ABSTRACT

India is a heavily populated country, and therefore, the electricity demand is continuously growing. Another vital aspect of refrigerant-based cooling is energy use, contributing a larger share of the emissions, i.e., about 70%. As per the International Energy Agency (IEA), refrigeration and air conditioning cause 10% of the global CO_2 emissions; therefore, efficient and effective energy appliances are of immense importance for sustainability. Demand Side Management is a method of influencing the electricity consumers' demand for electricity during peak hours, thus reducing the load on distribution and generation companies and avoiding installing new power plants.

This research brings together a comprehensive volume of information, techniques, and guidelines for use in demand-side management (DSM) planning and implementation in one convenient source. It examines some significant DSM programs, from the smart grid, renewable energy sources such as solar, battery storage, and appliance efficiency programs to interruptible rate and strategic marketing efforts. Special features include: What to expect in energy renewable source options, customer load control options, and electric load impact of new technologies. The present research systematically provides the solution to the India's energy security problems by efficiently managing the energy demand at the consumer via DSM options under the current utility framework, especially smart grid, time-of-use, renewable energy sources, storage systems, and energy efficient technologies that has huge potential for overall energy savings along with significant reduction in carbon emissions. 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 ‘Time of Day’ (ToD) tariff. Further, a storage system's importance is studied by comparing the daily savings for cases with and without storage availability. 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 and reduced CO_2 emissions.

Results show that the utilization of PV generation per day is 172.307 units compared to 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 approach. In 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 and ends at around 6:00 pm 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 reduces the total reduced cost incurred by the electricity customer. The monthly savings in this case is 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.

Presently simulations are performed to gauge the power generation capacity using standard solar panels for 50 locations in India. Results are obtained for five cities each in 10 states. Once the simulations are completed, the software can generate a report that gives us information about the monthly radiation data, the losses, the amount of irradiation, and the system's amount of energy. The overall cost of generation is calculated, and the total amount of electricity generated in 25 years is also calculated.

Optimum cost efficiency levels for DSM options that all the DSM options suggested in this research are cost-efficient for the consumers and 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, J&K some states). 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 under PM KUSUM Scheme. This highlights the government's importance 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 there is a need to explicitly recognize ‘demand side resources’ as an alternative resource option in the energy resource basket of electric utilities on the policy front. Based on the overall cost-effectiveness, more efficient devices should be promoted by market pull and 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.

Energy-efficient appliances and ToU: A study is conducted for sample 16000 residential premises and studied their load profiles appliances wise and calculated average hours used of these appliances in view of ToU and ToD tariff. Results are encouraging and found a 15 to 20 % reduction in energy bills with energy conservation and shifting consumption to off-peak hours. If appliances are replaced with energy-efficient appliances such as Inverter type 5 star rated Air conditioners and efficient lighting system, LED the energy savings increases to manifold and CO_2 emissions reduction target can be achieved systematically with DSM programs.

Energy Efficient Air Conditioners: The residential sector is likely to be the driver of growth for air conditioning in India in the next two decades due to the low existing penetration of ACs in India. It constitutes the dominate share of the sector's cooling energy consumption at around 40 % in 2017-18 to growing around 50 % in 2037-38. Room Air conditioners show the highest growth at around 11 times of the current baseline in terms of installed TR and significant potential for optimization & energy savings.

India is at the crossroads for adopting the right policy approach to 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.