

Nuclear Engineering

**Presentation to the
Westinghouse Science Honors Institute**

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University of Pittsburgh**

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Fuels Licensing Engineer
Westinghouse Electric Company**

Topics

- * History of Nuclear Power Metzger
- * Fission & Radioactivity Brichacek
- * How a Nuclear Power Plant Works Metzger
- * Current Events in Nuclear Power Brichacek
- * Applications & Metzger
The University of Pittsburgh's
Nuclear Engineering Program

JD Metzger

The History of Nuclear Power



The Beginning

- * 1934 – Enrico Fermi's Group Bombards Uranium w/ Neutrons
 - * Postulates the creation of transuranic elements
 - * Ida Noddack criticized Fermi's conclusions & suggests possible fission of uranium
 - * Ida Noddack's paper is ignored



Enrico Fermi



Ida Noddack

Fission is Verified

- * 1939 –chemists Otto Hahn and Fritz Strassmann chemically verify alkaline metals in uranium bombarded with neutrons
- * 1939 – Lisa Meitner and nephew Otto Frisch postulate fission model based upon Niels Bohr's liquid droplet hypothesis.



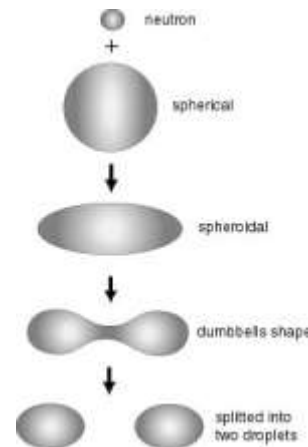
Lisa Meitner & Otto Hahn



Fritz Strassmann



Otto Frisch



The Chicago Pile, CP-1

The First Man-Made Nuclear Reactor

- * Enrico Fermi leads a group of scientists to build a Graphite reactor in squash courts under Alonzo Stagg Field stadium, at the University of Chicago
- * December, 2 1942 at 3:25 pm CP-1 went critical



Critical!



Reunion, 1946

Atomic Bombs

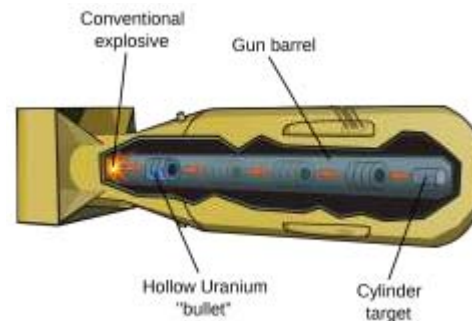


J. Robert
Oppenheimer

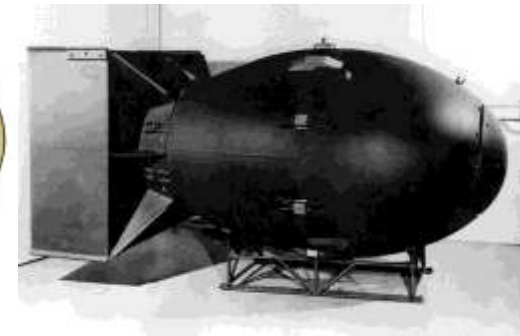
- * 1943 – The Manhattan Project centered at Los Alamos NM, lead by J. Robert Oppenheimer.
- * July 16, 1945 – Trinity Test
- * August 6, 1945 – Little Boy dropped on Hiroshima, Uranium, 16kT, >200,000 deaths.
- * August 9, 1945 – Fat Man dropped on Nagasaki, Plutonium, 21 kT, >200,000 deaths.



Trinity



Little Boy



Fat Man

Pittsburgh

The Birthplace of Nuclear Power

- * Bettis Atomic Power Laboratory, West Mifflin, is the birthplace of nuclear power!
- * Naval Captain Hyman Rickover started the Nuclear Naval Program in 1948.
- * 17 January, 1955 - USS *Nautilus* (SSN-571) "Underway on nuclear power."
- * 2 December 1957 - The Shippingport Atomic Power Station, "the world's first full-scale atomic electric power plant devoted exclusively to peacetime uses." (where Beaver Valley Nuclear Power Plant is today.)



Admiral
Hyman Rickover

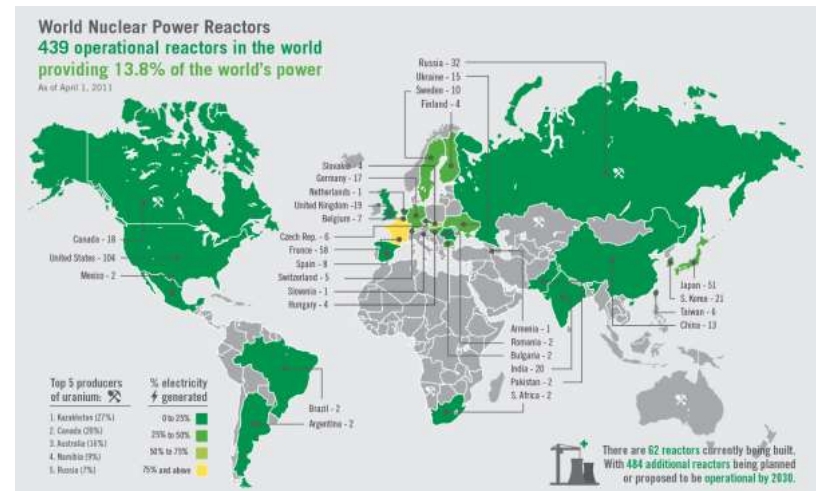
USS *Nautilus* (SSN-571)



Shippingport Atomic
Power Station

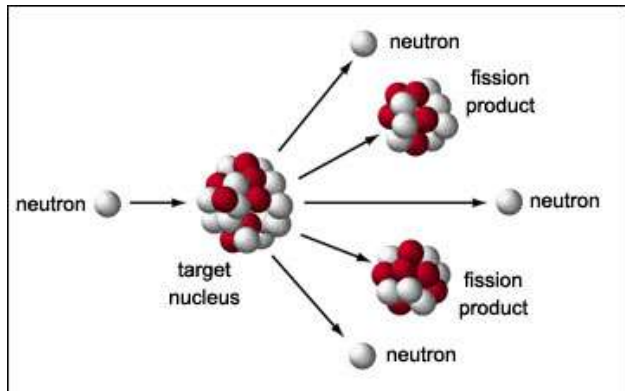
Nuclear Power Today

- * Today
 - * 439 Operating Nuclear Power Plants produces 13.8% of world's electricity
 - * 104 Operating Plants in the US produces 20% of US electricity
- * Nuclear Power is Carbon free.



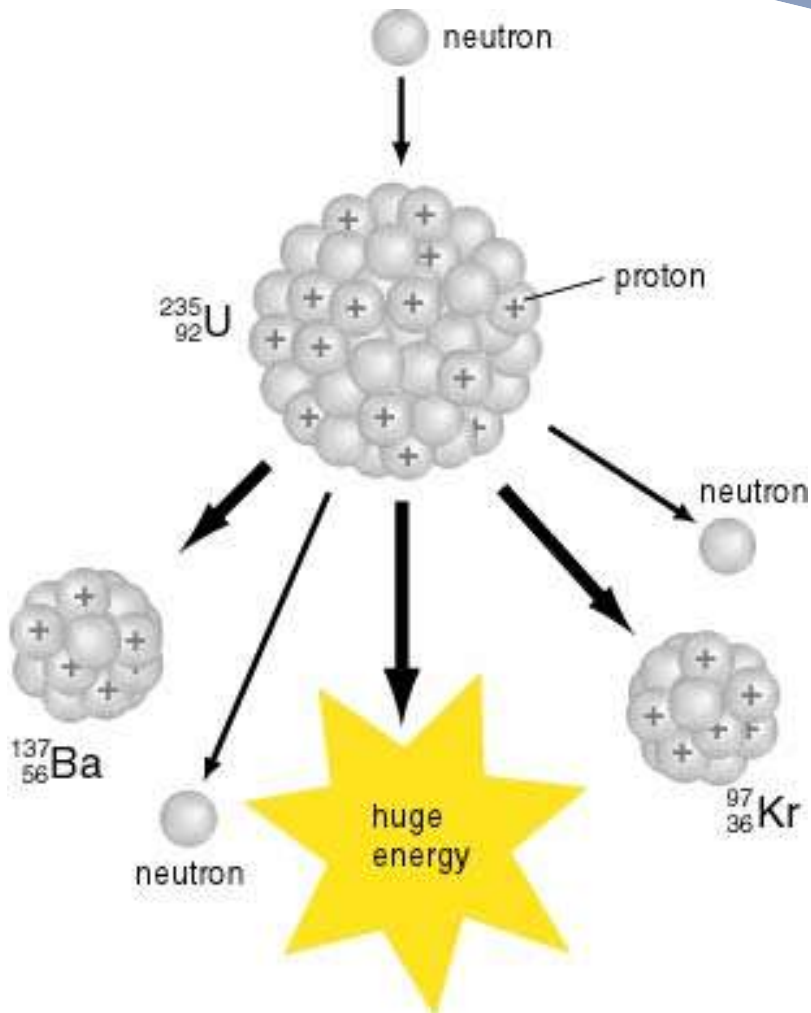
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Fission and Radioactivity



Nuclear Fission

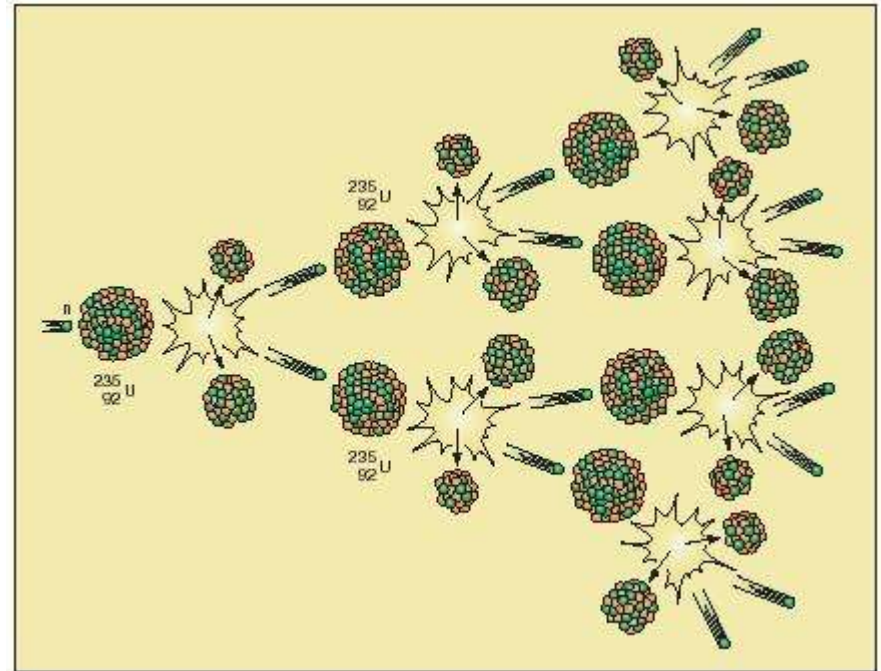
How Fission Works



- * Neutron hits a target nucleus
- * Nucleus becomes excited
- * Nucleus splits into two daughter nuclei and releases 2-3 neutrons
- * Gives off massive amounts of energy

Nuclear Chain Reactions

- * As a result of fission, neutrons are released from the atom
- * These neutrons are slowed down by a moderator
- * The neutrons then go on to collide with another target nucleus and cause another fission.
- * This process is repeated numerous times and is referred to as a “Nuclear Chain Reaction”



Nuclear Chain Reactions

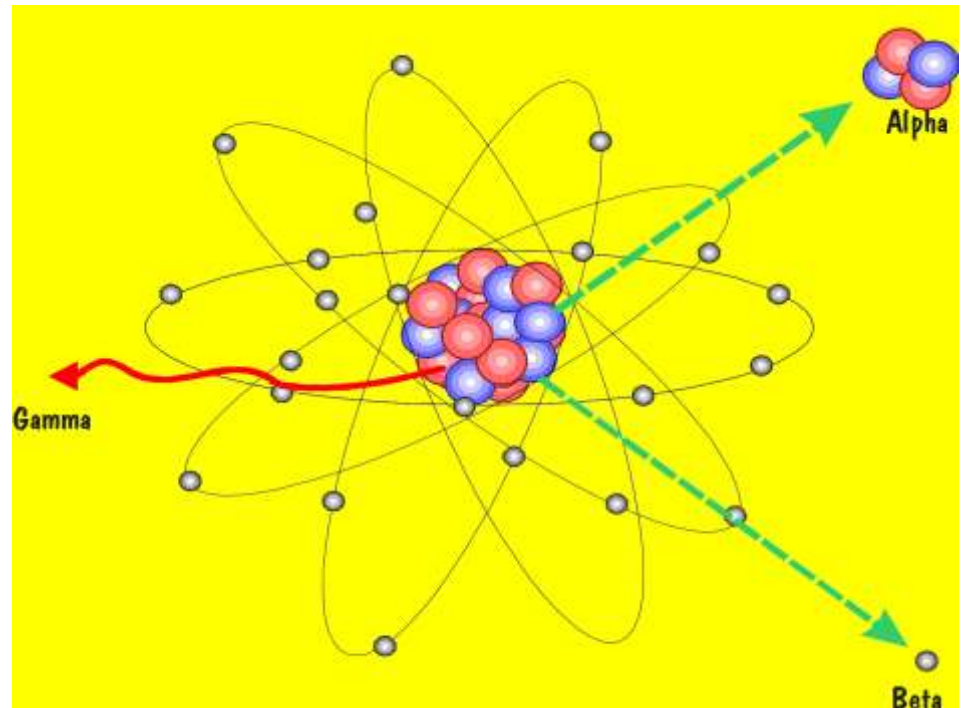
- * Not all atoms will easily undergo nuclear fission
 - * Certain isotopes are easier to split apart than others
- * Uranium-235 is a *fissile* material
 - * Will fission when collides with a slow moving, thermal neutron
 - * Easy to split apart which is why it is used in nuclear reactors
- * Uranium-238 is a *fissionable* material
 - * Will undergo fission only if hit with a fast moving neutron

Fission Products

- * When an atom fissions, it usually splits into 2 daughter atoms referred to as “Fission Products”
- * Fission Products usually are in an excited, unhappy state
- * To return to the ground state, the Fission Products must get rid of their extra energy
- * This is accomplished through radioactive decay

Radioactive Decay

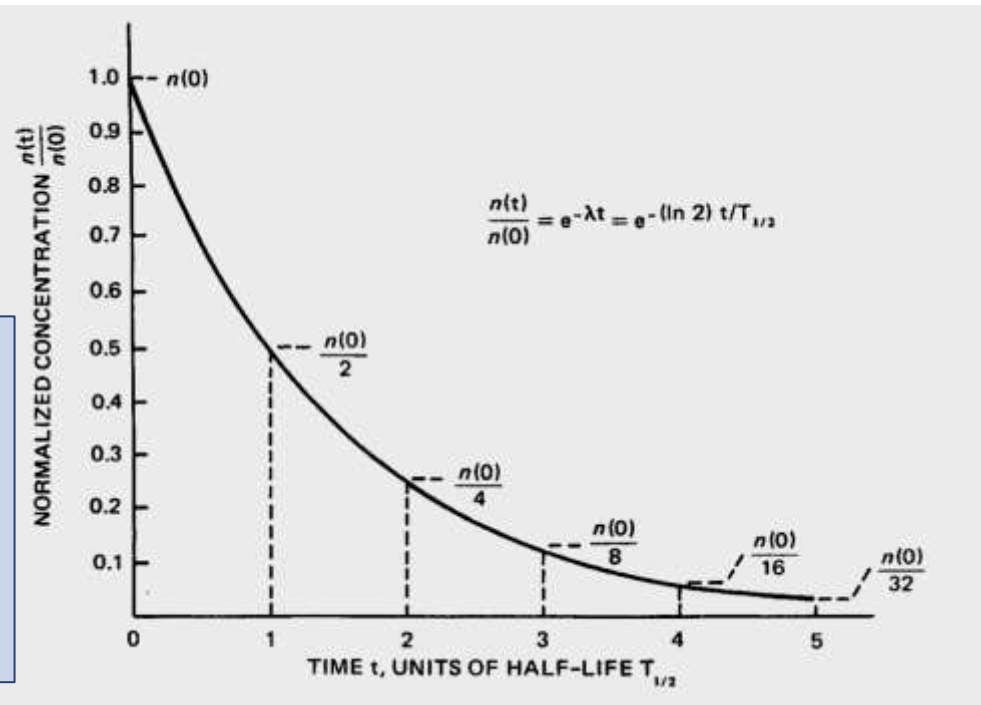
- * There are three main types of radioactive decay
 - * Alpha (α) decay
 - * ${}^4\text{He}$
 - * Beta (β) decay
 - * Electron
 - * Gamma (γ) decay
 - * Photon



Radioactive Half-Life

- * “Half-life” is the amount of time it takes for the amount of a radioactive material to decrease by half
- * Varies greatly depending on material

URANIUM 232	70 yr
233	160 000 yr
234	250 000 yr
235	700 000 000 yr
236	23 000 000 yr
238	4 500 000 000 yr



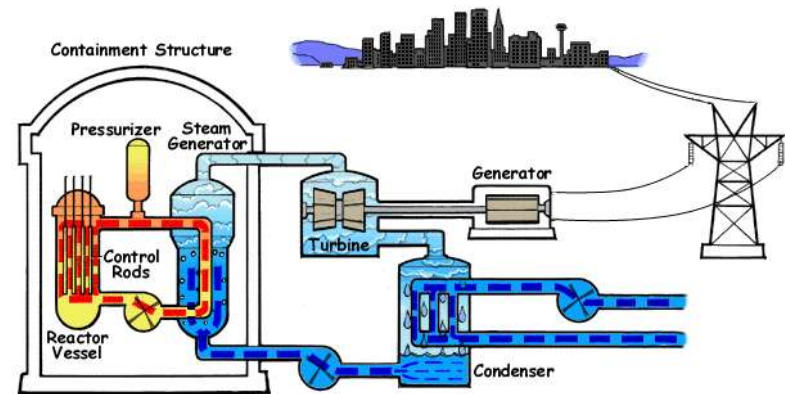
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How a Nuclear Power Plant Works



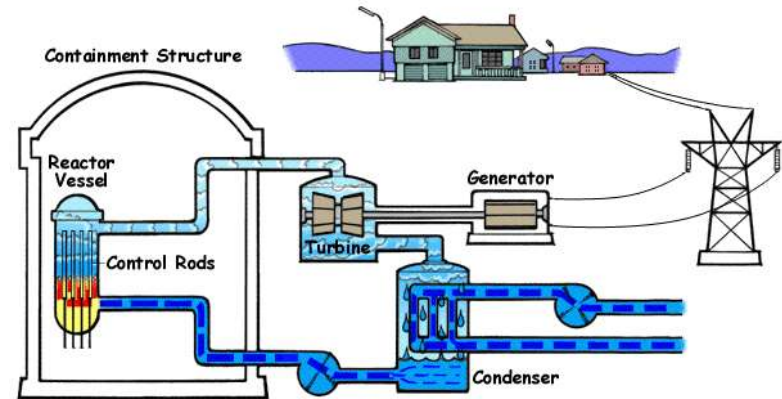
Pressurized Water Reactor

- * PWR's are ~ 2/3 of all reactors in the world.
- * Primary Loop
 - * 2200 psia, 550°F
 - * Water never boils
- * Secondary Loop
 - * Steam Generator
 - * Turbine – Generator
 - * Condenser
 - * Pump
- * Waste Heat Loop
 - * Cooling Tower to air
 - * Directly to lake, river or ocean



Boiling Water Reactor

- * BWR's are $> 1/3$ of all reactors in the world.
- * One Loop
 - * Reactor
 - * Water boils in reactor
 - * Turbine – Generator
 - * Condenser
 - * Pump
- * Waste Heat Loop
 - * Cooling Tower to air
 - * Directly to lake, river or ocean



Nuclear Fuel

- * Nuclear Fuel
 - * ~96.5% U-238, fissionable & fertile
 - * ~3.5% U-235, fissile
 - * UO_2 – ceramic fuel with very high melting point (2865 °C or 5189 °F)
- * Cladding – Zirconium Alloys
 - * Low neutron absorption
 - * Stable at operating conditions

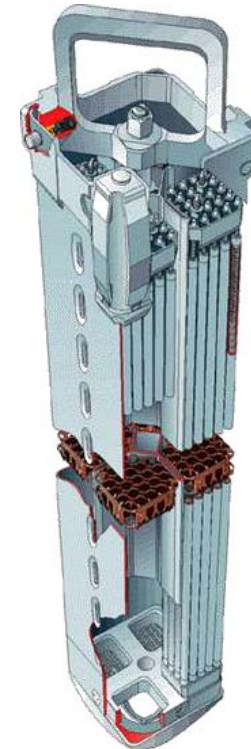


Fuel Assemblies

- * PWR
 - * 17 x 17, 264 rods, 25 control rod positions
 - * 12 to 13 feet long
 - * Open array
 - * Control rods are 25 rods inserted from the top.
- * BWR
 - * 8 x 8, 62 rods, 2 open positions
 - * 10 to 11 feet long
 - * Canned array
 - * Control rod is a crucifix inserted from the bottom.



PWR

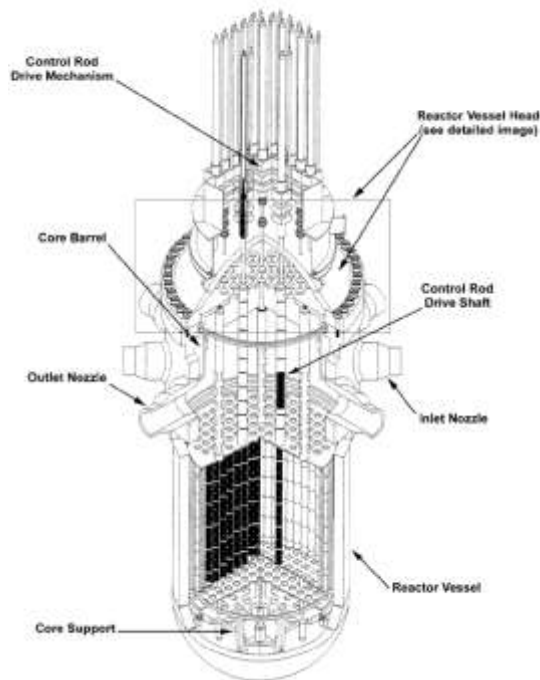


BWR

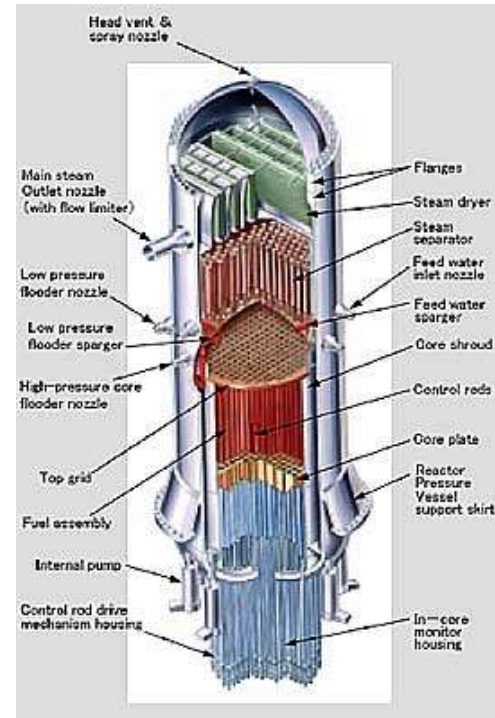
Nuclear Reactors

PWR

Typical Pressurized Water Reactor



BWR



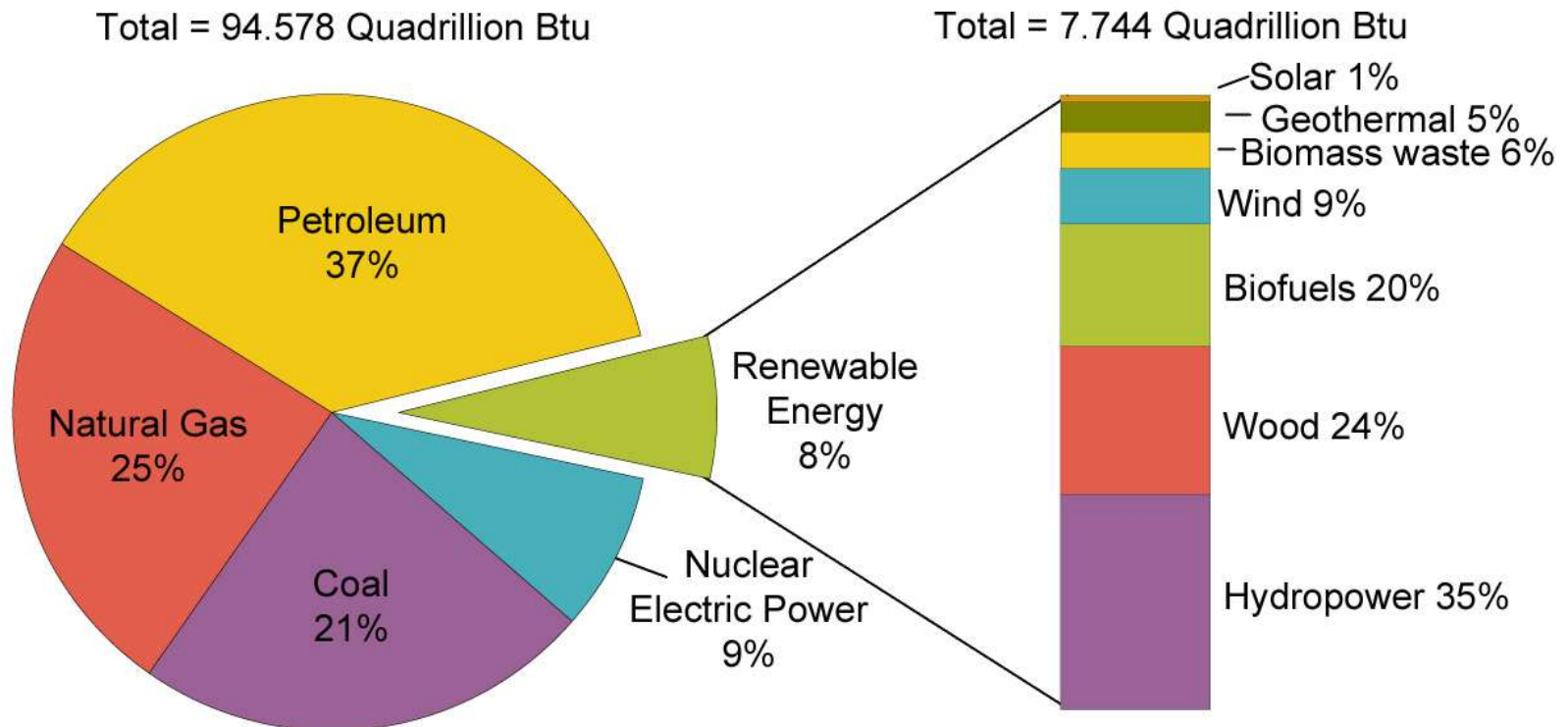
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Current Events in Nuclear Power



Energy Breakdown

U.S. Energy Consumption by Energy Source, 2009



Note: Sum of components may not equal 100% due to independent rounding.

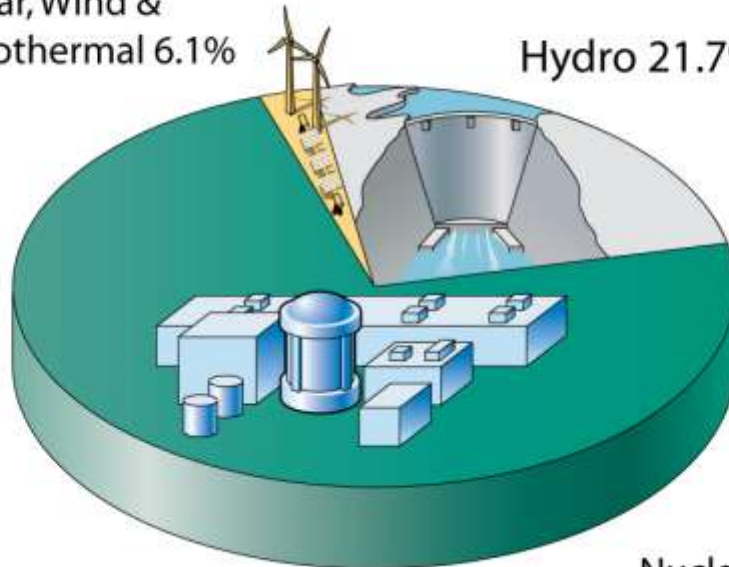
Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 1.3, Primary Energy Consumption by Energy Source, 1949-2009 (August 2010).

Emission Free Energy

Sources of Emission-Free Electricity 2008

Solar, Wind &
Geothermal 6.1%

Hydro 21.7%

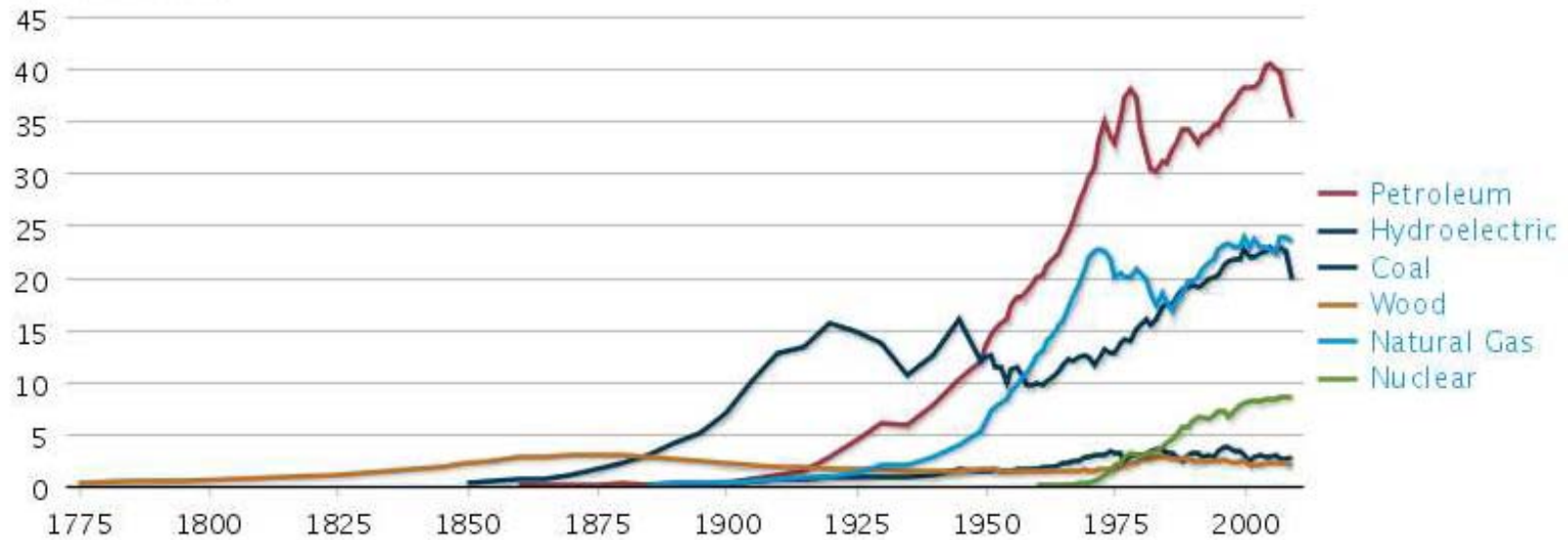


Nuclear 72.3%

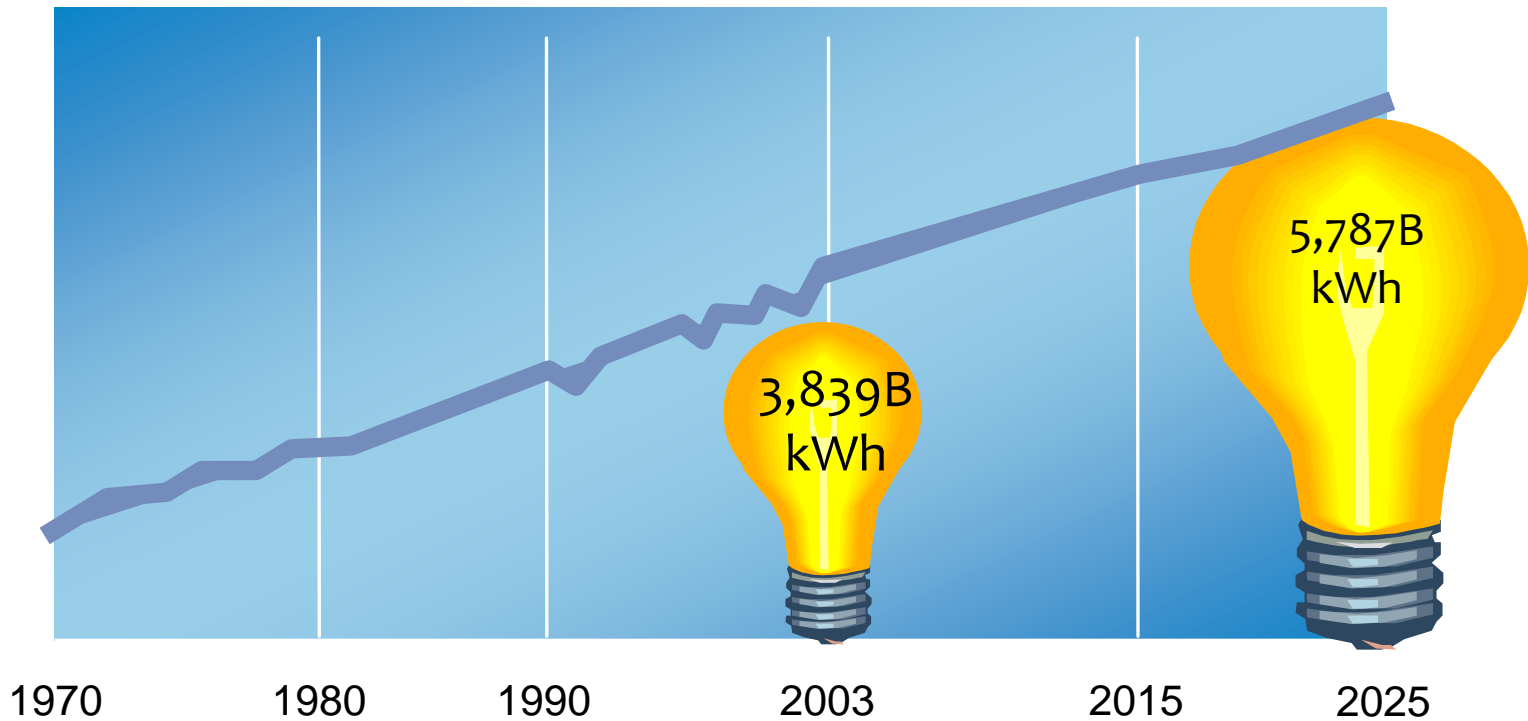
History of US Energy Use

History of energy consumption in the United States

quadrillion Btu



Energy Demand



Source: U.S. Department of Energy

Perks of Nuclear Energy

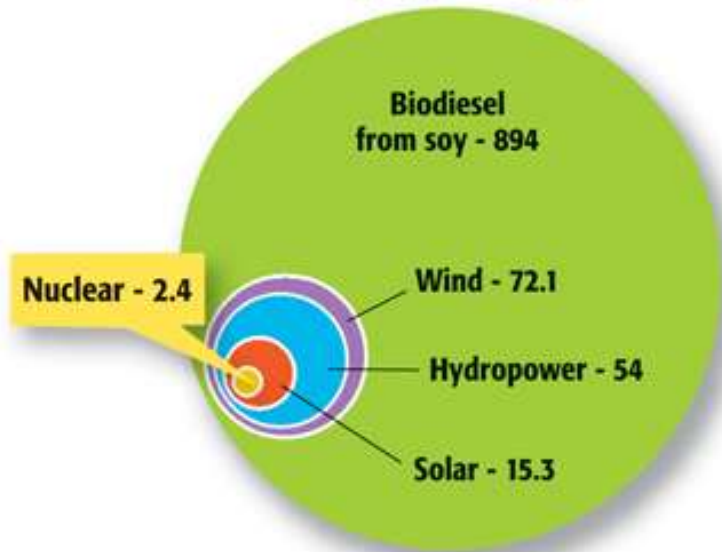
Capacity and Cost

- * Nuclear plants operate at ~90% capacity in the US
 - * Coal Plants operate at ~85% capacity
- * Cost Effective
 - * In 2009, the cost of nuclear energy was 21.69 Mills/kwH; the cost of fossil fuel plants was 40.48 mills/kwH
 - * Includes operation, maintenance, and fuel costs

Perks of Nuclear Energy

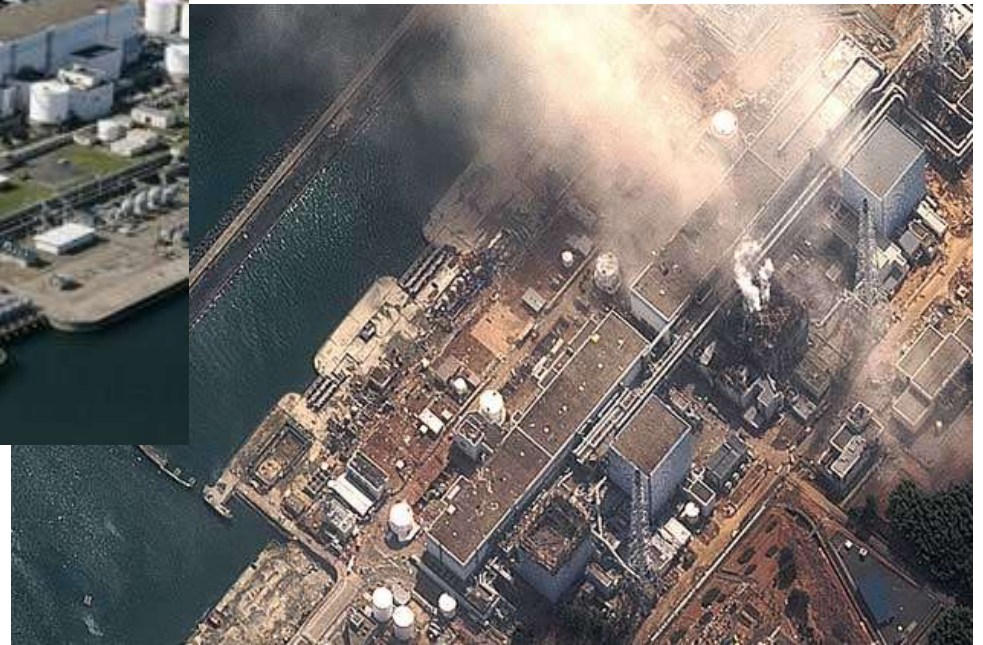
Land Use

Land Use Intensity by Energy Source



- * Land Use Intensity:
 - * Land intensity can be measured using the land area (km²) required to deliver a standard amount of economically useful energy.
- * Others(est. 2030)
 - * coal is 9.7
 - * natural gas 18.6
 - * petroleum 44.7

Drawbacks of Nuclear Power



Fukushima's Impact

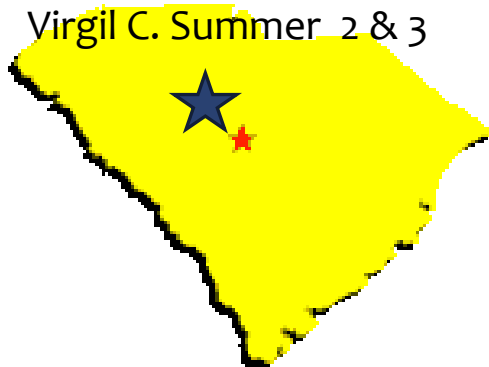
Countries Pro-Nuclear

- * United States
- * China
- * Finland
- * United Arab Emirates
- * Sweden
- * France

Countries Anti-Nuclear

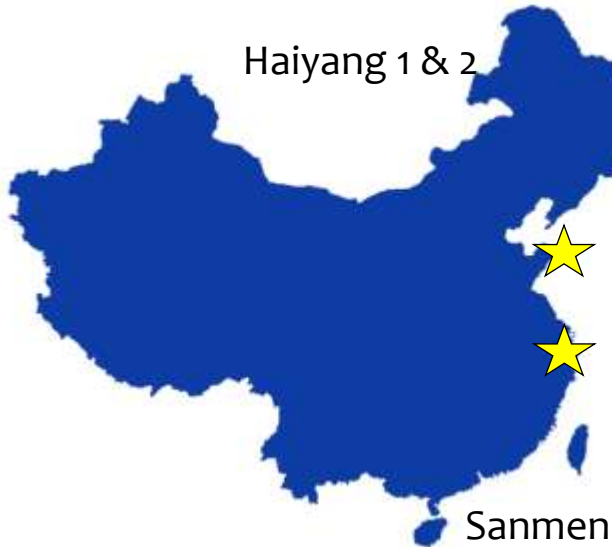
- * Germany
- * Italy
- * Switzerland

New Build - Domestic



New Build - Internationally

Haiyang 1 & 2

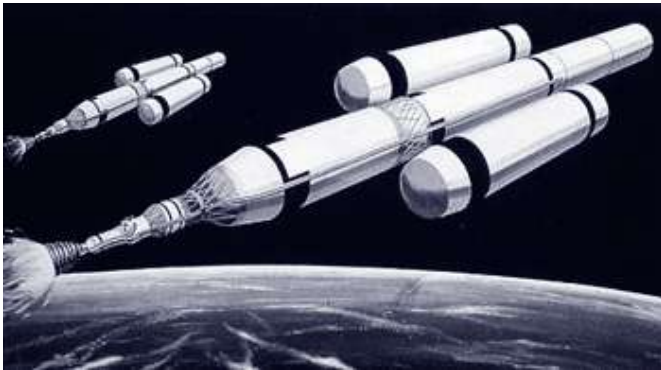


Sanmen 1 & 2



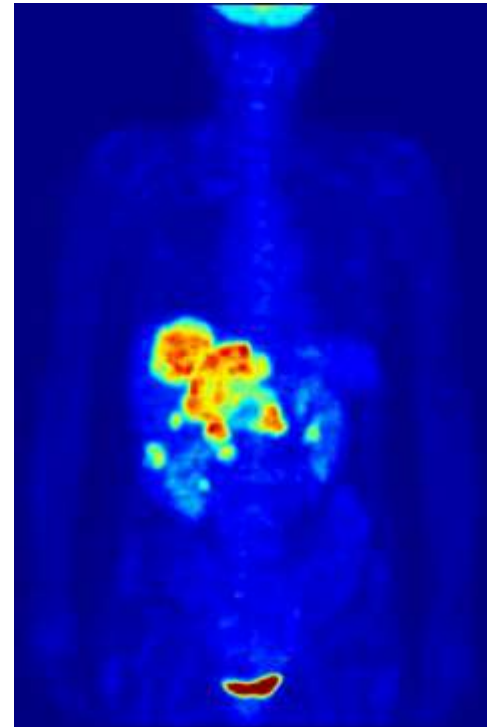
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Applications & The University of Pittsburgh's Nuclear Engineering Program



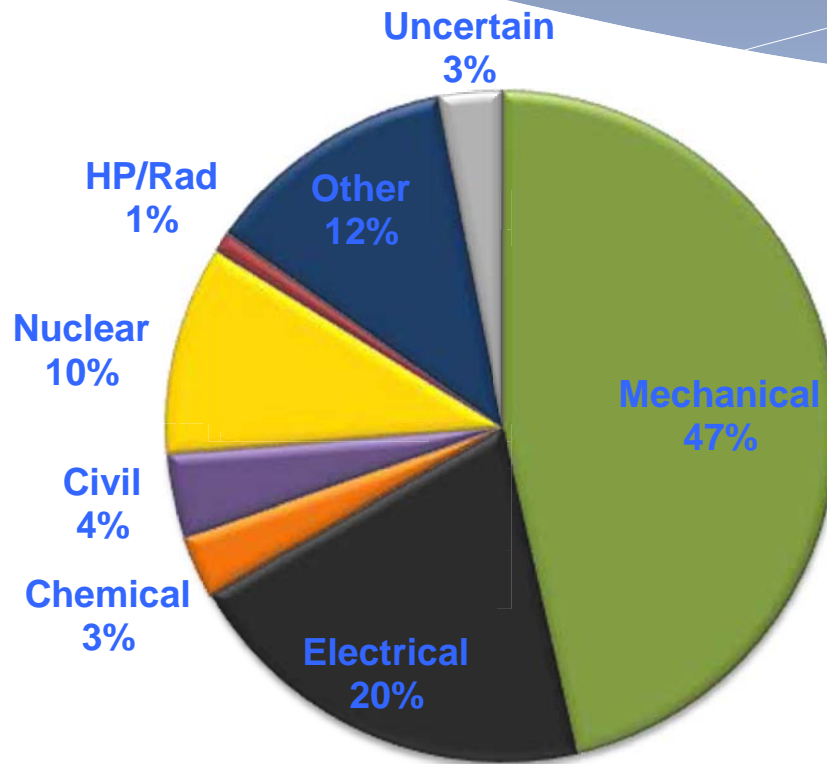
Nuclear Medicine

- * Nuclear medicine is a branch or specialty of medicine and medical imaging that uses radionuclides and relies on the process of radioactive decay in the diagnosis and treatment of disease.



Maximum Intensity Projection (MIP) of a wholebody positron emission tomography (PET) acquisition of a 79 kg weighting female.

Commercial Nuclear Power's Demand for Engineers by Degree

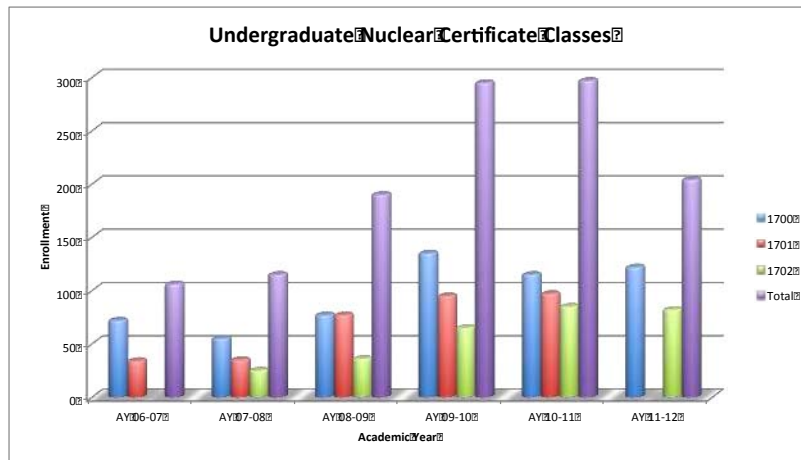


Close to 75% in
Mechanical
Electrical
Civil
Chemical

Ref: Provided w/ permission by E. McAndrews-Benavides, NEI
Manager, Industry Infrastructure.

Data is from the NEI's 2008 Work Force Survey.
Additional Nuclear Engineers would be accepted if they were willing to work in systems engineering,
design engineering and the operations department.

Pitt's Undergrad Nuclear Program



- * Undergraduate Certificate in Nuclear Engineering
 - * Earn is with any other engineering degree (math or science degree)
 - * Three Nuclear Courses
 - * ENGR 1700 Introduction to Nuclear Engineering
 - * ENGR 1701 Fundamentals of Nuclear Reactors
 - * ENGR 1702 Nuclear Power Plant Technology
 - * Two other courses in your major.

Join Us at Pitt in Our
Nuclear Engineering Program!

Questions?