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LETTER

Kerosene subsidies for household lighting in India: what are the impacts?

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Abstract

Kerosene subsidy reform is a key policy concern in India and other developing countries. As kerosene is widely used for lighting in India, any price change will likely have considerable public welfare impacts on the large fraction of the poor who do not have access to reliable electricity supply for lighting. In this study, we assess historic kerosene use for residential lighting across population groups separated by urban/rural, expenditure, and electricity service levels using data from India. Consumption trends are used to inform a service demand model and evaluate how changes in fuel price, electricity connection, and supply reliability influence environmental, health and economic outcomes. We find that users relying on kerosene for supplemental lighting—in combination ('stacked') with electricity—accounted for 64% of residential kerosene consumed for lighting in 2005. Tested scenarios that addressed service needs of supplemental users had the greatest welfare benefits, especially in the future. Scenarios reducing $PM_{2.5}$ emissions from kerosene lighting can avert between 50 and 300 thousand disability adjusted life years relative to a baseline scenario in 2030. Lighting kerosene is highly price sensitive, resulting in a drop in demand of 97% in a scenario in which current subsidies are phased out by 2030. Deadweight loss of the subsidy in 2005 is estimated at \$200–950 million, with three quarters attributable to supplemental kerosene lighting. Support for cleaner lighting technologies not reliant on fossil fuel subsidies would appear to be 'no regrets' or 'co-benefits' options for India, and could be implemented in parallel with subsidy removal.

Introduction

Many low- and medium-income countries subsidize kerosene with the intent of providing modern cooking and lighting services to poor households. Such subsidies have come under heavy criticism on economic grounds because of the often heavy financial burden on governments and because subsidizing kerosene directly is not an efficient way to reach the poor [1, 2]. Often heavily encouraged by international financial organizations, there have been attempts by governments to reduce kerosene subsidies that have sometimes had to be reversed because of domestic political difficulties due to heavy public resistance [3]. This illustrates a major problem with untargeted subsidies—they are difficult to take away. In addition, because of its similarity to diesel, with which it can be mixed, subsidized kerosene is often diverted away from its intended recipients into other sectors [2]. This is a significant reason why the Government of India recently announced placing kerosene under its direct benefit transfer scheme [4]. Despite the good intent of such subsidy programs, the inefficiencies due to poor targeting and diversion severely limit their effectiveness [5], and likely do not promote the best or most cost-effective solution given the increased availability of more efficient fuels and technologies for delivering the same (or better) level of service even in areas with poor electricity coverage, such as liquefied petroleum gas (LPG) and solar lamps [6–8].

In recent years, it has become recognized that kerosene subsidies pose other problems as well due to the increased use they encourage. Evidence is accumulating that whether used as a cooking or lighting fuel, air pollution emissions from simple kerosene-fueled devices pose significant health risks, possibly greater on a per-mass basis than biomass smoke [9]. In addition, kerosene lighting is now understood to be a significant source of black carbon (BC) emissions—an important climate-altering pollutant—in several parts of the world including South Asia [10]. Finally, with the rise of concern about fossil CO_2 emissions, there is growing criticism of subsidies for any fossil fuel [11].

The most successful elimination of kerosene subsidies in recent history was in Indonesia where in just a few years starting in 2007, kerosene subsidies were phased out while slightly increasing LPG subsidies as well as instituting a range of other facilitating actions. The result was a massive shift from kerosene to LPG for cooking apparently saving the Indonesian treasury billions of dollars in net subsidy each year, increasing the efficiency and convenience and lowering the cost of cooking for tens of millions of households [12].

The largest use of subsidized kerosene in the world is in India where there have been calls to follow the Indonesian example to relieve the approximate USD 5 billion [4] subsidy burden on the taxpayer each year, as well as achieve other benefits [13]. Unfortunately, however, the kerosene situation in India is quite different in that, unlike Indonesia, most kerosene is used for lighting not cooking. Thus reducing kerosene subsidies could potentially have considerable public welfare impacts on the large fraction of the poor who do not have access to reliable electricity supply. Indonesian households, on the other hand, were more than 90% electrified at the start of their switch out of kerosene.

Thus, to facilitate a shift from kerosene to cleaner and more efficient alternatives in India, and potentially elsewhere, requires a detailed understanding of its role in lighting, which is the purpose of this paper.

Kerosene as a lighting fuel

Achieving adequate household illumination challenges many families in India as well as other developing countries. An estimated 1.2 billion people lacked access to electricity in 2010 [14], while likely many more experienced frequent supply interruptions. In the absence of electricity, homes frequently turn to fuel-based light sources for illuminating their homes and businesses [15]. Often encouraged by government subsidies, kerosene-fueled lamps are a common light source,—used by 380 million in India in 2011 for *primary* lighting [16], not including those reliant on it for backup light. The most economically accessible and widely used kerosene lamps provide poor illumination relative to electricity and can be highly inefficient [17], converting as much as a tenth of the fuel carbon to health-impacting and climate-altering particulate matter (PM) [10]. Even after electricity connections are achieved, households may continue to rely on kerosene or other inefficient light sources, such as candles, for some years [18].

Lack of residential lighting is recognized as a household energy problem; however, compared to studies of cooking, few efforts have quantified the potential impacts or benefits of kerosene replacement. Consequently, lighting activities are often absent from health and climate assessments that discuss improvements to the ‘household’ sector. Factors linked to residential lighting, particularly electricity [7] and access to cleaner petroleum-based fuels [8], however, may influence other energy activities which co-exist in the same household energy system. By strengthening the understanding of individual system components, it may be possible to improve the effectiveness of future residential energy programs.

This study aims to improve the understanding of welfare impacts resulting from the most widely used fuel-based lighting source globally—kerosene—and to begin to estimate the potential impacts of efforts to reduce its use. We specifically examine the role of kerosene for supplemental lighting within homes with electricity, and the associated impacts of use in this context in India. This analysis is facilitated by a nationally representative household survey with detailed energy end-use information.

- From an analysis of a nationally representative household survey from 2005, trends in kerosene consumption for lighting are reported in relation to household and energy access characteristics, to examine drivers of use.
- Residential consumption of kerosene for lighting in India is estimated in 2020 and 2030 under a baseline scenario and alternate scenarios that modify the electricity grid connection rate, electricity service reliability (hours of electricity available), kerosene price (subsidization), and use of clean replacement technology.
- Pollutant emissions and adult health burden from outdoor particulate matter ($PM_{2.5}$) exposures are evaluated in 2020 and 2030 under a baseline scenario and alternate scenarios. The economic impact of the kerosene subsidy in 2005 is quantified through its deadweight loss (DWL) and social (external) costs are estimated.

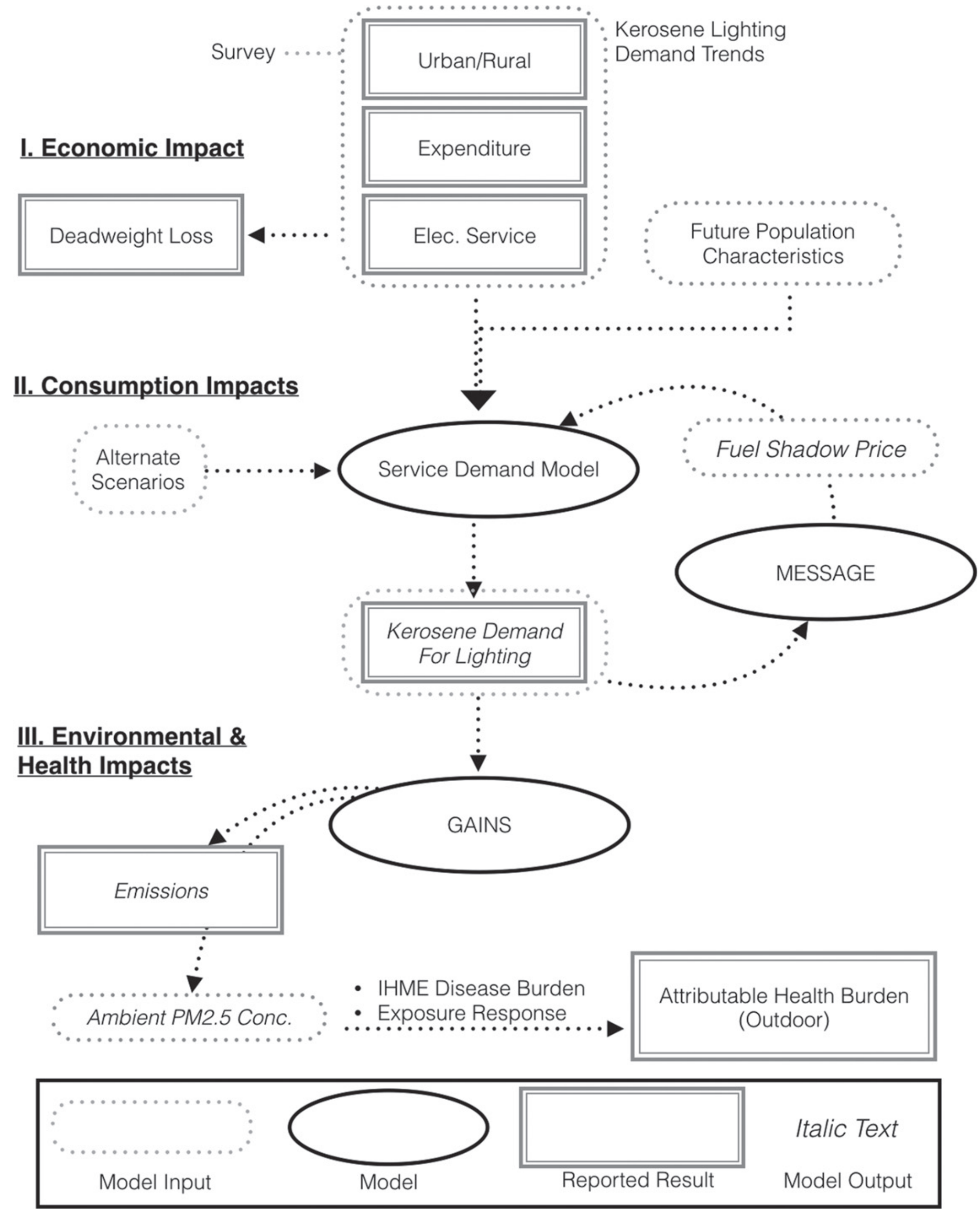

Figure 1. Study workflow.

Methods

Study overview

Figure 1 presents a schematic of the study workflow. An analysis of the India Human Development Survey (IHDS) 2005 [22] was performed to quantify historic consumption of kerosene for lighting and consumption characteristics across heterogeneous household groups. Survey-based trends informed a service demand model for kerosene, which was linked to the widely used integrated assessment model, Model for Energy Supply System Alternatives and their General Environmental Impacts (MESSAGE) [23], to allow for residential demand to be influenced by macro feedbacks from the larger energy system, particularly via energy prices. Alternate future scenarios were used to test the effect of fuel price, electricity connection and electricity supply reliability on future consumption of kerosene for lighting. Pollutant emissions from kerosene lighting and outdoor $PM_{2.5}$ concentrations for calculating changes in health burden were estimated using the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model [24, 25].

Table 1. Baseline and alternate scenarios used to examine future changes and impacts of residential kerosene consumption for lighting services .

Scenario	Abbreviation	Description
Baseline scenario	*Baseline*	No measures taken to increase electricity coverage or improve supply beyond changes associated with growing household income.
Alternate scenarios: reliance on kerosene		
Universal connection	*UC*	Complete electricity connection coverage by 2030, no additional efforts to improve supply.
UC + supply reliability	*UCS*	Universal connection scenario and all houses have more than 16 hrs of supply per day by 2030.
Replacement Technology	*Solar*	All kerosene lighting is replaced by household pico-solar lights by 2030.
Alternate scenarios: kerosene pricing		
Subsidy Phase-out	*SPO*	Linear reduction in the unit subsidy such that residential kerosene is sold at 2030 market prices.
Full subsidy	*FS*	Bounding scenario assuming all residential kerosene at subsidy price after 2005

Survey and base year analysis

The IHDS obtains household expenditure and quantity of kerosene consumed in the previous 30 days, as well as the activity for which it is mainly used, including options of 'combination use' and 'no use'. Information on consumption and activity is collected regardless of the position of kerosene in the household energy hierarchy (e.g. primary, secondary etc), thus providing a measure of 'any use'. We assume that all kerosene use reported is used to meet the specified service or combination of services. 'Primary users' are defined as households without electricity connection using kerosene for any lighting, and 'supplemental users' as having electricity connection, of any service level, using kerosene for any lighting. To facilitate analysis, we disaggregated the population into thirteen groups over three levels: geographic sector (urban or rural), total household expenditure ($/person-year) and electricity service level (no electricity, service less than 16 h d^{-1}, greater than 16 h d^{-1}). The currency used for analysis was purchasing power parity of 2005 ($), unless specified otherwise.

Alternate scenarios and future kerosene consumption

Alternate scenarios were developed to examine the effect of kerosene price, electricity connection rate, and electricity reliability on future (2020, 2030) demand for kerosene as a lighting fuel (table 1). Kerosene demand in the future was adjusted for changes in population size, household income, kerosene price, and their associated feedbacks, based on methods developed for the Global Energy Assessment [26, 27]. We include a replacement scenario (*Solar*) where primary and supplemental kerosene lighting services are entirely replaced by 2030 with clean lighting technology independent of the grid. This technology is assumed here to be pico-solar LED lamps equivalent in price and performance to entry-level devices meeting the Lighting Global Minimum Quality Standards [6, 28], although we recognize that numerous technological options for replacing kerosene exist [6]. Alternate scenario, interventions/actions are assumed to progress linearly after 2005. Further details on alternate scenarios (S1.3) and future demand dynamics (S1.4) are provided in the *SI*.

Impacts

We performed an examination of selected environmental (pollutant emissions), health (health impacts from outdoor $PM_{2.5}$) and economic (DWL) consequences of kerosene lighting in India. Impacts were apportioned between primary and supplemental user groups when possible.

Estimated quantities of kerosene used for lighting services were combined with device stock estimates and emission factors to add domestic lighting as a sector within the GAINS emission inventory for India. As part of GAINS, outdoor concentrations of primary $PM_{2.5}$ are estimated using a source-receptor relationship derived from the TM5 model [29]. All generated emissions are assumed to reach the outdoors.

Changes to kerosene lighting activities on health burden associated with exposure to outdoor $PM_{2.5}$ are reported as the difference between health burden under alternate scenarios and the baseline scenario in 2020 and 2030. Diseases associated with outdoor $PM_{2.5}$ included in the 2010 Global Burden of Disease (GBD) for adults over 24 years [30] are considered and reported in disability adjusted life years (DALYs). Background future disease rate projections are based on historic trends in India, guided by procedures described elsewhere [31]. Disease risk estimates were calculated using nonlinear exposure response functions developed for the 2010 GBD, and used to calculate attributable burden using techniques described and applied elsewhere [31–34]. Exposures occurring indoors are likely an important contributor to kerosene lighting impacts but are not evaluated here. Epidemiological evidence associating health risks with reported kerosene use in the home, or micro-environmental exposures are few [9], and require confirmation before the burden due to indoor exposure can be estimated with confidence.

The past economic impact of kerosene used for lighting in India was estimated by calculating its DWL. DWL is a measure of the economic inefficiency resulting from an imposed change in the price of a commodity away from its natural equilibrium price. Fuel subsidies reduce the price observed by the consumer, resulting in more consumption than would likely occur at a market price (no subsidy). Fossil fuel subsidies are also unique because of the potential for their emissions to impose social (external) costs. We value some of these external costs by calculating the social cost of CO_2 and BC emissions on climate, restricting this to consumption of DWL kerosene. Methods used are informed by those described in [35].

Results

Historic consumption trends in India

In 2005, 64% of kerosene users reported lighting as their main end-use, with cooking reported by 20%, heating 2%, and combination use (assumed cooking and lighting) by 14%. Thirty three percent of all households were classified as primary kerosene lighting users. This is 8% greater than the percent of houses using kerosene as a main lighting source using National Sample Survey Organization (NSSO) data from a similar time period [36, 37]. Adding supplemental lighting users to primary users increases national kerosene lighting user prevalence in 2005 to 61%.

Kerosene consumption for residential lighting was estimated at 4670 Gg (95% CI: 4300, 5100) in 2005, constituting approximately 70% of kerosene used by houses. Rural populations accounted for approximately 70% of total residential kerosene consumption (5000 Gg) and eighty percent (3840 Gg) was consumed for lighting services. By end-use, cooking in urban areas was slightly greater (420 Gg, 51%) than lighting (350 Gg, 43%). Conversely, lighting accounted for 80% (3840 Gg) of residential kerosene use in rural areas (Cooking: 920 Gg, 19%). Heating constituted 2% (160 Gg) of total kerosene use. Assuming average kerosene consumption and lumen efficiencies yields daily household lighting service level of approximately 7–8 h per day and roughly 200 lumen-hours, or two lamps operating 3–4 h each day, approximately.

Supplemental lighting accounted for 64% of kerosene consumed for residential lighting in 2005 (2980 Gg). Consumption by primary users constituted 36% (1690 Gg) of lighting kerosene. In rural areas, 60% (2270 Gg) of lighting kerosene was used for supplemental light, and increased to 85% (710 Gg) in urban areas where electricity connection rates exceeded 90%. Kerosene consumption estimates were within 15% of those derived from NSSO surveys [36, 37].

Kerosene for lighting was observed over all levels of electricity service (figure 2), suggesting that while electricity has the expected effect of reducing kerosene dependency, there exist unmet lighting service needs not addressed through initial grid connections. This is consistent with field observations, suggesting that kerosene is often still relied upon a as mobile light sources and for illuminating rooms without electrical wiring [18].

Figure 3 illustrates trends in rural lighting consumption over per-capita expenditure for three electricity service levels. The trend is approximately lognormal, with consumption increasing with expenditure and plateauing above \$2.00 PC d^{-1}, approximately. The difference in consumption rates and saturation levels across electricity service groups is suggestive of a modifying effect of electricity service on kerosene consumption. Fitted curves in figure 3 suggest that non-electrified households consume more kerosene than electrified houses at similar expenditure levels—although significant overlap occurs below \$1.00 PC d^{-1}. For the two electrified groups, there is an apparent difference above \$2.00 PC d^{-1}, but significant overlap below.

Estimated future demand and impacts under alternate scenarios

Alternate scenarios were tested to examine how changes to dependence on kerosene, resulting from changes to electricity service level, kerosene price and kerosene replacement, could affect kerosene demand and selected downstream welfare impacts. Changes are evaluated in the base year (2005) and 2020, and 2030.

Kerosene demand

Under the baseline scenario (baseline), there is gradual reduction in kerosene consumption for lighting that continues beyond 2030, indicating a continued reliance on non-grid lighting energy for the next decades (figure 4). Universal electricity connection (UC) by 2030 provides a modest 10% reduction in kerosene consumption between 2010 and 2030, relative to the baseline. Complementing UC with better electricity supply reliability (greater than 16 h d^{-1}, UCS) reduces consumption by an additional 20% over the same period. Kerosene reductions due to electricity access are attenuated in the future by an opposing effect of income growth.

The largest deviations from baseline, without assumed replacement of kerosene (*Solar*), result from changes to kerosene price. Between 2005 and 2030, total demand is reduced by 80% from baseline as a result of a steady annual removal of the subsidy (SPO scenario). High price sensitivity has a similarly strong effect under the full subsidy bounding scenario (FS), roughly doubling demand. While the magnitude of changes is sensitive to demand elasticity, overall trends remain similar, with UAS yielding the greatest reduction among the electrification scenarios, and removal of the subsidy yielding the greatest reductions in kerosene overall. High price sensitivity is consistent with findings from a village level pilot study in India, which

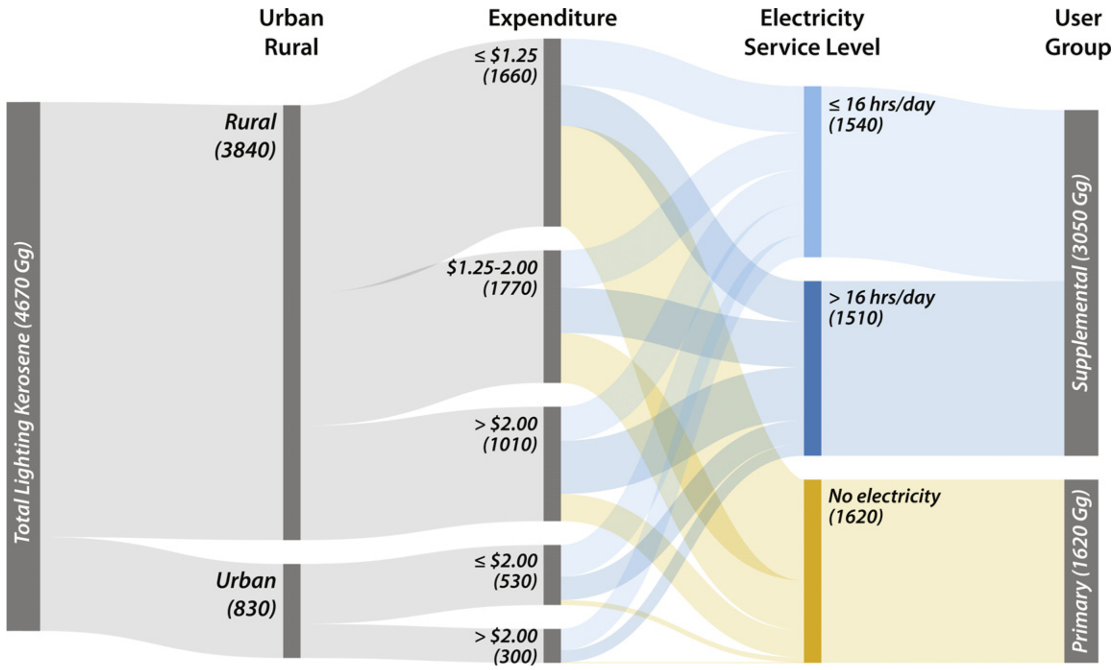

Figure 2. Kerosene used for residential lighting in India (2005) across sub-populations and use as either primary or supplemental lighting.

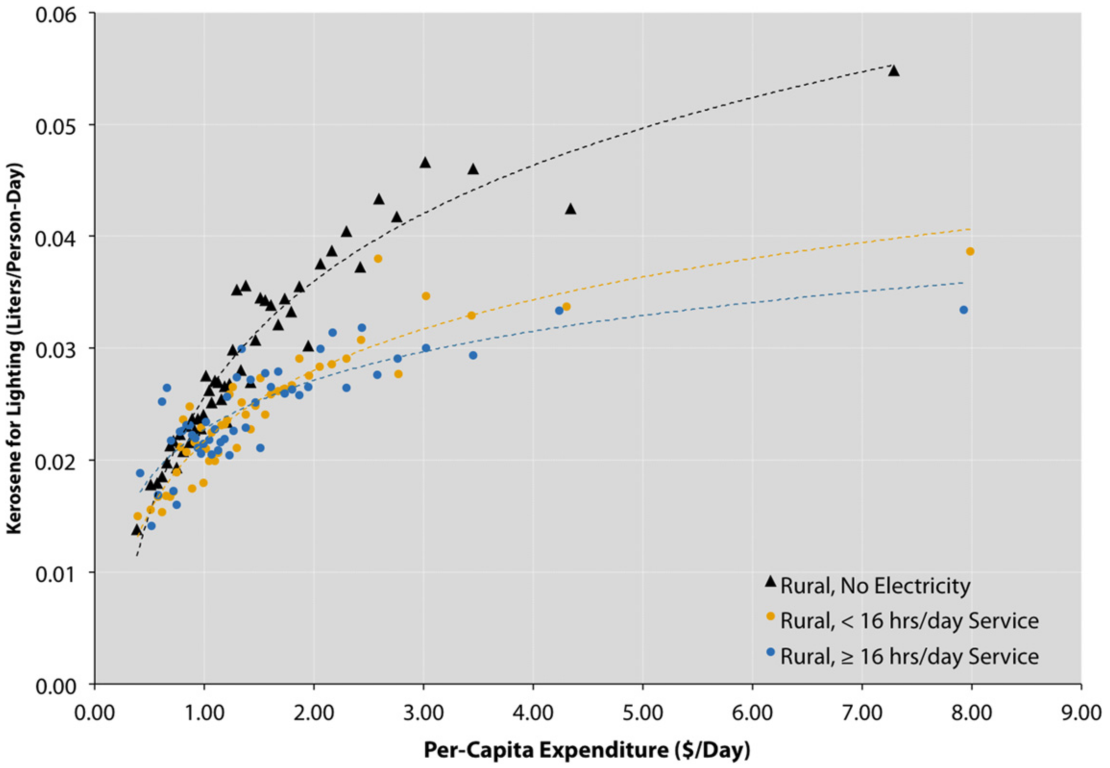

Figure 3. Rural kerosene consumption for lighting (liters/person-day) versus household per-capita expenditure ($/day) among reported users. Values are compressed into 50 expenditure groups for visual clarity and dashed lines represent the lines of best-fit.

measured an 85% reduction in kerosene sales several months after the replacement of the kerosene subsidy with unconditional cash transfers [1]. Previous studies have also found consumption of residential fuels to be highly sensitive to price [38], and for cooking services specifically [39].

Using kerosene demand, we estimated the financial benefit of an effort that would support residential lighting services using pico-solar lighting in place of kerosene. Assuming a steady annual phase-in of pico-solar beginning in 2015–16 and completing in 2030, and continued support (replacement every 5 years),

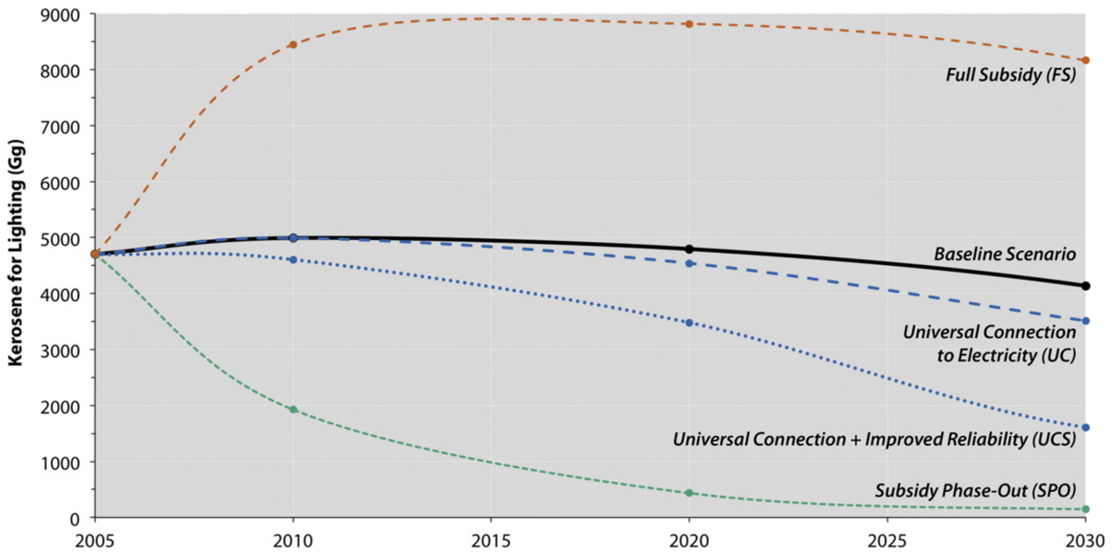

Figure 4. Consumption of kerosene for lighting in 2005 and projected consumption in 2020 and 2030 under the baseline scenario and alternate scenarios that influence electricity connection rates, service levels, and kerosene price.

accrued net present benefits are estimated at \$12 billion. A more rapid transition that is complete by 2020 but is continuously supported through 2030 yields a present value benefit of \$18 billion. These benefits result solely from fuel consumption reductions and do not consider other changes to household welfare or foreign exchange as a result of reduced import of crude oil. For example, we do not consider differences in the quality of service (e.g. lumens) or costs associated with implementation potentially against (e.g. distribution infrastructure) or in favor of (e.g. economy of scale) of the replacement pico-solar devices.

Pollutant emissions and health impacts from outdoor primary $PM_{2.5}$

$PM_{2.5}$ emissions from primary and supplemental use of kerosene for residential lighting in 2005 were estimated at 250 Gg, increasing national $PM_{2.5}$ emissions from all sectors by 3%–4%, using GAINS emission inventories. Particulate emissions are rich in BC (~92% BC), resulting in an increase of 20%–25% compared to not considering kerosene lighting as a source. End-use emissions from cooking and lighting together accounted for 35% of $PM_{2.5}$ emissions and 65% of BC emissions. Co-emitted organic carbon (OC) and sulfur dioxide (SO_2) contributed less than 0.5% to national emissions of either pollutant. The CO_2 emission rate was estimated to be less than one percent of national CO_2 emissions (13 Mt).

Use of kerosene for supplemental lighting accounted for approximately 60% of the $PM_{2.5}$ emissions from this source. Trends in emissions across population groups closely reflected consumption trends, but do not scale proportionally due to differences in lighting device stock efficiencies. Compared to the national average, the fraction of PM emissions attributable to supplemental lighting is greater in urban areas (85%), and lower in rural areas (45%). Under alternate scenarios not assuming complete replacement (Solar scenario), $PM_{2.5}$ emission reductions of 18% (UC) to 96% (SPO) by 2030 are estimated (figure 5).

Mitigation of adult health burden in India due to changes in outdoor $PM_{2.5}$ resulting from reduced kerosene lighting activity are modest (figure 5). The GAINS model aggregates over all anthropogenic emissions of $PM_{2.5}$. Thus, outdoor primary $PM_{2.5}$ burden from kerosene lighting is reported as the difference in DALYs between alternate scenarios and the baseline scenario, and primary or supplemental uses are not differentiated. Improvements to electricity connection and supply reliability are estimated to avert 50–180 thousand DALYs relative to the baseline scenario in 2030, equivalent to approximately 0.3%–1.3% of adult outdoor $PM_{2.5}$ burden. More aggressive reduction pathways acting through pricing (SPO) or replacement (Solar) yield greater reductions of 270–300 thousand DALYs (1.9%–2.1% adult outdoor $PM_{2.5}$ burden).

Economic impacts: DWL and selected social costs

The DWL from subsidization of kerosene lighting was estimated at \$950 million. For comparison, the under-recovery by oil companies in the same year has been estimated at \$3.3 billion [2]. Assuming unit elasticity and linear demand yields a more conservative, lower bound, estimate of \$200 million. Only 20% of DWL was attributed to consumption for primary lighting (non-electrified houses), with the majority of DWL attributed to supplemental lighting services (electrified households).

The social cost of carbon (SCC) emissions acting through climate impacts from DWL kerosene used for lighting was estimated at \$70 million for CO_2, assuming a current social cost of \$32 per ton CO_2. Caution is

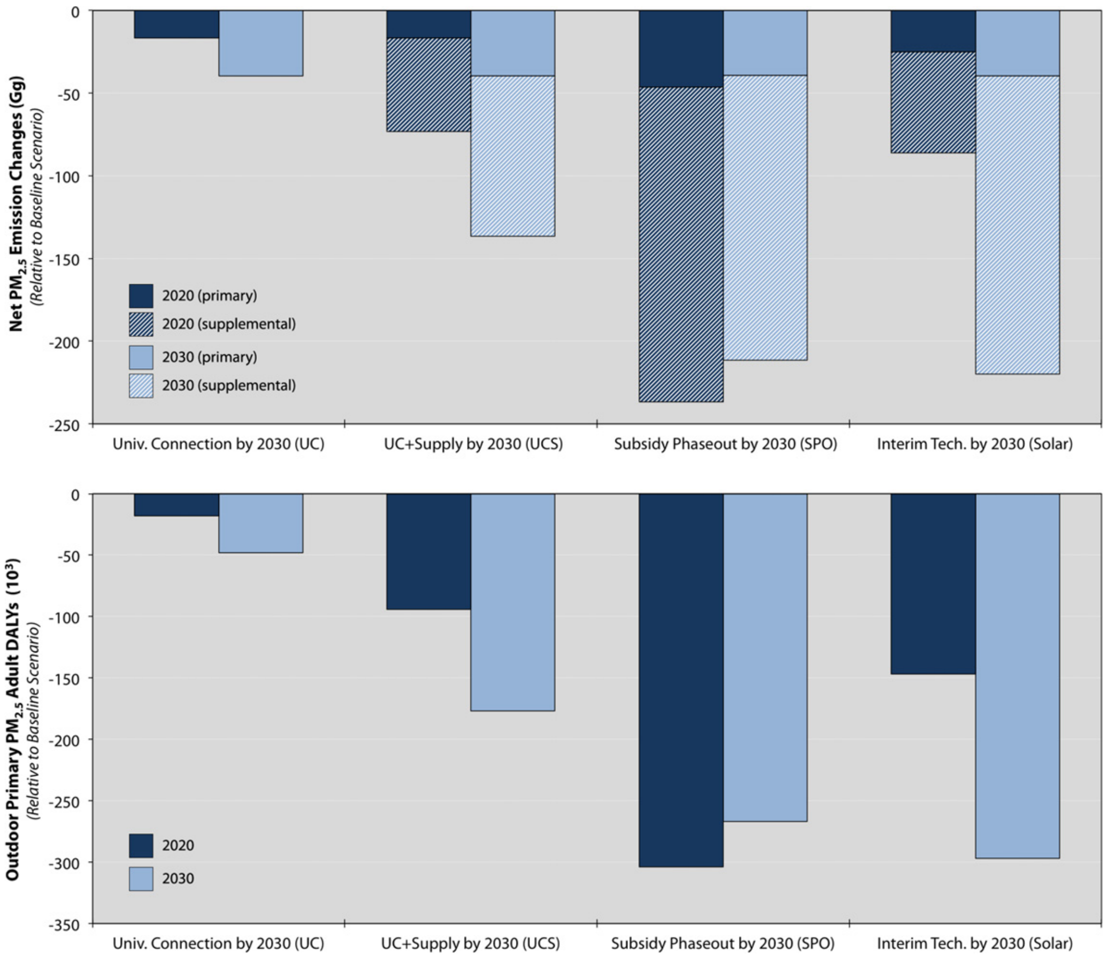

Figure 5. Change in (top) $PM_{2.5}$ emissions and (bottom) adult DALYs from outdoor primary $PM_{2.5}$ exposure relative to the baseline scenario in 2020 (dark bar) and 2030 (light bar) under selected alternate scenarios. The patterned area of $PM_{2.5}$ emission bars corresponds to the component attributable to supplemental lighting. DALYs are not apportioned between primary and supplemental lighting.

warranted in comparing effects of short-lived climate agents like BC with those of longer-lived greenhouse gases. Nevertheless, by applying a conservative CO_2 equivalence of 700 [40], a first approximation of SCC for BC of $850 million is estimated. Further information on DWL and social cost estimates are available in the *SI text* (S2.5).

Discussion

This study is among the first assessments of kerosene lighting characteristics for primary *and* supplemental lighting, and the most comprehensive assessment of associated historic and future welfare impacts. This work will benefit from refinement, but represents a step towards understanding lighting within the household energy system of developing countries as well as benefits of replacement of kerosene subsidies for meeting lighting services.

The use of multiple fuels and technologies to meet similar energy service needs, often termed 'energy stacking', has been observed for residential cooking activities [41, 42], and lighting [43]. Efforts to characterize stacking are often motivated by its attenuation of intervention or energy transition benefits. Few studies, however, have quantified the impacts and opportunities from addressing stacking practices, particularly in the future or for non-cooking services.

The consumption of kerosene for supplemental lighting was approximately equal to the amount consumed for primary lighting (used in houses without electricity). However, characteristics and contributions of supplemental users may be overlooked, as they often are, if only 'main/primary' sources of any household service are measured. Top-down fuel estimates may do a better job capturing total residential fuel use, but then must be disaggregated across end-uses. Providing a better accounting of supplemental fuel use and identifying the services the fuel provides will help to improve and constrain, for example, pollutant inventories used to study household energy policies or mitigation options being considered to reduce air pollution or climate impacts.

Clear differences in kerosene consumption for lighting are observed across groups differing in electricity reliability level, illustrating the general importance of considering this factor. Our scenarios suggest that little change in kerosene demand can be expected till 2030 (less than 10%), if electricity coverage improves, but are not accompanied by better supply reliability or access to affordable kerosene alternatives. In rural areas in particular, we find that while kerosene use reduces as electricity reliability improves, kerosene consumption will persist. This suggests that, in addition to reliability, issues of affordability and latent lighting demand may ensure continued reliance on kerosene and other non-grid light sources. Thus, electrification programs may maximize population benefits by simultaneously increasing financial access to technologies resilient to grid reliability—for example, providing affordable access to solar lamps and chargeable CFL bulbs.

Efforts that simultaneously address primary and supplemental lighting may also carry considerable economic co-benefits. Replacement of kerosene lighting services with one example of currently available technology, pico-solar lamps, in 2015–2016 would yield a present value benefit of approximately $12 billion by 2030. A rapid replacement by 2020, with continued support through 2030, would increase benefits to $18 billion. Although cost-effectiveness of currently available technologies is promising, viability is still contingent upon their affordability and distribution. Annualized costs, for example, mask important distinctions between the cost structure of kerosene and non-fuel-based light sources. Support for innovative financing schemes that convert lump sum upfront costs into a stream of smaller payments more reflective of household income flow may be one solution, but require further evaluation.

While removal of kerosene subsidies would yield major reductions in kerosene demand, as well as economic and environmental benefits, it is unclear whether the net impact to households would be beneficial in the absence of clean and affordable alternatives. In 2005, subsidy DWL in India was estimated at $200–950 million, before considering social costs, with over three quarters attributed to use by electrified houses. In the absence of affordable and clean alternatives to kerosene, however, households may turn to other inefficient energy sources to meet lighting services, or perhaps worse, be left in the dark. Shifting subsidies to clean lighting technologies less vulnerable to diversion and robust to electricity reliability would provide continued support for lighting services in low-income households, while alleviating some of the fiscal burdens of inefficient kerosene subsidies.

We find that reductions in the use of kerosene for lighting would result in modest benefits to outdoor air quality and national disease burden. Reductions to primary outdoor $PM_{2.5}$ resulting from scenarios reducing kerosene use for lighting were estimated to avert between 50 and 300 thousand adult DALYs in 2030. Like effects on kerosene consumption, maximum health benefits were observed under scenarios in which supplemental uses of kerosene for light were reduced. Burden from exposures occurring in the house (indoor air pollution) is not evaluated here and further research is needed to better understand the degree to which kerosene abatement affects exposure and risk in this context.

Limitations

There are several limitations to this study. The analysis here was performed using historical data from India, which may not be representative of all regions relying on kerosene for lighting services. Historical data and trends are based on a cross sectional survey from 2004 to 2005, but represented the most comprehensive data available for a detailed assessment of lighting activities at a national scale and for exploring supplemental lighting. We have focused solely on lighting demand in this analysis, without considering how changes in access to household energy carriers for cooking and other services might impact kerosene demand—and vice versa. This is an important consideration, given that new energy sources could conceivably alter other activities in the home. We also do not consider how a more rapid deployment of decentralized electrification solutions might affect the rate of increase in electricity availability and reliability among rural households and their demand for kerosene. However, a broader analysis of these developments might be an area for future research.

Conclusions

Recent national commissions [44] have called for substantial reduction of kerosene subsidies in India, but have not yet been followed by strong action, perhaps partly because of concerns about the full implications for the country, particularly for the poor. The analysis presented here, however, should provide additional support for such efforts. We have found that there would likely be sizeable benefits of reducing kerosene lighting on population, economic, and environmental welfare in India. Solutions that reduce reliance on fuel based lighting for supplemental, as well as primary uses, may provide the largest overall benefits, especially in the next decade. Even more rapid transitions away from kerosene subsidies than considered in this study will likely accelerate the realization of benefits evaluated here, but should consider how and if lighting services in houses are affected as a result of such transitions. Support for cleaner lighting technologies not reliant on fossil fuel subsidies would appear to be ‘no regrets’ or ‘co-benefits’ options for India, and could be implemented in parallel with subsidy removal, although careful monitoring and evaluation is necessary to verify the effectiveness of any proposed alternative.

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