissions – nearly 70%. According to the International Energy Agency (IEA), refrigeration, and air conditioning (RAC) causes 10% of the global CO_2 emissions. That being said, 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 being systematically ratcheted up. These positive actions need to be further strengthened in line with the increase in energy use for addressing the cooling demand.

6.2. Rooftop Solar

Renewable energy options, especially solar energy show a strong potential to replace conventional fossil fuel-based electricity generation. DSM is a method of influencing electricity consumers' demand for electricity and thus reducing the load on distribution and generation companies. With the help of DSM tools, consumers can modify their demand so that the installation of new power plants could be avoided. This paper studies the load pattern in the industrial sector of Jalgaon, Maharashtra, and their potential for rooftop solar installations. 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. To run the optimization, the simulation software used is MATLAB.

6.2.1. ***Results and Discussion***

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 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 result of the case is presented in Figure 6.2. 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. If the generation from PV panels exceeds the demand for some period, the excess PV power remains unutilized.

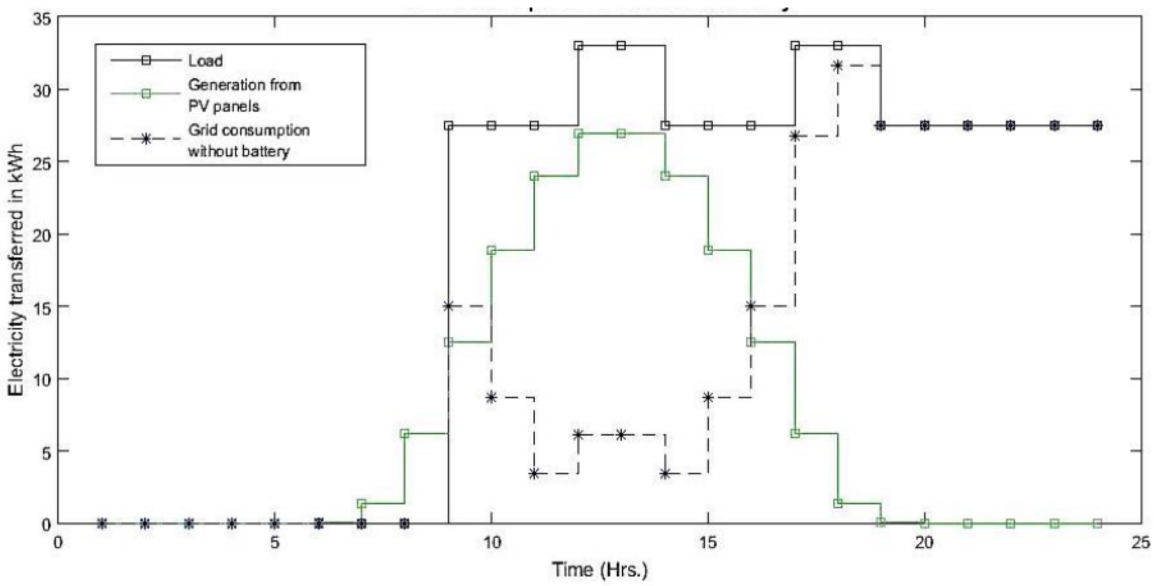

Figure 6.1 Power consumption profile without battery storage

The analysis results (Figure 6.1) 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. The load in the concerned industrial building is concentrated in the PV generation duration contrary to any household consumption, where the load is concentrated in the morning and evening with lower consumption during the daytime. Thus, high utilization of the PV panels is achieved even without having a storage system in place.

For the second case, the storage system is considered, and to optimize the output of the system, the previously discussed optimization model is used. By solving the linear optimization problem, which is given in the previous section, we can obtain a result, which gives total reduced cost incurred by the electricity customer. The monthly savings, in this case, was INR 1587.8, which is 16.77% higher. In this case, the PV utilization 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. This reasoning is supported by the results of various power flows shown in Figure 6.2.

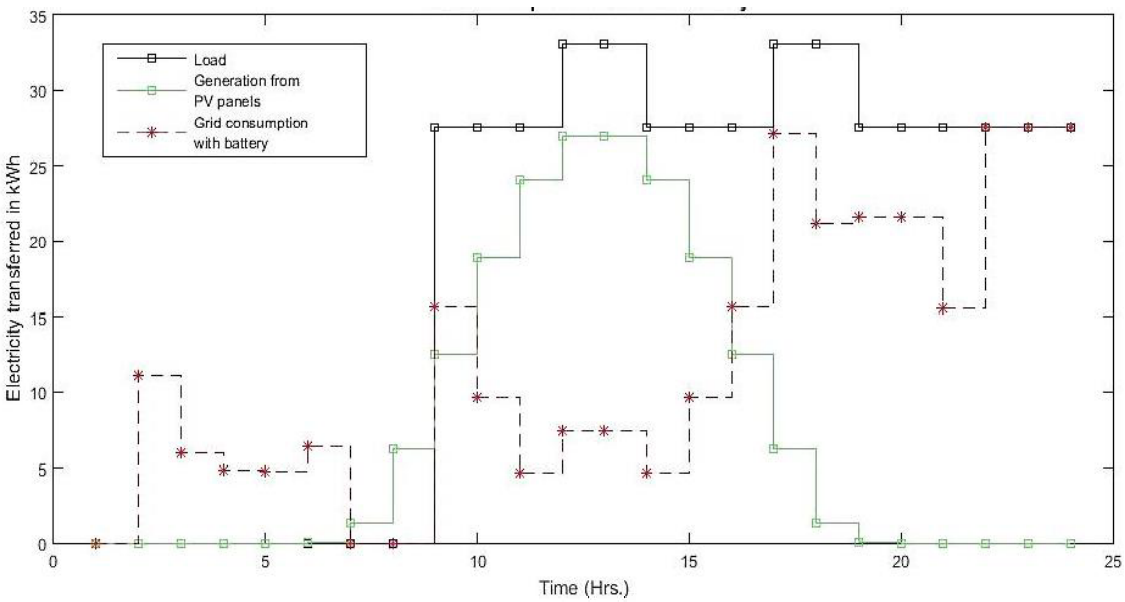

Figure 6.2 Power consumption profile with battery storage.

6.2.2. ***Conclusion and Future Prospects***

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 Time of Day (TOD) tariff are available.
- Solar energy utilization through PV generation systems is higher when such a hybrid system is available compared to stand-alone systems without battery storage.

Future work related to this topic on the following aspects is to be done

- 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 eliminating the need for an additional power plant or some reduced generation capacity of newly proposed power plants need 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.

6.3. Optimum Efficiency Levels

The following costs per unit of electricity have been calculated for comparisons in previous chapters:

Table 6.1 Costs per unit of electricity

Category	**Cost (INR/kWh)**
Consumer Tariff	5
Overall Cost of Electricity Generation and Transmission	3.42
Overall Cost of Electricity (Environmental costs included)	6.2
COE Rooftop Solar PV	1.55
COE Efficient Room AC	1.58
COE Solar Pump	2.45

The consumer tariff is INR 5 per kWh. The overall cost of generation and transmission of electricity calculated INR 3.42. Overall Cost of Electricity considering environmental effects calculated as INR 6.2 per kWh. We have further calculated cost of electricity generated from rooftop solar is INR 1.55 per kWh. Cost of Electricity of efficient room air conditioner calculated as INR 1.58 per kWh. Cost of electricity of Solar pump calculated as INR 2.45 per kWh.

- ***Consumer Tariff:*** The consumer tariff gives the price consumer must pay for per unit of electricity. If the COE of the DSM option is less than the consumer tariff of electricity, the option is feasible and cost-effective for the consumer. The critical cost-efficiency of any DSM option or energy-efficient device for the consumer can be found by equating its COE with electricity's consumer tariff.
- ***Overall Cost of Electricity Generation and Transmission:*** This is a representative cost for the total technical cost of generating and transmitting electricity through the grid. If

the COE of the DSM option is less than the Overall Cost of Electricity Generation and Transmission, then it is economically feasible in the overall sense. Critical economic cost-efficiency of any DSM option or energy-efficient device can be found by equating its COE with the Overall Cost of Electricity Generation and Transmission.

- ***Overall Cost of Electricity (Environmental costs included):*** This cost includes all the social, economic, and environmental effects associated with power generation. If cost-effectiveness is considered using this Overall Cost of Electricity (Environmental costs included) the widest, most inclusive definition of cost-effectiveness is achieved.

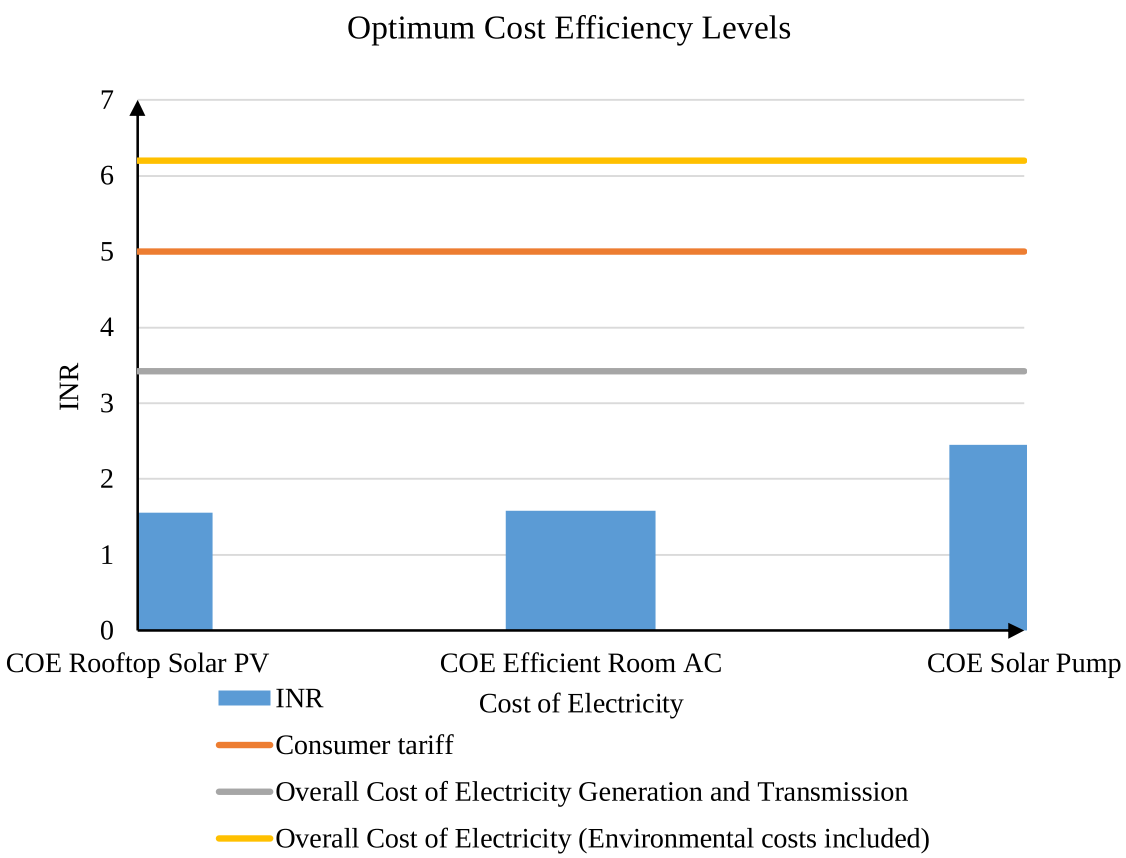

Figure 6.3 Optimum cost efficiency levels for DSM options

It can be seen from the chart above that all the DSM options suggested in this research are cost-efficient for the consumers, as well as from the economic and environmental perspectives. The horizontal lines represent the critical levels for cost-efficiency for different categories. If the COE of the DSM option or any other energy efficient technology is below the critical levels, the technology is feasible.

6.4. Total Energy and Emissions Saving

Total energy savings that can be achieved from the DSM options suggested have been already calculated in the previous chapter. We have also calculated the emissions through sources of energy. Using this data, the overall savings have been calculated and tabulated below.

Total CO_2 Emissions=CO_2 emissions per kWh×Energy saved in kWh

6.4.1 *Room Air Conditioners*

Table 6.2: Total energy and Emission Saving Potential from Efficient Room ACs

Scenario	Electricity Saved Over Baseline Scenario (GWh)		CO_2 Emissions Saving (tonnes)		Economic Benefit in (Crore INR)	
	2030	**2040**	**2030**	**2040**	**2030**	**2040**
50% 5-star	1913.77	7242.58	1569291	5938916	290.3189	1098.699
75% 5-star	6697.14	25336.88	5491655	20776242	1015.956	3843.605
100% 5-star	11480.51	43432.24	9414018	35614437	1741.593	6588.671

6.4.2 *Rooftop Solar PV System with Batteries*

Total Energy Saved (124 GW capacity) = 42050 GWh

CO2 Emissions Saving (tonnes) = 34,481,000 tonnes

Economic Benefit in (Crore INR) = 6379 Crores

6.4.3 *Solar Pumps*

Farmers benefited from 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

6.4.4 *Household Appliances, A Case Study of energy conservation, ToU and improvement in energy efficiency*

A study for sample of 16000 residential premises of Jalgaon city of Maharashtra is carried out and studied their load profiles appliances-wise and 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.

Table 6.3 discusses the average usage in hours per day of widely used residential appliances. These average usages have been used to calculate the total consumption over the year.

Table 6.3 Appliance wise average consumption per month Actual and after energy conservation. It also shows Appliance-wise average consumption per month in Summer and Winter season in MJ.

Table 6.3 Appliance wise average consumption per month actual and after energy conservation

House	Average consumption per month (MJ)	Average consumption per month with conservation (MJ)	Amount of Energy Saved per month (MJ)	House	Energy in summer (MJ)	Energy in winter (MJ)	Average consumption per month (MJ)
House 1	3427.945	2546.305	881.6401	House 1	28846.28	12289.06	3427.945
House 2	1949.677	1612.314	337.3631	House 2	16550.7	6845.429	1949.677
House 3	3746.963	3012.203	734.7602	House 3	30528.66	14434.89	3746.963
House 4	3015.81	2571.21	444.6	House 4	26505.36	9684.36	3015.81
House 5	5027.562	4273.362	754.1998	House 5	44467.49	15863.26	5027.562
House 6	1434.924	1266.084	168.8402	House 6	12349.15	4869.936	1434.924
House 7	2827.576	2301.736	525.8401	House 7	24450.56	9480.352	2827.576
House 8	1903.5	1589.94	313.56	House 8	16169.76	6672.24	1903.5
House 9	5342.882	4777.323	565.5598	House 9	45454.87	18659.72	5342.882
House 10	5783.378	5025.219	758.1598	House 10	49187.35	20213.19	5783.378

Results are encouraging and found 15 to 20 % savings in electricity bills with energy conservation. It is concluded that if all appliances and lighting loads are replaced with energy-efficient lighting systems with LEDs and other appliances replaced with energy-efficient appliances, the energy savings go up to 62% with the execution of all DSM options together.

It results in an effective reduction of consumers' energy bills. The details are given in Appendix C

6.5. Inferences and Recommendations

6.5.1. *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.

6.5.2. *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 being 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 the efficiency of air conditioning through other means. Thus, new innovative technologies are urgently needed in this field. The space cooling sector presents unique opportunities for optimizing cooling demand, including 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 have 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.

6.5.3. *Energy Efficiency in Residential Appliances*

- 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.

6.5.4. *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 INR445.3 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.

6.5.5 *Household Appliances, Jalgaon City case study*

- This study reveals very encouraging results. It is found that consumers' electricity bills are reduced to 15 to 20 % with energy conservation and shifting of energy use from peak hours to non-peak hours. The result shows that if the lighting load is replaced with an energy-efficient lighting system with LEDs and all other appliances replaced with energy efficient appliances, the energy savings go up to 62% with all DSM options executed together. It results in an effective reduction of consumers' energy bills. The details are placed in Appendix C.

Authorities should take cognizance of above benefits and must create awareness among society members, institutions, general public.