Study and Analysis of Energy Consumption Trends of Slum Area, Identifying Their Problems and Providing Effective Feasible Solutions with a Socio-Economic Perspective

A survey and case example of Saraswati Nagar, Takia Dhantoli, Nagpur.

Harishankar R Shukla, Sangyan Sonone, Mandar S Joshi, Vishvas V Raina

Student 3rd Year, Student 3rd Year, Student 3rd Year, Student 3rd Year

BE Power Engineering

National Power Training Institute (Ministry of Power, Government of India), Nagpur, India.

Abstract: In this day and age it's very difficult to imagine living a life without consistent and adequate supply of electricity but it still remains a harsh reality for a major section of our population. A detailed Energy survey was conducted by our team in a slum area of Saraswati Nagar, Takia Dhantoli, with an aim to understand the current trends of energy consumption of that area on the basis of types & number of appliances used, energy rating of appliances, consumption hours, cognizing their daily practice to use and handle various appliances, what measures they take to reduce electricity bills & their LPG usage. This survey revealed various difficulties (harsh truth) about lives of people who reside there, typically the unaffordability of electricity bills, use of firewood for heating purpose, unawareness about the best practices of use of appliances, sharing of electric meters and so forth.

This paper aims to detail the factors affecting the electricity consumption of residents of Takia Dhantoli from a socioeconomic perspective. Secondly it aims to enumerate the problems of the residents related to their electricity consumption. From the acquired data and further analysis this paper presents several solution strategies reducing the burden of bill on these people. Investigating the use of solar energy in lighting, electrification application as well use Solvatten for purification and heating of water. Proposing a long term solution by setup of solar rooftop leasing and net metering,

Index Terms- **Energy,Solar,Lease,Heater,Light,Consumption.**

1. INTRODUCTION

Kraft and Kraft (1978) investigated the relationship between economic growth and the energy consumption of UN covering the sample period from 1947-1974.Ozturk (2010) examined the relation by considering about 100 studies with uniform distribution. In all these studies over the years, it is seen that energy consumption is one of the leading factor in economic growth of a country. With the economic growth of a country which is measured by the increase in Gross Domestic Product (GDP), the energy consumption also increases, and with this increase in energy consumption, increases the energy demands.

India being the world's fastest growing economy is witnessing an ever increasing energy demands and will continue to do so. In 2013, India observed a higher GDP growth which was, according to US EIA, accompanied by greater growth in energy consumption. But with this speed of growth there are still some sections of society which are not being able to match the level of increasing consumption, particularly the urban slums.

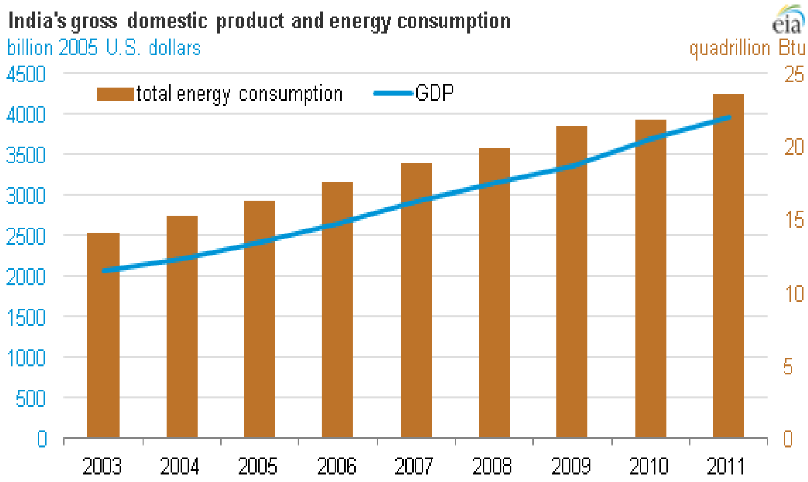

Fig no.1. The Energy Consumption v/s GDP plot of India over the years (Issued by the US EIA).

This paper aims to analyse the energy consumption trends of urban slums, using the data collected by a survey conducted at Saraswati Nagar, Takia Dhantoli area, Nagpur, Maharashtra, India.

2. RESEARCH METHODOLOGY

The slum area that we chose for energy survey was Saraswatinagar, Takia, Dhantoli, which is a densely populated area with a population around 6000 & average income of people living over there is [(₹12000 - ₹15000)/month] as stated by the ward member of that area Mr.Lakhan Yerawar. This area has recently got distribution of land titles to slum dwellers. According to research conducted by Mr.Deepak Mahadeorao Wankhede Human development index of that area was found to be 0.237.

Mr.Abhijeet Hedau was our local guide for the Energy Survey conducted by our team in that area, as he was familiar with Saraswatinagar slum area. The sample size of our survey was 55 homes. Sample size for this survey was purposely chosen, which covered houses from different income strata,from poorest of poor to mid high range income source families.
The tool used in survey was questionnaire format. The objective to use questionnaire format was to have a good interaction with local dwellers.

According to the Load Generation Balance Report 2018-19 produced by CEA of India, the peak electric load met was 160.7 GW with a short fall of requirement by 3.3 GW. This deficit is the arch reason for load shedding in India. Citing this reason they were enquired about the load shedding problem in their area to which they answered they had no problem of load shedding in that area.

Further they were enquired about what different appliances they use in their house and number of these appliances. To get acquainted with their awareness level regarding energy saving, they were asked whether they are aware of energy star rating of appliances, what practices they followed to reduce their energy consumption which in turn leads to reduction in their electricity bills. They were catechized about number of their family members.

Some other forms of energy source like firewood, dung cakes, LPG cylinders that they use in their daily routine was our part of our discussion. Their awareness regarding renewable sources and energy efficient appliances was also our matter of interest.

3. DATA INTERPRETATION

Sample size- 55 homes

Table no.1:

Data collected from the survey area.

SR. NO	TYPES OF APPLIANCES	NO. OF APPLIANCES
1	COOLER	53
2	FAN	80
3	REFRIDGERATOR	15
4	COLOUR TELEVISION	22
5	INCANDESCENT BULB	10
6	CFL	22
7	LED	57
8	TUBELIGHTS	13

Average no. of appliances per household= (No. of appliances) / (sample size) (1)

After performing above calculations, we get,

Table no.2:
Average number of appliances per household.

TYPES OF APPLIANCES	AVGERAGE NO. OF APPLIANCES PER HOUSEHOLD
COOLER	0.96
FAN	1.45
REFRIDGERATOR	0.27
COLOUR TELEVISION	0.4
INCANDESCENT BULB	0.18
CFL	0.4
LED	1.03
TUBELIGHTS	0.23

Table no.3:
Average power rating and running hours per day of various appliances.

TYPES OF APPLIANCES	AVGERAGE POWER RATING(WATTS)	AVG. RUNNING HOURS
COOLER	232	12
FAN	37	10
REFRIDGERATOR	200	12
COLOUR TELEVISION	127	3.75
INCANDESCENT BULB	60	3
CFL	15	6
LED	7	6
TUBELIGHTS	43	4

3.1. Average energy consumption per household per day (kWh)

(Avg. energy consumption per household per appliance per day) = [(Power rating) * (avg. running hours)*(Avg. no. appliances per household)] / 1000 (2)

(Total energy consumption per household per day) = (Summation of avg. energy consumption per household per appliance per day for different appliances)

Total energy consumption per household per day = 4.19 kWh

Units consumed per month= [(Total energy consumption per household per day) *30]

Avg. electricity bill per household= ₹ 540.74

4. FINDINGS

The survey shed light on various aspects of the lives of people living, which surfaced various problems regarding the consumption and availability of reliable and cheap electricity. The people living there could not afford water heaters and therefore were primarily dependent on firewood as a source of heat. This is a very primitive way of water heating,for drinking as well bathing in winters, as it is inefficient, inconvenient as it is time consuming and impacts the surroundings negatively increasing air pollution. The water was sometimes heated using LPG that is better than firewood but costly.

The dwellers even had a lack of proper knowledge about the best practices of using various appliances and did not know significant concepts like peak hours, arrears therefore felt that they had unusually high electric bills.

Houses that were very small or the homes with residents which did not reside there on a permanent basis had not connected a meter to the house and were using connections from a different house nearby sharing the load on a single meter. This practice of load sharing is discouraged as it makes the house with the origin of sharing prone to fire hazards and varietyof faults. Due to the proximity of the houses a fire can be a devastating catastrophe claiming a lot of lives and property in damages.

The people living there are the prime victims of load shedding if and when demand for shedding arises during peak summer as most other slum and rural areas are as well due to lack of adequate generating capacity of our nation. The people living there are part of the poor section of our society and most of them found it difficult to pay their electricity bills and some even failed at it to collect arrears thereby inflating the bills even further till it reached the point of disconnection. This ultimately led to them load sharing which as discussed is a bad practice.

Solutions

To grow and develop a country needs to lift its poorest of the poor out of poverty improving their standards of living, this makes them capable to be consumers of more goods with higher disposable income hence stimulating the economy to grow faster and bigger. One of the indicators of growth is Energy consumption per capita 1122 KWh which in many western countries is 12071 KWh USA, 4795 KWh UK etc. we have miles to go to reach that target. The people dwelling in these parts of society need innovative solutions which are within their means.

This paper details a few such solution which can help these people save money to put to other uses like education, self employment, increase the standards of living all together.

4.1 SOLAR ENERGY

Solar energy is abundant and easily available especially in the areas like Nagpur with over 300 sunny days it has a great potential to be harvested and used for the greater good of the socio-economically poor people who live in the slum areas. It is a great option but its installation cost upfront prohibits any steps in the right direction. The slum dwellers have an average annual income of ₹ 12000-15000 per annum. The cheapest of the solar solutions can easily run up to ₹1,00,000 which makes it an unaffordable luxury for the people. Solar systems are costly even for an average middle class individual who will have to save at least 100000 to put a 1kw system on the rooftops. Traditionally, to make these solutions affordable to the average middle class people have come up with third party ownership/leasing and power purchase agreements to sell the energy directly to a different generating utility and hence feed the grid apart from their use. These models use net metering using a bi-directional meter to measure both the export /import of the electricity bill. A second meter called solar meter is used to measure gross electricity generated by the solar panels. This model has worked really well and is one of the reasons increase the rooftop solar proliferation to 3399 mw up by 1538 mw in just a year (till September 2018)

This model can be further adapted to lower tier households to accommodate their needs and fit into their shallow pockets. There are various obvious benefits to inexpensive solar power to poor households.

- It bridges the deficit in generation and demand at peak hours, which requires addition of massive plants with capacity to ramp up and down rapidly.

- There is no transmission and distribution losses because power is generated on site and utilized which could end up saving at least 20%
- The utility gets cheaper power at the time of surges and otherwise by signing short term PPAs hence end up saving a lot of capital
- It also creates a layer of redundancy in case of failure of transmission, distribution or the grid itself.
- It provides cheaper electricity to the residents of the area helping them reduce stress on their pockets

There are certain non-obvious benefits as well which help these people as well the whole society in general by pushing affordable solar power

It doesn't stress our environment as much as building additional TPPs and erecting transmission structures for them. It results in more power more production as well as maintenance and operation can be conducted by locals with adequate training hence increase employment it the area

To full fill this need using solar energy we can setup different sizes of systems namely 2 KWp, 4KWp, 25 KWp

Payback period (year) = installation cost/Total revenue(per year) (3)

Total revenue = (units generated by the panel- units consumed) * rate (4)

(Rate is decided in the PPA)

Cost of panels (300 KWp) upfront was found to be roughly ₹12000 at 16% efficiency polycrystalline.

4.1.1 CASE 1-

2 KWp System

Cost per Wp ₹ 40

Payback period comes to 3-4 years

4.1.2 CASE 2-

3 KWp System

Cost per Wp ₹ 35

Payback period was calculated to 2-3 years

4.1.3 CASE 3-

25 KWp System

Cost per Wp ₹29

Payback period comes down to less than 1.5 years.

The difference in payback periods was found to be significant and the difference in the cost of generation drastically reduced as the capacity of system increased. The average consumption of a household was found to be about 4 units in a day and an average 200 Wp panel can deliver that need even on a sub-par day. These costs can further be brought down government subsidy which is around 20% for residential rooftops, the government as an impulse for deeper penetration in these areas can increase the subsidy on residential rooftop solar in urban and rural slums.

In the face of still high cost the poorest of poor might opt out of the program but to have total inclusion and make this program even more affordable companies can fix the rate at ₹ 500 which is less than the current electricity bill and make these a long term payment plan for say 5 years at a modest interest rate (say 13% p.a for 3years) therefore making it feasible for all the residents.

4.2 SOLVATTEN SOLAR WATER HEATER

Solvatten water heaters are dual functioning water treatment and solar water heating system implemented in Kenya. According to an article by UNFCCC, this device is benefitting 12,900 people in Nairobi, urban slums. Almost 62 million liters of water have been treated since 2012.
As mentioned earlier of the water heating problems of the slum areas, this comes as a feasible solution for people living there moreover, as a plus point it also provides them with purified drinking water.

This device harnesses the solar energy to treat and heat water, eliminating the use of firewood. Each unit works as a portable solar water heater, which also functions as a water decontaminator.
Ultra violet rays from the sun is used in heating and eliminating the pathogens in 10 litres of water within 2-3 hours moreover, no consumables such as chemicals or batteries are required for working of the Solvatten units. One year of using Solvatten unit saves 5-6 midsized trees. It can be implemented in almost any area with adequate sunlight. The temperature range of these heaters is 55-75 °C.
Considering a family of 4 members, if they use firewood to heat water at the cost of ₹35, which will last for 2 days. Say for a year it costs them about ₹3200 (considering they use firewood for only 6 months). And a single Solvatten unit costs about ₹3000. The life span of these units is 7-10 years.
Considering this, the initial investment cost on these Solvatten units is recovered only in 1 year. This proves to be a long term solution for delivering clean water as well as hot water when required.

4.3 BOTTLE OF LIGHT

The buildings in Saraswati Nagar, Dhantoli were built very compact and closer together so that the natural lightning cannot be directed naturally into the buildings. Hence, they have to use lights (Incandescent bulb, CFLs or LED) in daytime also.

Solar bottle bulb is an invention that is highly effective enough to be used in huge number for those without sources of interior lightning. This invention is very and excessively cheap, requires only a bottle, some roofing materials, water and minimum amount of regularly found chemical and no electricity is needed.

4.3.1 MAJOR ADVANTAGES

- Low cost and open source technology which enables the solution to be easily replicated and transferred to other areas.
- Low environmental impact as it uses recycled material and contributes to reduction of local and global carbon emissions.

Table no.4:
Life span of various light emitting devices.

Type of bulbs	Life Span
LED	50000 HOURS
INCANDESCENT LIGHT BULBS	1200 HOURS
CFLs	8000 HOURS
SOLAR WATER BOTTLE	43800 HOURS

Table no.5:
Comparison of electricity in watts consumed by different light emitting devices having same luminance.

TYPES OF BULBS	WATTS OF ELECTRICITY USED COMPARE TO 60 WATT BULB
LED	6 T0 8
INCANDESCENT LIGHT BULBS	60
CFLs	13 TO 15
SOLAR WATER BOTTLE	CAN GIVE LIGHT EQUIVALENT TO 60 WATT BULB WITHOUT ELECTRICITY

Table no.6:
Analysis of various toxins present in different light emitting devices.

TYPES OF BULBS	CONTAINS TOXIC MERCURY	RoHS COMPLIENT
LED	NO	YES
INCANDESCENT LIGHT BULBS	NO	YES
CFLs	YES	NO
SOLAR WATER BOTTLE	NO	NO (Plastic bottle is recycled)

Table no.7:
CO_2 emission per year by different light emitting devices.

TYPES OF BULBS	CO2 EMISSION 30 BULBS PER YEAR (POUNDS PER YEAR)
LED	451
INCANDESCENT LIGHT BULBS	4500
CFLs	1051
SOLAR WATER BOTTLE	0

Table no.8:

Cost comparison of various light emitting devices having same luminance.

TYPES OF BULBS	COST COMPARE TO 60-WATT BULB ($)
LED	5
INCANDESCENT LIGHT BULBS	1
CFLs	2
SOLAR WATER BOTTLE	LESS THAN 1

4.4. AWARENESS

Awareness or the lack thereof is one of the major challenges we are going to face it is an uphill battle which needs to be won. Various outlets have been successful in providing enough information about various government schemes like Ujaala Yojna and other schemes these outlets can be used to provide other kinds information like best practices to use appliances, arrears and other concepts like load sharing, peak hour demand etc. this can help a long way in creating a shared knowledge base for these people enabling them to make the right choices and save additional future effort and rapidly enrich and full fill their lives.

Slum dwellers were unaware about the best practices to be used for operating refrigerator at low energy consumption and in a highly efficient manner. They had a habit of switching off the refrigerator during the midnight hours due to their misconception that it will lead to energy savings but that ultimately has an opposite impact.
According to experts Refrigerators work to keep the internal temperature set value. Whenever the temperature is reached, the compressor is turned off. When the temperature increases, the compressor is again turned on to start cooling. So, one don't have to turn off the whole refrigerator manually. If you keep the refrigerator off for longer time, the temperature inside may go too high and compressor has to work harder to cool it down wasting lot of energy and load on compressor.
Numerous foods in refrigerator might have bacteria on them, and the cold temperature inhibits the bacteria from multiplying (or at least slows it down). If the food warms up, the bacteria will reach harmful level faster. For this reason USDA recommends the food left in unplugged fridge for more than four hours be tossed.

5. CONCLUSION

The above solutions have a great potential to ease the lives of the slum dwellers. The initial cost of the project is slightly inhibitive in case of Solar pv cells but it can be easily made affordable with a combination of net metering, leasing and short term loans bringing the cost down to their electricity bills or slightly less and after breaking even providing free energy for the rest of its lifetime roughly next 15-20 years. By the use of larger scale solar photo voltaic systems, the energy cost can be brought down further. This makes solar power inclusive and feasible for all. The problem of Water heating and a clean drinking water Solvatten solar water heater can be used to provide for those needs. Its initial cost can be recovered in a year and it can be reliably used for the next 7-10 years without any maintenance cost. All the above developments and any other ones for that matter can be accelerated if become aware of the practices good for them. Then we might not have to work to give them what they need rather they will themselves ask for all the things that are good for them and represent their best interests.

REFERENCES

[1] Kraft, J and Kraft, A. 1978. Relationship between energy and GNP. Journal of Energy Finance and Development, 3(2): 401-03.

[2] Ozturk, I. 2010. Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy Policy, 38, 340-349.

[3] Ozturk, I and Kalyoncu, H. 2011. Energy consumption and economic growth in Turkey: Cointegration and Causality Analysis. Romanian journal of economic forecasting,

[4] Wankhede, D. 2014. Human development of slum dwellers in Nagpur city: Geographical Perspective. Zero Mile International E-Journal,

[5] Borozan, D. 2013. Exploring the relationship between energy consumption and GDP: Evidence from Croatia. Elsevier

MNRE (Govt. of India). 2012. Solvatten Launched in India. InSolTherm Times, Vol-2, Issue-1.