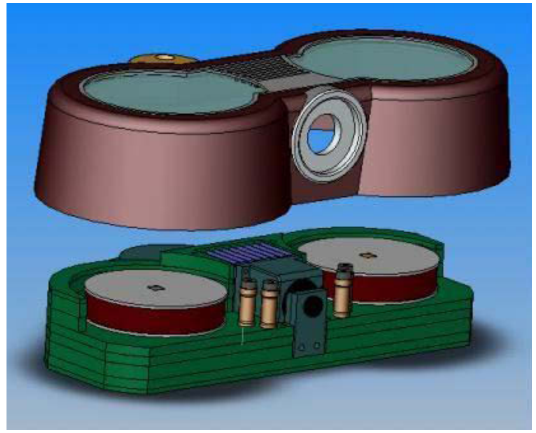
D-Lab: Energy

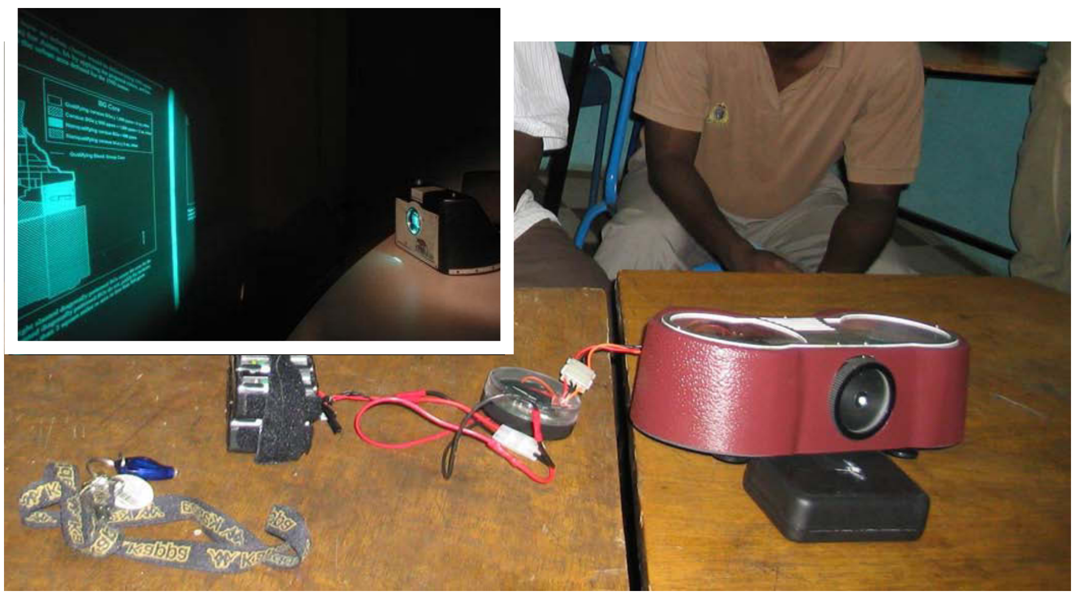
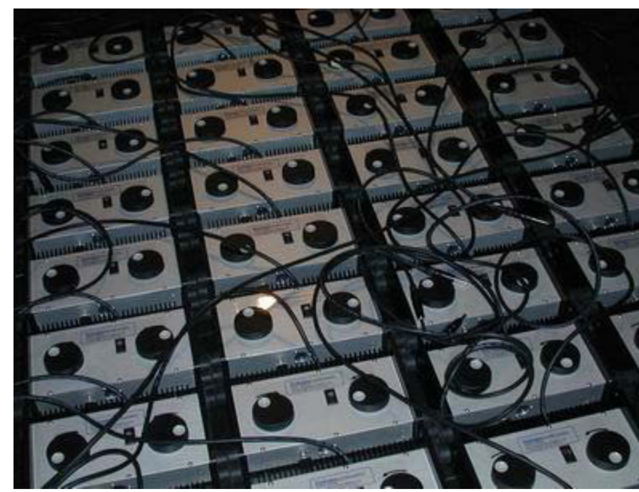
Week 3: Lighting & Trip Introduction

Video about Kinkajou Projector:

http://www.youtube.com/watch?v=5B_RK61NI1Q

KINKAJOU PROJECTOR

Courtesy of Design that Matters. Used with permission.

KINKAJOU POWER

Courtesy of Design that Matters. Used with permission.

Lighting Fundamentals for the Developing World

Slides adapted from Susanne Seitinger, used with permission.
Smart Cities, MIT Media Lab

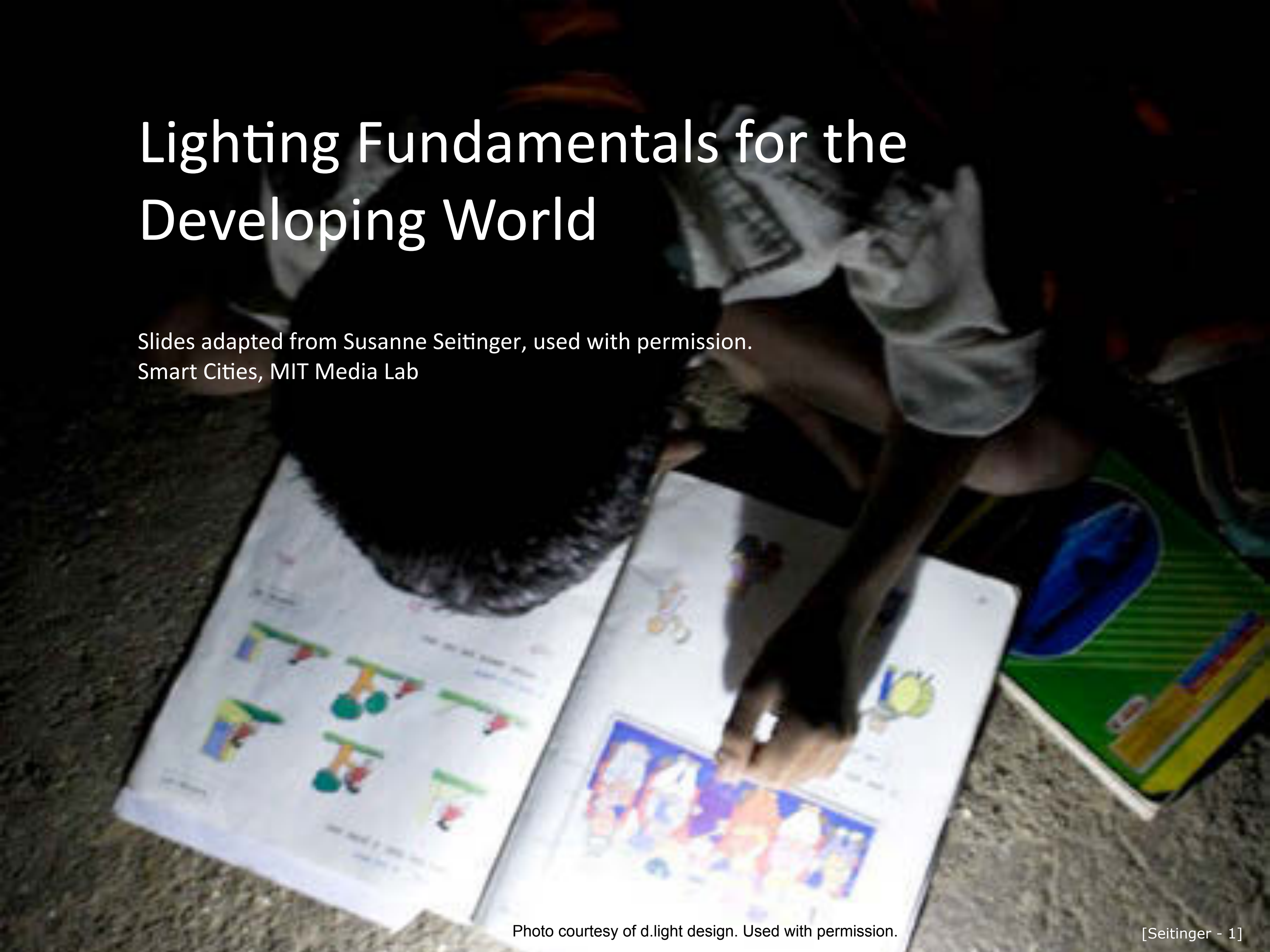


Photo courtesy of d.light design. Used with permission.

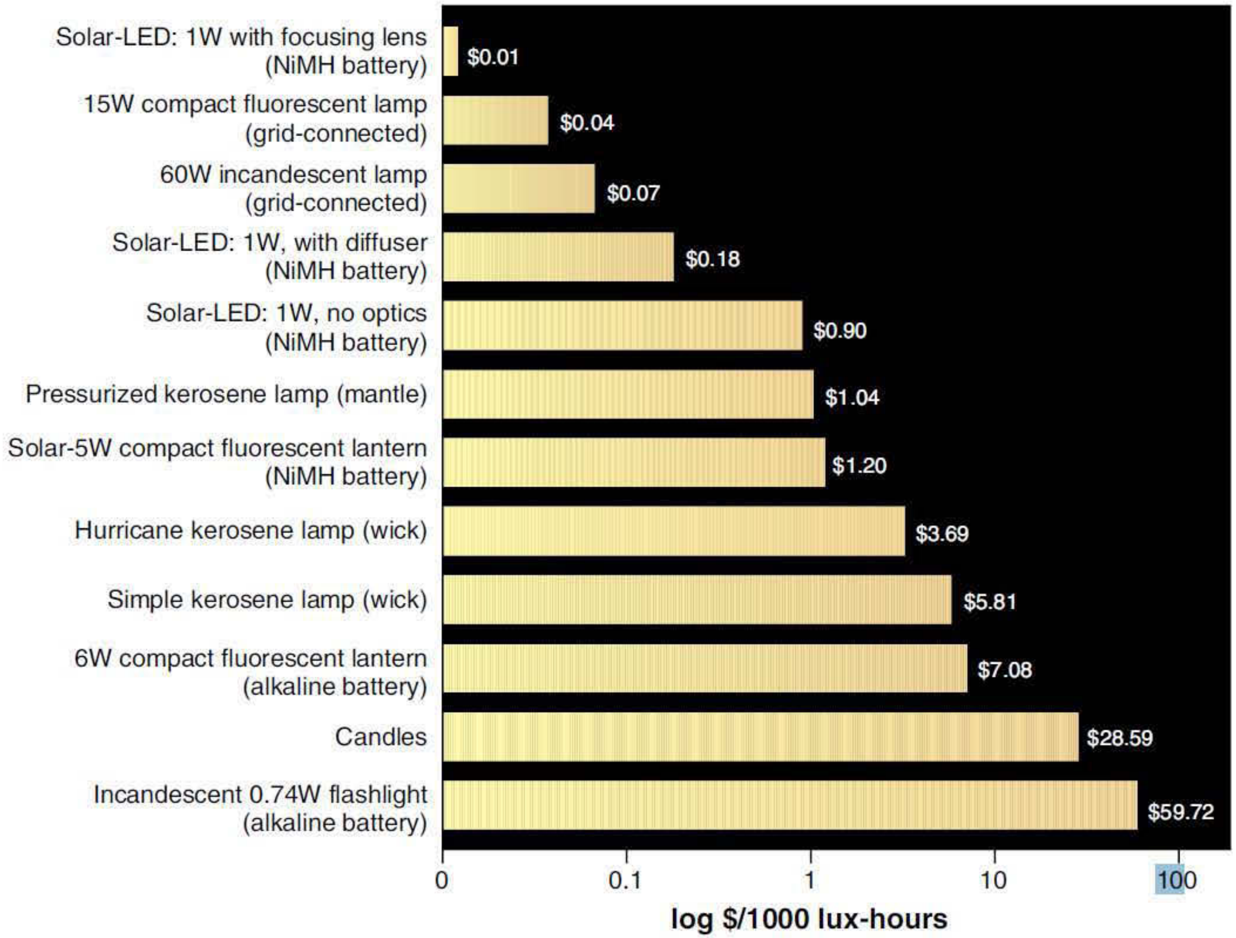
lighting infrastructure context

- approx. **1.6 billion people** do not have access to electricity (IEA 2002), 1/3 of this population lives in India

- International Energy Agency predicts a **less than 1% annual decline** in this number by 2030

- 1 in 4 people exclusively rely on **other fuels**
  kerosene, dung, wood, diesel,
  candles, battery-powered flashlights

the poor pay est. $38 billion per year for fuel-based lighting



Mills, E. (2005). "The Specter of Fuel-based Lighting" *Science.* Vol. 308. pp.1263-1264.
http://light.lbl.gov/pubs/mills_science_fbl_full.pdf

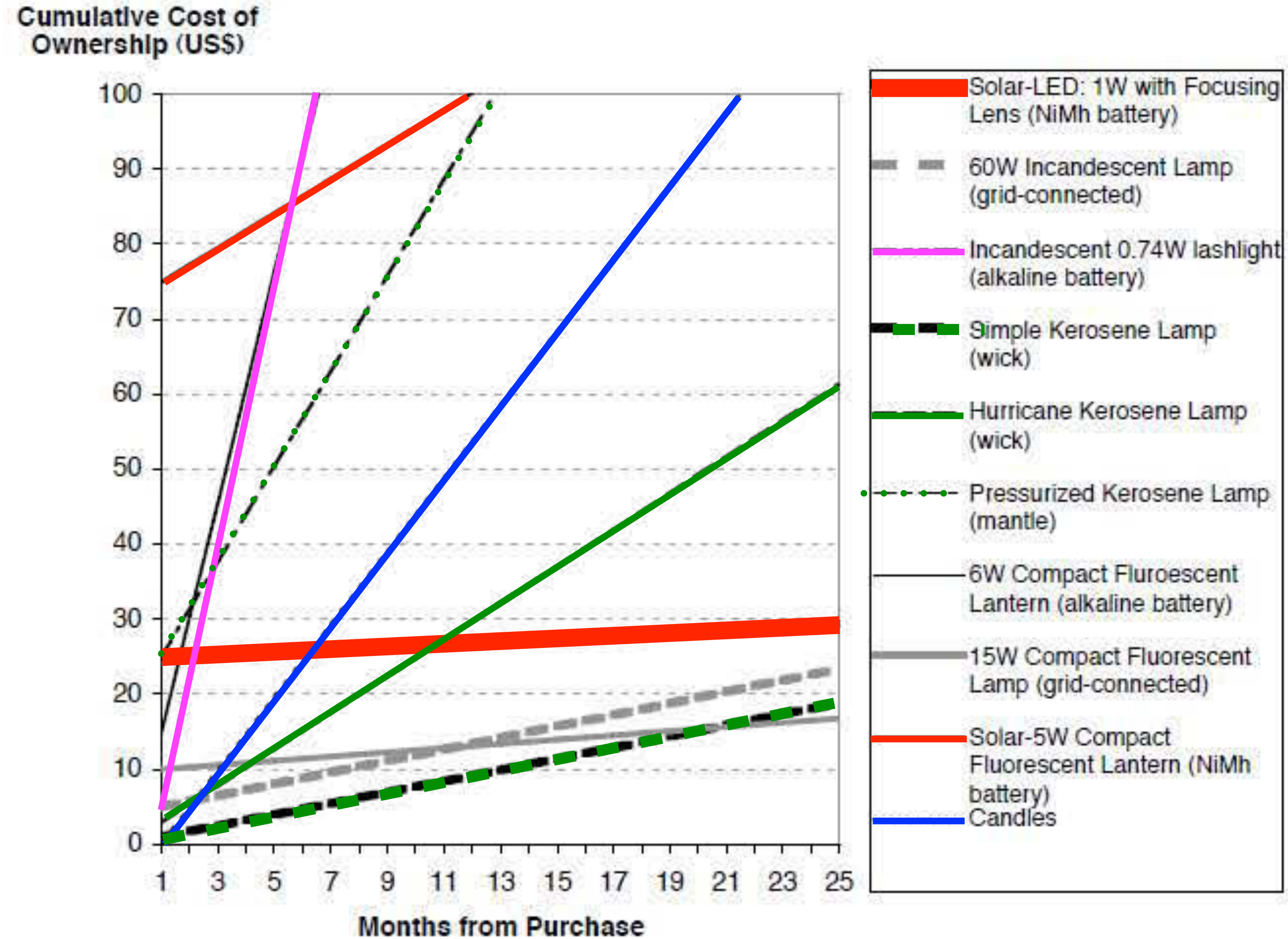


Figure S6. First costs (y-intercept) and cumulative operating costs (slope). Economic payback time (months) for WLED system (heavy black curve) occurs when heavy black curve crosses that of competing technology. Slope is proportional to operating cost (replacement batteries, lamps, candles, wicks, etc.)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

http://light.lbl.gov/pubs/mills_science_fbl_full.pdf

[Seitinger - 4]

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 CO_2/MJ
Electricity emissions factor	1100 grams CO_2/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.

Source: Supplement to Mills, E. "The Specter of Fuel-based Lighting." Science 308 (2005): 1263-4.

financial costs

up to 30% of household income spent on light

compared to 3% in the USA

(2009, Buildings Energy Data Book & US Government Bureau of Labor Statistics Consumer Expenditure Survey)

environmental costs

- 200 Mt of CO_2 emissions for fuel-based lighting in off the grid situations (all lighting – 1889 $MtCO_2$)
- improper disposal of batteries
- deforestation where wood replaces other fuels
- light pollution through too much light (poor luminaires, poor lanterns)

social costs

- home-based work and chores becomes difficult at night
- certain crops or types of agricultural work (fishing, salt farming) can have peak-periods that require work around the clock
- lack of time for community activities
- disruption of education, children cannot complete school work
- disruption of health care services (dental care, surgery, emergency relief efforts)
- security

[Seitinger - 8]

health costs

- breathing kerosene fumes
- smoke in tight indoor spaces
- particulate emissions from burning fuels
- maternal mortality rates
- danger of fires started by kerosene lanterns or candles
- eye-strain

describing the quality of the visual environment

describing, measuring and designing lighting is always a highly

contingent, dynamic process, dependent on

- task performance requirements (mostly visual)
- mood and atmosphere
- appearance, aesthetic judgments (subjective)
- visual comfort
- health, safety and well-being
- social communication
- point of view
- cost
- environmental concerns

References:
Inst. of Lighting Engineers (2005). Chapter 1. The Outdoor Lighting Guide., IESNA Handbook. 2000. Chapter 10: Quality of the Visual Environment.

brightness

•intensity and amount of light together

•people perceive brightness in relation to the surroundings

•top: naturally bright light, captured in the size of the halation through the photo lens

•bottom: glowing, spiritual feeling

glare

one area of the scene is much brighter than the rest of the area.

Philips. (2004) *Talk Atmosphere*. p.10-11.

contrast

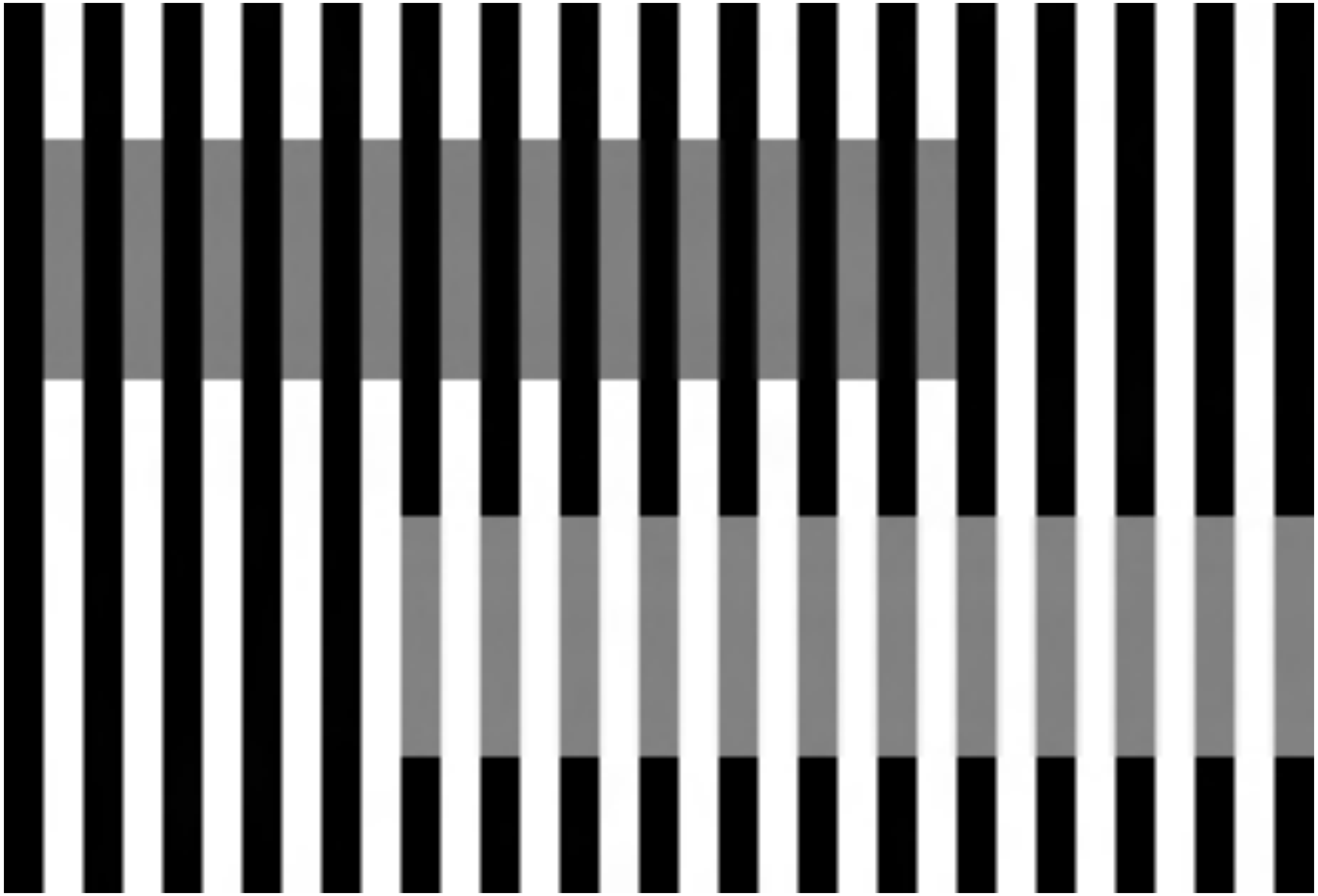
"…difference in appearance of two or more parts of a field seen simultaneously or successively."

(Inst. of Lighting Engineers (2005). Chapter 1. The Outdoor Lighting Guide.)

Without contrast you can't see anything!

•top: positive contrast: object is brighter than the background

•bottom: negative contrast: objects is darker than the background, silhouette



http://www.cs.dartmouth.edu/farid/illusions/white.html

successive contrast

when viewing the current stimulus is affected by the previously viewed stimulus – White’s Illusion

For a cool animation of White’s illusion, see:
http://web.mit.edu/persci/gaz/gaz-teaching/flash/white-movie.swf

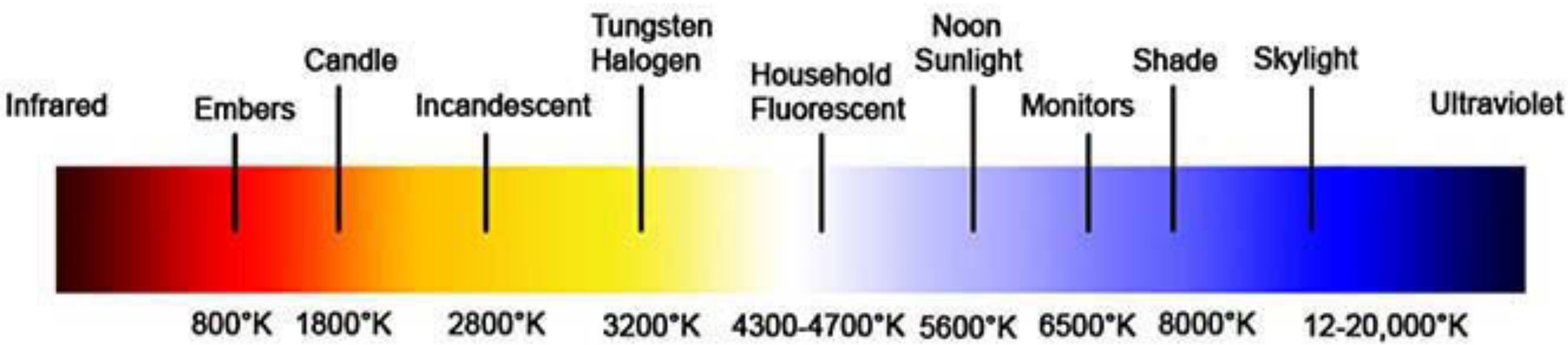
[Seitinger - 14]

candle in dark vs. brightly lit room

Girl with a Candle
Godfried Schalcken
c. 1670-75

[Seitinger - 15]

color temperatures



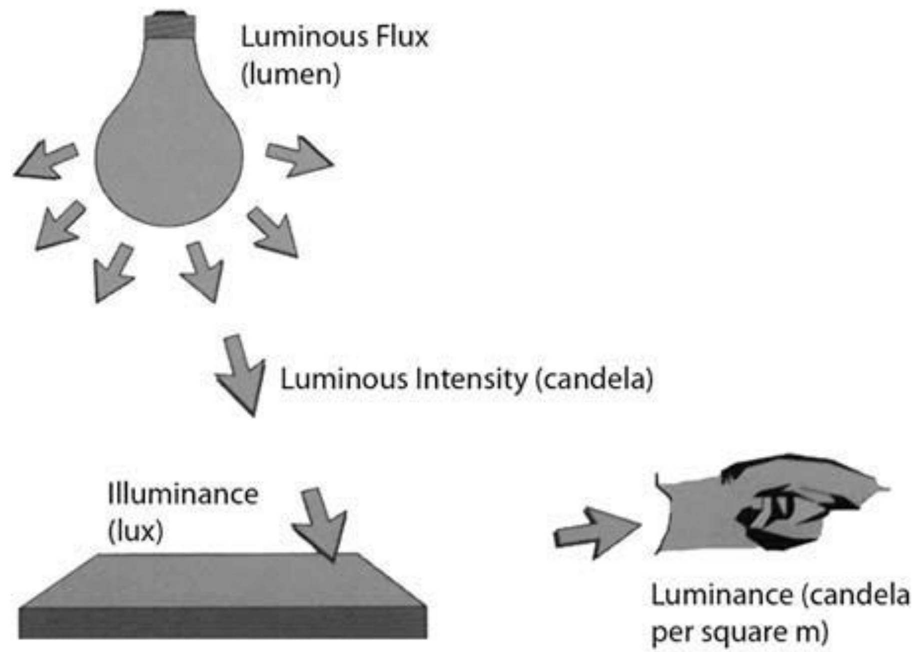
Courtesy of Lowel Light Inc. Used with permission.

http://www.lowel.com/edu/images/colortemp/colortemp.jpg

[Seitinger - 16]

some terms

- **flux F** (lumen): total quantity of light emitted
- **luminous intensity I** (candela cd, lumens per steradian): lumens per unit solid angle (ω) distribution of light, because light is dependent on the radiance pattern of a light source
- **illuminance E** (lux (lumens per square meter) or footcandles (lumens per square foot)): magnitude of light on a surface, used to specify lighting levels b/c it's not dependent on the position of the observer
- **luminance L** (candela/m^2): luminous intensity that reaches the eye
- **brightness**: subjective measure based on what people perceive



Inst. of Lighting Engineers (2005). Chapter 1. In *The Outdoor Lighting Guide*, p. 3.

SI photometry units

Quantity	Symbol	SI unit	Abbr.	Notes
Luminous energy	Q_v	lumen second	lm·s	units are sometimes called talbots
Luminous flux	F	lumen (= cd·sr)	lm	also called *luminous power*
Luminous intensity	I_v	**candela** (= lm/sr)	cd	an SI base unit
Luminance	L_v	candela per square metre	cd/m^2	units are sometimes called "nits"
Illuminance	E_v	lux (= lm/m^2)	lx	Used for light incident on a surface
Luminous emittance	M_v	lux (= lm/m^2)	lx	Used for light emitted from a surface
Luminous efficacy		lumen per watt	lm/W	ratio of luminous flux to radiant flux
SI • Photometry				

http://en.wikipedia.org/wiki/Candela

how to use a basic light meter?

measuring illuminance E (lux (lumens per square meter) or footcandles (lumens per square foot)):

- compare vertical surfaces with horizontal surfaces
- where is the light source (best guess)
- stray light sources
- measure at eye-level versus higher or lower, measure at the task surface (horizonally)

rule of thumb: 10 lux = 1 footcandle

[Seitinger - 19]

Illuminance	Example
10^{-5} lux	Light from Sirius, the brightest star in the night sky
10^{-4} lux	Total starlight, overcast sky
0.002 lux	Moonless clear night sky with airglow[2]
0.01 lux	Quarter moon
0.27 lux	Full moon on a clear night
1 lux	Full moon overhead at tropical latitudes[4]
3.4 lux	Dark limit of civil twilight under a clear sky
50 lux	Family living room
80 lux	Hallway/toilet
100 lux	Very dark overcast day
320–500 lux	Office lighting
400 lux	Sunrise or sunset on a clear day.
1,000 lux	Overcast day ; typical TV studio lighting
10,000–25,000 lux	Full daylight (not direct sun)
32,000–130,000 lux	Direct sunlight

[Seitinger - 20]

IESNA recommended lighting levels for tasks (2000)	avg. horizontal illuminance (lux)	avg. vertical illuminance (lux)
general lighting	50	---
circulation	30	30
dining	50	---
kitchen counter	300-500	50-100
reading	300-500	50-100
desk work	300-500	30-100

Data from *The IESNA lighting Handbook: Reference & Applications*. Mark S. Rea, Editor in Chief. Illuminating Engineering Society of North America, 2000.

IESNA recommended lighting levels for outdoor spaces (2000)	avg. horizontal illuminance (lux)	avg. vertical illuminance (lux)
bikeways (in commercial areas, by roadways)	10	20
bikeways (distant from roadways)	5	5
active-inactive building entrances	50-30	30
floodlit buildings, monuments in dark surroundings	n/a	30
floodlit buildings, monuments in bright surroundings (light to dark surfaces)	n/a	30-100
garden general lighting	5	2
garden pathways	10	3

Data from *The IESNA lighting Handbook: Reference & Applications*. Mark S. Rea, Editor in Chief. Illuminating Engineering Society of North America, 2000.

[Seitinger - 22]

measuring light levels today: determining appropriate levels of lighting

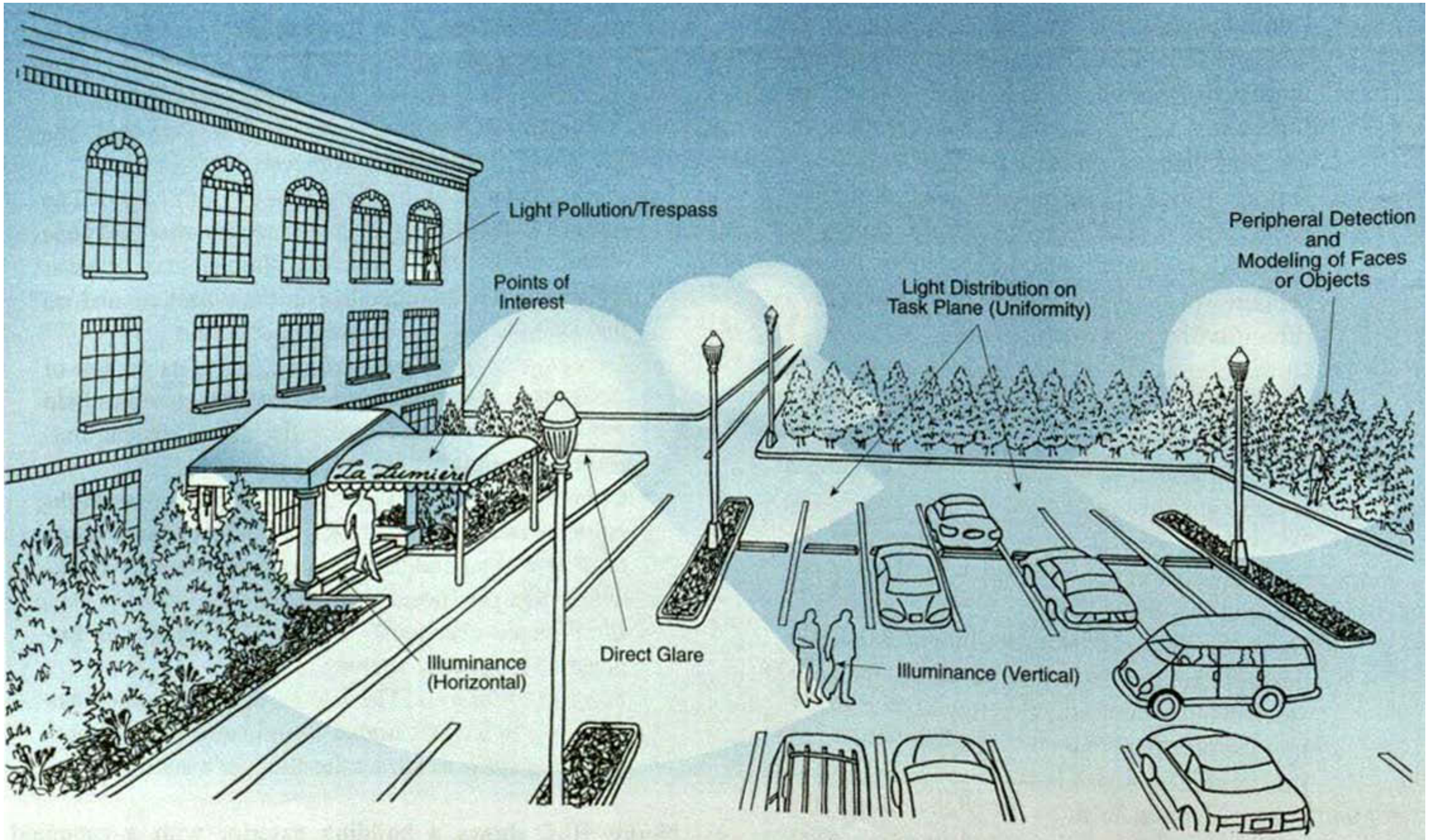
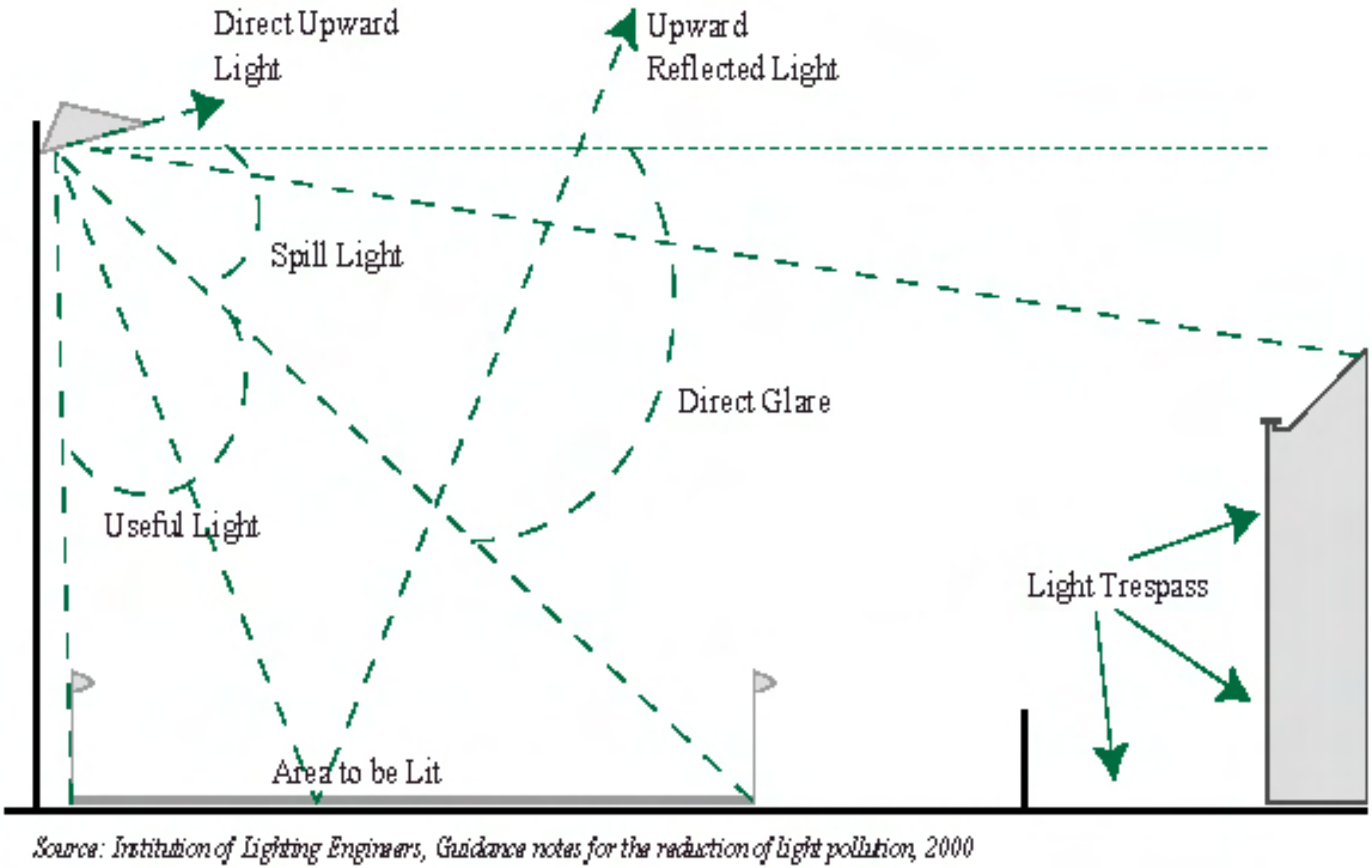


Figure 10-6. Restaurant entry/parking lot.

Illuminating Engineering Society. (2000) *Lighting Handbook*. Ch.10, p.10



http://www.publications.parliament.uk/pa/cm200203/cmselect/cmsctech/747/74701.gif

http://www.darksky.org

kerosene hurricane lamp vs. LED lamp

http://nurulight.com/wp-content/uploads/2009/12/Child-with-kerosene-lantern1.jpg

feature	fuel-based light	electric light (battery or grid)
brightness	5 lux (lumens/m^2) over 1-3 m^2	50-10 lux (lumens/m^2) over 1-3 m^2 *typical US home*
quality of the light	flickering, uneven distribution, more vertical light than horizontal light (bad for tasks), …	even, controllable, dimmable, good color rendering (in some cases), …
reliability	fuel may run out, cost, …	charging, life-span of battery, recycling,… sporadic grid power, …

[Seitinger - 26]

Several slides with photos removed due to copyright restrictions.
See lecture video for details.

lighting examples

D.Light Design
Kiran Solar Lantern

Who:
D.Light Design

Where:
Worldwide, produced in China, focused on India

What:
Kiran Solar Lantern

Impact:
bringing down the cost (only $10)
4x brighter than a kerosene lamp
two settings, high and low (4 or 8 hours)

http://www.greenlaunches.com/alternative-energy/kiran-is-the-most-affordable-solar-lamp.php

http://www.dlightdesign.com/home_global.php

Courtesy of d.light design. Used with permission.

[Seitinger - 28]

Grameen Shakti
Solar Home Systems (SHSs)

Who:
Grameen Shakti, NGO

Where:
Bangladesh

What:
more than 100,000 solar home systems, 4000 per month on average

Impact:
focusing on the combined goals of poverty and climate change

key innovation is the financial package offered to users who paid in installments

Solar PV Program

Rural electrification through solar photovoltaic (PV) technology

Rural electrification through solar PV technology is becoming more popular, day by day in Bangladesh. Solar Home Systems (SHSs) are highly decentralized and particularly suitable for remote, inaccessible areas. GS�s solar program mainly targets those areas, which have no access to conventional electricity and little chance of getting connected to the grid within 5 to 10 years. It is one of its most successful programs. Currently, GS is one of the largest and fastest growing rural based renewable energy companies in the world. GS is also promoting Small Solar Home System to reach

Building systems

s.

SHSs can be used to light up homes, shops, fishing boats etc. It can also be used to charge cellular phones, run televisions, radios and cassette players. SHSs have become increasingly popular among users because they present an attractive alternative to conventional electricity such as no monthly bills, no fuel cost, very little repair, maintenance costs, easy to install any where etc.

GS installed SHSs have made a positive impact on the rural people. GS has introduced micro-utility model in order to reach the poorer people who cannot afford a SHS individually. Another successful GS venture is Polli Phone which allows people is off grid areas the facilities of telecommunication through SHS powered mobile phones.

GS has developed an effective strategy for reaching people in remote and rural areas with solar PV technology. It involves:

- Soft credit through installments which makes SHSs affordable
- Advocacy and Promotion
- Community involvement and social acceptance
- Effective after sales service
- Blending Technology with Market Forces

[Seitinger - 29]

Task Lights
SELCO India, Silk farmers


Courtesy of SELCO Solar Pvt. Ltd. Used with permission.

Who:
Silk farmers

Why:
Dependent on kerosene lamps to feed silkworms

What:
Finance: Unable to pay the upfront cost of the system, SELCO along with its partner S3IDF worked with a local cooperative bank to provide collateral security for the farmer to avail loan.

Technical: Providing a single home light system with two light points to enable portability of light for the farmer in different rooms.

Impact:
Saving on purchase of kerosene
Lower mortality rate of silk worms

http://www.selco-india.com/

Read about the case studies here: http://www.selco-india.com/pdfs/selco_booklet_web.pdf

Task Lights
SELCO India, Solar Powered Headlamps

Who:
Midwives, flower pluckers, construction workers, rubber tappers

Why:
Require hands free light for their occupation. Current use is either kerosene lamps or battery operated lights.

What:
1 W LED, 2.4V headlamp

Impact:
- Savings from purchase of kerosene
- Enhancing productivity
- Improving safety
- Improving brightness and visibility

Courtesy of SELCO Solar Pvt. Ltd.
Used with permission.

http://www.selco-india.com/

Read about the case studies here: http://www.selco-india.com/pdfs/selco_booklet_web.pdf

Sources for statistics:
http://eetd.lbl.gov/EMills/PUBS/PDF/Global_Lighting_Energy.pdf
http://light.lbl.gov/opportunity.html
http://www.iea.org/work/2007/cfl/Waide.pdf
http://light.lbl.gov/pubs/mills_science_fbl_full.pdf
http://light.lbl.gov/pubs/fisherman-led-rpt.pdf
http://buildingsdatabook.eren.doe.gov/docs/xls_pdf/2.1.5.pdf

Some organizations:

International Commission on Illumination, http://www.cie.co.at/
Illuminating Engineering Society of North America, http://www.ies.org/
Light up the World Foundation, http://www.lutw.org/
The Lumina Project, http://light.lbl.gov/
Lighting Africa, http://www.lightingafrica.org/

SELCO CASE STUDY

"The best financial lesson I learned is from a street vendor, who told me Rs300 a month is expensive, but Rs10 a day is fine"

Harish Hande

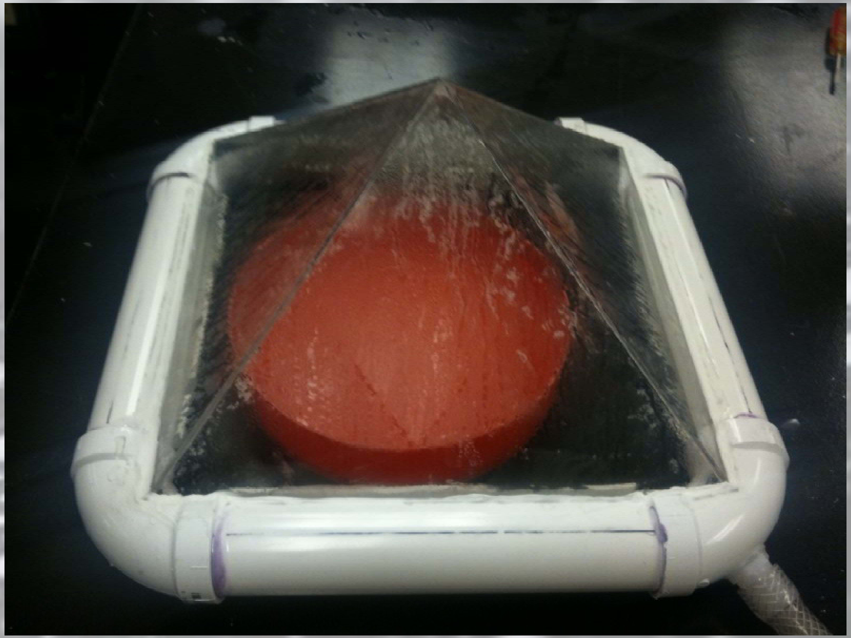
See video at:

http://nexus.som.yale.edu/design-selco/?q=node/100

COMMUNITY PARTNER INTRO & LAST YEAR'S PROJECTS

SOLAR WATER DISTILLER

A solution for preserving battery life



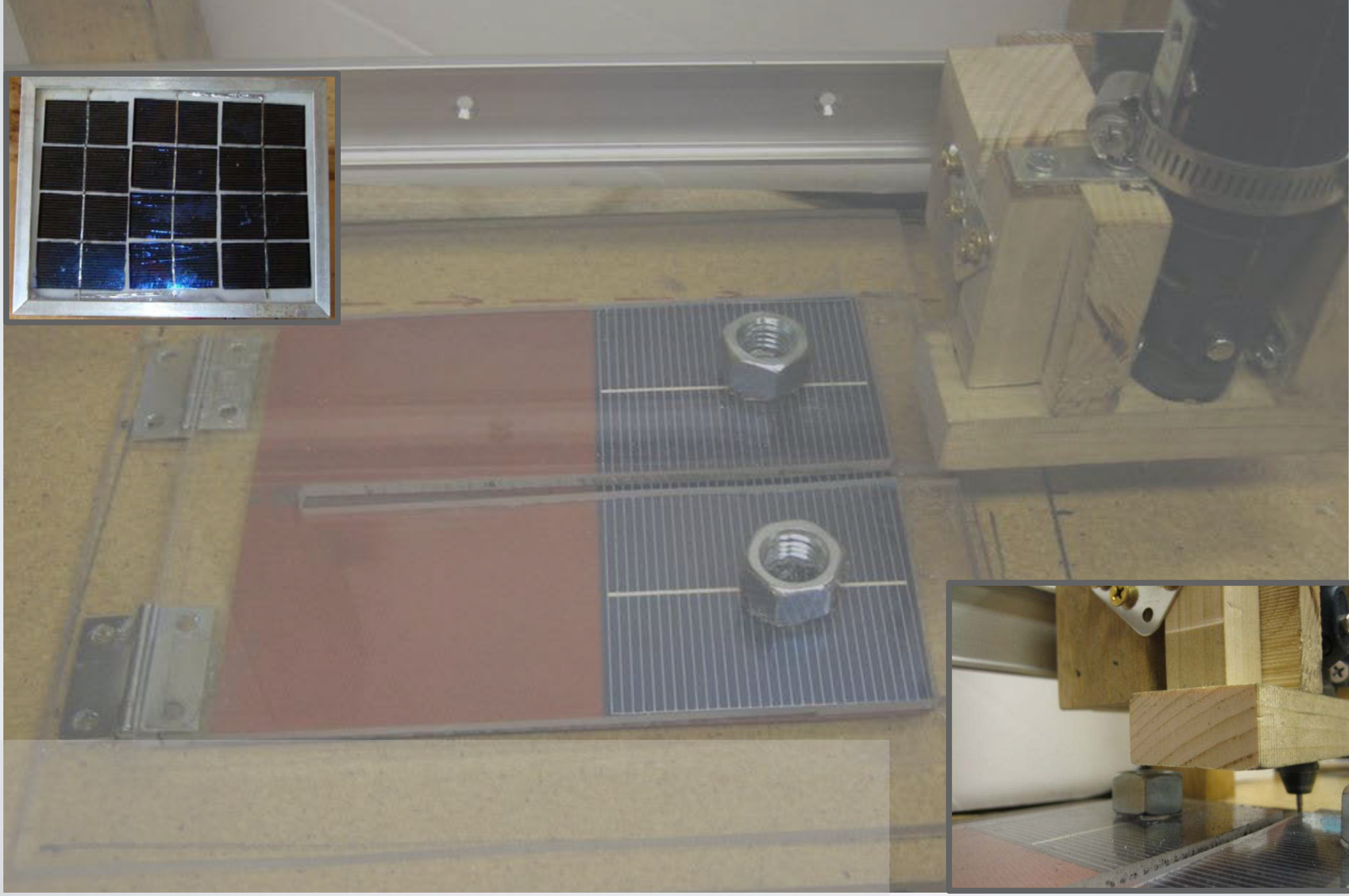
Courtesy of MIT students. Used with permission.

D-Lab Energy: Bag Sealer

Goal: Develop a low energy, low cost mechanism for rapidly sealing juice bags for sale at market

Final Design	
Total Power Consumption	36W
Seal Time	10 sec
Total Cost	$70-90
Safe, easy to use, and creates consistent, durable seals	

Solar Cell Slide-Cutter



Courtesy of Tyler Liechty and 3 other MIT students. Used with permission.

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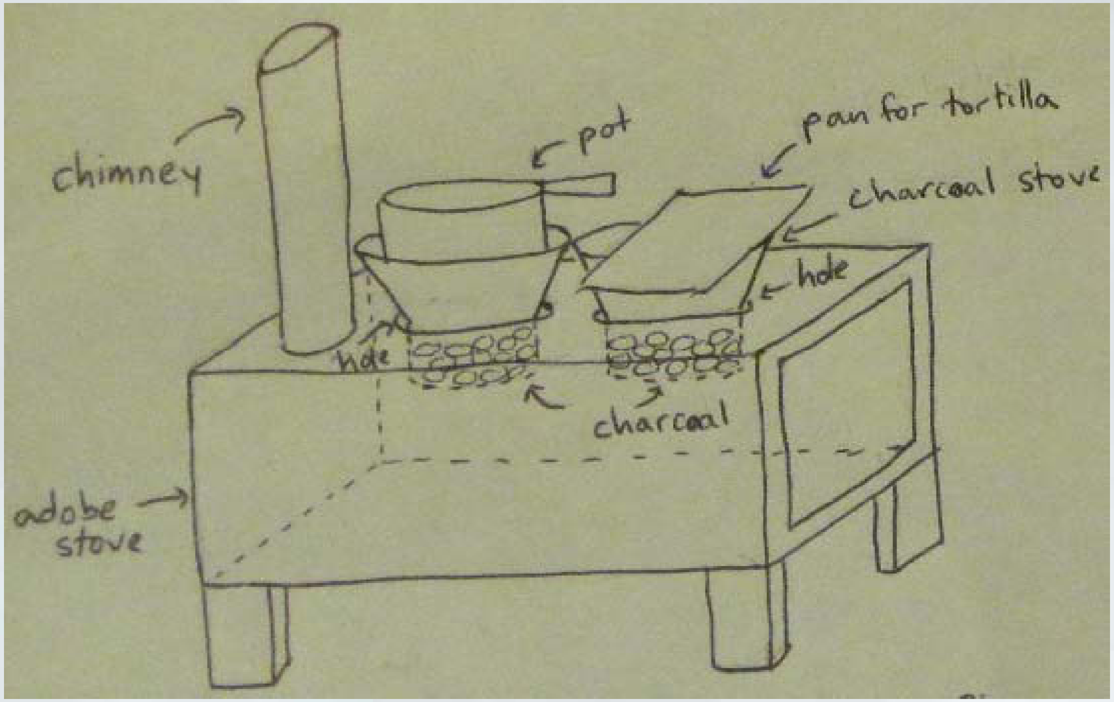

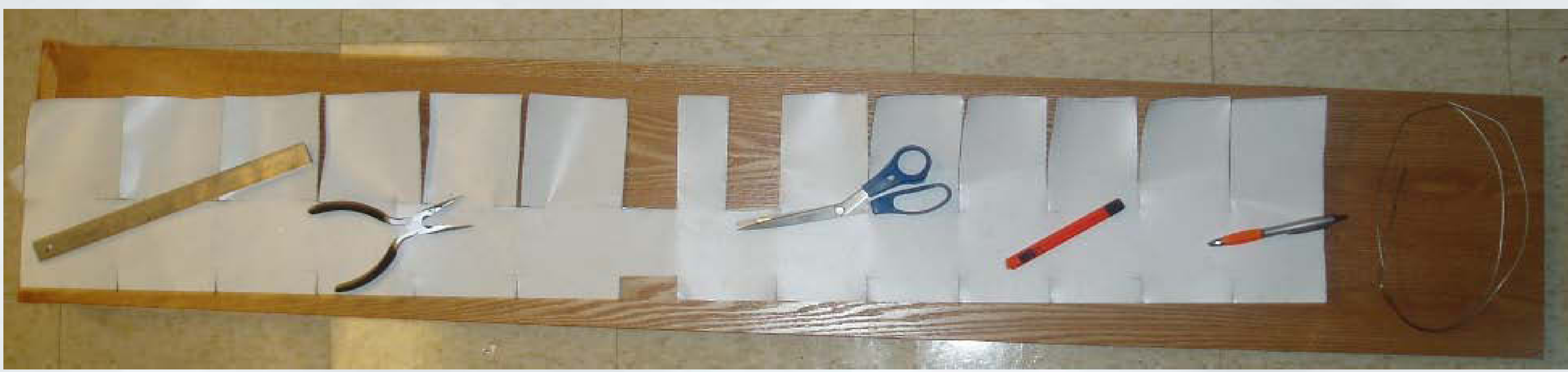

Courtesy of MIT students. Used with permission.

Community Partner Introduction

Public domain image (source: U.S. CIA).

AsoFenix http://asofenix.org/

Description: Small Nicaraguan-based NGO focused on rural sustainable development.

Where: El Roblar in the department of Boaco, 45 min. hike into this community, located in the mountains. Pit latrines, bucket showers (maybe), hammocks.

Projects:
- feed chopper electrification using micro-hydro turbines
?- biodigesters, review designs, possibly designing an internal mixer
?- continuation of OJ bag sealer project
?- ¿más?

GrupoFenix

http://www.grupofenix.org/

Description: Small NGO that researches, develops and applies appropriate, renewable energy technologies in Nicaragua. Focused on supporting community self-determination, local responsibility for the projects, and preserving natural resources. Mujeres Solares de Totagalpa.

Where: Totogalpa, just south of Ocatal. Some electrification, comparative wealth, pit latrines, bucket showers.

Projects:
- solar cooker refinement
- ag. charcoal making skill & business plan development
- cell phone chargers
- continuation of stove project

Other Possibilities

- **Collaboration with D-Lab Health**
- **Charcoal from invasive sea lilies in Jinotega**

PROJECT TIMELINE

- By this Friday, online survey for project preferences
  - must be completed by Monday, Feb 21
- Project teams formed by Wednesday, Feb 23
- Initial research & sketch model prototypes for March 16

Muddy Cards!

Week	Class	Lab
Feb 2	Introduction: Energy, Units, Esti-mation, Energy Usage Worldwide, Class Overview	Human Power Lab
Feb 9	Energy Storage & Micro Grids Initial Trip Planning	Energy Storage Lab
Feb 16	Lighting Community Partner Introduction	Biogas & biodiesel lecture & construction
Feb 23	Solar Thermal & PV **Quiz I**	Solar Panel Construction, Installation, and Operation
Mar 2	Wind & Micro-Hydro Trip Planning	Savonius Wind Turbine Construction & Testing
Mar 9	Cooking, Stoves, & Fuel Biogas digester testing	Charcoal Making & Stove Testing
Mar 16	**Trip Plan Presentations** **Quiz II**	Trip Prep
Mar 23	Trip	Travel, Learn, Apply

EC.711 D-Lab: Energy
Spring 2011