# Achieving Certified Emission Reduction in Rural Domestic Energy Sector Through Alternative Fuel Replacement

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**Abstract-** Since the Kyoto protocol agreement, clean development mechanism (CDM) has garnered large emphasis in terms of Certified Emission Reduction (CER) not only amidst the global carbon market but also in India. This paper attempts to assess the economic as well as environmental impact of CDM implementation towards sustainable development and the CO2 emission by replacing fossil fuels with alternative fuels like biogas and biomass particularly in rural domestic energy sector based on Intergovernmental Panel on Climatic Change (IPCC) guidelines. A detailed survey was undertaken in the state of Kerala, in southern part of India to map the rural domestic energy consumption pattern. The data collected was analyzed that throws insight into the interrelationships of the various parameters that influence domestic energy consumption. The interrelationships between the different parameters were modeled that optimizes the contribution of individual energy resources on end applications. The results were used to estimate the feasible extent of $CO_2$ emission reduction through replacement of various conventional energy resources with alternative energy sources, vis-à-vis their 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, Certified Emission Reduction, Carbon dioxide emission reduction, Alternative Energy Sources, Economic Analysis.

## 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 harvest the benefits of sustainable development has been ill addressed.

India as a rapidly developing nation has a massive 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 meticulously [1, 2]. In this study, it is attempted to assess the environmental as well as economic feasibility potential to improvise rural domestic energy efficiency, particularly in the domestic sector and explore measures that can be framed as projects under the CDM [3]. 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 necessities, on the whole in rural India. Presently, these traditional fuels are gradually getting replaced by commercial fuels such as coal, petroleum, natural gas and electricity. With the appreciation of fossil fuels being the major cause of climatic change and air pollution, the focus of energy planners has shifted towards renewable resources such as biogas and biomass and energy conservation.

This paper attempts to present the details of the exploration 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, the study area. Section 3 focuses on an inquisitive analysis of the data collection and its validation. The CO2 emission reduction analysis by interchanging the conventional energy resources with alternative energy sources like biogas and biomass is presented in Section 4 which is followed by its economic influence in the study area in Section 5. The major 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

The Indian energy scenario shows a drift in the energy balance mainly due to the differed energy sources in India. The country faces enormous challenges in meeting its energy needs and providing ample energy both in terms of sufficient class and measure to users in a sustainable manner and at plausible costs. If the energy production pattern is analyzed, coal and oil account for about 65% [4]. 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 utilization 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. 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 opportunity for energy conservation [5].

*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 141,079 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 under pressure to contend with devastating increases in production costs.

At the same time, due to limited new generation capacity additions and short rain fall, Kerala is experiencing severe and persistent 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. Since, more than 2/3rd of the energy consumed in Kerala is for domestic use; even a minor modification in the pattern of domestic energy consumption can bring substantial changes to the overall energy consumption.

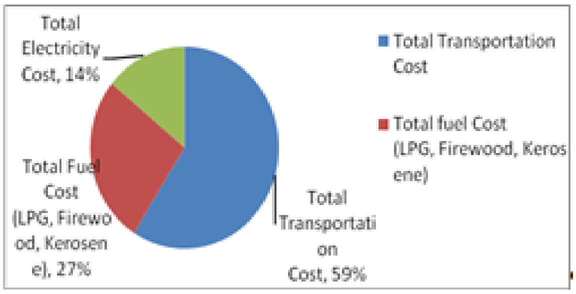


**Fig. 1.** The Distribution of Total Energy Cost per month in Kerala

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. The distribution of the energy costs towards different applications is presented in Figure 1.

## 3. Data Collection and Methodology

In this study, the state of Kerala, situated 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. The households were selected methodically with equal possibility, with a random start. The Districts administratively are a collection of panchayats, each of which is further sub divided in to wards 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 through a questionnaire, prepared for the purpose that provides for gathering minute and precise details regarding the energy usage. In order to verify the sufficiency of the sample size for 95% confidence interval the following equation was employed [6]:

$$N' = \left( \frac{20\sqrt{N\sum X^2 - (\sum X)^2}}{\sum X} \right)^2 , \quad \text{where} \quad N=1700$$

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 [7]. For all the sets of data, stepwise regression (SWR) was carried out separately using SPSS and the regression equations were obtained. The weightages evaluated through regression model were used for modeling the energy utilization pattern in to a linear programming (LP) model that optimizes per capita energy consumption. The LP analysis was carried out that optimizes the contribution of individual energy resources on end use applications. The results were used to estimate the feasible extent of CO2 emission reduction through use of various other energy resources such as alternative energy options like biogas and biomass.

## 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 cooking and 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 where as around 78% of rural people used firewood and chips as major source of energy for cooking. There has been an increase in the proportion of households using electricity as major source of lighting by 11% (from 37% to 48%) in rural areas and by 6% (from 83% to89%) in urban India since 1993-1994 [8]. There was decrease in the percentage of households using kerosene as primary source of energy for lighting, from 62% to 51% in rural India, and from 17% to 10% in urban India, since 1993-94 [9, 10].

One of the preceding studies on determinants of energy consumption concludes that income is a weak predictor of residential energy consumption, elucidating only 38% of energy consumption. The consumption of energy 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 disparity in the average consumption of energy across all the districts were tested. The results of both these tests indicate that there are significant differences in the average energy consumed by the households in the different districts and across different slabs of usage. This justifies the sample selection and its purpose. The quantity of electricity and different fossil fuels used in the rural sector for lighting and cooking application in domestic sector in Kerala is given in Figure 2.

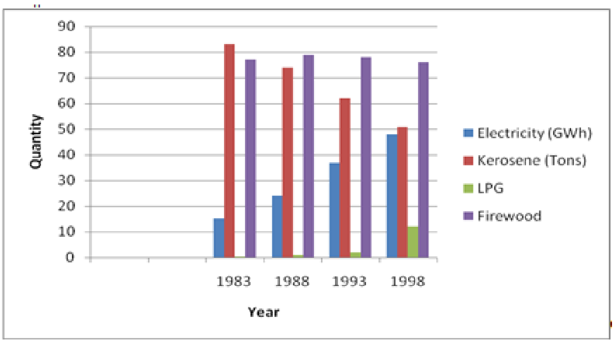


**Fig. 2.** Electricity and fossil fuels used in Kerala domestic sector for cooking and lighting (Source: NSS Report No. 464: Energy Used by Indian Households, 1999-2000)

The deviation in electricity and kerosene usage for lighting pertaining to rural sector from the year 1983 to 2000 and trend in energy usage established through data analysis is depicted in Figure 3. The trend analysis show that, in the lighting sector, the usage of electricity is increasing where as the usage of kerosene is decreasing in the rural sector. This increased dependence on electricity for lighting can be credited to considerable difference in cost of appliances and operating cost. Most households in the state presently has been electrified, albeit availability being inhibited by frequent load shedding, black outs, and voltage fluctuations.

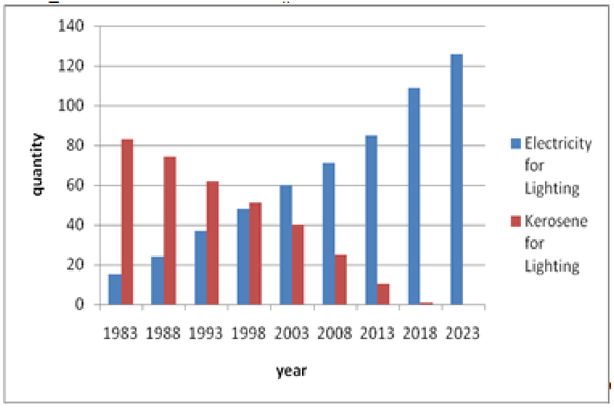


**Fig. 3.** Trend showing the usage of electricity and kerosene from 1983 to 2030 (Rural sector)

The Kerala households have perceived remarkable increases in modern fuel use in recent years in particular, for cooking. Changing patterns of household activities and livelihood underline this growth. Firewood and Biomass fuels, until recently has been prevailing household energy sources in Kerala particularly for cooking purposes, however, play only a curtailed role in present household scenario. Even the dominance of kerosene appears to be diminishing as cooking source.

The variation of firewood and LPG usage for cooking in rural sector from the year 1983 to 2000 and trend in firewood and LPG usage established through data analysis is depicted in Figure 4. LPG demand has increased rapidly in Kerala in recent years whereas the use of firewood as a fuel is decreasing. One of the major concerns from the Kerala states outlook on energy consumption pattern is the increased availability of LPG to the poor sections of the society. Hence any attempt to implement CDM in this sector would essentially be addressed through replacement of LPG with alternative energy resources such as Bio gas or Bio mass.

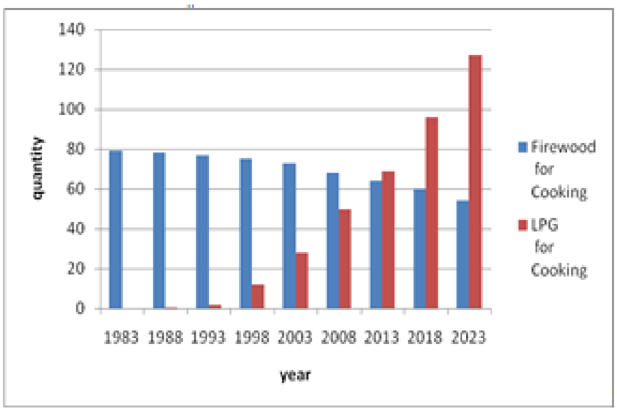


**Fig. 4.** Trend showing the usage of firewood and LPG from 1983 to 2030 (Rural sector)

The various trend equations for the lighting and cooking applications are given in the Table 1. The CO2 emission from electricity and fossil fuels can be found out by the IPCC guide line 2006 which is as follows:

$CO_2$ emission from electricity use = [(kWh consumed X Electricity emission factor)/ (Transmission and distribution efficiency)].

$CO_2$ emission from fossil fuel use = [fuel consumed X Net Calorific Value (NCV) X $CO_2$ Emission factor].

The electricity emission factor for India is 0.0008 per ton of CO2/kWh with Transmission and distribution Efficiency of 75%.

**Table 1.** Trend equations showing the usage of conventional fuels in Kerala

| Energy Sources | Application | Trend Equations | $R^2$ Value |
|---|---|---|---|
| **Electricity** | Lighting | $y = 0.02x^2 - 77.38x + 74813$ | 0.997 |
| **Kerosene** | Lighting | $y = -0.02x^2 + 77.46x - 74874$ | 0.998 |
| | Cooking | $y = -0.005x^2 + 19.99x - 19996$ | 0.999 |
| **LPG** | Cooking | $y = 0.095x^2 - 377.4x + 37494$ | 0.961 |
| **Firewood** | Cooking | $y = -0.02x^2 + 79.34x - 78606$ | 0.981 |

By using the above formula, the CO2 emission for Kerala from electricity and fossil fuels used for cooking and lighting in rural sector was worked out and the results are presented in Figure 5.

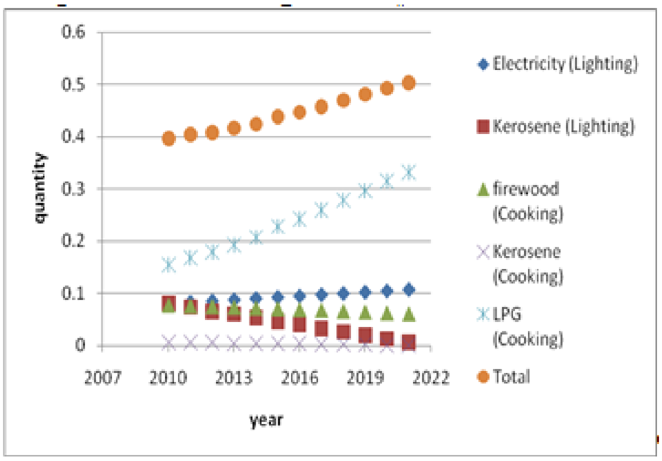


**Fig. 5.** CO2 emission (in million tons) for Kerala from electricity and fossils fuels

Figure 6 depicts the trend analysis on the variation of total CO2 emission till 2040. The projected Kyoto target analysis for the required total CO2 emission due to energy utilization for lighting and cooking applications in relation with base year (1990) emission rate is presented in Table 2. From the table, it can be observed that about 42 % of the Kyoto target can be achieved by the year 2021. The estimated variation showing the percentage of Kyoto target till 2040 is depicted in Figure 7, which indicates achievement of 100% target would be possible by the year 2033.

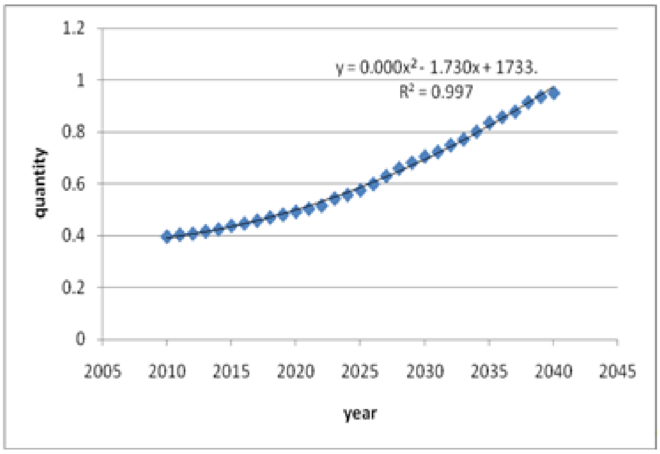


**Fig. 6.** Trend analysis- variation of total CO2 emission till 2040

**Table 2.** The Kyoto target analysis for required CO2 emission

| Emission as on 1990 (mT) | Year | Emission from 2012 onwards | $CO_2$ reduction requirement | Percentage of Kyoto Target |
|---|---|---|---|---|
| 0.775 | 2012 | 0.8321 | 0.1164 | 16.257 |
| | 2013 | 0.8471 | 0.1314 | 18.353 |
| | 2014 | 0.8606 | 0.1449 | 20.239 |
| | 2015 | 0.8811 | 0.1654 | 23.103 |
| | 2016 | 0.8977 | 0.1820 | 25.423 |
| | 2017 | 0.9221 | 0.2064 | 28.832 |
| | 2018 | 0.9474 | 0.2317 | 32.367 |
| | 2019 | 0.9708 | 0.2551 | 35.636 |
| | 2020 | 0.9957 | 0.2800 | 39.115 |
| | 2021 | 1.0212 | 0.3055 | 42.678 |

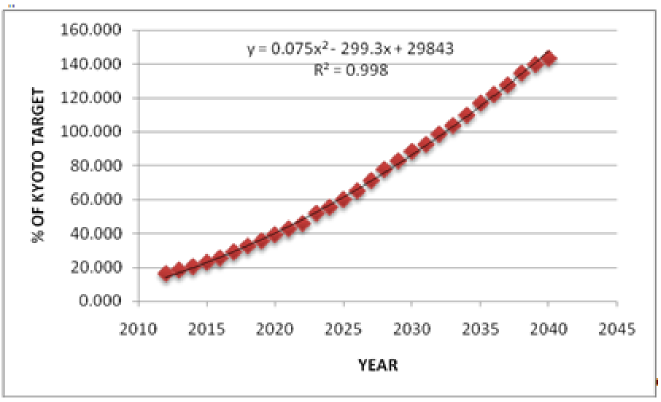


**Fig. 7.** Trend analysis- variation of Percentage Kyoto Target with year (Rural sector)

*Energy resource replacement options:*

Based on the above computational results, alternate strategies for energy resource replacements were contemplated 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 x 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 x 0.1x d.

Using the above estimates, 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 variation of biogas or biomass replacement scenarios with $CO_2$ emission reduction in million Tons in the rural domestic sector is depicted in Figure 8 and 9 respectively. From these tables it is very much obvious that the replacement of firewood with biogas or biomass is very effective in reducing the CO2 emission in the state.

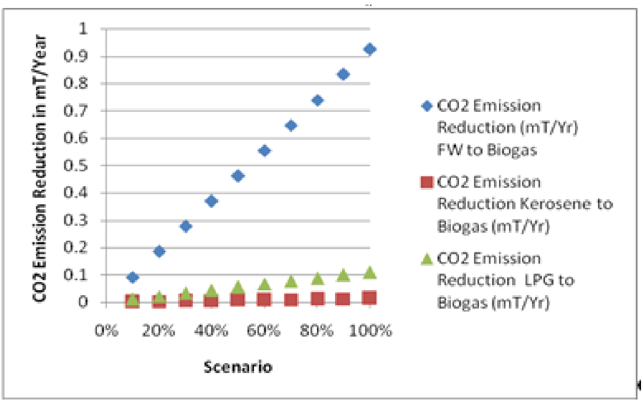


**Fig. 8.** The variation of Biogas replacement scenario with CO2 emission reduction in mT

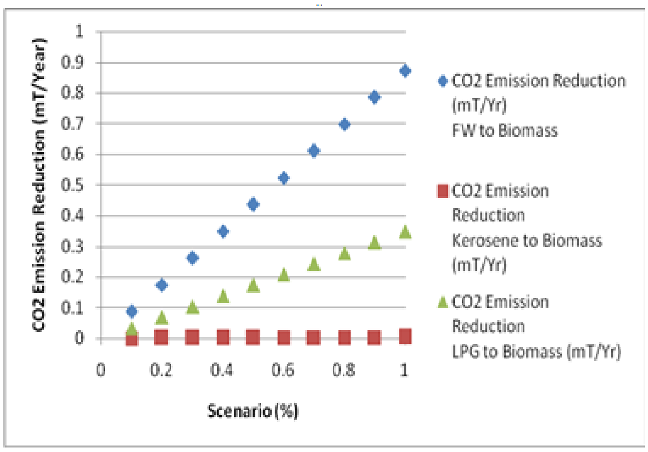


**Fig. 9.** The variation of Biomass replacement scenario with CO2 emission reduction in mT

## 5. Economic impact in study area

The results obtained from the $CO_2$ 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 x m- b] x 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. 1 kg of fuel A = 'm' kg of fuel B

The energy requirement equivalence for a given application was arrived at, with the assumption that, for economically and demographically analogous 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 biogas = 0.25kg of LPG = 0.48 kg of Kerosene = 5.275kg of firewood. In the case of biomass the energy resource equivalence were estimated as, 1 kg of firewood = 0.1896 kg of biomass = 0.00446kg of LPG = 0.0909 kg of Kerosene. The costs were computed based on the prevailing rates of the energy resources in the study area.

The cost reduction achievable through replacement of different fuels with biogas and biomass were computed and it is very much evident that the percentage wise cost reduction is almost 100% while replacing the traditional energy sources with biogas, along with a substantial $CO_2$ reduction. In the case of firewood replacement with biomass, around 91% cost reduction is possible.

The Figure 10 and 11 portrayed the different cost saving by the various fuel replacement options with biogas and biomass respectively. From the Figure 10, it can be safely concluded that the cost saving by replacing firewood with biogas is more economical, while replacement of biogas with Kerosene or LPG are almost the same with only insignificant cost saving.

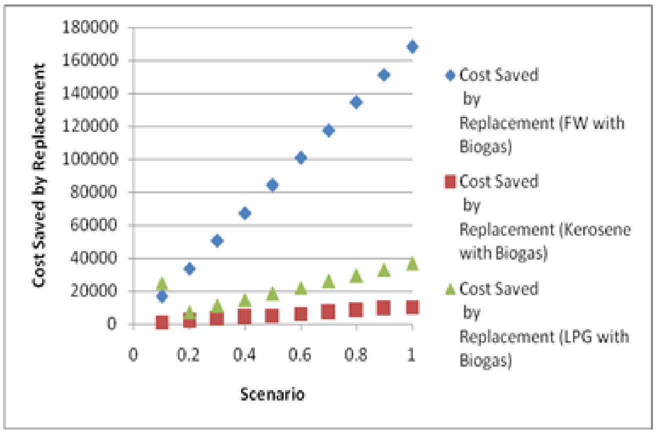


**Fig. 10.** Cost saved by different fuel replacement options with biogas

From the Figure 11, it can be identified that the cost saving by replacing firewood or LPG with biomass is more economical where as the replacement of biogas with Kerosene yields only insignificant cost saving.

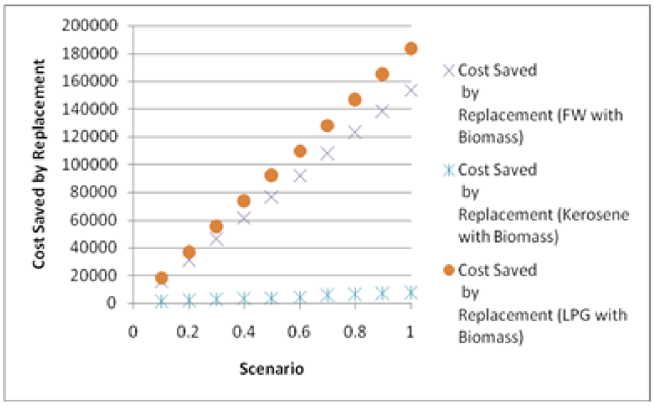


**Fig. 11.** Cost saved by different fuel replacement options with biomass

## 6. Major Findings

From the figures 8 and 9, it can be observed that, in the case of firewood replacement with the biogas, 100% Kyoto target can be achieved with replacement of 77% firewood consumption by biogas and by replacing 81% of firewood consumption with biomass, 100 % Kyoto target can be achieved. The corresponding cost expected to be saved would be INR 128,179 and 123,910 respectively. Also, it is clear that there is not very much $CO_2$ emission reduction by replacing kerosene with biogas or biomass. But there is substantial cost reduction by replacing LPG with biomass while the replacement will not generate considerable $CO_2$ reduction when biogas is used as the alternative fuel. From Figure 11, it is evident that there is significant cost reduction by replacing firewood or LPG with biomass as compared to the replacement of kerosene. From these analyses, it is apparent that the replacement of firewood with biogas or biomass is not only cost effective but also environment friendly. Further, in all the above replacement scenarios it can be observed that the R2 value is around 0.963 which is fairly satisfactory. Firewood and kerosene had been leading household energy sources in the state of Kerala, particularly for cooking purposes until the last two decades, however has been reduced to a limited role in present household scenario. Kerala households have witnessed dramatic increases in the use of modern energy fuel resources over recent years, particularly for lighting and cooking. The analysis emphasizes the benefits of replacing firewood or LPG or Kerosene with alternative fuels from both environmental as well as economical standpoint.

## 7. Conclusion

The results from the analysis presented herein is an earnest endeavor in modeling energy consumption pattern in the state of Kerala in India, pinpointing the various factors influencing energy usage and its economic impact, especially in the rural domestic energy sector, that could form a foundation for energy planning in not only in the state but also for India as a whole. The results indicate the promising scope of replacing conventional energy resources with non-conventional energy resources available in rural areas that at once achieve $CO_2$ emission reduction as well as reduction in usage cost. 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 development of potential alternative energy resources like biogas and biomass, particularly in rural India. The study presents only the details relevant to the energy requirement patterns in rural domestic sector. However the study methodology can be extended to other areas of energy generation and applications.

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