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Energy Efficiency and Audits

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Abstract: **This research paper is primarily based on methods of saving energy and an in-depth analysis of a survey conducted on energy efficiency within residences in India. This paper provides an understanding into how different methods of energy saving can be beneficial both socially and economically, empirically demonstrating the long term cost-benefit analysis from every proposed change. The paper statistically analyses the data from the survey, understanding the various causes of high energy consumption in residences.**

1. INTRODUCTION

In a technologically and industrially evolving world, energy consumption has become synonymous with natural degradation resulting in diminishing earthly resources. Growing concerns over the natural environment, sparked by extensive research, have resulted in individuals working towards environmental and climatic safety. After National Geographic's declaration that half the world's land must be naturally conserved to prevent impending doom in 2030, countries have greatly increased their awareness regarding the environment *(Leahy)*. From celebrating 5th June annually as Environment day to forming the UN Environment Assembly, international bodies are working towards climate and environmental preservation in all forms.

However, one key factor commonly overlooked in the quest of environmental conservation, is energy consumption. Factories, industries and households all consume large amounts of energy, releasing various toxins into the air, land and water ("How Does Saving Energy Help The Environment."). While initiatives such as 'Green Earth', the government of India imposing a carbon tax of 50 rupees per tonne and the invention of tradeable permits, certain industries have reduced their carbon production *(Joshi)*. However, there has been a simultaneous surge in industrialization, with over 1,20,000 firms created in India, rendering these solutions effective only in the short run*(Pathak)*.

The main surge in energy consumption can related to the increase in carbon footprints from residences and households. With increased automation and technological advances, individuals tend to spend large periods of time at their homes, resulting in them consuming high amounts of electricity through various appliances within their houses. This has been further aggravated by the current Coronavirus pandemic that has rendered individuals unable to step outside their houses. In fact, based on a study across the world, there has been a 45% rise in residential energy consumption during the COVID-19 period *(Chunekar)*.

The issue of energy consumption is not insurmountable. Simplistic lifestyle changes and application of new devices would result in a greater energy efficiency, especially in households. Energy Efficiency refers to the practice of using less energy to provide a the same output of energy i.e. reducing the amount of energy wasted ("British Geological Survey"). Further a reduction in energy usage has been empirically demonstrated to have cost benefits along with environmental benefits, due to the increased yield within a household.

Therefore, it remains imperative to tackle the issue of energy efficiency using simple long term solutions that have experimentally proven beneficial in the past. It is ideal to start from a micro level, in households and residences, to tackle the global challenge of energy overusage.

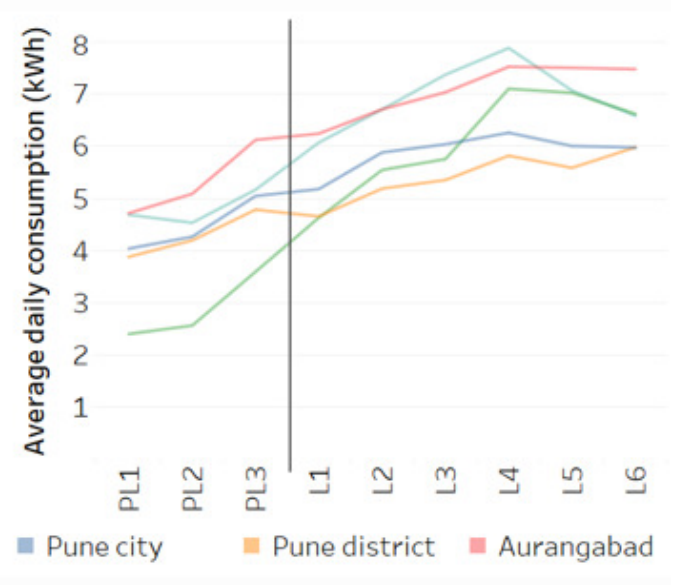


Fig. 1. Energy Consumption during COVID 19

The above graph is an indication of the increase in energy consumption in residential areas and households during the COVID-19 period in cities and localities within the country.

2. RESEARCH METHODOLOGY

To address the issue of energy efficiency and conduct energy audits, I shall be relying on both primary and secondary data.

The primary data collected by me is through an extensive survey of numerous households (attached in the appendix below), where questions regarding simple practices such as closure and opening of windows have been correlated with the rating of their appliances. This primary data shall form the essence of my analysis.

Further, I have used secondary sources in the form of available research papers, reports by authorities such as the government of India, and other studies conducted by the different organizations such as UNNATEE. Further, secondary data has been procured from several areas to understand the statistics surrounding carbon/greenhouse emissions in any form and the associated cost (economically and socially). The secondary data will support my primary data and show the macro effect of certain practices.

Source of Data	Sample	Reason
Online Articles	Pathak, Analiza. "Economic Survey 2020: India Ranks Third in Number of New Firms Created." *English*, 31 Jan. 2020, www.indiatvnews.com/business/news-economic-survey-2020-india-ranks-third-in-number-of-new-firms-created-584679.	Reputed sources periodically providing key information
Case Studies	Leahy, Stephen. "Half of All Land Must Be Kept in a Natural State to Protect Earth." *To Save Earth 30 Percent of the Planet Must Be Protected, Study Says*, 19 Apr. 2019, www.nationalgeographic.com/environment/2019/04/science-study-outlines-30-percent-conservation-2030/	Cause and effect analysis of key events by international organisations
Financial Reports	December 21, 2017. "Energy Efficient Appliance Benefits." *Expert Electric Blog*, 21 Dec. 2017, www.expertelectric.ca/blog/th e-benefits-of-energy-efficient-appliances/.	Quantitative analysis of effects of energy efficiency measures
Research Papers	British Geological Survey 1998 - 2017 (c)NERC www-bgs@bgs.ac.uk. "What Is Energy Efficiency?" *What Is Energy Efficiency? | CCS | Climate Change | Discovering Geology | British Geological Survey (BGS)*, www.bgs.ac.uk/discoveringGeology/climateChange/CCS/whatIsEnergyEfficiency.html.	Highly accredited researchers providing in-depth analysis and data different appliances and energy consumption

3. WORKING OF ENERGY

As described in the Paris Convention, all forms of energy do not represent "bad energy". The main form of energy that has a negative effect on the environment is burning of fossil fuels, or in some cases nuclear fusion. Consumption of energy in these forms leads to an increased carbon footprint due to production of carbon dioxide, methane and other toxic gases into the environment.

However, approximately 18% of energy produced is 'clean energy'. This may be in the form of wind energy, hydroelectricity or even solar energy. Based on empirical data, even households that have abstained from the use of solar energy inevitably consume some proportion of it as light energy filtering through the windows or other similar forms.

Therefore, along with a reduced consumption of energy in households, to reduce the carbon footprint on a macro level, it is imperative to increase the production of 'clean energy'. Further, since these forms of energy are created through natural resources, the resources expended can be re-used, ensuring long-term legitimacy of these sources.

4. KEY APPLIANCES

There are several typical appliances found in our household that consume large volumes of energy that can be improved empirically. Newer appliances have indicated greater energy efficiency as well as a reduced cost in the long run and are therefore beneficial for usage.

- ***BLDC Fan***

The power wattage of a common fan is approximated around 75 watt, while that of a BDLC super efficient fan is approximated at 28 watt, resulting in energy saving of around 50 watt at 63% ("Super Efficient BLDC Fan Program"). The second most ideal fan, a BEE 5-star ceiling fan consumes 50 watt of power.These fans can be availed at approximately Rs. 2000 from online and offline retailers (varies based on retailer). The usage of the fan for just 90 hours, would be enough to offset the cost, as it would consume around 5 kWh of energy (amounting to a greater cost). Further, every old fan replaced with such a fan would result in the 2-3% less energy consumption in the household, based on average energy consumption.

- ***LED Lights***

Commonly referred to as LED, Light Emitting Diodes are fairly new invention but are highly effective in reducing energy consumption in any house.

1. *Long Life Span* – The components of an LED and the way they generate light have resulted in a significant extension of an LED's lifespan. Where other bulbs' lifespans are shortened through both proper and improper usage, the LED bulb's low heat levels, durability, and energy efficiency make it possible for it to outlast other types of bulbs by thousands of hours.

Type of Bulb	Approximate Lifespan(hours)
Incandescent	750-2000
Fluorescent	24000-36000
CFL	8000-20000
Halogen	2000-4000
LED	**35000-50000**

2. *High Brightness and Intensity* – LEDs are capable of emitting an extremely high level of brightness. That's why wattage is no longer a viable measurement of brightness – instead, look at a bulb's lumen output when you're making the switch to LEDs or other energy-efficient lighting.

Type of Bulb	Lumen
Incandescent	450
CFL	2400
LED	4000

3. *Low Radiated Heat*– While an incandescent bulb operates by heating its filament to a temperature that produces light, an LED bulb emits electromagnetic energy as light when electrified. By turning energy into light instead of heat (rather than using heat to generate light), LEDs are able to operate at a significantly lower temperature than other types of light bulbs.What little heat LEDs do generate is dissipated by a special heat sink, which is designed to absorb any heat and disperse it safely away from the diodes. While the actual fixture or base can feel warm to the touch, LEDs themselves don't emit infrared radiation in their beam, meaning there is no warmth to it. This makes them optimal for use in heat-sensitive areas, such as displaying artwork because they won't cause fading or other heat damage to paints or dyes.

4. *High Reliability* – LEDs are a very durable and reliable form of lighting – they can operate safely in colder temperatures, and can withstand more impact and vibration than other light bulbs because they have no filaments or other fragile parts. This stability makes them ideal for use in areas that will be subject to temperature fluctuations, inclement weather, and jostling, such as outdoors or in ceiling fan fixtures*(Levison).*

5. *Cost Benefit Analysis*

A study conducted by researchers at Glamox concluded that LEDs, in the long run, LEDs are less costly along with the aforementioned benefits.

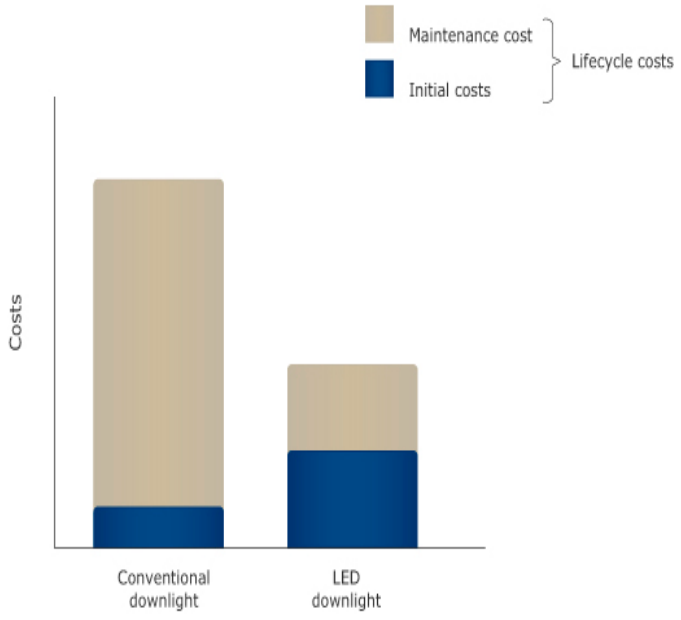
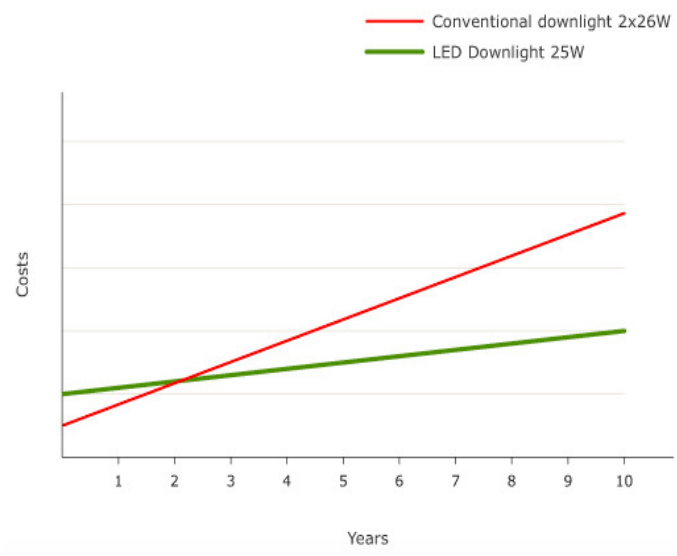


Fig. 2. Costs of LED vs Conventional Downlight

Reference: ("Cost Benefit Analysis")



**Note that this graph assumes 8 to 16 hours, on average, of usage a day*

The graph indicates that for approximately the same wattage of an LED and conventional down-light, although there is a higher initial cost of using an LED, it is more cost beneficial in the long run.

Lastly and most importantly, LEDs use 70-90% less energy than incandescent bulbs, limiting the burning of coal in the process. Switching to LEDs has cured asthma and other respiratory disorders *(MacEachern).*

- **5 Star Appliances and Equipment**

Pushed by the Bureau of Energy Efficiency, It is imperative that all equipment used be of 5 star category. 5 star category, although expensive due to a high initial cost, has energy saving benefits in the long run.

- Air Conditioners
- Heaters
- Refrigerators
- Dish Washer
- Washing Machine
- Dryers

1. *Long Term Money Saving* – Although there is a high initial cost involved, there is a long term profit from using highly rated appliances. According to a study conducted, those who switched to 5 star appliances saved approximately 30% on their electric bills ("Energy Efficient Appliance Benefits"). This cumulatively far exceeds the cost of the products, and you a rebate within 2 years.
2. *Environmentally Friendly* – Using energy efficient appliances reduces the use of energy, therefore reducing use of natural resources such as coal and oil. A study conducted by the United States Environment Protection Agency indicated an average family could save 130,000 pounds of greenhouse emissions over a lifetime by switching to 5 star rated appliances *(Thomas)*. Should every household employ this idea, the net reduction in greenhouse emissions, within India itself, would be trillions of pounds.

   An important idea to note is that based on BEE ratings, an appliance considered 5 star several years ago may qualify under the same category anymore due to innovation and new techniques. Therefore, to minimize energy consumption, it is imperative to replace appliances periodically, especially when their rating drops.

- **Geyser**

  While Geysers are seemingly simple appliance, they correspond a very high cost in terms of energy and their effect on the environment.

  Storage geysers often take periods of time to heat up resulting in delays for individuals. However, they are inarguably cheaper and better for the environment. While storage geysers have wattage around 2 kW, instant geysers have a basic wattage of around 4-4.5 kW. Since the second heats up immediately, it requires high amounts of heat energy to be immediately supplied, thereby resulting in high power values *(Lokesh)*.

  Instant geysers consume approximately 3.13 times the energy consumed by storage geysers, which results in high costs of electricity every month.

  Further, storage geysers are cheaper to install than instant geysers as well, resulting in high amounts of savings by consumers from the same.

  Based on Demand Side Management, another key understanding about geysers is the load utility. Switching on a storage geyser for several hours prior to use is as detrimental as using an instant geyser. Therefore, an optimal technique would be to use a storage geyser switched on 15-20 minutes prior to usage.

5. KEY FORMS OF HUMAN BEHAVIOUR

Behavioral economics has shown us that the psyche of the consumer and producer, at every turn, play an important role in determining the market of a good. Similarly, the human rationale also dictates the energy consumption of human beings. Psychologically proven to be forgetful, it is essential for human beings to be constantly reminded about simple tasks that often go a long way in conserving energy, saving money and saving the environment.

- ***Closing the door while using heaters or Air Conditioners***

  It is essential to do so otherwise air easily escapes through doors, in form of leakages, resulting in lesser cooling or heating. Behaviorally, it leads to lowering or increasing of temperature for air conditionersor heaters respectively, resulting in higher energy consumption than required.

- ***Keeping refrigerators outside the kitchen***

  Refrigerators emit heat during use in order to achieve thermal equilibrium with their cooler inside. Typically, individuals locate their refrigerator within the kitchen itself. However, the ambient temperature in the kitchen, especially while cooking, is high. To reach equilibrium with this new temperature, the refrigerators starts emitting warmer air, resulting in higher energy consumption.

- ***Unplugging Appliances***

  A key reason for wasteful energy loss is not unplugging appliances. While small appliances such as phone chargers cause little energy loss in the short run, they cumulatively add up. Further, larger appliances such as ovens, toasters and mixers require high amounts of energy if not unplugged. Therefore, it remains imperative that these appliances are unplugged at all times to promote energy efficiency.

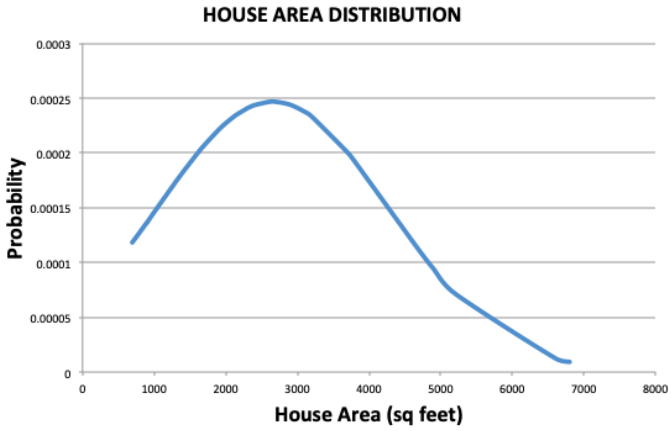
- ***Changing Wall colour***

  Wall colours have a large effect on energy efficiency as well. Lighter colours result in light and other forms of energy being reflected back, reducing leakages. On the other hand, dark colours absorb 70-90% of available radiations, resulting in greatly reduced energy efficiency ("How to choose paint colours"). Further, dark colours retain heat for longer periods of time. In a tropical climate such as India, this leads to increased use of the air conditioner, another deterrent to energy savings. While painting, there is a Light Reflectance Value associated with each paint, which should be considered while choosing the paint (lower the better). However, in terms of cost, it is advised against repainting one's house for the energy saving of approximately 5-6% is far lesser than the cost of repainting and remodeling an entire residence.

6. DATA ANALYSIS AND IMPLEMENTATION

This survey was primarily conducted in households will available resources to purchase technology. These households were large in size and part of larger residences.

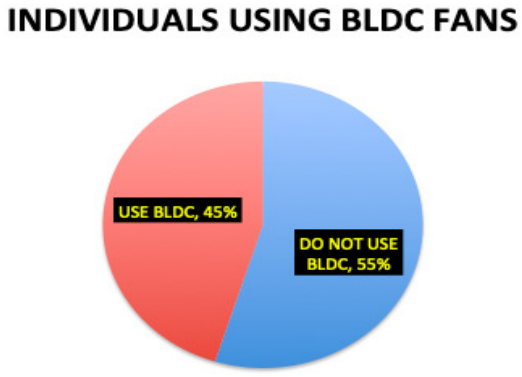
Prior to understanding the usage of different appliances and methods to implement and optimize the same, below is a graph outlining the probability mass function of the carpet area of the houses analyzed through the survey. All areas are given in Square Feet.



As can be seen from the graph above, the areas of residences analyse vary based on the normal distribution curve. Further, with a high mean value of 2657 square feet, the effect of appliances and quality of products in such houses has a greater effect than smaller residences.

1. BDLC Fan Usage

Below is a pie chart outlining the usage of BLDC fans in the households, based on data collected in the survey.



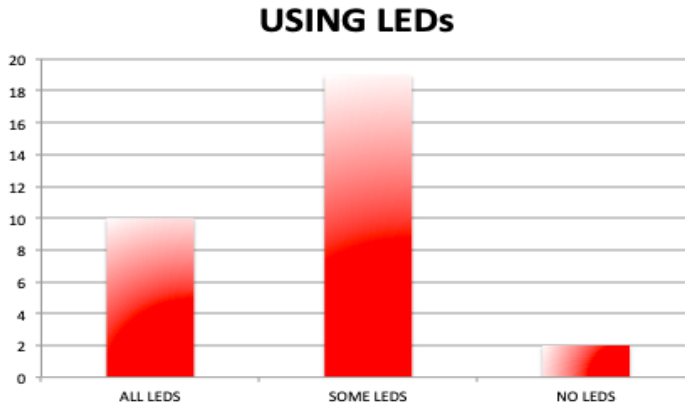
From the survey, 45% of individuals were seeing to be using BLDC fans. While being a relatively new technology, it is cost-efficient and cleaner as indicated above.To install BLDC fans, individuals can buy new fans such as the Super BLDC fan from Tata Motors, or purchase the BLDC Brushless Plugin which can be installed in their current fans. While the Brushless plugin in cheaper than a new fan, the benefits are similarly reduced as opposed to a new fan.Another top quality fan is the "Airzon Fan".

Description	Traditional Fan	Airzon Fan
Power Consumption	75 watt	33 watt
Time Used	16 hours	16 hours
Energy Consumed	1.2 kWh	0.53 kWh
Energy cost per unit	Rs 6.35	Rs 6.35
Energy Cost Per Day	Rs 7.62	Rs 3.25

It has a payback period of approximately 1.5 years. Further, it is able to operate at 140-280V range, without any change in quality ("Why Airzon").

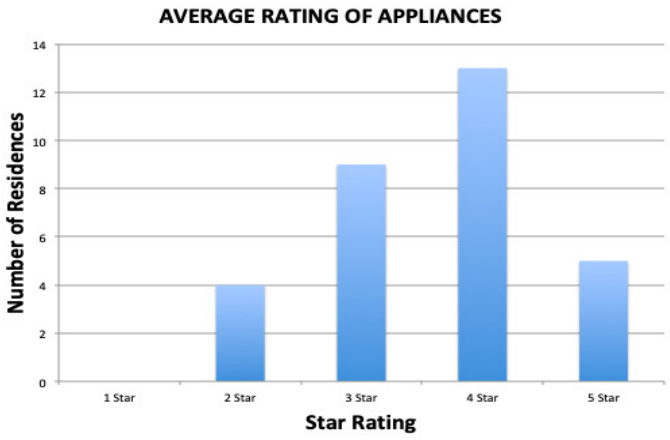
2. *LED Lights*

The graph below outlines the number of people using LEDs in their houses.



As is seen in the graph above, a larger proportion of individuals use all or some LEDs in their houses. However, it is imperative that they switch to complete usage of LED lights. To do so, Compton LEDs or Tata LED bulbs are ideal.

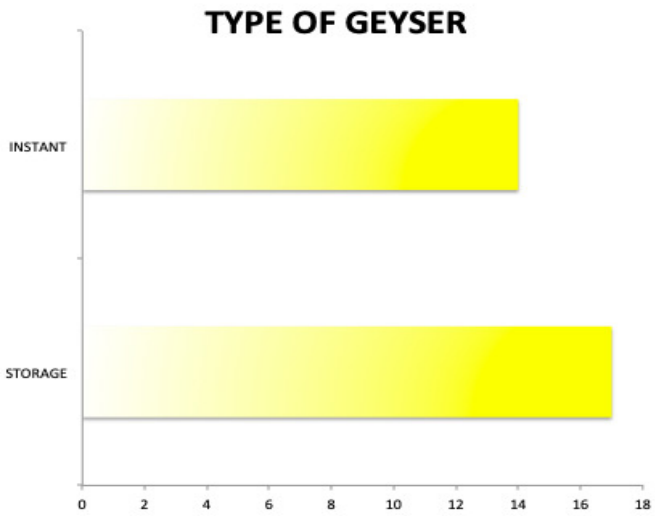
3. *Star Rating*



The above represents the star rating of appliances represents the different ratings based on the survey. While no house has an average star rating of '1', it is imperative that they have an approximate rating of 4 or 5 stars. Newer models of refrigerators and airconditioners from Panasonic, Hitachi etc. tend to have a 5 star rating.

4. *Type of Geyser*

The graph below outlines the types of geysers used by individuals.



As can be seen here, a larger part of individuals use a storage geyser. However, based on the survey, they tend to keep their geysers on for longer periods than ideal. This results in overheating of water and high energy consumption, reducing the utility of a storage geyser. While the ideal Geyser is the Racold Pronto Neo 6 Liter, there are several storage geysers that automatically stop heating the water after it has reached a certain temperature. These geysers reduce energy consumption, promoting a cleaner environment and a reduced cost.

5. *Use of Internet of Things (IOT)*

While there are several negative effects of a technologically evolving world on the environment, the introduction of Internet of Things(IOT) can also be viewed as a boon as opposed to a bane.

To improve cost-efficiency, a small and cheap IOT-based device, costing around Rs. 1000, can be connected to a wifi router. This is useful in relation to integration to behavior, where the IOT-based devices can monitor your usage of an appliance and give your cost-efficient returns with a better alternative, with reference to energy consumption, for your current device.

7. CONCLUSION

Both empirical and theoretical evidence has suggested that employing new technologies, which reduce energy consumption, is beneficial for it reduces the carbon footprint of the environment while reducing costs in the long run. Further, the survey conducted suggests that individuals are either unaware or have overlooked basic key factors in their appliances. While using newer and cleaner technology in individual housing may only have a micro effect, by extrapolating data to larger areas, we can see that the effect of cleaner technology is very large in reducing the carbon footprint and eventually reducing global warming.

ACKNOWLEDGEMENT

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