ELECTRICITY 101
“Is it a fact—or have I dreamt it—that, by means of electricity, the world of matter has become a great nerve, vibrating thousands of miles in a breathless point of time?”

— Nathaniel Hawthorne, 1804-1864
American Novelist
A BRIEF HISTORY OF THE U.S. POWER INDUSTRY
The Early Years

- Mid-1700s—Interest in harnessing power of electricity
- 1882—First workable electric system built by Edison at Pearl Street Station
Industry Formation

• 1890s—Electric utilities began to develop primarily in urban areas because of economies of scale

• Industry had characteristics of a “natural monopoly”
  —A natural monopoly is where, for technical and social reasons, it is most efficient to have only one provider of a good or service
    • Provided service regarded as vital to economic and social fabric of community (i.e., a “public utility”)
    • Operated through large, integrated networks
    • Highly capital-intensive

• 1907—State regulation of electric utilities began in New York and Wisconsin
  – Regulation spreads to two-thirds of states by 1920
Industry Formation

- By 1920s—Most urban areas are electrified
- Exclusive utility franchises (monopoly rights) also came with an “obligation to serve” all customers in the defined regions
- Limited federal regulation of multi-state utilities

Times Square, New York, 1920s
Holding Companies

• 1920s—Many small utilities were consolidated and became parts of larger “holding companies”
  – Holding companies own other holding companies and operating companies. This is a common corporate structure in many industries.
  – The rapid growth, consolidation, and complexity of the utility industry outpaced the ability of many local regulators at the time.

• 1929—Stock market crash revealed that many holding companies were over-leveraged
  – As a result, federal and state governments strengthened utility regulation.
Federal Regulation

1935: Congress passed federal legislation addressing interstate utility operations

- The Federal Power Act
  - Interstate sales of electricity
  - Primarily regulates shareholder-owned utilities

- The Public Utility Holding Company Act (PUHCA)
  - Corporate structure of utilities

FDR signs legislation

© Corbis
Federal Regulation

- Federal and state regulatory scrutiny has grown significantly since 1935
  - The federal government regulates interstate power sales and services; mergers; corporate structure
  - State governments regulate retail electric service; mergers; facility planning and siting

- Other federal and state laws, rules, and regulations also apply to the electric utility industry, including, but not limited to:
  - Anti-trust laws / Dept. of Justice / FTC
  - SEC requirements, including Sarbanes-Oxley
  - Environmental regulations/EPA
America Electrifies 1930-1970

- Electricity finds many new applications in homes and businesses
- New power plants are built to meet customer needs
  - Because of economies of scale, electricity prices actually go down as larger and more efficient power plants come on line
- Transmission lines begin to connect utilities to one another
  - What we refer to today as "the grid" begins to take shape
To encourage competition, Congress re-examined rate regulation model of natural monopolies, including:

- Railroad, natural gas, trucking, airline, and telecom industries

Public Utility Regulatory Policies Act of 1978 (PURPA)

- Requires utilities to purchase electricity produced by cogenerators and small power producers
- Federal government expands regulatory role in state rate policies

1979—Motorists line up for first day of gas rationing

- Creates new class of “exempt wholesale generators” to sell power in competitive wholesale markets
- Expands FERC’s authority to order transmission-owning utilities to provide transmission access to other wholesale market players
- Increases energy efficiency standards for buildings, appliances, and federal government
- Encourages development of alternative fuels and renewable energy
- Expands clean coal programs
- Reforms and streamlines nuclear plant licensing
• During the 1990s, a number of states adopted different models to encourage competition among generators to serve retail customers.
Energy Policy Act of 2005 Electricity Initiatives

- Requires mandatory reliability standards
- Promotes transmission investment and facilitates transmission siting
- Repeals PUHCA and reforms PURPA
- Promotes fuel diversity
- Increases energy efficiency
- Gives FERC stronger consumer protection, anti-market manipulation authority
HOW DOES THE SYSTEM WORK?
Electricity: It’s All About Conversions

• Energy can neither be created nor destroyed - it can only be transformed (converted) from one form to another

• Our lives are surrounded by energy conversion technologies:
  – Chemical to thermal
    • Home furnace using fuel oil, natural gas or wood
  – Chemical to thermal to mechanical
    • Automobile engine
  – Chemical to electrical
    • Fuel cell
  – Electrical to mechanical
    • Electric motor
  – Electrical to radiant
    • Toaster, light bulb

• Power plants are simply energy conversion facilities converting fuel and energy sources into electricity
• **Watt (W)**—The basic unit of measure of electric power. The power dissipated by a current of 1 ampere flowing across a resistance of 1 ohm.

• **Kilowatt (kW)**—A unit of power equal to 1,000 watts.

• **Kilowatt Hour (kWh)**—A unit by which residential and most business customers are billed for monthly electric use. It represents the use of one kilowatt of electricity for one hour.
  
  – *A 100 watt light bulb burning for 10 hours would use 1 kilowatt-hour of electricity.*

• **Megawatt (MW)**—A unit of power equal to one million watts.

• **Megawatt Hour (MWh)**—The use of 1 million watts (or 1,000 kilowatts) of electricity for one hour. This term is used most often for large-scale industrial facilities and large population centers.
  
  – *The average U.S. household uses 11.3 MWh (11,327 kWh) of electricity every year.*

• **Power** (measured in Watts) equals its current (measured in Amps) times its voltage (measured in Volts) or Volts X Amps = Watts.
How Does the System Work?

Electricity, where it comes from and how it gets to me

1. Electricity is generated and leaves the power plant
2. Its voltage is increased at a “step-up” substation
3. The energy travels along a transmission line to the area where the power is needed
4. Once there, the voltage is decreased or “stepped-down,” at another substation
5. A distribution power line carries the electricity
6. Electricity reaches your home or business
Generation

Generating Power and Getting It to the Consumer
Transmission

- Thick wires on tall towers carry high-voltage electricity from power plants to local communities and connect one region to another.
• Thinner wires on smaller towers (or in some cases underground) carry much lower voltage power to homes and businesses
Sounds Simple, What’s the Catch?

- Electricity cannot be stored, so supply (generation) must be produced exactly when needed to meet customer demand and to avoid system failure.

- Level in “lake” must be kept constant at all times.

- Laws of physics dictate that power flows on path of least resistance, not necessarily where we’d like it to.

Individual “Lake” Model
Sounds Simple, What’s the Catch?

“Lakes” Network Model

G = Generator
C C = Customer
Different Types of Ownership-Structure

- Shareholder-Owned Utilities
- Cooperatively Owned Utilities
- Government-Owned Utilities
  - Federally Owned Utilities
  - State-Owned
  - Municipally Owned
  - Political Subdivisions
Percentage of Customers Served By Each Type of Provider

- Shareholder-Owned Electric Companies and Affiliates: 72.2%
- Municipal Systems: 11.1%
- Cooperatives: 12.3%
- Political Subdivisions: 2.5%
- Energy Service Providers: 1.0%
- State Projects: 0.9%
- Federal Utilities: <0.01%

Source: Edison Electric Institute Business Information Group
Size and Footprint of the Shareholder-Owned Electric Industry

- Capital Invested = $533.6 Billion (as of December 31, 2005)
- 300,000 Operations Employees (2001 total)

Percentage of Ultimate Customers Served

Shareholder-Owned Electric Utilities and Affiliates 72.2%

Other 27.8%

Source: Edison Electric Institute Business Information Group
1985 represents the base year. Graph depicts increases or decreases from the base year.

Source: U.S. Department of Energy, Energy Information Administration (EIA)
1980 represents the base year. Graph depicts increases or decreases from the base year.
Fuel Sources for Electricity Generation

Following section would incorporate Tim's graphics that come from the Fuel Diversity pie chart that appears on slide 10.
* “Other” includes generation by agricultural waste, batteries, chemicals, geothermal, hydrogen, landfill gas recovery, municipal solid waste, non-wood waste, pitch, purchased steam, solar, sulfur, wind, and wood.

Note: Numbers exceed 100% due to rounding
Source: U.S. Department of Energy, Energy Information Administration (EIA), 2005 data
Different Regions of the Country Use Different Fuel Mixes to Generate Electricity

*“Other” includes generation by agricultural waste, batteries, chemicals, geothermal, hydrogen, landfill gas recovery, municipal solid waste, non-wood waste, pitch, purchased steam, solar, sulfur, wind, and wood.

Fuel Diversity: Key to Affordable and Reliable Electricity

- No individual fuel is capable of meeting all of our nation’s electricity demands
- Maintaining the diversity of available fuel resources helps to ensure that we do not become too dependent on one fuel source
- Fuel diversity protects consumers from contingencies such as fuel unavailability, price fluctuations, and changes in regulatory practices
- Fuel prices greatly affect the price of electricity—today, fuel costs are on the rise
Environmental Aspects of Fuel Diversity

- Fuel choices allow environmental impacts to be balanced and still assure reliable, cost-effective power supply to consumers.
- Any fuel source for generating electricity involves some environmental impact.
- Environmental effects can be air emissions, water quality impacts, fish and wildlife impacts, waste disposal concerns, and aesthetics.
- Environmental impacts are significantly less than they were a decade ago.
Electricity Generation from Coal

- Coal is a fuel source for 50% of electricity generated in the United States.
- Most abundant domestic energy resource—U.S. has about 25% of world’s total coal reserves (275 billion tons) and consumes 25% of world’s coal used annually.
- Significant improvements in pre- and post-combustion emission reduction technology.
- Like prices for other fossil fuels, coal prices are increasing, rising from $1.22 cents/million Btu in 1999 to $1.54 cents/million Btu in 2005.
- Developing clean coal technologies, resolving coal delivery problems, and maintaining coal’s ability to compete on costs are key drivers to future use of coal.
Electricity Generation from Nuclear

- 103 nuclear power plants in the U.S. provide 19% of this nation’s electricity
- Nuclear power produces no sulfur dioxide, nitrogen oxides, mercury, or carbon dioxide emissions
- Uranium is plentiful and efficient. One pellet of enriched uranium—the size of the tip of your little finger—is the equivalent of 17,000 cubic feet of natural gas, 1,780 pounds of coal, or 149 gallons of oil
- Existing nuclear power plant performance continues to improve
- High construction costs and used fuel disposal are two major challenges to building new plants
Electricity Generation from Natural Gas

• 18.7% of total current generation is gas-based; in past decade, almost 95% of new plants have been gas-based

• Lower emissions than other fossil fuels

• Low capital costs and regulatory barriers for other fuels make gas-based generation easier to site and build

• Declining production, limited access to natural gas supplies, and rising demand are causing natural gas prices to increase dramatically

• The average price electric utilities paid for natural gas rose from $2.57 cents/million Btu in 1999 to $8.20 cents/million Btu in 2005

• Large volumes of onshore and offshore natural gas are off limits due to moratoria, regulation

• U.S. isolated from global market and its plentiful supply and lower prices
Electricity Generation from Hydropower

- 6.5% of electricity generation is from hydro—largest source of renewable energy
- Low-cost domestic fuel, emissions free, abundant in some regions, helps contribute to system reliability
- Provides flood control, navigation, irrigation, recreational and fish and wildlife benefits
- Difficult licensing renewal process often results in generating capacity reductions and loss of flexibility to operate facility for electric reliability purposes. Energy Policy Act of 2005 contains provisions to improve the hydropower licensing process
Electricity Generation from Non-Hydro Renewables

• Generation from non-hydro renewables is 2.4%; expected to increase to 4.4% by 2030

• Biomass produces 1.6% of generation; wind, 0.4%; geothermal, 0.4%; solar, 0.01%

• Largely CO₂ emission free. (Emissions from biomass combustion are CO₂-neutral to the extent that they represent atmospheric carbon fixed in plant material through photosynthesis, a process that can be repeated indefinitely.)

• Renewable technologies face high initial capital costs

• Current and future challenges include geographic limitations, intermittent nature, transmission availability, frequent expiration of production tax credit, environmental and aesthetic challenges
Today’s Electric Utility Rate Environment
Electricity: A Great Value

- The national average price for electricity today is less than what it was in 1980, when adjusted for inflation.
- Even with recent price increases, the growth rate for electricity prices remains comparable to, and even lower than, other important consumer goods.

Sources: U.S. Department of Labor, Bureau of Labor Statistics (BLS), and U.S. Department of Energy, Energy Information Administration (EIA)
The Costs to Generate Electricity Are Rising

- Fuel prices greatly affect the price of electricity
- Fuel prices have risen considerably since 1999, particularly for natural gas
- At the same time, demand for electricity continues to grow
Demand for Electricity Is Growing

- While efficiency improvements have had a major impact in meeting national electricity needs relative to new supply, the demand for electricity continues to increase
  - According to EIA, electricity consumption is expected to increase at least 40 percent by 2030

- To meet this increasing demand, electric utilities must invest in a new generation of baseload power plants, those that run continuously to meet the country’s minimum demand
  - According to EIA, 245 gigawatts (GW) of new capacity—both electric power sector capacity and customer-owned distributed generation—will be needed by 2030
Infrastructure Investment Costs Are Growing

• Significant increase in investment coinciding with surge in generating capacity
  – Since 2000, industry has invested more than $23 billion in nation’s transmission system
  – From 2006-2009, industry is planning to invest $31.5 billion in the transmission system, nearly a 60% increase over the amount invested from 2002-2005

• Benefits include newer technologies, bigger markets, lower prices, reliability
Environmental Compliance Costs Are Significant

- All electric utilities are subject to hundreds of environmental rules, including dozens of federal and state air and water quality requirements created in the wake of the Clean Air Act and Clean Water Act.

- From 2002-2005, the electric utility industry spent $24 billion on compliance with federal environmental laws; state and local rules drive that total even higher.

- According to the U.S. Environmental Protection Agency, complying with two new federal regulations—the Clean Air Interstate Rule and the Clean Air Mercury Rule, which are aimed at further reducing power plant emissions of NO\textsubscript{x}, SO\textsubscript{2}, and mercury—will cost the electric utility industry $47.8 billion between the years 2007 to 2025.
As part of the transition to competition, many state policymakers decreed that customers’ bills would be frozen, and in many cases reduced, typically for a period ranging from two to ten years.

The first rate caps were put in place in 1997, and the last are set to expire in 2011.

As rate freezes and reductions are being phased out, many customers perceive that their rates are being “increased,” when in fact they are reflecting the costs already incurred by utilities.
What Are Utilities Doing To Help Control Rising Prices?

• Many utilities try to “hedge” or enter into long-term, fixed contracts for fuel at set prices
  – *Not all companies have this option, and such forward contracts cannot cover all fuel needs*

• Utilities have increased the productivity (capacity factors) of their power plants while at the same time decreasing their operations and maintenance costs

• Electric utilities have taken a leading role in developing energy efficiency and demand response programs for residential, commercial, and industrial customers
  – *Between 1989 and 2005, electric utility efficiency programs saved about 797 billion kilowatt-hours of electricity—enough electricity to power nearly 74 million average U.S. homes for one year*
LOOKING FORWARD
• By 2030, average household consumption is expected to increase by more than 11 percent

• This increase will be entirely driven by appliance-related consumption, reflecting the use of computers and other digital technologies

• The amount of electricity needed for heating, refrigeration, and clothes washing is expected to decline as efficiency increases
• Greater demand for electric power does not translate directly into higher household expenditures

• The average American household’s total spending on electricity has fallen steadily over time
Key Challenges

- Natural gas supply
- Fuel diversity
- Environmental policy
- Coal transportation
- Rising costs of doing business
- Need for increasing infrastructure investment
• Electric utilities are entering a new cycle of growth and investment, and a new era of ratemaking

• If utilities are able to make investments in infrastructure improvements, benefits will include:
  – Long-run reductions in operating costs
  – Enhancements of reliability and power quality
  – Improvements in competitive power markets
  – Cleaner generation
  – Increased customer choice and control over energy use
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