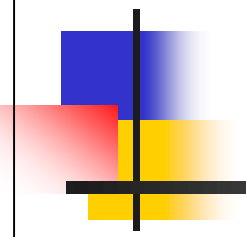
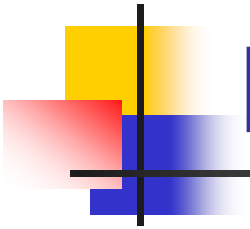


EN 653/PS 611
Energy Policy Analysis

Energy Access
L4 (10th January 2019)



Framework

- Decisions
- Stakeholders
- Policies
- Goals
- Criteria
- Analysis

Energy Goals

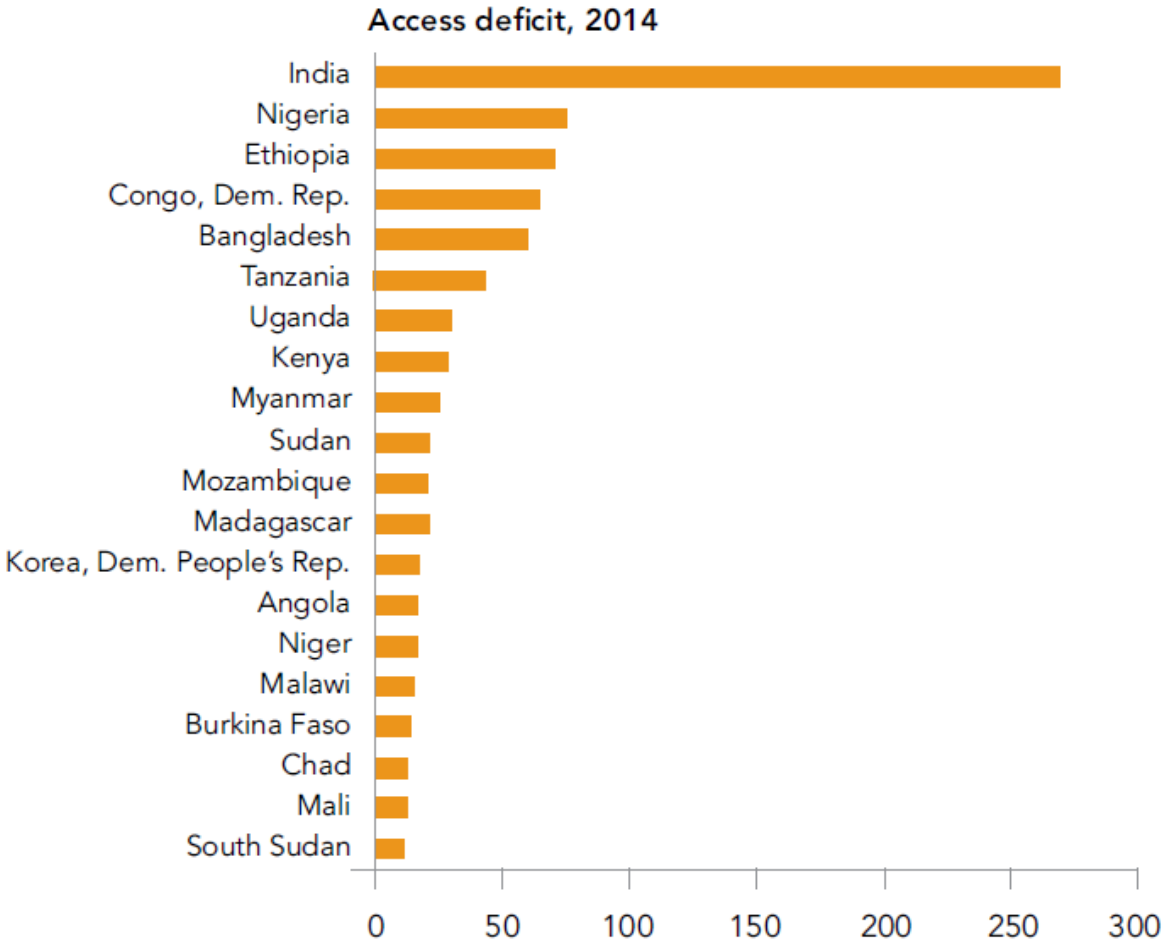
- Increase Energy Access
- Develop capacities for energy transitions
- Enhance Energy Security
- Manage Energy Related Market Power
- Manage Energy Resource Endowments
- Reduce Environmental and Human Health Impacts
- Accelerate Energy related Technological change
- Co-ordinate and implement international energy related policies

Energy Access - definition

"*a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average*"

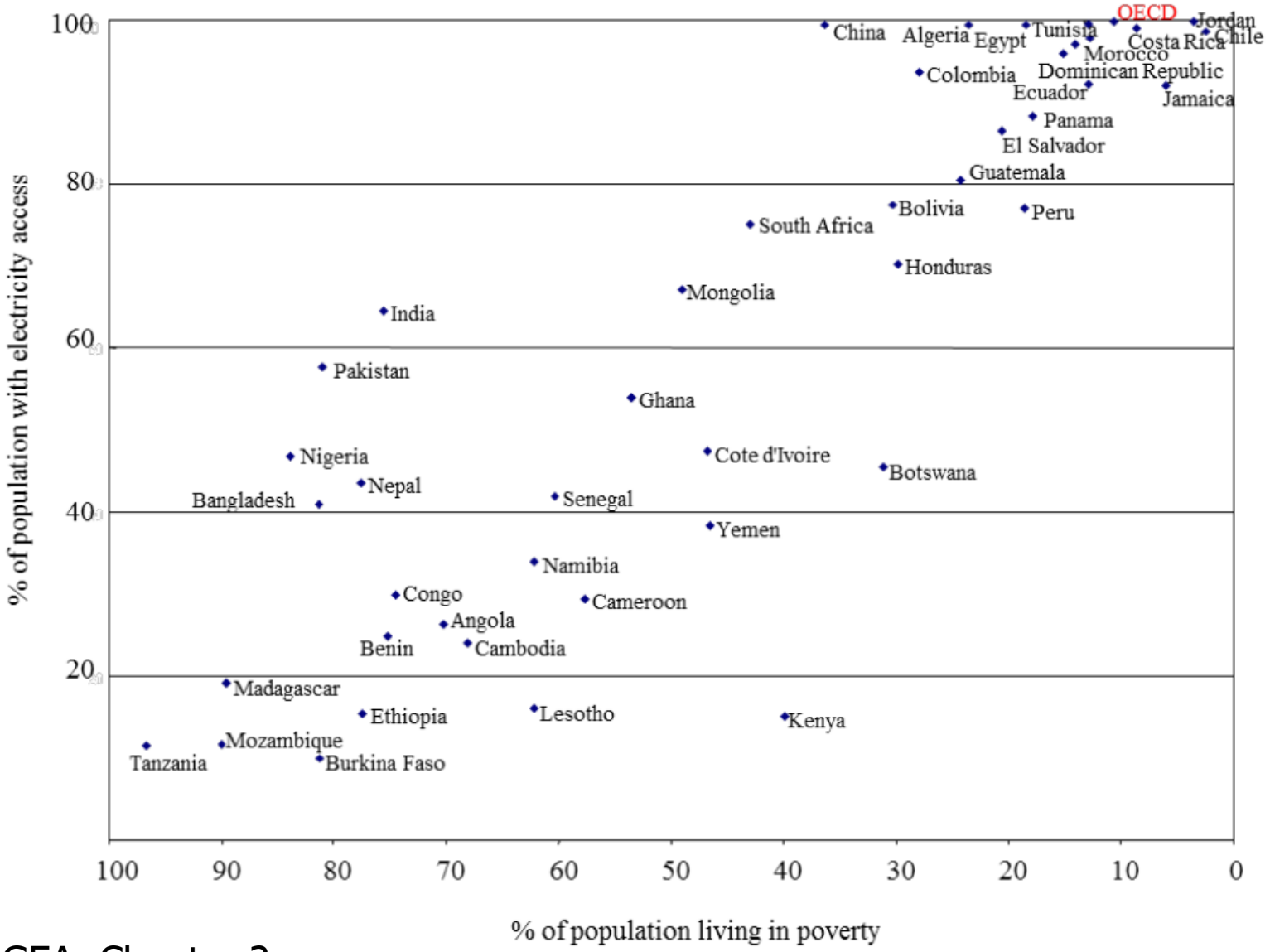
IEA definition (WEO 2017 special report)

Energy Access Deficit



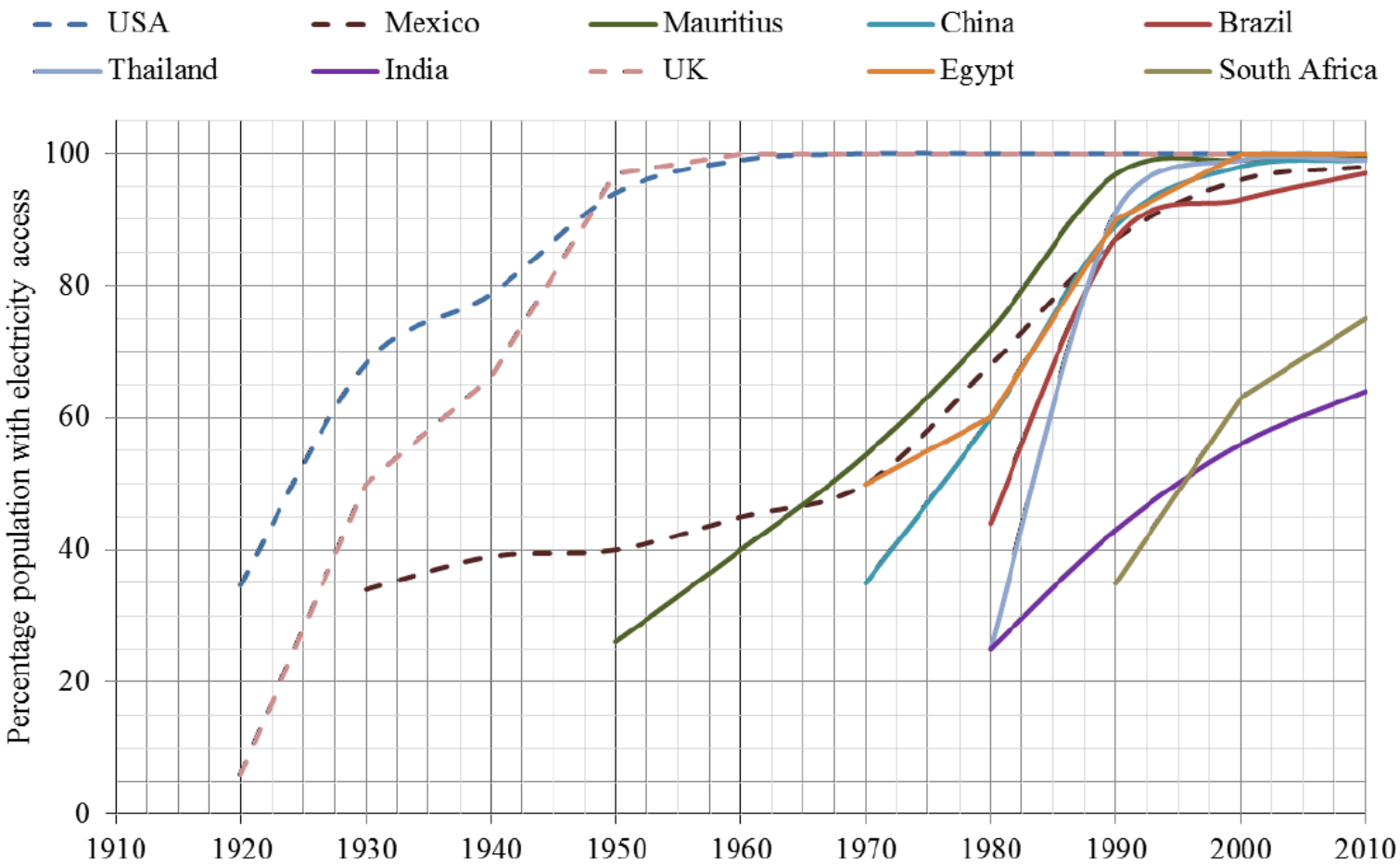
Source: IEA and World Bank 2017

Access to electricity versus poverty levels



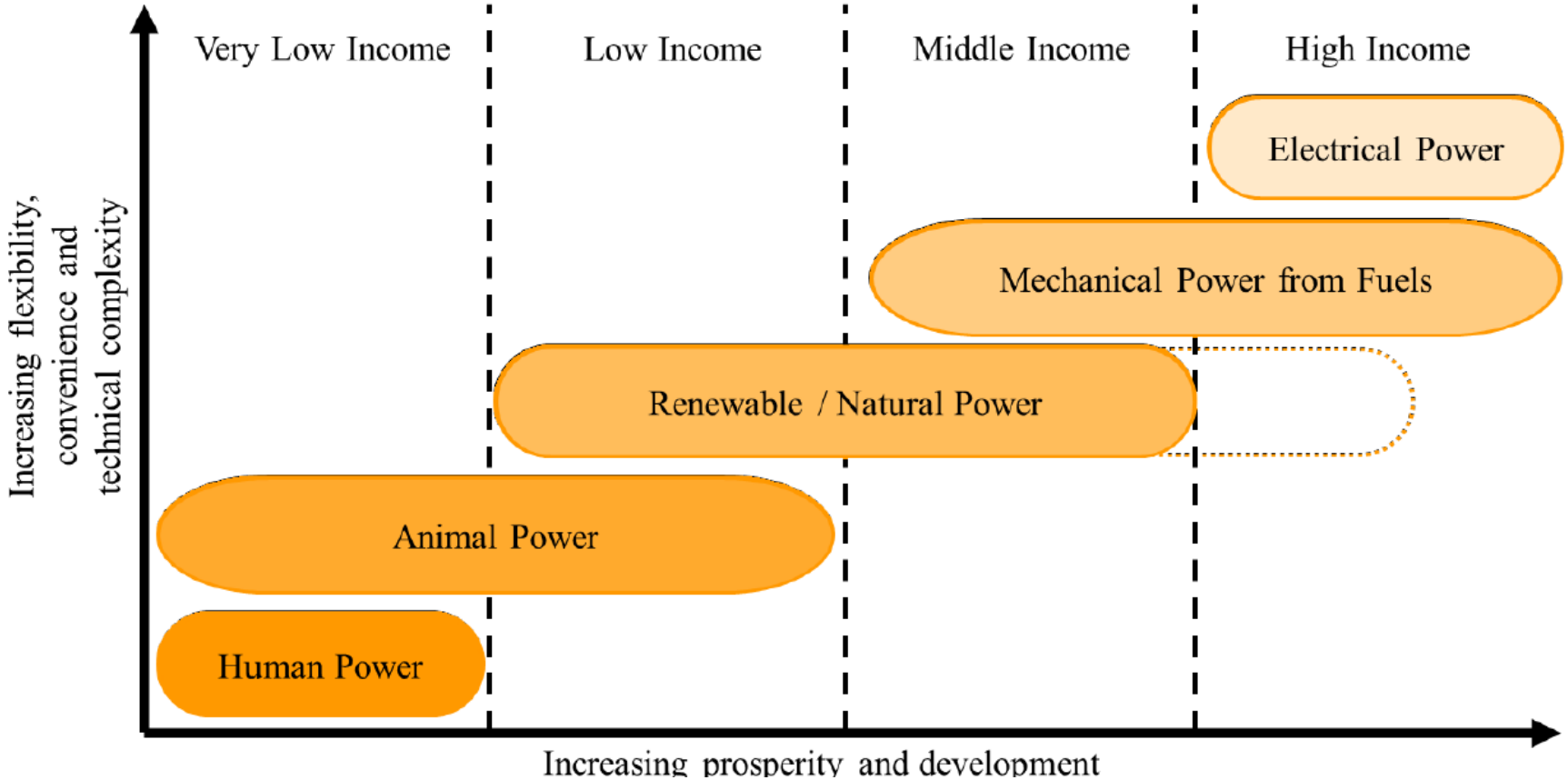
GEA, Chapter 2

Historical Household Electrification Rates



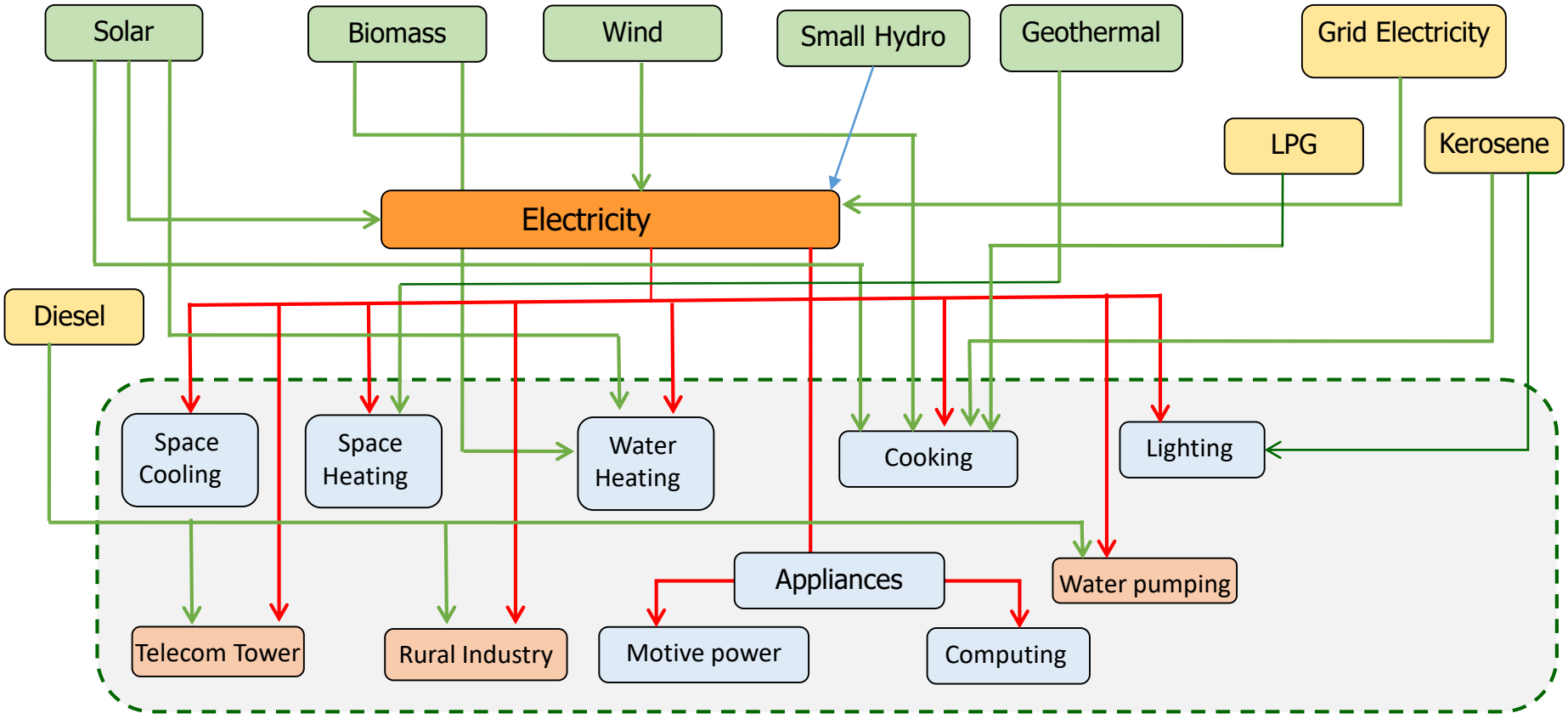
GEA, Chapter 19

Mechanical Power Ladder

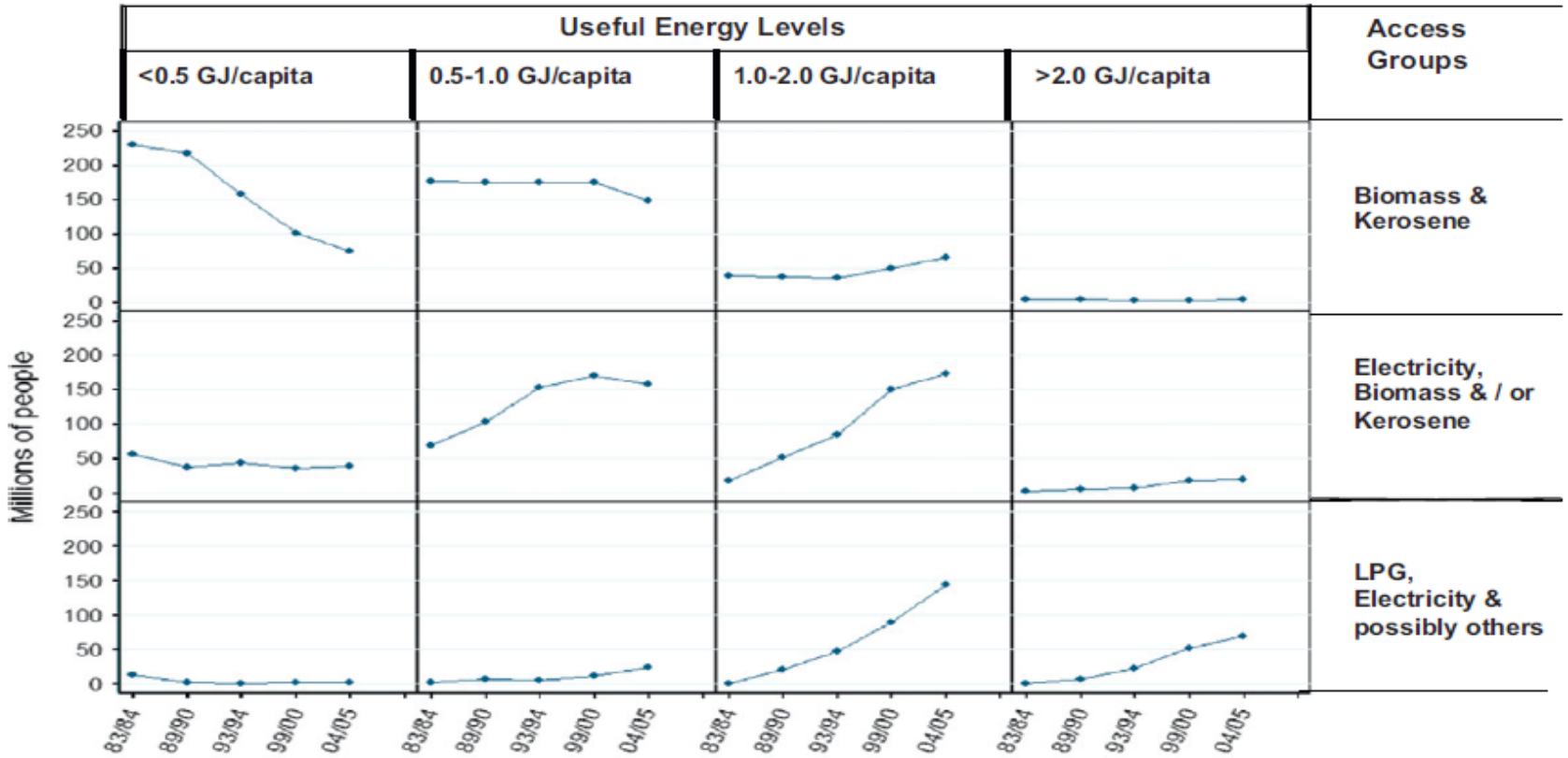


GEA, Chapter 19

Pathways for End Uses

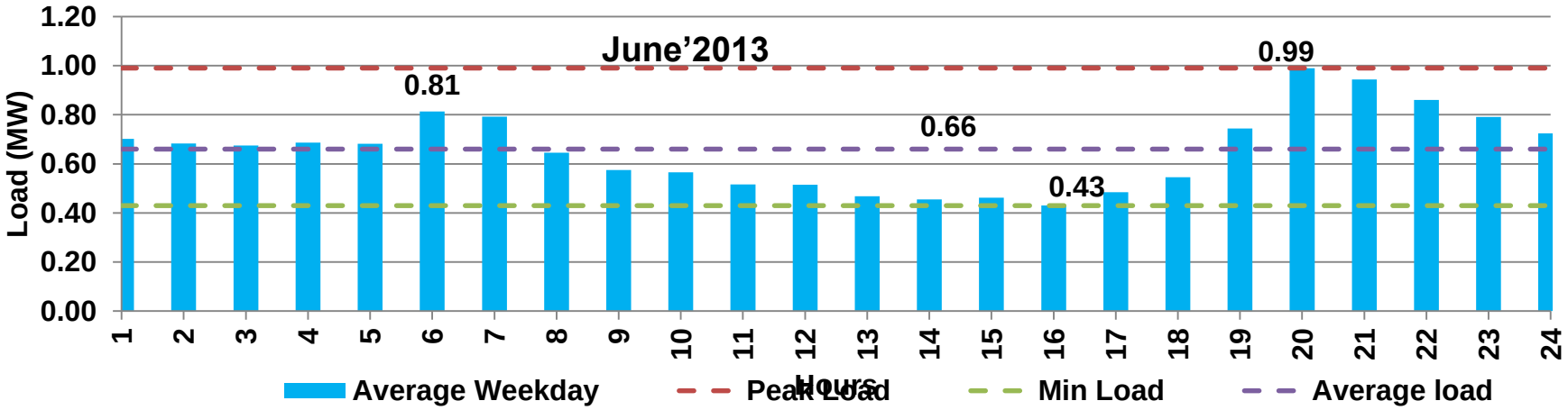


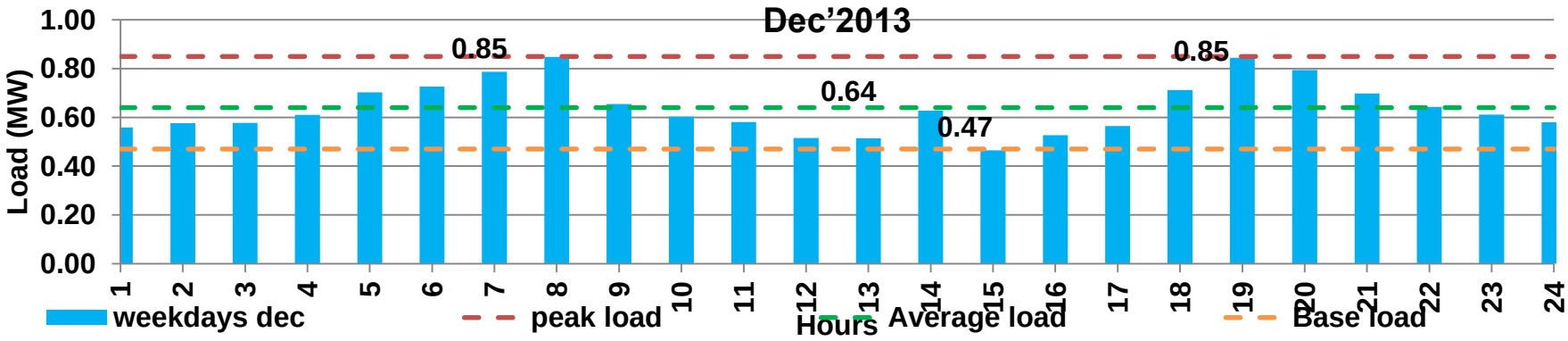
Energy Poverty and Fuel Mix- India



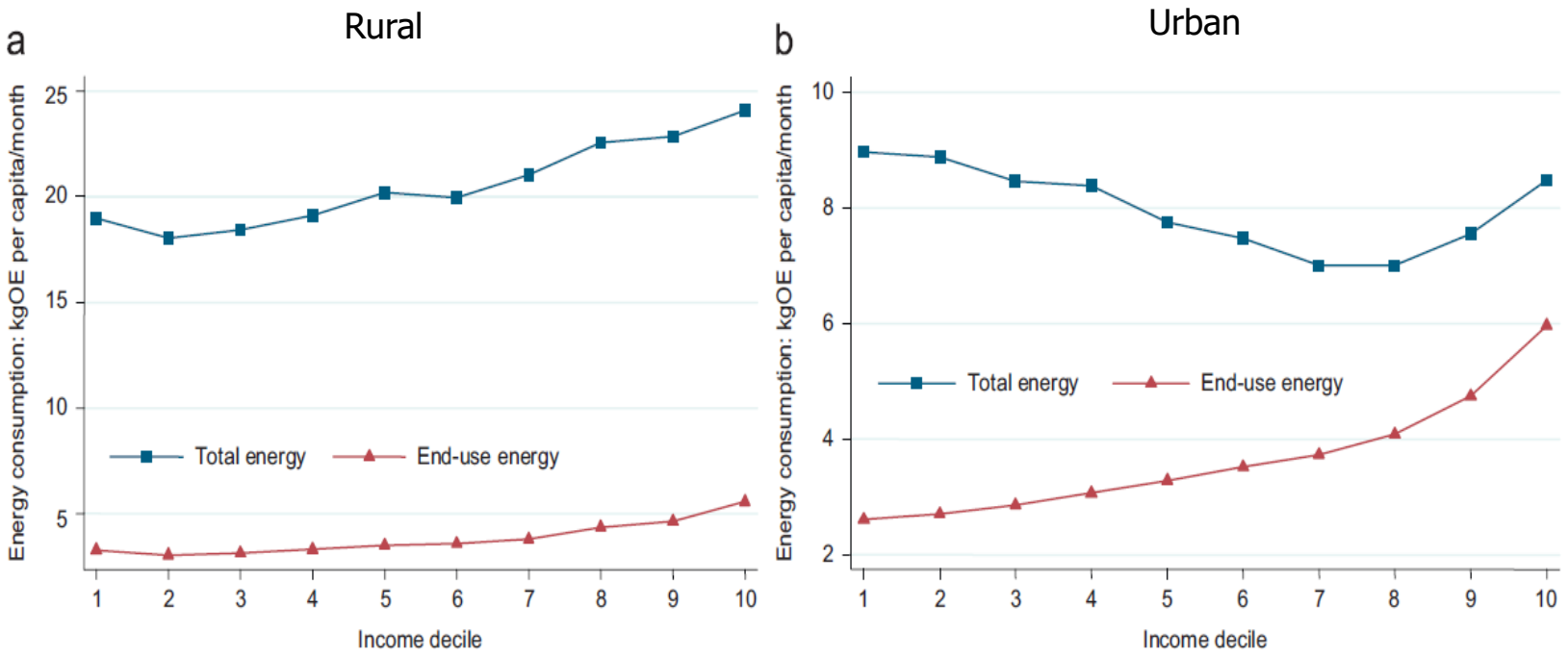
Pachauri and Spreng, 2011, Energy Policy

Ransai Feeder Data Analysis



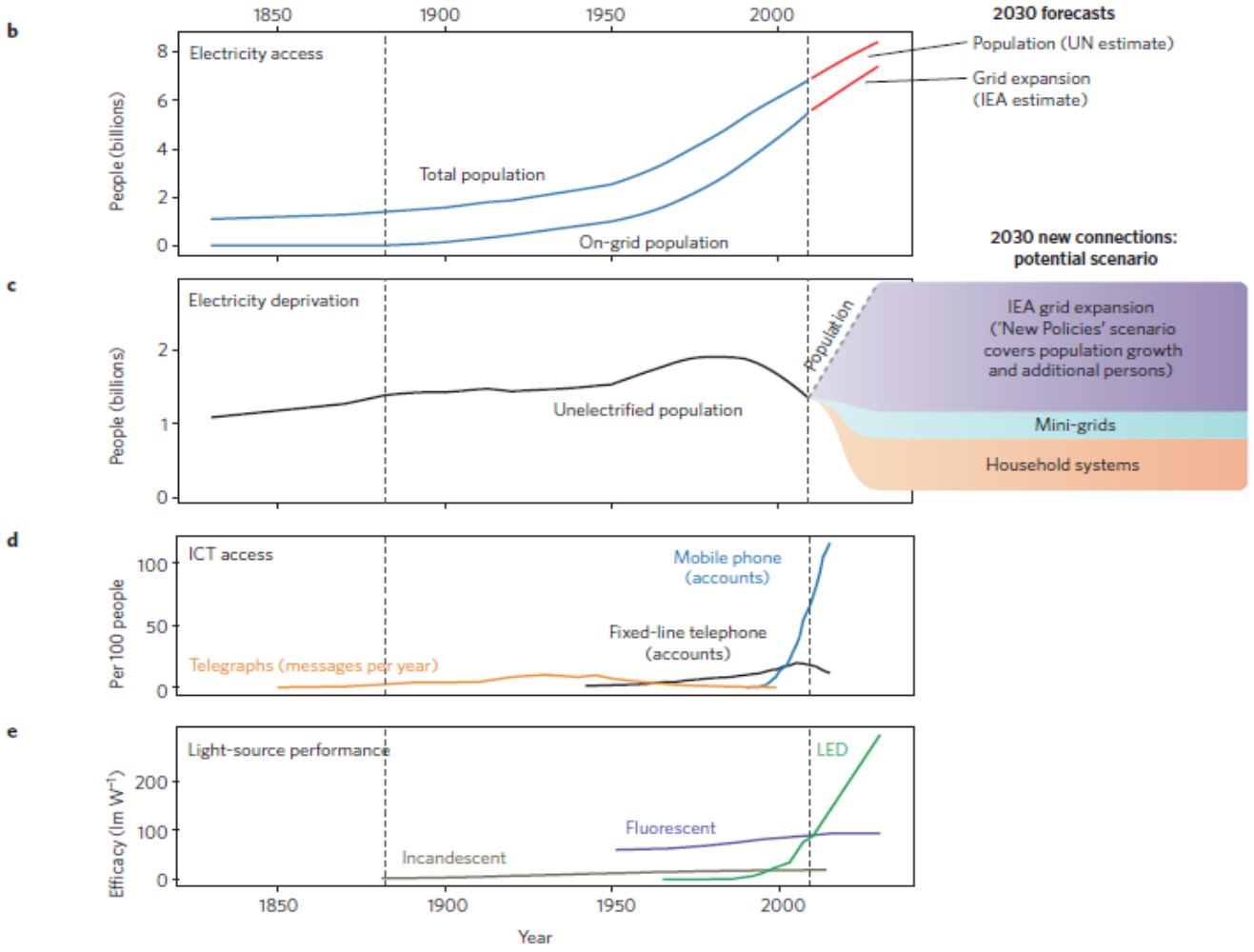


Energy Use Household (2005)

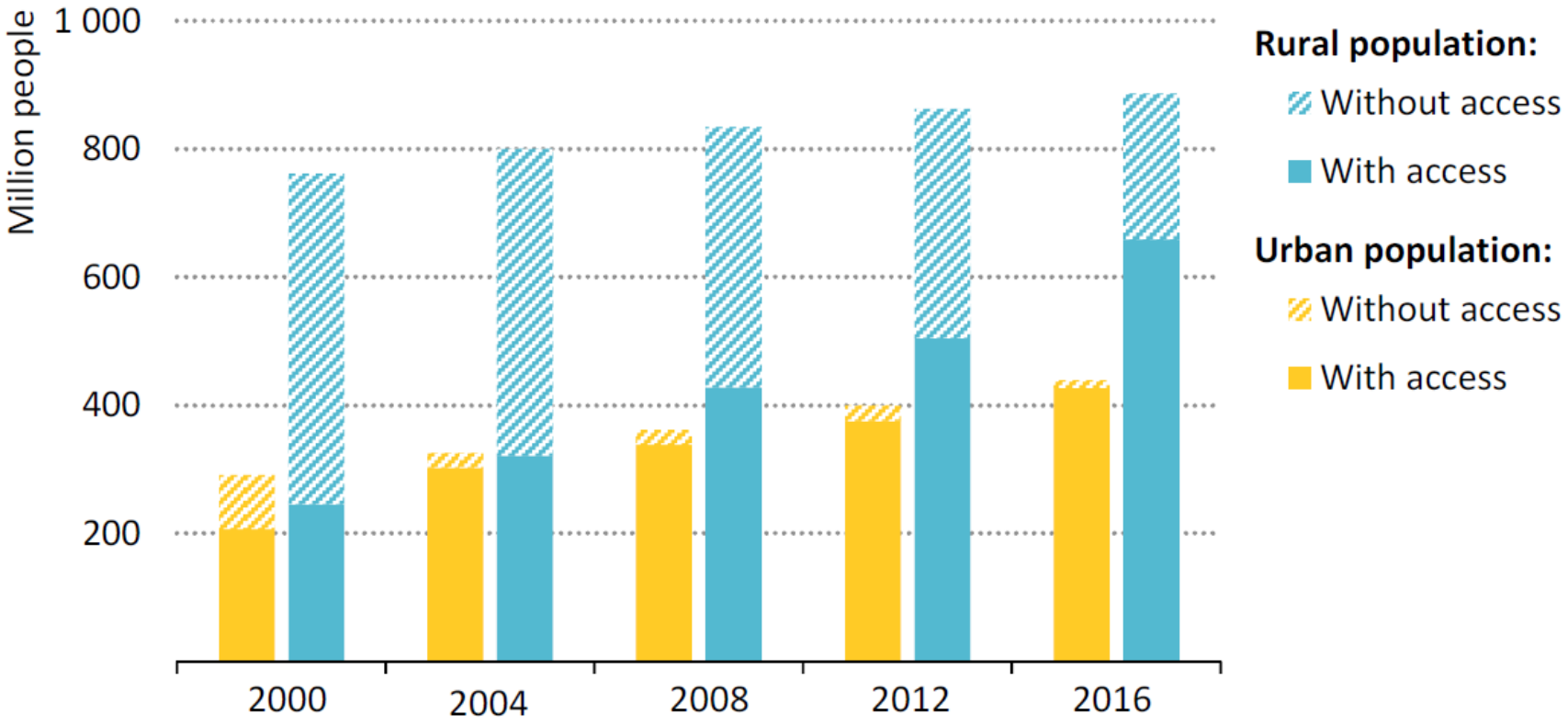


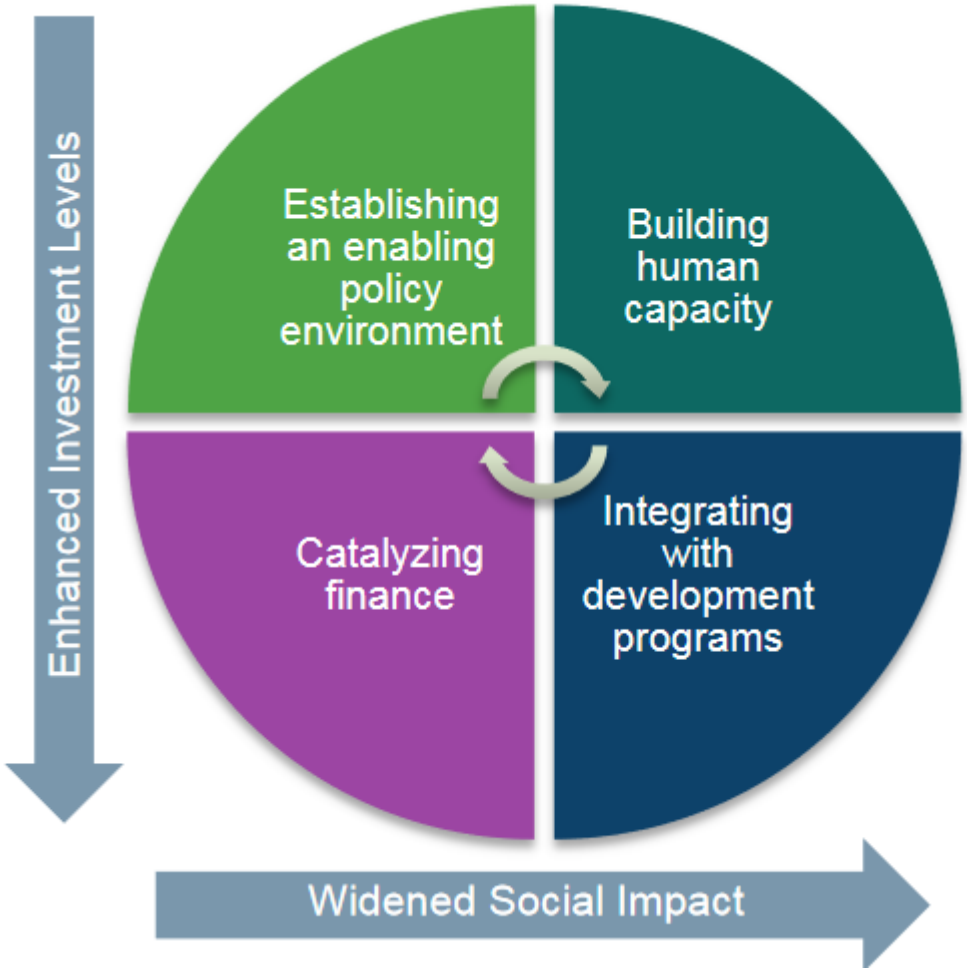
Khandker et al, 2012

Global Electricity Trends



India – Electricity Access



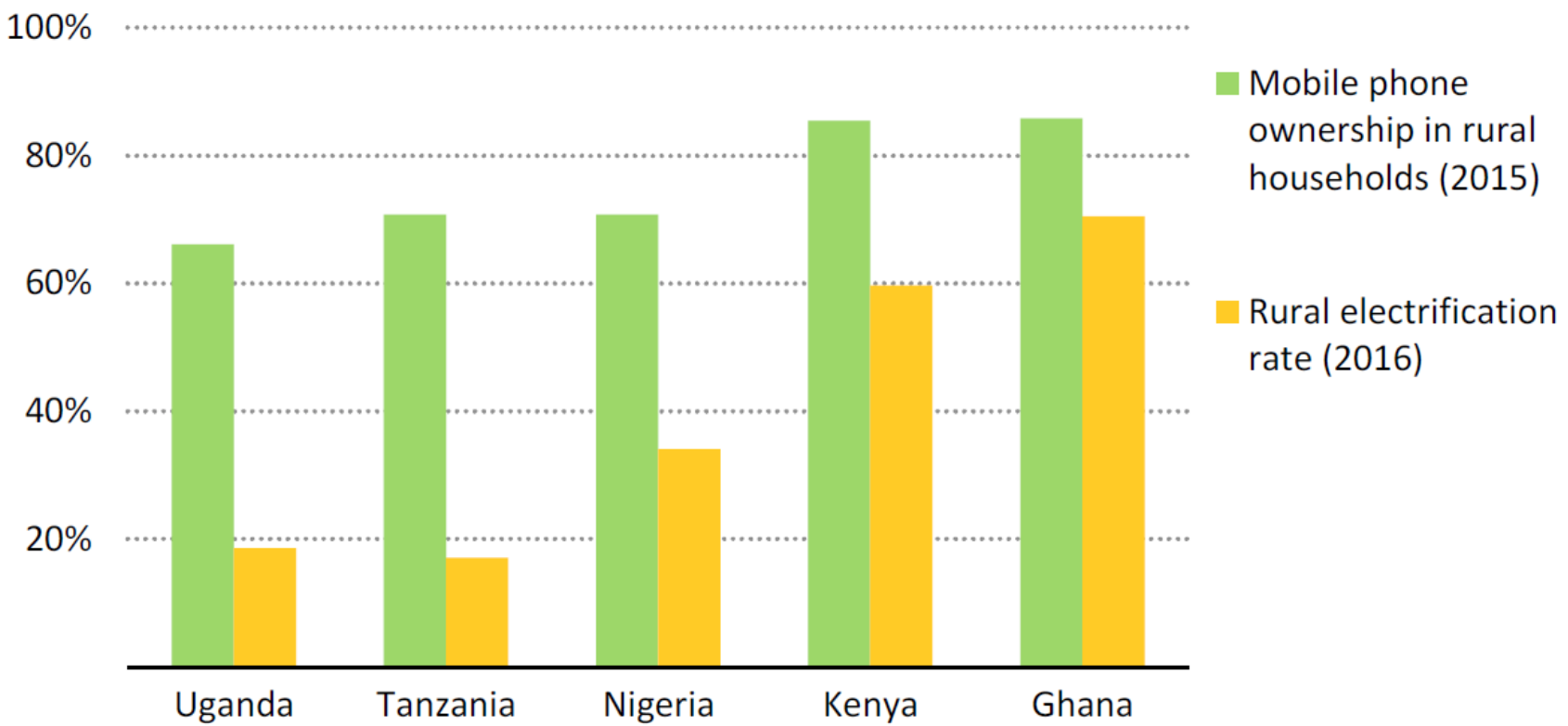

Establishing an enabling policy environment
Building human capacity
Catalyzing finance
Integrating with development programs
Enhanced Investment Levels
Widened Social Impact

NREL, 2015

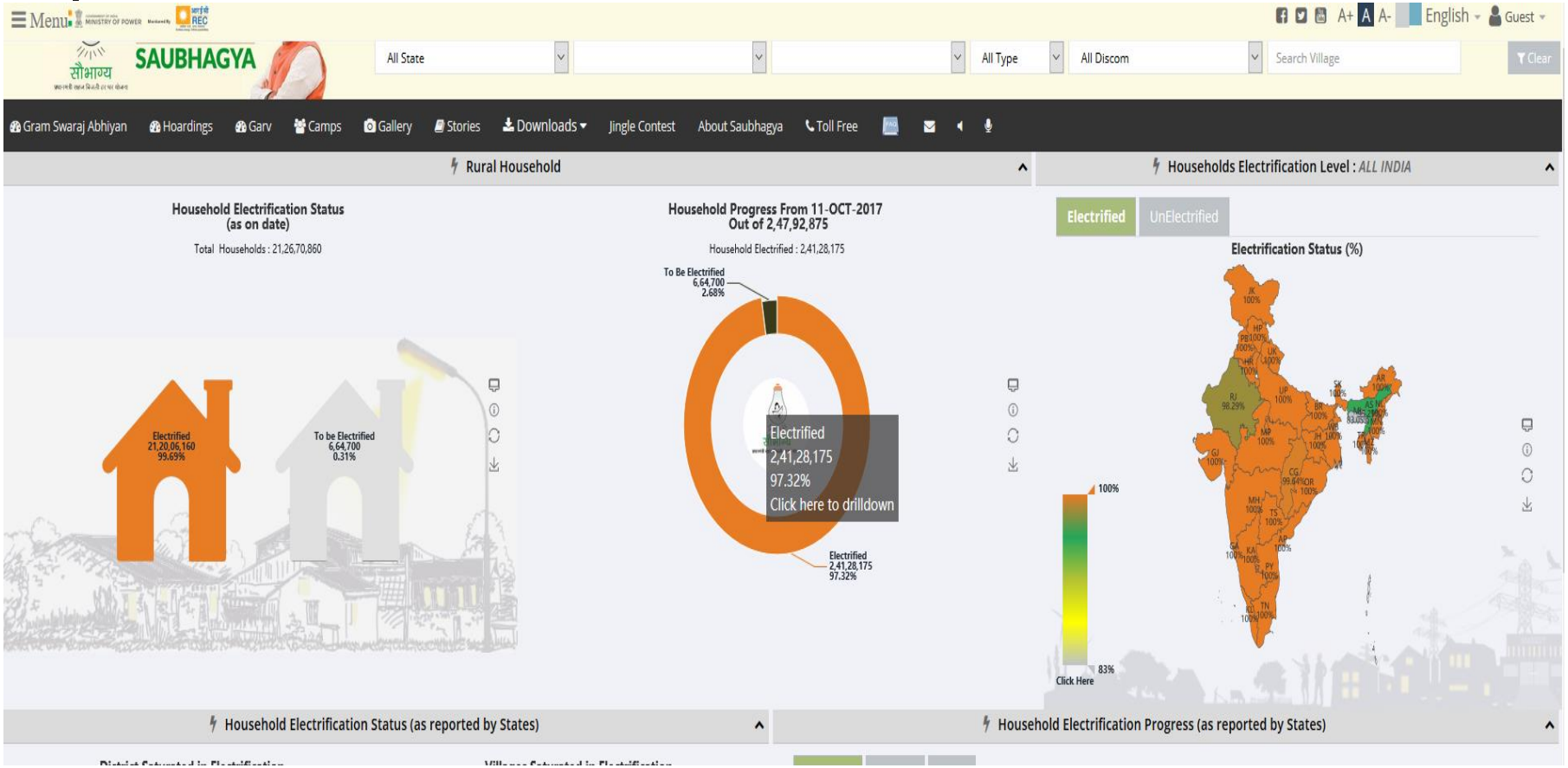
Energy Access Policies

- BPL schemes- Electricity connection- Kutir Jyoti- wiring, meter, one connection (tribal, Annual income < 27000 Rs/ year)
- Bhsagya jyoti scheme
- Pradhan Mantri Har Ghar Sahaj yojana

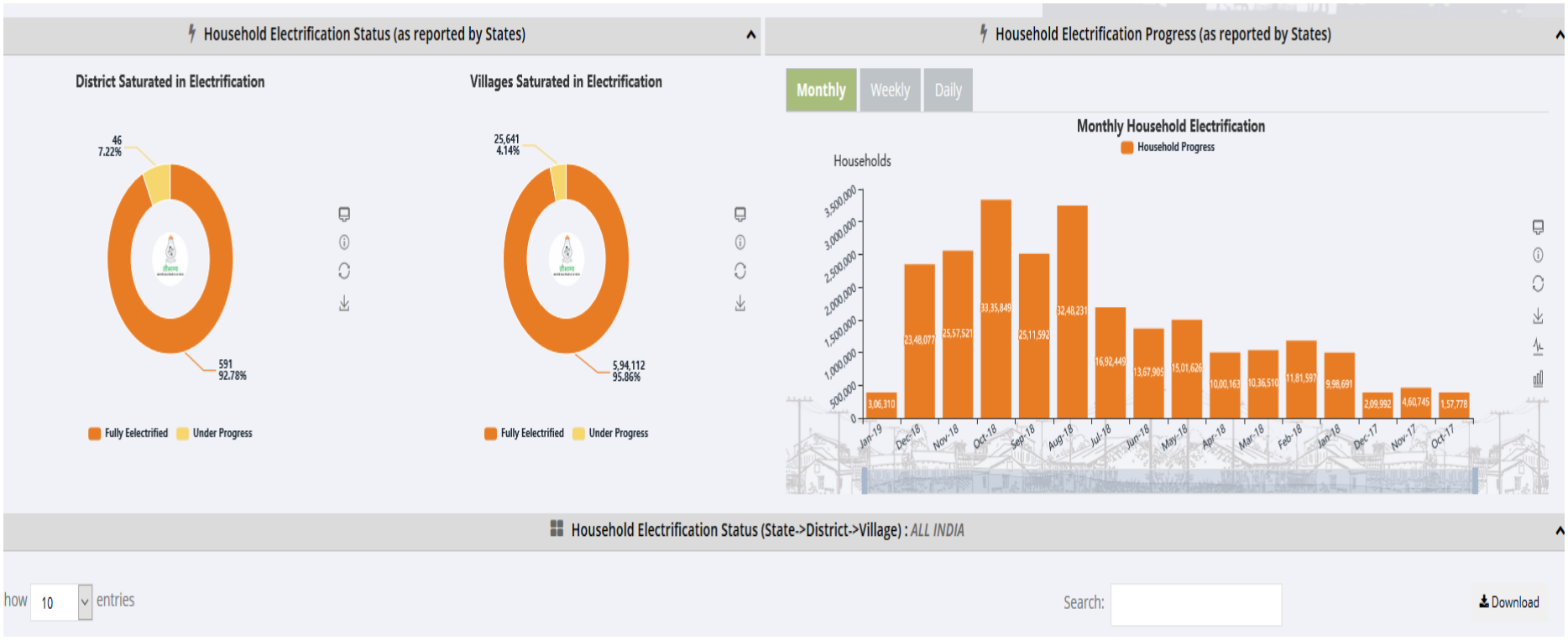
Electrification and Mobile phone



Saubhagya Scheme

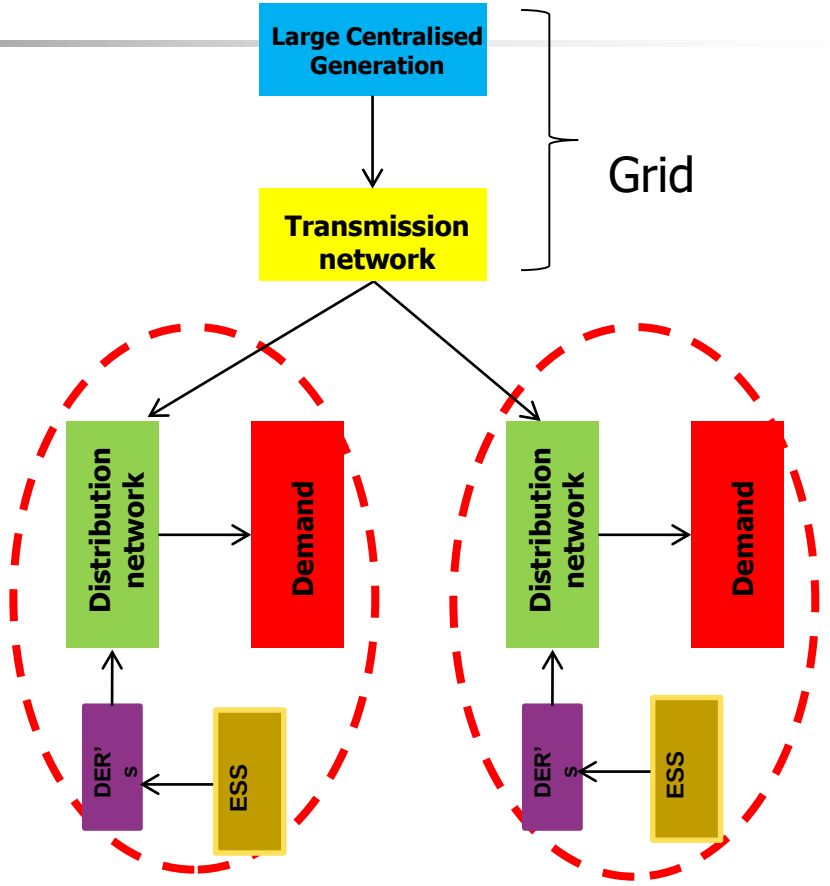


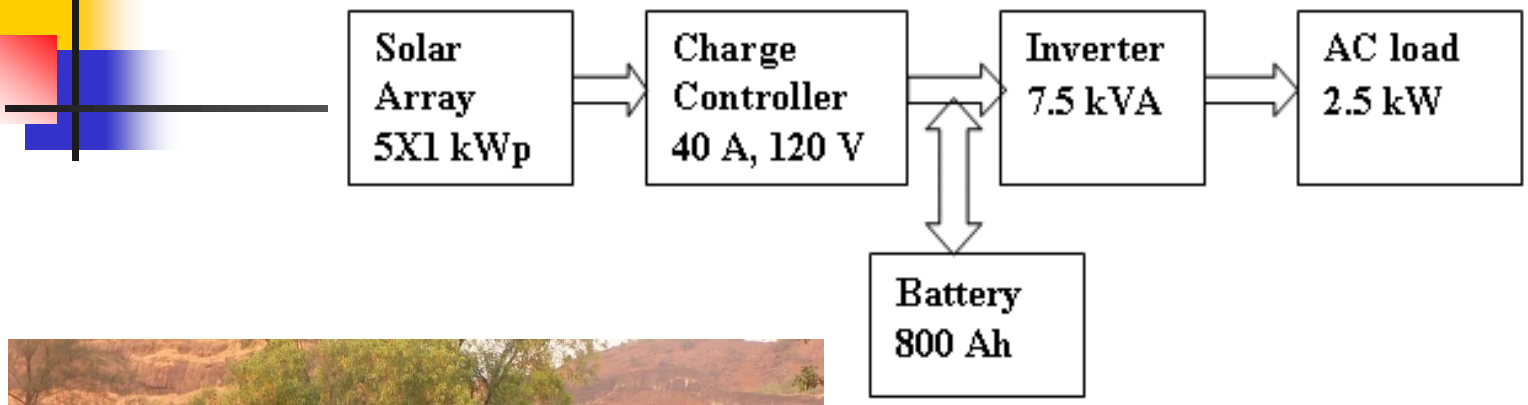
Saubhagya Scheme- Contd

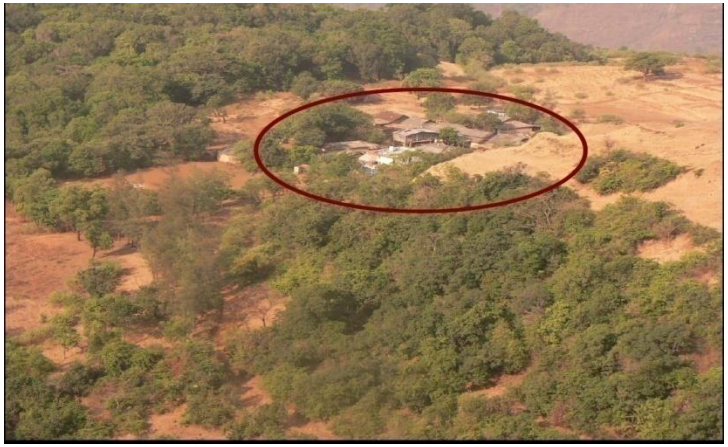


What is a microgrid?

- **Interconnected loads, distributed generation and energy storage devices**
- **Within clearly defined electrical boundary**
- **A single controllable entity with respect to the grid with bidirectional power flow**



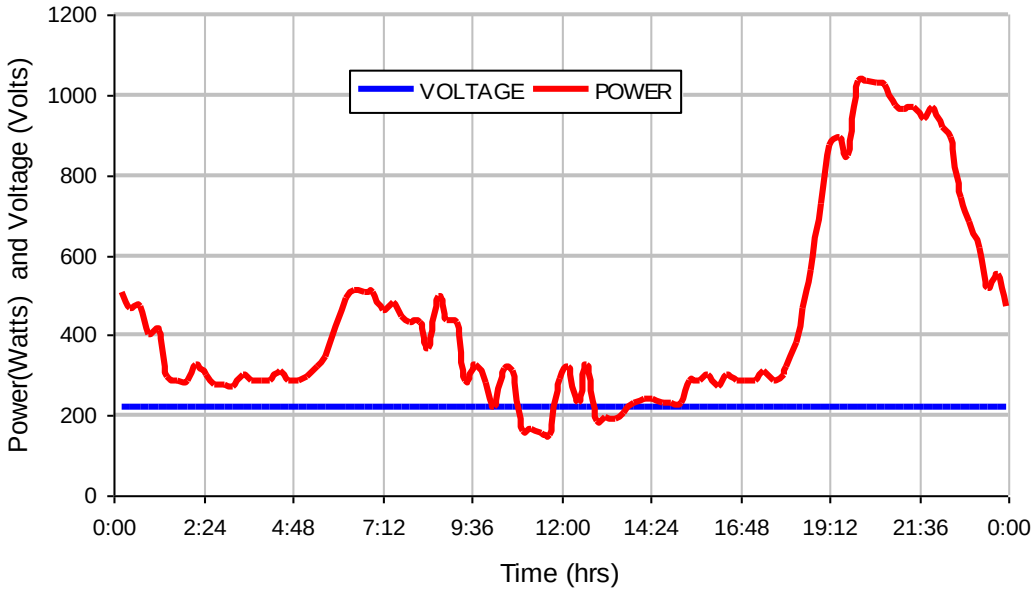




No. of house holds: 29
Connected load : 1.4 kW

5 kWp Solar PV power plant at Rajmachi Village, Maharashtra

Measurements



Integrated design-Summary

Name of the plant	Connected Load (kW)	Plant Capacity		Distribution loss (%)		Plant capacity factor (%)		Energy cost Rs / kWh	
		Existing	Designed	Existing	Designed	Existing	Designed	Existing	Designed
Solar PV, Rajmachi	1.4	5 kWp	4 kWp	4.6	0.5	8.3	11.5	32	25
Biomass gasifier, Dissoli	6.9	10 kW	10 kW	12.3	2.0	8.8	12	29-37	21-25
Biomass gasifier, Lonarwadi	10.7	20 kW	10 kW	14.6	2.7	5.6	14	43-54	16-25

Gram Oorja, Darewada ,Pune

Location	Darewada, Pune, Maharashtra
Size of power plant	9.36 kW
Number of households	36 connections + street lights+pumps
Overall cost of project	₹30,00,000
Tariff	₹20 per unit (prepaid meter)
LCOE	₹22
Implemented by	Gram Oorja
Funded by	CSR fund from Bosch solar
Energy services for	Lighting, television, irrigation
Grid interconnectivity	Not grid ready

Source: Minigrids Electricity for all, CSE, 2016

Gram Power – Rajasthan

Micro-grid technology provider Gram Power has installed prepaid smart metres in Pali district, Rajasthan

Location	Neechli Babhan, Rajasthan
Size of power plant	5.5 kW
Number of households	80 connections
Overall cost of project	₹25,00,000
Tariff	₹31.25 per unit (prepaid meter)
LCOE	₹27.00
Implemented by	Gram Power
Funded by	MNRE Subsidy, Foreign Funds
Energy services for	Lighting, Television
Grid interconnectivity	Grid ready
Grid presence	No

Source: Minigrids Electricity for all, CSE, 2016

Husk Power System - Sahebganj Village

Location	Neechli Babhan, Rajasthan
Size of power plant	32 kW
Number of households	400 connections
Overall cost of project	₹18,00,000
Tariff	₹30 for 100 W
LCOE	₹6.90
Implemented by	Husk Power Systems
Funded by	MNRE and Husk Power
Energy services for	Lighting, television, flour mill
Grid interconnectivity	Not grid-ready
Grid presence	Yes

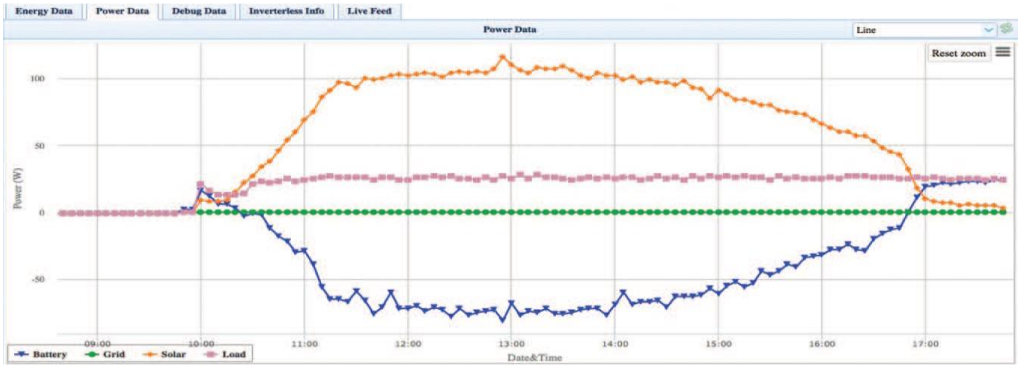
Source: Minigrids Electricity for all, CSE, 2016

Bhomji Ka Gaon,Rajasthan

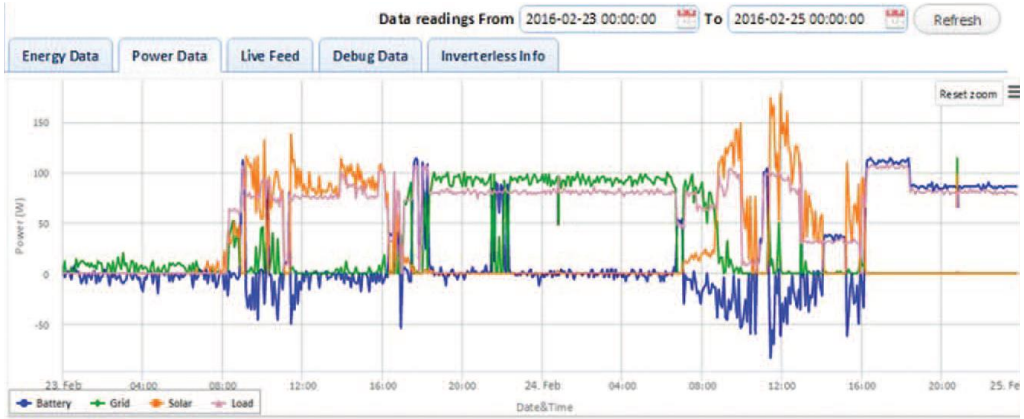
Off grid dc inverter less system, Rajasthan

Location	Bhomji Ka Gaon
Type	On grid and off grid connections
Size of power plant	500 kWp
Number of households	4000

Source: Solar-dc Microgrid for Indian Homes, IEEE, 2016

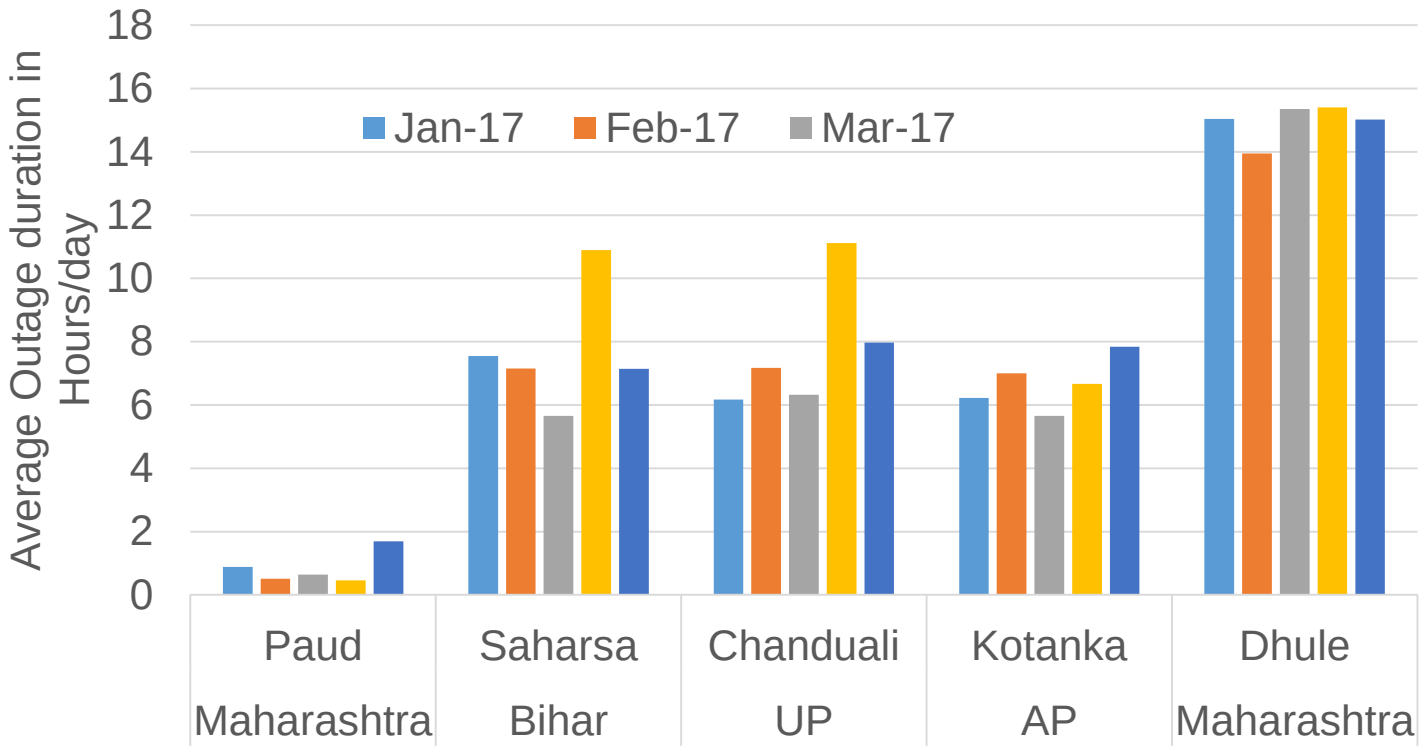


The power data measured over a day in an off-grid home in Rajasthan with a solar dc Inverter less system on 25 February 2016



The power data measured in an on-grid home with a solar-dc inverterless system from 23 February 2016
to 24 February 2016.

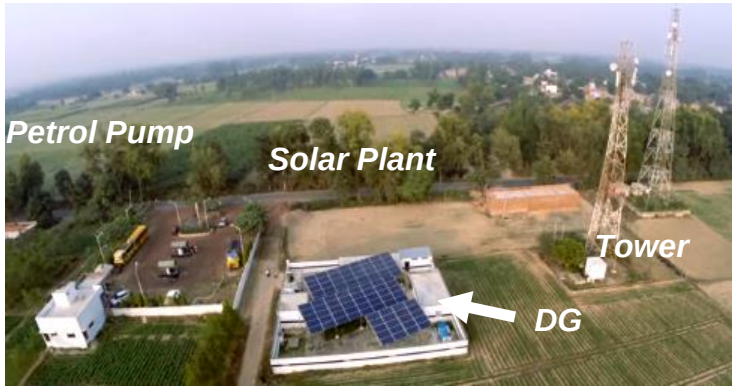
Rural Electricity Outage



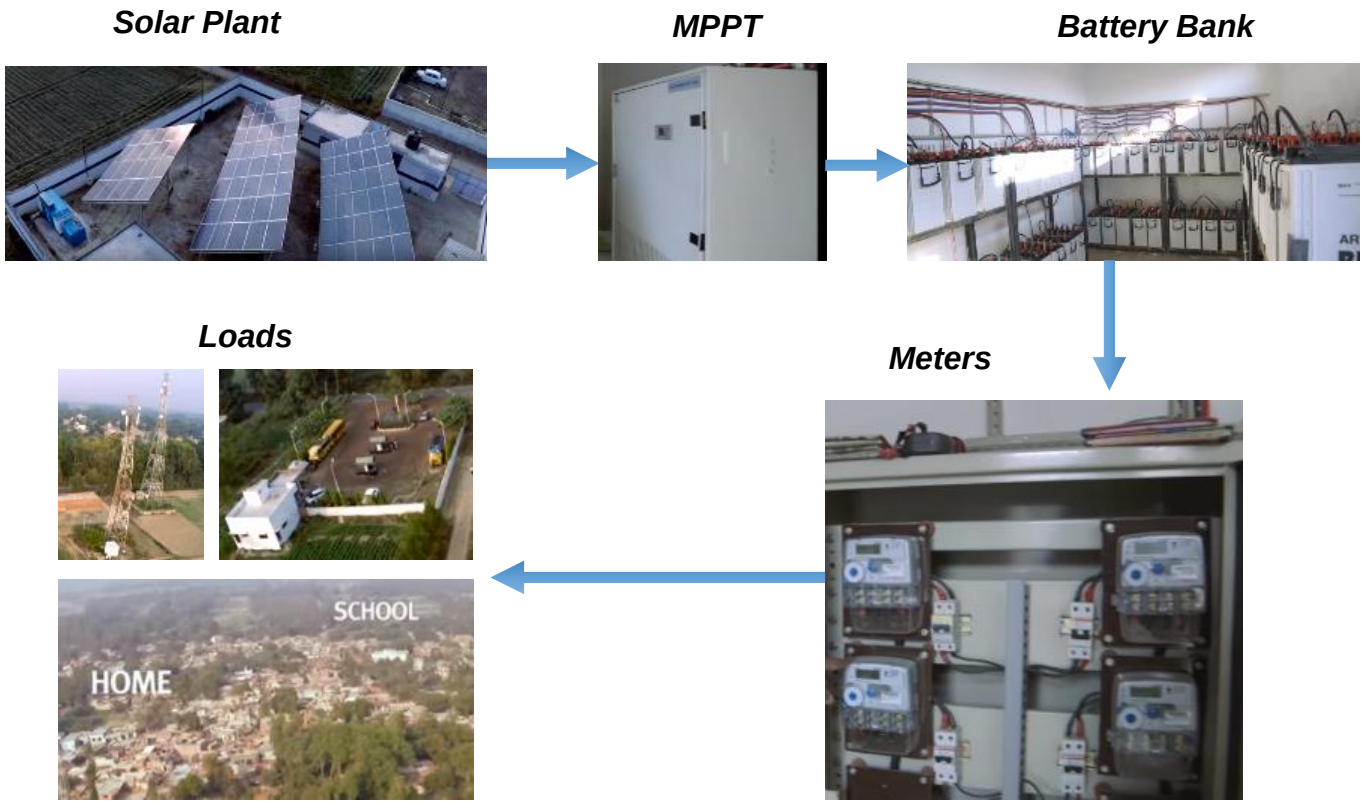
http://www.watchyourpower.org/download_raw_data.php

Successful Commercial development – OMC power

- Running more than 50 plants in UP
- Solar PV based power generation systems
- Typical plant size – 30-36 kW, 150 kWh battery back up,
- Focused around – Telecom tower as key customer – Agreements with telecom tower suppliers
- Meter based charging to large customer like Telecom tower, other productive loads, package to community customer
- Use of DG as back up power for rainy seasons



OMC power – Plant



Husk Power – Biomass gasification based power generation system

- Running more than 50 plants in Bihar & UP
- Operation through various model based on level of engagement (Ex. BOOM – Build own operate & Maintain)
- Biomass Gasifier engine based power generation system, typical plant size – 32 kW
- Rice Husk as fuel – Engagement with rice mills for bulk procuring
- Focused around – Market places, small productive loads, collection on daily basis
- Electricity supply in Different packages
- Unique features:
  - ✓ Local fuel utilization – Lower fuel cost
  - ✓ Gas cleaning system – uses rice husk
  - ✓ Low cost material and local fabrication – Low capital cost
  - ✓ Training and capacity building of operator – Low downtime
  - ✓ Local material for distribution network – Low cost
  - ✓ Use of waste Ash from gasifier – Intense making ; local job creation

Husk Power – Biomass gasification system

Mini grid based on Hybrid system – HUSK Power

- Recently husk power has installed hybrid system with an intent to supply 24X7 electricity
- Around 3-4 hybrid plants being operated by Husk power
- Technology – Biomass gasifier engine system, Solar PV system and Battery
- Technical Arrangement: Electricity supply during day time by Solar PV system and during evening time by Biomass gasification system
- Electricity supply in Different packages
- Motivation for hybrid system:
  - ✓ Lower solar PV cost
  - ✓ Increasing demand from users
  - ✓ Willingness to use electricity in day time also

COMPANY	OUTREACH	CURRENT TARGET	COUNTRIES	ENERGY SOURCE	SIZE RANGE	FOCUS/INNOVATION
E.ON	7 systems, 420 customers	1m people in 10 years	Tanzania	Solar, bio-diesel	6–12kW	Standardisation for scale; Establish track record for finance Cellphone payment
GHAM POWER	3 micro-grids	>100 micro-grids in 10 years	Nepal	Solar	1–10kW	PPA with N-cell (telecoms) for reduced risk revenue stream Rent-to-own agreements
HUSK POWER	15,000 house-holds, several 100 businesses	75,000 house-holds, 10,000 businesses, 125 agro units	India Tanzania	Biomass, Solar	15–250kW (biomass); 20kW (solar)	Accept >5 year payback Targeting 8–10 year loans Rural empowerment 3-year expansion plan Inclusive business model
INENSUS	Supports mini-grid development in Africa with related management systems and consultancy		Senegal	Solar, Wind	5–10kW	Low-cost smartcard meter Sale of "electricity blocks" "MicroPowerEconomy" delivery system—flexible tariffs & micro-credit
M-KOPA	340,000 homes (Mar 16)	+500 homes/ day	Kenya, Tanzania, Uganda,	Solar	5–20W	PAYG business model Small SHS, LEDs & mobile phone charging services
POWERGEN (RENEWABLE ENERGY)	20+ mini-grids	50 mini-grids in 2016	Kenya & Tanzania, Zambia	Solar	1–6kW	Mini-grids compatible with central grid standards
POWERHIVE	4 sites, 1500 people (~300 connections)	100 villages	Kenya, Philippines (Africa/Asia expansion)	Solar	~20kW	Integrated tech system; Mobile money networks for pre-payment Dedicated software—predict revenue streams;
RUAHA POWER	1 pilot project (JV with Husk Power)	100 projects	Tanzania	Solar, biomass	300kW	Business model without subsidies Build Own Operate model Pre-payment meters
SPARKMETER	3 Earthspark mini-grids in Haiti	No fixed target	Asia, Africa, Latin America	Service for all types of mini-grids	0–500W	Metering with mobile payment system Cloud-based software "Gateway" usage dbase

	Decentralized Renewable Energy: Biomass and Small Hydro	Solar Home Systems	Solar Lanterns	Energy-Efficient Cookstoves
Potential Market /yr	Rs 94.06 billion	Rs 1.26 billion	Rs 855 million	Rs 1.11 billion
Avg Price	IRs 8 to 13 /kWh (B) INR 2 to 2.5 /kWh (H)	Rs 7,000 - 20,000	Rs500 -1,600	Rs 150 -1,100
Competitive Advantage	operational reliability , low upfront cost.	Customised solution.	Kerosene replacement	Reduced fuel costs; health benefits
Business Model	B: Company-owned minigrids; electricity priced to existing fuel expenditure levels. H:using existing grid infrastructure; paid at government-tariffs.	Sold on credit, in partnership with local banks. Users typically pay 10 to 25 percent upfront and the rest in installments.	Bulk sales to corporate, NGO, and (MFI) partners; sold directly to consumers through local retailers.	Sold through multiproducts rural distributors and retailers; partnerships with MFIs and NGOs.

Source:IFMR- WRI, 2010

Selco Case study

- For profit company – Solar Home systems – started 1996 – sold about 100,000 SHS
- 90% of products – credit schemes
- Partnership with 9 banks – interest rates between 12-17%
- Financing Institutions pay 85% of the amount- monthly payments of Rs 300- 400 over a period of 5 years
- Financing/ repayment options – tailormade to end users – paddy farmers – repayment schedule based on crop cycle, street vendors – daily payments – Rs 10
- Funding from REEP – meet margin amount for poor customers, reduce interest rate

Source: SELCO, 2011

DESI Power

- Biomass based power solutions – Bihar- 25 kW to 100 kW
- Local distributors – decide pricing
- Registered under CDM and sold CERs to Swiss buyer
- MNRE funds, Promoters Equity, ICICI Loan
- Monthly rate based on no of bulbs / loads, Circuit breaker to limit consumption
- Irrigation pump users Rs 50/ hour, Household Rs 120- 150 per month
- Underground trunk wiring-distribution
- Enabling micro-enterprises –battery charging station, flour mill, workshop etc
- Tie up with Telecom towers – increasing capacity factor

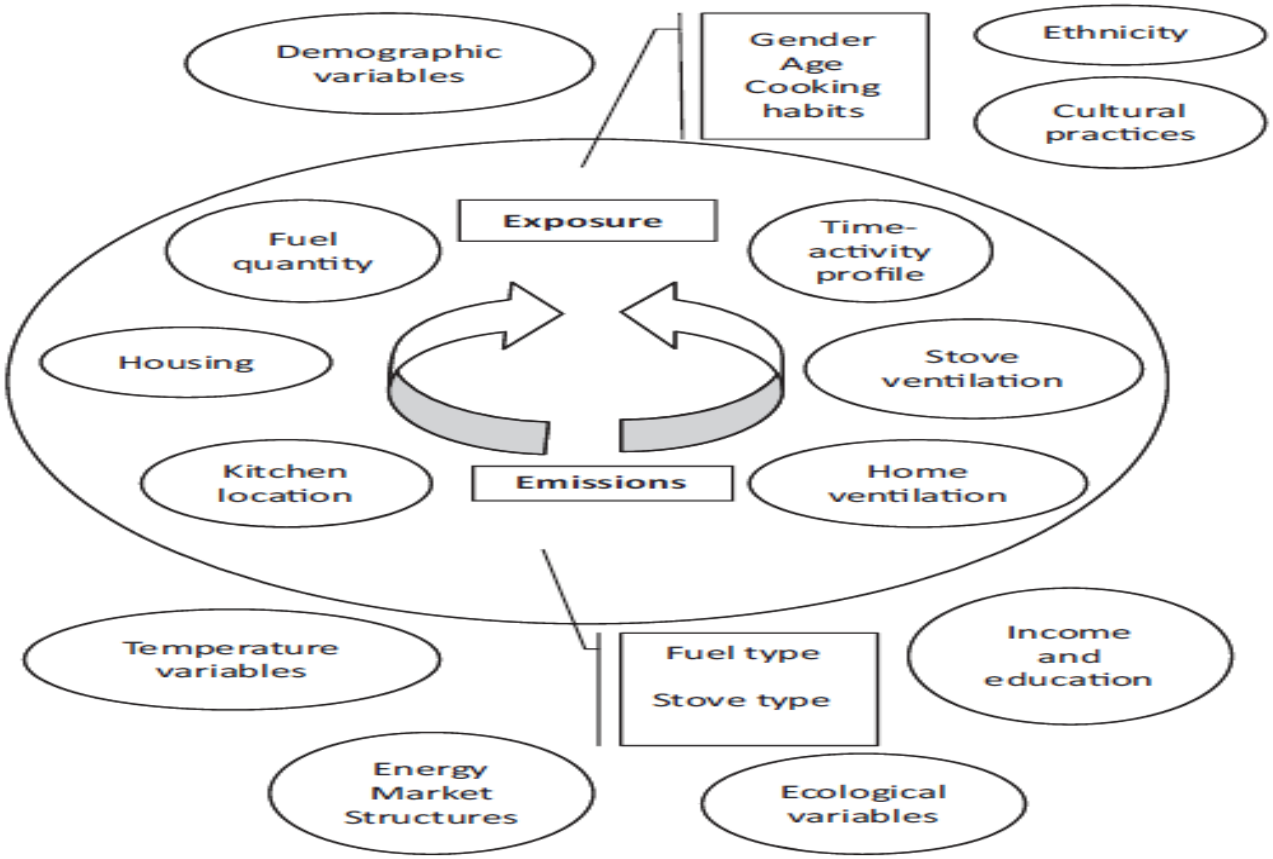
Husk Power

- Initial funding – prize money
- 30-100 kW – biomass gasifiers- based on rice husk
- Energy audit of households
- Focus on household demand for lighting
- Lower production, operating costs – use of bamboo, asbestos
- Overhead pole wiring
- Directly reach end user

Disability Adjusted Lost Years

- One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. (Source: WHO)
- DALY = YLL +YLD

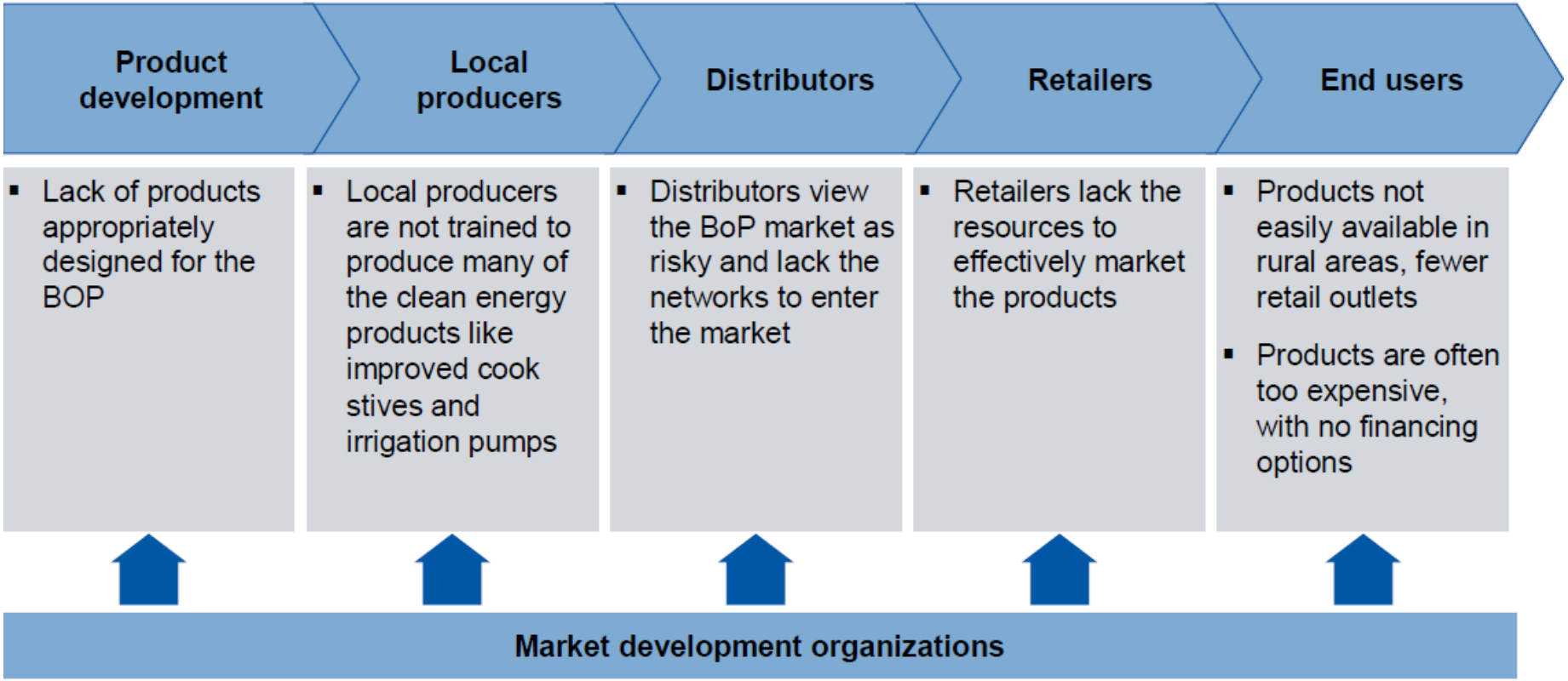
Indoor Air Pollution



GEA Chap 4

Unmet needs : Targeting the poor

Unmet needs along the supply chain

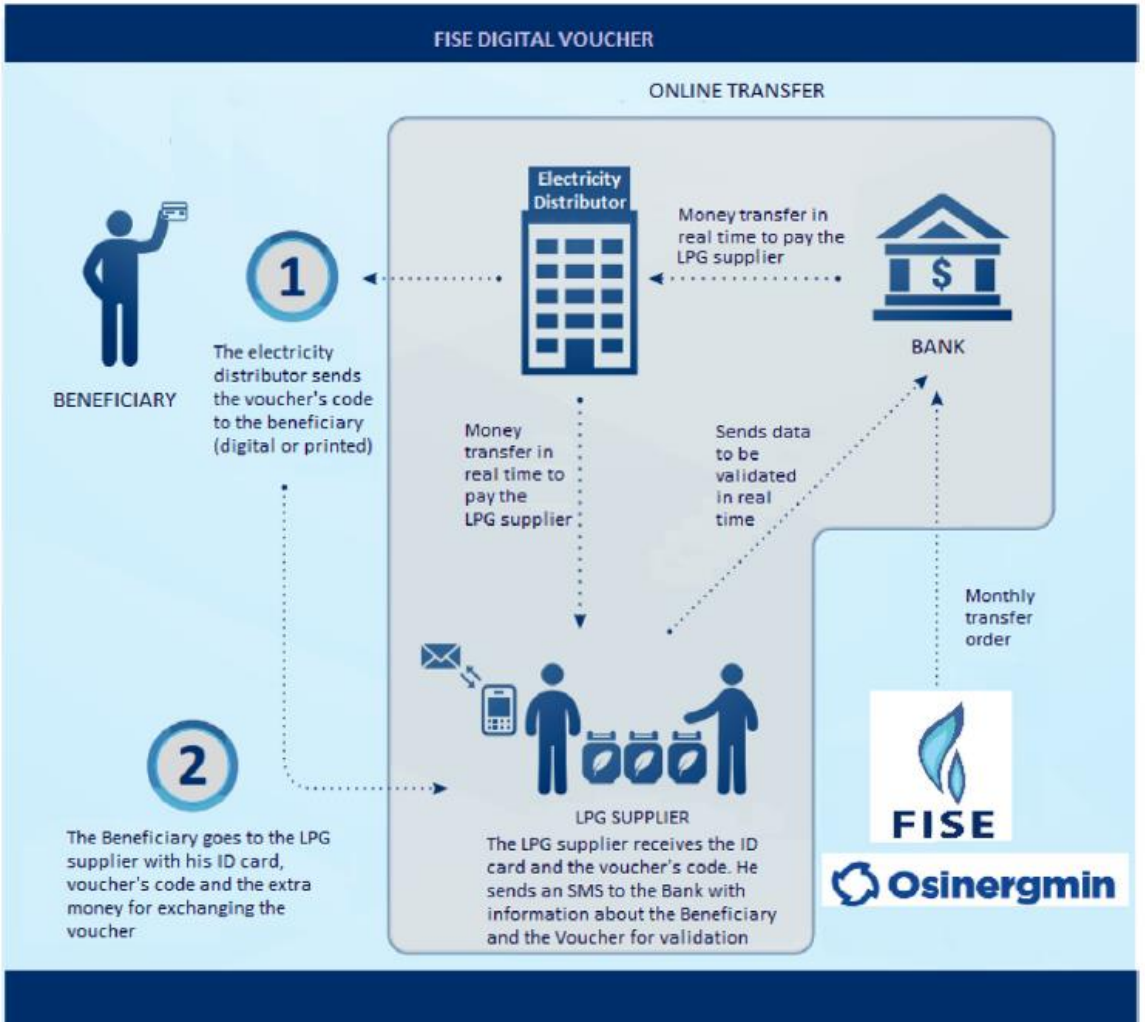


Source:IFMR- WRI, 2010

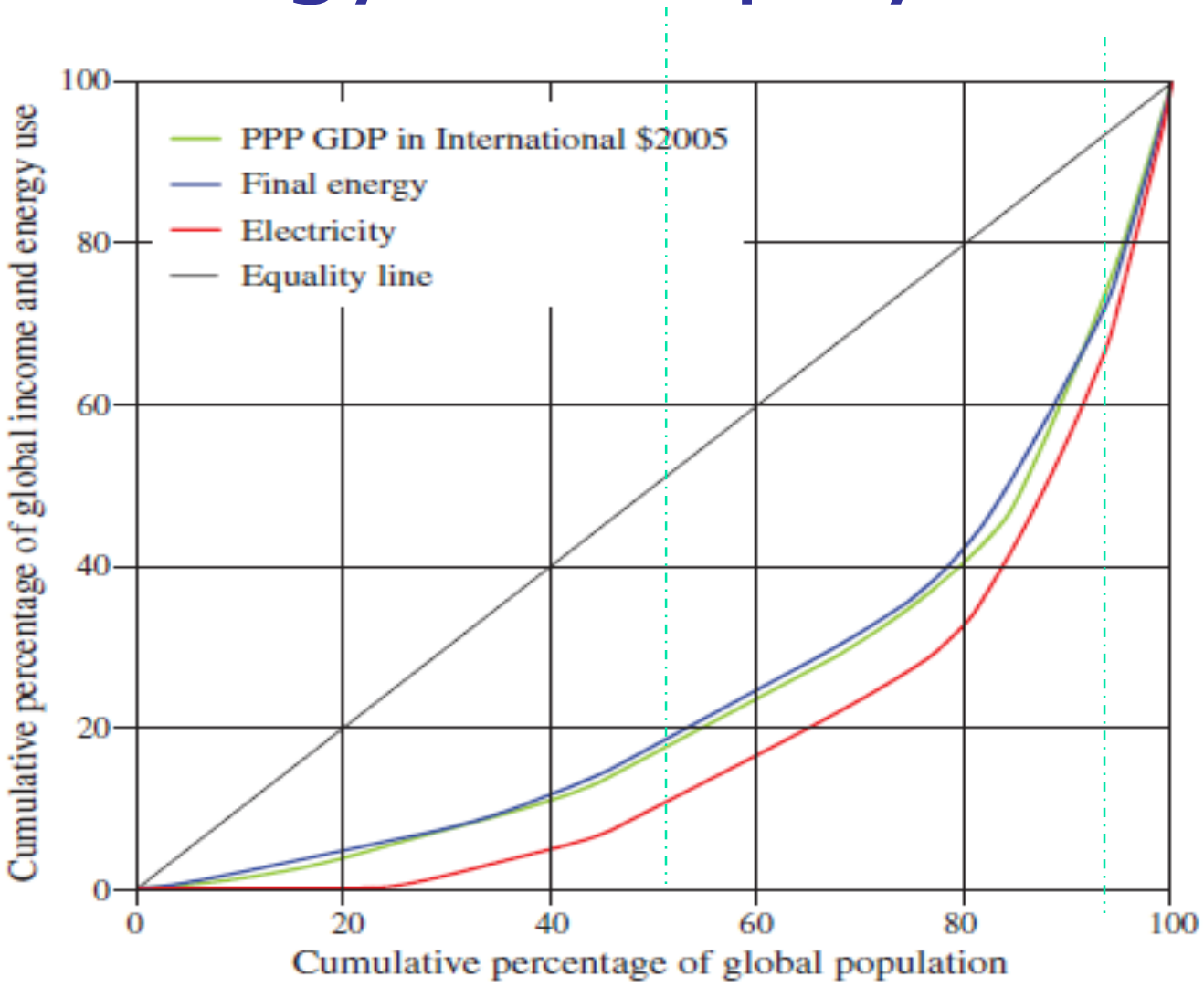
Biomass Cooking and Gasifier Stove

Source: www.arti-india.org/

Assessment LPG Access Peru



Energy and Equity



Source: GEA, 2012

Lorenz Curve

- L(x) – Proportion of income earned by the lowest x proportion of population
- L(0) = 0 L(1) =1, L increasing function
- Extreme Cases

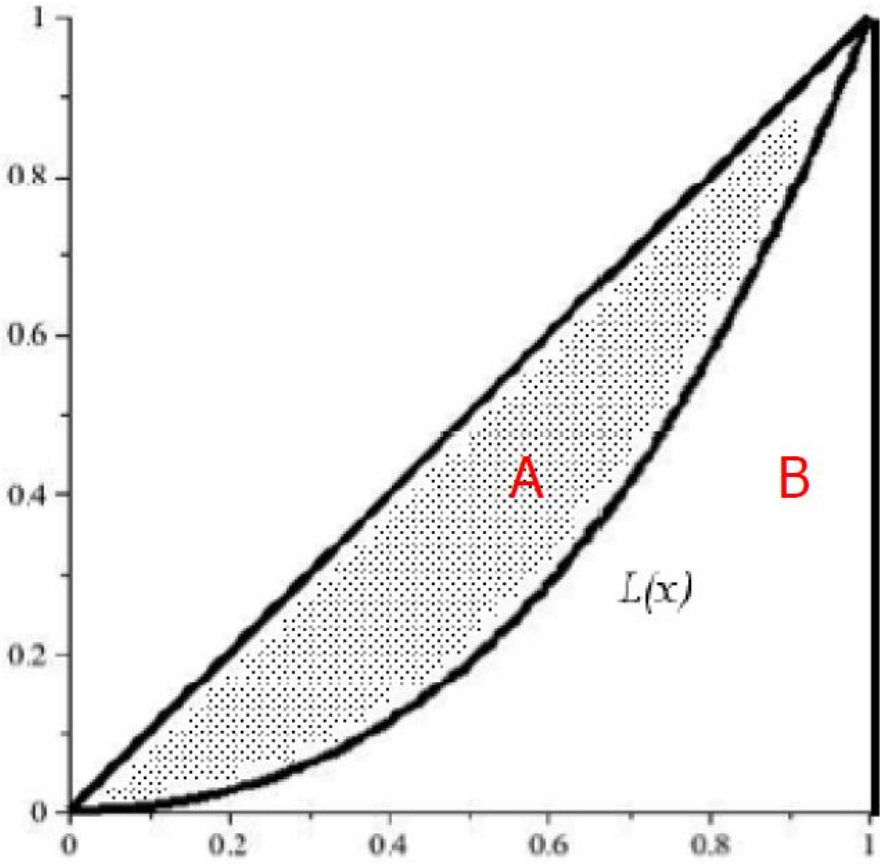
  L(x) = x 45% line Absolute equality – all earn the same

  Absolute Inequality

  L(x) = 0 0≤ x < 1, L(1) =1

Nobody earns any income except one person

Lorenz Curve



Gini Coefficient

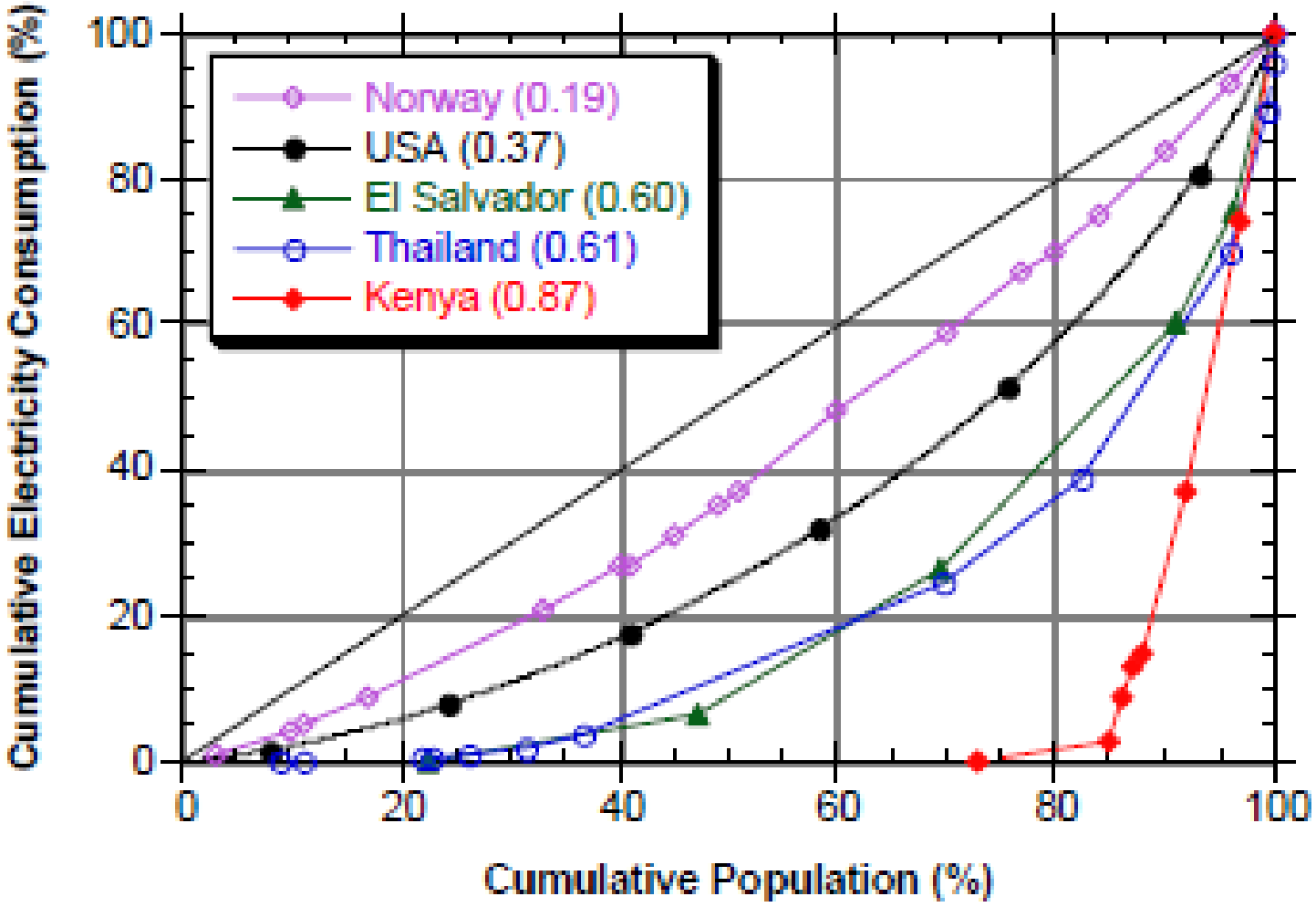
- Gini coefficient = A/ (A+B)
- A+ B = 0.5
- Gini coefficient = 2 A

$$= 2\int (x - L(x))dx$$

$$= 1\text{-}2B = 1 - 2\int L(x)dx$$

$$G_c = 1 - \sum_i (Y_{i+1} + Y_i)(X_{i+1} - X_i),$$

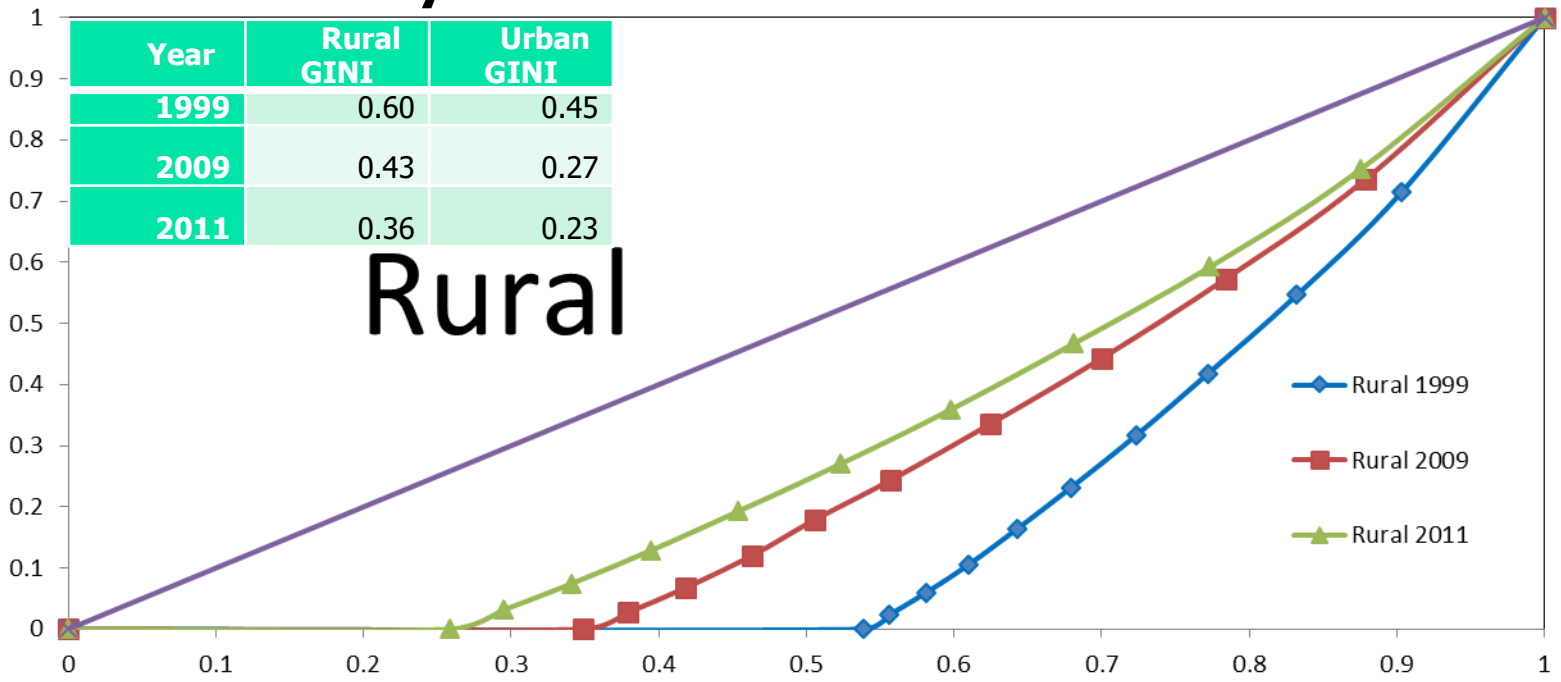
Residential Electricity Gini (Select countries)



Source: Jacobsen, Energy Policy , 2005

Electricity Lorenz Curves India

Year	Rural GINI	Urban GINI
1999	0.60	0.45
2009	0.43	0.27
2011	0.36	0.23



Source: K.Mehta 2014