

Job creation and energy savings through a transition to modern off-grid lighting

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ABSTRACT

A market transformation from inefficient and polluting fuel-based lighting to solar-LED systems is well underway across the developing world, but the extent of net job creation has not previously been defined. This article finds that current employment associated with fuel-based lighting represents approximately 150,000 jobs. New jobs will accompany the replacement technologies. A survey of major solar-LED lighting companies finds that 38 such jobs are created for each 10,000 people living off-grid for whom stand-alone solar-LED lights are suitable. Applying this metric, the number of new jobs already created from the current uptake of solar-LED lighting has matched that of fuel-based lighting and foreshadows the potential creation of 2 million new jobs to fully serve the 112 million households globally that currently lack electricity access, are unlikely to be connected to the major grid, micro-grids, or are able to afford more extensive solar systems. A likely greater number of additional jobs and employment income will be indirectly created or preserved via indirect employment, re-spending of energy savings, conservation of foreign exchange, enhanced literacy, and improved working conditions. In contrast, central grid expansion is unlikely to provide any net increase in jobs. The case of solar-LED lighting demonstrates that policymakers have tools to increase the pace of in-country job creation in the context of sustainable development, while minimizing job displacement, and improving the quality of employment. These tools include stimuli for domestic manufacturing or assembly of products; supporting peripheral businesses and services, such as training, recycling, financing, and impact assessment; and removing market barriers that slow the uptake of emerging technologies.

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Light and livelihood: a broad view

The challenge of providing high-quality and affordable illumination to the 1.2 billion people currently lacking access to electricity grids has long been recognized (Dutt, 1994), and solar-LED lanterns have emerged as a highly cost-effective means of achieving this goal (Mills, 2005). The global employment effects of a transition from kerosene and other lighting fuels and supplies to electric alternatives such as solar-LED lanterns have not previously been examined (IRENA, 2013). A methodology has recently been developed and applied in the 15-country ECOWAS region of West Africa (Mills, 2014). This article significantly expands that work to include all developing countries, and identifies the net effect of potential job losses and job gains.

In retrospect, few would regret the loss of employment among those who cared for horses following the advent of the car. However, such job displacement should be understood and mitigated to the full extent possible. When considering competing lighting alternatives it is important to assess not only direct employment outcomes, but also a host of indirect factors that influence livelihoods. For example, excessive expenditures for lighting divert incomes and diminish the value of wages. In addition to imposing higher operating costs, fuel-based

illumination can create suboptimal and unsafe work conditions through effects on indoor air quality, fire safety, and visual performance (Mills, 2016a), thereby eroding the quality of livelihoods.

The patterns and demographics of employment are another consideration. While most manufacturing of solar-LED lighting components is focused in a small number of countries (often industrialized ones) and assembly takes place predominantly in China and India, this research focuses on the highly diversified in-country distribution and sale segments of the value chain, where the majority of jobs stand to be lost and gained. The quality and decency of employment must also be considered (ILO, 2012). For example, fuel-based lighting jobs, like other jobs in the fuel supply chain, may in some cases involve child labor, illicit activities such as smuggling and black-market pricing, undocumented migrant workers, or jobs based entirely outside of the country of concern. Emerging alternative technologies are not immune from these concerns, but stand to be less problematic in this regard.

Methods

This article develops model-based employment estimates—informed by field data—because no comprehensive survey data exist to enable

tabulation of the numbers of direct, let alone indirect, jobs created by fuel-based lighting or alternative technologies. The approach utilizes two techniques for estimating baseline employment from the production and selling of lighting fuels and supplies and a third technique for estimating job creation from alternative solar-LED technologies.

1. Current-day upstream employment from lighting fuel production is estimated as the fraction of total petroleum-sector jobs corresponding to kerosene's share in total petroleum production.
2. Estimates of baseline downstream employment from selling lighting fuels and products are derived from "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 a given population served. These job intensities are applied to other off-grid lighting inputs such as diesel fuel, batteries, and candles.
3. Estimates of job-creation by the emerging solar-LED lantern industry are developed based on a survey of solar-LED lantern companies operating across the developing world as of late 2013. Seventeen companies were contacted and invited to contribute data in a standardized format. Respondents included four of the larger manufacturers and four of the larger distributors representing the majority of global production of products quality assured by Lighting Global at the time. The countries/markets served by respondents included Ethiopia, Haiti, India, Kenya, Malawi, Tanzania, and Zambia. The primary countries of manufacture/assembly include China, India, and various points in Africa. The types and numbers of jobs were collected and normalized per million lanterns sold. A central value across the responses is then applied to the overall market size to derive estimates of current and potential job creation.

A global estimate by the International Finance Corporation (IFC) concludes that approximately 274 million households are without modern lighting and electricity (IFC, 2012), of which 112 million can afford or best be served by individual solar-LED lanterns. The remaining segments can afford more extensive upgrades, such as complete solar home systems or access to the central grid or micro-grids. Moreover, there are an estimated 1 billion people with intermittent access to electricity grids who utilize fuel-based lighting during power outages (Bloomberg New Energy Finance, 2016). While these secondary and tertiary segments can utilize solar-LED lighting, the associated employment is not estimated here.

Various types of indirect jobs were also not estimated, including production of the raw materials and components (e.g. batteries, LEDs, PV panels, switches, housings) comprising the lighting products, contract manufacturers' employees who are not employees of the downstream branding and distribution companies, entities involved in shipping and customs, independent system re-charging enterprises, and third-party entities involved in financing. As a proxy for contract manufacturing, an estimated 105 manufacturers and 127 suppliers are producing and distributing these products at the wholesale level (Bloomberg New Energy Finance, 2016), but their employee base is not known. Emerging jobs in areas such as training and recycling were also not quantified. Secondary income provided by solar-LED lanterns that also enable phone charging would create additional jobs but is not evaluated here. Ultimate job creation would thus be even greater than estimated here. IRENA (2013) estimates that direct jobs associated with renewable energy represent one-third of total jobs in the off-grid solar sector.

The practical distinction between having any (even part-time) employment versus none at all is central to an individual or family's economic viability, so this study focuses primarily 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. Similarly, many people maintain multiple modes of obtaining income. For example, SunnyMoney, which by mid-2015 had sold 1.7 million solar-LED lights across five East African countries, has augmented the incomes of 600 sales agents by approximately 30% (SolarAid, 2015).

Given the lack of comprehensive survey data, the estimates presented here are largely model-based and thus embody uncertainties. Results are presented as highly rounded values to avoid over-precision. The scaled-up estimates of livelihoods provided by kerosene selling are cautious insofar as they assume that every market has vendors dedicated solely to kerosene.

Current employment situation

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 the primary lighting fuel, kerosene, given that it represents a minor sub-component of the overall petroleum-sector value chain. As of 2015, only 26 out of 146 developing countries produced kerosene domestically and thus the vast majority did not host any related upstream jobs (USEIA, 2016).¹

The job-intensity of oil refining is approximately 392 barrels per worker per day (Kojima et al., 2010). If kerosene-related jobs are also created at this level of job-intensity, the global kerosene output in the peak year of the past decade (1.1 million barrels of kerosene per day globally) (USEIA, 2016) would be equivalent to only 2800 jobs. Approximately 80% of this kerosene is destined for end-uses other than lighting (e.g., cooking, heating) (Mills, 2016b), so the lighting-related value could be substantially lower. Moreover, it could be argued that crude oil no longer needed for kerosene will be produced and used instead for the production of other petroleum products, without a net reduction of labor input.

Candles are a more important lighting fuel than kerosene in many countries (Wei, 2012). Within the developing world, only Brazil, China, South Africa, and Venezuela are among the major wax manufacturers (approximately half of which is used for candle production). Regionally, only China and Europe are net exporters of wax. Most developing countries are thus net importers the raw material for making candles and thus do not enjoy the jobs created by its production. Employment data are not available on in-country candle manufacture.

The lighting energy downstream

The energy downstream is far more job-intensive than the upstream, particularly in the developing world where distribution and retail sales are not highly mechanized. It is important to identify the downstream points where employment could be most at risk as kerosene is displaced by alternatives. At the wholesale level, and at almost every subsequent node, kerosene is one of many petroleum products being moved or sold. Similarly, lighting equipment is almost always sold with other goods, even by informal vendors (Fig. 1).

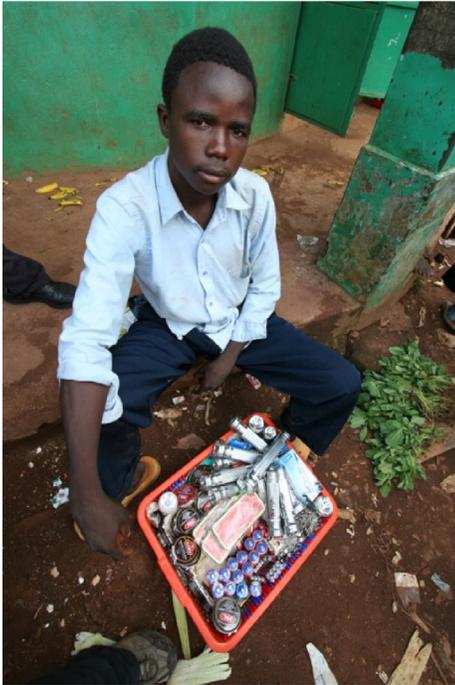
A diverse product offering is thus the norm at the retail level, for example, within petrol stations that derive the vast majority of their income from transportation fuels and who have no employees that deal exclusively with kerosene. Petrol stations also have far lower rates of employment per unit of fuel sold than do micro-enterprises. This also applies within shops where kerosene is commonly only one of a large variety of commodities sold. Moreover, the emerging solar-LED lighting alternatives are being sold through many of these same outlets, and thus the revenue can remain within that sector even as technology/fuel choices evolve.

In many developing countries, the informal sector represents the vast majority of employment (Cohen et al., 2000). No statistical information exists on the extent of employment among informal lighting fuel and supply sellers. The International Labor Organization offers technical guidelines for this purpose (ILO, 2013), and has a specific statistical

¹ This value includes countries producing less than 500 barrels per day of the fuel.



Informal marketplace scenes, with kerosene lanterns, wicks, and fuel dippers being sold alongside a wide variety of household goods, hardware, and sundries.



Informal hawker, selling flashlights, batteries, shoe polish, and safety pins.



Informal hawker, lamp wicks, toothbrushes, and safety pins.

Fig. 1. Illustrations of lighting equipment (lamps, wicks, batteries, torches) being sold among other goods. (photos: Evan Mills).

definition and category for street vendors, but does not differentiate those selling lighting fuels and equipment from other goods. It is thus necessary to develop estimates from field observations.

Kerosene and related lighting accessories (wicks, lamps, etc.) are sold widely within the informal sector (Fig. 2). The simplest format for these microenterprises is an individual who purchases a few liters of kerosene at a time from petrol stations or other bulk distributors and resells in very small quantities using deciliter-sized dippers or pre-measured soft drink bottles. They thus lack purchasing power, and must resell at some markup from standard retail price levels and extract their livelihood from that difference. Tracy and Jacobson (2012) surveyed kerosene prices in five countries (Ghana, Kenya, Mali, Senegal, and Tanzania), attempting to identify the markup on resold kerosene outside of urban areas. Results varied from 23 to 170%, with a population-weighted average markup of 46%.

Solar Aid has conducted interviews with kerosene traders in rural Kenya and Malawi, providing further insight into their dynamic retail situation (Box 1). Of the 23 traders interviewed, only two sold only

kerosene and among the others kerosene represented only one-quarter of total revenues. Average revenues ranged from \$0.16 to \$2.18 per day, with markups about one-third of those assumed in the model. 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-sector workers are highly vulnerable to kerosene supply shortages and other hardships. Upstream hoarding and the resulting shortages for vendors are common, resulting in lost income (Sunday Trust, 2009). Similarly, intermediaries often smuggle lighting products between countries when there are large price differences (typically due to disparate subsidies). This is a particularly acute and large-scale problem in Nigeria and India where (Mills, 2016b). Candles are also reported to be among the top goods smuggled between certain countries (Golub and Mbay, 2008). Thus, local citizens do not always enjoy the employment associated with lighting fuel transportation and sales. Increases in taxation or reductions in subsidies can also curb fuel demand abruptly, as can supply disruptions due to a wide range of factors.



Fig. 2. Young girls selling tin lamps (left) and kerosene (right) in Northern Vietnam. (photos: Evan Mills).

Placing additional pressure on these sellers, some countries, including Ghana (Modern Ghana News, 2011) have attempted to ban all forms of street vending.

Field observations for the East African towns of Mai Mahiu and Kagarita (Kenya) indicate that a representative estimate for the density of small-enterprise kerosene sellers that region is 2–3 informal vendors of kerosene per town of approximately 10,000 inhabitants (Alstone, 2013). An alternative approach to deriving this number is to estimate the amounts kerosene purchased from vendors together with likely price markups to determine corresponding net revenues. The full-time equivalent numbers of people employed can then be estimated by assuming a standard wage (Table 1).² This method arrives at a similar value as those observed in Mai Mahiu and Kagarita.³ Many inputs to this calculation could well vary by plus or minus 50% depending on the combined effect of electrification rates, kerosene lighting's market share, energy prices, and profit margins. In practice there is a mix of lighting fuels and techniques (ranging from kerosene to candles to non-rechargeable flashlights). Given insufficient data on the relative proportions of lighting strategies by country and that all are sold in similar ways, we assume that the labor intensity associated with the number of sellers serving a given population is comparable to that derived here for kerosene irrespective of the mix of actual lighting supplies.

Applying the derived employment intensity to the non-electrified population of deemed appropriate targets for stand-alone solar-LED lighting systems (112 million households), results in a global base of approximately 150,000 jobs providing current fuel-based lighting.

People who make and provide the equipment that consumes lighting fuels are part of the fuel-based lighting workforce as well. While the familiar “hurricane lamp” is typically imported, lower-cost, less efficient and more polluting “tin lamps” are typically handcrafted from used food cans, bottles, or other containers (Fig. 3). However, no data are available on the numbers of people making tin lamps (or candles

or flashlights) in the developing world. Given the simplicity of the fabrication process, one worker can make large numbers of simple kerosene lamps in a day. These typically sell at \$0.10 each, which, when applied to the framework presented in Table 1, and cautiously assuming every household used kerosene for lighting, would result in only about 3% as many jobs as those associated with the sale of kerosene and other lighting inputs. Note that many users probably fabricate their own simple lamps, thus not creating employment for others.

Potential impacts on the quantity and quality of employment from new technologies

The effect of new technology introduction on livelihoods will be the net result of job displacement from fuels and supplies no longer used and job creation associated with the emerging technologies.

Effects of kerosene demand reduction

The lighting fuel sector is routinely subjected to “stress tests” that could be expected to yield observable adverse 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, 2016b). Yet, whether in the event of considerable demand growth in countries such as The Gambia or Sierra Leone or highly volatile and otherwise declining demand in many others (e.g., Cote d'Ivoire, Liberia, and Niger), no substantive national-level reports or references have been reported regarding changes in employment. The aforementioned case studies in Malawi and Kenya also did not reveal a material effect on employment.

In 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 identifiable references to employment impacts (USEIA, 2016).

These observed changes in kerosene demand reduction are much more abrupt than would be experienced even under programs for introducing replacements for fuel-based lighting. Gradual and predictable change provides time for adapting to potential employment

² Thanks to Peter Alstone for suggestions about methods for estimating scale of independent kerosene sellers.

³ 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 would correspond to approximately 1.5% of all hawkers, a plausible ratio.

Box 1

Interviews with kerosene traders in Malawi and Kenya.

Interviews with kerosene traders in Malawi and Kenya

SolarAid has conducted surveys in localities within Malawi and Kenya where they have aggressively introduced solar-LED replacements for kerosene lighting. Of 30 markets visited in Malawi in 2013, 57% were found to have informal kerosene sellers. Of 8 markets visited in Kenya, all had informal kerosene sellers. In these markets just over 40% of consumers reported using kerosene for lighting.

Only 2 of the 23 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. Kerosene was sold at a 17% and 15% mark-up, and represented 27% and 28% of total vendor income, and with net earnings of \$1.24 and \$15.25 per week in Malawi and Kenya, respectively.

In Malawi, the kerosene was sourced on the black market or smuggled in from outside the country by 8 of the 14 traders.

The vendors reported about 50% reduction in sales over the prior year. Most attributed this to increased availability of low-cost, non-rechargeable LED torches (flashlights) and/or solar-charged lanterns. Several also noted that kerosene shortages were a factor. Most had adapted to the reduced demand. One spoke of their kerosene business as “dying a natural death.” The displacement of kerosene did not emerge as a disruptive factor in employment.



Context	Malawi	Kenya
District	Mzimba South	Bomet
Date of survey	Oct-13	Nov-13
Active promotion of quality Solar-LED products	no	yes
Number of markets visited	30	8
Markets with kerosene sellers	57%	100%
Public interviewed	341	349
Consumers		
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%
Traders		
Kerosene traders interviewed	14	9
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 (\$/day)	\$0.16	\$2.18
Reduction in sales over past year (average)	52%	46%
Reduction in sales over past year (median)	33%	67%
* for those traders selling kerosene together with other goods		
Exchange rates (12/2015)		
Malawi	403.2 MWK/USD	
Kenya	85.2 KES/USD	

Source: Kat Harrison, Solar Aid, Personal Communication

Table 1
Hypothetical kerosene seller and lamp maker employment for an unelectrified town with 10,000 population.

	Kerosene fuel sellers		Lamp makers	
<i>End-user demand parameters</i>				
Consumer purchases (3 lamps)	50	Liters/household-year	3	Lamps/household-year
Occupancy	4.5	People/household	4.5	People/household
Households using kerosene lighting	2222	Households	2222	Households
<i>Economic parameters</i>				
Fraction purchased from small vendors	25%		100%	
Sellers materials costs	1	US\$/liter	0	\$/lamp
Seller's markup	46%	(Tracy and Jacobson, 2012)	0.10	\$/lamp
Gross revenues from small sellers	40,556	\$/year	667	\$/year
Net revenues	18,656	\$/year	667	\$/year
Share of net revenue allocated to labor	50%		100%	
Proceeds available for salaries	\$9328	\$/year	\$667	\$/year
Individual seller's net income	10	\$/day	10	\$/day
Days worked by each seller	300	days/year	300	days/year
Equivalent full-time jobs	3.1	Jobs	0.2	Jobs

displacement. Moreover, transformation will not likely be complete, even in the medium term. Kerosene is also being promoted in some circles as an improved fuel for cooking.

Emerging technologies: “solar livelihoods”

LED lanterns have become increasingly popular. Many of these are being sold through the same value chains as the fuel-based lighting equipment they replace (Fig. 4). Leading providers of solar-LED lanterns



Fig. 3. Manufacture of kerosene-fueled “tin” lamps from discarded food cans: Kibera, Kenya. (photo: Evan Mills).



Fig. 4. LED torches (flashlights) for sale in rural marketplace in Senegal. (Photo: Evan Mills).

to developing country markets were contacted for this study to help benchmark the current and potential job-creation dimensions of new technologies and business models. Eight companies responded, identifying job intensities of twelve work categories, as shown in Fig. 5.

These product developers, distributors and retailers provided data for their activities 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 (about one-eighth of the total world market at the time). Only employees located within developing counties were included, while employees of the third-party contract manufacturers retained to produce the lamps are not counted.

According to the data provided, there are about 17,000 workers per million lanterns introduced into the market annually across the entire production-to-sales process. Many of these workers handle other products at the point of sale, although some only sell lighting products. 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 mix of a wide variety of job categories. Population densities likely influence labor needs in certain segments of the value chain (e.g., product distribution), particularly in rural areas. As noted above regarding lighting fuels, because the level of employment varies, these should be regarded as a combination of part- and full-time jobs.

This result comports with empirical results from the large-scale programs by Grameen Bank in Bangladesh, where a staff of 12,000 people had by 2012 installed one million small (30 W to 100 W) solar home systems (Grameen Shakti, 2012). Grameen is 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). This estimate also

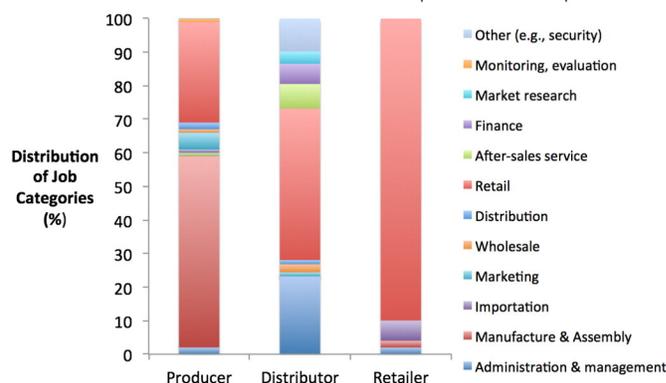


Fig. 5. Type and distribution of jobs in the solar-LED lighting marketplace.

In-country Job-creation Potential for Solar-LED Lighting Sale and Distribution

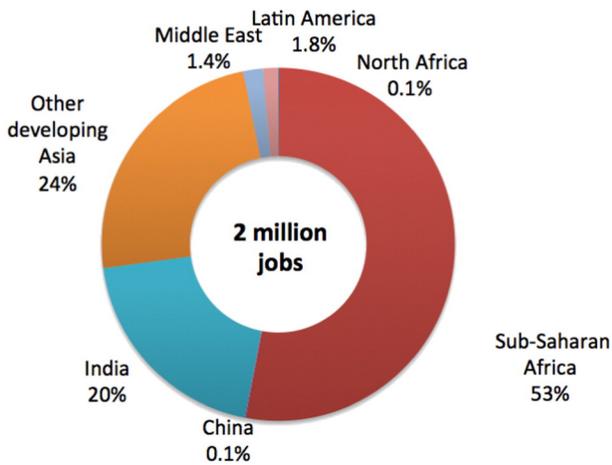


Fig. 6. Jobs by region, apportioning the unelectrified population (IEA 2015) to households at the rate of 4.4 people per household for the year 2013.

agrees with the ratio of 50 systems per worker noted in an assessment of small-scale solar PV employment potential in Ethiopia (Ethio Resource Group, 2012). The mixture of job types would of course vary significantly between small commodity lantern technologies and larger customized solar home systems.

These job-creation intensities can be used to estimate employment at scale. For this purpose, each of the previously defined 112 million eligible households is assumed to be able to afford three improved solar-LED lanterns, each with a service life of three years. This corresponds to an ongoing replacement rate of 112 million LED lanterns each year. Given the job intensity of 17,000 jobs per million lanterns, the corresponding volume of sales would employ approximately 2,000,000 people (Fig. 6). The underlying assumption of a three-year product life 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 numbers of jobs will decline proportionately, all other things equal.

Although the off-grid solar lighting market is still in the initial phases of development, 44 million solar-LED lanterns had been sold globally as of mid-2015, with a marginal rate of 10 million units per year and a projected annual growth rate of 34% (Bloomberg New Energy Finance, 2016). More than 100 companies now focus on stand-alone solar lanterns and solar home kits. Based on the job-intensity derived above, the current sales rate corresponds to approximately 150,000 jobs created to date. Note that approximately half of these products are certified under the Lighting Global quality assurance program.

Indirect employment effects of reduced dependency on fuel-based lighting

There are multiple second-order effects of improved lighting technology on the quality and quantity of employment. These may be broken into the broad categories of reduced costs associated with inefficient lighting expenditures, increased potential for domestic spending to create employment due to improved balance of trade, improved earnings for microenterprises, improving educational outcomes, and improved health and safety conditions.

- Cost savings from improved lighting are analogous to newfound income. A detailed field study following solar-LED lantern deployment

to 134 households across 20 villages in the Philippines determined that homeowners saved 4060 PHP (US\$86) per year in lighting costs (Planete d'Entrepreneurs, 2011). Assuming that household expenditures on lighting fuels hypothetically represent 5% of household income, then for every 20 households that convert from fuel-based lighting, a full job-equivalent worth of income is collectively retained by the general population. An eventual complete transition away from fuel-based lighting thus translates to an aggregate level of income preservation equivalent to approximately 6 million jobs globally, roughly triple the direct job creation associated with the solar-LED lantern industry. Some of these savings are required to finance the substitute technology, but the replacements typically pay for themselves many times over during their useful service lives.

- At a macro-economic level for oil-importing countries, 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 support the economy, potentially contributing to increased employment prospects.
- 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 (Practical Action, 2012). A survey of 17 sub-Saharan African countries found that complete lack of electricity in the workplace ranges from 92% in Mali and Niger to 12% in South Africa (Fig. 7). The costs of fuel-based lighting for businesses can be high, up to 50% of wholesale revenues in the night-fishing sector (Mills et al., 2014a). Low-quality fuel-based light also compromises businesses' ability to attract customers and effectively display their wares (Fig. 8). One detailed field study following solar-LED lantern deployment in the Philippines determined that businesses earned an additional 17,052 PHP (US\$363) per year thanks to improved illumination (Planete d'Entrepreneurs, 2011). A separate study of 50 microenterprises in Ghana also found that the availability of solar lighting increased revenues (Obeng and Evers, 2010).
- 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 assessment found that children of solar system buyers complete twice as much homework as do those limited to kerosene lighting (Solar Aid, 2013). Another assessment found a 45% increase in study time at home (Planete d'Entrepreneurs, 2011). Education and literacy are, in turn, important precursors to future employment and wages.
- Fuel-based lighting is associated with very significant adverse health and safety risks, which can lead to reduced or lost employment if sufficiently acute (Mills, 2016a). These impacts include burns, poisonings, compromised respiratory and visual health, premature death, and adverse outcomes in clinics that lack electricity (Orosz et al., 2013). 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.

Policy strategies for managing the transition

Policymakers concerned with off-grid lighting markets and livelihood face multiple challenges and opportunities (IRENA, 2011).

Understanding and minimizing dislocation caused by technology changes

Improved estimates of the numbers of businesses and individuals selling lighting fuels and products are needed. Detailed market data are required in order to pinpoint workers at risk of losing livelihood as markets transition. Information must also be gathered on upstream employment in fuel-distribution workers, candle production, operators of small generators for lighting and other services, and the livelihoods

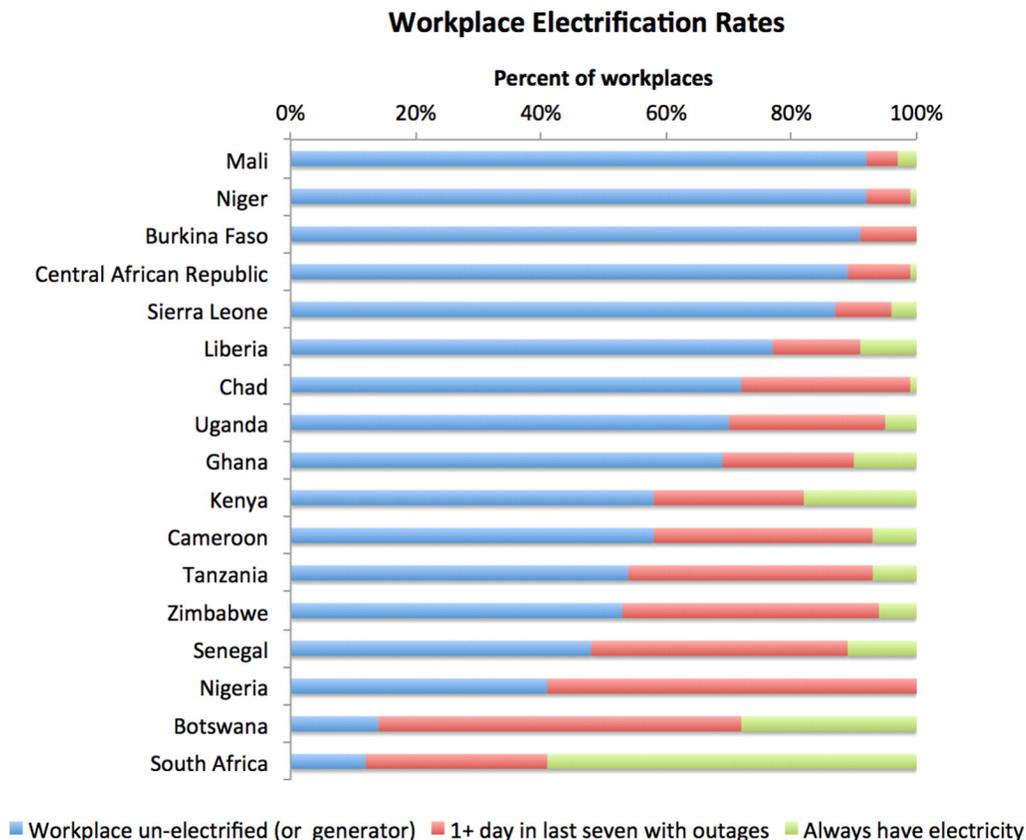


Fig. 7. Deficits of electricity at workplaces in selected countries. (Tortora and Rheault, 2012).

of those who manufacture fuel-based lanterns and other lighting equipment.

Dislocation of livelihoods and other problems already occur in fuel-based lighting markets, for example, where fuels are smuggled across borders or black markets that result in lost tax revenues, ultimately affecting government ability to support its citizens. In other cases, dealers at various points in the value chain adulterate kerosene with cheaper fuels, and resell the deadly, explosive fuel (Mills, 2016a). These dynamics must be better understood and due consideration given to the sometimes illicit nature of the associated sellers' livelihoods. The presence of fuel subsidies also undermines the profitability of kerosene sellers (Mills, 2016b).

The location of manufacturing is a consideration when examining solar-LED alternatives. The vast majority of LED lanterns are manufactured in Asia. Constraints to shifting production elsewhere include the need for worker training, competitiveness of local labor rates, tariff structures, and, lack of well-developed domestic component manufacturing supply chains and technology assembly facilities. That said, approximately 10% of global solar-LED lantern manufacturers produce their products in Africa and 14% produce in India, while most of the balance produce in China (Lighting Africa, 2013). In some cases, hybrid arrangements as illustrated by the German company Solux shipping components for in-country assembly (Fig. 9).

In another example of local manufacture, an entity in Kenya uses charitable donations to furnish local groups with kits to assemble simple LED lanterns using recycled materials, with proceeds reinvested in further lantern production or other enterprises (Fig. 10). SDFA Kenya reports production of approximately 5000 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 (Fig. 11) (USAID, 2013).

Supporting energy access pathways with maximal job creation

Another key policy variable to consider is displacement of fuel-based lighting through centralized electrification programs versus distributed, grid-independent lanterns. The rate of electrification is not keeping pace with population growth in sub-Saharan Africa and certain other regions. IFC (2012) estimates that central electrification is suitable for only 21 million of the 274 million currently unelectrified homes in the developing world.

It has also long been known that renewable energy technologies create nearly ten-times as many jobs per unit of energy output than does centralized electricity production (Kammen et al., 2004). As this ratio is on a par with that found here between kerosene and solar-PV lanterns, conversion from fuel-based lighting to the central grid would yield negligible net job creation compared to the off-grid pathway. It would, also shift jobs from lower-income villagers to demographically quite different utility employees.

Accelerating employment benefits

Education and training can create jobs and help ensure that the broader workforce is prepared to assume them. For example, "BarefootCollege.org," trains 100 grandmothers annually, and has helped to deploy LED lanterns to 40,000 households. Grameen Shakti has trained 5000 women as solar PV installers (Barug, 2008).

Many workers that presently sell kerosene through informal micro-enterprises may not have the appropriate skills to assume new jobs associated with solar-LED products. Some organizations are offering technical assistance to help these workers become knowledgeable about new technology. For example, one small-scale



Fig. 8. Uses of fuel-based lighting in work environments: Senegal, Tanzania, India. (photos: Evan Mills).

distributor interviewed for this study had recruited 7 of 11 current employees from among previous kerosene sellers. Another company approaches kerosene vendors as potential purveyors of their LED lanterns (Arena 2010)—providing charging services using pedal power (Fig. 12)—and has sold a total of 10,000 solar-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 (Presterio, 2010).

Efforts should be made to ensure that new employment opportunities are decent, comply with local laws, and avert problems sometimes encountered by those selling lighting fuels, e.g., child labor, gender imbalances, discriminatory practices, or unsafe work environments.

Many structural barriers impede the affordability and uptake of alternatives to fuel-based lighting. These can be addressed through policy strategies such as eliminating fuel subsidies (Mills, 2016b) and import duties or taxes on new technologies, ensuring consumer differentiation



Fig. 9. Solux program in Zanzibar (TZ) 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. Since that time, the technology has evolved from CFL to LED light sources. (Photos: Evan Mills).

among high- and low-quality products that will otherwise spoil markets (Mills et al., 2014b).

Assessing the indirect implications of improved lighting

Data on the aforementioned indirect impacts of low-quality lighting as well as the benefits of improved lighting are sparse. Policymakers can play an important role in supporting better research and data collection. In particular, 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.

Conclusion

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. New jobs are being created in order to produce, distribute, sell, and service new technologies, and to implement the business models and financing mechanisms bringing them to market. On balance, the transition will create more than ten-

times more jobs than it displaces, while improving the availability and quality of light in workplaces and homes, enhancing worker safety and productivity, and conserving scarce income. These estimates apply only to the 112 million lower-income subset of non-electrified households (less than half), and do not include intermittently electrified households or businesses.

The key role for policymakers 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 disruption as the transition proceeds. Many tools are available to help minimize adverse impacts on livelihoods. These include stimuli for domestic manufacturing or assembly of products (already occurring to a limited degree in some countries); supporting the creation of peripheral businesses and services such as training, recycling, financing,



Fig. 10. Women's collective assembles simple LED lanterns in Kenya. (Photo: SFDA, 2012).



Fig. 11. Women's collective assembles simple LED lanterns in Liberia. (Photo: USAID, 2013).



Fig. 12. Nuru Energy attempts to engage former kerosene sellers to sell and recharge locally made LED lanterns using pedal power. (Photos: IFC, 2012).

impact assessment, and carbon trading; and removing market barriers that slow uptake of improved lighting equipment.

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