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SOCIO-ECONOMIC ANALYSIS OF TWO POT RAISED MUD IMPROVED COOKSTOVE IN THE CONTEXT OF NEPAL

HARI BAHADUR DARLAMI
Tribhuvan University, Institute of Engineering,Pulchwok Campus, Lalitpur, Nepal

SUVITA JHA
Kathford International College of Engineering and Management, Tribhuvan University, Nepal
National Basic School, Kathmandu, Nepal

BISHNU KUMARI BUDHA
Corresponding Email*: haridarlami@ioe.edu.np

ABSTRACT:

Biomass cookstove is extensively used for cooking and space heating in the rural area of Nepal. Its thermal efficiency and emission performance keeps prominence economically, socially and environmentally. Chimney operated two pot raised mud Improved Cookstove (ICS) is one of the most promoted cookstove in the context of Nepal. Benefit cost ratio has been found maximum for geometrically optimized best dimension cookstove and minimum for grate and insulation used cookstove in best dimension. Net benefit of cookstove has been increased with the grate and insulation. Marginal abatement cost of best dimension cookstove has been found minimum NPR. 445/tCO$_2$eq and maximum for the cookstove with the use all the accessories NPR 600 tCO$_2$eq. Best dimension cooostove has been found best rank from benefit cost ratio and abatement cost aspect. The goal of this study is to perform socio-economic and environmental analysis of the two pot raised mud ICS for four family members.

KEYWORDS: Cookstove, net benefit, benefit cost ratio, abatement cost

INTRODUCTION:

Biomass is one of the widely available renewable energy resources which is using for cooking and space heating purpose since long time. In the context of Nepal, 60.9% people are using fuelwood for cooking purpose [1]. Use of improved cookstove by improving thermal efficiency and combustion performance can reduce energy consumption, contribute to environment and improve human health [2]. Fuelwood consumption and subsequent environmental pollution can be reduced by improving the thermal efficiency of cookstove and through optimum use of biomass fuel [3].Till date around 1.3 million improved cookstove disseminated and about 2 million people are still using traditional cookstove in Nepal.

Thermal efficiency can be increased by using appropriate chimney [4,5], optimum combustion chamber height [6], optimum side opening (Sharma, 1993), appropriate interconnecting tunnel [7], better thermal properties and structural strength of combustion chamber [8] .

Use of grate has great importance for pre-heating of the air coming from the below grate. Ther air coming from below the grate, carries heat from the char and ash which results the better combustion and increases thermal efficiency [9]. Thermal efficiency of cookstove can be improved by 3% to 5% by using grate [10].

ICS have the ability to get carbon credits not only because of their contribution to climate-change mitigation but also they can yield major co-benefits in terms of energy access for the poor people. Besides,

they may result in improved rural health, environmental, agricultural and economic benefits [11].

Improved cook stoves focuses on the "triple benefits" such as in improved health and time savings, preservation of forests and associated ecosystem services, and in reducing emissions that contribute to global climate change [12].

The environmental benefit of the cookstove was assessed based on two metrics: locally from reduced deforestation and globally, attributable to reductions in carbon emissions [13]. Improved cookstove displacement of inefficient, polluting traditional stoves is critical to achieving health benefits [14]. During decision making with environmental aspect, emission-reduction targets need to decide which abatement measures to implement, and in which order [15].

There are different types cookstoves are promoting by keeping thermal efficiency. Its benefit cost analysis keeps importance economically and socially. The aim of this paper is perform socio-economic analysis of cookstove.

1. Materials and Methods

This includes fabrication of cookstove, its thermal efficiency test, calculation of fabrication and material cost, calculation of carbon emission reduction and social benefit analysis for different types of cookstoves.

Thermal efficiency of cookstove has been obtained by water boiling test. Fabrication cost, construction, material cost and accessories have been taken from local market cost, carbon reduction is calculated by using AMS II.G/v06 methodology and cost of carbon has been taken from current market rate. Thermal efficiency of the cookstove has been obtained by water boiling test at Renewable Energy Test Station, Khumaltar Lalitpur. Thermal efficiency of traditional cookstove has been taken 10% as per Methodology AMS-II G.

1.1 Emission reduction calculation

Emission reduction calculation for ICS is carried out by using the equation suggested by the AMS II.G/v06 methodology [16] for the estimation of GHGs emission reduction from the household biomass cookstoves is

$$\mathrm{ER_{y,i}} = \mathrm{B_{y,savings}} \times \mathrm{N_{y,i,a}} \times \frac{\mathrm{\mu_{y,i}}}{365} \times \mathrm{f_{NRB,y}} \times \mathrm{NCV_{NRB}} \times \mathrm{EF_{projectedfossilfuel}} - \mathrm{LE_y} \quad (1)$$

Where

$\mathrm{B_{y,savings,i,a}}$: Quantity of woody biomass saved in tons per cook stove device of type i and age in year y.

Fuelwood consumption per day for existing cookstove 1 and improved cookstove 2 can be calculated as

$\mathrm{N_{y,i,a}}$: Number of project devices of type i and age operating in year y

$\mathrm{\mu_{y,i}}$: Number of days of utilization of the project device during the year 'y'

$\mathrm{f_{NRB,y}}$: Fraction of woody biomass saved by the project activity in year y that can be established as non-renewable biomass using survey methods or government data or default country specific fraction of non-renewable woody biomass ($\mathrm{f_{NRB}}$) values available on CDM website.

$\mathrm{NCV_{NRB}}$: Net calorific value of the non-renewable woody biomass that is substituted (IPCC default for wood fuel, 0.015 TJ/ton, wet basis)

$\mathrm{EF_{projectedfossilfuel}}$: Emission factor for the substitution of non-renewable woody biomass by similar consumers (81.6 ton CO_2/ TJ).

LE_y: Leakage emissions in year y

a) Calculation of $B_{y\ saving}$

$$B_{y,savings} = B_{old} \times \left(1 - \frac{\eta_{old}}{\eta_{new,i,a=1} \times \Delta\eta_{y,i,a}}\right) \quad (2)$$

Where:

B_{old}: Quantity of woody biomass used in the absence of the project activity in tons per device

η_{old}: Efficiency of the device being replaced (fraction), determined using thermal efficiency of existing cookstove at optimum feeding

$\eta_{new,i,a=1}$: Thermal efficiency of the device of type i being deployed as a part of the project activity (fraction), using the Water Boiling Test (WBT) protocol

$\Delta\eta_{y,i,a}$: Factor to consider the efficiency loss of the project device type i due to its aging at the year y, as expressed as follows

$$\Delta\eta_{y,i,a} = \frac{\eta_{new,i,a}}{\eta_{new,i,a=1}} \quad (3)$$

Where

$\eta_{new,i,a}$ is thermal efficiency of device i with age determined using WBT and $\eta_{new,i,a=1}$ is the thermal efficiency of the device at its first year of operation

$\Delta\eta_{y,i,a}$ is be determined through sample surveys of the project device type i for batches of stoves with the same age at each year of crediting period.

B_{old} is determined as the product of the number of devices multiplied by the estimated average annual consumption of woody biomass per device (tons/year).

b) Default values of fraction of non-renewable biomass for Least Developed Countries and Small Island Developing States (version 01.0), $f_{NRB,y}$ = 0.86.

$$\text{Leakage emission } LE_y = \text{Total emission} \times (1 - \text{Leakage factor}) \quad (4)$$

Leakage factor = 0.95 (IPCC)

Assumptions

- ICSs installed are considered to be operational for 365 days in a year and consumers (households and institutions) are assumed to be using ICSs exclusively.
- Single number of ICSs per household has been considered.

1.2 Cost benefit analysis

Cost and benefit analysis has been done for decision making for the installation of Improved Cook Stove at different conditions. Cost benefit analysis has been performed for the three member household. This includes installation cost (sum of trained technician cost, material cost, the cost of grates and chimneys) and yearly maintenance. Benefit from cookstove use has been obtained by combination of the monetary value of fuel saving and carbon emission reduction from cookstove use. Marginal abatement cost of cookstove has been obtained and compared for cookstove fabricated with different dimensions and accessories.

RESULTS AND DISCUSSION:

Two pot raised cookstove has been fabricated as per Alternative Energy Promotion Center (AEPC) model. Mud mortar has been prepared for the preparation of bricks which is composed of 5/8 fraction clay or local mud, 2/8 fraction rice husk or saw dust and 1/8 fraction cow or buffalo dung by volume.

Table 1 Cost of cookstove at different fabrication condition

Particular	Cost of cookstove (NPR)	
	Initial	Yearly maintenance
a. TCS	1,000	100
b. Initial ICS	3,490	250
c. Best dimension	3,490	250
d. Best dimension with grate or insulation	3,790	250
e. With use of insulation, grate in best dimension	4,090	450

The experimental values of thermal efficiencies of cookstove are shown in Table 2. The efficiency of the modified cookstove has been found higher than the cookstove with initial dimension. Among the modified cookstoves, the efficiency of the cookstove with all the accessories has been found highest followed by the cookstove with grate or insulation and the cookstove with the best dimension.

Table 2 Thermal efficiencies of cookstove

S.N.	Fabrication condition	Thermal efficiency
1.	Initial ICS	17.9%
2.	Best dimension	22.4%
3.	With use of grate or insulation in best dimension	23.6%
4.	With use of insulation, grate in best dimension	24.7%

Table 3**Error! Not a valid bookmark self-reference.** presents emission reduction of the cookstove. Fuelwood consumption has been taken 2.5 kg per capita per day i.e 912 kg/year [17]. Now each traditional cookstove households are consuming 3.65 metric tonnes fuelwood per year for four family household. Market price of the carbon reduction has been obtained with the agreement between with AEPC for the cookstove 1.224tCO_2eq/ tonne [18].

Table 3 Emission reduction input parameter

Parameters	Value	Reference
Lifetime of a cookstove	3 years *	As per stakeholder consultation
Fuelwood consumption	3.650 ton/year	For 4 family members
Efficiency-Traditional cookstove	10%	Methodology AMS-II G
Efficiency of cookstove	As per table 2	
Market price of carbon	\$5/tCO_2eq	As per agreement with AEPC
Dollar exchange rate	1\$=NPR 117	January 30,2021
Efficiency derating factor ICS	10%	Assumption
Emission factor of fuelwood	1.224tCO_2eq/ tonne	IPCC rate [18]
Discount rate	6%	Assumption
Cost of fuel for hill area	NPR. 5000/tonne	Average market rate

* after three years cookstove should be repaired for full performance

Fuelwood consumption decreases with the modification of design of cookstove and use of for different accessories in the cookstove shown in Table 4. Fuelwood consumption will be reduced to one third with dimension optimization and use of accessories.

Table 4 Comparison of fuelwood consumption per household per year

Year	Total fuel consumption per at different fabrication condition (metric tonnes)				
	TCS	Initial dimension	Best dimension	Use of grate or insulation	With all accessories
I	3.65	2.03	1.63	1.55	1.48
II	3.65	2.25	1.81	1.72	1.64
III	3.65	2.50	2.01	1.91	1.82

With the use of ICS, fuelwood saving per household per year increases as shown in Table 5.This shows that fuel wood saving each year decreases due to 10% derating factor each year.

Fuelwood saving in initial dimension cookstove is low in comparison to other stove.

Table 5 Fuelwood saving trend per household per year in comparison with traditional cookstove

Year	Fuel saving for the use of cookstoves at different fabrication condition (Tonne)			
	Initial dimens-ion	Best dimension	Use of grate or insulation	With all accessories
I	1.62	2.021	2.10	2.17
II	1.40	1.839	1.93	2.01
III	1.15	1.638	1.74	1.83

With the use of ICS, emission reduction per household per year increases as shown in Table 6.

Table 6 Emission reduction per household per year

Year	ER (tCO_2 eq) with the use of fabrication condition cookstoves			
	Initial dimension	Best dimension	Use of grate or insulation	With all accessories
I	1.54	1.92	2.00	2.06
II	1.33	1.75	1.80	1.91
III	1.09	1.56	1.65	1.73

Net benefit and benefit cost ratio of cookstove are shown in Figure 1. Net benefit and benefit cost ratio of initial dimension cookstove has been found the lowest. So, modification on initial dimension cookstove keeps importance for both cost aspect and social aspect. Benefit cost ratio for the best dimension cookstove has been found the highest. In best dimension cookstove, it has been fabricated with dimension modification in the in the initial dimension cookstove. Trend of net benefit is in increasing and benefit cost ratio has been found decreasing with the use of grate and insulation. Main reason behind this that fuel saving during use of grate or insulating material in the combustion chamber is less in comparison to cost of accessories. For cookstove promotion decision, net cost benefit will be prominent factor. Modification on the cookstove have importance economically. Every improvements on the components have the financial value but its social benefit aspect may not improve.

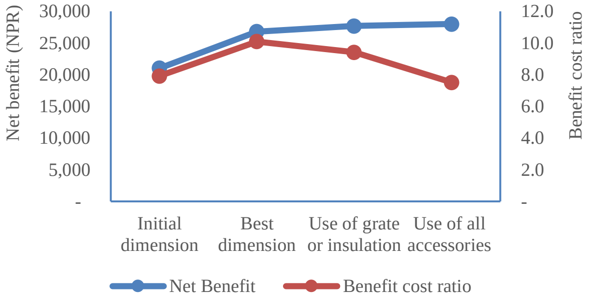

Figure 1Net benefit and benefit cost ratio

Marginal abatement cost of cookstove has been found lowest for the best dimension cookstove and the highest cookstove with use of insulation and grate for existing cookstove as shown in Figure 2. From environmental and cost view point, the best dimension cookstove has been found the highest ranking and cookstove with use of all accessories has been found the lowest ranking.

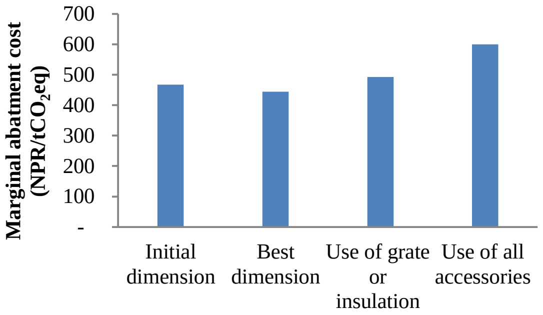

Figure 2 Marginal abatement cost due to efficiencies of different cookstove

From social benefit and marginal abatement aspect, the best dimension cookstove is in the highest rank. From economic view point, use of insulation and grate in the best dimension cookstove saves more fuel and money during its working period.

CONCLUSIONS

- The net benefit for initial dimension, best dimension, use of grate or insulation and use of all accessories cookstove for four family in the context of Nepal have been found NPR 21,040; NPR 26,801; NPR 27,678 and NPR 27,995, respectively. Net benefit of cookstove has been increased with the use accessories.

- Benefit cost ratio has been found maximum for best dimension cookstove i.e. 10.1 and minimum for the all the accessories used cookstove i.e. 7.5.
- Marginal abatement cost of best dimension cookstove has been found minimum NPR 445/tCO_2eq and maximum for the cookstove with the use all the accessories NPR 600 tCO_2eq.
- Best dimension cooostove has been found best rank from benefit cost ratio and abatement cost aspect.

REFERENCES:

1) C. Bureau and O. F. Statistics, “Annual household survey 2015/16,” vol. 16, 2016.
2) K. Smith, “Health,energy, and green house-gas impacts of biomass combustion in household stoves.Energy Sustainable Development 1994;1(4):239.,” 1994.
3) M. Sedighi and H. Salarian, “A comprehensive review of technical aspects of biomass cookstoves,” Renew. Sustain. Energy Rev., vol. 70, no. November 2016, pp. 656–665, 2017, doi: 10.1016/j.rser.2016.11.175.
4) J. Prapas, M. E. Baumgardner, A. J. Marchese, B. Willson, and M. DeFoort, “Influence of chimneys on combustion characteristics of buoyantly driven biomass stoves,” Energy Sustain. Dev., vol. 23, pp. 286–293, 2014, doi: 10.1016/j.esd.2014.08.007.
5) J. Agenbroad, M. DeFoort, A. Kirkpatrick, and C. Kreutzer, “A simplified model for understanding natural convection driven biomass cooking stoves-Part 2: With cook piece operation and the dimensionless form,” Energy Sustain. Dev., vol. 15, no. 2, pp. 169–175, 2011, doi: 10.1016/j.esd.2011.04.002.
6) P. K. K. Bussmann P., “Parameter analysis of a simple wood burning cook stove. In: Proceedings of M. Sedighi, H. Salarian Renewable and Sustainable Energy Reviews 70, 656–665 International Heat Transfer Conference. San Francisco; 1986 p. 3085–3090.,” 2017.
7) S. K. Sharma, “Improved Solid Biomass Burning Cookstoves: a Development Manual,” no. 44, Asia Regional Cookstove Programme and Energy Research Centre of Panjab University, Chandigarh, 1993, p. 125.
8) J. K. Kumar R, Lokras SS, “Development, analysis and dissemination of a three pan cook stove. Bangalore: Indian Institute of Science.,” 1990.
9) K. B. Sutar, S. Kohli, M. R. Ravi, and A. Ray, “Biomass cookstoves: A review of technical aspects,” Renew. Sustain. Energy Rev., vol. 41, pp. 1128–1166, 2015, doi: 10.1016/j.rser.2014.09.003.
10) P. Gusain, “Cooking energy in India. Development Alternatives, Vikas Publishing House Pvt. Ltd.;. New Delhi: India,” 1990.
11) J. Gill, “Improved stoves in developing countries. A critique,” Energy Policy, vol. 15, no. 2, pp. 135–144, 1987, doi: 10.1016/0301-4215(87)90121-2.
12) M. A. Jeuland and S. K. Pattanayak, “Benefits and costs of improved cookstoves: Assessing the implications of variability in health, forest and climate impacts,” PLoS One, vol. 7, no. 2, 2012, doi: 10.1371/journal.pone.0030338.
13) C. Barstow, R. Bluffstone, K. Silon, K. Linden, and E. Thomas, “A cost-benefit analysis of livelihood, environmental and health benefits of a large scale water filter and cookstove distribution in Rwanda,” Dev. Eng., vol. 4, p. 100043, 2019, doi: 10.1016/j.deveng.2019.100043.
14) A. Shankar et al., “Maximizing the benefits of improved cookstoves: Moving from

acquisition to correct and consistent use," Glob. Heal. Sci. Pract., vol. 2, no. 3, pp. 268–274, 2014, doi: 10.9745/GHSP-D-14-00060.

15) A. Vogt-Schilb, S. Hallegatte, and C. de Gouvello, "Marginal abatement cost curves and the quality of emission reductions: a case study on Brazil," Clim. Policy, vol. 15, no. 6, pp. 703–723, 2015, doi: 10.1080/14693062.2014.953908.

16) UNDP, "Nationally Appropriate Mitigation Action on Access to Clean Energy in Rural Kenya Through Innovative Market Based Solutions," p. 23, 2016.

17) K. Das, G. Pradhan, and S. Nonhebel, "Human energy and time spent by women using cooking energy systems: A case study of Nepal," Energy, vol. 182, pp. 493–501, 2019, doi: 10.1016/j.energy.2019.06.074.

18) IPCC, "No Title," 2006, [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/2006gl/.