Energy Consumption Pattern and Environmental Impact: A Case Study of Residential Sector in India

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Abstract. Energy is fundamental to the economic progress of the nation and is vital in every sector of an economy for survival and growth. The consumption of energy is going to rise further in the near future, as it sees an increase in population. The energy used in the residential sector is a critical area for the campaign to conserve energy. In this backdrop and with the growing share of India in global energy use and Carbon dioxide emissions, this paper aims to analyse the pattern of energy consumption in the residential sector of the South Indian city, Karnataka State, India and also estimates the environmental impact in terms of CO₂ emission. The energy efficiency level is computed in terms of Specific Energy Consumption and Energy Intensity. The factor analysis is carried out by Principal Component Analysis (PCA) method to find factors influencing energy efficiency and energy consumption. Also, these factors are studied and analysed using multiple regression models.

Keywords: Energy; energy efficiency; environmental impact; residential sector; specific energy consumption

3. Introduction
The importance of energy is a crucial ingredient in economic growth as well as in any strategy for improving the quality of human life. Energy consumption in the residential sector is usually because of cooking, lighting, water heating, space heating and electric appliances. The energy use in the residential sector is an essential zone for battles to monitor energy. Energy sparing in the home makes benefits for the family unit as lower vitality bills and for the network everywhere as lower imports. Households constitute a main target group as they are major contributors to the emission of greenhouse gases and consequently, to global warming. For residential buildings, the physical size of a structure is one key pointer of the measure of vitality utilized by its tenants, in spite of the fact that wage level and various different components, for example, climate, additionally can influence the measure of vitality expended per household. Likewise, tenants of bigger homes have a tendency to be more well-off, and therefore, they keep an eye on possessing more vitality utilizing machines, including different TVs and PCs and a wide cluster of other electronic gadgets, (for example, computerized video recorders and set-top boxes) whose activity devours extensive measures of power. The primary purpose of this work focused on household energy consumption and conservation is to understand the factors influencing energy consuming behaviours.

By 2040, there will be 2.8 billion family units on the planet, and development of almost 50 percent from 2010. These families will require vitality for lighting, cooking, boiling water and refrigeration, and in addition, the power to run everything from PCs to ventilation systems. Each district will see a net increment in family units through 2040; however, development will be especially solid in Africa,
China, India and Latin America. By 2040, these four districts will represent around 60 percent of all family units on the planet. Through 2040, overall advancement in family units will more than counterbalance anticipated upgrades in private vitality productivity, bringing about rising interest in this segment. Energy consumption belongs to the realm of technology, but energy conservation belongs to the realm of society. In creating nations, 72% of the total populace lives, however they represent just 23% of the world's aggregate vitality utilize. Nonetheless, if considering the way that they produce a for every capita wage of around $300 every year, it turns out to be certain that, regardless of their low vitality utilization, they are exceptionally wasteful in their energy to utilize. Energy preservation is likewise vital on the grounds that utilization of non-inexhaustible sources, impacts nature. Carbon dioxide (CO₂) in the climate goes about as a straightforward cover that adds to the Earth-wide temperature boost of the earth, or nursery impact. It is conceivable that this warming pattern could fundamentally change our climate. Conceivable effects incorporate a risk to human well-being, ecological effects, for example, rising ocean levels that can harm beach front regions and real changes in vegetation development designs that could make some plant and creature species end up terminated. Current arrangement endeavours to decrease a worldwide temperature alteration are insufficiently served by their solid dependence on built-up meanings of vitality effectiveness. These definitions to a great extent evade the natural goal of diminished CO₂ outflows since they neglect to successfully consider total levels of vitality utilize or the unpredictability of the connection amongst proficiency and discharges.

Energy efficiency creates generous money related funds while all the while enhancing natural quality. In spite of these advantages, creating nations like India are passing up a major opportunity for energy productivity openings and rather focusing on expanded energy generation. Household’s energy conservation has been a topic of interest within social and environmental psychology research for a number of decades. Residential sector constitute an important target group since they are also major contributors to the emission of greenhouse gases and hence global warming. The experience of the last 30 years shows that the rise of gross energy demand has by far exceeded the growth rates of population. There is ample scope for energy saving in the residential sector with the use of modern energy efficient equipment’s. Residential energy emission caused by warming and cooking has the biggest effect on premature mortality with China and India feeling a great part of the effect, a worldwide report has found. With 13.6 lakh deaths every year, China represents most noteworthy number of air pollution deaths in which the size of indoor pollution is higher than road transport. India comes second with 6.45 lakhs deaths, 50 percent of which are caused by the residential energy sources. While most extreme mortality is found in the northern and eastern areas from Jammu & Kashmir to Assam, pockets of western, central and peninsula regions also witness indoor pollution shortening human lives. Comprehensively, open air contamination prompts more than 30 lakh unexpected losses for every year, which quite a bit of it detailed in Asia. The worldwide mortality connected to air contamination is unequivocally impacted by these high numbers in Asia, says the investigation distributed by Michael Jerrett, 2015 in the September 17, 2015 issue of Nature. A group of researcher from Max Planck Institute in Nicosia, Harvard School of Public Health, Boston, and King Saud University, Riyadh, carried out the study. Despite the fact that analysts in the past have announced the harming impacts of air contamination in South Asian nations including India, the new examination is sufficiently clear confirmation that household pollution causes a larger number of deaths in the country than industrial or vehicular.

Recently, the Central Electricity Authority (CEA) has warned Karnataka State that, it would face difficult times in the financial year 2015-16. The aggregate power accessible in the State for November 2015 is 4500 million units against the necessity of 5676 MU, meaning a deficiency of 19.8 percent. The CEA, top power policymaking body in the Ministry of Power, has said in its Load
Generation Balance report for 2015-16. Along these lines, the State will be shy of 21.44 percent of intensity from November 2015 to March 2016. Poor precipitation, low stockpiling of water in hydel repositories and expanded request from the horticulture part will add to the power emergency. Hence, the State need to purchase electricity from outside and it will be burden to the users by increasing the cost of electricity. The study in the South Indian city of Karnataka state reveals that, Electricity is the major carrier in residential and commercial sectors. High level of awareness should be created using energy efficient technologies to reduce environmental impacts. And also the financial support should be provided by the governments to improve energy efficiency.

This paper analyses the energy consumption using consumption patterns, environmental impact of energy use in the residential sector. The energy consumption pattern is based on different energy carriers used and also based on the specific parameters like family size, area of energy utilization. The factors influencing the energy efficiency and energy consumption in the residential sector are also studied. The different types of factors which influence the energy efficiency and also the energy consumption are examined using statistical tools. The analysis is carried out using the SPSS (Statistical Package for Social Science) version 20.

4. Methodology
Detailed review of the literature followed by identification of research gaps and subsequent discussion with experts in the field of Energy Management facilitated the development of a theoretical framework for the study, as shown in Figure 1.

![Figure 1. Theoretical framework](image)

The primary data required for the study are gathered through canvassing a structured questionnaire, administered personally. Essentially, a questionnaire must serve two capacities: it must make an interpretation of research targets into particular inquiries the respondent can reply, and it must inspire the respondent to coordinate with the review and to outfit the data accurately. The questionnaire covered different aspects of household energy consumption, energy consuming appliances and the attitude and behaviour of individual towards energy, etc. Nevertheless, the questionnaire has sections covering following aspects:

- General Information of the Facility
- Demographic and Economic Background
- Different Types of Energy Consuming Devices Used
- Variables that Influence Energy Efficiency and Energy Consumption

A study was conducted in various households in different locations in Davangere city, Karnataka, India.

| Table 1: Basic Indicators of case studies |
|-----------------------------------------|
| City                          | Davangere |
| Land Area (sq.km)  | 77        |
| Population (2011)   | 435,128   |
| Population density (people/sq.km) | 5700     |

Davangere is at the focal point of Karnataka, 14°28' N scope, 75°59' longitude and 602.5 meters (1,977 ft) above ocean level.
Socioeconomic and energy data were collected from randomly selected samples. Samples of 50 households (almost all from the middle income group) are chosen for the pilot study. The questions specific to energy in the survey were on the primary source of energy for lighting, cooling and cooking, etc. The other data required for accomplishing the stated objectives includes: annual energy requirements (for lighting and cooking, etc.), CO$_2$ emission factor, and environmental factors. The data for estimating these parameters has been obtained from catalogues, journal papers and from equipment manufacturers.

3. Results and discussion

3.1. Energy consumption pattern in residential sector

The energy consumption pattern is studied for the different households from the energy data, which were collected from different residential buildings. The energy data were collected from 50 households at different locations in Davangere city. Further, various energy consuming devices and their estimated daily usage were also noted down. Generally in residential sector buildings, electricity and LPG are the primary energy carriers. Without these energy carriers life of the urban people would be unimaginable. Electricity is used for different devices used in the households like refrigerator, Television (TV), fan, washing machine, etc. LPG is the primary energy carrier for cooking purposes in the urban households. The amount of electricity used is noted in terms of kWh. The LPG used for cooking was collected in terms of Kgs and is then converted to kWh. The number of persons in each home or family size is noted down during the survey. Also noted down is the floor space area for all the buildings.
Figure 3. Energy consumption pattern

From Figure 3 it can be seen that, the annual LPG consumption is more compared to the annual electricity usage. About 54% of energy is shared by the LPG and 46% is shared by electricity in all residential buildings. The share of the LPG is more in the residential sector because most of the energy used in this sector is for cooking purpose. The electricity is required for the equipment’s like Television, refrigerator, washing machine, mixer, lighting, etc., which can be considered as secondary need, but LPG is the prime requirement in every urban household for cooking purpose. In some households, the LPG is also used for gas geysers to provide hot water for bath.

3.2. Specific energy consumption (SEC)
Apart from the energy related data in the survey, total area of residential buildings (in terms of sq. ft.), no. of people residing or family size in residential buildings are also collected. Then, the specific energy consumption is calculated as total annual energy consumed per sq. ft. of area. Specific energy consumption is also calculated in terms of energy consumed per capita in residential buildings.

In the residential sector, the energy used per sq. ft. of floor space area is represented in terms of SEC, Specific energy consumption = 1.8779 kWh/sq. ft. of floor space area. For each sq. ft. 1.8779 kWh of total energy is consumed in residential sector. Energy used by an individual is represented as, Specific energy consumption = 906.1866 kWh/capita. Each individual consumes about 906.1866 kWh of energy annually. Although this value less compared to developed countries, it is much more compared to previous year values in India and it is increasing much rapidly.

Another Energy efficiency indicator, i.e., economic-thermodynamic indicators, popularly called EI (Energy Intensity) is also estimated in this study. The annual income of the family in residential buildings is noted down while collecting the energy data. The SEC is calculated using energy consumed per lakh of annual income in case of residential buildings. EI (Energy Intensity) is calculated by using energy data which were collected during the survey, as follows:
Energy Intensity (EI) = 637.0847 kWh per lakh rupee of annual income.

3.3. Environmental impact in residential sector
The residential sector includes the wide variety of buildings and a wide range of energy consuming devices. The heft of ozone-depleting substance emanations caused by these structures is from vitality use for warming, cooling, and lighting, with the extra utilization of household high temp water, refrigeration, electronic gear, and different activities. CO₂ is the major gas in the category of greenhouse gases because it produces 60% of the human-enhanced greenhouse effect that leads to global warming. The emission of CO₂ is to be calculated for different energy consuming devices in different residential sector buildings.
Figure 4. Annual CO₂ emission by the type of energy carrier

To calculate CO₂ emission for various energy consuming devices, the corresponding emission factor is required. The emission factor for electricity is 0.82 kg CO₂/kWh (CEA, 2009). It is observed that, major contributor for CO₂ emission in the residential sector is refrigerator. The refrigerator is used round the clock in residential sector. This causes more CO₂ emission. This is followed by the tube lights, TV, fans, AC, etc. In the residential sector, the CO₂ emission caused by other energy carrier is LPG. The electricity causes about 76% of total annual CO₂ emission in the residential sector whereas LPG has a share of 24%, as shown in Figure 3. Although LPG has a large share in total annual energy consumption (54%) compared to electricity (46%), the annual CO₂ emission of LPG is less (24%) compared to electricity (76%).

As per the World Bank, the energy consumption in India is 0.606 toe/capita. The same is correlated with the data obtained from the survey in Davangere city, as shown in figure 5. Also the CO₂ emission is calculated for both the results. It is found that, around 12.8% of energy is consumed by Davangere city alone in India per annum, whereas CO₂ emission stands around 33% of the country annually.

3.4. Energy saving options
Decreased aggregate discharges of carbon dioxide, different gases and forerunners to nearby contamination are measures of natural advance. The majority of ozone harming substance outflows caused by structures is from vitality use for warming, cooling, and lighting, with extra use for boiling water, refrigeration, cooking, electronic hardware, and different tasks. An assortment of energy
sparking choices is accessible for the residential sector. Table 2 shows some of the strategies to save the energy consumption in residential sectors.

Table 2: Annual savings by alternative energy efficient equipments

| Appliances                        | Annual electricity consumption (kWh) | Annual CO₂ emission (kg) | Annual cost savings (Rs.) |
|-----------------------------------|--------------------------------------|--------------------------|---------------------------|
| Incandescent Lamp (ICL)           | 292                                  | 239.44                   | 2044                      |
| Compact Fluorescent Lamp (CFL)    | 58.4                                 | 47.88                    | 408.8                     |
| **Savings**                       | **233.6**                            | **191.56**               | **1635.2**                |

**Annual saving by replacing a Desktop with Laptop**

| Appliances                          | Annual electricity consumption (kWh) | Annual CO₂ emission (kg) | Annual cost savings (Rs.) |
|-------------------------------------|--------------------------------------|--------------------------|---------------------------|
| Desktop with CRT screen             | 584                                  | 478.88                   | 4088                      |
| Laptop                              | 87.6                                 | 71.83                    | 613.2                     |
| **Savings**                         | **496.4**                            | **407.05**               | **3474.8**                |

**Annual saving by replacing a Regular fan with a 5 star rated fan**

| Appliance                           | Annual electricity consumption (kWh) | Annual CO₂ emission (kg) | Annual cost savings (Rs.) |
|-------------------------------------|--------------------------------------|--------------------------|---------------------------|
| Regular fan                         | 237.25                               | 194.55                   | 1660.75                   |
| BEE 5 star rated fan                | 183.59                               | 150.54                   | 1285.13                   |
| **Savings**                         | **53.65**                            | **44.01**                | **375.62**                |

**Annual saving by replacing a 2 star rated AC with a 5 star rated AC**

| Appliance                           | Annual electricity consumption (kWh) | Annual CO₂ emission (kg) | Annual cost savings (Rs.) |
|-------------------------------------|--------------------------------------|--------------------------|---------------------------|
| 1.5 ton split AC, 2 star            | 5752.4                               | 4716.97                  | 40266.8                   |
| 1.5 ton split AC, 5 star            | 4818                                 | 3950.76                  | 33726                     |
| **Savings**                         | **934.4**                            | **766.21**               | **6540.8**                |

**Annual saving by replacing an electric water heater with solar water heater**

| Appliance                           | Annual electricity consumption (kWh) | Annual CO₂ emission (kg) | Annual cost savings (Rs.) |
|-------------------------------------|--------------------------------------|--------------------------|---------------------------|
| Electric Water Heater               | 273.75                               | 224.475                  | 1505.63                   |
| Solar Water Heater                  | 0                                    | 0                        | 0                         |
| **Savings**                         | **273.75**                           | **224.475**              | **1505.63**               |

3.5. Factors influencing specific energy consumption

A Total of twenty four variables are selected from the questionnaire in order to find the main factors which influence the Specific Energy Consumption (SEC). After completing the empirical study, a reliability test is run on the obtained data using SPSS (Statistical Package for Social Science) software version 20. The reliability of a measure indicates the stability and consistency with which the instrument measures the concept and helps to assess the ‘goodness’ of a measure. One of the most commonly used reliability coefficient is ‘Cronbach’s Alpha’. Alpha is based on the internal consistency of a test. The test conducted for the data in this study produced a Cronbach’s alpha value of 0.843 with a sample size of 50, a Cronbach’s alpha value of 0.843 is considered satisfactory. Kaiser-Meyer-Olkin (KMO) & Bartlett’s Test of Sphericity is a measure of sampling adequacy that is recommended to check the case to variable ratio for the analysis being conducted. The estimation of the KMO of Sampling Adequacy for the arrangement of factors is 0.634, which would be named as unremarkable, which is agreeable. Bartlett's trial of sphericity tests the speculation that the connection framework is a character grid; i.e. every slanting component are 1 and all off-diagonal components are 0, inferring that the majority of the factors are uncorrelated. On the off chance that the noteworthiness
esteem for this test is not as much as the alpha level, at that point dismiss the invalid theory that the populace lattice is a character network. In this test, the significance value is 0.00; therefore this analysis meets the requirement.

Table 3: Total Variance Explained for SEC

| Component | Extraction Sums of Squared Loadings | Rotation Sums of Squared Loadings |
|-----------|------------------------------------|----------------------------------|
|           | Eigen value | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1         | 5.835       | 24.314        | 24.314       | 4.074 | 16.974        | 16.974       |
| 2         | 4.371       | 18.214        | 42.528       | 3.443 | 14.347        | 31.322       |
| 3         | 2.651       | 11.047        | 53.574       | 3.347 | 13.947        | 45.269       |
| 4         | 1.821       | 7.588         | 61.163       | 2.715 | 11.313        | 56.582       |
| 5         | 1.491       | 6.214         | 67.377       | 2.320 | 9.668         | 66.250       |
| 6         | 1.126       | 4.694         | 72.070       | 1.397 | 5.820         | 72.070       |

Factor analysis is used for data reduction and to identify a small number of factors that explain most of the variance that is observed in a much larger number of manifest variables. Principal Component Analysis (PCA) method is used for extracting factors as it is most appropriate when the correlation matrix is singular. The solution is then rotated for ease of interpretation using varimax rotation. As Eigen values greater than one are only considered, a total of six components from the extracted solution meet this criterion. Six extracted components explain about 72% of the variability in original 24 variables incorporated in the study, as shown in Table 3. Table 3 shows that almost 72% of the total variance is attributable to the first six factors. Hence, the complexity of the data got reduced considerably by the use of these six components with only 28% loss of information. Thus, a model with six factors is adequate to represent the data.

Figure 6. Scree plot for the variables

The Scree plot shown in Figure 6 helps in determining the optimal number of components. It is a plot of the total variance associated with each factor. Typically, the plot shows a distinct break between the steep slope of the large factor and the gradual trailing off of the rest of the factors. For the most part, the segments are extricated on the lofty slant. The parts on the shallow soak contribute little to the arrangement. The last enormous drop happened between the sixth and seventh segments. Thus, the initial six segments are considered.

Under each of the derived components, all variables with correlation coefficients greater than 0.45 (as obtained by the rotated component matrix) are considered significant as shown in Table 4.
Remembering these factors the elements are fittingly named in this table. In this manner, these elements have been positioned in view of the normal factor scores.

Based on the rankings obtained, it may be observed that the ‘Subsidy factor’ is the most important factor and the ‘Economic factor’ is the least important one in influencing household’s adoption of energy efficiency. This study is conducted for almost all middle class families of the residential sector. The people in this group think that subsidy by the government should be provided and are important for energy efficiency. The second most important factor is ‘Attitudinal factor’. The people are concerned about the environment and they are willing to adopt and willing to invest in energy efficient technologies, but they think that government should provide subsidies for these technologies. Those who are actually not investing in these technologies are not having awareness about general environmental issues. They think that the maintenance cost energy efficient technologies is more. Hence, they are not comfortable with these technologies. Therefore, less number of energy efficient technologies in households is observed.

The factors discussed in table 4 are considered as non-technical factors, these factors are obtained by the perception based measurements, through personal interviews during the survey. Along with these factors, technical factors which are considered in the questionnaire are also included in multiple regression analysis in order to analyse the factors influencing energy efficiency. Thus, total ten variables are considered in multiple regression analysis, including six non-technical factors obtained by factor analysis and four technical factors. These four factors are the number of energy star products, number of CFLs used, the ratio of CFLs to ICLs used and the ratio of CFLs to tube lights used. This information is directly obtained in the questionnaire and is converted to five to one scale (Likert scale).

| Component | Variables                        | Correlations (Factor loadings) | Mean variable score | Average variable score | Factor name          | Rank |
|-----------|----------------------------------|--------------------------------|---------------------|------------------------|----------------------|------|
| 1         | Savings                          | 0.905                          | 2.46                |                        | Economic factor      | VI   |
|           | Income                           | 0.868                          | 2.50                |                        |                      |      |
|           | Area of house                    | 0.817                          | 1.84                |                        |                      |      |
|           | Education                        | 0.722                          | 3.16                |                        |                      |      |
|           | Expenditure                      | 0.690                          | 2.08                |                        |                      |      |
|           | Ownership                        | 0.541                          | 4.22                | 2.71                   | Govt. policy factor  | IV   |
| 2         | Govt. effort                     | 0.882                          | 3.80                |                        |                      |      |
|           | Govt. incentive                  | 0.858                          | 3.64                |                        |                      |      |
|           | Risk coverage                    | 0.822                          | 3.40                |                        |                      |      |
|           | Regulations                      | 0.808                          | 3.52                |                        |                      |      |
| 3         | Attitude towards change          | 0.830                          | 4.12                |                        |                      |      |
|           | Concern for environment          | 0.716                          | 4.26                |                        |                      |      |
|           | Willingness to adopt            | 0.680                          | 4.74                |                        |                      |      |
|           | willingness to invest            | 0.649                          | 3.32                |                        |                      |      |
|           | Initial investment               | 0.644                          | 2.88                | 3.864                  | Attitudinal factor   | II   |
| 4         | No. of energy efficient          | 0.834                          | 2.94                |                        | Technology factor    | V    |
|           | technologies                    |                                |                      |                        |                      |      |
|           | Degree of satisfaction           | 0.713                          | 3.64                |                        |                      |      |
|           | Maintenance cost                | 0.570                          | 3.70                |                        |                      |      |
|           | Importance of technology        | 0.471                          | 2.54                |                        |                      |      |
| 5         | Ego factor                       | 0.857                          | 3.56                |                        |                      |      |
|           | Liking towards technology       | 0.702                          | 3.70                |                        |                      |      |
|           | Awareness                       | 0.595                          | 3.64                |                        |                      |      |
|           | Adequacy of information         | 0.574                          | 3.76                | 3.665                  | Personal factor      | III  |
| 6         | Govt. subsidies                 | 0.730                          | 4.26                | 4.26                   | Subsidy factor       | I    |
The factor scores obtained in principal component analysis are used in multiple regressions, with the SEC (kWh/sq. ft.) in the households as the dependent variable. Ordinary Least Squares (OLS) relapse investigation was done to survey the nature and greatness of the connection between the SEC and the ten factors. In general, the OLS strategy performed great. The typicality and homoskedasticity presumptions were not damaged. Multicollinearity between the logical factors was not an issue, recommending that every one of the free factors is a one of a kind measurement of the SEC level. The conditions were fitted utilizing the forward choice technique of the SPSS software. An important part of any statistical procedure that builds models from data is establishing how well the model actually fits. A commonly used measure of the goodness of fit is $R^2$. If all the observations fall on the regression line, $R^2$ is 1. If there is no linear relationship between dependent and independent variables, $R^2$ is 0. In the current study, the Adjusted $R^2$ of 0.857 and significance F change at 0.000 was obtained, thereby establishing the usefulness of the model. It has a reasonably good explanatory power with adjusted $R^2$ being 0.857. R (Multiple correlation coefficients) value of 0.942 indicated a strong relationship between the dependent variable and the considered independent variables.

The standardized beta coefficients for all the factors are obtained from the Collinearity statistics table. It is found that Attitudinal factor (ATTDFACT) and number of energy star products (NOFSTRPROD) are found less significant, i.e., greater than 0.10. This value should be less than 0.10 for significant result. Therefore, ATTDFACT and NOFSTRPROD are eliminated and again regression analysis is carried out for remaining eight factors. By doing this the adjusted $R^2$ value has increased to 0.858 and all the factors resulted significant as the significance values are within the limit, as shown in table 5.

By using the beta coefficients the regression equation is formed. Higher the beta coefficient, the larger is the extent that factor influences the energy efficiency (dependent variable).

| Table 5: Collinearity Statistics for SEC |
|-----------------------------------------|
| Model                     | Unstandardized Coefficients | Standardized Coefficients | t    | Sig. |
| (Constant)                | 0.608                        | 0.218                      | 2.785 | 0.008 |
| ECONFACT                  | -0.582                       | 0.046                      | -12.753 | 0.000 |
| GOVTPOLFACT               | 0.122                        | 0.043                      | 2.866 | 0.007 |
| TECHFACT                  | -0.184                       | 0.047                      | -3.937 | 0.000 |
| PERSNFACT                 | 0.094                        | 0.044                      | 2.138 | 0.039 |
| SUBDYFACT                 | -0.119                       | 0.047                      | -2.511 | 0.016 |
| NOOFCFL                   | -0.193                       | 0.042                      | -4.581 | 0.000 |
| RATIOCFLICL               | 0.354                        | 0.046                      | 7.720 | 0.000 |
| RATIOCFLTUB               | 0.155                        | 0.036                      | 4.280 | 0.000 |

Dependent Variable: SEC

The resulting regression equation obtained is,

$$Y = b_0 + b_1F_1 + b_2F_2 + b_3F_3 + \ldots + b_nF_n$$

(1)

Where:

- $Y$ = Energy Efficiency (SEC) or Total Energy Consumption (Depending on the analysis required)
- $b_0$ = Constant
- $b_1, b_2, b_3, \ldots, b_n$ = Coefficients of the independent variables
- $F_1, F_2, F_3, F_4, \ldots, F_n$ = Factor Scores

$$SEC = 0.608 - 0.752 \times F_1 + 0.158 \times F_2 - 0.238 \times F_4 + 0.121 \times F_5 - 0.153 \times F_6 - 0.284 \times F_8 + 0.440 \times F_9 + 0.272 \times F_{10}$$

(2)

Where $Y$ is the energy efficiency (SEC) in the households and $F_1$ to $F_{10}$ are the factor scores. The ranking of factors based upon the beta values is shown in Table 6.
Table 6: Ranking of Factors based on Beta values for SEC

| Factor                              | Beta value | Ranking |
|-------------------------------------|------------|---------|
| Economic factor                     | -0.752     | I       |
| Ratio of CFLs to ICLs used          | 0.440      | II      |
| No. of CFLs used                    | -0.284     | III     |
| Ratio of CFLs to Tube light         | 0.272      | IV      |
| Technical factor                    | -0.238     | V       |
| Government Policy factor            | 0.158      | VI      |
| Subsidy factor                      | -0.153     | VII     |
| Personal factor                     | 0.121      | VIII    |

From this table it is clear that in every household the ‘economic factor’ is the most important criterion for energy efficiency. Income, education, ownership, etc., are important variables of the economic factor. As the education level and level of income is improving, people are likely to invest in energy efficient technologies resulting in improved energy efficiency (reduced SEC). Ownership of building is also an important criterion. Theoretically, if the respondent has his own house, he is likely to save energy and he will be focussing on increasing energy efficiency. On the other hand, if the respondent is living in a rented house, he will not think much about the energy efficiency. On the whole, people think about the economic factors, primarily before adopting energy efficient technologies. Also, ‘ratio of CFLs to ICLs used’ and ‘number of CFLs used’ are important factors as they are technical factors and are directly proportional to the energy efficiency. Interestingly, ‘subsidy factor’ is placed at the second from the bottom in this regression analysis. The people think least about the government subsidy, contrary to the result obtained in the factor analysis. The least significant factor is ‘personal factor’. Awareness, adequacy of information, etc., are the main variables of the personal factor. Though people have less awareness about the energy efficient technologies and about general environmental issues with non-adequate information provided by the firms, their impact is not appreciable as per this analysis.

3.6. Factors influencing total energy consumption

Total ten variables are selected from the questionnaire in order to find the main factors which influence the Total Energy Consumption (TEC). After completing the empirical study, a reliability test is conducted for the obtained data using SPSS software. The Cronbach’s alpha value obtained is 0.667. The obtained Cronbach’s alpha value is greater than 0.60 and hence is considered to be satisfactory. The value of the KMO of Sampling Adequacy for the set of variables is 0.577, which would be labelled as mediocre, which is satisfactory. In case of Bartlett’s test of sphericity tests, the significance value is 0.00; therefore this analysis meets the requirement. The factor analysis is not necessary in this case, because the numbers of factors considered are manageable. Therefore, multiple regression analysis can be carried out directly. Result showed an Adjusted R² of 0.943 and significance F change at 0.000 indicating the usefulness of the model. It has a good explanatory power with adjusted R² at 0.943. R (Multiple correlation coefficients) value of 0.977 indicated a strong relationship between the dependent variable and the considered factors. The dependent variable is TEC.

The standardized beta coefficients for all the factors are obtained from the Collinearity statistics table. It is found that the only Cost of energy consumed (COSTOFENE), Family size (FAMILYSIZE), Number of energy efficient technologies owned (ENEEFFTECH) and Area of the building (AREA) are significant. Out of ten variables, only these four variables are within the limit of significant values. This value should be less than 0.10 for significant result. Therefore, for only four variables again regression analysis is carried out. With this, the adjusted R² value has increased to 0.945. Again, only three factors are significant (Table 7). The remaining ENEEFFTECH factor is not considered in the regression equation because it is not significant. By using the beta coefficients the regression equation...
is formed. Higher the beta coefficient, to a large extent that factor influences the total energy consumption.

**Table 7: Collinearity Statistics for TEC**

| Model          | Unstandardized Coefficients | Standardized Coefficients | t      | Sig.  |
|----------------|----------------------------|---------------------------|--------|-------|
| (Constant)     | 739.361                    | 140.377                   | 5.267  | 0.000 |
| ENEEFTTECH     | -9.611                     | 29.544                    | -0.011 | -0.325| 0.746 |
| FAMILYSIZE     | 90.279                     | 37.508                    | 0.091  | 2.407 | 0.020 |
| AREA           | 58.905                     | 35.284                    | 0.061  | 1.669 | 0.102 |
| COSTOFENE      | 812.119                    | 34.548                    | 0.915  | 23.507| 0.000 |

Dependent Variable: TEC

The resulting regression equation is,

\[ TEC = 739.361 + 0.091 \times F_6 + 0.061 \times F_7 + 0.915 \times F_9 \]  

(3)

**Table 8: Ranking of Factors based on Beta values for TEC**

| Factor                  | Beta value | Ranking |
|-------------------------|------------|---------|
| Cost of energy consumed | 0.915      | I       |
| Family size             | 0.091      | II      |
| Area of the building    | 0.061      | III     |

From table 8 it is clear that in every household the ‘cost of energy consumed’ is the important criterion for total energy consumption. This factor is directly proportional to the TEC. As the cost of energy increases, automatically TEC also increases and vice versa. The second most important factor is the ‘family size’. It is a hypothesis that, as the family size increases TEC increases. In other words, it can be said that as the number of persons increase in a household, they are likely to consume more energy and hence the increase in the TEC. Area of the building is the least important factor which reflects a weak influence on TEC.

4. Conclusion

The study of energy consumption pattern revealed that electricity and LPG are the main energy carriers used in the residential sector. The energy efficiency level is also studied in terms of Specific Energy Consumption (SEC) and Energy Intensity (EI). The various factors which influence the energy efficiency in residential sector was analysed using multiple regression analysis. Both technical and non-technical factors are considered in regression analysis. The beta coefficient of factors revealed that Economic factor and No. of energy star products are the most influencing factors of energy efficiency in this sector.

In view of the present study, it may be concluded that there is substantial scope for energy efficiency improvements in residential sector. High levels of awareness about energy effective technologies are to be generated and economic & financial benefits are required to be supported for energy efficiency improvement and reduction in the environmental impact. Improvement in energy efficiency initiative can go a long way in the sustainable development of this sector of the economy.

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