NUCLEAR POWER

Outline: I. Time line
 II. Nuclear Decay and fission
III Light water and Breeder Reactors
IV Disposal of Nuclear Waste (..April 24)
V Fusion
Senate Energy and Natural Resources Chairwoman Lisa Murkowski (R-Alaska) expressed disappointment that unrelated policy issues are jeopardizing energy legislation.

Bipartisan frustration over the lack of a vote on curbing superpolluting hydrofluorocarbons (HFCs) spilled onto the Senate floor last night, derailing — at least for now — the energy package that was widely expected to pass before the end of the week.

In a surprise move, senators voted 47-44 last night on a key procedural vote for the bipartisan energy package, falling short of the 60 votes needed for the bill to advance.

Majority Leader Mitch McConnell (R-Ky.) switched his vote to no so he could push the chamber to revisit the matter.

But that’s unlikely until there’s an agreement to satisfy backers of legislation, S.2754, to phase down HFCs.

Sen. John Kennedy (R-La.), a chief sponsor of the measure, made good on his pledge to block other amendments on the energy bill if he did not receive a vote on his proposal.
NUCLEAR POWER
REACTORS
IN OPERATION

449

TOTAL NET
INSTALLED
CAPACITY

396 547
MW_e

NUCLEAR POWER
REACTORS
UNDER
CONSTRUCTION

55

http://www.iaea.org/PRIS/home.aspx
I. Timeline

12/2/42 FIRST SUSTAINED AND CONTROLLED FISSION

7/16/45 FIRST DETONATION OF PLUTONIUM NUCLEAR WEAPON

1946 FORMATION OF AEC WITH A NAVAL AND A CIVILIAN REACTOR BRANCH

12/8/53 ATOMS FOR PEACE INITIATIVE BY EISENHOWER

1954 PRESSURIZED WATER NAUTILUS SUBMARINE GOES TO SEA

8/30/54 ATOMIC ENERGY ACT ALLOWS PRIVATE OWNERSHIP OF NUCLEAR REACTORS

1960 COMMERCIAL YANKEE ROWE (PWR) AND DRESDEN I (BWR) PRODUCE 170 MWe
Young engineer works on new ways to remove heat from atomic reactors

An atomic reactor running at full efficiency creates a tremendous amount of heat in its core. By removing this heat and putting it to work boiling water to make steam, atom-made electricity is produced.

One of the men responsible for designing new, more efficient ways to remove heat from atomic reactors is 29-year-old Doctor Salomon Levy — Design Analysis supervisor in the Atomic Power Equipment Department’s Reactor Engineering Unit.

Levy’s Work Interesting, Vital

To study this problem of heat transfer, G.E. recently constructed a heat-transfer system. By electrically simulating the heat produced in a reactor, it is possible to determine the maximum rate at which heat can be removed from a reactor to make steam.

Dr. Levy conceived the idea of building this complex system, designed it and supervised its construction. At present, Levy works with this system to study new problems of heat transfer and fluid flow encountered in atomic power plants.

25,000 College Graduates at General Electric

When Salomon Levy came to General Electric in 1953, he already knew the kind of work he wanted to do. Like each of our 25,000 college-graduate employees, he was given his chance to grow and realize his full potential. For General Electric has long believed this: Whenever fresh young minds are given the freedom to make progress, everybody benefits — the individual, the company, and the country.

Educational Relations, General Electric Company, Schenectady 5, New York

Progress Is Our Most Important Product

GENERAL ELECTRIC
POWER DEMONSTRATION PROGRAM

• MANY REACTOR CONCEPTS ACCEPTED BY AEC (Atomic Energy Commission), USING ORGANIC, GAS, LIQUID METAL, HOMOGENEOUS AND MOLTEN SALT COOLANTS.

• TWO WINNERS EMERGED: PRESSURIZED WATER REACTOR (PWR) AND BOILING WATER REACTOR (BWR) BECAUSE THEY COULD TAKE ADVANTAGE OF LARGE NAVAL PROGRAM, SPONSORED BY AEC NAVAL REACTOR BRANCH.

• EXPERIMENTAL BOILING WATER REACTOR (EBWR) PRODUCED 5 MWe AT ANL ON 12/56.

• SHIPPINGPORT PWR PRODUCED 60 MWe IN 12/67
Boiling Water Reactors (BWR):

- 35 operable reactors in the United States are BWRs.
- BWRs allow fission-based heat from the reactor core to boil the reactor’s coolant water into the steam that is used to generate electricity.
- General Electric built all boiling water reactors now operational in the United States.
PWRs use nuclear-fission to heat water under pressure within the reactor.

This water is then circulated through a heat exchanger (called a "steam generator") where steam is produced to drive an electric generator.

The water used as a coolant in the reactor and the water used to provide steam to the electric turbines exists in separate closed loops that involve no substantial discharges to the environment.

Of the 104 fully licensed reactors in the United States, 69 are PWRs.
Pressurized Heavy Water Reactors (PHWR):

- PHWRs have been promoted primarily in Canada and India, with additional commercial reactors operating in South Korea, China, Romania, Pakistan, and Argentina. Canadian-designed PHWRs are often called "CANDU" reactors.
- Heavy water reactors now in commercial operation use heavy water (D₂O) as moderators and coolants.
- No successful effort has been made to license commercial PHWRs in the United States. PHWRs have been popular in several countries because they use less expensive natural (not enriched) uranium fuels and can be built and operated at competitive costs.
- The continuous refueling process used in PHWRs has raised some proliferation concerns because it is difficult for international inspectors to monitor.
- Additionally, the relatively high Pu-239 content of PHWR spent fuel has also raised proliferation concerns.
- PHWRs, like most reactors, can use fuels other than uranium and the ACR series of reactors is intended to use slightly enriched fuels. Particular interest has been shown in India in thorium-based fuel cycles.

http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/china/candu.html
High Temperature Gas-cooled Reactors (HTGR):

- HTGRs are distinguished from other gas-cooled reactors by the higher temperatures attained within the reactor.

- Among the future uses for which HTGRs are being considered is the commercial generation of hydrogen from water.

- In some cases, HTGR turbines run directly by the gas that is used as a coolant. In other cases, steam or alternative hot gases such as nitrogen are produced in a heat exchanger to run the power generators.

- The most famous U.S. HTGR example was the Fort Saint Vrain reactor that operated between 1974 and 1989. Other HTGRs have operated elsewhere, notably in Germany. Small research HTGR prototypes presently exist in Japan and China.

- The proposed Next Generation Nuclear Plant (NGNP) in the U.S. will most likely be a helium-based HTGR, if it is funded to completion.

http://www.nuc.berkeley.edu/designs/mhtgr/mhtgr.GIF
Sodium-cooled reactors reactors:
• Toshiba 4S reactor in Alaska is being proposed.
• Sodium-cooled reactors use the molten (liquid) metal sodium as a coolant to transfer reactor generated heat to an electricity generation unit.
• Sodium-cooled reactors are often associated with “fast breeder reactors (FBRs)” though this is technically not the case in the 4S design.
CURRENT SITUATION

- 61 nuclear power plants with 99 nuclear reactors
- 69 PWRs and 35 BWRs (Last one in May 1996 - Tennessee)
- 727 GWhr IN 2015, 19.5% OF U.S. ELECTRICITY
- ON-LINE STAY ABOVE 90 PERCENT
- LOWEST PRODUCTION COSTS OF 1.7¢ PER kWhr
- LIFE EXTENSION FROM 40 TO 60 YEARS
- NO GREENHOUSE GASES OR AIR POLLUTION
II. Nuclear decay

- Not all combination of protons and neutrons are stable.

- For a given element, the stable isotopes have a somewhat greater number of neutrons than protons.

*Figure 3.5* Proton-neutron ratio for stable isotopes formed via beta emission [beta particles ($\beta^-$) are high-energy electrons emitted by the reaction: ($\beta_n$) → proton ($p^+$) + $\beta^-$.]*
• Unstable nuclei undergo nuclear decay to form stable nuclei.
• Nuclear decay processes release a large amount of energy.
• This release of energy during nuclear decay is called radioactivity.
• Radioisotopes are isotopes of an element that are unstable and undergo nuclear decay.
### Table 7.2  Types of Nuclear Radiation

<table>
<thead>
<tr>
<th>Type</th>
<th>Symbol</th>
<th>Consists of</th>
<th>Charge</th>
<th>Change to nucleus that emits it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>$^{4}_{2}\text{He}$</td>
<td>2 protons, 2 neutrons</td>
<td>2+</td>
<td>The mass number decreases by 4, and the atomic number decreases by 2.</td>
</tr>
<tr>
<td>Beta</td>
<td>$^{0}_{-1}\text{e}$</td>
<td>an electron</td>
<td>1−</td>
<td>The mass number does not change, and the atomic number increases by 1.</td>
</tr>
<tr>
<td>Gamma</td>
<td>$^{0}_{0}\gamma$</td>
<td>photon of energy</td>
<td>0</td>
<td>No change in either the mass number or in the atomic number.</td>
</tr>
</tbody>
</table>
Nuclear decay

- Alpha decay
  \[ ^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn \]
- Beta decay
  \[ ^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e \]
- Positron (anti-electron) emission
  \[ ^{11}_{6}C \rightarrow ^{11}_{5}B + ^{0}_{1}e \]
- Electron capture
  \[ ^{11}_{6}C + ^{0}_{-1}e \rightarrow ^{11}_{5}B \]
- Gamma-ray (high energy photons) emission
U-238 Radioactive Decay Series

Radioactive isotopes undergo decay until they reach a stable species.

All isotopes of all elements with atomic number 84 (Po) and higher are radioactive.
Half-life: the time required for the level of radioactivity to fall to one-half of its value.

\[ \frac{d[A]}{dt} = -k_1[A] \]

\[ \frac{\ln[A_0]}{[A]} = kt \]

Or \[ \frac{[A]}{[A_0]} = e^{-kt} \]

\[ t_{0.5} = \frac{0.693}{k} \]

\[ [A] = [A_0] \times e^{-kt} \]
Steady State Analysis of Radioactive Decay Series

A \rightarrow B \rightarrow C \rightarrow D \rightarrow

\frac{d[C]}{dt} = 0 = k_p[B] - k_D[C]

\frac{[C]_{ss}}{[B]_{ss}} = \frac{k_p}{k_D} = \frac{t_C}{t_B}

Expression is useful to determine the steady state concentration of radioactive material

Half life of $^{226}$Ra is 1600 years – decays to produce $^{222}$Rn with half life 2.8 days

The ratio of steady state concentration of Radium to Radon is $(2.8/365)/1600$ or $\sim 6.5 \times 10^{-6}$

So Radon concentration remains low compared to Radium since decays quicker than it is formed
Half-life: the time required for the level of radioactivity to fall to one-half of its value.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium-238</td>
<td>$4.5 \times 10^9$ years</td>
</tr>
<tr>
<td>Potassium-40</td>
<td>$1.3 \times 10^9$ years</td>
</tr>
<tr>
<td>Plutonium-239</td>
<td>24,110 years</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>5715 years</td>
</tr>
<tr>
<td>Cesium-137</td>
<td>30.2 years</td>
</tr>
<tr>
<td>Strontium-90</td>
<td>29.1 years</td>
</tr>
<tr>
<td>Thorium-234</td>
<td>24.1 days</td>
</tr>
<tr>
<td>Radon-222</td>
<td>3.82 days</td>
</tr>
<tr>
<td>Iodine-131</td>
<td>8.04 days</td>
</tr>
<tr>
<td>Plutonium-231</td>
<td>8.5 minutes</td>
</tr>
<tr>
<td>Polonium-214</td>
<td>0.00016 seconds</td>
</tr>
</tbody>
</table>
What is Fission and How Does it Produce Energy?

**Nuclear fission** is the splitting of a large nucleus into smaller ones with the release of energy.

Energy is released because the sum of the masses of these fragments is less than the original mass.

This missing mass (about 0.1 percent of the original mass) has been converted into energy according to Einstein's $E=mc^2$ equation.
What is Fission and How Does it Produce Energy?

$$E = mc^2$$

Consider this: $c^2$ is equal to $9.0 \times 10^{16}$ m$^2$/ s$^2$

When mass is in kg, the energy units are kg m$^2$/s$^2$, which is equivalent to 1 joule.

The large value of $c^2$ means that it should be possible to obtain a tremendous amount of energy from a small amount of matter - whether in a power plant or in a weapon.
What is Fission and How Does it Produce Energy?

\[ E = mc^2 \]

For 1.0 g of matter:

\[ E = (1.0 \times 10^{-3} \text{ kg})(3 \times 10^8 \text{ m/s})^2 \]
\[ E = (1.0 \times 10^{-3} \text{ kg})(9.0 \times 10^{16} \text{ m}^2/\text{s}^2) \]
\[ E = 9.0 \times 10^{13} \text{ kg m}^2/\text{s}^2 = 9.0 \times 10^{13} \text{ J} \]

Equivalent to

33,000 tons of TNT
One gram of U-235 can produce $7.2 \times 10^7$ kJ, which is equivalent to ~2.5 tons of high-grade coal (33 kJ/g).

2-3 neutrons are released per fission, thus setting a chain reaction.
How to make fission take place and sustain?

- Fission is an extremely rare event, even among uranium atoms.
- Fission of $^{235}\text{U}$ is induced by thermal (slow) neutrons.
- Not all neutron collisions with uranium nuclei lead to fission.
- A critical mass of 15 kg of pure $^{235}\text{U}$ is needed to sustain the nuclear chain reaction (the break-even point!).
Figure 3.12  Fuel cycle for the light-water nuclear reactor; dashed lines are not yet part of the U.S. cycle.
1. Isotope Enrichment

- Natural uranium isotope composition: 99% $^{238}\text{U}$, 0.7% $^{235}\text{U}$. \(\rightarrow\) Isotope separation necessary to achieve $>3\%$ $^{235}\text{U}$ (minimal needed for light-water reactor).

- Enrich $^{235}\text{U}$ through UF$_6$ by gaseous diffusion: $^{235}\text{UF}_6$ diffuses faster than $^{238}\text{UF}_6$. (Enrichment factor $(^{238}\text{UF}_6/^{235}\text{UF}_6)^{0.5}$

- Gas diffusion has now largely been replaced by

  348 diffusion stages are required to achieve 0.7 to 2.8% enrichment (needed for light-water reactors)

A cascade of gas centrifuges at a United States enrichment plan
Gas Centrifuge

A gas centrifuge comprises an evacuated casing containing a cylindrical rotor which rotates at high speed in an almost friction-free environment.

- The uranium is fed into the rotor as gaseous uranium hexafluoride (UF6) which also rotates.
- The centrifugal forces push the heavier uranium 238 (U-238) closer to the wall of the rotor than the lighter U-235.
- The gas closer to the wall becomes depleted in U-235 whereas the gas nearer the rotor axis is enriched in U-235.

Source: "The Uranium Enrichment Plant Almelo," published by Urenco Nederland B.V.
www.exportcontrols.org/centrifuges.html
2. Fuel Rod Assembly

Actual size of fuel pellet

Fuel rod
Fuel assembly

Nuclear fuel pellet

Reactor core

Cooling tower
A nuclear reactor is a device in which nuclear chain reactions are initiated, controlled, and sustained at a steady rate (as opposed to a nuclear explosion, where the chain reaction occurs in a split second).

3. Pressurized Light Water Reactor
4. Breeder Reactor

Breeder reactor operates with fast neutrons, water coolant is replaced by liquid sodium.

Probability of $^{238}\text{U}_{92}$ absorbing a neutron is maximal for fast neutrons and not thermal neutrons.

Use of breeder reactor can stretch the supply of uranium fuel by at least a factor of 50.

Leaking of molten sodium can be a major problem.
Great! We extracted clean energy .......... 

......... Now what to do with spent nuclear fuel
5. Storing spent nuclear fuel

When spent fuel is first removed from a reactor, it is placed in a special pool of water contained in a steel-lined concrete basin.

- The water cools the spent fuel and protects workers and the public from radiation.

- After cooling move the fuel to dry-storage containers made of steel and/or concrete to shield radiation (yet to be done!).

- The containers are either placed upright on concrete pads, or stored horizontally in metal canisters in concrete bunkers.

- Right now, nuclear waste is piling up in a lot of places around the country.

- Nuclear waste will stay radioactive for thousands and thousands of years.
IV Disposal of Nuclear Waste

Disposition of High-Level Nuclear Radioactive Wastes

- **Storage on or near surface**
  - distributed
  - centralized

- **Geological repository**
  - open retrievable geological disposition
  - sealed geological disposal

Feasible, safe, secure as long as resources are continually committed

Feasible, safe, secure with reduced active measures

Options open decreasing degree of reversibility
Permanent disposal options

For decades, experts throughout the world have studied many options for permanently disposing of nuclear waste — including:

• Leaving the material at current storage sites
• Burying it in the ocean floor
• Putting it in polar ice sheets
• Sending it into outer space
• Placing it deep underground in a geologic repository
Proposed High Level Nuclear Waste Storage in Yucca Mountain, Nevada

MORE ON THE NUCLEAR WASTE IN APRIL
I. Reactor safety concern

- Highly radioactive materials released to the environments.
- 1979, Three Mile Island, USA
- 1986, Chernobyl, Ukraine, thousands died and many more got ill.
- 1999, Tokaimura, Japan, 49 workers gravely overexposed.

Taken as a whole, the human toll of the nuclear industry is not worse than in a number of non-nuclear large-scale industrial accidents.
II. Weapons proliferation

- $^{235}\text{U}$ is not a concern. (A bomb requires $>93\% \ ^{235}\text{U}$ whereas conventional fuel rods are only slightly enriched. Enrichment of $^{235}\text{U}$ to achieve weapons-grade requires a major commitment of resources.)
- $^{239}\text{Pu}$ is a concern. ($^{239}\text{Pu}$ is created in a uranium reactor. No isotope enrichment is needed to produce weapons-grade fuel.)
- $^{239}\text{Pu}$ can be relatively easily recovered from reprocessed reactor fuel.
Risks of nuclear power

III. Nuclear waste disposal

- The waste must be isolated from the environment for exceedingly long periods. (10 half-lives of the radioisotopes in the waste; Pu has a half-life in the order of 10,000 yr.)
- Temporary storage
- Transportation is a potential hazard
On 26 April 1986, reactor # 4 at the Chernobyl Nuclear Power Station, 100 km north from Kiev, blew up during a routine daily operation. Nearly nine tons of radioactive material - 100 times as much as the Hiroshima bomb - were hurled into the sky. Winds over the following days, mostly blowing north and west, carried, fallout into Belarus, as well as Russia, Poland and the Baltic region.

Control rods were made of graphite (unlike those used in the U.S.) which caught on fire.
Chernobyl-What Happened: April 26, 1986

While performing a safety test on Reactor #4, technicians allowed a power surge that reached 120 times the rated capacity of the reactor.

The surge, or "slow nuclear explosion", ripped open the core, including cooling water pipes, and caused a huge steam explosion.

The 4,000 ton concrete covering over the reactor was blown away. Fires broke out in many places all over the site.

Fifty different radioactive isotopes were released, with half-lives spanning from two hours to 24,000 years.

These isotopes were shot 1.5 miles into the sky.
Chernobyl: Political Consequences

Distrust of government.

Soviet Union cover up: Sweden and Poland were the first nations to bring attention to the accident.

Other nations attempted to downplay the health effects of the accident in their own nations.

Public opposition to building additional nuclear power plants increased significantly worldwide.

Chernobyl Today
http://www.nytimes.com/packages/khtml/2005/06/14/international/20050615_CHERNOBYL_AUDIOSS.htm
WASHINGTON — The fragile bipartisan consensus that nuclear power offers a big piece of the answer to America’s energy and global warming challenges may have evaporated as quickly as confidence in Japan’s crippled nuclear reactors.

### TABLE 3.3 PATHS OF ENERGETIC PARTICLES IN BIOLOGICAL TISSUE

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>Range in biological tissue*</th>
<th>Relative biological effectiveness$^\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td>0.005 cm</td>
<td>10 – 20</td>
</tr>
<tr>
<td>beta</td>
<td>3 cm</td>
<td>1</td>
</tr>
<tr>
<td>gamma</td>
<td>$\sim$20 cm</td>
<td>1</td>
</tr>
</tbody>
</table>

Some hazardous radioactive isotopes

<table>
<thead>
<tr>
<th>Element</th>
<th>Type of radiation</th>
<th>Half-life</th>
<th>Site of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{239}\text{Pu}$</td>
<td>alpha</td>
<td>24.360 years</td>
<td>Bone, lung</td>
</tr>
<tr>
<td>$^{90}\text{Sr}$</td>
<td>beta</td>
<td>28.8 years</td>
<td>Bone, teeth</td>
</tr>
<tr>
<td>$^{131}\text{I}$</td>
<td>beta, gamma</td>
<td>8 days</td>
<td>Thyroid</td>
</tr>
<tr>
<td>$^{137}\text{Cs}$</td>
<td>beta, gamma</td>
<td>30 years</td>
<td>Whole body</td>
</tr>
</tbody>
</table>

*For a 6 Mev particle.

$^\dagger$ Accounts for the fact that cell damage increases as the density of the damage sites increases.
rad = “radiation absorbed dose” – absorption of 0.01 J of radiant energy/kg tissue

rem = “roentgen equivalent man” = $Q \times$ (number of rads)

where $Q$ is a relative biological effectiveness factor

1 Sv = 100 rem

### Table 7.3: Physiological Effects of a Single Dose of Radiation

<table>
<thead>
<tr>
<th>Dose (rem)</th>
<th>Dose (Sv)</th>
<th>Likely effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–25</td>
<td>0–0.25</td>
<td>No observable effect</td>
</tr>
<tr>
<td>25–50</td>
<td>0.25–0.5</td>
<td>White blood cell count decreases slightly</td>
</tr>
<tr>
<td>50–100</td>
<td>0.5–1</td>
<td>Significant drop in white blood cell count, lesions</td>
</tr>
<tr>
<td>100–200</td>
<td>1–2</td>
<td>Nausea, vomiting, loss of hair</td>
</tr>
<tr>
<td>200–500</td>
<td>2–5</td>
<td>Hemorrhaging, ulcers, possible death</td>
</tr>
<tr>
<td>&gt;500</td>
<td>&gt;5</td>
<td>Death</td>
</tr>
</tbody>
</table>
V. Nuclear Fusion

1. \( ^1D + ^1T \rightarrow ^2He + p \)
   
   \( \text{deuterium} \quad + \quad \text{tritium} \quad \rightarrow \quad \text{helium-4} \quad + \quad \text{neutron} \)
   
   Ignition Temperature (°C) \( 1-2 \times 10^8 \)

2. \( ^1D + ^1D \rightarrow ^2He + p \)
   
   \( \text{deuterium} \quad + \quad \text{deuterium} \quad \rightarrow \quad \text{helium-3} \quad + \quad \text{neutron} \)
   
   Ignition Temperature (°C) \( 5 \times 10^8 \)

3. \( ^1D + ^1D \rightarrow ^1D + p \)
   
   \( \text{deuterium} \quad + \quad \text{deuterium} \quad \rightarrow \quad \text{tritium} \quad + \quad \text{proton} \)
   
   Ignition Temperature (°C) \( 5 \times 10^8 \)

4. \( ^1D + ^1He \rightarrow ^1He + p \)
   
   \( \text{deuterium} \quad + \quad \text{helium-3} \quad \rightarrow \quad \text{helium-4} \quad + \quad \text{proton} \)
   
   Ignition Temperature (°C) \( 10 \times 10^8 \)

5. \( ^{11}B + p \rightarrow ^{11}B + He \)
   
   \( \text{boron-11} \quad + \quad \text{proton} \quad \rightarrow \quad \text{boron-11} \quad + \quad \text{helium-4} \)
   
   Ignition Temperature (°C) \( 10 \times 10^8 \)

Breeding of Tritium from Lithium

6. \( ^{6}Li + \text{slow neutron} \rightarrow \text{tritium} + ^{4}He \)

7. \( ^{7}Li + \text{fast neutron} \rightarrow \text{tritium} + ^{4}He + \text{neutron} \)
Nuclear Fusion

• Advantages
  – Safer than fission technologies (No runaway reactions)
  – Simpler post-shutdown or emergency cooling systems
  – Radioisotopes created in the process are much shorter-lived.

• Disadvantages
  – Substantial technical challenges remain.
  – Economic competitiveness of fusion is unknown at present.
Will Nuclear Power be the future source of energy?

Advantages
- No green house gas (CO₂) emission
- Minimal air pollution under normal operating conditions.
- After the initial capital investment, produces relatively cheap electricity

Disadvantages
- Potential for disastrous accidents
- Nuclear weapons proliferation
- Disposal of nuclear waste
CURRENT NUCLEAR POWER PLANT PERFORMANCE IS SAFE AND COMPETITIVE AND CONSIDERABLY SUPERIOR IN TERMS OF AIR POLLUTION AND GREENHOUSE EMISSION

REVIVAL OF NUCLEAR POWER IN PROGRESS WITH 3 TO 6 NEW PLANTS OPERATING BY 2015.

U.S BEGINNING TO PURSUE FULL UTILIZATION OF NUCLEAR FUEL.

MORE SELECTIVE AND ACCELERATED PROGRAM NEEDED TO OVERCOME ANTICIPATED POLITICS. ONLY WITH SIGNIFICANTLY INCREASED UTILIZATION OF NUCLEAR FUEL WILL THE U.S. ACHIEVE LONG TERM SUPPLY OF ELECTRICITY WITH MINIMAL ENVIRONMENTAL IMPACT.
World Water Day, on 22 March every year, is about taking action to tackle the water crisis. Today, 1.8 billion people use a source of drinking water contaminated with feces, putting them at risk of contracting cholera, dysentery, typhoid and polio.

http://www.worldwaterday.org/

Does your bottled water contain plastic?

FOREIGN OIL DEPENDENCE IS CRAZY

LET'S GO WITH SOLAR PANELS...

...MADE IN CHINESE FACTORIES...

..POWERED BY COAL...

..AND SHIPPED ACROSS THE GLOBE TO PROVIDE ELECTRICITY!

NEXT... MORE NUCLEAR PLANTS...

...WILL CHINA LOAN US THE MONEY?

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