Engineering, Economics & Regulation of the Electric Power Sector

ESD.934, 6.974

Session 1. Wednesday February 3, 2010

Introduction

Prof. Ignacio J. Pérez-Arriaga

Do you agree with this rule?

"On Oct. 23, 2009, FERC approved a MISO interim proposal for spreading costs associated with network upgrades that are needed to accommodate new generation interconnection. Under the new scheme, generators will pay 100% of the interconnection costs for lines below 345kV and 90% for facilities at or above 345kV (with the extra 10% paid by all of MISO), a cost that is too high for the wind generators, the national wind association contends".

(Source: *Energy Washington Week*, 19 Nov-2009)

Does this make sense to you?

The availability of credits can be further complicated by potential economic mechanisms, whereby coal plants "may choose to limit operating hours in order to sell their emission credits as green house gas constraints increase"

Terry Boston, President and CEO of PJM Interconnection in Norristown, PA, in reference to the potential distortions that CO2 emissions could bring to the electricity market.

(Excerpt from NERC *2008 Climate Initiatives report*)

Some questions

- Should cogeneration be subsidized?
- Why so little investment in transmission lines took place in the US for more than a decade, until recently? Should anybody do something about it or should it be left to market forces?
- Should the remuneration of distribution utilities be linked to the level of quality of service that they provide?
- Are smart meters a good idea? Are the potential benefits worth the cost & trouble of changing the present meters?
- How to compute electricity tariffs?

More questions

- Should the purchase of electricity be liberalized as the telecom service or a regulated tariff is fine?
- How to detect if agents in a wholesale electricity market are abusing any market power they might have? Can this market power be mitigated somehow?
- Can investment in generation capacity be left entirely to the market or some kind of intervention is warranted?
- What is going on in the electricity sector around the world? Are liberalization & markets really working?

And still more questions

- Are the “standard tax credits” that are presently used in the US a sound mechanism to promote generation from renewable sources such as wind?
- Why the feed-in tariffs of Germany, Denmark & Spain are so successful? Or are they maybe too successful? Is there a fool-proof method to promote renewables?
- Can one rely on markets to achieve sustainability objectives? How to mix markets & public policies?
- Has the worldwide liberalization process been successful in increasing the rate of electrification for the one third of mankind without access to electricity? What is the right approach?

What this course is not *(1 of 2)*

- 6.691. **Seminar in electric power systems**
  - Focus is on detailed engineering aspects of modeling power devices & systems
- 6.061. **Introduction to electric power systems**
  - A sound engineering power systems course, with no economics or regulatory content
- 14.44. **Energy economics & policy**
  - Focus is on economic models & instruments for a variety of sectors *(including electricity; requires significant economic background)*

What this course is not *(2 of 2)*

- 1.801. **Environmental law, policy & economics: Pollution prevention & control**
  - Focus is on legal & general environmental aspects
- 1.816/11.369. **Energy policies for a sustainable future**
  - More general, less emphasis on regulation, all energies instead of just power systems

What this course is about

- Basically restricted to the electric power sector
- Covers technological, economic & legal aspects, without a formal treatment of any one of them
- Focus *(& this is the spinal cord of the course)* is on regulatory aspects, thus making use of engineering, economy & law
  - No formal training in any of these matters is required, although it is very welcome
- Addresses current open issues in the regulatory practice & research

Logistics

- Introductions
- Classroom *(speak up!)*
- Syllabus
- Resources, books on reserve
- Recitations
- Homework, Term paper *(and marathon day)*
- Grading
- Visit to ISONE
- Slides *(more in handout than shown in class)*
- Office hours
- Punctuality *(the class will start / finish¿? on time)*

Homework 1

- Select one power system of interest to you, preferably within the provided list
- During the course you will have to learn about it, analyze it under different viewpoints and suggest improvements to its regulatory framework. It may used also in the term paper
- This first assignment just consists of making your choice and writing a few pages *(a couple of pages is enough)* with the system you have chosen, reasons for it and the sources of information that you have found so far
- Get familiar with the “Resources” document

Term paper

- Options
  1. Individual
     - From a list of prescribed topics
     - Exceptionally: a student’s proposed topic
  2. Team (groups of 3), a large case study with N topics to be prepared/defended individually/collectively

Questions?

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Module A. Session 1

Power system operation & management *(1 of 2)*

Prof. Ignacio J. Pérez-Arriaga

Study material

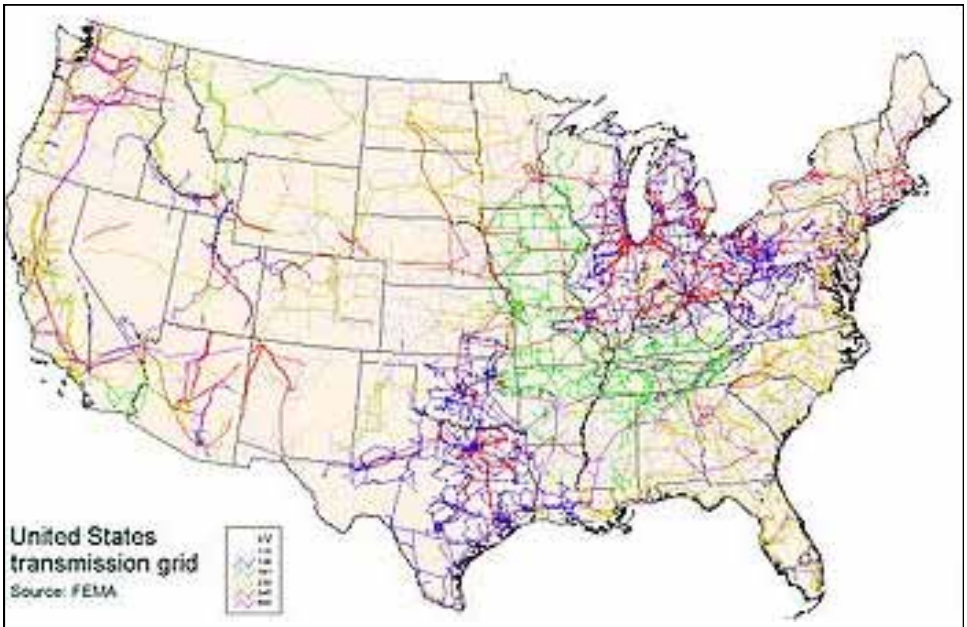
- "**Electric energy systems: An overview**", by I.J. Pérez-Arriaga, H. Rudnick & M. Rivier; chapter 1 of the book:
  - Gómez-Expósito, A., Conejo, A.J. & Cañizares, C., editors. (2009) *Electric energy systems: Analysis and Operation*. CRC Press, Taylor & Francis Group.
- "**Resources**"

Readings

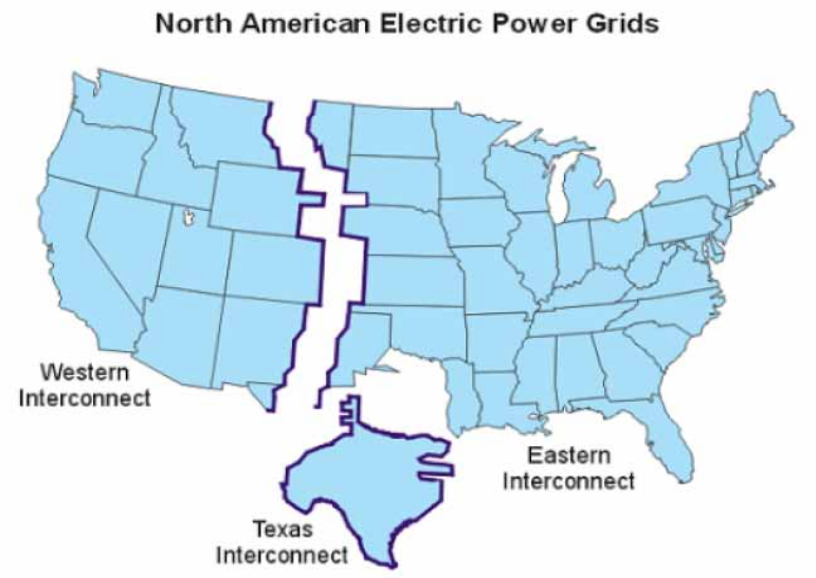
This is background information that can be read at any time

- "**The role of electricity**", Eurelectric, 2007
- "**EPRI PRISM study: The power to reduce CO2 emissions**", Electric Power Research Institute (EPRI), 2007
- "**Low carbon electricity systems**", KEMA, 2009

Electric power systems... A first impression



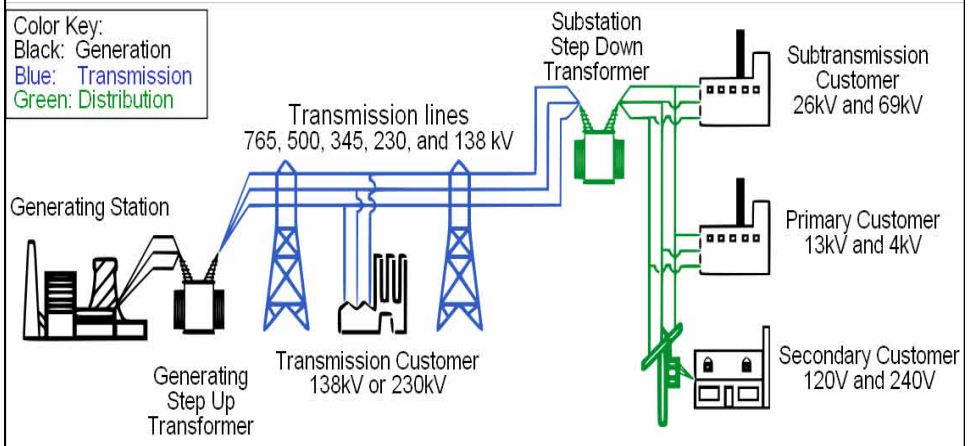
The US is actually three interconnected systems...



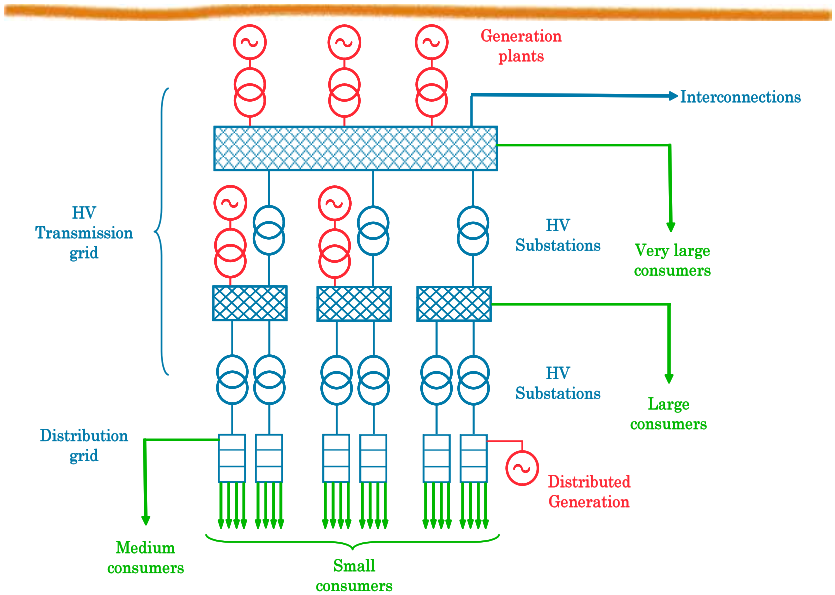
... and here they are

This is the “classical” path of electricity:

generators ➔ networks ➔ demand



A power system in schematic form ...



Electric power systems
The different perspectives

- A power system (or the electric power industry) can be contemplated from a diversity of perspectives
  - In the 1st part of module A (today) we shall focus on the physical description & some engineering aspects
  - In the 2nd part of module A (next day) we shall look at how it is managed & regulated: a mix of economic, engineering & also legal issues
  - However, the course will concentrate on regulatory issues
    - regulation of the several activities involved in the supply & consumption of electricity will be the common thread that we shall follow during the course

Outline *(1 of 2)*

- **Background**
  - A first global impression
  - What's so special about electricity?
  - A bit of history of the sector
- **The technological perspective**
  - Generation
  - Transmission
  - Distribution
  - System operation, protection & control
  - The environmental impact

Outline *(2 of 2)*

- **The economic & managerial perspectives**
  - Economic data & orders of magnitude
  - Time scales
    - Expansion planning
    - Operation planning
    - Operation
    - Protection & control

What's so special about electricity?

- Electricity is an essential (public?) service
  - guarantee of supply & price are politically sensitive issues
- Electricity cannot be easily stored, i.e. delivery is practically instantaneous
  - Generation & demand are permanently in balance
- Supply of electricity requires networks, where electricity is injected or retrieved *but cannot be traced*
  - Network duplication does not make economic sense
- Also *(not so special)*
  - Large & dedicated investments
  - Complex decision making under much uncertainty
  - Predictable cyclical variations in demand

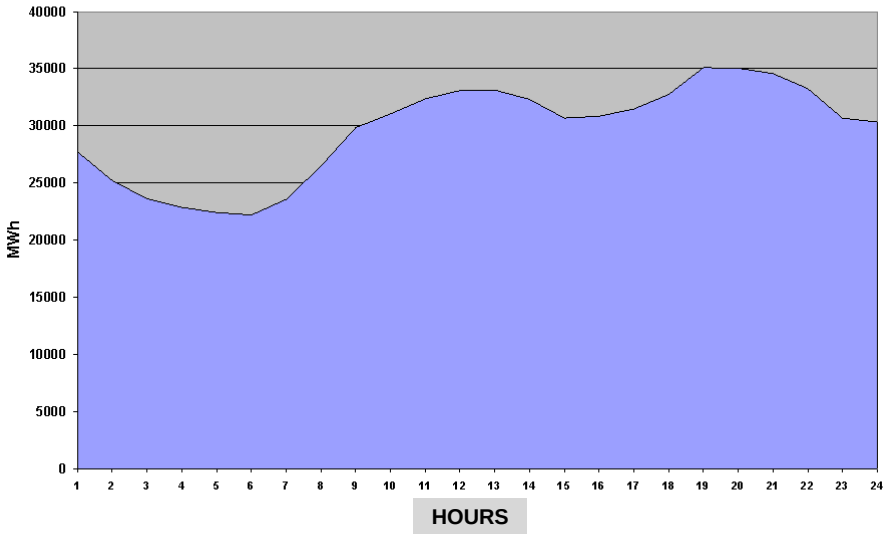
Some history of the sector

- Scale: first electric light systems *(individual, DC)* (1870), larger *(collective, DC)* (1882)
- Voltage: 100 V DC (1882), 15 kV AC (1884), 3 phase AC (1891), 150 kV (1910), 245 kV(1922)
- Large interconnected systems (UK, 1926, ~ 500 plants)
- Vertically integrated plus small distributors
  - From local, private & unregulated, to large regulated monopolies with or w/o state intervention
- 50 & 60 cycles/sec frequency
- Mostly stable model until 1990s ➔ unbundling + liberalization

Demand of electricity

DAILY DEMAND *(Spanish market)*

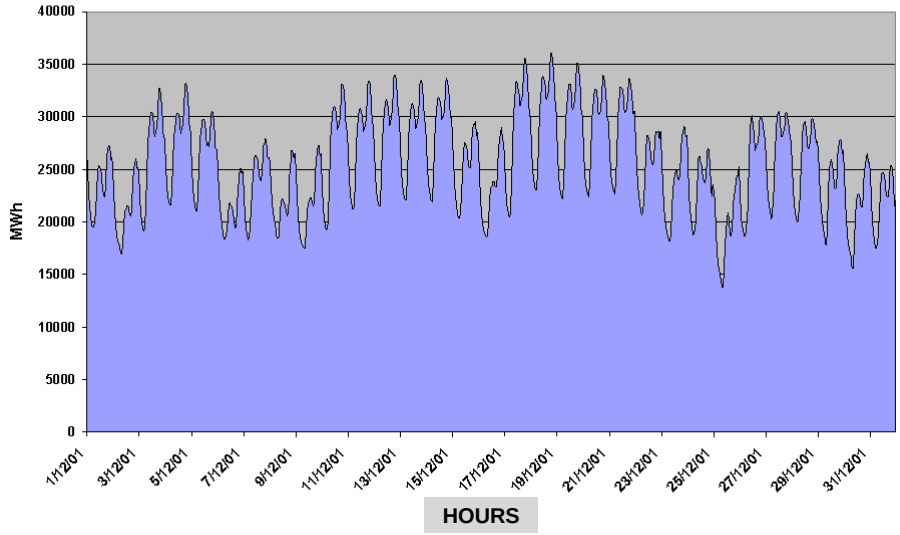
(19/12/2001)



Source: REE *(Spanish National System Operator)*

MONTHLY DEMAND *(Spanish market)*

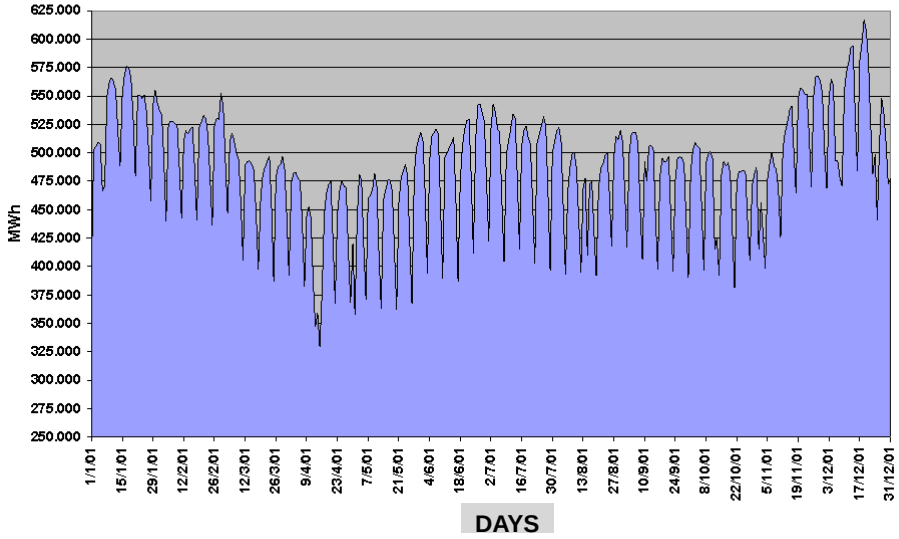
DECEMBER 2001



Source: REE *(Spanish National System Operator)*

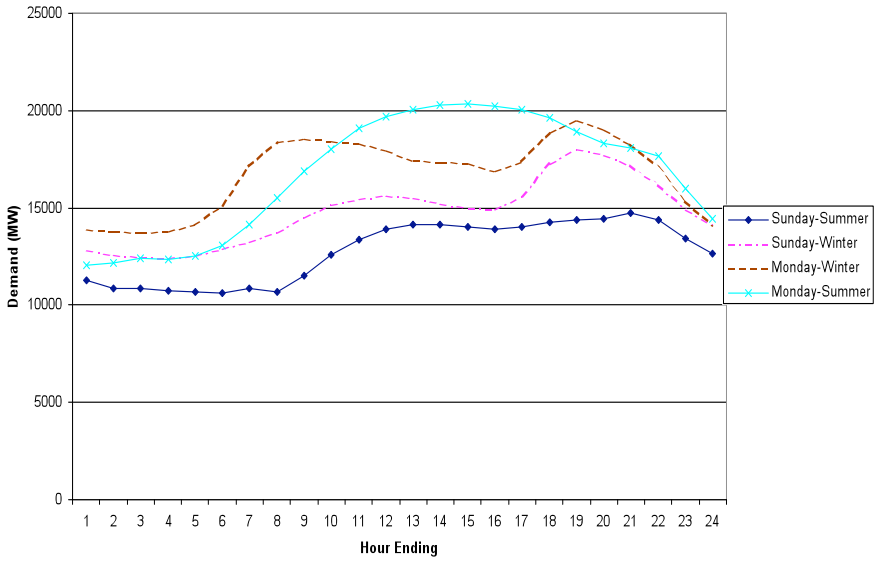
ANNUAL DEMAND *(Spanish market)*

2001



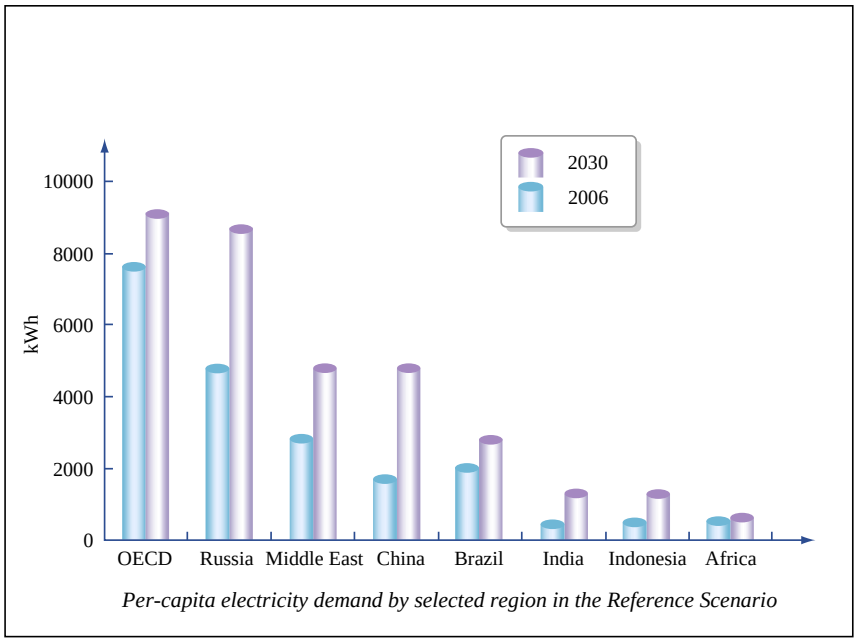
Source: REE *(Spanish National System Operator)*

Daily demand in New England during some representative days



Electricity demand & GDP

- Numerous statistics show the close relationship between GDP growth *(or reduction)* & electricity demand growth *(or reduction)* , in basically all countries
- But GDP & electricity consumption are not the same in all countries
  - The next slides show that difference
  - They also show that “too much” electricity consumption does not help to improve the level of human development
  - And, most importantly, they show that below a threshold in electricty consumption is not possible attain a minimum level of development

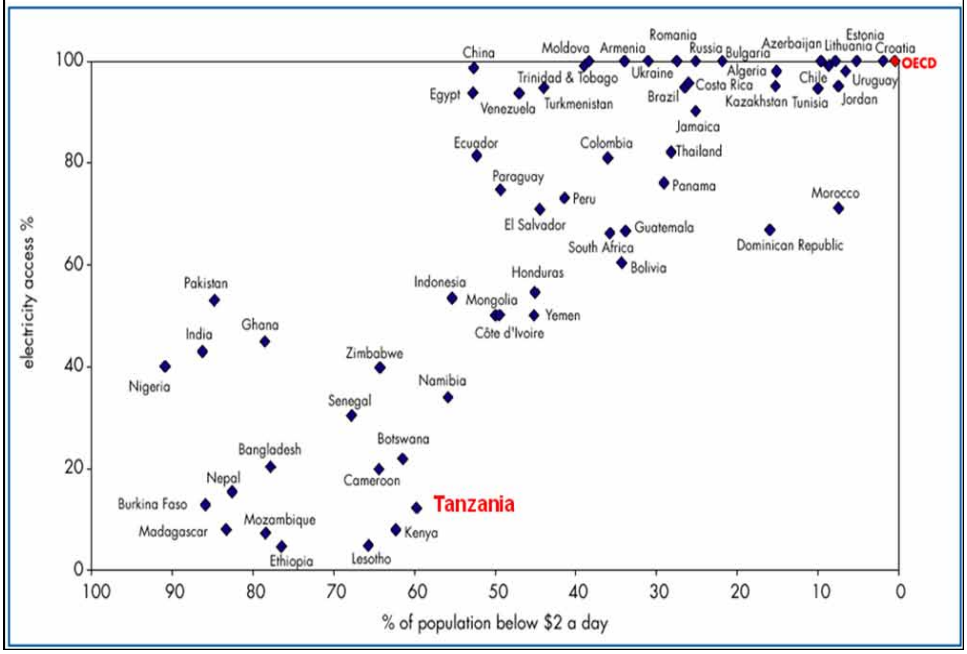


Per-capita electricity demand by selected region in the Reference Scenario

Source: World Energy Outlook 2008

Image by MIT OpenCourseWare.

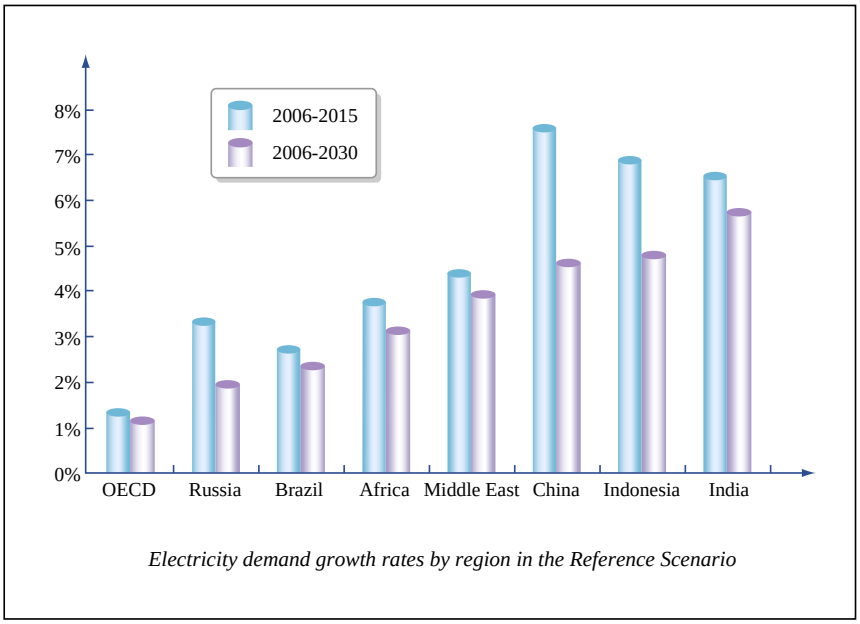
Population Below $2/day versus Access to Electricity



	2008				Projections			
	Population without access (millions)	Electrification rate (%)			Population without access (millions)		Electrification rate (%)	
		Overall	Urban	Rural	2015	2030	2015	2030
Africa	589	40	67	23	627	700	45	54
North Africa	2	99	100	98	2	2	99	99
Sub-Saharan Africa	587	29	57	12	625	698	36	47
Non-OECD Asia	809	77	94	67	765	561	80	87
China	8	99	100	99	5	0	100	100
India	405	65	93	53	385	294	69	79
Other	396	63	85	48	374	267	68	81
Latin America	34	93	99	70	18	13	96	98
Middle East	21	89	98	71	11	5	95	98
Sub-Total	**1453**	**72**	**90**	**58**	**1420**	**1279**	**75**	**81**
E. Europe/Eurasia and OECD	3	100	100	100	2	2	100	100
Sub-Total	**3**	**100**	**100**	**100**	**2**	**2**	**100**	**100**
World	1456	78	93	63	1422	1281	80	84

Electricity access in the Reference Scenario

Image by MIT OpenCourseWare.



Electricity demand growth rates by region in the Reference Scenario

Source: World Energy Outlook 2008

Image by MIT OpenCourseWare.

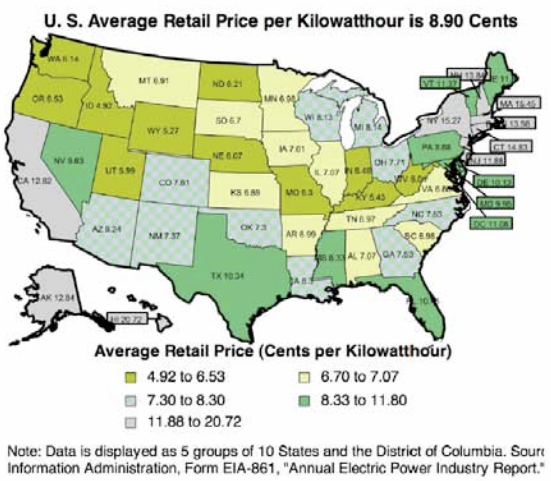
Price of electricity

US Electricity Market in numbers

	Retail Prices (c/kwh)	# Customers
Residential	10.65	123,949,916
Commercial	9.65	17,377,219
Industrial	6.39	793,767
Transportation	9.7	750
Total	9.13	142,121,652

- Average Residential Monthly Use: 936 kWh
- Average Residential Monthly Bill: $99.70

US Electricity Market in numbers



Note: Data is displayed as 5 groups of 10 States and the District of Columbia. Sour
Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

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