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The Evolution of Energy

A brief history of energy highlighting significant milestones and inflection points

For thousands of years, mankind has been adapting to new environments and creating new technology. Our ability to harness energy and create utility is a prime example. Throughout history, the world has undergone several significant energy transitions, from coal to nuclear power to natural gas. Today, we're seeing another transition in progress—the shift to renewable energy. Many experts believe this transition is critical for the long-term health of the planet and will ultimately drive economic growth.

Benefits of World Economies Going Green

- Revenue Boost
- Job Creation
- Lower Overhead Costs
- Improved Public Health

Wood

The Skinny:
Wood, the primary source of energy for thousands of years, was used in:

until the 1600s | until the late 1700s

The price of wood gradually increased as harvesting efforts were forced to move farther away from urban industrial centers.

Advantages:	Challenges:	Key Stat:
Abundance and convenience prior to the Industrial Revolution	Urbanization drove wood prices higher as harvesting moved to more far-flung locations	**6%** of the world's primary renewable energy supply

Major Milestones:

- primary fuel for heating and cooking in homes and businesses
- used for steam in industries, trains and boats

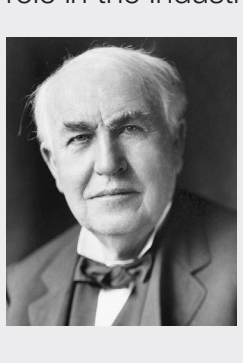
Inflection Point:

Urbanization pushed wood prices higher as harvesting efforts moved to more far-flung locations. For the industrializing world, the shift from wood to coal brought enormous benefits. Expanding rail networks and steam ships transformed trade and offered average Americans greater mobility.

Source: U.S. Energy Information Administration, Food and Agriculture Organization

Coal

The Skinny:
The transition from wood to coal was gradual over time but accelerated in 1790 with the invention of the steam engine and its role in the Industrial Revolution.



In 1882, coal-powered steam engines that generated electricity were pioneered by Thomas Edison. Although coal use was once common in the industrial, transportation, residential and commercial sectors, today the main use of coal in the United States is to generate electricity.

Advantages:	Challenges:
Energy density, abundance, role in trade and utility in transportation	Over time, rising prices, depleted resources, pollution and associated health risks posed challenges

Key Stats:

1B Tons of coal produced by the United States annually for each of the last 15 years	**91%** of U.S. coal consumption is used for electric power

Major Milestone:

1924 The coal industry reached peak employment with over 860,000 miners employed.

Inflection Points:
The price of coal quickly declined as adoption spread with the price per ton falling to $3 in the 1850s from $7 to $10 in 1830s. The economic benefit of using coal as a preferred energy source became clear and U.S. coal consumption grew by more than 100 times in the next 50 years.

Pollution became an increasing concern as air quality around the world worsened. Rising costs of transportation, dwindling supply and deteriorating air quality led to the pursuit of a more efficient, more abundant and less dangerous source of energy.

Source: U.S. Energy Information Administration, Arcadia Publishing: Evolution of the Coal Industry in America

Nuclear

The Skinny:
Nuclear energy was touted as an alluring replacement to coal. Uranium is plentiful globally, cost-effective to mine and splitting atoms can create an unlimited amount of energy. Demand for nuclear energy boomed in the second half of the 20th century, with scores of power plants being built across the United States.

Advantages:	Challenges:	Key Stats:
Nearly unlimited supply, inexpensive to mine uranium, no greenhouse gases	Costly safety regulations, project delays, increased construction costs, radioactive waste	**58** Number of nuclear power plants in the United States, the most in the world

Major Milestone:

1ST In the 1950s, Arco, Idaho becomes the first U.S. city to be powered by a nuclear reactor.

Inflection Point:
The transition to a society dependent on nuclear energy ultimately stalled in the aftermath of the Three Mile Island disaster. The meltdown released radioactive gases and discharge into the nearby community, racking up nearly $1 billion of cleanup costs and large public outcry.

Source: U.S. Energy Information Administration

Natural Gas

The Skinny:
In the late 1920s, improvements in the welding and metal sectors led to more efficient modes of transportation, which made natural gas commercially viable. Next, machines were invented that heated air and fuel to spin turbines that generated electricity, which pushed natural gas into the mainstream. Further adoption came with the invention of hydraulic fracturing or "fracking."

Advantages:	Challenges:	Key Stat:
Abundant supply in the United States, cleanest fossil fuel, employs 1.2 million people	Costly infrastructure, flammable, carbon emissions, environmental risks	**41%** of the energy used by U.S. industry is natural gas

Major Milestones:

1821 William Hart dug the first successful U.S. natural gas well in Fredonia, New York.

1885 Robert Bunsen's invention—the Bunsen burner—opened vast new opportunities to use natural gas.

Inflection Point:
The widespread use of fracking and broad-based deregulation in the industry enabled the natural gas industry to boom, resulting in an industry-low LCOE that prompted utility companies to transition away from coal. By 2016, natural gas had surpassed coal as the United States' preferred source of energy.

Source: U.S. Energy Information Administration, American Public Gas Association

Levelized Cost of Electricity (LCOE)

LCOE calculates present value of the total cost of building and operating a power plant over an assumed lifetime.

Source: Corporate Finance Institute

Wind

The Skinny:
Early U.S. settlers built windmills for irrigation and home power generation. As the modern-day electrical grid developed, the use of wind declined. In the 1970s, the use of wind power generation saw a resurgence as a result of technological innovations, which drove down cost and improved efficiencies.

Advantages:	Challenges:
The base structure of these turbines is relatively small, enabling the farmer to continue to simultaneously grow crops or graze livestock on the land. The earnings from wind turbines provide a buffer to fluctuating commodity prices and are usually secured by long-term leases of 20 years or more.	Lower (but improving) operating capacity Recycling of materials used in turbines

Key Stats:

67% decline in its levelized cost of energy (LCOE) since 2012 for offshore wind	**7.3%** Wind power's share of total U.S. energy generation

Major Milestones:

1941 The Chicago World's Fair showcases 15 windmill companies and their wind turbine designs.

1978 Congress passes the Public Utility Regulatory Policies Act of 1978, which requires companies to buy a certain amount of electricity from renewable energy sources, including wind.

1980 The first large (utility-scale) wind farms are installed in California.

1993 The National Wind Technology Center (NWTC) is built to be the nation's premier wind energy technology research facility.

2020 Siemens launched the largest ever wind turbine, a 14-megawatt model with a 222-meter rotor diameter.

Inflection Points:
During the 1970s, soaring gas prices renewed interest in wind power and fueled more in-depth research of wind turbines. The rise of wind-sourced power benefited from economies of scale, with the LCOE declining by 71% between 2009 and 2020.

Consistent declines in the cost have driven rapid growth for wind-development projects and incentivized traditional farmland owners to lease their land for wind turbines.

Source: U.S. Energy Information Administration, Office of Energy Efficiency & Renewable Energy

Solar

The Skinny:
Solar energy projects can be classified into three main segments: residential, commercial and utility. The adoption of solar panels by the residential community represents one of the fastest-growing segments in the industry as consumers opt for cheaper utility prices and a smaller carbon footprint. Similarly, commercial projects have included the use of solar energy on building rooftops. The electricity generated from these structures can be shared by multiple tenants or entities within a single building.

Advantages:	Challenges:
Lower-cost access to electricity, lower maintenance costs, multiple uses	Requires large spaces, storage is costly, weather dependent

Key Stats:

94% drop in cost to produce a solar PV panel between 2000 and 2017	**64.2GW** installed in the U.S. as of the end of 2018–enough to power 12.3 million American homes
1.6% of total U.S. electricity generation	**10.6GW** installed in the U.S. in 2018
1ST or 2ND ranking in capacity added to the U.S. electric total every year since 2013	**1.47M** solar panels in use across the contiguous 48 states

Major Milestones:

1921 Albert Einstein wins the Nobel Prize for his theories explaining the photoelectric effect.

1954 Daryl Chapin, Calvin Fuller and Gerald Pearson develop the silicon photovoltaic cell at Bell Labs—the first solar cell capable of converting the sun's energy into enough power to run everyday electrical equipment.

1973 The University of Delaware builds Solar One, one of the world's first photovoltaic (PV) powered residences.

1982 Hans Tholstrup drives first solar-powered car, the Quiet Achiever, 2,800 miles between Sydney and Perth in 20 days—10 days faster than first gas-powered car.

1996 The world's most advanced solar-powered airplane, the Icare, flew over Germany.

Inflection Point:
In the 1970s, when oil prices quadrupled and gas stations had lines for blocks, it became apparent that the world needed a more diverse energy system. In 1977, the United States embraced the development of solar energy by creating the Solar Energy Research Institute.

Source: U.S. Energy Information Administration, Solstice, Stanford University