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Low-cost energy conservation measures power saving impact on electronic appliances usage

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ABSTRACT

Energy conservation measures use less energy to reduce costs and the environmental impact without compromising the consumer's comfort level. Low-cost energy conservation measures play a critical role in power saving on the usage of electronic devices. The paper compares two different facilities using air-conditioning applications to study the impacts of low-cost energy conservation measures (LCECM) in real-time operations. The effect was recorded at both facilities by lowering the air-conditioning running time and increasing its set temperature ensuring that there was no compromise in occupants' comfort level. As per international performance measurement and verification (IPMV) protocol A, data analysis was done using pre- and post-experiment readings. IPMVP output was analyzed more by running a t-Test in the SPSS software. Results indicated energy conservation with a cumulative impact on carbon footprint, environment, and cost of importing fossil fuel. The limitations of this study are that the energy conservation measurements were made with limited facilities and respondents' restrictions.

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1. INTRODUCTION

The finite fossil fuel resources available on our planet are depleting daily. Conserving energy whenever possible benefits individuals and our larger energy systems [1]. By fine-tuning the controls and usage of software to manage energy at any facility, energy conservation activity is a low-cost measure [2] Reducing energy consumption at home and increasing energy savings do not require purchasing energy-efficient products [3]. Administrative and corrective measures have huge energy-saving potential [4]. It has easy implementation with a short payback period, primarily administrative and remedial actions, including training [5]. Improving energy efficiency by imparting behavioral training use of renewable energy and practicing low-cost measures for energy conservation [6], transparency of energy data, and digitalization of the energy market will strengthen the energy conservation program [7]. Energy conservation also impacts demand-side management and load curves [7]. Human energy usage behavior can positively impact the consumption of energy [8]. Reducing energy consumption is an urgent priority in both domestic and commercial [8]. Energy users' behavior pattern has considerable potential for utility savings adjustments [9]. Heating and cooling costs contribute to an average home's utility bills [10]. Reducing the intensity and frequency of heating and cooling can result in considerable savings [3], [11]–[13]. The paper includes two case studies undertaken at two facilities with air-conditioning to study the impacts of low-cost energy

conservation measures (LCECM) in actual operations [7]. By referring to the example of air-conditioners, the paper aims to promote awareness and energy-efficient practices in using electronic appliances in domestic and commercial applications.

2. LITERATURE REVIEW

If well-structured, tailor-made LCECM training is given to the building occupants on energy-saving behavior. Studies suggest that if the management provides a conducive working atmosphere, the building occupants can improve their energy usage behavior by practicing the learned tips and guidelines [12], [13], leading to efficient utilization of energy as a whole for the building. LCECM is something that most of us know but gets overlooked or ignored due to our preconceived mindset of thinking it to be insignificant [11], [14]. However, it can be practiced daily if it becomes a habit [14]. The government of India has initiated the energy conservation building code (ECBC) 2016 [15] to improve the energy index of any building through such LCECMs. Still, it is left optional and not obligatory [16]. Suppose its implementation is mandated under ECBC as mandatory [4], [17]. It can help reduce energy usage daily in the Indian commercial building sector, saving cost, energy, and the environment through operational excellence [10], [18]. The training of energy users for power saving can be done through some Dos and Don'ts instructions [16]. Expenditures made in implementing energy conservation measures in a commercial building are more investments than expenditures [17]. The analysis of power saving is usually done by collecting feedback from the participants through questionnaires about their intentions of applying the instructions for energy conservation [19]–[21]. There is always a gap between choosing to do an action and action [22], [18]. Therefore, the studies were indirectly done. Since saving is daily at the consumer's end [21], [23], there is a need for direct measurement in actual application to see the substantial impact [22], [24]-[26]. Insufficient energy conservation measures in the domestic and commercial usage of electronic appliances coupled with a non-mandatory requirement under ECBC is resulting in opportunity loss to save energy and increasing associated costs.

3. METHODOLOGY

Actual field data on Air-Conditioning applications were measured over 90 working days divided into three groups of 30 days each at two different facilities to assess the actual impact of LCECM on Energy conservation due to energy usage behavior change. The LCECM training is provided by the Indian Association of Energy Management Professionals (IAEMP) trainers as part of their regular energy awareness program on low-cost energy conservation measures in the Gundi industrial area. Out of 318 listed companies, only 79 companies were operating daily. A total of 27 organizations out of these 79 daily operating companies agreed to be part of the LCECM training, and out of 27, only 02 commercial site owners decided to collect meter readings. The detail of these commercial sites is presented in Table 1. The electric meter readings were taken before and after LCECM training at two study sites; the meter reading was made during the same months but in subsequent years. Therefore, the temperature difference did not impact the measured readings. The temperature variation was 30 °C (300 to 330 °C) over these 90 working days for the readings before and after the LCECM training. Measurements were recorded in an excel sheet. Each of these groups had 30 working days of data. Data analysis was done as per (international performance measurement and verification protocol – A) "IPMV protocol A" [6], [27], and the formula below used is to determine the quantum of savings.

"Savings = (Baseline Period Energy – Reporting Period Energy) ± Adjustments."

The analysis results were analyzed more by running a t-Test in the SPSS software.

Field data in the application of air-conditioning was recorded at the two facilities – the dining hall and the food court. The facility owners allowed the researchers to collect the data with the restriction of only the existing measuring mechanism. Data were measured for 90 working days. In consultation with the researcher, the facility engineer recorded the actual data on the consumption of energy in three batches of 30 working days each. before and after the LCECM training. Data before the training was considered as the energy during the baseline period. The post-training data was recorded with the increased set temperature of air-conditioning and lowered operating time without compromising the comfort level of the occupants and was considered as the energy during the reporting period. The required deviation in time and temperature was included to ensure no complaints by the users of the facility regarding a compromise with their comfort level. A complaint box with adequate visibility and announcement was placed to report any compromise in the comfort level. There was no complaint about any of the two facilities. The study ensured that climatic conditions on air-conditioning concerning ambient temperature did not adversely impact the meter reading. The ambient temperature ranged from 33 ℃ to 30 ℃ between September and January.

4. DATA ANALYSIS

The impact of offsetting the air-conditioning set temperature and optimizing the air-conditioning running hours, without compromising the occupants' comfort level, on energy consumption is made at two sites as detailed in Table 1. The air-conditioning running time was optimized and lowered by 30 minutes in 14.30 hours. The set temperature of air-conditioning was optimized by increasing the set temperature by 1 ℃. The consumption data of energy before and after LCECM training was analyzed to find the savings in energy. The air-conditioning running time was optimized and lowered by 20 minutes in 2 hours of operating duration, and the set temperature of air-conditioning was optimized by increasing the set temperature by 20 ℃. The ten ceiling fans which were not running before were also switched ON during the meter reading duration after the LCECM training. Before and after the LCECM training, energy consumption data was analyzed for energy saving (savings = (Energy in baseline period–energy in reporting period) ± Adjustments, Ref: IPMVP – A, as shown in Table 2).

The savings on each day for the 1st, 2nd, and 3rd 30 days cycles were 0.55 MWh, 0.64 MWh, and 0.7 MWh. This corresponds to 17.1%, 19.9%, and 21.7% savings in energy at the 1st site. While on the 2nd site, the savings on each day in the 1st, 2nd, and 3rd 30 days were 3 KWh, 3.02 KWh, and 3.12 KWh. This corresponds to 20.4%, 20.6%, and 21.3% savings in energy. To identify the energy savings impact on the output using IMPV protocol [26] through meter reading, the researcher checked it statistically by applying a t-Test and analyzing it using SPSS software, as shown in Table 3. The results are highly significant justifying IPMVP- A analysis report. The savings at each of the two sites understudy as highlighted in Figure 1.

Table 1. Details of buildings and meter readings

Site/Building under Study	SNP Complex (Site 1)	CSSR Corp (Site 2)
Location	Food court	Dining hall
Area (sq. Ft)	8000	600
The capacity of AC (TR)	358	25
Duration of readings	3 Sept 2017 - 10 Jan 2018 3 Sept 2018 - 10 Jan 2019	
Average ambient temp.	33 °C to 30 °C	
running hours	6.30 AM to 9 PM	12.30 PM to 2.30 PM
Condition for meter reading	Before LCECM training After LCECM training	Before LCECM training After LCECM training
Calculation basis	Average of 30 days	Average of 30 days

Table 2. Savings as per IPMVP-A

Analyze	Study site number	First 30 days	Second 30 days	Third 30 days
Average daily power consumption before training	1 (MWh)	3.24	3.21	3.24
	2 (KWh)	14.72	14.7	14.68
Average daily power consumption after training (MWh)	1 (MWh)	2.68	2.57	2.5
	2 (KWh)	11.72	11.68	11.55
Daily average savings (MWh)	1 (MWh)	0.55	0.64	0.7
	2 (KWh)	3	3.02	3.12
Daily average savings %	1 (MWh)	17.1	19.9	21.7
	2 (KWh)	20.4	20.6	21.3

Table 3. t-Test on LCECM-A (a) paired sample statistics and (b) paired samples test

(a)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SNP_Before	3.2152	90	.19223	.02026
	SNP_After	2.5786	90	.16936	.01785
Pair 2	CSSRP_Before	14.7006	90	.04656	.00491
	CSSRP_After	11.6524	90	.10449	.01101

(b)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SNP_Before - SNP_After	.63667	.24468	.02579	.58542	.68791	24.685	89	.000
Pair 2	CSSRP_Before - CSSRP_After	3.04818	.09893	.01043	.3.02746	3.06890	292.289	89	.000

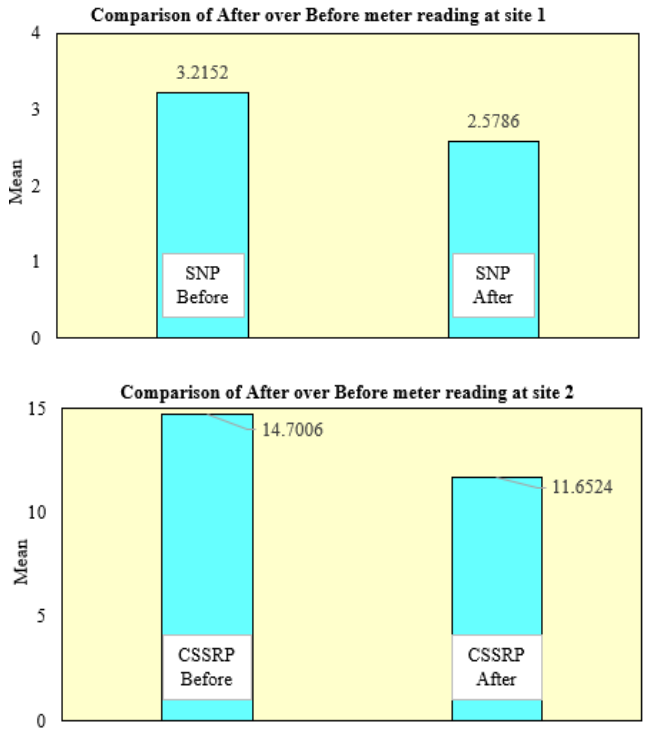

Figure 1. Comparative score after over before recording reading of meter

5. FINDINGS

The data for consumption of energy prior to and after LCECM training was analyzed for energy saving at both sites. On the first Site, air-conditioning running time was optimized and reduced by 30 minutes in 14.30 hours of operation. In addition, the set temperature of air-conditioning was optimized by increasing the set temperature by 1 $°C$. Daily savings for the 1st, 2nd, and 3rd sets of 30 days were 0.55 MWh, 0.64 MWh, and 0.7 MWh. This corresponded to 17.1%, 19.9%, and 21.7% savings in energy. On the second site, the air-conditioning running time was optimized and reduced by 20 minutes in 2 hours of operation. The set temperature of air-conditioning was optimized by increasing the set temperature by 2 $°C$. The ten ceiling fans which were not running before were also switched ON during the meter reading duration after the LCECM training. Energy savings every day during the 1st, 2nd, and 3rd 30 days were 3 KWh, 3.02 KWh, and 3.12 KWh. That eventually resulted in 20.4%, 20.6%, and 21.3% savings in energy. Direct Meter readings show 17.1-21.7% highlighting monthly energy savings in an air-conditioning application. The energy-saving is on two counts. Firstly, by increasing the air-conditioner set temperature by 1 °C. Secondly, reducing the air-conditioner 'Switch ON' duration by 20 minutes without compromising the comfort level of the occupants. Field measurements were first analyzed using IPMVP protocol – A and then a t-Test to confirm the actual savings.

6. DISCUSSION

ABC theory by behavioral scientist BF Skinner on behavioral changes is tested and tried in many applications. Studies were done both by a structured tailormade training program and with application-specific Dos and Don'ts in the past. However, no investigation was based on the ABC theory of energy conservation or energy management application. In this study, two things were particular. First, a seasoned hands-on energy conservation professional imparted a tailor-made training program; the second is actual energy conservation at two different facilities by two other applications [27], [28]. This was done first through the feedback from a set of questionnaires from the employees who received the training and then measured the energy consumption by a meter over 90 working days each before and after the training [29]. The meter readings were first tested according to IPMVP protocol A to establish energy savings. Then the same data was t-Tested by SPSS software to reconfirm the significance level. The measured energy saving was 20%, and the considerable level was very high. The study has determined that by imparting LCECM training to energy users, there is enough potential to manage the usage of electronic appliances in both the

domestic and commercial sectors. Implementing these measures can save a significant amount of energy without compromising their comfort level.

7. CONCLUSION

LCECM training, if designed and executed in-house by the organization, then does not cost any money to the organization, but if the same is done by engaging an expert from the industry, then it costs a negligible amount of money which can be recovered from the savings in organization's monthly energy bill in few months. Therefore, the monetary burden to implement such energy conservation measures is minimal and affordable for any organization. The more significant impact is building a work culture that will impact the organization. The same will be done, practiced, and encouraged by the employees wherever they go after working hours, like in public places and with their residents. The cumulative impact will be a change in energy usage behavior in the country in a few years, leading to energy conservation and a positive impact on the environment and government exchequer for a reduction in energy import bills.

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