Lecture 8: The Grid

Pete Schwartz, *Cal Poly Physics*

Evolution of American Electrical Generation

1) Total Electrical Generation Capacity

2) Size of Individual Generators, Vertical Integration

3) Efficiency: Pressure, Temperature, Size

4) Cost of Electricity Decreases

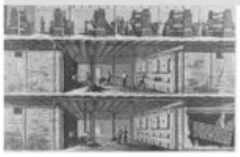
5) The California Energy Curve!

$) Duty Cycle (Capacity Factor) and Price of Electricity

The Pearl Street Grid (New York City), 1883

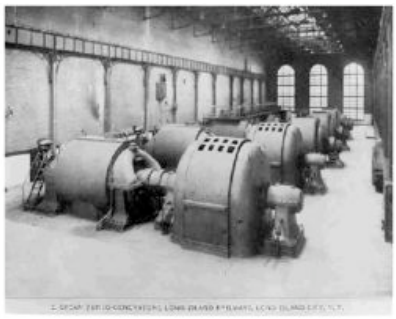
Downtown: to show importance

257 Pearl Street: coal fired; DC power, low voltage
Underground lines, ~ 1 mile



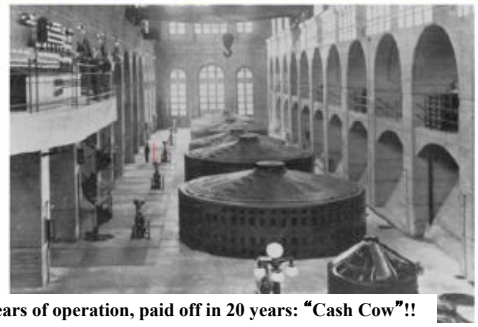
- Edison. Samuel Insull, and the First (direct current) Utility
- Electricity as an Energy Source
- … great, now, what do we do, or
- How to make it into a commodity?

Natural Monopoly?



Steam turbo-generators, Long Island Railways, c. 1907

12,000 kW Capacity Generators at the Susquehanna hydroelectric station, c. 1912



69 years of operation, paid off in 20 years: "Cash Cow"!!

Vertical Integration: Fuels, Generation Facilities, Distribution: safety

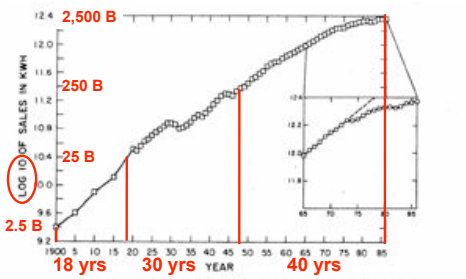
Electricity was a product without a market!

Gold Medallion:

"2. To raise the electrical Content of new construction Beyond the present minimum."

Figure 13. Basic goals of the Live Better Electrically, Reprinted with permission from McGraw-Hill, publish

Figure 14. Advertisement for the All-Electric Home, with Betty Furness, Ronald Reagan, and Fran Allison. Reproduced from *Better Homes and Gardens*, October 1956, with permission from the Edison Electric Institute.



Sales of electricity, 1900–86. This logarithmic graph shows steady growth of electricity sales until 1973, when the Arab oil embargo and much higher energy costs spurred conservation efforts by users. Data are from Edison Electric Institute, *Edison Electric Institute Pocketbook of Electric Utility Industry Statistics*, 34th Ed. (New York: Edison Electric Institute, 1988.)

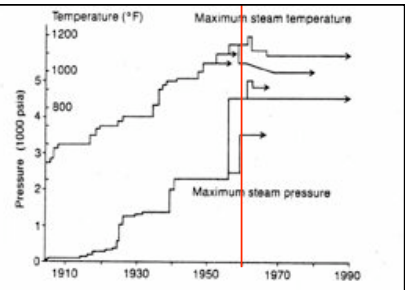


Figure 24. Graph illustrating how maximum steam pressures and temperatures of turbines increased until the early 1960s, yielding greater thermal efficiencies. Reprinted with permission from Vol. 12, *EPRI Journal* (December 1987), p.

Efficiency = $\frac{T_H - T_C}{T_H}$

Thermal Efficiency of Electricity Production Increases

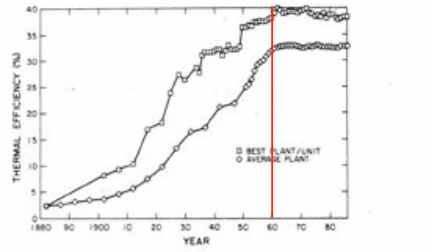
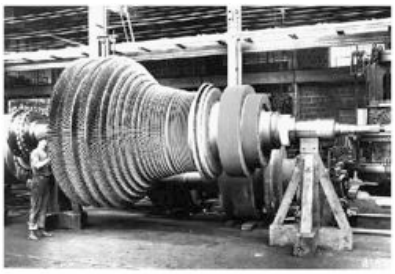
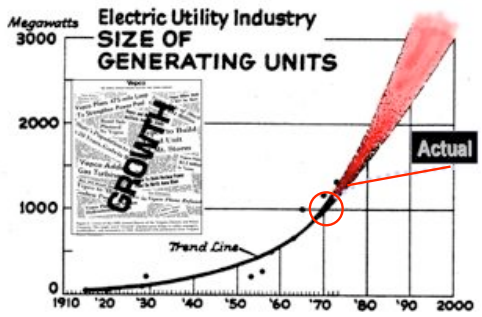


Figure 1. Thermal efficiency of generating units, 1880–1986. Thermal efficiency of power units increased gradually throughout the industry's history, plateauing in the 1960s. For the years after 1965, the data on the top curve relate to the most efficient *unit*. Before 1965, the data relate to the best plant – a combination of units. Data are from Federal Power Commission publications and annual reports of best thermal efficiency in *Power Engineering* magazine.



Westinghouse Turbine Rotor, 1925



Virginia Public Energy Company Report Cover

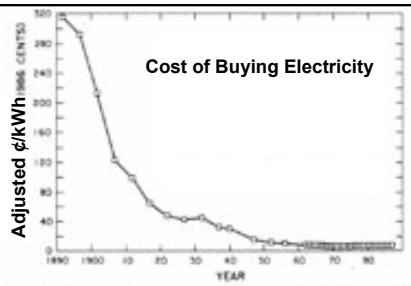
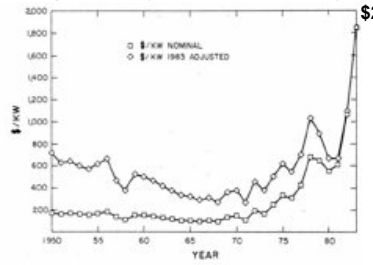


Figure 7. Average adjusted price of electricity. For residential service, the real (inflation-adjusted) price of electricity fell (in terms of 1986 cents) from over 300 cents per kilowatt-hour to about 7 cents per kilowatt-hour. Beginning in the late 1960s, the real cost of electricity ceased declining, so that the price in 1986 was about the same as it was in 1970. Data are from Edison Electric Institute, *Edison Electric Institute Pocketbook of Electric Utility Industry Statistics*, 30th Ed. (New York: Edison Electric Institute, 1984) and "1988 Statistical Report," *Electrical World* 202 (April 1988): 61.

Cost of Building Electricity Generation Capacity

$2 per Watt



Incremental cost of generating plants. The cost of building a new plant on a per-unit basis decreased until the late 1960s, despite increases in the cost of almost all materials and labor. Exploitation of larger power units that demonstrated scale economies was responsible for the drop. After 1967, building expenses increased dramatically, contributing to the reversal of the industry's trend toward declining overall costs. Data are from Leonard S. Hyman, *America's Electric Utilities: Past, Present, and Future* (Arlington, VA: Public Utilities Reports, 1983).

Annual Added Generator Capacity

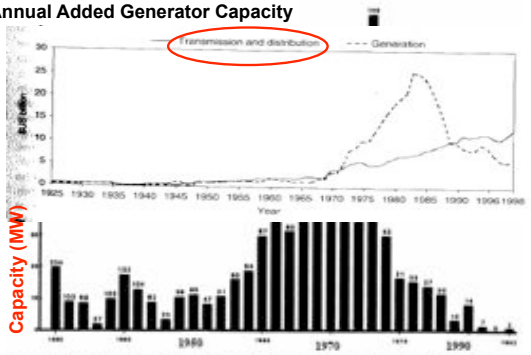
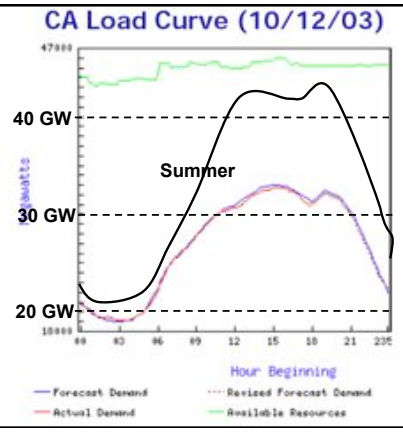
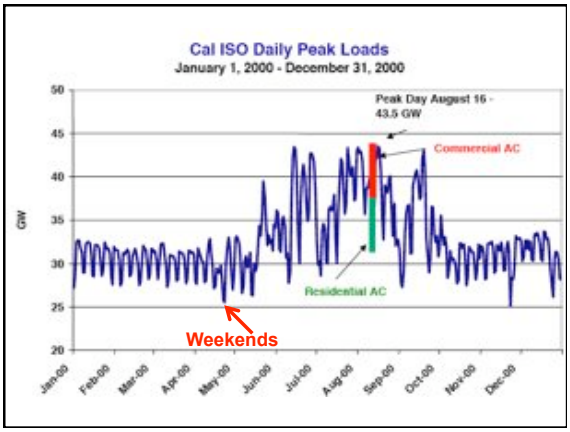
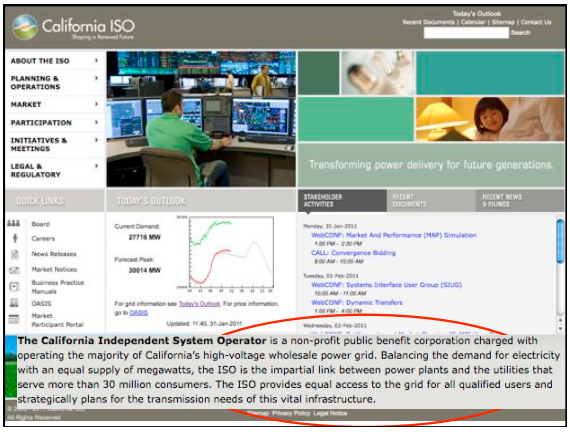


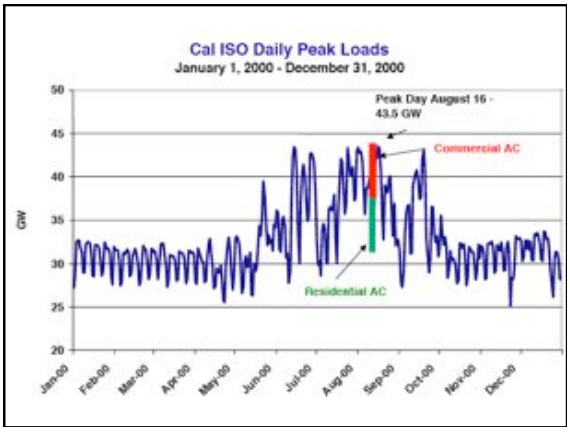
Figure 25. Capacity and number of turbine generators ordered in the United States. An ordering "panic" hit the utility industry in the late 1960s and peaked in 1973. Reprinted with permission from the American Electric Power Company.

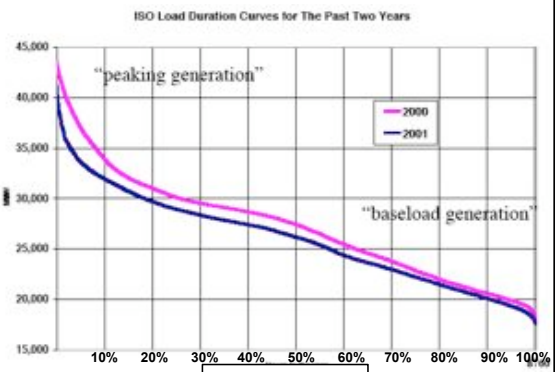
Solar Energy only works in the Day Time











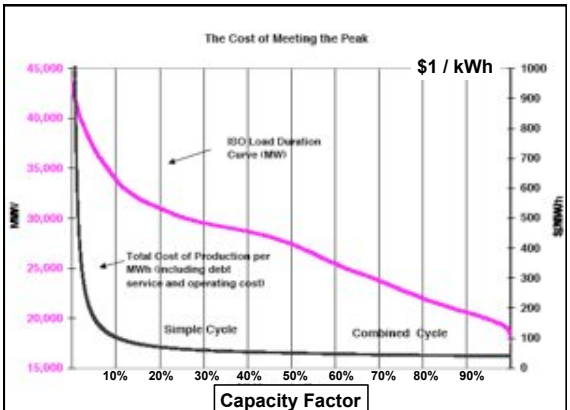
Cost of Producing Electricity, consider one year:

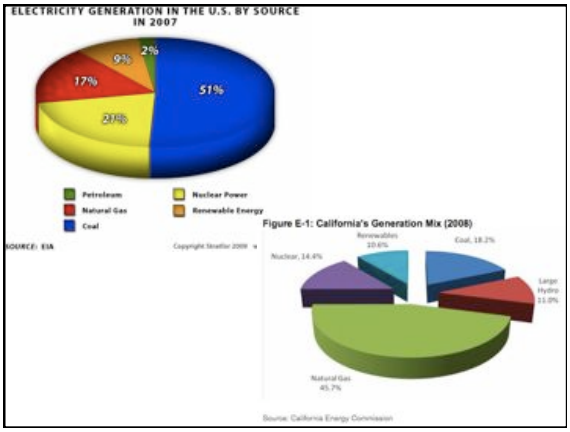
$$\$/kWh = \frac{\text{Total Costs}}{\text{Total Electrical Energy Generated}}$$

$$\frac{\text{Mortgage Payments + Fuel}}{\text{Electrical Energy Generated}}$$

$$\frac{\text{Fixed Cost + (constant A)* Capacity Factor}}{\text{(Constant B)* Capacity Factor}}$$

$$\frac{\text{MP + (Fuel Price)*(P*yr* Capacity Factor)/}\eta}{\text{P* (1 year) * Capacity Factor}}$$





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$$\frac{\text{MP + (Fuel Price)*(Fuel Amount)}}{\text{Electrical Energy Generated}}$$

$$\frac{\text{MP + (Fuel Price)*(Electricity Generated)/}\eta}{\text{Power*Time}}$$

$$\frac{\text{MP + (Fuel Price)*(P*yr* Capacity Factor)/}\eta}{\text{P* (1 year) * Capacity Factor}}$$