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Viewpoint

# Making the clean available: Escaping India's Chulha Trap

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## HIGHLIGHTS

- Pollution from cooking with solid fuels is largest health hazard for Indian women and girls.
- 700 million Indians are caught in a trap using solid fuels with little change in number exposed for decades.
- Efforts to make the biomass fuel clean through advanced stoves have made only modest progress in decades.
- A major new effort is needed to make the clean available, in the form of gas and electricity.
- This will require forging new partnerships and rethinking how these fuels are currently promoted.

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ABSTRACT

Solid cookfuel pollution is the largest energy-related health risk globally and most important cause of ill-health for Indian women and girls. At 700 million cooking with open biomass *chulhas,* the Indian population exposed has not changed in several decades, in spite of hundreds of programs to make the "available clean", i.e. to burn biomass cleanly in advanced stoves. While such efforts continue, there is need to open up another front to attack this health hazard. Gas and electric cooking, which are clean at the household, are already the choice for one-third of Indians. Needed is a new agenda to make the "clean available", i.e., to vigorously extend these clean fuels into populations that are caught in the Chulha Trap. This will require engaging new actors including the power and petroleum ministries as well as the ministry of health, which have not to date been directly engaged in addressing this problem. It will have implications for LPG imports, distribution networks, and electric and gas user technologies, as well as setting new priorities for electrification and biofuels, but at heart needs to be addressed as a health problem, not one of energy access, if it is to be solved effectively.



## 1. Energy ladder revisited

The conceptual household fuel ladder has been used for decades to frame issues in household energy (see OTA, 1992 for an early version) and can be applied now in a major reframing of an important energy policy issue. The version in Fig. 1 uses rough population distributions across fuel and income categories for India in 2012 and shows that the poor use biomass fuels for cooking in simple open cookstoves, *chulhas*, with the poorest relying on agricultural residues. A large fraction of the population uses woody fuels, which are often from small trees and brush along roads, fields, and other areas not part of forests. Coal is used only by about 10% of the households in just a few eastern states. In the past, kerosene has been the first of the non-solid fuels as income rises, but is now used for cooking by less than 5% of the country mainly in cities, although much more commonly used for lighting in those many parts of the country where power is unavailable or unreliable. Biogas made from animal waste has a small, but still important niche among rural households with sufficient animals. Liquefied petroleum gas (LPG) is the first truly clean fuel used by large fractions of the population and, in recent years, piped natural gas (PNG) has come into cities. Electric cooking has been used by a relatively small part of the population, but as explained below seems to be expanding rapidly (Government of India, 2013).

Shown in this figure is the phenomenon of "stacking" i.e., that movement up the energy ladder does not usually mean an instant complete shift from one fuel to another, but an addition of the new to the old with slow transition over time upwards to new mixtures. Thus, parts of the population use more than one fuel for cooking. Indeed, stacking exists at every income as even the world's wealthiest households with gas cookstoves will also use a range of electric cooking appliances.

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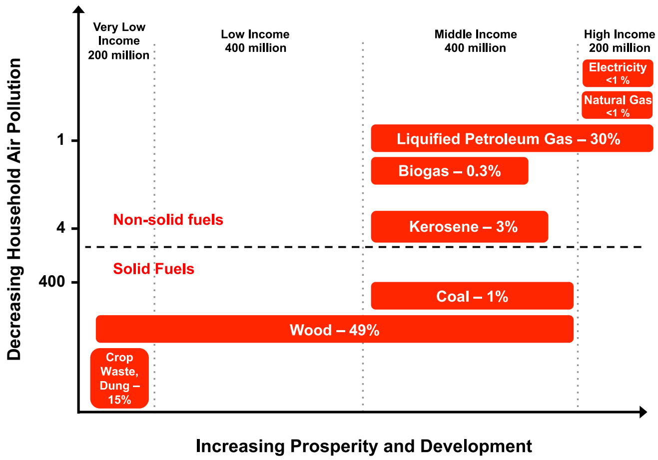


**Fig. 1.** India's household energy ladder for 2012. The percent of households nationally using each fuel as their primary cookfuel is shown, but the distribution across income groups is approximate. The total population was about 1.2 billion. Note the extensive "stacking" of fuels among some groups. The vertical axis is marked with the relative emissions per meal of combustion particles, the best measure of health risk as a ratio to LPG. The line between non-solid (92 million households) and solid fuels (169 million household) thus represents well more than two orders of magnitude difference in cookstove emissions. The percentages are based on the national census in 2011–2012 (LPG=liquefied petroleum gas; PNG=piped natural gas).

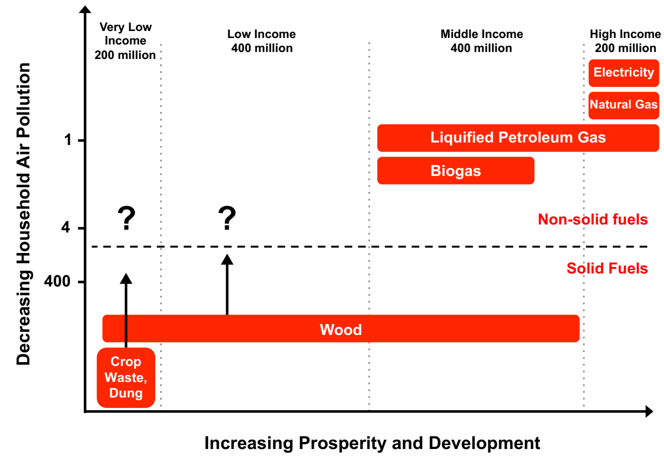


**Fig. 2.** Making the available clean. This shows the approach of most current attempts to provide clean cooking to poor populations, which is to develop and disseminate advanced stoves that reduce the pollution exposures from using the available biomass fuels. To date, such stoves have not become nearly as clean as gaseous fuels, but progress may someday bring models that are. (Kerosene and coal are removed in this figure since they are both discouraged in India for health and economic reasons and also declining nationally).

Why does this matter? It matters because the use of solid fuels for cooking imposes large impacts on the health of the world in general and India in particular. The reason is illustrated by the line between sold and non-solid fuels in the figure representing a factor of $>100$ in pollutant emissions per meal (Jetter et al. 2012; Smith et al, 2000). Recent estimates for India are that more than one million premature deaths occur annually from household air pollution (HAP) due to solid cookfuels, making it the most important risk factor examined for Indian women and girls and important for men and boys as well (Lim et al., 2012). In addition, about 25% of outdoor particle pollution emissions and significant contributions to $CO_2$ and shorter-lived greenhouse pollutants can be accounted to the incomplete combustion and poor energy efficiency characterizing solid fuel combustion in traditional Indian chulhas (Smith et al., 2005; Chafe et al., 2014). With 3.9 million premature deaths annually, traditional uses of solid cookfuel are now understood to be the largest single environmental health threat in the world even though only affecting about 40% of the world population (Smith et al., 2014).

One might think that this problem will go away by itself, i.e. as incomes move to the right on the figure populations will naturally adopt cleaner non-solid fuels. Although the fraction of the population using clean fuels in India has grown with development, the total number using solid fuels has stagnated at about 700 million for decades (Bonjour et al., 2013). These people are caught in what might be called the Chulha Trap, having experienced development in many ways but not in cooking fuel. There are more people using solid fuels today than anytime in Indian history. The number globally, about 2.8 billion, is more than the entire world population in 1950

What is needed are ways to fill the "empty quarter" of the figure—the upper left quadrant. What can be done to provide clean cooking to the poor to cut the health impact substantially?

## 2. Making the available clean

Although the scale of the impact has only recently been fully established, it has been recognized for decades that there is need for public action to reduce the burdens on health, women's time, and the environment. In addition to thousands of small efforts by community groups and NGOs around the world, there have also been a number of large efforts by national governments, including two national programs in India, and international agencies to improve the way traditional biomass fuels are used. Initially, these focused mainly on energy efficiency, but more recently have focused directly on emissions of health-damaging pollution.[2] This approach is illustrated by Fig. 2 representing attempts to make the available fuel (biomass) clean through better stove technologies. Such efforts have brought some successes and show signs of more by application of more advanced combustion and manufacturing techniques tied to international standards. To date, however, in spite of there being more than 50 years since the first "smokeless chulhas" introduced in India in the 1950s, "improved" biomass stoves have had essentially no demonstrable impact on the national health burden.

The reasons are multiple, but three stand out. First, it extremely difficult to burn cleanly a highly variable solid fuel, like locally gathered biomass, in small low-cost devices. Blowers, pellets, two-stage combustion, and other innovations help, but to date have not brought any biomass cookstove down close to the emissions of gas fuels. Second, those that are developed represent novel devices that must then fit local cooking needs and other expectations, not an easy accomplishment either. Third, making this task even harder is that the HAP exposure–response relationships for major diseases are highly supra-linear (Burnett et al., 2014). This means that to actually reduce health impacts significantly stoves have to be extremely clean in daily use – not just a factor of 2–3 below the chulha, but 20–30 times less – something only achievable today by gas or electricity at scale, and by biogas and ethanol in small areas.

[2] Current examples are the Global Alliance for Clean Cookstoves (http://www.cleancookstoves.org/), the efforts of International Standards Organization on cookstoves (http://www.iso.org/iso/), and the World Health Organization's health-based guidelines for stoves (http://www.who.int/heli/risks/indoorair/indoorair/en/).

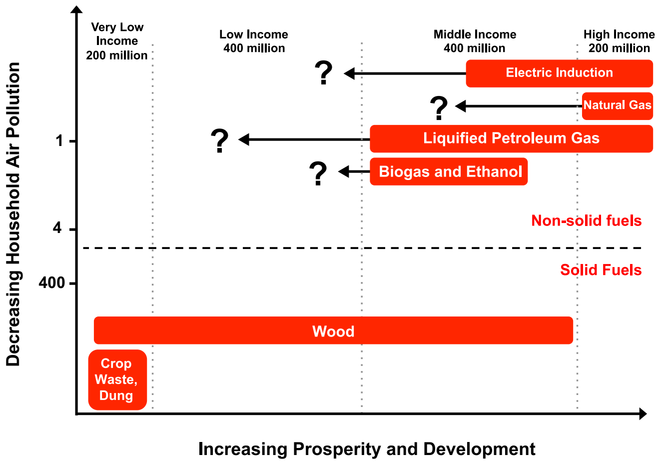


**Fig. 3.** Making the clean available. Here, efforts are taken to greatly expand the use of the primary clean fuels in India, electricity and gas. Widespread dissemination poses more financial challenges than the advanced biomass stoves represented in Fig. 2, but starts with the considerable advantage of promoting technologies that are intrinsically clean and well adopted in most parts of the world already.

## 3. Making the clean available

A completely different strategy is possible to fill the Empty Quarter, however, which is illustrated by the arrows in Fig. 3 – making the clean available. It is no mystery as to what is clean and acceptable – gas and electricity. Indeed, they are relied on by ~60% of the world's households today, ~35% in India, and cook every imaginable cuisine without difficulty. Any woman who is used to them and has a choice is not likely to want to go back down the ladder to open cookfires for daily use. The problem, however, is that she often does not have the choice because of cost and reliability.

All kinds of gas fuel, including biogas and piped natural gas, burn cleanly and should be promoted, but only LPG shows the capacity at present to reach large rural areas of the country. Neither LPG nor electricity is reliable in most of rural India today, however, although there are exceptions. Their prices have also been a barrier to the poor, but it is difficult often to separate out household responses to reliability from those to price.

Electric cooking has traditionally been considered only an option at the top of the energy ladder, i.e., for the wealthy urban household. This perception is too narrow, however, because of technological advances in recent decades. Cooking is not just one task and highly efficient low-cost electric cooking appliances already pick up cooking tasks everywhere reliable electricity is available. These widely include electric rice cookers, water kettles, and microwaves, but also specialized cooking devices for local foods, such as pancake and roti makers in China and India, respectively. Call it stacking, or call it using efficient devices for specialized purposes, it is making an impact both to reduce household pollution and time use and, on the other side, to add to power demand.

In spite of such specialized devices, however, people still need a stove, which has not been considered a good policy option for electricity due to the low efficiency and high power of traditional electric coil stoves. Relatively recently, however, a new electric cooking technology has come on to the scene that is radically changing this assessment. Induction cookstoves (ICs) generate the heat directly in the cooking vessel and are up to 50% more efficient and twice as fast, depending on cooking task. Creating no high temperatures in the stove itself and having no flame, they are also safer and keep kitchens cooler. Being electro/electronic devices with no moving parts (except a small fan) and not experiencing large temperature swings, they can be long lived and benefit from spectacular economies of scale in manufacture. Currently, portable induction cookstoves with warranties can be ordered on the web in lots of 500 up to 60,000 a month at less than US$8 each.[3]

The new generations of portable ICs are experiencing rapid growth in sales in countries with reliable power—Indonesia and China, for example. Even in India, which does not yet have reliable power for most of its population, the estimated sales growth rate for the next five years is 35% per year. Dozens of brands from India, China, Japan, and Europe are competing.[4]

Equally important, although frustratingly slow in the last decades, it is clear that true national electrification is coming in India, as it already has in other middle-income countries. Access has grown substantially in India, but reliability is still low, a factor of nearly equal importance to conferring benefits (Pachauri et al. 2012; Rao, 2013). Incorporation into the current decision calculus of the health benefits it could bring through clean cooking might help enhance the case for more rapid deployment of this essential element of human welfare.

In Kerala, one of two Indian states currently with reliable power, ICs have already made sufficient inroads to change the traditional distribution of power demand during the day, with a rapidly growing morning peak because of cooking. This is driven not only by convenience but because ICs are cheaper for cooking than even subsidized LPG for most households. Even in areas where power is still not reliable, ICs have made inroads into the commercial sector in the country such as the ubiquitous small tea shops because they are more convenient, faster, and cheaper than unsubsidized LPG, the traditional fuel, which becomes the backup when the voltage drops.

It is too early to know whether the IC revolution will penetrate into rural biomass-using areas as electricity becomes more reliable, but it seems likely that it represents a true leap-frog technology, i.e. it attracts users to move from the LPG rung of the ladder to electricity or skip LPG entirely. The technically straightforward but financially challenging prospect of linking ICs to local solar or biomass power generation is also intriguing.

It can also be used as a way to take advantage of special local situations. For example, availability of hydropower and high costs of LPG has led to a national IC dissemination being implemented in Ecuador. In India, the National Aluminum Company has distributed ~9000 ICs to its employees who have power from its captive plants.

Extending LPG down the income distribution also depends on more reliable supply chains in India as well as developing new approaches to distribution including more thoughtful and efficient ways of recruiting, financing, and supplying distributors. That distributorships are so lucrative that the granting of one often leads to law suits by disappointed competitors, indicates that that there is suppressed demand and scope for expansion even under existing financial arrangements.

New technologies, which have played such an important role in electric cooking, are needed in the LPG arena as well, which is dominated by 50-year old technologies with little innovation. Smaller, lighter, and safer cylinders offer ways to disseminate more efficiently to dispersed poor populations. More efficient LPG burners transferring heat via radiation instead of conduction are also found in the engineering literature (Pantangi et al. 2011). Indeed, wide variation in the measured efficiency of ICs would indicate that technological innovation may provide benefits here as well. Every increase in efficiency means the cost of fuel per meal

[3] http://huigu.en.alibaba.com/product/870802178-218422626/cooker_electric_commercial_induction_cooker.html.

[4] http://www.technavio.com/report/induction-cooktop-market-india-2012-2016.

drops, thus allowing that many people to afford these clean technologies.

Rapid expansion of LPG and electricity for cooking would entail major costs that could not immediately be picked up by the poor households themselves in many cases. It is important to note, however, that this does not mean that the funds devoted would be somehow "wasted". Hypothetically, if the LPG for 100 million households were to be paid by the Indian government, implausible politically at present and probably not needed for widespread adoption, the cost would be about US$20 billion per year.[5] This is a big number, but conservative calculation of the economic benefits in Indian conditions from the health improvement and time savings due to the elimination of biomass cookfuel, however, would indicate an annual benefit exceeding $30 billion.[6] In other words, it would apparently be well worth the societal investment, although tricky to implement since the benefits occur diffusely and the costs in this scenario too obviously accrue just to the taxpayer. New ways of financing and better targeting of what are now termed subsidies will be needed to justify them as social investments.

Those who are concerned that supplying LPG or coal-based electricity will increase $CO_2$ emissions should consider that cooking fuels for the world's poor would account for a small part of global emissions under any scenario and small improvements (a few percent) in modern energy sectors would easily compensate (Smith, 2002, 2014). This is without even considering the reduction in the shorter-lived greenhouse pollutants that would come from reducing solid cookfuel use (Unger et al., 2010). It is not the cooking of the poor that is a long-term threat to the climate and no commitment to clean fuel would bring more benefits anywhere else.

What is needed, therefore, is innovation not only in advanced cooking technologies themselves, but also in the modalities of financing, distribution, and marketing that will bring the benefits of clean fuels to a much larger number of households in a sustainable manner, politically and economically. And do so in a reasonable time—say by 2030 to match the Global Energy Assessment (GEA, 2012) and the goals of UN's Sustainable Energy for All Initiative.[7]

## 4. Summary

Making the clean available is kindred strategy to those applied in the international health arena. The health sector does not rely on NGOs and local community groups to develop vaccines and anti-retroviral drugs, but works to develop the best and most effective possible interventions using modern technology. Then, by negotiating price reductions, royalty flexibility, and pre-purchase agreements, it works to bring down the price. In parallel, it works to put into place the local supply chains to bring these effective interventions to poor populations, which has important roles for NGOs and community groups. It however does not promote different vaccines for the poor and the rich—health is for all. It is time that HAP was treated like the large health problem it is by working on all approaches including making the clean available.

In addition, there are more fundamental barriers to treating household air pollution seriously in India, including a refractory bias against rural areas illustrated by slow growth in rural female education and status that is framed in terms of household energy as "rural women do not want to change away from biomass but rather do things just as their mothers did". In health, however, we do not have rural vaccines and urban vaccines or antibiotics that work for men and not for women, but work to overcome these biases to obtain agreed health goals for all with the best available technologies. There is no excuse for rural women having to cook with health-damaging smoke levels that would not be acceptable to urban women.

The strategy is thus to work to bring down the price and increase the reliability such that gas and electricity substitute in great measure for biomass. These are industries that can handle the scale involved. In India, this process is complicated, but also potentially benefited by other big changes occurring in the next years, for example, the inexorable movement toward full electrification and large-scale introduction of piped natural gas in many cities. The slower population growth expected in most income groups in the next decade should make it easier to address the basic household inequity behind the current situation, i.e. make actual progress in providing clean cooking to all instead of just treading water with 700 million continuing to be caught in the Chulha Trap for many more decades. There is no mystery about which cooking fuels are clean and well accepted. They are what I and nearly all the readers of this Viewpoint use: gas and electricity. There seems little justification for not working much harder to find ways to engage with new actors, such as the petroleum and power sectors, to extend these fuels to populations that continue to suffer significant ill-health because of their lack.

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[5] At US$200/household-year.

[6] At US$1.70/workday for saved time and two-thirds the estimated reduction of DALYs – disability-adjusted life years – at the Indian per capita GDP/DALY [http://www.who.int/choice/en/].

[7] http://www.se4all.org/.

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