STOVES ON THE CARBON MARKET[*]

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ABSTRACT
It is explored how programmes for introducing (improved) woodstoves can be justified in terms of greenhouse gas reduction at competitive cost. The discussion is put in the context of real life observations in Asia and alternative justifications for stove programmes. A few options for putting stoves on the international 'carbon market' are briefly analysed. Tentative results show that a stove project could well result in reduction of CO2 emission at a cost of less than 2 US$/ton.

HISTORY OF STOVE PROMOTION

Improved stoves have been promoted more or less systematically since the late 1970's. Amulya Reddy's work on the 'hidden energy crises' in rural India has done a lot to alert donors, NGO's and even governments. In the same period (1975) World Watch came with its alarming report on deforestation which was assumed to be caused by fuelwood use. Hence, stove promotion efforts focused entirely on efficiency improvements, which was supposed to help the stove users and save the world forests. Interesting results were obtained in the laboratories, e.g. Krishna Prasad's group at Eindhoven University. For instance, they showed that a more efficient stove could still result in consuming more fuel (because of poor turn-down ratio). At Twente University we coined the statement that 'designing an improved stove is easier than designing an improved user of the stove'.

In the early 1980's Pandey and Smith came up with the health implications of stoves in traditional kitchens. The comparison with 'smoking 20 packets of cigarettes a day' was a message everybody could understand. Still, we have the impression that the message was not fully taken by the stove world. Soon after, other aspects received a lot of attention in international stove programmes like the ones supported by ITDG, GTZ and other organisations. These aspects focused on e.g. user convenience, gender, and strategies for implementation for instance by linking with village woodlots etc.

Generally, we know of more stove programmes which failed or were only partly successful, than success stories. International donors became a little bit tired of stove programmes, although some stayed on board. Inspired by the compelling results of Pandey and Smith, RWEDP has tried to actively pursue the health aspects along with gender issues.

PRESENT STOVE SITUATION

We can safely state that the majority of the world's households using woodfuel still lack a proper stove. How come? Our wild guess is that the money and brains spent for rural electrification is at least a thousand times more than the money and brains spent for improved stoves, or stoves at all. It is definitely not a matter of money only. The key issue is that electricity has far more powerful stakeholders than woodstoves. Apparently, we don't have the brains to overcome that! Rather than aiming at an overview of today's stove situation, I like to share some specific observations.

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In India, the Ministry of Non-Conventional Energy Sources (MNES) recently informed us that in their stove programmes priority is now given to women's health aspects rather than to efficiency. That means only stoves with chimneys are being promoted even when that sacrifices efficiency. Also extensive gender training was taken up.

In Vietnam, the Institute of Energy has developed a stove for rice straw. It is being successfully introduced by the Women's Organization. The beauty of the stove is that it combines increased efficiency (30%) with safety and health. Dry straw is highly flammable and when a proper stove was lacking, windows were kept closed to avoid wind entering the kitchen. Now, even poor farmers buy the stoves for cash. They are very much aware of the fuel savings which cuts expenses for buying fuel, and they enjoy the fresh air.

In Laos until one and a half year ago, virtually nobody in rural areas had a stove. People used simple tripods. Thanks to the Participatory Development and Training Center (PADETC), stoves are being introduced at a rate of more than 15,000 a year. The stoves save about 30% fuel and people buy them for cash. Many of the users appreciate the time saved for fuelwood collection, which they can now apply for productive work in cottage industries. In terms of CO2 saving for the atmosphere, the equivalence of the woodfuel saving by this stove programme would be closing down a 5 MW fossil fuel power plant.

Numerous North-American households use woodstoves for their main daily space heating needs. It is hardly known that per capita woodfuel consumption in North America is about the same as in South Asia [Hulscher, 1997]. One third of all that wood energy in North America is used in the domestic sector. The households avail of proper stove technology and the kitchens are not really smoky.

COMMON MISCONCEPTIONS ABOUT WOOD ENERGY

Deforestation?

It is still assumed by many that woodfuel use is the main or general cause of deforestation. The assumption is inherited from the 'fuelwood gap theory' which assumed that all woodfuel was derived from forests. By know we know that roughly 2/3 of all fuelwood in Asia does not come from forests but rather from agriculture land, which fills the presumed gap. However, the assumption may still be welcome to illegal loggers and their accomplices as an alibi. RWEDP is trying to fight this misconception [RWEDP, 1997].

Dirty?

Many people consider wood a dirty fuel. They have in mind the dirty kitchens and dirty hands. Gas and oil products are considered clean fuels. I do not agree. When I am in a street in Bangkok behind an old truck, I do not particularly think of diesel as a clean fuel. The point is that not the fuel is dirty or clean, it is the technology which makes the difference. Woodfuel with proper technology is clean.

Traditional/modern

Wood and other biomass energy technology is often described as either traditional or modern. This is misleading, because all sorts of technologies exist in between the two extremes. This applies to the domestic as well as the industrial sector.

Trapped in poverty?

It is widely assumed that people turn away from woodfuel when their income rises. This assumption is even fuelled by Worldbank reports, substantiated by misleading information. We can read slogans like 'biomass fuel traps people in poverty'. As already mentioned, per capita North America uses as much biomass energy as South Asia, whereas its per capita income is 40 times higher. Data from Thailand show that woodfuel use per capita increased by 68% in a period of 16 years when incomes tripled [Hulscher, 1997].

Sustainability and emissions

Some people believe that using woodfuel always adds to emissions, because they overlook the re-growth of woodfuel. That is obviously wrong. What counts is the net emission of the total woodfuel cycle. It matters whether that cycle is sustainable, which means re-growth is at least as much as use. If the cycle is not sustainable, saving woodfuel, e.g. by using an improved stove, reduces net emissions. However, if the cycle is sustainable, saving woodfuel by an improved stove will not necessarily reduce net emissions, because the surplus wood will decompose by natural processes. Decomposition also results in emission of greenhouse gas (mainly CO2). For the actual emissions, also the degree of completeness of the combustion plays a role.

Our home garden

Even though gases diffuse world wide in the global atmosphere, sustainability is a concept applicable to localised areas. The reason is that woodfuel is not being shipped the world round, but rather stays within an area of, say, 20 km in diameter, or even less. Think of a home garden as the prime source of woodfuel, which is common in Bangladesh, Sri Lanka, Java and elsewhere. If the owner cuts a tree, space becomes available for a new tree to grow. If she cuts more than can re-grow in the home garden, the cycle is not sustainable. If she cuts less, the surplus wood will eventually die, decompose and emit greenhouse gases anyway. In the latter case, woodfuel use is sustainable and saving woodfuel would not necessarily matter for world climate. Hence, planet earth is our common home garden in terms of greenhouse gases, but not in terms of woodfuel supplies!

JUSTIFICATION OF STOVE PROGRAMMES

The studies of Natarajan [Natarajan, 1999] of the National Council of Applied Economic Research (NCAER) in India show that the improved stove programmes in India have an economic return on investment of more than 200%. The calculations account solely for estimated consumer benefits in terms of fuel saving and producer benefits in terms of additional employment, leaving aside benefits of saved time, improved health and reduced greenhouse gas emissions. Still, the stove programmes are not considered successful. In a financial analysis from the user's point of view, the return on investment is negative because the users do not value fuel saving. It has been estimated [Venkata, 1999] that less than 1% of the total fuelwood used in India has been saved as a result of disseminating 23 million improved stoves in the last 16 years by the National Programme.

The studies of Wang and Smith [Wang & Smith, 1998] show that improving domestic energy is cost effective entirely based on health benefits. Additional benefits for greenhouse gas reduction are extra.

The example from the successful programme in Laos and elsewhere shows that under certain conditions improved stoves can pay for themselves in terms of time saved. Basically, fuelwood is still abundant in most places in Laos, but collecting it takes time. That time is more profitable when used for making handicrafts.

We observe that, depending on local conditions, stove programmes can be economic on three different and independent grounds, leaving aside additional grounds: fuel saving, health benefits, and time saving. Our question is now: Can a stove programme also be economic in terms of reducing greenhouse gases? Two years ago RWEDP has estimated [RWEDP, 1997] that woodfuel users in Asia save some 600 million ton of CO2 annually for the world community, by not using coal as an (hypothetical) alternative household fuel. Can we translate such information into a stove programme?

The important lessons from India and elsewhere have been that a stove programme in order to be self-propelling, requires personal benefits for the users which are being clearly perceived and appreciated by them. The (only?) alternative could be systematic interventions and/or campaigning for the sake of public interest. This is relevant for a 'greenhouse stove programme', as the target groups may not perceive world climate as a personal benefit.

CASES ON STOVES FOR GREENHOUSE MITIGATION

Five different cases are analysed for proposing stove programmes on the carbon market. All cases are based on existing technologies, i.e. available stoves. New and highly relevant cases could arise when stove designs will be developed purposely for emission reduction [Grover, 1999].

Case I: Improved fuelwood stove under conditions of woodfuel scarcity (Thailand)

This case applies to an area where domestic woodfuel use is not entirely sustainable, now or in the near future. That means more woodfuel is consumed than actually will re-grow in the area. This may apply, for instance to North-east Thailand, Nepal, Pakistan, and parts of Myanmar and Vietnam. Here, data from Thailand are used to analyse the case. For Thailand, fuel consumption data have been measured in detail, though emission data of wood stoves are not yet fully known.

Woodfuels are widely used in Thailand and consumption is still increasing. The 'traditional stove' represents an average of the common Thai bucket stoves based on fuelwood, which costs about 1.5 US$ and has an average efficiency of 19.8%. Far less popular is the improved bucket stove (model RFD-2), even though it has an average efficiency of 28.7%, because it costs 4 US$ and the potential user may not fully understand or appreciate its economies. However, it has been observed that users generally stick to the improved stove once they have experienced its benefits. Our exercise aims to analyse the costs and benefits of the improved fuelwood stove in terms of greenhouse gas saving. Thus, the marginal costs of the improved stove are to be charged to the greenhouse beneficiary (the 'carbon buyer' in a scenario of emission trading) and not to the user of the stove. Emissions of CO2, CO and CH4 have been measured for the improved Thai wood stove [Bhattacharya, 1999], but not for the traditional one. For the latter, data from Philippine stoves have been used [Smith, et al, 1991]. Emissions of N2O and TNMOC are not known and no impact difference has been assumed for the two stoves.

With the named assumptions, the results (Annex 2.I) show that the cost of the improved Thai bucket stove is justified by greenhouse gas savings when we attach a value of 0.8 US$ to a ton of CO2 saved from the atmosphere. Note that programme costs have not yet been included in the estimate.

Case II: Improved fuelwood stove under conditions of woodfuel scarcity (India)

This case is similar to Case I, but it is based on a more complete set of emission data for the stove under consideration [Smith, et al, 1999]. However, woodfuel consumption data are not available, and an assumption had to be made. For the assumption a conservative estimate has been taken, based on consumption data from Thailand. The result (Annex 2.II) shows a CO2 reduction cost of 1.2 US$/ton. Note that programme costs have not yet been included in the estimate.

Case III: Improved fuelwood stove under sustainable woodfuel use (India)

This case applies to areas where domestic woodfuel is used on a sustainable basis. That means as much wood re-grows as is being used as fuel, and any woodfuel being saved in that area would be left to decompose naturally, which process implies emitting CO2 anyway. So, in terms of CO2 there would be no gain from woodfuel saving and in the calculation no allowance is made for that. This situation applies to most areas in Asia, and may be elsewhere. It means that, as different from Case I and II, no greenhouse benefits are obtained from CO2 saving. The benefits are only from the reduction of other greenhouse gases, which in this case are the same as for case II. Like in case II, emission data are known, though for the consumption estimates had to be made. The results (Annex 2.III) show a CO2 reduction cost of 1.7 US$/ton. Note that programme costs have not yet been included in the estimate.

Case IV: Improved charcoal stove under sustainable woodfuel use (Thailand)

This case is similar to case I, though applied to charcoal rather than fuelwood. It is based on a more complete set of emission data for the charcoal fuel. A (conservative) estimate for the fuel consumption has been made. The results (Annex 2.IV) show a CO2 reduction cost of 1.2 US$/ton. Note that programme costs have not yet been included in the estimate.

Case V: Substitution of coal by sustainable fuelwood (China)

This case applies to an area where people use coal as a domestic fuel, particularly where the coal is of poor quality and largely consists of fines. Hence, users could be interested in switching to woodfuel. This may apply to certain areas in China, India and Vietnam. In China, the option may go along with policies to re-afforestate upstream river areas in order to prevent erosion and flooding. The case is based on woodfuel costs from a sustainable plantation [Hall, et al, 1993]. Emission data for both the coal and wood stoves are known [Zhang, et al, 1999] though estimates had to be made for the fuel consumption.

The results (Annex 2.V) show a negative cost for CO2 reduction of 4.8 US$/ton CO2 by the substitution, because wood as a fuel is cheaper than coal, whereas the stove prices are the same for wood and coal. The exact result would further depend on local conditions for the plantation. One-time carbon sequestration by the growing trees will add to the benefit. For a detailed calculation, the emissions from woodfuel harvesting and processing versus coal mining and processing should also be taken into account. Note that programme costs have not yet been included in the estimate.

Summary of cases

Case	improvement	supply	example	CO2 red. Ton/ lifetime	CO2 red. $/Ton
I	wood stove	scarce	Thailand	3.0	0.8
II	wood stove	scarce	India	4.3	1.2
III	wood stove	sustainable	India	3.0	1.7
IV	charcoal stove	sustainable	Thailand	2.9	1.2
V	wood for coal	sustainable	China	1.8	-4.8

DISCUSSION OF OPTIONS

The above cases show that wood stove programmes can help reduce greenhouse gases at basic costs of less than 1.7 US$/ton CO2 (apart from programme costs). More detailed estimates can be made, and also the overhead costs of a stove programme should be accounted for. The basic results are quite attractive under current market conditions, as many greenhouse projects are being undertaken at costs of 5US$/ton CO2 and more. Hence, it is found that woodstove programmes can be economic on four different and independent arguments, as summarised below. Of course, all arguments 1-4 can be put together to make an even stronger case. Different stove promoters (e.g. governments, NGOs, donor countries) may be interested in different combinations of arguments. Some donors may even be interested in the full set of justifications.

1) fuel saving

The fuel saving argument will work in area's where users pay money for the fuel they need (cf. the rice straw stoves in Vietnam). It would still require dedicated efforts from local organisations to overcome initial barriers.

2) time saving

The time saving argument will work in area's where users value their time, e.g. for income earning opportunities. Again, efforts from local organisations will be necessary to overcome initial barriers.

3) health benefits
The health saving argument would need internalising external benefits (health) into domestic energy programmes. This requires estimating benefits in economic terms as well as raising awareness amongst governments, international organisations, etc.

4) greenhouse gas saving
The greenhouse gas saving argument opens up a new approach to stove programmes. The argument is promising because the need for internalisation of externalities (global climate change) is being accepted in energy portfolio's. Some Annex 1 countries of the Kyoto Protocol have already voluntary engaged in pilot projects and/or Activities Implemented Jointly (AIJ) at CO2 reduction costs of 5US$/ton and more [VROM, 1998]. In the current dynamic market for CO2 reduction costs it can be attractive to opt for a reduction project of short duration. A woodstove project would basically have a duration of only 2 years (apart from preparation and evaluation time), whereas many other greenhouse projects, including e.g. biogas projects, need a duration of 15 years or more.

OUTLINE OF A STOVE PROJECT FOR THE CARBON MARKET

Some industrialised countries have already engaged in Activities Implemented Jointly (AIJ) in order to gain experience and/or prepare for international carbon trading, Clean Development Mechanism (CDM), etc. A greenhouse project for, say, 1 million improved stoves could be proposed for such interest. A ‘greenhouse stove project’ will differ from conventional stove projects in the sense that the criteria for success do not include development objectives, sustainability, etc, though they may be very much appreciated as additional benefits. Rather, the only criterion for success is that the households do use the improved stoves during the agreed period.

Here, a project is designed according to Case I above, for Thailand as an example. Common wood and charcoal stoves are already widely bought in this country, but the main barrier to the introduction of improved stoves is the cash requirement. At this point the greenhouse funding should come in. The target area may be North-east Thailand which is relatively poor. Thailand's Department of Energy Development and Promotion (DEDP) wishes to introduce 5 million improved stoves anyway, but it may not have the means to implement that. The greenhouse stove project would then consist of the following activities.

0) <u>Preparatory measurements</u>
Emissions of traditional stoves must be measured in laboratory tests, and for the improved stove the emission data must be complemented with N2O and TNMOC. The test results will imply a go/no-go for the project. The testing could be completed within three months by one person. Checks should be made on the role of CO2 in the overall GWP, in order to establish to what extend the case would depend on sustainability of the woodfuel. It is anticipated that in any case greenhouse benefits can be achieved at a cost of maximum 1.6 US$/ton CO2 equivalent, whether or not the woodfuel supply conditions are sustainable (cf. the results of both case I and IV above).

1) <u>Defining the baseline situation</u>.
Proper sampling methods must be designed and implemented in order to define the baseline in terms of current stove use and emissions. Emission measurement techniques must be applied. Time period required about 6 months by two experts.

2) <u>Design of method for production and dissemination of improved stoves</u>.
Generally, energy subsidies are not what one wants to advocate (though in most countries they are still being provided to fossil fuel based energy). However, an option for implementing the greenhouse stove programme would be to compensate the stove producers for the extra costs of producing an improved stove (2.5 US$ per stove extra) so that they can be marketed for the same price as the common stoves. Hence, a way of implementing the stove programme is to come to agreements with the stove manufacturers. Currently, the manufacturers are not really interested in producing improved stoves, because these are hard to sell for the price of 4 US$. The agreement should imply that the manufacturer is compensated the equivalence of 2.5 US$ out of the project budget for each improved wood stove which he produces and sells for the old price of

1.5 US$. One way of implementing the compensation to the stove manufacturers can be to not pay in cash but rather in the form of supplying the stove metal encapsulation. The encapsulation represents a big share of the extra stove production costs. The encapsulation could be labelled so as to be identifiable for the buyers.

The agreement with the manufacturers could further imply that the manufacturer stops producing the old wood stoves. Virtually all major stove manufacturers in the region (about 50) will have to be addressed. The majority of them already avail of the skills to produce the improved stoves, but some may need additional training. Awareness and information campaigns to the general public, explaining the benefits of a labelled stove, can further support the actions. The activities indicated for this stage of the project may require 9 months for 3 experts.

3) <u>Starting up production and marketing</u> of 1 million wood stoves may take a period of 6 months. In this period, records and regular checks have to be made by 3 project experts.

4) <u>Utilising the stoves</u> is to be for a period of (at least) 2 years. In this period, which can start at the same time as the previous stage, records and regular checks have to be made by 3 project experts.

5) <u>Measuring the results</u> of the project in terms of stove use and emissions, again, should be done by taking proper samples in the area of dissemination of the improved stoves. It may be realistic to not aim for a success rate of 100% but rather, say, 75%. Two experts will be needed for up to 2 years after completion of the previous stage of the project.

Hence, the project for 1 million improved wood stoves would take about 5 years in total. The budget can be estimated as follows. The extra cost of improved wood stove production is set at 2.5 million US$ (1 million times 2.5 US$). A success rate of 75% will be targeted. The project costs include 180 expert months, as well as an operational budget for training, travels and publication campaigns (see Annex 3). These project costs may be estimated at 0.8 million US. The total project for 1 million stoves would then cost 3.3 million US$. The CO2 saving can be estimated as 750,000 times 3.0 ton per stove during its lifetime, which is 2.25 million ton. The CO2 reduction costs, including the full programme costs, will then be 3.3/2.25=1.5 <u>US$/ton</u>.

CONCLUSION

A woodfuel stove project could well be put on the international 'carbon market' at competitive cost for greenhouse gas emission reduction. As an example, a project for introduction of 1 million improved bucket stoves in North-east Thailand in order to save 2.3 million ton of CO2 could be implemented in about 5 years at a total cost of about 3.3 million US$. This will result in a cost of <u>1.5 US$/ton CO2 reduction</u>. Other projects at acceptable CO2 reduction costs can also be feasible, like substituting existing coal stoves by wood stoves. New and highly relevant cases could arise when stove designs will be developed purposely for emission reduction.

REFERENCES

Bhattacharya, S. C., et al, 1999, *Emissions from Biomass Energy Use in Some Selected Asian Countries* (forthcoming)

Fuglestvedt J.S., et al, *Direct and indirect global warming potentials of source gases*, CICERO Report 1994-1, Oslo 1994, p. 69

Grover, P. D., 1999, *Cost Estimates for a 'Dream Stove' for Asia,* RWEDP, Wood Energy News, Vol.14 No.3 (forthcoming)

Hall, D. O. et al, 1993, *Biomass for Energy: Supply prospects,* chapter 14 of "Renewable Energy - sources for fuels and electricity", published by Earthscan Publications Ltd, London, 1993

Hulscher, W., 1997, *Fuel Complementation Rather than Substitution*, RWEDP, Wood Energy News Vol.12 No.2

Natarajan, I., 1999, *Social Costs and Benefits of the National Programme on Improved Chulha*, RWEDP, Wood Energy News Vol.14 No.2

Natarajan, I., 1999, *Improved Chulha Programme - Does It Really Benefit the Poor?*, RWEDP, Wood Energy News Vol.14 No.3 (forthcoming)

RWEDP, 1997, *Regional Study on Wood Energy Today and Tomorrow in Asia*, RWEDP, Field Document No.50

Smith, K. R., et al, 1999, *Household Stoves in India,* prepared for Office of Research and Development of U.S. Environmental Protection Agency

Smith, K. R., et al, 1991, *Greenhouse Gases from Biomass and Fossil Fuel Stoves in Developing Countries: A Manila Pilot Study*, Chemosphere, vol. 26, Nos. 1-4

Venkata R. P., 1999, *Policies, Institutions and Biomass Fuels,* RWEDP, Wood Energy News Vol.14 No.3 (forthcoming)

VROM (Ministry of Housing, Spatial Planning and the Environment, the Netherlands), 1998, *The Netherlands's Programme on Activities Implemented Jointly*

Wang, X. D. & Smith, K. R., 1998, *Near-term Health Benefits of Greenhouse Gas Reductions: A Proposed Method for Assessment and Application to China,* WHO/EHG/98.12, Office of Global and Integrated Environmental Health of World Health Organization

Zhang, J., et al, 1999, *Greenhouse Gases and Other Airborne Pollutants from Household Stoves in China: A Database for Emission Factors,* Atmospheric Environment (forthcoming)

Annex 1

General data and assumptions

A. GWP of GHGs

Global warming potentials of various greenhouse gases for different time horizons (according to IPCC results and more recent estimates)

Greenhouse gas	20 years	50 years	100 years	200 years	500 years
CO_2	1	1	1	1	1
CH_4 (direct effect)	35	19	11	7	4
CH_4 (incl. indirect effect)	71	39	23	15	8
N_2O	260	270	270	240	170
CO	7	4	2	1	1

(Source: Fuglestvedt et al. 1994)

The GWP of one molecule of CO2 is set =1, to which the GWP of other gases are placed in relation. For instance, in a period of 20 years, one molecule of CH4 causes a direct warming effect which corresponds to that of 35 molecules of CO2.

For all cases in Annex 2, the time horizon of 20 years has been applied.

B. Assumptions

1. The average actual delivered energy needed for a household of four people is 4.4 GJ/year. This figure is based on measurements in Thailand (Case I).
2. The life time of stoves in all the cases is 2 years.
3. Molecular weight of TNMOC is 18 per carbon atom and its GWP is: one molecule of TNMOC causes a warming effect which corresponds to that of 12 molecules of CO2.

B. Calculation

1. Fuel consumption (kg/year) = (4.4 GJ effective x 1000) / (stove efficiency) / (fuel heating value)
2. GWP (in CO2 equivalent, kg/year) = $\sum$[GWP$_i$ x emission factor$_i$ x (molecule weight CO2 / molecule weight$_i$)]

Annex 2 Cases I-V

I	FUELWOOD - non-sustainable use	Thai bucket stove		
		Trad.	Impr.	+/-
1	Stove price in US$	1.5	4.0	2.5
2	Stove efficiency in %	19.8	28.7	9
3	Stove lifetime in years	2	2	0
4	Fuel heating value in MJ/kg	15.0	15.0	
5	Average effective energy delivered in GJ/year [a]	4.4	4.4	
6	Fuel consumption kg/year [b]	1488	1026	461
7	Carbon content of the fuel in %	50	50	
8	Emission factor in g per kg dry fuel [c]			
	CO_2 (mw=44, GWP=1)	1620	1612	
	CH_4 (mw=16, GWP=35)	9.00	13.8	
	CO (mw=28, GWP=7)	99	68.8	
9	Global Warming Potential in CO_2 equivalent, in kg per year [d]	5319	3795	1524
10	Carbon unaccounted for in kg per year (in ash and/or as PIC)	13	21	
11	CO_2 emission reduction over lifetime of an improved stove in kg	0	3049	3049
12	CO_2 reduction costs in US$/ton [e]			**0.8**

Notes

[a]	fuel burning rate g/min (measured)	28.4	17.9	
	total cooking time per day in hour (estimate)	2.5	2.5	
	effective energy delivered in GJ/year (rate*time*heating value*efficiency)	4.6	4.2	
	average effective energy delivered in GJ/year	**4.4**	**4.4**	
[b]	cons=energy delivered/heating value/efficiency			
[c]	emission factors of traditional stove assumed the same as measured in Philippines			
	emission factors of improved stoves measured in Thailand			
	emission factors N_2O and TNMOC for both stoves not known - no impact assumed			
[d]	GWP=fuel times emission factor times GWP of CO_2, CH_4 and CO			
[e]	marginal stove cost / CO_2 reduction			
	based on the principle that the carbon buyer pays for the marginal cost of the improved stove			

II	FUELWOOD - non-sustainable use	Indian stove [a]		
		Trad.	**Impr.**	**+/-**
1	Stove price in US$	0	5.0	5.0
2	Stove efficiency in %	18.10	25.70	7.60
3	Stove lifetime in years	n.a.	2	n.a.
4	Fuel heating value in MJ/kg	15.1	15.1	
5	Fuel consumption kg/year [b]	1610	1134	476
6	Carbon content of the fuel in %	50	50	
7	Emission factor in g per kg dry fuel [c]			
	CO2 (mw=44, GWP=1)	1374	1373	
	CH4 (mw=16, GWP=35)	9.40	4.11	
	N2O (mw=44, GWP=260)	0.18	0.28	
	CO (mw=28, GWP=7)	64.70	63.61	
	TNMOC (mw=18, GWP=12)	9.65	9.78	
8	Global Warming Potential in CO2 equivalent, in kg per year [d]	5345	3205	2139
9	Carbon unaccounted for in kg per year (in ash and/or as PIC)	135	101	
10	CO2 emission reduction over lifetime of improved stove in kg	0	4278	4278
11	CO2 reduction costs in US$/ton [e]			**1.2**

Notes

[a]	Indian stove: trad=Acacia-3 rock; Impr.=Acacia-improved metal stove
[b]	assuming 4.4 GJ effective energy per year for a family of 4 (cf. note a for case I)
[c]	data from measurements
[d]	fuel times emission factor times GWP of CO2, CH4, N2O, CO, and TNMOC
[e]	marginal stove cost / CO2 reduction
	based on the principle that the carbon buyer pays for the marginal cost of the improved stove

III	FUELWOOD - sustainable use	Indian stove [a]		
		Trad.	Impr.	+/-
1	Stove price in US$	0	5.0	5.0
2	Stove efficiency in %	18.10	25.70	7.60
3	Stove lifetime in years	n.a.	2	n.a.
4	Fuel heating value in MJ/kg	15.1	15.1	
5	Fuel consumption kg/year [b]	1610	1134	476
6	Carbon content of the fuel in %	50	50	
7	Emission factor in g per kg dry fuel [c]			
	CO2 (mw=44, GWP=1)	1374	1373	
	CH4 (mw=16, GWP=35)	9.40	4.11	
	N2O (mw=44, GWP=260)	0.18	0.28	
	CO (mw=28, GWP=7)	64.70	63.61	
	TNMOC (mw=18, GWP=12)	9.65	9.78	
8	Global Warming Potential in CO2 equivalent, in kg per year [d]	3133	1649	1484
9	Carbon unaccounted for in kg per year (in ash and/or as PIC)	135	101	
10	CO2 emission reduction over lifetime of improved stove in kg	0	2968	2968
11	CO2 reduction costs in US$/ton [e]			1.7

Notes

[a]	Indian stove: trad=Acacia-3 rock; Impr.=Acacia-improved metal stove
[b]	assuming 4.4 GJ effective energy per year for a family of 4 (cf. note a for case I)
[c]	data from measurements
[d]	fuel times emission factor times GWP of CH4, N2O, CO, and TNMOC; and CO2 neutral under sustainable use
[e]	marginal stove cost / CO2 reduction
	based on the principle that the carbon buyer pays for the marginal cost of the improved stove

IV	CHARCOAL - sustainable use	Thai stove [a]		
		Trad.	Impr.	+/-
1	Stove price in US$	1.5	5.0	3.5
2	Stove efficiency in %	24.00	29.00	5.00
3	Stove lifetime in years	2	2	0
4	Fuel heating value in MJ/kg.	29.0	29.0	
5	Fuel consumption kg/year [b]	575	476	99
6	Carbon content of the fuel in %	80	80	
7	Emission factor in g per kg dry fuel [c]			
	CO2 (mw=44, GWP*=1)	2150	2300	-150
	CH4 (mw=16, GWP=35)	15	15	
	CO (mw=28, GWP=7)	300	170	130
8	Global Warming Potential in CO2 equivalent, in kg per year [d]	2726	1576	1150
9	Carbon unaccounted for in kg per year (in ash and/or as PIC)	7	25	
10	GWP of charcoal production (2.9kg CO2/kg charcoal)	1667	1379	287
11	CO2 emission reduction over lifetime of improved stove in kg	0	2875	2875
12	CO2 reduction costs in US$/ton [e]			**1.2**

Notes

[a]	Thai stove: trad=traditional bucket stove; Impr.=improved bucket stove
[b]	assuming 4.4 GJ effective energy per year for a family of 4 (cf. note a for case I)
[c]	data from measurements
[d]	fuel times emission factor times GWP of CH4, N2O, CO; and CO2 neutral under sustainable use
	TNMOC assumed negligible
[e]	marginal stove cost / CO2 reduction
	based on the principle that the carbon buyer pays for the marginal cost of the improved stove

V	Substitution of coal by sustainable fuelwood	Chinese stove [a]		
		Coal	Fuel wood	+/-
1	Stove price in US$	5.0	5.0	0.0
2	Stove efficiency in %	23.41	21.42	-1.99
3	Stove lifetime in years	2	2	0
4	Fuel heating value in MJ/kg	19.2	16.2	
5	Fuel price in US$ per Ton [b]	16.0	9.0	-7.0
6	Fuel consumption kg/year [c]	978	1264	
7	Fuel costs in US$/year for one family	15.7	11.4	-4.3
8	Carbon content of the fuel in %	80	50	
9	Emission factor in g per kg dry fuel			
	CO2 (mw=44, GWP=1)	2550	1550	
	CH4 (mw=16, GWP=35)	0.02	7.92	
	CO (mw=28, GWP=7)	66.2	69.5	
	TNMOC (mw=18, GWP=12)	0.02	6.84	
10	Global Warming Potential in CO2 equivalent, in kg per year [d]	3210	2311	899
11	Carbon unaccounted for in kg per year (in ash and/or as PIC)	74	44	
12	CO2 emission reduction over lifetime of substituted stove in kg	0	1798	1798
13	CO2 reduction costs in US$/ton [e]			-4.8

Notes

[a]	Chinese stove: coal =metal stove without flue using honeycomb coal briquette;
	fuelwood =metal stove without flue using fuelwood
[b]	based on ORNL study on fuelwood plantation costs in Yunnan province in China [Hall, et al, 1993]
[c]	assuming 4.4 GJ effective energy per year for a family of 4 (cf. comment in Note 1 for case I)
[d]	fuel times emission factor times GWP of CO2, CH4, CO, and TNMOC; but CO2 neutral for sustainable fuelwood
[e]	marginal stove cost / CO2 reduction
	based on the principle that the carbon buyer 'pays' for the marginal fuel cost (which are negative in this case!)

The result of negative carbon reduction cost shows that this case is a win-win situation!

Summary of cases

Case	improvement	supply	example	CO2 reduction (Ton/ lifetime)	CO2 reduction (US$/Ton)
I	wood stove	scarce	Thailand	3.0	0.8
II	wood stove	scarce	India	4.3	1.2
III	wood stove	sustainable	India	3.0	1.7
IV	charcoal stove	sustainable	Thailand	2.9	1.2
V	wood for coal	sustainable	China	1.8	-4.8

Annex 3 Stove project costs

STOVE PROJECT COSTS

STAFFING	**phase**	**experts**	**month**	**Staff X month**	**US$/month (x1000)**	**US$ (x1000)**	**US$ (x1000)**
	0	1	3	3	2	6	
	1	2	6	12	2	24	
	2	3	9	27	2	54	
	3	3	6	18	2	36	
	4	3	24	72	2	144	
	5	2	24	48	2	96	
				180	2	360	**360**
OTHER	office		66		1	66	
	training					100	
	travels					75	
	promotion					150	
	unallocated					49	
						440	**440**
GRAND TOTAL							**800**

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