Nuclear Energy

“Nuclear power is a hell of a way to boil water.”
- Albert Einstein
• Following World War 2, additional nuclear weapons testing was moved to part of the Marshall Islands, called the Bikini Atoll (11°N).

  – This testing was codenamed “Operation Crossroads.”
• Two nuclear devices were detonated at sea as part of Operation Crossroads.
  – The purpose was to study the effects of a nuclear blast on an armada of naval ships.
• The first blast, called Shot Able, was dropped from a plane (July 1, 1946). The second, Shot Baker, was detonated underwater, beneath the ships (July 25, 1946).
• Different species of lab animals were placed on several ships, to test for radiation poisoning following the blast.
Operation Crossroads Fallout

- Glenn Seaborg, chairman of the Atomic Energy Commission, called Baker “the world’s first nuclear disaster.”
- The target ships of Shot Baker were all heavily contaminated with radioactive fallout.
  - Many were so “hot” that they could not be safely decontaminated and had to be sunk.
Atoms for Peace - December 8, 1953

• As the Bikini nuclear testing continued, President Dwight Eisenhower gave a famous speech to the United Nations:

  “My country wants to be constructive, not destructive.”

  “…the United States pledges before you its determination to help solve the fearful atomic dilemma--to devote its entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life.”
• Equipment and technology were provided to schools, hospitals, and research institutions to help develop nuclear technology towards more peaceful goals.
  – The primary goal: electricity generation.
• Optimism for the new technology was very high.
• Lewis Strauss, chairman of the Atomic Energy Commission, predicted that,

  “Our children will enjoy in their homes electrical energy too cheap to meter.”
Nuclear Reactors

• The process of converting nuclear energy into electricity is similar to that of using fossil fuels.
  – Water is boiled, the steam is passed through a turbine, which spins a generator.
• As with nuclear bombs, the primary fuel is uranium-235.
  – Uranium ore is enriched and formed into fuel pellets.
  – The fuel pellets are stacked into long, cylindrical fuel rods.
  – Control rods, made of a neutron-absorbing material, are placed amongst the fuel rods. They can be removed and inserted to adjust the rate of the chain reaction.

Withdraw control rods, reaction increases

Insert control rods, reaction decreases
• One big advantage to nuclear power is that, under normal conditions, it does not release any air pollution, only steam.
• Through the late 1970s, many new reactors were constructed all over the United States.
• Since that initial boom, few new reactors have come online.
Nuclear Accidents

• In 1979, a movie called “The China Syndrome” was released.
  – Fictional story about a California nuclear plant that experienced a near-meltdown of its nuclear core.
• Ten days following the movie’s release, the Three Mile Island partial meltdown occurred.
  – A relief water valve stuck open, allowing water to escape from the core.
  – A **meltdown**, when the fuel and control rods physically begin to melt due to the heat surge within the reactor, **partially** occurred.
  – No major leak to the environment occurred.
• In 1986, a full meltdown occurred at the Chernobyl nuclear plant located in Ukraine (formerly Soviet Union).

• A test was being conducted on the reactor to see how the backup water pump generators would respond to a full power outage.
  – The control rods were fully removed.
  – At some point, the fission chain reaction began occurring uncontrollably.
  – An explosion ripped apart the containment building, spreading radioactive fallout throughout the area and into the atmosphere.
• The burning core was eventually extinguished.
• The nearby employees’ town, Pripyat, was permanently evacuated.
• A 30km radius around the plant, called the exclusion zone, has been designated as uninhabitable.
Fukushima March 11, 2011

• The most recent meltdown occurred following a massive earthquake and tidal wave off the coast of Japan.

• The generators powering the water pumps of some of the Fukushima Daiichi reactors were flooded.
  – Without cooling water, the core overheated and experienced a meltdown.
• Contaminated water from the plant leaked into the Pacific.

• Top predators, like bluefin tuna, caught in the Pacific have positively tested for small amounts of radioactive fallout.
  – A single serving of tuna has less than half of the exposure from an arm x-ray.
  – Some recent studies indicate that the western coast of North America showed very limited signs of having any radioactivity that can be attributed to Fukushima
Radioactive Waste Management

• About 100,000 tons of low-level waste (clothing) and about 15,000 tons of high-level waste (spent-fuel) waste is stored in the U.S. from reactor usage.

• Spent fuel rods are temporarily placed in deep water pools while they cool down and the fission reaction slows.
  – Waste is then moved to large casks of metal and concrete near the reactor.
• The U.S. Department of Energy announced plans to build a high-level waste repository near Yucca Mountain, Nevada in 1987.

• The facility met three important criteria for long-term waste storage:
  – Low moisture.
  – Geologically stable.
  – Far away from major population centers.

• Plans to use Yucca have since been halted, due to objections from Nevada residents.
  – No long-term storage plan has been accepted by the U.S.
• Some alternative methods of nuclear waste disposal have been researched.
  – Transmutation uses the waste as fuel in a different type of reactor, which converts it to a less-dangerous waste.
  – Geologic disposal involves depositing the waste deep below the Earth's crust in stable rock formations.
The country's 99 nuclear reactors produced 805 billion kWh in 2016, almost 20% of total electrical output. There are two reactors under construction.
Energy Efficiency
Percentage of energy input retained when converting fuel to electricity

- Coal: 29%
- Oil: 31%
- Natural gas: 38%
- Biomass: 52%
- Solar: 207%
- Nuclear: 290%
- Hydro: 317%
- Geotherm: 514%
- Wind: 1,164%

Source: Energy Points
The Wall Street Journal
## Electricity Cost
Cost to produce 1 MWh

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<th>Source</th>
<th>Cost</th>
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<tbody>
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<td>Natural gas</td>
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</table>

*2009 dollars for plants entering service in 2016
Source: EIA
The Wall Street Journal