UNEP

Light for Life:

Identifying and Reducing the Health and Safety Impacts of Fuel-Based Lighting

United Nations Environment Programme

BMZ Federal Ministry for Economic Cooperation and Development

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Contents

1. Summary

The 1.3 billion people around the world who earn approximately one dollar per day pay a much higher percentage of their income for low-grade and polluting fuel-based illumination than people who have regular access to electric lighting. This inequity is compounded by adverse health and safety issues including: burns; indoor air pollution; poisoning due to ingestion of kerosene fuel by children; compromised visual health; maternal health issues; and, reduced service in health facilities illuminated solely or sporadically with fuel-based lighting.

These adverse impacts of fuel-based lighting disproportionately impact women and children. The consequences are tragic. This study compiles and synthesizes information on the health and safety impacts of fuel-based lighting from 112 data sources and 33 countries. It reviews a wide range of information sources, from news stories, reports from the development community and peer-reviewed medical literature. It includes examples from the Economic Community of West African States (ECOWAS), where 178 million people lack access to the electricity grid.

Energy efficient, off-grid lighting solutions offer the most promising and scalable means to eliminate adverse health outcomes associated with fuel-based lighting, while lowering the costs and reducing greenhouse-gas emissions. This study suggests next steps and policy options to improve the lives of people who depend on off-grid lighting services. Policies and programs seeking the greatest possible benefit should target the most impacted geographical and demographic user groups. Improved lighting technologies for use by women and children will yield particularly significant health benefits. Examples include: improved illumination in healthcare facilities; and, safe and efficient lighting systems distributed and promoted where housing is dense and poorly defended from fire and where fuel adulteration is common.

2. Overview

Approximately 1.3 billion people throughout the developing world (one-fifth of humanity), lack access to electricity and rely instead on fuel-based lighting (IEA 2011)[1]. Uncounted businesses also find themselves in the same situation, and additional users on the electric grid face routine outages or energy costs forcing reversion to fuel-based light sources. Today, more people than the world's population at the time Edison introduced electricity, spend nearly USD 40 billion annually (100 times the cost of an equal amount of electric light) to operate highly inefficient and dangerous lamps (Mills 2005). Fuel-based lighting contributes to climate change—which is also a health and safety risk—by releasing substantial amounts of greenhouse-gas emissions (Mills 2005) and black carbon (Lam *et al.,* 2012a). Lighting fuels are burned largely indoors and in close proximity to people, but no corresponding estimates of mortality have been made.

Many fuels are used to generate light, including kerosene[2], propane, candles and bio fuels. Quantifying the health impacts is of critical importance because of the magnitude of people it potentially impacts. Adverse health effects are recognized (Baker and Alstone 2011) but specific data and statistical indicators are rarely used in making the business case for alternatives. Improved information on current risks and potential health benefits of alternatives could also help identify and prioritize policy and market-based initiatives to replace fuel-based lighting with grid- and grid-independent alternatives powered by electricity.

Many households use kerosene for lighting (UNEP 2013). Kerosene is also a primary cooking fuel among approximately four percent of urban populations and two percent of rural populations in less-developed countries (Legros *et al.* 2009).The use of liquid fuels for lighting is not only far more common than as a primary fuel for cooking, and combustion in stoves is far more complete, producing fewer particulate emissions per unit of fuel burned than do lanterns.

The diverse morbidity and mortality risks suggested by the literature include: burns (arising from structure fires as well as explosions from adulteration of kerosene with other fuels); health risks from indoor air pollution; poisoning from non-intentional ingestion of kerosene fuel by children; compromised visibility and visual health; a variety of maternal health issues; and, adverse or suboptimal outcomes in health-service facilities illuminated solely or sporadically with fuel-based light.

Long-lasting, substantial mental and emotional injury may also result from these incidents, adding to costs of medical aid, lost work time and lowered productivity, and replacing lost homes and property. The literature does not systematically address these very crucial impacts that follow the initial acute consequences arising from the off-grid lighting hazard. Disproportionate effects on women and children are illustrated by improved maternal and infant mortality outcomes, and increased infant birth weights when solar-electric lighting is introduced in areas not reached by the grid. Anecdotal reports also suggest reduced sexual violence when sufficient illumination is provided in public areas (Associated Press 2013; UNDP 2012; Peacock 2013).

2.1 Scope and Review Method

Existing documentation of off-grid lighting risks is far more extensive than typically cited in the energy and development literature, yet far less developed and academically rigorous than that of other energy-related risks, such as those from cooking with solid fuels. These include news reports, informal reports and other literature, as well as peer-reviewed scientific papers. As a result, assembling a comprehensive picture of the existing knowledge requires assessing a broad range of sources. The goal here is to gather and categorize the information provided in all relevant sources, rather than to perform a critical review.

The majority of peer-reviewed studies are written by medical professionals analyzing outcomes for patients in individual hospitals. This body of work focuses particularly on burns and ingestion. While this provides a measure of risk prevalence and incidence, it is more often an underestimate, especially in developing countries where many injuries go unreported. On the other hand, only those with more severe injuries are admitted to hospitals. Also, hospital records can attribute lighting to acute impacts, such as injuries (e.g. burns, poisonings), but not to disease from chronic exposures (e.g. air pollution). Nevertheless,

[1] This report builds on Mills (2012).

[2] Common synonyms for kerosene include paraffin, no. 1 oil, coal oil, and lamp oil.

the available literature provides a high-level picture of the diversity of risks and potential for other adverse health impacts that have yet to be formally measured.

This body of literature, paints a detailed picture of specific risks, including: unhealthful indoor air quality, injuries, poisonings, and compromised visual health. Moreover, the low quality of fuel-based illumination has negative impacts the delivery of healthcare in poorly lit facilities. Few prior efforts (Mills 2012; Lam et al 2012b) have been made to synthesize or conduct a meta-analysis of the literature and reported data. This study provides the broadest review to date, in which 112 reports were identified, that contains relevant field data spanning 33 countries (Table 1). Underpinning the summary provided in this report, a database with additional detail and references has been posted online[3].

Table 1. **Summary of reports—examined for this study—on health and safety incidents and impacts related to fuel-based lighting, from sources including books, journals, monographs, news articles and online media**

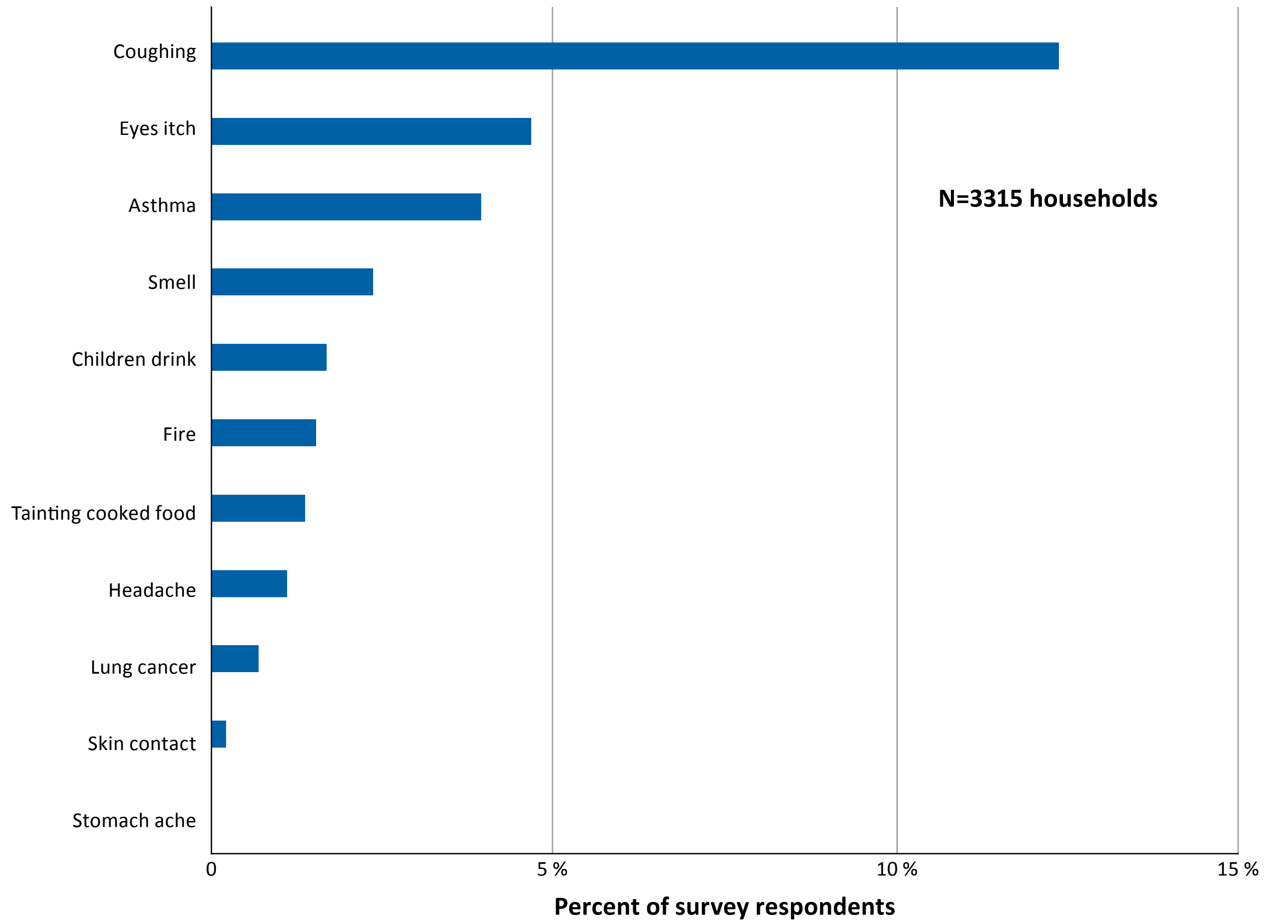
Type of incident or impact	Number of reported incidents or impacts	Number of countries in which each type of incident or impact occurred	Countries in which incidents or impacts occurred
Structure fires	21	10	Bangladesh, China, India, Liberia, Namibia, Nepal, Philippines, Senegal, South Africa, Tanzania
Kerosene burns	18	8	Bangladesh, India, Mozambique, Nepal, Nigeria, South Africa, Sri Lanka, Zimbabwe
Kerosene explosions	21	6	India, Niger, Nigeria, Papua New Guinea, Sierra Leone, South Africa
Kerosene ingestion	33	21	Antigua and Barbuda, Barbados, China, Ghana, India, Iraq, Israel, Jamaica, Jordan, Kenya, Libya, Malawi, Malaysia, Nepal, Nigeria, Pakistan, Sierra Leone, South Africa, Sri Lanka, Zimbabwe
Indoor air quality* (laboratory and field studies)	7	3	Ghana, Malawi, Nepal
Visual performance or health	7	8	Ethiopia, Ghana, Kenya, Nepal, Tanzania, Thailand, Zambia
Women's health	5	4	India, Nigeria, Sierra Leone, Tanzania, Zambia
TOTAL	112	33	

[3] Online database of health-related impacts from kerosene lighting. https://docs.google.com/a/lbl.gov/spreadsheet/ccc?key=0Avq_VXuy99CEdFVMaHJySWVsNnVvZkF2Nm4tN2pqMXc#gid=0

2.2 Self-reported Versus Independently Documented Risks

While the toxicity of smoke from the combustion of kerosene, the leading lighting fuel, has long been established within the medical literature (Pattle and Cullumbine 1956), only about one in four lighting users are aware of health risks. For example, a statistically representative survey of 3,300 fuel-based lighting users across five sub-Saharan African countries found 26% to have related health concerns (Baker and Alstone 2011). For this same group, perceived risk of fuel-based lighting on health varied widely: 57% in Zambia, 44% in Kenya, 21% in Tanzania, 15% in Ghana, and 5% in Ethiopia. Figure 1 summarizes the concerns expressed by these users of kerosene lighting.

Figure 1. **Health and safety risks perceived by fuel-based lighting users (Ethiopia, Ghana, Kenya, Tanzania, Zambia)**



Perceived health consequences of fuel-based lighting and inadequate service levels.
(Source: Baker and Alstone 2011)

A study in the Philippines found that only 9% of users noted safety and health benefits as a reason for seeking alternatives to fuel-based lighting (Planète d'Entrepreneurs 2011). The only demographic factor reported to correlate with reduced injury so far is income with wealthier individuals using safer practices (Schwebel *et al.* 2009a).

2.3 Synthesis of Current Understanding

The literature collected in this report provides a high-level, global picture of the nature of morbidity and mortality risks associated with fuel-based lighting:

- Fuel-based lighting is a significant cause of severe burn injuries, with particularly high death rates (24% on average) in cases reported by hospitals in which kerosene is adulterated with other fuels and results in explosions. Where destructive house fires are involved, decimating the hard-earned wealth of uninsured poor people, the resulting poverty and deprivation from being homeless can lead to additional harm.

- Indoor pollutants from fuel-based lamps include multiple hazardous materials, with concentrations of particularly unhealthful particles, an order of magnitude higher than health guidelines. Correlations with cataract and tuberculosis have been observed, but require further study to confirm and quantify causal links to off-grid lighting.

- Unintentional ingestion of kerosene is a risk unique to children. It is typically the number-one cause of child poisoning in developing countries, with an average mortality rate of 7% for the studies reviewed.

- Low illumination levels from fuel-based lanterns are only 1% to 10% of those recommended by lighting authorities in industrialized countries. Users complain of vision-related problems and eye irritation, but formal measures of health and welfare impacts are limited. Inadequate illumination in clinics creates a visual performance challenge that may impede the delivery of quality healthcare; it also discourages patients from seeking care. Some reports detail the risks of adverse outcomes such as maternal and infant mortality as well as difficulties maintaining good sanitation, which can lead to increased incidence of infections.

- Existing data suggests that fuel-based lighting injuries and pollutant exposures disproportionately affect women and children.

- Replacing intrinsically dangerous fuel-based lighting with electric light sources is the most promising and scalable way to reliably eliminate these risks.

There are few large-scale or statistically representative assessments of health impacts associated with off-grid lighting. As described below, many studies report that accidental ingestion of kerosene is the primary case of child poisoning in the developing world. In South Africa alone, over 200,000 people are estimated to be injured or lose property each year due to kerosene-related fires, or 400 per 100,000 (Paraffin Safety Association 2012a). Kimemia *et al.,* (2014) estimate that 40%, or 400 to 700 of all settlement fires per year are attributed to candles, and 14% of burn injuries. Also in South Africa, 79,750 very young children are estimated to unintentionally ingest kerosene each year (160 per 100,000; occurring in 3.6% of all households) of which 60% develop a chemically induced pneumonia (Paraffin Safety Association 2004). In Bangladesh, kerosene lamps are responsible for 23% of infant burns (Mashreky *et al.* 2008), corresponding to about 17,000 annual injuries nationally. Three multi-year reviews of admissions to Nigerian hospitals attributed approximately 30% of all burn cases to kerosene (Asuquo *et al.* 2008; Oludiran and Umbese 2009; Olaitan *et al.* 2007). Even higher burn rates (approximately 40%) are attributed to kerosene lamps in Sri Lankan homes, with 150 to 200 lives lost annually, with a cost for associated medical care of USD 1 million annually (Shepherd and Perez 2007).

A complex array of social, political, and behavioural factors contribute to the problem including: lack of product safety labelling or warnings; illiteracy (inability to receive communications about risk); overcrowding (contributes to rapid spread of fires and peoples' proximity to lantern emissions); corruption and fuel subsidies (resulting in fuel adulteration (Mills 2014a)); unsupervised children; poverty (inability to afford child-safe containers for fuels); cultural practices, such as keeping lamps next to young children while they sleep, to ward off "evil spirits" (Mashreky *et al.* 2008), and ineffective or counterproductive folk remedies, for example, inducing vomiting after kerosene ingestion (which causes undesirable aspiration of kerosene into the lungs) (Adam 2012; Azizi *et al.* 1994); and, unwillingness or inability to seek or access professional care.

The following sections provide further details, organized by type of health and safety risk.

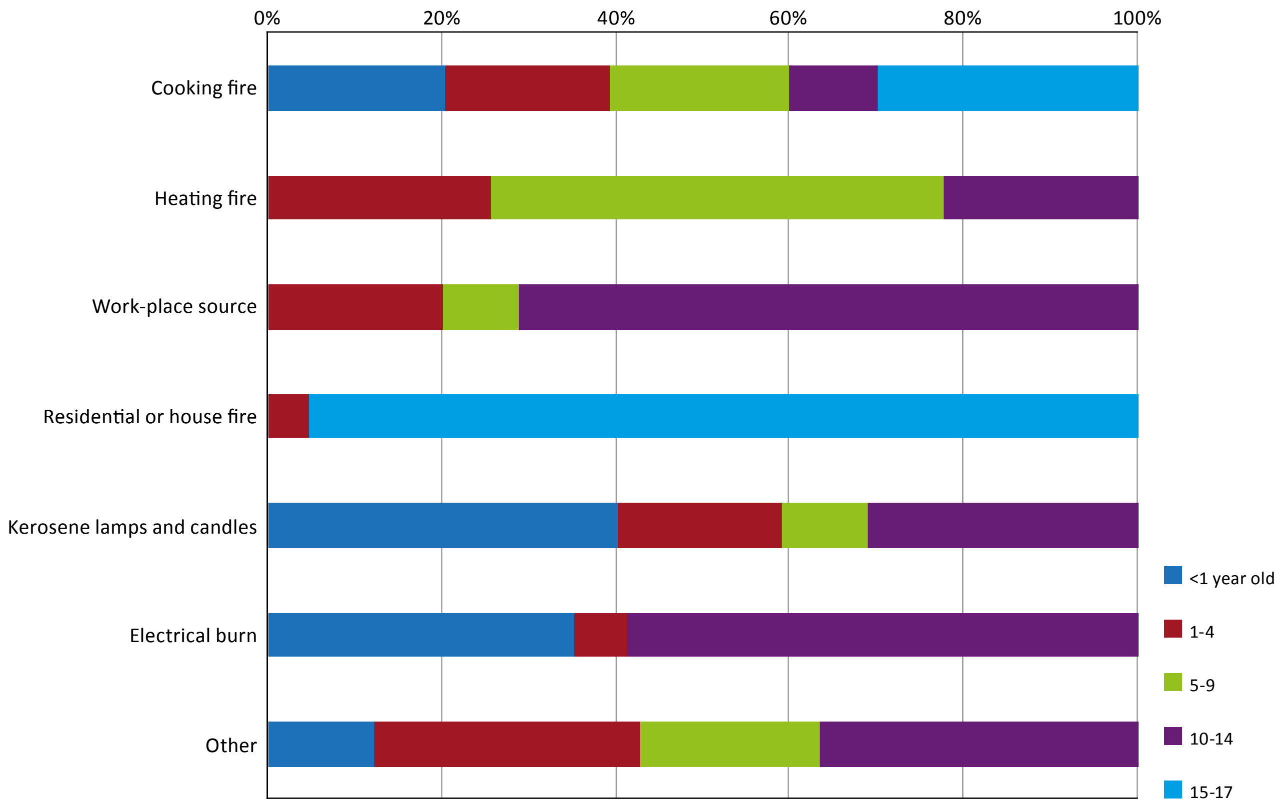
3. Health and Safety Risks

3.1 Burns

There is no global estimate of burn-injuries attributable to fuel-based lighting. However, it is known that more than 95% of deaths worldwide from fires and all types of burns occur in the developing world. The mortality rate is five times higher in low- and middle-income populations in Africa than in high-income countries in Europe (World Health Organization 2002a). In Southeast Asia, the rate is 8.3-times greater than in Europe. The World Health Organization estimated global deaths from burns and smoke inhalation during fires were on the order of 322,000 in the year 2002, which Peck *et al.* (2008) refer to as likely a “gross underestimate.” In an even lower estimate, the number of burns was placed at 195,000 for the year 2008 (World Health Organization 2012b).

Burns are a leading cause of injury among children, and fuel-based lighting is the primary cause among young children[4]. In southern India, burns are the number-two cause of injury-related mortalities among children, just over half of which are due to lanterns (9.3% of total injury-related mortalities) (Kanchan *et al.* 2009). A survey of 134 households in the Philippines found that 18% had experienced burns due to kerosene (presumably lighting plus cooking) (Planète d’Entrepreneurs 2011).Mashreky *et al.* (2008) found that burns caused by fuel-based lighting occur disproportionately more for infants than do other causes of burns (Figure 2).

Figure 2. **Distribution of burn injuries by age group, Bangladesh**



Infants incur about 40% of the burns caused by fuel-based lighting in Bangladesh, a higher share than any other type of burn injury. Source: adapted from Mashreky et al. (2008)

[4] See http://www.healthmetricsandevaluation.org/gbd/visualizations/gbd-cause-patterns

Lighting-related burns can result from structural fires, direct contact with hot lamps or flames, and explosions due to the adulteration of kerosene with other fuels. These injuries are often followed by infection, and subsequently can be followed by disability and psychosocial trauma. These events are pervasive in the developing world, with incidents documented in Bangladesh, China, India, Liberia, Mozambique, Namibia, Nepal, Nigeria, Papua New Guinea, the Philippines, Senegal, South Africa, Sri Lanka, Tanzania, and Zimbabwe.

The publications reviewed here reflect a three percent weighted-average death rate from regular burns and 24% in the case of lantern explosions. It is important to reiterate that the literature is based on studies of individuals admitted to hospitals, and thus reflects only a small subset of all cases that occur. These cases tend to be particularly severe. For example, of the 1,368 cases studied by Jayaraman *et al.* (1993) one-third were fatal.

Statistics for burns caused by lighting fuels other than kerosene are rare. The Paraffin Safety Association of South Africa (2012), collected extensive data on injuries associated with lighting by candles. They find that candles—three-times more common than kerosene for lighting in South Africa (Statistics South Africa 2012)—are implicated in one-third of burn injuries in the country, with 58% of the injuries involving males. Females are in the majority for the zero to 24-year age group. Elsewhere in sub-Saharan Africa, candles are used as a source of light in non-electrified households by 79% in Zambia, 20% in Ethiopia, 19% in Tanzania, 18% in Ghana, and 10% in Kenya (Baker and Alstone 2011).

3.1.1 Structure Fires

Over a century ago, large fires in China, displacing 1,000 families in one case, were traced to kerosene lamps imported from the United States of America. This problem was relayed by the U.S. President to Congress as a matter affecting foreign relations with China (Office of the President 1888). Many fires in residences in the developing world are caused by fuel-based lighting. When fires occur in informal settlements, slums or camps for displaced persons, they spread rapidly due to crowding and flammability of housing materials. Newspaper accounts report large fires, such as one affecting 3,000 people in a Philippine informal settlement in 2009, killing 16 (*Daily Mail* 2009)[5]. The former fire chief in Monrovia, Liberia notes the occurrence of an average of one candle-related “shack fire” every week (Dawson 2013). Particularly tragic fires such as a fire in Senegal (where at least 9 children died) involve indentured children or orphans that were confined without an opportunity to escape (Nossiter 2013).

Nearly 24,000 fires in informal housing settlements were recorded nationally in South Africa between 1998 and 2006, resulting in 1088 deaths (Birkenshaw 2008).Kimemia *et al.,* (2014) estimate the number of fires at about one-third this level. Swart (2012) estimates that 30% of shack fires in the country are started by candles. Kimemia *et al.,* (2014) put the value at 40% of fires and 15% of burn injuries. A random sample of households in South Africa found that kerosene-related fires (presumably for cooking as well as lighting equipment) had occurred in 6.3% of all households (Matzopoulos *et al.* 2006)[6].

3.1.2 Explosions Resulting from the Adulteration of Kerosene with Other Fuels

Some unscrupulous oil merchants adulterate kerosene with gasoline or diesel when those fuels are even slightly less expensive, or during times of kerosene scarcity (Lawal 2011; *The Telegraph* 2011). Unintentional adulteration can also occur when end-users use the same containers for gasoline and kerosene or suppliers upstream inadequately isolate or flush mixed-use pipelines or tanks. Adulteration creates a volatile mix that can ignite and explode[7]. The resulting injuries are severe, and often fatal.

[5] Other examples include fires destroying 200 homes in India in 2010 (*Thaindian News* 2010), and 1,500 homes – killing 15– in Bangladesh in March 2000 (*Associated Press* 2000). Refugee camps are also vulnerable, as in the case of a Nepali camp where 1,200 of 1,500 homes were burned by a fire suspected to have been started by a lantern, leaving 12,000 homeless (UCRI 2010).Slum fires are a routine occurrence.

[6] One fire there, attributed to a single candle, killed two people while destroying 500 homes and leaving 2,000 people homeless (*The Mercury* 2010).

[7] The lowest temperature at which kerosene vaporizes and forms an ignitable mixture in air is at least 38C, which drops to about 5C with only 10% adulteration with gasoline (Shepherd and Perez 2007). Explosions occur most easily when lanterns are refueled while lit, and the evaporating fumes ignite.

Reports of exploding kerosene lanterns and stoves are particularly common from Nigeria (Table 2), where subsidies tend to keep gasoline prices lower than in much of sub-Saharan Africa (Africa Pulse 2012). Subsidies are also high in Cameroon, the Republic of Congo and Sierra Leone. A report of adulteration that impacted 2,500 people, of which 368 (14%) died, came from Nigeria's Edo region (Bernard 2011). In one household, 8 of 10 family members were killed (Ugburo *et al.* 2003). These incidents are frequent; long-term studies find chronically high rates of hospital admissions due to explosions in Nigeria. Given that individuals often purchase kerosene in small quantities, this amount of adulterated kerosene could be disseminated to large populations.

Table 2. **Illustrative "Epidemics of Kerosene Disasters" caused by fuel adulteration**

Year	Location	People injured/killed [Female: Male]	Source
1984	Lagos, Nigeria	53/30 [1.9:1]*	Grange et al. (1988)
1994	Rajasthan, India	303/37	Gupta et al. (1996)
2001	Lagos, Nigeria	116/18 [1.5:1]	Oduwole et al. (2003)
2001	Lagos, Nigeria	59/35 [1.3:1]	Ugburo et al. (2003)
2001	Madang, Papua New Guinea	38/5	NDMO (2001)
2004	Edo State, Nigeria	2500/368	Bernard (2011)
2011	Port Harcourt, Nigeria	1/5	Nigeria News (2011)
2011	Edo State, Nigeria	1/8	Daily Independent (2011)
2011	Duhbri, India	62/8	The Telegraph (2011)
2012	Edo and Delta States, Nigeria	11/11	Tamuno (2012)

* Ratio in month of burn disaster (March). Ratio 1:1 in earlier periods.

Three multi-year reviews at Nigerian hospitals attributed around 30% of all burn cases to kerosene fuel explosions (stoves plus lanterns) (Dongo *et al.* 2007; Asuquo *et al.* 2008; Olaitan *et al.* 2007). In the latter study, injuries to females outnumbered those to men by nearly 3:1. In another study (covering just one month), 96% of burn admissions were due to kerosene device explosions. Of those burned, 62% were children and 60% were female; the average body-area burned was 24% (with a 44% overall mortality rate) (Oduwole *et al.* 2003). The month covered by the study followed the discovery that a petroleum storage depot deliberately adulterated the kerosene. Oludiran and Umebese (2009) found that 52% of children (half below the age of 3) admitted to a hospital for burns received their injuries from exploding kerosene lanterns or stoves, with burns covering between 6% and 50% of body area. Oduwole *et al.* (2003) observed 100% mortality for cases with burns covering more than 18% of total body area. Another author found that half the admissions were children, with a nearly 6-fold increased admission rates at one hospital following an incident in 1984, with 47% mortalities versus none for burns in the same month, prior year (Grange *et al.* 1988).

Reports of kerosene adulteration have also emerged from India, Niger, Nigeria, Papua New Guinea, Sierra Leone and South Africa. One event in India (Gupta *et al.* 1998) affected 303 people. With only 10 beds available in the local hospital's emergency burn unit, many patients were turned away or referred to distant hospitals. In another case from India, 72,000 litres of fuel were adulterated (*The Telegraph* 2011).

3.2 Indoor Air Pollution

Inhalation of particulates resulting from indoor combustion can cause a range of adverse health effects ranging from tuberculosis to cancer (Bai *et al.* 2007; Dockery *et al.* 1993; Dominici *et al.* 2003), and asthma (Lam *et al.* 2012b). Poor indoor air quality in developing countries creates a large societal burden, both economic and humanitarian (Zhang and Smith 2007). As of 2010, an estimated 2.6 to 4.4 million deaths (Lim *et al.* 2012) occur each year from poor indoor air quality associated with cooking with solid fuels in the developing world.

These deaths are sometimes incorrectly attributed to lighting; no such estimate has been in fact been made. While particulate matter concentrations from cook stoves have been extensively studied, characterization of particulate concentrations from fuel-based lighting has received minimal attention (Schare and Smith (1995); Fang and Zhang (2001), Apple et al (2010), and Van Vliet et al., (2013). This is particularly puzzling since fuel-based lighting and dirty cooking fuels often exist in the same households. Lighting combustion is generally poorer than in liquid-fuelled stoves; the mix of particle types and sizes will vary by fuel and even lantern type.

According to Poppendieck's estimate, human inhalation of particulate matter from simple wick lamps is about 5-times less than that of cook stoves, yet is also about 5-times more than from ambient air (2010)[8]. Lam (2013) found the gap between lighting and cooking to be smaller than this. Fullerton *et al.* (2009) found higher levels of particulate matter associated with macrophage cells in people living with kerosene lamps, particularly simple wick-based lamps but also hurricane lanterns and candles, which have particularly incomplete combustion (Apple *et al.* 2010).

Fuel-based lanterns are located in close proximity to users; they emit indoor air pollutants that can be inhaled deeply into the lungs. Emissions resulting from burning kerosene include carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen dioxide, formaldehyde, and various volatile organic carbons (VOCs). Potentially harmful effects include impairment of ventilatory function (Behera *et al.* 1991), and a higher incidence of acute lower respiratory infection among those using kerosene and bio fuels (Sharma *et al.* 1998).

Van Vliet *et al.* offers one of the only studies to measure particulates in actual occupied homes, and found a significant contribution from kerosene lanterns above that traced to bio fuels used for cooking. Measurements by Apple *et al.* (2010) demonstrated that night vendors who use a single simple wick lamp in simulated high-air-exchange market kiosks will likely be exposed to dangerous particulates matter (PM) 2.5 concentrations that are an order of magnitude greater than ambient health guidelines (WHO 2006). Thanks to more efficient combustion, using a hurricane lamp will reduce exposure to PM2.5 and PM10 concentrations by an order of magnitude compared to a simple wick lamp. There are no known standards regulating emissions of, or exposure to, particulates produced from fuel-based lanterns. It should be noted that the particulate emissions of kerosene lanterns (and likely candles (Zai *et al.* 2004) also represent significant amounts of black carbon, strongly implicated in climate change (Lam *et al.* 2012a). Estimates of ultimate indoor exposure to total PM emissions found that those of kerosene lamps were approximately three times that of candles (Fan and Zhang 2001).

One of the potential consequences of indoor pollutants from kerosene lanterns is tuberculosis, a major health issue in the developing world. In the only study to explore the role of lighting, researchers found the odds of having tuberculosis in Nepal were more than nine times greater for women using kerosene lamps for indoor lighting than those using electric light (Pokhrel *et al.* 2010). The authors did not have detailed measures of lighting behaviours that may have contributed to this risk but note that kerosene lamps may burn less efficiently, for longer hours, and release emissions closer to users than do stoves.

Kerosene contains known carcinogens such as benzene (American Cancer Society 2006) and probable ones such as formaldehyde (US EPA 2012), but studies have not been done on the risks associated with indoor concentrations resulting from the use of lanterns. The composition of kerosene varies by refiner.

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[8] Per Poppendieck *et al*., for outdoor-ambient conditions and indoor conditions with lamps, inhalation mass (versus absorbed dose) is based on the product of average inhalation rate 4.5 L/min, exposure duration (2.5 hours per day for lamps, 10 hours for ambient), and average measured particle concentration from Apple *et al*. (2010). Values for cooking were based on multiple filter measurements performed over periods of 8 to 24 hours, with cooking occurring intermittently during those periods, assuming all particle mass was from stoves and that the occupant was inside while the cooking fuel was burning, evaluated at the aforementioned breathing rate.

Studies to date on the indoor air quality impacts associated with lighting fuels have focused on kerosene. Little assessment has been made of health issues associated with lighting-related uses of certain other fuels, including candles, diesel, animal and vegetable oils, dung, or fuel wood. Fine *et al.* (1999) identified approximately 150 organic compounds present in candle smoke and unburned candle wax. Concerns in addition to fuel-combustion products are wicks made with lead cores as a stiffening agent[9] and lantern mantles made with radioactive thorium, neither of which are accompanied with safety warnings or disposal instructions when sold in the developing world. Burning wicks have been shown to yield indoor concentrations of lead above ambient air standards and workplace standards (Wasson *et al.* 2002).

3.3 Poisoning

Unintentional poisoning resulting from the drinking of kerosene has been reported in Antigua and Barbuda, Barbados, China, Ghana, India, Iraq, Israel, Jamaica, Jordan, Kenya, Libya, Malawi, Malaysia, Nepal, Nigeria, Pakistan, Sierra Leone, South Africa, Sri Lanka, and Zimbabwe. Most studies on poisonings in the developing world (such as Osaghae and Sule 2013) have identified kerosene to be a leading cause of poisoning in children, ranging from 25% to 65% of all cases in the literature reviewed here. In Ghana, 79% of physicians surveyed confirmed this view (Arthur 2012). Having an appearance and density similar to that of water and frequently stored at floor level in ordinary beverage containers, kerosene is non-intentionally ingested by children. This risk is ironically compounded by lack of adequate illumination. In all 36 cases (51% of all child poisonings) reported in a Malaysian study (Azizi *et al.* 1994), kerosene was kept in a soft-drink bottle, typically on the kitchen floor.

According to one source (Nisa *et al.* 2010), ingesting as little as one millilitre of kerosene can cause complications, while ten millilitres can be fatal. Common complications include respiratory effects and pulmonary damage. Additional impacts include gastrointestinal irritation, fever, central nervous system impairment, fever, myocarditis and leukocytosis. A broader literature review identified that the chemical form of pneumonia occurs in 12% to 40% of the cases (Carolissen and Matzopoulos 2004)[10]. Sufficient dosages can lead to coma and death. There was a seven percent average death rate (weighted by number of deaths) across 20 studies reporting mortality rates, with a large variance in outcomes across studies (Carolissen and Matzopoulos 2004). Among the particularly high mortality levels, a rate above five percent was observed in a six-year hospital study in Nigeria (Belonwu and Adeleke 2008).

3.4 Illuminance Levels and Compromised Visual Performance

The illuminance levels recommended by professional illuminating engineering societies for electric lighting are 10 to 100 times greater than the levels provided by fuel-based lanterns (Mills and Borg 1999)[11]. Insufficient illumination can lead to poor visual performance, fatigue and eye strain. Research is inconclusive on whether sustained, insufficient illuminance levels and eye strain contribute to myopia (near-sightedness) (Kittle 2008; Gauna 2012).

A study of home lighting in a rural Nepali village led to recommended levels in the 5 to 15 lux (lumens per square meter) range for general-purpose lighting, primarily for cooking and socializing, and 25 lux for reading (Bhusal *et al.* 2007). These levels are far below the levels recommended by illuminating engineering societies, but higher than the levels typically provided by fuel-based lighting. The dominant fuel type in the Nepali study was burning *jharro* (resin soaked pine sticks)[12]. Interviews of a small number of fuel-based lighting users in the field indicate that night vendors find the illuminance levels from fuel-based lanterns inadequate (Alstone *et al.* 2010).

A study in households using solid cooking fuels noted differences in cataract incidence depending on whether a home's light was provided by electricity or kerosene, with the risk twice as high for households using kerosene lighting (Pokhrel *et al.* 2005).

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9 Outlawed in the USA since 2003.

10 Kerosene ingestion accounted for a considerable proportion of all pediatric admissions at state hospitals across South Africa, ranging from 5.5% to 16.5% of all admissions, with markedly higher rates (up to 78%) in lower-income areas where kerosene is most widely used (Carolissen and Matzopoulos 2004).

11 Recommended levels of illumination are based on laboratory and field studies of specific visual tasks and visual performance needs. They may also consider glare, fatigue and eye strain.

12 "*Jharro* is a resin rich oden stick from the high elevation Himalayan pine tree whose flame provides smoky but minimally adequate indoor lighting," according to Nepal's Rural Integrated Development Service. http://www.rids-nepal.org/index.php/Light.html

The authors noted that the risk of cataracts is generally higher in developing countries and that more females than males are blind from cataracts, but there is no causal theory supporting a linkage with pollutants emitted during combustion. Cataract risks are wavelength-dependent, with ultraviolet being the most harmful, and, to a lesser degree, infrared. This author has not identified any studies that conclude that exposure to fuel-based lighting is a significant risk factor for cataracts.

In a recent set of interviews conducted by the author and colleagues, night fishermen in Tanzania reported multi-hour periods of reduced vision after each evening's handling of lanterns. Interviewers recorded self-reported claims of high incidence of blindness in old age (Mills *et al.* 2014). This purportedly resulted from repeated periods of close proximity to pressurized lanterns (which have 10 times the luminous output of typical wick lamps, from a mantle with very high luminosity). Eye strain and poor eyesight attributed to glare and direct exposure to the luminance of very high output pressure lanterns are mentioned in other surveys conducted across sub-Saharan Africa (Baker and Alstone 2011).

Impaired visual performance (including disability glare) are, in turn, risk factors in subsequent accidents and injuries. Similarly, inadequate illumination invites crime (Associated Press 2013; UNDP 2012; Peacock 2013).

Reliable, high-quality illumination is essential for the effective delivery of health services. Many facilities in the developing world operate only intermittently at night due to fuel availability and the inability to provide good care with only lanterns (Solar Aid 2012). Orosz *et al.* estimate that there are approximately 86,000 health clinics throughout the developing world that lack electricity, of which more than half are in Africa (2013).

Approximately 287,000 maternal mortalities occurred globally in 2010, 99% of which occurred in developing countries (WHO 2012c). Two 2012 field studies document child delivery illuminated with kerosene lanterns or with light from makeshift, repurposed cell phones (Solar Aid; Stachel). These studies also note that lack of light keeps some populations from even attempting to visit a clinic or hospital at night. The cost of kerosene is a hardship for many healthcare providers. Lack of electricity also presents challenges for keeping mobile phones charged, equipment sterile, and powering key tools for communicating with patients and staff.

3.5 Disproportionate Impacts on Women and Children

Women and children bear the brunt of the health hardships associated with off-grid lighting (Alstone *et al.* 2011). For context, the rate of childhood unintentional injury deaths (from all causes) in the developing world is nearly four times that of the industrialized world, with 875,000 affected each year (Balan and Lingam 2012) and with millions more sustaining non-fatal injuries.

The preceding discussion of conditions in health clinics identifies particular issues concerning maternal and infant health. In their analysis of the national household survey in India, Lakshmi *et al.* (2013) discovered an unexpectedly higher rate of stillbirths in women who rely on kerosene rather than electricity for lighting.

The issue of non-intentional fuel ingestion almost uniquely impacts children, especially infants and toddlers, and is typically the primary cause of child poisoning in the developing world.

Studies of lamp explosions due to fuel adulteration found two-fold higher impacts among children than adults: 62% versus 38% injury (Grange *et al.* 1988) and 57% versus 25% mortality (Ugburo *et al.* 2003). Female to male ratios were also higher in both studies.

Lighting-related burn injury rates are higher for females and children in many studies (Balan and Lingam 2011), with one study finding a 3:1 ratio in India (Kumar *et al.* 2002). Functional, social, and psychological impairment due to burns has been identified as one of the most devastating causes of child injury. In a nationwide study for Bangladesh, in which 171,000 households were visited, rural children were found to have a four times greater incidence of burn than those in urban areas; and, kerosene lamps were responsible for 23% of burns sustained by infants and 11% for children aged one to four years (Mashreky *et al.* 2008). In the same study, burns were the fifth leading cause of illness among the children aged one to 17 years of age, and the third leading cause for children aged one to four.

Burns from all causes are reported as the leading cause of death among children in South Africa (Mrubata and Dhlamini 2008). An extensive study in India (Epstein *et al.* 2013) found lower infant birth rates and higher neo-natal mortalities were associated with households that used kerosene as a cooking fuel.

To the extent that women and children spend more time indoors than men—and that children are intrinsically more vulnerable to hazards—they are differentially exposed to indoor air quality and lamp-explosion risks. A study of 345 people in 55 Kenyan households found that children of each gender up to the age of four, spend roughly equal times indoors. However, females in all other age groups spend between one and four hours more per day indoors than males do (Ezzati and Kammen 2002). Males spend less overall time indoors than these other groups. A major study of 4,612 individuals drawn from representative locations in Bangladesh found that infants spend the most time indoors: approximately 20 hours per day, declining to 16 hours per day for individuals up to the age of 60. After age 60 females' time indoors returns to a level of nearly 20 hours per day, while time spent indoors by males' increases only to 16.5 hours per day. All groups of females over the age of 12 spend more time indoors (1.4 to 3.2 hours more per day) than do males. The Bangladesh study concluded that, "young children and poorly-educated women in poor households face [indoor air] pollution exposures from cooking that are four times those for men in higher-income households organized by more highly educated women," with half of the effect due to income and half to age and gender (Dasgupta *et al.* 2004).

Data indicating location by time of day (and use of lighting by time of day) would be needed to determine if lighting-related emissions exposures differ materially among these groups. Men and children not participating in cooking activities will receive a larger share of their indoor air pollution exposures from lamps.

4. Alternatives to Fuel-Based Lighting

4.1 Health Benefits of Introducing Solar LED Off-grid Lighting

Substantial and diverse health and safety risks are posed by fuel-based lighting. Other researchers also conclude that the transition from fuel to electric-based lighting would help reduce health and safety risks (Kimemia *et al.,* 2014). In addition to improved health outcomes, are multiple benefits of addressing these risks. In particular, eliminating fuel-based light sources would also deliver a significant reduction in greenhouse gas emissions (Mills 2005), while supporting new forms of employment (Mills 2014b), and weaning governments of the burden of fuel subsidies that often exceed expenditures on healthcare (Mills 2014a).

Grid electrification programs have attempted to displace lighting fuels for decades, but in many places, the rate of progress with respect to low-income populations is very slow. In some parts of the world, particularly sub-Saharan Africa, the number of people using fuels for lighting is still increasing. A far more promising and scalable approach for energy access is the use of small-scale solar or grid-charged light emitting diode (LED) lighting systems, many of which provide more, better, and safer light at a lower total cost of ownership (see Mills 2005). Many examples have been documented[13].

Accounts of benefits are based on end-user reports, rather than on rigorous independent studies. A field study of 500 homes in the Philippines observed near complete elimination of health and injury issues following replacement of kerosene lanterns with grid-independent LED lanterns[14] (Figure 3a). A study of 209 households in Ghana found that a far higher rate (89%) of households using only kerosene for lighting reported having blackened nostrils (from soot) in the mornings than those using a mix of kerosene and solar lighting (24%) (Obeng *et al.* 2008).

[13] Numerous case studies are documented on LuminaNET: http://luminanet.org/page/field-projects-directory

[14] In this report, the shorthand term "LED lantern" is used to describe a broad category of lighting products that have emerged over the past decade. Common attributes are: high-efficiency "white" LED light sources; compactness and portability; a battery or other form of storage that allows grid-independent operation, charging either from dedicated renewable (typically solar ~10 peak watts) power source or a temporary grid connection (as mobile phones are charged); a larger degree of affordability than first-generation fluorescent devices; and they are "plug-and-play", i.e., no need for professional installation. Within these broad criteria are found many variations including light output (level and directionality), charging time, battery life, and, the presence of secondary functions such as phone charging.Quality also varies widely and those considered viable alternatives to fuel-based lighting have high levels of performance and truth-in-advertising such as those recognized by the Lighting Global product quality assurance program. There is no consensus on terminology, and descriptors such as lamp, lantern, torch, light, and pico power will often be used to describe some or all of the products in this category.

Figure 3a. **Health and safety indicators with and without kerosene lighting**

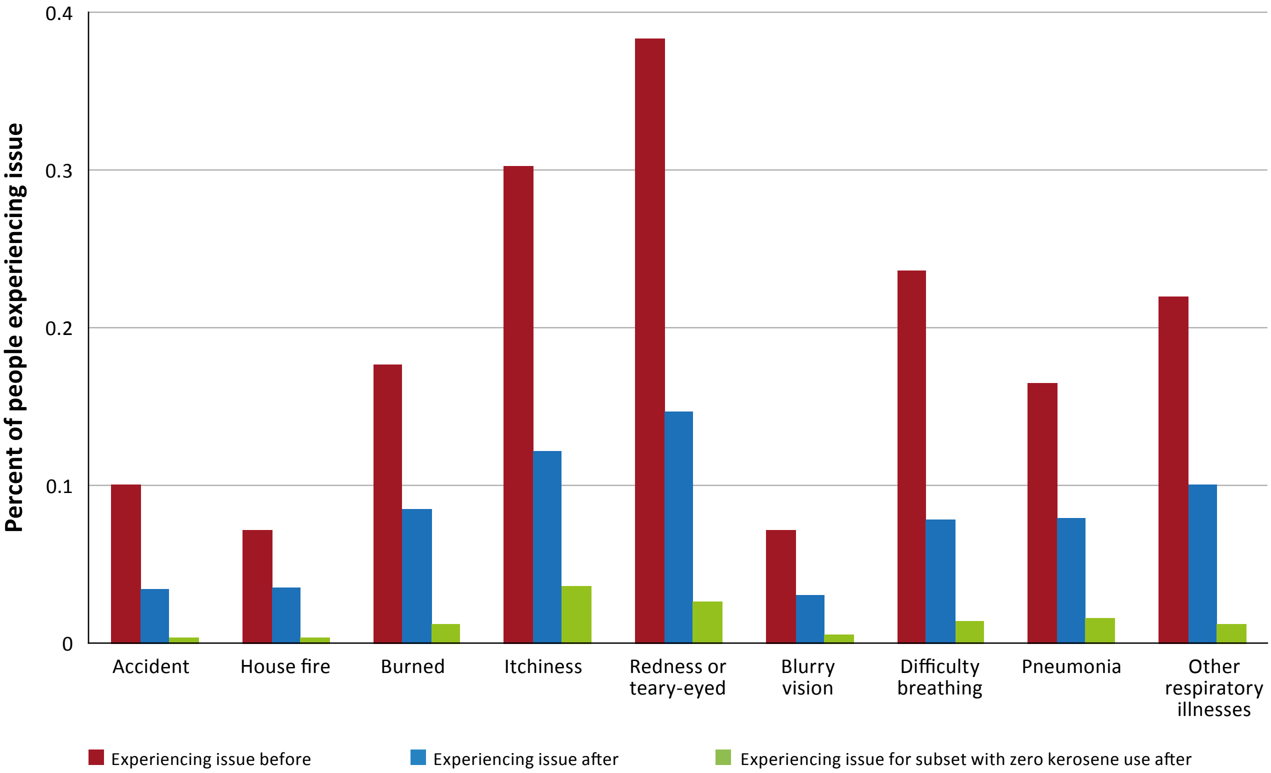
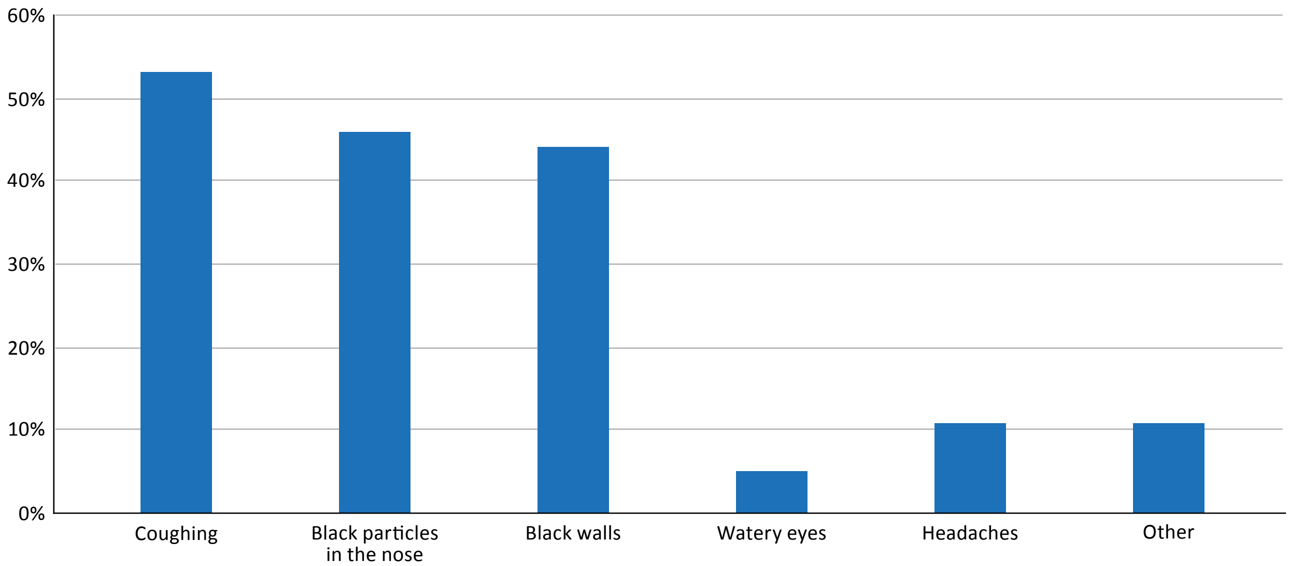


Figure 3b. **Occupant-reported reductions in problems related to indoor air quality**



Figures 3a and 3b. *Data from Philippines. (a) Changes in user-reported health and safety problems believed to be associated with kerosene lanterns before and after receipt of LED-solar replacements among 500 homes in the Philippines (Thatcher 2012). Recipients were re-interviewed one month after receiving the fuel-free lamps. Note that 66% of the homes still used some kerosene after the intervention (blue bar).*
Symptoms were reduced much farther among the 27% of homes that completely eliminated kerosene use.
(b) Separate study, 109 households reporting.

Refugee camps are particularly at risk for destructive fires caused by lanterns, as well as violence against women and children at night. In 2014 in West Africa alone, The UN High Commissioner on Refugees (UNHCR) supports and protects over a million people of concern. For security and safety lighting is an essential service. UNCHR has initiated efforts to introduce solar lighting, with 60% of people reporting improved safety at night (UNDP 2012; UNHCR 2012).

Solar Aid installed 30 solar electricity and lighting systems in rural health facilities in Tanzania (Solar Aid 2012). Preliminary results found reduced rates of infection (including HIV); these outcomes were attributed to better illumination and associated ease of maintaining sanitation. Longer and more consistent operating hours reportedly induced more individuals to seek health care rapidly and more mothers to give birth in clinics. This improved access to services at night led to reduced patient waiting times during the day. Patients cited the benefit of not being expected to bring their own lantern and/or fuel to ensure treatment at night. The study claims a "clear increase" in safe baby deliveries at night, improved detection of postpartum hemorrhage, tears, or problems with the baby. Staff accounts indicated improved morale.

In a larger trial by Solar Aid, light was brought to clinics in Malawi, Tanzania, and Zambia that serve over 5,000 patients per month (Solar Aid 2011). Non-specific improvements to security and morale among workers and patients are reported to translate into a higher quality of service and better engagement of both staff and patients.

Nigeria has one of the highest maternal mortality rates in the world. One company has completed solar lighting installations at 26 Nigerian healthcare locations (along with power for cell phones and foetal monitors); and, follow-up surveys have been conducted (Stachel 2012). All locations reported a higher proportion of mothers coming to clinics for delivery, particularly night deliveries. Lighting provided particular benefits for complicated deliveries. Reliable illumination allowed for an increased rate of caesarean section surgeries to be performed at night. Blood bank procedures were also improved via increased ease and accuracy for testing the blood, together with refrigeration. Every site reported an improvement in health worker morale and willingness to come to work at night. Similar work was done in Sierra Leone, which has more than 1,000 non-electrified rural clinics (Stachel 2013).

4.2 Health Considerations for Replacing Fuel-based Lighting with Alternatives

A switch to electric lighting is the most promising pathway for fully eliminating the risks associated with fuel-based light sources. Nonetheless, the generation and distribution of electricity are not risk-free, particularly when electricity is produced with fossil fuels or nuclear fission. Second-order issues such as the diversion of scarce water for power plant cooling and the concerns associated with electricity transmission lines, should also be considered. Distributed renewable energy based generation mitigates most of these supply-related concerns.

Off-grid lighting systems based on renewable energy sources require some form of energy storage, typically batteries that can have associated health and safety risks. These end-use illumination devices may contain potentially harmful substances, for example, mercury-containing lamps. From a lifecycle perspective, the environmental and health implications of the energy embodied in creating electric lighting systems must be considered, too.

First-generation electric off-grid lighting systems relied on large solar panels, large lead-acid batteries (used in a context in which there was rarely a process for recovery, recycling and reuse), and mercury-containing lamps. Fortunately, the rapid transition in the past decade to highly miniaturized pico-photovolatic systems has dramatically reduced the physical amounts of materials involved as well as waste-management concerns. Mercury-containing lamps have been displaced by higher efficiency LED lamps or LED modules. Due to reduced power requirements, the batteries and solar panels can be far smaller. The off-grid lighting product industry is beginning to make a rapid transition to lower environmental impact technology. For example, the share of lithium-ion batteries used in off-grid lighting products rose from 5% in 2010 to 40% in 2012, while the shares of lead-acid batteries fell from 35% to 27% (Lighting Africa 2013).

New off-grid lighting products should be designed so that they do not compromise visual performance or health. For example, LED lanterns can be designed with shields to reduce glare. Commonly used low to mid-power white LEDs, the preferred light source for off-grid applications, are not regarded as eye safety risks (USDOE 2013)[15].

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[15] Most white LEDs do not emit ultraviolet or infrared radiation; however, blue wavelengths (in high color temperature lamps), if delivered with high power and intensity, can damage the retina. When a set of products geared for the off-grid market were tested using the IEC 62471 safety test protocol, one barely entered the "moderate risk" level after 58 seconds of exposure (Lighting Global 2013). This occurred under a worst-case test condition (holding the LED as close as possible to the eye while remaining in focus). These risks can be eliminated, and glare significantly reduced (and thus light *quality* increased), by utilizing a diffusing lens or material in front of the LED. Bluish light may also disrupt circadian rhythms, although this has not been attributed to LEDs thus far. LEDs are available that provide "warmer" (lower color temperature" illumination. While low-light conditions can cause temporary eye strain and perhaps nearsightedness over a long timeframe, off-grid LED systems will virtually always provide higher light levels than the flame-based products they replace. Care should be taken to develop minimum illuminance standards and best practice application guides for these products.

5. Policy Strategies and Considerations

Fuel-based lighting is associated with a strikingly wide array of health and safety risks. The underlying drivers are many, with no single solution. Other authors have enumerated the causal factors, low levels of risk perception among at-risk populations, and available prevention strategies (Paraffin Safety Association 2004; Schwebel *et al.* 2009a-b; Mrubata and Dhlamini 2008; Swart and Bredenkamp 2012).

Approaches for better understanding the risks and reducing lighting-related injuries and loss of life can be grouped into the following broad categories.

More robust national-level data on lighting fuel choices, using clearly defined and consistent definitions

- Baseline data is essential to identifying overall populations at risk, and the associated geographies. Better country-level data on the incidence of fuel-based lighting (including non-household contexts and among electrified populations) and the fuels used to do so are key needs. A particular information deficit includes the degree to which cooking fuels are used to provide light after cooking tasks are complete.

- Time-budget data is critical to understanding not only total hours spent indoors (important for assessing exposure to risks from cooking risks), but also what portion of that time is during hours where artificial lighting is in use.

- The degree of substitution achieved when electric alternatives are introduced is important information for determining residual risks where replacement technologies have been deployed.

More lab-based research on lighting technology characteristics

- Most testing of the emissions from fuel-based lighting equipment has focused on kerosene lamps. To this should be added diesel, animal and vegetable oils, dung, and fuel wood. Emissions from each will have unique chemical constituents and levels of particulates.

More rigorous and focused field-based epidemiological studies investigating risks and the potential benefits of alternatives

- The literature on this topic is new in the broader context of health and development research, and its quality is uneven. Systematic national or community-scale epidemiological information on lighting-related risks in the developing world is rare, with Ghana and South Africa making the greatest progress to-date in this respect. More centralized statistics should be gathered, per standardized methods, and used to better understand population-level risks.

- Moreover, most existing studies fail to separate lighting fuels from other sources of energy-related exposures and risk. A review of the relatively large body of literature on cooking-related risks may provide some lighting-related contextual information collected that would be useful. Van Vliet *et al.* (2013) is one example of a study that gathered and analyzed such information.

- Several studies have tabulated user-reported reductions in symptoms or safety outcomes when solar-LED lighting has been introduced, but no scientifically rigorous assessments have been reported.

Improved consumer education, standards, and supporting energy policies

- Health and safety education is a critical need. For literate user groups (a subset of the overall population at risk), product labelling and other safety warnings could help reduce incidence of injury and death from fuel-based lighting. Other media, such as radio programs or in-person community health presentations, can also deliver safety information and introduce information about safer off-grid products. Such efforts, however, will not reach many populations.

- Although one in five people in the world are exposed to indoor pollution from fuel-based lighting on a daily basis, only World Health Organization guidelines exist for certain associated pollutants. Few national governments recognize that indoor air pollution is a public health concern that merits high priority. This gap must be bridged.

- Regulation and oversight of fuel handling, and more strict consequences for fuel adulteration, may reduce (but not eliminate) the life-threatening practice of mixing other fuels with kerosene. Energy price subsidy practices contribute to this problem, and thus subsidy reform is a tool for reducing this particular risk.

- Kerosene has long been subsidized and represented as a “clean” or “healthy” fuel when used instead of bio fuels. Subsidies undermine the cost-effectiveness of substituting non-combustion lighting systems, while extending kerosene supply for cooking purposes works as cross-purposes from eliminating it for lighting purposes.

Transition to alternatives to fuel-based lighting, to reduce health and safety impacts

- Any prospective change in lighting technology should be assessed both in terms of health and safety risks. Combustion emissions, injury risk, and visibility-safety risks should all be assessed. Work is ongoing to assess the adequacy of illumination levels for poor populations who cannot afford lighting systems that replicate the levels of illumination expected by affluent societies.

- Fossil fuel-based lighting technologies can, to some extent, be re-engineered, for example, to reduce tip-over risks of lanterns, improve combustion efficiency, or eliminate lead from candle wicks. However, many fuel-based lighting devices are hand-manufactured using discarded metal or glass containers, severely limiting any opportunity for a centralized solution. Cleaner-burning kerosene or propane lanterns are substantially more expensive to purchase and operate than standard “tin” lamps, further limiting their potential. Kerosene can be easily coloured to help distinguish it from water, but this precaution does not prevent consumption by young children. Some organizations have promoted improved fuel-based lanterns (WHO and UNICEF 2008). This, however, addresses fire risk at best, while doing little to address indoor pollution, child poisoning by ingestion of fuel, fuel-adulteration hazards, and emissions of greenhouse gases.

- Replacement of intrinsically dangerous fuel-based technologies with electric alternatives (e.g., LED lanterns) is the most promising way to eliminate the myriad risks of lighting fuels. It reduces the cost of lighting as well, thereby supporting broader goals to alleviate poverty. It is encouraging that a wide variety of effective and affordable technologies have recently emerged in the market. A host of policy strategies are being brought to bear to accelerate the uptake of these alternatives to fuel-based lighting. In addition to displacing hazardous lighting practices, these new technologies also enable the introduction of light into areas that are presently not lit at all, in turn enhancing safety in a variety of ways.

Policies and programs seeking the greatest possible benefit should target the most impacted geographical and demographic user groups. Examples include improved illumination in healthcare facilities, substitutes for kerosene lighting where housing is dense and poorly defended from fire (slums) and where fuel adulteration is particularly common due to fuel subsidy imbalances and other factors. Systems such as South Africa’s mapping of fuel-related injuries could be emulated to deploy targeted programs for grid-independent electric lighting replacements for fuel-based lighting. Improved technologies for women and children will yield particularly significant health benefits.

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About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: climate change, harmful substances and hazardous waste, resource efficiency.

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

> The International Environmental Technology Centre – IETC (Osaka), which promotes the collection and dissemination of knowledge on Environmentally Sound Technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment.

> Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> Chemicals (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> Energy (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

For more information:

see www.unep.org/dtie

This study reveals several critical impacts of fuel-based lighting on the population in developing countries. It synthesises the existing literature that addresses the broad range of health and safety risks and rationalizes data across multiple studies to better describe and quantify the human impacts. The study also identifies means to address the challenges of phasing out fuel-based lighting.

The en.lighten initiative also invites readers to consider two companion studies: *Light and Livelihood: A Bright Outlook for Employment in the Transition from Fuel-based Lighting to Electrical Alternatives;* and, *Lifting the Darkness on the Price of Light: Assessing the Effect of Fuel Subsidies in the Off-Grid Lighting Market.*

The United Nations Environment Programme (UNEP)-Global Environment Facility (GEF) en.lighten initiative was established in 2009 to accelerate a global market transformation to environmentally sustainable lighting technologies by developing a coordinated global strategy and providing technical support for the phase-out of inefficient lighting. The initiative is a public/private partnership between UNEP, OSRAM, Philips Lighting, National Lighting Test Centre (China) and the Australian government's Department of Industry with the support of the GEF.

For more information about the en.lighten initiative, please visit: www.enlighten-initiative.org

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