Nuclear Ithaca

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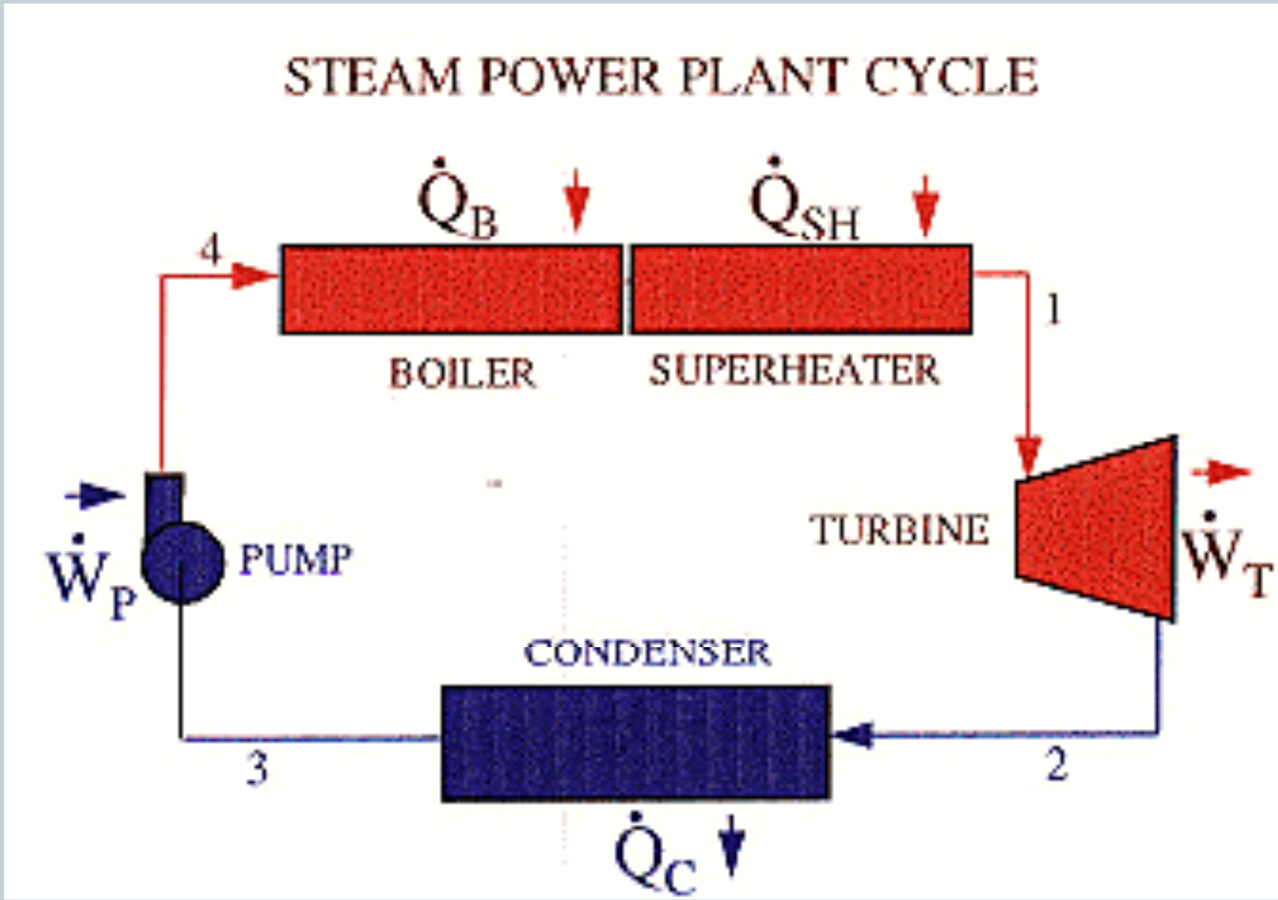
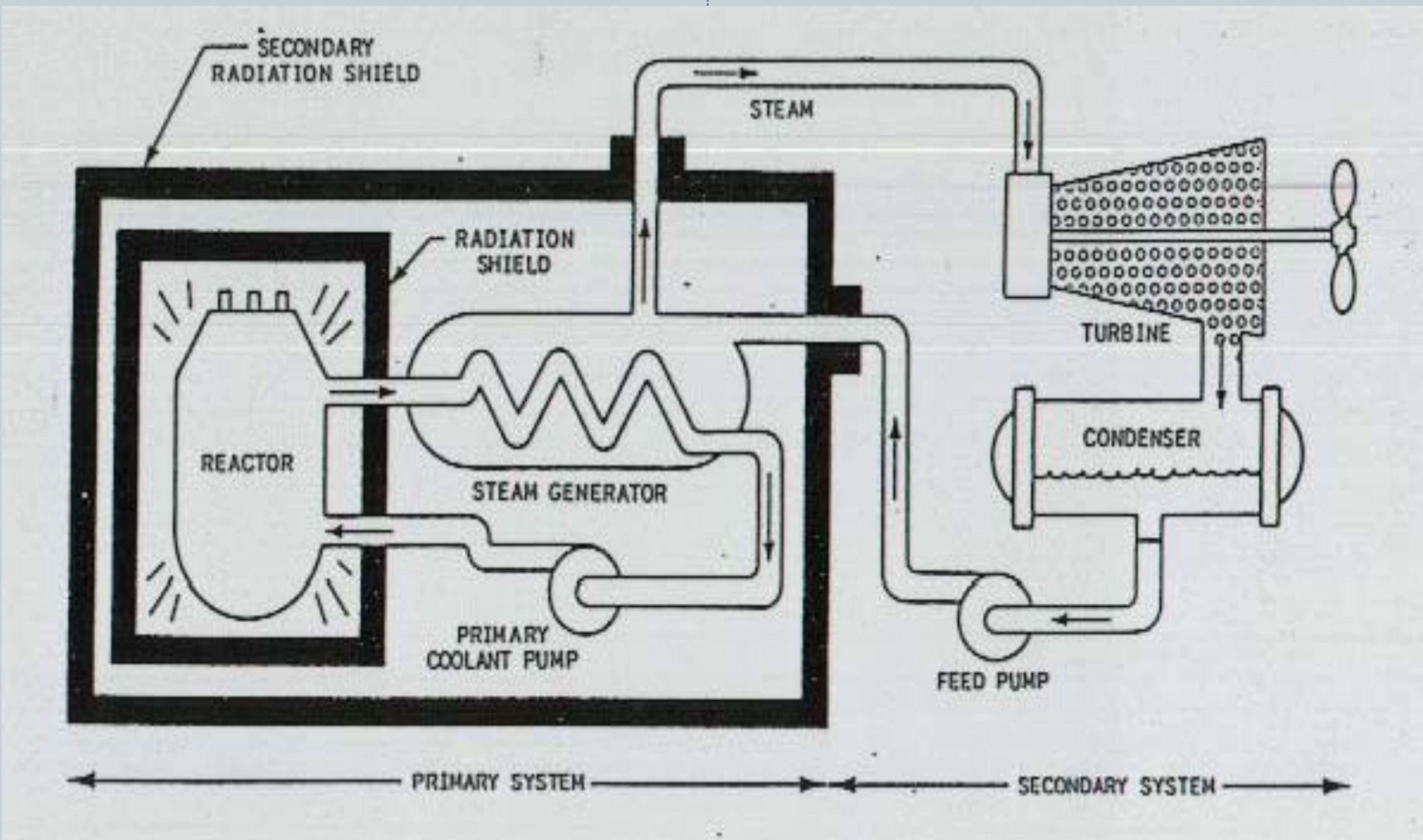
What is Nuclear Power?

Steam Cycle



http://www.cartage.org.lb/en/themes/sciences/physics/thermodynamics/basicthermodynamics/steampower/steampower.htm

Nuclear Cycle



Concerns

- Water Contamination
- Fuel Disposal
- Investment Risks
- Security, Political
- In our case

Groundwater Contamination

- **Tritium**
  - Tritium is a radioactive isotope of the element hydrogen.
  - Tritium occurs naturally in the upper atmosphere
  - Nuclear power plants account for less than 0.1% of total background dose
  - Everyone is exposed to small amounts of tritium every day, because it occurs naturally in the environment and the foods we eat.
  - Half of the tritium is excreted within approximately 10 days after exposure.

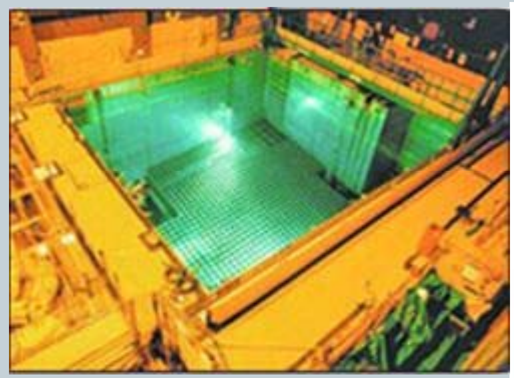
- **Strontium -90**
  - Strontium-90 (Sr-90) is a radioactive isotope that is produced in nuclear fission, the splitting of an atom's center that releases energy.
  - Sr-90 takes about 29 years to lose half of its radioactivity.
  - Approximately 99% of the Sr-90 in the environment comes from weapons testing fallout. And most of the remaining 1% comes from the Chernobyl accident.
  - Sr-90 released from nuclear power plant is so low that it is usually at or below the minimum detectable activity of sensitive detection equipments, not to mention far away from the plant.

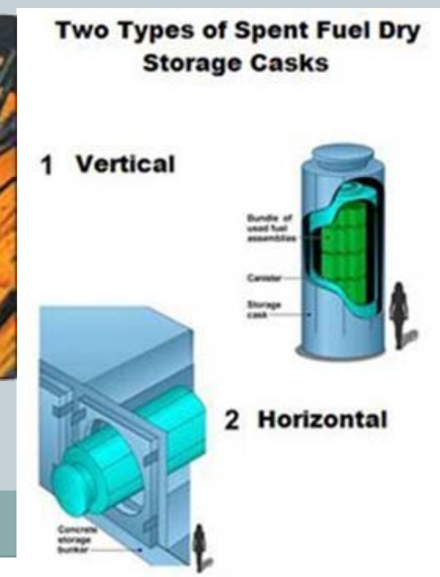
Fuel Disposal

- **Low Level Waste (LLW)**
  - LLW includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation.
  - Current LLW repositories
    - Barnwell, South Carolina
    - Richland, Washington
    - Clive, Utah

- **High Level Waste (HLW)**
  - Spent reactor fuel
  - Waste materials remaining after spent fuel is reprocessed

- **Storage and Transportation**





Security

- **Domestic Safeguards**
  - Physical Protection
    - Nuclear Facilities
    - In transit
  - Material Control (Special Nuclear Materials)
    - Strategic SNM
    - SNM of moderate strategic significance
    - SNM of low strategic significance

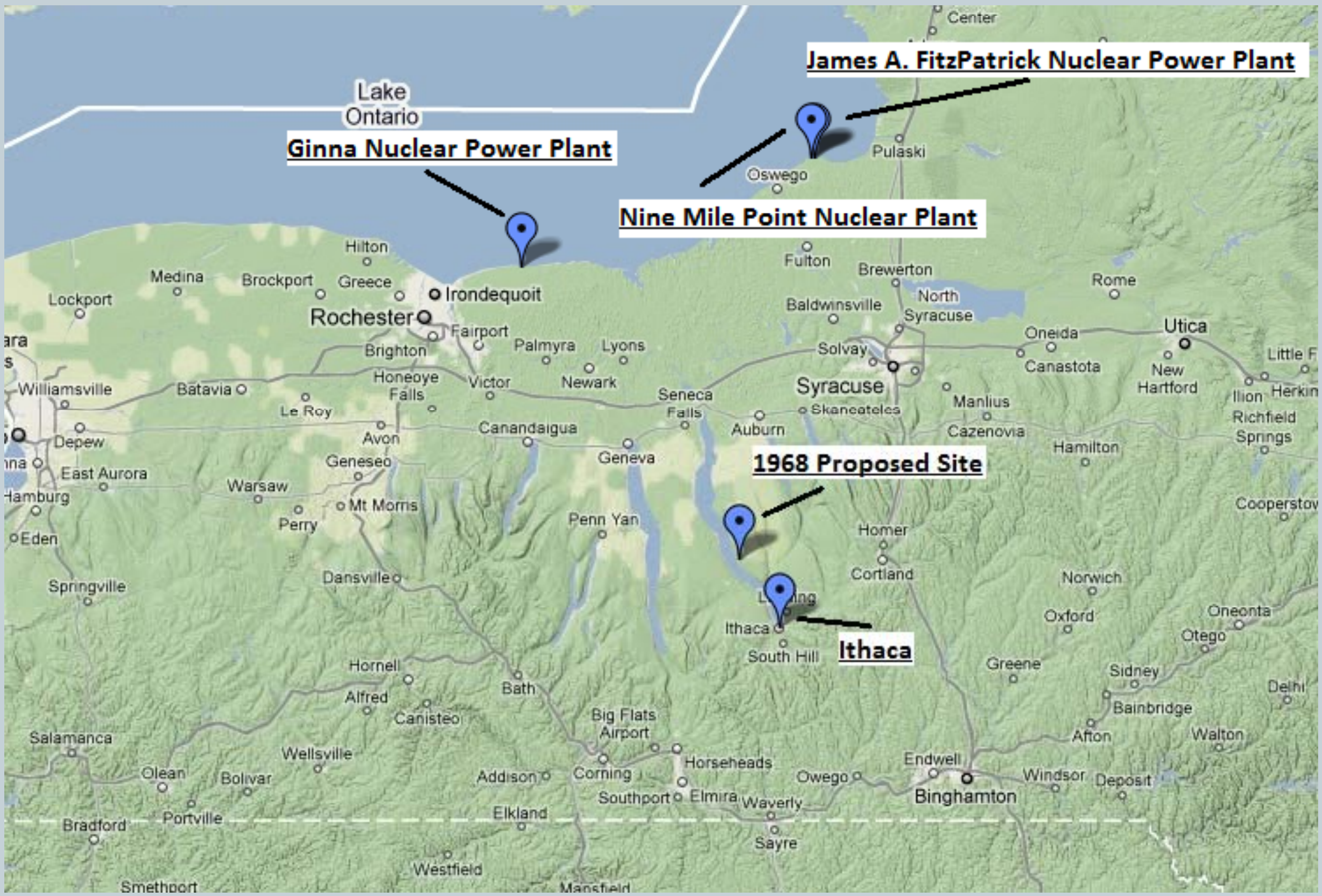
- **Information Safety**
  - Classified Information
    - National Security Information (NSI)
    - Restricted Data (RD)
  - Safeguards Information (SGI)
  - Sensitive Unclassified Non-Safeguards Information (SUNSI)

Capital Risks

- Initial cost
  - Nature of nuclear power plants is higher initial cost and lower maintenance cost.
- Highly Trained Operators
  - More filters applied
  - Higher pays
- Other Risks
  - Before building the plants
  - During the construction of the power plants.
  - After completion of the construction.
- Solutions

Community Response

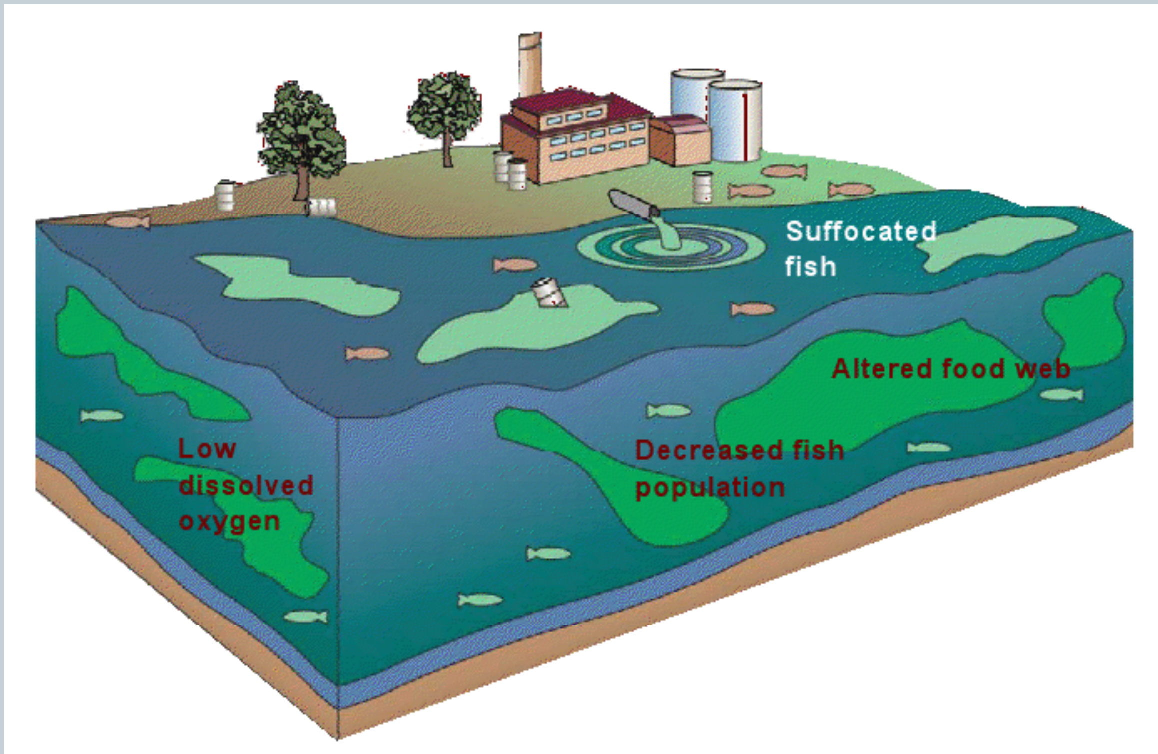
1968 Proposed Sites



http://www.ithacahours.com/archive/ithacapower/8812.html

Bell Station

1968 – Bell Station



In April 1969 a controversy over 'thermal pollution' postponed construction of a proposed Nuclear Plant at Bell Station.

Opposition to construction of nuclear power plants has taken many forms. This one occurred at Madison, Wisc.

March 1973 – NYSEG President announces NUS Study results

> "We propose to continue to work cooperatively with all groups that share and are working for our common objectives. We invite their cooperation… but no special interest or single objective can be controlling. The greatest good for the greatest number must be our basic motivation as we plan ahead together for the future."

April 1973 – Information meeting for public

Public Concern

By 1973, public concern had shifted away from thermal pollution and waste heat issues.

"As experience with the operation of fission reactors accumulates, more and more evidence of unreliability, malfunctioning, and unpredictability of the technology are appearing."

(CCSCL, Newletter, April 1973)

NYSEG Letters **Opposing** Bell Station:

- 45% – reactor safety and nuclear waste
- 20% – lake ecology
- 9% – preserving lake for recreation
- 5% – conserving power
- 21% – did not elaborate

Ithaca Journal **Opposing** Bell Station (of 98):

- 39 – risks associated w/ nuclear power
- 23 – criticized the NYSE&G experts
- 20 – objected to NYSE&G procedures
- 21 – called for increased citizen responsibility
- 10 – criticized local officials as non-representative
- 5 – criticized federal agencies and licensing procedures
- 31 dealt with consumer issues and proposed various methods to reduce the use of electricity

NYSEG Letters **Favoring** Bell Station:

- 18% - need for more power
- 10% - confidence in federal, state and corporate responsibility for safety
- 9% - confidence in NUS report
- 50% - did not specify

Ithaca Journal **Favoring** Bell Station (of 22):

- 4 – risks trivial compared to benefits
- 7 – confidence in NUS and NYSE&G decision-making process
- 12 – need more energy sources
- 1 – impact on local tax base
- 1 – pollution caused by movie theater industry more widespread than potential pollution by Bell Station
- 10 – questioned the representatives of those opposing the plant: "a few college men from Cornell keeping the people all worked up."

	Favored	Opposed
Officials/Business Owners	63%	15%
Skilled Worker Group	43%	37%
Persons in Professional and Technical Occupations	31%	48%

Although the intensity of public opinion, as expressed through letters and petitions, appeared to be strongly negative, most organizations were **in favor** of Bell Station.

AES Cayuga (formerly NYSEG Milliken)

http://farm4.static.flickr.com/3435/3726780187_49d6a683be.jpg

Misconceptions

We're all familiar with Homer running the plant. But…

- Operators must have a BS in Engineering
- Require several years of related experience

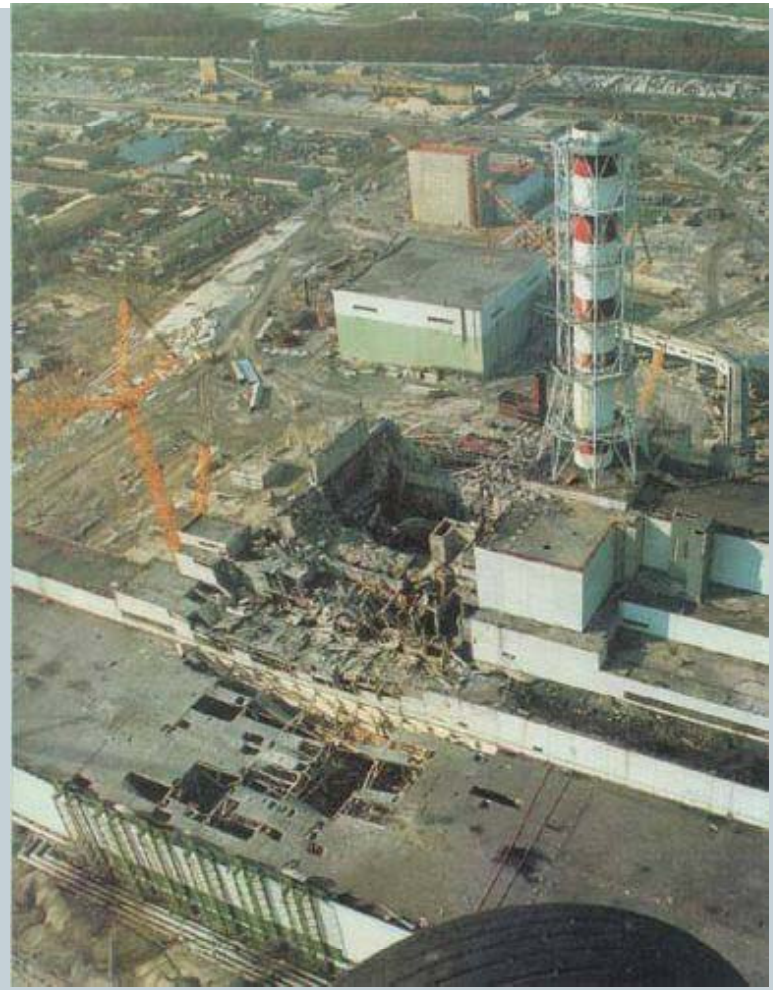
Misconceptions – Three Mile Island

March 29, 1979

- What happened then?
  - Mechanical Failure => Human Error
  - Two lines of defense still not breached–
    - Essentially all radioactivity remained sealed in the thick steel reactor vessel
    - Vessel remained sealed inside containment building
- Resulted in NO Deaths or Injuries!
  - EPA monitoring concluded that the radiation release did not amount to even 1 cancer related death
- Average dose of radiation to individuals within 10 miles equivalent to 1 chest x-ray.
- Maximum dose received by anyone equivalent to only 1/3 of the average background radiation received by US residents in a year

Misconceptions - Chernobyl

- Chernobyl did not have a containment structure like Three Mile Island did
  - If it did, disaster would have been averted
- 28 people died in 1986 from Acute Radiation Syndrome
- 19 more died from 1986-2004 from different causes
- Estimated that 4,000 people may die earlier than otherwise expected due to the increased cancer risk



Misconceptions – Risk Assessment

Nuclear Meltdown

- Fuel Meltdown expected once in 20,000 years of reactor operation.
  - 2 out of 3 melt-downs would result in no deaths
  - 1 out of 5 would result in 1000+ deaths
  - 1 out of 100,000 meltdowns, ther would be 50,000 deaths
  - AVERAGE = 400 deaths per meltdown

Coal Burning

- Air pollution from coal estimated to cause 10,000 deaths per year
  - Therefore, would need to have 25 nuclear meltdowns PER YEAR for nuclear power to be as dangerous as burning coal!

Misconceptions – Worst Case Hypothetical Failures

Nuclear Meltdown

- Meltdowns probable to occur once every 20,000 years
  - Noticeable deaths are expected in only 2% of reactor melt-down accidents
  - Over 100 deaths can be expected in only 0.2% of meltdowns
  - Only 1 out of 100,000 meltdowns would result in 3,500 sudden deaths

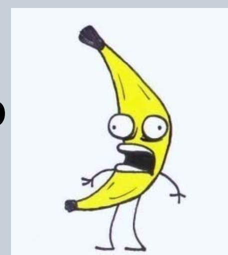
Other technologies

- To date, largest # of noticeable deaths from coal burning air pollution incident (London, 1952)
  - Resulted in an extra 3500 deaths in just one week
- If we consider hypothetical, other potential disasters are much worse
  - Hydroelectric dam failure could cause 200,000 instant deaths in California

Misconceptions – Everyday Radiation Exposure

Everyday Exposure

- Background radiation
  = 360 millirem/year
- Living within 50 miles of coal burning plant
  = .03 millirem/year
- Food we eat contributes 40 millirem of radiation/year
  - Potassium is radioactive!



- Smoking contributes up to 16,000 millirem/year
- Average exposure of X-Ray technician
  = 500 millirem/year

Exposure from Nuclear Power Plant

- Average exposure of nuclear power plant worker = 240 millirem/year
- Reduces life expectancy by less than one hour
  - Other technologies such as coal, oil, or gas, reduce life expectancy by 3-40 days.
- Additional radiation exposure from living near nuclear power plant = .009 millirem/year
  - 3 times less than coal!

Local Energy Consumption

- Populations

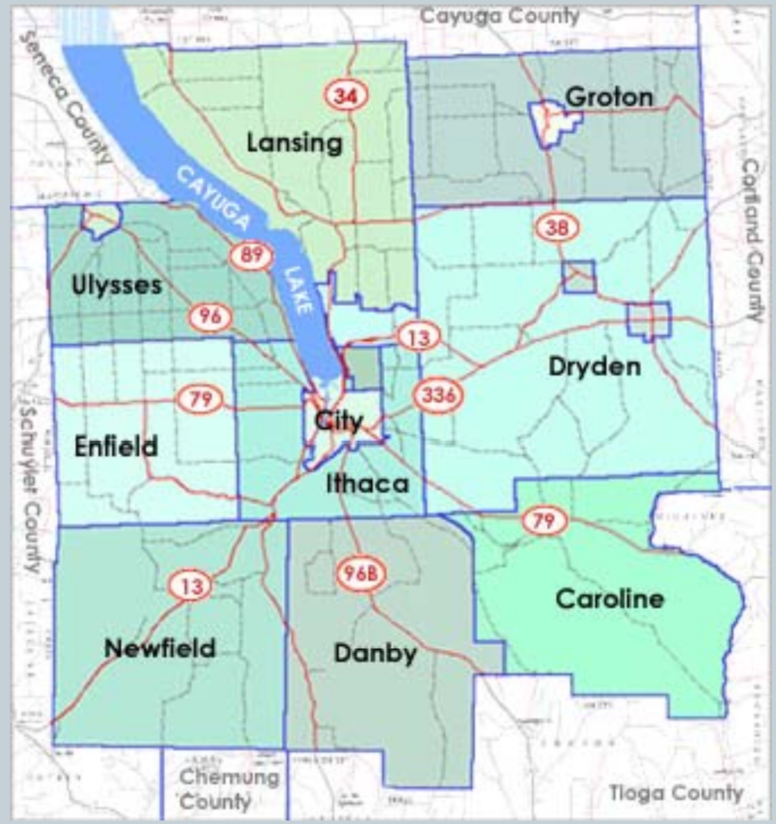
-Tompkins County = 101,779

-Ithaca = 30,013

- Total energy required (estimate)

-Tompkins County ≈ 1050 MW

-Ithaca ≈ 310 MW



Tompkins County Emissions

- Total County Emission

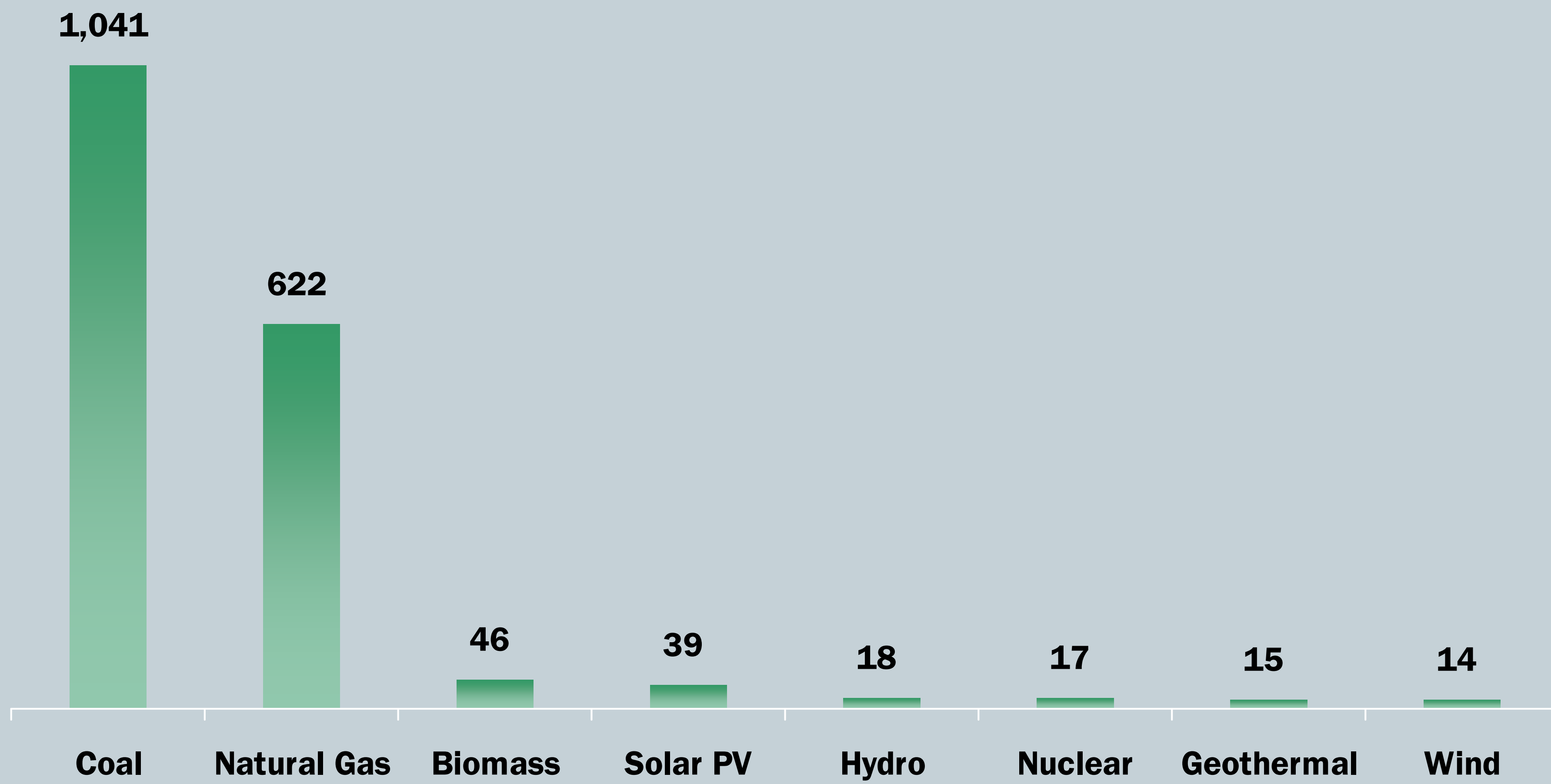
-1,179,254 MtCO_2e

- Tompkins County 2020 Energy Strategy: to reduce 20% below 2008 emission levels

-277,512 MtCO_2e reduction

Comparison of Life-Cycle Emissions

Tons of Carbon Dioxide Equivalent per Gigawatt-Hour

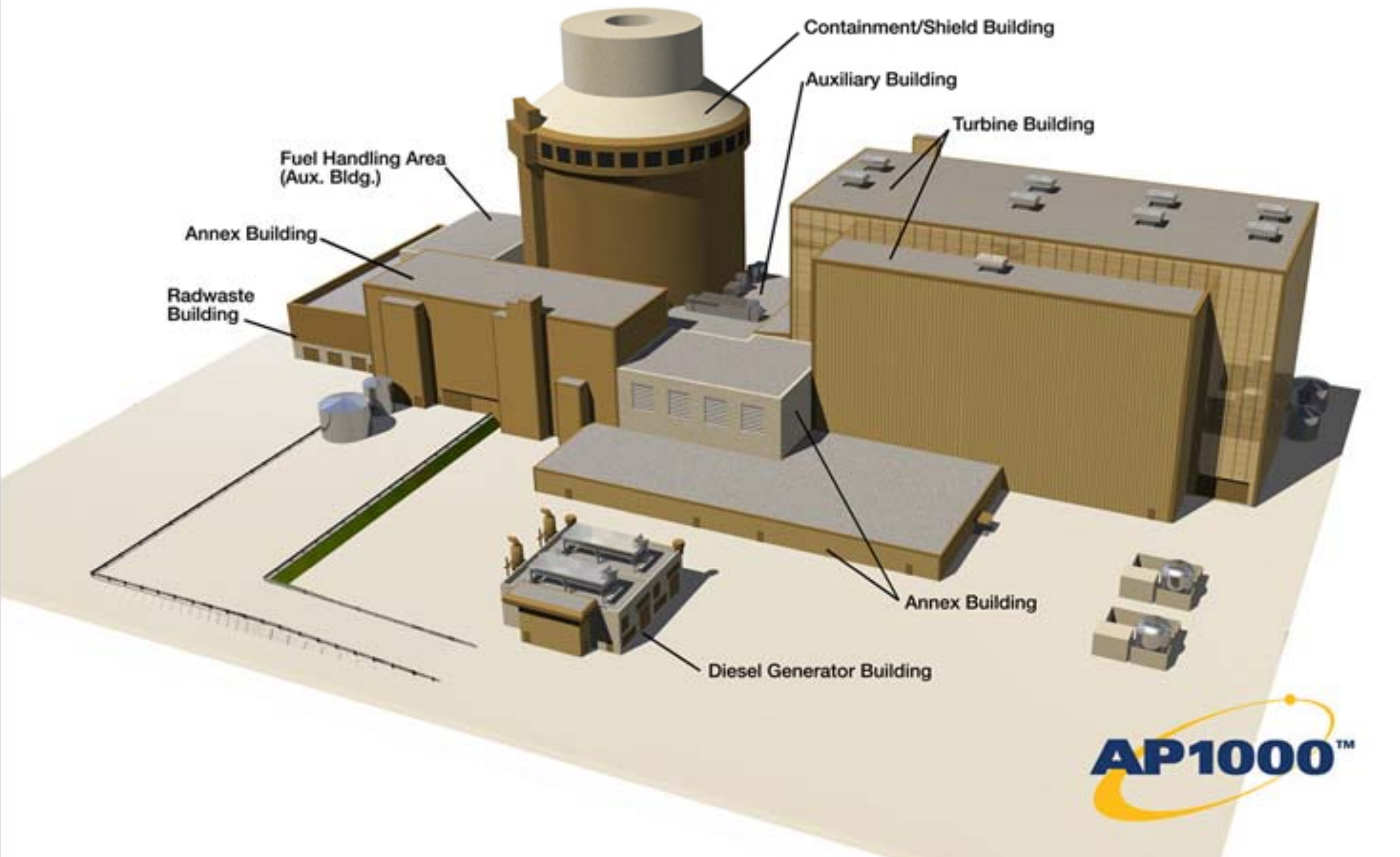


Source: "Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis," Paul J. Meier, University of Wisconsin-Madison, August 2002.

AP 1000 At a Glance

- Evolutionary Improvement on the AP 600
- Advanced Pressurized Water Reactor
- Generation III + Reactor
- 1154 MW
- First of its kind to be approved by the Nuclear Regulatory Commission
- 12 expected to complete in China by 2015, 100 by 2020
- 14 proposals in the U.S, one official approval and contract agreement at the Vogtle plant in Georgia.

The Westinghouse AP1000™



Safety Specifications

•Passive Core Cooling System

-DC operated valves shut down the reactor within 30 minutes of overheating, even if reactor operators take no action

•Breeder Technology

-Used fuel produced by the AP1000 can be stored indefinitely in water on the plant site

•Low Probabilistic Risk Assessment

-CDF (Core Damage Frequency) →
1/100 of currently operating plants
1/20 of maximum CDF deemed acceptable for new plants

•In-Vessel Retention of Core Damage

-Reactor becomes flooded and cooled

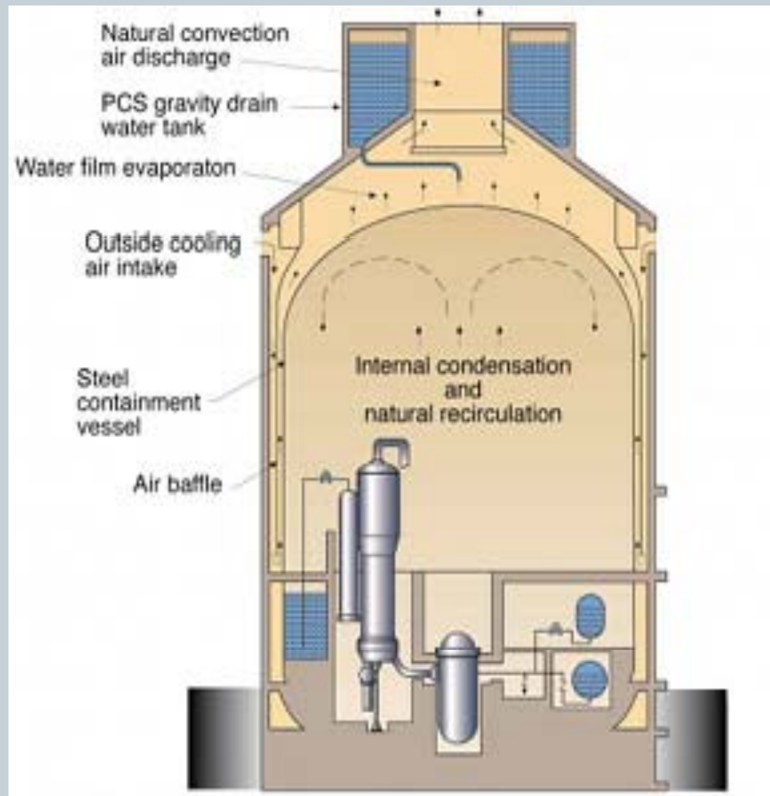


Figure 3. AP600 Passive Containment Cooling System

Economic Competitiveness

- **Construction Costs**

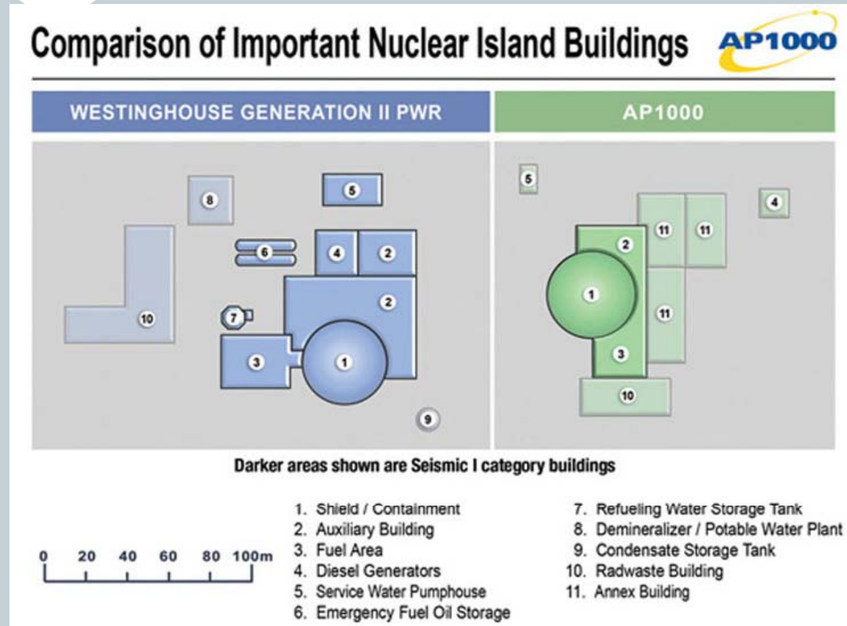
-Passive Safety System cuts cost

-Modular Construction cuts cost and construction time

-Simplified Plant Arrangement

-Smaller Area Required than Generation III plants (45 percent)

- "Nuclear Island" (smaller and less costly seismic buildings



50% fewer safety-related valves
35% fewer pumps
80% less safety related piping
85% less control cable
45% less building volume

Why have plants failed?

Main Contributions to Cost

- The construction cost of building the plant.
- The operating cost of running the plant and generating energy.
- The cost of waste disposal from the plant.
- The cost of decommissioning the plant.

Construction Cost is why plants have failed in the past

→Shoreham, Long Island. Almost 6 billion dollars! In 1989!

Capital Cost

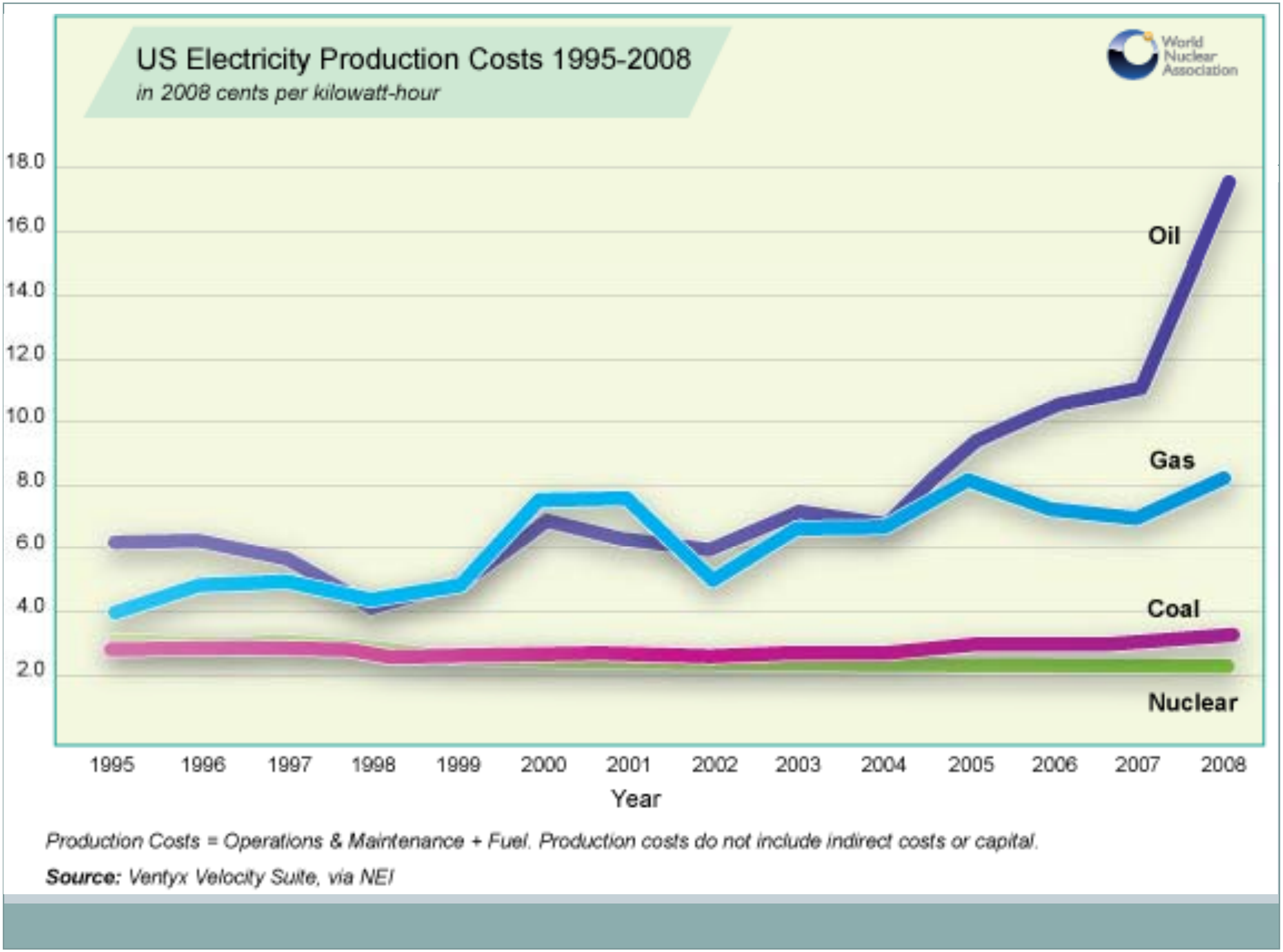
- Investment can contribute to 70-80% of electricity cost
- Over all cost very sensitive to chosen discount rate
- AP1000

-Modular Design

-3D plant model linked to construction schedule

Operating Cost

- Security
- Operation and Maintenance
- Fuel Cost



US Electricity Production Costs 1995-2008
in 2008 cents per kilowatt-hour
World Nuclear Association
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
Oil
Gas
Coal
Nuclear
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year
Production Costs = Operations & Maintenance + Fuel. Production costs do not include indirect costs or capital.
Source: Ventyx Velocity Suite, via NEI

Waste Disposal

- 1/10 cent is added onto electricity cost to pay for transportation and storage of waste
- Currently US has no disposal site so current plants must be able to store waste indefinitely

Decommissioning

- Typical Nuclear lifespan: 40-60 years
- US requires plants to set aside funds to decommission plants
- Can cost $300 million or more

AP 1000 in Ithaca

Calculation

- Construction cost- $2000 per kW
- Operating Cost- 1.6 cents per kWhr
- Waste Disposal Cost- .10 cents per kWhr
- Decommissioning- $300 per kW
- WACC- 10%
- Capacity Factor- 90%
- Lifespan- 60 years

AP 1000 in Ithaca

Comparison

- **Cost to consumers- about 3-4 cents per kWhr**
- **Current cost in Ithaca is between 9-10 cents per kWhr**

1 billion dollar construction cost

I/R	3 years	4 years	5 years	7 years
5%	2.2	2.3	2.4	2.7
6%	2.4	2.5	2.7	3.1
7%	2.6	2.8	3.0	3.6
8%	2.8	3.0	3.3	4.4
9%	3.0	3.3	3.7	5.5
10 %	3.3	3.6	4.2	7.2

1.4 billion dollar construction cost

I/R	3 years	4 years	5 years	7 years
5%	2.6	2.8	2.9	3.3
6%	2.9	3.0	3.2	3.8
7%	3.1	3.3	3.6	4.6
8%	3.4	3.7	4.1	5.6
9%	3.7	4.1	4.7	7.1
10 %	4.0	4.6	5.4	9.5

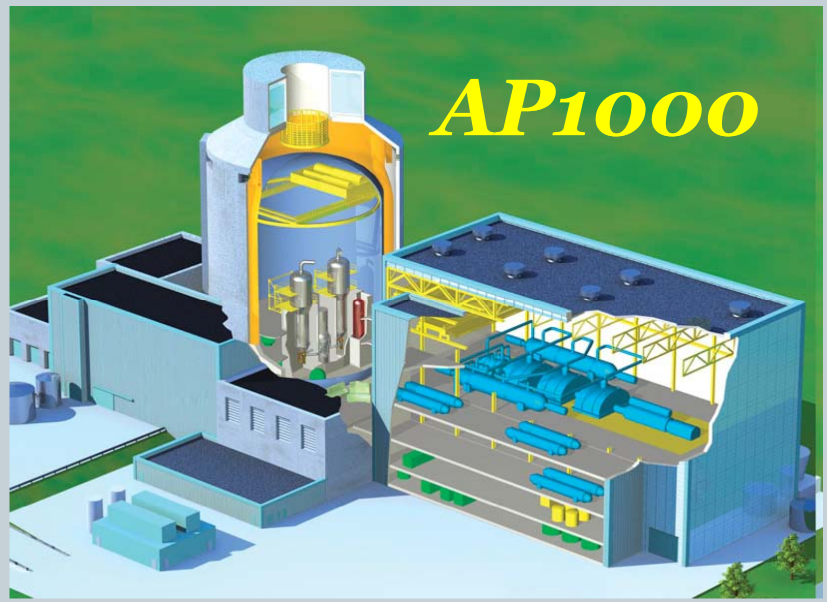
2 billion dollar construction cost

I/R	3 years	4 years	5 years	7 years
5%	3.2	3.4	3.6	4.1
6%	3.5	3.9	4.1	4.9
7%	3.9	4.2	4.6	6.0
8%	4.3	4.7	5.3	7.4
9%	4.7	5.3	6.1	9.6
10 %	5.2	6.0	7.1	13.1

- Claimed by Westinghouse
- Compares Interest Rate and Construction Cost and Time.
- Numbers are in cents per kWh

Future of Nuclear

- Thorium Fuel Source
- Ocean Uranium Mining
- Breeder Reactors
- Fusion



Thank you

Nuclear Slide Show 2010 Notes

#1 Can a nuclear facility provide enough power for Ithaca and the local area? A look into the risks, benefits, and safety of nuclear energy may help answer that question. Here, an attempt to explore that and other questions is addressed through a look at the background of nuclear energy – including the nuclear steam cycle – and its potential role in Tompkins County.

#3 "Power plants generate electrical power by using fuels like coal, oil or natural gas. A simple power plant consists of a boiler, turbine, condenser and a pump. Fuel, burned in the boiler and superheater, heats the water to generate steam. The steam is then heated to a superheated state in the superheater. This steam is used to rotate the turbine which powers the generator. Electrical energy is generated when the generator windings rotate in a strong magnetic field. After the steam leaves the turbine it is cooled to its liquid state in the condenser. The liquid is pressurized by the pump prior to going back to the boiler. A simple power plant is described by a Rankine Cycle."

(http://www.cartage.org.lb/en/themes/sciences/physics/thermodynamics/basicthermodynamics/steampower/steampower.htm)

#4 Here, a nuclear reactor works with a steam generator in the generation stage. This cycle operates at a higher efficiency than the steam cycle. It requires a small amount of fuel to operate.

#6 Water containing trace amounts of various radioactive materials is normally released from U.S. nuclear power plants under controlled, monitored conditions that meet conservative NRC limits to protect public health and safety.

Materials detected to date in groundwater around nuclear power plants include Tritium and Strontium 90.

Tritium:

Tritium is a radioactive isotope of the element hydrogen. Tritium occurs naturally in the upper atmosphere when cosmic rays strike air molecules. It is also produced during nuclear weapons explosions, and commercially in nuclear reactors producing electricity. Tritium has a half-life of 12.3 years. The most common form of tritium is in water, since both radioactive tritium and non-radioactive hydrogen react with oxygen in the same way to form water. Tritium replaces one of the stable hydrogens in the water molecule, H2O, creating tritiated water, which is colorless and odorless.

Tritium has several commercial uses in self-luminescent devices, such as exit signs in buildings, aircraft dials, gauges, luminous paints, and wristwatches. It is also used in life science research and in studies investigating the safety of potential new drugs. Tritium is one of the least dangerous radioactive isotopes known. It emits very weak radiation and leaves the body relatively quick. Since tritium is almost always found as water, if ingested, it goes directly into soft tissues and organs, and is expelled from the body along with the water.

Humans receive approximately 82% of their annual radiation dose from natural background radiation, 15% from medical procedures (e.g., x-rays), and 3% from consumer products. Doses from tritium and nuclear power plant effluents are a negligible contribution to the background radiation to which people are normally exposed, and they account for less than 0.1% of the total background dose (NCRP, 1987).

Strontium-90:

Strontium-90 (Sr-90) is a radioactive isotope that is produced in nuclear fission, the splitting of an atom's center that releases energy. It comes from three sources:

1: fallout from above-ground explosions of nuclear weapons testing worldwide from 1963 to 1980

2: radioactive releases from the 1986 Chernobyl nuclear power plant accident in the Ukraine

3: radioactive releases from nuclear power plants into the environment.

Approximately 99 percent of the Sr-90 in the environment comes from weapons testing fallout. Since Sr-90 takes about 29 years to lose half of its radioactivity, the fallout-based Sr-90 still remains in the environment at nominal levels. Most of the remaining one percent of Sr-90 in the environment came from the Chernobyl accident. At individual U.S. nuclear power plants, the amount of Sr-90 released is so low that it is usually at or below the minimum detectable activity of sensitive detection equipment. Radiation doses from Sr-90 to people living within 30 miles of a U.S. nuclear power plant are a tiny fraction of a percent of the annual dose an average person in this country receives from all sources.

Sr-90, if ingested, tends to mimic calcium when it is in the body and therefore becomes concentrated in calcified tissues such as bones and teeth. If ingested in quantities that produce very large doses (about a thousand times higher than what we all receive from natural radiation), Sr- 90 is known to increase the risk of bone cancer and leukemia in animals, and is presumed to do so in people. Below these doses, there is no evidence of excess cancer.

They all have commercial use.

Sources:

http://en.wikipedia.org/wiki/Strontium

http://en.wikipedia.org/wiki/Tritium

http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html

#7 Low Level Waste:

Low-level waste includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipments and tools, luminous dials, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissues. The radioactivity can range from just above background levels found in nature to very highly radioactive in certain cases such as parts from inside the reactor vessel in a nuclear power plant. Low-level waste is typically stored on-site by licensees, either until it has decayed away and can be disposed of as ordinary trash, or until amounts are large enough for shipment to a low level waste disposal site in containers approved by the Department of Transportation.

Current LLW disposal sites are:

EnergySolutions Barnwell Operations, located in Barnwell, South Carolina
U.S. Ecology, located in Richland, Washington
EnergySolutions Clive Operations, located in Clive, Utah

High Level Waste:

High-level radioactive wastes are the highly radioactive materials produced as a byproduct of the reactions that occur inside nuclear reactors. High-level wastes take one of two forms:

1: Spent reactor fuel when it is accepted for disposal

2: Waste materials remaining after spent fuel is reprocessed

Spent nuclear fuel is used fuel from a reactor that is no longer efficient in creating electricity, because its fission process has slowed. However, it is still thermally hot, highly radioactive, and potentially harmful. Until a permanent disposal repository for spent nuclear fuel is built, licensees must safely store this fuel at their reactors.

Reprocessing extracts isotopes from spent fuel that can be used again as reactor fuel. Commercial reprocessing is currently not practiced in the United States, although it has been allowed in the past. However, significant quantities of high-level radioactive waste are produced by the defense reprocessing programs at Department of Energy facilities, such as Hanford, Washington, and Savannah River, South Carolina, and by commercial reprocessing operations at West Valley, New York.

Currently no HLW repository being built in the US, but few being proposed.

Storage of Spent Nuclear Fuel:

1: Spent Fuel Pools – 20 feet under water.

2: Dry Cask Storage – multi layered on land storage.

Transportation of Spent Nuclear Fuel:

Because of the residual hazard, spent fuel must be shipped in containers or casks that shield and contain the radioactivity and dissipate the heat.

Over the last 30 years, thousands of shipments of commercially generated spent nuclear fuel have been made throughout the United States without causing any radiological releases to the environment or harm to the public.

Sources:

http://en.wikipedia.org/wiki/Radioactive_waste

http://www.nrc.gov/waste.html

http://en.wikipedia.org/wiki/Radioactive_waste_disposal

#8 Domestic Safeguards:

Ensuring that special nuclear material within the United States is not stolen or otherwise diverted from civilian facilities for possible use in clandestine fissile explosives and does not pose an unreasonable risk owing to radiological sabotage. The users of the special nuclear and certain quantities of biproduct material apply safeguards to protect against sabotage, theft, and diversion.

Strategic SNM

SNM of moderate strategic significance

SNM of low strategic significance

See further information below for details.

Information Safety:

protect classified and sensitive unclassified non-safeguards information (SUNSI) related to U.S. government programs for the physical protection and safeguarding of nuclear materials or facilities to ensure that such information is protected against unauthorized disclosure. The NRC protects three types of information:

Classified Information:

- National Security Information (NSI)
- Restricted Data (RD)

Safeguards Information (SGI)

Sensitive Unclassified Non-Safeguards Information (SUNSI)

Further Information:

Category I, Strategic SNM (SSNM)

Strategic special nuclear material means

Uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope), Uranium-233, or Plutonium.

Category I, SSNM means SSNM in any combination in a quantity of 2 kgs or more of plutonium; or 5 kgs or more of U-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope); or 2 kgs or more of U-233; or 5 kgs or more in any combination computed by the equation grams = (grams contained U-235) + 2.5 (grams U-233 + grams plutonium). This is often referred to as a formula quantity.

Category II, Special nuclear material of moderate strategic significance

Category II, Special nuclear material of moderate strategic significance means

Less than a formula quantity of strategic special nuclear material but more than 1,000 grams of uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope) or more than 500 grams of uranium-233 or plutonium, or in a combined quantity of more than 1,000 grams when computed by the equation grams = (grams contained U-235) + 2 (grams U-233 + grams plutonium); or 10,000 grams or more of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope).

Category III, Special nuclear material of low strategic significance

Category III, Special nuclear material of low strategic significance means

Less than an amount of special nuclear material of moderate strategic significance (see category II above) but more than 15 grams of uranium-235 (contained in uranium enriched to 20 percent or more in U-235 isotope) or 15 grams of uranium-233 or 15 grams of plutonium or the combination of 15 grams when computed by the equation grams = (grams contained U-235) + (grams plutonium) + (grams U-233); or Less than 10,000 grams but more than 1,000 grams of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope); or 10,000 grams or more of uranium-235 (contained in uranium enriched above natural but less than 10 percent in the U-235 isotope).

Sources:

http://www.nrc.gov/security/info-security.html

http://www.nrc.gov/security/domestic.html

http://www.nrc.gov/security/domestic/mca/snm.html

http://www.nrc.gov/security/domestic/phys-protect.html

#9 High Initial Cost:

Nature of nuclear power plants are usually tend to be relatively heavier on initial investment. However the maintenance of the operation is relatively lower than that of the other energy sources.

Highly Trained Operators:

Engineers and Operators hired for the nuclear power plants are limited based on various qualities of the candidates. A higher trained personnel is desired. Higher demand comes with higher cost, a nuclear power plant has to take this factor into account even though it might require significantly lower amount of employee comparing with other energy sources power plants.

Other Risks:

All the cost factor contribute to the over all investment risks of the power plant.

Risks before project:

Capital spent in the project for initiating the project. Research, Designing, Consulting, Legal, Accounting, etc

Risks during project:

During the years of construction, unexpected events.

Risks after completion:

After completion, before the turnover period, unexpected events.

Solutions

Contracts, Insurances, Approvals and assurance from government.

#10 Going to go over some of the community concerns regarding nuclear plants particularly using Indian Point as an example case of an existing power plant with a lot of controversy. Will talk about some of the issues raised in Tompkins County during the 1968 proposed site for a nuclear plant on cayuga lake.

In 2003, the NRC found that a record number of unplanned outages at both units could have been avoided had Entergy corrected known problems. In August 2005 the IP2 spent fuel pool was found to be leaking about 2 liters of radioactive water a day, while IP3 was shutdown due to a malfunctioning control rod. With the NRC's demonstrated lack of effective oversight and Entergy's apparent disregard for public safety, renewing Indian Point's licenses for another twenty years puts everyone living in the shadow of this plant at risk.

Both IP2 and IP3 have been plagued with major safety problems for decades and remain vulnerable to terrorist attack. A major concern regarding indian point are terrorist attacks. Entergy, the company that owns Indian Point

Croton resident Gary Shaw was a co-plaintiffs in a litigation against Entergy, the company that owns Indian Point. Shaw, a resident of Croton, combs the shores of the Hudson River with his wife, an artist, searching for natural materials, such as driftwood.

People are worried about how they are affected at an individual level. Not how the environment is being impacted. It is very much a "how will this harm me and my friends and family?" outlook on the situation. They see the potential exposure and all they know is "radiation is bad."

This is not to say that all people are against nuclear power. Some people rally in support of Indian Point arguing that it is cleaner than other energy sources and that concerns about terrorism should be directed at minimizing terrorism itself rather than removing the nuclear power plants.

One article emphasizes the positive effects of indian point. Good for economy, better than fossil fuel combustion and related illnesses and deaths from fossil fuel pollution, worker and public safety in mining coal and gas explosions.

Below – more detailed from the article about why IP is good:

An economic engine for the state, Indian Point directly provides about 2,500 jobs.

Closing the twin reactors means more illnesses and deaths thanks to increases in ozone and smog from additional fossil fuel combustion as well as more electricity-supply problems - brownouts and blackouts that would affect services like transportation and life-sustaining air conditioning during heat waves. Oh, and your electric bill will soar.

To replace indian point, we'll have to build an alternative. And right now, only fossil fuel plants can do the job. New York would have to buy power from coal-fired and gas-fired plants. The result: The region would face an increase in pollution from lead, mercury, and soot, which already kill 24,000 Americans a year.

Then there's the threat to worker and public safety. In 2010 alone, natural-gas accidents have already killed 14 people - a power plant in Connecticut and a pipeline in a California neighborhood exploded.

Read more: http://www.nydailynews.com/opinions/2010/11/22/2010-11-22_cuomo_dare_not_pull_the_plug.html#ixzz16cMyAcmp

#11 In 1968, NYSE&G proposed to build an 830-Megawatt nuclear power plant on Cayuga Lake called Bell Station. The controversy at that time in tompkins county was about the thermal pollution of cayuga lake. NYSEG had planned to discharge hot water directly into Cayuga Lake as part of an open-circuit cooling system for the plant. Environmentalists protested that such a discharge would adversely affect the lake's ecosystem and wanted the utility to build cooling towers instead.

Thermal pollution occurs because the cooling water heats up the lake environment. Decreases amount of dissolved oxygen and shocks life to death with sharp temperature change.

Fearing cost delays, NYSEG postponed indefinitely the construction of the Bell Station to provide more time for additional research on cooling systems.

More details on thermal pollution:

The primary effects of thermal pollution are direct **thermal shock** , changes in dissolved oxygen, and the redistribution of organisms in the local community. Because water can absorb thermal energy with only small changes in temperature, most aquatic organisms have developed enzyme systems that operate in only narrow ranges of temperature. These **stenothermic** organisms can be killed by sudden temperature changes that are beyond the tolerance limits of their metabolic systems. The cooling water discharges of power plants are designed to minimize heat effects on local fish communities. However, periodic heat treatments used to keep the cooling system clear of fouling organisms that clog the intake pipes can cause fish mortality. A heat treatment reverses the flow and increases the temperature of the discharge to kill the mussels and other fouling organisms in the intake pipes. Southern California Edison had developed a "fish-chase" procedure in which the water temperature of the heat treatment is increased gradually, instead of rapidly, to drive fish away from the intake pipes before the temperature reaches lethal levels. The fish chase procedure has significantly reduced fish kills related to heat treatments.

Read more: Thermal Pollution - water, effects, environmental, United States, types, impact, industrial, wells, power, sources, use, Sources, Environmental Effects, Abatement http://www.pollutionissues.com/Te-Un/Thermal-Pollution.html#ixzz16WRmFQdY

http://www.pollutionissues.com/Te-Un/Thermal-Pollution.html

http://books.google.com/books?id=dgsAAAAMBAJ&pg=PA32&lpg=PA32&dq=cayuga+nuclear+1968&source=bl&ots=HKt8LrI-Bd&sig=ZfCbO7AdZ-FptW09riJAzAMZ-dg&hl=en&ei=sdnyTKSQKoS8lQeMmIi-DA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBoQ6AEwAA#v=onepage&q=cayuga%20nuclear%201968&f=false

#12 In 1973, NYSEG proposed a design similar to the 1968 design for a General Electric boiling water reactor with a once-through cooling system. This was in anticipation of increasing energy demands in the area.

NUS = Nuclear Utility Service

NYSEG President announces findings from the NUS study. Study addresses concerns of thermal pollution and was a highly technical report that concludes there would be minimal effect on the aquatic environment. President emphasizes that efforts should keep in mind the greatest good and greatest number

A technical information meeting was held soon after for the public and was followed by a 2 ½ hour angry discussion that suggested the community might be unwilling to be sacrificed for the "greatest number."

http://books.google.com/books?id=dgsAAAAAMBAJ&pg=PA32&lpg=PA32&dq=cayuga+nuclear+1968&source=bl&ots=HKt8LrI-Bd&sig=ZfCbO7AdZ-FptW09riJAzAMZ-dg&hl=en&ei=sdnyTKSQKoS8lQeMmIi-DA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBoQ6AEwAA#v=onepage&q=cayuga%20nuclear%201968&f=true

#13 By 1973, state and federal regulations for environmental protection had been established for several years. While the regulatory context remained controversial, it was no longer as ambiguous. There had been years of discussion in the press and popular journals about the risks associated with the operation of nuclear reactors.

Several groups were formed to oppose the construction of Bell station, which are now all included in the Cayuga Lake Watershed Network.

Thus the focus of concern shifted from ecological impact to problems of transporting and disposing of nuclear wastes, the reliability of reactor safety mechanism, reactor core defects that would allow the release of radioactive gases, and the danger of human error or sabotage.

#14 The breakdown of the concerns outlined in letters to NYSEG and the Ithaca Journal show that most people opposed to the plant were concerned with safety, validity of NYSEG's assessments, preservation of the ecology, and distrust in officials.

Those favoring bell station focused more on the need for more power and confidence in federal, state, and corporate responsibility. Some people blamed Cornellians for keeping the people all worked up, since the Cornell Community had provided the majority of the scientific evidence against Bell Station.

#15 The Ithaca Journal poll found that among officials and business owners, 63 percent favored the plant and 15 percent were opposed; in the skilled worker group, 43 percent favored the plant and 37 percent were opposed; among persons in professional and technical occupations, 31 percent favored the plant and 48 percent were opposed.

Those with commercial or labor interests tended to favor the plant for immediate economic reasons. Those opposed to the plant were predominately from highly educated groups of professionals concerned with long term risks.

However, when NYSE&G reopened the power plant issue by inviting written comments from all segments of the community, the strong opposition led them to abandon its plans and instead build Bell Station in Somerset on Lake Ontario, where the project was welcomed.

#16 The NYSE&G President then recommended to his board of directors that an 850-megawatt coal-fired plant be constructed on the Cayuga Lake site to deal with the rising power needs and use the space they had already pre-licensed and invested so much money in. The press and citizen groups were surprised but emphasized their success and chose not to oppose NYSE&G's new plan.

Although in public they argue in terms of ecology and distrust in the company's scientific studies and problems with procedures, overall it seems that people are concerned with their personal safety from nuclear radiation and explosions. Cancer, mutations of the fetus, etc.

This excerpt highlights that regardless of how difficult it is for nuclear power to be completely and perfectly safe, people will expect it to be before they accept it.

While you may or may not find these concerns reasonable, they are what worry local residents and these concerns must be addressed before any advancements can be made in nuclear here in tompkins county. You cannot simply say it won't happen. Must assure them that if something terrible does happen that there will be a safe and effective backup plan, that it will not be dangerous or affect anyone.

#17 The operators at nuclear power plants --

http://www.physics.isu.edu/radinf/np-risk.htm

The candidate must have a high school diploma or equivalent. Individuals who have a BS in engineering or the equivalent can apply for the Senior Reactor Operator license directly, without first obtaining a Reactor Operator license, getting at least a year of experience, and then taking another examination (written, walk-through, and simulator) to upgrade their license to the higher level.

The candidate must have several years of related experience and complete extensive classroom, simulator, and on-the-job training covering reactor theory, thermodynamics, power plant components, system design and operation, integrated plant operations, and emergency response.

#18 What happened with 3-Mile Island then?

http://www.physics.isu.edu/radinf/np-risk.htm

Even in the Three Mile Island accident where at least two equipment failures were severely compounded by human errors, two lines of defense were still not breached--- essentially all of the radioactivity remained sealed in the thick steel reactor vessel, and that vessel was sealed inside the heavily reinforced concrete and steel lined "containment" building which was never even challenged. It was clearly not a close call on disaster to the surrounding population.

Resulted in no deaths or injuries.

In the aftermath of the accident, investigations focused on the amount of radiation released by the accident. According to the American Nuclear Society, using the official radiation emission figures, "The average radiation dose to people living within ten miles of the plant was eight millirem, and no more than 100 millirem to any single individual. Eight millirem is about equal to a chest X-ray, and 100 millirem is about a third of the average background level of radiation received by US residents in a year."[37][57]

#19 What about Chernobyl? That was a disaster!

http://www.physics.isu.edu/radinf/np-risk.htm

Chernobyl did not have a containment structure like 3 Mile Island did. If there was a containment structure, the disaster would have been averted.

Russia, Ukraine, and Belarus have been burdened with the continuing and substantial decontamination and health care costs of the Chernobyl accident. A 2006 report prepared by the Chernobyl Forum, led by the World Health Organization (WHO) states, "Among the 134 emergency workers involved in the immediate mitigation of the Chernobyl accident, severely exposed workers and firemen during the first days, 28 persons died in 1986 due to ARS (Acute Radiation Syndrome), and 19 more persons died in 1987-2004 from different causes. Among the general population affected by Chernobyl radioactive fallout, the much lower exposures meant that ARS cases did not occur". It is estimated that there may ultimately be a total of 4,000 deaths attributable to the accident, due to increased cancer risk.[6]

#20 Worst Cases: Nuclear Meltdown vs. Coal

http://www.physics.isu.edu/radinf/np-risk.htm

Risks from reactor accidents are estimated by the rapidly developing science of "probabilistic risk analysis" (PRA). A PRA must be done separately for each power plant (at a cost of $5 million) but we give typical results here: A fuel melt-down might be expected once in 20,000 years of reactor operation. In 2 out of 3 melt-downs there would be no deaths, in 1 out of 5 there would be over 1000 deaths, and in 1 out of 100,000 there would be 50,000 deaths. The average for all meltdowns would be 400 deaths. Since air pollution from coal burning is estimated to be causing 10,000 deaths per year, there would have to be 25 melt-downs each year for nuclear power to be as dangerous as coal burning.

#21 What's the worst that could happen?

Very high radiation doses can destroy body functions and lead to death within 60 days, but such "noticeable" deaths would be expected in only 2% of reactor melt-down accidents; there would be over 100 in 0.2% of meltdowns, and 3500 in 1 out of 100,000 melt-downs. To date, the largest number of noticeable deaths from coal burning was in an air pollution incident (London, 1952) where there were 3500 extra deaths in one week. Of course the nuclear accidents are hypothetical and there are many much worse hypothetical accidents in other electricity generation technologies; e.g., there are hydroelectric dams in California whose sudden failure could cause 200,000 deaths.

#22 The Concern over radiation

http://www.physics.isu.edu/radinf/np-risk.htm

Since natural radiation is estimated to cause about 1% of all cancers, radiation due to nuclear technology should eventually increase our cancer risk by 0.002% (one part in 50,000), reducing our life expectancy by less than one hour. By comparison, our loss of life expectancy from competitive electricity generation technologies, burning coal, oil, or gas, is estimated to range from 3 to 40 days.

http://www.deq.idaho.gov/inl_oversight/radiation/radiation_guide.cfm

If you live near a nuclear power plant, you'll receive about .009 millirem of radiation each year.

Foods that are rich in potassium, like fruits, beans and lentils, vegetables, and some whole grains, expose us to radiation as potassium decays. Less than one quarter of one percent of the potassium in foods we eat is radioactive. The food we eat exposes us to about 40 millirem of radiation each year.

An x-ray technician works with x-ray machines every day, resulting in exposure to about 500 millirem of radiation each year.
The standards are set such that a nuclear plant worker can receive up to 5,000 millirem each year, but a Nuclear Regulatory Commission report says the average exposure for a nuclear power plant worker is 240 millirem per year.

http://www.pbs.org/wgbh/pages/frontline/shows/reaction/interact/facts.html

Coal plant, living within 50 miles: .03 mrem

#23 The current 2009 estimates for Tompkins County is 101,779 by the US census. If we assume that the average person consumes around 10.3 kW, which approximately the US average, Tompkins county required power should be around 1050 MW.

References:

http://quickfacts.census.gov/qfd/states/36/36109.html

http://factfinder.census.gov

#24 The total Tompkims county estimated emissions is 1,179,254 MtCO2e in 2008. Tompkins county legislature has made a goal to reduce their greenhouse gas emissions with their energy strategy. Their goal is a 20% reduction in emission of 2008 levels by 2020 and a 80% reduction of 2008 levels by 2050

References:

http://www.tompkins-co.org/planning/energyclimate/index.htm

#25 From a study conducted by the University of Wisconsin-Madison, which looked at the Life-Cycle Emissions (examines from the beginning of construction, operating maintenance, to the end) Nuclear energy is ranked among the lowest in emissions, only beaten by geothermal and wind but compared to traditional power sources, it is a lot cleaner. The chart here compares the carbon dioxide equivalent emitted per gigawatt-hour
References:

"Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis," Paul J. Meier, University of Wisconsin-Madison, August 2002.

#26 Westinghouse's AP1000 reactor is the first Generation III + reactor to be approved by the Nuclear Regulatory Commission

<u>Generation III +</u>

→Development of any Generation II Reactor incorporating improvement in fuel technology, thermal efficiency, passive safety or standardized design. The AP1000 is noted particularly for its improvements in safety and economics (will discuss specifics on later slides)

Chinese Units will be the first to be built in the following locations:

The Sanmen Nuclear Power Plant in Zhejiang will have six units. Site construction for the first two began in February 2008; operation is scheduled for 2013–15.

The Haiyang Nuclear Power Plant in Shandong also has six units planned, with construction started in July 2008, for operation in 2014 or 2015.

Additionally, China has officially adopted the AP1000 as a standard for inland nuclear projects. It is expected that they will have 100 complete by 2020, according the the CEO of Westinghouse.

US Projects:

As of January 2010, applications for Combined Construction and Operating Licenses have been filed for fourteen AP1000 reactors in the United States, two each at

Shearon Harris Nuclear Power Plant in North Carolina,

William States Lee III Nuclear Generating Station in South Carolina,

Virgil C. Summer Nuclear Generating Station in South Carolina

Vogtle Electric Generating Plant in Georgia.

Levy County Nuclear Power Plant in Florida,

Turkey Point Nuclear Generating Station in Florida

Bellefonte Nuclear Generating Station in Alabama.

On April 9, 2008, Georgia Power Company reached a contract agreement with Westinghouse and Shaw for two AP1000 reactors to be built at Vogtle. The contract represents the first agreement for new nuclear development since the Three Mile Island accident in 1979. The COL for the Vogtle site is to be based on the revision 16 to the AP1000 design. On February 16, 2010, President Obama announced $8.33 billion dollars in federal loan guarantees to construct the two AP1000 units at the Vogtle plant.

References

http://www.bloomberg.com/news/2010-11-25/westinghouse-expects-more-reactor-orders-from-china-on-clean-energy-demand.html

http://www.ap1000.westinghousenuclear.com/ap1000_safety.html

http://en.wikipedia.org/wiki/AP1000

#27 Picture from
http://www.ap1000.westinghousenuclear.com/images/graphics/lg_ec1.jpg

#28 Passive Core Cooling System is a key component in the safety of this reactor. Heat from nuclear decay is produced even after the reactor is shut down so removing this heat after the reactor shutdown is key to avoiding a reactor melt down. The PCCS uses less than twenty explosively and passively operated valves. No reactor operators are needed for this process if the core becomes too hot. The electrical system required for initiating the passive systems doesn't rely on external or diesel power and the valves don't rely on hydraulic or compressed air systems. The safety system incorporates the use of gravity rather than electricity or pumps to ensure that a melt down cannot occur.

The Breeder Technology used is not completely efficient, but produces much less radioactive waste than Generation II plants. The final waste product could be stored indefinitely at the site of the reactor. The risk of public radiation exposure is listed as 4 parts per 10 million.
There are extremely low Core Damage Probabilities (as compared to Generation III or less reactors) The AP1000 meets the U.S. NRC deterministic-safety and probabilistic-risk criteria by a fairly significant margin. Results of the Probabilistic Risk Assessment (PRA) show a very low core damage frequency (CDF) that is 1/100 of the CDF of currently operating plants and 1/20 of the CDF deemed acceptable for new reactors.

The AP100 is designed to eliminate an accident such as core melt. In this event the AP1000 operator can flood the reactor space surrounding the reactor vessel with water to submerge the reactor vessel. The cooling is sufficient to prevent molten core debris in the lower head from melting the steel vessel wall and spilling into the containment.

Passive Safety Systems

In addition there are multiple other passive safety systems.

-Containment Isolation System- fluid lines penetrating the containment boundary are isolated

-Passive Containment Cooling System- water effectively cools the containment in the unlikely event of an accident so the design pressure is not exceeded, and the pressure is rapidly reduced. Natural circulation and water evaporation contribute to the cooling system.

Main Control Room Emergency Habitability System- main control room can be isolated in case of high airborne radiation levels, and the emergency habitability system is a set of compressed air tanks connected to a main and alternative air delivery line. The system provides the ventilation and pressurization needed to maintain a habitable environment for up to 11 people for 72 hours following any design-basis accident.

References:

http://www.ap1000.westinghousenuclear.com/ap1000_safety.html

http://web.archive.org/web/20070807115318/http://www.westinghousenuclear.com/AP1000/public_safety_licensing.shtm

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V4D-4K2SMCR-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=1d47061a51dad6d8e942b33500e767a0

http://en.wikipedia.org/wiki/AP1000

#29 The Passive Safety system is a key component to the reduced cost of the AP 1000. The amount of safety-grade equipment needed is lessened because of the passive safety system design. Because of this, less Seismic Category I material is needed. This material is some of the most expensive involved in a nuclear reactor and the AP1000 design cuts approximately 45 percent of it (when compared to older Gen II and III reactors), which greatly reduces cost.

Two main contributions to construction costs of a nuclear plant are: cost of financing during the construction phase and the cost of skilled-craft labor hours require to build the plant. The construction of the plant in modules helps reduce both of these factors.

AP1000 plant arrangement provides separation between safety-related and non-safety related systems. The smaller and more compact design reduces cost. The systems can be organized into the following structures:

Nuclear Island

Turbine Building

Annex Building

Diesel Generator Building

Radwaste Building

Nuclear Island-
This is a description of the use of the seismic material in the AP 1000. The volume of these seismic buildings is much smaller than those in previous nuclear power plant designs. This results in huge savings because seismic material costs roughly three times as much as non-seismic material. The nuclear island is designed to withstand the effects of casualties such as fires and flooding without loss of capability to perform safety functions.

Compared to Generation II plants of the same power, the AP1000 provides the following numbers for reduced size and construction costs:

50% fewer safety-related valves

35% fewer pumps

80% less safety related piping

85% less control cable

45% less building volume

References:

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V4D-4K2SMCR-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=1d47061a51dad6d8e942b33500e767a0

http://www.eia.doe.gov/cneaf/nuclear/page/analysis/nucenviss_2.html

https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-732%20Rev%201.pdf

#30 The main contributions to the cost of a nuclear plant are listed above

In the past (1970's and 80's) nuclear plants did NOT fail because of nuclear accidents. They were simply inefficient as compared to fossil fuels. This was due to poor planning and wasting money during the construction phase. As a result, many plants did not even operate. Long Island residents still pay an increase in taxes due to the extremely expensive plant in Shoreham, Long Island, which was never actually even used. The plant cost over 6 billion dollars to install upon completion in 1989.

References:

http://nuclearinfo.net/Nuclearpower/WebHomeCostOfNuclearPower

http://en.wikipedia.org/wiki/Shoreham_Nuclear_Power_Plant

#31 Since the construction of a nuclear plant takes a relatively long time, the capital cost is an important factor in determining the economics of nuclear energy. The investments can contribute up to to 70-80% of electricity cost. And since there is such a high upfront cost, the economics of a nuclear plant is very sensitive to the discount rate chosen. Also any delay in construction time will drive up the overall cost of electricity since the plant can not bring in revenue until it is completed.

#32 For operating cost for nuclear plants are similar to coal plants although for nuclear, O&M make up 75% of the cost while fuel cost is 25%. Some of the O&M cost is direct for security. Nuclear plants are likely to be the best protected private sector facilities in the US.

References:

"NUREG-1350 Vol. 18: NRC Information Digest 2006-2007" (PDF). Nuclear Regulatory Commission. 2006

#33 After the initial capital cost investment, which is a sunk cost, nuclear power plants become a very profitable. As you can see from the chart, the production cost, which is O&M and fuel cost, are among the lowest in the US (just a little above 2 cents/kW-h) and makes them very efficient for base-load power supply.

References:

Venfyx Velocity Suite via NEI

#34 As you call know after the fuel has been spent, it needs to disposed. The US tacks on a tenth of a cent per kW-h to the electric bill to pay for the cost of transporting and disposing at a waste at a nuclear waste site. Yucca Mountain was a propose site until Obama decided against it. As a result, current plants must be able to store the waste on site indefinitely.

#35 Nuclear plants need to be decommissioned after their lifespan which is typically 40-60 years. This involves dismantling, safe storage or entombment. The operators are required by the NRC to set aside money during operations to cover the cost.

For the AP1000, it was decommissioning in mind so the cost is a very small proportion of the overall cost of power generation.

References:

Decommissioning a Nuclear Power Plant, 2007-4-20, U.S. Nuclear Regulatory Commission

http://analysis.nuclearenergyinsider.com/qa/nei-speaks-westinghouse

#36 These numbers come from a model that accounts for the mentioned main costs. This is the number it costs to operate a plant, not the number that would be charged to consumers. They are from a conservative estimate for the construction cost. Westinghouse claims that after the first several reactors, the construction cost should be reduced to 1 billion. These numbers come from a plant that cost 1.4 billion to construct. The price of electricity in Ithaca currently came from minutes taken at a Tompkins County meeting. The price of fuel is .05 cents per kWhr and was not mentioned on the slide. However, it was included in the calculation.

References:

meetings.tompkins-co.org/Citizens/FileOpen.aspx?Type=12&ID=1189

http://nuclearinfo.net/Nuclearpower/WebHomeCostOfNuclearPower

http://www.world-nuclear.org/info/inf02.html

#38 References:

http://nuclearinfo.net/Nuclearpower/WebHomeCostOfNuclearPower

#39 Thorium Fuel Source – "Thorium, as well as uranium, can be used as a nuclear fuel. Although not fissile itself, Th-232 will absorb slow neutrons to produce uranium-233 (U-233), which is fissile (and long-lived). The irradiated fuel can then be unloaded from the reactor, the U-233 separated from the thorium, and fed back into another reactor as part of a closed fuel cycle. Alternatively, U-233 can be bred from thorium in a blanket, the U-233 separated, and then fed into the core. In one significant respect U-233 is better than uranium-235 and plutonium-239, because of its higher neutron yield per neutron absorbed. Given a start with some other fissile material (U-233, U-235 or Pu-239) as a driver, a breeding cycle similar to but more efficient than that with U-238 and plutonium (in normal, slow neutron reactors) can be set up. (The driver fuels provide all the neutrons initially, but are progressively supplemented by U-233 as it forms from the thorium.) However, there are also features of the neutron economy which counter this advantage. In particular the intermediate product protactinium-233 (Pa-233) is a neutron absorber which diminishes U-233 yield.

Over the last 40 years there has been interest in utilising thorium as a nuclear fuel since it is more abundant in the Earth's crust than uranium. Also, all of the mined thorium is potentially useable in a reactor, compared with the 0.7% of natural uranium in today's reactors, so some 40 times the amount of energy per unit mass might theoretically be available (without recourse to fast neutron reactors). But this relative advantage vanishes if fast neutron reactors are used for uranium."

(http://www.world-nuclear.org/info/inf62.html)

Ocean Uranium Mining – Process of extracting uranium ore from seawater. "One possibility for maintaining fission as a major option without reprocessing is low-cost extraction of uranium from seawater. The uranium concentration of sea water is low (approximately 3 ppb) but the quantity of contained uranium is vast – some 4 billion tons (about 700 times more than known terrestrial resources recoverable at a price of up to $130 per kg). If half of this resource could ultimately be recovered, it could support for 6,500 years 3,000 GW of nuclear capacity (75 percent capacity factor) based on next-generation reactors (e.g., high-temperature gas-cooled reactors) operated on once-through fuel cycles."

(http://www.wise-uranium.org/upusa.html#SEAWATER)

Breeder Reactors – "A Breeder Reactor is a nuclear reactor that "breeds" fuel. A Breeder consumes fissile and fertile material at the same time as it creates new fissile material. Production of fissile material in a reactor occurs by neutron irradiation of fertile material, particularly Uranium-238 and Thorium-232. In a breeder reactor, these materials are deliberately provided, either in the fuel or in a Breeder Blanket surrounding the core, or most commonly in both. Production of fissile material takes place to some extent in the fuel of all current commercial nuclear power reactors. Towards the end of its life, a uranium PWR fuel element is producing more power from the fissioning of plutonium than from the remaining uranium-235. Historically, in order to be called a breeder, a reactor must be specifically designed to create more fissile material than it consumes."

(http://www.3rd1000.com/nuclear/nuke101g.htm)

Fusion – "Nuclear fusion is the energy source of the future. It is what provides the sun and the stars with the energy to shine continuously for billions of years. The first generation fusion reactors will use deuterium and tritium for fuel because they will fuse at a lower temperature. *Deuterium* can be easily extracted from seawater, where 1 in 6500 hydrogen atoms is deuterium. *Tritium* can be bred from lithium, which is abundant in the earth's crust. In the fusion reaction a deuterium and tritium atom combine together, or fuse, to form an atom of helium and an energetic neutron. It only takes a small amount of these isotopes to produce a lot of energy! The deuterium-tritium fusion reaction results in an energy gain of about 450:1!! No other energy source we can tap releases so much energy for the amount that is input."

(http://www.worsleyschool.net/science/files/fusion/nuclearfusion.html)