



# LIGHT AND LIVELIHOOD:

*A Bright Outlook for Employment  
in the Transition from  
Fuel-Based Lighting to  
Electrical Alternatives*



UNITED NATIONS ENVIRONMENT PROGRAMME

BMZ



Federal Ministry  
for Economic Cooperation  
and Development



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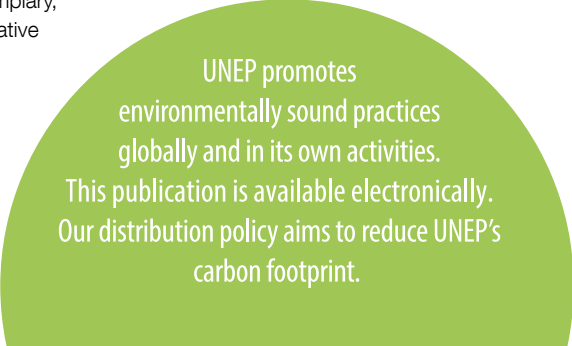
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# 1. Summary

This study examines the impact of a market transformation to off-grid lighting in terms of job loss and job creation. It focuses on the Economic Community of West African States (ECOWAS), where 178 million people lack access to the electricity grid. The study provides statistics and introduces policy tools that governments can use to stimulate the production of new, energy efficient lighting technologies and the growth of associated jobs.

The study estimates that employment from kerosene distribution represents approximately 20,000 full-time jobs throughout ECOWAS. This is equivalent to one full-time kerosene retailer per 10,000 people who live off-grid. Extrapolating the results of the surveys conducted for this study indicates that up to 15,000 new jobs have already been created in sub-Saharan Africa as a result of the transition to efficient off-grid lighting. The potential jobs-to-population ratio for alternative technologies and associated value chains is 30 jobs per 10,000 people living off-grid, which corresponds to the possible creation of 500,000 new, lighting-related jobs throughout ECOWAS. In this region, increased market penetration of solar lanterns, for example, could create approximately 30 times more jobs—and often higher-quality jobs—than fuel-based lighting does. This positive result reflects the common finding that renewable and energy efficiency create many times more jobs than do non-renewable energy systems, particularly for non-oil producing countries.

The study documents that policymakers have tools to increase the pace of job creation, while proactively minimizing any disruption throughout the transition process. Policy tools include: stimuli for domestic manufacturing or assembly of products; supporting peripheral businesses and services, such as training, recycling, financing, and carbon trading; removing market barriers that slow the uptake of efficient lighting; and, equipping a workforce able to engage in the manufacture, distribution and sale of efficient lighting technologies.

## 2. Overview

In retrospect, few would regret the advent of the car because of the loss of employment among those who cared for horses. However, such loss of livelihood is real and should be understood and mitigated to the full extent possible. The effects of a transition from kerosene and other lighting fuels to electric alternatives such as light emitting diode (LED) lanterns (Mills 2005)<sup>1</sup> have not previously been examined. With few exceptions (for example, Solar Aid 2012), if even mentioned, the issue is treated only parenthetically.

When considering alternatives, it is important to compare and contrast not only direct employment outcomes, but also a host of indirect effects, including quality of illumination and its cost for commercial and household users. The cost of lighting for homes diverts residents' incomes and subtracts value from their wages. In addition to the role that furnishing lighting fuels and equipment plays in the creation of livelihoods, illumination itself also plays a very real role in work environment and quality of work performed there. The level and quality of fuel-based illumination creates suboptimal and sometimes unsafe working conditions.

The demographics of employment are another consideration. Fuel based lighting jobs, like other jobs in the fuel supply chain, may in some cases involve child labour; illicit activities such as smuggling, migrant workers; or jobs based entirely outside of the country of concern. Emerging alternative technologies are not immune from these concerns. The quality and decency of employment must also be considered. The International Labour Organization defines decent employment as having four components: productive job and adequate incomes; social protection; rights at work; and social dialogue (ILO, et al 2009; 2011; 2012).

The practical distinction between having any employment versus none at all, is central to an individual or family's economic viability. Thus, this study focuses more on the presence or absence of employment rather than the number of hours or level of income. Many people in off-grid communities are underemployed, working less than what elsewhere might be considered as full time. Similarly, many people maintain multiple modes of earning money, some in the formal sector, others in the informal sector.

This study develops simple model-based estimates because no primary survey data exists to describe the numbers of direct, let alone indirect jobs, created by fuel-based lighting. Kerosene is by far the lighting fuel of concern when evaluating livelihood impacts, even where it is not the dominant lighting fuel. This is because other sources such as liquid propane gas (LPG), candles, battery-powered torches, or fuel wood are rarely if ever sold alone and thus are less critical to marginal employment. While kerosene has multiple uses aside from lighting, notably cooking (primarily in urban areas), charcoal-starting and heating, the majority of its use at a national level in ECOWAS and elsewhere is usually for lighting. Distributed smaller diesel generators are also used by entrepreneurs to provide lighting (especially in night markets) and can be regarded as yet another form of grid-independent fuel-based lighting. One estimate puts the combined electrical capacity of such generators at 6,000 megawatts (MW) in Nigeria alone (Adam Smith International 2013)<sup>2</sup>; however, no macro-level estimates of the employment associated were identified.

<sup>1</sup> In this report, the shorthand term "LED lantern" is used to describe a broad category of lighting products that have emerged over the past decade. Common attributes are: high-efficiency "white" LED light sources; compactness and portability; a battery or other form of storage that allows grid-independent operation, charging either from dedicated renewable (typically solar ~10 peak watts) power source or a temporary grid connection (as mobile phones are charged); a larger degree of affordability than first-generation fluorescent devices; and they are "plug-and-play", such that there is no need for professional installation. Within these broad criteria are found many variations including light output (level and directionality), charging time, battery life, and, the presence of secondary functions such as phone charging. Quality also varies widely and those considered viable alternatives to fuel-based lighting have high levels of performance and truth-in-advertising such as those recognized by the Lighting Global product quality assurance program. There is no consensus on terminology, and descriptors such as lamp, lantern, torch, light, and pico power will often be used to describe some or all of the products in this category.

<sup>2</sup> For perspective, assuming 6h/day operation and a thermal efficiency of 15%, this level of generation corresponds to 1.3 billion kWh of electricity production per year, and 12 MT/year CO<sub>2</sub> emissions.

## 2.1 Scope and Review Method

This study uses two techniques for estimating baseline employment from the production and selling of kerosene and one technique for estimating job creation from alternative electric technologies.



*Generators are used by entrepreneurs to provide power during grid outages or to vendors without grid connections: Senegal*

- Estimates of baseline upstream employment from production of kerosene are derived by apportioning total petroleum-sector jobs for kerosene to the proportion that kerosene represents in total domestic kerosene production or refining.
- Estimates of baseline downstream employment from selling kerosene are based on “bottom-up” estimates of the revenues generated by kerosene sellers, converted to jobs assuming a standard working wage. These are validated against field observations of the ratio of kerosene sellers to an overall population served.
- Estimates of job-creation by the emerging LED lantern industry are developed based on a survey of LED lantern producers operating in the Africa marketplace. The survey was conducted by the author of this study in late 2013. Seventeen companies were contacted and invited to contribute data in a standardized format. Respondents included three manufacturers and four distributors and included some of the largest market players. The types and numbers of jobs were collected and normalized per million lamps sold. A central value across the responses is then applied to the potential market size to derive an estimate of ultimate job creation potential for the future.

These methods along with their results are elaborated more fully in the following sections.



*Kerosene sellers with empty containers due to acute supply shortages in Malawi*

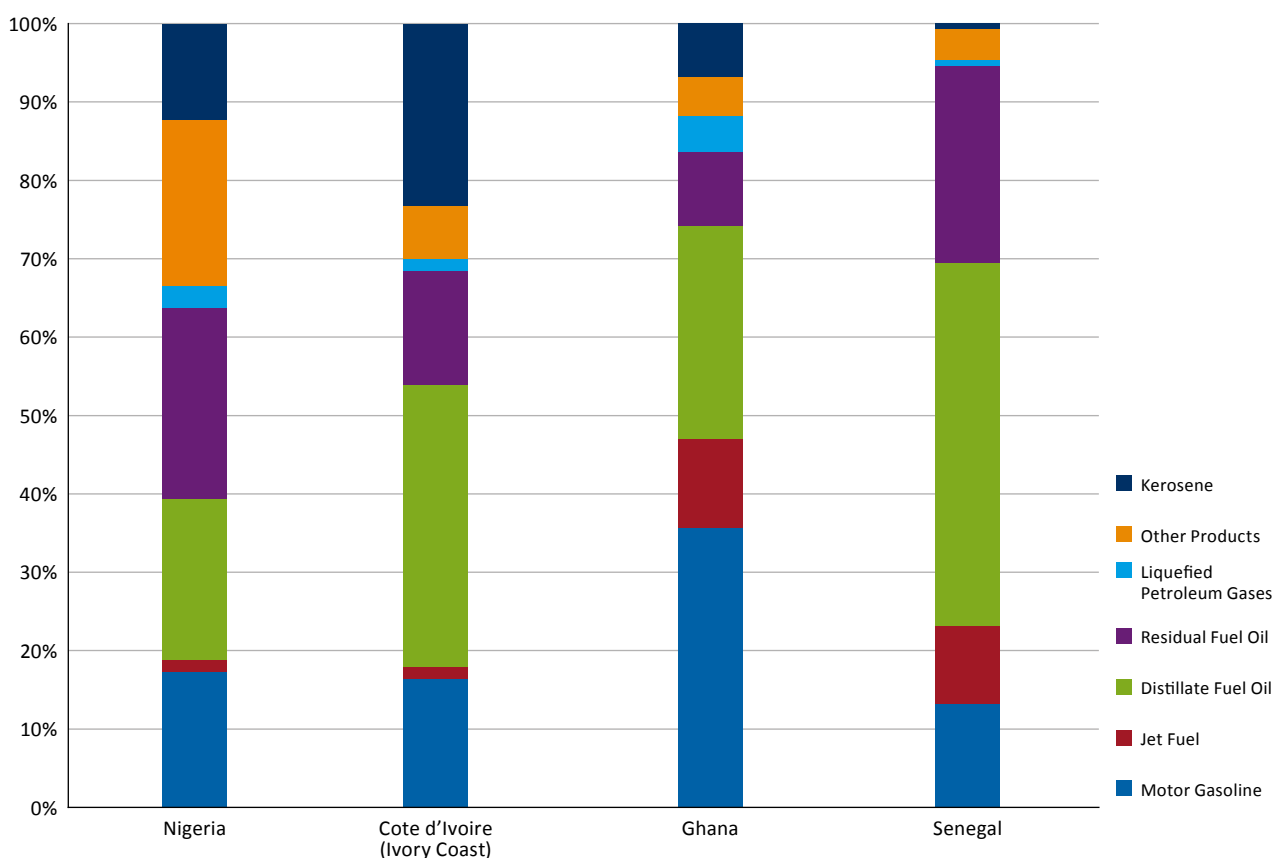
# 3. Current Employment Situation

## 3.1 The Lighting Energy Upstream

Energy supply has a very low “job intensity” compared to alternate activities that provide energy efficiency services (in this case, illumination). This is particularly so for kerosene given that it represents a minor sub-component of the overall petroleum-sector value chain in ECOWAS countries. All but four ECOWAS countries (Cote d'Ivoire, Ghana, Nigeria and Senegal) import all of their lighting fuels and thus, do not host any domestic upstream jobs associated with lighting fuel production or refining (Figure 1). All ECOWAS countries, but Cote d'Ivoire, consistently consume more kerosene than they produce, and thus any reductions in oil imports improve the balance of trade.

**Figure 1. Kerosene's share in domestic petroleum product output: 2010**

Source: USDOE/EIA data



The job-intensity of oil refining in the United States of America is approximately 392 barrels per worker per day (Kojima *et al.* 2010). If we were to assume that we could estimate kerosene-related jobs at the same level of job-intensity, then the output of ECOWAS countries in the peak year of the past decade (40,000 barrels of kerosene per day) would be equivalent to only 100 jobs<sup>3</sup>.

Given this brief overview of upstream kerosene markets in ECOWAS, reductions in kerosene consumption would have negligible if any, adverse impact on employment. Jobs that are, in principal, displaced by reductions in demand could presumably be reabsorbed elsewhere within the energy sector, particularly given the portability of associated skills.

<sup>3</sup> i.e., 40,000 barrels-day x 1 worker/392 barrels-day = 102 workers



### 3.2 The Lighting Energy Downstream

The energy downstream is far more job-intensive than the upstream. It is important to identify the points where jobs could be most at risk. Figure 2 portrays the structure of kerosene distribution and sale. At the wholesale level, and at almost every node, kerosene is one of many petroleum products being moved or sold (often together with trucking transportation fuels). Similarly, lighting equipment is almost always sold with other goods, even by informal vendors.

**Figure 2. Depiction of kerosene value chain**  
*Areas of particular concern where kerosene is sold/handled exclusively are circled in red*



No statistical information exists on the extent of employment among kerosene sellers. The International Labour Organization offers technical guidelines for this purpose (ILO 2013), and has a specific statistical definition and category for street vendors, but does not differentiate those selling lighting fuels and equipment from others. Recently, Solar Aid conducted interviews with kerosene traders in rural Kenya and Malawi, giving some insight into their dynamic retail situation (see next page).

## Interviews with kerosene traders in Malawi and Kenya

SolarAid has conducted surveys in localities within Malawi and Kenya where they have introduced solar-LED replacements for kerosene lighting, in an attempt to saturate the market. Of 30 markets visited in the Mzimba South district of Malawi in 2013, 57% were found to have kerosene sellers (Solar Aid 2013b). In these areas, 22% of 341 consumer respondents listed kerosene as their primary lighting fuel, with an additional 20% reporting kerosene as a secondary lighting fuel.

Only 2 of the 14 vendors interviewed sold kerosene exclusively, with the remainder selling a variety of other goods such as soap, batteries, salt, sugar, bread, soft drinks, and diverse consumables. For the 10 of 12 vendors responding to the relevant survey questions and who sold multiple goods, kerosene represented 27% of total income. The kerosene was sourced on the black market or brought in from outside the country by 8 of the 14 traders.

The traders sold an average of only 2.6 litres of kerosene each week, at a price of 1,536 MWK per litre (\$3.57 per litre), earning a gross profit of 17% of the prices they pay for the fuels. These sales represented very low revenues for these vendors, approximately \$2.50/week (range \$0.50-\$7.00 per week).

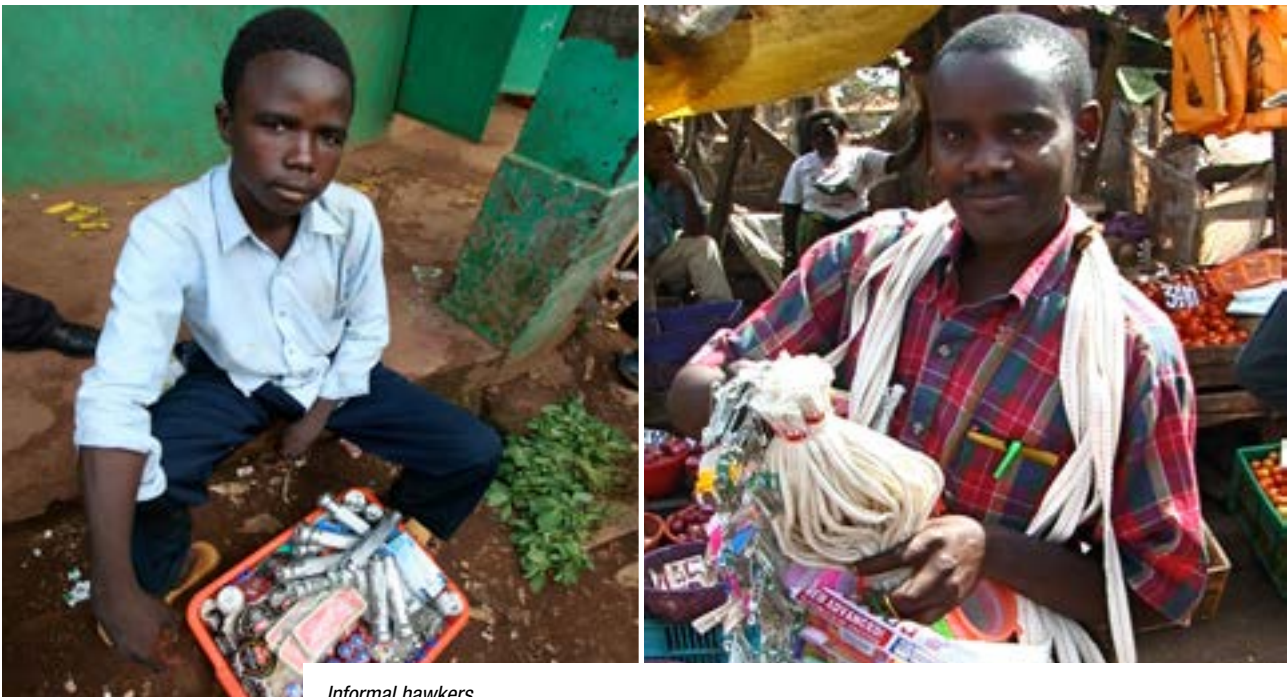
The vendors noted an average 50% reduction in sales over the past year. Most attributed this to low-cost non-rechargeable LED torches (flashlights) and/or solar-charged lanterns. Several also noted that kerosene shortages were an additional cause of reduced sales. Most had made adjustments to the reduced demand. One spoke of their kerosene business as “dying a natural death.”

See detailed survey in Appendix C.



Several oil industry representatives were contacted in the course of research for this report. None had quantitative insight into the upstream or downstream employment associated with lighting fuels.

A diverse product offering is the norm at the formal retail level, for example, within petrol stations that derive the vast majority of their income from transportation fuels and who have no employees that deal exclusively with kerosene. Formal petrol stations also have far lower rates of employment per unit of fuel sold than do micro-enterprises that sell far smaller quantities. This varied product selection applies within shops where kerosene is only one of a large variety of commodity goods sold. Moreover, the incumbent solar lighting alternatives are being sold through many of these outlets, and thus the revenue associated with retail can remain within that sector.



*Informal hawkers*



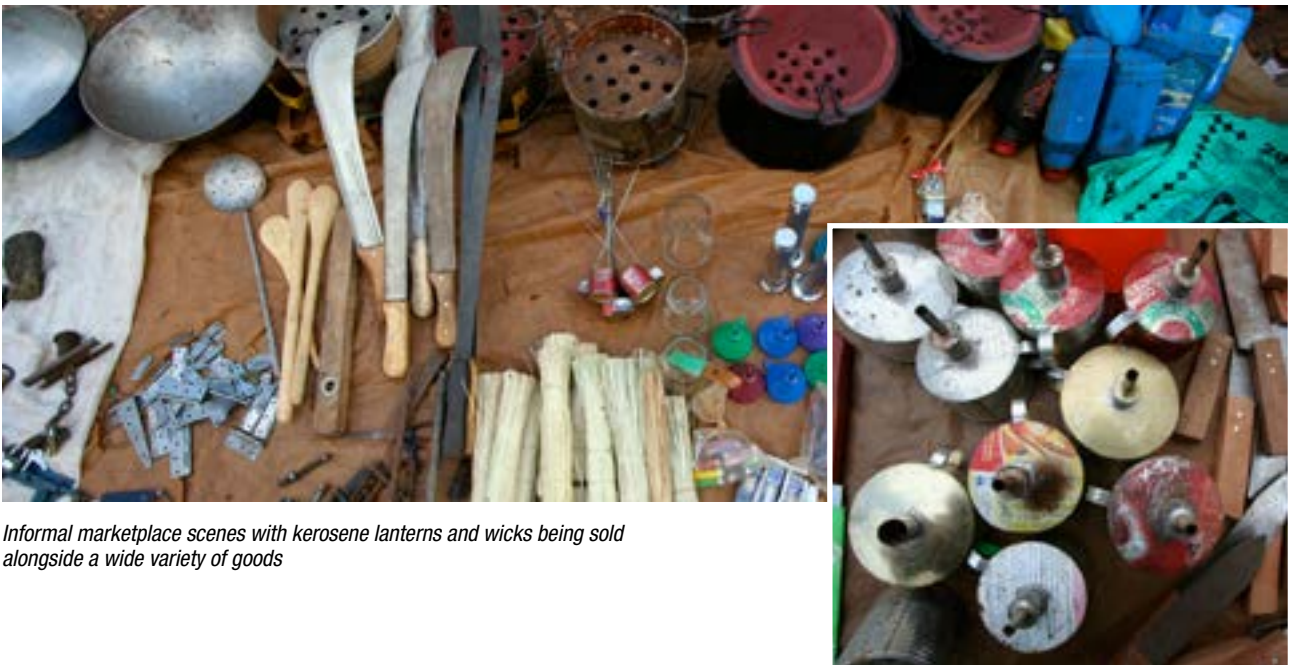
*Kerosene vendors in Nigeria*



*Kerosene is often resold in very small quantities*

In many developing countries, the informal sector represents the vast majority of employment (Cohen *et al.* 2000). Women often fill these jobs. Women's entrepreneurship is more common in Africa than anywhere else, and according to the Africa Competitive Report African women make up 50 percent of the self-employed and 25 percent of employers (Alstone *et al.* 2011). Of most concern are fuel vendors that sell kerosene exclusively.

The simplest form of these microenterprises is an individual who purchases a few litres of kerosene at a time from petrol stations or other distributors and resells in thus small quantities using decilitre-sized dippers or pre-measured soda bottles. They lack bulk purchasing power, and must resell at some markup from standard retail price levels and extract their livelihood from that difference. At least in some areas, these enterprises tend to be pushed out by more well-funded businesses that purchase the fuel by the barrel and dispense it using a simple pump (Alstone *et al.*, 2013).



*Informal marketplace scenes with kerosene lanterns and wicks being sold alongside a wide variety of goods*

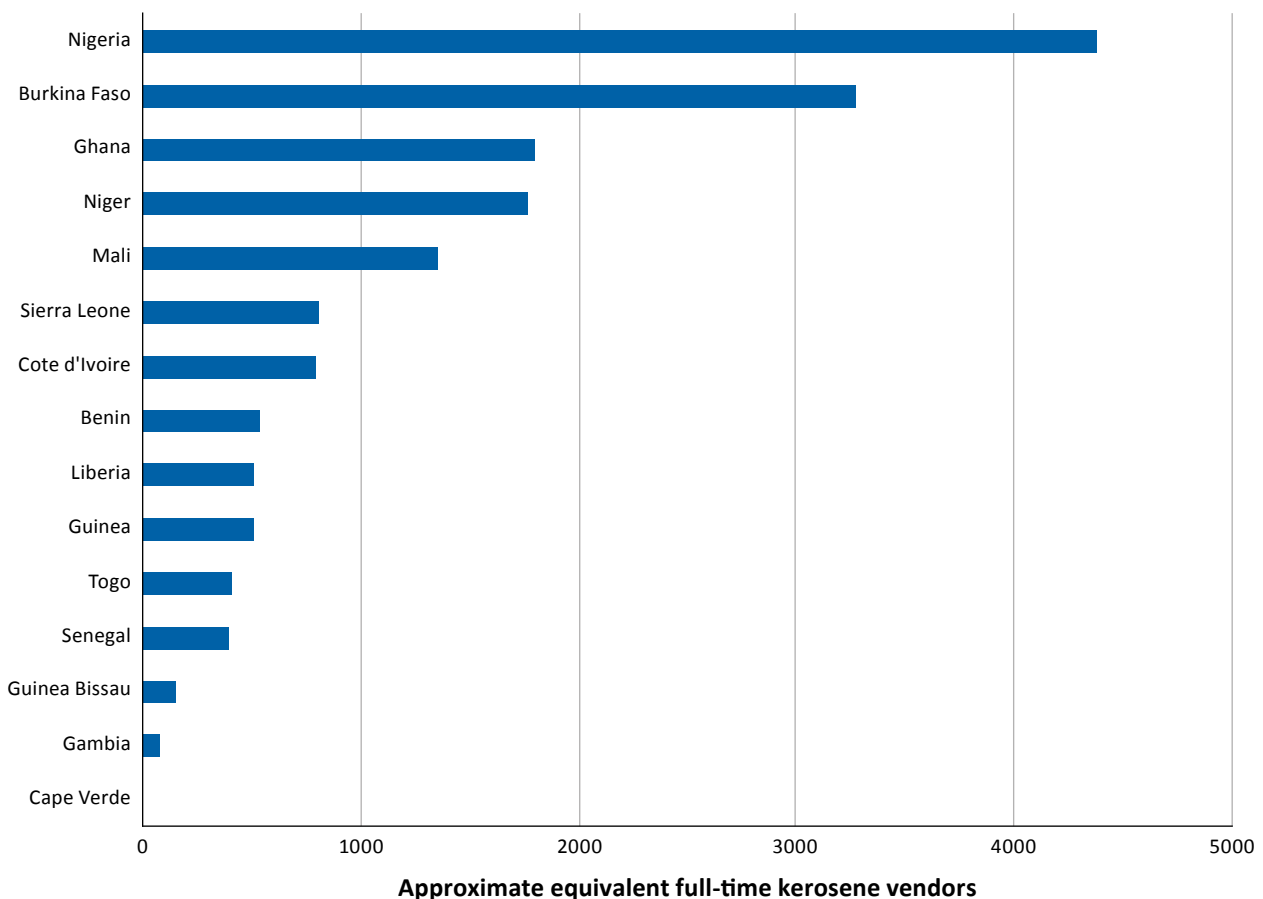
Tracy and Jacobson (2012) surveyed kerosene prices in five countries (Ghana, Kenya, Mali, Senegal, and Tanzania), attempting to identify the markup on resold kerosene. Results varied from 23% to 170%, with a population-weighted average markup of 46%.

Informal-sector workers are highly vulnerable to kerosene supply shortages. This is a particularly acute problem in Nigeria where fuel diversion is noted as “massive” (Udo 2012; Ajayi 2012; Mills 2014a). Upstream hoarding and the resulting shortages for informal vendors are common, resulting in lost income (Sunday Trust 2009). Similarly, intermediaries often smuggle fuels between countries when there are large price differences (typically due to disparate subsidies). In Niger, for example, 20% to 30% of all oil products consumed nationally is smuggled in from neighbouring countries (ESMAP 2009). Thus, local citizens do not always enjoy the income, or it is otherwise obtained through illicit methods. Increases in taxation or reductions in subsidies can also curb fuel demand abruptly, as can supply disruptions due to a wide range of factors.

Spot observations for the East African towns of Mai Mahiu and Kagarita, Kenya (Alstone 2013) indicate that a representative estimate for that region is three informal vendors of kerosene per town of approximately 10,000 inhabitants. An independent way of deriving this number is to use the likely price markups and kerosene consumption as a proxy for the corresponding net revenues and thus numbers of people employed given a standard wage<sup>4</sup>. This method arrives at a similar value as observed in Mai Mahiu and Kagarita (See Appendix A, Table A-1)<sup>5</sup>. Many of the inputs to this calculation could well vary by 50%, up or down, depending on the combined effect of electrification rates, kerosene lighting’s market share, energy prices, and profit margins. The estimates for ECOWAS countries are shown in Figure 3.

### Figure 3. Estimate of kerosene reseller jobs: ECOWAS

Source: Author analysis



<sup>4</sup> Special thanks to Peter Alstone for conceptual suggestions about methods for estimating scale of independent kerosene sellers.

<sup>5</sup> For context, a total of 40,000 street hawkers (220 per 10,000 population) have been reported for Kenya (Cohen *et al.* 2000). The value of 3/10,000 could correspond to approximately 1.5% of all hawkers, a plausible ratio.

The number of kerosene sellers serving a given population for lighting purposes can be expected to be far lower in West African countries where candles often have a much larger market share than kerosene for lighting. A concerted effort by researchers to identify rural kerosene sellers in three West African countries found only one seller in a radius of 50 kilometres from an urban centre in Senegal, two sellers in Ghana, and only three or four in Mali (Tracy and Jacobson 2010). Placing additional pressure on these sellers, some countries, including Ghana (Modern Ghana News 2011), have attempted to ban all forms of street vending. Thus changes in kerosene demand are one of many challenges to the informal workforce.

According to UNEP's off-grid lighting model, the ECOWAS region has 178 million people lacking access to the electricity grid. Based on the method described above, we estimate that the equivalent of 20,000 full-time kerosene-only sellers serve off-grid lighting users in ECOWAS (Figure 3 and Appendix A).

People who make and provide the equipment that consumes lighting fuels are part of the "lighting workforce" as well. While the familiar "hurricane lamp" is typically imported, lower-cost, less efficient and more polluting tin lamps are hand-crafted from used metal cans. However, no data was identified on the numbers of people making tin lamps or candles in Africa.



*Manufacture of kerosene-fueled "tin" lamps: Kibera, Kenya*

## 4. Potential Impacts on the Quantity and Quality of Employment as New Technologies Come Online

In practice, any transition away from kerosene and other lighting fuels will be gradual, over a period of years. This provides time for adapting to any potential employment displacement. Moreover, transformation will not likely be absolute even in the medium term. Instead, given the suppressed demand for light, an old kerosene lamp may be retained and moved into a previously unlit area. Kerosene is also being promoted as an improved fuel for cooking and has other uses as well (Appendix B). Meanwhile, smaller startup companies representing replacement technologies do not benefit from economies of scale and other efficiencies and are thus relatively more job-intensive than larger, more mature ones. One would expect that this would contribute an additional, temporary, spike in job creation in the near term.

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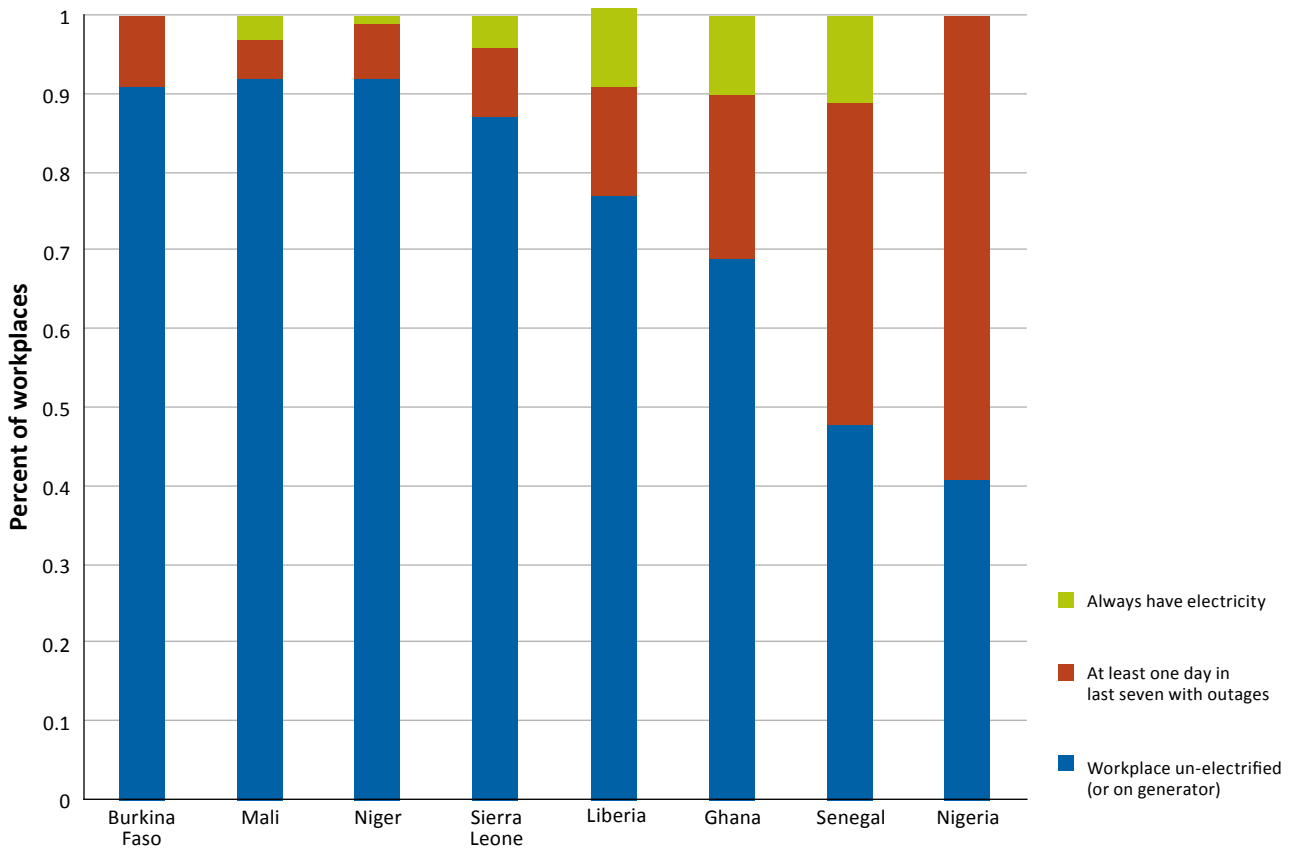
The kerosene sector is routinely subjected to “stress tests” that could be expected to yield employment impacts. This occurs, for example, when highly volatile prices spike, either due to world market prices or to a relaxation of subsidy policies (Mills 2014a). Livelihoods have also been challenged as kerosene demand has fallen (or risen) sharply for any combination of reasons. Yet, whether concerning considerable demand growth in ECOWAS countries such as The Gambia or Sierra Leone, or highly volatile and otherwise down-trending demand in many others (Cote d’Ivoire, Liberia, and Niger), no substantive national-level reports or references have been found regarding adverse employment impacts. These observed levels of kerosene demand reduction are much more rapid and abrupt than would be experienced even under aggressive programs for introducing replacements for kerosene lighting. For the few kerosene-producing countries, upstream developments have also been dramatic. For example, kerosene production in Nigeria fell from a peak of over 45,000 barrels per day in the late 1990s to approximately 10,000 barrels today, with no mention of employment impacts (USEIA 2013).

Meanwhile, many second-order effects of kerosene on the quality and quantity of employment must be considered. They may be broken into the broad categories of reducing opportunity costs, improving existing earnings, improving the work environment and health, and creating new earning opportunities (Practical Action 2012).



*Uses of fuel-based lighting and candles in work environments in Senegal and Tanzania*

**Figure 4. Deficits of electricity at workplaces in selected ECOWAS countries (Tortora and Rheault 2012)**



- Assuming that household expenditures on lighting fuels represent five percent of income, then for every 20 households that convert from kerosene, a full job-equivalent worth of income is collectively retained by the general population. An eventual transition away from fuel-based lighting translates to income preservation equivalent to approximately three-quarters of a million jobs throughout the ECOWAS community (Appendix A, Table A-2), or 45 jobs per 10,000 non-electrified population, or 45-times more than the one job per 10,000 people presently held by small-scale independent kerosene resellers.
- At a macro-economic level, reducing kerosene use improves a country's balance of trade, retaining more wealth within the national economy. If the savings are spent domestically, they can spur the economy; potentially contributing to increased employment prospects, particularly in local distribution.
- In addition to households that have a cottage industry, many formal and informal workplaces lack grid electricity, resulting in compromised lighting conditions where fuel-based lighting is employed. Such businesses rate the lack of electricity access as one of the top constraints on their growth, although providing electricity does not automatically translate into more employment (Practical Action 2012). A survey of 17 sub-Saharan African countries asked about lighting in the workplace. Complete lack of electricity in the workplace ranges from 92% in Mali and Niger to 12% in South Africa (Tortora and Rheault 2012). Some of these reports are about temporary outages (due to power cuts) but others are about ongoing problems due to lack of electrification, for which fuel-based lighting clearly plays a role. Power cuts create additional, substantial, and often costly deficits in lighting at workplaces, especially those without back-up power generation systems (Figure 4).



*Uses of fuel-based lighting and candles in work environments in Senegal and Tanzania*

- Costs of fuel-based lighting for these businesses can be high, up to 50% of wholesale revenues in one sector. The low quality of fuel-based light also compromises businesses' ability to attract customers and effectively display their wares. While some cases, such as the introduction of motors may reduce the need for labour, improving the provision of lighting is not a substitute for labour.
- Learning environments in schools and residences are significantly compromised by reliance on fuel-based lighting. Orosz *et al.* (2013) estimate that 140,000 schools in Africa lack access to an electrical grid. One recent assessment found that the children of solar system buyers complete twice as much homework each day as do those limited to kerosene lighting (Solar Aid 2013). Education and literacy are important precursors to future employment and wages.
- Fuel-based lighting is also demonstrated to be associated with very significant adverse health and safety risks, which, in turn, can lead to unemployment if sufficiently acute (Mills 2014b). These impacts include burns, poisonings, compromised respiratory and visual health, premature death, and adverse outcomes in clinics that lack electricity<sup>6</sup>. Reliable, sufficient and high-quality illumination is essential for the effective delivery of health services. Many of these clinics can operate only intermittently at night due to fuel availability and the inability to provide good care with only lanterns (Solar Aid 2012). Compromised health and healthcare services translate into reduced earning power for healthcare providers and recipients, not to mention the burden of the costs of treatment.
- As noted above, not all kerosene transactions are legal, otherwise beneficial to the poor, or even (in the case of smuggling) to the national economy.

<sup>6</sup> Orosz *et al.* estimate that as of 2012, 86,000 clinics in the developing world lack access to electricity; more than half of these clinics are estimated to be in Africa (2013).



## Kerosene and employment: fishing at night

Fishing at night requires illumination to attract fish to netting areas. People whose livelihood depends on night fishing are among the most intensive users of fuels for lighting. A typical pressurized kerosene lantern for this purpose consumes one or more litres of fuel per night (information in this box is derived from Mills *et al.* 2014).



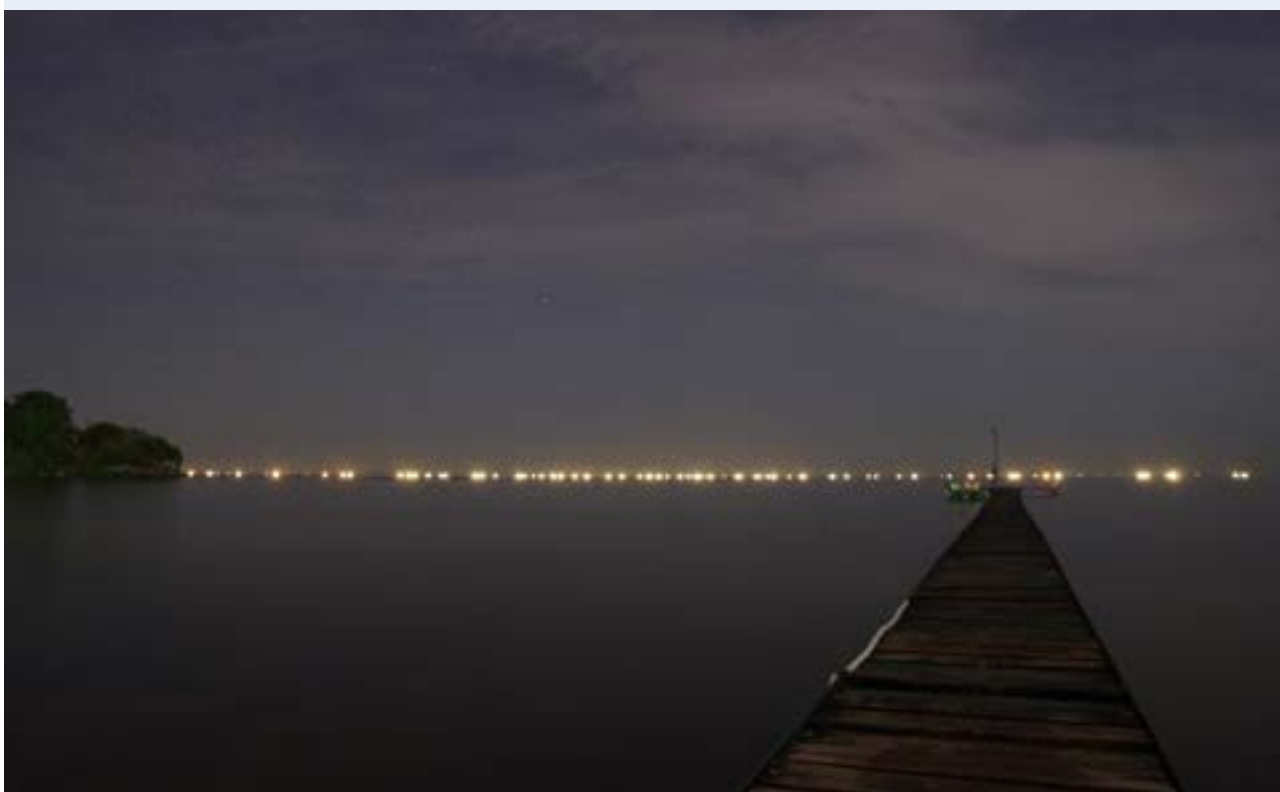
In many cases, kerosene is provided by members of the fishing team, who are not compensated separately for their time spent acquiring, transporting, and dispensing the fuel. In other cases, particularly remote lakeside fishing camps, kerosene is brought to remote fishing camps by individuals who supply the camps with a variety of materials and supplies. As kerosene is one of many goods (including substantial amounts of fuel for boat motors), reductions in demand would not have a material effect on their employment.

Meanwhile, the costs of kerosene have significant adverse impact on the value of the workers' incomes. Typically, 50% of their daily income is diverted to purchase lighting fuels. Thus, shifting away from fuel-based lighting would improve net incomes once the capital costs were

recovered, or immediately if microfinance is used. The time required to recover the additional capital investment in replacement LED lanterns is estimated to be less than one year, thus improving cash flow on an ongoing basis.

In some circumstances, intermediaries extract significant concessions when workers have a night with low yields (for example, taking the next night's fish at a below-market price). In this case, reducing dependency on kerosene would also reduce the associated cash-flow risks.

A secondary effect of fuel-based lighting is that workers are exposed for long hours and in close proximity to extremely high intensity lamp mantles. Many report difficulty in seeing for hours after the night's work is completed. This stands as a concrete example of the ways in which fuel-based lighting lower the quality of work and the work environment.



## 4.1 Emerging Technologies: “Solar Livelihoods”

LED lanterns entered the African marketplace a decade ago, and have become increasingly popular. Many of these are being sold through the same value chains as the prior fuel-based lighting equipment. Companies that provide LED lanterns to African markets were contacted for this study to help benchmark the current and potential job-creation dimensions of new off-grid lighting technologies and business models. Seven companies responded, identifying job intensities of the thirteen work categories, as shown in Figure 5. When applied to the potential LED lantern market, the ratio of products per worker is used here to estimate macro-level job creation.

Respondents represented large and small producers, distributors and retailers. They provided examples of LED lantern sales or distribution in Ethiopia, Haiti, India, Kenya, Malawi, Tanzania and Zambia. In aggregate, the responses reflected the employment associated with annual sales of approximately one million LED lanterns per year (a large portion of the total world market). Some companies provided information for specific submarkets; others for their global operations. Only employees located within developing countries were included. Various third-party jobs were not tallied, including contract manufacturers who are not employees of the companies, entities involved in shipping and customs, independent charging enterprises, and third-party entities involved in financing. Emerging jobs in areas like training and recycling were not quantified. Actual job creation would thus be even greater.



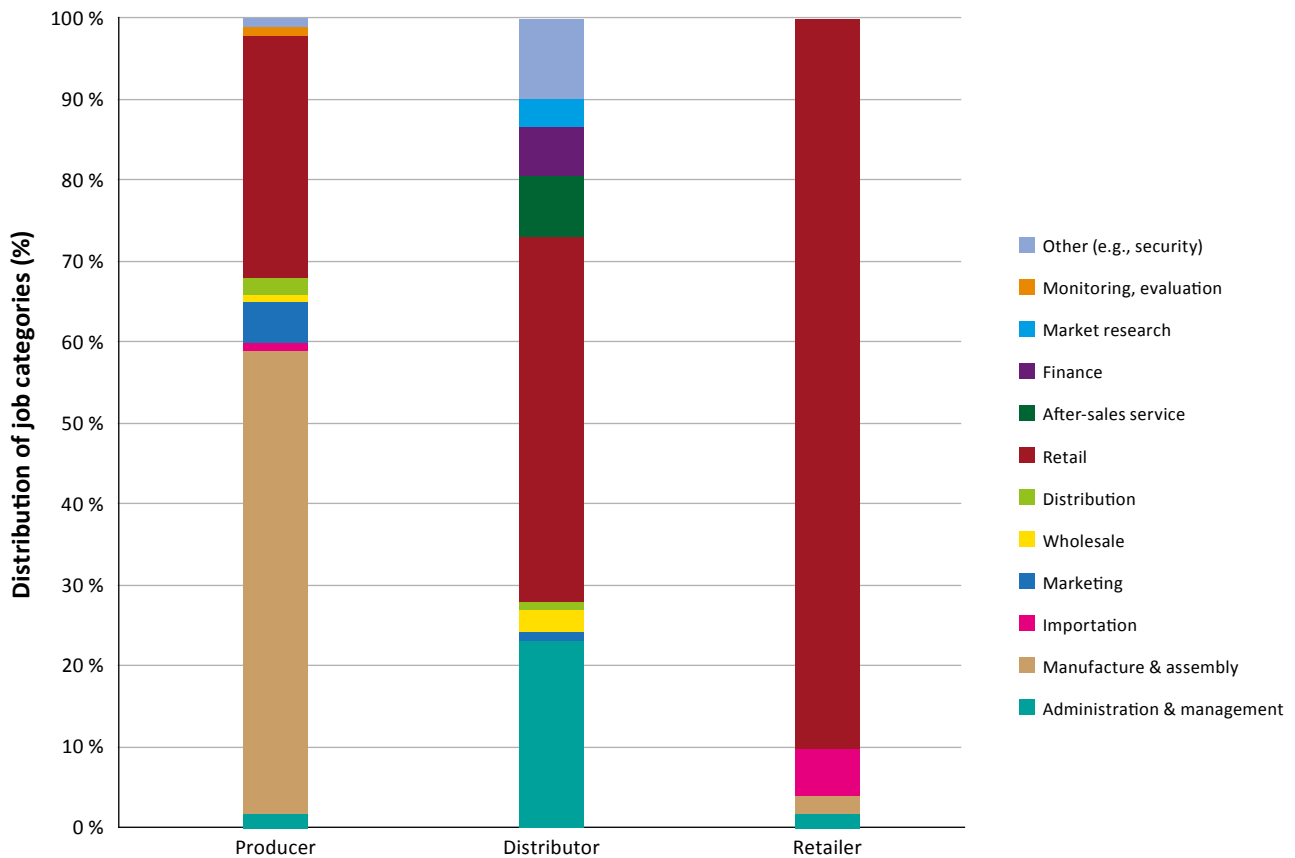
*LED torches (flashlights) for sale in rural marketplace in Senegal*

Major developers and manufacturers reported that on an annual basis, approximately 300 LED lanterns can be attributed to the efforts of one worker, while large distributors reported approximately 6,000 lanterns handled per worker per year. The responding companies focused primarily on retail sales reported 50 to 100 lanterns annually per employee<sup>7</sup>. Start-up and new companies indicated significantly lower volumes of lanterns per employee, or, more jobs per a given level of sales. Many of these workers handle other products at the point of sale, although some only sell lighting products.

<sup>7</sup> These values should be regarded as approximations and will vary based on business model, local conditions, the level of a company's maturity and efficiency, and full inclusion of a wide variety of job categories. Because the level of employment varies, these should be regarded as a combination of part- and full-time jobs.

**Figure 5. Type and distribution of jobs in the pico-solar marketplace**

Source: Author analysis



Based on the results of the survey, a working estimate of job-creation in a hypothetical mature market— based on values reported by industry players—is 17,000 workers per million LED lanterns sold per year across the entire value chain. This loosely comports with a real-world, large-scale achievement by Grameen Bank in Bangladesh, where a staff of 12,000 people had installed one million small (30W to 100W) solar home systems (Grameen Shakti 2012) by 2012. They are currently installing 1000 systems daily, or, 33,000 workers per million systems. This implies about 30 systems annually per worker (these are larger and more complex than the LED lanterns discussed in this report), which also agrees roughly with the job-creation ratio of one-to-50 adopted in an assessment of employment potential in Ethiopia (Ethio Resource Group 2012).

To estimate the size of the potential regional workforce, we: applied the above ratios to the ECOWAS region, used the UNEP estimate of a population of 178 million persons without grid access in ECOWAS, (equivalent to 33 million candidate households), and assumed that each household could afford three improved lanterns each with a service life of three years. The result is that the ongoing replacement rate would be 33 million LED lanterns each year. This volume of LED lantern manufacturing, importing, distributing and retail sales would employ approximately 500,000 people<sup>8</sup>.

In a transition to efficient off-grid lighting, more jobs will be created than are lost, for several reasons. Firstly, fuel (and energy supply more generally) has very few embedded jobs, as it is a centralized and highly industrialized product, whereas the alternatives are capital assets rather than consumable resources. Those selling the final product to consumers only earn the markup amounts after expenses. Retail kerosene sellers usually sell many other goods, and those upstream only get a tiny fraction of their employment from kerosene compared to the other petrol products. Solar lighting jobs are more singularly focused and labour-intensive in most cases. The estimates presented here are based on a cautious assumption of three-year product life, which translates to a steady process of manufacturing and delivering replacement products. If product performance and durability are improved over time (a challenging goal in practice), the corresponding numbers of jobs will decline proportionately.

<sup>8</sup> 33 million LED lanterns per year times 17,000 workers per million lanterns per year:  $33 \times 17,000 = 561,000$ .



In practice, there will be segments of the market that can afford more extensive changes, such as complete solar home systems. One study estimates that 66% of the population in ECOWAS will have access to individual electricity supply technologies, such as solar (ECOWAS 2006). Some will also eventually have access to the central grid or mini-grids. A global estimate by the International Finance Corporation (IFC) concludes that approximately 112 million households (out of a total 274 million without modern lighting and electricity) are best suited for solar and rechargeable lanterns (IFC 2012), the largest share of the entire market in need. In contrast, only 21 million of these households are deemed reachable by grid extension (and over a longer timeframe).

Many of the approximately 20,000 full-time equivalent workers in ECOWAS that presently sell kerosene through informal micro-enterprises may not have the appropriate skills to assume new jobs associated with efficient lighting products. To address this concern, some organizations are offering technical assistance to these workers so that they can become knowledgeable about new technology. For example, one small-scale distributor interviewed for this study had recruited seven of 11 current employees from previous kerosene sellers. Another company claims to be expressly approaching kerosene vendors as potential purveyors of their LED lanterns (Arena 2010). The latter company provides charging services using pedal power and has sold a total of 10,000 LED lanterns in Rwanda through 70 local franchisees (IFC 2012). In India, Solar Tuki has engaged kerosene sellers, who reportedly welcomed the opportunity because of constant interruptions to their business due to kerosene shortages (Prester 2010).

Although the off-grid solar lighting market is still in its early phases of development, 2.7 million quality LED lanterns (or current rate of about 1,000,000 per year) had been sold in sub-Saharan Africa as of mid 2013 (Lighting Africa 2013). Based on the method developed in this report, this quantity of lanterns sold corresponds to approximately 15,000 jobs created (or augmented) to date. Lighting Africa projects that sales of LED lanterns will rise to 20 to 28 million by 2015, which, per the estimation method developed for this study, could create 100,000 to 150,000 jobs across Africa in a relatively short timeframe.

In addition to displacing lighting fuels, new lighting equipment will also displace traditional fuel-based lighting equipment. These new products can readily displace old ones in a retail environment, thus having negligible impacts on jobs. Indeed, to the extent that new products have higher price points, they potentially increase vendors' incomes. While the quality or "decency" of these new jobs is likely to be as high as or higher than those associated with fuel-based lighting, policymakers should still strive to ensure that working conditions and practices are appropriate (IRENA 2011).



*Nuru Energy attempts to engage former kerosene sellers and recharge locally-made LED lanterns using pedal power*

## 4.2 Local Manufacture of LED Lanterns

The vast majority of LED lanterns are manufactured in Asia. Those who suggest that these products could and should be made within Africa must consider barriers such as: quality control concerns, need for worker training, potentially higher labour costs than in other parts of the world, tariff structures, and, lack of well-developed component supply chains and technology assembly facilities. That said, domestic manufacture and assembly is already occurring to a limited degree within Africa (see below).

### Manufacture of LED lanterns in Africa

Approximately 10% of global rechargeable and LED lantern manufacturers produce their products in Africa, 14% produce in India while most of the balance produce in China (Lighting Africa 2013). For example, the German company Solux ships components for assembly in-country. They have thus far assembled over 16,000 of their products in developing countries such as Burkina Faso and Togo.

As another local example of green job creation, an entity in Kenya uses charitable donations to furnish groups with kits to assemble simple LED lanterns using recycled materials. Local youth are trained in assembly methods. When the LED lanterns are sold, the proceeds are reinvested in (subsequently unsubsidized) further lantern production or other enterprises. SDFA Kenya reports production of approximately 5,000 lanterns annually as of 2011 (SDFA 2012). A similar project based in Liberia funds women's groups to manufacture simple LED lanterns using discarded water bottles as a lantern housing. The components are donated. Sales from the first set of LED lanterns are intended to enable the microenterprises to become self-sustaining (USAID 2013).



*Women's collective assembles simple LED lanterns in Kenya*



*Solux program in Zanzibar (Tanzania) in which students are trained to assemble solar lanterns and lease them to community members. Pins on the map represent participating schools as of 2006. The technology has now evolved from CFL to LED light sources.*

### 4.3 Central versus Distributed Electrification

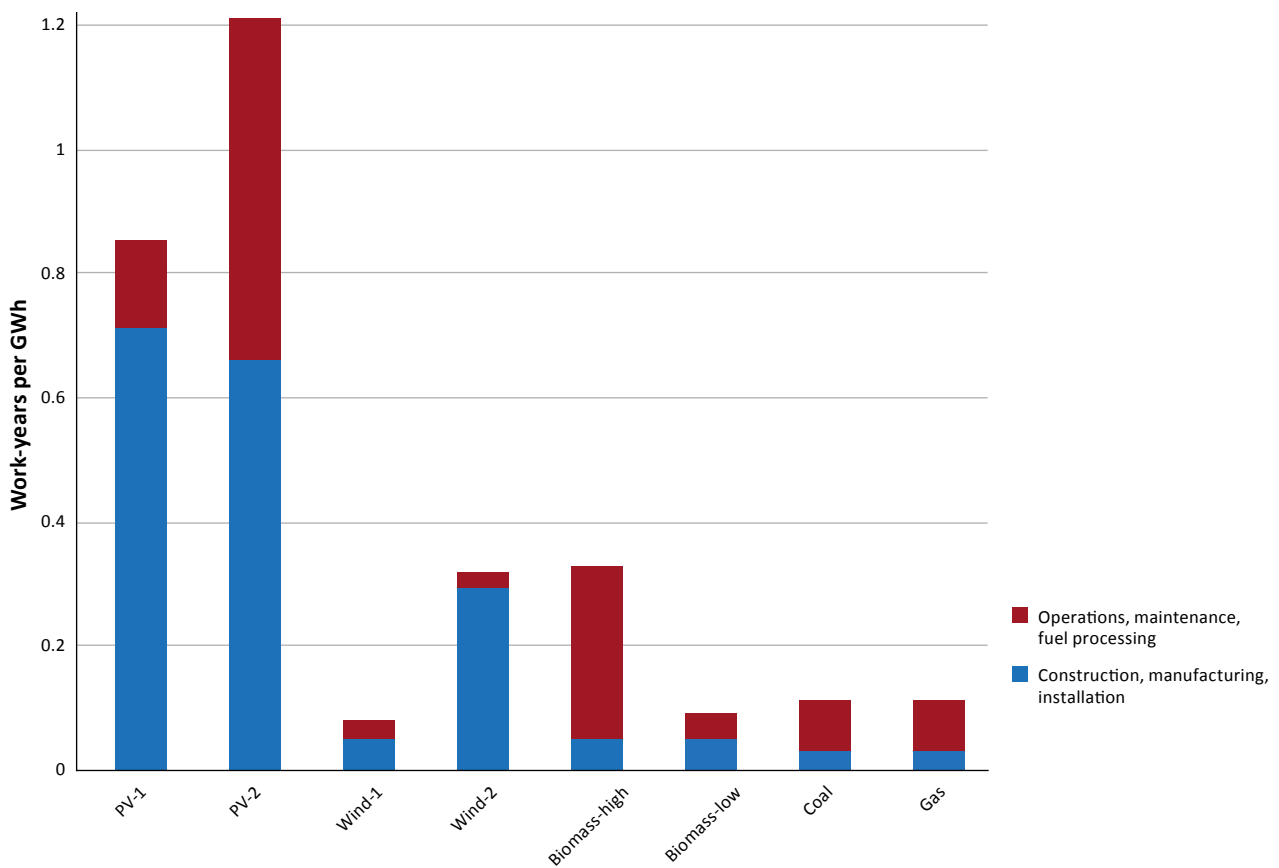
Another key variable to consider is displacement of fuel-based lighting through centralized electrification programs (when villages first have access to the electrical grid) versus distributed, self-contained lanterns. However, the rate of electrification is not keeping pace with population growth in sub-Saharan Africa, and costs of service are far higher than offered by the emerging grid-independent solutions.

Renewable energy technologies, particularly the photovoltaic cells often used to power LED lanterns, create nearly ten-times as many jobs per unit of energy output than does centralized electricity production (Figure 6), and a far higher ratio compared to project development jobs such as installation of solar panels.)

**Figure 6. Electricity production based on renewable creates significantly more jobs than fossil fuels**

(GWh represents average installed power, derated for availability and intermittence)

(Kammen et al. 2004)



## 5. Policy Strategies to Ensure Net Job Benefits through the Transition

The transition to efficient off-grid lighting is irreversibly underway. New jobs are being created in order to make, distribute, sell, and service new technologies, and to launch the business models bringing them to market. On balance, the transition will create far more employment than it displaces, while improving the availability and quality of light in workplaces, enhancing worker safety and productivity, and conserving the scarce income earned by all workers who formerly used fuel-based lighting at home. This finding is consistent with other studies

Policymakers concerned with off-grid lighting markets and livelihood face three main challenges<sup>9</sup>:

- 1) Understanding and minimizing any dislocation caused by technological changes.
- 2) Accelerating and ensuring maximum employment benefits from new markets created in the transition to efficient lighting.
- 3) Assessing the indirect implications of lighting choices for the quality and safety of lighting in work environments.

Across all of these themes is a need for more standardizing definitions, measurement, verification, and evaluation methods. This is a core focus of the UNEP en.lighten initiative, and represents yet another avenue for livelihood creation.

### 5.1 Understanding and Minimizing Dislocation Caused by Technology Changes

Data on markets are required in order to pinpoint those workers who are at risk of losing livelihoods as markets transition. To more precisely identify the livelihoods potentially at risk, improved estimates of the numbers of businesses and people selling kerosene—particularly those selling exclusively kerosene—are needed. New information must also be gathered on employment in fuel-distribution workers, candle production, operators of small generators for lighting and other services, and the livelihoods of those who manufacture fuel-based lanterns and other lighting equipment.

Dislocation of livelihoods already occurs in fuel-based lighting markets, for example, where fuels are smuggled across borders. Black markets result in lost tax revenues, ultimately affecting a government's ability to support its citizens. In other cases, dealers at various points in the value chain adulterate kerosene with cheaper fuels, and then resell the deadly, explosive fuel (Nigerian Eye 2012; Mills 2014b). These dynamics must be better understood and due consideration given to the value of the associated sellers' livelihoods. The presence of fuel subsidies also undermines the profitability of kerosene sellers (Mills 2014a). Inspiration may be taken from governmental efforts to respond to massive employment losses among woodcutters in Ethiopia, as the government actively pushed for substitution of kerosene for fuel wood as a cooking fuel (Shanko and Rouse 2010)<sup>10</sup>.

<sup>9</sup> The International Renewable Energy Agency offers a series of considerations for policymakers interested in ensuring that ample and decent jobs are created in conjunction with renewable energy initiatives (IRENA 2011). Some of these may apply or be adapted for off-grid lighting concerns.

<sup>10</sup> As a result, the numbers of wood providers to the capital city fell from 42,000 to 3,500 (a 92% drop), and only 2000 new jobs were directly attributed to improved cookstoves, which serve 90% of the households. In response, the International Labour Organization organized women fuel wood gatherers into an association that provided alternative employment. Some were re-employed as forest guards; wage laborers for reforestation, water supply projects, and other purposes; or other forestry stewardship positions. In a related example, Nigeria has embarked on an effort to eliminate fuel wood and kerosene for cooking. The program aims to distribute LPG cylinders to 20 million homes within 5 years (Voice of America 2013). In another, perhaps related example, the multi-national \$750M "Global LPG Partnership" aims to introduce LPG to 50 million homes across Africa, creating 150,000 jobs in the process (United Nations 2013).



*Students learning about lighting economics*

## 5.2 Accelerating and Ensuring Maximal Employment Benefits from New Markets

Policymakers can support various strategies to mitigate dislocation, such as cultivating domestic markets for manufacture, sale, and service of emerging technologies. Education and training facilitated by public entities or non-governmental organizations can create some jobs and help ensure that the broader workforce is prepared to assume these new jobs and understands the value of improved lighting. For example, “BarefootCollege.org,” trains 100 grandmothers annually. Collectively this organization has helped to deploy LED lanterns to 40,000 households. Grameen Shakti has trained 5,000 women as solar photovoltaics installers (Barug 2008).

Efforts should be made to ensure that new employment opportunities are decent, and do not replicate problems sometimes encountered by those selling lighting fuels, e.g., child labour, gender imbalances, discriminatory practices, or unsafe work environments. New business services such as recycling, microfinance, and carbon trading can create additional employment beyond the core activities of lighting manufacturing, distribution and sales.

Many barriers exist to the affordability and uptake of alternatives to fuel-based lighting. These can be addressed through policy strategies such as eliminating fuel subsidies (Mills 2014a) and import duties or taxes on new technologies, ensuring that the market rationally differentiates among high- and low-quality products that will otherwise spoil markets.



*Educating villagers about off-grid lighting alternatives*





*LED torches appearing in mixed-goods street vendor shops*

### **5.3 Assessing the Indirect Implications of Lighting Quality and Safety**

Lighting based on combustion, which also generates insufficient illumination levels, is a major health and safety concern (Mills 2014b). National data on the dimensions of these risks are sparse. Policymakers can play an important role in requesting and supporting better research and data collection to provide evidence and to analyze the effects of changes in lighting on the quality of working environments.

Similarly, the “productive use” benefits of improved lighting are often cited, but poorly defined for off-grid markets. New research could better quantify the value of more and better lighting in the retail context and in other work environments, such as healthcare facilities. Improved productivity translates into greater revenues, and, in effect, improved livelihoods.

As occurred a century ago in the industrialized world, the transition away from kerosene and other fuel-based lighting in developing countries is now irreversibly underway. The key opportunity for policymakers in ECOWAS and in other regions is to maximize the pace of job creation associated with new technologies and businesses that can replace inefficient and polluting lighting fuels, while proactively minimizing any disruption as the transition proceeds. Policymakers have at their disposal many tools to help minimize any dislocation of livelihoods. These include stimuli for domestic manufacturing or assembly of products (already occurring to a limited degree in some ECOWAS countries); supporting the creation of peripheral businesses and services such as training, recycling, financing, and carbon trading; removing market barriers that slow uptake of improved lighting equipment; and, equipping a workforce able to engage in the manufacture and sale of new technologies. While direct subsidy of new technologies is a risky practice (and subsidies already skew the market in favour of supply-side technologies over energy savings), and can be disruptive to free-market forces that are already strong in this sector, other approaches could prove valuable.

## 6. References

- Abena, A.T. 2010. "Nuru Energy: Sustainable Lighting for Rural Dwellers." *Tempo Africa*. <http://tempoafrica.com/2010/10/nuru-energy-sustainable-lighting-for-rural-dwellers/> [Accessed July 24, 2014]
- Adam Smith International. 2013. "The Light is Getting Brighter in Nigeria." *The Guardian*. <http://www.theguardian.com/global-development-professionals-network/adam-smith-international-partner-zone/nigeria-power-electricity-africa> [Accessed July 24, 2014]
- Ajayi, O. 2012. "Whither the Kero-Direct Scheme?" *National Mirror*, October 19. <http://nationalmirroronline.net/new/wither-the-kero-direct-scheme/> [Accessed July 24, 2014]
- Alstone, P. 2013. Personal communication, September 28
- Alstone, P., C. Niethammer, B. Mendonça, and A. Eftimie. 2011. "Expanding Women's Role in Africa's Modern Off-Grid Lighting Market." Lighting Africa and the International Finance Corporation. Retrieved from [http://www.esmap.org/sites/esmap.org/files/gender\\_lighting\\_highres\\_LOW%20RES.pdf](http://www.esmap.org/sites/esmap.org/files/gender_lighting_highres_LOW%20RES.pdf) [Accessed June 13, 2014]
- Alstone, P., K. Radecsky, A. Jacobson, and E. Mills. 2013. "The Dynamics of Off-grid Lighting Adoption." Lumina Project Technical Report #12, 25pp. Retrieved from <http://light.lbl.gov/pubs/tr/Lumina-tr12-lighting-adoption.pdf> [Accessed June 13, 2014]
- Barug, D.C. 2008. "Creating green jobs through renewable energy technologies in rural Bangladesh." Presented at the Research Conference: Green Jobs for Asia and the Pacific. Jointly organized by the International Institute for Labour Studies, Policy Integration Department and Regional Office for Asia and the Pacific, Niigata, Japan, 21-23 April
- Cohen, M, M. Bhatt, and P. Horn. 2000. "Women Street Vendors: The Road to Recognition." The Population Council, New York, New York, 24pp. Retrieved from <http://www.popcouncil.org/uploads/pdfs/seeds/seeds20.pdf> [Accessed July 24, 2014]
- Economic Community of West African States. 2006. ECOWAS White Paper for a Regional Policy. Retrieved from [http://www.uncsd2012.org/content/documents/165ecowas\\_white\\_paper.pdf](http://www.uncsd2012.org/content/documents/165ecowas_white_paper.pdf) [Accessed June 13, 2014]
- ESMAP. 2009. "Petroleum Product Markets in Sub-Saharan Africa: A Comparative Efficiency Analysis of 12 Countries." Retrieved from [http://www.esmap.org/sites/esmap.org/files/121201061719\\_SSA\\_downstream\\_doc\\_with\\_new\\_cover.pdf](http://www.esmap.org/sites/esmap.org/files/121201061719_SSA_downstream_doc_with_new_cover.pdf) [Accessed June 13, 2014]
- Ethio Resource Group. 2012. "Solar Energy Vision for Ethiopia." Freiburg and Addis Ababa, 28pp. Retrieved from [http://www.sun-connect-news.org/fileadmin/DATEIEN/PV-Industry-ET-04-09-12\\_final.pdf](http://www.sun-connect-news.org/fileadmin/DATEIEN/PV-Industry-ET-04-09-12_final.pdf) [Accessed July 24, 2014]
- Mills, E., T. Gengnagal, and P. Wollburg. 2014. "Solar-LED Alternatives to Fuel-based Lighting for Night Fishing." *Energy for Sustainable Development* 21:30-41. Retrieved from <http://evanmills.lbl.gov/pubs/pdf/night-fishing-esd.pdf> [Accessed July 24, 2014]
- Grameen Shakti. 2012. News Release: "Grameen Shakti Makes a World Record in Non-Grid Power Generation." [http://www.gshakti.org/index.php?option=com\\_content&view=article&id=190&Itemid=73](http://www.gshakti.org/index.php?option=com_content&view=article&id=190&Itemid=73) [Accessed July 24, 2014]
- IFC. 2012. "From Gap to Opportunity: Business Models for Scaling Up Energy Access." International Finance Corporation, IFC Advisory Services, 170pp. Retrieved from <http://www.ifc.org/wps/wcm/connect/ca9c22004b5d0f098d82cfbbd578891b/EnergyAccessReport.pdf?MOD=AJPERES> [Accessed July 24, 2014]
- ILO et al. 2012. "Working towards sustainable development. Opportunities for decent work and social inclusion in a green economy" (UNEP, ILO, IOE and ITUC) Retrieved from [http://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS\\_181836/lang-en/index.htm](http://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS_181836/lang-en/index.htm) [Accessed June 13, 2014]
- ILO. 2009. "Green jobs: Improving the climate for gender equality tool, brochure" Retrieved from [http://www.ilo.org/gender/Events/WCMS\\_101505/lang-en/index.htm](http://www.ilo.org/gender/Events/WCMS_101505/lang-en/index.htm) [Accessed June 13, 2014]
- ILO. 2011. "Climate change and labour: The need for a "just transition" Retrieved from [http://www.ilo.org/actrav/what/pubs/international-journal-labour-research/WCMS\\_153352/lang-en/index.htm](http://www.ilo.org/actrav/what/pubs/international-journal-labour-research/WCMS_153352/lang-en/index.htm) [Accessed June 13, 2014]

- ILO. 2013. "Measuring Informality: A Statistical Manual on the Informal Sector and Informal Employment." International Labour Office, Geneva, 323pp. Retrieved from [http://www.ilo.org/wcmsp5/groups/public/-/dgreports/-/dcomm/-/publ/documents/publication/wcms\\_222979.pdf](http://www.ilo.org/wcmsp5/groups/public/-/dgreports/-/dcomm/-/publ/documents/publication/wcms_222979.pdf) [Accessed July 24, 2014]
- IRENA. 2011. "IRENA Working Paper: Renewable Energy Jobs: Status, Prospects & Policies." International Renewable Energy Agency. 29pp. Retrieved from [https://www.irena.org/DocumentDownloads/Publications/Renewable\\_Energy\\_Jobs\\_abstract.pdf](https://www.irena.org/DocumentDownloads/Publications/Renewable_Energy_Jobs_abstract.pdf) [Accessed July 24, 2014]
- Kammen, D.M., K. Kapadia, and M. Fripp. 2004. "Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?" RAEI Report, University of California, Berkeley. Retrieved from <http://rael.berkeley.edu/sites/default/files/very-old-site/renewables.jobs.2006.pdf> [Accessed July 24, 2014]
- Kojima, M., W. Matthews, and F. Sexsmith. 2010. "Petroleum Markets in Sub-Saharan Africa." ESMAP / World Bank, New York, 66pp. Retrieved from [http://siteresources.worldbank.org/INTOGMC/Resources/336099-1158588096604/eifd15\\_ssa\\_oil\\_markets.pdf](http://siteresources.worldbank.org/INTOGMC/Resources/336099-1158588096604/eifd15_ssa_oil_markets.pdf) [Accessed June 13, 2014]
- Legros, G, I. Havnet, N. Bruce, and S. Bonjour. 2009. "The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa." World Health Organisation and UNDP, 130pp. Retrieved from [http://content.undp.org/go/cms-service/download/asset/?asset\\_id=2205620](http://content.undp.org/go/cms-service/download/asset/?asset_id=2205620) [Accessed June 13, 2014]
- Lighting Africa. 2013. "Lighting Africa Market Trends Report 2012." International Finance Corporation, 98pp. Updates on market impacts: <http://lightingafrica.org/results/> [Accessed June 13, 2014]
- Mills, E. 2014a. "Lifting the Darkness on the Price of Light: Assessing the effect of subsidies for fuels in the off-grid lighting market." [UNEP, December 2014]
- Mills, E. 2014b. "Light for Life: Identifying and Reducing the Health and Safety Impacts of Fuel-Based Lighting." [UNEP, December 2014]
- Mills, E. 2005. "The specter of fuel-based lighting," *Science*, 308:1263-1264, 27 May. Retrieved from [http://light.lbl.gov/pubs/mills\\_science\\_fbl\\_full.pdf](http://light.lbl.gov/pubs/mills_science_fbl_full.pdf) [Accessed July 23, 2014]
- Modern Ghana News. 2011. "Hawkers Defy AMA Bye-Laws." April 1. <http://www.ghananewsagency.org/social/hawkers-defy-ama-new-bye-laws-27338> [Accessed July 24, 2014]
- Nigerian Eye*. 2012. "NNPC Warns Nigerians to Stop Patronising Road Side Kerosene Vendors." March 30. <http://www.nigerianeye.com/2012/03/nnpc-warns-nigerians-to-stop.html> [Accessed July 24, 2014]
- Orosz, M.S., S. Quoilin, and H. Hemond. 2013. "Technologies for heating, cooling and powering rural health facilities in sub-Saharan Africa." *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 2013(227):717. Retrieved from <http://pia.sagepub.com/content/early/2013/08/21/0957650913490300.abstract> [Accessed July 24, 2014]
- Practical Action. 2012. "Poor People's Energy Outlook: 2012." Schuermacher Center, Warwickshire, 110pp. Retrieved from <http://practicalaction.org/media/download/16129> [Accessed July 24, 2014]
- Prester, T. 2010. "Better by Design: How Empathy Can Lead to More Successful Technologies and Services for the Poor." *Innovations*, MIT Press, Summer, pp 105-119. Retrieved from [http://static.squarespace.com/static/5267f3a6e4b0da2bab9939e3/t/528b77e0e4b01f10c844f9fe/1384871904149/INNOV-TECH4SOCIETY\\_FINAL\\_BetterByDesign.pdf](http://static.squarespace.com/static/5267f3a6e4b0da2bab9939e3/t/528b77e0e4b01f10c844f9fe/1384871904149/INNOV-TECH4SOCIETY_FINAL_BetterByDesign.pdf) [Accessed July 24, 2014]
- SDFA. 2012. "Sustainable Development for All – Kenya: Annual Review 2011/2012", Nairobi, 17pp. Retrieved from <http://sustainabledevelopmentforall.org/annual-review-2011-2012.html> [Accessed July 24, 2014]
- Shanko, M. and J. Rouse. 2010. "The Human and Livelihoods Cost of Fuel-Switching in Addis Ababa." *Boiling Point*, Issue 51. Retrieved from <http://www.hedon.info/TheHumanAndLivelihoodsCostOfFuel-switchingInAddisAbaba?bl=y> [Accessed July 24, 2014]
- Solar Aid. 2012. "More About Kerosene..." <http://renewablegill.tumblr.com/post/26411834605/more-about-kerosene-the-solaraid-big-hairy> [Accessed June 13, 2014]
- Solar Aid. 2013. "Impact Report." London. 12pp. Retrieved from <http://www.solar-aid.org/assets/Uploads/Publications/Impact-report-web-updated.pdf> [Accessed July 24, 2014]

- Solar Aid. 2013. Interviews with kerosene vendors, data furnished courtesy of Kat Harrison.
- Sunday Trust*. 2009. "Unending Pains, Agonies of Kerosene Scarcity." October 25. <http://www.dailytrust.com.ng/sunday/index.php/business/617-unending-pains-agonies-of-kerosene-scarcity> [Accessed July 24, 2014]
- Tortora and Rheault. 2012. "In Sub-Saharan Africa, Most Workers are Without Electricity." Gallup. Retrieved from <http://www.gallup.com/poll/151889/Sub-Saharan-Africa-Workers-Without-Electricity.aspx> [Accessed June 13, 2014]
- Tracy, J. and A. Jacobson. 2012. "The True Cost of Kerosene in Rural Africa." Lighting Africa Report. 10pp. Retrieved from [http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/kerosene\\_pricing\\_Lighting\\_Africa\\_Report.pdf](http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/kerosene_pricing_Lighting_Africa_Report.pdf) [Accessed July 24, 2014]
- Truran, G. 2009. "Household Energy Poverty and Paraffin Consumption in South Africa." *Boiling Point*, Issue 56, pp2-6. Retrieved from [http://www.hedon.info/docs/BP56\\_Truran.pdf](http://www.hedon.info/docs/BP56_Truran.pdf) [Accessed July 24, 2014]
- Udo, B. 2012. "Petroleum Minister Alison-Madueke Indicted over N310 Billion Illegal Subsidy Payment on Kerosene." *Sahara Reporters*, April 22
- United Nations. 2013. "Global LPG Partnership." Sustainable Energy for All. <http://www.se4all.org/commitment/global-lpg-partnership/> [Accessed July 24, 2014]
- USAID. 2013. "Building a Micro-Enterprise around a Solar Product." US Agency for International Development, Washington, D.C. <http://www.usaid.gov/results-data/success-stories/building-micro-enterprise-around-solar-product> [Accessed July 24, 2014]
- USEIA. 2013. International energy statistics. U.S. Department of Energy, Energy Information Administration. <http://www.eia.gov/countries/index.cfm?view=consumption> [Accessed June 13, 2014]
- Voice of America. 2013. "Nigeria to Switch to Clean Cooking Gas." March 6. <http://www.voanews.com/content/nigeria-to-switch-to-use-clean-cooking-gas/1616606.html> [Accessed July 24, 2014]

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## Appendix A. Estimation of Kerosene Reseller Jobs in ECOWAS Countries

The method outlined in Table A-1 estimates how many full-time-equivalent kerosene sellers are required to serve 10,000 people who primarily use kerosene for lighting. The derivation assumes that one-quarter of kerosene is bought from small sellers versus petrol stations and other sellers of multiple goods who earn only a small portion of their revenues from kerosene. The portion of revenues that are converted to salaries is a function of the markup (46% in this case) from seller's own purchase price (\$1/litre in this case) and the residual share of income to salaries versus other costs of doing business (assumed at 50%). The net funds available for salaries are then converted to jobs assuming an income level of \$10/day in this case.

Table A-2 develops country-specific values using the method outlined in Table A-1, adjusted for local variations in the key variables, namely share of lighting provided by kerosene and retail price build-ups. These job intensities are then applied to the overall un-electrified population to derive the number of jobs by country. The footnotes provide detailed assumptions and sources.

**Table A-1. Hypothetical kerosene-only seller employment for an unelectrified town with 10,000 population\***

Source: Author analysis

End-user demand parameters	
Lighting fuel use (where kerosene is primary fuel)	70 liters/household-year
Occupancy	5.5 people/household
Households using kerosene lighting	1,818 households
Economic parameters	
Fraction purchased from small kerosene vendors	25% of households in town
Seller's wholesale fuel purchase price	1.00 US\$/ liter
Seller's markup	46%
Gross revenues from small sellers	46,455 \$/town/year
Gross revenues minus fuel cost	21,369 \$/town/year
Share of net revenue to non-fuel expenses	50%
Proceeds available for salaries	10,685 \$/town/year
Seller's net income	10 \$/day
Days worked	300 days/year
Equivalent full-time jobs	<b>3.56</b> Jobs

\* Based on input assumptions approximating conditions in Mai Mahiu, Kenya.

**Table A-2. Estimated kerosene-only seller employment for ECOWAS countries**

Source: Author analysis

	Population [1]	Unelectrified % [2]	Unelectrified Population	Household Size [1]	Kerosene price [3]	Seller's markup (%) [4]	Kerosene lighting share [5]	Jobs/10,000 unelectrified population	Equivalent full-time seller jobs [6]	Equivalent households' earning allocated to lighting kerosene [7]
<b>Benin</b>	8,849,892	75%	6,655,119	5.36	1.27	46%	25%	0.80	531	20,646
<b>Burkina Faso</b>	16,468,714	85%	14,064,282	5.36	1.29	46%	72%	2.32	3,259	110,652
<b>Cape Verde</b>	491,621	5%	24,581	4.60	1.58	46%	25%	1.16	3	1,336
<b>Cote d'Ivoire</b>	19,737,800	53%	10,401,821	5.36	1.20	46%	25%	0.75	781	46,047
<b>Gambia</b>	1,728,394	95%	1,641,974	5.36	0.75	46%	25%	0.47	77	4,032
<b>Ghana</b>	24,391,823	40%	9,634,770	5.10	1.01	170%	19%	1.86	1,794	45,436
<b>Guinea</b>	9,981,590	80%	7,985,272	5.36	1.46	46%	17%	0.62	495	15,835
<b>Guinea Bissau</b>	1,515,224	88%	1,333,397	5.36	1.71	46%	25%	1.07	143	3,535
<b>Liberia</b>	3,994,122	97%	3,874,298	5.36	1.23	46%	42%	1.29	500	15,654
<b>Mali</b>	15,369,809	83%	12,756,941	5.36	1.29	30%	50%	1.06	1,348	71,714
<b>Niger</b>	15,511,953	91%	14,115,877	5.36	1.39	46%	36%	1.25	1,768	52,112
<b>Nigeria</b>	158,423,182	49%	78,261,052	5.36	1.01	46%	22%	0.56	4,368	325,243
<b>Senegal</b>	12,433,728	58%	7,211,562	5.36	1.48	29%	23%	0.54	388	26,687
<b>Sierra Leone</b>	5,867,536	90%	5,280,782	5.36	1.03	46%	59%	1.52	805	32,305
<b>Togo</b>	6,027,798	80%	4,822,238	5.36	1.33	46%	25%	0.84	403	14,063
<b>TOTAL</b>	300,793,186	59%	178,063,968					<b>0.94</b>	<b>16,663</b>	<b>785,298</b>

Incomes to purchase lighting fuel (per 10,000)=&gt; 44

[1] UNEP en.lighten energy model

[2] UNEP en.lighten energy model

[3] IMF price database. Prices end-2011, with the exceptions of (Cote d'Ivoire and Gambia, end-2008, and Guinea Bissau mid-2008)

[4] Surveyed values from Tracy and Jacobson (2012) for Ghana, Mali, and Senegal. Weighted average of those results (46%) applied to remaining countries (values in italics).

[5] Gallup Poll: 2010-2011. <http://www.gallup.com/poll/149276/Electricity-Charges-Sub-Saharan-Africans-Wellbeing.aspx> Values in italics are estimates in lieu of country-specific data.

[6] Derived by computing the ratio of total net income for kerosene reseller (given population size, prices, markups, net of their expenses) to an assumed wage per reseller (detailed example in Table A-1). The methodology requires numerous uncertain assumptions, particularly the share of kerosene for lighting (assumed at 25% given the wide use of candles in many Ecowas countries), fraction of kerosene purchased from kerosene-only vendors (25%), reseller markups, salary of reseller (\$10/day). Aggregate kerosene demand is estimated by applying a typical per-household consumption of 70 liters per year, and assuming 5.5 people per household. Does not include illicit employment such as smuggling.

[7] Derived assuming that 5% of household income is spent on kerosene, on average, among those households relying on the fuel for illumination.

## Appendix B. Kerosene as a Cooking Fuel

While kerosene is promoted actively as a “clean” cooking fuel for developing countries, it has only achieved a 4% market share (11% urban, 2% rural; Legros et al. 2009). With one striking exception, in ECOWAS countries kerosene is used less than 2% of the time as a cooking fuel, and often well under 1% — and less so in rural areas than in urban areas. In half of the cases, kerosene has no measurable use for cooking. In Nigeria, however, kerosene has a 54.6% market share for cooking in urban areas and 7.3% in rural areas. More detail can be found in the WHO database<sup>11</sup>. An important caveat with the surveys underlying this information is that they report only the primary cooking fuel, and thus miss secondary uses of kerosene for cooking.

**Table B-1. Use of kerosene as a primary cooking fuel: ECOWAS (Legros et al., 2009)**

	National	Rural	Urban	Year
Benin	1.9%	0.9%	3.2%	2006
Burkina Faso	0.4%	0.4%	0.4%	2007
Cape Verde	0.0%	0.0%	0.0%	2006
Ivory Coast	0.0%	0.0%	0.0%	2006
The Gambia	0.2%	0.0%	0.3%	2005-2006
Ghana	0.6%	0.1%	0.6%	2006-2008
Guinea	0.1%	0.0%	0.2%	2005
Guinea Bissau	0.0%	0.0%	0.0%	2006
Liberia	0.0%	0.0%	0.0%	2007
Mali	0.0%	0.0%	0.0%	2006
Niger	0.0%	0.0%	0.0%	2006
Nigeria	23.0%	7.3%	54.6%	2007
Senegal	0.0%	0.0%	0.0%	2006
Sierra Leone	0.7%	0.3%	1.4%	2007
Togo	0.5%	0.1%	1.2%	2006

<sup>11</sup> [http://www.who.int/indoorair/health\\_impacts/he\\_databasecont/en/index.html](http://www.who.int/indoorair/health_impacts/he_databasecont/en/index.html)

## Appendix C. Interviews with Kerosene Traders in Malawi and Kenya

Context	Malawi	Kenya
<b>District</b>	<b>Mzimba South</b>	<b>Bomet</b>
Date of survey	oct.14	nov.14
Active promotion of quality solar-LED products by SunnyMoney	no	yes
Number of markets visited	30	8
Markets with kerosene sellers	57%	100%
Kerosene traders interviewed	14	9
Public interviewed	341	349
<b>Consumers</b>		
Using kerosene as primary fuel for lighting	22%	38%
Using kerosene as secondary fuel for lighting	20%	5%
Using LED lights	65%	44%
of which using solar-LED lights	1%	42%
of which using LED torches	64%	2%
<b>Traders</b>		
Traders selling exclusively kerosene	2	0
Kerosene as % of total revenues*	27%	28%
Distance traveled to obtain fuel (average km)	31	184
Median sales (liters/week)	2.0	100
Kerosene purchase price (\$/liter)	\$3.25	\$1.00
Sale price (\$/liter)	\$3.81	\$1.15
Price markup	17%	15%
Earnings (gross daily before expenses)	\$0.16	\$2.18
Reduction in sales over past year	52%	46%
Reduction in sales over past year (median)	33%	67%
* for those traders selling kerosene together with other goods		
Exchange rates:		
Malawi	403.196	MWK/USD
Kenya	85.22	KES/USD

Source: Kat Harrison, Solar Aid



## About the UNEP Division of Technology, Industry and Economics

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

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

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

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

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

- > The International Environmental Technology Centre – IETC (Osaka), which promotes the collection and dissemination of knowledge on Environmentally Sound Technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment.
- > Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- > Chemicals (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- > Energy (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- > OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- > Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

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

For more information:

**see [www.unep.org/dtie](http://www.unep.org/dtie)**

This study analyses the role of market transformation on job creation in West Africa for the case of off-grid lighting. If the use of fuels for off-grid lighting is reduced or eliminated in developing countries, supply chain changes may lead to job gains or losses.

The en.lighten initiative also invites readers to consider two companion studies: *Light for Life: Identifying and Reducing the Health and Safety Impacts of Fuel-Based Lighting*; and, *Lifting the Darkness on the Price of Light: Assessing the Effect of Fuel Subsidies in the Off-Grid Lighting Market*.

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

For more information about the en.lighten initiative, please visit: [www.enlighten-initiative.org](http://www.enlighten-initiative.org)

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