

# Analysis of the Energy Access Improvement in Developing Countries through Rural Electrification

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# Outline

- Background and purpose
- Regression analysis
- Model analysis
- Result
- Conclusion

# Energy and poverty reduction

## Health

- Using modern energy reduces exposure to hazardous pollutants.
- Avoiding drudgery improves health condition.
- Access to electricity enables vaccination and medicine storage.

## Education

- Lighting appliances enables to study at night.
- Utilization of modern energy results in freeing up from drudgery and creating time for study.
- Electricity helps narrow the digital divide through Information Communication Technologies (ICTs).

## Energy

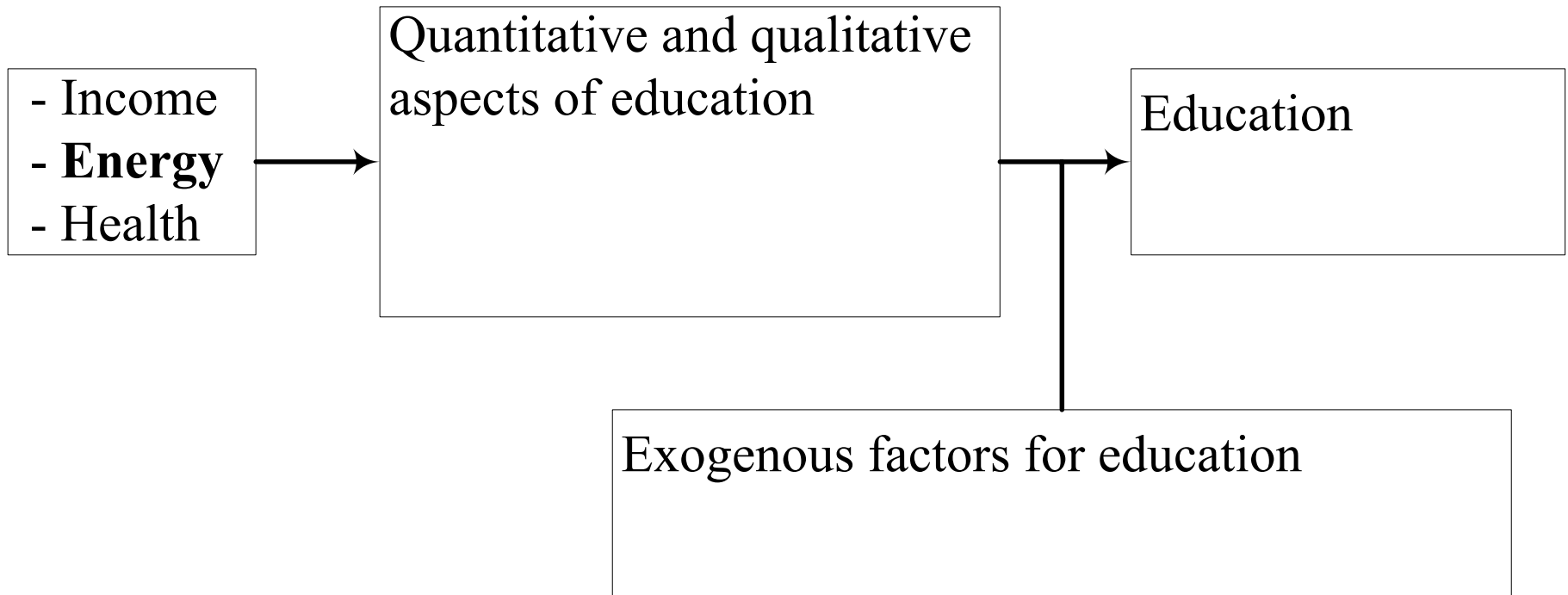
## Income

- Enterprise development through electrification creates job.
- Mechanization in industry achieves higher productivity.
- Small-scale energy system generates local industry.

## Environment

- Reduction in use of fuelwood prevents deforestation.
- Use of efficient appliances saves energy consumption.
- Application of renewable energy promotes climate protection.

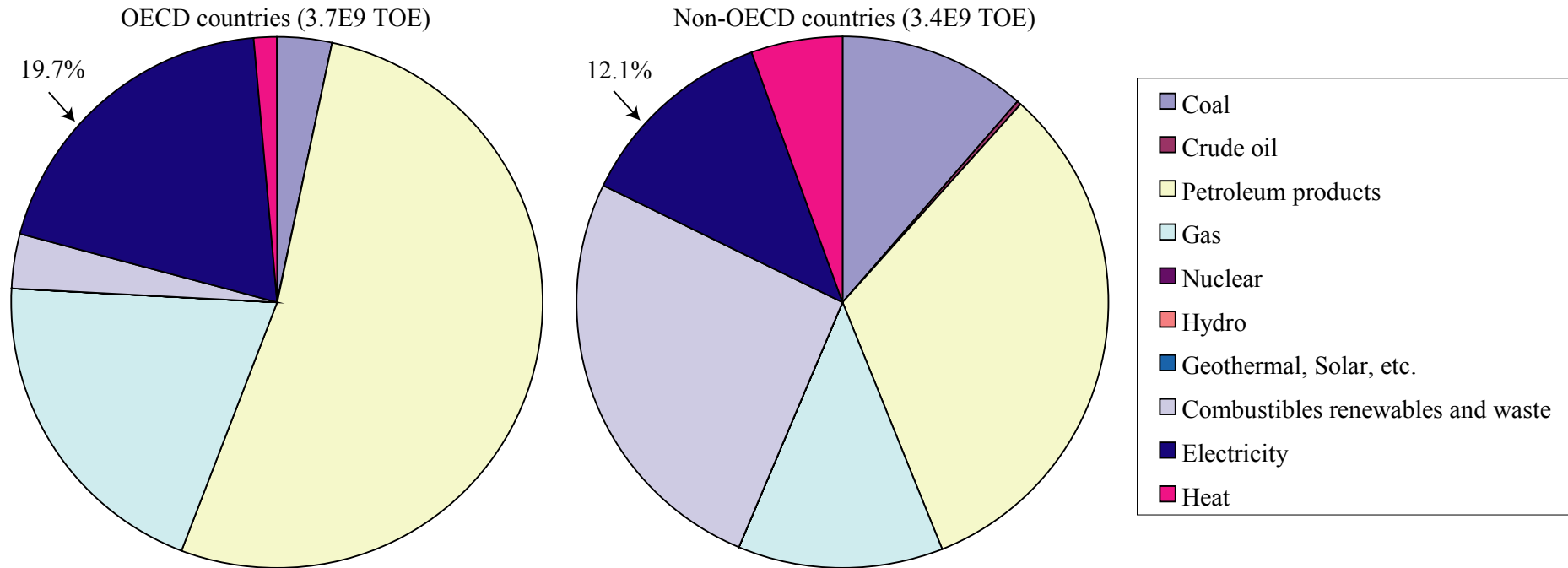
# Energy and education



- increase in number of  
access to education.

# Electricity consumption in developing countries

Total final energy consumption



Developing countries	2000	2030
Population without electricity	1.6 billion	1.4 billion
Population dependent on traditional biomass	2.4 billion	2.6 billion

Source: IEA, IEA Information Centre. <http://www.iea.org/Textbase/subjectqueries/index.asp>  
 IEA, 2002. Energy & poverty. In: World energy outlook 2002.

# Energy situation in India

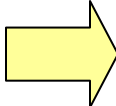
- Country as a whole increases electricity consumption steadily.
  - Electricity consumption: 360.4TWh (2003)
  - Growth rate: 6.3% (2003)
- Electrification rate
  - Village electrification: 74.4-76.1%
  - Household electrification: 43.5%
- Energy policy of the Government of India for electrification
  - “Mission 2012: Power for All”: Complete household electrification by the year 2012.

Source: Central Electricity Authority, 2005. General review 2005.  
Ministry of Power, 2005. [http://powermin.nic.in/rural\\_electrification/status.htm](http://powermin.nic.in/rural_electrification/status.htm).

# Purpose

- Reveal the relation between energy and education in rural areas of developing countries.
- Analyze the possibility of energy access improvement through electrification.
- Estimates the potential of increase in literacy rate quantitatively.

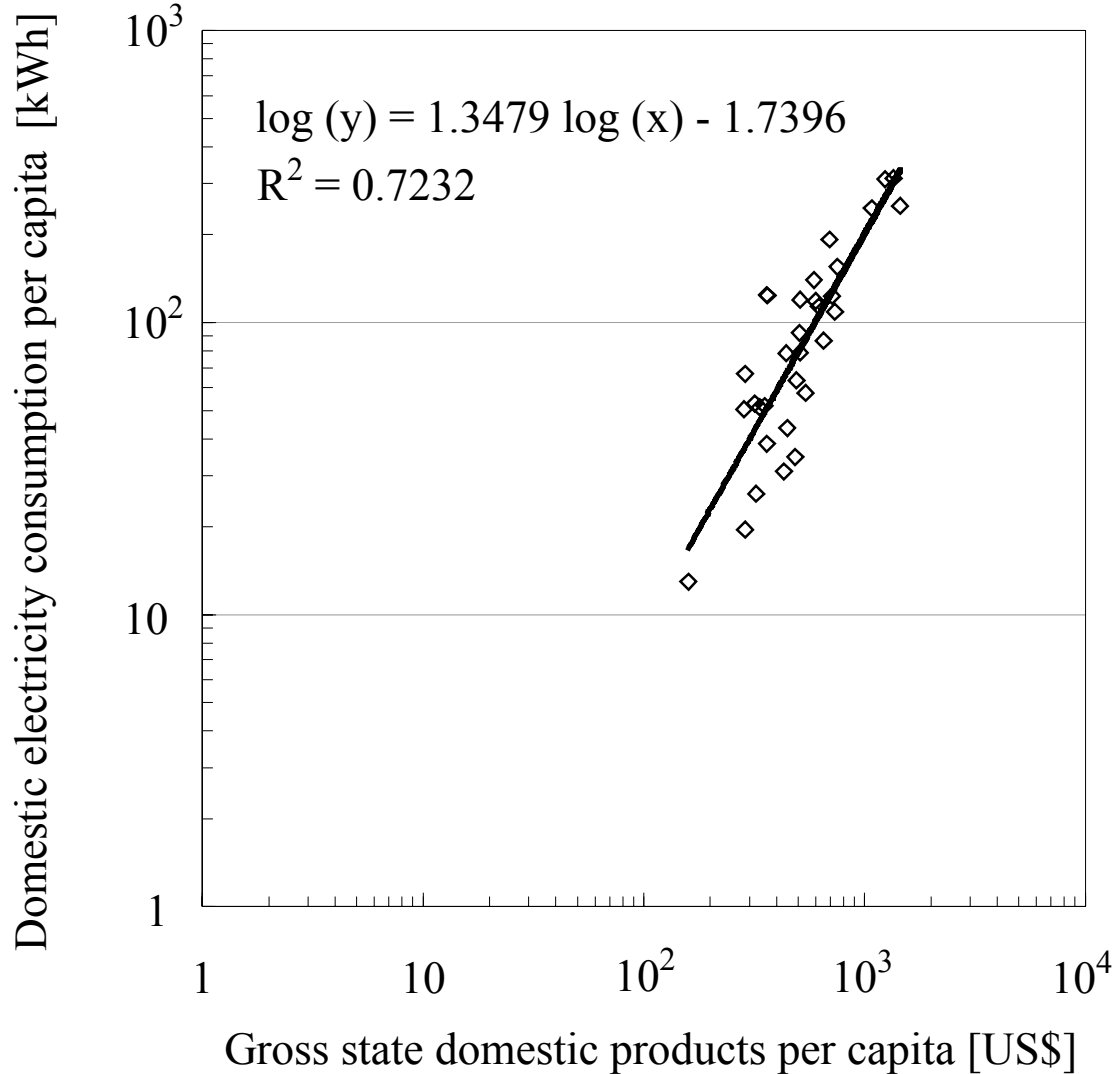
# Procedure of the study

1. Regression analysis
    - Reveal the relation between energy and education.
  2. Model analysis
    - Develop an energy-economic model.
  3. Estimation of the potential of increase in literacy rate
    - Based on the result of both of the regression and model analyses.
-  Design the framework of energy access improvement and socio-economic impacts.



# Regression analysis

# Income and energy



- Sample size: n = 32  
(28 states, 3 union territories,  
1 national capital territory)

Source: Central Electricity Authority, 2005. General review 2005.

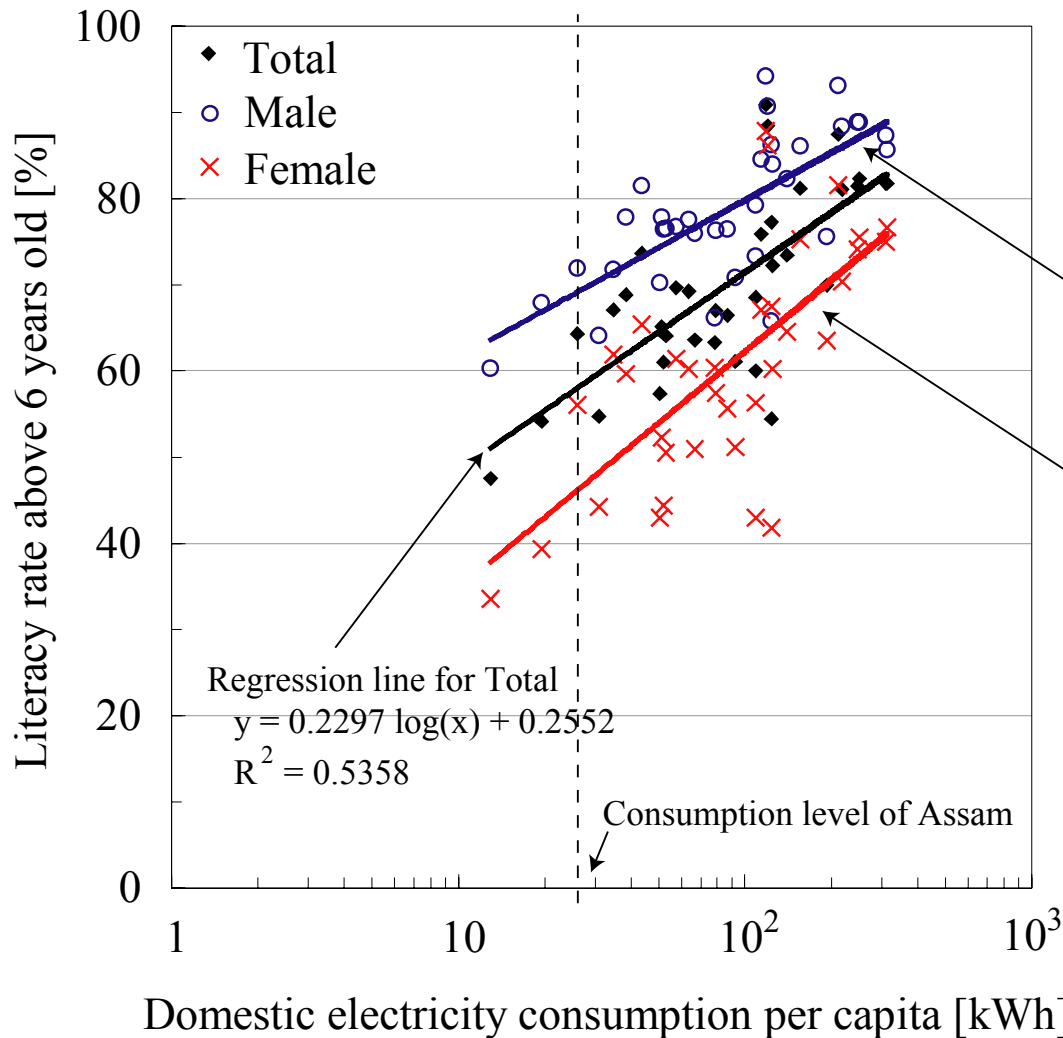
Central Statistical Organization, 2005. [http://mospi.nic.in/6\\_gsdp\\_cur\\_9394ser.htm](http://mospi.nic.in/6_gsdp_cur_9394ser.htm).

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# Literacy rate and electricity consumption



- Sample size: n = 35  
(28 states, 6 union territories,  
1 national capital territory)

Regression line for Male  
 $y = 0.1827 \log(x) + 0.4329$   
 $R^2 = 0.5241$

Regression line for Female  
 $y = 0.2755 \log(x) + 0.0717$   
 $R^2 = 0.4764$

Regression line for Total  
 $y = 0.2297 \log(x) + 0.2552$   
 $R^2 = 0.5358$

Consumption level of Assam

Source: Central Electricity Authority, 2005. General review 2005.

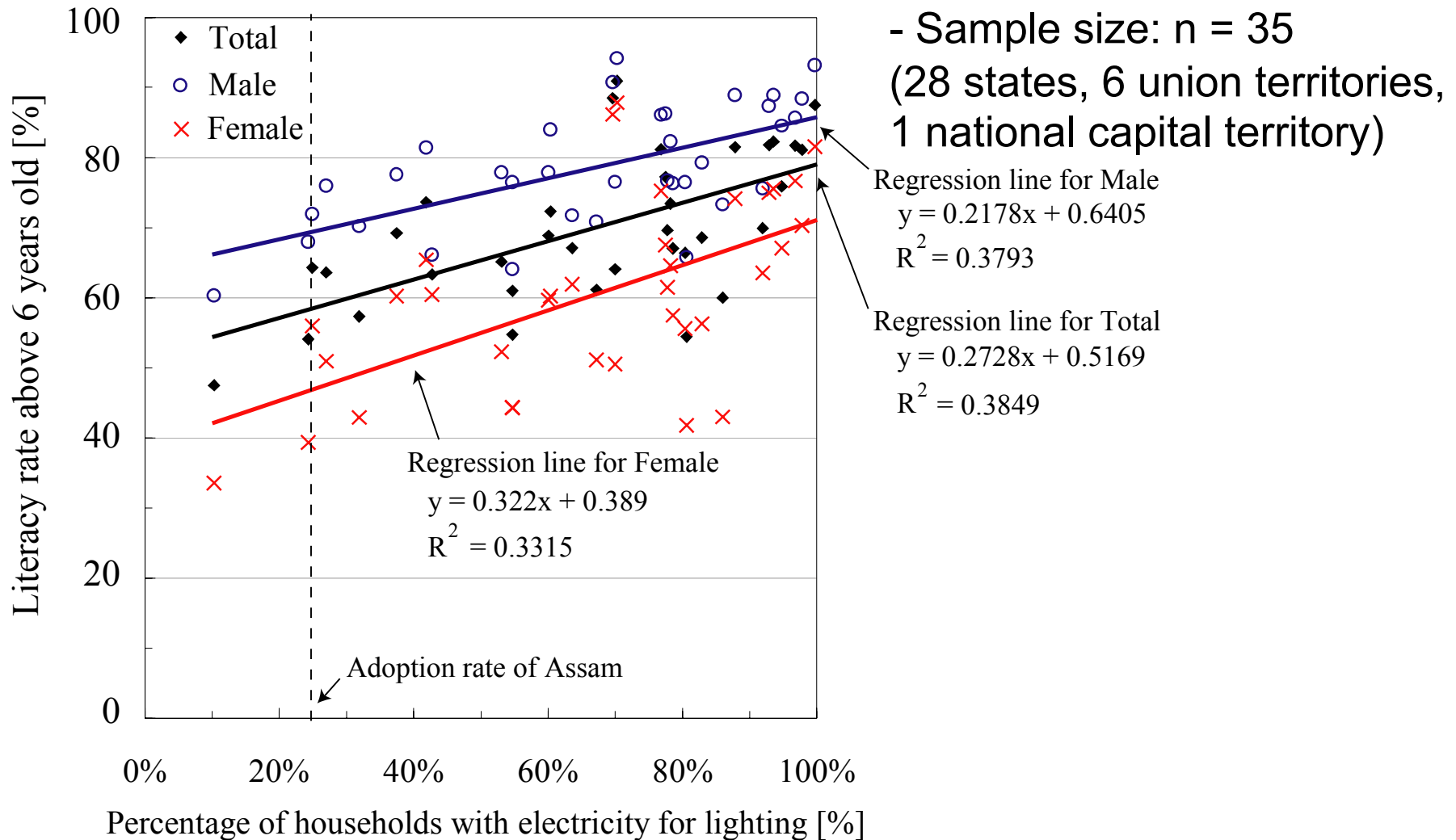
Office of the Registrar, 2005. Census of India 2001. <http://www.censusindia.net>.

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# Literacy rate and electricity utilization (1)



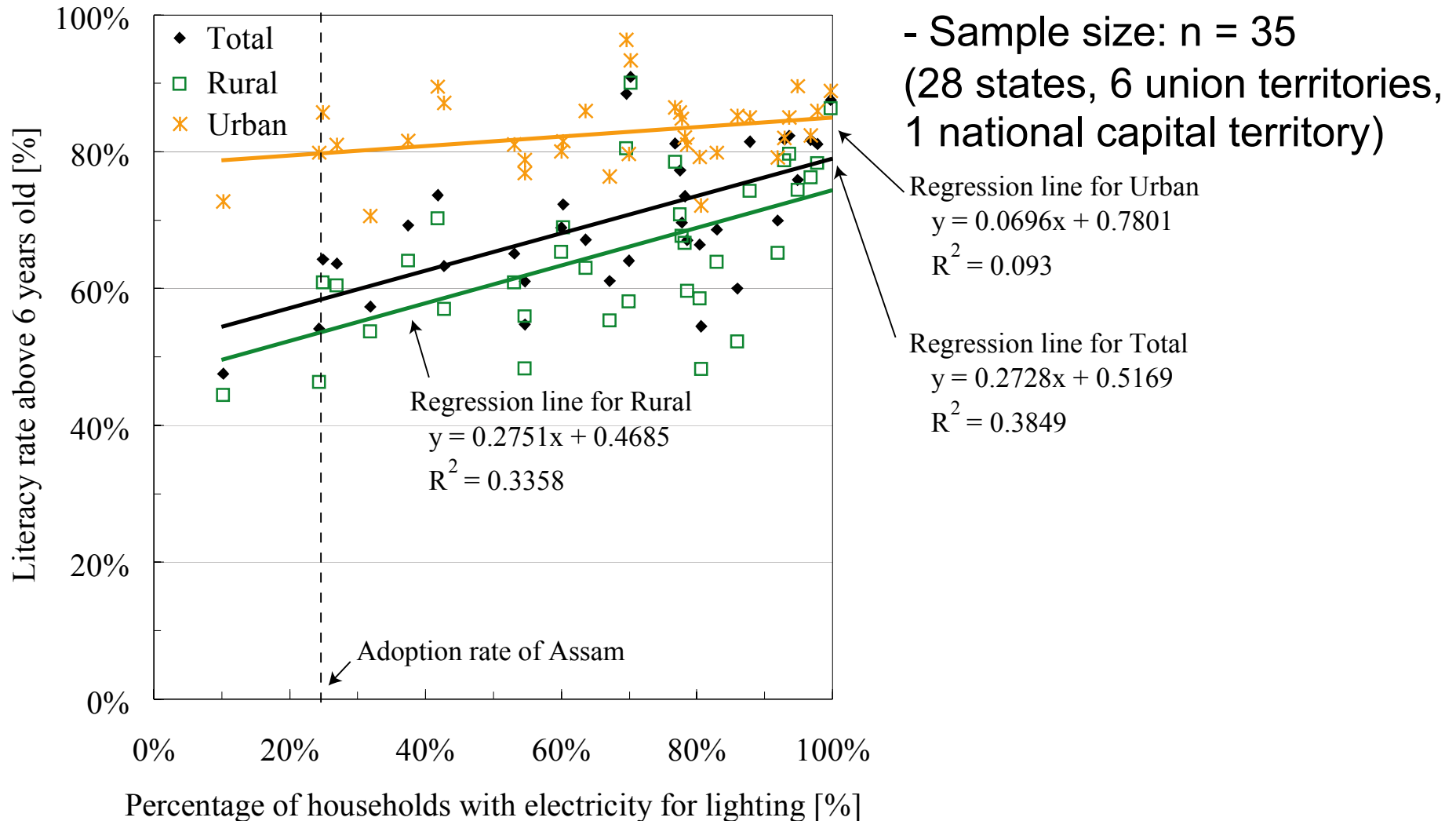
Source: Office of the Registrar, 2005. Census of India 2001. <http://www.censusindia.net>.

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# Literacy rate and electricity utilization (2)



Source: Office of the Registrar, 2005. Census of India 2001. <http://www.censusindia.net>.

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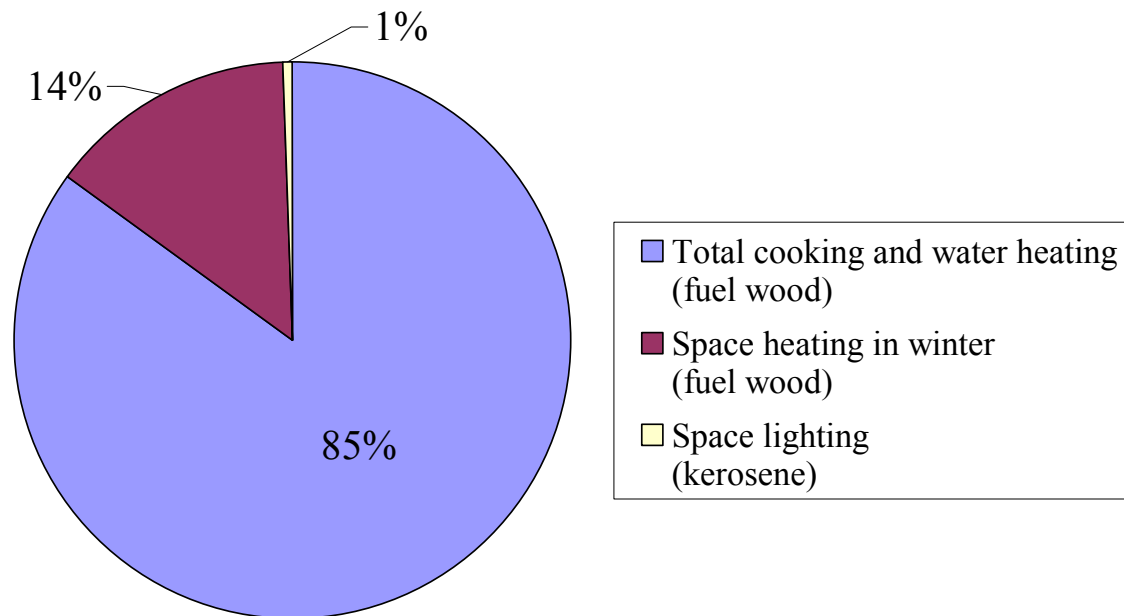


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# Model analysis

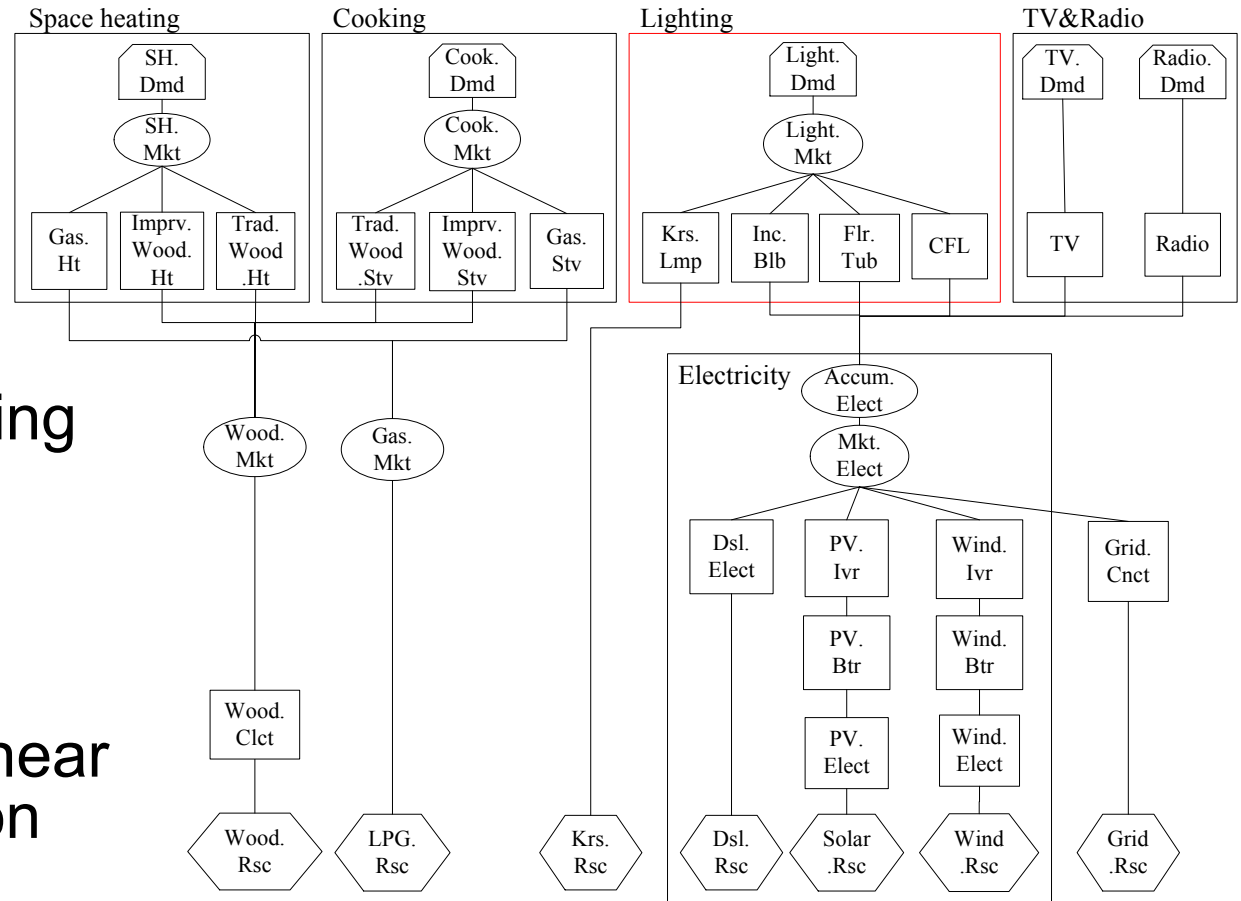
# Areas analyzed

- Country: Republic of India
- Description of the areas – Rural areas of Assam
  - 5,958 persons (485 households).
  - Un-electrified.
  - Rely on kerosene for lighting demand.



Source: Sarmah et al., 2002. Energy profiles of rural domestic sector in six un-electrified villages of Jorhat district of Assam.

# Energy access model



- Focusing on lighting demand of rural households.
- Analysis periods: 2004 - 2012
- Applying a non-linear partial optimization tool.

## Abbreviation:

SH: Space heating  
Imprv: Improved  
Tub: Tube  
Krs: Kerosene

Cook: Cooking  
Stv: Stove  
CFL: Compact Fluorescent Lamp  
Dsl: Diesel

Light: Lighting  
Lmp: Lamp  
Flr: Fluorescent  
Cnct: Connection

Dmd: Demand  
Inc: Incandescent  
Ivr: Inverter  
Cnct: Connection

Mkt: Market  
Blb: Bulb  
Btr: Battery  
Rsc: Resource

Trad: Traditional  
Flr: Fluorescent  
Elect: Electricity



# Cost of lighting devices

	Unit cost [US\$]	Life [hour]	Energy consumption per unit-hour [kWh]
Kerosene lamp	0.602	1,500	0.400
Incandescent bulb	0.241	1,000	0.060
Fluorescent tube	1.205	10,000	0.040
CFL*	4.819	10,000	0.011

\*CFL: Compact Fluorescent Lamp

Source: Jana and Chattopadhyay, 2004. Block level energy planning for domestic lighting – a multi-objective fuzzy linear programming approach.  
Kumar et al., 2003. Disseminating energy-efficient technologies: a case study of compact fluorescent lamps (CFLs) in India.

# Cost of power generation

	Capital cost [US\$/kW]	Fixed O&M [US\$/kW]	Variable O&M [mills/kWh]	Life [Year]	Efficiency [-]
Diesel generator	289	7.229	6.024	10	0.278
PV	7229	180.72	0	25	1
Wind	1479	36.97	0	20	1
Grid electricity*	919	29.87	1.246	30	0.234

## \*Gas steam power plant

Source: Banerje, 2006. Comparison of options for distributed generation in India.

Central Electricity Authority, 2005. Broad status of thermal power projects in Assam.

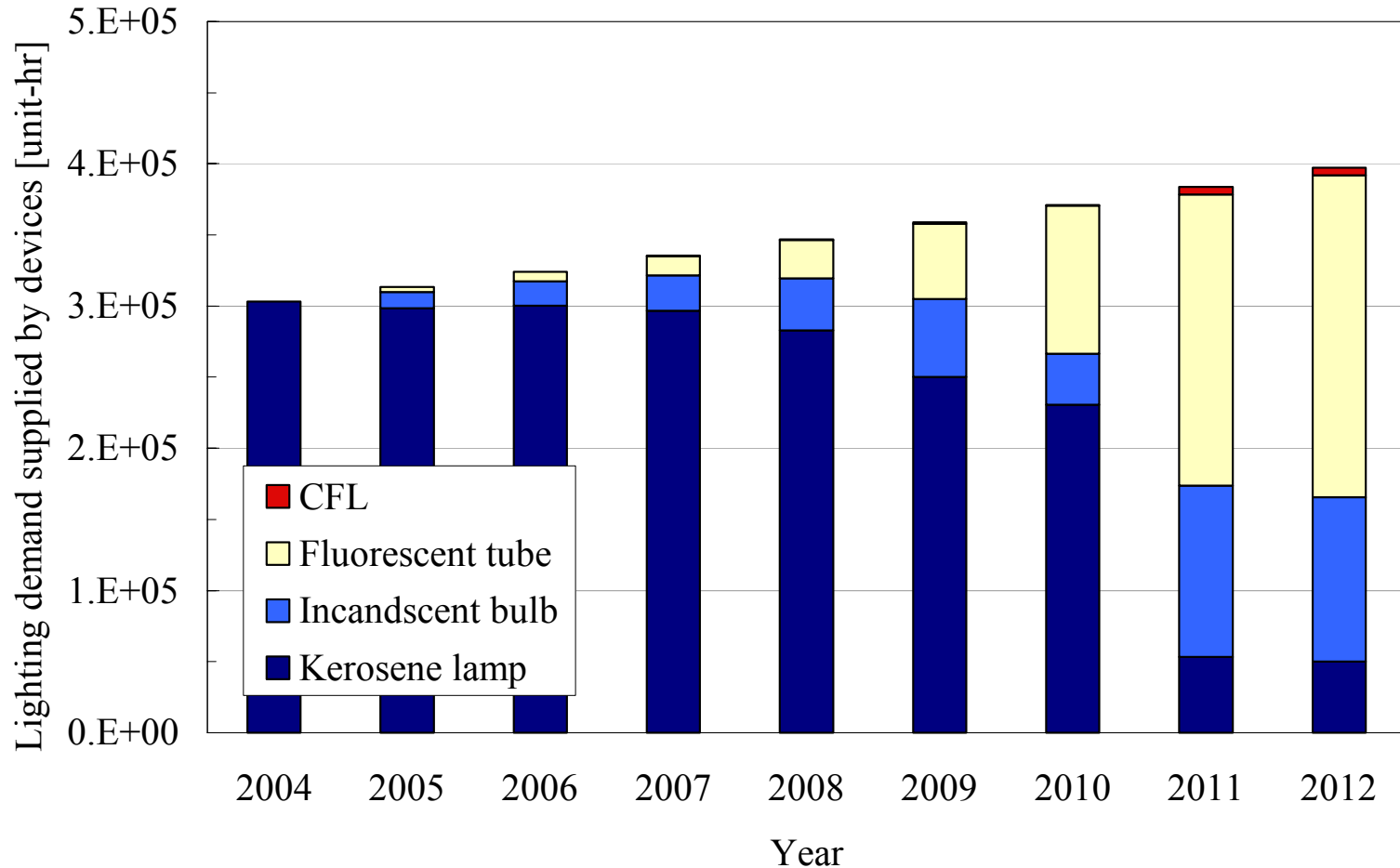
Central Electricity Authority, 2005. General review 2005.

Chakrabarti and Chakrabarti, 2002. Rural electrification programme with solar energy in remote region – a case study in an island.

TERI et al., 1999. Potential for use of renewable sources of energy in Asia and their cost effectiveness in air pollution abatement.

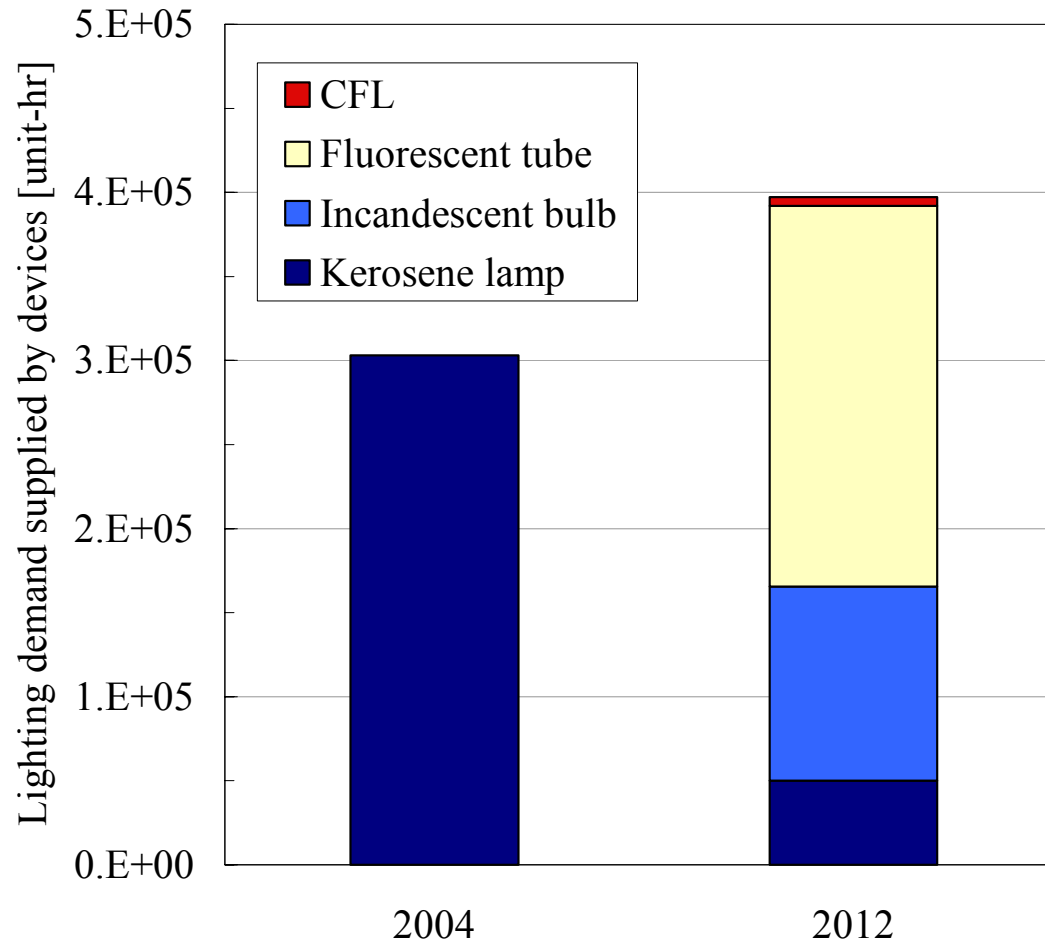
Tongia and banerjee, 1998. Price of power in India.

# Changes in energy demand supplied by lighting devices



- Electric lighting appliances are widely adopted by the rural households by the year 2012.

# Comparison of lighting demand by devices between the year 2004 and 2012



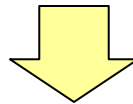
- 87% of the households use electric lighting appliances in 2012.
- Fluorescent tube supplies 57% of the total lighting demand.

# Potential of increase in literacy rate

- Percentage of households without electricity for lighting
  - 75.1% of households in Assam.
- Assume that the adoption rate of the result of the model analysis is applied to the whole Assam
  - 87% of the unelectrified households are electrified.
  - additional 66% of the households obtain electricity.
- Apply the value of slope of the regression line for “Rural” in the regression analysis
  - The literacy rate above 6 years old in Assam increases from 60.9% to 79%.

# Conclusion

- Percentage of households with electricity for lighting correlates the literacy rate above 6 years old, in particular, in rural areas.
- Electric lighting appliances are adopted by 90% of the rural households in the year 2012.
- Assuming the dissemination of electric lighting appliances in Assam as a whole, it is expected that the literacy rate potentially increases by 18 points.



Combined with other quantitative approaches, energy-economic models provide the framework of energy access improvement including socio-economic aspects.