International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 536
Fax: +43 2236 807 503
E-mail: riley@iiasa.ac.at
Web: www.iiasa.ac.at

Final Report

OUTLOOK FOR CLEAN COOKING IN CENTRAL AMERICA BY 2030

Shonali Pachauri, Colin Cameron, Narasimha D. Rao

Energy (ENE) Program, International Institute for Applied Systems Analysis (IIASA)

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Abbreviations and Acronyms

ALRI	Acute Lower Respiratory Infections
CDM	Clean Development Mechanism
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
fNRB	Fraction Non-Renewable Biomass
GACC	Global Alliance for Clean Cookstoves
GEA	Global Energy Assessment
GHG	Green House Gas
IAQ	Indoor Air Quality
ICS	Improved Biomass Cook Stoves
IHD	Ischemic Heart Disease
Kg	Kilogram
LPG	Liquid Petroleum Gas
MJ	Mega Joule
PJ	Peta Joule
PM2.5	Particulate Matter 2.5 micrometers in diameter
PPP$	Purchasing Power Parity Dollar
SE4ALL	Sustainable Energy for All
WHO	World Health Organization

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Executive Summary

The number of people dependent on solid fuels in Guatemala, Honduras and Nicaragua has been rising steadily, even though the fraction of population without access to clean cooking has declined. This poses challenges for achieving the first objective laid out in the United Nation's Sustainable Energy for All ((SE4ALL)) vision of ensuring universal access to modern energy services by 2030. In this report, we assess household cooking energy patterns in these three Central American countries, and provide recommendations to improve access to clean cooking by 2030. We identify key knowledge and policy gaps in achieving universal access. Employing available data from household surveys, we develop a cooking energy service demand model to examine alternative future transition scenarios to achieve a universal clean cooking goal by 2030. We examine alternate pathways of achieving universal clean cooking objectives in each country, and quantify the health and emissions implications of changes in fuel demand between a baseline and alternative transition scenarios.

Guatemala

With a population of 14.7 million and a per capita GDP of $6947 ($2011), Guatemala is the largest and richest of the Central American countries. Yet, currently 94 percent of rural households and 54 percent of urban households rely on traditional cooking fuels and stoves. In 2010, we estimate that 5,407 premature deaths in Guatemala were attributable to solid fuel combustion in traditional stoves. Guatemala has uniquely high LPG and fuelwood prices, which further exacerbates energy poverty. The government aims to provide 6.5 million improved cook stoves (ICS) over the next decade.

In the absence of additional policies, 95 percent of households in urban Guatemala are likely to adopt clean fuels or stoves by 2030 from income growth (ES-1). For rural households, transitioning to clean cooking by 2030 will be a much larger challenge. About half of rural Guatemalans will be unable to afford clean fuels or stoves in 2030. As a result, about 3,533 lives could be lost from continued dependence on solid fuels in the region in 2030.

Under a rapid transition to clean fuels, about 2.7 million people would benefit from a transition away from solid fuel use in 2030. This transition would avoid as many as 1,956 premature deaths in 2030 (ES-2). A capital grant on ICS (biomass), however, is unlikely to have an impact in Guatemala, as long as fuelwood costs remain high. This also implies that the government's policy to scale up ICS may be challenging to implement under present fuelwood prices. Furthermore, higher penetration of ICS is unlikely to reduce premature deaths from indoor air pollution.

Implementing policies that enable a shift to cleaner cooking in the region will reduce cooking energy demand and GHG emissions (ES-3). Even in the absence of policies, final energy demand reduces 23 percent by 2030 from 2010 levels, due to the four-fold efficiency gains of LPG stoves. With policies aimed at a rapid transition to cleaner fuels like LPG by 2030, final energy use could be lower by 17 percent relative to the no new policies or baseline scenario. However, LPG demand would likely exceed that in the baseline by about 7 percent. As a consequence of these changes in cooking energy demand, total CO_2 emissions by 2030 are expected to rise about 5 percent relative to 2010. However, this increase could be more than offset by a reduction in non-CO_2 Kyoto gas emissions from reduced fuelwood use, assuming all of the fuelwood used is carbon neutral. If, on the other hand, 35 percent of the fuelwood used is non-renewable, Kyoto emissions in the rapid transition scenario could be 26 percent lower than in the baseline in 2030. Climate finance might thus have a potentially larger role in financing clean cooking projects in the region, but the suite of greenhouse gases accounted for needs to be expanded, and there need to be improvements in how offset methodologies account for climate benefits of clean cooking.

Honduras

Honduras has a per capita income of $4345 ($2011) and about 7.6 million inhabitants, of which just over half live in urban areas, and about 65 percent live below the national poverty line. Eighty percent of rural households and 22 percent of urban households still rely on fuelwood for cooking. We estimate that in 2010 4,298 premature deaths in Honduras were attributable to solid fuel combustion in traditional stoves.

By 2030, about a quarter of the urban population and close to 40 percent of rural households could still rely on traditional fuelwood stoves (ES-1). This could cause about 4,941 premature deaths from indoor air pollution.

Under a rapid transition to cleaner fuels like LPG, about 98% of the population, or about 2.8 million people could move off solid fuel use by 2030. This transition would be to avoid as many as 4,473 premature deaths in 2030 (ES-2).

An ICS grant policy would likely lead to the uptake of ICS by 1.6 million Hondurans in 2030. Such a policy would cost below US2010$1 per beneficiary. As a practical matter, stove subsidy policies, if combined with a massive scale-up of improved cook stoves, might be a cost-effective interim solution, where for many rural households a shift away from biomass may be out of reach in the short term. However, in contrast to a transition to LPG, an ICS policy would not appreciably reduce premature deaths from indoor air pollution.

Implementing policies that enable a shift to cleaner cooking in the region will reduce cooking energy demand and GHG emissions (ES-3). Even in the absence of policies, final energy demand reduces by 12 percent by 2030 from 2010 levels, due to the four-fold efficiency gains of LPG stoves. Under a rapid LPG transition scenario, final energy use reduces by 31 percent relative to the no new policies scenario. However, LPG demand would likely exceed that in the baseline by about 11 percent. As a consequence, total CO_2 emissions by 2030 are expected to rise about 15 percent relative to 2010. However, this increase could be offset by a reduction in non-CO_2 Kyoto gas emissions from reduced fuelwood use, even assuming that all of the fuelwood used is carbon neutral. However, if 35 percent of the fuelwood used is non-renewable, Kyoto emissions in the rapid transition scenario could be 42 percent lower than in the baseline in 2030. Climate finance might thus have a potentially larger role in financing clean cooking projects in the region, but the suite of greenhouse gases accounted for needs to be expanded, and there need to be improvements in how offset methodologies account for climate benefits of clean cooking.

Nicaragua

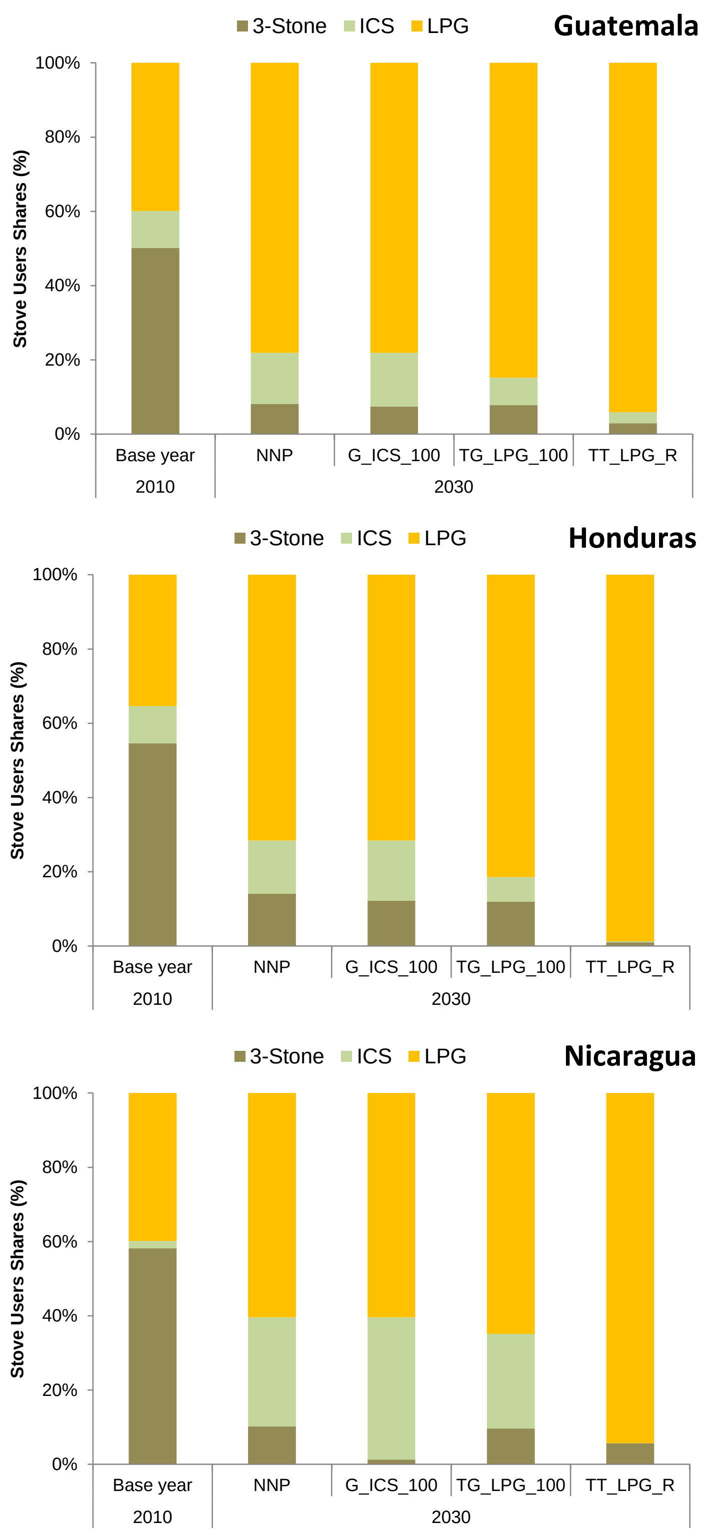
Nicaragua has the lowest per capita income $4,215 ($2011) and energy consumption (2.6 barrels of oil equivalent in 2009) among Central American countries. The number of people using solid fuels in Nicaragua has stayed relatively constant for two decades, even as the share of people using solid fuels has been on the decline with increasing LPG use. Currently, 46 percent of urban Nicaraguans and almost all rural households use fuelwood for cooking. In 2010, we estimate that 2,648 premature deaths in Nicaragua were attributable to solid fuel combustion in traditional stoves.

The analysis indicates that with rising income more than 95 of the urban population will be able to afford modern cooking fuels by 2030 in the absence of any policies. However, for rural households transitioning to clean cooking by 2030 will be a much larger challenge. In the absence of additional policies, more than three quarters of rural Nicaraguans will not be able to afford clean fuels or stoves in 2030 (ES-1). This would cause about 3,266 premature deaths from indoor air pollution.

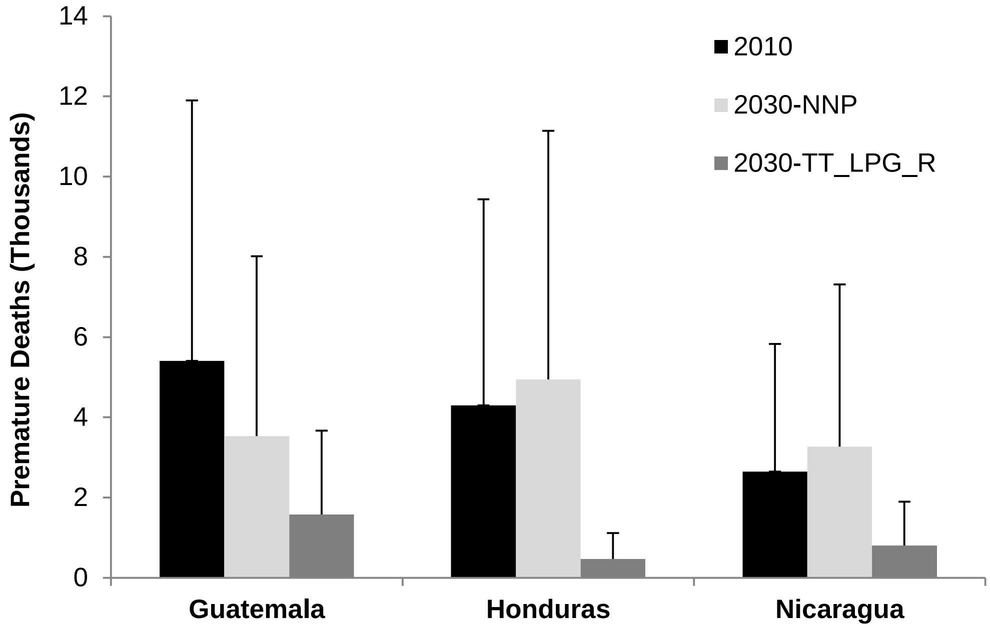
Due to the relatively low fuelwood prices in Nicaragua, capital grants for improved cook stoves (ICS) would be effective in bringing about a transition to more efficient fuelwood stoves in Nicaragua. Such a policy could benefit 2.2 million people and is estimated to cost only US2010$0.6 per beneficiary. However, to move off solid fuels and gain the full health benefits of clean cook stoves, a rapid transition to cleaner fuels like LPG would be necessary. Such a transition could benefit an estimated 1.85 million people, and avoid as many as 2,460 premature deaths in 2030 (ES-2).

Implementing policies that enable a shift to cleaner cooking in the region will likely reduce cooking energy demand and GHG emissions (ES-3). Even in the absence of policies, final energy demand reduces by 18 percent by 2030 from 2010 levels, due to the four-fold efficiency gains of LPG stoves. Under the rapid transition to LPG scenario, final energy use reduces by 24 percent relative to the no new policies scenario. LPG demand would likely exceed that in the baseline by about 6 percent. As a consequence, total CO_2 emissions by 2030 are expected to rise negligibly by about 1 percent relative to 2010. This increase could be more than offset by a reduction in non-CO_2 Kyoto gas emissions from reduced fuelwood use, even if fuelwood used is carbon neutral. However, if 35 percent of the fuelwood used is non-renewable, emissions in the access policies scenario could be 37 percent lower than in the baseline in 2030. Climate finance might thus have a potentially larger role in financing clean cooking projects in the region, but the suite of greenhouse gases accounted for needs to be expanded, and there need to be improvements in how offset methodologies account for climate benefits of clean cooking.

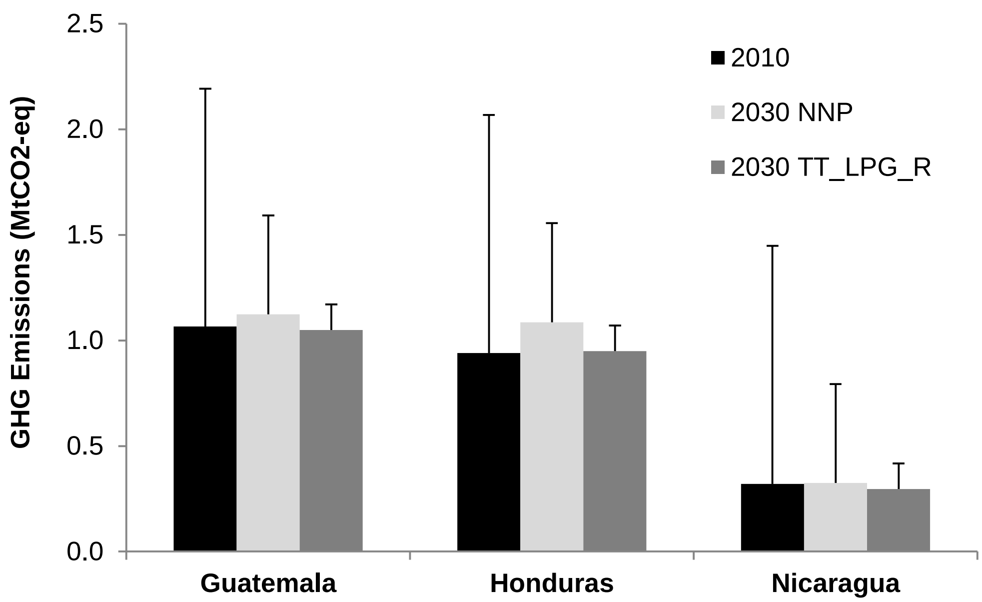
ES-1: Stove user shares under different policy scenarios for reducing solid-fuel dependence (in all cases, up to 95 percent access to ICS or LPG). NNP: No new policies; G_ICS_100: ICS stove grants of 100 percent; TG_LPG_100: LPG stove grants of 100 percent targeted to rural households and urban households earning <$5(PPP2010)/day; TT_LPG_R: Rapid transition to LPG targeted to rural households and urban households earning <$5(PPP2010)/day.



ES-2: Premature deaths from solid fuel use in 2010 and 2030 under a baseline or No New Policies (NNP) scenario and a Rapid Transition to LPG Fuel Scenario (TT_LPG_R) targeted to rural households and urban households earning <$5(PPP2010)/day. Error bars depict confidence intervals for a high relative risk rate.



ES-3: Greenhouse gas emissions for the baseline and future policy scenarios. Error bars represent additional CO_2 emissions under the conservative assumption that 65 percent of biomass is renewably sourced. NNP: No new policies; TT_LPG_R: a Rapid Transition to LPG Fuel Scenario targeted to rural households and urban households earning <$5(PPP2010)/day.



1 Introduction

1.1 Study Objectives

A first step to designing more effective policies and programs to scale up the adoption of improved cookstoves or transition to clean cooking fuels is to understand how the demand for cooking services and the choices regarding fuels and stoves is influenced by costs, prices and income and affordability. Drawing on available data, we assess household cooking energy patterns in the Central American countries of Guatemala, Honduras and Nicaragua. Based on this assessment, we provide recommendations to improve access to clean cooking by 2030 and highlight important knowledge and policy gaps. The available data are employed in a cooking energy service demand[1] model to determine existing patterns of cooking energy demand and assess alternative future pathways to achieve universal clean cooking access by 2030. The impacts of alternative pathways for achieving universal clean cooking objectives in each country for health and emissions as a result of changes in fuel demand under a baseline and alternative transition scenarios is also assessed.

The availability of data across the three countries varies widely. For the case of Guatemala, where detailed and nationally representative household survey data are available, a more in depth estimation of current cooking energy service demands for different rural and urban income groups is used to inform and assess future transition scenarios to achieve universal access to clean cooking by 2030. For the other two countries of focus, i.e. Honduras and Nicaragua, existing information and data limitations restrict the level of analysis that can be undertaken. However, the available data is employed in conjunction with adjusted cooking energy service demand curves derived from the Guatemalan data to assess alternative future cooking fuel scenarios in these two countries and assess the outlook for achieving a universal clean cooking goal by 2030. The future scenarios also account for future national economic and population growth projections. The projections and methods used to calculate the policy costs, health and

[1] Throughout this report cooking energy service demand or cooking energy needs are represented in useful energy or service terms (i.e. energy that reaches the pot rather than delivered or final energy) after accounting for the combustion efficiencies of the fuels and stoves deployed.

emissions impacts of alternate policy scenarios are informed by the Global Energy Assessment (GEA) and the work building on this (Pachauri et al. 2013; Riahi et al. 2012).

1.1.1 Structure of this Report

The report is organized as follows. The next section provides a description of the current household cooking energy situation in Guatemala, Honduras and Nicaragua respectively, and the recent trends in the use of cooking fuels. Section 3 focuses on the assessment of alternative future transition scenarios to enable a swifter transition to cleaner burning and more efficient cooking fuels and/or stoves by 2030, and their impacts in terms of health and emissions. The final section offers some concluding perspectives and overall lessons and policy implications for achieving universal access to clean household cooking in the region by 2030, in line with the United Nation's Sustainable Energy for All (SE4ALL) goal.

The rest of this section discusses some background to the region and motivation for the study, focusing specifically on recent national trends in residential cooking energy use in the three countries.

1.2 Background and Motivation

The three countries of focus in this study – Guatemala, Honduras and Nicaragua – are among the poorest countries in the Americas. For the region of Central America, as a whole, over two-fifths of the population still depends on solid fuels for cooking and a quarter still lacks access to electricity ((SE4ALL) 2013). In these three countries, from one third to one half of the population lacks access to electricity (Figure 1). The share of population dependent on solid fuels in Guatemala, Honduras and Nicaragua is also higher than the regional average for Central America, with over half the population still reliant on solid fuels. Of the close to 18 million solid fuel users in Central America in 2010, over 87 percent lived in one of these three countries, with the largest number in Guatemala. Thus, one of the major challenges still facing these Central American countries is to provide access to modern energy services to their populations and reduce reliance on traditional solid biomass energy, such as fuelwood, which is still used in inefficient and polluting traditional stoves to meet household cooking and other thermal needs.

Recent trends suggest that while the fraction of population dependent on solid fuels decreased from 68 percent to 55 percent in these three countries, the total number of people dependent on solid fuels rose from 12.2 million to 15.2 million between 1990 and 2010 ((SE4ALL) 2013). This was because population growth in the region outpaced the transition away from solid fuel cooking. Traditional biomass, especially fuelwood for cooking, also continues to account for more than a third of the region's final energy consumption (Díaz 2010). In the three countries of focus, biomass still accounts for between 40-60 percent of national final energy consumption (Table 1).

Figure 1: Map of the region with current status of population share with access to electricity and non-solid cooking fuels by country (source: SE4ALL 2013 – WB-GTF report).

It is well established now that a transition away from the use of solid fuels like fuelwood burnt in traditional stoves has far-reaching benefits for economic development and poverty alleviation (Pachauri et al. 2012a). In Central America alone, it is estimated that 37,000 premature deaths in 2010 were attributable to household air pollution from biomass cooking (of which, about 10 percent were children) (Lim et al. 2012). Improving household conditions through the use of advanced stoves, cleaner and more efficient fuels, and better ventilation has the potential to substantially improve health. The indoor air quality (IAQ) guidelines on household fuel combustion just issued by the WHO indicate that in order to protect public health, levels at or below IT-1 for PM2.5 (35 μg/m3) are needed (WHO 2014). However, field evaluation studies show that most solid fuel cookstoves lead to kitchen PM2.5 concentrations of up to ten (or more) times higher than IT-1.

Table 1: Basic Macro Indicators for Guatemala, Honduras and Nicaragua in 2011/2012. Source: World Development Indicators, WB, SE4ALL 2013 – WB-GTF, and OLADE Energy Balances

Indicator	Units	Guatemala	Honduras	Nicaragua
Area	sq. km.	107160	111890	120340
Population	millions	14.71	7.78	5.91
Density	persons/sq. km.	137	70	49
Urbanization	percent	50	52	58
GDP/capita (PPP)	2011$	6957	4345	4215
Gini Index	Index	52	57	53
Poverty gap at $2 a day (PPP)	percent	11	13	14
Urban high income (>$5 a day) population	percent	40	15	36
Electrified population	percent	82	83	78
Population using non-solid fuels	percent	43	49	46
Biomass share in total final energy use	percent	56	43	64
Residential share in total final energy use	percent	60	47	70

In the past, national energy policies and poverty reduction strategies in many developing countries, including those in Central America, have often either neglected the issue of energy access for the poor completely or focused solely on electrification (Ekouevi 2013). Policies lacked targets and timelines to meet the energy needs of the poor. In many instances there has also been a misalignment between national priorities and budgetary allocations for rural energy in the past, resulting in a lack of coherence between strategies and plans and program implementation on the ground. However, in the following section, we discuss recent energy policy statements focusing on the household cooking sector, which suggest a new and renewed focus on reversing this. Recent trends in cooking energy use in the three Central American countries are also presented.

1.2.1 Recent Experience with Improved Cook Stoves

Recent energy policy statements from the regions governments recognize the challenges faced by the residential cooking energy sector. The "2020 Central American Sustainable Energy Strategy", focuses on securing the sustainability of the region's energy supply, as well as seeking ways of reducing the demand for oil-based products, increasing the supply of renewable energy sources and incorporating new technologies, improving energy efficiency, increasing access to energy services for isolated and lower-income populations; and mitigating the effects of energy use and production on the environment. All countries in the region are also signatories to the Sistema de la Integración Centroamericana (SICA - Central American Integration System). SICA has identified clean cooking as the region's high priority in its Sustainable Energy Strategy for 2020 with a goal to reduce fuelwood consumption and install one million efficient stoves by 2020 (SICA 2009).

There have been several programs initiated in the past to disseminate improved biomass cookstoves and/or accelerate a transition to cleaner cooking fuels globally and in the region, but they have had limited impact. The governments of the three countries have also undertaken projects to promote efficient fuelwood stoves in order to reduce consumption and indoor pollution. However, these projects have lacked institutional coordination and have been implemented with little integration with other energy and development policies. A recent IFC study highlights several barriers both on the consumers and producers or distributors end that are responsible for the limited adoption and scale-up of clean cooking solutions (Ekouevi 2013). The most important among these are issues of awareness, affordability and availability of better cooking alternatives, as well as the lack of capital both for consumers and producers/distributors. In Nicaragua, studies indicate that the success in the dissemination of efficient stoves has been very limited - only 5.4 percent of homes in Nicaragua were reported to use efficient stoves (OLADE 2010). This is despite the fact that a large number and variety of potential solutions have been developed and tested in pilot programs, and supported by social entrepreneurs, international development agencies and foundations (Puzzola et al. 2013). This is also in spite of the fact that Central America has a long history of improved cookstoves development, starting with the introduction of the Lorena stove in the 1970s. However, several studies indicate that there continues to be a wide divide between technologies, policies, delivery methods, and long-term adoption (Wang et al. 2013).

The costs of cooking fuels and stoves, taste and cultural preferences, ease of use, and other product attributes, etc. play an important role in decisions concerning cook stove adoption and use. Preferences vary not only across cultures, but also within them, based on a number of contextual conditions including geography, weather and whether households are located in urban or rural settings. One of the primary challenges hampering the wide-scale dissemination of improved cookstoves has been learning and adapting technologies to these preferences. Another challenge has been establishing institutions for maintenance and replacement of stoves. Most common improved stoves are also expensive for the average family in Central America. For this reason, financial mechanisms and incentives tailored to local circumstances are needed for large-scale programs. Financial support is also needed to offset the high upfront costs of advanced stoves. Globally, there are few commercial models for large-scale dissemination of affordable cookstoves, particularly for the rural poor. These challenges have been surmounted in a few cases through strong government commitment to stove dissemination (e.g., China), innovative business models that target lower income, but not the poorest, households (e.g., India), and regional cooperation to increase the scale of dissemination (e.g., Kenya and neighboring countries). Future efforts can build on the lessons learnt from these experiences (Pachauri et al. 2012b).

1.2.2 Stove Grants and Financing Policies

Overcoming barriers to the adoption of cleaner stoves, including consumers inability to pay and liquidity constraints, requires putting in place appropriate consumer financing strategies. In poor rural areas, in particular, existing fuel markets consist largely of fuelwood that is locally collected, often at no monetary cost. This implies that there is little economic incentive for households to buy improved stoves. In such circumstances, the question is not whether consumer financing or grants are required or not, but rather how these should be designed and targeted. Existing evidence suggests that demand for environmental health technologies in low-income households is highly price elastic, so that stove price rebates or grants may stimulate household purchase of cleaner stoves (Miller & Mobarak, 2011; Beyene, et al., 2012). Such rebates or grants also need to be supplemented with information and education programs aimed at inducing behavior change and to encourage long-term adoption and sustained use of cleaner stoves.

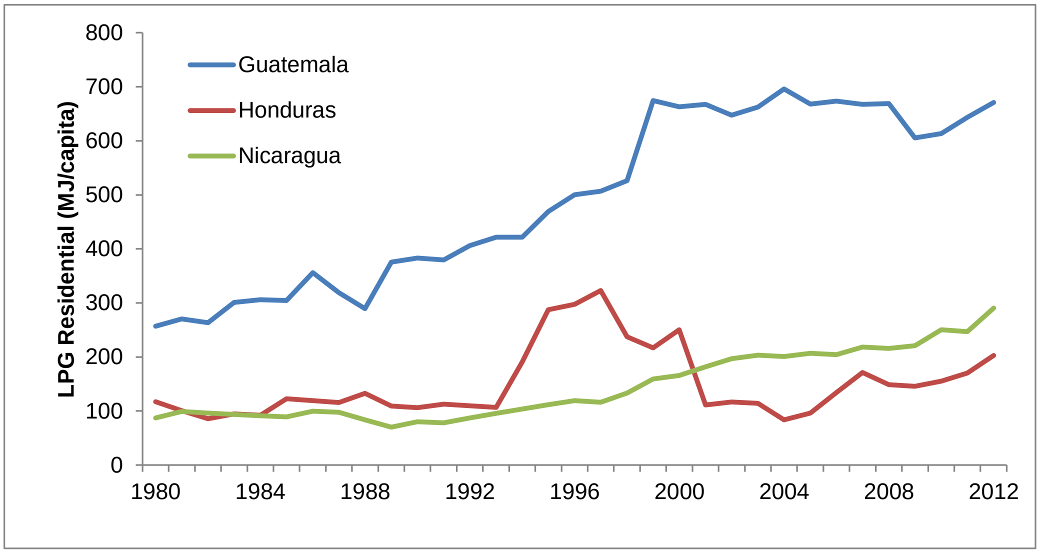
Several examples already exist of alternative consumer financing models that include at one end purely commercial loans or credit from commercial banks, stove manufacturers, distributors, or retailers. Such credit or loans for the purchase of stoves make payments in installment feasible for end users, allowing for more flexible repayment which is more in sync with cash inflows. In recent years, microfinance and carbon finance have also emerged as attractive options for making new stoves affordable for low-income consumers and for increasing stove sales. At the other end of the continuum, direct cash transfers, rebates or grants to consumers to reduce the upfront cost of the stove for the end user have also been employed. Some examples of the use of such rebate programs in the region include the dissemination of ONIL stoves free of cost to end-users in Guatemala, and the dissemination of cleaner stoves under Guatemala's Social Fund Program (WB 2010).

1.2.3 LPG Growth

The use of LPG for cooking has steadily increased in the last decades, particularly in Nicaragua. However, the substitution of LPG for fuelwood has slowed, and even reversed, in some countries (e.g., Guatemala and Honduras) (Figure 2). This is, in part, due to the removal of subsidies. The use of LPG is concentrated in cities, due to the lack of supply infrastructure in rural areas. Aside from cost and availability, resistance to switching to LPG is also driven by personal preferences, such as its lack of suitability for making tortillas (Wang et al. 2013).

Both Guatemala and Nicaragua have deregulated all petroleum fuel prices. Guatemala imposes a tax on LPG, while Nicaragua neither taxes nor subsidizes LPG. Honduras regulates the wholesale and retail prices of oil products in the country based on import parity criteria (WB-ESMAP 2010), and has a small subsidy for LPG. Significant transportation and distribution costs of LPG, particularly in rural areas, have restricted the wider adoption of this fuel in the region.

Figure 2: LPG for residential use in Guatemala, Honduras and Nicaragua. Source: IEA (2014), "Extended world energy balances", IEA World Energy Statistics and Balances (database).



1.2.4 Experience with Targeted National Programs to Promote LPG in Other Regions

In most developing countries, household income and the costs associated with using LPG (LPG prices and upfront costs for an LPG stove and connection) are the main determinants of its use (Kojima 2011). As is evident elsewhere too, in all three countries studied here, household LPG use is seen to increase with income (see Section 2.5). This suggests that a universal price subsidy for LPG could be regressive. Such a policy would also be counter to recent efforts to deregulate petroleum fuel prices in the region. However, at existing price levels, LPG is unaffordable to a large fraction of the population in these countries, which suggests that financial support of some kind is necessary to promote a switch to LPG. While beneficiary selection and benefit delivery mechanisms might differ, targeted delivery, smart subsidies, or conditional cash transfer policies that have been implemented in other countries could provide lessons for the region. In what follows, two of the world’s largest national programs focusing specifically on promoting LPG use are discussed.

Brazil’s Bolsa Família (Family Grant) Program: The program was created by the Brazilian Federal Government in 2004 to reduce poverty through conditional cash transfers to low-income households. The program aims to ensure the basic human right to adequate nutrition, education and health for all Brazilians. The program also includes a subsidy of R$15 (US$7.5) every two months, specifically for the purchase of LPG, targeted at households with a per capita income below R$140 per month. Recent appraisals of the program have been generally favorable as regards its objectives to reduce poverty, inequality, and hunger (Mourão and Jesus 2012). Yet studies show that the beneficiary selection and conditioning criteria for targeting the program are restrictive and that many of the urban poor remain excluded (GNESD 2013). Also, the LPG subsidy level is out of sync with current LPG retail prices, which are deregulated in the country. The cost of LPG was R$24 per 13kg cylinder in 2002 and rose to R$40 in 2011. However, the subsidy amount has remained unchanged since 2002. This lack of indexing the cash payout or subsidy amount to the rising price of LPG has reduced the effectiveness of the scheme in recent years. Nevertheless, the Bolsa Família remains a centerpiece of social policy in Brazil and, with 26% of the Brazilian population covered in 2011, is one of the largest conditional cash transfer programs in the world. With over a decade of experience, the architecture and implementation of the program provide important lessons for other countries.

India's PAHAL (Pratyaksh Hanstantrit Labh) or Direct Benefits Transfer for LPG (DBTL) Consumers Scheme: Initially launched in June 2013 by the Government of India but subsequently suspended, the scheme was re-launched in November 2014 in 54 districts and has been extended all over the country with effect from January 1, 2015. The objective of the program is to better target beneficiaries, prevent diversions or leakages and corruption, and reduce the fiscal burden of subsidies. Under the scheme, the cash differential between market and subsidized price is directly transferred to consumers' bank accounts to enable them to buy up to a total of 12 cylinders annually at market price. The amount of the subsidy has been fixed at INR568 (US$ 9.2) per 14.2kg cylinder. The scheme does not target low-income households specifically, but allows self-selection potentially to all LPG consumers. With an estimated 90 million households having signed on, according to the Indian Ministry of Petroleum and Natural Gas (MoPNG), this is already the largest conditional cash transfer program in the world. There are concerns, however, that poor levels of financial inclusion and lack of banking facilities in rural and remote areas could pose serious problems for the effectiveness of such a direct deposit subsidy scheme. The inclusion of post offices, co-operative banks, and other such agencies in the scheme may be one way to improve access points for rural consumers. Careful monitoring and evaluation of the scheme in the future could provide important insights for consideration by governments in Central America.

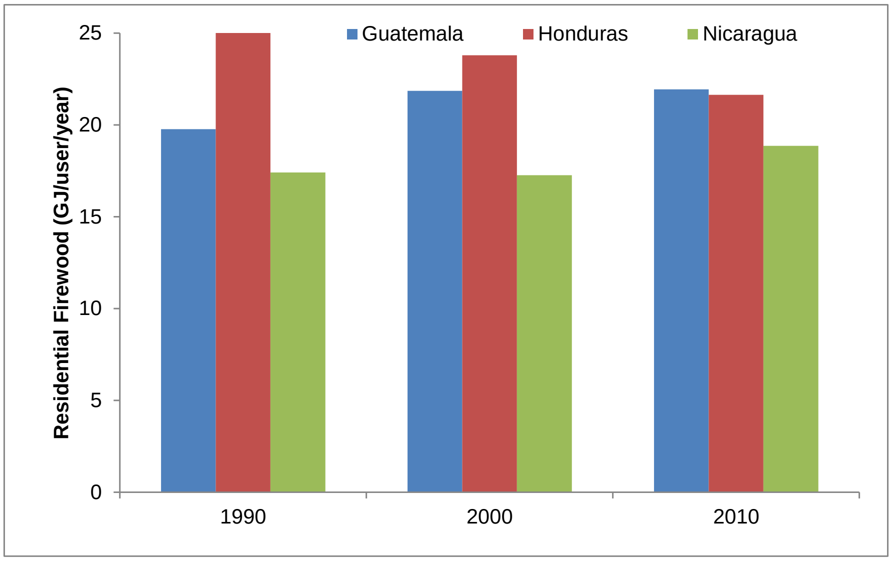
1.2.5 Fuelwood Growth

The populations of Guatemala, Honduras, and Nicaragua remain highly dependent on fuelwood as a source of energy. Quantitative assessment of fuelwood and other biomass use is notoriously difficult and uncertain, since a significant share of the biomass is collected or traded in informal markets. The main sources of data on residential biomass consumption at the national level for the region are OLADE energy balances, which are sourced from national sources, the IEA, and the FAO. Large discrepancies are evident in the estimates between these sources. In what follows, data is sourced from the Tropi-WESTAT interactive Wood Energy Statistics (Suber 2013), which is a multi-source database that assembles and harmonizes worldwide wood fuel data, in comparable units, from the IEA, FAO, other United Countries (UN) agencies, and from national sources and thematic studies.

In aggregate, residential consumption of fuelwood has increased steadily in all three countries over the last few decades despite a gradual reduction in the share of population using the fuel. There has been a slight decrease in the average per capita fuelwood consumption over this period, but the average consumption among fuelwood users has remained almost unchanged or even slightly increased in Guatemala and Nicaragua (Figure 3). In Honduras, there has been a marginal decrease.

A significant share of biomass used continues to be collected directly by end-users in all three countries. However, an increasing share of fuelwood utilized is being traded in regional markets, particularly in urban areas. It is difficult to make a more detailed analysis of fuelwood prices without regionally specific surveys as fuelwood transactions tend to be highly localized. Existing evidence suggests that fuelwood prices have risen in recent years, though there continue to be significant variations in prices across regions even within the same country (Wang et al. 2013).

Figure 3: Residential use of fuelwood per user of fuelwood in Guatemala, Honduras and Nicaragua. Source: Tropi-WESTAT (Suber 2013), Database of Pan-Tropical Woodfuels Statistics; and SE4ALL, 2013 -WB-GTF.



Little information is available to determine how much of the biomass used for cooking in the region is renewably harvested. This information is crucial for determining the CO_2 emissions from burning fuelwood. One regional estimate of sustainable fuelwood, defined as the wood harvested or collected that does not contribute to loss or degradation, is cited at 60 percent (Wang et al. 2013). Data on the extent of forest area in all three countries, suggests that there has been significant deforestation in all three countries over the last two decades (Table 2). However, how much biomass cooking has contributed to this trend is unknown.

Table 2: Forest area as a share of total national land area. Source: World Development Indicators, WB.

	1990	1995	2000	2005	2010
Guatemala	44%	42%	39%	37%	34%
Honduras	73%	65%	57%	52%	46%
Nicaragua	38%	35%	32%	29%	26%

The most recent and comprehensive analysis of the contribution to global forest loss of fuelwood harvesting for meeting cooking demands concludes that about 27 to 34 percent of wood fuel harvested worldwide would be considered non-renewable (Bailis et al. 2015). According to the assessment, this is estimated based on whether or not annual harvesting exceeds incremental re-growth. For the year 2009, estimates of the fraction of non-renewable biomass extraction from the study for Honduras and Nicaragua are significantly higher than the global average. For Guatemala this is estimated at 32 to 35 percent, for Honduras 64 percent, and for Nicaragua 58 percent (Bailis et al. 2015).

2 Descriptive Analysis of Household Cooking Patterns

This section presents and compares trends in cooking fuel use in the three countries (Guatemala, Nicaragua and Honduras), summarizes the efforts to shift the population towards cleaner and more efficient stoves, and highlights any peculiarities in each country that reflect challenges for expanding modern energy access. This summary is based on a number of energy studies and reports on improved cook stoves (ICS) for Central America, and on an analysis of three household surveys, one in each country (see Section 2.1). Following a brief discussion of the survey data sources used in the study, individual country insights are presented. This is then followed by a comparative synthesis.

2.1 Surveys and Data Sources

The availability of data across the three countries varies widely. Wherever possible, the most recent and most comprehensive surveys have been used. However, information on expenditures and quantities of fuels used for cooking is limited in all three countries. For Guatemala, we use the 2006 National Survey of Living Conditions (Encuesta Nacional de Condiciones de Vida – ENCOVI) (INE 2006), which is the most nationally representative of the three surveys used. The ENCOVI 2011 (INE 2011), though a more recent survey from Guatemala, did not contain the data on cooking expenditures and quantities needed for our analysis. For Honduras, we use data from the CEPAL-EZ, "Encuesta Leña Honduras", México, 2011, a small survey with limited rural and urban coverage, focusing specifically on the use of fuelwood for household cooking (CEPAL-EZ 2011). For Nicaragua, we use the Encuesta Ingresos y Gastos de los Hogares 2006-2007, with representative urban coverage, conducted by the Banco Central Nicaragua (Banco de Nicaragua 2007). The data from the surveys is further supplemented by energy balances and statistics from the IEA and OLADE, aggregate national data on fuelwood consumption from the Tropi-WESTAT database (Suber 2013), and information on energy prices and costs from the surveys and official or cited sources (CEPAL 2010; ECLAC 2014; WB-ESMAP 2010).

2.2 Guatemala

Guatemala is the largest country in Central America with a population of 15 million, which is twice the size of Honduras, the second most populous country in the region. About half of the Guatemalan population lives in urban areas, and more than half lives below the national poverty line (see Table 3). In 2011, about 30% of the total population lived on less than PPP$2/capita/day, but in rural areas about 70% lived below the national poverty line (WB-WDI). Though, Guatemala has a higher average per capita income than the other two countries, Guatemala along with Honduras are currently among the countries with the most unequal distributions of income in all of Latin America (Gindling and Trejos 2013). According to World Bank estimates, the country had a Gini index of 52 in 2011, with the bottom 40% of the population holding only 12% of total income or consumption.

The residential sector in Guatemala consumes over 98% of national biomass energy (INAB 2012). According to the ENCOVI 2011 survey (INE 2011), which is the most recent nationally representative data source, 94 percent of rural households and 54 percent of urban households continue to rely on traditional cooking fuels and stoves. About 28 percent of urban households and 47 percent of rural households collect all the fuelwood they consume, while others collect a portion and purchase the rest (GACC 2014). It is thus estimated that for the remaining 1.3 million households who purchase all or a part of the fuelwood they consume, fuel savings could be a significant motivator for adopting improved stoves. Unfortunately, neither the ENCOVI 2006 nor 2011 household surveys contain information on the existing use of improved biomass cook stoves.

The situation regarding access to cooking fuels in the country has not changed significantly since 2006, when the previous ENCOVI survey was conducted (see Table 6 in Section 2.5). LPG is the second most prevalent cooking fuel in Guatemala after fuelwood, with 52 percent of Guatemalan households using LPG for at least some of their energy needs (INE 2011). LPG use is far more prevalent among urban households, who consume 77 percent of the total residential LPG demand (INE 2011). LPG uptake in rural areas is limited in part by infrastructure and distribution problems (Wang et al. 2013). Other fuels, such as charcoal are used very little and make up a negligible share of total cooking fuel demand (INE 2011).

Compared to the other countries in this analysis, Guatemala has the highest fuel prices for purchased fuelwood, LPG, and electricity (see Table 4). Remarkably, the price of LPG per unit useful energy is roughly equivalent to that of purchased fuelwood in Guatemala if burned on a traditional (three-stone) stove. Fuelwood purchasers may choose not to switch to LPG either because it is not easily available, or is less suitable fuel for preparing tortillas or because they cannot afford the outright expense of buying a 25-lb LPG fuel cylinder and instead prefer to purchase fuelwood in small increments daily (GACC 2014; Wang et al. 2013).

Table 3: Poverty and inequality indicators by country. Source: WB-World Development Indicators

	Guatemala	Honduras	Nicaragua
GDP per capita, PPP (constant 2011 international $)	6957	4345	4215
Share of population under national poverty line (%)	54	62	43
Share of population under PPP$2/capita/day (%)	30	29	21
Share of population under PPP$1.25/capita/day (%)	14	16	9
Share of rural population under national poverty line (%)	71	65	63
Share of urban population under national poverty line (%)	35	59	27
Share of income held by bottom 40% of population (%)	12	9	14
Gini index	52	57	53

Table 4: Mean fuel prices by country and fuel

		Mean Fuel Price per unit Final Energy (2010 US$/GJ)		
		Firewood	**LPG**	**Electricity**
Guatemala	Price	6.89	28.11	62.34
	Source	INE 2006	INE 2006	INE 2006
Honduras	Price	4.02	20.79	28.25
	Source	CEPAL-EZ 2011	ESMAP 2010	CEPAL 2010
Nicaragua	Price	0.75	21.20	32.26
	Source	Nicaragua 2007	INE 2006	CEPAL 2010

2.2.1 Improved Cook Stove Policies

Guatemala's Energy Policy 2013-2027 also addresses the issue of fuelwood consumption and identifies goals including: a 15% reduction of industrial fuelwood consumption; a 10% increase in energy plantations; and the instillation of 100,000 improved biomass cook stoves. More recently, in November 2013, the government of Guatemala launched the National Strategic Plan for the Sustainable Use of Wood, and in May 2014 it has also developed a separate "Strategy on

Clean Cookstoves & Clean Cooking Solutions”. The strategy goals for 2014-2024 include the installation of 65,000 improved cookstoves per year over the next ten years, and to inform 70% of the population on the sustainable use of fuelwood (GACC 2014). The President of Guatemala has declared this issue a priority across ministries, and, in addition to the targets, has committed to implementing programs that support innovation, finance for demand, market development and awareness-raising. A wide range of improved biomass cook stoves have been installed in Guatemala over the last two decades. The most common stove models are the Onil, Nixtamal, and La Utz, with the Onil stove being the most prevalent at around 90,000 stoves disseminated since 2002 (GACC 2014).

2.3 Honduras

Honduras had about 7.6 million inhabitants, of which just over half lived in urban areas, and about 65 percent lived below the national poverty line (Table 3). In 2011, about 29% of the total population lived on less than PPP$2/capita/day, but in rural areas about 65% lived below the national poverty line (WB-WDI). According to World Bank estimates, the country had a Gini index of 57 in 2011, with the bottom 40% of the population holding only 9% of total income or consumption.

In contrast to the other two Central American countries, a fraction of the population relies on electricity for cooking. While there has been a reduction in the share of population dependent on solid fuels for cooking, the number of people using solid fuels has risen over the last couple of decades (see Figure 4 in Section 2.5). The share of biomass in total final energy consumed in the country also remains very high (over 60 percent). National aggregate fuelwood use over the last two decades has remained more or less constant, implying that the average use per consumer of biomass has declined marginally over this period.

The most recent nationally representative survey information from Honduras for 2011/2012 is from the Demographic and Health Survey (DHS) (INE 2013). These data suggest that 80 percent of rural households still rely on fuelwood for cooking. Among urban households, close to 70 percent rely primarily on either LPG or electricity, but 22 percent still use fuelwood for cooking. These aggregate numbers, however, mask large differences in the pattern of household cooking energy use across income groups. Location and income are significant factors influencing the choice of cooking fuels in Honduras. Results from a small sample survey of household fuelwood use in Honduras in 2011 by CEPAL (CEPAL-EZ 2011) (Table 5) are quite consistent as regards the estimate of share of rural households using fuelwood. Of these, about half primarily collect fuelwood while the rest purchase it. In urban areas, the CEPAL survey suggests that about half of all households are using some fuelwood for cooking, but only about a quarter of households that consume fuelwood in urban areas collect it.

Table 5: Household cooking energy choices in Honduras in 2011. Source: CEPAL-EZ, "Encuesta Leña Honduras", México, 2011. Note: Percentages don't sum to 100 as some households use multiple fuels.

Sector	Income Group (PPP$/cap/day)	Fuelwood	Fuelwood buyers	Fuelwood +ICS	Kerosene	LPG	Electricity
Rural	<2	96%	42%	2%	0%	2%	4%
	2-5	83%	52%	6%	0%	13%	12%
	> 5	52%	63%	7%	0%	31%	24%
Urban	<2	73%	69%	4%	0%	22%	8%
	2-5	55%	62%	0%	2%	25%	27%
	> 5	39%	74%	0%	1%	29%	46%

Differences in cooking energy use patterns among household groups in Honduras are also evident when comparing the amounts of different fuels consumed and the share of income spent to buy them. The CEPAL survey only included questions on how much fuelwood is used and what expenditures, if any, are incurred in purchasing it. Information regarding the amounts and expenditures incurred on non-solid fuels by households for cooking in Honduras is not available. Information from other data sources, suggests that the gap between LPG and electricity prices is the lowest in Honduras (Table 4). This might be one reason why households in this country report cooking with electricity. The reliability of LPG supply to households in this country might be another factor explaining this trend.

2.3.1 Improved Cook Stove Policies

Honduras' Scaling-up Renewable Energy Program Investment Plan prepared by the country's government also aims to provide efficient cook stoves to 50,000 people while reducing greenhouse gas emissions by 200,000 tons. The plan that was approved in 2011 aims to provide over $12 million in grants and concessional loans to help finance energy efficiency and energy access projects in the country. The funding was provided through the Scaling-up Renewable Energy in Low Income Countries, which is one of the Climate Investment Funds. More recently, the national government's vision of Honduras to 2038 emphasizes strengthening capacities and creating opportunities to help people out of poverty. The Strategic Plan developed to achieve this vision includes several, actions, programs and project items that could provide more favorable enabling conditions for a more rapid adoption of cleaner cooking in the country. The Honduras, Ministry of Energy, Natural Resources, Environment and Mines, joined the Global Alliance for Clean Cookstoves (GACC) this year, and in November 2014 agreed to designate 20 million US Dollars per year to be invested in clean cookstoves, in order to achieve a goal of reaching 400,000 households with a clean stove per family in the period 2014-2017. During the first half of 2014, about 50,000 clean cookstoves were distributed in 94% across the country (GACC 2014). This dissemination included the purchase and installation of the stove, training on the use of the clean cookstove, follow up monitoring of use and maintenance.

2.4 Nicaragua

Nicaragua is the smallest and poorest of the three countries. Its population has grown over the last two decades at 1.7 percent to 5.8 million in 2010. Nicaragua has the lowest per capita income ($4,215/cap in 2011) and energy consumption (2.6 barrels of oil equivalent in 2009) among Central American countries. In 2011, about 20% of the total population lived on less than PPP$2/capita/day, but in rural areas over 60% lived below the national poverty line (see Table 3). According to World Bank estimates, the country had a Gini index of 53 in 2011, with the bottom 40% of the population holding only 14% of total income or consumption. Its poverty reflects also in the composition of fuel use – 45 percent of primary energy (64 percent of final energy) came from biomass in 2011. Over 90 percent of fuelwood use is for home cooking, while the rest is used by small-scale rural and artisanal industries (e.g., bakeries, lime and brick production, and charcoal) (Terrado 2005).

The number of people using solid fuels has stayed relatively constant for two decades (Figure 4), even as the share of people using solid fuels has been on the decline due to increasing LPG use.

This share is nevertheless higher than that in Honduras and Guatemala. This is driven by the fact that two-thirds of the population use fuelwood, which meets over 90 percent of residential energy needs (Díaz 2010).

Relatively little is known about the characteristics of solid fuel use in Nicaragua, particularly in rural areas, where 97 percent of the population used fuelwood in 2010 (Wang et al. 2013). Even in urban areas, where a higher share of the population lives than in the other two countries, 46 percent still use biomass. Further insights can be drawn from the household survey used in this report, which was conducted only in cities. According to this survey, at least 86 percent of the urban population that earns less than PPP$2/day cooks with fuelwood. At least a fifth of even the higher income urban population (who earn >PPP$5/day) also cooks with fuelwood (Table 6).

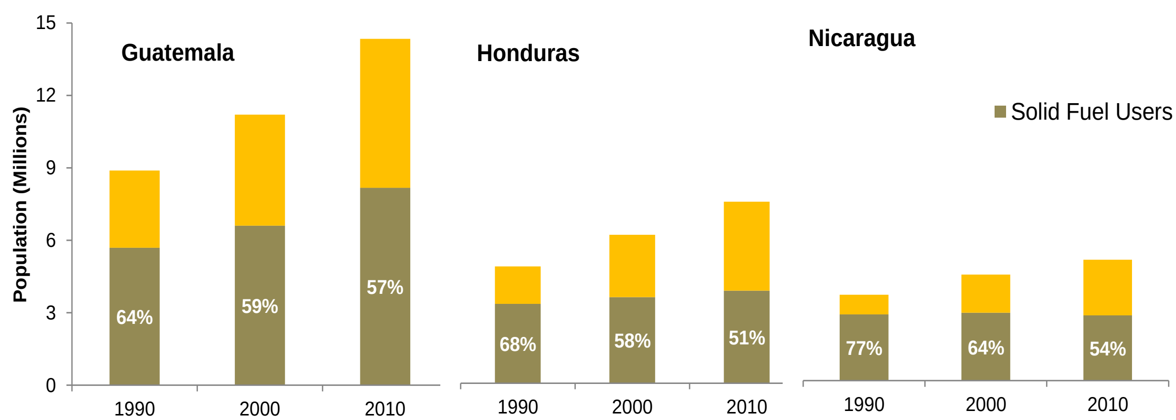
A large share of the fuelwood users in cities appears to purchase commercially-traded fuelwood. This can be inferred from the share of households purchasing fuelwood in the survey (35 percent) and the total population share that uses fuelwood in cities (46 percent). Households pay a wide range of prices, at an average of US$0.75 per gigajoule (Table 4). The quantity of biomass used in urban households is not known, but has been estimated by other sources at ~1.3 kg/cap/day (ECLAC 2014).

Both the prices and the per capita usage of fuelwood in cities are lower in Nicaragua than in Honduras and Guatemala (Table 4, Table 7). This may explain the higher population share that is dependent on fuelwood in cities. It also may explain why so many urban non-poor households use fuelwood instead of gas. On a useful energy basis, the average price of fuelwood is less than a tenth of that of LPG. Given that electricity is even more expensive than LPG, and based on previous field studies on cook stoves, Nicaraguans do not use electricity for cooking in any appreciable numbers.

2.4.1 Improved Cook Stove Policies

Nicaragua has established a national convening authority (Ministry of Energy and Mines) to develop a fuelwood strategy and support the development of efficient stoves (Wang et al. 2013). The National Program for Sustainable Energy Use of Wood and Charcoal in Nicaragua for 2013 to 2022 is a result of activities initiated by the Ministry of Energy and Mining. Its aim in the short-term is to accelerate a greater use of modern energy services by the Nicaraguan population and its vision statement is "To help improve the quality of life of the chain of actors in the fuelwood and charcoal value chains". This vision by 2022 will be achieved through five strategic objectives:1) Ensure sustainable production and availability of forest energy resources; 2) Develop and implement innovative models of technologies for efficient and sustainable use of fuelwood and charcoal; 3) Strengthen the management of political, legal, policy for the efficient and sustainable use of fuelwood and charcoal frame; 4) Strengthen the technical and organizational actors in the value chain of fuelwood and charcoal capabilities; 5) Strengthen financial mechanisms for sustainable development of the value chain of fuelwood and charcoal. The second objective foresees the installation of a total of 400,000 clean stoves over a period of 10 years.

Figure 4: Solid fuel dependence in Guatemala, Honduras and Nicaragua: 1990-2010. Sources: SE4ALL, 2013 – WB GTF.



2.5 Comparative Summary

There are common observable patterns in cooking fuel use in the three countries, yet there are distinct differences that influence the uptake of modern energy services. In the tables that follow we present some of the key patterns observable from the household surveys.

Table 6: Summary of household cooking energy use patterns in Guatemala, Honduras and Nicaragua. Source: Household surveys (see Section 2.1). Blanks indicate data could not be inferred from the surveys. Note: *Gas/Electricity column reflects the use of both only in Honduras. Electricity for cooking is not prevalent in Guatemala or in Nicaragua. Biomass use in Nicaragua imputed assuming uniform cooking energy needs. LPG use in Honduras is also imputed.

Classification By	**General Population Characteristics**				**Gas/ Electricity Users***			**Biomass Users (Purchasers)**			**Biomass Users (Collectors)**		
Income Group	HH Size	Avg. Income	Pop Share	Cooking	Gas Use	Users	Exp. Share	Bio purch.	Users	Exp. Share	Bio Coll.	Users	Exp. Share
2005PPP$/capita/day	Average	PPP$/cap/day	(%)	Exp. Share	MJ/cap/day	(%)	(%)	MJ/cap/day	(%)	(%)	MJ/cap/day	(%)	(%)
Rural Guatemala 2006													
0-2	6.4	1.2	26%	7.8%	3.1	4%	1.9%	37.5	32%	8.7%	37.3	68%	0%
2-5	5.7	3.3	34%	4.9%	3.4	14%	0.8%	38.2	43%	4.7%	44.3	55%	0%
>5	4.8	12.0	40%	2.1%	4.0	45%	0.3%	35.7	46%	1.9%	43.6	40%	0%
Urban Guatemala 2006													
0-2	5.9	1.3	4%	13.5%	3.8	20%	2.0%	28.9	53%	13.5%	38.5	41%	0%
2-5	5.2	3.5	16%	6.9%	3.9	44%	0.8%	31.0	56%	5.2%	36.3	24%	0%
>5	4.2	19.5	80%	1.6%	5.0	87%	0.2%	26.5	27%	0.8%	35.1	8%	0%
Rural Honduras 2011													
0-2	6.6	1.2	40%		0.8	6%		50.1	41%	6.7%	43.6	53%	0%
2-5	4.7	3.1	43%		4.0	26%		55.3	44%	1.8%	66.0	37%	0%
>5	3.3	10.7	17%		7.6	55%		58.1	33%	1.1%	75.2	16%	0%
Urban Honduras 2011													
0-2	6.2	1.3	23%		3.5	30%		43.1	51%	6.0%	49.8	22%	0%
2-5	4.6	3.3	48%		6.0	52%		52.6	34%	2.1%	54.6	16%	0%
>5	3.3	9.8	28%		10.7	74%		82.8	29%	1.3%	73.0	7%	0%
Urban Nicaragua 2006/07													
0-2	8.5	1.6	3%	5.0%	2.1	14%	5.0%	48.1	84%	5.1%		2%	0%
2-5	6.7	3.6	35%	3.6%	3.3	48%	3.3%	43.2	53%	3.6%			
>5	4.9	12.0	62%	1.8%	5.0	78%	1.9%	34.7	22%	1.6%			

Some of the key similarities observable are:

- In all three countries, solid fuel dependence is increasing in absolute numbers, but decreasing as a percentage of the total population (Figure 4). This reflects growing population in rural areas without viable substitutes for fuelwood, combined with increasing use of LPG in cities.
- In all three countries, fuelwood consumption is substantial in urban areas, though to a greater extent in Nicaragua and Guatemala than in Honduras (Table 6).
- Per capita fuelwood use is similar across the countries, at 2.5-2.8 kg/cap/day (Table 7).
- Fuelwood meets a substantial part of cooking needs even in the high income group, between a quarter (in Guatemala) and almost a half (in Honduras). (Table 8)
- Traditional diets are fairly similar across the three regions, possibly implying that cooking preferences factor into fuel choices in similar ways, such as with respect to making tortillas.
- LPG prices are relatively similar across the countries, in comparison to fuelwood price differences (Table 4).

Table 7: Fuelwood and LPG consumption. Source: Household survey data for Guatemala from 2006 and for Honduras from 2011 (See Section 2.1). Fuelwood use in Nicaragua from CEPAL, 2014. [x]LPG use in Honduras imputed.

	Fuelwood	LPG
	Average Use (National)	Average Use (Urban)
	kg/cap/day	MJ/cap/day
Guatemala	2.83	1.8
Honduras	2.52	4.7[X]
Nicaragua	2.54	2.95

There are also some important differences in both demographics and energy use patterns. Nicaraguans have particularly large households in urban areas compared to the other countries. Furthermore, although Nicaragua and Honduras have comparable and lower GDPs per capita than that of Guatemala, because of Nicaragua's high income inequality, the share of urban high income population (earning >PPP$5/cap/day) (at 62 percent) is closer to that of Guatemala (80 percent), than Honduras (28 percent). This may have implications for the future uptake of LPG, since this income group typically is the most likely to switch completely away from traditional fuels. The differences in energy use patterns reflect some of these demographic differences:

- Cooking energy needs differ across and within the countries, despite similar diets. Cooking useful energy demand is highest in Honduras and lowest in Nicaragua. Cooking energy demand increases with increasing income in these two countries, but decreases among wealthy Guatemalans. Given that urban Guatemala is substantially richer, it is possible that food habit changes there may not have as yet penetrated in the cities of Honduras and Nicaragua.
- Among the urban populations, fuelwood prices differ significantly – Guatemalans pay almost double the price as Hondurans, while Nicaraguans pay an order of magnitude less than Guatemalans. This reflects in their corresponding cooking budgets, which points to the inelasticity of energy use to fuel prices.
- Among urban households, the share of LPG that meets total cooking energy demand is highest in Guatemala, followed by Nicaragua and Honduras, which is consistent with the population share in the highest income group in the three countries (Table 8).

Table 8: Cooking energy needs and LPG share for Guatemala, Honduras and Nicaragua. Sources: Household surveys (See Section 2.1). Data for rural Nicaragua is unavailable.

Income Groups (2005PPP$/cap/day)	**Total cooking needs (MJ/cap/day)**		**LPG share of useful energy (%)**	
	Urban	Rural	Urban	Rural
Guatemala				
<2	5.1	5.7	13%	1%
2-5	5.0	6.4	32%	6%
>5	4.3	6.3	77%	27%
Honduras				
<2	7.1	7.2	30%	7%
2-5	8.0	9.9	45%	24%
>5	11.1	9.6	58%	48%
Nicaragua				
<2	3.0		6%	
2-5	3.0		30%	
>5	3.5		62 %	

3 Clean Cooking Scenarios to 2030

The previous two sections have shown that despite a gradual increase in the fraction of population using modern cooking fuels in Guatemala, Honduras and Nicaragua over the last couple of decades, the number of people without access to clean cooking fuels or stoves has continued to rise. Reversing this trend will require significant advances to be made in the rapid diffusion of low-cost, high performing and standardized stoves, and implementation of creative financing mechanisms to enable low-income households to afford modern cooking options. In what follows, we explore possible future scenarios for achieving a universal clean cooking target by 2030 in these three countries. We assess the implications of the scenarios for future energy demand, greenhouse gas (GHG) emissions and for health. We assess the GHG and health impacts using the methods developed for the GEA (see (Pachauri et al. 2013; Riahi et al. 2012) and the Appendix for details on methods). The largest impacts in terms of reductions in final cooking energy demand, emissions, and health benefits occur with a transition to cleaner fuels like LPG. While a shift to better biomass ICS, also bring some benefits, these are rather modest and not presented in all the results that follow.

The starting point for the future scenario assessment is data on existing energy choices and the demand to meet cooking energy needs in each of the three countries (see Sections 1 and 2). The estimates of energy choices and demand are based on bottom-up analysis using detailed household survey data for each of the countries. The evaluation of pathways to clean cooking focuses on scenarios that increase the penetration of cleaner fuels like LPG, and/or reduces the upfront costs associated with the purchase of cleaner stoves (LPG, improved biomass cook stoves) for consumers. The policies for reducing the cost of cleaner stoves include rebates/ grants or microfinance loans at a 15 percent rate of interest. The objective of these policies is to make it cheaper and easier for households to purchase the end-use equipment or stoves needed to meet cooking energy demands. Table 9 provides an overview of the different access scenarios constructed and is discussed further in the following section.

The following section provides a broad overview of the overall approach and methods employed, including details of the policy scenarios constructed to assess the transition in household cooking energy services in these countries.

3.1 Methods, Model and Policy Scenarios Description

The household survey sources described in Section 2.1 and presented in the previous section are used as the basic input for calibrating a cooking energy demand and choice model. The model is used to evaluate the share of each different fuel-stove combination used to satisfy cooking energy demand for each population sub-group based on the observed preferences from the household surveys. We divide the population on income and urban/rural status to represent differences in the affordability and availability of cooking fuels (see section A.1.1 in the Appendix). We account for changes in population and income over time by using projections from the GEA database. We use the Global Energy Assessment's medium scenario ("GEA-M") as a source of population and income data and projections (see section A.1.2 in the Appendix).[2] For fuel price projections we use the GEA-M forecasted electricity and LPG prices (see section A.1.3 in the Appendix). To represent future changes in household size, cooking energy demand, and cooking expenditure, we estimate the relationship of these variables as a function of income (see section A.1.4 in the Appendix for further details on methods and modeling approach).

To estimate fuel demand, our cooking demand and choice model is calibrated to initial conditions that are inferred from the above-mentioned household surveys. We derive a demand curve for each cooking fuel-stove for each population sub-group from these surveys by fitting a function between the quantity of fuel purchased and the cost to cook with that fuel-stove combination (see section A.1.4 in the Appendix). Our underlying premise is that affordability and availability of fuels and stoves are the key factors influencing consumer cooking preferences. Cooking cost is determined as a function of not only the fuel price, but also the price of the stove. To incorporate stove costs into the overall cooking cost, we amortize stove prices over the total useful energy delivered. The stove cost is amortized using a discount rate unique to each population sub-group calculated as a function of total household income. We order fuels according to their convenience to reflect the known progress of households up an "energy ladder", with LPG being the first choice, followed by improved cook stoves, and the default (last resort) being the three-stone biomass stove (Pachauri et al 2012a). Total cooking demand is met

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[2] Global Energy Assessment - Toward a Sustainable Future. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. GEA database available at http://www.iiasa.ac.at/web-apps/ene/geadb/.

in order of these fuels, with quantities determined by their respective demand curves (see section A.1.4.2 in the Appendix).

Of the three countries analyzed in this study, only the Guatemala survey provides sufficient data to derive demand curves directly from the survey. It includes both fuel demand and price for fuelwood and LPG for a nationally representative sample of the population. The survey, however, provides no information on the type of stove used for cooking with fuelwood. The demand for improved biomass cookstoves (ICS) was in this case estimated by using data on fuelwood purchases as a proxy for household willingness-to-pay for ICS. We therefore only estimate demand for ICS among households purchasing fuelwood. The demand curves estimates from Guatemala are adapted in conjunction with information from the household surveys from Honduras and Nicaragua to develop independent demand models for each country (see section A.1.4 in the Appendix).

In order to evaluate alternative future transition scenarios and their effectiveness in accelerating a transition to better cooking fuels and/or stoves, we construct a set of distinct future pathways as described in Table 9. The transition scenarios are constructed to assess the impacts of a wider penetration of cleaner fuels like LPG and/or the effectiveness of grants/ rebates or microfinance credit to reduce the initial investment or lower upfront costs associated with the purchase of better stoves. In the case of targeted scenarios, the beneficiaries are all rural populations and households spending less than PPP$5/capita/day in urban areas.

In our baseline scenario, no new access policies (NNP) are assumed, but a gradual shift to clean cooking is assumed as clean cooking becomes more affordable with rising incomes and growing urbanization in all three countries. However, recent trends and analysis from the region suggest that there are other barriers to adoption, such as customs, traditions and tastes, and a lack of awareness regarding the adverse effects of traditional cooking practices that could hinder a transition to clean cooking (Ekouevi 2013; Wang et al. 2013). We model growing LPG penetration with rising income levels in our baseline or no new policy (NNP) scenario. However, growth in LPG penetration is constrained by the preferences observed in the household surveys that reflect some of these non-monetary constraints on cooking choices (see section A.1.4 in the Appendix).

The alternative household energy transition scenarios include those that explore various rebate or grants policies for the purchase of better stoves (ICS, LPG or electric stoves) or those that explore a transition to better fuels (e.g. LPG). The grants policies for stoves range from moderate @50% to aggressive @100% rebates on the stove price. The grants or rebates scenarios for ICS and electric stoves are applied universally, whereas for LPG stoves these are targeted to rural households and households spending less than PPP$5/capita/day in urban areas. Three alternative scenarios for transition to the use of LPG fuel for cooking are also explored, which are also targeted to the same population segments. The fuel switching or transition to LPG fuel scenarios range from slow to moderate to rapid, with the rapid scenario being the most aggressive, achieving almost universal access to clean fuels by 2030.

Table 9: Policy Scenarios for Assessing Future Household Cooking Transitions. Note all Targeted* policies are for all rural and <PPP$5/capita/day households in urban areas

	Scenario Name	**Description**
1	**NNP**	No new policies (a business-as-usual scenario)
2	**G_ICS_50**	Grant or rebate on improved biomass stoves, @50%
3	**G_ICS_100**	Grant or rebate on improved biomass stoves, @100%
4	**TG_LPG_50**	Targeted* Grant or rebate on LPG stoves, @50%
5	**TG_LPG_100**	Targeted* Grant or rebate on LPG stoves, @100%
6	**G_EIS_50**	Grant or rebate on electric induction stoves, @50%
7	**G_EIS_100**	Grant or rebate on electric induction stoves, @100%
8	**TT_LPG_S**	Targeted* Transition to LPG Fuel_Slow
9	**TT_LPG_M**	Targeted* Transition to LPG Fuel_Moderate
10	**TT_LPG_R**	Targeted* Transition to LPG Fuel_Rapid

The policy costs of reducing dependence on traditional stoves and solid fuels for the different transition scenarios relative to the baseline (that is, over and above the shift achieved from income growth) is also estimated for the stove rebate or grants scenarios and presented in the following sections. We estimate the net present value costs for the applicable goal in the grant or stove rebate transition scenarios. The results for microfinance schemes are equivalent to those of grants for stoves. We show the results only for scenarios of grants, since our focus is on public policy costs, while in the case of microfinance schemes the private sector is often able to cover the costs of their operations through the interest payments they receive.

The impacts of the alternative policies on clean cooking access in the countries are sensitive to the future price trajectory for modern fuels, like LPG. We assume future price increases for LPG as projected in the GEA-M scenario (Riahi et al., 2012). However, recent trends from the region suggest that LPG prices have increased at a significantly higher rate (an increase of roughly 50% in real terms over the period 2003-2011) (Kojima, 2013). In the extreme case, that future price increases mirror the trend over the last decade, achieving a clean cooking outlook by 2030 would be significantly more challenging (see section A.1.3.5 in the Appendix). Higher LPG price rises in the future could also make a shift to electric cooking more affordable in these countries.

3.2 Scenarios for Accelerating Clean Cooking Access in Guatemala

In 2010, over half of total cooking demand in the country was met with traditional biomass stoves. In urban areas over 70% of demand was met with non-solid fuels, however, in rural areas about 85% was met with traditional biomass stoves. In the baseline or no new policy (NNP) scenario, in urban areas of Guatemala, the analysis suggests that only 5% of the population is likely to be unable to afford clean fuels or stoves by 2030. For rural households, transitioning to clean cooking by 2030 will be a much larger challenge. In the absence of additional policies, about half of rural Guatemalans will be unable to afford clean fuels or stoves in 2030. This translates to about 2.7 million people overall who would not be able to afford LPG stoves by 2030 without policies targeted specifically towards expanding modern energy access.

Examining the impact of the alternative policy packages on the numbers of people dependent on solid fuels in Guatemala suggests that the rapid transition to LPG fuel (TT_LPG_R) scenario could bring solid fuel use down to 5% by 2030, and benefit about 43% of the poorest population (based on poverty levels in 2010). The impacts of different transition scenarios alter both the shares of different stoves as well as the total achievement of clean cooking access (Figure 5). A capital grant for the purchase of ICS has little impact in Guatemala, where fuelwood costs are so high that reduced stove costs do not significantly change the total cooking cost of cooking with ICS. Similarly, as LPG prices are highest in Guatemala, stove costs have a relatively low share in total cooking costs and stove grants for LPG stoves are likely to shift only 1.1 million people to the use of LPG by 2030 (Table 10).

Figure 5: Pathways for reducing solid-fuel dependence in Guatemala under the range of transition scenarios (shown in Table 9). (a) Solid fuel dependence over time.; (b) Fuel-stove shares under different transition scenarios (not all achieve same total level of access).

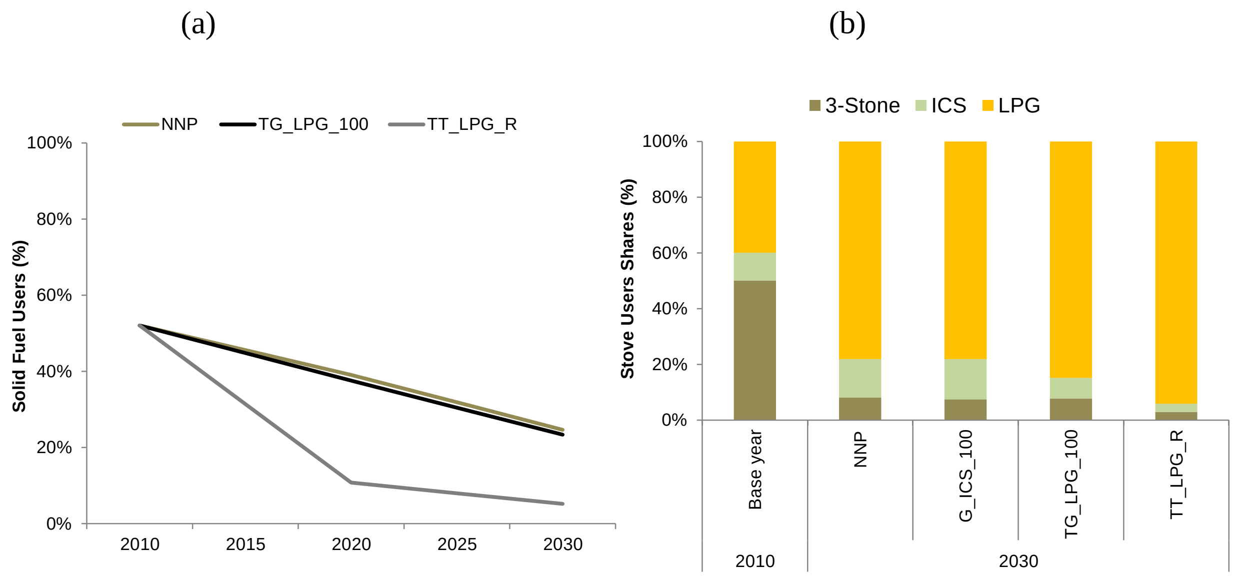


Table 10: Policy costs for grants for the period 2010-2030 for achieving access to clean cooking in 2030 for Guatemala.

	G_ICS_50	G_ICS_100	TG_LPG_50	TG_LPG_100
Population Migrated (Mill.)	0.06	0.13	0.54	1.15
Cost per year (Mill. US_{2010}\$/year)	3.29	6.73	12.15	26.69

3.3 Scenarios for Accelerating Clean Cooking Access in Honduras

In Honduras, about 55% of total cooking demand in the country was met with traditional biomass stoves in 2010. In urban areas about 45% of demand was met with non-solid fuels, however, in rural areas over 75% was met with traditional biomass stoves. In the baseline or no new policy (NNP) scenario, in urban areas of Honduras, the analysis suggests that over three quarters of the population is likely to be able to afford clean fuels or stoves by 2030. Among rural households, however, about two-thirds will be unable to afford clean fuels or stoves in 2030 in the absence of additional policies.

As in the case of Guatemala, the rapid transition to LPG fuel scenario (TT_LPG_R) is the most effective policy for enabling a transition to clean cooking fuels in Honduras by 2030 (Figure 6).

The policy, targeted to rural households and urban households living below PPP$5/capita/day, would benefit the bottom 60% of the population in the country in 2010. Such a policy could make clean fuels affordable almost universally (to about 98% of the population) by 2030. A scenario in which a rebate or grant is provided for the use of electric induction cookstoves in the region (not shown in the figures) is also somewhat effective only in Honduras, which is the only country out of the three analyzed that currently uses electricity for cooking due to its low electricity prices. Such a capital subsidy on electric stoves could benefit up to 45% of the population in 2030. However, a more aggressive increase in electricity prices in the region or slow growth in installed capacity would make such a transition less feasible.

Under the rapid transition to LPG fuel pathway, about 2.8 million people can move off solid fuel use in 2030. An ICS grant or rebate policy is also reasonably effective here, since fuelwood prices are not as high as in Guatemala. Such a policy could benefit 1.6 million Hondurans in 2030 and would cost below US2010$1 per beneficiary (Table 11). As a practical matter, stove grant policies, if combined with a massive scale-up of improved cook stoves, might be a cost-effective interim solution in Honduras, where for many rural households a shift away from biomass may be out of reach in the short term. In Honduras, LPG stove grants are also relatively more effective as compared to Guatemala.

Figure 6: Pathways for reducing solid-fuel dependence in Honduras under the range of policy scenarios (shown in Table 9). (a) Solid fuel dependence over time. (b) Fuel-stove shares under different policies (not all achieve same total level of access).

(a) (b)

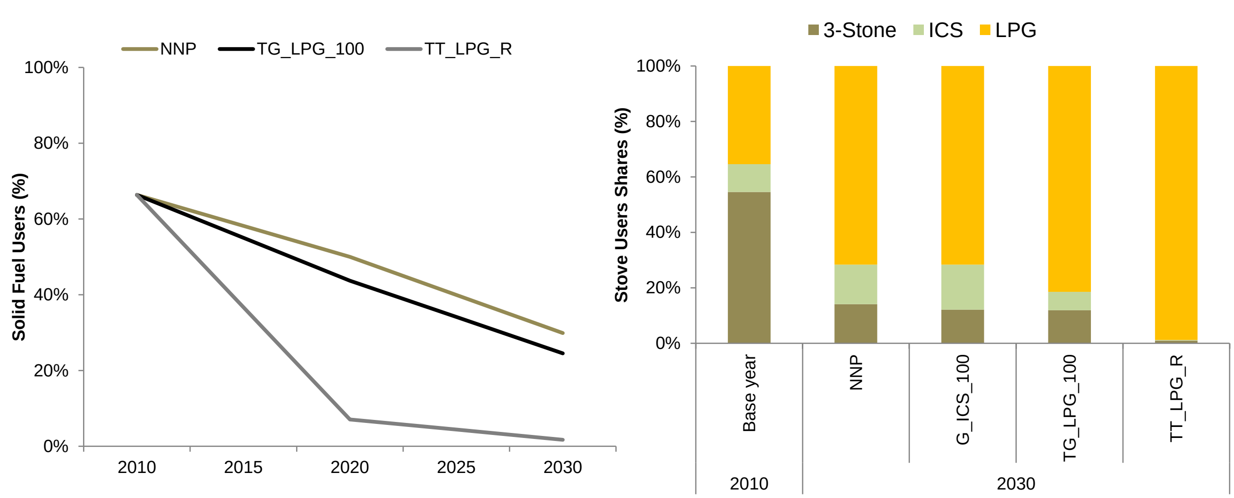


Table 11: Policy costs for grants for the period 2010-2030 for achieving access to clean cooking in 2030 for Honduras.

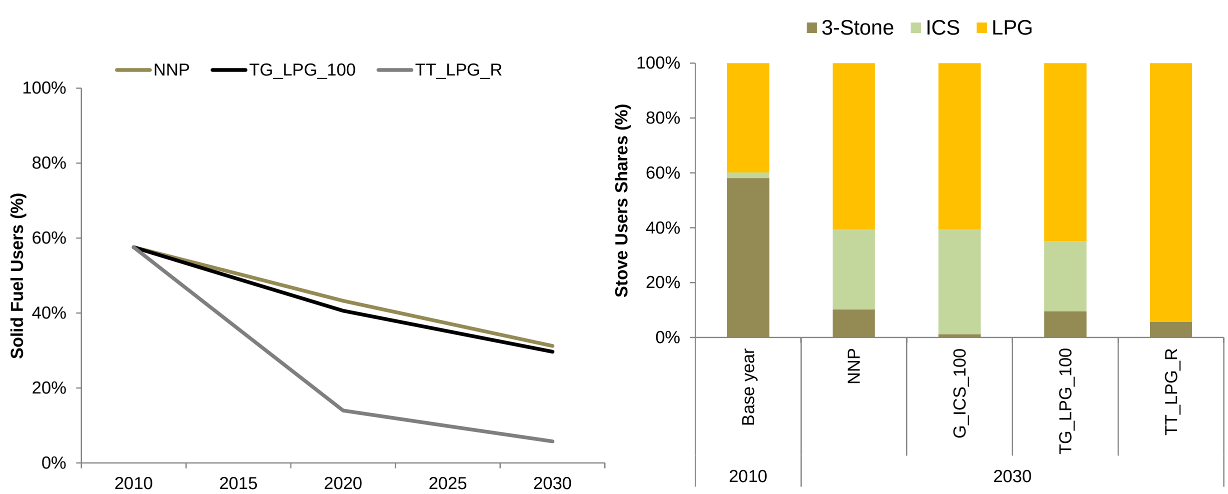
	G_ICS_50	G_ICS_100	TG_LPG_50	TG_LPG_100
Population Migrated (Mill.)	0.10	0.22	0.52	0.84
Cost per year (Mill. US_{2010}\$/year)	0.04	0.10	0.02	0.04

3.4 Scenarios for Accelerating Clean Cooking Access in Nicaragua

In 2010, over half of cooking energy demand in Nicaragua was met with traditional solid fuel stoves. In urban areas, about two-thirds of total cooking energy demand was met with non-solid fuels in 2010, but among rural Nicaraguans over 90% relied on solid fuels for cooking. In the baseline or no new policy (NNP) scenario, in urban areas of Nicaragua, the analysis suggests that only 6% of the population is likely to be unable to afford clean fuels or stoves by 2030. Among rural households, however, about three quarters will be unable to afford clean fuels or stoves in 2030 in the absence of additional policies.

Figure 7: Pathways for reducing solid-fuel dependence in Nicaragua under the range of policy scenarios (shown in Table 9). (a) Solid fuel dependence over time. Upper limit represents no new policies (shift results from income growth); (b) Fuel-stove shares under different policies (not all achieve same total level of access).

(a) (b)



The different policies alter both the shares of different stoves as well as the total achievement of clean cooking access (Figure **7**). Fuelwood prices are the lowest in Nicaragua of the three countries studied (Table 4). As a result, total levelized cost of three-stone and improved cook stoves are very close even without the stove grants (see section A.1.3.4 in the Appendix). Therefore, a grant or rebate on ICS is very effective in bringing about a transition to the use of improved biomass stoves in Nicaragua. Such a policy could benefit 2.2 million of the population and is estimated to cost US2010$0.64 per person benefited (Table 12).

Table 12: Policy costs for grants for the period 2010-2030 for achieving access to clean cooking in 2030 for Nicaragua.

	G_ICS_50	G_ICS_100	TG_LPG_50	TG_LPG_100
Population Migrated (Mill.)	0.54	0.74	0.12	0.27
Cost per year (Mill. $US_{2010}$$/year)	0.029	0.108	0.001	0.002

3.5 Implications for Future Cooking Energy Demand and GHG Emissions

The impact of alternative transition scenarios for improving access to clean cooking on cooking energy requirements is depicted in Figure 8. With population growth, cooking energy demand is expected to increase over time. However, due to the shift towards more efficient stoves (traditional stoves are ~15 percent efficient in comparison to ~25 percent for ICS and 60 percent for LPG stoves) even in the absence of policies, final energy demand reduces by 18 percent. Under the rapid LPG transition scenario, final energy use reduces by 29 percent relative to the no new policies scenario. These reductions are similar in all three countries. However, the relative share of the reduction in each country from income growth and transition implementation differ, and depend on scenarios' effectiveness in increasing clean cooking access and also by the penetration of LPG relative to that of ICS. Thus, in Honduras, energy demand reduction from a rapid transition to LPG is the highest, followed by Nicaragua and then Guatemala.

The changes in final energy demand also have implications for greenhouse gas (GHG) emissions. Current cooking practices that use traditional biomass are associated with significant emissions of non-CO_2 Kyoto gases (e.g. CH_4, N_2O) and aerosols (e.g. Black Carbon) due to incomplete combustion (Grieshop et al. 2011). Furthermore, the sustainability of the fuelwood feedstock is another driver of cookstove GHG performance, as the non-renewable harvest and combustion of biomass results in the emission of CO_2 into the atmosphere. We account for all

Kyoto GHG emissions in our estimates (see section A.1.7 in the Appendix for applied emission factors).

Figure 8: Cooking final energy demand in 2010 and 2030 under different scenarios. See Table 9 for a full description of scenarios.

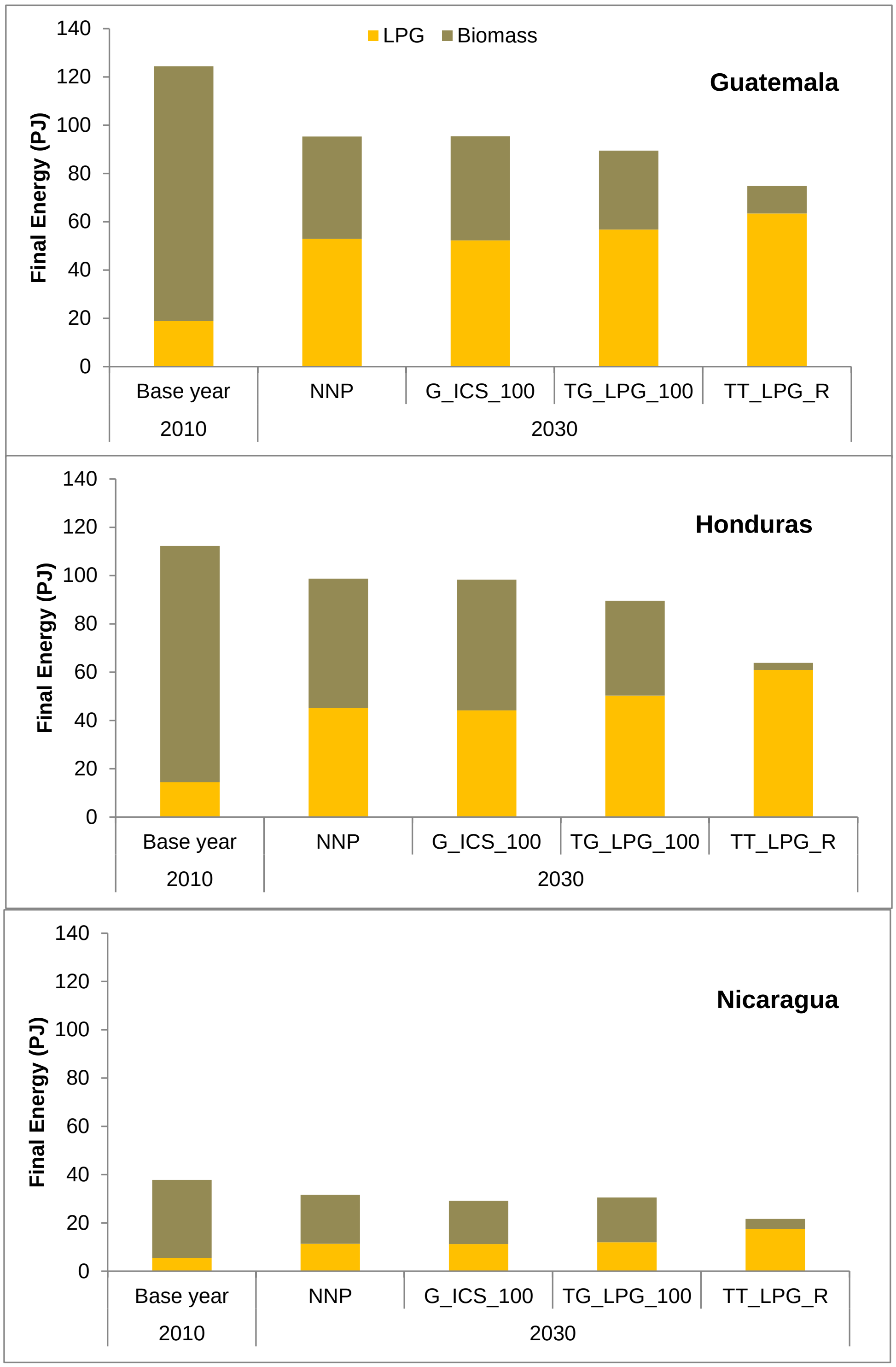
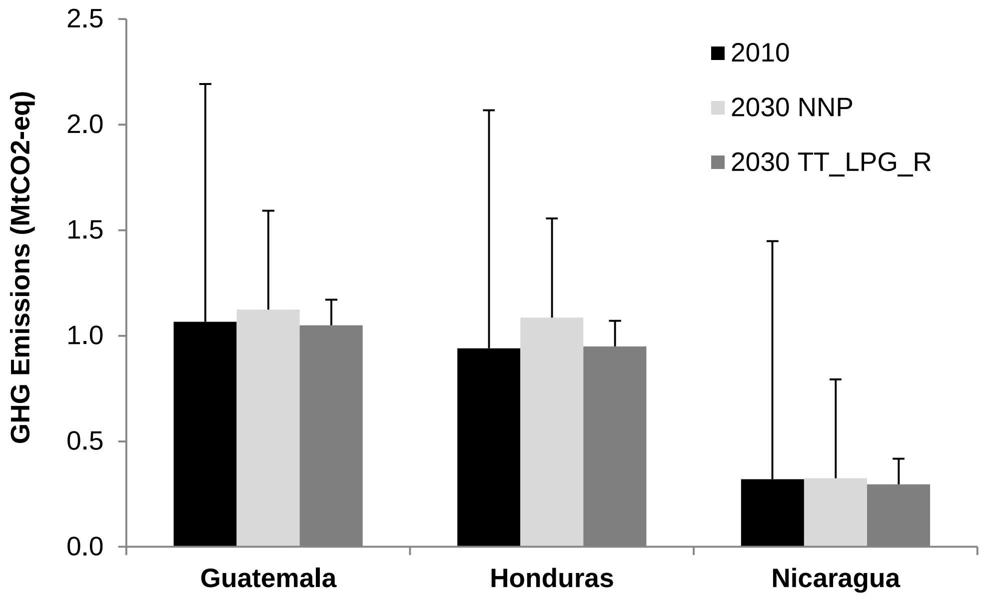


Figure 9 presents the impacts of alternate transition scenarios on total GHG emissions for 2010 and 2030. Compared with the year 2010, GHG emissions in 2030 are projected to increase by 9 percent (collectively in the three countries) without any policies, but would be 1 percent lower in the rapid transition to LPG scenario. Most of the increase in emissions is accounted for by the additional LPG demand for cooking. However, the net impacts of the access policy are marginally favorable due to the efficiency improvements associated with LPG use in place of biomass.

In the analysis presented in the figure, the error bars depict the additional CO_2 emissions that would result under the assumption that 35 percent of biomass used for cooking in these countries is renewably harvested. The assumption of 35 percent as the fraction of non-renewable biomass (fNRB) in the region is conservative given estimates of the range of values for a sub-set of least developed countries as calculated for CDM and carbon offset projects (CDM 2012), and as noted for the region in Bailis et al. 2015 (see Section 1.2.5). Accounting for the CO_2 emissions from non-renewable biomass use suggests that the emissions impacts of achieving universal clean cooking access in the region could be even more favorable for the climate. Emissions in this case could be 35 percent lower than in the baseline in 2030. There is also growing evidence of the warming effects of Black Carbon, emitted from existing traditional biomass stove technologies (Ramanathan and Carmichael 2008). However, as this is not included in the current list of Kyoto gases its effects are not accounted for in this analysis.

Figure 9: Greenhouse gas emissions for the baseline and future policy scenarios. Error bars represent additional CO2 emissions under the conservative assumption that 65 percent of biomass is renewably sourced.

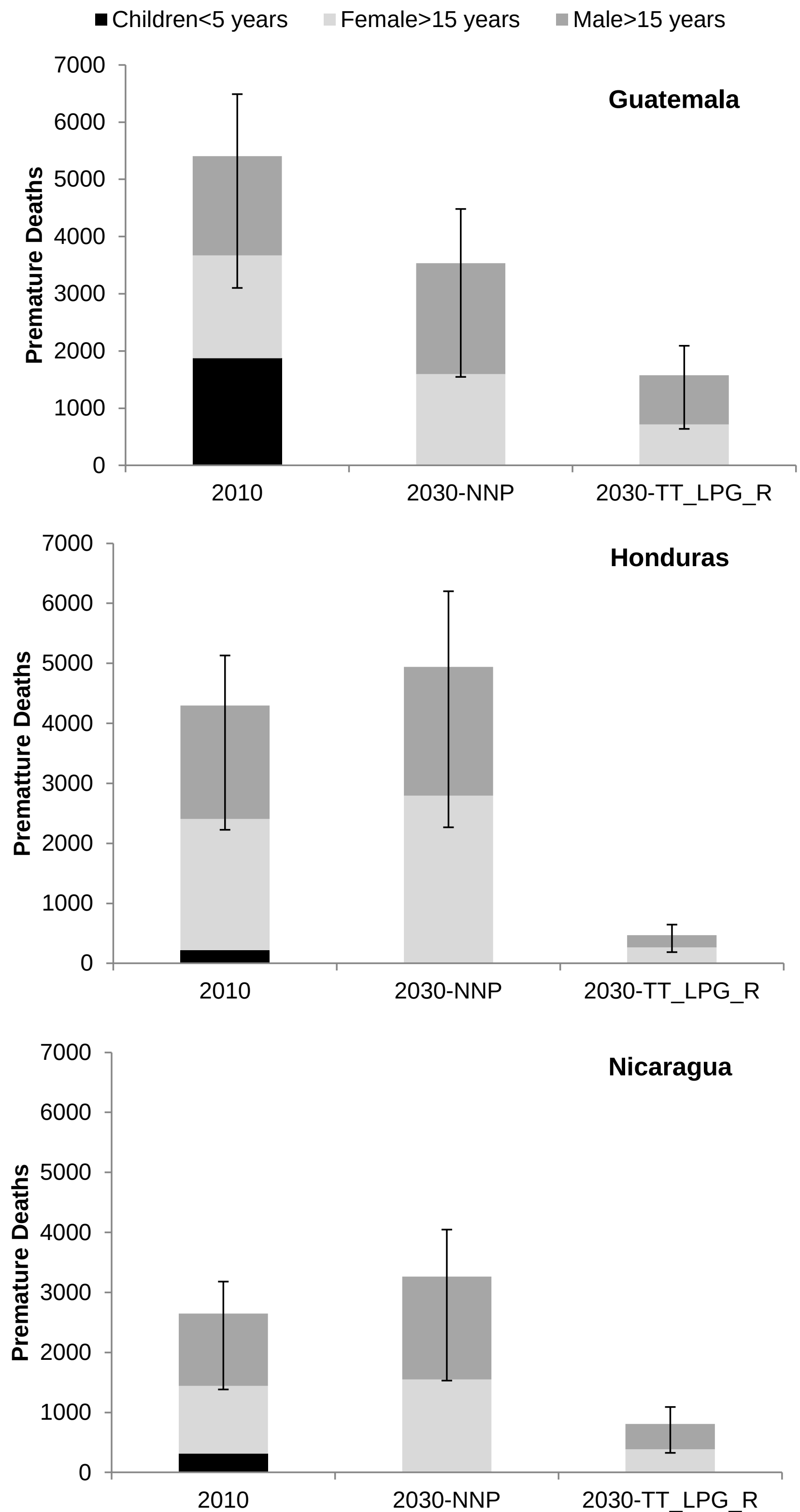


3.6 Health Benefits of Clean Cooking Access

Exposure to particulate matter from household cooking remains a major cause of death and disability in these three countries. Documented adverse health effects of household solid fuel cooking include acute respiratory infections in young children, as well as chronic obstructive pulmonary disease, ischemic heart disease, strokes and lung cancer in adults (Lim et al. 2012; Smith et al. 2014). We use one of the core WHO health and development indicators, ‘‘proportion of population using solid fuels,’’ or solid fuel users (SFU) as a proxy for actual exposure to household air pollution following the Global Burden of Disease (GBD) 2010 methodology to estimate the health impacts of household air pollution. The latest estimates of relative risks for diseases due to household air pollution are used to estimate the burden of those diseases with strong epidemiological evidence for an enhanced risk due to solid fuel use (see section A.1.8 in the Appendix for a summary of risk rates) (Smith et al. 2014). We consider mortality related outcomes for males and females over the age of 15 years, as well as include the effects for children below the age of 5 years, given the long-standing evidence that household air pollution from solid fuel use is a leading risk factor for acute lower respiratory infection ALRI in young children (Lim et al. 2012). Based on the new WHO IAQ guidelines, we assume that the diffusion of ICS would not have significant health benefits, and any benefits would lie within the uncertainty range of the estimated impacts for the low and high relative risk interval (WHO 2014).

In 2010 total deaths attributed to solid fuel combustion in traditional stoves in the three countries studied amounted to 12,353 (Low RR: 6,709, High RR: 14,804), with the impacts felt mainly by women and children (Figure 10). An almost equivalent number of deaths, about 11,740 are estimated in 2030, in the NNP scenario. Although there is uncertainty associated with these estimates, policies that achieve universal access to clean cooking by 2030 have the potential to avert about 8,890 (Low RR: 4,193, High RR: 10,909) premature deaths in 2030. In other words, in the absence of any new policies to enhance access to modern cooking fuels or devices, it is estimated that in 2030 almost an equivalent number of lives will be lost due to household air pollution, compared to estimates for 2010. Deaths attributable to acute lower respiratory infection (ALRI) among children under 5 are seen to decline between 2010 and 2030 even in the absence of any access policies, but deaths due to chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD) and strokes in adults are expected to increase during the same period. These trends are in line with those reported by others (for e.g. (Bailis 2005)), who find that the observed decline in childhood ALRI mortality over time is a result of an improvement in other factors reducing the risk of this communicable disease, whereas the upward trend in adult incidence of non-communicable diseases is mainly due to an increasing ageing population share, particularly in Honduras and Nicaragua.

Figure 10: Premature deaths from solid fuel use in 2010 and 2030 under different policy scenario. Error bars represent uncertainty intervals for low and high relative risk rates.



4 Conclusions and Lessons for a Clean Cooking Outlook by 2030

Reducing fuelwood use for cooking in Central America is an important policy imperative. With rising income, over 90 percent of urban residents currently using biomass in Guatemala and Nicaragua are likely to shift to clean fuels of their own accord. However, in urban Honduras, where per capita income is projected to be lower, about a quarter of the urban population could still be relying on traditional fuelwood stoves for cooking in 2030. In rural areas, solid fuel dependence is likely to be much higher**.** Without supporting policies, between 40-50 percent of rural Guatemalans and Hondurans, and a higher share of the population in rural Nicaragua, are unlikely to find clean fuels or stoves affordable in 2030. In 2010, 12,353 premature deaths were estimated to be attributed to traditional stove use. This number could remain almost unchanged with 11,740 estimated deaths by 2030 in the absence of new policies. From a climate perspective, GHG emissions from cooking, from population and income growth, would see a modest increase (~9 percent) from 2010 levels, since efficient LPG will replace inefficient biomass. If some extent of existing biomass use is assumed to be non-renewably harvested, then even in the absence of any policies, emissions might be expected to decrease due to the high CO_2 emissions from unsustainable biomass harvesting.

We have examined a set of cooking energy transition scenarios for a shift to LPG and improved cookstoves to assess some key impacts of achieving universal access in the three countries by 2030. We find a rapid transition to LPG scenario as the most beneficial. Such a transition would need to be targeted to the rural and poor urban populations. By 2030, such a transition scenario could make cooking with LPG affordable to an additional 7.3 million people in these three countries. Under such a scenario 8,890 premature deaths could be prevented in 2030. The GHG impact is at worst marginal, if one assumes (conservatively) that biomass were renewably harvested. However, if 35 percent were not, which is far less than what literature suggests, the rapid transition to LPG scenario could lead to a 35 percent reduction in GHG emissions relative to the baseline in 2030. A policy of grants or microfinance loans for improved biomass cookstoves (ICS) purchases could be an effective interim solution for certain regions, particularly in Nicaragua, where fuelwood is purchased and prices are low, so that stove costs constitute a much larger share of total cooking costs for the population. Such a policy would cost US$1 million/year and benefit up to 2.2 million people relative to the baseline in 2030.

Recent policy initiatives and government pledges in these countries have targeted a scaling up of efforts to disseminate improved biomass cookstoves (ICS) in the region. We find the recent targets are on par with what we observe as feasible transitions to ICS in the region, when grants or microfinance for the stoves are made available. In the case of Nicaragua, the targets set (40,000 stoves per year) might be conservative, as a much more rapid uptake of ICS may be feasible according to this analysis. However, achieving these more ambitious goals would require significant institution building and strengthening in order for the massive scale-up in new ICS dissemination this would entail.

Central American countries have been deregulating LPG markets over the last decade. Future policies aimed at making cleaner fuels like LPG more affordable will need to focus on better design and implementation for targeting or consider cash transfers and other social service delivery mechanisms for the poor as an alternative. This will require additional capacity building to strengthen the administration of governance systems and local institutions in the region.

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Appendix

A1 Methods

A1.1 Population Grouping

Two of the most significant determinants of household cooking fuel and stove choices are the availability and affordability of fuel-stove combinations (Heltberg 2004; Pachauri et al. 2004; Prasad 2008). To represent differences in fuel-stove *availability*, we split the population into rural and urban sub-groups using reported household sector from the household surveys. We then further divide these sub-groups into categories of total household expenditure to represent differences in the *affordability* of fuel-stove combinations. Rural and urban sectors were initially divided into 3 expenditure tiers each. Expenditure divisions were chosen to represent significant poverty benchmarks but also to maintain approximately even population between groups in the start year of the model. These expenditure group divisions are defined as having per capita daily expenditure in 2005 PPP$ below $2/day, $2-$5/day, and over $5.00/day. This resulted in a roughly even distribution of the rural population between groups in the base year, but a skewed distribution toward higher groups in the urban population. We therefore combined the lower two urban groups such that the urban population would be divided into households spending under $5.00/day and those spending over $5.00/day, resulting in a total of 5 population sub-groups – henceforth referred to as “expenditure groups.”

A1.2 Income and Population Projections

We adjust the population and income for expenditure groups in future years based on rural/urban specific projections of GDP and population from the Global Energy Assessment’s medium scenario (“GEA-M”) (Riahi et al., 2012). These projections are down-scaled from rural/urban to the 5 expenditure groups using methods described in Pachauri et al. 2013. Table A13 and Table A14 show the projected population and wealth in the base year, 2010, 2020, and 2030.

Table A13. Population projection in millions by expenditure group

	Guatemala			Honduras			Nicaragua		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
R1	1.781	0.991	0.409	1.5	0.905	0.244	0.736	0.441	0.115
R2	2.428	2.041	1.334	1.65	1.513	0.923	0.973	0.806	0.461
R3	3.056	5.101	6.799	0.745	1.729	2.995	0.776	1.356	2.081
U1	1.447	1.168	0.788	2.638	2.757	2.128	1.265	1.003	0.377
U2	5.664	8.79	12.362	1.082	2.232	4.202	2.072	3.076	4.353

Table A14. Income projection by expenditure group in 2010 MER$

	Guatemala			Honduras			Nicaragua		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
R1	217.98	217.98	217.98	254.53	254.53	254.53	211.98	211.98	211.98
R2	609.11	609.11	609.11	659.62	659.62	659.62	549.35	549.35	549.35
R3	2360.29	3273.78	5042.72	2327.74	2682.98	3913.31	1337.88	1793.26	2777.21
U1	566.04	566.04	566.04	555.78	555.78	555.78	685.29	685.29	685.29
U2	3694.38	5351.00	7900.27	2110.61	2550.13	3499.44	2388.43	3177.22	4967.63

A1.3 Fuel Prices and Cooking Costs

A1.3.1 Fuel Prices

This analysis models household demand for purchased firewood, LPG, and electricity. Charcoal and kerosene were excluded from this analysis because they supply a negligible share of total market demand for cooking energy in this region. Fuel prices for the three modeled fuels were derived from household surveys when available by taking the weighted mean of reported fuel expense divided by reported fuel use. Where fuel price data was not available from household surveys, fuel prices were taken from literature. We report prices in 2010 MER$/gigajoules of final energy (GJ_{FE}). Final energy refers to the total energy available in a fuel if combustion were 100% efficient. Useful energy is the actual amount of service delivered – i.e. joules of heat produced. Table A15 includes the fuel prices used and their respective sources.

Table A15. Mean fuel prices by country and fuel (2010 MER$/$GJ_{FE}$).

		Firewood	LPG	Electricity
Guatemala	**Price**	6.89	28.11	62.34
	Source	INE 2006	INE 2006	INE 2006
Honduras	**Price**	4.02	20.79	28.25
	Source	CEPAL-EZ 2011	ESMAP 2010	CEPAL 2010
Nicaragua	**Price**	0.75	21.20	32.26
	Source	Nicaragua 2007	INE 2006	CEPAL 2010

A1.3.2 Future Fuel Price Trajectory

Fuel price development in future years is accounted for using price projections from the GEA-M scenario of the Global Energy Assessment (GEA) (Riahi et al. 2012). This is a relatively conservative price projection relative to recent historical trends (Kojima, 2013), but serves as a valuable baseline given its use in other energy modeling analysis. The difference between the 2010 GEA price and the base year fuel price derived from the household surveys is used as a fixed difference in all future model time-steps. Firewood prices were assumed constant throughout the duration of the model timeline because there are no reliable price forecasts. Table A16 presents the fuel price projections for each country.

Table A16. Fuel price trajectory by country (2010 MER$/$GJ_{FE}$).

		2010	2020	2030
Guatemala	**LPG**	28.11	29.23	30.32
	Electricity	62.34	63.09	64.28
Honduras	**LPG**	20.79	22.02	23.23
	Electricity	28.25	29.08	30.38
Nicaragua	**LPG**	21.20	22.36	23.50
	Electricity	32.26	33.05	34.28

A1.3.3 Stove Prices

Stove efficiencies, lifetimes, and costs were taken from Ekholm et al., 2010 and WB, 2011.

Table A17. Stove costs and attributes

Stove Type	Efficiency	Lifetime (years)	Price (2010 MER$)
Three Stone	0.15	3	0.00
ICS	0.25	10	50.73
LPG	0.6	15	83.68
Electric	0.75	15	104.28

Stove prices are annualized differently for each expenditure group in each year as a function of the group's discount rate, the stove price, and the stove's lifetime. We calculate expenditure group specific implicit discount rate as a function of total household expenditure using equation 1 from Train, (1985):

$$\boldsymbol{D_e = -0.162 \times ln(X_e) + 1.9558} \quad (1)$$

where D is group specific implicit discount rate (%), e is expenditure group, and X is household expenditure per year ($).

A1.3.4 Total Cooking Costs

Based on these inputs, we calculate total cooking cost per unit useful energy for each group in each year using equation 2:

$$Cooking\ Cost = \frac{Fuel\ Price}{Stove\ Efficiency} + \frac{Annualized\ Stove\ Price}{Cooking\ Energy\ Demand^{3}} \quad (2)$$

Resulting cooking costs for year 2010 are presented in Table A18 in gigajoules useful energy (see section A1.3.1 for definition).

Table A18. Total cooking cost of three fuel-stove combinations in 2010 accounting for both fuel and annualized stove costs (2010 USD/GJ_{UE}). ICS = Improves Biomass Cook-Stove, LPG = Propane Stove, ELC = Electric Induction Cook-Stove.

	Guatemala			Honduras			Nicaragua		
	ICS	LPG	ELC	ICS	LPG	ELC	ICS	LPG	ELC
R1	30.15	49.76	101.92	18.33	37.34	48.32	5.73	38.86	55.62
R2	30.38	51.60	97.00	18.53	38.77	46.23	5.48	39.67	52.39
R3	29.17	49.71	89.23	17.86	37.68	42.53	4.87	38.48	48.20
U1	28.53	50.53	83.84	17.33	37.89	39.90	6.36	41.08	48.14
U2	30.55	50.66	83.26	18.55	38.06	39.87	6.06	39.99	46.46

[3] "Cooking Energy Demand" refers to the weighted mean for annual household demand for useful cooking energy.

A1.4 Demand Curve Estimation

A1.4.1 Demand Curve Methodology

To assess fuel demand in each expenditure group, we use household surveys to derive expenditure group specific demand curves. We regress a best-fit power function, weighted on household multiplier, of each household's demand for a fuel against that household's cooking costs on both fuel and stove.

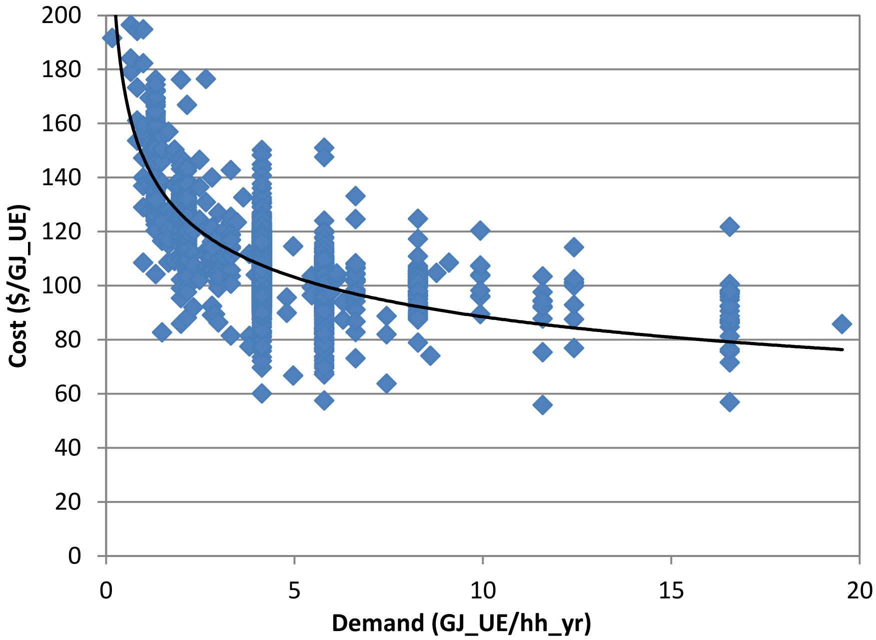
The power curve is chosen over other regressions because we assume that observed price elasticity is constant. In order to use a power curve for a given fuel, we must exclude survey respondents reporting no use of that fuel. The curve must then be adjusted to reflect the demand of the group as a whole rather than solely the subset of that group that used the fuel. We adjust by multiplying the demand for a fuel by the percentage of total useful cooking energy met with that fuel in each expenditure group. The result is a market demand curve for an expenditure group's average household.

The demand curve equation takes a form of Eq. (3):

$$\mathbf{D_e^f} = \mathbf{a_e^f} \times \left(\mathbf{C_e^f}\right)^{\mathbf{b_e^f}} \times \mathbf{S_e^f} \tag{3}$$

Where ***e*** is expenditure group, ***f*** is fuel type, ***D*** is demand for useful cooking energy, ***C*** is cooking cost per unit useful energy including stove and fuel, ***S*** is share of total cooking energy demand met by fuel ***f***, and ***a*** and ***b*** are coefficients. We present an example demand curve in Figure A11.

Figure A11. Example demand curve LPG demand for Guatemala U2 expenditure group.



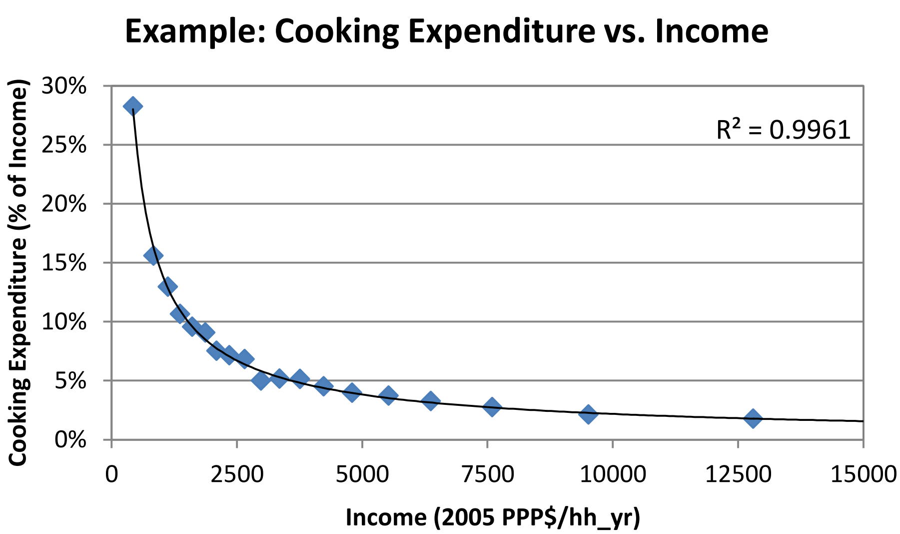
A1.4.2 Fuel Tier Structure

To model how consumers choose between fuels, we assume “fuel-preference tiers.” The premise of this system is that consumers prefer to meet their cooking needs with clean, easy-to-use fuels such as LPG, but will shift to dirtier and more time-consuming fuels (firewood) when the cost of cooking with modern fuels is too high. LPG and electric induction are assumed to be the top-choice (Tier 1) fuel-stove options for all consumers. We assume the service of these two fuel-stove combinations is equally desirable and therefore assume the cheaper Tier 1 fuel will be chosen. We then assign improved biomass cook-stoves (ICS) as a Tier 2 cooking system and traditional (three-stone) biomass stoves as Tier 3. Demand is calculated first for tier 1. If tier 1 demand satisfies the total cooking energy demands for that expenditure group, no other fuels are used. If tier 1 demand is too low to meet that group’s energy demands, tier 2 fuels are used. If both tier 2 and tier 1 demand is less than group energy demand, tier 3 is used to satisfy all remaining demand.

A1.4.3 Adjustments for Future Years

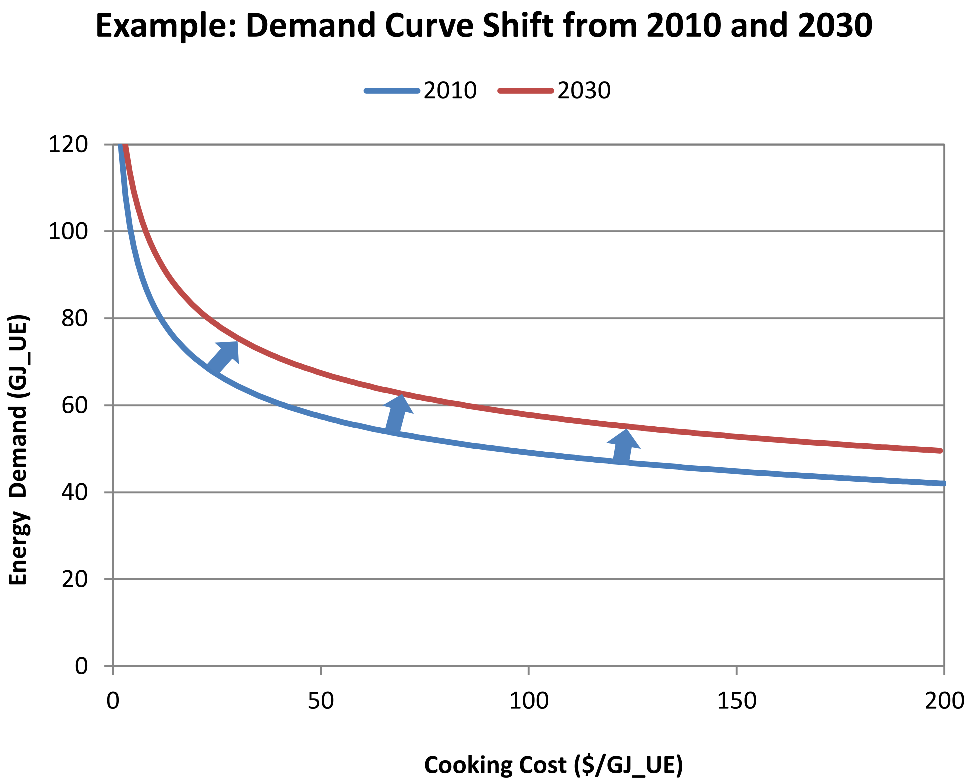
We assume that each group's total cooking energy demand is fixed in a given year – meaning low or high fuel prices will not result in a household using more or less energy for cooking, but only change which fuels that household uses. In the base year, we use the weighted mean cooking energy demand for each group from the household survey. In future years, however, group cooking energy demands do change as a function of household size and expenditure. We account for these factors by regressing income against household size, expenditure on cooking, and cooking energy demand from the household survey. Figure A12 illustrates and an example function for rural Guatemala.

Figure A12. Example regression of cooking expenditure against income for rural Guatemala using 20 population sub-divisions**.**



Demand curves are then adjusted in future years to account for increases in wealth by increasing coefficient ***a*** by the change in household cooking expenditure relative to the base year. We illustrate this process in Figure A13.

Figure A13. Example of demand curve adjustment from 2010 to 2030.



A1.4.4 Data Gaps and Assumptions

Of the three countries analyzed in this study, only the Guatemala survey provided sufficient data to derive demand curves directly from the survey. It included both fuel demand and price for firewood and LPG and did so for a representative sample of the population (13,686 households). The survey provided no information on type of stove used for cooking with firewood. We were therefore unable to directly estimate demand for improved biomass stoves (ICS). To model ICS demand, we used firewood purchases as a proxy for household willingness-to-pay for ICS. The ICS demand curve was calculated assuming all survey respondents cooked on three stone stoves, but subsequent ICS demands were calculated including ICS stove costs.

We assumed all electricity use reported in the survey was used for lighting and appliances and therefore did not directly estimate an electricity demand curve. Instead, we assume electric induction provides equivalent service to LPG and therefore use the LPG demand curve for both fuels.

LPG use was extremely sparse among poor income groups and consequently we were unable to infer representative LPG demand curves for these groups. To address this issue, we adjusted the demand curves for the wealthiest expenditure group in each sector (R3 and U4) to intersect the mean LPG demand and price for the poorer groups in the same sector. We assumed coefficient ***b*** from the source groups remained constant within their sector and adjusted coefficient ***a*** accordingly. In other words, demand (***D***) and cooking cost (***C***) were set for the base year as the weighted mean from the survey for each group, coefficient ***b*** was set to equal ***b*** in the demand curve for the corresponding wealthy group, and ***a*** was determined using equation (4):

$$\mathbf{a_e^f} = \frac{\mathbf{D_e^f}}{\mathbf{C_e^f}^{\mathbf{b_e^f}}} \tag{4}$$

The Nicaragua and Honduras household surveys did not include fuel expenses and did not collect data on multiple fuels. We therefore adjusted the demand curves from Guatemala to be used in Honduras and Nicaragua using the same method described above to adjust the Guatemalan LPG curves for poorer groups.

A1.5 Policy Scenarios

We report results for only stove price subsidies. We also modeled stove micro-financing, but we do not present those results as they are indistinguishable from the stove subsidy scenarios. In this analysis, we model 10 policy scenarios for each country. Stove subsidies for ICS were not restricted to these groups because the demand for ICS is naturally restricted to poorer groups.

Stove grants were set at levels of 50% and 100% subsidy for the ICS, LPG, and electric stoves. Stove grants were modeled by reducing the cost of the stove by the percentage of the grant. Table A19 shows the 10 policy scenarios for each country modeled for each country.

Table A19. Policy scenarios for assessing future household cooking transitions. Targeted policies are available only to rural households and urban households earning under PPP$5/capita-day.

	Scenario Name	Description
1	**NNP**	No new policies (a business-as-usual scenario)
2	**G_ICS_50**	Grant or rebate on improved biomass stoves, @50%
3	**G_ICS_100**	Grant or rebate on improved biomass stoves, @100%

4	**TG_LPG_50**	Targeted* Grant or rebate on LPG stoves, @50%
5	**TG_LPG_100**	Targeted* Grant or rebate on LPG stoves, @100%
6	**G_EIS_50**	Grant or rebate on electric induction stoves, @50%
7	**G_EIS_100**	Grant or rebate on electric induction stoves, @100%
8	**TT_LPG_S**	Targeted* Transition to LPG Fuel_Slow
9	**TT_LPG_M**	Targeted* Transition to LPG Fuel_Moderate
10	**TT_LPG_R**	Targeted* Transition to LPG Fuel_Rapid

A1.6 Policy Costs

Annual costs for each policy are calculated for 2020 and 2030 and cumulative policy costs are calculated over the period from 2020 to 2030. The annual cost of stove grants in a given year is calculated as the number of stoves purchased in that year multiplied by the annualized stove cost subsidized in each year. To estimate the cumulative policy cost from 2020 to 2030, we assume the 2020 prices only in that year and use 2030 prices from 2021-2030 in accordance with GEA-M. Annual costs are then discounted to 2010 MER$ in each year and summed.

Policy cost per beneficiary is calculated by dividing annual policy cost by the number of persons "migrated" by the policy. In the case of ICS grants, "people migrated" refers to those who used traditional three-stone stoves in 2030 in the NNP scenario but switched to using an ICS stove in 2030 in the policy scenario. In the case of LPG stove, "people migrated" refers to those using either three-stone or ICS in 2030 in the base case but who use LPG in 2030 in the policy scenario.

A1.7 Emissions

Kyoto gas emissions are assessed for each modeled stove using standard IPCC emission factors. HFC, PFCs, and SF6 are not displayed as they are negligible for these fuels. We represent only emissions at the point-of-use and do not include "upstream" emissions.

Table A20. Stove emissions in tons carbon equivalent per kilowatt-year.

Stove Type	**CO_2**	**CH_4**	**N_20**
Three Stone	0.962	0.202	0.030
ICS	0.962	0.202	0.030
LPG	0.480	0.001	0.000
Electric	0.000	0.000	0.000

A1.8 Health Impacts

To estimate the health impacts of solid fuel use we use the methodology developed by the Global Burden of Disease project (GBD 2010). Further details regarding the methods based on estimating the population attributable fraction (PAF) for health outcomes associated with exposures to household pollution can also be found in (Rao et al., 2012). We employ the latest relative risk estimates (see Table A21) for diseases associated with exposure to pollution from solid fuel combustion, and use the population dependent on solid fuels as an exposure surrogate.

Table A21: Relative Risks for diseases associated with household air pollution. Source: Smith et al., 2014.

Disease	Sex/Age	Relative Risk	95% Confidence Interval
Acute Lower Respiratory Infections (ALRI)	M/F <5 y	2.88	(2.03-3.84)
Chronic Obstructive Pulmonary Disease (COPD)	F>15 y	2.3	(1.73-3.06)
Chronic Obstructive Pulmonary Disease (COPD)	M>15 y	1.9	(1.15-3.13)
Lung cancer (LC)	F>15 y	1.81	(1.07-3.06)
Lung cancer (LC)	M>15 y	1.26	(1.04-1.52)
Cataracts	F>15 y	2.47	(1.63-3.73)
Ischemic Heart Disease (IHD)	F>15 y	1.98	(1.4-2.2)
Ischemic Heart Disease (IHD)	M>15 y	1.97	(1.4-2.2)
Stroke	F>15 y	2.07	(1.4-2.4)
Stroke	M>15 y	2.03	(1.3-2.4)

The policy scenarios explored in the report affect the overall health impacts by effectively modifying the proportion of the population exposed i.e. depending on solid fuels. In order to estimate the future health impacts for the exposed population in 2030, we project the background disease deaths using age-specific data on deaths attributable to each disease for the years 1990, 1995, 2000, 2005, and 2010 from the Institute for Health Metrics and Evaluation (IHME, 2014) and population by age and sex data from the UN. The historical data on background deaths are then extrapolated to 2030, adjusting for population growth. This is done by (1) dividing historic deaths for each age and sex category by corresponding population size; (2) projecting the per-capita death trend; (3) then multiplying by the projected future population to arrive at future deaths. A similar methodology has previously been employed by Murray et al. (2007).

Table A22 below presents results of our estimates of health impacts for 2010 and 2030 for the no new policies (NNP) scenario as well as the FPS_LPG_50 scenario that achieves near universal access to clean cooking by 2030.

Table A22: Estimated health impacts from household air pollution in 2010 and 2030

Disease	**Sex and Age**	**Attributable Burden (Deaths)**								
		Guatemala			**Honduras**			**Nicaragua**		
		2010	2030 NNP	2030 TT_LPG_R	2010	2030NNP	2030 TT_LPG_R	2010	2030 NNP	2030 TT_LPG_R
ALRI	M/F <5	1874	0	0	218	0	0	313	0	0
COPD	F>15	291	193	89	409	530	53	189	279	73
COPD	M>15	244	200	89	315	387	36	179	279	67
LC	F>15	84	95	43	55	61	6	29	42	10
LC	M>15	46	56	23	22	19	1	25	32	7
IHD	F>15	1116	1077	480	1293	1640	154	693	1028	253
IHD	M>15	1178	1394	621	1212	1333	125	792	1177	289
Stroke	F>15	306	232	105	431	563	54	219	198	50
Stroke	M>15	269	286	128	344	408	39	210	231	57
Total		**5407**	**3533**	**1577**	**4298**	**4941**	**468**	**2648**	**3266**	**806**

A2 Sensitivity Analysis

We test a scenario in which LPG prices increase more rapidly than they do in our base case price projection. We assume 50% growth in LPG price over each 10-year model time-step starting after 2010 to roughly match the price increases reported by Kojima (2013) over the period from 2003 and 2011. These prices are displayed in Table A23:

Table A23. Fuel price trajectory for a high LPG price sensitivity analysis (2010 MER$/GJFE).

		2010	**2020**	**2030**
Guatemala	**LPG**	28.11	42.17	63.25
	Electricity	62.34	63.09	64.28
Honduras	**LPG**	20.79	31.19	46.78
	Electricity	28.25	29.08	30.38
Nicaragua	**LPG**	21.2	31.8	47.7
	Electricity	32.26	33.05	34.28

We compare the NNP, targeted TT_LPG_R, as well as a blanket T_LPG_R policy scenario for the high LPG price projection with the same scenarios using the GEA-M price projection for total population reliance on solid fuels (Figure A14) and policy cost per beneficiary in 2030.

Figure A14. Solid fuel use in 2030 as a percent of population for both the original and high LPG price scenarios with no new policy (NNP), universal rapid LPG transition, and targeted rapid LPG transition.