Impact of a Rice Hull Stove on Fuel Expenditures and Greenhouse Gas Emissions in Rural Households in Negros Occidental, Philippines

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Introduction and objectives

The Philippine Agricultural Climate Change Project is a CIDA supported project aimed at eliminating field burning of sugarcane field residues and rice hulls. Its goal is to reduce greenhouse gas emissions and poverty through more effective use of these residues. An improved rice hull stove is being introduced into the Western Visayas region of the Philippines as a means to prevent field burning of rice hull. It is being used as a substitute fuel for rural households as a means to replace firewood and charcoal use. The adoption of an improved rice hull stove is projected to have a positive impact on the household economy and on the reduction of GHG emissions from the reduction in use of traditional cooking fuels. The objective of this study is to quantify the influence of the improved rice hull stove on household fuel use and expenditure, and on GHG emission mitigation. The study will seek to answer three main questions:

1. What is the impact of the rice hull stove on the use of other fuels for cooking (fuelwood, charcoal and LPG)?
2. How have household cooking expenditures changed after the acquisition of the rice hull stove?
3. What are the GHG emission reductions derived from substituting rice hull for other cooking fuels using the LT 2000 stove?

Fuel and energy models

The improved rice hull stove used in the survey, the LT-2000, was an improved version of the Lo Trau stove from Vietnam. None of the recently introduced Mayon Turbo Stoves were being used in communities at the time the survey was taken. A comparison of the types, quantities and costs of cooking fuels used by households before and after the acquisition of the LT 2000 stove was used to determine the fuel types rice hulls substituted for, the quantity of fuel replaced, and the change in cooking fuel expenditures.

The comparison was very simple (in mathematical terms) and encompassed data on types of fuel used, and on quantities and costs for each fuel both in Philippino Pesos and US dollars (at an exchange rate of 51:1). A time frame of one month was considered a reasonable period for households to report their fuel use and expenditures. An important assumption used in the analysis is that other factors affecting fuel use and expenditures remained constant before and after a household acquired a LT-2000 stove. The validity of the results of the analysis depends on the accuracy of this restriction.

Household energy use, energy cost, and GHG emission reductions were estimated utilizing the results on fuel use and expenditures as input for simplified models of cooking and GHG emissions. The model to estimate energy use and cost was based on the assumption that fuels have a uniform energy content and deliver heat output to the cooking pot with a uniform thermal efficiency. Energy content and thermal efficiency values for each fuel were obtained from the available literature (End Note 2). In the case of rice hull stove the thermal efficiency was estimated based on the amount of delivered energy it displaced from charcoal, firewood and LPG and the quantity of rice hull utilized.

The equation used in the analysis is:
household energy use/month (MJ) = Σ (fuel use (kg) x energy delivered (MJ/kg))
where Σ is the summation for all fuels (fuelwood, charcoal, LPG and rice hull).

GHG emission reductions were estimated using data collected for local fuel use and expenditures. The model that was used assumed that fuelwood and charcoal are harvested from renewable biomass, and that rice mills and farmers dispose of the rice hull by burning. CO_2 emissions from the combustion of biomass are not counted because growing plants sequester the carbon emitted as CO2. NO_x was also not included as data was not available. However, the other GHGs from biomass combustion (CH_4, N_2O, CO, & TNMOC) are included. Charcoal is a source of GHG, both when it is produced and when it is consumed. Kerosene is also accounted for as it is used as a firestarter by rural households. It should be noted that local data is preferred to IPCC default data, if it is properly referenced and documented.

The IPCC Sectoral Approach is a detailed GHG accounting methodology developed to help countries assess their national GHG inventories. It is also considered a standard methodology that can be applied to smaller projects. REAP proceeded with GHG calculations as follows:

Small-scale combustion of fuel is categorized by IPCC Reporting as a GHG Source (1-Energy, A-Fuel Combustion Activities, 4-Small Combustion, b-residential). The equation used to estimate GHG emission was:

$$E_i = (A_i - B_i) \times EF_I \times CR_i \times GWP_i$$

E = emission reduction (kg of CO2 equivalents)
A = amount of fuel consumed per month after the LT 2000 stove was acquired
B = amount of fuel consumed before
EF = Emission Factor (i.e. carbon mass pollutant / mass fuel)
CR = Conversion Ratio (i.e. Molecular Mass pollutant / Molecular Mass of carbon)
GWP = Global Warming Potential (over a 100-year time horizon)
i = fuel type.

Fuelwood and Charcoal Price Survey

A visit was made to local markets in Negros to assess the price of fuelwood and charcoal in urban markets and the trading weights of these commodities. No data was gathered in rural markets as prices were assessed from the survey of rural households using the stove.

The Household Survey

To obtain data on household fuel use and expenditures a survey was conducted among households that had acquired the LT 2000 stove by December 2001. The questionnaire had three sections. The first section gathered demographic data of the household. The second section obtained data on fuel types used, quantities consumed, and expenditures incurred per month both before and after the purchase of the LT 2000 stove. The final section collected user's feedback about the performance of the LT 2000 stove and alternatives to improve the marketing strategy (see End Note 1 for a copy of the questionnaire).

The selection of the sample was done following a two step process. First, the Province of Negros Occidental was divided into geographic zones. Second, the number of households was chosen according to the quantity of stoves distributed to each zone. Households were contacted by the marketing team during the marketing tour in each zone and asked whether they wanted to participate in the survey. The selection process was rather random, therefore the sample chosen is considered to be representative of the population of LT 2000 users. In December 2001 and January 2002, personal interviews were conducted by the PDG marketing team staff of 99 households mainly in rural upland areas of southern Negros Occidental.

The Results

Background information

Of the 99 responses collected, 86 were usable and were subsequently used for the final analysis. The average household buying a stove had 6 members, earned a total annual income of P38564 ($756 USD), had a per capita income of P7241 ($142 USD), and derived 53% or P20482 ($401 USD) from farming. The average income of users was lowest (data not shown) for those who were mainly firewood users (P36959 annual income) while those using LPG was highest at P51218. Those described as charcoal users (consuming more than two sacs, or approximately 30 kg per month) were also of a higher income bracket at P50700 of annual income. Nonetheless most charcoal users burnt firewood to meet a large part of their cooking fuel needs. Households in the Philippines tend to use several cooking methods for reasons of convenience and taste. LPG is sometimes used for convenience to ease the rural households ability to get children hot meals before they go off to school early in the morning. Charcoal is a preferred fuel for grilling chicken and fresh fish and often used in the rainy season as a primary or supplemental cooking fuel in rural areas because of problems of accessing dry fuelwood.

In Negros Occidental the rice hull stove has mainly been marketed to date in rural areas of southern Negros Occidental. As such, data was collected from a variety of markets to better understand local fuel pricing. The average cost of a sack of charcoal was 61 pesos (4.18p/kg) in rural areas (Table 1). The market study of urban markets indicated a higher price of 86 PhP (5.85p /kg) in urban areas. Firewood prices were on average 1.49p/kg in rural areas and 2.00p/kg in urban markets in Negros Occidental. These prices are in a similar price ratio of urban to rural, and firewood to charcoal, as the 1995 household survey (Table 2). The biofuel prices are lower today as the peso has depreciated from 25.7:1 USD (1995 average) to 51:1 USD (December 2001) in the past 6 years.

Overall rural prices are roughly about 1/3 rd less than urban markets owing to higher marketing and transport costs. In larger urban centres, firewood prices tend to increase more as the commodity is not as transportable as charcoal. It would appear that if rice hull would be accessible near urban areas it would be a highly effective at reducing household cooking costs.

Table 1. Price of Firewood and Charcoal in Rural and Urban Negros Occidental

Location	*Fuelwood (price in pesos/kg)*	*Charcoal (Price in pesos/kg)*
December 2001 PACCP Survey		
Negros Occ(Rural)	1.49	4.18
Kabankalan City (urban)	1.70	5.01
Hinigaran (urban)	Na	6.29
Pontevedra (urban)	2.19	6.35
Bago City (urban)	2.12	5.87
1995 Department of Energy Household Survey		
Western Visayas (Urban)	2.85 (1.44)	7.22 (3.64)
Western Visayas (Rural)	2.48 (1.25)	7.28 (3.67)
Philippine (Urban)	3.23 (1.63)	9.76 (4.93)
Philippine (Rural)	2.29 (1.15)	7.38 (3.73)

Note 1: figures in brackets are adjusted to a 2001 peso exchange rate versus the dollar.
Note 2. The average weight of a sac of charcoal was 14.7kg and the average weight of a bundle of firewood was 6.7kg. Firewood weights are generally more variable as they are often sold in 10 peso bundles.

Users' feedback on the Stove

Respondents were asked a series of questions regarding their experience with the LT 2000 to help improve understanding of the consumer acceptance of the stove (End Note 4). The majority of respondents (72%) had been using the stove for less than 6 months and expected the stove to last for at least 2 years (77%). All but one user considered their stove to be in good condition. On average, respondents used the LT 2000 to perform 76% of their cooking. Approximately half the users mentioned experiencing difficulties starting the fire. Smoke emissions and accessing fuel was also mentioned as problems by 12 % and 10 % of the users respectively. Controlling heat output and putting out the fire were also mentioned as problems by approximately 5% of users. Overall, LT 2000 users found the stove advantageous for heating up quickly, lowering fuel cost, and reducing smoke emissions compared to their previous cooking system. Stove owners thought that providing a user's manual with the stove and offering public demonstrations were the best ways to enhance the acceptance of the stove among potential consumers.

Fuel use and expenditure variation

The information about household fuel use and expenditures is summarized in Tables 2 and 3. The number of households using each fuel type and the average household fuel use indicate that the fuel switch happened mainly from fuelwood to rice hull. However, the rice hull stove appeared to be an effective substitute for the use of charcoal. Overall, consumption of firewood, charcoal, and LPG decreased by 73%, 76% and 46% respectively. The number of households using charcoal also declined by 65%, indicating that the rice hull stove is highly effective at reducing charcoal use for daily cooking needs. Poor upland families in Negros seldom enjoy fresh fish and chicken, which tend to be grilled with charcoal by wealthier families. In the case of LPG, the number of users and consumption decreased more moderately which indicates that these households enjoy the convenience of LPG for many cooking applications. A more convenient rice hull cooker could likely reduce LPG use further as there appears to be considerable savings from the switch.

In an average household, 143.5 kg of rice hull replaced 144.5 kg of fuelwood, 4.5 kg of charcoal and 0.6 kg of LPG on a monthly basis (Table 2). Thus a rice hull stove would be projected to save 1734 kg of firewood, 54 kg charcoal and 7.2 kg LPG on an annual basis.

Table 2. Impact of the Rice Hull Stove on Fuel use Patterns/month

. Statistic		Before	After
Number of households using	fuelwood (buyers)	39	30
	fuelwood (gatherers)	42	24
	charcoal	20	7
	LPG	11	7
	rice hull	-	86
Average fuel use:	fuelwood	199.9 kg	55.4 kg
	charcoal	5.9 kg	1.4 kg
	LPG	1.3 kg	0.7 kg
	rice hull	-	143.5 kg

An estimate of the rice hull cooker use efficiency was made of 13%. This was based on the assumption that the total amount of delivered energy used before and after the introduction of the rice hull cooker remained the same.

According to the survey prior to introduction of the stove. Households were using an estimated 4656 MJ/year of energy given the average fuel consumption and estimated thermal efficiencies of energy use of 10.25%, 15% and 60% for fuelwood, charcoal and LPG respectively. This quantity of energy was 46% higher than the estimate used in a previous analysis (3170MJ) of household energy use for cooking in the Philippines (Samson et al 2001). This may be explained by the fact that low income upland Negros families are on average larger than the national average, that a major group of the energy users was fuelwood gatherers (as they do not pay for their fuel, they may not restrain their fuel consumption) and that some of the fuel gatherers also use firewood for cooking pig feed (primarily kangkong a leafy vegetable). This initial fuel and energy survey did not fully allow for distinguishing fuelwood consumption between the buyers, gatherers and households who met there fuelwood needs by both buying and gathering. However, the data indicated on a yearly basis those only gathering used on average 2945 of fuelwood compared to 2119 kg used by buyers, and that the former consumed 21% more energy for cooking than the latter.

Economic Impacts from the Introduction of the Rice Hull Stove

Average total cooking cost fell by 63% when using the LT 2000 stove (Table 3). The drop is explained by the low cost of rice hull, which can be obtained for free from rice mills and transported for a low price. Using the LT 2000, households saved on average $1.87 per month on cooking fuel and firestarter costs. Firestarter represented 11% of the savings. Assuming that cooking costs remain constant throughout the year, the monthly savings were extrapolated to $22.41 per year. Households cooking with the LT 2000 saved at least 33% (compared to gathered fuelwood) and as much as 96 % (compared to charcoal). Rice hull cooking is less expensive than gathered fuelwood for cooking because paper is primarily used for firestarting with rice hull. In the case of fuelwood, it is commonly ignited with kerosene.

Table 3. Effect of Introduction of a Rice Hull Stove on Fuel Expenditures/year

. Statistics	Before	After
Average total fuel cost	P 1631 ($31.98)	P 593 ($11.62)
Average fire starter cost	P 184 ($3.60)	P 79 ($1.55)
Average total cooking cost	P 1814 ($35.58)	P 672 ($13.17)

Estimated Annual Costs of Various Purchased Fuel Systems

The annualized cost of cooking represents the annual fuel costs for operating a stove and the annual cost of the stove over its given lifespan. Stove costs were obtained through a market assessment in Kabankalan, Negros Occidental, during December 2001. Annual stove costs were determined using an annuity formula. The interest rate used was the average lending rate published by the Central Bank of the Philippines. Stove lifetimes were assumed to be 6 years for an LPG stove, 1 year for a charcoal stove, and 3 years for the LT 2000 stove.

A greater difficulty in assessing differences between the annualized cooking costs between the various cooking systems were the aforementioned differences in the amount of energy used per household by fuelwood gatherers and purchasers. As such for this analysis, comparisons are only made between purchased fuel systems. We assume all purchased fuel systems use the same amount of delivered energy as fuelwood buyers. Thus the average household energy required is the equivalent of 2119kg of fuelwood, 826 kg charcoal and 127 kg LPG based on thermal efficiencies of 10.25%, 15% and 60% for fuelwood, charcoal and LPG. Rice hull was estimated at 2031 kg of fuel based on a thermal efficiency of 13%. These values are similar to the 1995 Household energy consumption survey for fuelwood (2022 kg in rural households having an income <P60,000 P), and LPG (national average of 116 kg and a rural average of 106).

Annual cooking cost

The results are presented in Table 4 and Figure 2. LPG annual cost is the highest ($77.32), which is partly explained by high fuel price and partly by high stove price. Stove cost is very low in Negros for households cooking with fuelwood and charcoal, because they use very cheap and simple clay stoves or improvised stone and iron bar stoves (Samson et al 2001). The annual cost of firewood and charcoal cooking systems were very similar at $61.98 and $67.54. The annual cost of cooking with rice hull ($4.87) is divided in almost equal parts between fuel consumption ($1.95) and stove cost ($2.92).

Overall, the cost of cooking with a rice hull cooker is projected to reduce household cooking costs by 92-94%. Cooking with a rice hull cooker was similar to fuelwood gatherers (data not shown), who experienced an annual cost of ($2.73) for kerosene consumption[1]. These results show that households cooking with rice hull can save $57.11, $62.67 and $72.45 per year, compared to purchasing LPG, fuelwood and charcoal respectively. It should be noted that the analysis assumed all the cooking is done with the selected fuel. Therefore, the savings calculated apply to households that switch from cooking exclusively with LPG, fuelwood or charcoal, to

[1] The annual cost of gathered fuelwood corresponds to the cost of fire starter. The annual cost of rice hull includes transportation and fire starter costs.

cooking exclusively with rice hull. However, this is not always the case. For example, the survey done in Negros Occidental indicated that households generally use a mix of cooking fuels. Many households partially switched to using rice hull but still continued cooking with other fuels.

Table 4. Estimates of Annualized cooking costs for various primary fuel cooking options available in Negros Occidental

	LPG	Fuelwood buyers	Charcoal	Rice Hull
Cost of fuel per year[c]	62.25	61.98	67.21	1.95
Annual cost of Stove[d]	15.07	0.00	0.33	2.92
Total Cost (US$) [e]	**77.32**	**61.98**	**67.54**	**4.87**

Assumptions:

1) The cost of equipment was annualized considering their expected life-span and using an average of the lending interest rates published by the Central Bank of the Philippines.
2) Cooking equipment life-span: LPG (6 years), charcoal (1 year), rice hull (3 years).
3) Stove prices are market prices in Negros Occidental (December 2001): LPG and tank (P3015), charcoal (P15), rice hull (P350).
4) Fuel consumption for LPG and charcoal was estimated at 127 kg and 826 kg (Samson et al 2001). These consumption estimates were based on the estimated fuel conversion efficiencies of these fuels in comparison to wood. The baseline of wood fuel purchased was 2119 kg/yr with an efficiency of 9.5%. The efficiency of rice hull use was estimated to be 13% and 2031 kg were consumed.
5) Fuel prices were calculated from the survey of households in Negros Occidental: LPG (25PhP/kg), purchased fuelwood (1.49PhP/kg), gathered fuelwood (almost zero, it includes only fire starter cost), charcoal ($4.18 USD/kg), and rice hull (almost zero, it includes transportation and fire starter costs).

The cost estimates of the various cooking systems differ somewhat from those obtained by Samson et al (2001) (with the exception of LPG) mainly due to the devaluation of the peso that has dropped the value of charcoal and firewood when converted into US dollars. However, the actual cost of operating a rice hull stove was only $4.87 USD/year compared to the estimated $17.56 USD in the aforementioned study. This low cost was due to rice hulls being freely available, as well as a lower stove cost than projected. Overall, it appears an improved rice hull cooker has significant potential to reduce cooking costs compared to the alternative purchased cooking systems presently in use.

Impact on greenhouse gases emission

Table 5 shows that each household using the LT 2000 stove reduced direct GHG emissions by 487.8 kg of CO_2 equiv/year and indirect GHG emissions by 493.9 kg CO_2 equiv/year, for a total of 981.7 kg CO_2 equiv/year. The main source of emission reduction was the decrease in the use of fuelwood. Charcoal had a relatively large contribution because of the high GWC coefficient that includes both its production and consumption. Kerosene for fire starter offered similar abatement possibilities as LPG.

Table 5. Impact of the LT-2000 Rice Hull Stove on GHG Emissions

Fuel	Before (kg)	After (kg)	Fuel Use Reduction (kg)	Greenhouse Gas Emission Reductions (kg CO2 equiv)					GWC*
				CO2	CH4	N2O	CO	TNMOC	
Fuelwood	2398.8	664.8	1734	0	243.75	150.17	216.39	152.78	0.44
Charcoal	70.8	16.8	54	0	43.36	10.54	53.48	68.65	3.26
LPG	15.6	8.4	7.2	22.21	0.01	0.73	0.22	1.35	3.41
Kerosene	10.32	3.48	6.84	16.69	0.04	0.30	0.19	0.82	2.64
				Direct GHG = 487.8			Indirect GHG = 493.9		
				Total GHG Emissions = 981.7 kg CO2 Equiv per year					

*Global Warming Commitment = kg CO2 Equiv per kg of fuel

There are also other areas for further investigation. The assumption that rice mills and farmers burn the rice hull needs verification. A survey of a representative sample of rice mills and farmers would achieve this objective. In addition, GHG emissions from burning rice hull needs to be determined for the stoves. There is also evidence that fuelwood and charcoal are not sustainably harvested at present exploitation rates in the Western Visayas. If this is the case, substituting rice hull for these fuels would have an important influence on CO2 emissions particularly if it helped lead to afforestation.

Conclusions

The largest absolute impact from introducing the LT 2000 was a drop in fuelwood consumption. The average rice hull stove was found to save 1734 kg of firewood, 54 kg charcoal and 7.2 kg LPG per year in fuel. However, in relative terms, charcoal consumption suffered the biggest reduction in usage. Households using charcoal for cooking fell by 65% and charcoal consumption decreased by more than 76%. This result is consistent with the concept of the energy ladder[2]. Rice hull is a better substitute of fuelwood and charcoal than it is of LPG. LT 2000 users displaced 73% of the energy used for household cooking and made significant household savings even though many households that adopted the stove are fuelwood gatherers. On the average, households adopting the rice hull stove saved P1078 ($21.13 USD) per year if fuel expenditures and stove costs are included. This savings of 1078 pesos represents an average savings of about 2.8% of total household income. Annualized cooking cost estimates of purchased fuel systems (using only one fuel for all cooking requirements) found cooking with a rice hull stove to be 248 PhP ($4.87 USD) or 92-94% cheaper than using LPG (3943 PhP or $77.32 USD), charcoal (3444 PhP or $67.54 USD) and firewood (3160 PhP or $61.98 USD). This savings would represent 7.6% to 10.4% of the total average household income. Finally, an average household adopting the rice hull stove was able to reduce their emission of GHG by 982 kg of CO_2

[2] The energy ladder is an imaginary ladder whose steps are occupied by the different cooking fuels. Agricultural waste and fuelwood occupy the lower steps, whereas LPG and electricity occupy the highest steps.

equiv./year. The decrease in emissions came mainly from the substitution of fuelwood for rice hull. The potential for inaccurate estimates of fuel consumption and expenditure from respondents is an important limitation to the study. Future surveys will attempt to improve on the methodology used in the current study. An improved rice hull stove, The Mayon Turbo, has superseded the LT 2000 in the Western Visayas and will be used for these surveys.

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