The overall worldwide saving potential from domestic cooking stoves and ovens

Authors
Oliver Adria (CSCP)
Jan Bethge (CSCP)

Reviewer:
Dr. Stefan Thomas (WI)
Antoine Durand (WI)
Dr. Claus Barthel (WI)
Heike Volkmer (GIZ HERA - Poverty-oriented Basic Energy Services)
Stefan Salow (GIZ HERA - Poverty-oriented Basic Energy Services)

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1. The overall worldwide saving potential from domestic cooking stoves and ovens

Potentials for improved energy efficiency of cooking stoves and ovens are large. Taken together, a reasonable estimate is that the potential exists to reduce total worldwide energy consumption and greenhouse gas emissions for residential cooking by more than a third, despite growth in population.

In developing countries especially, energy improvements can be achieved at rather low costs and on a wider-scale, entail important co-benefits such as reduced emission of greenhouse gases and deforestation as well as dramatic health improvements for household members. Depending on existing stove models and fuels, as well as on local traditions of cooking and fuel processing, e.g. charcoal making, potential reductions in fuel inputs of up to 80 per cent at very low costs are possible.

It is estimated that in developing countries about 730 million tonnes of biomass are burned every year (WHO 2007), which amounts to more than 1 billion tonnes of CO_2 emitted into the atmosphere. Not all of this is for cooking, but in addition to direct emissions from fuel combustion, there are further emissions e.g. from land use for collecting wood. Hence, as estimated by Grupp (2004), total greenhouse gas emissions from biomass cooking are around 1.3 billion tonnes of CO_{2eq} per year, or two thirds of the total for residential cooking. It is estimated that the new generation of advanced biomass cooking stoves would reduce CO_2 emissions by about 50 per cent.

Also in developed countries large potentials for increasing energy efficiency can be found, but tapping them is often related to higher costs. Although, for example, an energy savings potential of 286PJ/yr, or almost 50%, exists in the European Union (EU) (period between 2010 and 2025), costs related to realising these savings are often relatively high, hence realisation of saving 43.25PJ/yr is seen to be cost-effective in that period (Mudgal 2011).

However, numbers presented here should be taken with a caveat. According to the FAO (2010), due to the underlying data that is either unavailable or subject to considerable fluctuation, estimates of global emissions reduction from the improved efficiency of cooking stoves are uncertain.

Obtaining accurate activity data for residential fuel use is quite difficult and so are calculations of overall energy saving levels. Even in fossil-fuel energy statistics, the allocation of fuel to residential, commercial, or agricultural uses is mostly not broken down. In contrast to fossil fuels, many solid biomass fuels are traded or gathered by the users and do not form part of a formal economic network, so that the official recording associated with fossil-fuel uses does not occur. Thus, consumption levels of fossil fuel are often estimated based on different survey data. But as these surveys are not available for all regions or indeed years, they may be extrapolated relying on rough population surveys, per-capita consumption, or economic data. Other studies estimate biomass consumption for cooking by relying on figures about food consumption. Thereby reported uncertainties of 50-100 per cent stay extremely high, but are a rather common phenomena (Bond, Venkataraman, & Masera, 2004; Habib et al., 2004). Estimating overall potentials of energy saving in residual cooking in developed countries is somewhat easier as more accurate data provides a much clearer picture, especially data collected from the EU member states which is rather detailed and advanced (EC, 2011a, 2011b). However, enormous differences between countries also occur in the EU context so that the application of the EU example on other developed countries such as Japan or the US, Australia and Canada must be considered as rather limited.

Against the backdrop of the difficulties described here concerning accurate data, global potentials for energy efficiency in the cooking sector will be illustrated by representative examples, which seem to provide feasible data and insights in overall potentials. Representative examples from the developing world will be Uganda and India, while the EU will provide an exemplary case for industrialised countries.

1.1 Improved biomass cooking stoves and their potential in Developing Countries

1.1.1 Summary

With improved biomass cooking stoves or type of fuel changes, households that today rely on solid biomass for cooking could save around 12 EJ/year of energy. There are two predominant ways to reduce the cooking energy consumption in developing countries. One way is to introduce and promote more efficient cooking stoves, preferably by establishing a local market. Another one is to switch to more efficient fuels. This includes, but is not necessarily limited to a switch to LPG or kerosene, an easier way is a more efficient use of solid biomass – for example in charcoal production. Here better government regulation and cooperation with the private sector can cut down on inefficient illegal production and instead lead to a sustainable production that increases efficiency while supporting local industries and households (GIZ HERA 2008, 2010).

Data available from field studies in India and East Africa show that energy savings largely vary depending on availability of improved stoves and local cooking habits. Realisation of saving potentials is mostly relatively cheap and ranges between 8.3 and 19.4 GJ per household per year, according to data from India and East Africa. Moreover, dissemination of improved cooking stoves will reduce emissions of greenhouse gases and health risks to household members. Economic analysis by the WHO shows that improved biomass cooking stoves provide direct net cost savings plus co-benefits, while a switch to LPG or ethanol would have net direct costs, but they would be outweighed by the co-benefits.

In developing countries, more than 2.5 billion people are still using highly inefficient solid biomass for cooking. In some rural areas of developing countries, up to 95 per cent of people still rely on biomass as their primary fuel for cooking (see figure 1). About 80 per cent of their total energy consumption is related to cooking processes (Pohekar, Kumar, & Ramachandran 2005; Smith et al. 2000). Calculations indicate that without new policies being introduced, residential biomass demand in developing countries will rise from 771 Mtoe (ca. 32,3 EJ) in 2004, to 818 Mtoe (ca. 34,2 EJ) in 2030 (IEA & OECD 2006). With an estimated 2.727 billion people relying on traditional biomass in 2030, this calculates to 12.6 GJ/person. If 80 % is still used for cooking, this will be around 10 GJ/person per year.

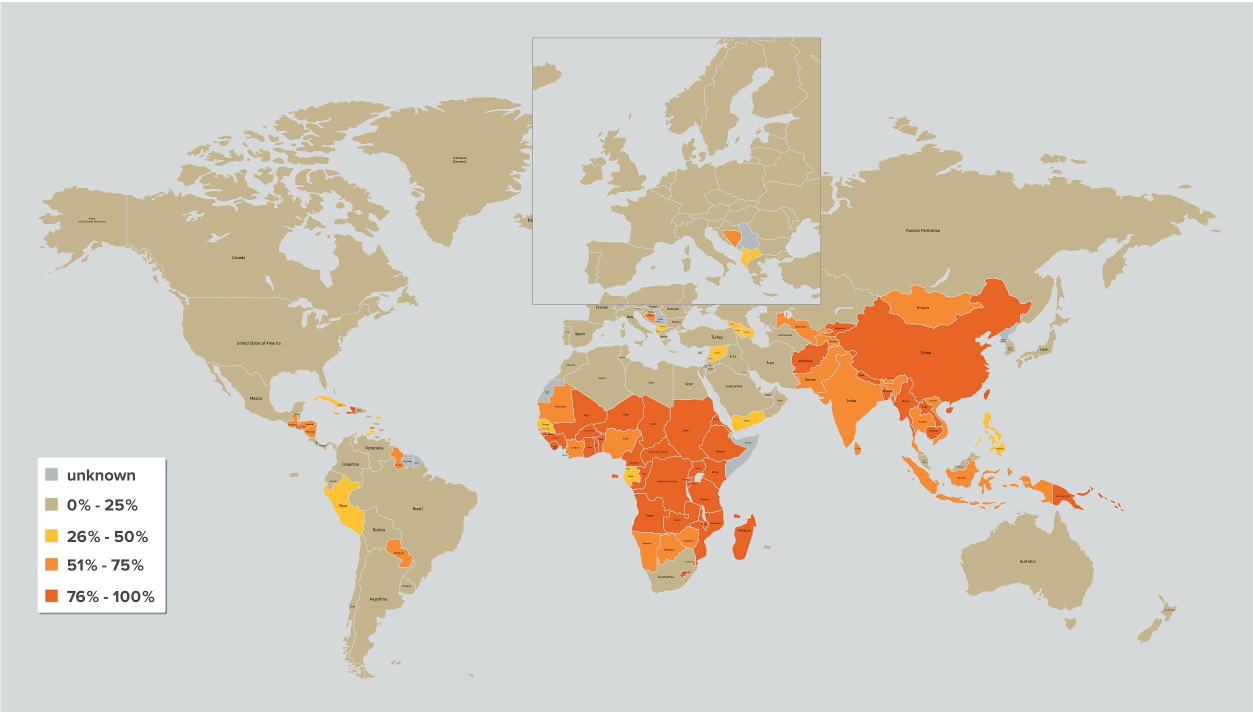

Figure 1: Energy poverty in people's homes - Percentage of population using solid fuels (Millennium Development Goal indicator 29), 2003 or latest available data

Source: WHO 2006

An analysis by the WHO (World Health Organization) shows that making improved stoves available, by 2015, to half of those burning biomass fuels and coal on traditional stoves in 2005, would even result in a negative intervention cost of US$ 34 billion a year as the fuel cost savings due to greater stove efficiency exceed the investment costs (WHO 2006). It also generates a further economic return (non-energy benefits) of US$ 105 billion a year over a ten-year period, cf. Table 1. By contrast, a net intervention cost of US$ 13 billion a year would be needed to halve the number of people cooking with solid fuels by providing them with access to LPG by 2015 but will give a payback in non-energy benefits of US$ 91 billion (cf. Table below). For ethanol, the net intervention cost increases to US$ 43 billion – this is due to higher fuel prices and lower fuel efficiency.

Table 1: Non-energy benefits from the use of improved biomass cooking stoves, modern biofuels, or LPG. Costs and benefits of different intervention scenarios were estimated using 2005 as the base year and a 10-year time horizon, taking into account demographic changes over this period. The analysis was conducted for 11 WHO subregions to reflect variations in (i) the availability, use and cost of different fuels and stoves; (ii) disease prevalence; (iii) health care seeking as well as quality and cost of health care; (iv) the amount of time spent on fuel collection and cooking; (v) the value of productive time based on Gross National Income per capita; and (vi) variations in environmental and climatic conditions. A 3% discount rate was applied to all costs and benefits. See Evaluation of the costs and benefits of household energy and health interventions at global and regional levels for a detailed description ot the method and the results of a range of intervention scenarios by WHO subregion as well as of the sensitivity analysis.

	If 50% of the population cooking with solid fuels in 2005 switch to cooking with liquefied petrolium gas by 2015	**If 50% of the population cooking with solid fuels in 2005 switch to cooking with modern biofuels by 2015**	**If 50% of population cooking with solid fuels in 2005 switch to cooking on an improved stove by 2015**
Health care savings	384	384	65
Time savings due to childhood and adult illness prevented: school attendance days gained for children and productivity gains for children and adults	1 460	1 460	510
Time savings due to less time spent on fuel collection and cooking: productivity gains	43 980	43 980	88 100
Value of deaths averted among children and adults	38 730	38 730	13 560
Environmental benefits	6 070	5 610	2 320
Total benefits	90 624	90 164	104 555

Source: WHO 2006

1.1.2 Example: Energy saving potential in India

In India, every household which is still currently using traditional wood stoves could save 16 GJ (or 67 %) and 1680 kg of CO_2 annually at very low costs when an improved woud stove is used. Switching cooking fuel from wood to biogas could even save 19.4 GJ (or 80 %) and 2520 kg CO_2 annually per household but would entail a 30 times higher investment per saved GJ. However, it would still have lower life-cycle costs than traditional wood stoves.

The domestic sector accounts for nearly 40 per cent of the overall primary energy consumption in India, whereas about 90 per cent of this is due to cooking. Moreover, energy demand related to cooking in India grows by about 8 per cent annually (Pohekar et al. 2005). In 2000, the total energy consumption related to cooking in India was estimated to be 6325 PJ. Around 84 per cent of this amount was used by households from rural areas of the country (Habib et al. 2004). The high demand for cooking energy used in rural India is also related to its high dependency on biomass fuels. More than 90 per cent of rural households in India still depend on wood fuel, cow dung and agricultural residues. But other households have shifted to modern energy carriers like LPG and electricity, which represented about 15 per cent of household energy consumption in 2000. In total, cooking accounts for 92 per cent of gross energy consumption by the poor, while this share is only 60 to 70 per cent of the total energy consumption of high income groups (Pohekar et al. 2005).

Generally spoken, there are two main different ways to achieve improved energy efficient levels in India. On the one hand, households can perform a fuel-switch from inefficient wood-fuelled cooking stoves to more efficient ways of cooking with kerosene, LPG or biogas. On the other hand households can only exchange the stove technology to improved cooking stoves still using biomass fuels such as wood. Other ways that can be used in addition also include the introduction of energy-efficient cooking devices like pressure cookers and heat retainers, or more efficient cooking practices for e.g. fuelwood use. In terms of energy efficiency, traditional wood stoves have the lowest levels of energy efficiency of about 10 per cent, while improved cooking stoves achieve on average an efficiency of about 30 per cent. A fuel switch to traditional kerosene stoves would reward households with energy efficiency levels of about 35 per cent, improved kerosene stoves achieve an efficiency of 45 per cent, while stoves which use biogas or LPG achieve energy efficiencies of 55 to 60 per cent. Best available figures of annual energy consumption for cooking by the residential sector in India suggest, that a household's annual energy use for cooking in India is 24 GJ when using a traditional wood stove, 8 GJ when using an improved wood stove, 9.8 when using a traditional kerosene stove, 6.51 when using an efficient kerosene stove, 7.5 when using LPG and 4.6 when using biogas (Reddy 2003; Reddya & Balachandrab 2006). Annualised lifecycle costs are highest with LPG stoves, followed by traditional kerosene stoves, traditional wood stoves, biogas stoves and the lowest improved wood cooking stoves. The annualised lifecycle costs consist of capital and annual energy costs, taking into consideration estimated life spans of stoves.

For households in India, large energy saving potentials result from the above stated figures. Switching from a traditional wood stove to an efficient wood stove would save 16 GJ per household. Performing a fuel switch by replacing a traditional wood stove to an efficient kerosene stove would allow savings of 17.5 GJ per household. Replacing traditional wood stoves by an LPG stove would achieve energy savings of 16.5 GJ, while a biogas stove saves 19.4 GJ. Although achieved savings as a result of switching to biogas would be larger, its investment would be 30 times higher compared to the distribution of improved wood cooking stoves. However, it would still have lower life-cycle costs than traditional wood stoves. Despite being cost-effective over its lifetime, a major barrier to its dissemination is that due to a lack of financing mechanisms, the capital cost or generally lower investment is often the most important consideration. While switching to improved cooking stoves is related to a return on investment of 64 percent per year and will pay for itself through fuel savings in a few months, switching to modern fuels does not pay for itself, except in the case of biogas. The striking driver behind fuel switches to cleaner fuels such as biogas or LPG is that they are more convenient in their usage. Of about 222 million households in India, an estimated 64.3 per cent are still using wood as fuel for cooking. Although there are no figures about the share of households, which use improved wood cooking stoves, it can be reckoned that the larger part i.e. 142.7 million households using fuel wood, have enormous energy saving potentials, which they could tap through employing energy efficient wood stoves or by making a fuel switch.

1.1.3 Second example: Energy saving potential in East Africa

Especially in the rural areas of East African countries, up to 99 per cent of the households still use biomass for cooking. In Tanzania every household could save around 14 GJ annually by replacing the three-stone fire with an improved cooking stove. In Uganda the overall saving potential is at least 8.3 GJ per household each year.

In many East African regions, households still use wood fuelled three stone fires for cooking. For instance, survey data from Uganda and Tanzania shows that about 99 per cent of households, in rural areas of these two countries, still use wood, agricultural residues and other biomass for cooking (Edwin Adkins et al. 2010). Hence, several improved cooking stove programmes have been trying to introduce improved cooking stoves on a household level. Field tests of different locally produced and imported rocket stoves show that their use reduces wood fuel consumption by 22 to 46 per cent compared to a three-stone fire. The size of an average household in Uganda in the region, in which the survey was conducted, was found to be 6.4 persons, while in Tanzania it was found to be 7.6 persons. With local cooking habits taken into consideration, research indicates that the saving potentials concerning fuel wood used for cooking in households are roughly 700kg/year (14GJ/year) in Tanzania and 420kg/year (8.3GJ/year) in Uganda when using the so called StoveTec, a rocket stove designed in the US and produced in China (Edwin Adkins et al. 2010). These figures show how much local cooking behaviour and food, which is prepared in the respective region, influence outcomes from savings associated with food. The saving potentials expressed in used wood fuel per household can be translated into energy saving potentials in joules by using the calorific value of the used fuels. Although this value is influenced by factors such as the quality and moisture of the wood, averaged values indicate the calorific value for wood to be 20 MJ/kg, for crop residues (rice husks) 15 MJ/kg and for cow dung cakes 18 MJ/kg (FAO 1983)[1]. Therefore, wood savings of 700 kg per year and household would correspond with energy savings of about 14 GJ per household in Tanzania and 420 kg/year to 8.3 GJ in Uganda. The use of more efficient stove models, such as the Save80 or more efficient types of the rocket stove would improve energy savings per household even further. The costs of tapping these saving potentials depend on the type of improved stove and costs related to supplying it to the place where it is needed. The StoveTec rocket stove was offered at a price between $20 to 22 in the regions of the survey in rural Uganda and Tanzania (Edwin Adkins et al. 2010). Survey data from Uganda and Tanzania clearly shows that financial incentives could rapidly increase the willingness of households to switch from the three-stone fire in use to advantageous stove designs and thereby support energy savings. Households were asked about their willingness to buy improved cooking stoves at different prices. The household survey shows that less than 20 per cent in Tanzania and about 32 per cent of households in Uganda would buy the StoveTec if it were available at a price of $17.5. In contrast, almost 90 per cent of households would purchase the StoveTec if it were available at $5 in Uganda and Tanzania likewise (Edwin Adkins et al. 2010). Next to the price and energy saving of stoves, other factors form local preferences towards different stove types. Survey data from Uganda for instance shows that households largely reject a locally produced rocket stove called *Ugastove* due to its design and materials even if tests show that it is more efficient in terms of fuel savings compared to the StoveTec. Reasons for the rejection were a small feeding hole, which does not allow to feed it with larger amounts of fuel and extends cooking times, as well as the perception of household members that you burn yourself more easily when using *Ugastove* (Edwin Adkins et al. 2010).

[1] Values depend on different variables as such as the type of wood or moisture content of the fuel unit.

1.2 Energy-efficient gas and electric cooking stoves and their potential in Developed Countries

Sophisticated gas and electric cooking stoves are already on a relatively high technological level. However, there are still significant potentials—up to 50 %—to further improve the energy efficiency of modern cooking stoves. These can be tapped by realising a combination of design options with existing electric and gas ovens and hobs. However, such interventions are often more expensive, whereas savings at lower costs would be much smaller but still significant.

While biomass cooking stoves, which are widely used in developing countries, have efficiency levels of 8 to 35 per cent (UNFCCC 2006), energy-efficient gas and electric cooking stoves provide efficiency levels of up to 80 per cent of the electricity or gas input. Compared to developing countries, energy saving potentials with modern cooking stoves are far smaller and less cost-efficient. As reliable data about energy saving potentials is not available for different countries, the EU-27 and North America are used here as the representative examples for potential energy saving through the improvement of sophisticated cooking stoves and ovens in developed countries.

1.2.1 Example: Energy saving potentials in the EU

The overall energy consumption of the stock of cooking appliances in the EU reached 575 PJ in 2007. The realisation of combined improvement options with cooking appliances could reduce the related annual energy consumption for these appliances by a range of 43.25 PJ to 286 PJ in the period between 2010 and 2025 (Mudgal 2011).

Gas and electric appliances are predominantly used for cooking in the EU. Electric hobs and ovens clearly dominate the market, but shares vary largely across and within countries depending on cooking habits and availability. If the energy demand along the whole life-cycle of cooking appliances is considered, then it appears that more than 90 per cent of all energy is consumed during the use phase. Best available figures from scenarios in the EU state that the total energy consumption of modern cooking appliances in the EU reached 575 PJ in 2007 (EC 2011a; Mudgal 2011). With a total consumption of 266 PJ, domestic electric ovens had the biggest share of the overall consumption of cooking appliances in 2007. The second highest energy consumption for cooking is related to the use of the stock of domestic electric hobs, which accounted for 188 PJ in 2007. The EU stock of gas hobs consumed 80 PJ in 2007, while domestic gas ovens were responsible for the consumption of 41 PJ. On average, highest life-cycle costs arise from electric hobs (905 €), followed by electric ovens (858 €), gas hobs (519 €) and gas ovens (477 €).

Taking into consideration different improvement options for domestic cooking appliances reveals significant energy saving potentials for the EU. Improvements include for instance better insulation, reduced thermal mass, enhanced temperature and heat accuracy or cooking and pot sensors, but efficiency might also depend on users.

Combining different improvement option scenarios shows that energy saving potentials for the stock of domestic electric ovens in the EU will accumulate to 42 per cent, if the best available technology (BAT) is used. The overall efficiency of domestic gas ovens in the EU could be improved by 25 per cent. Realising the BAT will at the same time reduce the life cycle costs of the appliance by 4.3 per cent. If priorities are laid on minimizing lifecycle costs, energy savings would be at 39 per cent, while life cycle costs could be reduced by 16 per cent.

The second largest energy saving potential can be found with domestic gas ovens. With BAT, reductions of 25 per cent could be realised, but only by entailing a rise in lifecycle costs of 23 per cent. A more desirable option could be to reduce the energy consumption of domestic ovens by 12 per cent and thereby only entailing savings in lifecycle costs of 1 per cent. A maximum of 16 per cent of energy saving is possible with domestic gas hobs, but then these need to be bought with a rise in lifecycle costs of 39 per cent.

Reducing the energy consumption of gas hobs without a rise in lifecycle costs was found to be impossible according to EU-specific analysis. Domestic electric hobs are similar to gas hobs concerning their energy saving potentials. Tapping energy saving potentials was found impossible without rising lifecycle costs. The maximum saving of 14 per cent is only possible at an increase in lifecycle cost of 4 per cent (Mudgal 2011). Taking all these energy saving potentials together, combined realisation of several improvement options with domestic cooking appliances in the EU could reduce energy consumption by 286 PJ (as amaximum) over a period from 2010 to 2025. This would be just under 50 per cent of the current cooking energy consumption level. The most cost-efficient option, taking into consideration lifecycle costs of cooking appliances, would be realising energy savings of 43.5 PJ per year. This option would not see any realised energy savings with domestic hobs but realised energy savings with domestic ovens would reduce their lifecycle costs by 8.5 per cent (on average).

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Dr. Stefan Thomas • bigee@wupperinst.org

Wuppertal Institute for Climate, Environment and Energy • Doeppersberg 19 • 42103 Wuppertal • Germany • Phone: +49 (0)202 2492-129