A Comparative Study of Energy Consumption Pattern and Environmental Impact in Residential Sector of Indian Cities

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Abstract. India is a home to 18% of total world’s population, utilizes only 6% of the world’s essential primary energy. India’s energy utilization has multiplied since 2000 and the possible for further rapid growth is massive. Urbanization is taking place at a faster rate in India. Understanding the relationships between carbon emission growth and energy utilization is vital for establishing upcoming scenarios and can make possible improvement and adaptation to environmental change. This paper investigates the range of socioeconomic aspects that influence energy utilization pattern and CO2 emission in the residential sector of two South Indian cities. Also, factors have been analysed by Principal Component Analysis (PCA) to find factors affecting energy efficiency.

1. Introduction
Globally, India positions fourth in energy utilization, however, it isn’t plentifully supplied with energy resources. Being the second most heavily populated countries in the world, how India deals with its industrialization and urbanization processes will matter for national and worldwide worries about energy efficiency, pollution and environmental change. India, the second most densely inhabited nation in the world, with 1.32 billion people; India is anticipated to be the globe’s most populous country by 2022, surpassing China. Urbanization is rising at a faster rate in India. According to the 1901 census, population residing in urban areas in India was 11.4%, this number has increased to 28.53%, according to the 2001 census, and crossing the 30% as per 2011 census. India has been responsible for right around 10% of the rise in global energy demand since 2000. Its energy demand in this period has multiplied, pushing the nation’s share in worldwide demand up to 5.7% in 2013 from 4.4% towards starting of the century. Residential electricity utilization (for those with access) stays far below the world average and is 10 times lower than OECD levels. India is contributing more than the other nation to the anticipated rise in worldwide energy requirement, energy demand per capita still in 2040 is 40% below the global average. An extra 315 million people, roughly the population of the United States (US) at present, are likely to live in India’s cities by 2040. The demand for residential sector for energy in the non-OECD countries has gone up by an average of 2.1% per year. In India, there is an average annual increase of 3.2% from 2012 to 2040. India and China represents 27% of the globe’s residential energy utilization in 2040, up from 19% in 2012. The energy utilization in the residential sector is an important area for campaigns to conserve energy. Energy saving in the home creates benefits for the household in the form of lower energy bills and for the community at large in the form of lower imports. Households are the main target group as they are key contributors to the
emission of greenhouse gases (GHG) and, to global warming. Non-OECD countries account for 59% of the rise in world’s CO₂ emissions from 2012 to 2040. CO₂ emissions in India is raised by 2.7% per year, accounting for 30% of the total non-OECD Asia increase in CO₂ emissions.

Karnataka is the eighth largest state by population. According to the 2011 census of India, the population density was 319 per km² and 38.67% of the people lived in urban areas. The level of urbanization in Karnataka increased by 4.58 per cent, from 33.99% in the 2001 Census to 38.57% in 2011. Energy consumption increases with urbanization. Urbanization is one of the main demographic and economic trends occurring in developing nations, with essential outcomes for development, energy use, and prosperity. Household buildings, energy saving have been a subject of interest within social and environmental psychology research for a number of decades. Residential sector constitute an important target group since they are also one of the key contributors to the release of greenhouse gases and hence global warming. At present, the share electricity consumption by residential sector in India is around 20-30%. Many researches were done in case of residential sectors, but there is ample scope for energy saving in with the use of modern energy efficient equipment’s. In this back drop and with the growing share of India in global energy use and CO₂ emissions, analysis of energy consumption in the residential sector assumes significance. This study aims comparative study of energy consumption pattern, factors influencing the energy efficiency and environmental impact of energy usage in two major cities of Karnataka. The different types of factors which influence the energy efficiency and also the energy consumption are examined using the SPSS (Statistical Package for Social Science). The energy-intensive cluster chosen for the study is different localities of residential sector buildings within the corporation limits of Davangere and Hubballi city, Karnataka.

2. 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 preparation of questionnaire for the study. The primary data required for the study are gathered through canvassing a structured questionnaire, administered personally. Basically, a survey must serve two functions: it should translate research objectives into particular questions the respondent can answer, and it should encourage the respondent to help with the survey and to provide the information correctly. 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 and Hubballi city, Karnataka, India. Since it is impossible to study an entire population, simple random sampling method is selected out of various sampling techniques to collect socioeconomic and energy data. 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.), CO₂ 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
Urban communities offer most important way to shrink energy requirement and to moderate the impact of worldwide environment change, similarly as they force the wealth of their countries. Data from various reports and studies can at times be unsuited for the reason that unlike definitions of a city are employed. To overcome this difficulty, the paper uses the description of a city based on local
organizational definitions. The overview of two South Indian cities, Davangere and Hubballi are shown in table 1.

| City    | Davangere | Hubballi |
|---------|-----------|----------|
| Land Area (sq.km) | 77        | 406.59   |
| Population (2011)  | 435,128   | 1,349,563|
| Population density (people/sq.km) | 5700    | 4500    |

3.1 Comparison of energy consumption pattern and emission

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 355 households, almost all from the middle income group at different locations in Davangere and Hubballi city. Further, various energy consuming devices and their estimated daily usage were also noted down. Generally in residential sector buildings, electricity and LPG (Liquid Petroleum Gas) 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 Kg’s and is then converted to kWh. The number of persons in each home or family size is noted down during the survey.

From figure 1 it can be seen that, in Hubballi total energy consumption is around 585 MWh, out of which 55% of energy is shared by LPG and 45% is by electricity. Total energy consumption in Davangere residential sector is around 225MWh. About 56% of energy is shared by LPG and remaining 44% is shared by electricity. In both cities the share of the LPG is more 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. Also, the total energy consumption is more in Hubballi compared to Davangere is because of mainly population. Total energy consumption in Hubballi is almost double compared to Davangere city. But, the population in Hubballi is nearly three times more than the Davangere city (table 1). Because of the population density in Davangere is more compared to Hubballi city, the energy consumption in Davangere is more.

The residential sector includes the wide variety of buildings and a large range of energy consuming devices. The greenhouse gas emissions caused by buildings is from energy use for heating, cooling, and lighting, with additional use of domestic hot water, refrigeration, electronic equipment, and other operations. CO\(_2\) 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 CO\(_2\) is to be calculated for different energy consuming devices in different residential sector buildings. It is observed that, major contributor for CO\(_2\) emission in the residential sector is refrigerator. The

![Figure 1 Energy consumption pattern in two cities](image-url)
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 Hubballi residential sector whereas LPG has a share of 24%, as shown in figure 2. Whereas in Davangere, electricity causes around 75% of total annual CO₂ emission and LPG has a share of 25%.

![Figure 2: Annual CO₂ emission in two cities](image)

![Figure 3: Comparison of energy consumption and CO₂ emission](image)

Urban communities and urban activities are generally responsible for worldwide increment in greenhouse gases emissions, but study displays that the emissions from urban areas are further related to utilization patterns and income per capita to a certain extent than the urbanisation levels. While comparing cities energy utilization and carbon emissions, it is critical to examine the complexities involved, not only the size of an economy and residential consumption pattern. In this study the emission performance of urban areas are calculated in terms of CO₂ emissions per capita. Emissions per capita are a superior indicator than emissions alone because it internalises some of the equity debates (Dhakal 2008). A comparison of energy and associated CO₂ emissions from Davangere and Hubballi is shown in figure 3. Also figures show the Indian energy consumption and CO₂ emission.

### 3.2 Factors influencing Specific Energy Consumption

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. One of the most commonly used reliability coefficient is ‘Cronbach’s Alpha’. The test conducted for the data in this study produced a Cronbach’s alpha value of 0.813 with a sample size of 179 in Davangere, whereas Cronbach’s alpha value is 0.712 in Hubballi with sample size of 176. A Cronbach’s alpha value of greater than 0.6 is considered satisfactory. Kaiser-Meyer-Olkin (KMO) & Bartlett’s Test of Sphericity is a measure of inspecting sufficiency that is prescribed to check the case to variable proportion for the examination being directed. The value of the KMO of Sampling Adequacy for the set of variables is 0.694 in Davangere and 0.612 in Hubballi, which would be labelled as mediocre, which is satisfactory. Bartlett's test of sphericity tests the theory; i.e. every single corner to corner component is 1 and all off-slanting components are 0, inferring that the greater part of the factors is uncorrelated. If the significance value for this test is less than the alpha level, then reject
the null hypothesis that the population matrix is an identity matrix. In this test, the significance value is 0.00 in both cases; therefore this analysis meets the requirement.

Factor analysis is used for data reduction and to recognize a small number of factors that explain most of the variance that is observed in a much larger number of visible 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. The values of the extraction communalities which indicate the amount of variance in each variable that is accounted for by the components were found to be satisfactory as they range from 0.6 to 0.9. It reveals that the extracted components represent the variables well. As Eigen values greater than one are only considered, a total of six components from the extracted solution meet this criterion in case of Davangere city, whereas five components in case of Hubballi. The extracted six components explained about 72% of the variability in the original twenty four variables included in the study for Davangere, and almost 72.82% of the total variance is attributable to the first five factors for Hubballi as shown in Table 2.

Table 2 Total variance explained for SEC in both cities

| Case: Davangere city | 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       |

| Case: Hubballi city | Component | Extraction Sums of Squared Loadings | Rotation Sums of Squared Loadings |
|---------------------|-----------|-------------------------------------|----------------------------------|
|                      | Eigen value | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1                    | 6.910      | 36.370      | 36.370       | 6.415 | 33.762       | 33.762       |
| 2                    | 3.044      | 16.022      | 52.392       | 2.108 | 11.096       | 44.857       |
| 3                    | 1.641      | 8.637       | 61.029       | 2.087 | 10.985       | 55.842       |
| 4                    | 1.170      | 6.157       | 67.186       | 1.937 | 10.195       | 66.037       |
| 5                    | 1.071      | 5.634       | 72.821       | 1.289 | 6.784        | 72.821       |

Table 2 shows that around 72% of the total variance is attributable to the first six factors in Davangere city and 72.8% of the total variance is attributable to the first five factors in Hubballi city. Hence, the complexity of the data got reduced considerably by the use of these six and five components with only 28% and 27.2% loss of information respectively in both cities. Thus, models with six and five factors are adequate to represent the data.

Figure 4 Scree plot for variables in Residential sector
The Scree plot shown in figure 4 helps in determining the optimal number of components. Generally, the components are extracted on the steep slope. The components on the shallow steep contribute little to the solution. The last big drop occurred between the 6th and 7th components. Hence, the first six components are retained in case of Davangere city (figure 4-a). Whereas, in case of Hubballi city first five components are retained (figure 4-b).

Under each of the derived component, all variables with correlation coefficients greater than 0.45 (as obtained by the rotated component matrix) are considered significant as shown in Table 3 and 4. Keeping these variables in mind the factors are appropriately named in this table. Subsequently, these factors have been ranked based upon the average factor scores.

| Component | Variables | Correlations (Factor loadings) | Mean variable score | Average variable score | Factor name | Rank |
|-----------|-----------|--------------------------------|---------------------|------------------------|-------------|------|
| 1 | i) Savings | 0.905 | 2.46 | | | | |
| | ii) Income | 0.868 | 2.50 | | | | |
| | iii) Area of house | 0.817 | 1.84 | | | | |
| | iv) Education | 0.722 | 3.16 | | | | |
| | v) Expenditure | 0.690 | 2.08 | | | | |
| | vi) Ownership | 0.541 | 4.22 | | | | |
| 2 | i) Govt. effort | 0.882 | 3.80 | | | | |
| | ii) Govt. incentive | 0.858 | 3.64 | | | | |
| | iii) Risk coverage | 0.822 | 3.40 | | | | |
| | iv) Regulations | 0.808 | 3.52 | | | | |
| 3 | i) Attitude towards change | 0.830 | 4.12 | | | | |
| | ii) Concern for environment | 0.716 | 4.26 | | | | |
| | iii) Willingness to adopt | 0.680 | 4.74 | | | | |
| | iv) Willingness to invest | 0.649 | 3.32 | | | | |
| | v) Initial investment | 0.644 | 2.88 | | | | |
| 4 | i) No. of energy efficient technologies | 0.834 | 2.94 | | | | |
| | ii) Degree of satisfaction | 0.713 | 3.64 | | | | |
| | iii) Maintenance cost | 0.570 | 3.70 | | | | |
| | iv) Importance of technology | 0.471 | 2.54 | | | | |
| 5 | i) Ego factor | 0.857 | 3.56 | | | | |
| | ii) Liking towards technology | 0.702 | 3.70 | | | | |
| | iii) Awareness | 0.595 | 3.64 | | | | |
| | iv) Adequacy of information | 0.574 | 3.76 | | | | |
| 6 | Govt. subsidies | 0.730 | 4.26 | | | | |

Table 3 Correlations, Factor names and Rankings for Residential Sector in Davangere city
Table 4. Correlations, Factor names and Rankings for Residential sector in Hubballi city

| Component | Variables | Correlations (Factor loadings) | Mean variable score | Average variable score | Factor name | Rank |
|-----------|-----------|--------------------------------|---------------------|------------------------|-------------|------|
| 1         | i) area of house | 0.665 | 3.08 | | | |
| 1         | ii) concern for environment | 0.880 | 2.84 | | | |
| 1         | iii) attitude toward change | 0.907 | 2.86 | | | |
| 1         | iv) ego, prestige, status | 0.685 | 2.90 | | | |
| 1         | v) willingness to adopt | 0.916 | 3.31 | 3.038 | Personal factor | IV |
| 1         | vi) maintenance cost | 0.694 | 3.11 | | | |
| 1         | vii) liking towards technology | 0.758 | 2.76 | | | |
| 1         | viii) govt. subsidy | 0.755 | 3.02 | | | |
| 1         | ix) importance of technology | 0.756 | 3.46 | | | |
| 2         | i) regulations | 0.840 | 3.80 | 3.78 | Govt. Policy factor | I |
| 2         | ii) risk coverage | 0.822 | 3.76 | | | |
| 3         | i) govt. incentives | 0.921 | 3.52 | | | |
| 3         | ii) govt. efforts | 0.646 | 3.84 | | | |
| 3         | iii) awareness about general environmental issues | 0.570 | 2.81 | 3.39 | Subsidy factor | II |
| 4         | i) initial investment | 0.571 | 3.28 | | | |
| 4         | ii) degree of satisfaction | 0.676 | 3.02 | | | |
| 4         | iii) no. of energy efficient technology owned | 0.807 | 2.92 | 3.11 | Technology factor | III |
| 4         | iv) adequacy of information | 0.507 | 3.22 | | | |
| 5         | Willingness to invest | 0.794 | 2.9 | 2.9 | Economic factor | V |

This study is conducted for almost all middle class families of residential sector. 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 in Davangere city. Based on the rankings obtained in case of Hubballi city, it may be observed that the ‘Government policy factor’ is the most important factor and the ‘Economic factor’ is the least important one. The people are concerned about 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.

4. Conclusion
Based on the present study it may be concluded that there is significant scope for energy efficiency improvements in residential sector. From the outcome of study it can be seen that people are more oriented towards Government policies, subsidies provided, attitude and awareness towards energy efficient technologies. With the creation of high levels of awareness about energy efficient technologies, economic & financial benefits are also 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 the sector of our economy.
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