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Household air pollution, health, and climate change – clearing the air

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Abstract

Air pollution from use of household solid fuels is now recognized to be a major health risk in developing countries. Accordingly, there has been some shift in development thinking and investment from previous efforts only focused on improving efficiency of household fuel use to those that focus on reducing the exposures to the air pollution that lead to this health impact. Unfortunately, however, this is occurring just as the climate agenda has become to dominate much of the international sustainable development discourse and action. Thus, instead of optimizing approaches that centrally focus on the large health impact, the household energy agenda has been hampered by constraints imposed by a narrow definition of sustainability, one primarily driven by the desire to mitigate greenhouse emissions by relying on renewable biomass fueling so-called improved cookstoves. In reality, however, solid biomass is extremely difficult to burn sufficiently cleanly in household stoves to reach health goals. In comparison to the international development community, however, some large countries, notably Brazil historically and more recently, India, however, have with their own resources substantially expanded the use of liquefied petroleum gas (LPG) in their household energy mix, with major impacts on their national energy picture. The net climate impacts of such approaches compared to current biomass stoves are minimal or non-existent and that the social and health benefits are, in contrast, potentially great. LPG can be seen as a transition fuel for clean household energy, with induction stoves powered by renewables as the holy grail (an approach already being adopted by Ecuador). The enormous human and social benefits of clean energy, rather than climate concerns, should dominate the household energy access agenda today.

Tweetable Abstract: Household fuel pollution is a social not a climate problem

Key Words: LPG, Net GHG emissions, sustainability, biomass fuel, India, Brazil, Ecuador

1. Introduction

Addressing the climate challenge while advancing development needs goes to the heart of a conundrum for developing countries and other actors in the climate/development arena. Effective management of this perceived tension is the key to developing-country political support and engagement on the climate issue. The ideal actions, of course, are those that provide an opportunity to meet pressing development needs while also resulting in greenhouse gas mitigation. But as is often the case, the reality turns out to be more complicated and the navigation of the climate/development nexus may lead to outcomes where developmental aspects are not given sufficient attention in the urgent push to tackle the climate problem. Household air pollution (HAP) from solid cookfuel is a case in point.

2. The HAP Problematique

The environmental, social, and human health consequences of the reliance of a significant part of the developing world on biomass burnt in traditional cookstoves have been well articulated for about four decades now, although the health component has only relatively recently been explored fully (Lim, et al. 2012; Smith et al., 2014).

As a result, there have been a number of efforts since the 1980s to promote so-called improved biomass cookstoves (IBCs) in many parts of the world.[1] As understanding of the household cooking energy *problematique* has evolved (from a natural resource conservation problem to an environmental and social problem to a health and climate problem), so have the objectives of programs aimed in this area.

In addition to the human and social impacts of relying on traditional biomass cookstoves such as the drudgery and time lost in collecting firewood, the current state of the scientific understanding indicates that health impacts resulting from direct exposure to biomass cooksmoke lead to about 2.2-3.6 million excess deaths/year and about 3.9-6.4% of global mortality (GBD, 2015), making air pollution (household and ambient) the largest environmental source of ill-health globally. The two types of air pollution are linked, however, in that about 500,000 deaths of the total mortality due to ambient air pollution is attributable to the contribution of household fuels to it globally (Chafe et al., 2014; Lelieveld, et al., 2015; Guttikunda, 2017).

The products of incomplete combustion of biomass in cookstoves lead to climate impacts, both through carbon dioxide (CO2) and such climate-related gases as methane (CH4), nitrous oxide (N2O), carbon monoxide (CO), and non-methane volatile organic contaminants (NMVOCs) as well as black carbon, with the latter receiving substantial attention in recent years, motivated by a desire to enable quick action on climate change through a focus on short-lived climate forcing (SLCF) agents, especially given the inability of major industrialized economies to take the lead on significantly reducing CO2, the major greenhouse gas. The co-benefits of reducing many SLCFs, such as reduction in local air pollution and health impacts, provides an additional impetus for focusing on these greenhouse pollutants (Bruce et al., 2017).

[1] We use "improved" here in deference to common practice, although believing it to be a poor term – improved in what way and compared to what?

Accordingly, most major household clean cooking energy programs now cite health as well as climate benefits as the underlying key rationale for these efforts.[2] In addition to these gains from improved stove performance, other developmental objectives such as entrepreneurship and job creation, use of local resources, local and women's empowerment, and forest protection also often enter the picture. Here, however, we focus on just health and climate.

Re-examining the 'conventional wisdom'

With all the focus and activities on the HAP area, two aspects have remained more or less unchanged over the years: the main solution of choice, IBCs; and the number of people continuing to cook with traditional cookstoves, around 2.7 billion (Bonjour, et al., 2013).

IBCs have the advantage that they can use a locally available, often free, energy source. Furthermore, devices that allow for better combustion of biomass reduce the resulting pollution of local and non-CO2 greenhouse gas pollutants. At the same time, since biomass is often thought an entirely renewable resource, it often is assumed that the use of IBCs effectively also would lead to net zero CO2 emissions.

The reality is rather different. IBCs, while less polluting than their traditional three-stone counterparts in laboratory tests, usually do not have as good performance in the field (Jetter et al. 2014; Shen et al., 2018). That is not surprising since the operating conditions under actual use differ greatly from the laboratory, with far less consistent operator behavior and less consistency of biomass used, including size and moisture content (WHO, 2014). Indeed, even the term 'improved' is often rather loosely used in reality, with no uniform performance standards for the dissemination of stoves that may be labeled as cleaner and/or more efficient[1]. Evolving standards/guidelines from the ISO and WHO, however, show promise in helping with this vagueness (WHO, 2014; ISO, 2012)

The latest understanding of non-linear nature of air pollution exposure-risk relationship also suggests that emission from cookstoves have to be reduced significantly in order to adequately protect human health (Smith et al., 2014; Burnett et al., 2014) Unfortunately, even today's best IBCs are not yet able to reliably deliver this level of performance in the field. Progress is proceeding, however, and perhaps eventually there will be devices that are clean, attractive, and reliable to be promoted as health-giving interventions.

We ourselves have proposed a global innovation prize as a way to motivate and bring on board a variety of actors who may have the capabilities to develop a clean-burning, robust, and affordable biomass cookstove (Sagar and Smith,

[2] For example, the 2016 Progress Report of the Global Alliance for Clean Cookstoves is titled "Clean Cooking: Key to Achieving Global Development and Climate Goals." http://cleancookstoves.org/

2013). But as with any technical change, the rate of progress is uncertain, especially in this case where the clean combustion of solid fuels is naturally constrained by the physics of fuel-air mixing and the high heterogeneity of biomass sources and that there is no enormous market to drive deep and sustained technical change.

The experience with scaling up of delivery of IBCs has also been mixed. While a total of few hundred million improved cookstoves have indeed been disseminated over 35 years in a number of developing countries (including India, Nepal, Kenya, Sri Lanka, and Peru), these numbers are dominated by the large program in China that ended in the mid 1990s. That they are far less than what is needed is evinced by the increasing number of people who are continuing to cook with traditional cookstoves outside of China. This is not surprising since establishing production, supply, and servicing chains at this scale of delivery would indeed be an enormous task. In addition, it should be noted that the small set of IBCs that seem most capable of reducing exposures require processed biomass briquettes or biofuels such as ethanol, which itself requires a second supply chain. Also, monetizing biomass through this second supply chain may have unintended consequences in terms of local biomass supply and use patterns – induced demand in the commercial sector, for example. Furthermore, many of these IBCs have had relatively short lifetimes in actual use and are not replaced by households due to their not being perceived as offering significant benefits and/or meeting their needs (Puzzolo et al, 2016)

It is also observed, although not as systematically studied, that most of these IBCs do not completely replace traditional stoves, but rather are "stacked" in that they are used along with some continued use of traditional devices (Piedrahita et al., 2011; Lewis et al., 2012; Rehfuess et al., 2014; Pillarisetti et al.. 2014) The health benefit, however, depends even more on reducing the use of the traditional polluting devices than directly using the newer cleaner devices.,

As things stand at present, IBC programs have had only limited success in replacing traditional biomass for cooking energy (GACC website). And even where they have done so, the lack of sufficient reduction in air pollution exposures in real household IBC use undercuts their promise of major improvements in health risk, although such devices do somewhat address the climate issue (WHO 2014).

Given these issues with IBC performance and dissemination, it is perhaps surprising that such cookstoves continue to be a centerpiece of clean household cooking energy. To our mind, the continued impetus behind clean cookstoves programs in reality stems more from climate change concerns expressed as a focus on renewable energy. This is evinced by the rapid rise in funding for programs such as Global Alliance for Clean Cookstoves (GACC) and Energising Development (EnDev) an energy access partnership currently financed by six donor countries. If health is indeed a key element of the focus on clean cooking energy, it is difficult to justify the continuing emphasis on such devices rather on other demonstrated clean fuel solutions.

Notably, there also is a dominance of 'market-based" approaches in major clean cooking energy programs. EnDev facilitates the dissemination of these stoves through self-sustaining markets. GACC and the World Bank support market-based approaches that brings together the assets of the public and private sectors to ensure positive financial, social, and environmental returns to potentially address household air pollution at scale. If health was the dominant rationale for driving these programs, however, the priorities would have been driven by health outcomes and would target at-risk populations accordingly, as is the case for the health arena generally. In the delivery of vaccines and other basic health services to the poor, for example, the approach is not primarily a local market approach. It is understood that the health benefits of immunization is a beneficial social investment and that public policy should ensure an appropriate outcome; (if needed, through provision of free or subsidized vaccines, for example.

3. Making the clean available

There are clean cooking solutions to replace use of solid fuels that have existed well before IBC programs. Indeed, from essentially zero in the late 1800s, more than 60% of the world's population (over 4 billion people) cooks with liquefied petroleum gas (LPG)/piped natural gas (PNG) and/or electricity. In the currently developed countries, this transition occurred a century ago or more and was mostly driven by normal market mechanisms, although often facilitated by public policy, particularly in the power sector. In this way household cooking shifted in North America and Europe, for example. Indeed, the common American saying "Now you're cooking with gas" originated as an advertising slogan by gas companies late in the 19th century designed to lure women away from cooking with coal or wood to a modern efficient and aspirational fuel. Many marketing approaches that are finding a renaissance today were applied, including zero interest loans to encourage the penetration of gas appliances as well as heavy door-to-door marketing (Smith, 2010). These sources are also increasingly widespread in the developing world via normal business channels to the growing middle class (although often with some subsidy).

The promotion of gas and electricity as household fuels has not, until quite recently, been linked to the health agenda surrounding continued use of biomass. Primarily in India starting in 2015, but also beginning in a few other countries, however, there recently have been major government-led programs launched to enhance the use of LPG driven in large part by health concerns.

We have suggested elsewhere that this pathway of promoting what is well established already to be clean could be seen as working harder to "make the clean available," which should be taken up even more strongly as it offers a way to bring clean cooking to billions more as it already has to so many (Smith and Sagar, 2014). It also has delivery systems already in place to operate at the scale required.

Cooking with gas: a second revolution

In mid-last-century, some lower middle income countries (LMICs) instituted major policy initiatives to promote LPG among their poor (Troncoso, 2017).

An early success: LPG in Brazil[3]

Brazil's population in 1936 was approximately 6 times less than today, i.e., 36million living mostly in rural areas. Less than one million lived in the largest cities of Rio de Janeiro, São Paulo and Recife (in the Northeast), which were the only ones using piped gas for cooking and heating and there only in central areas. The others and all other areas in Brazil used fuelwood and charcoal for cooking. LPG was introduced in that year using bottles of methane to be used by the Hindenburg dirigibles, which were discontinued after fire destroyed one. (Silva, 2007)

In 1939, only 395 households in Rio de Janeiro used LPG (less than 0.1% of the households in the state at that time), but thanks to a successful marketing campaign that number reached 5,160 in 1942. From then on, companies such as Standard Oil entered the market and consumption reached 10.000 tonnes of LPG in 1949 compared to 30 tonnes in 1938. The main driver was the fact that gas stoves were imported directly by the company and supplied along with the gas connection. The strategy was to donate gas stoves to foster natural gas take over of the place occupied by fuelwood and charcoal in Brazilian households. As the result, the gas companies presented an idea of evolution whose apex was gas, relegating fuelwood as obsolescent in this modern and cleaner lifestyle. Also, there were sanitation and modernization campaigns in urban areas, in which gas stoves were illustrate in magazines and other media outlets as instruments to improve family health and to decrease working time in kitchens.

The LPG subsidies started in 1973 and were in place until the year 2000. During the 1990s, LPG price policy began to be adapted to the introduction of a market economy, initiating a gradual process of price liberalization and withdrawal of subsidies in the end of 2000. Between 1973 and 2000, the fuelwood consumption decreased about 65 percent, which shows the success of the governmental intervention on replacing wood-based energy by LPG in Brazilian households. (Jannuzzi et al., 2004).

The expansion of LPG use in Brazil is due to a combination of an intense urbanization process and of governmental intervention based on price regulation and subsidies. In 1920, Brazil was a rural country. The country's urbanization rate increased from 26 percent in 1940 to 84 percent in 2010 and it is expected to reach 90 percent by 2020.

[3] Much of this section is based on "GLP Os pioneiros: meio século de história" Câmara Brasileira do Livro, São Paulo, CL-A Comunicações S/C Ltda, 1987.

Figure 1. *Major phases in the Brazilian LPG program from 1920 to present. Usage data represent a different metric than used by WHO in the Global Burden of Disease assessment, which shows higher numbers of households using LPG in Brazil (Bonjour et al. 2013). This is partly due to different databases being used, but seems mainly to be understood as the values in this figure representing the equivalent number of households solely using LPG, while the WHO database can be interpreted as those households using at least 51% LPG. The difference between these two numbers is one measure of the "stacking" being undertaken by many households, i.e. continued use of wood as LPG comes in.* From the Brazilian Energy Balance, Ministry of Mines of Energy, Brasilia, years 2010, 2011, 2012, 2013, 2014, 2015, 2016.

[Fig 1, see at end of this document]

In 2014, there were less than ten million people relying on traditional use of biomass for cooking, which corresponds to approximately 5% of the country's population. Currently, the majority of Brazilian citizens live in urban areas and large cities. The last comprehensive survey on households' composition and expenditure – the 2009's Consumer Expenditure Survey (Pesquisa de Orçamentos Familiares) – shows that 16 percent of Brazilian households own a stove that uses fuelwood or charcoal for cooking. The survey also shows that 59 percent of these cooking stoves are located in rural areas of the country. Currently, there are 5 570 municipalities in Brazil, from which only 227 (e.g. less the one percent) of them have no local distributor of LPG.

The distribution of LPG in Brazil is an activity regulated by the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP). The distributors receive the product from the refineries and supply the LPG resellers or sell directly to large consumers in industry and commerce through tank trucks. More than 190 bases located in the five geographic regions of Brazil give support to this operation.

An emerging success?: LPG for the poor in India

Starting in 2015, the Government of India (GoI) and the three Oil Marketing Companies (OMCs) that sell most LPG in the country embarked on three major programs to actively promote LPG to the poor – each pioneering, aggressive, and relying heavily on both sophisticated social marketing and what is summarized in India as "JAM" (financial inclusion through access to banking facilities (Jan Dhan), the "Aadhaar" card as a universal ID, and Mobile phones).

The first program, Pahal, shifted to paying subsidy fuel payments directly into people's bank accounts and thus enabling the sale of all LPG at market rates, greatly reducing diversion of LPG to the non-household sector. The second, "Give it Up," (GIU) persuaded middle-class households to voluntarily give up their subsidies to connect the poor through the companion "Give it Back" campaign, with a website that showed the name of the poor person who benefited from each subsidy that had been given up. (Smith and Sagar, 2016) As of June 2017, over 10 million people had "given it up."[4] The third program, Pradhan Mantri Ujjwala Yojana (PMUY), underway now, aims to provide free connections[5] to a total of 50 million poor households by 2019 with 25 million already installed by July 2017.[6] This has the potential of having a significant impact because many households can afford the monthly subsidized cost of LPG but have not had the upfront cash to pay for the connection costs, including deposit on the LPG cylinder and the stove itself (Smith, 2017), although there are remaining questions about the level of LPG uptake by those who have received a connection (Kishore, 2017)

The result is a remarkable increase in the historically modest expansion of LPG connections. Although the 6-7% growth in connections continues for the middle class, now 6-7% more occurs among the poor through GIU and PMUY. It is thus double the old rate, albeit only now for a bit more than two years. The country now expects to cover more than 90% of all households early next decade with clean cooking, although the official target is currently 80 percent by 2019. This is a transformation in the household cooking energy space in any country, but especially so for one of India's size, and due to innovations of several kinds in policy measures.

Notably, this push did not come directly from the health or environment sectors, which nevertheless benefit. Indeed, over time we can expect less ill-health in village households among women and men due to a range of diseases associated with cookstove smoke, with particular benefits for children due to lower pneumonia rates and for newborns due to a reduction of the rate of low birthweight (Smith et al., 2014).

One of the lessons of the LPG experience in India is the implications of scale. With 18,700 local distributors, each with 20-40 employees operating house to house, and plans to hire 10,000 more distributors underway, the LPG industry will soon have an army of a half million outside of cities to wield in promoting and servicing its product locally.[7] When combined with a well-functioning infrastructure from port to neighborhood[8], a high degree of quality control and transparency (for example, a website with every LPG beneficiary under the GIU scheme) and moving toward near universal cashless transactions via JAM, it seems likely that this transformation will be sustained. It also is a substantial job creation and contribution to the national economic agenda. Indeed, the PM's

[4] http://mylpg.in/index.aspx, accessed June 20, 2017

[5] "connection" has a specific meaning in India – a formal account established with a distributor for which a fee is usually required to cover the deposit on the initial cylinder, hoses, regulator, etc. Only through such a connection does a customer have access to subsidized LPG. These connection costs can be a barrier to poor households and are thus covered in the new government programs. Stoves can be obtained independently or by zero interest microfinance in all states, or from state or charitable funds in some.

[6] http://pib.nic.in/mobile/mbErel.aspx?relid=167449, accessed August 6, 2017

[7] Personal conversation with MoPNG officials,

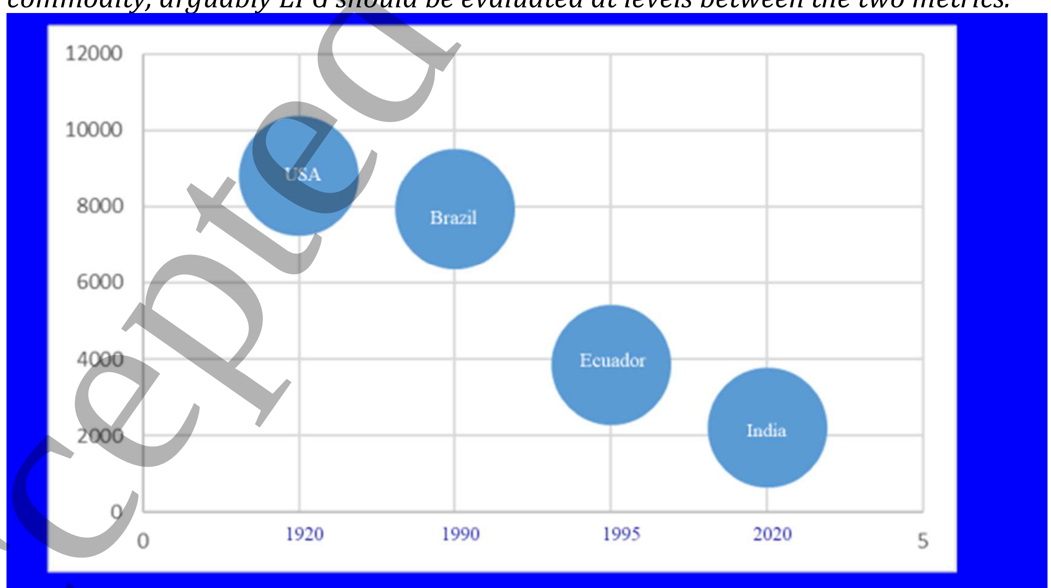
[8] Many urban consumers receive refills at the household and doing so for everyone is a goal of the Ministry, but is difficult to achieve in many rural areas where refills are often provided at the village level.

chief economist has noted that "LPG is leading the way" in bringing the rural poor into the main economy[9].

The 1.2 billion USD devoted to the PMUY program is a small fraction of other major national subsidy programs, such as the rural employment scheme and the food subsidy scheme (Bose 2017; Chakrabarti et al., 2016). Hard to say it is expensive, particularly when it is accompanied by more focused targeting of subsidies. Indeed, it would seem that the program can soon claim to be a social investment, not a subsidy. Both come from the taxpayer, but the former has a much different connotation when focused on the poor.

The time period and level of economic development of when three countries with aggressive LPG policies reached/will reach substantial coverage of clean cookfuels is presented in Figure 2 (along with data for the United States). It shows the GDP/capita at the approximate date in which each achieved or will achieve 80% penetration of LPG and/or natural gas fuel. Note that the US had a $8800 income (in 2010 dollars) at the time, with each of the other three reaching, through policies and subsidies of different kinds, 80% penetration at lower and lower incomes, with India poised to achieve this milestone by 2020. At that time, it will have an income per capita some one-fourth of what occurred with the USA 100 years earlier.

Figure 2. *Rough ranking of the point when 80% of household fuels had started to be supplied by gaseous fuels in four countries over the 20th century by GDP/capita in 2010 US dollars. Even though not precise, due to data difficulties, the trend has clearly been downwards, with India achieving this objective a real GDP/capita about four times lower than the US, albeit 100 years later. An analysis by PPP-corrected GDP, shows smaller differences, but, as an internationally traded commodity, arguably LPG should be evaluated at levels between the two metrics.*



[9] LPG Conference, MoPNG, Bhubaneswar, Sep 2016

4. Clean cooking and climate: getting the calculus right[10]

Although gas and electric options can significantly reduce household air pollution and the attendant health impacts, they do result in some greenhouse gas emissions, either through direct fossil combustion in the case of LPG/PNG or indirectly through the current dependence of most electricity generation systems on fossil fuels. Unfortunately, many development agencies seem to believe this conflicts with the other major agenda, i.e., countering climate change, as evinced by a lack of focus on promoting LPG as a clean cooking option in the face of the limitations of IBCs in achieving health outcomes. This has led to the lack of focus on (and sometimes opposition to) the "make the clean available" agenda, either actively or through passive neglect, in most of the major bilateral donors, development banks, and large private foundations.

We make the case, however, that when the situation is examined carefully, there are essentially no circumstances in which the scale of the climate impacts, if any, from a major substitution of biomass by LPG could be considered sufficient to warrant imposing barriers on its dissemination as widely as possible from the health side (Smith, 2002; Smith, 2014).

In terms of climate, biomass comes in two major flavors: sources that are harvested renewably such as agricultural residues and, in many areas, woodfuel; and fuelwood harvested non-renewably thus potentially increasing deforestation or at least putting pressure on biomass resources. Estimates are that some 30% of woodfuel is harvested without replacement (non-renewably) worldwide, although with wide variation (Bailis et al., 2015). The carbon in this wood is emitted to the atmosphere in the same net climate-altering mode as carbon in coal or petroleum, i.e. essentially a fossil fuel, although with carbon recent in origin.

Biomass combustion produces methane and N2O, both included in the Kyoto portfolio on major GHGs as well as "non-Kyoto" SLCFs, including the gases carbon monoxide (CO), non-methane volatile organic contaminants (NMVOCs), nitrogen oxides (NOx), and sulphur oxides (Sox) and black carbon particles. In addition, biomass burning creates so-called organic carbon particles, which have a net cooling effect. Here the calculus turns on how the different non-CO2 emissions from biomass stoves are counted. Most analyses still rely on the 100-year global warming potentials (GWPs) developed by Intergovernmental Panel on Climate Change (IPCC) for the Kyoto Protocol in 1997 to account for the major other combustion-related GHGs (even if these values have evolved over time in subsequent IPCC assessments); the situation for the non-Kyoto" SLCFs is more complicated since there are no "official" GWPs . A shorter time period (such as 20 years) focuses attention on nearer-term climate change, shifts more emphasis to the shorter-lived climate forcers, and thus even more favors clean combustion.

A life-cycle analysis performed by United States Environmental Protection Agency (USEPA), which compared 100-year CO2-eq emissions per meal in India

[10] For a more detailed examination of this issue, see Bruce et al, (2017)

across fuels including estimates of the impacts of several important SLCFs, including black carbon (Cashman et al,,2016), found traditional renewable biomass fuels to produce 50-66% of the CO2-eq of LPG. An analysis of 20-year warming found that LPG had fewer emissions under Indian conditions when all Kyoto gases were included, but no black carbon (Smith et al., 2005). A sophisticated comparison of the relative global warming impacts in the year 2020 of emissions of all major greenhouse species, including SLCFs, in 2000 found biomass used in cookstoves to be the second largest greenhouse sector globally after on-road transport globally (Unger et al., 2010).

If we ignore the non-CO2 climate-active gases and particles emitted and the CO2 emissions from coal and nonrenewable wood, to focus only on the remaining roughly 60% of today's solid fuel cooking (about 1.6 billion people; Bonjour, et al. 2013)) that seems to come from renewable woodfuel, how does the resulting CO2 penalty from LPG stack up compared to other global GHG sources? If all 1.6 billion converted to LPG, the total annual extra CO2 emissions would be of the order of 0.2 billion tonnes CO2/year. To put in context,

- Total global emissions from fuel combustion were about 32 billion tonnes in 2014 and have been growing at an average of 2% annually for a decade (IEA, 2016).
- Emissions from the transport sector were over 7.5 billion tones in 2014 (IEA 2016a). In fact, from commercial aircraft alone worldwide, were 0.78 billion tonnes in 2015[11] and, unlike cooking, demand for flying is growing rapidly.

In India, transport alone is currently responsible for about 0.23 billion tons of CO2 but is growing annually at 7% (IEA 2016a). If the annual growth rate were to be lowered to 6%, the reduction in annual CO2 emissions by 2025 would be sufficient to compensate for the CO2 produced by all LPG needed to replace renewable biomass use in households.

Thus, shift to LPG cooking globally among the poor would be equivalent to far less than one year's growth in the global total and unlike other types of demand even in developing countries, cooking energy demand is slow to grow in households, given that household size is declining everywhere and the number of meals cooked is not likely to increase.

Although not discussed further here, we note that similar arguments apply to electrification, even powered if by coal (Smith 2014). Indeed, the argument is probably even stronger due to the many other social benefits that are brought by electricity in addition to clean cooking Even where electricity is currently made with coal, its use in induction stoves would only create a miniscule extra addition to CO2 emissions. Replacing all biomass cooking by coal-fired electricity, for example, would only produce the CO2 released by 3% of the OECD power system.

[11] http://www.atag.org/facts-and-figures.html, accessed August 6, 2017

5. The Holy Grail: electric with renewables?

The appropriate electric technology for clean cooking now seems to be in hand. Electric induction stoves, the first fully new cookstove technology in a hundred years, has recently come on the scene in a large way in some parts of the world. Where there is reliable electric power, it offers a leap-frog, and completely clean household, alternative. For example, Ecuador is working to change out every stove in the country to induction through a major government program, although one largely driven by the desire to use their own hydroelectric resources instead of imported LPG.

The Induction Stove Program of Ecuador[12]

The Ecuadorian Efficient Cooking Plan (ECP) for clean cooking aims to change three million LPG based stoves to induction stoves, as the first energy policy program to introduce time-saving, energy efficient, clean, and inexpensive cooking facilities for an entire country. The ECP is linked to the change of the energy mix, which seeks energy sovereignty and access to clean energy for Ecuador. For this purpose, was necessary to invest in new infrastructure of hydroelectric power plants. This is because a low price of electricity is needed to make attractive the change. In case of Ecuador, more than 80% of electricity will be generated by less-expensive hydroelectric power.

For all these changes, a large state investment was necessary. In case of Ecuador, the government is investing US$11.6 billion in new hydroelectric power stations, and transmission infrastructure by 2022. The Ecuadorian government estimates an investment of US$6 billion in hydropower plants, US$1.2 billion in improved transmission infrastructure, US$3.4 billion in household distribution, and US$1.1 billion in the ECP and the National Efficient Electric Heater Program. This represents 11 % of national GDP (Villacis et al. 2015). To pay for these contracts, between the years 2009 and 2016, the Ecuadorian government has undertaken four contracts with China. The final amount is about US$4 billion, which was related to sale of an anticipated 200 million barrels of petroleum. It is assumed that part of the money for these contracts has gone to the improvement of the electric grid and ECP.

It is necessary to take into account that the Ecuadorian government promotes induction stoves to reduce the consumption of subsidized LPG: For the general population for domestic use: a 15 kg bottle of LPG costs US$1,60 (official price), while in neighbor countries (Peru and Colombia) this price is on average thirteen times higher. The total cost of this subsidy to the government was about US$690 million per year, with approximately 5% of subsidized LPG lost to smuggling and 15% used for non-household purposes. In addition, approximately 78% of Ecuador's bottled LPG is imported, which creates major dependency and a significant outflow of national funds abroad.

To accommodate induction stoves, the electric distribution network requires an adjustment, especially at the level of energy distribution -- transformers, primary

[12] Much of this section is based on Martínez-Gómez et al. (2016, 2017)

feeders and connections. Large cooking loads inject excessive harmonics into the electrical network and can result in adverse effects on power quality (Kit et al., 2012). Achieving an appropriate coincidence factor could avoid electrical grid problems such as overheating of conductors and mechanical oscillation of electrical devices that would affect the operation of the distribution network.

The ECP is aimed at replacing LPG only in the residential sector. Industrial or commercial sector do not apply for the ECP. Families could register to ECP with the light sheet and the identity certificate in a large warehouse. The family can access financing through the local electricity company over 72 months. In addition, the electricity company will install a 220V meter at home, also with financing.

The government of Ecuador was planning in 2014, to purchase induction stoves in 4 zones for $265 and 2 zones for $155, and it was intended to add a set of cookware composed of three pots and a pan for $ 35. All stoves and cookware were designed and tested for Ecuadorian conditions. In addition, it was intended that the most disadvantaged families in Ecuador, somewhat more than 50% or about 2 million, would have the stove for free through the ECP. While the next 22% could purchase the stove with a 50% discount plus financing.

The induction stoves ascribed to the ECP have a limited electric power of 4 kW, which limits electric distribution network requirements. Induction stoves that do not ascribe to the ECP pay customs tariffs of 50 %.

Currently, as part of the NECP, induction stove adopters receive a 100% subsidy on the initial 80 kWh consumed per month, which is thought to be sufficient for an average family. This subsidy will be maintained until 2018. In addition, electricity cost for additional consumption is 0.092 US$ / kWh, subsidized rate. But even with this subsidy the population shows some reluctance to migrate to induction stoves immediately. Currently, about 500,000 families are attached to the PEC, none of which has acquired free or discounted stoves. In 2014, it has been estimated for this stage around 2 million of families had induction stoves. The population see the costs related to changing induction stoves above to maintain LPG stoves and use subsidized LPG. In addition, in areas where the induction stove has been given as Plan Fronteras, the population maintains the LPG stoves because of the low cost of fuel.

Induction stoves are one of the most efficient cooking techniques (Kastillo et al., 2016). Because the power comes from new hydroelectric power plants, the energy demand of the country should actually decrease until 2032. In addition, the CO_2 equivalent emissions should reduce since the power comes from hydropower, although GHG emissions per kWh from hydro in Brazil range according to power density and the amount of flooded vegetation (Dos Santos et al, 2006). Presumably the new dams in Ecuador, however, will not produce much flooded vegetation because, most are located in the highlands, between the Andes and Amazonian Ecuador.

Induction stoves have advantages in safety and energy efficiency compared traditional stoves, which stimulate users to change from traditional to induction stoves. Traditional cooking is strongly rooted in the habits of Ecuadorians, however, thus effective incentives are also required to achieve the transition to electricity. In addition, the government of Ecuador has carried out marketing through advertisements on television, radio, social networks and websites. In addition, politicians, including the President of Ecuador and the Minister of Electricity and Renewable Energies have explained the ECP in different communication media. The Minister has also attended workshops to show how to cook with induction stoves.

The large subsidy of LPG represents a great barrier to changing fuel in Ecuador, as society has become accustomed to a high subsidy and consequent inefficient use. Now, however, it seems the country may have found a way to a new system that benefits the poor and leads the country to self-sufficiency in household fuels, but one that requires substantial effort and excellent timing.

Once connected to the power grid, however, the power source can be shifted to solar or other renewables over time. It sets up the households for the long-term future.

6. Reshaping the clean cooking agenda

We suggest that the clean cooking agenda move away from a climate-first approach to recognize that the health impacts of HAP merit highest priority. This will not only be correct as to ultimately benefit those who have do not have access to modern cooking energy services but also build trust between various stakeholders in the climate and development arenas. The global community could apply its considerable resources and intellectual capacity to develop more productive ways of linking the climate and development domains. In this way it can place the climate problem in the context of the larger sustainable development challenge facing humanity.

In addition, traditional biomass users generally are quite poor and hence have had historically low emissions so in a sense they have already contributed to climate protection, even if an involuntary fashion (Sagar, 1999). So it is just as well that they are able to benefit from the limited fossil fuel that can be used cleanly and efficiently. In fact, their link to the climate arena really should be seen as one where the industrialized high-emitting, world owes them a ‘natural debt’ (Desai, et al., 2015) and therefore it would be appropriate to use some part of the climate finance flows to help this most disadvantaged of groups.

As the framing of the household cooking issue shifts from an energy or climate perspective to health, the ethical picture shifts as well. As much as possible, the provision of health interventions (vaccines, antibiotics, antiretroviral drugs, clean water, etc.) attempts to treat everyone’s health as equal – we do not push approaches in rural areas that would be completely unacceptable in urban settings. LPG or electricity are acceptably clean for use by rich and poor worldwide, unlike the current generations of advanced biomass stoves, which would not be acceptable in urban areas. They are just not clean enough.

We believe the time has come for well-meaning organizations to reassess the deployment of cooking systems that the people in these organizations would never use themselves. Perhaps it might be justified if there was no knowledge of anything else, but now we have all the evidence needed that IBCs are not acceptably clean for people while gas and electricity are. And 60% of the world uses the latter energy sources for all cuisines already, essentially proving their viability.

As a CO2 molecule released anywhere has the same climate impact as one released anywhere else, is cooking of the poor really the best task to put at the margin in terms of climate action? As shown above, no matter how accounted LPG, cooking would is a part of the global climate picture. It is difficult to argue against the proposition that the global upper and middle class (in rich and poor countries) cause climate change, not the cooking of the poor.

In this vein, LPG, PNG, and induction stoves powered by fossil-electricity could be seen as a bridging approach to a more sustainable future. Ideally, over time, one would promote cooking solutions that fully protect human health and the climate but the interim solution should not be one that sacrifices human health for marginal or even no gains for the climate.

In fact, gas, mostly in the form of natural gas, is already serving as a transition fuel for the modern world. It is helping us move past coal, the worst of the solid fuels in terms of both health and climate. In the end, however, most observers believe that large-scale energy solution for society will largely be electricity made from renewable sources (e.g., Edenhofer et al., 2012). Similarly, a parallel transition can occur for poor households using solid biomass. In fact, what better use for a fossil fuel (whether gas or coal-derived electricity) than one with the highest social value use, i.e., cooking for the poor?

In order to best facilitate this reshaped clean cooking agenda, we suggest three categories of focus:

Improving delivery models

Whenever a new technology of any sort is adopted, it rarely fully displaces the old instantly as old habits dies hard. High usage is needed, however, as well as reduction in use of the old polluting technology, for full health benefits to be obtained. As LPG and induction cookstoves seems nearly universally aspirational, it would be useful to focus research and action agendas on ways to enhance access by making these clean fuels and technologies available and shortening the “stacking” period in stove parlance when both old and new stoves are used (i.e. to substantially reduce the use of biomass). This is typical for health interventions where it is not enough just to deliver condoms, bednets, institutional delivery facilities, etc., but also ways are needed to incentivize people to use them and to stop the unhealthy traditional practices.

This may mean ensuring a connection and stove (whether LPG or electric induction) is easily available and at zero or affordable cost for the poor; it may mean fuel subsidy levels tailored to populations in various economic strata and various risk levels (e.g., pregnant women); and it may mean ensuring that the supplies of the clean fuel (LPG or electricity) are steady rather than sporadic. It also may mean innovative public outreach campaigns to help the populace understand the benefits of switching to clean cooking - this could allow the overcoming of factors such as inertia and social barriers that often prevent the uptake of new technologies. In fact, it also would be important to understand who to target in households and communities – and tailor messages to these actors. Such efforts can build on the programs and lessons learned from, public health and other relevant experiences of various countries.

Strengthening finance for clean cooking

IBCs have been seen as particularly attractive since the operating costs are negligible in principle since biomass may be available free or cheaply (although the reality may be very different in many cases). In the case of LPG or electricity, there is both the initial cost of the transition (establishing a fuel/electricity supply and procuring a cookstove) as well as operational costs of recurring energy use through use of LPG and/or electricity. Most poor people may not have sufficient finances available to cover both (or either) and therefore may need some subsidies (as is the case in the health, as mentioned earlier).

India has initiated several innovative ways to promote and finance extensive expansion of LPG, including widespread application of IT systems and creative retargeting of subsidies into avenues that can be better characterized as social investments. But beyond domestic resource mobilization, there may be international possibilities of linking together the climate and HAP domains in creative ways include, for example, using the revenues raised from a tax on airline travel or gasoline use globally to fund access to clean cooking energy for the poor, while contributing to the mitigation of the growth of these GHG emissions sectors. Similarly, a tax on luxury electric appliances could be used for a similar purpose. The common theme here is linking energy use by the well off to energy access for the poor, thereby also promoting climate equity. Yet another possibility could be a global competition for the most innovative policy to couple climate mitigation and clean cooking.

Enhancing technological options

While LPG and induction cookstoves already exist, it should be possible to further improve their efficiency. Indeed, at the end of the Obama administration the USDOE had pending efficiency standards for US standard cooking appliances that would not only save billions of dollars for consumers in saved fuel but also reduce CO_2 emissions by several hundred million tonnes (USDOE, 2016). A push for more efficient cooking appliances would yield benefits not only for the poor but also contribute to the reduction of cooking-related GHG emissions even from developed countries.

One can also imagine that an effort to optimize for a solar-PV and induction cookstove combination (that may also require new energy storage solutions) may yield useful results in terms of developing technologies that can serve in remote areas where the grid may not reach in the near term (or at all). Such a technology solution may also have the potential of piggybacking on the enormous solar PV and enhanced energy storage push in across the world, while also providing other energy services in remote/poor households also. This can be explored either through the standard route of targeted R&D or perhaps more relevant, through an innovation prize and/or advanced market commitment approach to induce innovation in these areas.

At the same time, it is valuable to continue efforts to "make the available clean" by developing a truly clean-burning biomass cookstove, for example, through a global innovation prize as envisaged by us earlier (Sagar & Smith 2013), in a way that is driven by health rather than climate. .

7. Conclusion

Provision of clean energy services lies at the intersection of climate, health, and energy access and therefore present an important test case for how developing countries, working with the global community, can balance among these overlapping but sometimes competing agendas. In the end, the most robust solutions are likely to be those that satisfy multiple agendas simultaneously and pave the way for a sustainable and just world and certainly not those that sacrifice developmental imperatives at the altar of small amounts of climate mitigation.

With that backdrop, the push for improved biomass cookstoves needs to be re-examined, given that they do not protect human health adequately while delivering some climate benefits. LPG, being clean, efficient, and easily stored and transported in small amounts, is a one-time gift from nature that is available now. Let it be used for the highest social purpose – providing clean household energy to improve the lives of the very poorest among us, starting with women and children. Like gas in the developed world, however, it should be seen as a step toward using renewable electricity-– the ultimate clean and sustainable energy source – for meeting household cooking energy needs.

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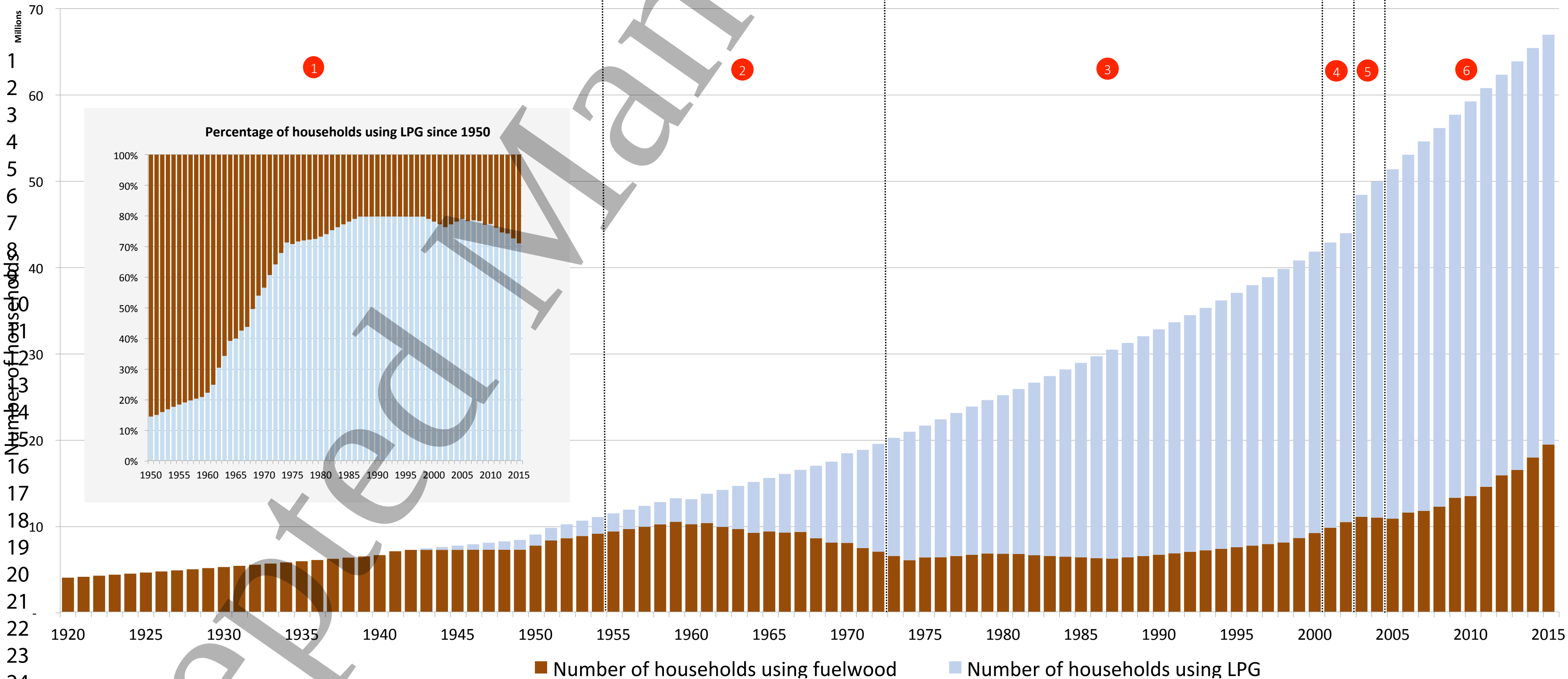
Estimate of Brazilian households using fuelwood or LPG between 1920 and 2015



1. No direct intervention
2. Governmental incentives for LPG usage
3. Governmental subsidies to all citizens
4. Market price
5. LPG voucher (Auxílio Gás)
6. Incorporation of the LPG voucher into the Family Allowance (Bolsa Família)

Source: Prepared by the authors based on data from Jannuzzi (2004), Morais (2005), Uhlig (2009), MME (2010-2016), IBGE (2016), and EPE (2017)