WLPGA

COOKING
FOR LIFE

SUBSTITUTING LPG FOR WOOD: CARBON AND DEFORESTATION IMPACTS

A report to the World LPG Association

ATLANTIC CONSULTING

JULY 2018

Contents

Highlights: Substituting LPG for Wood

- According to the International Energy Agency, somewhere between 800 million and two billion people will switch from traditional cooking with wood to other fuels (such as LPG) over the 2015-30 period.

- LPG is far more energy concentrated than wood: annual per capita cooking requires 43 kg instead of 400 kg of wood. LPG transfers 50% of its energy content to the pot, compared to wood's 10-20%.

- Unlike wood, an LPG fire can easily be turned on and off. Instead of emitting choking smoke, its exhaust is problem-free for indoor use. These advantages lead to improved wealth and health.

- Burning wood is dramatically less carbon-efficient than burning LPG. Wood consists of 50% fuel. The rest is molecularly-bound oxygen plus left-over moisture. Neither of these burns, and vaporising the moisture wastes energy. LPG, by contrast, is all fuel. Per unit of delivered cooking heat, burning wood generates about five times the carbon of LPG.

- Switching from wood to LPG can reduce cooking's carbon emissions significantly. In the tropics, where much traditional cooking happens, switching cuts net-CO_2 output to the atmosphere by 60%.

- If, as the International Energy Agency projects, the 800 million to two billion people switching from wood instead used LPG , this would create to a net annual atmospheric reduction of 170-415 million t of carbon dioxide. That lower figure is about equal to the annual emissions of Pakistan or the Netherlands; the larger is about that of South Africa or the United Kingdom.

- If, as the International Energy Agency projects, the 800 million to two billion people switching from wood instead used LPG, the annual savings per person are 211 kg CO_2, or 1.055 tonnes for an average developing-world household of five people. This latter figure is equal to the emissions of an average, new European car being driven for some 8,000 km.

- If the 2015-30 swap away from wood, as forecast by the IEA, went to LPG, it would prevent deforestation for much the same reasons as it would reduce net carbon emissions. It could save 800 thousand to two million hectares/year of forest a year, 16-40% of the current deforestation globally.

- Switching 100 households from consuming 200 tonnes of harvested wood a year to consume instead 21.5 tonnes of LPG would save one hectare of forest each year. Each household would save about 100 square metres of forest. A typical 13 kg cylinder of LPG would avert deforestation of a 6 m^2 forest area.

Sparing carbon and trees – one stove at a time

Cooking with LPG, rather than wood, combats global warming and deforestation.

In developed and developing countries, biofuels could hardly be viewed more differently. In developed countries they are modern, even trendy, with broad government support driving consumption levels to record highs. In the developing world, typified by the traditional three-stone fire, biofuels are a symbol of the not-so-good-old days. Known mainly by their common names of wood and charcoal, they are a barrier to economic progress and a major source of illness.

Governments have recognised this, prompting a revolution in energy use that is already underway. Part of this involves a massive shift from cooking with wood and other forms of biomass to cooking with LPG. According to the International Energy Agency's (IEA) vision of the future, somewhere between 800 million and two billion people will switch from traditional cooking with wood to other fuels (such as LPG) over the 2015-30 period.

For users, the reasons are obvious. LPG is far more energy concentrated: annual per capita cooking requires 43 kg, as opposed to 400 kg of wood. It cooks more efficiently, transferring 50% of its energy content to the pot, compared to wood's 10-20%. Unlike wood, an LPG fire can easily be turned on and off. Instead of emitting choking smoke, its exhaust is problem-free for indoor use. All these advantages lead to improved wealth and health.

Somewhat less obvious, but still important are the benefits to the natural environment. Switching from wood to LPG can significantly reduce emissions of the number one greenhouse gas, carbon dioxide, and it can seriously mitigate the scourge of deforestation. So increased substitution of a fossil fuel for a biofuel can yield serious benefits for nature.

RE-THINKING BIOFUELS

This might have seemed unimaginable some ten years ago, when biofuels were viewed by many as a cure-all for our warming climate. By the end of the last decade, both Europe and America, prompted mainly by the desire to cut carbon, announced bold targets for biofuels with their Renewable Energy Directive and Renewable Fuels Standard.

However, even before the ink on these acts was dry, the pendulum of informed opinion began to swing back from euphoria to caution. Critical voices that have been sounding since mid-decade began to find traction in policy advice issued by the IEA (Task Force 38 on Greenhouse Gas Balances of Biomass and Bioenergy Systems), the US EPA (Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources), the European Environmental Agency (Greenhouse Gas Accounting in Relation to Bioenergy) and ISO (13065: Sustainability Criteria for Bioenergy). They called not for a wholesale rejection of biofuels, but for a more nuanced view – i.e. sometimes they are good, sometimes they are bad.

In the case of traditional cooking, wood comes out poorly against LPG, both on carbon emissions and deforestation. The analyses behind these conclusions have similarities, but they are not identical. We should consider them individually.

CARBON SAVINGS - CALCULATED

The classic carbon-related argument for using wood as a fuel can still be heard regularly: "The tree will grow back." Unfortunately, in the time-constrained battle against global warming, this is not enough, because the tree grows back too slowly. Even in the fastest-tree-growing areas of the tropics, it takes forests more than 60 years to regenerate after a harvest. Regrowth takes at least a decade longer in temperate zones and in boreal regions can last for one-to-two centuries. In any of these cases, this is nowhere near soon enough to meet the 80% emissions-reduction targeted by the G8 nations for 2050.

Besides, simply growing back the tree does not create carbon neutrality. Even in a tropical zone, it will take more than a century, post-combustion, for LPG and wood to come to parity in their carbon emissions. By most policy measures, that will be too late.

One of the main reasons for this is that burning wood is dramatically less carbon-efficient than burning LPG – and the primary cause for this is chemistry. Typical air-dried wood consists of only about 50% fuel. The rest is molecularly-bound oxygen (in carbohydrates and lignin) plus left-over moisture (a fresh-cut tree contains some 50% water by weight). Neither of these burns, and vaporising the moisture steals valuable combustion energy. LPG, by contrast, is all fuel. There also is an inherent difference in carbon content. Dry wood has far more carbon atoms than hydrogen atoms, while in propane and butane – LPG's main constituents – carbon atoms are in the minority.

Already in pre-combustion the carbon gap is wide: there, wood is nearly 50% more carbon-intensive (per unit of energy) as LPG. Combine that with its lower combustion efficiency, and the die is cast. Per unit of delivered cooking heat, burning wood generates about five times the carbon of LPG.

So, switching from wood to LPG can reduce cooking's carbon emissions significantly. Over 63 and a half years (the average regeneration period for a harvested forest in the tropics, where much traditional cooking happens) switching cuts net-CO_2 output to the atmosphere by 60%. The tree finally does grow back, and this analysis fully accounts for that. Still, LPG is the cleaner option.

All these changes, stove-by-stove, can add together to a globally significant impact. If, as the IEA projects, the 800 million to two billion people switching from wood instead used LPG, this would create to a net annual atmospheric reduction (over 63 and a half years) of 170-415 MT of carbon dioxide. That lower figure is about equal to the annual emissions of Pakistan or the Netherlands; the larger is about that of South Africa or the United Kingdom. At a more human scale, the annual savings per person are 211 kg CO_2, or 1.055 tonnes for an average developing-world household of five people. This latter figure is equal to the emissions of an average, new European car being driven for some 8,000 km.

SPEAKING FOR THE TREES

Sadly, in much of the developing world, the tree does not even grow back, slowly or otherwise. As the UN's Food and Agricultural Organisation points out in its latest 'Global Forest Resources Assessment' of 2015, deforestation is continuing its centuries-long march.

Globally it has slowed slightly since the millennium, but deforestation continues and comes off a severely depleted base. Across most of the developing regions of Africa, Asia and Latin America, unsustainable harvesting drove carbon stock in forests down to record lows. At the whole-earth level, says the FAO, half of the wood harvested was for fuel. The question is: how much of this wood was intentionally harvested as such, and how much was a 'residue' or waste of harvesting for other reasons (lumber, plantation, pasture, cropping or industrial/commercial/residential use). This clearly deserves further investigation, yet a survey of the science suggests a rough 50/50 split. Particularly in urban areas, wood supplies are being sourced as on-purpose products, not unavoidable residues or wastes.

The 2015-30 swap away from wood as forecast by the IEA, if it went to LPG, could seriously dent this forest rundown, and for much the same reasons as it would reduce net carbon emissions. It could save 800 thousand to two million hectares/year of forest a year, 16-40% of the current global total.

At a more personal scale, switching 100 households from consuming 200 tonnes of harvested wood a year to consume instead 21.5 tonnes of LPG would save one hectare of forest each year. Each household would save about 100 square metres of forest. A typical 13-kg cylinder of LPG would avert deforestation of a 6 m2 forest area.

It will take a village, a lot of villages, not to mention some major cities. But this could make a serious dent in carbon emissions and save forests, which of course are the planet's lungs, home to much biodiversity, and – especially in developing countries – a key source of employment. Switching from wood to LPG is an idea whose time has come.

1.0 Introduction

In the developing world, one of every two households cooks with a traditional wood fire. This study investigates the impact on carbon dioxide emissions and deforestation, if that cooking were done instead with an LPG stove.

1.1 THE GLOBAL SHIFT AWAY FROM TRADITIONAL BIOMASS COOKING

In the latest year of estimation, 2015, about one-third of the world's population – some 500 million households totalling to 2.5 billion people – cooked with solid biomass[1] using 'traditional' methods[2] (International Energy Agency, 2017, p 58). All these people are in the developing world, in which they account for 45% of its 5.7 billion inhabitants.

Since the millennium there was some shift away from traditional biomass. In 2000 some 55% of the developing world cooked traditionally with solid biomass, by 2015 this had fallen to 45%. However, because the developing population had grown from 4.9 billion to 5.7 billion, the absolute figure stayed almost constant at about 2.5 billion.

From 2015 to 2030, the shift away from traditional biomass is expected to continue. The IEA projects two scenarios:

- New Policies – a business-as-usual scenario, accounting for current programmes and progress, population growth, economic growth, urbanisation rate and the availability and price of different fuels.
- Energy for All – in September 2015, 193 countries adopted the Sustainable Development Goals (The 2030 Agenda for Sustainable Development)[3] that aim to end poverty, improve health and gender equality, protect the planet and ensure peace and prosperity for all. One of the goals is to ensure access to affordable, reliable and modern energy for all by 2030 (Sustainable Development Goal 7.1). This scenario assumes that Goal 7.1 would indeed be reached by 2030.

Under these scenarios, from 2015 to 2030, about 1.3 billion people will convert away from using traditional biomass for cooking. Some of them will convert from traditional biomass to improved biomass. Nonetheless, between 800 million to two billion will convert away from biomass altogether.

TABLE 1: WORLD USERS OF BIOMASS FOR COOKING, BILLIONS

	2000	2015	2030	
			Scenario: New Policies	Scenario: Energy for All
Developing world population	4.9	5.7	6.8	6.8
Users of traditional biomass	55%	45%	30%	0%
Users of improved biomass			3%	16%
Users of traditional biomass	2.68	2.57	2.04	0
Users of improved biomass			0.204	1.088
Total users biomass			2.244	1.088
Converted from traditional biomass, 2015-30			1.02	3.06
Converted from biomass to non-biomass, 2015-30			0.816	1.972

Source: IEA, 2017.

[1] Solid biomass is mainly charcoal and wood, but it also includes dung, agricultural residues, wood waste and other solid wastes.
[2] Typically a 3-stone fire, with a poorly-operating chimney or no chimney at all.
[3] https://sustainabledevelopment.un.org/post2015/transformingourworld.

1.2 WHAT COULD THIS MEAN FOR GREENHOUSE GAS EMISSIONS AND DEFORESTATION?

Traditional biomass cooking has three major drawbacks:

- Environmental damages: excess emissions of greenhouse gases and deforestation.
- Economic disadvantage to its practitioners. Traditional-cooking households spend significant (and increasing) amounts of their time collecting fuel, time that could be more productively spent in other types of work.
- Injury and disease to its practitioners. Carrying wood exposes carriers to potential assault by humans or animals, plus bodily damage from the strain. Ailments such as asthma, bronchitis, child pneumonia, lung cancer, chronic obstructive pulmonary disease, heart disease, as well as low birth-weight in children can be caused by chronic exposure to the exhausts of traditional cookers.

This paper focuses on those environmental damages. Chapter 2 compares the net carbon-dioxide emissions of cooking with traditional biomass (wood) to cooking with LPG. Chapter 3 compares the deforestation impacts of cooking with wood to those of cooking with LPG.

2.0 Reducing carbon emissions by substituting LPG for wood

Some 500 million households in the developing world cook over an open fire fuelled by wood or charcoal. By switching to LPG, each of these households can cut its net carbon emissions by 60%. The IEA foresees a major shift away from traditional biomass cooking from 2015 to 2030. If this shift were to LPG, the reductions would range from 170-415 million tonnes of CO_2 emissions per year. These savings are significant. To put them in perspective, in 2015: Pakistan and the Netherlands each emitted about 170 million tonnes; South Africa and the United Kingdom each emitted close to 415 million tonnes.

2.1 METHOD

This analysis compares the carbon dioxide emissions of traditional cooking with wood to cooking instead with LPG. The comparison is done using the general approach of life-cycle assessment or carbon footprinting (ISO, 2006a) (ISO, 2006b) (BSI *et al*., 2011). The functional unit is 1 GJ output of delivered cooking heat[4].

The comparison assumes that there are only two options – wood or LPG – and that one of them will be adopted. This is not shown explicitly in the main analysis, i.e. no baseline is shown. Near the end of the paper (section 2.4) this is presented with an explicit baseline as defined by (Johnson and Tschudi, 2012).

2.2 DEFINITION OF THE SYSTEMS

There are two main sub-systems in this type of cooking: the cooking system (of which there are two types, LPG and wood), and the forest system.

2.2.1 The cooking systems

For the base case comparison, four definitions (Table 2) are most important: carbon intensity, thermal efficiency, product/residue split and fuel required.

TABLE 2: KEY COMPONENTS OF THE COOKING SYSTEMS, BASE CASE

Fuel	Carbon intensity kg CO_2/GJ (LHV)	Thermal efficiency Fuel LHV to cooking heat delivered	Product/residue split	Fuel required kg/GJ delivered heat
Wood	105.4[5] (Johnson and Tschudi, 2012)	15% (World Bank, 2006, p 39) (International Energy Agency, 2017, p 124)	100% product, 0% residue	400 (World Bank, 2006, p 39)
LPG	8.0 well-to-stove (UK Dept of Business Energy & Industrial Strategy, 2016, p 13) plus 64.0 stove-to-stack, i.e. combustion (DECC and DEFRA, 2010) equals 72.0 well-to-stack	50% (International Energy Agency, 2017, p 124)	100% product, 0% residue	42.9 (World Bank, 2006, p 39) (DECC and DEFRA, 2010) (IEA, 2017)

Source: Xxxx

[4] 1 GJ of delivered cooking heat is the approximate amount consumed in the developing world by one person in one year.
[5] Combustion only.

Carbon intensity of wood is taken from previous work by the author; for LPG it is from authoritative government sources. Both are consistent with values found in general literature. It is assumed that carbon in either fuel is converted fully to carbon dioxide. Thermal efficiencies are taken from a World Bank and an IEA review. For LPG, the efficiency is now estimated at 50%, whereas previously it was 60%. This is because 'real-life' efficiencies have been found to be lower than those reached in laboratory testing (International Energy Agency, 2017, Box 3.3, p 67). Both wood and LPG are assumed to be products, i.e. produced on purpose, as opposed to residues or wastes (European Commission, 2009). An average developing-world family consists of five people (Bongaarts, 2001) (Bongaarts, 2011) that annually consume 5 GJ of useful energy in cooking (World Bank, 2006, p 39), i.e. 1 GJ per person per year. At 15% efficiency, 1 GJ delivered heat requires 400 kg of wood[6]; at 50% efficiency, 1 GJ requires 42.9 kg of LPG.

For LPG, this is considerably higher than the 22 kg/person-year quoted by the IEA (IEA, 2006, p 15) (IEA *et al*., 2010, p 22). However, this is not a disagreement, rather a case of different definitions. The 36-kg figure applies if the household cooks only with LPG. The 22-kg figure is an estimate of LPG usage in typical households, which often use multiple cooking fuels (World Bank, 2011a) (World Bank, 2011b). For instance, as (Ruiz-Mercado *et al*., 2011) report, families in Mexico's highlands typically use four different cookers: a three-stone fire, a Patsari stove, an LPG stove and a microwave oven. The first two burn biomass to prepare traditional foods such as tortillas and tamales; LPG is used for soups, meats and re-heating; the microwave is used for re-heating and making popcorn.

2.3 IMPACT ASSESSMENT

Carbon dioxide emissions are measured for the cooking and forest systems and compared for the two fuel types, wood and LPG. CO_2 is the most accurately, most consistently measured global warmer emitted in fuel combustion, and it is the predominant source of global warming. For wood, only combustion emissions are measured in the cooking system. Emissions from cultivation, harvest, transport and preparation are not included. For LPG, all emissions are included from 'well-to-stack'.

The two other main greenhouse-gases emitted in fuel combustion – methane and nitrous oxide – are not measured, because there is not a reliable set of emissions factors for either of these for either fuel (Johnson, 2012, Appendix A). Black carbon emissions are also not included, because black carbon has yet to be included in conventional impact assessment methods (BSI *et al*., 2011). For LPG, black carbon emissions are negligible (Atlantic Consulting, 2010). For wood, however, black carbon emissions can be significant. A study of wood burning (for heat, not cooking) in the United Kingdom (Mitchell *et al*., 2017, p 431) finds that "Black carbon has surpassed carbon dioxide to become the most important component of RSF[7] radiative forcing" in the UK.

2.3.1 Wood vs LPG, in theory

Using the definitions above, the net carbon emissions of the two systems (wood and forest; LPG) have been plotted over time (Figure 1). Negative numbers mean carbon has been emitted to the atmosphere; positive numbers mean it has been sequestered.

In both systems, 1 GJ of cooking heat is delivered, which calls for 400 kg of air-dried wood and 42.9 kg of LPG (a bit more than three typical 13-kg cylinders). The emissions, which are treated as a pulse in year zero, are derived from the factors above (Table 2).

Wood's emissions are:
105.4 ÷ 15% x 100% = 702.4 kg CO_2/GJ

whereas LPG's emissions are:
72.0 ÷ 50% x 100% = 144.0 kg CO_2/GJ.

According to normal conventions of life-cycle accounting, the CO_2 emissions from LPG are not offset by re-sequestration, but the emissions from wood are[8]. Wood emissions are re-sequestered completely by the end of the 'relaxation' period. We have presented the re-sequestration as a linear progression[9]. For each system, the net carbon emission is simply the area above/under each curve (Figure 1), in units of CO_2 tonne-years. In keeping with conventions of environmental accounting, no discounting has been applied to future emissions.

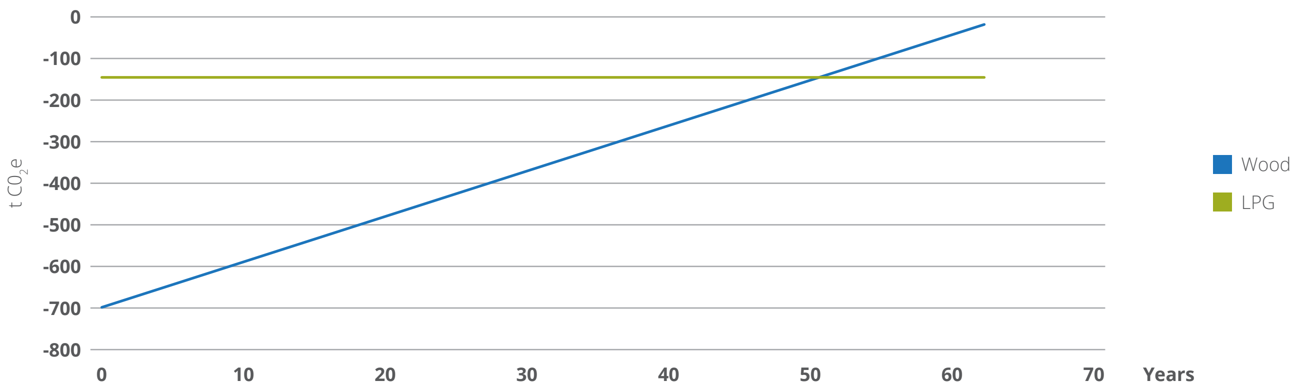
[6] At 15% moisture, a fairly typical value for air-dried wood.

[7] RSF is residential solid fuel, i.e. nearly all wood plus a small amount of coal.

[8] The qualification starting this sentence is critical. In actual fact, of course the carbon dioxide from LPG is re-sequestered along with that from wood. Life-cycle assessment is an accounting method, which treats 'bio' CO_2 differently to 'fossil' CO_2.

[9] Real-world measurements suggest an S-curve, but this should not affect results significantly, if the entire relaxation period is considered.

FIGURE 1: NET CARBON EMISSIONS FOR 1 GJ DELIVERED HEAT, WOOD VS LPG, BASE CASE



Source: Xxxx

2.3.2 What is the relaxation period? What is the time horizon?

Answers to these two are critical and not obvious. For both we have defined 'base case' definitions, which seem most reasonable. We also have examined sensitivities to those.

According to (Müller-Wenk and Brandao, 2010, Table 2, p 178), the relaxation time for a tropical forest (to cropland) is 62-65 years. A tropical forest is the most likely setting associated with traditional cooking (see section 2.5), so a relaxation time of 63 and a halfyears has been chosen for the base case.

Choosing a time horizon is a more difficult question. This is also addressed by (Müller-Wenk and Brandao, 2010, p 174), who refer to the time horizon as a 'cut off point': "As the global warming effect of a CO_2 quantity depends on its average stay in air, we want to find out... the average time a CO_2 molecule stays in air. A meaningful average can be calculated only if the curve is cut off after a finite number of years, which means that the climatic influence of CO_2 after this cut-off point is considered to be negligible. A cut-off at year 100 would result in a mean CO_2 stay in air of 47 and a half years, while a cut-off at year 500 gives a mean stay in air of 157 years. The choice of this cut-off point should be such that comparisons with CO_2 originating from land use are not heavily distorted; it can be shown that a cut-off at year 100 would be too short, unduly favouring carbon from fossil combustion, so that we prefer a cut-off at 500 years."

Clearly, a longer time horizon favours wood, and a shorter one favours LPG. Unlike (Müller-Wenk and Brandao, 2010), who apparently want to favour bio over fossil fuels, this analysis is aimed at finding results that do not favour a particular fuel type, but instead, sensibly inform policy. To that end, there seem to be three choices of time horizon:

- Equal to the relaxation period, i.e. the time required for the forest to return to its state of immediately pre-harvest. For a tropical forest, this is 63 and a half years (Müller-Wenk and Brandao, 2010, Table 2, p 178).
- Linked to a policy target, say the 80% carbon reduction by 2050, agreed by the G8 nations in 2009. This gives a time horizon of 2050-2013, or 37 years.
- 100 years, the time horizon typically used in carbon footprints.

For the base case, we have used the 63 and a half year cut off for a tropical forest, because this is the time required for the forest to return to its incipient state. This choice is justified by the 'Sustainability criteria for bioenergy' as proposed for ISO 13065 (Corr, 2013), which says:

If the production of a bioenergy product is linked to specific time periods (e.g., seasonal products can range from annual grasses and crops to short- and long-rotation forest), the assessment of GHG emissions and removals should cover the relevant period in the life cycle of the product.

- *For perennial crops the time period for assessment of the GHG emissions and removals including carbon stock change shall consider at least one entire rotation period.*
- *The rotation period for perennial crops and forest can range from a few years to more than 100 years. Therefore, it may be necessary to extrapolate emissions and removals if data is not available for the full rotation period. It is essential to document and justify the assumptions and procedures used to estimate the emissions and removals.*

As sensitivities, we have also examined other time horizons and relaxation periods.

2.3.3 Product vs waste/residue wood

Clearly, not all wood used in traditional cooking is a product, i.e. intentionally produced for use in this application. Some is waste or residue that would be disposed or would decompose if not used.

Hard data on the actual split in volumes, for wood used as fuel and for wood used otherwise, are sparse, and hypotheses differ. Researchers such as (Nagothu, 2001) postulate that wood used as fuel comes mainly from residues, whereas researches such as (Sharma *et al.*, 2009) contend that it is mainly harvested from a standing forest. Both sides probably are right: in certain areas, that is. What is lacking is a regional or global view – except in the case of India, where (Reddy and Srinivas, 2009) have estimated a 50/50 split between wood produced as a product and wood produced as a residue.

In the base case, we have assumed 100% product wood, so that the carbon effects of other factors are highlighted. In the sensitivities, other percentages are assessed. Obviously, at 100% residue or waste, the footprint of wood cooking would be zero.

2.3.4 Base case results

The net carbon emissions are calculated by integrating the area above the curves (Figure 1). In the base case, this comes out to 22.302 CO_2 tonne-years for wood and 9.144 CO_2 tonne-years for LPG. Switching from harvested wood to LPG reduces net carbon emissions by 59%.

2.3.5 Sensitivities

As the preceding text foreshadows, there are several important sensitivities to this analysis, so these have been calculated with respect to the base case. Except for two, the descriptions (Table 3) should be self-explanatory. One exception is the 'soil carbon' scenario. The base case assumes no emissions of soil carbon occur in wood harvesting; the sensitivity assumes that 10% of soil carbon is emitted (and then re-sequestered over the relaxation period) during harvest. The other exception is the 37-year time horizon. This is chosen, because 2050 – the target date for 80% carbon reductions agreed by the G8 nations – is 37 years away from now.

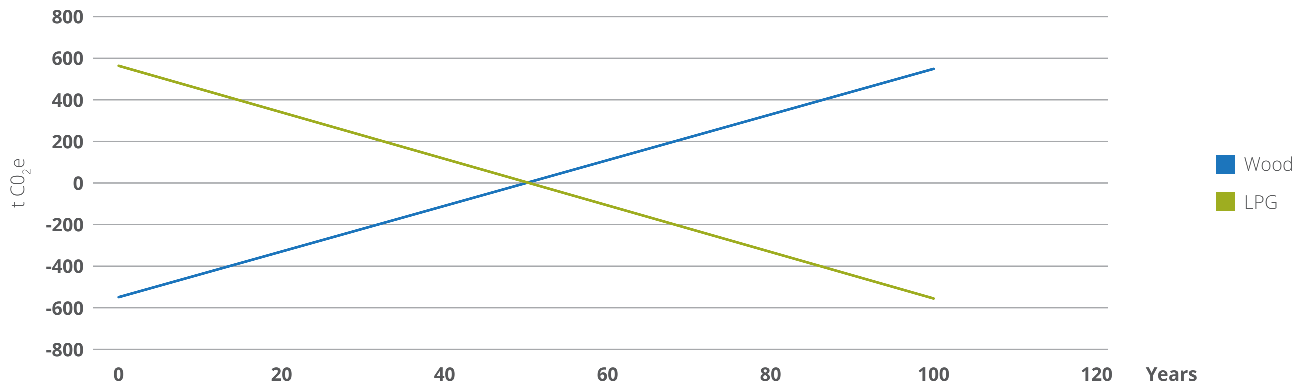
Not surprisingly, the greatest sensitivities are to: time horizon, and the use of residue or waste wood. The latter is the greatest sensitivity of all, because by life-cycle accounting convention, waste/residue wood is carbon neutral. At a 60/40 mix of waste and product wood, the wood emissions are equal to those of LPG.

TABLE 3: NET CARBON EMISSIONS FOR 1 GJ DELIVERED HEAT, WOOD VS LPG, SENSITIVITIES

Scenario	Net carbon emissions C02 t-years		Carbon reduction, wood to LPG switch
	WOOD	**LPG**	
Base case	**-22'302**	**-9'144**	**59%**
TIME HORIZON			
Base case 63.5 years	**-22,302**	**-9,144**	**59%**
37 years	**-18,213**	**-5,328**	**71%**
100 years	**-14,380**	**-14,400**	**0%**
RELAXATION TIME			
Base case 63.5 years	**-22,302**	**-9,144**	**59%**
Temperate forest, 74 years	**-25,990**	**-10,656**	**59%**
Boreal forest, 238 years	**-83,589**	**-34,272**	**59%**
SOIL CARBON, 10% EMISSION			
Base case 0%	**-22'302**	**-9'144**	**59%**
10%	**-26,339**	**-9,144**	**65%**
WOOD STOVE EFFICIENCY			
Base case 15%	**-22'302**	**-9'144**	**59%**
10%	**-33,453**	**-9,144**	**73%**
20%	**-16,727**	**-9,144**	**45%**
RESIDUE OR WASTE WOOD			
Base case 0%	**-22'302**	**-9'144**	**59%**
50% waste wood	**-11,151**	**-9,144**	**18%**
58% waste wood	**-9,367**	**-9,144**	**2%**
66.7% waste wood	**-7,438**	**-9,144**	**-23%**

Source: Xxxx

FIGURE 2: NET CARBON EMISSIONS FOR 1 GJ DELIVERED HEAT, WOOD VS LPG, MODELLED CONSEQUENTIALLY



Source: Xxxx

2.4 A CONSEQUENTIAL VIEW

As noted above (section 2.1), the analysis so far assumes an 'either or' choice, i.e. people will use either wood or LPG as cooking fuel. However, this choice is not shown explicitly in the modelling. So the results have been re-plotted (Figure 2) in a 'consequential' fashion to make that baseline explicit.

For LPG, the net emissions start off positive, because the 702.4 kg CO_2/GJ of wood emission has been avoided; only the 144.0 kg CO_2/GJ of LPG emissions have been made. This diminishes over time, as CO_2 is steadily sequestered into the forest. For wood, the function is inverted. This method of presentation (Figure 2) clearly shows the short-term benefits of switching to LPG. After just over 50 years, net emissions for LPG are slightly negative (more global warming) and for wood are slightly positive (less global warming).

This highlights a key sensitivity: the relaxation period. In the very best case for wood – a tropical relaxation period of 63 and a half years – it still takes 50 years for it to become marginally lower carbon. In non-tropical areas, it will take longer.

2.5 IMPLICATIONS FOR ENERGY POLICY

Nearly half of the developing world's population – 2.6 billion people – still uses traditional biomass cooking (Table 4). This is

7% more than in 2000 (Table 5), but there have been much larger changes within the regions. Sub-Saharan Africa and India have passed China, which has cut its number of biomass-cookers by more than half. Indonesia has also reduced its numbers by about two-thirds, whilst all other regions have increased theirs.

The IEA and other sources imply that the vast majority of this cooking, in numbers of people and in volume of fuel, is with wood (a significant portion of that converted to charcoal), but precise figures are not specified. (Charcoal is much higher in carbon emissions (Johnson, 2009), but this has not been assessed in this analysis.) How much of the wood is waste or residue? This is a topic worth further analysis: the latest figures are from around 2000 (Table 5), and they are incomplete.

In any case, for areas that use more than about 40% product wood, there are carbon savings to be achieved from a switch to LPG. By product wood, we mean either stemwood deliberately harvested for use as fuel or for conversion to charcoal. For areas using half product, half residue/waste, a carbon savings of nearly 20% can be realised. At 100% product wood, a switch to LPG can eliminate 60% of the net carbon emissions.

As outlined in Section 1.1 and directly above, the IEA foresees a major shift away from traditional biomass cooking from 2015 to 2030. If this shift were to LPG:

- Under the 'New Policies' scenario, this would save 170 million tonnes of CO_2 emissions per year.
- Under the 'Energy for All' scenario, this would save 415 million tonnes of CO_2 emissions per year.

TABLE 4: POPULATIONS COOKING WITH TRADITIONAL BIOMASS, 2015

Region	People cooking with biomass, millions	
	IN 2015	CHANGE FROM 2000-2015
Sub-Saharan Africa	800	+225
India	780	+195
China	300	-406
Latin America	240	+144
Other South Asia	195	+67
Other East Asia	190	+53
Indonesia	60	-95
N Africa, Middle East	Negligible	-8
SUM	2,565	+175

Source: IEA, 2017

TABLE 5: BIOMASS COOKING, WOOD HARVESTED FOR FUEL, DEVELOPING WORLD (approx. year 2000)

Country	People cooking with biomass, millions	% of population	% wood from forest
China	706	56	74
India	585	58	51
Sub-Saharan Africa	575	89	NA
Indonesia	155	74	35
Other East Asia	137	37	60-90
Other South Asia	128	41	15-75
Latin America	96	23	NA
N Africa, Middle East	8	0.05	NA
DEVELOPING COUNTRIES TOTAL	2,390	52	NA

Sources: (IEA, 2002, p 391), (Arnold et al., 2003, Table 4, p 12)

3.0 Avoiding deforestation by substituting LPG for wood

Some 500 million households in the developing world cook over an open fire fuelled by wood or charcoal. Perhaps half of these use wood intentionally harvested for fuel that could be used for other purposes or simply left standing, while the other half use residues such as dung, rice husks or sticks. Supplying this wood demands the annual harvest of 2.5 million hectares of forest. If this were instead supplied by an equivalent amount of liquefied petroleum gas (LPG), 55 million tonnes, those 2.5 million hectares of forest would be spared annually – equivalent to nearly half the rate of global deforestation. At a more personal scale, switching 100 households from consuming 200 tonnes of harvested wood a year to 22 tonnes of LPG would annually save one hectare of forest. Each household would save about 100 square metres of forest. Seen at user scale, a typical 13-kg cylinder of LPG would avert deforestation of a 6 m2 forest area.

3.1 CLEANER COOKING AND DEFORESTATION

Deforestation is a well-recognised problem and a proxy for other problems. Probably the most prominent are carbon depletion, desertification, habitat endangerment (reduction of biodiversity), impairment of social amenity, soil erosion and threat to local livelihoods (UN Food and Agricultural Organization, 2015a).

The link between deforestation and traditional cooking was first highlighted in the literature by Erik P Eckholm, who wrote that "firewood is the main source of energy for fuel used by the majority of people today, but in many parts of the world it is becoming harder to find or disappearing with use" (Eckholm, 1975, p 31). The logical policy response, Eckholm contended, was tree planting on a "massive scale", and this was attempted under a *Tropical Forestry Action Plan* launched in 1985 by the United Nations' Food and Agricultural Organisation. Under this action plan, tree-planting projects proliferated. Most of them, such as India's Social Forestry programme, focused on community woodlot planting (Arnold *et al*., 2003, p 4-5). Unfortunately, for various reasons, "these did little to augment fuelwood supplies for rural users", and even in urban areas, "shifts away from domestic woodfuel use were not taking place on a very large scale" (Arnold *et al*., 2003, p 5).

Partly because of this failure, and also thanks to increasing recognition of traditional cooking's other negatives (noted above), development-policy over the past decade has moved somewhat away from tree-planting toward a greater focus on two other targets: a) substituting other fuels for wood in cooking, and b) improving cookstove performance, regardless of fuel, in terms of fuel efficiency, emissions, durability and safety (Arnold *et al*., 2003, p 7) (Dept for International Development, 2002) (ISO, 2012) (Maes and Verbist, 2012).

One substitution option is to switch from wood to LPG. Clearly, this option meets the criteria of large increases in combustion efficiency, fuel efficiency, or both, proposed by (Ruiz-Mercado *et al*., 2011, p 7557). Two studies have posited a link between LPG substitution of wood and slowing or reversing deforestation. One, by (Nautiyal and Kaechele, 2008), reports on a Himalayan district where LPG substitution increased the health of adjacent forests. Another documents an area in Southeast China, where substitution of wood has "unexpectedly caused significant progress in hilly ecosystem restoration, particularly in mitigation of soil erosion and forest degradation" (Wang *et al*., 2012). Neither of these studies quantifies the relation of fuel switching and deforestation.

This chapter addresses that missing answer: it assesses how switching from wood to LPG can avoid deforestation.

3.2 METHOD

This paper estimates the deforestation impact of substituting LPG for wood in traditional cooking. It does so by use of two calculation models, which both use inputs from the public domain. In broad terms, the method is similar to that of life cycle assessment.

First is a model of avoided deforestation model on a *micro scale*. It models consumption of wood and LPG for cooking, normalised to an average household in the developing world,

TABLE 6: AVOIDED DEFORESTATION, MODELLED ON A MICRO SCALE

Quantity	Unit	Item	Reference
5	GJ/yr	Average household cooking, useful energy consumed	(World Bank, 2006, p 39)
2	t	Wood/household, 15% moisture, traditional stove[10]	(World Bank, 2006, p 39)
15%		Moisture, wet basis, in the wood	
50%		C content in wood, bone dry	Numerous, confirmed by (Lamlom and Savidge, 2003)
0.85	t/yr	C emitted by wood combustion[11]	
86	t C/ha	Above ground forest C, global midpoint	(Wissenschaftlichen Beirats der Bundesregierung Globale Umweltveränderungen, 1998, p 48)
101	Households	Use 1 ha of forest, above ground	
99	m2	forest saved per household to LPG	
180	kg/yr	LPG, average household cooking (for 5 GJ useful energy)[12]	(World Bank, 2006, p 39)
18	t	Avoided deforestation, amount of LPG to save 1 ha of forest	
7	m^2	Avoided deforestation, per 13-kg cylinder of LPG	

Source: Xxxx

and relates this to avoided deforestation through substitution of wood by LPG. Second is an avoided deforestation model on a *macro scale*. It extrapolates the micro model to a global scale and compares it to prevailing deforestation rates.

3.3 AVOIDED DEFORESTATION, ON A MICRO-SCALE

This model (Table 4) develops a carbon-emissions equivalent for wood in cooking, normalised to an average household in the developing world. This is then related, by forest carbon stock, to deforestation caused by consumption of wood.

The three elements of the model (Table 4), shaded blue, red and green, are presented respectively in more detail in the following three subsections.

3.3.1 Carbon emissions from cooking with wood, in developing-world households

An average developing-world family consists of five people (Bongaarts, 2001) (Bongaarts, 2011) that annually consume 5 GJ of useful energy in cooking (World Bank, 2006, p 39), i.e. 1 GJ per person per year. At 15% efficiency, 1 GJ delivered heat requires 400 kg of wood per person, or 2 tonnes per household. A moisture content of 15% is typical for air-dried wood. This equates[13] to a lower-heating-value of 16 MJ/kg, which is within the normal range of heating values – 15-20 MJ/kg – reported for air-dried wood.

The conversion efficiency defined by the World Bank for the traditional wood stove is 15% (World Bank, 2006, p 39) (International Energy Agency, 2017, p 124). Carbon content of wood fuel is assumed to be the rule-of-thumb value of 50% of dry weight. Two papers (Lamlom and Savidge, 2003) (Martin and Thomas, 2011) have shown a variation of about + 3% around 50%. For the accuracy of this analysis, 50% is therefore a reasonable assumption.

The conversion, then, is two tonnes wood x (1-15%) x 50% carbon = 0.85 tonnes carbon[14] passes through the average household per year as wood cooking fuel.

[10] Assumes about 16% thermal conversion, wood.

[11] Molecular carbon, not carbon dioxide.

[12] Assumes about 60% thermal conversion, LPG.

[13] Calculated according to GJ/tonne = 19.2 - (0.2164*MC), where MC is the moisture content in percent of total weight, as reported at: http://www.woodenergy.ie/frequentlyaskedquestions/.

[14] Molecular carbon, not carbon dioxide.

3.3.2 Carbon content of forests

In the 1990s a 'Scientific Advisory Council of Global Environmental Change' to the German federal government was charged by the-then Environment Minister, Angela Merkel, with conducting a special audit of biological sources and sinks of carbon dioxide. The audit was published in June 1998 (Wissenschaftlichen Beirats der Bundesregierung Globale Umweltveränderungen, 1998).

In the compiled by the Council, from various sources including the Intergovernmental Panel on Climate Change, a compendium of forest carbon-concentrations for various regions and countries (Appendix Table 2, p 48). The global midpoint for above-ground concentration is 86 t C/hectare, with regional values ranging from 28-174 t C/hectare. (Below-ground concentrations are much higher; the global midpoint is 189 t C/hectare.) For this estimate, we have used the above-ground midpoint of 86 t C/hectare.

3.3.3 Equivalent deforestation, actual or avoided by LPG substitution

Dividing the previous two results into each other gives the following finding: 101 average households consume one hectare of above-ground vegetation of an average forest to fuel their cooking for one year. This equates to 99 m^2 of forest per year.

What if that wood is substituted by LPG and therefore allowed to remain as forest? As presented in Section 2.2.1, the equivalent amount of LPG needed to supply the 5 GJ of cooking is 214.6 kg, or 42.9 kg per GJ. (This presumes 50% stove efficiency and a lower-heating value for LPG of 46.6 MJ/kg, both of which are consistent with normal reported ranges.)

So, 22 kg of LPG, if used to replace wood, would avert one hectare of deforestation, or one t would avert 0.46 hectares of deforestation. Seen at user scale, a typical 13-kg cylinder of LPG would avert deforestation of a 6 m^2 forest area.

3.4 AVOIDED DEFORESTATION, ON A MACRO-SCALE

This macro model (Table 7) extrapolates the micro model to a global scale, and compares it to prevailing deforestation rates.

The four elements of the model (Table 7), shaded red, blue and green, are presented respectively in more detail in the following three subsections.

TABLE 7: AVOIDED DEFORESTATION, MODELLED ON A MACRO SCALE

Quantity	Unit	Item	Reference
2.565	Million	People using biomass fuels, global	(IEA, 2017)
5	People	Average household size, developing world	(Bongaarts, 2001) (Bongaarts, 2011)[15]
513	Million	Households using biomass fuels, global	
50%		Households using product/byproduct wood	(Reddy and Srinivas, 2009, p 997)
257	Million	Households using product/byproduct wood	
55	Million	t LPG to replace product/byproduct wood	
2.37	Million	ha forest saved	
5.21	Million	ha deforestation[16]/yr, 2010-2015	(UN FAO, 2015b, p 9)
53%		Deforestation averted/yr	

Source: Xxxx

3.4.1 Households cooking with traditional biomass

Nearly half of the developing world's population – 2.6 billion people – still uses traditional biomass cooking (Table 4). This is 7% more than in 2000 (Table 5), but there have been much larger changes within the regions. Sub-Saharan Africa and India have passed China, which has cut its number of biomass-cookers by more than half. Indonesia has also reduced its numbers by about two-thirds, whilst all other regions have increased theirs.

TABLE 8: POPULATIONS COOKING WITH TRADITIONAL BIOMASS, 2015

Region	People cooking with biomass, millions	
	IN 2015	CHANGE FROM 2000-2015
Sub-Saharan Africa	800	+225
India	780	+195
China	300	-406
Latin America	240	+144
Other South Asia	195	+67
Other East Asia	190	+53
Indonesia	60	-95
N Africa, Middle East	Negligible	-8
SUM	2,565	+175

Source: IEA, 2017

[15] In developing countries, average household-size (i.e. number of people) declined steadily from the mid-1970s up to around 2000, but from 2000 to the present the size has remained about the same.

[16] Net annual forest change.

TABLE 9: BIOMASS COOKING, WOOD HARVESTED FOR FUEL, DEVELOPING WORLD (approx. year 2000)

Country	People cooking with biomass, millions	% of population	% wood from forest
China	706	56	74
India	585	58	51
Sub-Saharan Africa	575	89	NA
Indonesia	155	74	35
Other East Asia	137	37	60-90
Other South Asia	128	41	15-75
Latin America	96	23	NA
N Africa, Middle East	8	0.05	NA
DEVELOPING COUNTRIES TOTAL	2,390	52	NA

Sources: (IEA, 2002, p 391), (Arnold et al., 2003, Table 4, p 12)

The IEA and other sources imply that the vast majority of this cooking, in numbers of people and in volume of fuel, is with wood (a significant portion of that converted to charcoal), but precise figures are not specified. (Charcoal is much higher in carbon emissions (Johnson, 2009), but this has not been assessed in this analysis.) How much of the wood is waste or residue? This is a topic worth further analysis: the latest figures are from around 2000 (Table 5), and they are incomplete.

3.4.2 Wood supply: residue or waste versus product or byproduct

This paper assumes that using biomass residues or wastes as fuel does not contribute to deforestation. This assumption is common and has even been incorporated in legislation (European Commission, 2009). Conversely, this paper assumes that product (or byproduct) wood does contribute to deforestation.

Hard data on the actual split in volumes, for wood used as fuel and for wood used otherwise, are sparse, and hypotheses differ. Researchers such as (Nagothu, 2001) postulate that wood used as fuel comes mainly from residues, whereas researches such as (Sharma *et al*., 2009) contend that it is mainly harvested from a standing forest. Both sides probably are right: in certain areas, that is. What is lacking is a regional or global view – except in the case of India, where (Reddy and Srinivas, 2009) have estimated a 50/50 split between wood produced as a product and wood produced as a residue.

The macro model in this paper (Table 7) adopts that 50/50 estimate. To some extent, it is corroborated by the estimates of(Arnold *et al*., 2003, Table 4, p 12).

3.4.3 Deforestation rates, and LPG aversion of deforestation

For the 50% of wood produced as a product or byproduct, an equivalent amount of LPG is 214.6 kg/household (Table 4) x 513 million households x 50% = 55 million tonnes LPG. This amounts to about 18% of global LPG demand in 2018. In the coming decade, this percentage will decline, as significant new sources in the Middle East, Russia and the USA come onstream.

Applying the conversion of 101 households/hectare (Table 6) to 268 million households (half of 513 million) equals 2.5 million hectares of forest that annually would not be consumed for fuel, if the wood were substituted with LPG.

As a benchmark, this is equivalent to 53% of net global deforestation per year over the 2010-2015 period, 4.8 million hectares (UN FAO, 2015b, p 9). Obviously, deforestation does not progress at equal rates everywhere, but the developing world is clearly in deficit (Table 10). The exceptions are China and to a lesser extent India, which thanks to substantial reforestation programmes skew the total for Asia to a slight positive.

What if this same logic is applied to the IEA's forecast shift away from traditional biomass cooking from 2015 to 2030 (Section 1.1)?

TABLE 10: NET ANNUAL FOREST LOSSES, BY REGION (2010-2015)

Region	Change in forest area Million hectares/year
Africa	-2.8
Asia	+0.8
Europe	+0.4
North and Central America	+0.1
Oceania	+0.3
South America	-2.0
SUM	-4.8

Source: UN FAO, 2015b

If we assume that half of the households that shift away from biomass had been using product wood and the other half residue/waste wood, then:

- Under the 'New Policies' scenario, this would save 800 thousand hectares of forest per year. This is about 16% of the current global sum, and is roughly equal to the net contribution of Asia.
- Under the 'Energy for All' scenario, this would save 1.95 million hectares of forest per year. This is about 40% of the current global sum, and is roughly equal to the net deficit of South America.

4.0
References

Arnold, M., Köhlin, G., Persson, R., Shepherd, G., 2003. *Fuelwood revisited: What has changed in the last decade?* Center for International Forestry Reserach, Jakarta.

Atlantic Consulting, 2010. *Clearing the Air: Black Carbon, Climate Policy and LPG*.

Bongaarts, J., 2011. *Can Family Planning Programs Reduce High Desired Family Size in Sub-Saharan Africa?* Int. Perspect. Sex. Reprod. Health 37, 209–216.

Bongaarts, J., 2001. *Household size and composition in the developing world*. Population Council.

BSI, Carbon Trust, UK DEFRA, 2011. Publicly Available Specification 2050:2011. *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*.

Corr, C., 2013. ISO/CD 13065, *Sustainability criteria for bioenergy: Greenhouse gas methodologies*.

DECC, DEFRA, 2010. *Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting*.

Dept for International Development, 2002. *Energy for the poor: Underpinning the millennium development goals*. UK Dept. for International Development.

Eckholm, E.P., 1975. *The other energy crisis: firewood*. Worldwatch Institute.

European Commission, 2009. *Renewable Energy Directive*.
IEA, 2017. *Energy Access Outlook*. IEA Publ. doi:10.1007/978-0-85729-268-1

IEA, 2006. *Energy for cooking in developing countries*. International Energy Agency, Paris.

IEA, 2002. *Energy and poverty*. International Energy Agency, Paris.

IEA, UNDP, UNIDO, 2010. *Energy Poverty: How to make modern energy access universal?* International Energy Agency, Paris.

ISO, 2012. *Guidelines for evaluating cookstove performance*. IWA 112012, ISO Int. Work. Agreem.

ISO, 2006a. 14044: *Environmental management – Life cycle assessment – Requirements and guidelines*.

ISO, 2006b. ISO 14040: *Environmental management – Life cycle assessment – Principles and framework*.

Johnson, E., 2009. *Charcoal versus LPG grilling: a carbon-footprint comparison*. Environ. Impact Assess. Rev. 29, 370–378. doi:10.1016/j.eiar.2009.02.004

Johnson, E., Tschudi, D., 2012. *Baseline effects on carbon footprints of biofuels: The case of wood*. Environ. Impact Assess. Rev. 37, 12–17.

Johnson, E.P., 2012. *Carbon footprints of heating oil and LPG heating systems*. Environ. Impact Assess. Rev. 35, 11–22.

Lamlom, S.H., Savidge, R.A., 2003. *A reassessment of carbon content in wood: variation within and between 41 North American species*. Biomass and Bioenergy 25, 381–388. doi:http://dx.doi.org/10.1016/S0961-9534(03)00033-3

Maes, W.H., Verbist, B., 2012. *Increasing the sustainability of household cooking in developing countries: Policy implications*. Renew. Sustain. Energy Rev. 16, 4204–4221.

Martin, A.R., Thomas, S.C., 2011. *A reassessment of carbon content in tropical trees*. PLoS One 6.

Mitchell, E.J.S., Coulson, G., Butt, E.W., Forster, P.M., Jones, J.M., Williams, A., 2017. *Heating with Biomass in the United Kingdom: Lessons from New Zealand Intergovernmental Panel on Climate Change*. Atmos. Environ. 152, 431–454. doi:10.1016/j.atmosenv.2016.12.042

Müller-Wenk, R., Brandao, M., 2010. *Climatic impact of land use in LCA-carbon transfers between vegetation/soil and air*. Int. J. Life Cycle Assess. 15, 172–182.

Nagothu, U.S., 2001. *Fuelwood and fodder extraction and deforestation: Mainstream views in India discussed on the basis of data from the semi-arid region of Rajasthan*. Geoforum 32, 319–332.

Nautiyal, S., Kaechele, H., 2008. *Fuel switching from wood to LPG can benefit the environment*. Environ. Impact Assess. Rev. 28, 523–532.

Reddy, B.S., Srinivas, T., 2009. *Energy use in Indian household sector - An actor-oriented approach*. Energy 34, 992–1002.

Ruiz-Mercado, I., Masera, O., Zamora, H., Smith, K.R., 2011. *Adoption and sustained use of improved cookstoves*. Energy Policy 39, 7557–7566.

Sharma, C.M., Gairola, S., Ghildiyal, S.K., Suyal, S., 2009. *Forest resource use patterns in relation to socioeconomic status*. Mt. Res. Dev. 29, 308–319.

UK Dept of Business Energy & Industrial Strategy, 2016. 2016 *Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors*.

UN Food and Agricultural Organization, 2015a. *Global Forest Resources Assessment 2015* - Desk reference.

UN Food and Agricultural Organization, 2015b. *Global Forest Resources Assessment 2015*.

Wang, C., Yang, Y., Zhang, Y., 2012. *Rural household livelihood change, fuelwood substitution, and hilly ecosystem restoration: Evidence from China*. Renew. Sustain. Energy Rev. 16, 2475–2482.

Wissenschaftlichen Beirats der Bundesregierung Globale Umweltveränderungen, 1998. *Die Anrechnung biologischer Quellen und Senken im Kyoto-Protokoll: Fortschritt oder Rückschritt für den globalen Umweltschutz?*

World Bank, 2011a. *Who uses bottled gas? Evidence from households in developing countries*, Policy Research Working Paper.

World Bank, 2011b. *The role of LPG in reducing energy poverty, Extractive Industries for Development Series*.

World Bank, 2006. *Energy policies and multitopic household surveys, Energy and Mining Sector Discussion Paper*. World Bank.

WLPGA
182, avenue Charles de Gaulle
92200 Neuilly-sur-Seine, France
Tel: +33 1 78 99 13 30

association@wlpga.org
www.wlpga.org