Fuelling the transition:

Costs and benefits of using modern cooking fuels
as a health intervention in India

TRADITIONAL FUELS

MODERN COOKING FUELS

KEROSENE

ELECTRICITY

FIREWOOD

LPG

DUNG -
CAKES

BIOGAS

COAL

प्रयास

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न

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Costs and Benefits of using Modern Cooking Fuels
as a Health Intervention in India

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प्रयास

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About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non-governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of society, in particular. Prayas is registered as a SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

Prayas (Energy Group) or PEG is an energy policy research organization that works on a gamut of issues in the electricity and energy sectors. PEG's activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. PEG members have been part of several official committees constituted by ministries, erstwhile Planning Commission and NITI Aayog.

Prayas (Health Group) or PHG is committed to generate evidence based discourse on emerging issues on sexual and reproductive health and rights (SRHR). We also strive towards improving access to health care for these issues. We work towards taking scientific evidence to communities in simple, sensitive, non-judgmental, empowering and effective manner. PHG is actively involved in socio-behavioral and epidemiological research, awareness building, programmatic interventions and provision of clinical and counseling services especially to persons living with HIV.

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Executive Summary

There is mounting evidence of the severe health impacts of household air pollution from burning traditional fuels such as firewood, agricultural residue, dung, coal and kerosene for cooking. This is particularly relevant in the Indian context where more than 75% of rural households in India primarily use such fuels. Therefore, there is a growing consensus on the need to transition to more modern fuels and technologies such as Liquid Petroleum Gas (LPG), PNG (Piped Natural Gas), biogas and electricity.

This report is about a cost effectiveness study to assess the costs and the consequent health benefits for transitioning to modern fuels by 2030 in 20 states in India. The objective of the study was to understand the order of magnitude of impacts of different transition pathways for the country as a whole and further on state, urban-rural and gender lines. The study also analysed the impacts of stacking modern fuels with traditional fuels. Besides modern fuels and technologies, improved cook stoves can also play a role in the transition and the potential role of this technology was also assessed in the study. Based on this, some policy relevant insights to inform programme designs and investment decisions are provided.

The study was conducted using the CEFTI (Cost Effectiveness of Fuel Transition in India) model developed by Prayas. In CEFTI, the fuel used for cooking, the efficiency of the stove and the useful energy required to cook is used to estimate the magnitude of fuel required to meet cooking needs in every scenario. Health impacts for any transition pathway or scenario in CEFTI are estimated as the disease burdens or Disability Adjusted Life Years (DALYs) attributable to exposure to $PM_{2.5}$ emissions in an average kitchen, while health benefits are assessed as the DALYs averted in three of the 'intervention' scenarios with respect to the Baseline scenario. The diseases for which DALYs have been estimated are ALRI (acute lower respiratory infection), COPD (chronic obstructive pulmonary disease), IHD (ischemic heart disease), lung cancer (LC) and stroke using the integrated exposure response (IER) method. CEFTI also accounts for appropriate cessation lags for the disease burden to manifest. CEFTI estimates cost as the overall financial cost to the economy in each scenario at 2015 prices, and it includes the cost of the fuel, connection cost, dedicated infrastructure cost, distribution cost and the cost of the stove. The assumptions for various parameters such as unit costs, efficiencies and per-capita cooking energy requirements as well as estimates used for projections are based on literature and consultation with experts.

Four scenarios, namely Baseline, PMUY, Multi-fuel and SDG, were developed to assess the impact of various transition options, where each scenario consists of a set of assumptions about penetration of different cooking fuels across states up to 2030. The Baseline scenario represents the future that largely follows past trends while accounting for recent policy announcements. The PMUY scenario represents the case when the Pradhan Mantri Ujjwala Yojana (PMUY) is successfully implemented and supplemented by other measures to increase use of LPG on a sustained basis. The Multi-fuel scenario represents the case when, along with LPG, other modern fuels are also pushed aggressively across the country resulting in somewhat greater penetration of modern fuels than the PMUY scenario. The SDG scenario represents the case when India meets its Sustainable Development Goal objective of providing modern energy access to all citizens by 2030, i.e. there

is zero solid fuel use (SFU). However, the transition is not fuelled by LPG alone. In addition to these scenarios, analysis on the impact of stacking and the assessment of the potential role of improved cook-stoves (ICS) was also conducted. These were done as modifications to the scenarios described above.

The important findings of the analysis are that:

- **All transition scenarios are cost-effective:** The transition is cost-effective in all scenarios even with stacking which erodes away the health impacts. The cost per averted DALY is lower than India's per-capita GDP in all scenarios, making the transition highly cost-effective as per the WHO's CHOICE model. The more aggressive the shift, the greater the cost-effectiveness, with the SDG scenario being the most cost-effective.

- **Health impacts are significant and an early transition is desirable:** About 4% to 15% of India's disease burden due to the five diseases studied can be averted by a transition to modern cooking fuels. Given the lag in realizing the benefits from the transition, it is desirable for the transition to start early.

- **Policy focus to be on rural areas and on fuel price rationalisation:** The bulk of the investments required and health benefits realized are from rural areas, implying that the policy focus needs to be rural. The cost of the cooking fuel accounts for more than 80% of the total cooking cost, indicating that consumer price of cooking fuels would be critical to encouraging sustained adoption among poor households.

- **Minimal macro-economic impacts due to fuel imports:** Increased use of fuels such as LPG and PNG, can lead to increased imports but the increased demand has a negligible overall macro-economic impact. The sensitivity analysis shows that the major conclusions of the analysis are invariant with changing some of the key assumptions.

- **Need for an early shift away from stacking to optimize investments:** The health impacts of the SDG scenario with high solid-fuel stacking and Multi-fuel scenario with moderate solid-fuel stacking are comparable to the Baseline scenario without stacking. Stacking is also less cost-effective than not stacking, making a strong case to completely shift to modern fuels.

- **ICS not a replacement for modern fuel but can reduce SFU impact:** In a variant of the Multi-Fuel scenario where ICS is part of the transition, it is seen that 20% fewer DALYs are averted than the Multi-fuel scenario. This is despite the former having fewer solid fuel users. However, the health impacts of solid fuel use and stacking can be reduced through using ICS to the tune of about 4%. But if modern fuel users continue to use ICS then the attributable DALYs increase by 23%. Therefore, ICS has a potential role to play as a bridge fuel in the transition for households that may find a complete shift to modern fuels unaffordable or inconvenient, but it is important to ensure that once a household shifts to modern fuels, it eventually uses only modern fuels.

In addition, the following policy-relevant insights emerge from the study:

- **Focus on modern fuel uptake, not just LPG connections:** India's ambitious PMUY programme is a good beginning to prioritise uptake of modern fuels. However, this programme and others like it would be truly successful in realising the health benefits only if they succeed in shifting households away from using traditional fuels to modern fuels completely, which is unlikely with a connection oriented approach. As stacking erodes away benefits, efforts should also be made to reduce stacking of biomass with modern fuel.

- **Focus on programme design to promote ICS as a bridge/ intermediary fuel:** Even though ICS cannot be a replacement for modern fuels, a push for increased uptake of the best-in class improved cook stoves can reduce the impact of biomass use and thus can also reduce the impact of biomass stacking in the transition. Effective promotion of ICS requires creation of retail markets for ICS, biomass pellets and better supply and production chains.

- **Efforts to rationalise fuel prices to make modern fuels more affordable:** As consumer fuel pricing would be a very important factor in the uptake and continued use of modern fuels, a well-designed pricing regime and delivery mechanisms/networks along with targeted and increased fuel subsidies to the needy is necessary.

- **Investment planning to account for likely switching between modern fuels:** Though LPG may typically be the 'first' modern fuel most Indian households would adopt; they may switch to other modern fuel options as they become available, convenient and affordable. This suggests that future investments, particularly for LPG, need to be carefully planned, to avoid excess capacity. Having said that, most initial investments, especially network investments in rural areas of relatively 'less developed' states, will definitely be very beneficial.

- **Multi-fuel approach requires investment in R&D:** Investments could focus on scaling up manufacturing of new technologies and fostering new and innovative business models catering to the realities in rural India especially to promote community-based biogas systems and improved cook stoves.

- **Need for a multi-dimensional approach:** A strategy that is multi-pronged and customised to state-specific situations is likely to be more cost-effective and yield better results than a one-size-fits-all strategy. Since modern fuel promotion is also a health and gender intervention, agencies involved in such initiatives could also have an important role to play in ensuring the success of the program. Therefore, a strategy with a greater role for other central government agencies such as the Ministry of Health and Family Welfare and the Ministry of Women and Child Development, and respective state governments would be more effective than a top-down single-ministry initiative.

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1 : Introduction

There is mounting evidence that Household Air Pollution (HAP) caused by using solid fuels for cooking is one of the major contributors to mortality and disease in India (MoHFW, 2015). HAP can cause many diseases. In fact, four of the five leading contributors to Disability Adjusted Life Years[1] (DALYs) in the country — Lower Respiratory Infection (LRI), Chronic Obstructive Pulmonary Disease (COPD), Ischemic Heart Disease (IHD), and Haemorrhagic (HS) and Ischemic Stroke (IS) — can be caused by HAP among other reasons (ICMR, PHFI, IHME, 2017). HAP contributes to DALYs attributable to the following diseases in these proportions: LRI – 34%, COPD – 26%, IHD – 16%, HS – 17% and IS – 14% (IHME, 2017). Recent evidence also indicates that smoke from residential biomass is the largest source of outdoor $PM_{2.5}$[2] air pollution (IIT Bombay, HEI, IHME, 2018). In addition, there is an emerging body of literature on the harmful consequences of cooking using solid fuels and the costs and benefits of using modern fuels (Patel, Khandelwal, Leavey, & Biswas, 2016; Jeuland & Pattanayak, 2012; IIASA, 2017; Pillarisetti & Smith, 2017; Pachauri, van Ruijven, Riahi, van Vuuren, Brew-Hammond, & Nakicenovic, 2013; Smith & Sagar, 2014; Lamichhane, Sharma, & Mahal, 2017). Finally, it is women and girls who bear the brunt of collecting solid fuels and cooking by using them (Desai & Vanneman, India Human Development Survey -II (IHDS-II) 2011-12, 2016; Desai, Dubey, Joshi, Sen, Shariff, & Vanneman, 2010; Practical Action Consulting, 2015).

In recognition of these aspects, the Government of India has initiated the Pradhan Mantri Ujjwala Yojana (PMUY) to provide subsidised Liquefied Petroleum Gas (LPG) connections to 5 crore poor households (PIB, 2016a). Eliminating the use of solid fuels is also consistent with India's attempts to meet Sustainable Development Goals (SDGs) by 2030 (PIB, 2016b). Goal three of the SDGs targets prevention of deaths of new-borns and children and substantial reduction in deaths and illnesses from hazardous chemicals and air, water and soil pollution, while goal seven targets provision of access to modern and clean energy for all citizens.

Thus, there is a broad emerging consensus that India needs to embark on a cooking fuel transition. However, there is not enough India specific, policy-relevant analysis, particularly in the context of recent government initiatives such as the PMUY. Costs and health impacts of stacking solid and modern fuels have not been well studied, nor is there any rigorous assessment of the potential role improved biomass cookstoves (ICS) can play during the transition to modern fuel use.

In this paper, we present an India-specific analysis of the costs and health benefits of different pathways of transitioning to modern cooking fuels[3]. Further, the analysis is disaggregated to the extent possible to derive finer insights into certain aspects, e.g. insights specific to certain states or along the urban-rural divide.

The 'modern' fuels considered are mature fuels and technologies that are known to cause no observable health impact upon their use, namely gaseous fuels (LPG, Piped Natural Gas or PNG,

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1. A measure of the overall disease burden expressed as person years lost due to ill health, disability or early death. For more details, please see: http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/.
2. Fine particulate matter of 2.5 microns or less
3. In this report, we use the term 'fuels' as short for 'fuels and technologies', since it is the combination of the stove and fuel that defines the costs and emission characteristics.

and biogas) and electricity. ICSs are another potential candidate though they burn solid fuels and it is not yet established that they can be as clean as modern fuels (Smith & Sagar, 2014; Rosenthal, Quinn, Grieshop, Pillarisetti, & Glass, 2017). In this study, ICS is evaluated as a cooking technology option in two ways: it is included as a 'modern' fuel option in one of the transition pathways, and it is evaluated as an 'intermediate' fuel where households 'stack' with ICS, i.e. the cooking needs are met with a combination of ICS and either a modern fuel or a traditional fuel. In addition, we also analyse the costs and health impacts of a more common form of stacking where a household stacks a modern fuel with a traditional fuel such as firewood or dung cakes.

The primary objectives of this report are as follows:

- Understand the broad implications of the different transition pathways to modern fuels and their relative costs and benefits
- Gain deeper insights into the transition through a disaggregated analysis to the extent possible along state, urban-rural and gender lines
- Understand the impacts of stacking (where multiple fuels are used by a household for cooking, instead of a single fuel) which is a reality in practice but about which there is limited understanding and modelling
- Analyse the potential role that ICS can play in the transition
- Gain policy relevant insights to inform programme designs and investment decisions

Thus, the purpose is to gain a broad understanding of order-of-magnitude impacts and make policy suggestions. In particular, the exact numbers resulting from the analysis are of less interest than the larger trends and messages that can be inferred. The robustness of the insights is further strengthened by a sensitivity analysis to ensure that the important findings are not invalidated by changing key input assumptions.

The analysis in the paper is based on a custom-developed model called CEFTI (pronounced 'Safety'), which stands for Cost-Effectiveness of Fuel Transitions in India. CEFTI calculates the costs and benefits of transitioning to modern fuels in Indian households under different pathways or scenarios over a period from 2015 to 2030. CEFTI is used to perform three separate analyses: a) costs and benefits of transitioning to modern fuels along different pathways, b) impacts of stacking traditional fuels with modern fuels and c) potential role of ICS. Sections 2 and 3 present the primary analysis in the report regarding the costs and benefits of different transition pathways to modern fuels. Section 2 describes the analysis methodology in brief including the important assumptions, the transition scenarios considered and the CEFTI model, while important analysis results and findings are presented in Section 3. Sections 4 and 5 present the methodology and results of the additional analyses related to the impacts of stacking and the role of ICS respectively. Some of the limitations of our analysis due to various constraints are described in Section 6. As these constraints are removed, the analysis can be made more robust by incorporating the changed assumptions and values into the analysis. Section 7 concludes the report by summarising the policy-relevant insights from the analysis.

In the interests of brevity, the main body of the report only presents a broad outline of the methodology, assumptions and results, which are described in detail in the supplementary appendices[4].

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4. The appendices are available on the Prayas website at http://www.prayaspune.org/peg/publications/item/376.

2 : Analysis Methodology

Figure 1: Scope of the Analysis
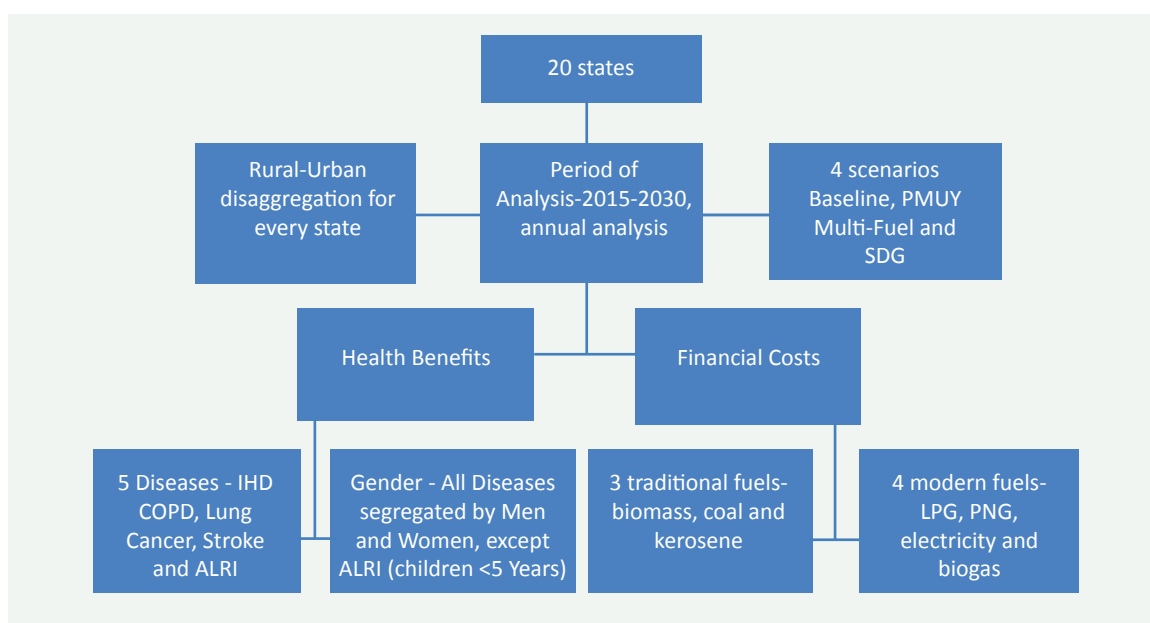
Figure 1 is a schematic representing the scope of the analysis, which is described in this section. The analysis considers 19 of India's largest states[5] and one grouping of states, the North East[6]. For simplicity, the North East is also referred to as a state in this paper. These 20 states together have about 97% of India's population and households, and about 99% of households using traditional fuels, thus practically covering the entire country (Census, 2011). The period for the analysis is over 16 years from 2015 to 2030 — a reasonable time period to achieve significant transition, with the terminal year coincident with the target year for the SDGs. The analysis results are presented for the period from 2019 to 2030 to allow for a significant portion of the cessation lag for the health impacts associated with a fuel shift from 2015 to take effect.

2.1   Fuels and technologies

The primary cost-benefit analysis is performed on seven fuels and corresponding stove technologies. These are biomass (which encompasses firewood, agricultural residue and dung-cakes), coal (including charcoal), kerosene, LPG, PNG, electricity and biogas. Of these, the first three are considered 'traditional fuels' and represent the set of fuels to transition away from. Note that use of biomass as a fuel in the main analysis indicates its usage in a traditional stove, whereas

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5.   The 19 states are Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal. Andhra Pradesh here refers to the unified state before it was bifurcated into Telangana and Andhra Pradesh.

6.   The North East grouping in the report comprises of seven states: Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura.

use of biomass in ICS is discussed in a separate analysis in Section 4. Two of the three traditional fuels are solid fuels (biomass and coal) whose health impacts are well understood and have been quantified for many diseases. Kerosene is known to have health impacts such as impaired lung function, an increased risk of tuberculosis and other infectious diseases, asthma and cancer, but the impacts have not been quantified (Lam, Smith , Gauthier, & Bates, 2012). Therefore, health impacts are only calculated for the two solid fuels.

The four modern fuels considered do not have any noticeable health impacts. For biogas, we only consider cow-dung based biogas since there is comparitively less certainty about the maturity and economics of biogas technologies from other sources such as from food waste, human waste, sewage and agricultural residue. Similarly, the analysis does not consider other potential futuristic cooking technologies and fuels such as solar concentrators, heat storage systems and vegetable oils.

It is generally considered that India's attempts to introduce ICS as a solution to the cooking challenge have not been very successful so far (Kishore & Ramana, 2002). However, recent improvements in ICS technology require that it be considered as an option. A representative of the best-in-class tier-4 ICSs[7] is used in the analysis in Section 5 to understand the potential role they can play.

2.2   Diseases considered

Health impacts from solid fuel combustion primarily arise due to exposure to fine particulate matter of 2.5 microns or lesser ($PM_{2.5}$) that can be inhaled. Multiple epidemiological studies from developing countries and exposure-response data available from several particle exposure settings show a positive association (class I evidence) between certain diseases and exposure to $PM_{2.5}$. For the current analysis, only the following five diseases have been considered, for which quantitative relationships between disease and pollution exposure has been established in literature (Ochir & Smith, 2014).

1. Acute Lower Respiratory Infection (ALRI), in children < 5 years
2. Chronic Obstructive Pulmonary Disease (COPD), in men and women > 15 years
3. Ischemic Heart Disease (IHD), in men and women > 15 years
4. Cerebrovascular Disease (CD) or Stroke, in men and women > 15 years
5. Lung Cancer (LC), in men and women > 15 years

More than 70% of people aged above 60 years in India were found to have cataracts, with a greater prevalence among women (Vashist, et al., 2011). There is also sufficient evidence of increased risk of contracting cataract due to solid fuel use (Smith, et al., 2014). However, it is not considered in our analysis because there is insufficient epidemiological data to model its risk as a function of exposure.

2.3   Scenarios analysed

The primary analysis consists of four different scenarios each of which represents a transition pathway away from traditional fuels. Each scenario is based on different assumptions about the future under different possible policies, technologies, market structures and pricing regimes, and is characterised primarily by the assumptions regarding penetration (i.e. percentage of households using a fuel as the primary cooking fuel) of different fuels. Some assumptions common to all scenarios of the primary analysis are:

• A household uses only one fuel for cooking (this restriction is relaxed in the stacking analysis)

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7.   In particular, we consider the Mimi Moto tier-4 stove. See http://catalog.cleancookstoves.org/stoves/434 for more information.

- A household that switches from a traditional fuel to a modern fuel continues to use a modern fuel

- The penetration of modern fuels increases over time, though the modern fuel mix and its rate of adoption vary across scenarios

- Use of kerosene is phased out by 2030 across the country in all scenarios, while the use of coal is phased out in most regions of the country except in a few scenarios and states

- Usage of PNG is restricted to urban areas, while that of biogas is restricted to rural areas. LPG and electricity are used in both urban and rural areas.

- Two models for biogas are assumed, the household model and community model, with the latter being the cheaper but less used option.

The first two assumptions are not close to the current reality. Most households use multiple fuels, stack and switch between modern and traditional fuels. However, it is important to understand the cost-effectiveness for an ideal case scenario to assess the impact of other options which are closer to reality.

The scenarios are briefly described below.

- **Baseline scenario:** Future penetrations of modern fuels largely follow past trends based on the 2001 and 2011 census, with some changes to account for recent policy announcements such as PMUY which is expected to increase the reach of LPG compared to past trends. Over a third of the country continues to use solid fuels in 2030 in this scenario.

- **PMUY scenario:** This scenario assumes that PMUY is supplemented by other policy measures to incentivise households to use LPG on a sustained basis. Penetrations of other modern fuels remain very low consistent with historical trends. As a result of sustained use of LPG in this scenario, it is assumed that solid fuel use falls to 20% by 2030.

- **Multi-Fuel scenario:** Unlike the LPG-centric PMUY scenario, the focus in this scenario is not only LPG but also other modern fuels. Thus, while PMUY is successfully implemented, PNG, electricity and biogas too receive policy support in areas where they are deemed appropriate. The penetration of different modern fuels is modelled separately for rural and urban areas of each state depending on their resource and infrastructure availability. In comparison to the PMUY scenario, this results in greater penetration of PNG, electricity and biogas, but a lower, though significant penetration of LPG. However, the overall penetration of modern fuels is greater in this scenario than the PMUY scenario. As a result, solid fuel use in 2030 falls to 13% in this scenario.

- **SDG scenario:** This is a highly ambitious or optimistic scenario in which it is assumed that the government aggressively pushes for adoption of modern fuels to achieve goal seven of the SDGs of providing 100% access to clean, modern energy by 2030. This is aided by economic and technological trends favouring the adoption of modern fuels, and greater difficulty in accessing traditional fuels for price and availability reasons. As a result, in this scenario, there is no usage of traditional fuels for cooking in India by 2030. The mix of fuels in this scenario is similar to the Multi-Fuel scenario, but with a more aggressive transition to modern fuels other than LPG. As a result, LPG, while being the dominant fuel, plays a less prominent part in the later years than the PMUY and Multi-Fuel scenarios, while PNG, electricity and biogas play a more significant role than the Multi-Fuel scenario.

Appendix A describes the scenarios in detail, including important scenario drivers and state level penetrations. Table 1 presents a summary of the penetration of biomass and modern fuels across the country under the four scenarios in 2015, 2022 and 2030. Figure 2 presents the penetration of modern cooking fuels across various states in 2015, 2022 and 2030 in the various scenarios, to provide an understanding of the inter-state differences.

Table 1: Snapshot of percentage of households using different fuels (penetrations) across scenarios

Fuel	2015	2022				2030			
		Baseline	PMUY	Multi-Fuel	SDG	Baseline	PMUY	Multi-Fuel	SDG
Biomass	65%	53%	41%	36%	19%	36%	20%	13%	0%
Traditional	67%	53%	42%	36%	19%	36%	20%	13%	0%
LPG	31%	45%	57%	56%	67%	62%	78%	69%	58%
PNG	1%	1%	1%	3%	4%	2%	2%	8%	13%
Biogas	0%	0%	0%	2%	5%	0%	0%	4%	11%
Electricity	0%	0%	0%	3%	5%	0%	0%	6%	18%
Modern	33%	47%	58%	64%	81%	64%	80%	87%	100%

Note : Traditional fuels also include coal and kerosene other than biomass. Modern fuels are the four fuels shown in the table.

Figure 2: Modern fuel penetrations in various states in 2015, 2022 and 2030
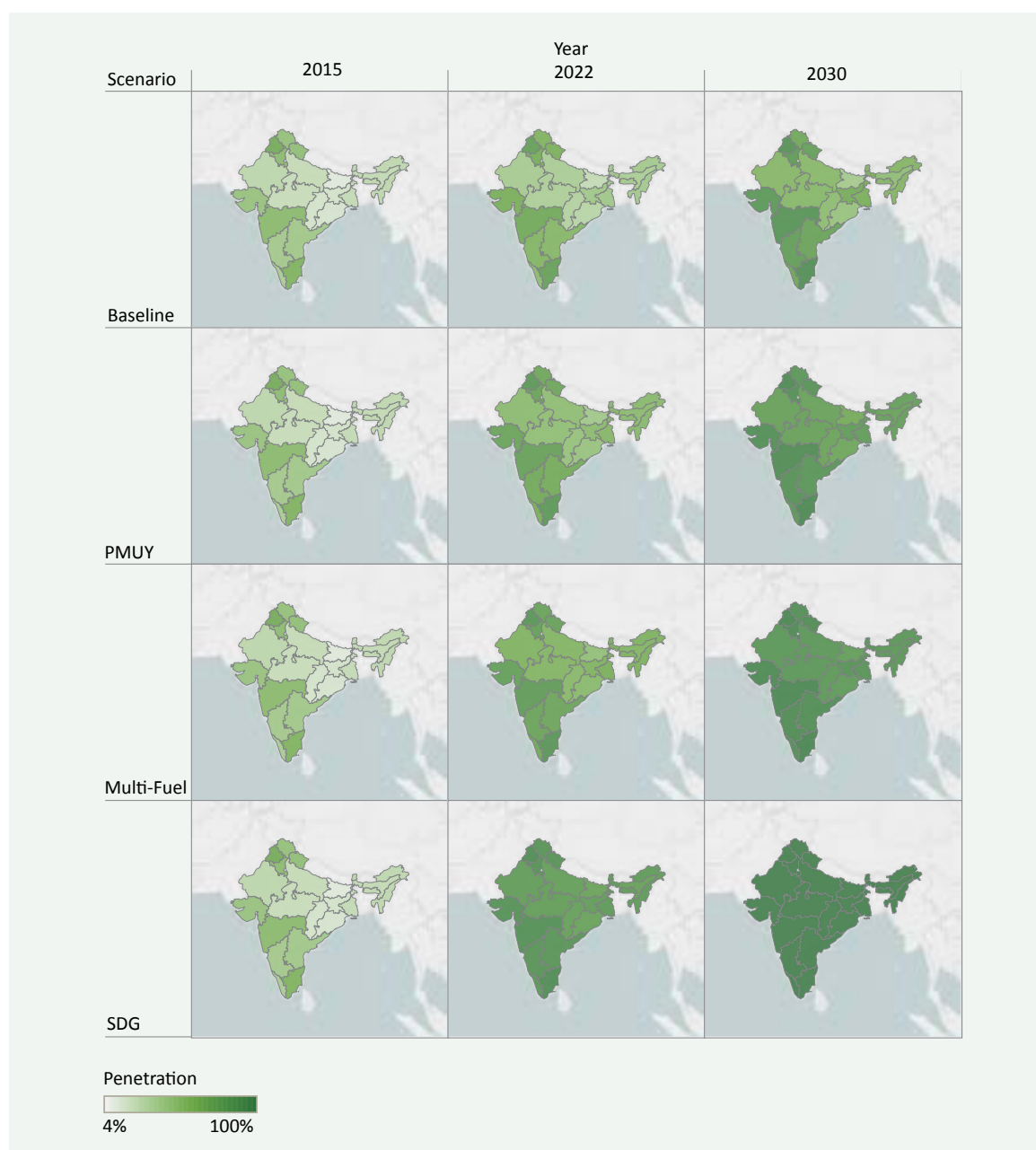
2.4 CEFTI model

This section describes how the CEFTI model estimates energy demand, health impacts, costs and determines cost effectiveness.

Energy demand estimation

Health impacts of solid fuel use in households, and the overall costs of cooking are estimated based on the quantities of various fuels in use. The scenarios describe the number of households that use each kind of fuel. In order to estimate the amount of fuel required by each household using a certain fuel, it is assumed that the useful cooking energy required per-capita per year is 1046 MJ (Mega-joules) (Sanga & Jannuzzi, 2005). As this is useful energy, it is largely independent of the energy content of the fuel and stove efficiencies.[8] The useful energy demanded by a household is converted into total energy demanded based on the efficiency[9] of the stove corresponding to the fuel used in the household, and the total energy demanded is converted into the quantity of fuel based on the energy content of the fuel (Malla & Timilsina, 2014).[10] Energy demand estimation is described in greater detail in Appendix B.1 and B.2.

Health impact estimation

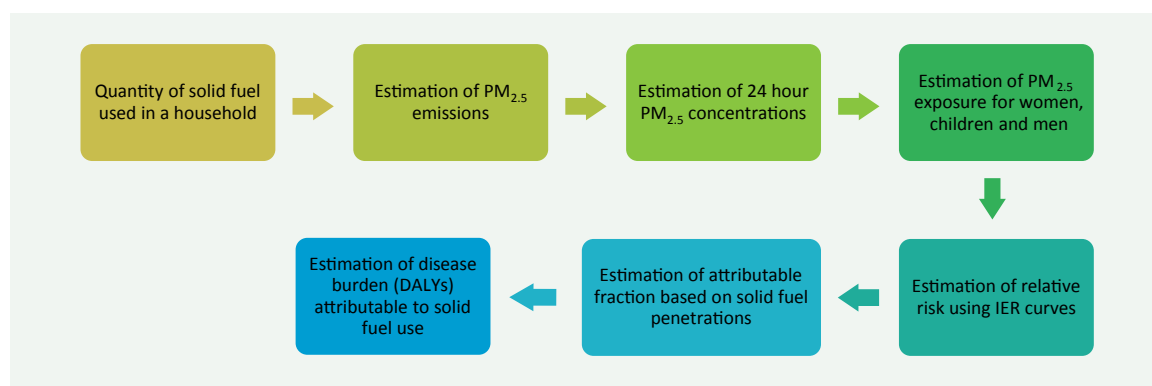**Figure 3: Estimation of disease-wise DALYs from solid fuel use**

Figure 3 presents a schematic for how disease burden is estimated from quantity of solid fuel use through a series of steps. Health impacts of households using solid fuels are estimated in CEFTI as a function of the exposure of individuals to $PM_{2.5}$ in an average kitchen using the Integrated Exposure Response (IER) method (Burnett, et al., 2014). The exposure is calculated from $PM_{2.5}$ concentrations using estimated exposure rates for women, children and men (Smith, et al., 2014, p. 191). $PM_{2.5}$ concentrations are calculated based on a single zone micro-environment model as a function of kitchen characteristics, the quantity of solid fuels burnt and their emission rates (WHO, 2014; Johnson, Edwards, Morawska, & Smith, 2014). Modern fuels are assumed to have no health impacts, while the health impacts of ICS are calculated based on emission rates for those stoves.

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8.   This estimate can vary with the type of fuel used to some extent and across regions and time, due to differences in socio-cultural aspects, incomes and cooking and eating habits (Habib, Venkataraman, Shrivastava, Banerjee, Stehr, & Dickerson, 2004). However a single estimate is used at the national level due to unavailability of better data. The estimate here is based on a literature survey of studies conducted between 1983 and 2003. Some of the studies were predominantly based on biomass use, while others were based on LPG use alone. An earlier estimate of 947 MJ for India was provided in the 1985 report of the Advisory Board on Energy while estimating future cooking energy demand (ABE, 1985). This estimate is used to test for sensitivity of the model results to this assumption.

9.   Note that 'efficiency' in this report refers to overall thermal efficiency which is a product of combustion efficiency (how much of the energy content of the fuel is converted to heat by burning) and heat transfer efficiency (how much of the generated heat is transferred to cooking vessel) (Venkatraman, D., Habib, Lam, & Smith, 2010).

10.   Similar steps are followed for ICS also, except that the quantity of solid fuel used (biomass pellets) and emission rate \ of $PM_{2.5}$ emissions are different (lower) for ICS compared to traditional biomass stoves. Appendix C.2 has the relevant details.

Disease burdens or disability-adjusted life years (DALYs) have been estimated only for those diseases, namely ALRI (acute lower respiratory infection), COPD (chronic obstructive pulmonary disease), IHD (ischemic heart disease), lung cancer (LC) and stroke, for which IER functions can be used to quantitatively estimate the relative risk (RR) of individual women, children and men exposed to $PM_{2.5}$ from solid fuel use. The relative risk is converted to overall disease burden due to exposure to HAP based on the background disease burden derived from WHO projections (Mathers & Loncar, 2006), and the population of women, children and men exposed to solid fuel combustion. The exposed population is in turn derived from the fuel penetration assumptions made for each scenario and the projections for overall population from 2015 to 2030. The DALYs accrue with an appropriate cessation lag for COPD, IHD, lung cancer and stroke. This is to account for the fact that, for many illnesses, it takes several years to develop in the exposed population. Hence, related health risks would also not reduce immediately after reduction in $PM_{2.5}$ exposure. There is no lag for ALRI due to its acute nature, however (Ochir & Smith, 2014; U.S. Environmental Protection Agency, 2010). Thus, CEFTI is able to estimate the disease burden (DALYs) for the five diseases arising due to exposure to solid fuel combustion for each of the four scenarios for each year of analysis.

Disease burdens or DALYs are estimated only at a national level since projections of background disease burdens are not available at the state level. Therefore, at the state level, we only estimate the attributable fraction, i.e. the proportion of the state's disease burden that can be attributed to solid fuel use.

The Baseline scenario is expected to play out in the absence of any new policy intervention, while the other three scenarios represent the situations under different possible combinations of policy interventions and techno-economic developments. Therefore, the PMUY, Multi-Fuel and SDG scenarios are seen as 'intervention scenarios' that induce a fuel transition beyond the Baseline scenario. The impact (in terms of health benefits) of the three intervention scenarios are compared by considering their respective averted DALYs (aDALYs), i.e. the DALYs saved by the intervention scenario as compared to the Baseline scenario. Estimation of health impacts is described in greater detail in Appendix B.3.

Cost estimation

CEFTI estimates cost as the overall financial cost to the economy of each scenario, measured in 2015 Rupees, irrespective of who incurs the cost. As a result, issues such as consumer subsidies and taxation are not relevant to this analysis. The cost to the economy includes the cost of the fuel, connection cost, dedicated infrastructure cost[11], distribution cost, cost of the stove, etc. It does not include opportunity costs, transaction costs, programme implementation costs and environmental costs which are harder to estimate. Fuel costs for the initial year are based on available data and projections for future costs which are mostly pegged to an appropriate commodity price index (such as crude oil or natural gas) from the World Bank (World Bank, 2015). Some fuel prices, such as for biomass and biogas, are estimated based on historical trends (CSO, 2012). Biomass dependant households can either collect biomass or purchase it from the market, but all users of coal and kerosene are assumed to purchase these fuels. The share of households purchasing biomass is estimated from surveys such as (Desai & Vanneman, 2016; CEEW, 2015) and projected based on assumptions about future biomass availability and alternative uses.

Estimating costs to the economy requires estimation of the quantity of fuel, stoves, connections, etc. required. The quantity of fuel is estimated as described earlier. Projections of population and household numbers derived from Indian census and United Nations projections (Census, 2006; United Nations, 2015) (described in detail in Appendix B.1), and scenario assumptions

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11. The infrastructure cost is amortised annually over the asset's life. Electricity infrastructure cost is not considered in this analysis since electricity has many other uses.

about penetration of different fuels, form the basis to estimate the number of connections, stoves, etc. required. Costs of stoves, connections etc. are taken from available market data and future projections are pegged to indices such as the metal price index from the World Bank. Figure 4 illustrates the estimation of demand and costs in CEFTI illustrates the estimation of demand and costs in CEFTI. Estimation of costs is described in greater detail in Appendix B.4.

Figure 4: Estimation of costs in CEFTI
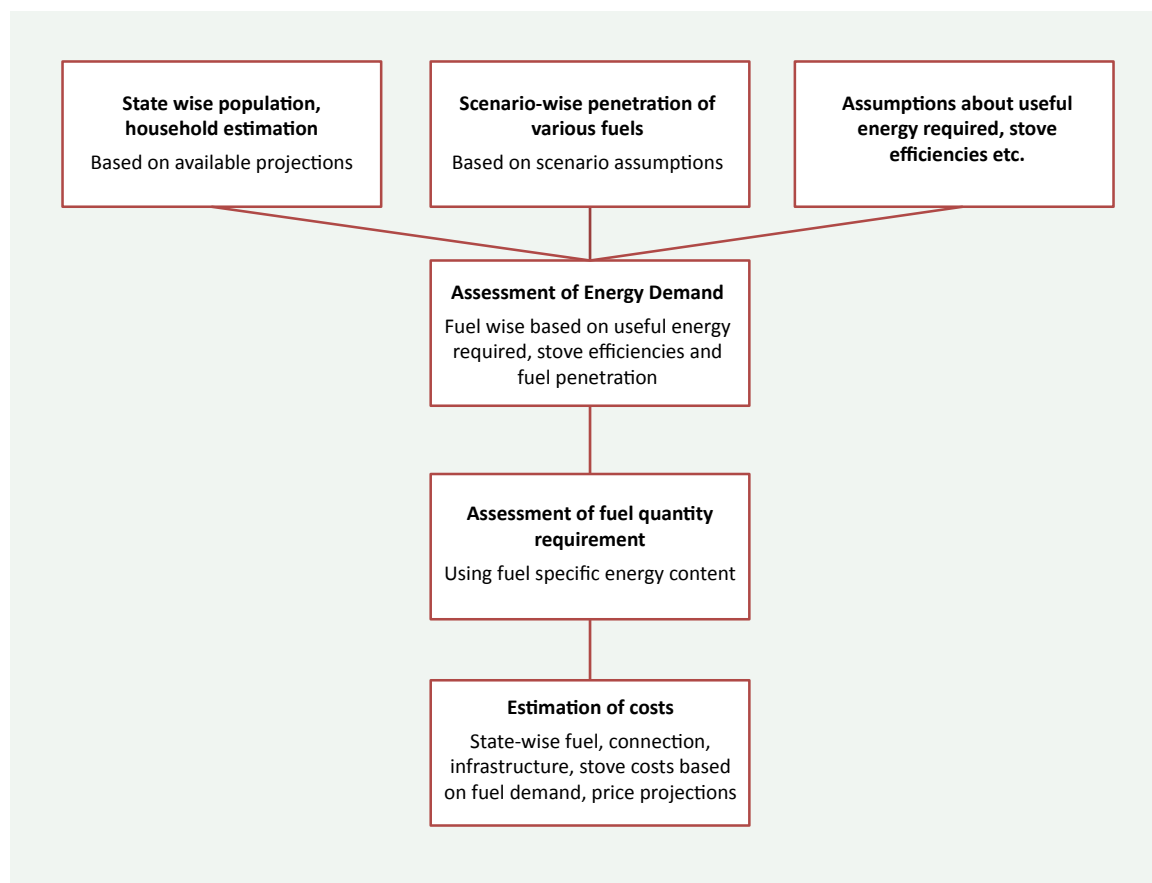
Cost-effectiveness

While the primary objective of our analysis is to understand the health implications of different scenarios, CEFTI also enables a cost-effectiveness analysis.

The cost-effectiveness of each of the intervention scenarios is measured in Rs / aDALY as the ratio of the incremental cost of the scenario (with respect to the Baseline scenario) to its aDALYs (Marseille, Larson, Kazi, & Rosen, 2015). This allows a comparison of the different intervention scenarios for their cost-effectiveness. Another way of estimating cost-effectiveness is the WHO-CHOICE model, according to which an intervention is considered 'cost effective' if its incremental cost per aDALY is less than three times the per-capita gross domestic product (GDP) of the country or region, and the intervention is considered 'very cost effective' if the incremental cost per aDALY is less than the per-capita GDP (WHO, 2001). To estimate cost-effectiveness as per the WHO-CHOICE model, the GDP for the base year was taken from government data, while projections have been based on the International Monetary Fund's World Economic Outlook (IMF, 2017). The CEFTI model enables assessment of cost-effectiveness using both these methods.

The assumptions and parameters considered for the CEFTI model are generally conservative in that they may underestimate health benefits and overestimate costs. For example, health impacts of some diseases such as cataract for which there is no sufficient quantifiable basis are not

considered. Similarly, the lagged health impacts of exposure to traditional fuels before the analysis period are not considered, nor are health impacts of exposure to kerosene combustion. Appendix B describes the CEFTI model in greater detail, including all the assumptions and formulae for calculating the costs and health impacts.

The analysis period comprises of calendar years. Even though the analysis period of the CEFTI model is from 2015–30, the costs and health impacts and benefits are reported for the period 2019–30. This is to allow for the cessation lag of health impact due to exposure to solid fuels to take effect and hence health benefits due to reduction in solid fuel exposure in the intervention scenario to be seen.

3 : Analysis Findings

3.1   The transition has significant health benefits

Figure 5: Aggregate (2019–30) disease-wise attributable DALYs under various scenarios
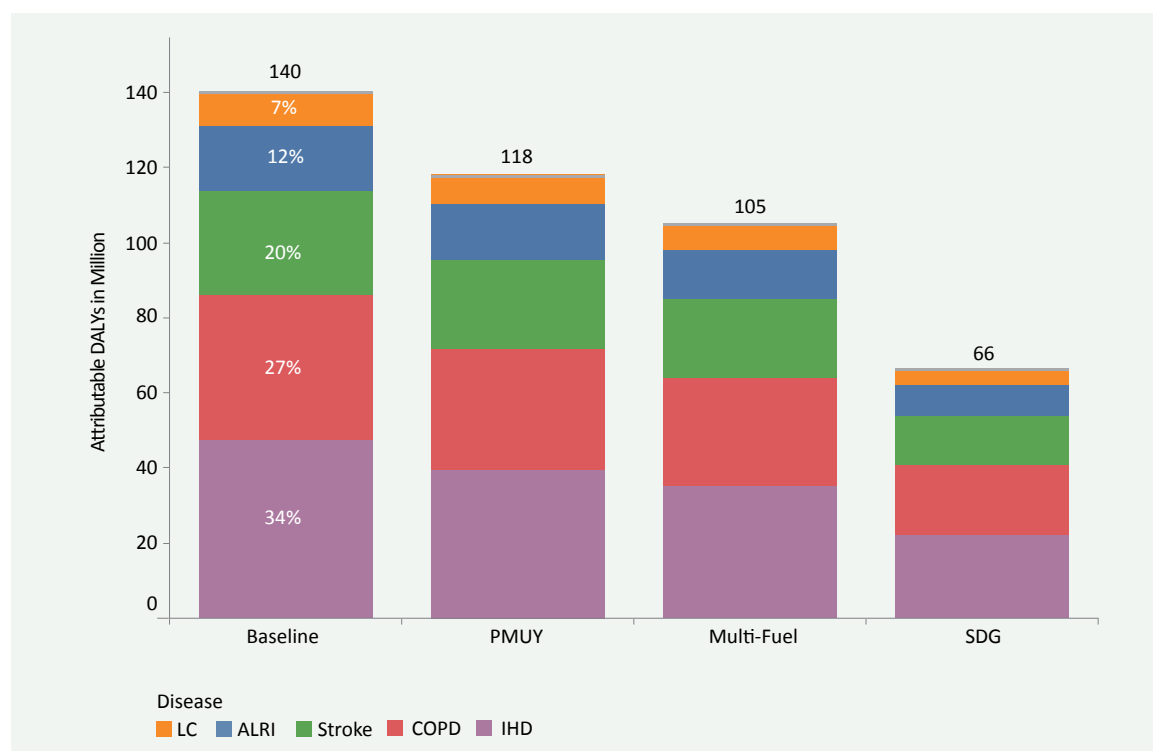
Note: The percentage share of diseases in aggregate (2019–30) DALYs remains more or less the same across scenarios.

Figure 5 shows the aggregate (2019–2030) disease-wise DALYs attributable to solid fuel use for the Baseline scenario and each of the three intervention scenarios, while Figure 6 shows the aDALYs for each of the three intervention scenarios on an annual basis. Since use of solid fuels is eliminated in the SDG scenario, it has the lowest aggregate attributable DALYs of all the scenarios, while the Multi-Fuel scenario has fewer DALYs compared to the PMUY scenario since it has a lower penetration of solid fuels.

About 74 million DALYs are averted between 2019 and 2030 in the SDG scenario, which represents nearly 15% of the 510 million background DALYs for the diseases considered and a 53% reduction in attributable DALYs compared to the Baseline scenario. Even in the least aggressive PMUY scenario, about 22 million DALYs (4% of the background DALYs) can be averted.

Note that, due to the time lag in reduction in disease burden after reduction in exposure to solid fuels, the entire benefits of a shift to modern fuels in all scenarios are not realised by 2030. It would take until 2045 for these benefits to fully materialise. This lag also means that DALYs attributable to solid fuel use do not reach zero by 2030 even in the SDG scenario.

Figure 6: Averted DALYs under various scenarios
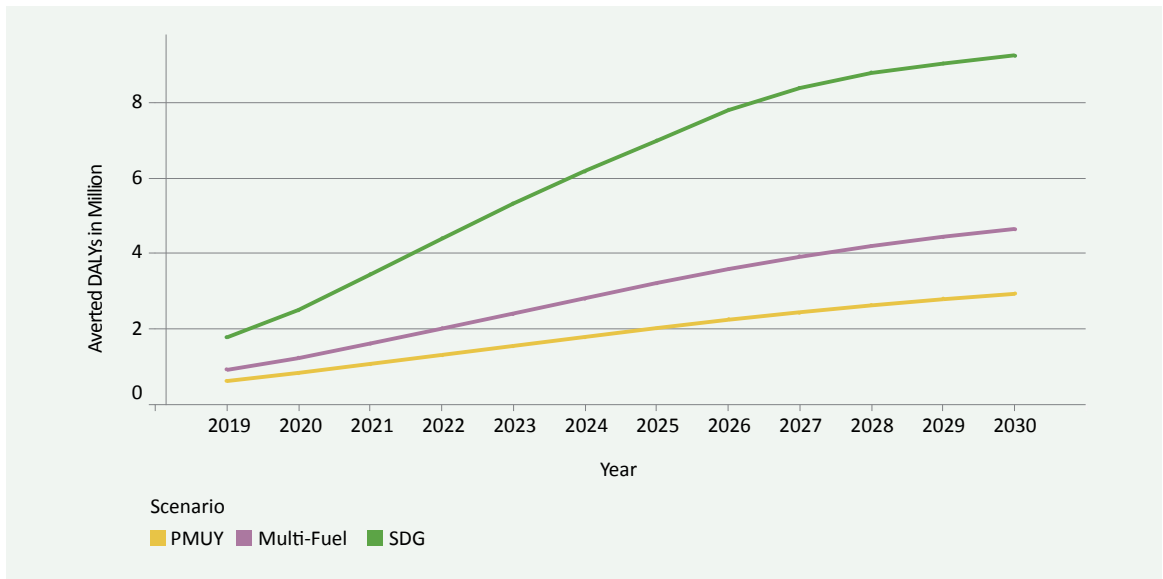
Given the heavy HAP-related health burden in India, transitioning away from traditional fuels to modern fuels leads to averting tens of millions of DALYs. Since there is a time lag involved in realising the health benefits from the fuel transition, it is necessary to begin an aggressive transition at the earliest.

3.2   The transition is very cost-effective

Figure 7: Cost per Averted DALY in 000 Rs
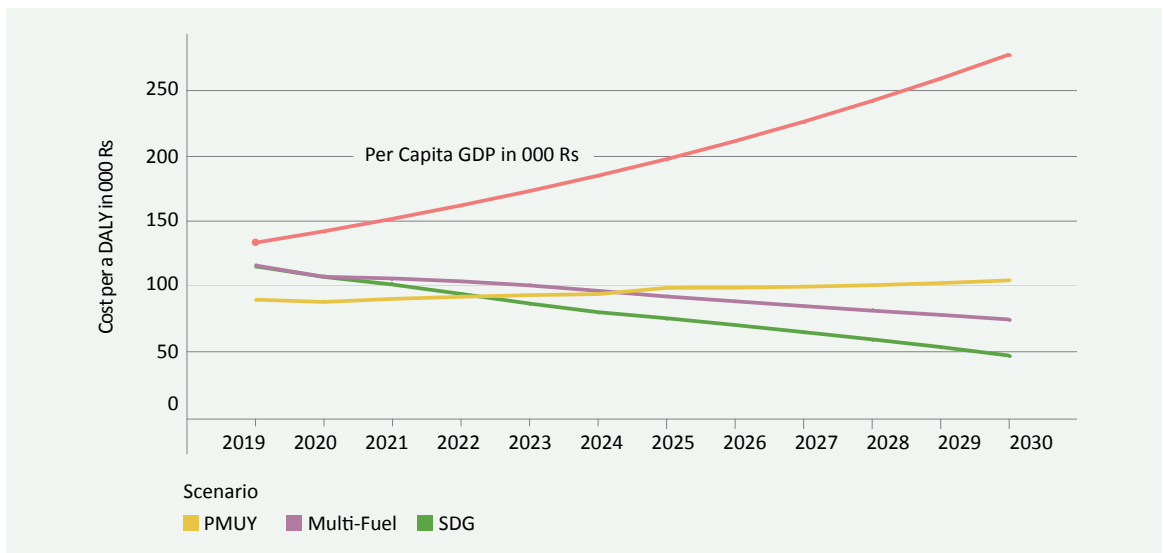
The SDG scenario is the most cost-effective intervention in 2030 and on an average between 2019 and 2030 in spite of it being the costliest intervention. This is because it averts the most DALYs suggesting that the health benefits of a higher modern fuel penetration outweigh the incremental costs. As can be seen from Figure 7, the cost per aDALY of the Multi-Fuel and SDG scenarios declines over the years as penetration of modern fuels increases, while it remains nearly constant for the PMUY scenario. This graph also shows that all three intervention scenarios are very cost-effective according to the WHO-CHOICE model, as the cost per aDALY is consistently lower than the annual per capita GDP.

The transitions are very cost-effective, with the cost per averted DALY being well below the per-capita GDP for all the years considered. Interestingly, the cost-effectiveness increases as the penetration of modern fuels increases across scenarios and over the years. Thus, increasing the penetration of modern fuels is a very cost-effective and desirable health intervention.

3.3   The problem is predominantly rural in nature

The cooking fuel problem is predominantly a rural phenomenon. The rural-urban divide of the aDALYs shows that rural areas contribute 81% of the aDALYs in the PMUY scenario to 87% in the SDG scenario. Similarly, almost all the incremental cost of an intervention scenario comes from rural areas. For example, out of a total additional cost of Rs 5.2 lakh crore in the SDG scenario, Rs 4.8 lakh crore are due to rural areas. This follows from the fact that urban areas already have fairly high modern fuel penetration as against rural areas. Moreover, rural areas also have more households. Figure 8 and Figure 9 present the aDALYs and costs of the three intervention scenarios disaggregated over rural and urban areas.

Figure 8: Urban and rural averted DALYs (aggregate of 2019–30) under various scenarios
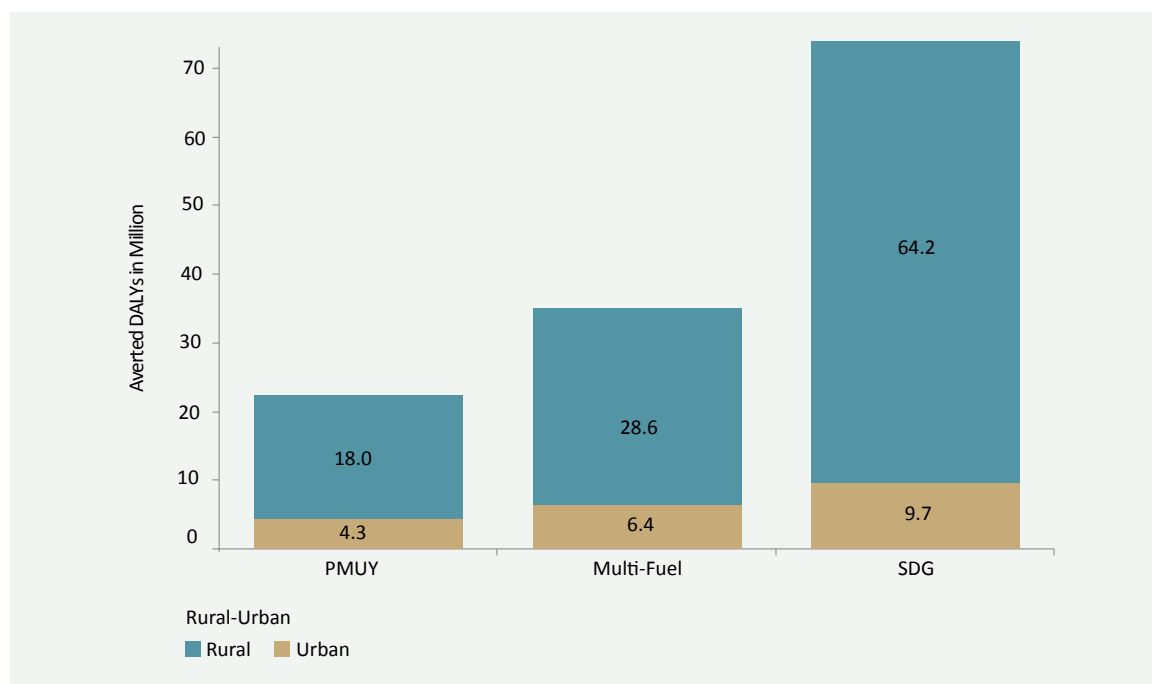
Figure 9: National aggregate (2019–30) costs to the economy of the four scenarios
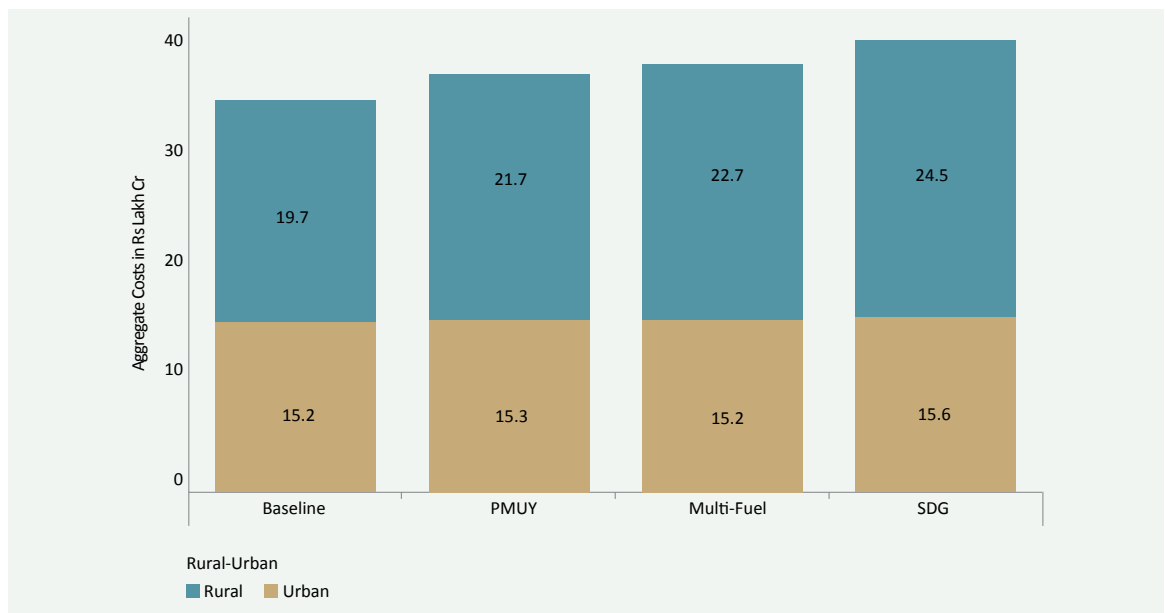
Rural households using freely available biomass would typically find affordability of modern fuels a challenge, apart from accessibility, as opposed to the majority of urban households who have to purchase biomass. For such urban households, cost of traditional fuels is comparable to modern fuels.

> The challenge of ensuring a transition away from traditional fuels is primarily a rural problem and there is an urgent need to make modern fuels affordable and accessible in rural areas. Policies and programs need to be designed to work in India's rural areas, which typically have lower disposable incomes, lower population densities, lower awareness and perhaps lower role of women in household decision making.

3.4 Fuel prices play an important role

Figure 10: Components of aggregate (2019–30) costs of all fuels[12]

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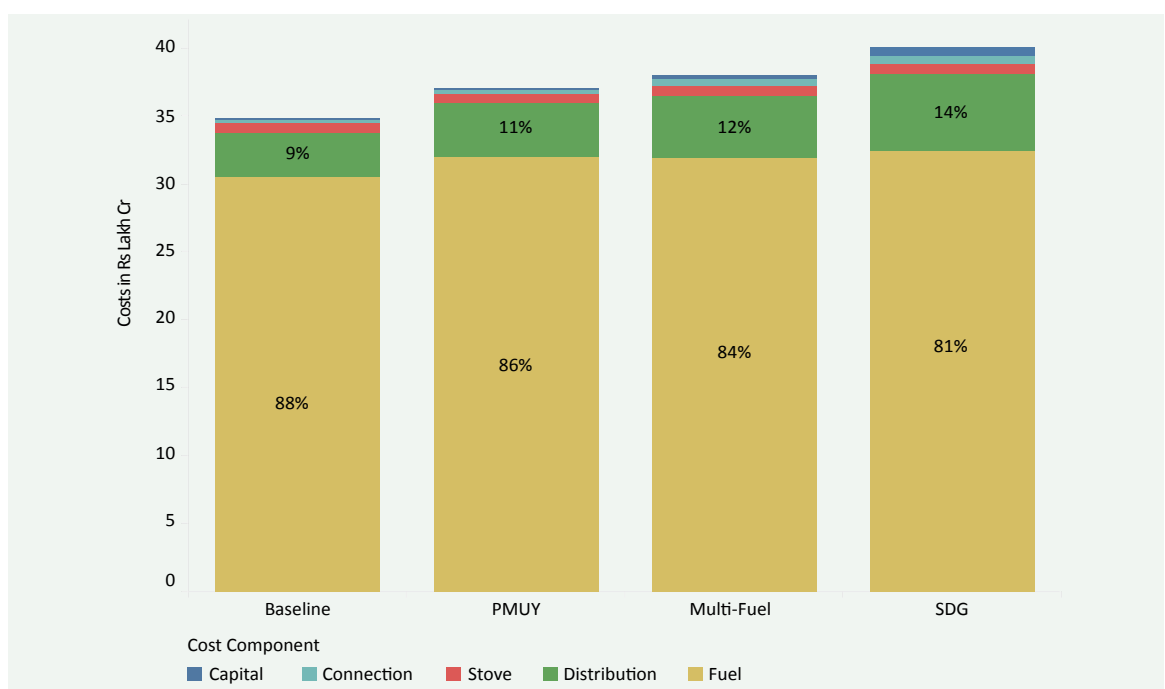
12. Only biogas has capital cost, and only LPG and PNG have connection costs. Distribution costs are accrued for kerosene and all modern fuels except biogas.

Of the different components of cost to the economy, such as the costs of connection, distribution, the stove and fuel, it is the recurring fuel cost that dominates the total cost of cooking. As shown in Figure 10, the share of fuel in total aggregate costs varies from 88% in the Baseline scenario to 81% in the SDG scenario. Thus, any policy decision that affects the (consumer) price of a fuel can have a significant impact on the uptake of modern fuels. It also follows that investments in distribution costs and infrastructure are relatively less costly.

> The price of fuel forms the bulk of the costs of using any cooking fuel. Therefore, consumer prices of modern fuels will be a critical determinant of the speed of transitioning, as it would determine their affordability. This is particularly so given that the challenge is predominantly rural where affordability is also lower.

3.5   Women and children gain more

Women and children are more exposed to the household air pollutants compared to men. Therefore, the relative risk for IHD, COPD, lung cancer and stroke is higher for women, as shown in Figure 11, with the difference being very prominent in the case of COPD and lung cancer. As a percentage of the background DALYs, the averted DALYs for women are slightly higher than those for men, whereas those for children (ALRI) are substantially higher. However, the absolute number of background DALYs is higher in men compared to women. Aggregated from 2019 to 2030, the background DALYs in men are 277 million, whereas in women they are 195 million. Therefore, though women are at a greater risk due to HAP, the averted DALYs for men are greater than women by 36% in the PMUY scenario and by 34% in the SDG scenario, both aggregated over 2019–30.

Figure 11: Relative risk and averted DALYs by gender in rural areas (Multi-Fuel Scenario)
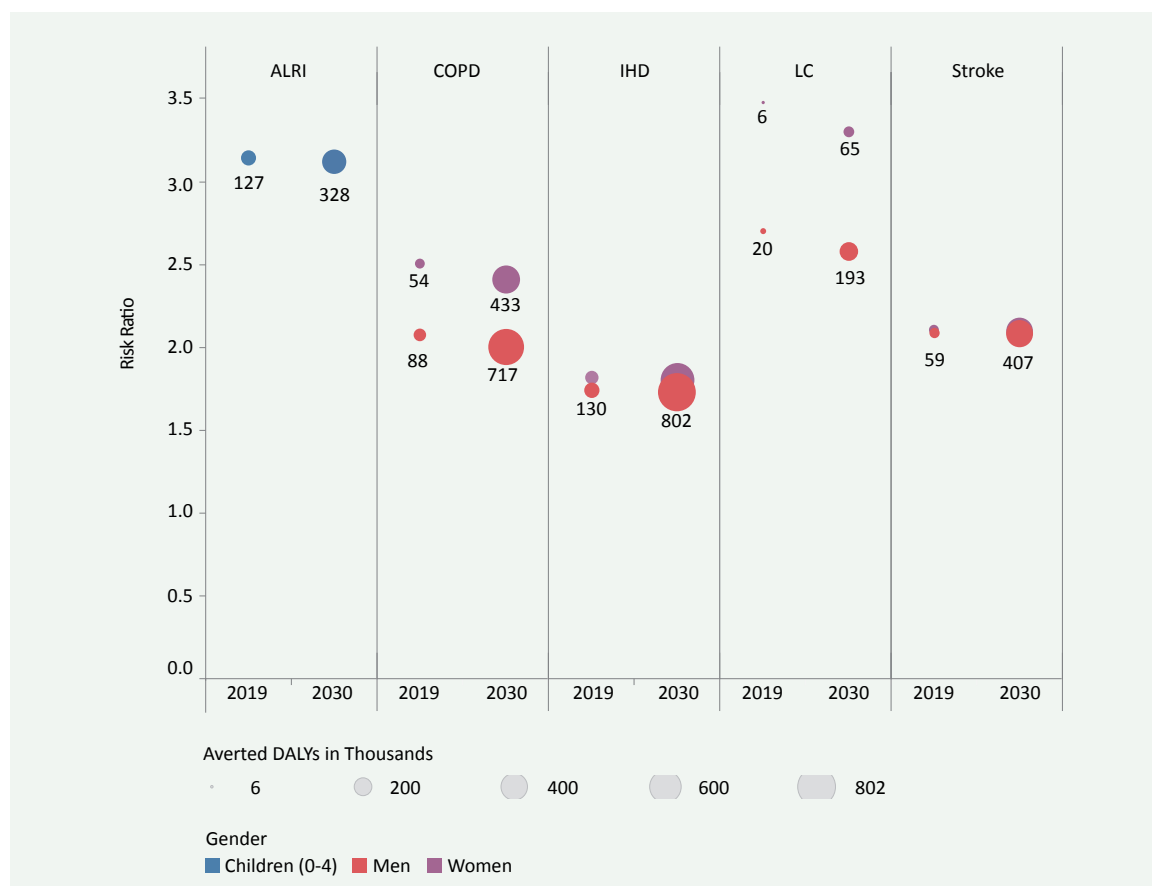
Note: The circles are sized according to the magnitude of averted DALYs in the Multi-Fuel scenario. The size criteria are given in the legend 'Averted DALYs in Thousands'.

Since women (and children) are more exposed to HAP, they stand to gain relatively more from a transition to modern fuels. The gains to women and girls get further amplified if one considers other benefits such as reduced drudgery in fuel collection and reduced time spent in cooking, which are not estimated in this analysis.

3.6   State-specific insights

Population attributable fraction (PAF) of a disease is the fraction of the disease burden that is attributable to a particular cause, in this case the use of solid fuels. Therefore, PAFs are higher in states where solid fuel use is higher as demonstrated in Figure 12 for the Multi-Fuel scenario. Thus, states with a high share of solid fuels such as Assam, Bihar, Chhattisgarh and Madhya Pradesh have higher PAFs than states in the 'medium' category such as Rajasthan, Kerala, Andhra Pradesh and Karnataka. In turn, these states have higher solid fuel use and hence PAF as compared to the 'low' solid fuel use states such as Gujarat, Haryana, Tamil Nadu and Maharashtra. For example, in 2015, about 50% to 60% of the COPD burden for women in the states with high solid fuel use can be attributed to solid fuels, while the range is about 42% to 55% for medium solid fuel use states and about 30% to 45% for low solid fuel use states. With increasing penetration of modern fuels, in the Multi-Fuel scenario in 2030, the ranges become about 15% to 25% for the high solid fuel use states, 8% to 17% for medium solid fuel use states, and 3% to 10% for low solid fuel use states. Any investment in penetration of modern fuels in the states with higher PAFs will be very valuable, as they stand to gain the most from a transition to modern fuels. Grouping of states based on penetration of traditional fuels is described in detail in Appendix A.

Figure 12: State-wise PAFs for Women (IHD, COPD) and Children (ALRI) in the Multi-Fuel Scenario

Another interesting observation is the 'eastward migration' of LPG use — from states such as Punjab, Haryana and Maharashtra to states such as Bihar, Jharkhand and Odisha. Such a shift is perhaps inevitable as people in the western states shift to other modern fuels which are more convenient and affordable, while LPG is picked up as the first-choice modern fuel in the eastern states. State-specific realities suggest prioritising different fuels in different states and areas. Thus, promoting electricity in a hilly state such as Himachal Pradesh, where electricity access is good, is likely to work better than promoting LPG. Rural areas of states such as Chhattisgarh, Gujarat, Haryana and Punjab with high cattle populations would do well from dung-based biogas, while promoting biogas may not be a useful option in Kerala with low cattle population.

These insights mainly follow from the fuel penetration assumptions that have been made for different states in the scenario definitions, which in turn have been based on their current realities, endowments and future plans.

Health benefits of the fuel transition would be directly proportional to the PAFs. Hence, it would be good to prioritise the states which currently have high solid fuel use for transitioning to modern fuels. The choice of the fuel mix would also vary depending on the state and its specific context. Factoring this into programme designs and plans is likely to lead to better and more cost-effective outcomes.

3.7   Fuel and energy related insights

Figure 13: Annual energy demand for cooking across scenarios
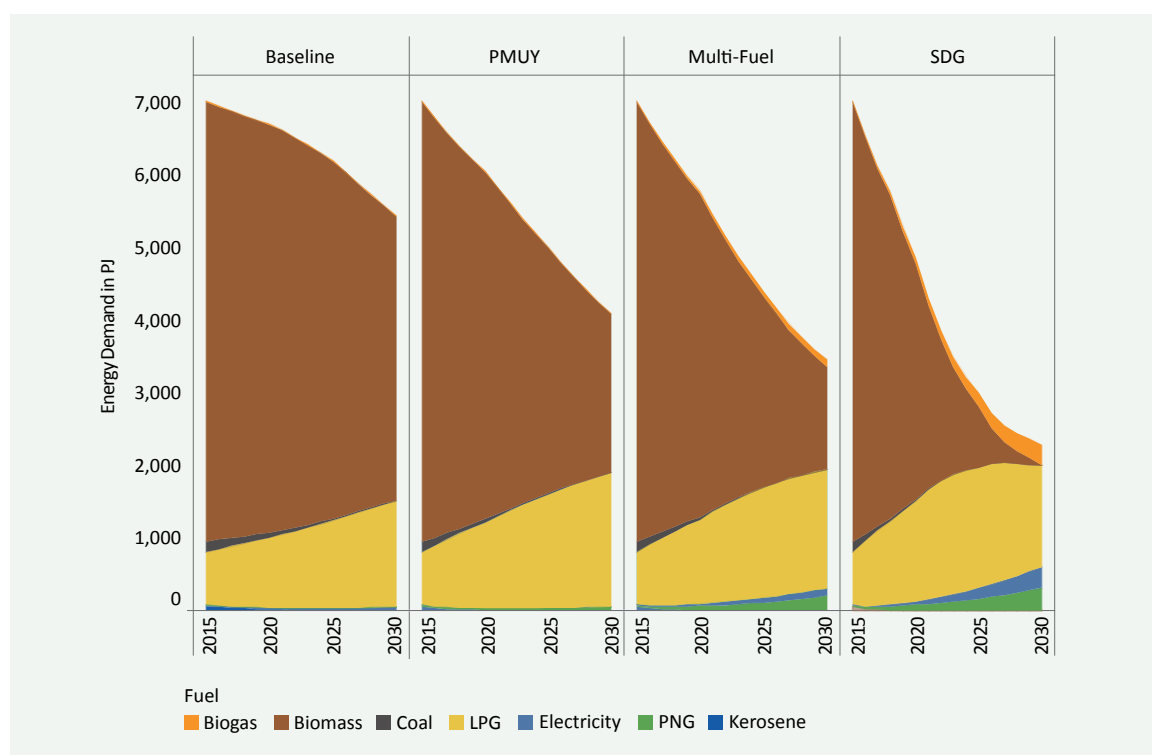
Modern fuels are not only less harmful but also more efficient than biomass. Therefore, a shift away from biomass (and other traditional fuels) to modern fuels results in a significant reduction in total primary energy demand for cooking as shown in Figure 13. As can be seen, the demand for biomass falls drastically while the demand for other fuels increases. Unsurprisingly, the energy demand is the least in the SDG scenario since it has the greatest modern fuel penetration.

By 2030, LPG is the most dominant cooking fuel in India in all scenarios including the SDG scenario in which it supports 58% of the households. This results in LPG demand increasing from about 16

million tonnes (MT) in 2015 to 41 MT in 2030 in the PMUY scenario, with the corresponding demands in the Multi-Fuel and SDG scenarios being 36 MT and 31 MT respectively.

One concern of increased LPG consumption could be its impact on India's oil imports, as the country is heavily import dependent for its petroleum use. In 2016–17, India's net import of crude oil and petroleum products was to the tune of 184 MT. Even if future oil imports increase at a slower rate than the recent past and all incremental LPG demand is met through imports, LPG imports would be less than 10% of the likely total oil imports in 2030.[13] Other measures such as phasing out of kerosene use, implementation of the Dedicated Freight Corridors to shift freight from road to rail, the thrust on electric mobility, increased focus on public transport and adoption of aggressive vehicle fuel efficiency norms, will all lower petrol and diesel requirements for transport and can easily offset the increased usage and import of LPG. Therefore, in the context of the likely benefits of the cooking fuel transition, increasing LPG imports are unlikely to be a matter of concern.

The demand for electricity in the SDG scenario is quite significant and reaches 82 TWh in 2030. This constitutes a not insignificant 4% of total electricity demand and 13% of likely residential electricity consumption in 2030. It could also result in a peak load of about 33 GW, about 10% of total peak load projected in 2030, as cooking is mostly done at certain times of the day.[14] However, the peak load question needs to be addressed in any case to deal with various other disruptions that are likely in the electricity sector, such as high renewables penetration, increased on-site generation, increasing presence of storage, 'smart' appliances and demand response. Therefore, increased uptake of electricity for cooking will not pose any new challenge though the likely increase in peak demand will have to be factored in.

> Overall energy demand for cooking would reduce drastically due to the greater efficiency of modern fuels compared to traditional fuels. LPG would be the dominant fuel in 2030 in all scenarios. The corresponding need for greater imports is unlikely to affect the country's energy security significantly. Increased use of electricity for cooking could increase peak load, but not pose a significant challenge for the future electricity system.

Appendix D describes some more results from the analysis undertaken.

3.8   Sensitivity of analysis findings

In the sensitivity analysis, certain key parameters were varied within a range relevant to that parameter to see how it impacts the cost effectiveness of a scenario. All the scenarios continued to remain very cost effective over the analysis period for all the sensitivity analyses, i.e. the changed cost per averted DALY continued to be less than the average per capita GDP. The results hold even with a 20% increase in fuel price and a 10% to 20% change in most parameters. Moreover, the SDG scenario retained its position as the most cost-effective scenario at the national level in all sensitivity cases. Thus, the sensitivity analysis shows the robustness of our analysis, since changing crucial model parameters or assumptions does not affect the principal conclusions about the cost effectiveness of interventions to increase modern fuel usage. Appendix C.3 describes the sensitivity analysis in detail.

> Though fuel costs are a major part of the total costs, the sensitivity analysis shows that even with significant change in fuel prices, all intervention scenarios remain very cost-effective with SDG remaining the most cost-effective. The interventions remain very cost effective when changes are made to other crucial assumptions such as useful energy requirements and emissions from solid fuels.

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13.   Prayas Analysis from (Ministry of Petroleum and Natural Gas, 2017).
14.   Prayas Analysis from (Central Electricity Authority, 2017).

4 : Stacking Analysis

4.1 Analysis Methodology

The analysis of the impacts of stacking (i.e. the use of multiple cooking fuels within a household to meet cooking energy needs) is an additional analysis that is undertaken. Since many households stack different cooking fuels, but there is limited data available about actual stacking behaviour, this analysis is based on different assumptions about how people stack fuels. It examines the stacking of solid and modern fuels which changes the exposure to solid fuels, alters the risk of disease and affects health benefits. In each stacking case, it is assumed that

a) some primary solid fuel users use modern fuels for a part of their cooking energy needs, and

b) some primary modern fuel users use solid fuels for a part of their cooking energy needs.

The proportions of solid and modern fuels used are defined by stacking cases. Three different stacking cases were considered in which households have 'low', 'moderate' or 'high' stacking with solid fuels as summarised in Table 2, depending on the shares of solid fuel and modern fuel use.

In the high stacking case, only 20% of the households that use solid fuels as the primary fuel stack with modern fuels for only 20% of their cooking needs — that is, most solid fuel using households depend predominantly on solid fuels. The situation is reverse with modern fuel using households with as many as 40% of them stacking with solid fuels for 40% of their cooking, i.e. many modern fuel using households depend a lot on solid fuels also. Thus, this scenario represents a very high usage of solid fuels due to stacking.

In the medium stacking case, 30% of the households that use solid fuels stack with modern fuels for 30% of their cooking, while 30% of the households that use modern fuels stack with solid fuels for 30% of their cooking. This represents the intermediate or moderate case of stacking with solid fuels.

The low stacking case is the reverse of the high stacking case, where 40% of the households using solid fuels stack with modern fuels for 40% of their cooking, and only 20% of modern fuel using households stack with solid fuels and that too, only for 20% of their cooking. Thus, this represents a really low use of solid fuels (SF) due to stacking.

For each of the cases above, DALYs are calculated for each of the four scenarios and compared with the corresponding no-stacking case. For the Baseline and PMUY scenarios with very low penetration of modern fuels other than LPG, it is assumed that the modern fuel involved in stacking is LPG and costs are correspondingly calculated for the stacking cases. Appendix C.1 describes the stacking methodology and assumptions in greater detail.

Table 2: Stacking Cases

Case	% of solid fuel users stacking with modern fuels	% of cooking done with modern fuels for stacking solid fuel users	% of modern fuel users who stack with solid fuels	% of cooking done with solid fuels for stacking modern fuel users
High solid fuel stacking	20%	20%	40%	40%
Moderate solid fuel stacking	30%	30%	30%	30%
Low solid fuel stacking	40%	40%	20%	20%

4.2 Results of stacking analysis

Figure 14 shows the attributable DALYs aggregated over 12 years (2019–2030) for different stacking cases and scenarios. In the figure, 'No Stacking' stands for use of a single fuel by a household as in the original scenarios from the main analysis. Expectedly, within any scenario, attributable DALYs increase with the amount of stacking with biomass, i.e. the high solid fuel stacking case has the highest attributable DALYs. As a result, the health impacts (attributable DALYs) of the medium stacking case of the SDG scenario are comparable to the PMUY scenario without any stacking, while the high stacking case of the SDG scenario is only marginally better than the no-stacking case of the Baseline scenario, though there is much lower modern fuel penetration in the PMUY and Baseline scenarios. Similarly, the health impacts of the medium stacking case of the Multi-Fuel scenario are comparable to the Baseline scenario without stacking.

Figure 14: Aggregate (2019–30) attributable DALYs in different stacking cases and scenarios
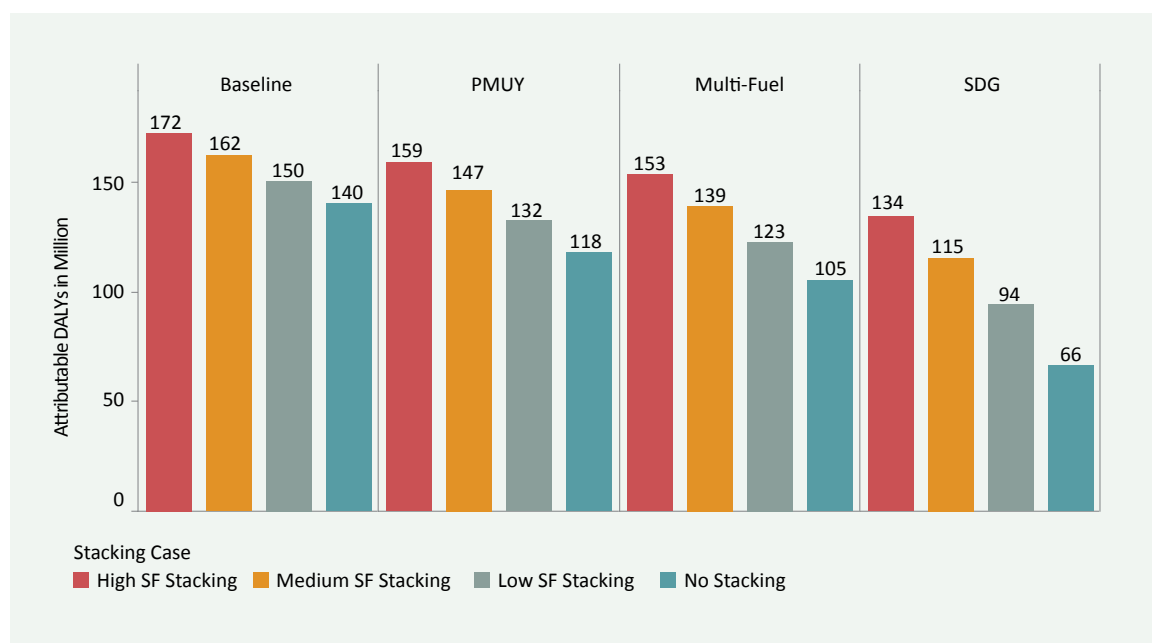
Note: SF stands for solid fuel

Across scenarios, the impact of stacking worsens as the number of primary modern fuel users increases, i.e. as we go from the Baseline to the SDG scenario. Compared to no stacking, the Baseline scenario has 32 million additional DALYs (23%) with high solid fuel stacking, a number that increases to 68 million (103%) in the SDG scenario. This shows that the expected health gains from

a fuel transition would not be possible without addressing stacking, particularly as penetration of modern fuels increases.

The cost per averted DALY of shifting to a scenario with higher modern fuel penetration increases as the level of stacking in the two scenarios increases. Thus, the average cost per averted DALY over 2019–2030 of shifting from the Baseline scenario with high stacking to the PMUY scenario with high stacking is around Rs 1,34,000, while it is only around Rs 98,000 for shifting from the Baseline scenario with no stacking to the PMUY scenario with no stacking. However, note that even the cost of around Rs 1,34,000 per averted DALY is very cost-effective. Thus, it is desirable to increase modern fuel penetration even in the presence of stacking, though stacking erodes many of the health benefits.

Even within a scenario, the cost per averted DALY of the intervention of eliminating stacking increases with increasing levels of stacking. For example, in the Baseline scenario, the cost per averted DALY of shifting from the high-stacking case to the no-stacking case is about Rs 18,000, while the cost per averted DALY of shifting from the high-stacking case to the medium-stacking case is around Rs 80,000. These costs for averting DALYs make it clear that eliminating stacking with solid fuels completely is also a very cost-effective 'intervention'.

> Elimination of stacking as an 'intervention' by itself is very cost-effective as is increasing modern fuel penetration even in the presence of stacking. Thus, both increasing modern fuel penetration and elimination of stacking are highly desirable on their own. However, stacking with solid fuels erodes much of the health impacts of shifting to modern fuels. Since stacking delivers less health benefits, it is also less cost-effective than not stacking, making a strong case to completely shift to modern fuels.

5 : ICS Analysis

Because of its much better efficiency and emissions characteristics compared to biomass stoves, an improved biomass cookstove (ICS) is another fuel technology option that traditional fuel users can transition to. To understand the possible role of ICS through its health impact and costs, two separate analyses have been undertaken. Firstly, ICS has been analysed as a possible fuel-technology option to understand its health impacts and costs. Secondly, ICS has been analysed as a possible bridge fuel towards full adoption of modern fuels by analysing its impact on stacking. Appendix C.2 describes the estimation of the health impacts of ICS and the methodology of the analysis in detail.

5.1   ICS as a fuel-technology option

An ICS-based variant of the Multi-Fuel scenario (called the ICS scenario) has been developed in which it is assumed that a portion of solid fuel users of the Multi-Fuel scenario use ICS instead, and also that a portion of the modern fuel users use ICS because modern fuels are not as affordable or accessible. Thus, in the ICS scenario, the number of modern fuel users and biomass users are both lower than the Multi-Fuel scenario with the gap being filled by ICS users.

In the ICS scenario, ICS penetrations are assumed to increase from 0% in 2015 to 17% in 2030 in rural areas. As a result, LPG penetration in rural areas reaches only 59% in 2030 (as against 65% in the Multi-Fuel scenario) and its national penetration is only about 65% in 2030 (as against 69% in the Multi-Fuel scenario). Similarly, the rural penetration of biomass in 2030 is only 16% as against 22% in the Multi-Fuel scenario. The penetrations of PNG, biogas, and electricity are marginally lower in the ICS scenario as compared to the Multi-Fuel scenario.

Aggregated over 2019–30, the ICS scenario averts 20% fewer DALYs than the Multi-Fuel scenario, in spite of its having fewer solid fuel users than the Multi-Fuel scenario (Figure 15). Thus, about 20% of the health benefits gained in the Multi-Fuel scenario are lost in the ICS scenario. The much greater efficiency of ICS compared to traditional biomass stoves means that the overall costs of the ICS scenario are lower than the Multi-Fuel scenario, since much lesser fuel is required for ICS than traditional stoves. Costs in ICS scenario are lower than the Multi-Fuel scenario in spite of the unit price of pellets used in ICS being significantly higher than that of purchased biomass and ICS itself incurring a higher cost compared to traditional stoves. However, given the considerably poorer health outcomes of the ICS scenario, ICS cannot be a lasting solution unless an ICS is developed with emissions comparable to modern fuels and stoves.

Figure 15: aDALYs of the ICS Scenario compared to Multi-Fuel Scenario
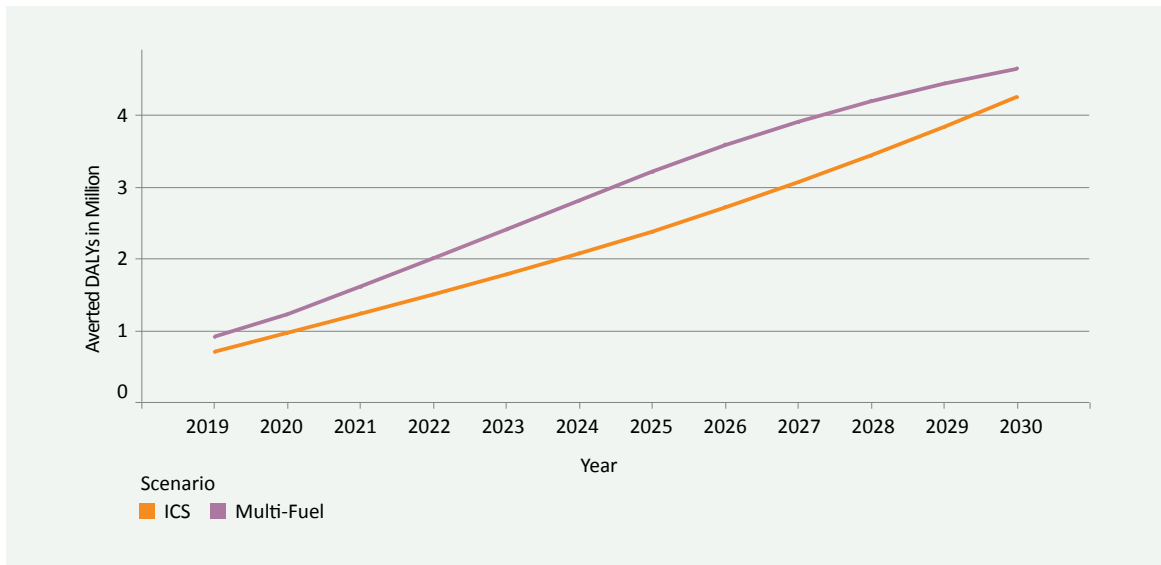

5.2   ICS as a bridge fuel

On the other hand, the analysis of ICS as a bridge fuel shows that it may have a role to play during the transition process to a modern fuel. The role of ICS as a bridge fuel is analysed in two ways to test the nearly maximal usage of ICS as a stacking option: when solid fuel using households stack with ICS and when modern fuel using households stack with ICS. Once again, the Multi-Fuel scenario is used as the basis for this analysis. In the first case, 40% of households using biomass in the Multi-Fuel scenario stack with ICS for 40% of their cooking needs, and in the second, 40% of households using LPG in the Multi-Fuel scenario stack with ICS for 40% of their cooking needs. The health impacts of these ICS stacking cases are then compared with the original Multi-Fuel scenario without stacking.

As expected, when biomass using households stack with ICS, the health outcomes improve, while they worsen when modern fuel using households stack with ICS. As can be seen in Figure 16, there is a reduction in attributable DALYs by about 4% when solid fuel users stack with ICS, while attributable DALYs increase by 23% when modern fuel users stack with ICS. Thus, while ICS can be a bridge fuel, it is important that once households shift to modern fuels, they use them exclusively because the gain in health benefits when solid fuel users stack with ICS is considerably lower than the loss in health benefit when modern fuel users stack with ICS.

Stacking solid fuels with ICS is also cheaper than using solid fuels exclusively because of improved efficiencies, thus making ICS a cost effective intermediate solution in the transition to modern fuels. However, since the efficiency and health benefits of ICS are contingent upon the right quality and kind of fuel (pellets, in the case of the ICS tier-4 stove considered in this analysis), having a reliable and affordable fuel supply chain is as important for ICS as modern fuels. The Tier 4 stove considered in this analysis comes with a small battery pack (for the forced draft fan) which requires regular charging.[15]

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15.   The cost and energy calculations in CEFTI do not include the cost of charging the stove's battery since this is expected to be miniscule.

Figure 16: Attributable DALYs in the Multi-Fuel Scenario
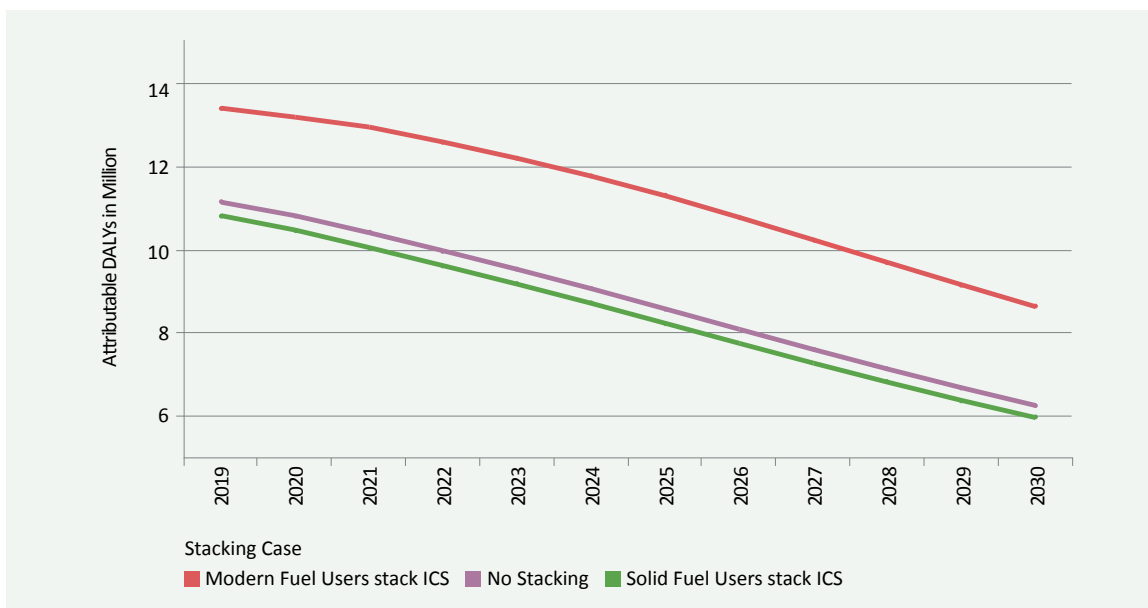
Stacking Cases: 1) Modern fuel users in the Multi-Fuel scenario stacking with ICS.
2) 'No stacking' stands for the original Multi-Fuel scenario from the main analysis where solid and modern fuels users do no stack with ICS.
3) Solid fuel users in the Multi-Fuel scenario stacking with ICS.

The relative health implications of ICS vis-à-vis modern fuels and solid fuels implies that currently available ICS is not a viable option as a lasting solution but has a potential role to play as a bridge fuel in the transition to modern fuels in households that may find a complete shift to modern fuels unaffordable or inconvenient. However, since the loss in health benefits due to using ICS instead of modern fuel is significantly greater than the gain in health benefit due to replacing biomass with ICS, it is important to ensure that households that shift to modern fuels eventually use only modern fuel for all their needs.

6 : Limitations

Many of the limitations of the current work are due to a lack of appropriate India-specific data, which has required the use of either international values or some suitable assumptions. Examples of such India specific data include the amount of useful energy required for cooking at the disaggregated level (accounting for regional and cultural variations), disease burden projections, long-term fuel price projections, Revised population projections, emission rates of biomass and coal combustion, parameters for single-zone model of an Indian kitchen- accounting for differences in room ventilation and kitchen area location across the country, IER curves and lag studies for disease risk due to HAP, and field performance data about tier-4 ICS. In all the above cases, we have used values from international literature. It is possible that a household switching to a modern fuel might return to using traditional fuels, but there is limited nationwide disaggregated data on this scenario and can be part of future improvements to the model. As and when better data and research findings become available, they can be incorporated into the model to make the analysis more robust.

The scenarios have been developed based on broad plausible storylines. In particular, scenario penetrations have not been derived from analyses of price elasticities, elasticity of fuel substitution, affordability, availability of alternatives, stacking behaviour, new stove adoption behaviour and so on. This is again due to a lack of sufficient information on these aspects. However, we believe that the developed scenarios have been crafted to cover a range of possibilities and hence the range of possible costs and health impacts. All results have been tested using a sensitivity analysis to ensure that the primary results do not get invalidated by changing the input assumptions. This further reinforces the robustness of our findings.

The analysis does not incorporate all costs and health benefits of a cooking fuel transition. Thus, costs do not include health costs due to morbidity and mortality (hospitalisation costs, out of pocket expenses, treatment costs, etc.), policy implementation costs and transaction costs. Similarly, health impacts such as those arising due to kerosene use and from diseases such as cataract are not considered. These have not been incorporated into CEFTI because of a lack of reliable data or research on them. Benefits other than health benefits have not been considered in the analysis either because of insufficient data and research to be able to quantify them. Adding these elements to the analysis would undoubtedly change some of the results of the analysis. However, we believe they are unlikely to change the fundamental findings or insights obtained from the analysis.

In some parts of the country and in some months of the year, solid fuels are also used for space and water heating purposes. Our analysis does not incorporate the health effects of such uses, which could reduce the gains in health benefits from the transition only for cooking use. However, since this is a localised practice for a few months of the year, we believe that incorporating this aspect would not affect the broader findings of this study.

7 : Way Forward

The fundamental message that comes through the analysis is that prioritising an aggressive shift away from traditional cooking fuels to modern fuels is very necessary to address not only clean energy access but also the associated health and gender challenges. The analysis also indicates that such an aggressive shift will not be very costly to the economy. The following are some policy-relevant insights that emerge from the analysis.

1. **Focusing on complete modern fuel uptake, not just connections:** India's ambitious PMUY programme is a good beginning to prioritise uptake of modern fuels. However, this programme and others like it would be truly successful only if they succeed in shifting households away from using traditional fuels to modern fuels completely, rather than households merely having LPG, PNG, biogas, or electricity connections. This would require significant improvement in affordability and reliability of supply of modern fuels, including supply of adequate feed for biogas plants.

2. **Impact of stacking:** The analysis of the implications of households stacking with solid fuels clearly shows that much of the potential benefits of shifting to a modern fuel are not realised with only a partial transition. This calls for policy measures to not only ensure a transition to modern fuel adoption but a complete transition to modern fuels over time.

3. **Role of ICS as an intermediary fuel:** Improved cookstoves cannot be a replacement for modern fuels but can play a significant role during the transition. The push for increased improved cookstove uptake can reduce the impact of biomass use and thus can also reduce the impact of biomass stacking. Among the ICS options available, the stove that has the lowest emissions and therefore the least health impact should be promoted. However, promotion of ICS will require creation of retail markets for stoves and biomass pellets.

4. **Consumer fuel pricing:** Fuel price is by far the largest component of the total cost of using modern fuels for cooking. Therefore, consumer fuel pricing would be a very important factor in the uptake and continued use of modern fuels, calling for a well-designed pricing regime and delivery mechanisms/networks along with targeted and increased fuel subsidies to the needy.

5. **Need for careful planning:** Though LPG may typically be the 'first' modern fuel most Indian households would adopt, they may switch to other modern fuel options as they become available, convenient and affordable. For example, it is quite likely that the development of dung markets in rural areas could bring down the cost of biogas and increase investments. This coupled with policy interventions, new technological and business models and scaling up could increase the adoption of cheaper community based plants. This is most obvious in the SDG scenario's LPG consumption, which peaks as early as 2019 in urban areas and around 2024 in rural areas. This suggests that future investments, particularly for LPG, need to be carefully planned, particularly in urban areas of some states. Having said that, most initial investments, especially network investments in rural areas of relatively 'less developed' states, will definitely be very beneficial. Investments in electricity distribution should also factor in a potential increase in peak demand due to cooking, and newly electrified households demanding more than the normative demand of 250W–500W, which is the current assumption for network expansion or strengthening activities.

6. **Need for multi-pronged strategy:** A strategy that is multi-pronged and customised to state-specific situations is likely to be more cost-effective and yield better health benefits. This calls for not only promotion of multiple possible cooking fuel options, but also tailoring them to specific contexts and fostering the right environment, such as enabling the development of appropriate markets and choices. Since modern fuel promotion is also a health and gender intervention, agencies involved in such initiatives could also have an important role to play. It would also require engaging with multiple agencies at the state level, since a one-size-fits-all solution is unlikely to work in a country as diverse as India with different resource and infrastructure availability across states. Therefore, a strategy with greater role for other central government agencies such as the Ministry of Health and Family Welfare and the Ministry of Women and Child Development, and respective state governments would be more effective than a top-down single-ministry initiative. A national clean cooking mission could enable such concerted and collaborative efforts to accelerate the transition.

7. **Investing in R&D:** Investments could focus on scaling up manufacturing of new technologies and fostering new and innovative business models catering to the realities in rural India especially to promote community-based biogas systems. From a long-term point of view, the government may consider investing in R&D programmes to develop alternative, sustainable and as-clean-as-modern-fuel technologies, fuels such as biogas from non-dung sources, solar cooking and improved ICS, tailored to the Indian situation. This can be promoted through government scientific institutions or other established research laboratories in the country.

If India can develop policies and programmes factoring in these aspects, it can overcome one of its most serious energy access problems while addressing some of its most serious health challenges and empowering women and girls of the country, thus targeting many developmental goals simultaneously.

8 : References

ABE. (1985, May). Towards a perspective on energy demand and supply in India 2004-05. *Report of the Advisory Board of Energy*. Government of India.

Burnett, R., Pope , A., Ezzati, M., Olives, C., Lim, S. S., Mehta, S., et al. (2014, April). *An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure.* Retrieved May 8, 2017, from Environmental Health Perspectives: https://ehp.niehs.nih.gov/1307049/#r14

CEEW. (2015). *Access to clean cooking energy and electricity.*

Census. (2006, May). Report of the technical group on population projections constituted by the national commission on population. New Delhi: Office of the registrar general and census commissioner.

Census. (2011). *Household Level Indicators.* New Delhi: Census of India.

Central Electricity Authority. (2017). *19th Electric Power Survey of India.* New Delhi: Central Electricity Authority.

CSO. (2012). *Item-wise details for consumer price index.* Retrieved May 5, 2017, from Consumer Price Indices Warehouse: http://164.100.34.62:8080/AllIndia_Item_CombinedInflation_2012.aspx

Desai, S., & Vanneman, R. (2016). *India Human Development Survey -II (IHDS-II) 2011-12.* Ann Arbor MI: ICPSR36151-v5.

Desai, S., Dubey, A., Joshi, B., Sen, M., Shariff, A., & Vanneman, R. (2010). *Human Development in India: Challenges for a Society in Transition.* Oxford University Press.

Habib, G., Venkataraman, C., Shrivastava, M., Banerjee, R., Stehr, J. W., & Dickerson, R. R. (2004). New methodology for estimating biofuel consumption for cooking: Atmospheric emissions of black carbon and sulfur dioxide from India. *Global Biogeochemical Cycles, 18*(3).

ICMR, PHFI, IHME. (2017). *India: Health of the Nation's States - the India state-level disease burden initiative.*

IHME. (2017). *GBD Compare | Viz Hub.* Retrieved January 23, 2018, from https://vizhub.healthdata.org/gbd-compare/

IIASA. (2017). *Greenhouse Gas Air Pollution Interaction and Synergies*. Retrieved May 3, 2017, from http://gains.iiasa.ac.at/models/

IIT Bombay, HEI, IHME. (2018). *Burden of Disease Attributable to Major Air Pollution Sources in India.*

IMF. (2017, April 3). *Real GDP Growth.* Retrieved May 8, 2017, from World Economic Outlook Historical Forecast data: https://www.imf.org/external/pubs/ft/weo/data/WEOhistorical.xlsx

Jeuland, M., & Pattanayak, S. K. (2012). Benefits and Costs of Improved Cookstoves: Assessing the implications of health, forest and climate impacts. *PLoS One*.

Johnson, M., Edwards, R., Morawska, L., & Smith, K. R. (2014, November 11). *Review 3: Model for linking household energy use with indoor air quality.* Retrieved May 5, 2017, from WHO Indoor Air Quality Guidelines: Household Fuel Combustion: http://www.who.int/indoorair/guidelines/hhfc/Review_3.pdf?ua=1

Kishore, V. V., & Ramana, P. (2002). Improved cookstoves in rural India: how improved are they? A critique of the perceived benefits from the National Programme on Improved Chulhas (NPIC). *Energy*, 47-63.

Lam, N., Smith , K., Gauthier, A., & Bates, M. N. (2012). *Kerosene: A review of household uses and their hazards in low- and middle-income countries.* Retrieved April 28, 2017, from Journal of toxicology and environmental health Part B, Critical reviews.: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3664014/

Lamichhane, P., Sharma, A., & Mahal, A. (2017). Impact of cleaner fuel use and improved stoves on acute respiratory infections: evidence from India. *International Health*, 349-366.

Malla, S., & Timilsina, G. R. (2014). *Household Cooking Fuel Choice and Adoption of Improved Cookstoves in Developing Countries: A Review.* Policy Research Working Paper 6903, The World Bank, Development Research Group, Environment and Energy Team.

Marseille, E., Larson, B. A., Kazi, D. S., & Rosen, S. (2015, February). *Thresholds for the cost–effectiveness of interventions: Alternative approaches.* Retrieved May 8, 2017, from Bulletin of the World Health Organisation: https://www.researchgate.net/publication/275050415_Thresholds_for_the_cost-effectiveness_of_interventions_Alternative_approaches

Mathers, C. D., & Loncar, D. (2006, November). *Projections of Global Mortality and Burdenof Disease from 2002 to 2030.* Retrieved May 5, 2017, from PLOS Medicine: http://journals.plos.org/plosmedicine/article/file?id=10.1371/journal.pmed.0030442&type=printable

Ministry of Petroleum and Natural Gas. (2017). *Indian Petroleum and Naural Gas Statistics 2016-17.*

MoHFW. (2015). *Report of the Steering Committee on Air Pollution and Health Related Issues.* New Delhi: Ministry of Health and Family Welfare.

Ochir, C., & Smith, K. (2014, July). *Air Pollution and Health in Ulaan Bataar.* Retrieved May 8, 2017, from Prepared for the Ministry of Environment and Green Development, Ulaan Baatar, Mongolia: http://ehsdiv.sph.berkeley.edu/krsmith/publications/2014/UB%20Final%20Report%20-%20July%2010.pdf

Pachauri, S., van Ruijven, B. J., Riahi, K., van Vuuren, D. P., Brew-Hammond, A., & Nakicenovic, N. (2013). Pathways to achieve universal household access to modern energy by 2030. *Environmental Research Letters, 8*(2).

Patel, S., Khandelwal, A., Leavey, A., & Biswas, P. (2016). A model for cost-benefit analysis of cooking fuel alternatives from a rural Indian household perspective. *Renewable and Sustainable Energy Reviews*, 291-302.

PIB. (2016a, March 10). *Cabinet approves Pradhan Mantri Ujjwala Yojana - Scheme for Providing Free LPG connections to Women from BPL Households.* Retrieved March 28, 2016, from Press Information Bureau: http://pib.nic.in/newsite/PrintRelease.aspx?relid=137647

PIB. (2016b, Feb 26). *Sustainable Development Goal*. Retrieved Aug 2, 2017, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=136880

Pillarisetti, A., & Smith, K. (2017). *Household Air Pollution Intervention Tool*. Retrieved May 3, 2017, from https://hapit.shinyapps.io/HAPIT/

Practical Action Consulting. (2015). *Gender and Livelihoods Impacts of Clean Cookstoves in South Asia.* Global alliance for clean cookstoves.

Rosenthal, J., Quinn, A., Grieshop, A. P., Pillarisetti, A., & Glass, R. I. (2017). Clean cooking and the SDGs: Integrated analytical approaches to guide energy interventions for health and environment goals. *Energy for Sustainable Development*, 152-159.

Sanga, G. A., & Jannuzzi, G. D. (2005, September). *Impacts of efficient stoves and cooking fuel substitution in family expenditures of urban households in Dar es Salaam, Tanzania.* Retrieved March 7, 2018, from International Energy Initiative, Latin America: http://www.iei-brasil.org/pdf/e-d-paper-no-2590105.pdf

Smith, K. R., & Sagar, A. D. (2014). Making the Clean Available: Escaping India's Chulha Trap. *Energy Policy*, 410-414.

Smith, K. R., Bruce, N., Balakrishnan, K. R., Adair-Rohani, H., Balmes, J., Chafe, Z., et al. (2014, March). *Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution.* Retrieved May 8, 2017, from Annual Reviews: Public Health: http://www.annualreviews.org/doi/full/10.1146/annurev-publhealth-032013-182356?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub%3Dpubmed&

U.S. Environmental Protection Agency. (2010). *Final Regulatory Impact Analysis (RIA) for the SO2 National Ambient Air Quality Standards (NAAQS).*

United Nations, D. o. (2015). *World Population Prospects: The 2015 Revision, Population projections.* Retrieved September 13, 2016, from United Nations Department of Economic and Social Affairs: https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20(Standard)/ASCII_FILES/WPP2015_DB02_Populations_Annual.zip

Vashist, P, Talwar, B., Gogoi, M., Maraini, G., Camparini, M., Ravindran, R. D., et al. (2011, February). *Prevalence of Cataract in an Older Population in India: The India Study of Age related eye disease.* Retrieved January 16, 2018, from Ophthalmology: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3146699/

Venkatraman, C., D., S. A., Habib, G., Lam, N., & Smith, K. R. (2010). The Indian National Initiative for Advanced Biomass Cookstoves: The benefits of clean combustion. *Energy for Sustainable Development, 14*, 63-72.

WHO. (2001). *Macroeconomics and Health: Investing in Health for Economic Development.* Retrieved May 8, 2017, from Report of the Commission on Macroeconomics and Health chaired by Jeffery D. Sachs: http://www1.worldbank.org/publicsector/pe/PEAMMarch2005/CMHReport.pdf

WHO. (2014). *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion.* Retrieved May 5, 2017, from World Health Organisation: http://apps.who.int/iris/bitstream/10665/141496/1/9789241548885_eng.pdf

World Bank. (2015, October 25). *World Bank Commodities Price Forecast.* Retrieved May 5, 2017, from World Bank: http://pubdocs.worldbank.org/pubdocs/publicdoc/2015/10/966751445286237369/CMO-Oct-2015-Historical-Forecasts.pdf

9. List of Abbreviations

aDALYs	Averted DALYs
ALRI	Acute Lower Respiratory Infection
AP	Andhra Pradesh
CD	Cerebrovascular Disease
CEFTI	Cost-Effectiveness of Fuel Transitions in India
COPD	Chronic Obstructive Pulmonary Disease
CPI	Consumer Price Index
CSO	Central Statistical Organisation
CSS	24 hour Steady-State Concentration of $PM_{2.5}$
DALY	Disability-Adjusted Life Year
GBD	Global Burden of Disease
GW	Gigawatt
HAP	Household Air Pollution
HP	Himachal Pradesh
HS	Haemorrhagic Stroke
ICS	Improved biomass cookstove
IER	Integrated Exposure Response
IHD	Ischemic Heart Disease
LC	Lung Cancer
LPG	Liquefied Petroleum Gas
LRI	Lower Respiratory Infection
MJ	Megajoules
MMBTU	Metric Million British Thermal Unit
MoHFW	Ministry of Health and Family Welfare
MP	Madhya Pradesh
MT	Million Tonnes
NSSO	National Sample Survey Organisation
ORGI	Office of the Registrar General and Census Commissioner of India
PAF	Population Attributable Fraction
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter with diameter equal to or less than 2.5 microns
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped Natural Gas
PPAC	Petroleum Planning and Analysis Cell
RR	Relative Risk
SDG	Sustainable Development Goal
SEAR	South-East Asian Region
SF	Solid Fuel
SFU	Solid Fuel Use
TN	Tamil Nadu
TWh	Terawatt-hour
UP	Uttar Pradesh
WHO	World Health Organisation

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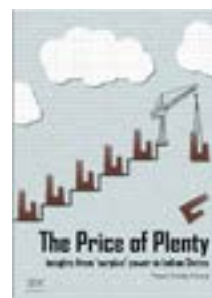

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सह तारुण्यभान

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It is estimated that more than half of the Indian households use solid fuels for cooking even in 2018. This is not only an important energy access problem but also one with very adverse health impacts. Household air pollution arising from burning solid fuels for cooking is one of the leading contributors to mortality and disease burden in India. At the same time, India is committed to achieving the Sustainable Development Goals which includes providing clean, modern fuels to all by 2030. The government has launched the Pradhan Mantri Ujjwala Yojana to distribute subsidised LPG connections to poor households.

In this context, we model and analyse four possible transition scenarios to modern cooking fuels and technologies, which shows that transition to modern fuel-technologies is a very cost-effective health intervention. The most aggressive transition involving a mix of modern fuels not only reduces the disease burden associated with cooking by more than half, but is also the most cost-effective. But if households do not shift to modern fuels completely, the analysis shows that stacking of solid fuels with modern fuels significantly erodes the health benefit of modern fuels. In order to help complete modern fuel adoption, consumer fuel pricing and targeted subsidies for poor households are necessary as fuel costs dominate the financial costs of the transition. The analysis also considers improved biomass cookstoves and concludes that the adverse health impacts from using even the best-in-class improved cookstoves are non-trivial. However, given their greater efficiency and lower emissions in comparison to traditional stoves, they can potentially be an intermediate technology in the shift to modern fuels.

The cooking fuel access problem is a multi-dimensional problem. Therefore, if India wants to rapidly fuel the transition to modern fuels, the solution should also be multi-dimensional and involve multiple fuels, stakeholders and strategies.

प्रयास

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न