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Performance Assessment and Analysis for Potential Promotion of Improved Cookstoves in Nepal under Market/Non-Market Mechanism

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Abstract

Biomass is still the leading energy supplier in the developing countries. International Energy Agency report reveals that there is an increase in the number of population using biomass for their primary energy need of cooking. In Nepal, fuelwood is still the main source of energy in national scale with a share of 78%. Projection shows that almost 63% of households use fuelwood for cooking in the year 2016. Estimation made for 2016, shows that 57% of households use fuelwood for cooking in terai region whereas the trends for hilly and mountain regions are 64% and 91% respectively. In this research two different intervention scenarios have been considered for developing Nationally Appropriate Mitigation Action in Nepal for clean cooking. Intervention scenario A is focused for the analysis of ICS promotion in three geographic regions of Nepal and in Intervention scenario B, clean cooking technologies have been considered and analysis has been done for the promotion as per government target mentioned in Sustainable Development Goal 7. The estimated total households in terai, hilly and mountain regions where ICS can be penetrated are 1,288,527; 1,114,967 and 307,966 for the year 2016. Under CDM, the calculation for 2016 shows total volume of emission reduction on promotion general type of ICS would be 4,162,170.41 t CO_{2e}. Under intervention A, in terai region, by the year 2030 a total of 96,028,132; 107,125,603 and 128,426,683 t CO_{2e} GHG emission reduction can be achieved by using general Mud ICS, Rocket mud stove and rice husk Gasifer stove respectively. Similarly, in hilly region, by the year 2030 a total of 76,599,852 and 80,728,485 t CO_{2e} GHG emission reduction can be achieved by using general Mud ICS and Rocket metallic stove respectively. For mountain region, total 61,445,184 t CO_{2e} GHG emission reduction can be achieved by the year 2030 on promoting Metallic ICS. Similarly, under intervention B which involves the shifting of fuelwood using households to LPG and other technologies as per the target of SDG7, total GHG emission reductions in terai, hilly and mountain regions by the year 2030 due to shifting of fuelwood using households to LPG has been estimated 21,473,517; 17,585,403 and 3,847,022 t CO_{2e} respectively.

Keywords

biomass – improved cookstoves – geographic regions – emission reduction

Introduction

Large parts of the world population still rely on traditional biomass for their primary energy needs for cooking. Talking about the same case for developing Asia, 51 % of total population residing there use traditional biomass as supplier of energy for cooking[1].About two-third of the total households (about 64 %) use Firewood as the usual source of fuel for cooking followed by LPG (21.03 %), cow dung (10.38 %). Bio-gas and Kerosene is used for cooking by 2.43 and 1.03 % of the total households respectively[2]. Attempts have been made for the proper utilization through the efficient and high-tech cookstoves which can bring significant positive impact on the environment, health and economic spheres of modern life. Attentions and efforts have been making in Nepal for the development and deployment of different type of ICS in the various geographic regions of the country under the number of policies and programmes lunched from both government and non-government side. In order to improve indoor air quality, thermal efficiency of stove and to protect forest and environment, Improved Cooking Stove (ICS) development and dissemination activities were initiated in Nepal from early 1950s. In early 1970s; the focus was on improving the fuel efficiency of stoves[3]. Since traditional biomass is the leading fuel to meet the energy need of the country and there is a lack of cleaner cooking solutions, most of the rural population in Nepal are subjected to the impact of less efficiently combusted biomass. Proper attempts are lacking for the market and non-market analysis based on the methodologies of Clean Development Mechanism (CDM) and Nationally Appropriate Mitigation Actions (NAMA) respectively for the improved cookstoves project in Nepal. This research has estimated the number of households using firewood as their main fuel for cooking in the three different geographic regions of the country. It has developed a plan for the installation of different types of biomass improved cookstoves in three geographic regions of Nepal so as to pave a way for the utilization of available biomass resources in efficient manner.

1. Methodology

1.1 Baseline for the analysis

The three geographical regions of the country i.e. Terai region, Hilly region and Mountain region have been considered. In the baseline the status of population using firewood for cooking in the seventy five districts of Nepal has been estimated and the total number of improved cookstoves installed in those districts has been collected.

1.2 Estimation of the households using firewood for cooking:

Firstly a study has been carried out to know the potential households in the country where ICS can be installed. For this the data from CBS has been taken as reference where the data regarding use of main fuel for cooking has been given for VDC level. While projecting first of all district wise household growth rate for each ten year period has been calculated by taking the data from census 1971 to census 2011 and an average of these four growth rates has been taken so as to make projection quite reasonable. But since we need the status of the households which are using firewood as main fuel for cooking and we have the corresponding data for the year 2011 only, it is required to estimate the number of households using firewood for cooking in the year 2016. For this estimation a factor has been calculated for the year 2011 which governs the proportion of total households of a district which are using firewood for cooking. Then multiplying and adjusting the total projected district wise households for the year 2016, number of households using firewood for cooking in this year has been estimated.

1.3 Use of GIS

Geographic information system (GIS) software has been used to identify the possible households where metallic ICS can be used. This software provides classified result based on the elevation of the location. Input data of the VDCs and districts of Nepal has been given to the software and based on that it provides result within the map of Nepal.

1.4 Selection of different ICS for analysis

Here mainly four types of ICS have been considered for the purpose of analysis. Two main categories are Mud ICS and Metallic ICS which are very popular in the Hilly regions and Mountain regions. Since till date different attempts have been made for the further improvements in the performance of these types of cookstoves, the modified types for the Mud ICS have been considered here and analysis has been carried out accordingly. The other two types of improved cookstoves considered here are Rocket stove and Rice husk Gasifier stove. These stoves being efficient with much lower emission as compared to those mentioned earlier are particularly suitable for Terai region.

1.5 Thermal efficiency test

To evaluate the performance and verify that cookstove has been improved, we have to perform a water boiling test of cookstove. The Water Boiling Test (WBT) is a simplified simulation of the cooking process. It is intended to measure how efficiently a stove uses fuel to heat water in a cooking pot and the quantity of emissions produced while cooking. The entire WBT should be conducted at least three times for each stove, which constitutes a WBT test set.

The water boiling test is a laboratory test which can be used to compare the performance of two or more stoves under similar controlled conditions, or the same stove under different conditions. It simulates the boiling/simmering type of cooking to some extent only. As a result, it does not necessarily reflect the actual stove performance, when food is cooked. A known quantity of water is heated on a cookstove. The volume of water evaporated after complete burning of the fuel is determined and thermal efficiency, η, is calculated as[4]:

$$\eta = \frac{4.186\Sigma[(P_{1i}-P_{1f})(T_{1f}-T_{1i}),(P_{2i}-P_{2f})(T_{2f}-T_{2i})]+2260xW_v}{f_d xLHV}$$

Where,
P_{1i} = Mass of pot1 of water before test (grams)
P_{1f} = Mass of pot1 of water after test (grams)
P_{2i} = Mass of pot2 of water before test (grams)
P_{if} = Mass of pot2 of water after test (grams)
f_d = Equivalent dry fuel consumed(grams)
T_{1f} = Water temperature (pot1) at start of test ($^\circ C$)
T_{2i} = Water temperature (pot1) at end of test ($^\circ C$)
T_{2f} = Water temperature (pot2) at start of test ($^\circ C$)
P_{21} = Water temperature (pot2) at end of test ($^\circ C$)
P_{2f} = Water vaporized(grams)
W=Water vaporized(grams)
LHV = Lower Heating Value of wood(kJ/Kg)

1.6 Clean development mechanism for ICS

Emission reduction credits can be an additional source of funding for household energy projects. Through the CDM, valuable carbon credits for certified emission reductions of greenhouse gases (GHGs) can be generated in developing countries. The generated funds can be used to enable emission reductions, which would otherwise not be possible. The CDM is one of the three flexible mechanisms to reduce GHG under the Kyoto Protocol[5]. To develop clean development mechanism (CDM) for ICS, total volume for the penetration of different ICS has been estimated. In three geographic regions of Nepal, considering two types ICS (mud ICS and metallic ICS), CDM calculations have been done based on the methodology AMSIIG recommended by UNFCCC. While developing CDM, calculations have been done considering that on promoting ICS in all potential households of three geographic regions, how much quantity of GHGs emissions can be reduced and how much carbon credit can be achieved.

1.7 Nationally appropriate mitigation actions for clean cooking

NAMAs are voluntary actions taken by developing countries to reduce GHG emissions. Their aim is to assist developing countries that wish to reduce emissions to a level below that of BAU, but they do not represent a legal obligation under the UNFCCC. Determining which actions to take under a NAMA is each country's sovereign right, since the definition of "appropriate mitigation action" is relative to a party's particular national circumstances. In general, NAMAs are designed to support efforts towards sustainable development, as interpreted by the host country[6]. Entire boundary of the Nepal where still large fraction of populations are using biomass in traditional cookstoves to meet their immediate energy need for cooking has been considered for this NAMA. Under this proposed NAMA, intervention scenario for different types of improved cookstoves has been made and analysis has been done for the promotion of suitable type of ICS in three different geographic regions of Nepal namely Terai, Hilly and Mountain. This NAMA focuses on a project which aims to provide cleaner cooking options to the households using traditional stove along with reduction in the GHGs emissions through the promotion and use of improved cook-stoves in all the households of Nepal which are using firewood as main fuel for cooking.

1.7.1 Intervention A: Promotion of different type of improved cooksotves in three geographical regions of Nepal by 2030

Still significant portion of the population residing mostly in rural areas are using traditional cookstoves. Promotion of different types of improved cookstoves in different regions will ensure the clean cooking solution to them and also helps to reduce the GHGs emission in significant extent including other socioeconomic benefits.

1.7.2 Intervention B: Promotion of other efficient cooking technologies besides ICS by 2030

Recently the GoN has declared sustainable development goal for 2016-2030 and is has considered and envisioned the supply of modern energy to all Nepalese by its SDG7[7]. One specific target of this goal is to reduce to 10 percent of households who use firewood as their primary fuel for cooking. Considering this goal, scenario for the intervention of following technologies has been considered:

- Electric cooking
- LPG
- Biogas

1.8 Emission reduction calculation methodology for ICS

Paragraph 12 of AMS II.G/v06 requires that the project participants assume that in the absence of the project activity, the baseline scenario would be the projected use of fossil fuels for meeting similar thermal energy needs. The actual baseline scenario is the use of NRB. Since NRB has higher carbon intensity than the fossil fuels proposed in AMS II.G, this assumption reduces the emission reductions significantly, making the outcome more conservative[8]. According to paragraph 13 of methodology AMS II.G/v06, emission reductions would be calculated as:

$$ER_y = \Sigma ER_{y,i}$$

Where,
i: Indices for the situation where more than one type of project device is introduced to replace the pre-project devices. ER_y = Emission reductions during year y in t CO_{2e} $ER_{(y,i)}$ Emission reductions by project device of type i during year y in t CO_{2e}

According to the methodology for households cook-stoves the calculation will proceed as

$$ER_{y,i} = \Sigma B_{y,saving} x N_y x \frac{\mu_y}{365} x f_{NRB,y} x NCV_{NRB} x EF_{Projected fossil fuel} - LE_y$$

Where,
$B_{y,savings}$: Quantity of woody biomass saved in tonnes
N_y: Number of project devices of type i and age a operating in year y
μ_y:Number of days of utilization of the project device during the year 'y'
$f_{NRB,y}$:Fraction of woody biomass saved by the project activity in year y
NCV_{NRB}:Net calorific value of the non-renewable woody biomass that is substituted
$EF_{Projected fossil fuel}$:Emission factor for the substitution of non-renewable woody biomass by similar consumers
LE_y: Leakage emission in year y

1.8.1 Calculation of $B_{y,saving}$

$$B_{y,saving} = B_{Old} x (1 - \frac{\eta_{old}}{\eta_{new} x \Delta\eta_y})$$

Where,
B_{Old} = Quantity of woody biomass used in the absence of the project activity in tonnes per device
η_{old} = Efficiency of the device being replaced
η_{new} = Thermal efficiency of the device of type i being deployed as part of the project activity
$\delta\eta_y$ = Efficiency derating factor

1.8.2 Calculation of B_{Old}

B_{old} is determined with one of the following two options:

1. Calculated as the product of the number of devices multiplied by the estimated average annual consumption of woody biomass per device (tonnes/year). This may be derived from historical data or a survey of local usage. itemCalculated from the thermal energy generated in the project activity as follows:

$$B_{old} = \frac{HG_{p,y}}{NCV_{biomass} x \eta_{old}}$$

Where,
$HG_{p,y}$ = Amount of thermal energy generated by the project devices in year y (TJ), if the thermal output of the devices can be directly measured

1.9 Emission reduction calculation methodology for LPG

GHG emission reductions achieved through the distribution of LPG cooking solutions in a given year y ($ER_{LPG,y}$)are calculated by comparing actual (project) emission ($PE_{LPG,y}$) with the emissions under a baseline scenario ($BE_{LPG,y}$)[9]

1.9.1 Baseline Emission($BE_{LPG,y}$)

Assumptions:

All LPG connections provided under the intervention will be considered to be operational and there will be one LPG connection per household.

It is assumed that households provided with LPG connections under this NAMA intervention are using LPG exclusively and that LPG stoves are used for 365 days in a year.
Here, the term LPG connection shall mean the LPG system consisting of LPG stove and cylinder. The baseline emission($BE_{LPG,y}$) shall be calculated as:

$$BE_{LPG,y} = B_{old} x N_y x \frac{\mu_y}{365} x f_{NRB,y} x NCV_{NRB} x EF_{Projected fossil fuel}$$

Where,
B_{old}: A default value of 0.5 tons per capita per year is used to derive this parameter for household cookstoves
N_y: The number of "LPG connections" operating in year y
μ_y:The number of days of utilization of the LPG connection during the year y. This will be counted from the date of commissioning of the connection.
$f_{NRB,y}$:Fraction of woody biomass saved by the project activity in year y
NCV_{NRB}:Net calorific value of the non-renewable woody biomass that is substituted
$EF_{Projected fossil fuel}$:Emission factor for the substitution of non-renewable woody biomass by similar consumers

1.9.2 LPG Emission($PE_{LPG,y}$)

Project emissions will be due to the use of LPG in the project scenario.

Assumption:

The total quantity of LPG supplied under the intervention will be consumed. Thus the quantity of LPG supplied under the intervention in year y is equal to quantity of LPG consumed in year y.

The project emissions ($PE_{LPG,y}$)are calculated as follows:

$$PE_{LPG,y} = N_y x \Sigma(Q_{cyl,LPG,i} x i) x NCV_{LPG} x EF_{LPG}$$

Where,
$Q_{cyl,LPG,i}$ = The number of LPG cylinders of capacity i supplied to each LPG connection (or household) during the year y.
i: Capacity of LPG cylinder in tons. This will be monitored ex post. LPG consumption of 0.12 tons/ household per year is used.
NCV_{LPG} = Net calorific value of LPG (TJ/ton). IPCC default for LPG, 0.0473 TJ/ton, is used.
EF_{LPG} = Emission factor of LPG(tCO_{2e}/TJ). IPCC default value 63.1 tCO_{2e}/TJ is used.

2. Results and Analysis

2.1 Firewood using households in three geographic regions

Based on the district wise households' data covering different sectors published by CBS as per the census 2011, district wise as well as geographic region wise number of households using firewood for cooking has been estimated for the base year 2016 [2].

Table 1: Households using firewood for cooking in three geographic regions of Nepal

Geographic Regions	Status of 2011	Estimation for 2016
Terai Region	1,429,005	1,694,664
Hilly Region	1,606,228	1,762,928
Mountain Region	434,990	467,999
Total	3,470,223	3,925,591

2.2 Current status of use of ICS

In order to understand the current status of use of biomass in Nepal, the available data has been segregated according to the three ecological regions namely Terai, Hilly and Mountain.

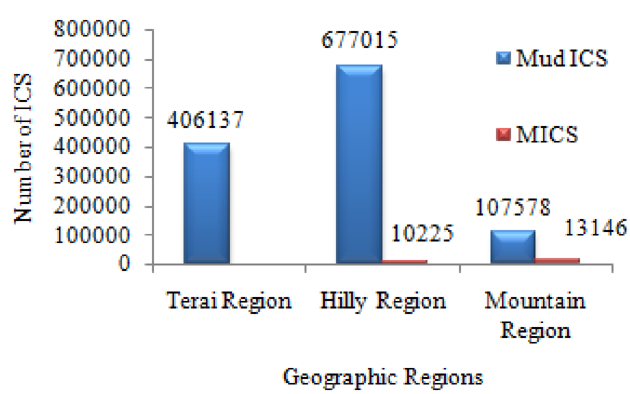

Figure 1: Current status of use of ICS

2.3 Promotion of ICS in intervention A

In this intervention scenario, number of households don not having access to the ICS and are using traditional cookstove for cooking in Terai, Hilly and Mountain region has been estimated. Here projection for the households using firewood for cooking has been projected using the household growth rate and data regarding the installation of improved cookstoves which has been taken from AEPC. Comparing these two figures the potential number of mud improved cookstoves which can be penetrated in three geographical regions of Nepal; Terai, Hilly and Mountain have been estimated as below.

2.3.1 In terai region

In Terai region main emphasis has been given for the penetration of mud improved cook-stoves. The chart below shows the current statistic of the possible households where ICS can be installed.

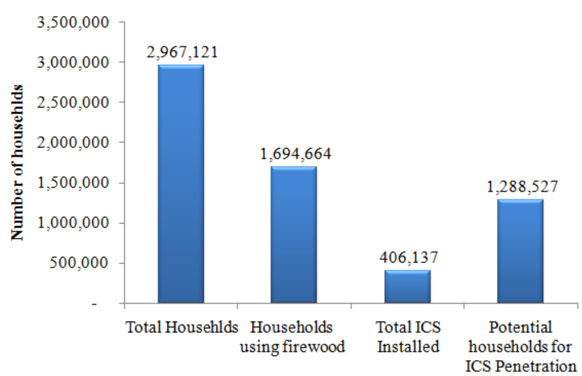

Figure 2: Potential penetration for ICS in terai region

2.3.2 In hilly region

Though both mud and metallic improved cookstoves are popular in Hilly region but the mud ICS is dominant. Here the scenario for the potential installation of ICS in this region has been given in bar chart.

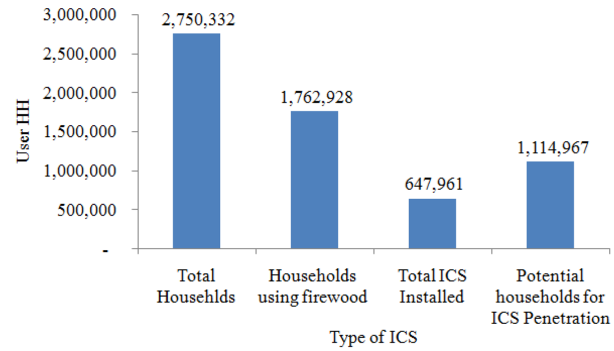

Figure 3: Potential penetration for ICS in hilly region

2.3.3 In mountain region

In Mountain region metallic ICS is also popular due to the location of the region in high elevation and cold climatic zone so there is appropriate condition to promote the MICS as compare to other two geographic regions.

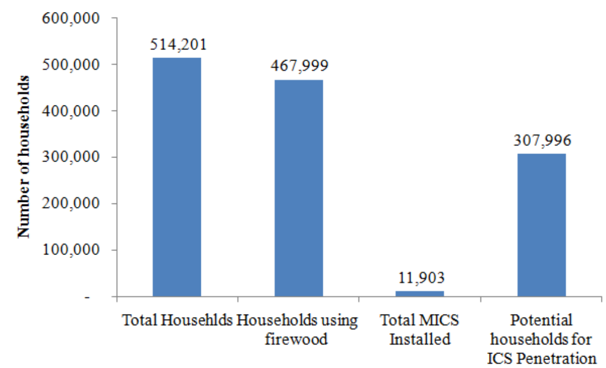

Figure 4: Potential penetration for ICS in mountain region

2.4 Performance analysis of existing ICS

Information regarding the performance of different types of biomass improved cookstoves has been provided by RETS Since thermal efficiency is the main parameter within the scope of this research while linking the improved cookstove project with market and non-market mechanisms for climate related funds and other possible assistances emphasis will be given to this parameter.

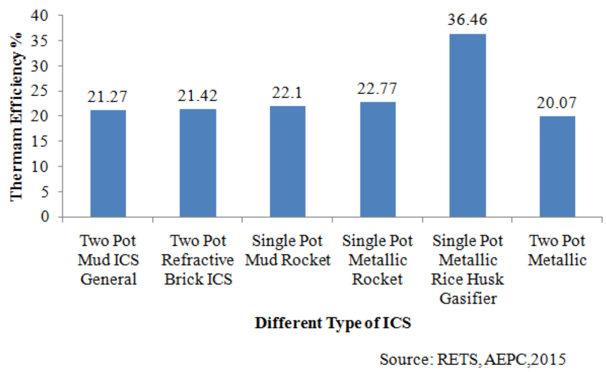

Figure 5: Thermal efficiency of different ICS

2.5 Net emission reduction under CDM

CDM calculation for ICS is carried out by using the equation suggested by the AMS II.G/v06 methodology for the estimation of GHGs emission reduction from the household biomass cookstoves.

Assumptions

1. ICSs sold under the NAMA will be considered to be operational for 365 days in a year and consumers (households and institutions) are assumed to be using ICSs exclusively.

2. Number of ICSs per household is considered to be one.

Table 2: Input parameters for CDM calculation

Paramenters	Value	Unit	References
Woody biomass consumption	3.07	tonnes/year	Calculated
Efficiency-traditional stoves	10	%	Methodology AMS-II G
Efficiency derating factor-ICS	10	%	Assumptions
Number of days of utilization	365	per annum	Assumptions
Factor of NRB	86	%	UNFCCC approved country report
NCV of woody biomass	0.015	TJ/ton	IPCC 2006
Emission factor	81.6	tCO_{2e}/TJ	Methodology AMS-II G
Leakage emission	0.95	N/A	Methodology AMS-II G

Table 3: Input parameters for CDM calculation

Geographical Regions	Emission Reduction in t CO_{2e}
Terai	1,977,904.75
Hilly	1,711,488.03
Mountain	472,777.63
Total	4,162,170.41

2.6 Emission reduction calculation under intervention A

Assumptions:

1. ICSs sold under the NAMA will be considered to be operational for 365 days in a year and consumers (households and institutions) are assumed to be using ICSs exclusively.

2. Number of ICSs per household is considered to be one

3. Service Life for the Mud ICS and Metallic ICS has been considered as 3 years and 11 years respectively.

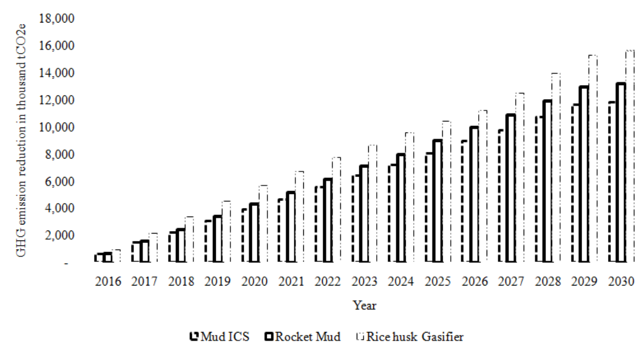

Figure 6: Total emission reduction in terai region

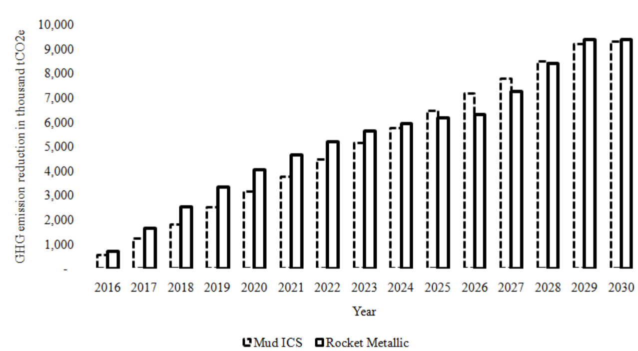

Figure 7: Total emission reduction in hilly region

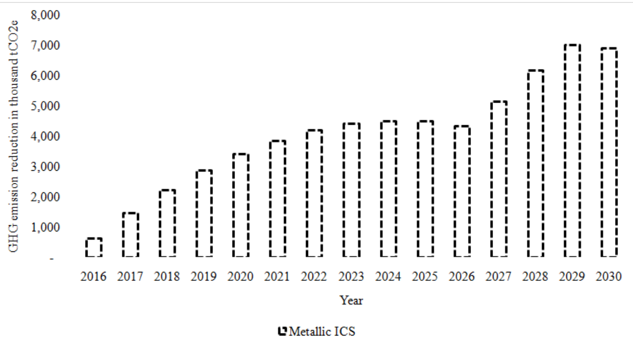

Figure 8: Total emission reduction in mountain region

2.7 Promotion of cleaner technologies in intervention B

In this intervention scenario the target set by the government in its SDG7 has been taken into consideration. By 2030 the number of households using firewood and other traditional biomass energy sources for cooking has been reduced to 10% of the total households in 2016 and to meet the energy demand with population growth rate, three dominant potential energy sources namely LPG, Biogas and Electricity have been taken into account.While developing intervention scenarios, here two targets as mentioned in SDG7 have been considered. One is to reduce the households using firewood for cooking to 10% of the total households and another is to limit the proportion of households using LPG for cooking 40% by the year 2030. Number of households using different cooking technologies in different years has been then approximated as per the targets considered earlier.

Assumptions:

1. Number reduction in households using fuelwood for cooking each year from 2017 to 2030 has been shifted to LPG
2. Households growth rate has been assumed constant for the analysis period
3. All LPG connections provided under the intervention will be considered to be operational and there will be one LPG connection per household
4. It is assumed that households provided with LPG connections under this NAMA intervention are using LPG exclusively and that LPG stoves are used for 365 days in a year

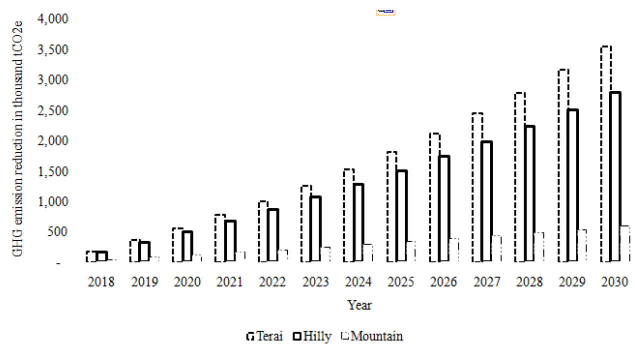

Figure 9: Emission reduction using LPG

3. Financial Estimation

Following assumptions have been considered for the financial estimations;

1. Under non- market mechanism to implement the project activity, the sources of finance can be internal and external. Government is the main internal financing source whereas sources like Green Climate Fund, NAMA facility and other potential organizations are external financing sources.
2. Under market mechanism Carbon credit will be achieved as per the quantity of GHG emission reduction because of the project activity and Administrative and verification Cost has been taken NPR2,001,600.
3. Here, unit cost of mud ICS , rocket mud ICS metallic ICS and gasifier stove have been assumed as NPR 3,000; 3,000; 4,000 and 5,000 respectively.
4. Calculations have been for different values of CER (Certified Emission Reduction) ranging from USD 1 to USD 5 per tone of CO_{2e} .

3.1 In terai region

In order to promote the different improved cookstoves in terai region under intervention scenario A, following amount of investment will be required.

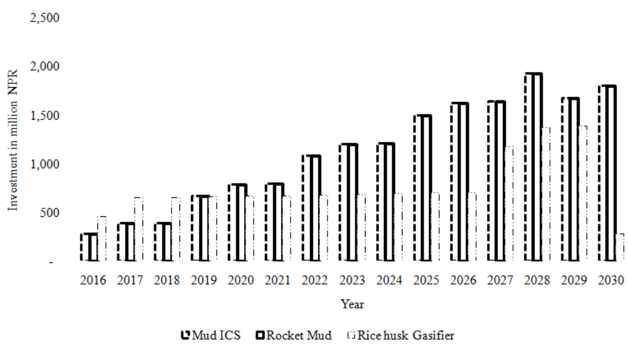

Figure 10: Investment required for terai region to promote different ICS

Figure below shows the potential revenue generation on using different ICS in terai region at different values of CER.

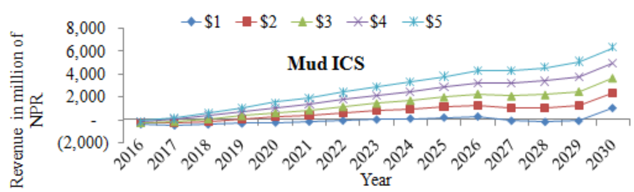

Figure 11: Revenue generation from Mud ICS

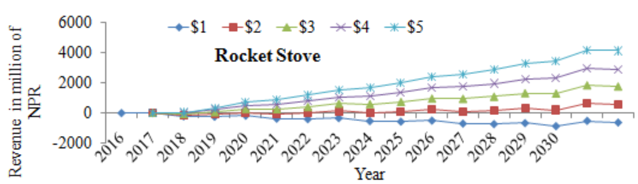

Figure 12: Revenue generation from Rocket stove

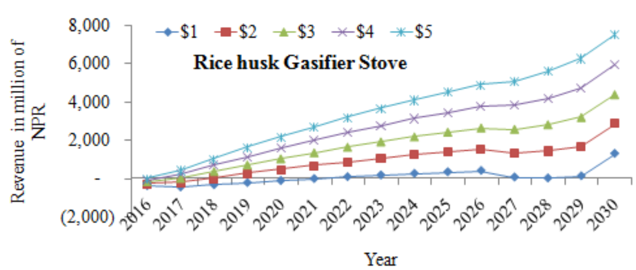

Figure 13: Revenue generation from rice husk Gasifier stove

3.2 In hilly region

In order to promote the mud improved cookstoves in hilly region under intervention scenario A, following amount of investment will be required.

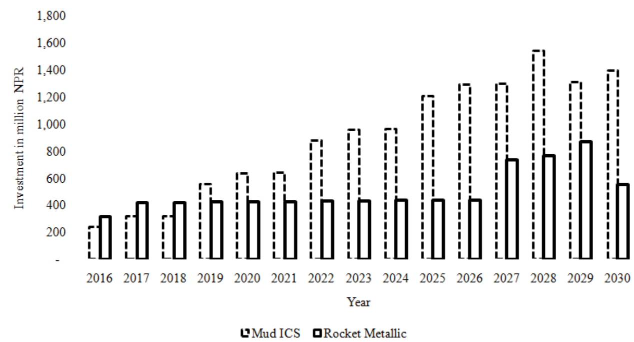

Figure 14: Investment required for hilly region to promote different ICS

Figure below shows the potential revenue generation on using different ICS in hilly region at different values of CER

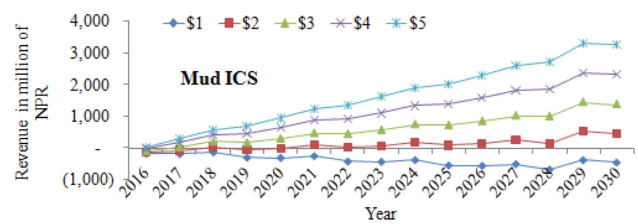

Figure 15: Revenue generation from Mud ICS

Figure 16: Revenue generation from Rocket stove

3.3 In mountain region

In order to promote the metallic improved cookstoves in mountain region under intervention scenario A, following amount of investment will be required.

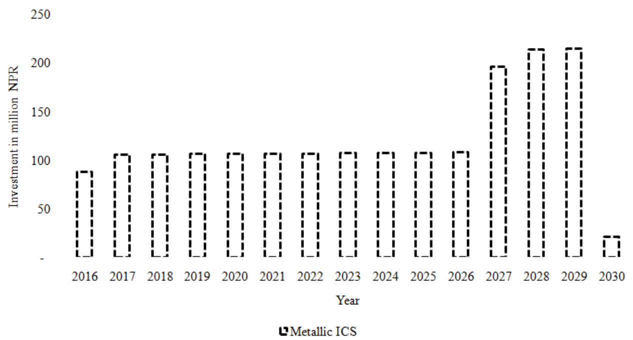

Figure 17: Financial Estimation for mountain region

Figure below shows the potential revenue generation on using Metallic ICS in hilly region at different values of CER.

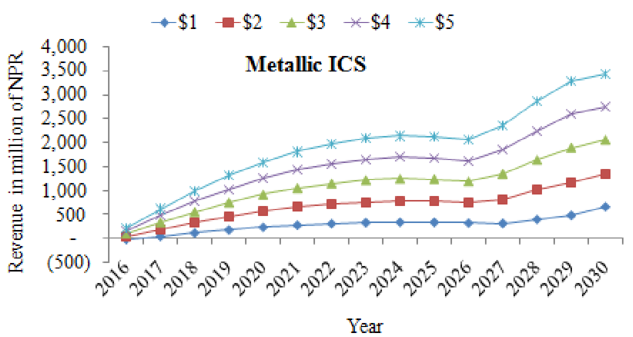

Figure 18: Revenue generation from Mud ICS

4. Conclusion

1. Form the research work it has been estimated that the total households in terai, hilly and mountain regions where ICS can be penetrated are 1,288,527; 1,114,967 and 307,966.
2. The thermal efficiency of general type of mud ICS, metallic ICS, metallic rocket and rice husk gasifier stove considered for the promotion scenarios are 20.32%, 20.07% , 22.77% and 36% respectively.
3. Under CDM, the calculation for 2016 shows total volume of emission reduction on promotion general type of ICS would be 4,162,170.41 tCO_{2e}.
4. Under intervention A, in terai region, by the year 2030 a total of 96,028,132; 107,125,603 and 128,426,683 tCO_{2e} GHG emission reduction can be achieved by using general Mud ICS, Rocket mud stove and rice husk Gasifer stove respectively.
5. Similarly, in hilly region, by the year 2030 a total of 76,599,852 and 80,728,485 tCO_{2e} GHG emission reduction can be achieved by using general Mud ICS and Rocket metallic stove respectively.
6. Under intervention A, for mountain region total 61,445,184 tCO_{2e} GHG emission reduction can be achieved by the year 2030 on promoting Metallic ICS.
7. Similarly, under intervention B which involves the shifting of fuelwood using households to LPG and other technologies as per the target of SDG7, total GHG emission reductions in terai, hilly and mountain regions by the year 2030 due to shifting of fuelwood using households to LPG has been estimated 21,473,517; 17,585,403 and 3,847,022 tCO_{2e} respectively.
8. Financial calculations show the revenue generation for the promotion of different ICS, for the different values of CER. It can be concluded that on achieving appropriate CER, there is optimistic possibility of promotion of intervention scenarios.

5. Recommendations

Further attempts can be done to increase the thermal efficiency of biomass cookstoves taking into account different affecting parameters like combustion chamber geometry and fabrication material. It would be more accurate and effective if cookstove promotion scenario has been analyzed in VDC wise. Emission reduction calculation and associated financial analysis can be done for the scenario of promotion of biogas, LPG and electricity as clean cooking technologies. Similar analysis can be done for other possible clean cooking technologies. This type of analysis can be done for the lighting sector in Nepal to explore the potentiality of market and non-market mechanism for this sector.

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