Energy and the Built Environment
CRP 470.004 /570.004

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Lecture 3

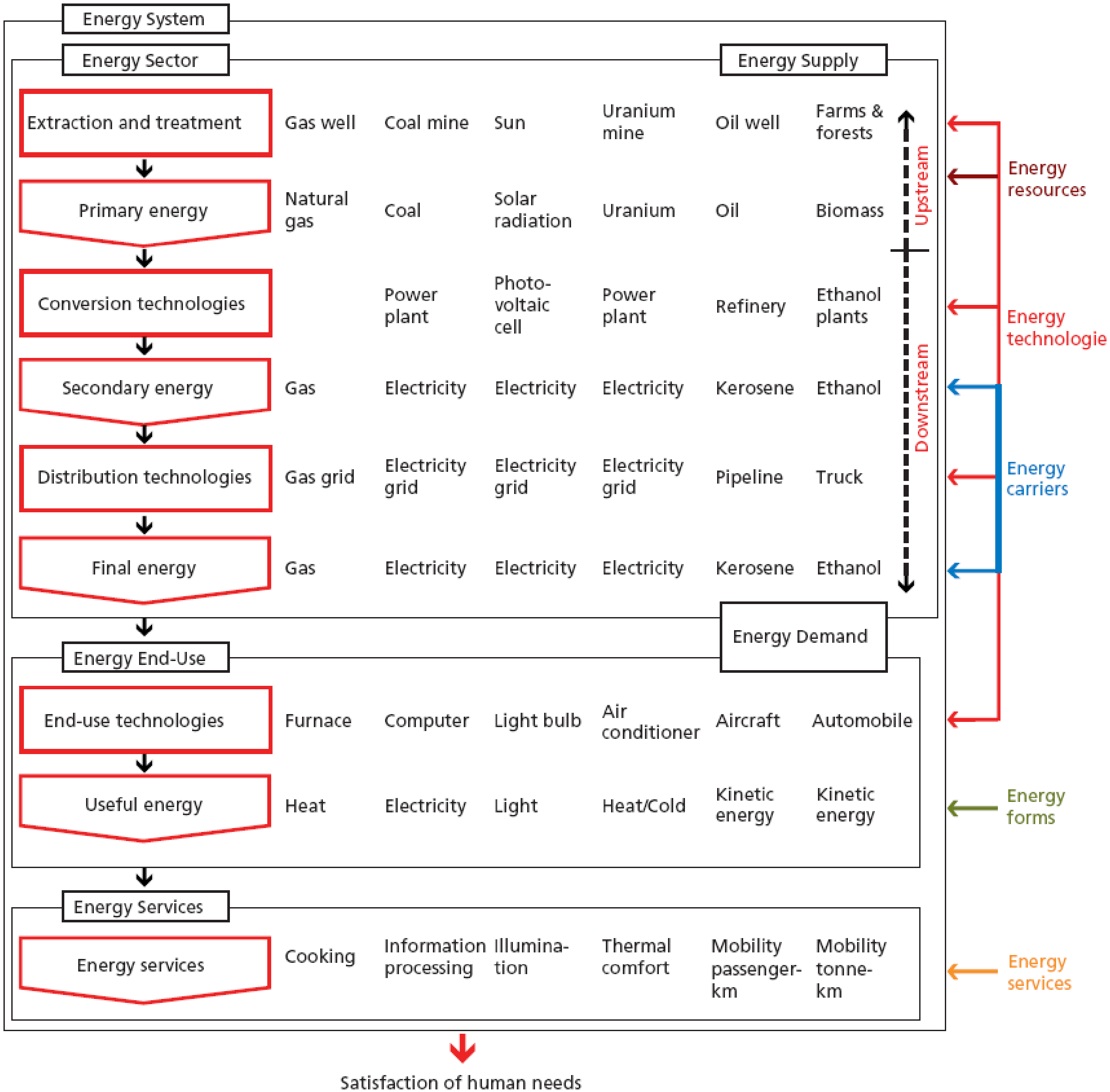
Global energy trends

Outline

- Discussion of readings
- Overview of global energy use
- Rural energy needs and options
- Examples from the field

Global energy challenges

- Oil dependency – concentrated in volatile regions, and finite
- Global energy supply is 80% fossil fuels
- Energy access
  - 3 billion cooking with solid fuels
  - 1.4 billion without electricity access



Source: Global Energy Assessment 2012, adapted from Nakicenovic et al., 1996

Energy security: the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of participating energy companies to meet current and future demand.

Energy equity: the accessibility and affordability of energy supply across the population.

Environmental sustainability: the achievement of supply and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.

RANK	Energy Trilemma Index (2014)	SCORE	RANK	Energy Security	RANK	Energy Equity	RANK	Environmental Sustainability
1	Switzerland	AAA	1	Canada	1	United States	1	Switzerland
2	Sweden	AAA	2	Russia	2	Canada	2	Costa Rica
3	Norway	AAB	3	Qatar	3	Australia	3	Albania
4	United Kingdom	AAA	4	Romania	4	Luxembourg	4	Colombia
5	Denmark	AAB	5	Colombia	5	Switzerland	5	Norway
6	Canada	AAB	6	Denmark	6	Qatar	6	Sweden
7	Austria	AAB	7	Bolivia	7	Saudi Arabia	7	Uruguay
8	Finland	ABB	8	United States	8	United Arab Emirates	8	Austria
9	France	AAB	9	United Kingdom	9	Hong Kong	9	Denmark
10	New Zealand	AAB	10	Australia	10	Austria	10	France
11	Germany	BBB	11	Nigeria	11	France	11	El Salvador
12	United States	AAC	12	Czech Republic	12	Oman	12	Gabon
13	Australia	AAD	13	Kazakhstan	13	Bahrain	13	Ireland
14	Netherlands	BBB	14	Argentina	14	Taiwan	14	Latvia
15	Spain	ABB	15	Slovakia	15	Norway	15	Mauritius

http://www.worldenergy.org/data/trilemma-index/

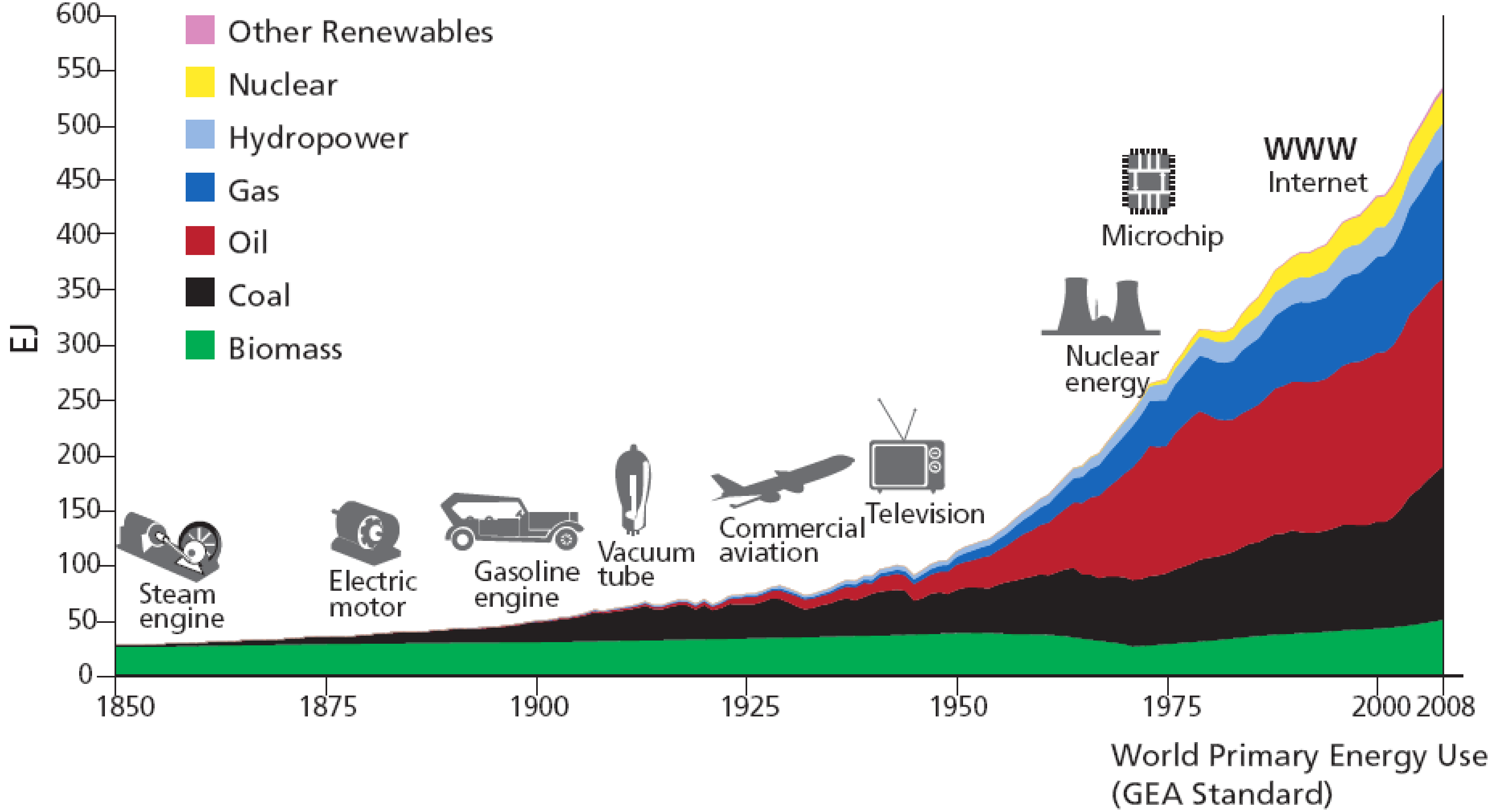
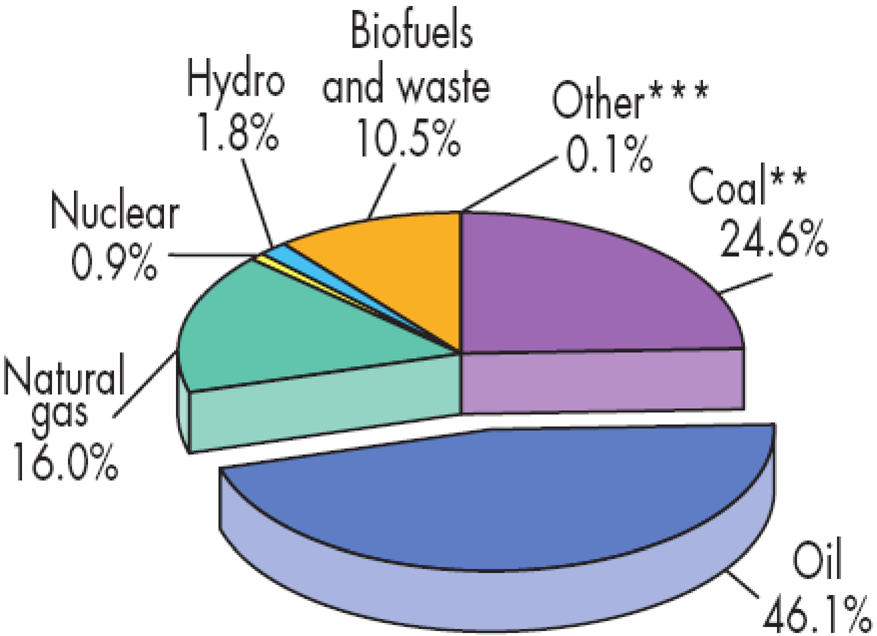


Figure SPM-1. | Evolution of primary energy shown as absolute contributions by different energy sources (EJ). Biomass refers to traditional biomass until the most recent decades, when modern biomass became more prevalent and now accounts for one-quarter of biomass energy. New renewables are discernible in the last few decades. Source: updated from Nakicenovic et al., 1998 and Grubler, 2008, see Chapter 1.[1]

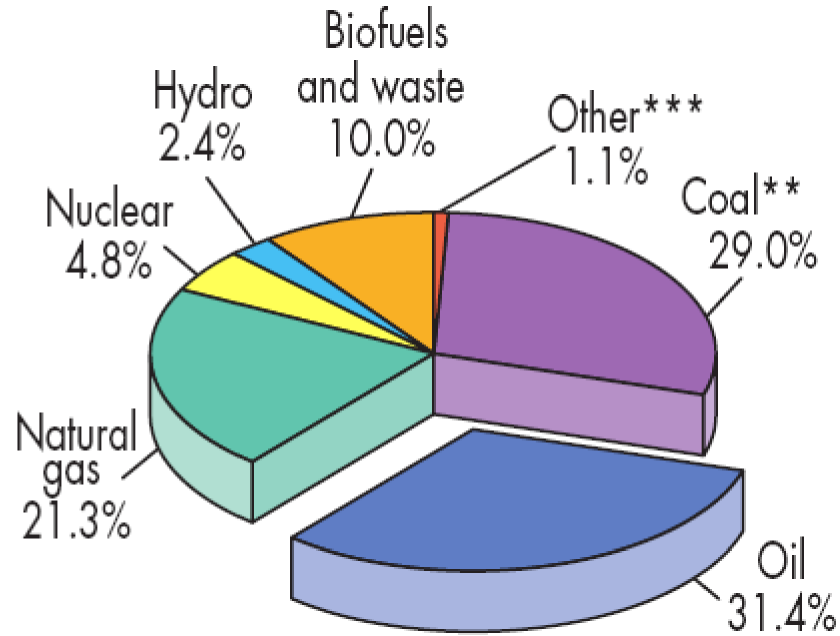
World total primary energy supply

1973



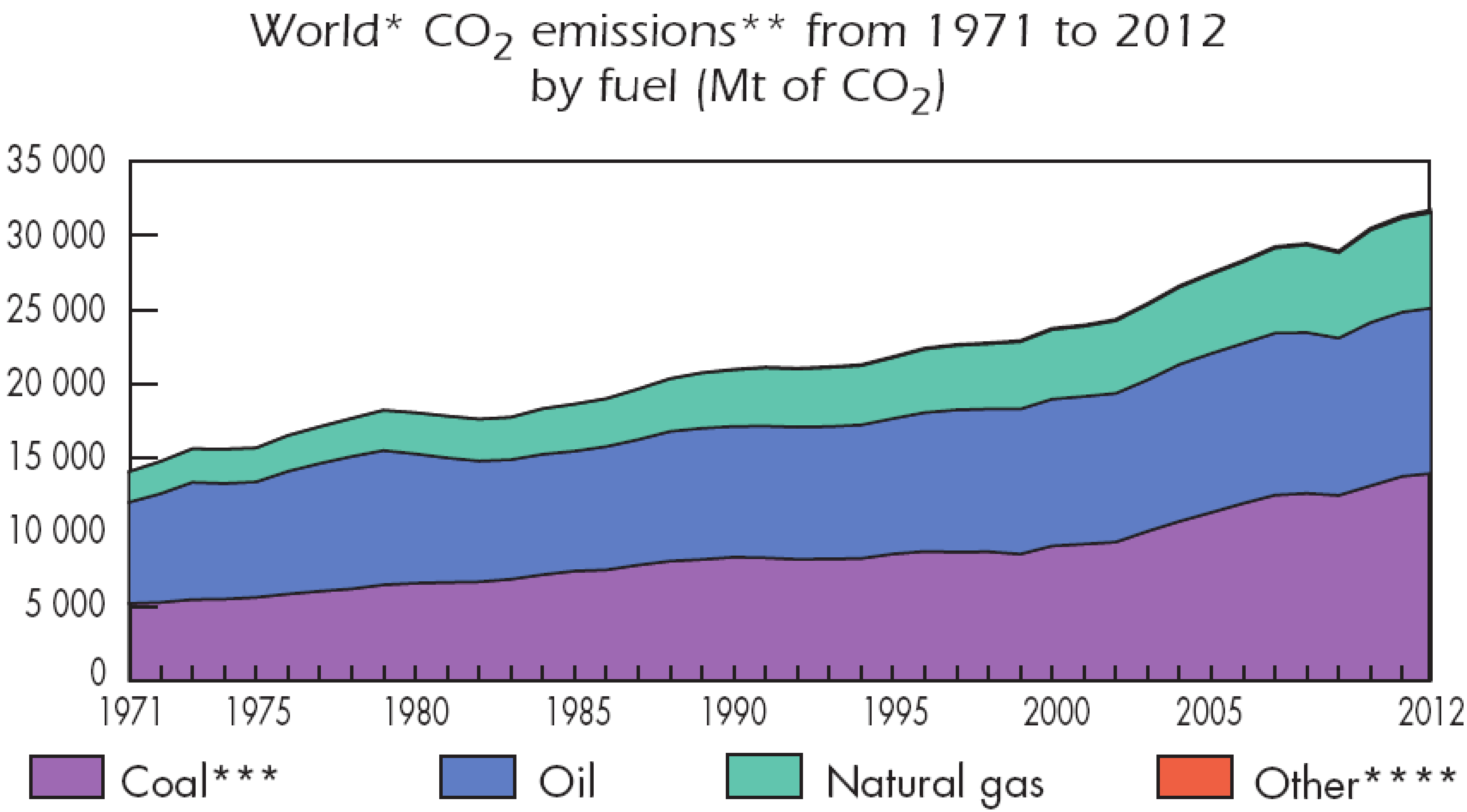
6 106 Mtoe

2012



13 371 Mtoe

Global energy



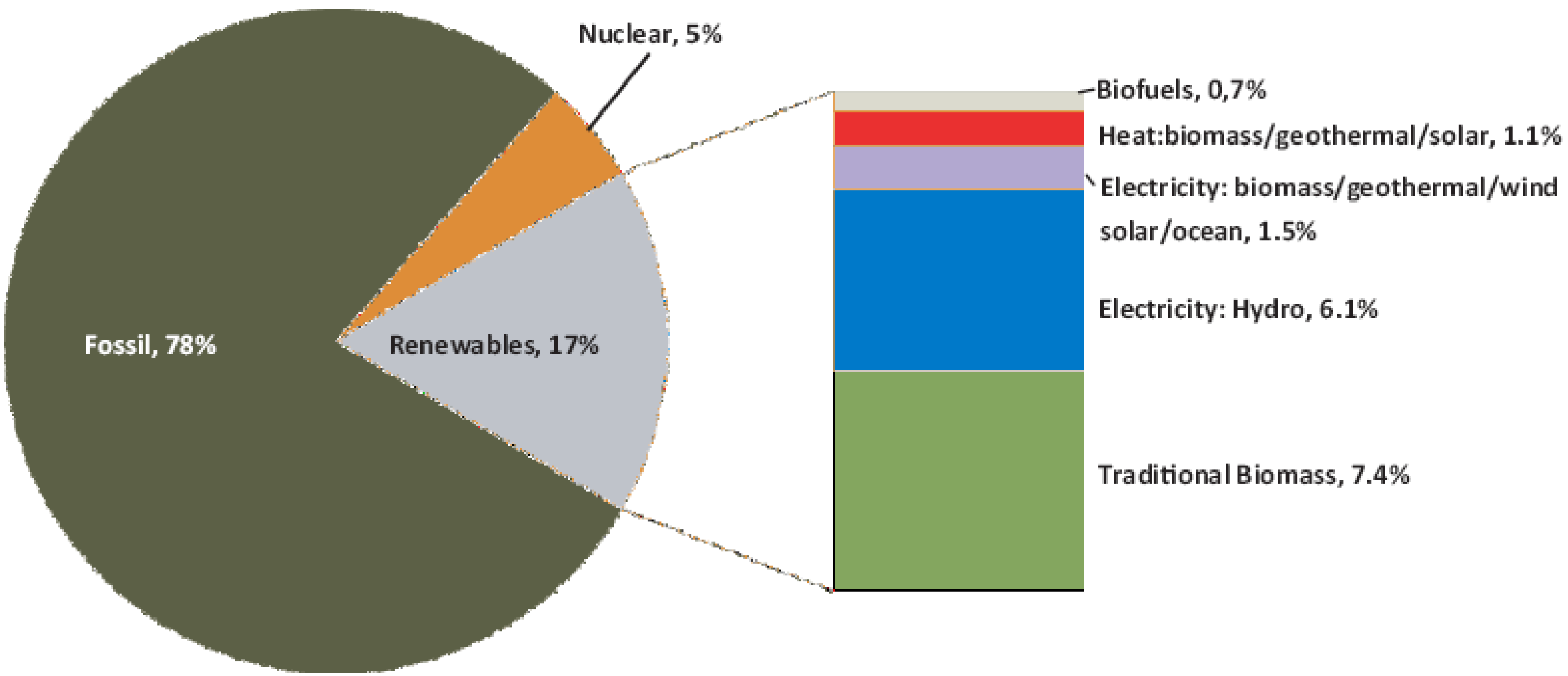


Figure TS-17 | Renewable share of primary energy use, 2009 (528 EJ). Source: Chapter 11.

Electricity Access

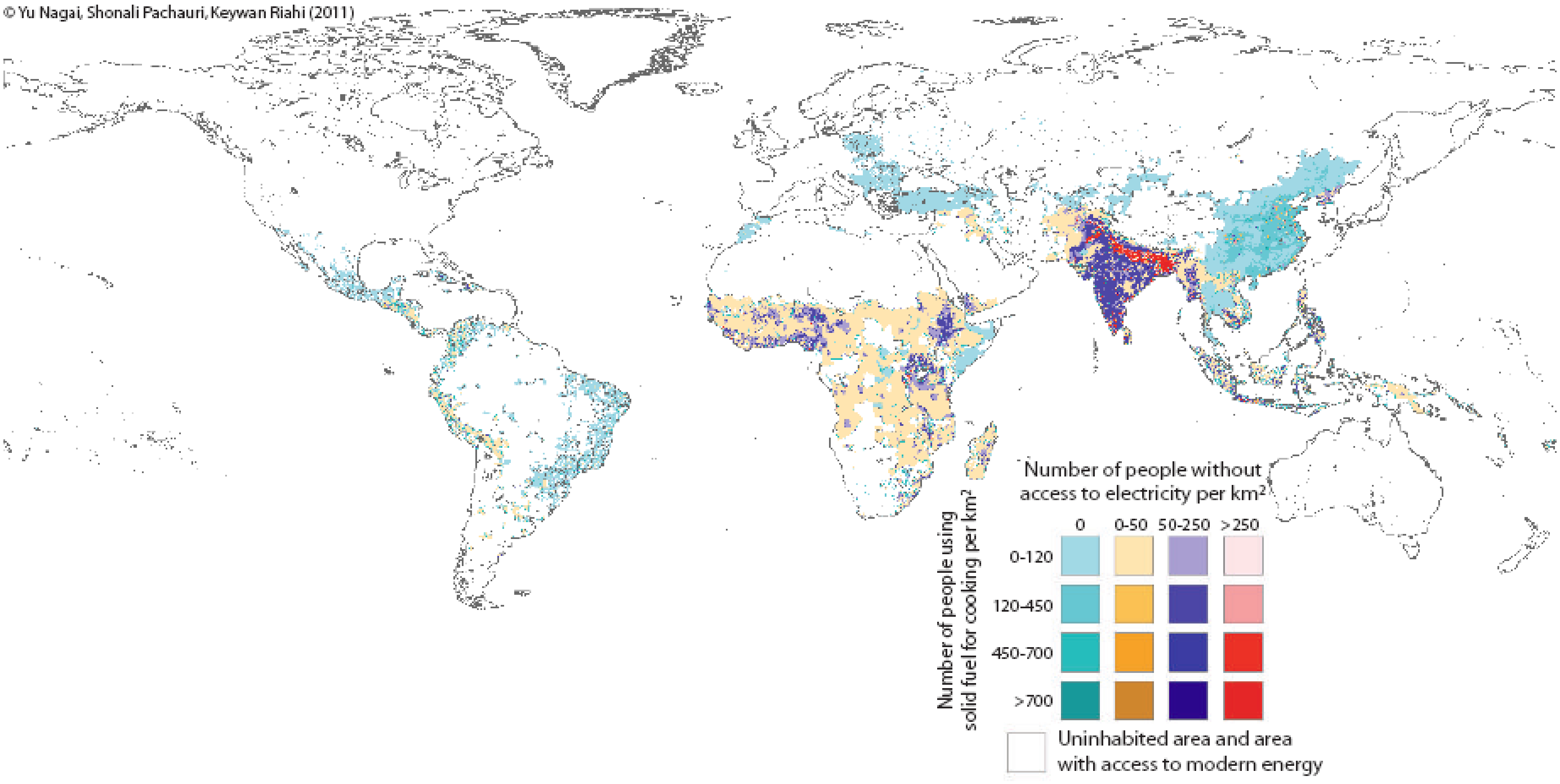
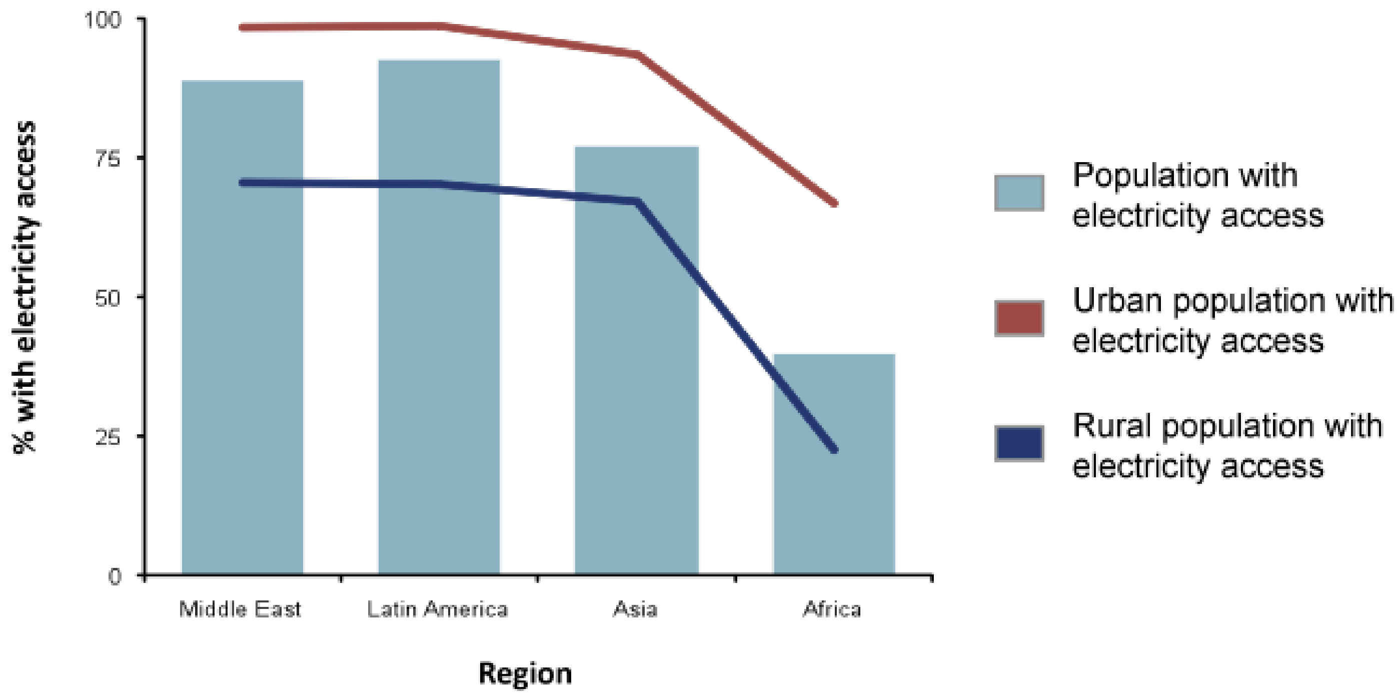


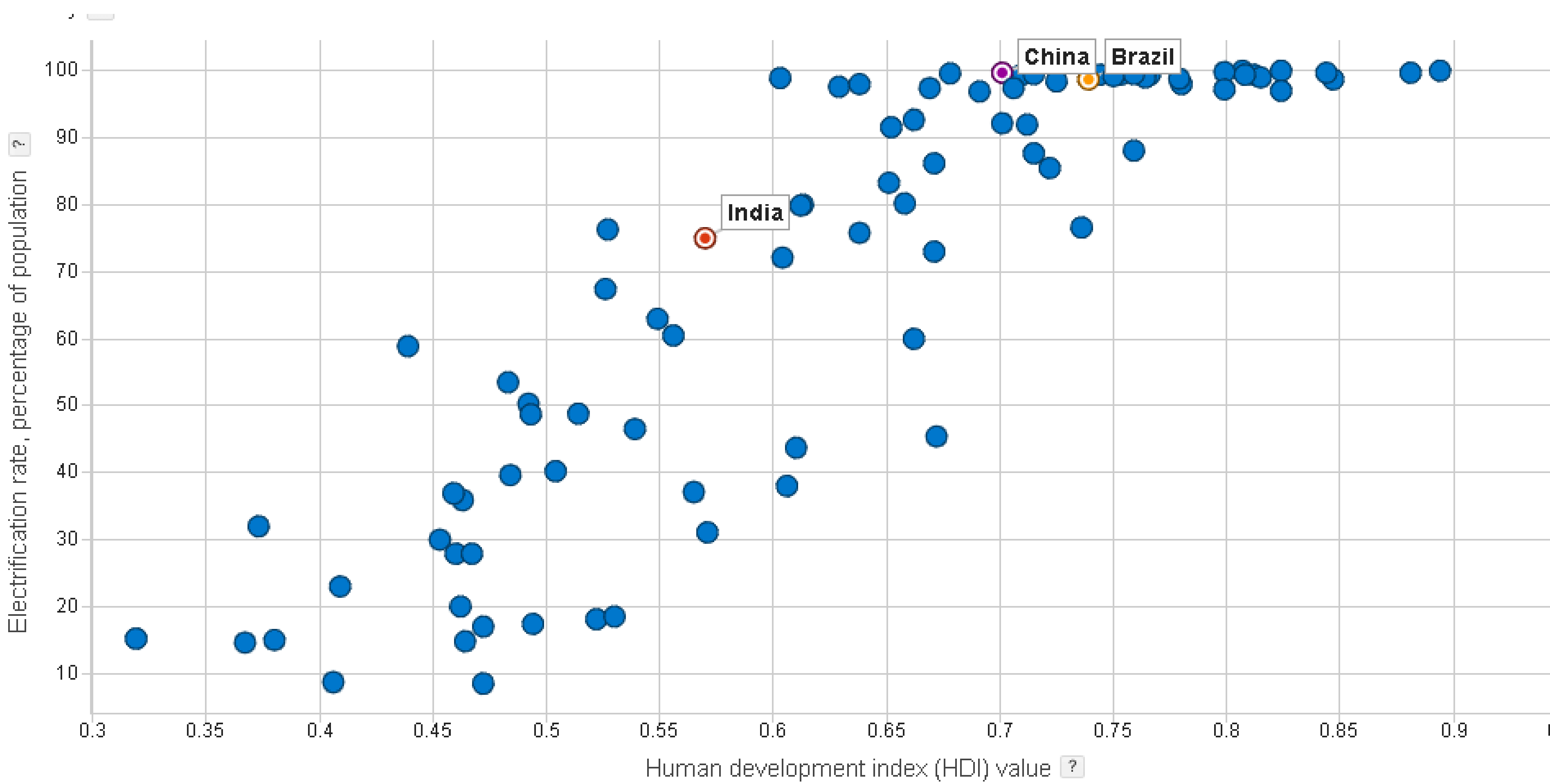
Figure SPM-10. | Density of population lacking access to modern energy carriers in 2005. Colored areas show people per km² without access to electricity and those that use solid fuels for cooking, e.g., dark blue and red areas show where people do not have access to electricity and cook predominately using solid fuels. Source: Chapters 17 and 19.

Electrification rate by geography (outdated)



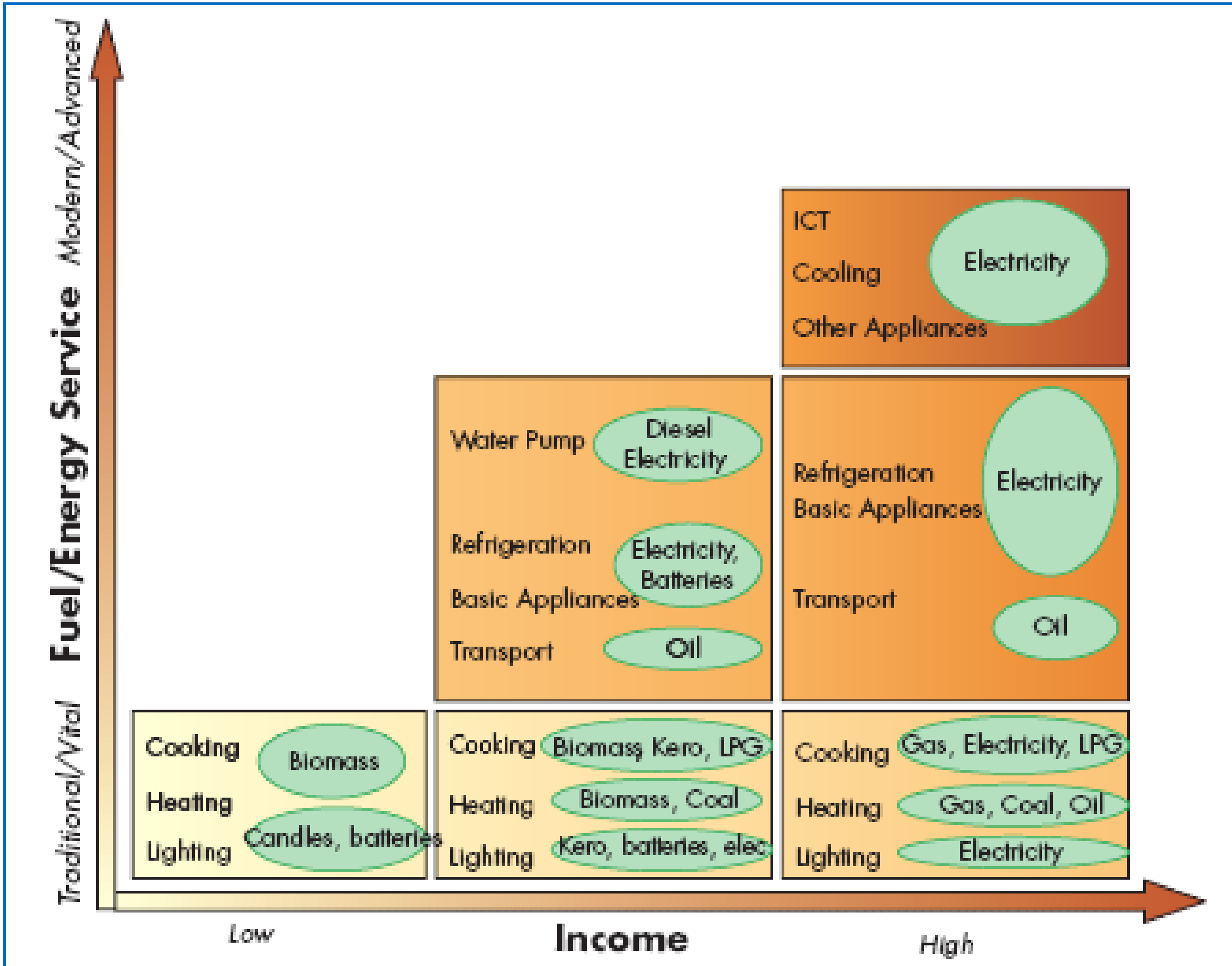
There remains a consistent gap of approximately 25% in the developing world between rates of urban and rural access to electricity, with that gap widening to more than 40% in Africa

Source: Dalberg research & International Energy Agency, Electricity Access Database, 2008.



Source: Google public data explorer

Figure 13.1: **Illustrative Example of Household Fuel Transition**



Note: ICT is information and communication technology.
Source: IEA analysis.

Total Energy Access

Source: http://practicalaction.org/totalenergyaccess

Practical Action's TEA standards

Energy service	Minimum standard
Lighting	300 lumens at household level
Cooking and water heating	1 kg woodfuel or 0.3 kg charcoal or 0.04 kg LPG or 0.2 litres of kerosene or ethanol per person per day, taking less than 30 minutes per household per day to obtain
	Minimum efficiency of improved wood and charcoal stoves to be 40% greater than a three-stone fire in terms of fuel use
	Annual mean concentrations of particulate matter (PM2.5) < 10 µg/m3 in households, with interim goals of 15 µg/m3, 25 µg/m3 and 35 µg/m3
Space heating	Minimum daytime indoor air temperature of 12C
Cooling	Food processors, retailers and householders have facilities to extend life of perishable products by a minimum of 50% over that allowed by ambient storage
	All health facilities have refrigeration adequate for the blood, vaccine and medicinal needs of local populations
	Maximum indoor air temperature of 30C
Information and communications	People can communicate electronic information beyond the locality in which they live
	People can access electronic media relevant to their lives and livelihoods
Earning a living	Access to energy is sufficient for the start up of any enterprise
	The proportion of operating costs for energy consumption in energy-efficient enterprises is financially sustainable.

Off-grid lighting options

Solar lanterns

Solar Home System

Rural microgrid

Lighting

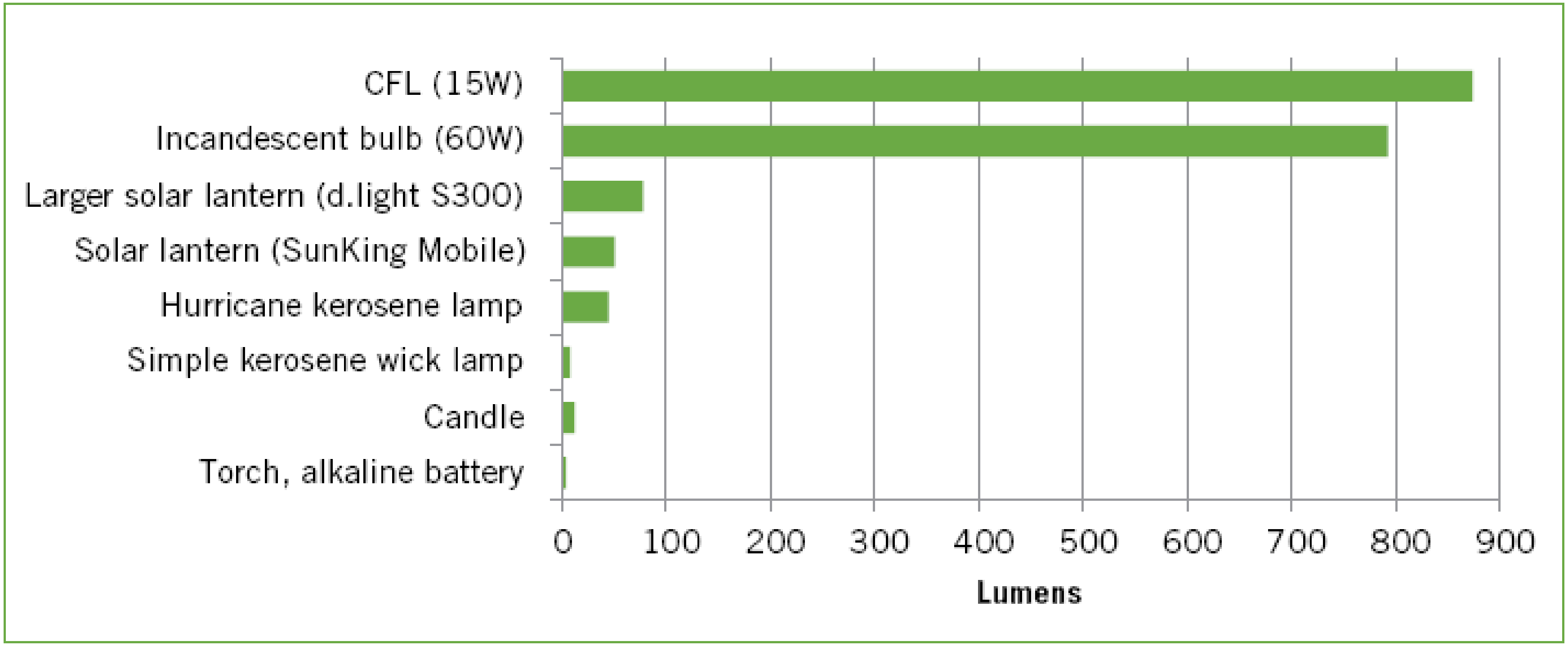
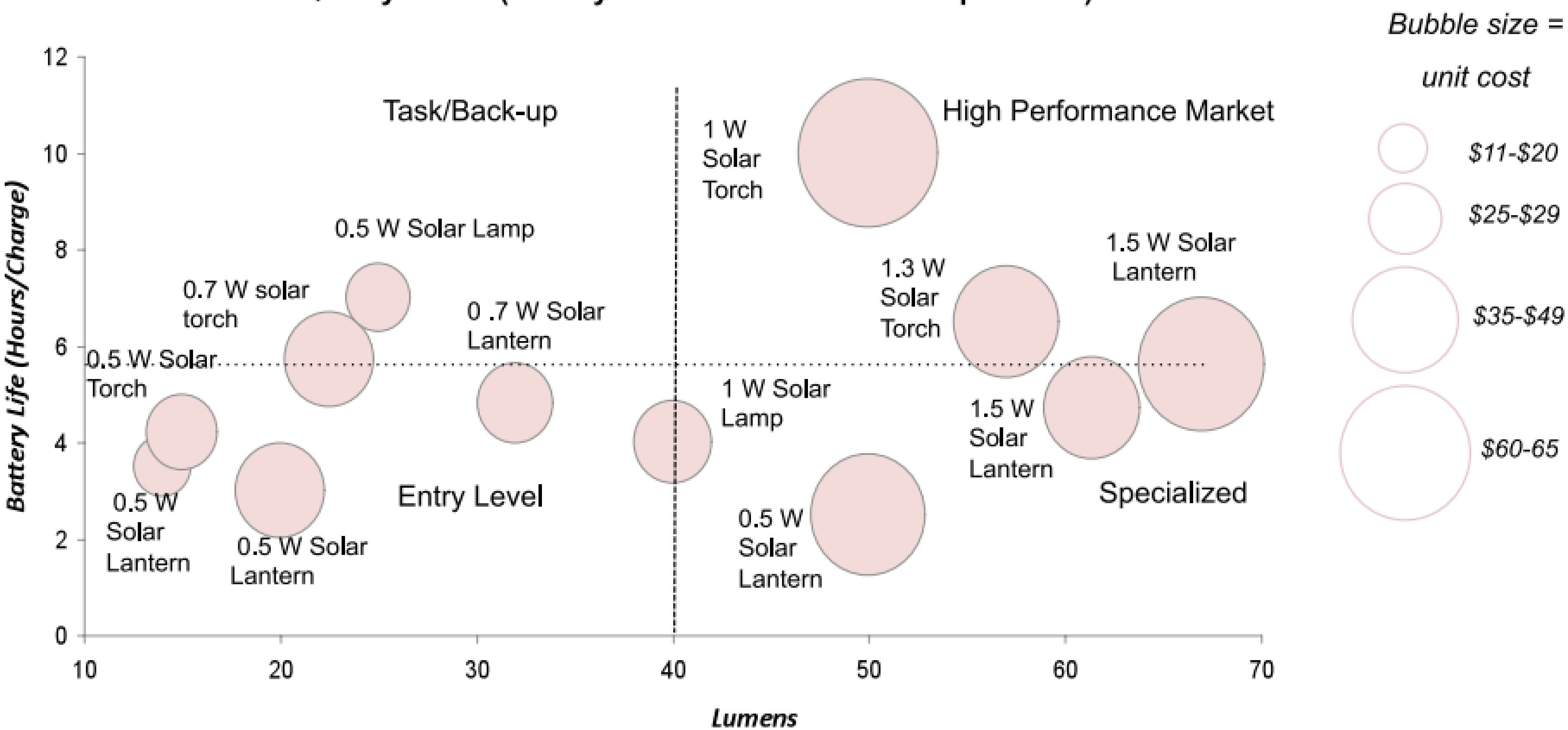


Figure 1.1 Amount of light from different sources
Source: Mills (2003) and product descriptions on Lighting Africa website

Diversity of lighting products

SPL Quality Matrix (Battery Life vs. Lumens for LED products)



Significant outliers exist in independently tested data which have been omitted pending further analysis

Source: REEEP, Lawrence Berkley National laboratory.

Important energy trends

Technology	SLA 	NiCd 	NiMH 	Li-Ion 
Energy Density	30-50 Wh/kg	45-80 Wh/kg	60-120 Wh/kg	90-190 Wh/kg
Recharge cycles	200-300	1500	300-500	300-1000 +
Durability	Lowest – performs poorly depending on temperature and overcharge/undercharge	Highest	High	High
Toxicity	Toxic	Acutely toxic	Benign	Benign
User Charging Requirements	Must always be kept in a charged condition	Lasts longer if battery is fully discharged each use	Lasts longer if battery is fully discharged each use	Lasts longer with partial rather than full discharges
Maintenance	Apply topping charge every 6 months	Discharge to 1V every 3 months to avoid memory effect	Less memory effect then NiCd	No Maintenance required. Loses capacity due to age regardless of use

Source: Dalberg Analysis

Source: “Off-grid lighting for the base of the Pyramid”, June 2010

The promise of DG

Table 3.3 Comparison of electricity supply options to provide a reliable 25 kWh/day supply

Technology	System size	Capital (US$)	Operating (US$/year)	Operation and maintenance assumptions
Solar PV system with batteries	6000 W panels 100 kWh batteries	$55,000 system $10,000 batteries	$2,550	1% system cost per year (includes maintenance and component replacement, does not include security); amortized cost of replacing the batteries every five years (20% of battery cost)
Wind turbine with batteries	8750 W turbine 100 kWh batteries	$44,000 system $10,000 batteries	$2,900	2% system cost per year; amortized cost of replacing the batteries every five years
Diesel engine generator	2.5 kW	$2,000	$6,400	$0.0075/kWh maintenance, $0.67/kWh fuel ($1/litre for fuel used), operating at 15 kWh per day at 67% capacity, and replacement of engine every ten years
Hybrid system	6000 W panels 50 kWh batteries 2.5 kW engine	$55,000 system $5,000 batteries $2,000 generator	$2,200	1% PV system cost per year; battery replacement every five years; 200 hours of engine operation per year; replacement of engine every ten years
Grid extension	n/a	$10,000+ per mile	$900	$0.10/kWh power

Source: USAID (2007)

Solar Home Systems: La Pintada

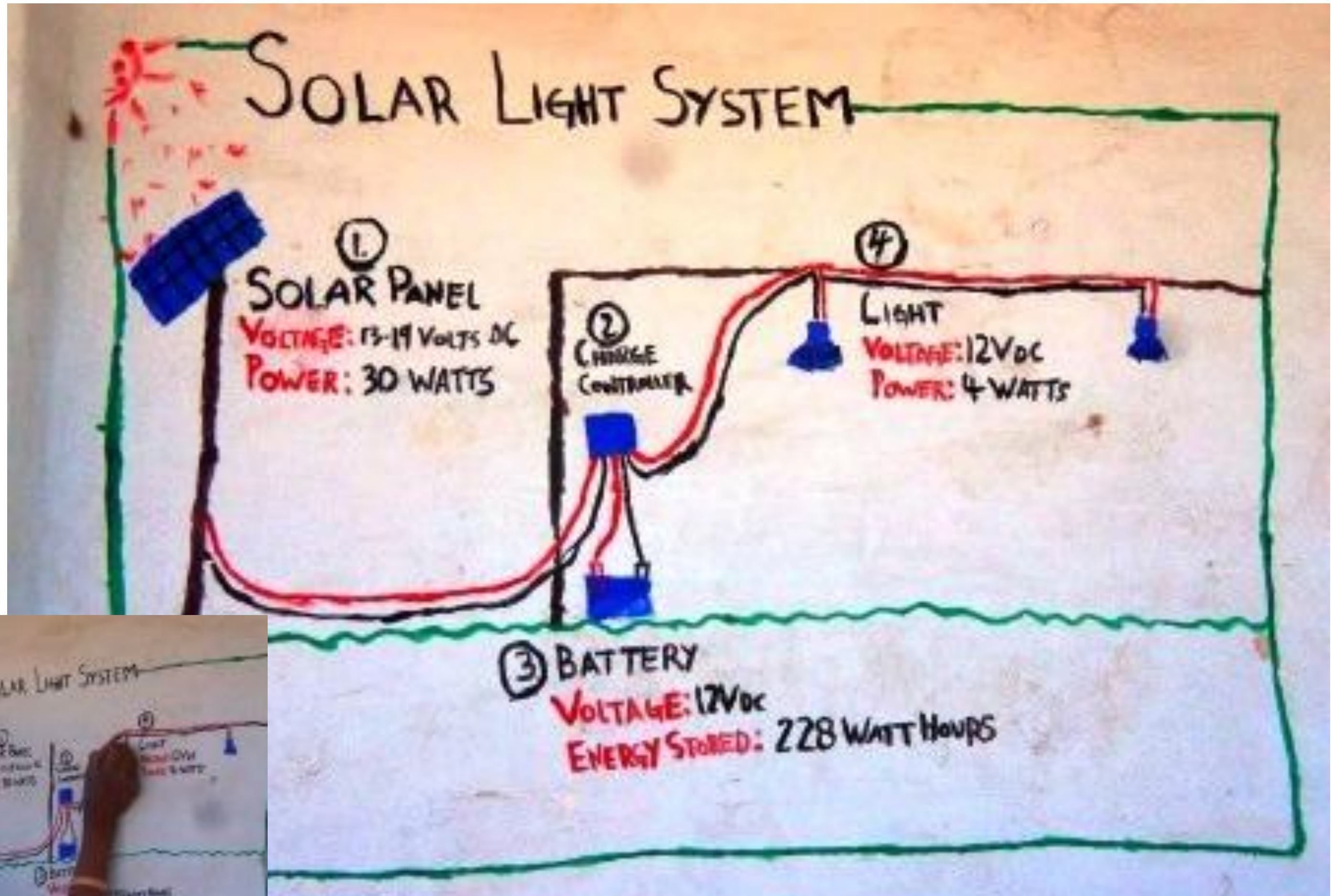
- ~20 homes of farmers
- Primarily coffee growers
- Systems are designed for two 7W CFL bulbs
- 100% subsidized
- Several months old
- Funded by Spanish funding

Using the systems

Using solar study lamps outside

Testing the lighting of one of the streetlights

System painted on wall

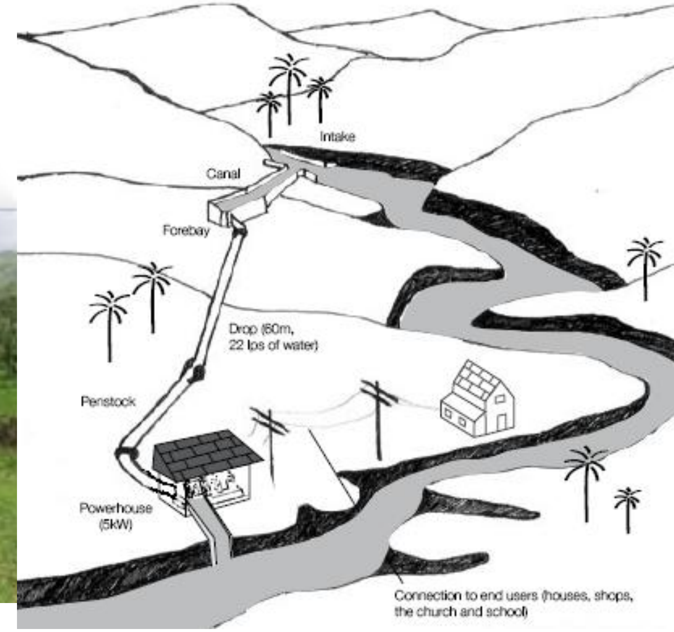


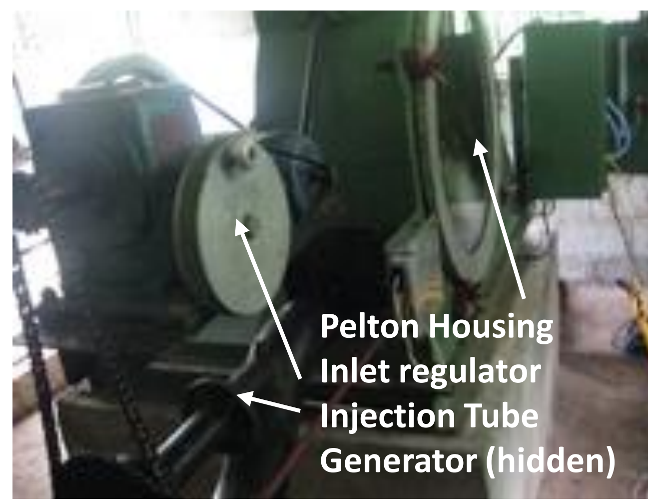
Community Center, Ahmedabad, Gujarat

- 12 day workshop, 2 hrs per day
- 12 children from 3 slums
- System installed in community center library for day-lighting

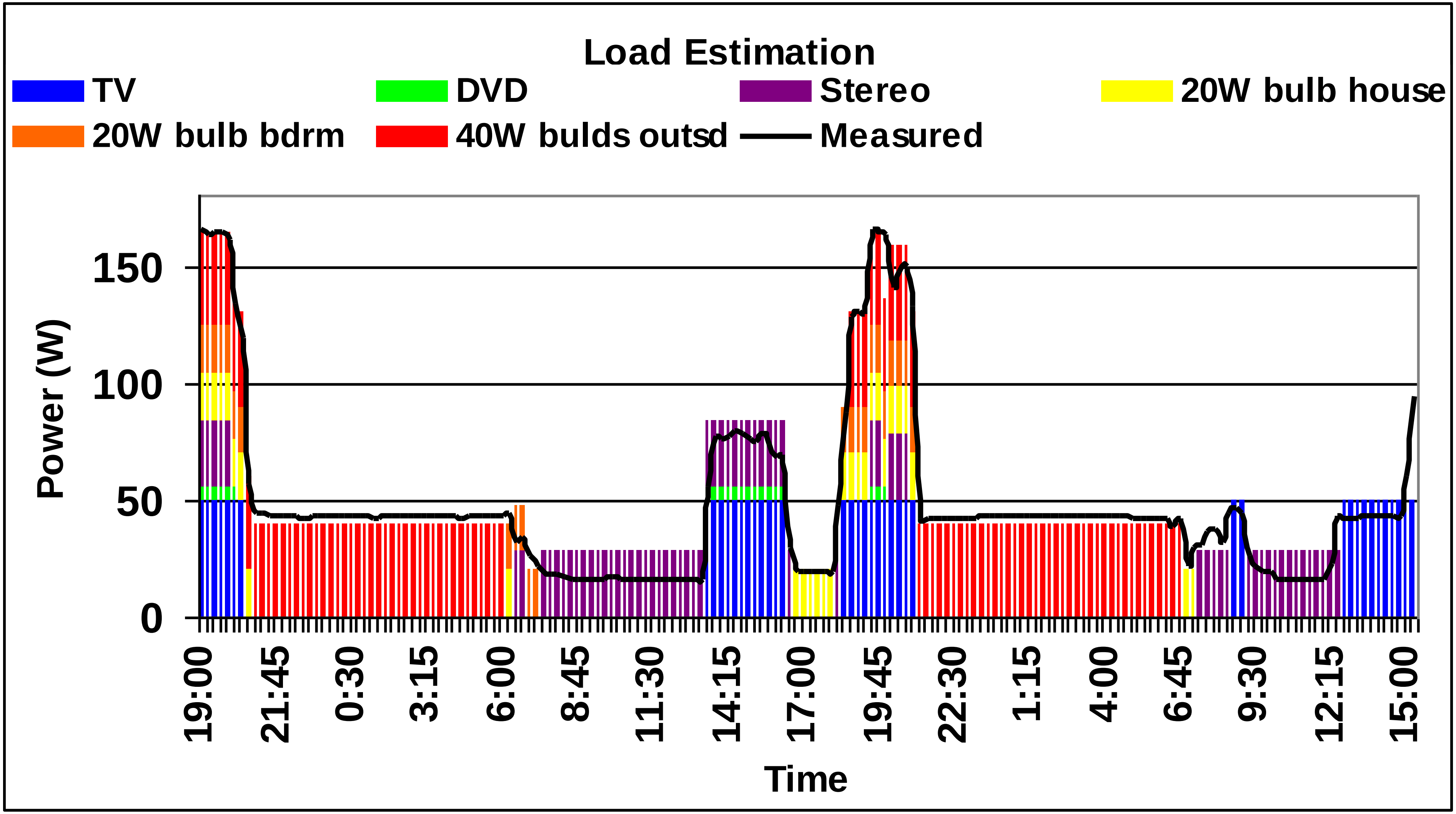
Microhydro - Malacatoya

- Asofenix
- 13 kW system w/ 22 houses
- Community installed/operated
- Over 1 yr old
- Primary use is lighting/TV
- 100% subsidized + in-kind labor



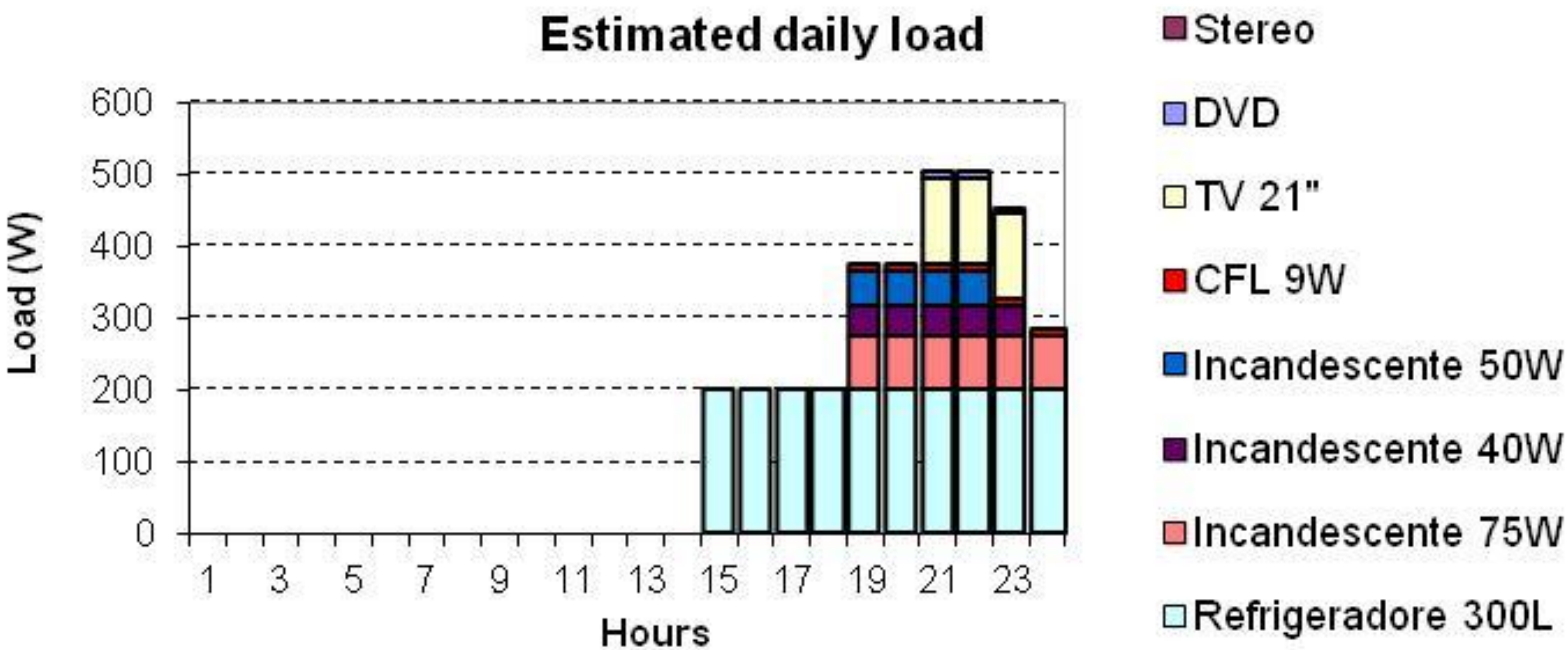


Load of a grid connected house in rural NI

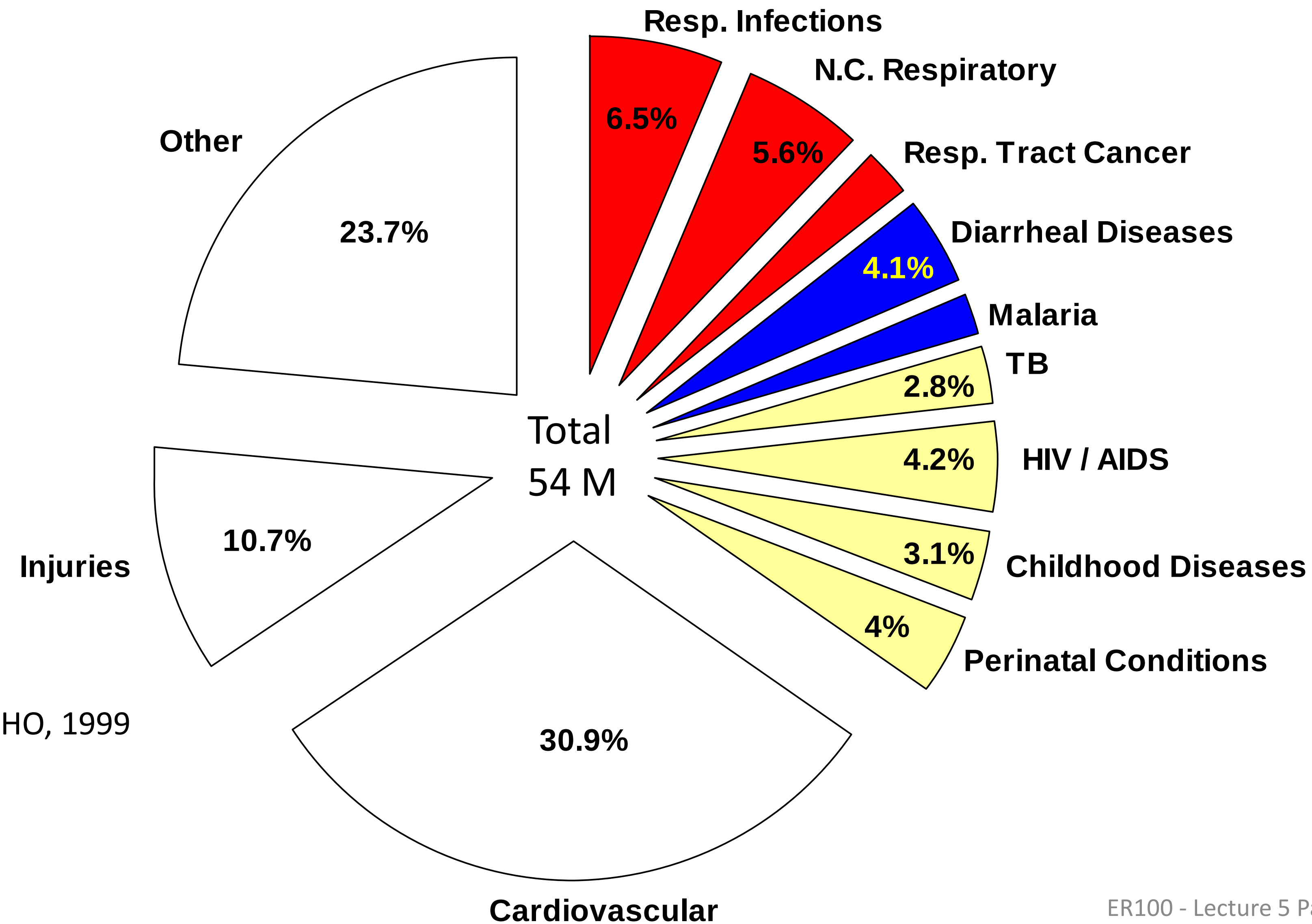


30 kWh/month. Efficient lighting ~ 55% of load, TV ~25% of load, Radio ~ 22% of load

On a diesel microgrid



The Global Distribution of Disease (Mortality)



source: WHO, 1999

Table 1: Typical conversion efficiency range of household cookstoves[7] by energy sources

Fuel source	Energy content (MJ/kg)	Conversion efficiency range (%)
Traditional (open fire or mud) stoves		
Fuelwood	16	13-18
Crop residue (straw, leaves, grass, maize, wheat)	13.5	9-12
Dung	14.5	12
Charcoal	30	10-22
Improved biomass cookstoves		
Fuelwood	16	23-40
Coconut shell (gasifier)	15.7	33-36
Crop residue (maize, wheat)	13.5	15-19
Charcoal	30	20-35
Biogas	22.8 (MJ/m^3)	50-65
Advance cookstoves		

Source:Malla et al, World Bank Policy paper 6903, 2014

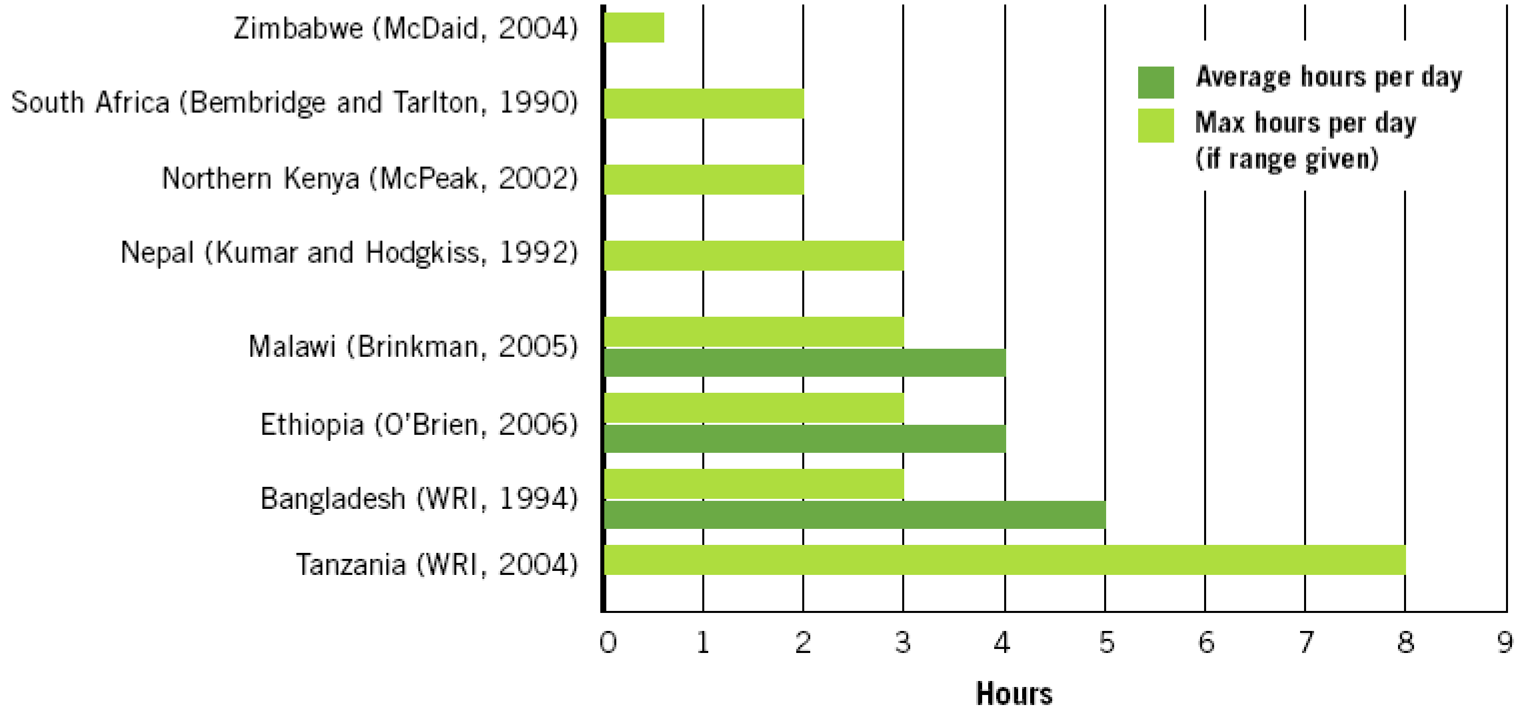


Figure 1.2 Selected data on time spent in collecting wood

Source: Poor people's energy outlook 2013, Practical Action

Motivation for biogas project

- Heavily deforested area
- Purchase wood from 10 km away at 6 Rs/kg
- School uses 35 kg of wood/day (200 Rs/day)

Other cooking technologies at school

Sarai cooker

Parabolic dish

Biggest challenge isn't technical – how to get kids and cooks to adopt these technologies that may require a little more management/attention…

Initial results of the school's system

Input

Feeding: ~ 10 kg dung/day

Output

Gas production: 200-300 l/day

Cooking: 200 liters/hour

1 hr cooking: 6 liters water, 2 kg dahl

Equivalent: 5 kg firewood

Biodigester record sheet

Characteristics of biogas

- 60-70 % methane and 30-40 % carbon dioxide
- 100 liters of biogas can power a stove for about 20 min, or a lamp for 1.5 hours

	Units	**Energy content (kWh)**
Biogas	kWh/100 L gas	0.7 (at 15 C, 1 atm)
natural gas (97% CH4)	kWh/100 L gas	1.1 (at 15C , 1 atm)
Propane	kWh/kg	13
dung	kWh/kg	4.2
wood	kWh/kg	4.4
charcoal	kWh/kg	8.1
kerosene	kWh/kg	12
kerosene	kWh/liter	9.72
gasoline	kWh/kg	13.3

Note: 1 kWh is the amount of energy used by ten 100W bulbs in 1 hour
10x100W = 1000 W = 1 kW. Energy = Power x Time = 1kW x 1 hr = 1kWh