Black Carbon Emissions from Kerosene Lamps

Potential for a new CCAC Initiative

Prepared for the Clean Air Task Force

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Executive Summary

Around 1.3 billion people worldwide still lack access to electricity. For many, kerosene (paraffin) is a common lighting fuel and kerosene lamp use is widespread in the developing world. New research has shown that these lamps emit significant amounts of black carbon, 20 times more than previously estimated. A total of 270,000 tons of black carbon is emitted worldwide each year, having a warming equivalent close to 240 million tons of CO_2.

Kerosene lamps emit a relatively small portion of global black carbon, but efforts to replace them are comparatively cheap and easy and viable alternative lighting sources exist. Moreover, in addition to mitigating climate change, there are significant health and development co-benefits to be attained by replacing kerosene lamps with non-fossil fuel-based lighting alternatives. Modern off-grid lighting alternatives include solar light emitting diode (LED) products, solar photovoltaic systems, and mini-grids and are generally safer and healthier than kerosene, and have brighter light, longer product lives, and lower lifecycle costs. Relatively low capital costs and the potential for substantial black carbon emissions savings make upgrading from kerosene lamps to off-grid lighting alternatives an attractive investment.

Many existing initiatives already aim to upgrade lighting sources from fossil fuel sources such as kerosene, either through increasing electricity access with grid expansion or by promoting and making available modern off-grid lighting alternatives. Grid expansion efforts are often expensive and slow-moving to implement, however, and off-grid solutions are important for achieving rapid action.

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. A number of off-grid lighting initiatives already exist, focusing largely on developing Sub-Saharan Africa and South Asia, where more than 95% of people without electricity live. Small-scale lighting projects in developing countries, especially in rural areas, are often financed by campaigns or NGOs. Other initiatives involve public private partnerships between businesses and NGOs or for-profit social enterprises that aim to increase access to modern lighting technology. A number of major programs are focused on building markets for off-grid products. Markets for non-fuel-based, off-grid lighting products have developed quickly, particularly in Africa, making products increasingly accessible and affordable.

Because simple wick lamps produce significantly greater black carbon emissions, countries with a high number of simple wick lamps can offer a proportionally greater return on investment than countries where glass-covered lamps are more common.

A new initiative on black carbon from kerosene lamps could make use of many of the CCAC's interests and strengths. Options under a potential CCAC initiative on reducing black carbon emissions from kerosene lamps include:

- Scaling up existing lighting programs
- Bringing high-level attention and raising awareness
- Promoting positive policy and regulatory environments
- Promoting use of quality assurance standards
- Reducing knowledge gaps
- Supporting access to consumer and commercial finance

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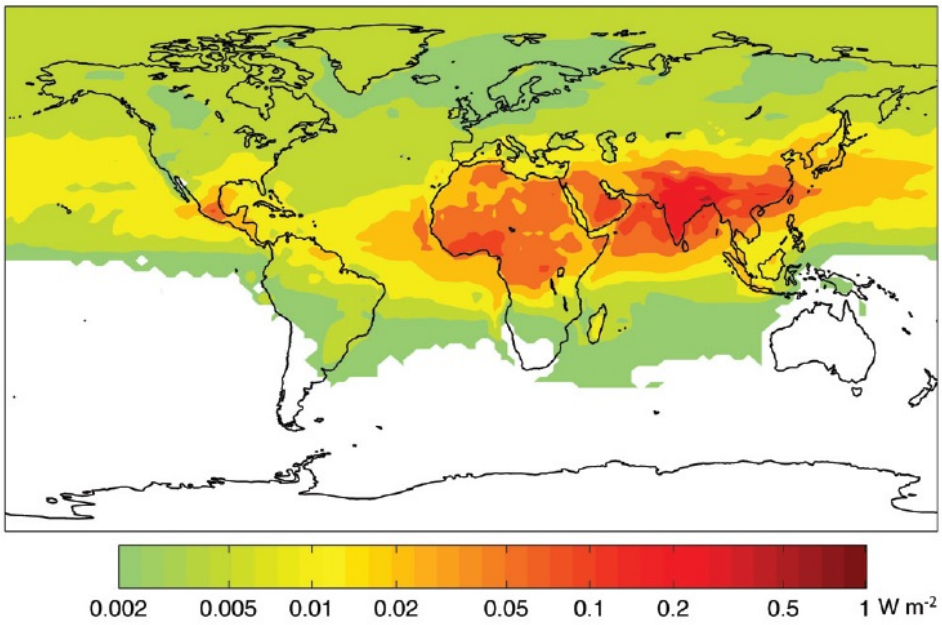
1 Black carbon and kerosene lamps

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 contributing to climate change. Black carbon particles have an intensely powerful heat-trapping effect, but only remain in the atmosphere for a few weeks, as opposed to carbon dioxide's (CO_2) atmospheric lifetime of hundreds of years. Black carbon is a major climate warmer, second only to CO_2, and together with other pollutants that have a similarly powerful but short-lived warming influence, is known as a 'short-lived climate pollutant' (SLCP).[1]

The use of kerosene lamps, which is widespread in the developing world, contributes to climate change by emitting the greenhouse gas (GHG) CO_2 in the same way as other types of fossil fuel combustion. However the lamps additionally emit black carbon, raising the lamps' contribution to climate change substantially.

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



Reproduced from 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.*

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.[2] The resulting climate warming impact is magnitudes greater than

[1] 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.

[2] 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.

prior calculations.[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 and reaches 0.5 watts per square meter (see Figure 1).

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 substantially more black carbon than glass-enclosed hurricane or pressurized mantle lamps.

Figure 2. Comparison of emission factors for black carbon

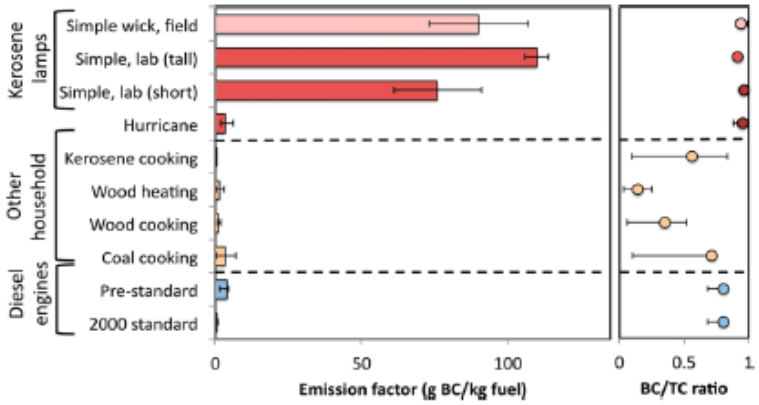


Figure 2. Comparison of emission factors for black carbon (EF_{BC}) and black carbon fraction of total aerosol carbon (BC/TC) for kerosene lamps, other household uses, and diesel engines. Error bars represent 90% uncertainty bounds.

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

Around 1.3 billion people worldwide still lack access to electricity.[5] For many people in developing countries, kerosene (paraffin) is a common lighting fuel that is both affordable (due in part to government subsidies) and accessible.[6] Household kerosene lighting sources, accounts for approximately 4 to 25 billion liters of kerosene use annually.[7]

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[3] Ibid.; Arne Jacobson et al., *Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development*, Global Views (Washington D.C.: The Brookings Institution, April 2013); *Lighting Africa Market Trends Report 2012* (Lighting Africa, June 2013).

[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*.

[5] International Energy Agency, *World Energy Outlook 2012* (Paris: OECD/ IEA, 2012).

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

[7] Jacobson et al., *Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for 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.[8]
- 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.[9] In India, 2.5 million people suffer severe burns caused by overturned kerosene lamps each year.[10]
- Poor light quality from kerosene lamps, which are often the sole source of lighting after daylight hours, 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 – even where the fuel is subsidized.[11]

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. 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 significant health and development co-benefits to be attained by replacing kerosene lamps with non-fossil fuel-based lighting alternatives.

2 Lighting upgrade efforts and barriers

Many existing initiatives already aim to upgrade lighting from fossil fuel sources such as kerosene, either through increasing access to electricity with grid expansion or by promoting and making available modern off-grid lighting alternatives. To replace kerosene lamps with more sustainable alternatives, either option is available.

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[8] 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.

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

[10] Ibid.

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

Projects in the former category, grid-based electrification, tend to be supported by international development banks and agencies, as well as government partners. Grid expansion provides reliable electricity and thus supports not only lighting, but also heat, household services, mechanical power, water pumping, cold storage, and more. However, the required infrastructure for grid expansion is expensive. In urban areas, extending the conventional electricity grid is a common solution to provide electricity for households, but rural areas can prove more challenging and expensive. Because of high upfront costs, public funding has traditionally helped support only large-scale extension projects.[12]

In addition to efforts to extend transmission, grid electrification requires that there be sufficient generation capacity to support newly connected areas. Sources of power generation vary in sustainability, and can use either fossil fuels or renewable energy sources. Therefore the total climate benefit of replacing kerosene-based lighting with electrification varies depending on the electricity source.

There are numerous donor-financed projects promoting access to energy through expansion of reliable on-grid electricity access, ranging from multi-billion dollar hydroelectric power and transmission projects to NGO or private sector initiatives on small-scale domestic energy needs.[13] However, as these are often expensive and slow moving to implement, off-grid solutions, which are the focus of this report, are also 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. Modern off-grid lighting alternatives include solar light emitting diode (LED) products, solar photovoltaic systems, and mini-grids.[14] These alternatives are generally safer and healthier than kerosene, and have brighter light, longer product lives, and lower lifecycle costs. As noted by Lam et al.,[15] even large-scale upgrading from one type of kerosene lamp to another can help decrease black carbon emissions, since hurricane lamps or pressurized mantle lamps emit far less black carbon than simple-wick lamps do.

Non fuel-based, off-grid lighting options to replace kerosene lamps are becoming increasingly accessible and affordable and the market for alternative off-grid solutions has developed quickly, particularly in Africa. 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.[16] This rapid rise has been enabled in part by falling prices and technology advances. As these gains continue, access to modern off-grid lighting systems is expected to increase further.

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[12] *From Gap to Opportunity: Business Models for Scaling Up Energy Access* (International Finance Corporation, May 2012).

[13] Arno Behrens et al., *Access to Energy in Developing Countries*, Study for Directorate-General for External Policies of the Union, November 2011.

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

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

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

Key market drivers of off-grid lighting upgrades include slow electrification rates, a growing need for off-grid charging of mobile phones, and increased expenditures on off-grid lighting.[17] Box 1 details major market barriers, alongside certain approaches for overcoming them.

Box 1. Major market barriers and approaches for overcoming them

- **Finance:** Lack of access to consumer and commercial finance is a major market barrier. Although lighting upgrades present significant cost savings to consumers over time when compared to kerosene, the initial cost barrier prevents purchases of alternatives. Most off-grid households are low income and lack access to financing options. Furthermore, some banks and microfinance institutions (MFIs) are reluctant to provide loans because they lack of awareness of market potential and product quality or choose not to extend credit in the face of high transactional and operational costs, high default risks, remotely located customers, and (in the case of solar lanterns) small loan ticket size, low repossession or collateral value, and a low warranty period.[18] Small and medium enterprises (SMEs) selling such products face a lack of accessible debt and equity capital, particularly for marketing and distribution, which creates additional market barriers.[19] Low-income households can benefit from microfinance programs to allow initial purchases, and new innovative sales models can reduce initial cost barriers.
- **Product quality:** Cheap and sub-standard products can erode consumer trust. Quality assurance programs as well as performance and safety standards can help increase transparency and improve both consumers' and lenders' confidence. If quality standards are too restrictive or narrow, however, certain technologies could be limited and products made more expensive –passing on costs on to consumers and limiting market reach to low-income households.
- **Need for after-sales services:** Once lighting products need repairs or batteries run out, there is a high likelihood of reverting back to kerosene lamps if there is no infrastructure in place for repairs or sales. For this reason, many existing initiatives have activities aimed at training and developing after-sales support systems.
- **Consumer awareness:** Many consumers in new markets are unaware of alternative off-grid lighting products and product benefits. Consumers are also often unaware that non-fuel-based alternatives can have overall costs savings, instead perceiving them to be more expensive because of the higher upfront costs. It can be challenging to reach consumers in rural areas, to find appropriate messaging techniques, and to overcome cultural, language, and other barriers to understanding. Awareness campaigns, tailored to regional needs, can help familiarize consumers with new products and quality-assured products and help educate consumers about monetary savings, health and safety benefits, and the

[17] Ibid.

[18] *Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines* (International Finance Corporation, 2012).

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

superior light quality and function of lighting upgrades.

- **Taxes and subsidies:** Many countries have kerosene subsidies that support energy access for low-income households by making the fuel more affordable for lighting and cooking, but make it harder for alternatives to compete. Kerosene subsidies artificially lower the relative savings of switching to solar off-grid lighting. Taxes and tariffs constitute other policy barriers. Solar companies are often hit with multiple taxes (import duty, excise duty, VAT, surcharges) that lead to a 5-30% increase in the price of the final product, making products less available to low-income consumers.[20] High import duties and VAT taxes on both parts (for domestic manufacturing) and finished products make it harder for businesses to deliver products and manage costs. A number of countries, including Tanzania, Ethiopia, and Uganda, have moved to reduce or eliminate such tariffs and are taking steps to improve market policies and encourage lighting upgrades (see Table 1).[21]

To reduce these barriers, many existing lighting initiatives aim to improve access to lighting upgrades through market development and support. These programs, such as the World Bank-IFC **Lighting Africa, Lighting Asia, and Lighting Global** programs, are focused on building markets for off-grid products and overcoming market barriers with activities on quality assurance, consumer protection, supporting finance, and consumer awareness and marketing campaigns.

Table 1. Kerosene subsidies, import duties, and taxes

Country	Kerosene subsidies	Import duties and taxes
Africa		
Cameroon	Reduced transport fees for kerosene in household use. Exempted from special tax of US$ 0.24/liter applied to other petroleum products.	Import duties of 20-30% and VAT 19.25% for photovoltaic (PV) systems.
DRC	Exempt from National Road Maintenance Fund tax.	Import duties of 10% and VAT 15% for PV systems.
Ethiopia	Exemption on taxes: VAT of 15%. Exemption of other taxes of 30% (excise, municipal taxes, and the Road Fund Levy).	Efficient lights for off-grid users must fit with solar PV equipment. For PV systems, 15% VAT and 10% surtax.
Ghana	Subsidized 23% in mining sector. Exempt from the Debt Recovery Levy and the Road Fund Levy.	10% duty on off-grid lighting. For PV systems, 12.5% VAT, 3.5% in other taxes/levies, duty applied for Balance of Systems.
Kenya	Cost of kerosene is 15% lower than cost of diesel due to lower Excise Duty and no applied Road Maintenance Levy.	16% VAT on solar and lighting products.

[20] Ibid.

[21] *Solar Lighting for the Base of the Pyramid - Overview of an Emerging Market*.

Country	Kerosene subsidies	Import duties and taxes
Nigeria	Reduced diesel and kerosene subsidies in 2011.	7% port surcharge and 1% inspection fee for LEDs, solar lanterns, and PV panels.
Rwanda	Certain charges in price structure are waived so that it is 25% cheaper than diesel.	Energy efficient lights subject to reduced import duties. PV kits are subject to reduced import duties.
Tanzania	Cost of kerosene is 41% lower than the cost of diesel (25% exclusion from VAT, other exemptions).	Efficient off-grid lights allowed under PV tax exemption.
Asia		
Bangladesh	Retail price of kerosene is ~1.1 USD per liter compared to a subsidized price of ~0.8 USD per liter.	No import duty on solar PV cells, modules/panels, and LEDs. Import duty of 40% for charge controllers, 25% for finished battery, 7.5% for raw lead, 26% for CFLs, and 25% for solar lanterns. Renewable energy equipment exempted from 15% VAT.
Cambodia	No subsidies	Import duties on solar panels have been recently brought down. Duties include 15% for batteries, 15% for plastic, 35% for electronics, and 7% duty on solar lanterns. 10% VAT.
India	Government offers a subsidy of 0.5 USD per liter. Kerosene price pre-subsidy is USD 0.8 and post-subsidy is 0.3 USD per liter.	No import duty for solar cells, modules, panels, LEDs, and charge controllers. 10% import duty on batteries and 5% solar lanterns. 5% VAT as opposed to higher rates for other products and services. Central excise duty exempted. Financial support is available for the PV industry for R&D projects in association with technical institutions.
Indonesia	Kerosene is heavily subsidized and is available at USD 0.27 per liter (subsidized).	No import duties on solar panels. Duties of 5-10% on solar lanterns, 5-10% on charge controllers, and 10% VAT.
Nepal	No subsidy, however, there is a government proposal for providing a subsidy of ~ 0.13 USD per liter (up to 5 litres1 every month) to people in off-grid areas. Students get subsidies on 10 liters per month.	No import duty on solar photovoltaic cells, modules/panels, and LEDs. 1% duty on batteries and 10% ready-made solar lanterns. VAT is free on components used in solar home systems (SHS) and SHS.
Pakistan	No subsidies	32% import duty levied on solar PV cells modules/panels, 0% on LEDs, 10% duty on batteries, and 15% on ready-made solar lanterns. VAT is free on components used in SHS. General sales tax of 17% applicable.
Philippines	No subsidies	No import duty on solar PV cells, modules, panels, and LEDs. Import tariffs 5-7% for solar lanterns. Import duties on batteries 15% and other components 3%. Import duties on SHS vary from 0-7%. VAT is 12%.

Sources: Revised Policy Study Report Note (Lighting Africa, August 2011); Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines (International Finance Corporation, 2012).; International Energy Agency, World Energy Outlook 2012 (Paris: OECD / IEA, 2012).; The Lumina Project, http://light.lbl.gov/; Lighting Africa, Policy Report Note: Democratic Republic of Congo, August 2012.

UNEP/GEF's **en.lighten** initiative focuses on promoting transitions to sustainable and energy efficient lighting technologies. A public-private partnership, en.lighten works with stakeholders to identify global best practices and share this knowledge and information; create policy and regulatory frameworks; address technical and quality issues; and encourage countries to develop national and/or regional efficient lighting strategies. Although much of the program is focused on promoting energy efficiency and phasing out incandescent lamps, the program works on off-grid lighting as well, primarily in West Africa.

The en.lighten initiative collaborates closely with the **Global Off-Grid Lighting Initiative (GOGLA)**. GOGLA was formed by the IFC and World Bank in 2012 as public-private initiative, designed to help provide a sustainable exit strategy for Lighting Africa in the future. In February 2012, GOGLA announced a new strategic partnership with UNEP.

Another initiative that takes a strong market-based approach is the **Global Lighting and Energy Access Partnership (Global LEAP)**, a voluntary forum created in 2012 to continue the work of the Clean Energy Ministerial's Solar and LED Energy Access Initiative, and bring together governments, the private sector, and development partners. Two of Global LEAP's major projects have been development of a quality assurance standard for solar LED lanterns within the framework of the IEC and launching product award competitions for off-grid appliances - one for LED lighting and one for color televisions.

The UN Secretary-General's **Sustainable Energy for All (SE4ALL) initiative** is a global initiative with three objectives to be achieved by 2030: providing universal access to modern energy services; doubling the global rate of improvement in energy efficiency; and doubling the share of renewable energy in the global energy mix. SE4ALL engages government, private sector, and civil society stakeholders - so far it has secured commitments of USD $320 billion across all three objectives. More than 50 governments from developing countries have joined the SE4ALL initiative and most have initiated assessments to determine challenges and opportunities in achieving SE4ALL goals.

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 lighting in rural areas, are often financed by campaigns or support programs of NGOs, often with international donor grants.[22] 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 program.

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

Table 2. Overview of major lighting initiatives[23]

Program	Description
Global	
en.lighten	The UNEP/GEF en.lighten initiative was established in 2009 to accelerate a global market transformation to environmentally sustainable, energy efficient lighting technologies, as well as to develop strategies to phase-out inefficient incandescent lamps to reduce carbon emissions and the release of mercury from fossil fuel combustion. The en.lighten initiative serves as a platform to build synergies among international stakeholders; identify global best practices and share this knowledge and information; create policy and regulatory frameworks; address technical and quality issues; and encourage countries to develop national and/or regional efficient lighting strategies. The initiative is a public/private partnership between the UNEP, OSRAM and Philips Lighting, the National Lighting Test Centre of China, and the Australian Agency for International Development and is funded through the GEF and en.lighten partners.
Global LEAP	Global LEAP is a voluntary forum bringing together governments, the private sector, and development partners to share knowledge and best practices and encourage self-sustaining commercial markets for energy access solutions. Global LEAP has activities in five main areas: product quality assurance, finance across the supply chain, market intelligence, consumer education, and policy. Global LEAP supported the development of a global standard for solar LED lanterns within the framework of the IEC and launched two Outstanding Product Awards competitions for off-grid appliances, for LED lighting and for color televisions. Member governments include Italy, the United States, Japan, and the United Kingdom. Multilateral development institution partners include the World Bank, IFC, African Development Bank, UNDP, and the GEF. The UN Foundation and TERI are development partners.
GOGLA	Formed in 2012 as public-private initiative, GOGLA was conceived out of the joint World Bank/IFC effort to provide a sustainable exit strategy for Lighting Africa initiative. GOGLA was been established to act as the industry advocate with a focus on SMEs. It is a neutral, independent, not-for-profit association created to promote lighting solutions that benefit society and businesses in developing and emerging markets. GOGLA has working groups for policy and regulations, quality and standards, business models and market intelligence, and life cycle and recycling. Supported by Lighting Africa, IFC, World Bank, U.S. Department of Energy, and UNEP.
Lighting Global	Lighting Global carries out activities of Lighting Africa and Lighting Asia that are global in nature. Lighting Global serves as an umbrella for the Quality Assurance framework**,** which was originally developed out of the Lighting Africa program.
UN Sustainable Energy for All (SE4ALL)	UN Secretary-General global initiative to mobilize action from all sectors of society in support of three objectives to be achieved by 2030: providing universal access to modern energy services; doubling the global rate of improvement in energy efficiency; and doubling the share of renewable energy in the global energy mix. SE4ALL is a multi-stakeholder effort that aims to mobilize governments, the private sector and civil society to make changes in the world's energy system. The initiative's Action Agenda highlights the objective of providing access to electricity through off-grid, micro- and mini-grid solutions, including targeted applications for productive uses. Commitments of USD $320 billion have been made across all three objectives.

[23] See Annex A for a more detailed overview of lighting initiatives.

Program	Description
EnDev (Energizing Development Programme)	EnDev provides energy access to households, social institutions, and small and medium-sized enterprises in developing countries in Africa, Asia and Latin America. This is done by extending and densifying power grids, installing hydropower plants and distributing solar home systems as well as helping to establish self-sustaining markets for the production and sale of improved (more efficient) cookstoves in countries in Africa, Asia, and Latin America. The effort is led by Germany and funded by the Netherlands, Norway, Australia, the UK, and Switzerland.
Africa	
Lighting Africa	Lighting Africa is a joint IFC and World Bank program that works towards improving access to better lighting in areas not yet connected to the grid. Lighting Africa accelerates development of markets for affordable, modern off-grid lighting solutions for low-income households and micro-enterprises. The program aims to provide efficient and clean lighting to 250 million people in Sub-Saharan Africa by 2030. Lighting Africa is supported by the Africa Renewable Energy and Access Grants Program, the Climate and Development Knowledge Network (CDKN), the Global Partnership on Output-Based Aid (GPOBA), the Energy Sector Management Assistance Program (ESMAP), the Global Environment Facility (GEF), Italy, Luxembourg, the Netherlands, Norway, the Public-Private Infrastructure Advisory Facility (PPIAF), the Renewable Energy and Energy Efficiency Partnership (REEEP), and the U.S.
Power Africa	Power Africa, announced by the U.S. in June 2013, will build on Africa's potential to develop both fossil fuels and renewables, build out power generation and transmission, and expand the reach of mini-grid and off-grid solutions. In its first phase, Power Africa will add more than 10,000 megawatts of electricity generation capacity. It will increase electricity access by at least 20 million new households and commercial entities with on-grid, mini-grid, and off-grid solutions. Power Africa supports investment in Africa's energy sector with policy and regulatory best practices, pre-feasibility support and capacity building, long-term financing, insurance, guarantees, credit enhancements, technical assistance, and more. The U.S. will commit USD $7 billion over the next 5 years to Lighting Africa. The African Development Bank (AfDB) expects to allocate as much as $3 billion over the next 5 years. Private sector partners are expected to invest over USD $23 billion. Power Africa will work closely with the AfDB, the governments of the six target countries, and a number of private sector partners.
Ghana Solar Lantern Distribution Project	The Government of Ghana is using money formerly allocated to fuel subsidies to fund replacement of kerosene lamps with solar lamps. The program will cost the government over GHC 2 million. The program is aimed at providing two hundred thousand solar lanterns to replace kerosene lanterns in off-grid homes over a period of five years. In the first phase, 20,000 solar lanterns will be distributed nationwide through a trade-in (kerosene lamp) or subsidy scheme (pay reduced cash fee). The second phase from 2014-2016 will support establishment of local assembly of solar lanterns with 50,000 solar lanterns will be assembled and distributed through 50% grant subsidy package. The third phase of 18 months will see a distribution of 130,000 solar lanterns and further reduced subsidy. The project will also market promotional support for development of a sustainable market.
Kenya Kerosene Phase Out	In August 2012, the Government of Kenya announced an ambitious plan to phase out the use of kerosene for lighting and cooking, and replace it with clean energy products. Norway pledged NOK 250 million over 5 years and signed an energy and climate agreement with Kenya to develop a framework policy for renewable energy and energy efficiency.
Asia	
Lighting Asia	Lighting Asia/India is an IFC market-transforming program, based off of Lighting Africa, with the objective of promoting both the value and presence of modern off-grid lighting. Work is primarily in India to date, but expanding to Bangladesh. Supported by the IFC, U.S., and Italy.

Program	Description
TERI LaBL	The Lighting a Billion Lives (LaBL) campaign has twin objectives of providing solar lanterns to poor rural households that lack electricity and making such service self-sustainable after it is established. TERI has coordinated the supply of around 75,000 solar LED lights (through the first half of 2012) to various Indian villages, and a few villages in Africa. LaBL mostly works in India, with some activity in Asia, but is expanding through local partnerships and is working with the Asian Development Bank's Lighting for All initiative to bring modern lighting to 50 million people in Asia-Pacific by 2015. LaBL trains local entrepreneurs and utilizes both fee-for-service and loan finance models.

3 Use of information on black carbon emissions

Many lighting programs and initiatives recognize the climate benefits of transitioning from fossil fuel off-grid lighting sources to cleaner alternatives, however the focus is more often on health and development benefits. In other words, climate benefits are welcomed and recognized, but are not often the driving force behind lighting upgrade initiatives.

Research recognizing the high level of black carbon emissions from kerosene lamps is relatively new, and as such has not yet been widely disseminated nor considered in deliberations on lighting upgrades. The majority of professionals working on lighting upgrades who were consulted for this study were, however, aware of the new research. The en.lighten initiative, Lighting Africa, and Global LEAP have expressly recognized the newly understood impacts of black carbon from kerosene lamps.[24] Private sector and industry in general were less aware of the research and in general, tend to put greater focus on health, safety, and product quality. Interviews also indicated that lighting professionals were largely unsure of how this new information could directly alter existing efforts, but generally felt that greater understanding of the full climate impacts of kerosene lamps would be useful in raising awareness and support regarding sustainable lighting alternatives.

Some lighting companies have looked to carbon finance to help meet financing needs and facilitate lighting upgrades. The United Nations Framework Convention on Climate Change (UNFCCC) has approved a methodology for financing substitutes of fossil fuel based lighting with LED/CFL lighting systems under the Clean Development Mechanism (CDM).[25] Projects can generate income via the generation of certified emission reductions (CERs), which can be sold on international emissions trading markets. However, with CERs currently selling at rock bottom prices of <$1 (as opposed to >$10 several years ago) there is little interest in such projects and consequently little investment. At higher carbon prices, there may be more interest in obtaining carbon credits and the additional revenue could help increase the profitability of lighting companies working at scale in developing countries and lower costs for

[24] See "FACT SHEET: GLOBAL LIGHTING AND ENERGY ACCESS PARTNERSHIP (GLOBAL LEAP)" (Clean Energy Ministerial, April 2013), http://www.cleanenergyministerial.org/Portals/2/pdfs/factsheets/FS_GlobalLEAP_April2013.pdf; *Lighting Africa Market Trends Report 2012*.

[25] See https://cdm.unfccc.int/methodologies/DB/41A0Q0QT5CUP3TMD57GC6RZ4YRV28M

consumers.[26] However, the CDM does not address black carbon and thus the projects generate CERs only from GHG savings. These are relatively modest for kerosene lamps, whereas including black carbon climate benefits would increase the carbon finance incentive.

4 Motivation for implementation in different regions

Of the nearly 1.3 billion people worldwide who still lack access to electricity, more than 95% live in either developing Asia or Sub-Saharan Africa and most live in rural areas.[27] Although electrification levels are improving, grid expansion is still not keeping up with population growth and power outages are common. World population is anticipated to rise to 8.6 billion in 2035, primarily in Asia and Africa.[28]

In Sub-Saharan Africa, nearly 70% of people do not have access to electricity, with the lowest rates of electrification found in the Democratic Republic of Congo (DRC), Tanzania, Kenya, and Ethiopia. Installed electricity capacity in Sub-Saharan Africa has grown relatively steadily by an annual average of 1.7% over the past two decades.[29] By 2030, Africa's un-electrified population is projected to grow to almost 700 million people, or 140-150 million households, surpassing Asia to become the largest un-electrified region.[30]

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.[31] In spite of rapid sales growth, overall market penetration in Africa remains low, reaching only 3.5-4% by the end of 2012 for the 115-120 million households in Africa, and even this small percent remains unsaturated for repeat sales.[32]

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.[33] Much of Asia's off-grid population is concentrated in South Asia, with 86% of people located in only seven countries: Cambodia, Bangladesh, Nepal, Pakistan, Indonesia, India, and the Philippines. Although Asia's off-grid population is higher, investment in Africa for off-grid lighting solutions is greater.[34]

Fuel-based lighting is a major expense for households and governments in Africa and Asia. Consumers in Africa spend between US$12 - 17 billion each year on fuel-based lighting,

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

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

[28] Ibid.

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

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

[31] Ibid.

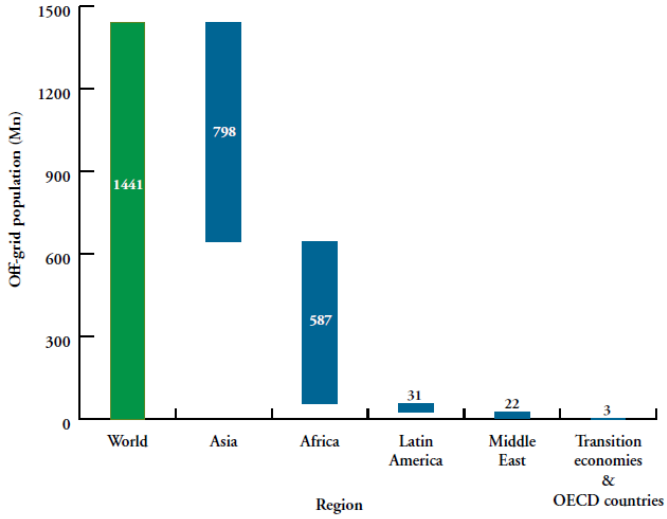
[32] *Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines*.

[33] Ibid.

[34] Ibid.

while consumers in Asia spend $9 - 13 billion annually.[35]

Figure 3. People without access to modern energy services by region (2009)



Reproduced from Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines.

The en.lighten initiative has created a global database of national lighting assessments for both on-grid and off-grid power. The assessments evaluate the level of financial savings, health benefits, and GHG reductions that could be achieved through a transition to sustainable off-grid lighting. The off-grid assessments also provide country-level evaluations that include estimates of the number of kerosene lamps used, for glass-covered and simple wick, and projected savings for kerosene if the country were to fully switch to solar LED lighting.[36] En.lighten is currently developing new off-grid assessments that will incorporate new research on black carbon emissions from kerosene lamps and reflect this data in the projections of potential climate savings.[37]

Table 3 illustrates potential black carbon reductions by country, offering a rough estimate of the achievable climate benefits of upgrading from kerosene lamps. Based on the en.lighten off-grid assessment data on kerosene lamps stocks and kerosene use and fuel burn rates from Lam et al.[38], calculations estimate annual savings in black carbon emissions under a scenario where a country's entire kerosene lamp stock were replaced with clean lighting

[35] 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.

[36] For more information on the off-grid lighting assessments and a description of the methodology used see: http://www.enlighten-initiative.org/CountrySupport/CountryLightingAssessments/MethodologyforCountryLightingAssessments.aspx

[37] The new assessments are expected to be available in early 2014.

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

alternatives.[39] The updated en.lighten assessments will offer more sophisticated calculations, however these estimates offer a demonstration of emissions and potential gains in individual countries.

Table 3. Annual kerosene use and black carbon emissions by country[40]

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**
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**

[39] 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.

[40] See Annex B for a full list of countries.

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)
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**
Madagascar	Households - 1.2 Businesses - 0.4 **1.6 million (20%)**	Households - 6.0 Businesses - 0.4 **6.4 million (80%)**	295	**14,774**
Niger	Households - 1.0 Businesses - 0.3 **1.3 million (20%)**	Households - 4.9 Businesses - 0.3 **5.2 million (80%)**	235	**14,565**
Uganda	Households - 9.1 Businesses - 1.3 **10.4 million (69.3%)**	Households - 4.5 Businesses - 0.1 **4.6 million (30.7%)**	593	**14,028**
South Africa	Households - 9.2 Businesses - 0.9 **10.1 million (70.6%)**	Households - 4.1 Businesses - 0.1 **4.2 million (29.4%)**	561	**12,880**
Malawi	Households - 0.9 Businesses - 0.3 **1.2 million (18.8%)**	Households - 4.7 Businesses - 0.3 **5.2 million (81.2%)**	234	**11,869**
Bangladesh*	Households - 2.9 Businesses - 0.5 **3.4 million (43.6%)**	Households - 3.9 Businesses - 0.5 **4.4 million (56.4%)**	303	**11,341**

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*

Table 3 also illustrates how the installed stock estimate for simple wick lamps is a determining factor for which countries have the highest projected annual black carbon emissions. While India tops the list based on sheer *numbers* of kerosene lamps – with an estimated 176.6 million kerosene lamps, using 6.7 billion liters of kerosene each year for lighting – Ethiopia's extremely high black carbon emissions relative to lamp numbers is based on a high prevalence of the simple wick variety, accounting for nearly 80% of kerosene lamps. Likewise, Afghanistan has only the eleventh highest level of annual kerosene use, but the seventh highest level of black carbon emissions – which again can be attributed to 76.2% of the country's kerosene lamps being simple wick lamps.

Box 2. National developments in target countries

- **India:** India has both the highest level of kerosene lamp use and of black carbon emissions from kerosene lamps. Approximately 400 million people in India are

without access to electricity, and this number is projected to increase as the country's population grows to 1.5 billion by 2035.[41] While India has added substantial electricity generation capacity in recent years, little of this reaches poor or rural households.[42] Kerosene is the most commonly used source of lighting for off-grid and under-electrified rural households across income segments.[43] India has one of the highest kerosene subsidies in the world, on which the government spends approximately USD 4 billion annually - about half of which goes towards lighting.[44] Kerosene subsidies are highly political, as the majority of consumers are rural and low-income households which are a critical voter base, and proposals to reduce or phase out subsidies have never been implemented. India's regulatory environment, however, is generally seen as encouraging for off-grid lighting manufacturers and investors.[45]

India's Ministry of New and Renewable Energy (MNRE) oversees programs promoting PVs, solar lanterns, and solar home systems (SHS). MNRE provides solar lanterns with subsidies to certain households in off-grid villages and as of 2010 had distributed approximately 800,000 lanterns.[46] The Indian government's National Solar Mission program, under the National Action Plan on Climate Change, aims to install 20 million grid-connected SHS by 2022.[47] It also lays out plans to establish a solar research centre, increase international collaboration on technology development, strengthen domestic manufacturing and increase government funding and international support.[48] India's Remote Village Solar Lighting Program aims to provide single-light SHS to 9,000 villages not covered under rural electrification programs and provides subsidies for up to 90% of costs or USD $160, whichever is less. It had distributed 600,000 SHS as of 2010.

- **Ethiopia:** Ethiopia has an electrification rate of only 17% alongside a rapidly growing population, with expected growth from 80 million to over 120 million people by 2030. In 2011, Lighting Africa estimated that "even with tremendous investments to rapidly scale up grid connection in Ethiopia, more than 12 million families will still be living without electricity by 2025."[49] By 2025, however, Ethiopia seeks to achieve middle-income status and is promoting development of a green economy as a way

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

[42] *Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines*; Behrens et al., *Access to Energy in Developing Countries*.

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

[44] Ibid.

[45] Ibid.

[46] Ibid.

[47] Ministry of New and Renewable Energy, "JNN Solar Mission: Scheme / Documents," n.d., http://www.mnre.gov.in/solar-mission/jnnsm/introduction-2/; GLOBE International, "India," in *The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 33 Countries*, Third, 2013.

[48] GLOBE International, "India."

[49] *Policy Report Note: Ethiopia* (Lighting Africa, August 2012).

of achieving both growth and sustainability.

Responsibility for rural electrification in Ethiopia is shared between the Ethiopian Electric Power Corporation (EEPCo), the national electricity utility, and the Rural Electrification Executive Secretariat (REES), which supports and promotes off-grid electrification. EEPCo's multi-donor[50] Universal Electricity Access Program (UAEP) aims to provide grid-based electrification to rural areas, with the goal of connecting 6,000 rural towns and villages from 2005 to 2015.[51] For off-grid energy, the Renewable Energy Fund (REF) supports pilot projects to foster private sector participation in the industry and provides flexible and innovative financing and has emphasized renewable energy in recent years, particularly solar photovoltaics and micro-hydropower.[52] It has had less resources available than the UAEP and has moved at a much slower pace historically. According to Lighting Africa, the REF is the main financial mechanism available in Ethiopia for use in disseminating off-grid lighting devices and could be scaled up further to support development of the off-grid lighting market.[53] The REES has collaborated with other government agencies and the Lighting Africa program to address market barriers to modern lighting.

Nigeria: Nigeria has the highest population in Africa, more than 150 million people, and over 80 million people are without access to electricity.[54] Power is often also unreliable and most private industries and small businesses have off-grid diesel generators as back up, resulting in high greenhouse gas emissions per unit of electricity.[55] Nigeria's electricity sector is relatively small and electricity supply is unreliable.[56] Population growth and underinvestment in the electricity sector has led to increased demand without accompanying increases in capacity and efforts to increase electricity access, both on- and off-grid, have been plagued by insufficient and inconsistent government support.[57]

The Nigerian government's overarching renewable energy policy plans an increased share of renewables in the national electricity supply with solar, small and large hydropower, biomass, biogas, and wind energy generation. The

[50] UEAP has mainly been financed by the Ethiopian government, with additional support from the World Bank, the African Development Bank, the Kuwait Fund, the Arab Bank for Economic Development in Africa, India, and others

[51] *Policy Report Note: Ethiopia*.

[52] Ibid.

[53] Ibid.

[54] Climate Investment Funds, "CLEAN TECHNOLOGY FUND INVESTMENT PLAN FOR NIGERIA," November 11, 2010, https://www.climateinvestmentfunds.org/cifnet/sites/default/files/Nigeria%20CTF%20Investment%20Plan%20-%20Endorsed_1.pdf.

[55] U.S. Energy Information Administration, "Nigeria," *Independent Statistics and Analysis*, n.d., http://www.eia.gov/countries/cab.cfm?fips=NI.

[56] Ibid.

[57] Belinda Baah, "Lights out? Nigeria's Electricity Woes," *Consultancy Africa Intelligence*, October 16, 2012; U.S. Energy Information Administration, "Nigeria."

Renewable Energy Programme of the Federal Ministry of Environment is aware of the effects of kerosene lamps on health, environment, and household incomes and has developed a program to phase out lamps in all schools in the country, aiming to provide mini-solar lamps to all children. There are also plans to phase out kerosene stoves in the city of Lagos.[58]

- **Democratic Republic of Congo (DRC):** At 11%, the DRC has one of the lowest rates of electrification in the world and kerosene lamps are commonly used as a lighting source.[59] The DRC government has set a goal for a national electrification rate of 60% by 2025.[60] Even under optimistic projections, however, around 75% of rural households and 16% of urban households will likely be without access to electricity in the next decade.[61] The DRC has received major grants for electrification projects from both the African Development Bank and World Bank.

  The DRC has no national climate change strategy, but is currently developing a national governance framework for reduced emissions from deforestation and forest degradation. In the DRC's first UNFCCC National Communication, the country recognized the need for improved access to clean energy and aimed to achieve this by improving electricity generation and distribution, replacing fossil fuels with renewable sources, and promoting the exploitation of a biogas reserve.[62] The DRC is also in a high potential area for solar.

- **Indonesia** is the fourth most populous country in the world and struggles to meet growing domestic energy demand due to inadequate infrastructure and a complex regulatory environment.[63] Electrification rates are low and funding is needed for the development of additional generation capacity, transmission, and distribution networks. Approximately 35% of Indonesia's population is off-grid, about 91% of which are located in rural areas and remote islands such as Nusa, Maluku, and Papua.[64] The Indonesian government has set a goal of 90% electricity coverage in households by 2020. To meet this goal, a "fast track" plan was designed in 2006 to add 20 additional GW to the grid by 2014; subsequent delays have revised the project's expected completion date to 2013.[65] However, plans for additional

[58] Femi Akinola, "Nigeria: Lagos to Phase Out Kerosene for Cooking Gas," *Daily Trust*, July 12, 2012, http://allafrica.com/stories/201207120262.html.

[59] *Policy Report Note: Democratic Republic of Congo* (Lighting Africa, August 2012).

[60] Ibid.

[61] Ibid.

[62] *Scaling-up Renewable Energy in Africa: Democratic Republic of Congo* (Norton Rose Fulbright, June 2012), http://www.nortonrosefulbright.com/knowledge/publications/58927/scaling-up-renewable-energy-in-africa-democratic-republic-of-congo.

[63] "Indonesia," *U.S. Energy Information Administration*, January 9, 2013, http://www.eia.gov/countries/cab.cfm?fips=ID.

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

[65] "Indonesia."

generation capacity rely heavily on coal, followed by geothermal energy, and also hydropower and gas.

The solar market is driven by the government's rural electrification program, which procures SHS from local companies and provides them to a limited number of households for free.[66] Under the program, the government accredits products and suppliers are responsible for installation and training of the local technicians to ensure after-sales services. So far, an estimated 260,000 SHS have been installed under the program, covering only 1.3% of the market.[67] Cited problems include a lack of ownership by beneficiaries, lack of after-sales services, and inadequate monitoring and evaluation by implementing agencies. The program does not cover solar lanterns. UNEP and TERI (see section VI below) are both piloting new market-based initiatives for SHS and solar lanterns in Indonesia.

5 Benefits and costs

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, education, etc. – and relatively easy and affordable options for actions. Relatively low capital investment and the potential for substantial black carbon emissions savings make upgrading from kerosene lamps to off-grid lighting alternatives an attractive investment.

Lam et al. estimated that 270,000 tons of black carbon is emitted globally each year from kerosene lamps.[68] Over the next 20 years, eliminating these emissions would be equal to reducing 5 gigatons of CO_2.[69] Lam et al. note that these calculations may even underestimate emissions, as the study's annual estimate of kerosene consumption for residential lighting is less than one-tenth that of prior studies, fuel burn rate calculations may not reflect decreased combustion efficiency from fuel impurities, and only residential use is considered. Estimates of kerosene consumption in the en.lighten assessments are higher than those used by Lam et al. and, according to Jacobson et al., yield a black carbon

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

[67] Ibid.

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

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

emission rate of 580,000 tons per year that is approximately twice as large as Lam's.[70]

The calculations in Table 3, which are based off of the en.lighten assessments, take into consideration commercial as well as residential kerosene lamp use. The potential annual black carbon savings worldwide based on these figures is even larger, at 701,902 tons of black carbon. As noted, en.lighten is currently updating the off-grid country lighting assessments to include black carbon emissions.

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.[71] The price tag of $200 billion is a fraction of the estimated nearly $1 trillion in cumulative investment needed to achieve universal access to electricity by 2030.[72]

The en.lighten assessments also estimate annual monetary savings from upgrading to solar LED systems in each country, as well as the time needed to repay the costs of upgrading. For instance, the assessments demonstrate that replacing all fuel-based lighting in Kenya would pay for itself in only seven months due to fuel savings.[73] Kenya currently spends around US$ 900 million per year on off-grid lighting. For most countries, the payback period is less than one year, depending on the local costs for LEDs and kerosene.[74] The costs of upgrading from kerosene lamps vary based on replacement technology and location. Off-grid LED lighting product costs range from under $10 for a small solar powered desk lamp to about $120 for multi-light mini-solar home systems (SHS).[75] The costs for LED lamps and other lighting products have fallen substantially in recent years and are likely to continue to do so, reducing costs further.

[70] Ibid.

[71] Ibid., 13.: "This analysis assumes a $35 retail price for a solar charged off-grid lamp that can deliver 120 lumens for six hours per day, charge a mobile phone three times per week and last three years. It also assumes kerosene prices of $1/liter and mobile phone charging at $0.15 per charge. In practice, the investment estimate is likely to be substantially lower than $200 billion because this value assumes that current price, performance and durability levels for LED lamps will remain constant. In fact, prices are likely to decrease and product performance and durability should increase because technological development is still in an early phase. Kerosene prices may also increase over time relative to current levels, which would increase the estimate of total potential savings. The calculations do not include discounting of future costs."

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

[73] UNEP News Centre, "Sustainable Off-Grid Lighting Solutions Can Deliver Major Developmend Climate Benefits."

[74] Ibid.

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

Figure 4. Typical range of prices of off-grid solar lighting products in Asia

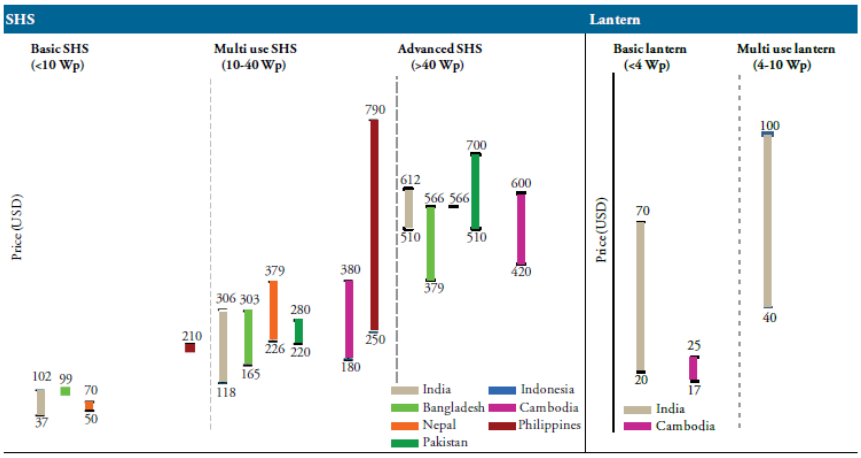


Figure 1.7: Typical prices of solar off-grid lighting products in Asia

Reproduced from Lighting Asia: Solar Off-Grid Lighting. Market Analysis of: India, Bangladesh, Nepal, Pakistan, Indonesia, Cambodia and Philippines.

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. Giveaway or subsidy-based programs may be able to distribute lighting upgrades quickly, but can be unsustainable in the long run. 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. Comprehensive market-based programs should include activities such as training, capacity building, and marketing programs, as well as microfinance.

Countries with a high number of simple wick lamps can offer a proportionally greater return on investment than countries where glass-covered lamps are more common, as replacing a simple wick lamps offers significantly greater emissions reductions than from glass-covered lamps.[76] From a cost-benefit perspective, countries with high levels of simple wick lamp usage may provide the cheapest and quickest reductions – even if they are not the countries with the highest kerosene lamp usage overall. A focused investment and coordinated strategy in these countries could help to target funds and make substantial, quick gains.

Investments in markets and policy environments also help reduce future costs and enable

[76] Given the disparity in emissions rates for different lamp types, upgrading from simple wick to glass-enclosed lamps could in theory could be a transition measure. However, while this approach would reduce black carbon emissions, it would not address other benefits (e.g., health, economic) from transitioning away from fuel-based lighting sources. Additional studies regarding consumer engagement and preferences and evaluation of market impact would be necessary before giving further consideration. Further, while initial cost are a barrier to using glass-enclosed lamps are high, other issues such as operating costs, are also influential: Hurricane lamps use fuel at a higher rate than many wick lamps, which means that they cost more to operate, creating an important barrier to use.

growth. As more players enter the market, distribution networks are strengthened, technologies improve, and products become cheaper and more accessible.

Large investments should be made in grid electrification and renewable generation as a long-term objective, but to achieve more rapid benefits, financing action on kerosene lamp upgrades and present an attractive option with relatively low-cost and scalable technologies.

6 Gaps in knowledge

There have been relatively few scientific studies to date looking specifically at black carbon emissions from kerosene lamps.[77] More data and research are needed to fill gaps in understanding and to improve emissions estimates. Additional scientific research and data would also create an improved basis for policy measures and foundation for political support.

There is relatively little data on which lamps are used - i.e. simple wick or hurricane - and where. As a result, 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. Further research is needed to better characterize kerosene lamp use patterns and associated burn rates.

A standard metric is needed to for assessing black carbon emissions and reductions. This has already been requested by some companies seeking a standardized framework to calculate climate benefits, and could be used in both the public and private sector. Such a framework should be transparent and relatively simple to enable wide use.

Finally, more empirical research could be used on when and how often households continue to use kerosene lamps after adopting upgrades.[78] Generally, households use less kerosene, but do not always displace the old lamps. The issue is not yet fully understood.

7 Potential for a CCAC initiative

The Climate and Clean Air Coalition (CCAC) is a, voluntary, international coalition aimed at reducing SLCPs. The Coalition's objectives are to address SLCPs by:[79]

1. Raising awareness of short lived climate pollutant impacts and mitigation strategies;
2. Enhancing and developing new national and regional actions, including by identifying and overcoming barriers, enhancing capacity, and mobilizing support;

[77] 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".

[78] The Ghana Solar Lantern Distribution Project (see Table 2 and Annex A) offers free solar upgrades through a trade-in program for old kerosene lamps (versus a subsidy otherwise).

[79] Climate and Clean Air Coalition, "About," http://www.unep.org/ccac/About/tabid/101649/Default.aspx.

3. Promoting best practices and showcasing successful efforts; and
4. Improving scientific understanding of short lived climate pollutant impacts and mitigation strategies.

CCAC partners include governments, intergovernmental organizations, private sector representatives, environmental groups, and members of civil society.[80] Since new research came out revealing the magnitude of black carbon emissions from kerosene lamps, a number of CCAC partners have expressed interest in addressing this issue through CCAC action. Given the CCAC's focus on black carbon and interest in achieving co-benefits, such as for health and development, a new initiative on reducing black carbon from kerosene lamps could make use of many of the CCAC's interests and strengths.

On the other hand, some interviewees for this report expressed concern that the CCAC is already overburdened with initiatives and does not have capacity to effectively take forward another initiative at this stage. Further, given that there are already a number of initiatives successfully working on lighting upgrades and market development, a new effort could crowd the landscape and duplicate efforts, making inefficient use of valuable resources.

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 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.

Bringing in additional financial resources and building capacity in CCAC countries could help existing programs scale up efforts and expand to new regions. For example, although Asia's off-grid population is higher, investment in Africa for off-grid lighting solutions is higher than in Asia and there are more active programs.[81] Lighting Asia is currently expanding to Bangladesh, and in the future hopes to expand to other countries, such as Nepal, and to continue project work.

Strong collaboration already exists between existing lighting programs, as well as between the private sector, NGOs, and governments. Still, cooperation could be further improved and the CCAC could help bring CCAC partners into networks and supporting outreach. Many

[80] Ibid.

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

CCAC partners are also already involved in lighting programs.

The market for off-grid lighting solutions has expanded rapidly in recent years with predictions for continued, sustained growth. Nonetheless, much of the market remains untapped and can use continued support as it grows. Lighting Africa notes that market structures are still at an early stage and will continue to need support from donors, development organizations, NGOs, and others for at least the next three to five years.[82] The CCAC should ensure that efforts under a new initiative do not disrupt the off-grid lighting market. Careless product giveaways and subsidies may be tempting due to the potential to more rapidly reduce emissions, yet gains may be short-lived without after-sales support and can harm businesses and entrepreneurial efforts.

Bring high-level attention and raise awareness

One of the CCAC's objectives is to raise awareness of SLCP impacts and mitigation strategies. The CCAC has brought high-level attention to the problem of SLCPs, engaged policymakers, and initiated new action to reduce SLCPs. 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. Acknowledging that kerosene lamps play an important role in climate solutions can foster awareness and promote subsequent action from CCAC state and non-state partners. Current awareness of the magnitude of climate impacts from kerosene lamps is relatively low. Increased attention could reframe the issue of kerosene lighting upgrades - which is primarily considered in terms of health and development benefits - as a climate priority.

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 the national and international levels.

Promote positive policy and regulatory environments

The CCAC is built around the idea of encouraging and enhancing national and regional action. 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 (see section 2). 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, support regulatory reform, and offer policy and technical support for developing policy frameworks. Existing programs have already experienced successes in creating awareness on policy

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

questions,[83] but new high-level action, particularly coming from other governments, could make a difference. Many CCAC state partners have relatively good policy environments, but could improve upon these further, taking measures such as adopting quality standards. It was, however, suggested that due to the sensitive nature of kerosene subsidies, it is better to take a "gentler" approach of addressing non-subsidy barriers first.

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.[84] 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). Global LEAP plans to encourage adoption of the framework, but has not yet had capacity or connections in order to do so and is hoping to work through partners with larger networks. Alongside efforts to promote positive regulatory measures, the CCAC could spotlight adoption of the standard.

Reduce knowledge gaps

Another CCAC objective is to improve scientific understanding of SLCP impacts and mitigation strategies. As discussed in section 6, there are a number of gaps in current data and research on kerosene lamp use. A new CCAC initiative could support improvement of data and produce new scientific, technical, and policy studies. The CCAC could further help coordinate survey efforts with partners, such as the World Bank, and could fund field data collection and sampling. The en.lighten program is currently sponsoring some studies (covering, e.g., health and safety benefits of off-grid lighting conversions, lighting fuel subsidies, and market transformation and job creation) but more is needed, particularly for field research. The CCAC can also support development of a standardized metric for calculating black carbon emissions and reductions (see section 6). 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

[83] For example, Lighting Africa was said by an interviewee to have had "moderate" success in dealing with policy questions.

[84] 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.

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.

Box 3. Cookstoves

Kerosene used for both lighting and cooking purposes. Like the lamps, kerosene-fueled cookstoves are sources of black carbon emissions and have been the target of a number of programs in recent years, such as the Global Alliance for Clean Cookstoves (GACC), to replace them with clean, efficient alternatives. The CCAC has also taken interest in this area with a recent initiative on domestic heating and cooking.

A new CCAC initiative on kerosene lamps should collaborate closely with the domestic heating and cooking initiative to find synergies. For example, awareness campaigns could combine efforts and resources, and efforts towards policy reforms could ensure that regulations achieve maximum benefits for low income families' lighting and cooking needs as well as environmental gains. For example, new research is being done on efficient kerosene stoves and on combined lantern and cooking stove, with some warnings against phasing out government subsidies for kerosene which support both lighting and cooking.[85]

The GACC already works closely with Lighting Africa and other lighting initiatives. Although the prospect of collaboration was highly encouraged, the idea of adding kerosene lighting to the domestic heating and cooking initiative met resistance, as there is not sufficient attention or resources to effectively tackle a new area at this stage.

8 Conclusions and next steps

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 CCAC 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 absent other measures 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

[85] http://www.business-standard.com/article/news-ians/don-t-phase-out-kerosene-researchers-tell-government-113082600349_1.html

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.

To form a new initiative, one or more partners 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 or have been identified as potential candidates based on policy priorities, capacity, and impact. It is not yet clear, however, who might have the capacity and determination to drive the issue forward. Before efforts are carried forward, further engagement should be taken with key partners (see corresponding memorandum) and additional evaluation made as to the institutional and financial capacity of the CCAC to invest in a new measure. Other options, at least as interim measures, should be evaluated, too: for instance, the CCAC could issue a high-level statement along with key members working in the lighting arena (e.g., World Bank, UNEP) to outline the problem and concrete opportunities for action and support.

CCAC action to reduce black carbon emissions from kerosene lamps might not dramatically alter the policy landscape, yet could have a positive and lasting impact by raising awareness, scaling up activities, and improving collaborative efforts.