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 Thomas Edison at Pearl Street Station

Pearl Street Station, New York

Schenectady Museum: Hall of Electrical History Foundation
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, requiring significant investment
- 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 service area
- 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 regulating interstate utility operations

- The Federal Power Act
  - Regulates interstate sales of electricity, primarily of shareholder-owned utilities

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

FDR signs legislation
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
• 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*
1970s: Rate Regulation Re-examined

- 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)
  - Required 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 © Corbis

- 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 regulatory models to encourage competition among generators to serve retail customers.
Energy Policy Act of 2005

• Requires mandatory reliability standards for all market players

• Promotes transmission investment and facilitates transmission siting by granting FERC backstop siting authority

• Repeals PUHCA and strengthens FERC’s consumer protection and merger authorities

• Promotes fuel diversity

• Increases energy efficiency

• Gives FERC stronger anti-market manipulation authority

• Reforms PURPA to suspend utility “must-purchase” obligation in competitive wholesale markets

Electricity Initiatives:

• Establishes stricter efficiency standards for variety of appliances; includes initiatives to strengthen building codes for commercial buildings

• Includes incentives to encourage development and production of electric drive transportation technologies, including plug-in hybrid electric vehicles

• Expands federal RD&D program for carbon capture and storage technologies

• Encourages deployment of smart grid technologies with federal matching funds for investment costs
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
Mega What?

- **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 11.2 MWh (11,202 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.
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 electricity “lake” must be kept constant at all times.

- Laws of physics dictate that power flows along path of least resistance; we cannot direct it along specific route.

Individual “Lake” Model

\[ G = \text{Generator} \]

\[ C = \text{Customer} \]
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

- 72.2% Shareholder-Owned Electric Companies and Affiliates
- 14.1% Public*
- 11.8% Cooperatives
- 1.9% Energy Service Providers

* Includes state projects, political subdivisions, and municipal systems.
Note: Federal Utilities serve <0.1% of customers.


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Industry must make significant investments to keep pace with growing demand for electricity.
THE INDUSTRY'S RECORD
Electricity & Economic Growth

Electricity Growth Is Linked to U.S. Economic Growth

Index 1986 = 100

Real GDP
Electricity Use
Total Energy Use

1986 represents the base year. Graph depicts increases or decreases from the base year.


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Increasingly Clean

Power Plants Reduce Emissions Despite Increasing Electricity Demand

Index 1986 = 100

- Real GDP ↑ 85%
- Electricity Use ↑ 64%
- SO₂ Emissions ↓ 42%
- NOₓ Emissions ↓ 54%

1986 represents the base year. Graph depicts increases or decreases from the base year.

Sources: U.S. Department of Energy, Energy Information Administration (EIA), U.S. Environmental Protection Agency (EPA), and U.S. Bureau of Economic Analysis.

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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.
What Are the Fuels Used to Generate Electricity?

2008 National Fuel Mix

*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Sum of components may not add to 100% due to independent rounding.


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Different Regions of the Country Use Different Fuel Mixes to Generate Electricity

*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Sum of components may not add to 100% due to independent rounding.


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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; fuel costs have fluctuated recently, but remain high by historical standards
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 48.5% 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 have increased in recent years, rising from $1.25/million Btu in 1999 to $1.78/million Btu in 2007

• Developing clean coal technologies, including carbon capture and storage 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 Natural Gas

• 21.3% of total current generation is natural gas-based; in past decade, almost 95% of new plants have been natural gas-based

• Lower emissions than other fossil fuels

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

• The average price electric utilities paid for natural gas rose from $2.38/million Btu in 1998 to $7.50/million Btu in 2007

• Natural gas prices fluctuated in 2008, but remain high by historical standards

• U.S. isolated from global market and its plentiful supply and lower prices
• 104 nuclear power plants in the U.S. provide 19.6% of the 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
• 5.9% 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 opportunities, 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 and other sources is 3.5%
- Biomass, wind, and geothermal generate the majority of non-hydro renewable-based power
- Largely CO$_2$ emission free. (Emissions from biomass combustion are CO$_2$-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
The national average price for electricity today is less than what it was in 1988, 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.
Electricity Use in the Typical U.S. Home

• Average U.S. home today is nearly 50% larger than average home in 1975

• Average U.S. household owns 24 consumer electronic products

Annual Electricity Use in the Typical U.S. Home Has Increased 60% Since 1970


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A typical U.S. household uses 934 kilowatt-hours of electricity a month.
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 23 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
Infrastructure Investment Costs Are Growing

• Investment in the electricity system on the order of at least $1.5 trillion will be required from 2010 – 2030:
  – Generation: $505 billion, assuming no changes in carbon policy or long-term price effects
  – Transmission: $298 billion
  – Distribution: $582 billion
  – Advanced Metering Infrastructure and Energy Efficiency/Demand Response: $85 billion

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

• The electric utility industry was projected to spend approximately $12.5 billion on environmental compliance measures in 2008

• The research, design, development, and deployment of new technologies needed to reduce greenhouse gas emissions will require greater investments
• 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 Customers Manage Their Electricity Bills?

- Electric utilities have taken a leading role in developing energy-efficiency and demand-response programs for residential, commercial, and industrial customers.

- Between 1989 and 2007, electric utility efficiency programs saved about 929 billion kilowatt-hours of electricity—enough electricity to power 83 million average U.S. homes for one year.
Edison Electric Institute supports legislation that reduces greenhouse gas (GHG) emissions by 80 percent below current emission levels by 2050, while providing strong consumer-protection measures to help reduce electricity price increases.

Effective consumer-protection measures include:

- Allocating emission allowances to the electric utility sector
- Including a “price collar” on emission allowances
- Setting reasonable and achievable emission reduction targets that align GHG reductions with the availability of cleaner technologies
- Allowing the wide and robust use of offsets, both domestically and internationally

To learn more, visit www.SmartClimatePolicy.org
• Addressing climate change requires an aggressive and sustained commitment to a full set of technologies, including:
  – Energy Efficiency
  – Renewables
  – Advanced coal technologies
  – Carbon capture and storage
  – Nuclear
  – Plug-in hybrid electric vehicles
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-term 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
Key Industry Challenges

- Climate change and other environmental policy
- Developing and commercializing advanced coal technologies and carbon capture and storage
- Licensing and building next generation of nuclear facilities and addressing spent fuel disposal
- Natural gas supply
- Developing battery and commercializing plug-in hybrid electric vehicles
- Building new transmission infrastructure, especially for renewables
- Rising costs of doing business
- Rate structure to encourage utility investment in energy efficiency
Edison Electric Institute (EEI) is the association of U.S. shareholder-owned electric companies. Our members serve 95 percent of the ultimate customers in the shareholder-owned segment of the industry, and represent approximately 70 percent of the U.S. electric power industry. We also have more than 65 International electric companies as Affiliate members, and more than 170 industry suppliers and related organizations as Associate members.

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