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Certified Emission Reduction (CER) Opportunities in Rural Domestic Energy Sector

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ABSTRACT

Since the Kyoto protocol agreement, clean development mechanism (CDM) has garnered large emphasis in terms of CER not only amidst the global carbon market but also in India. This paper attempts to assess the impact of CDM implementation towards sustainable development and the CO_2 emission 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 as a linear programming model 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 use of various energy resources. The analysis also provides a plat form for implementing CDM projects in the sector and related prospects with respects to the Indian scenario.

Keywords: *CDM, CER, CO_2 emission, Energy Consumption Pattern, Energy resource replacement.*

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 [1].

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 domestic 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. 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 [2].

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, the study area in Section 3. Section 4 focuses on an exploratory analysis of the data collection and its validation. The CDM implementation analysis and its cost impact are presented 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 last 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 float in the energy balance mainly due to the differed energy sources in India. The country confronts fulgurous 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% (Table 1). 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 [2].

Table I: Total installed capacity in India, (Source: Ministry of Power, Government of India, 2007)

Fuel	MW	Percentage
Thermal	99861.5	64.6
Hydro	36885.4	24.7
Nuclear	4120.00	2.9
Renewable Sources	15225.35	7.8

Total	156092.23	100

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 (Figure 1). 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 [3].

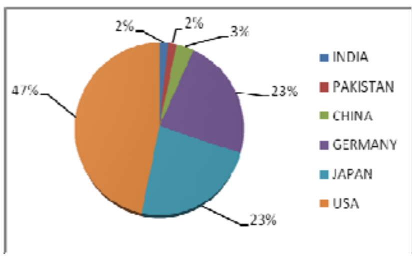

Fig 1: Per capita energy consumption

3. 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 existing capacity of Kerala power sector is depicted in Table 2. The per capita consumption of energy has increased from 16 kWh to 650 kWh. With the prodigious increase in world energy prices, the economy of Kerala is struggling to cope with overwhelming increases in production costs.

Table 2: Kerala- Existing Capacity (Source: KSEB, 2010)

Sl. No	Source	Installed Capacity(MW)
I	KSEB:- 1. Hydel 2. Thermal 3. Wind	 1888.60 234.60 2.03
II	Private:- 1. Hydel 2. Thermal	 33.00 177.44
III	NTPC-Kayamkulam	359.58
IV	Share from Central Grid	916.41
	Total	3565.66

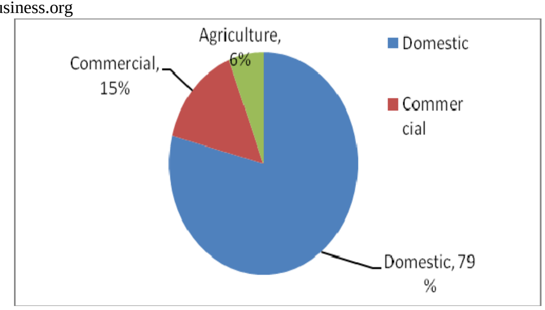

Fig 2: Consumer Profile, Electricity Distribution in Kerala (Source: KSEB, 2010)

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 Figure 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.

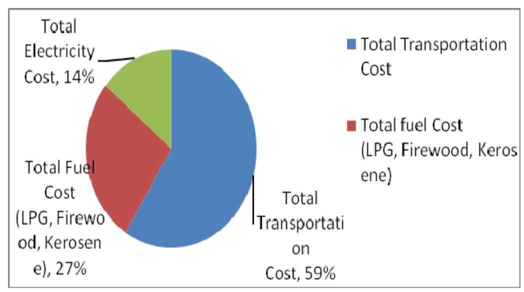

Fig 3: The Distribution of Total Energy Cost per month in Kerala

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 3.

4. DATA COLLECTION AND METHODOLOGY

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. 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 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 [4]:

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

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 [5]. For all the sets of data, stepwise regression (SWR) was carried out separately using SPSS and the regression equations were obtained. The weight ages evaluated through regression model were used for modeling the energy utilization pattern in to a linear programming model that optimizes per capita energy consumption. The LP analysis was carried out using LINGO version 12.0 that optimizes the contribution of individual energy resources on end user applications. The results were used to estimate the feasible extent of CO_2 emission reduction through use of various other energy resources such as alternate energy options.

5. 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. 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 [6,7].

One of the previous studies on determinants of energy consumption concludes that income is a weak predictor of residential energy consumption, explaining 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 differences 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 Table 3.

Table 3: 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)

Year	Sector	Electricity (GWh)	Kerosene (Tons)	LPG (Tons)	Firewood (Tons)
1983	Rural	15	83	0.2	77
1988	Rural	24	74	0.8	79
1993	Rural	37	62	1.9	78
1998	Rural	48	51	12	76

The variation 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 4. 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 reliance on electricity for lighting can be attributed to considerable difference in cost of appliances and operating cost. Most households in the state presently has been electrified, albeit availability is constrained by frequent load shedding, black outs, and voltage fluctuations.

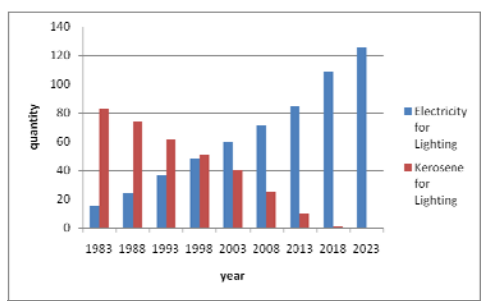

Fig 4: Trend showing the usage of electricity and kerosene from 1983 to 2030 (Rural sector)

The variation of firewood and kerosene usage for cooking in rural sector from the year 1983 to 2000 and trend in firewood and kerosene usage established through data analysis is depicted in Figure 5. The Kerala households have witnessed dramatic increases in modern fuel use in recent years especially for cooking. Changing patterns of household activities and livelihood underline this growth. Firewood and Biomass fuels, until recently has been dominant household energy sources in Kerala particularly for cooking purposes, however, play only a limited role in present household scenario. Even the

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dominance of kerosene appears to be diminishing as cooking source.

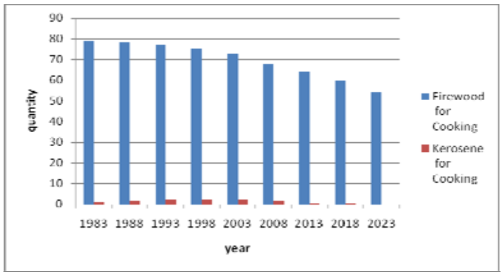

Fig 5: Trend showing the usage of firewood and kerosene from 1983 to 2030 (Rural sector)

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 6. 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 perspective 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.

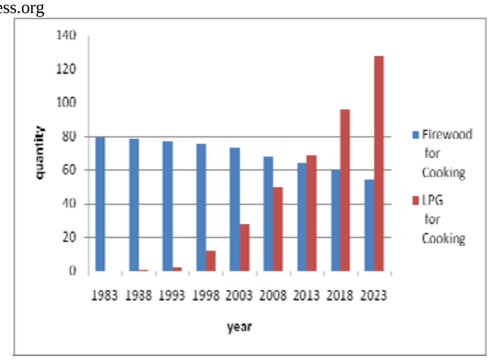

Fig 6: Trend showing the usage of firewood and LPG from 1983 to 2030 (Rural sector)

The various trend equations for the lighting and cooking applications are given in the Table 4. The CO_2 emission from electricity and fossil fuels can be found out by the IPCC guide line 2006 which is as follows:

CO_2 emission from fossil fuel use = fuel consumed x

Net calorific value (NCV) x CO_2 emission factor

CO_2 emission from electricity use =
[(kWh consumed X Electricity emission factor)/(Transmission and Distribution Efficiency)].

The electricity emission factor for India is 0.0008 per ton of CO_2/kWh with Transmission and Distribution Efficiency of 75%.

Table 4: Trend equations showing the usage of electricity and Kerosene 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 CO_2 emission for Kerala from electricity and fossil fuels used for cooking and lighting in rural sector was computed and the results are presented in Figure 7.

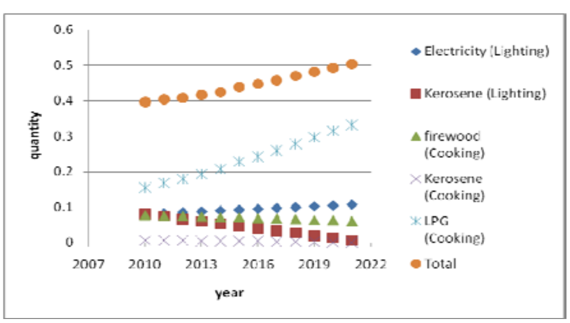

Fig 7: CO_2 emission (in million tons) for Kerala from electricity and fossils fuels

Figure 8 depicts the trend analysis on the variation of total CO_2 emission till 2022.

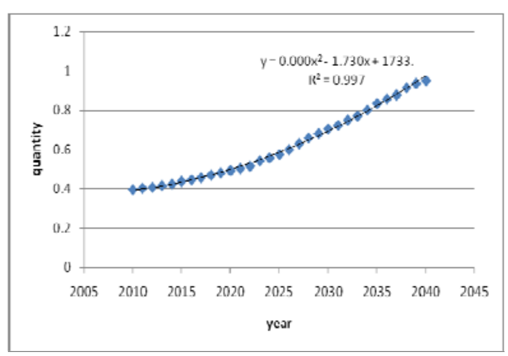

Fig 8: Trend analysis- variation of total CO_2 emission till 2040

The projected Kyoto target analysis for the required total CO_2 emission due to energy utilization for lighting and cooking applications in relation with base year (1990) emission rate is presented in Table 5. 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 9, which indicates achievement of 100% target would be possible by the year 2033.

Table 5: The Kyoto target analysis for required CO_2 emission

EMISSION AS ON 1990	YEAR	EMISSION FROM 2012 ONWARDS	CO_2 REDUCTION REQUIRE MENT	Percentage of Kyoto Target
0.775mt	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

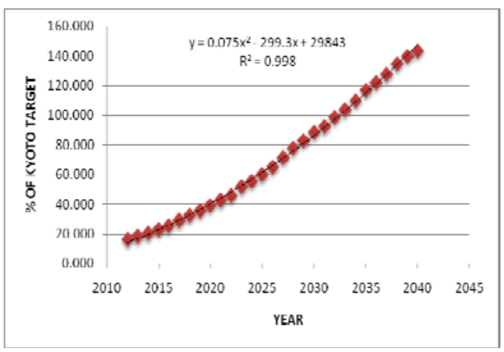

Fig 9: Trend analysis- variation of Percentage Kyoto Target with year (Rural sector)

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 x c) = d kg of CO_2 per kg.
Present fuel consumption = X million kg per year.
CO2 reduction for 10% of fuel A replacement with fuel B = X x 0.1x 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 6. The variation of replacement scenario with CO_2 emission reduction in million Tons in the rural domestic sector is depicted in Figure 10. From this table it is very much evident that the replacement of firewood with LPG is very effective in reducing the CO_2 emission in the state.

Table 6: The percentage Kyoto target achievable with fuel replacements

REPLACE-MENT SCENARIO (%)	FIREWOOD WITH LPG		FIREWOOD WITH KEROSENE		KEROSENE WITH LPG	
	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	0.103	14.40	0.085	11.92	0.002	0.27
20	0.206	28.82	0.171	23.85	0.004	0.53
30	0.310	43.24	0.256	35.77	0.006	0.80

40	0.413	57.66	0.341	47.70	0.008	1.07
50	0.516	72.08	0.427	59.62	0.010	1.33
60	0.619	86.50	0.512	71.55	0.011	1.60
70	0.722	100.87	0.597	83.47	0.013	1.87
80	0.825	115.32	0.683	95.40	0.015	2.13
90	0.929	129.74	0.768	107.32	0.017	2.40
100	1.032	144.16	0.854	119.25	0.019	2.66

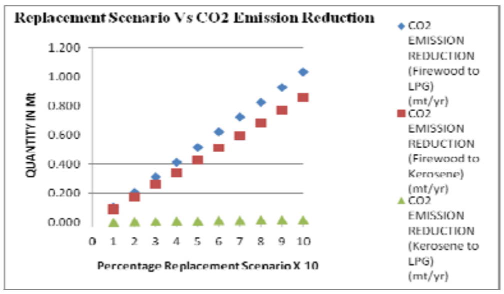

Fig 10: The variation of replacement scenario with CO_2 emission reduction in mT (Rural sector)

6. KEY FINDINGS

From the Table 6 it can be observed that, in the case of firewood replacement with the LPG, 100% Kyoto target can be achieved while replacing 70% of firewood with LPG whereas, in the case of kerosene; it can be achieved only by 85% replacement. But in the case of kerosene to LPG replacement scenario, there is not very much considerable reduction in the CO_2 emission. In all the above cases we can see that the R^2 value is around 0.988 which is very much satisfactory. Also, Kerala households have witnessed dramatic increases in modern fuel use in recent years especially for lighting and cooking. Firewood, kerosene and Biomass fuels, which were dominant household energy sources in the state of Kerala, particularly for cooking purposes until the recent past, have been reduced to a limited role in present household scenario. The study reveals that this increased reliance on LPG for cooking and electricity for lighting arises from a preference among consumers for more convenience and availability.

One of the major concerns from the Kerala state's perspective on energy consumption pattern is the decreasing 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.

7. CONCLUSION

The study results presented herein is a pilot attempt in modeling energy consumption patterns and trends in the state of Kerala in India, identifying the various factors influencing energy usage, especially in the domestic energy sector, that could form a basis for energy planning in not only in the state but also for India as a whole. The models envisaged to be developed is expected to aid in planning adaptation of CDM in the energy sector, which could go a long way in contributing to reduction in Carbon Emission Reduction through implementation of alternative energy potentials particularly in rural India. The pollution and the environmental hazards can be considerably reduced by proper operation and maintenance and replacement of fuels and technology. The study presents only minor area concerning the energy requirement patterns in rural domestic sector. However the study methodology can be extended to other areas of energy applications encompassing equally both rural and urban areas. The study results are a part of research work being pursued by the authors towards a wholesome solution to global sustainable development.

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