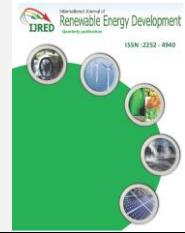




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Economic Impact of CDM Implementation through Alternate Energy Resource Substitution

K.J. Sreekanth*, S. Jayaraj, and N. Sudarsan

Department of Mechanical Engineering, National Institute of Technology, Kozhikode, Kerala- 673601, INDIA

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ABSTRACT: Since the Kyoto protocol agreement, Clean Development Mechanism (CDM) has garnered large emphasis in terms of certified emission reductions (CER) not only amidst the global carbon market but also in India. This paper attempts to assess the impact of CDM towards sustainable development particularly in rural domestic utility sector that mainly includes lighting and cooking applications, with electricity as the source of energy. A detailed survey has undertaken in the state of Kerala, in southern part of India to study the rural domestic energy consumption pattern. The data collected was analyzed that throws insight into the interrelationships of the various parameters that influence domestic utility sector pertaining to energy consumption by using electricity as the source of energy. The interrelationships between the different parameters were modeled that optimizes the contribution of electricity on domestic utility sector. The results were used to estimate the feasible extent of CO₂ emission reduction through use of electricity as the energy resources, vis-à-vis its economic viability through cost effectiveness. The analysis also provides a platform for implementing CDM projects in the sector and related prospects with respects to the Indian scenario.

Keywords: clean development mechanism, indian scenario, domestic energy consumption

1. Introduction

One of the important responses of Kyoto Protocol towards mitigation of global warming is Clean Development Mechanism (CDM) that has garnered large emphasis amidst the global carbon market in terms of Certified Emission Reductions (CER). While CDM aims to achieve sustainable development in energy production and consumption in developing countries, the results achieved through its implementation are still uncertain. More than four hundred studies have been undertaken since 1997 with respect to CDM. However, the contribution of these studies towards effective implementation of CDM at regional level and thereby reap the benefits of sustainable development has been ill addressed.

India as a rapidly developing nation has an enormous potential to benefit from CDM. The projects pertaining to CDM implementation, is expected to encourage private investments owing to the high rate of financial

returns. Indian economic growth at the present rate points to a huge increase in energy usage in both industrial and domestic sectors. However, studies and modeling in designing policies to address the related issues needs to be undertaken rigorously. In this study, it is attempted to assess the potential to improvise rural domestic energy efficiency, especially in the lighting sector and investigate measures that can be framed as projects under the CDM. India, a developing nation has long depended on traditional energy resources such as firewood, agricultural waste, animal dung and human power which are still continuing to meet the bulk of energy requirements, particularly in rural India. Presently, these traditional fuels are gradually getting replaced by commercial fuels such as coal, petroleum, natural gas and electricity (Tiwari 2000). With the recognition of fossil fuels being the major cause of climatic change and air pollution, the focus of energy planners has shifted towards renewable resources and energy conservation (Ramachandra 2009).

* Corresponding author:
Email: sreekanthkj@gmail.com

This paper attempts to present the details of the investigation and analysis undertaken in this study with Section 1 highlighting the need of the study as Introduction. Section 2 outlines the energy scenario in India, followed by energy scenario in Kerala. Section 3 focuses on an exploratory analysis of the data collection and its validation. The CO₂ emission reduction analysis by interchanging the conventional energy resources with electricity is presented in Section 4 which is followed by its economic impact analysis in Section 5. The key findings of the analysis are discussed in section 6. The major conclusions drawn from the study are presented in the final section.

2. Energy Scenario in India

India experiencing a GDP growth rate of 8% per annum, putting tremendous pressure on the power sector of the country. The deficiency in the supply of energy is generally met through imports from other countries. The Indian energy scenario shows a drift in the energy balance mainly due to the differed energy sources in India. The country deal with amazingly impressive challenges in meeting its energy needs and providing adequate energy both in terms of sufficient quality and quantity to users in a sustainable fashion and at tenable costs. If the energy production pattern is analyzed, coal and oil account for about 65%. The rest is met by hydro power, nuclear power and natural gas. In the generation sector about 60% is from coal fired thermal power plants and 70% of coal produced every year in India is being used for thermal power generation.

On the consumption side, about 55% of commercial energy consumption is by the industrial sector. Even though the per capita energy consumption in India is one of the lowest in the world, the energy intensity, which is energy consumption per unit of GDP, is one of the highest in comparison to other developed and developing countries (Fig.1.) (Devadas 1997).

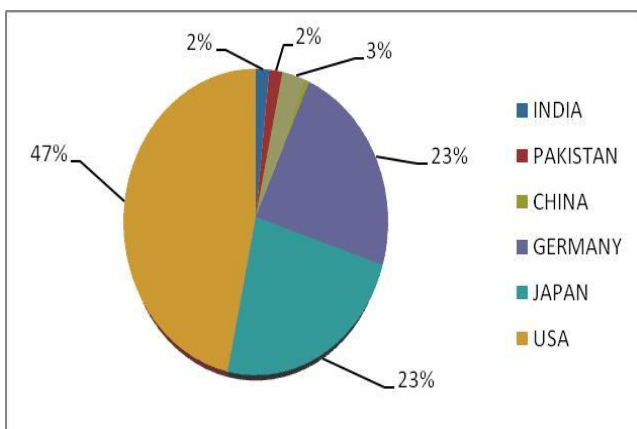


Fig. 1 Per capita energy consumption (Source: CMIE- (Centre for monitoring Indian economy-www.cmie.com))

The energy intensity is about 4 times that of Japan, 1.6 times that of USA, 1.5 times that of Asia and about 1.55 times that of the world average, rendering a large scope for energy conservation.

2.1 Energy Scenario in Kerala

Kerala's energy scenario is inextricably complex as compared with that of the nation. The installed capacity has expanded from 1,362 MW in 1947 to 1, 41,079 MW in January 2008. The per capita consumption of energy has increased from 16 kWh to 650 kWh. With the phenomenal increase in world energy prices, the economy of Kerala is struggling to cope with devastating increases in production costs. At the same time, due to limited new generation capacity additions and deficient rain fall, Kerala is experiencing severe and chronic energy shortages. The majority of energy in Kerala is consumed by households, which represent about 79% of all energy users and 46% of total electricity use. This is shown in Fig.2. Since, more than 2/3rd of the energy consumed in Kerala is for domestic use; even a minor alteration in the pattern of domestic energy consumption can bring significant changes to the total energy consumption. The important stages of energy transformation in an energy path comprises of generation, distribution, utilization and conservation. Cooking, lighting, heating, food processing and transportation are major energy end uses in Kerala.

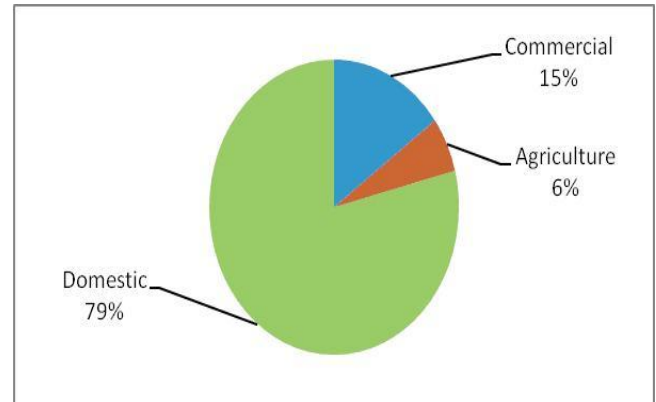


Fig. 2 Consumer profile of electricity distribution in Kerala

3. Data Collection and Verification

In this study, the state of Kerala, located in southern part of India is selected as the sample space. The region has been divided into 14 districts with a total population of 31,841,374. The survey enveloped the entire state, covering both rural and urban areas. The sampling design was based on a two stage- stratified random sampling procedure with the first stage comprising of rural areas and households forming the second stage units) (Choi & Thomas 2009). The households were selected systematically with equal

probability, with a random start. The Districts administratively are a collection of panchayats, each of which is further sub divided in towards each comprising about 1200 households. Data pertaining to randomly selected 120 households was taken to be the representative sample of the District. Data collection was carried out from May 2009 to September 2009, through a questionnaire, prepared for the purpose that provides for gathering minute and precise details regarding the energy usage details. In order to verify the sufficiency of the sample size for 95% confidence interval the following equation was employed (Bernes 1980):

$$N' = \left(\frac{20\sqrt{N \sum X^2 - (\sum X)^2}}{\sum X} \right)^2 \quad (1)$$

where $N=1700$ and X is the Per capita Income of the people.

The value obtained for N' was 764, as compared to the total data collected and hence the sufficiency was verified. For the purpose of data analysis, the state of Kerala was categorized into three regions namely, hilly, coastal and plain region based on geographic considerations. The data collected were also cross verified with data obtained from official statistics and other sources of information.

4. CDM Implementation Analysis

The National Sample Survey Organization (NSSO), in its sixth survey that is carried out once in five years included coverage of Non-agricultural Enterprises in the Informal Sector additionally. The highlights of the survey particularly applied to lighting sector reveals that at national level, electricity and kerosene accounted for 99% of the households as primary source for lighting in both rural and urban areas. There has been a decrease in the percentage of households using kerosene as predominant source of energy for lighting, from 62% to 51% in rural India, and from 17% to 10% in urban India, since 1993-94 (NSSO 1997). However, quantity of electricity used in Kerala domestic utility sector has witnessed an increase from 15 GWh in 1983 to 48 GWh in 1998, which is nearly threefold as per NSSO report, 1999-2000.

One of the previous studies on determinants of energy consumption concludes that income is a weak predictor of residential lighting energy consumption, explaining nearly 40% of energy consumption. The consumption of kerosene as a lighting fuel by a household essentially depends on the location and the socio-economic factors of the household. Using the SPSS regression analysis and EXCEL trend analysis, the differences in the average consumption of electricity across all the districts were tested. The results of both these tests indicate that there are significant differences

in the average quantity of electricity consumed by the households in the different districts and across different slabs of usage. This justifies the sample selection and its purpose. The trend analysis shows that the usage of electricity is increasing in the rural sector. The trend equation obtained for this application is given as:

$y = 2.24x - 4427$ with a R^2 value of 0.995. The CO_2 emission from electricity can be found out by the IPCC guide line 2006 which is as follows:

$$CO_2 \text{ emission from electricity use} = [(kWh \text{ consumed} \times \text{Electricity emission factor}) / (\text{Transmission and Distribution Efficiency})]$$

The electricity emission factor for India is 0.0008 ton of CO_2/kWh and for the Transmission and Distribution Efficiency of 75% (Lean & Smyth, 2010). By using the above formula, the CO_2 emission for Kerala from electricity is calculated for both urban and rural sector which is given in Table 1.

Table 1
CO₂ emission for Kerala from electricity

| Year | Quantity (mT) | Year | Quantity (mT) |
|------|---------------|------|---------------|
| 2010 | 0.0804 | 2013 | 0.0876 |
| 2011 | 0.0828 | 2014 | 0.0900 |
| 2012 | 0.0852 | 2015 | 0.0924 |
| 2016 | 0.0947 | 2020 | 0.1043 |
| 2017 | 0.0972 | 2021 | 0.1068 |
| 2018 | 0.0995 | 2022 | 0.1091 |
| 2019 | 0.1019 | 2023 | 0.1114 |

4.1 Fuel Replacement Options

Based on the above computational results, alternative strategies for energy resource replacements have been estimated in accordance with IPCC guidelines 2006.

- 1 kg of fuel A (energy replacement) = 'a' kg of fuel B.
- Emission factor for fuel A = 'b' kg CO_2 per kg.
- Emission factor for fuel B considering extraction and transportation = 'c' kg of CO_2 per kg.
- Emission reduction due to fuel A replacement with fuel B = $b - (a \times c)$ = 'd' kg of CO_2 per kg.
- Emission reduction due to fuel A replacement with fuel B = $b - (a \times c)$ = 'd' kg of CO_2 per kg.
- Present fuel consumption = 'X' million kg per year.
- CO_2 reduction for 10% of fuel A replacement with fuel B = $X \times 0.1 \times d$.

Using the above calculations, the replacement levels for different fuels and CO_2 reductions were calculated by assuming the following values: net calorific value of firewood = 15 MJ/kg, Calorific value of natural gas = 49.5 MJ/kg, Calorific value of Kerosene = 46.2 MJ/kg. The percentage

Kyoto target analysis and CO_2 emission reduction for Kerala with fuel replacement options especially in domestic sector is given in Table 2. The variation of replacement scenario with CO_2 emission reduction in million Tons in the rural domestic sector is depicted in

Table 2
The percentage Kyoto target achievable with fuel replacements

| Replacement Scenario | Firewood with Electricity | | Kerosene with Electricity | | LPG with Electricity | |
|----------------------|--|-------------------|--|-------------------|--|-------------------|
| | CO ₂ emission reduction (mt/yr) | % of KYOTO target | CO ₂ emission reduction (mt/yr) | % of KYOTO target | CO ₂ emission reduction (mt/yr) | % of KYOTO target |
| 10% | 0.0371 | 5.183 | 0.0031 | 0.432 | 0.0755 | 10.549 |
| 20% | 0.0742 | 10.367 | 0.0062 | 0.866 | 0.1509 | 21.083 |
| 30% | 0.1113 | 15.55 | 0.0093 | 1.279 | 0.2265 | 31.646 |
| 40% | 0.1484 | 20.73 | 0.0124 | 1.732 | 0.3019 | 42.18 |
| 50% | 0.1855 | 25.92 | 0.0155 | 2.166 | 0.3775 | 52.743 |
| 60% | 0.2226 | 31.10 | 0.0186 | 2.599 | 0.4529 | 63.277 |
| 70% | 0.2597 | 36.28 | 0.0217 | 3.032 | 0.5284 | 73.826 |
| 80% | 0.2968 | 41.47 | 0.0248 | 3.465 | 0.6039 | 84.374 |
| 90% | 0.3339 | 46.66 | 0.0279 | 3.898 | 0.6794 | 94.923 |
| 100% | 0.3710 | 51.83 | 0.0310 | 4.333 | 0.7549 | 105.471 |

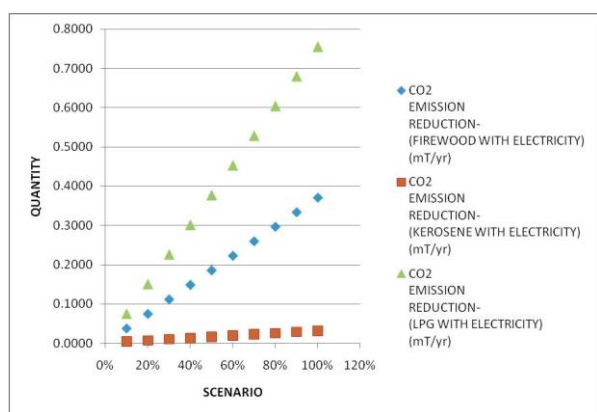


Fig. 3 The variation of replacement scenario with CO₂ emission reduction in mT (Rural sector)

From this table it is very much evident that the replacement of firewood with LPG is very effective in reducing the CO₂ emission in the state.

5. Economic Analysis

The results obtained from the CO₂ emission reduction analysis were extended to estimate the economic viability for implementation and the analysis carried out is highlighted. The economic implications of replacing fuel A with fuel B, was analyzed based on guidelines prescribed by the IPCC is presented:

By replacing 10% of fuel A with fuel B, the cost saved by 10% replacement = $[c \times m - b] \times 0.1a$.

where,

- a = Fuel A consumption in year 'Y',
- b = Cost of 1 unit of fuel A,
- c = Cost of 1 kg of fuel B and,
- 1 kg of fuel A = 'm' kg of fuel B.

The cost reduction achievable through replacement of different fuels were computed and presented in Table 3 to 5.

Table 3
Cost reduction analysis- Firewood replacement with electricity

| Firewood consumption in 2011 (kg) | Scenario (%) | Quantity (kg) | Cost for Firewood (INR) | Electricity Equivalent Quantity | Cost of 1kWh of Electricity | Cost of Electricity | Cost Saved by Replacement | Percentage Wise Cost Reduction |
|-----------------------------------|--------------|---------------|-------------------------|---------------------------------|-----------------------------|---------------------|---------------------------|--------------------------------|
| 51607 | 10 | 5160.7 | 32305.98 | 6977.27 | | 27909.07 | 4396.92 | |
| | 20 | 10321.4 | 64611.96 | 13954.53 | | 55818.13 | 8793.83 | |
| | 30 | 15482.1 | 96917.95 | 20931.80 | | 83727.20 | 13190.75 | |
| | 40 | 20642.8 | 129223.9 | 27909.07 | | 111636.3 | 17587.67 | |
| | 50 | 25803.5 | 161529.9 | 34886.33 | | 139545.4 | 21984.58 | |
| | 60 | 30964.2 | 193835.9 | 41863.60 | 4 | 167454.4 | 26381.50 | 13.61 |
| | 70 | 36124.9 | 226141.9 | 48840.86 | | 195363.5 | 30778.41 | |
| | 80 | 41285.6 | 258447.9 | 55818.13 | | 223272.6 | 35175.33 | |
| | 90 | 46446.3 | 290753.9 | 62795.40 | | 251181.6 | 39572.25 | |
| | 100 | 51607 | 323059.8 | 69772.66 | | 279090.7 | 43969.16 | |

Table 4
Cost analysis- Kerosene replacement with electricity

| Kerosene consumption in 2011 (kg) | Scenario (%) | Quantity | Cost for kerosene | Electricity Equivalent Quantity | Cost of 1kWh of Electricity | Cost of Electricity | Cost Saved by Replacement | Percentage Wise Cost Reduction |
|-----------------------------------|--------------|----------|-------------------|---------------------------------|-----------------------------|---------------------|---------------------------|--------------------------------|
| 939.7 | 10 | 93.97 | 1033.67 | 712.06 | 7 | 498.44 | 535.23 | 51.78 |
| | 20 | 187.94 | 2067.34 | 1424.12 | | 996.88 | 1070.46 | |
| | 30 | 281.91 | 3101.01 | 2136.17 | | 1495.32 | 1605.69 | |
| | 40 | 375.88 | 4134.68 | 2848.23 | | 1993.76 | 2140.92 | |
| | 50 | 469.85 | 5168.35 | 3560.29 | | 2492.20 | 2676.15 | |
| | 60 | 563.82 | 6202.02 | 4272.35 | | 2990.64 | 3211.38 | |
| | 70 | 657.79 | 7235.69 | 4984.40 | | 3489.08 | 3746.61 | |
| | 80 | 751.76 | 8269.36 | 5696.46 | | 3987.52 | 4281.84 | |
| | 90 | 845.73 | 9303.03 | 6408.52 | | 4485.96 | 4817.07 | |
| | 100 | 939.7 | 10336.7 | 7120.58 | | 4984.40 | 5352.30 | |

Table 5
Cost analysis- LPG replacement with electricity

| LPG consumption in 2011 (kg) | Scenario (%) | Quantity | Cost for LPG | Electricity Equivalent Quantity | Cost of 1kWh of Electricity | Cost of Electricity | Cost Saved by Replacement | Percentage Wise Cost Reduction |
|------------------------------|--------------|----------|--------------|---------------------------------|-----------------------------|---------------------|---------------------------|--------------------------------|
| 11321 | 10 | 1132.09 | 25121.08 | 12283.18 | 7 | 9458.05 | 15663.03 | 62.35 |
| | 20 | 2264.18 | 50242.15 | 24566.35 | | 18916.1 | 31326.06 | |
| | 30 | 3396.27 | 75363.23 | 36849.53 | | 28374.2 | 46989.09 | |
| | 40 | 4528.36 | 100484.3 | 49132.71 | | 37832.2 | 62652.12 | |
| | 50 | 5660.45 | 125605.3 | 61415.88 | | 47290.3 | 78315.16 | |
| | 60 | 6792.54 | 150726.4 | 73699.06 | | 56748.3 | 93978.19 | |
| | 70 | 7924.63 | 175847.5 | 85982.24 | | 66206.3 | 109641.22 | |
| | 80 | 9056.72 | 200968.6 | 98265.41 | | 75664.4 | 125304.25 | |
| | 90 | 10188.81 | 226089.7 | 110548.6 | | 85122.4 | 140967.28 | |
| | 100 | 11320.9 | 251210.7 | 122831.8 | | 94580.5 | 156630.31 | |

The energy requirement equivalence for a given application was arrived at, with the assumption that, for economically and demographically comparable households are expected to have similar per capita energy requirement. Based on the data collected the energy resource equivalence were estimated to be, 1 kg of firewood = 0.00446 kg of LPG = 0.0909 kg of Kerosene. The cost was computed based on the prevailing rates of the energy resources in the study area.

From the Table 3, it is very much evident that the percentage wise cost reduction is only 13.61 % while replacing the firewood with electricity, along with a substantial CO₂ reduction. In the case of kerosene replacement with electricity, around 52% cost reduction is possible which is clear from Table 4.

Table 5 indicates that there is considerable cost reduction of around 62.35% is possible while replacing LPG with electricity which can be attributed to the dwindling usage of electricity in primary applications.

Fig. 4 depicts the cost comparison of different fuel options under different scenarios. From the figure, it's very much evident that the cost is very much more for firewood and less for electricity. So, firewood not only increases the CO₂ emission, but also, it increases the overall expenditure.

The Fig. 5 presents the different cost saving by the various fuel replacement options. From the figure it can be identified that the cost saving by replacing firewood or LPG with electricity are yielding substantial cost benefit while only insignificant cost saving can be achieved through replacing kerosene with electricity.

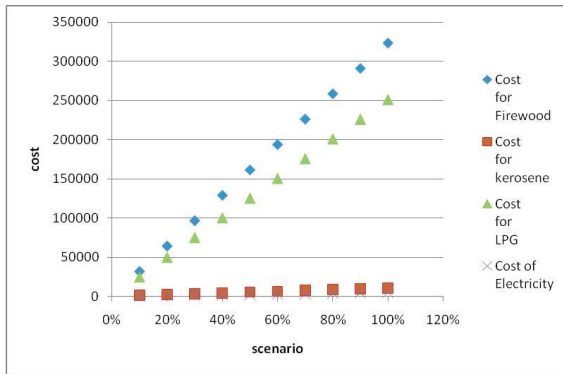


Fig. 4 Cost comparison of different fuel options

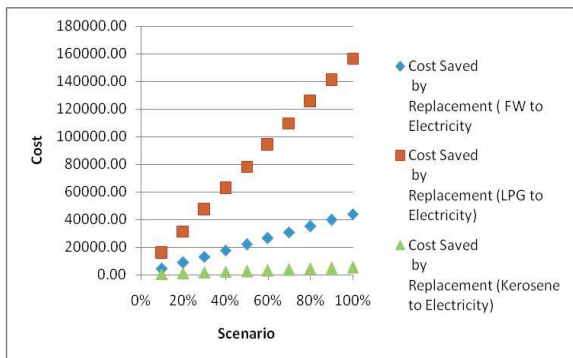


Fig. 5 Cost saved by different fuel replacement options (Rural sector)

6. Key Findings

While replacing the firewood, LPG and kerosene with electricity, there is the dual advantage of CO₂ emission reduction as well as cost saving. The maximum cost saved among the above three scenarios are when replacing LPG with electricity which is followed by kerosene replacement with electricity. But when the CO₂ emission too is considered, the most beneficial scenario is to replace firewood or kerosene with electricity. Also, the usage of dual fuels like LPG and electricity together can be promoted as a means to reduce CO₂ emission as well as to get maximum economical benefit.

In all the above cases it can be seen that the R² value is around 0.995 which is very much satisfactory. Firewood and Biomass fuels, until recently a dominant household energy source in Kerala particularly for cooking purposes, play only a limited role in current household activities. The study reveals that this increased reliance on modern energy resources such as electricity for lighting and LPG for cooking, arises from a preference among consumers for relatively more operational convenience and availability. The end result had been that, Kerala households have witnessed dramatic increases in use of modern fuel in recent years especially in domestic utility sector. Changing patterns of household activity and livelihood underlie this growth.

Electricity demand has increased rapidly in Kerala in recent years. Higher appliance saturations and more intensive lighting sources like electricity despite the decrease in household income, have spurred this growth. Electricity availability covers almost all households in Kerala, albeit subject to frequent load shedding, black outs, and voltage fluctuations. The average monthly per household and per capita consumption of electricity has been observed as 120 and 25 kWh, respectively.

7. Conclusions

The study results presented herein is a primary attempt in modeling energy consumption patterns and trends in the state of Kerala in India, identifying the various factors influencing that could form a platform for energy planning in not only in the state but also for India as a whole. The models predicted to be developed is expected to aid in setting up and acclimatization of CDM in the energy sector, which could go a long way in contributing to reduction in Carbon Emission Reduction. The methodology outlined is expected to aid not only in financial planning of CDM implementation in the energy sector, but also, can go a long way in contributing to reduction in Carbon Emission Reduction through exploitation of electricity as an alternative energy resources particularly in rural India. From the study, it can be concluded that, Kyoto target can well be achieved with replacement of LPG or Firewood consumption by electricity in not only cost effective manner but also with minimum impact on environment. However, in the case of kerosene replacement scenario, there is only insignificant reduction in the CO₂ emission as well as the cost. The study presents only minor area concerning the energy requirement patterns for lighting in rural sector. However the study methodology can be extended to other areas of energy applications surrounding equally both rural and urban areas.

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