Black Carbon Emissions from Kerosene Lamps

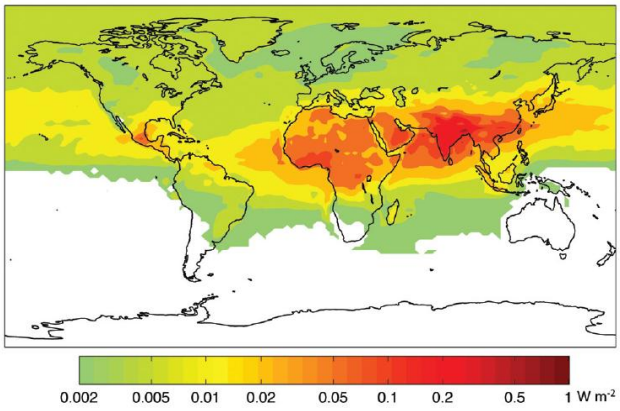
Potential for a new CCAC Initiative

Why black carbon and kerosene lamps?

Around 1.3 billion people worldwide still lack access to electricity. For many, kerosene (paraffin) is a common lighting fuel that is affordable (due in part to government subsidies) and accessible.[1] Kerosene lamps emit both carbon dioxide (CO_2) and black carbon. Black carbon is the result of incomplete combustion of fossil fuels, biofuels, and biomass. Black carbon particles absorb sunlight and heat the atmosphere, increasing radiative forcing, and are a major climate warmer, second only to CO_2.[2] Together with other pollutants having a powerful but short-lived warming influence, it is known as a 'short-lived climate pollutant' (SLCP).

New research has shown that kerosene lamps are significant sources of atmospheric black carbon and emit 20 times more than previous estimates, with 7-9% of fuel burned converted into black carbon particles.[3] While some sources of black carbon emit other non-black particles (organic carbon) that may have an offsetting cooling effect, kerosene lamps emit almost entirely black carbon and CO_2, both of which cause warming. At least 270,000 tons of black carbon per year is estimated to be emitted from kerosene lamps worldwide, having a climate warming equivalent close to 240 million tons of CO_2, or roughly 4.5% of the United States' CO_2 emissions.[4] The warming impact of black carbon emissions from kerosene lamps is highest around source regions, reaching 0.5 watts per square meter.

Figure 1. Direct BC radiative forcing from residential kerosene lighting (W/m2)



Reproduced from Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps"

[1] Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps."

[2] T.C. Bond et al., "Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment," *Journal of Geophysical Research: Atmospheres* 118 (2013): 5380–5552, doi:10.1002/jgrd.50171.

[3] Nicholas L. Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps," *Environmental Science & Technology* 46 (2012): 13531−13538.

[4] Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps"; Jacobson et al., *Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development*.

The amount of black carbon emitted by a kerosene lamp depends on a number of factors, most significantly lamp type. Simple wick lamps, using a rope or cloth wick extended from a metal or glass container, emit significantly more black carbon than glass-enclosed hurricane or pressurized mantle lamps.

Although kerosene lamps constitute a smaller overall source of black carbon than other major sources, such as diesel engines or industrial coal-burning, they are comparatively cheaper and easier to replace and viable alternative lighting sources already exist. Modern off-grid lighting alternatives include solar light emitting diode (LED) products, solar photovoltaic systems, and mini-grids.[5] These alternatives are generally safer and healthier than kerosene, and have brighter light, longer product lives, and lower lifecycle costs. Thus, alternatives to kerosene lighting are an attractive area for achieving quick and cost-effective climate benefits. Moreover, in addition to mitigating climate change, there are major health and development co-benefits to be attained by upgrading from kerosene lamps.

Important co-benefits for health and development

Transitioning from kerosene lamps to modern lighting alternatives not only offers a climate change mitigation measure, but also provides significant and well-documented health and socioeconomic benefits:

- Kerosene lamps pose significant health impacts, due both to chronic illness resulting from inhalation of fumes and to risk of injury due to fire. There is evidence that exposure to the lamps, which are used indoors and in close proximity to people, impairs lung function and increases the risk for respiratory disease, cancer, eye problems, and infectious disease, including tuberculosis.[6]
- Kerosene lamps also pose safety and fire risks. Kerosene is highly flammable and there is a high risk of accidents, burns, and even fatalities associated with lamp use. In Nigeria, for instance, thousands of people are maimed each year by lamp explosions, with a 13% fatality rate.[7] In India, 2.5 million people suffer severe burns caused by overturned kerosene lamps each year.[8]
- Poor light quality from kerosene lamps, which are often the sole source of lighting after daylight, limits productivity and opportunities for studying or income-generating work.
- Kerosene lamps are expensive to operate. Kerosene is costly both for low income households that buy it, and for governments that subsidize it. In parts of Africa, for instance, kerosene costs make up 10-25% of household monthly budgets.[9]

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[5] See Jacobson et al., *Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development*.

[6] Nicholas L. Lam et al., "Kerosene: a Review of Household Uses and Their Hazards in Low- and Middle-income Countries," *Journal of Toxicology and Environmental Health* 15, no. 6 (2012): 396–432, doi: 10.1080/10937404.2012.710134.

[7] *Solar Lighting for the Base of the Pyramid - Overview of an Emerging Market* (Lighting Africa, October 2010).

[8] Ibid.

[9] *Lighting Africa Market Trends Report 2012* (Lighting Africa, June 2013).

Target regions

More than 95% of people without electricity access live in either developing Asia or Sub-Saharan Africa and most live in rural areas.[10] Although electrification levels are improving, grid expansion is still not keeping up with population growth and power outages are common. In Sub-Saharan Africa, nearly 70% of people do not have access to electricity. Installed electricity capacity in Sub-Saharan Africa has grown relatively steadily by an annual average of 1.7% over the past two decades, though by 2030, Africa's un-electrified population is projected to grow to almost 700 million people, surpassing Asia.[11] Asia has the largest off-grid population in the world, with 22% of the population or 788 million people (55%) of the global off-grid population.[12] Much of Asia's off-grid population is concentrated in South Asia. Consumers in Africa spend between US$12 - 17 billion each year on fuel-based lighting, while consumers in Asia spend $9 - 13 billion annually.[13]

Table 1 illustrates potential black carbon reductions by country, offering a rough estimate of the achievable climate benefits of upgrading from kerosene lamps. Based on UNEP/GEF en.lighten off-grid assessment data on kerosene lamp stocks and kerosene use, and on fuel burn rates from Lam et al.[14], the calculations estimate annual savings in black carbon emissions were a country's entire kerosene lamp stock replaced with clean lighting alternatives.[15] Table 1 also illustrates how the installed stock estimate for simple wick lamps is a determining factor for which countries have the highest annual black carbon emissions.

Table 1. Annual kerosene use and black carbon emissions by country

Country	Installed stock estimates (millions) - Kerosene lamp - glass cover	Installed stock estimates (millions) - Kerosene lamp - simple wick	Annual kerosene saved (million liters)	Annual black carbon savings (tons)*
India	Households - 113.9 Businesses - 10.8 **124.7 million (70.6%)**	Households - 51.0 Businesses - 0.9 **51.9 million (29.4%)**	6700	**153,821**
Ethiopia*	Households - 5.0 Businesses - 1.6 **6.6 million (20.2%)**	Households - 24.5 Businesses - 1.5 **26 million (79.8%)**	1200	**59,950**

[10] International Energy Agency, *World Energy Outlook 2012*.

[11] *Lighting Africa Market Trends Report 2012*; Behrens et al., *Access to Energy in Developing Countries*.

[12] Ibid.

[13] UNEP News Centre, "Sustainable Off-Grid Lighting Solutions Can Deliver Major Development and Climate Benefits," February 20, 2013, http://www.unep.org/newscentre/Default.aspx?DocumentID=2704&ArticleID=9407&l=en.

[14] Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps."

[15] Annual black carbon savings were calculated by determining the amount of kerosene used annually (multiplying the percent share of each lamp type - glass or simple wick) and multiplying these figures by the emissions rate for lamp type as determined in Ibid.

Country	Installed stock estimates (millions) - Kerosene lamp - glass cover	Installed stock estimates (millions) - Kerosene lamp - simple wick	Annual kerosene saved (million liters)	Annual black carbon savings (tons)*
Nigeria*	Households - 39.8 Businesses - 3.8 **43.6 million (70.7%)**	Households - 17.8 Businesses - 0.3 **18.1 million (29.3%)**	2300	**52,680**
Democratic Republic of the Congo	Households - 4.1 Businesses - 1.3 **5.4 million (20.1%)**	Households - 20.3 Businesses - 1.2 **21.5 million (79.9%)**	999	**49,964**
Indonesia	Households - 33.1 Businesses - 3.1 **36.2 million (70.6%)**	Households - 14.8 Businesses - 0.3 **15.1 million (29.4%)**	2000	**45,917**
Afghanistan	Households - 8.9 Businesses - 1.2 **10.1 million (23.8%)**	Households - 25.6 Businesses - 6.8 **32.4 million (76.2%)**	604	**29,018**
Myanmar	Households - 16.2 Businesses - 1.5 **17.7 million (70.5%)**	Households - 7.3 Businesses - 0.1 **7.4 million (29.5%)**	992	**22,828**
Kenya	Households - 14.0 Businesses - 1.3 **15.3 million (70.5%)**	Households - 6.3 Businesses - 0.1 **6.4 million (29.5%)**	853	**19,629**
Tanzania	Households -11.7 Businesses - 1.6 **13.3 million (68.6%)**	Households - 5.9 Businesses - 0.2 **6.1 million (31.4%)**	763	**18,335**
Sudan	Households - 12.7 Businesses - 1.2 **13.9 million (70.6%)**	Households - 5.7 Businesses - 0.1 **5.8 million (29.4%)**	734	**16,862**

Sources: "Country Lighting Assessments," En.lighten, http://www.enlighten-initiative.org/CountrySupport/CountryLightingAssessments.aspx; Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps."
** = CCAC partner*

Existing landscape

Lighting and energy initiatives

Many existing initiatives already aim to upgrade lighting from fossil fuel sources, either through increasing electricity access with grid expansion or by promoting and making available modern off-grid lighting alternatives. Grid expansion, however, is expensive and often slow-moving to implement and off-grid solutions, focused on here, are needed to achieve rapid action.

In contrast to grid expansion mega-projects, smaller scale, decentralized off-grid lighting and energy projects can be more easily financed and implemented by combinations of international development agencies, local and international NGOs, and private companies. On the smaller end of the spectrum, many NGO programs and social enterprise organizations are working to spread modern off-grid lighting technologies. Small-scale projects in developing countries, especially in rural areas, are often financed by campaigns or support programs of

NGOs, often with international donor grants.[16] One of the largest and most impactful programs is the Energy and Resources Institute's (TERI) Lighting a Billion Lives (LaBL) in India, which provides solar lanterns to poor rural households and works to support a continued market and services. LaBL has coordinated the supply of around 75,000 solar lights to villages in India and Africa. Other initiatives involve public private partnerships between businesses and NGOs, or for-profit social enterprises that aim to increase access to modern lighting technology. Solar Aid, for example, sells lights through its social enterprise, SunnyMoney, generating income that is invested back into the charity program.

Other larger-scale lighting initiatives involve public private partnerships between businesses, NGOs, and governments. UNEP/GEF's en.lighten initiative works with stakeholders to share best practices, adapt policy and regulatory frameworks, address technical and quality issues, and encourage countries to develop efficient lighting strategies. The UN Secretary-General's Sustainable Energy for All (SE4ALL) initiative engages government (over 50 from developing countries so far), private sector, and civil society stakeholders to promote universal energy access, energy efficiency, and renewable energy.

A number of existing off-grid lighting initiatives aim to improve access to lighting upgrades through reducing market barriers[17] and supporting market development. These programs, such as the World Bank-IFC Lighting Africa, Lighting Asia, and Lighting Global programs, are focused on activities such as promoting quality assurance, consumer protection, supporting finance, and consumer awareness and marketing campaigns. The Global Lighting and Energy Access Partnership (Global LEAP), a voluntary forum bringing together governments, the private sector, and development partners, also takes a market-based approach and has worked on quality assurance standards and award competitions for off-grid appliances. The Global Off-Grid Lighting Initiative (GOGLA) was formed by the IFC and World Bank in 2012 as industry-driven initiative designed to provide a future exit strategy for Lighting Africa.

Market growth and development

Off-grid lighting alternatives to replace kerosene lamps are becoming increasingly accessible and affordable and the market has developed quickly, particularly in Africa. An advanced off-grid lighting market has emerged in Sub-Saharan Africa, focused on LEDs and LED-lamps operated with solar panels and rechargeable batteries. Sales growth for solar LEDs in Africa now exceeds 100 percent annually, with similarly high, although less well-documented, rates in Asia.[18] In spite of rapid sales growth, overall market penetration in Africa remains low, reaching only 3.5-4% by the end of 2012, and even this small percent remains unsaturated for repeat sales.[19] From 2009 to 2012, annual sales of modern off-grid lighting products in Africa rose 90-95% each year, growing from approximately 300,000 lighting products in Africa in 2009 to approximately 4.4 million units by the end of 2012.[20]

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[16] Behrens et al., *Access to Energy in Developing Countries*.

[17] Major market barriers include lack of access to consumer and commercial finance, poor product quality, insufficient after-sales services, lack of consumer awareness, and prohibitive taxes and subsidies.

[18] Ibid.

[19] *Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines*.

[20] *Lighting Africa Market Trends Report 2012*.

This rapid rise has been enabled in part by falling prices and technology advances. Other key market include slow electrification rates, a growing need for off-grid charging of mobile phones, and increased expenditures on off-grid lighting.[21] As market gains continue, access to modern off-grid lighting systems is expected to increase further.

What could the CCAC do?

Kerosene lamps are relatively 'low hanging fruit' and upgrading to alternative lighting sources can result in rapid climate benefits at low cost. Furthermore, the high ratio of black carbon emissions to other co-emissions (e.g., organic carbon) leaves no question regarding the signal resulting from reductions. Even though the lamps produce fewer total emissions than other black carbon sources, kerosene lamps offer clear benefits – for climate as well as health, development, and education – and relatively easy and affordable options for actions. Lam et al. estimated that 270,000 tons of black carbon is emitted globally each year from kerosene lamps.[22] Other calculations show that annual emissions of black carbon from kerosene lamps could be as high as 580,000[23] to 702,000[24] tons per year.

Relatively low capital investment and the potential for substantial black carbon emissions savings also make upgrading from kerosene lamps an attractive investment. Jacobson et al. estimate that the total investment to replace kerosene lamps worldwide with solar LEDs until 2030 is less than $200 billion - and that in practice the cost would be even lower, saving over $800 billion in avoided kerosene purchases and mobile phone charging fees.[25] The costs of upgrading from kerosene lamps vary based on replacement technology and location. However, although giving away new lighting products may appear attractive due to the low price and potential to rapidly reduce emissions, these gains may be short-lived without sustaining market structures in place. Once lighting products need repairs or replacement parts, recipients are likely to revert back to kerosene lamps if they are unable to pay the upfront costs for repairs or replacements or if there is no after-sales infrastructure in place. There is also criticism that large-scale giveaways and subsidies can flood the market, disrupting existing activities related to lighting without sustaining long-term market growth.

The CCAC is a, voluntary, international coalition of governments, intergovernmental organizations, private sector representatives, environmental groups, and members of civil society aimed at reducing SLCPs. Given the CCAC's focus on black carbon as a SLCP and interest in achieving co-benefits, a new initiative on reducing black carbon from kerosene lamps could make use of many of the CCAC's interests and strengths. Each individual CCAC initiative works differently, but the below highlights some general potential areas of focus for a new kerosene lamps initiative.

- **Scale up existing lighting programs and partnerships:** There are already a number

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[21] Ibid.

[22] Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps."

[23] Ibid.

[24] Annual black carbon emissions calculated by determining the amount of kerosene used annually (multiplying the percent share of each lamp type - glass or simple wick) in UNEP/GEF en.lighten off-grid lighting assessments and multiplying these figures by the emissions rate for lamp type as determined in Ibid.

[25] Ibid., 13.

of initiatives aimed at providing access to clean lighting sources and transitioning away from fossil fuel-based lighting such as kerosene lamps, as described in section 2. Rather than risk duplicating efforts and spreading resources thin, new CCAC action should focus on collaboration with existing programs to scale up efforts and increase capacity. The CCAC should make use of available expertise, infrastructure, and networks and leverage existing partnerships and cooperative efforts. Lighting program representatives who were interviewed expressed that additional funds and support, increased political attention, engagement with national governments, and research efforts could all help to expand and improve existing efforts. Additional resources could help existing programs scale up efforts and expand to new regions.

- **Bring high-level attention and raise awareness:** Endorsing action on reducing black carbon emissions from kerosene lamps would make a statement of the issue's value and could encourage and initiate further work. Current awareness of the magnitude of climate impacts from kerosene lamps is relatively low. Bringing the political spotlight to the issue can also help engage policymakers and integrate knowledge into planning processes. High-level advocacy efforts from the CCAC could in particular bring attention to best practices. Specific statements about the importance of reducing black carbon from kerosene lamps, supported by key evidence and options for concrete action, could create a platform for work at both the national and international scales.
- **Promote positive policy and regulatory environments:** By engaging with national governments, the CCAC can promote policies and regulations that help promote positive lighting alternatives. Kerosene subsidies and high taxes, duties, and tariffs on modern lighting technologies constrain the market for clean alternatives. A positive regulatory environment can instead help encourage imports of solar and off-grid lighting products along with local manufacturing and distribution. The CCAC can promote political engagement, particularly with CCAC state partners, and support regulatory reform and offer policy and technical support for developing frameworks.
- **Promote use of quality assurance standards:** Lighting Global has developed a voluntary quality assurance framework for off-grid lighting that includes test protocols, sampling requirements, minimum quality standards, and recommended performance targets. The framework originated from work through the Lighting Africa program and was made an International Electrotechnical Commission (IEC) standard in April 2013, with support from other partners.[26] Governments can now adopt and implement the IEC standard, although none have to date (however, the prior Lighting Africa framework was adopted by Ethiopia and others). Alongside promoting positive regulatory measures, the CCAC could spotlight adoption of the standard.
- **Reduce knowledge gaps:** There are a number of gaps in current data and research on kerosene lamp use. For instance, relatively few scientific studies to date looking specifically at black carbon emissions from kerosene lamps.[27] There is relatively little data on which lamps are used - i.e. simple wick or hurricane - and where. As a result,

[26] Available at: http://webstore.iec.ch/webstore/webstore.nsf/mysearchajax?Openform&key=62257&sorting=&start=1&onglet=1.

See also: http://www.iec.ch/affiliates/pdf/workshops/2013_tc82_standards_support_improved_access.pdf.

[27] Lam et al., "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps.": "the contribution of kerosene lighting devices to global BC [black carbon] emissions has not been investigated in depth".

current assessments have large error margins and relatively crude projections. Improved understanding of burn rates is also needed: Burn rates are typically based on field and lab measurements that are accurate for specific lamps and scenarios, however, a wide range of lamp varieties and practices exist in real life. Lastly, a standard metric is needed to for assessing emissions reductions. A new CCAC initiative could support improvement of data and produce new scientific, technical, and policy studies. More data and research are needed to fill gaps in understanding and to improve emissions estimates and create an improved basis for policy measures and a foundation for political support. Finally, more research could be used to understand when consumers continue to use or discard kerosene lamps.

- **Support access to consumer and commercial finance:** Through existing commercial channels and initiatives, the CCAC could help to increase access to finance for both consumers and SMEs. Lack of access to consumer and commercial finance is a major market barrier, but microfinance programs and innovative sales models can help to reduce cost barriers. CCAC partners could also be encouraged to make funds available and to support development of new funding models, such as climate finance mechanisms.

Conclusions and next steps

To form a new initiative, one or more partner must next create a proposal to submit for review by the Steering Committee and the Working Group. Initiatives should ideally be led by a mix of developed and developing countries and non-state partners. A number of state and non-state partners have expressed initial interest already.

Upgrading from kerosene lamps to modern, non-fuel-based lighting alternatives presents a win-win situation for climate, health, and development goals. Further, it matches CCAC objectives and builds upon partner strengths. Nonetheless, options for CCAC action are not necessarily obvious. While giveaways of lighting upgrades would offer rapid reductions of black carbon emissions, these might not be sustainable and would risk disrupting existing market structures and entrepreneurial efforts. Further, the landscape of existing lighting initiatives and programs is already heavily populated.

Any new initiative from the CCAC should work with and through existing lighting programs. CCAC funds could help to scale up work that is already being done and to expand current programs to new target areas. The CCAC could also support additional research and access to finance for SMEs. Beyond funding, the CCAC could bring to the table engagement opportunities with state partners (and through non-state partners) regarding policy reform and adoption of quality assurance standards. Lastly, and perhaps most importantly, the CCAC could use its platform to raise awareness and focus a spotlight on the issue's value and potential, with the hopes of putting lighting upgrades on policymakers' agenda and making it a policy and funding priority.

Although action is already being taken to transition from kerosene lamps to modern, clean lighting alternatives, more work is needed. CCAC action could have a positive and lasting impact through raising awareness, scaling up activities, and improving collaborative efforts.