Supporting Online Material
"The Specter of Fuel-based Lighting"
Evan Mills

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Overview

To facilitate comparisons among alternative fuel and electric lighting strategies, we developed a standardized engineering-economic analysis methodology.[1] To fill gaps in the existing literature, we evaluated the photometric performance of fuel-based lanterns, and 1-watt white light-emitting diode (WLED) light sources, with and without optical control (figs. S1-4). We coupled total cost of ownership and illumination performance data for an array of electric lighting alternatives to generate a ranking of costs per unit of lighting service provided ($/1000lumen-hours or $/1000 lux-hours), as well as a payback-time analysis for the LED system compared to other systems (figs. S5-6 and tables S1-5). Our methodology for energy use analysis is described elsewhere (Mills 2005). This work contributes to the existing knowledge base, as estimates of energy use in the literature do not typically specify operating conditions or assumptions, and measurements of luminous flux often overlook the optical (in)efficiencies of fuel-based lamps or the potential impact of optics when used with WLEDs.

Light Output, Distribution, and Efficacy for Fuel-based and WLED Light Sources

Methods

The process of producing light in fuel-based lamps is predicated on the inefficient combustion of fuel and the consequent production of particulates, the burning of which emits light. We evaluated the geometry of light output (luminous flux) from fuel-based lanterns using a calibrated gonio-photometer (figs. S1-2) constructed and located at Lawrence Berkeley National Laboratory. We utilized a smaller, special-purpose gonio-photometer (also constructed and located at LBNL) to evaluate WLED sources. The analysis allows comparison of these potentially interchangeable light sources.

Gonio-photometry is an established method for evaluating modern electric light sources, and the resulting photometric data are readily available (Mills et al. 1997). The gonio-photometer progressively scans an operating light source in both the horizontal and vertical planes, providing quantitative analysis of light distribution (typically in units of candelas, cd) in various directions. The results are logged using an automated data acquisition system. Measurements are integrated to estimate total luminous flux. We complement these data with light-level measurements made using standard illuminance meters.

[1] More information here: http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html

complement these data with light-level measurements made using standard illuminance meters.

Findings

Candlepower distributions for a traditional fuel-based lantern, Lamp 1 (22mm flat wick), are shown in fig. S3a for the case with a clean glass chimney. Total luminous flux is 82 lumens, or a maximum of 9-10 candelas in the horizontal direction.[2] The distribution of light is reasonably constant in a given horizontal plane, as can be seen by comparing the various colored curves. The one exception is the view at 90 degrees, which—because the wick's narrow rectangular cross section is presented on edge—"sees" only one-half to two-thirds as much light. Due to interference by the large lamp base, the vertical flux is lowest in the first 50 degrees of view as the angle of view sweeps outwards from the bottom of the lamp. This is undesirable for horizontal tasks such as reading, which tend to be located in this sector. Vertical tasks receive the maximum amount of illumination.

After approximately 10 hours of normal operation, significant soiling accumulated on the inner surface of the lantern's chimney (especially at the shoulder), resulting in both lower overall luminous flux (52 lumens) as well as considerable non-uniformity depending on which radial angle the lamp is viewed from (fig. S3b).

Figs. S3c-d depict the clean-chimney performance as well as the above-mentioned performance-depreciation problem for a second traditional hurricane-style fuel lantern (Lamp 2) with a smaller (12mm) and less-clean-burning wick after only eight hours of operation. Note the highly asymmetrical light distribution resulting from obstructions integral to the lantern's design. Due to the large base below and metal hood above the chimney, there is no light emission above approximately +/-140 degrees or below +/-60 degrees in the vertical plane, which reduces the overall optical efficiency of the system given that much of the light produced by the flame is absorbed as it strikes the inner surfaces of the lantern's base and cap. Luminous flux was 48 lumens with a clean chimney (6-7 cd), falling to only 8 lumens (as low as 1 cd) as soot accumulated on the chimney. The "dent" in flux at 150 degrees (horizontal) is due to the vertical metal brackets on either side of the chimney.

Fig. S3e presents results for the simple oil lamp (4mm cylindrical wick), with a clean chimney. Measured luminous flux was 8 lumens, or 0.7 cd in the brightest direction. The original hand-blown chimney lacked the clarity of machine-made glass, due to bubbles and other imperfections. Measured transmission losses were significant at 27%. Due to the relatively narrow base, this lamp does a better job of delivering light to tasks at lower angles of view.

We also performed goniometric analysis for white LED sources. The use of optics is an important determinant of performance. Figs. S4a-b illustrate the extremes. Diffusers and

[2] To determine illuminance at points perpendicular to the light luminous flux, the measured candelas are divided by the square of the distance from the object (in meters for lux and in feet for footcandles). For this analysis, a distance of one meter is assumed.

other types of optics can be applied to yield light distributions anywhere between these two extremes. Plots show only one radial dimension, as these sources yield highly symmetrical light distribution patterns for a moderately efficient (25 lumens per watt) WLED with (inefficient) polycarbonate optics. Measurements for more efficient systems have yielded over 600 lux at 1 meter.

Field Measurements of Electrified Households in the Developing World

Using standard illuminance meters (WattStopper FX-200 Illuminometer), we measured light levels (lux) in electrified households in China. The combination of poor installation (distance from task), low-efficiency (inexpensive incandescent lamps operating less than 10 lumens/watt), soiling of lamps by wood smoke, and low coefficients of utilization (owing to woodsmoke-blackened walls and ceilings), translate into remarkably low delivered lighting services (lux levels) and disproportionately high electricity usage.

Typical homes we inspected in rural China utilized one to two 20W to 150W incandescent lamps and delivered lighting services ranging from 1 to 50 lux (compared to Western standards of 300 to 500 lux for many common tasks). In many parts of the rooms, levels of even 1 lux could not be registered. With WLEDs, significantly higher illuminance levels consistent with our lab tests were attained (over smaller areas) with only 1W of power input.

We observed similar problems and opportunities in non-residential settings. Our measurements in schools, shops, and monasteries revealed even more significant opportunities, owing to higher incandescent lamp wattages (typically 150W) and significantly longer hours of use in these contexts. The issue is particularly worrisome in the case of schools schools, where light levels varied by a factor of ten around the classroom and learning problems and eyestrain are correlated.

As the electricity generation mix in China is dominated by coal, and prices are moving towards market-based values, the potential impacts of WLEDs are substantial among electrified households there, and presumably elsewhere in the developing world.

Summary and Conclusions

Fuel-based lighting energy use and luminous flux vary considerably depending on the type of technology used and degree of chimney soiling. As an indication of the importance of independent testing of fuel-based lighting technologies, we found rated light output 40% lower than manufacturers' ratings and energy use 2.4 to 3 times higher (Mills 2005).

Our measurements of fuel-based lamps indicate that light distribution (and, by inference, illumination) is highly non-uniform in both the horizontal and vertical planes, i.e., depending on the angle of view. In contrast, modern electric light sources typically exhibit a very uniform distribution at any given angle in the horizontal plane. Illuminance is particularly poor for reading or other tasks on horizontal surfaces. It is relatively good for vertical tasks such as weaving.

Our estimates of useful illuminance on typical tasks show that the fuel-based lamps deliver between substantially sub-standard levels of illumination when compared with western standards. The intensity of flux deteriorates considerably from these already inadequate levels (up to 83%) as the chimney becomes soiled. In contrast, lumen depreciation in electric lighting systems is typically in the single-digit range after many months of operation.

While not quantified here, the potential energy, economic, and environmental[3] benefits of WLEDs applied in already electrified households and other building types appears to be substantial, with associated opportunities for increasing service levels and thus the quality of life.

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[3] Our environmental analysis focused on greenhouse gas emissions (carbon dioxide). The widespread use of batteries for lighting in the developing world presents a major additional environmental and economic dimension.

Supporting Figures

Fig S1. Gonio-photometer during measurement of electric table lamp.

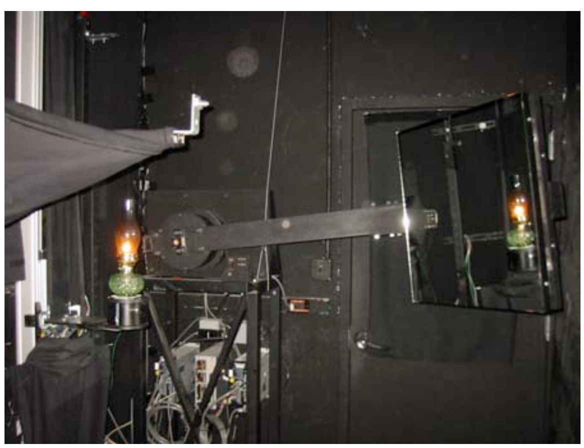
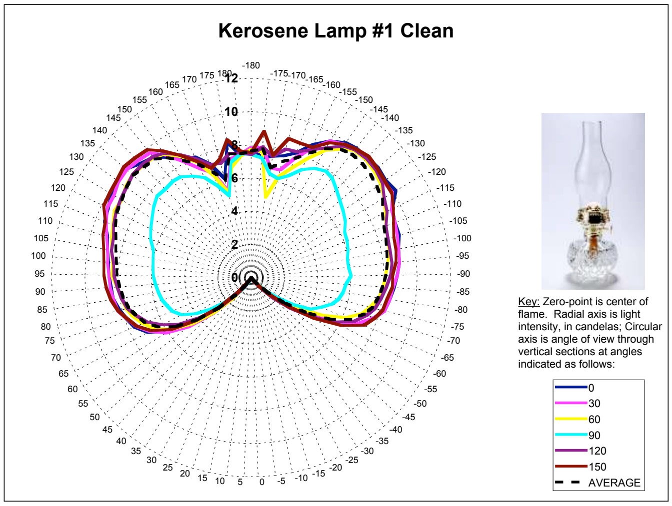
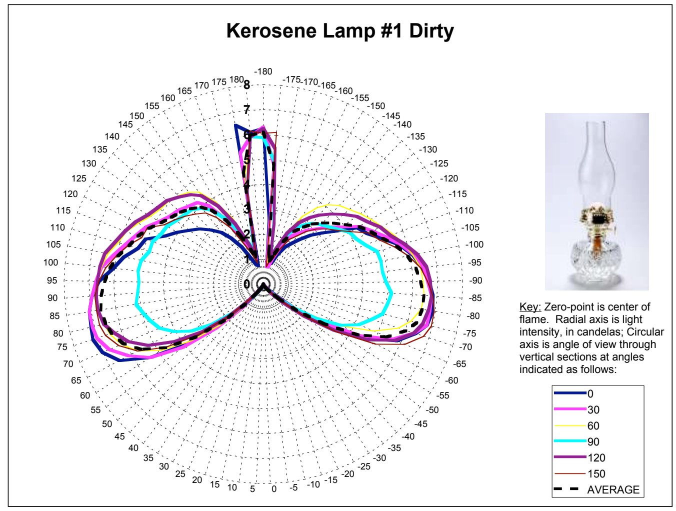
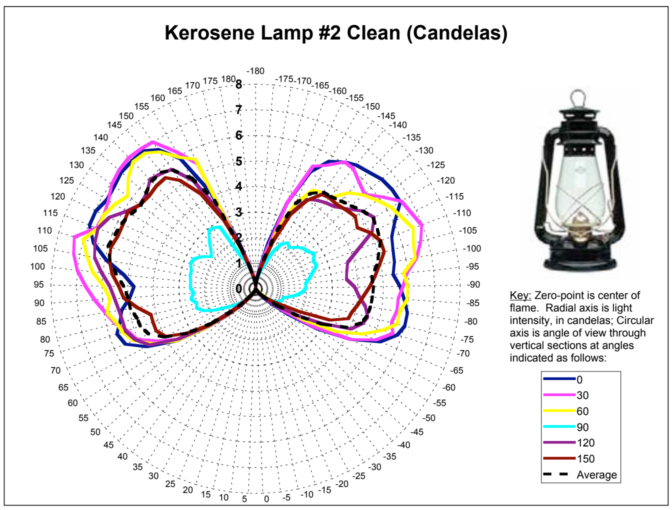
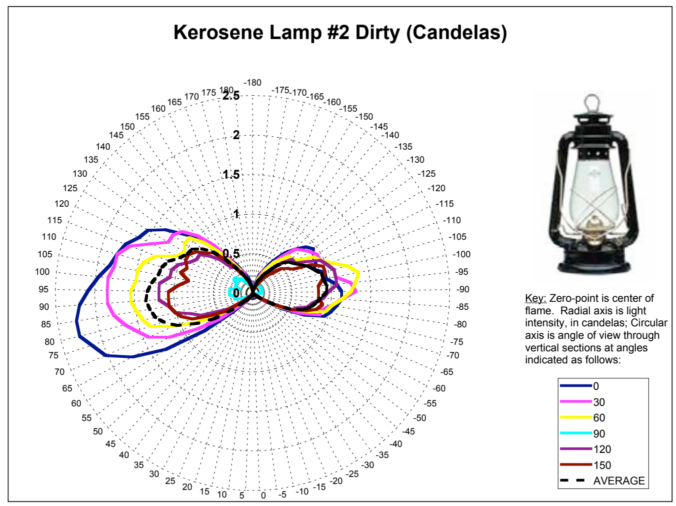


Fig S2. Gonio-photometer during measurements of kerosene lantern.









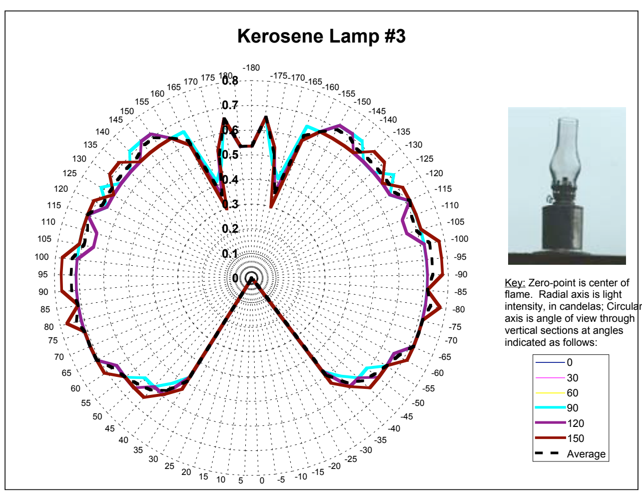


Figure S3a-e. Candlepower diagrams for typical kerosene lanterns. Goniophotometer measurements show strength and directionality of light emissions in the vertical plane and across various radial horizontal angles of view. Such analyses are routinely performed for electric lighting systems.

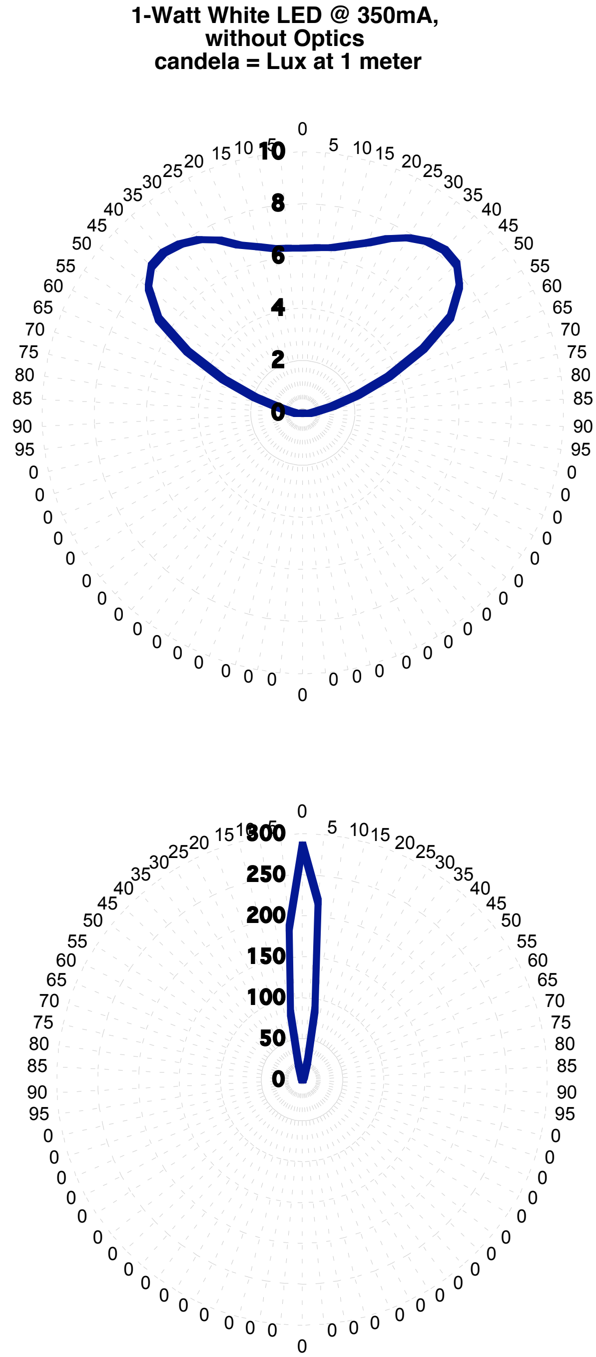


Figure S4a-b. Candlepower diagrams for 1W, 25lm white solid-state light sources (light-emitting diodes). Goniophotometer measurements indicate the strength and directionality of light emissions in the vertical plane and across various radial horizontal angles of view. The light source is identical in each panel (a) without and (b) with polycarbonate optical lens to gather and distribute light over narrow angle. Diffusers or other lens types yield an intermediary result between these two figures.

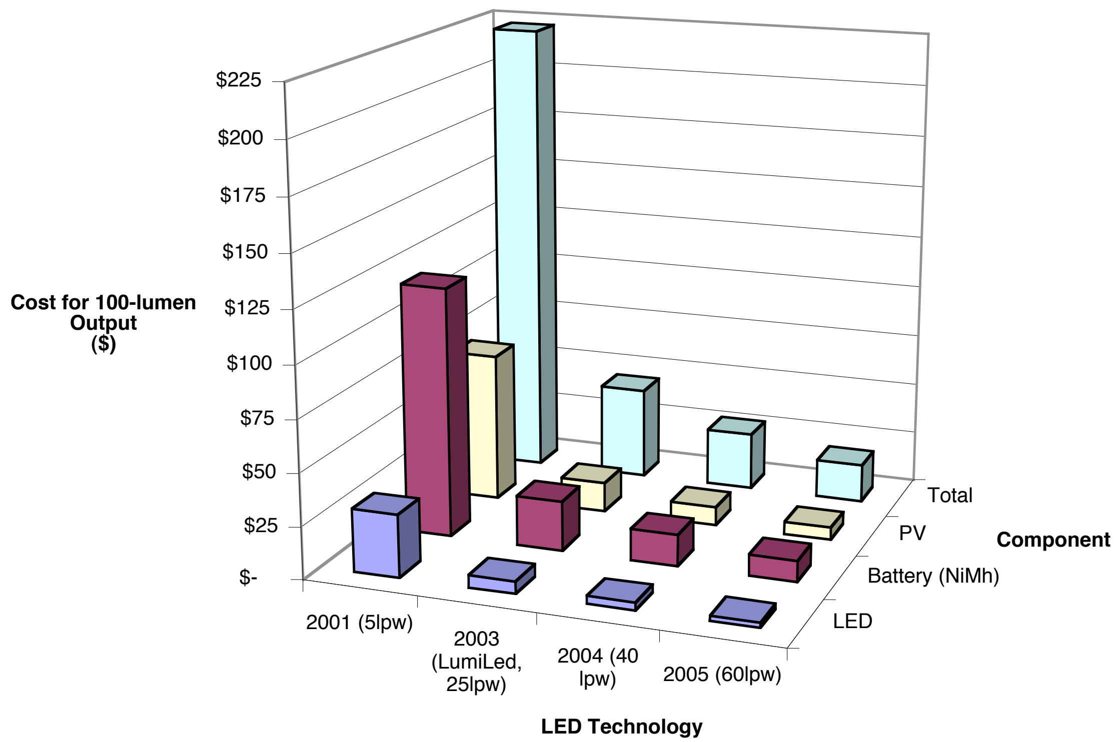


Figure S5. Effect of improving WLED efficiencies on photovoltaic and battery sizing and overall system cost. Standardized to 50-lumen output.

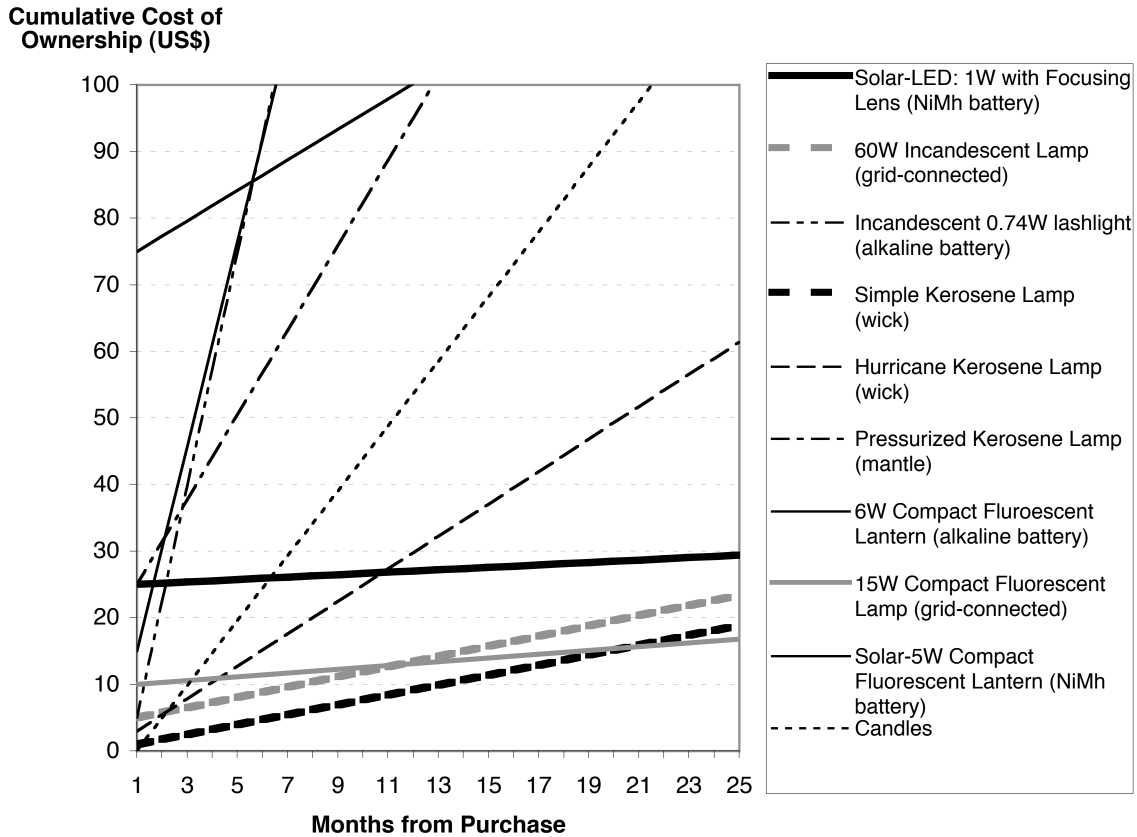


Figure S6. First costs (y-intercept) and cumulative operating costs (slope). Economic payback time (months) for WLED system (heavy black curve) occurs when heavy black curve crosses that of competing technology. Slope is proportional to operating cost (replacement batteries, lamps, candles, wicks, etc.) Curves for grid-connected sources shaded grey.

Supporting Tables

Table S1. Energy used for household fuel-based lighting in developing countries. To approximate the additional use of fuel by intermittently electrified households, as well as those without light in schools, workplaces, etc., we assume an effective un-electrified population of 2 billion. We take a kerosene lamp as the reference light source, with a rate of fuel consumption at 0.035 liters per hour, and a daily utilization rate of 4 hours. This is a proxy for a mix of lamp types, fuels, and range of utilization in practice. To approximate direct societal economic costs, we have excluded the effects of energy subsidies. Note: energy usage does not include evaporation from lanterns when notin use, which could be substantial.

Household lighting characteristics	
Population without electricity	2,000,000,000
People per un-electrified household	4
Unelectrified households	500,000,000
Fuel lamps per household	3.0
Number of lamps	1,500,000,000
Lamps per capita	0.75
Fuel consumption per lamp (liters per hour)	0.035
Average daily lamp use (hours per lamp)	4
Daily lamp-hours/capita	3.0
Annual energy use	
(liters kerosene)	76,650,000,000
(GJ)	2,793,892,500
(PJ)	2,794
[Mbod equivalent]	1.3
(MTOE)	65.6
Liters fuel per month per household	12.8
Liters fuel per month per capita	3.2
Cost comparision	
Cost of fuel-based lighting ($Billion/y)	38
Emissions comparison	
CO2 emissions from fuel-based lighting (MT CO2)	189
Comparative energy services and costs	
Energy services provided (1000 lumen-hours per lamp; 3 lamps per household and 4h/day operation)	
Fuel-based lighting (40-lumen lanterns)	175
Electric Lighting (60-watt lamps instead of fuel)	3942
Ratio:	23
Cost ($/year-household; all lamps)	
Electrified (IEA countries)	82
Fuel-based	77
Ratio:	0.9

Table S2. Equity considerations of fuel-based lighting: comparative performance of kerosene and electric lighting.

	White LED Lamp	Units	Ratio (fuel/LED)	Simple Hurricane Lamp	Units
Assumptions					
Energy price	0.10	$/kWh of electricity		0.5	$/liter of kerosene
Rate of energy consumption	1	Watt		0.035	liters/hour
Energy services provided	60	lumens	**0.67**	40	lumens
Carbon/energy	0.096	kgCO2/MJ	**0.76**	0.072	kgCO2/MJ
Energy Analysis					
Electricity	10.47	MJ/kWh			
Kerosene				36.45	MJ per liter of kerosene
Rate of energy use	0.01047	MJ/hour	**122**	1.27575	MJ/hour
Energy per unit of lighting service provided	0.2	MJ/klm-h	**183**	31.9	MJ/klm-h
Economic Analysis					
Energy price	9.55	$/GJ	**1.44**	13.72	$/GJ
Cost for equivalent lighting service	$0.0017	$/klm-h	**263**	$ 0.44	$/klm-h
Carbon/Service	0.02	kgCO2/klm	**138**	2.30	kgCO2/klm

Table S3. Comparative analysis of lighting systems for developing countries. Total cost of illumination services, including first costs and operation. Costs include initial purchase cost, fuel, electricity, wicks, mantles replacement lamps, and batteries. Performance characteristics of light sourc
price, $0.5/liter fuel price
household composition, lifestyle, relative fuel prices, and cultural preferences.

	60W Incandescent Lamp (grid-connected)	Incandescent 0.74W lashlight (alkaline battery)	15W Compact Fluorescent Lamp (grid-connected)	6W Compact Fluroescent Lantern (alkaline battery)	Solar-5W Compact Fluorescent Lantern (NiMh battery)	Candles	Simple Kerosene Lamp (wick)	Hurricane Kerosene Lamp (wick)	Pressurized Kerosene Lamp (mantle)	Solar-LED: 1W, no Optics (NiMh battery)	Solar-LED: 1W, with Dffuser (NiMh battery)	Solar-LED: 1W with Focusing Lens (NiMh battery)
Performance												
Rate of energy use (Watts or liters/hour)	60	0.74	15	6	6		0.01	0.035	0.10	1.0	1.0	1.0
Lamp, wick, or mantle service life (hours)	1000	15	5000	3000	3000	2.5	200	400	1000	50000	50000	50000
Replacement bulbs, wicks, or mantles (number per year)	1.5	97.3	0.29	0.49	0.49	584	7.3	3.7	1.5	0.00	0.00	0.00
Batteries	none	2 D Alkaline	none	4 D Alkaline	1 NiMh	none	none	none	none	3 AA NiMh	3 AA NiMh	3 AA NiMh
Replacement batteries (number per year)	0	360	0	365	0.73	0	0	0	0	2.190	2.190	2.190
Energy services provided												
Light output (lumens--lamp only)	792	3.8	873	131	213	10.0	7.8	40	400	60	60	60
Useful illumination (lux, including optical losses at typical working distance)	111	2.4	122	18	30	1.4	1.1	5.6	56	8	40	600
Efficiency (lumens/Watt)	13	5	58	22	36	0.2	0.08	0.11	0.80	60	60	60
First cost (lamp + fixture)	5	5	10	15	75	0.10	1	3	25	25	25	25
Annual Energy Consumption												
Electricity from grid (kWh)	88	0	22	0	0	0	0	0	0	0	0	0
Kerosene (liters)	0	0	0	0	0	0				0	0	0
							15	51	148			
Annual Operating Costs												
Energy	$ 8.76	$ -	$ 2.19	$ -	$ -	$ -	$ 7.30	$ 25.55	$ 74.22	$ -	$ -	$ -
Replacement batteries, wicks or mantles	$ -	$ 180.07	$ -	$ 182.50	$ 25.55	$ 58.40	$ 1.62	$ 3.65	$ 2.19	$ 2.19	$ 2.19	$ 2.19
Replacement bulbs	$ 0.44	$ 29.20	$ 1.17	$ 1.95	$ 1.95	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$ 9.20	$ 209.27	$ 3.36	$ 184.45	$ 27.50	$ 58.40	$ 8.92	$ 29.20	$ 76.41	$ 2.19	$ 2.19	$ 2.19
Operating cost per unit of service (1st cost amortized over three years)												
Cost of light ($/1000-lumen hours)	$ 0.01	$ 37.72	$ 0.00	$ 0.96	$ 0.09	$ 4.00	$ 0.78	$ 0.50	$ 0.13	$ 0.03	$ 0.03	$ 0.03
Cost of illumination ($/1000 lux-hours)	$ 0.06	$ 59.25	$ 0.02	$ 6.89	$ 0.63	$ 28.57	$ 5.60	$ 3.57	$ 0.93	$ 0.19	$ 0.04	$ 0.003
Operating cost per unit of service												
Light production ($/1000-lumen hours)	$ 0.008	$ 37.72	$ 0.003	$ 0.96	$ 0.09	$ 4.00	$ 0.78	$ 0.50	$ 0.131	$ 0.025	$ 0.025	$ 0.025
Index: CFL (grid) = 1.00	3	14,317	1	366	33	1,518	297	190	50	9	9	9
Illuminance ($/1000 lux-hours)	$ 0.06	$ 59.25	$ 0.02	$ 6.89	$ 0.63	$ 28.57	$ 5.60	$ 3.57	$ 0.93	$ 0.19	$ 0.04	$ 0.003
Index: CFL (grid) = 1.00	3	3,148	1	366	33	1,518	297	190	50	10.0	2.0	0.1
Total cost per unit of service (1st cost amortized over three years)												
Cost of light ($/1000-lumen hours)	$ 0.01	$ 38.02	$ 0.005	$ 0.99	$ 0.17	$ 4.00	$ 0.81	$ 0.52	$ 0.15	$ 0.12	$ 0.12	$ 0.12
Cost of illumination ($/1000 lux-hours)	$ 0.07	$ 59.72	$ 0.04	$ 7.08	$ 1.20	$ 28.59	$ 5.81	$ 3.69	$ 1.04	$ 0.90	$ 0.18	$ 0.01
Index: CFL (grid) = 1.00	1.8	1,593	1.0	189	32	762	155	99	28	24.0	4.8	0.3
1W LED (with optics) pack time,(years)	2.9	0.1	not applicable (lower 1st and operating cost)	0.1	0	0.4	3.6	0.8	-			
Carbon Dioxide Emissions per year (kg)	96	0	24	0	0		38	134	391	0	0	0

Assumptions for Table S3:

Lamp usage	4	hours/day
Household electricity price (from grid; rural)	0.10	$/kWh (World Bank 1996) can vary widely depending on local conditions).
D-cell Alkaline price	0.50	$ per battery (non-rechargable)
D-cell capacity	3.00	wh
AA-cell NiMh battery cost	1.00	$ per battery (rechargable)
AA NiMh battery life	500	cycles
Large NiMh solar lantern battery Life	500	cycles
CFL solar lantern NiMh replacement battery price	35	$ per battery
60W incandescent lamp price	0.30	$ per lamp
Simple kerosene wick price	0.22	$/length
Hurricane lamp wick price	1.00	$/length
Kerosene tie-on mantle price	1.50	$/mantle
Flashlight lamp ("bulb") wattage	0.74	2 D ind. cell flashlight; PR6; Philips
Flashlight lamp ("bulb") price	0.30	$ per lamp
Fixture price for grid-connected CFL or incandescent	5.00	($) simplest hard-wired connection or plug-in lamp
Compact fluorescent lamp price (grid-based)	4.00	$ per lamp
Replacement CFL price for solar lantern	4.00	$ per lamp
Fuel Price	0.5	$/liter
Lighting fuel (kerosene)	36.5	MJ/liter (45 MJ/kg; 0.81 kg/l)
Diesel w/v	0.87	kg/liter
Kerosene emissions factor	2.63	kg CO2/MJ
Electricity emissions factor	1100	grams CO2/kWh(e)

Notes & Sources:

• Most assumptions for electric light sources reflect high-quality western manufacturing (e.g. lamp life, efficacy); performance of some products can be much lo

• LED efficacies projected for end of 2005

• Lumen output values for standard electric sources are average mid-life values (including depreciation "maintenance factors" where applicable, based on IESNA Handbook Maintenance factor from fig. 6-40 IESNA handbook). Values for kerosene lamps are averages of tested levels.

• Derivation of lux values: for general electric sources, assumes even radiation in all directions from source 0.3 m high and 0.5 m from task (lux = 12% lumens). Room contributes another 2% from inter-reflections (3x3x2.5 m room with 50% surfaces). LED values are LBNL measurements, with varying degrees of optical control, 1 m from task. Kerosene measurements by LBNL goniophotometer at reading plane.

• Cost values shown are estimated final retail prices.

Table S4. Field reports of kerosene usage for lighting purposes.

Country	Usage (liters/month)	Source
Argentina	15.2–21.3	Kaufman et al (2000)
Bedoins	10-15	
Benin	3.0–11.7	Kaufman et al (2000)
Bhutan	5-20	Mills (2000)
Bolivia	5	Kaufman et al (2000)
Brazil	6.3	Costa (1997)
Burkina	12	Kaufman et al (2000)
Cape Verde	4-6	World Bank/UNDP/ESMAP 1990
China	7.3	UNIDO
Ecuador	13	ESMAP (1994, p. 107)
Ghana	4.8	Hagan and Addo (1994)
Guatemala	2	World Bank (2003)
Honduras	7.6	REPP
India	5	Laxmi et al (2003)
India	10	Power to Tackle Poverty
India	3.9	UNDP/ESMAP/World Bank (2003)
India (Rajastan)	5	Laxmi et al (2003)
Indonesia	16.4	Kaufman et al (2000)
Indonesia	15	Kaufman et al (2000)
Indonesia (Java)		
Low income	13.2	World Bank (1990)
Middle income	16.3	World Bank (1990)
High income	17.7	World Bank (1990)
Kenya	10.2	ESD
Nepal	2-8 liters/month (4.0 median)	Craine (private communication)
Nepal	4.25 (1 lamp)	LUTW
Peru	7.5	Kaufman et al (2000)
Sri	10.0–13.4	Kaufman et al (2000)
Tanzania	4-6	Ambeeka Energy Services (2000)
Togo	3.0–11.7	Kaufman et al (2000)
Zimbabwe	2.8	Kaufman et al (2000)

Table S5. Examples of domestic kerosene pricing around the world. Field reports of kerosene usage for lighting. Data reflect mix of currencies and years. Prices are those paid by households, with a mix of subsidies or taxes that vary from case to case. Other factors influencing price are proximity to urban centers; kerosene tends to become more expensive in remote areas and when purchased in small quantities. Note that all data predate the 2004-2005 oil price shock.

Country	Local price/liter	Currency	Exch/US$	**USD/liter**	Date	Source
Algeria	0.28	US$		**0.07**	Apr-99	USDOE/IEA (2001)
Argentina		US$		**0.44**	Dec-98	http://www.mof.gov.jm/taxmeasures/1999/consumption20tax.shtml
Argentina	1.77	US$		**0.47**	Apr-99	USDOE/IEA (2001)
Bangladesh	20	TK	55.66	**0.36**	May-04	http://www.thedailystar.net/2004/05/03/d40503011212.htm
Barbados	1	US$		**0.26**	Apr-99	USDOE/IEA (2001)
Bhutan	6	NU	46.94	**0.13**	1999	Mills (2000)
Bolivia		US$		**0.19**	Dec-98	http://www.mof.gov.jm/taxmeasures/1999/consumption20tax.shtml
Bolivia	0.72	US$		**0.19**	Apr-99	USDOE/IEA (2001)
Brazil	0.85	R	2.7385	**0.31**	May-97	Costa (1997)
Brazil	0.87	US$		**0.23**	Apr-99	USDOE/IEA (2001)
Cambodia		US$		**0.33**	1999	Mills (2000)
Chad	270	CFAF	506	**0.53**	Jun-09	World Bank
Chile	0.97	US$		**0.26**	Apr-99	USDOE/IEA (2001)
China	3.213	CNY	8.27	**0.39**	Jun-09	Jones et al
Columbia	0.83	US$		**0.22**	Apr-99	USDOE/IEA (2001)
Costa Rica	0.84	US$		**0.22**	Apr-99	USDOE/IEA (2001)
Cuba	0.32	US$		**0.08**	Apr-99	USDOE/IEA (2001)
Dominican Republic	1.16	US$		**0.31**	Apr-99	USDOE/IEA (2001)
Ecuador	15	S	25250	**0.00**	Jun-09	UNDP/ESMAP
El Salvador	0.89	US$		**0.24**	Apr-99	USDOE/IEA (2001)
Ethiopia				**0.38**	2005	B. Bayissa (personal communication)
Ghana		US$		**0.19**	1990	Hagan and Addo (1994)
Grenada	1.14	US$		**0.30**	Apr-99	USDOE/IEA (2001)
Guatemala	0.82	US$		**0.22**	Apr-99	USDOE/IEA (2001)
Guyana	0.71	US$		**0.19**	Apr-99	USDOE/IEA (2001)
Haiti	13.6	Gourdes	36.7	**0.37**	Jan-02	http://www.haitiprogres.com/2003/sm030108/eng01-08.html
Haiti	1.08	US$		**0.29**	Apr-99	USDOE/IEA (2001)
Haiti (black mkt)	27	Gourdes	36.7	**0.73**	Jan-02	http://www.haitiprogres.com/2003/sm030108/eng01-08.html
Honduras	13.73	Lps	12.76	**1.08**	Jul-97	http://www.marrder.com/htw/jul97/business.htm
Honduras	0.91	US$		**0.24**	Apr-99	USDOE/IEA (2001)
Hong Kong	1.45	US$		**0.38**	Apr-99	USDOE/IEA (2001)
India (actual)	16.54	Rs	43.5	**0.38**	Feb-03	Market price: http://www.rediff.com/money/2003/feb/19lpg.htm
India (black mkt)	20	Rs	43.5	**0.46**	Jul-04	Black Market http://www.deccanherald.com/deccanherald/july052004/d7.asp
India (subsidized)	17.55	Rs	43.5	**0.40**	Feb-03	Subsidized price: http://www.rediff.com/money/2003/feb/19lpg.htm
Indonesia	1000	Rp	8734	**0.11**	Jun-01	http://www.kompas.com/kompas-cetak/0106/21/ENGLISH/gove.htm
Jamacia	1.05	US$		**0.28**	Apr-99	USDOE/IEA (2001)
Jamacia				**0.44**	Dec-98	http://www.mof.gov.jm/taxmeasures/1999/consumption20tax.shtml
Kenya				**0.41**	1,997	ESN: http://www.esd.co.uk/downloads/
Kuwait	0.05	US$		**0.01**	Apr-99	USDOE/IEA (2001)
Liberia				**0.73**	2000	http://allafrica.com/stories/200009300011.html
Libya	0.11	US$		**0.03**	Apr-99	USDOE/IEA (2001)
Madagascar	160		635	**0.25**	May-84	World Bank (1987)
Myanmar	2.6	Kyats	6.42	**0.40**	Jan-05	http://www.ibiblio.org/obl/docs3/BNI2005-01-18.htm
Nepal	28	NRs	70	**0.40**	Apr-03	http://www.worldbank.org.np/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/NEPALEXTN/0,,contentMDK:20191793~pagePK:141137~piPK:217854~theSitePK:223555,00.html
Nepal	2	US$	1	**2.00**		Craine (n/d) -- remote locations
Nicaragua	0.97	US$		**0.26**	Apr-99	USDOE/IEA (2001)
Nicaragua				**0.78**	Jun-09	Albert et al.1997
Niger	160	CFAF	470	**0.34**	Jan-94	World Bank (1994)
Nigeria	65	N	131.88	**0.49**	Nov-04	http://www.afrika.no/Detailed/6601.html
Pakistan	19	RS	60	**0.32**	Jan-02	
Panama	0.97	US$		**0.26**	Apr-99	USDOE/IEA (2001)
Paraguay	1.04	US$		**0.27**	Apr-99	USDOE/IEA (2001)
Peru	0.91	US$		**0.24**	Apr-99	USDOE/IEA (2001)
Peru				**0.29**	Dec-98	http://www.mof.gov.jm/taxmeasures/1999/consumption20tax.shtml
Philippines	11	Peso	52.64	**0.21**	Mar-00	http://www.ibon.org/news/if/00/13.htm
Qatar	0.42	US$		**0.11**	Apr-99	USDOE/IEA (2001)
Saudi Arabia	0.44	US$		**0.12**	Apr-99	USDOE/IEA (2001)
Sri Lanka	24	SLRs	97	**0.25**	Feb-03	http://www.dailynews.lk/2003/02/14/new13.html
Suriname	1.36	US$		**0.36**	Apr-99	USDOE/IEA (2001)
Syria	8	Pounds	41.79	**0.19**	May-02	http://www.jordanembassyus.org/08172001001.htm
Tanzania				**0.50**	2000	Ambeeka Energy Services (2000)
Thailand	15		38.5	**0.39**	Jun-09	http://www.eppo.go.th/encon/encon-D07-PV-Final.doc
Trinidad				**0.18**	Dec-98	http://www.mof.gov.jm/taxmeasures/1999/consumption20tax.shtml
Trinidad and Tobagc	0.69	US$		**0.18**	Apr-99	USDOE/IEA (2001)
United Arab Emirate	0.79	US$		**0.21**	Apr-99	USDOE/IEA (2001)
Uruguay	1.51	US$		**0.40**	Apr-99	USDOE/IEA (2001)
US (New York)	0.5	USD	1	**0.50**	Apr-03	http://www.nyserda.org/nyepg.html
Venezuela	0.35	US$		**0.09**	Apr-99	USDOE/IEA (2001)
Zimbabwe	1.00	US$	1	**1.00**	Apr-02	Private Communication, Lasten Mika, Energy Technology Institute.

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