

04-Electricity Access

Off-Grid Electrical Systems in Developing Countries
Chapter 2.5–2.6

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Learning Outcomes

At the end of this lecture, you will be able to:

- ✓ describe the role of electricity in meeting the energy needs of a rural household
- ✓ define the terms *universal access*, *electrification rate*, and *Annual Growth Rate*
- ✓ compute the electrification rate and Annual Growth Rate for countries and regions

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Replace or Complement?

- Off-grid systems can be designed to partially or completely replace traditional fuels, or to complement them by powering devices that traditional fuels cannot supply (e.g. a mobile phone)
- Size, cost, and design of the system depends on the strategy selected

Example

Consider a household whose consumption is 60 GJ (16,667 kWh) per year from fuel wood and kerosene. Of this, 36 GJ from fuel wood is used for cooking and water heating on a cook stove with an efficiency of 12%, and 20 GJ from fuel wood is used for space heating. Kerosene is used for lighting, with an annual consumption of 4 GJ. Compute the annual energy required, in kilowatthours, to replace the fuel with electricity from the national grid. Assume the electric cook stove is 75% efficient and the electric lamps consume 45 kWh per year.

Example---Electric Cookstove Consumption

Of this, 36 GJ from fuel wood is used for cooking and water heating on a cook stove with an efficiency of 12%... Assume the electric cook stove is 75% efficient.

The electric cookstove reduces the consumption from water heating and cooking to:

$$36 \text{ GJ} \times 0.12 / 0.75 = 5.76 \text{ GJ} = 1600 \text{ kWh}$$

Example---Heating

...20 GJ from fuel wood is used for space heating

Assuming the same energy for heating is required from electricity

$$20 \text{ GJ} \times (1 \text{ kWh} / 0.0036 \text{ GJ}) = 5555 \text{ kWh}$$

Example: Total

The total electrical energy for complete replacement is:

$$\begin{array}{rcccl} 1600 \text{ kWh} & + & 5555 \text{ kWh} & + & 45 \text{ kWh} & = & 7201 \text{ kWh} \\ \text{cooking} & & \text{heating} & & \text{lighting} & & \end{array}$$

Exercise

Compute the annual expenditure of the same household if electricity is used to completely replace the traditional fuels, assuming the electricity is \$0.15/kWh.

Exercise

The consumption is 7201 kWh, so the annual cost is

$$7201 \text{ kWh} \times \$0.15/\text{kWh} = \$1080.15$$

This is likely far too expensive for a rural household, and represents an approximately six-fold increase in their energy expense (see Example 2.4)

Replace or Complement?

- Complete replacement of traditional fuels is not practical in most situations
- Common strategy:
 - Replace expensive, low-quality, and/or harmful fuels such as kerosene (lighting) and disposable batteries
 - Complement traditional fuels for applications like mobile phone charging, radios, television
 - Retain traditional fuels for heating and cooking

Use traditional fuels for thermal applications (heating, cooking)

How much electricity does a household need?

Household electricity requirements depends on local context and level of service provided



20 to 100 kWh/person/year



365 kWh/household/year
(1 kWh/day)

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Electricity Services

Service	Very-Low Power	Low-Power	Medium-Power	High-Power	Very High-Power
1. Lighting	Task	General	--	--	--
2. Communication & entertainment	Phone charging, radio	TV, computer, printer	--	--	--
3. Space cooling & heating	--	Fan	Air cooler	--	Air conditioner
4. Refrigeration	--	--	Refrigerator, freezer	--	--
5. Mechanical Loads	--	--	Water pump, food processor	Washing machine	Vacuum cleaner
6. Product heating	--	--	--	Iron, hair dryer	Water heater
7. Cooking	--	--	Rice Cooker	Toaster, microwave	Electric range (cooker)

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Electricity Services

Services	Consumption (kWh/person/year)
Task lighting	1
Light or TV or radio	2
Light, phone, radio, small TV	22
Light, phone, radio, TV, fan, productive uses	220

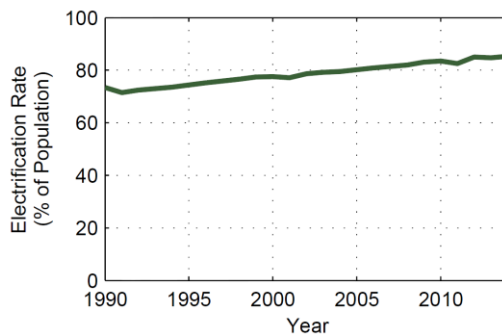
Type of technology used also affects consumption (e.g. LED versus compact florescent light)

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Electrification Rate (%): $100 \times \frac{\text{population whose house is connected to national grid}}{\text{total population}}$



2016 Electrification rate: 87.4%.
Over 1 billion without access to electricity

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Calculating Population with and without Access

- Population with access = total population x electrification rate
- Population without access = total population x (100 - electrification rate)
- Electricity access is a binary indicator, so
population with access plus population without access = total population

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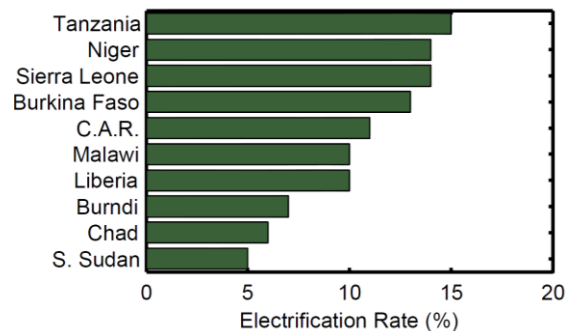
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Electricity Access Around the World

Electrification rate of SSA is approx. 40%

Rural penalty

- urban electrification rate: 96%
- rural electrification rate: 72%
- rural electrification rate in SSA is 15%



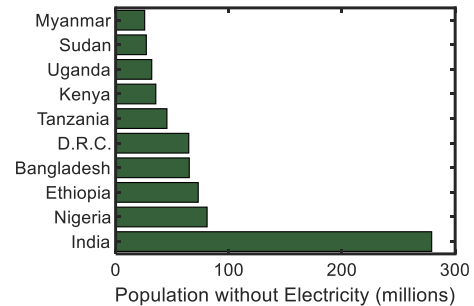
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Electricity Access Around the World

Approximately 80% of un-electrified live in just 20 countries



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The headlines



Chowkidar Narendra Modi ✓

@narendramodi (Indian Prime Minister Modi)



28th April 2018 will be remembered as a historic day in the development journey of India. Yesterday, we fulfilled a commitment due to which the lives of several Indians will be transformed forever! I am delighted that every single village of India now has access to electricity.

♥ 47.1K 9:58 PM - Apr 28, 2018



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The headlines

Every village in India now has electricity. But millions still live in darkness. --Washington Post

https://www.washingtonpost.com/world/asia_pacific/every-village-in-india-now-has-electricity-but-millions-still-live-in-darkness/2018/04/30/367c1e08-4b1f-11e8-8082-105a446d19b8_story.html?utm_term=.717711e32ff9

Modi Announces '100% Village Electrification', But 31 Million Indian Homes Are Still In The Dark --Forbes

<https://www.forbes.com/sites/suparnadutt/2018/05/07/modi-announces-100-village-electrification-but-31-million-homes-are-still-in-the-dark/#64670d0763ba>

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Achieving Universal Electricity Access

Universal electricity access: global electrification rate of 100%



Time

Realistically, universal access is decades away. (see Problem 2.9)



Investment

Estimated annual investment through 2030 is \$45 billion per year. Present investment is approx. \$10 billion per year.

Universal access is technically feasible, with relatively limited environmental impact depending on consumption

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Is progress really being made?

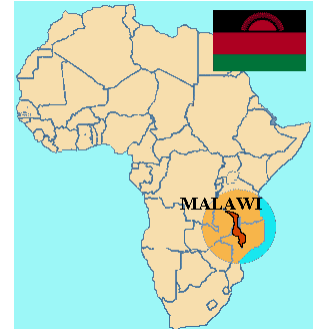
Malawi in 2010

- total population: 14.8 million
- electrification rate: 9%

Malawi in 2012

- total population: 15.7 million
- electrification rate: 10%

An increase of 1 percentage point in electrification rate shows progress



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Is progress really being made?

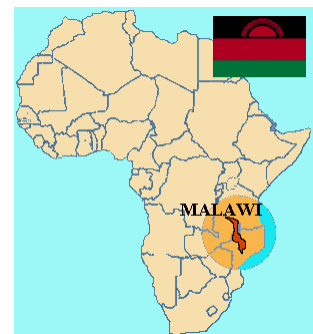
Malawi in 2010

- total population: 14.8 million
- electrification rate: 9%
- **population without electricity: 13.47 million**

Malawi in 2012

- total population: 15.7 million
- electrification rate: 10%
- **population without electricity: 14.13 million**

Number of people without electricity increased by 600,000!



Discussion

Do you consider Malawi to be making progress on electricity access?



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Is progress really being made?

Sub-Saharan Africa in 2013

- total population: 0.952 billion
- electrification rate: 36.5%
- **population without electricity: 604.5 million**

More people without access
in 2014 than in 2013

Sub-Saharan Africa in 2014

- total population: 0.979 billion
- electrification rate: 37.7%
- **population without electricity: 609.9 million**

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Is progress really being made?

Sub-Saharan Africa in 2015

- total population: 1.01 billion
- electrification rate: 38.4%
- **population without electricity: 622.2 million**

Electrification rate increasing
AND population without access
decreasing

Sub-Saharan Africa in 2016

- total population: 1.03 billion
- electrification rate: 42.8%
- **population without electricity: 589.2 million**

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Annual Growth Rate (AGR)

- Annual Growth Rate: quantifies the change in electricity access over a period of time
- AGR considers population growth dynamics as well as change in electricity access

$$\begin{aligned}
 AGR &= \frac{(A[y] - A[y - t]) - (P[y] - P[y - t]) \times \frac{1}{t}}{P[y]} \\
 &= \frac{\text{pop. without access year in year } y - \text{pop. without access in year } y - t}{P[y]} \times \frac{1}{\Delta t}
 \end{aligned}$$

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Annual Growth Rate (AGR)

$$AGR = \frac{(A[y] - A[y - t]) - (P[y] - P[y - t])}{P[y]} \times \frac{1}{t}$$

$$= \frac{(\text{pop. without access in year } y - t) - (\text{pop. without access in year } y)}{\text{population in year } y} \times \frac{1}{t}$$

$A[y]$: number of people with access to electricity in year y

$P[y]$: population in year y

t : period of time considered, years

Exercise

Compute the AGR of Malawi between 2010 and 2012

Malawi in 2010

- total population: 14.8 million
- electrification rate: 9%
- **population without electricity: 13.47 million**

Malawi in 2012

- total population: 15.7 million
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Exercise

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Malawi in 2012

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$$AGR = \frac{(\text{pop. without access in year } y - t) - (\text{pop. without access in year } y)}{\text{population in year } y} \times \frac{1}{t}$$

$$= \frac{13.47 - 14.13}{15.7} \times \frac{1}{2} = -0.021$$

If population without electricity increases, then the AGR will be negative


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