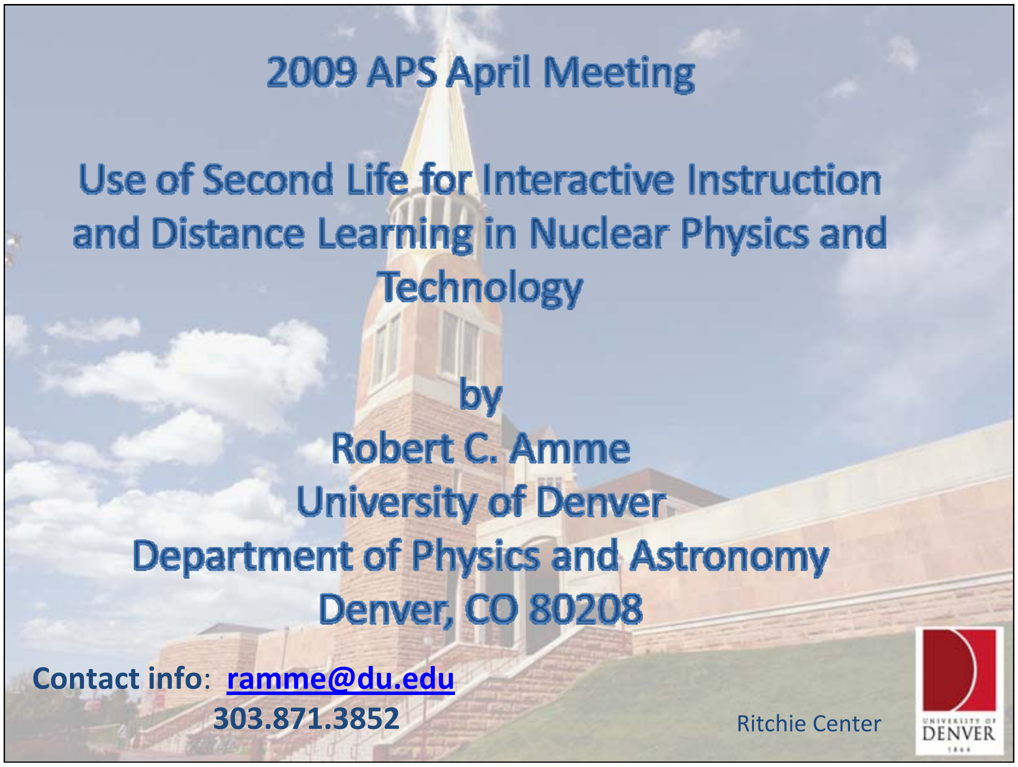
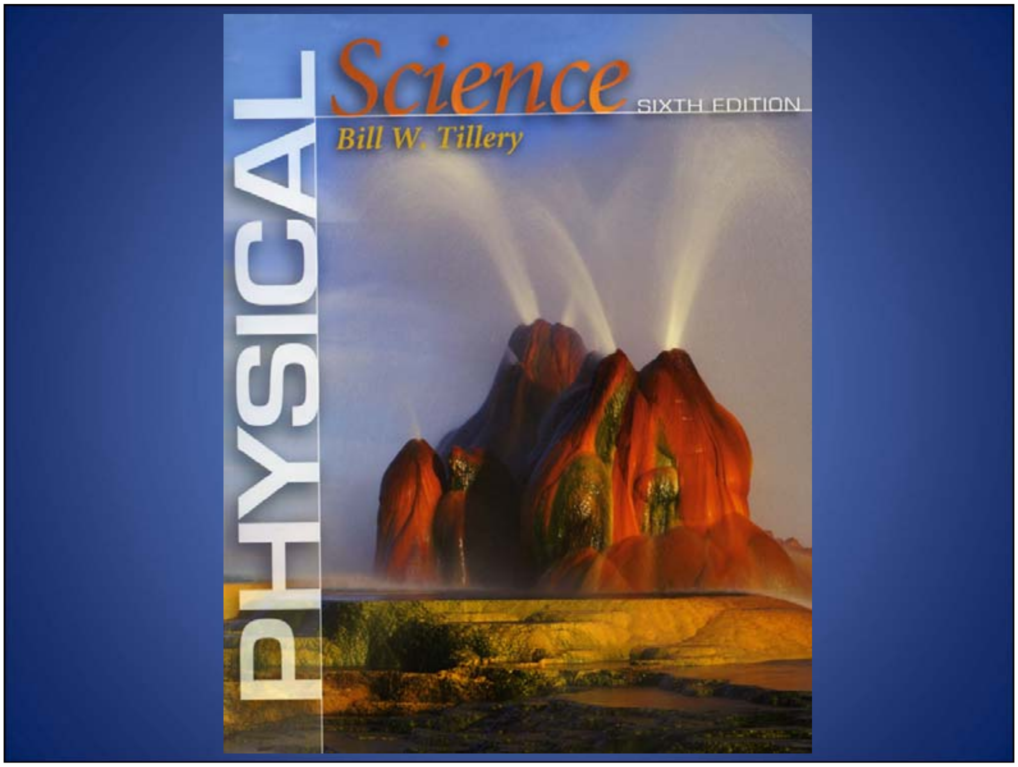
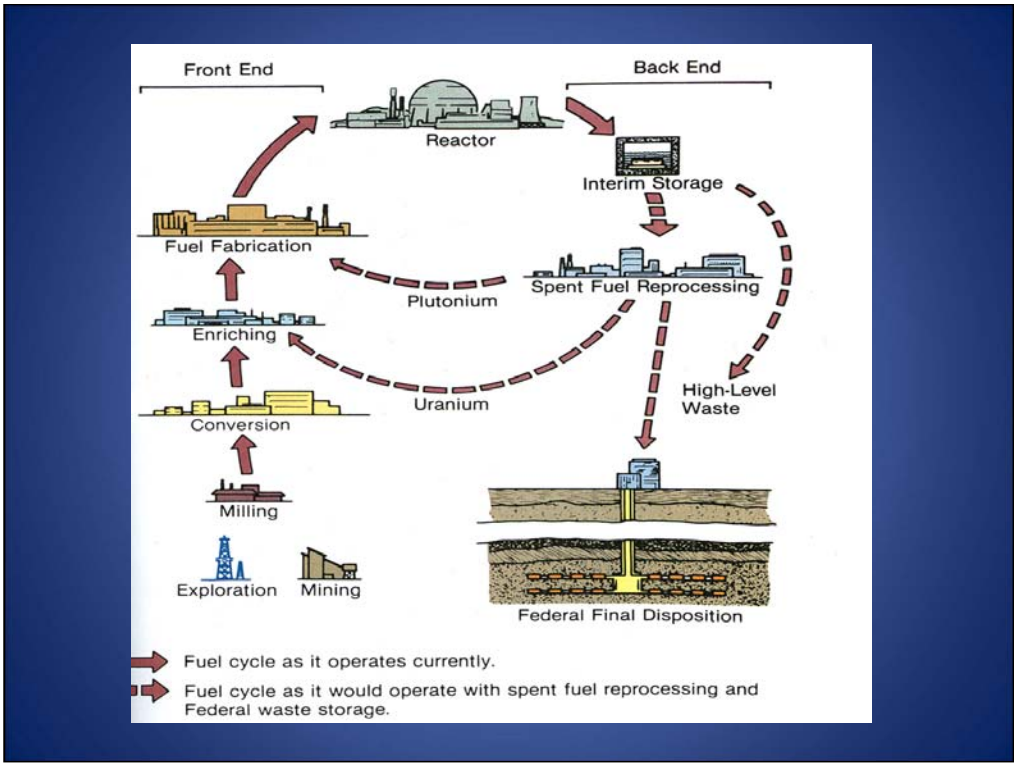


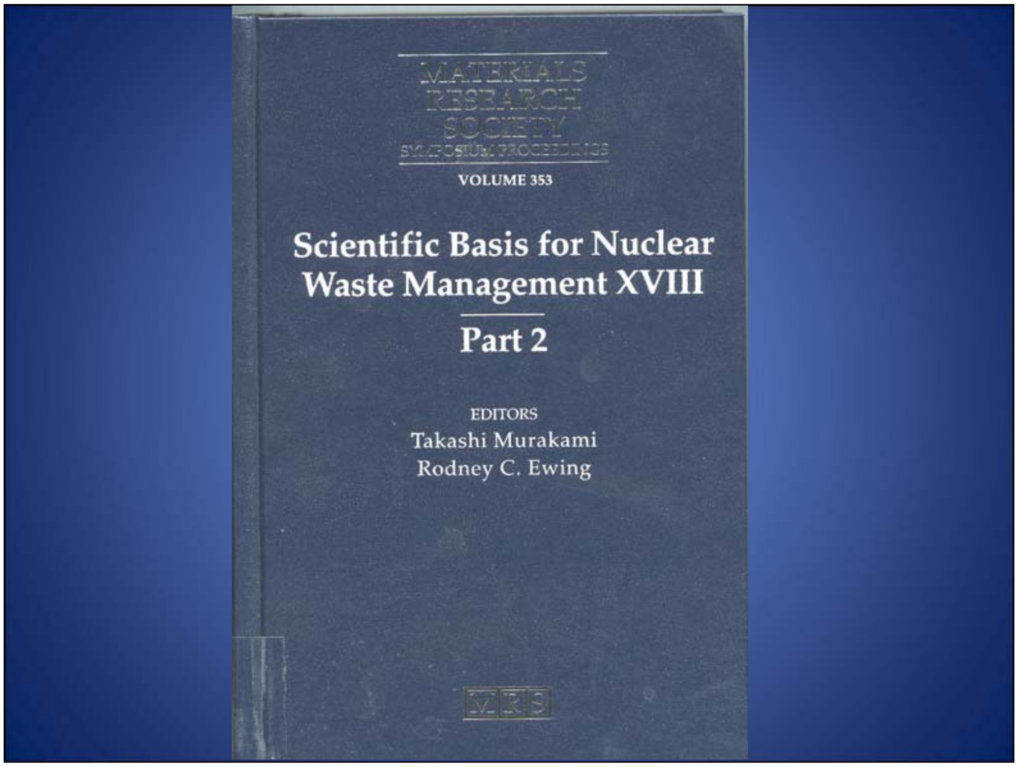
We are on a mission to familiarize the public with the nature of nuclear energy and its many benefits. We are troubled that far to little knowledge of nuclear energy is gained by students in middle- or high school. While science books may describe nuclear processes leading to fission and chain reactions, little of the technology of nuclear power, including the complete fuel cycle, the need for reprocessing used fuel, and the prospects for breeder reactors (fast neutron) is generally described.



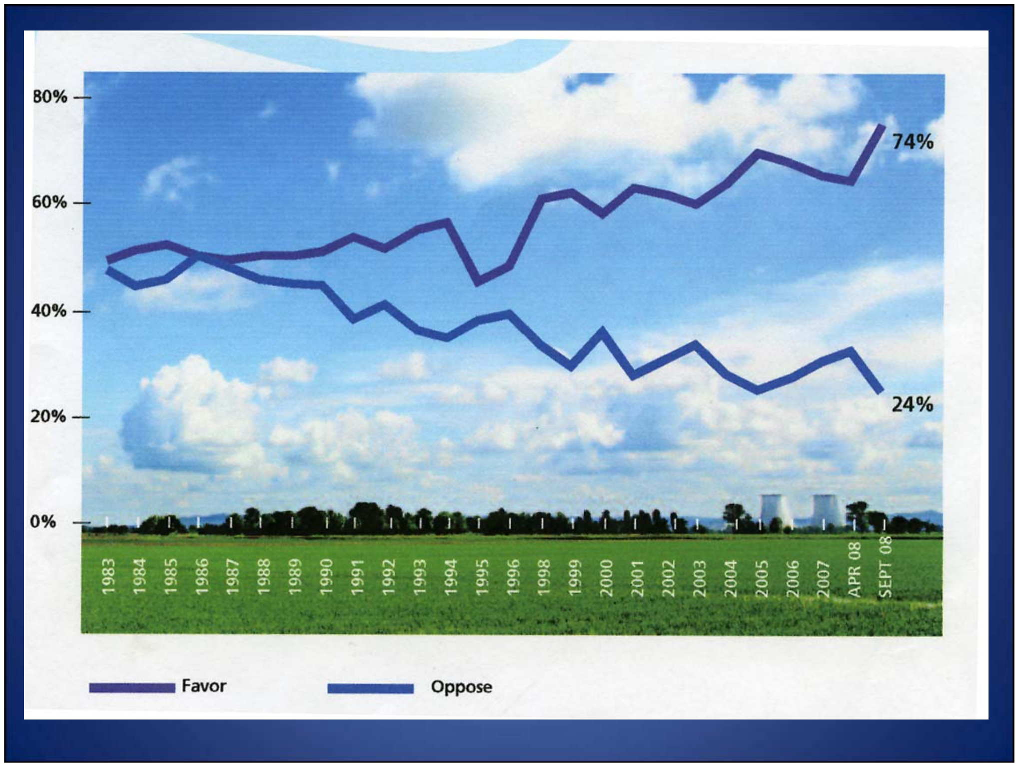
This college level Physical Science book, authored by Bill Tillery of Arizona State University, deserves acclaim for the treatment of nuclear energy. Regrettably, far too few students are exposed to such insightful texts.



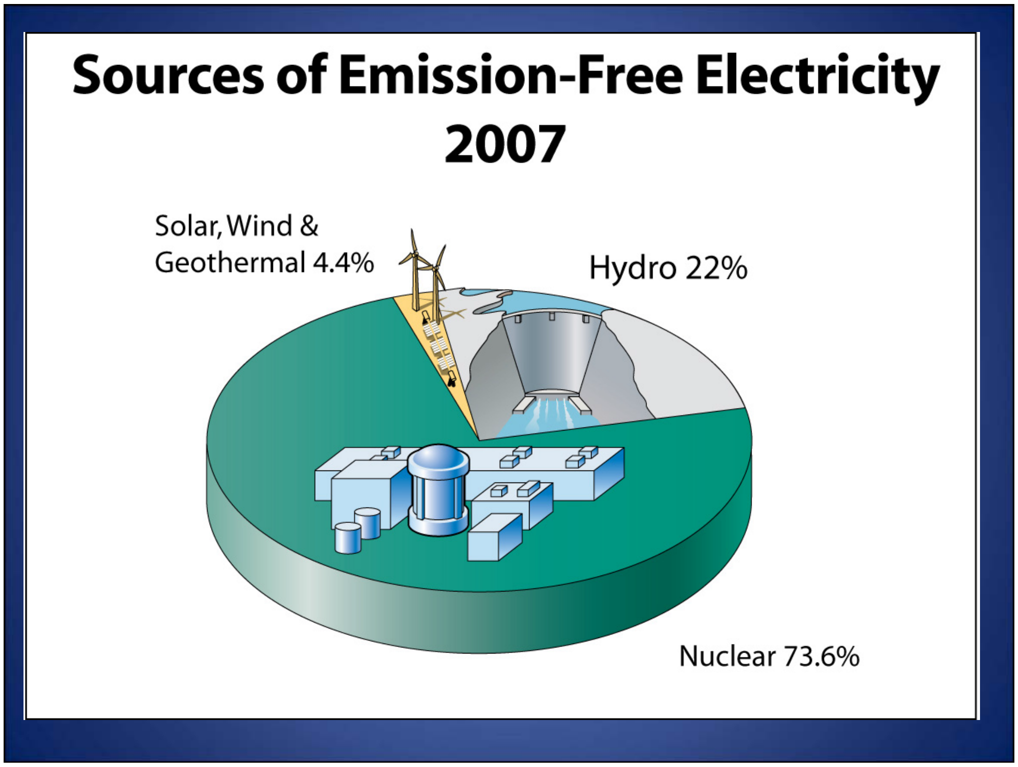
It is rare to find a high school level physical science text that touches on the subject of open and closed nuclear fuel cycles. This figure is from John W. Christensen's book, "Global Science" Kendall/Hunt Publishing Co., ISBN 0-8403-7483-6 (1996).



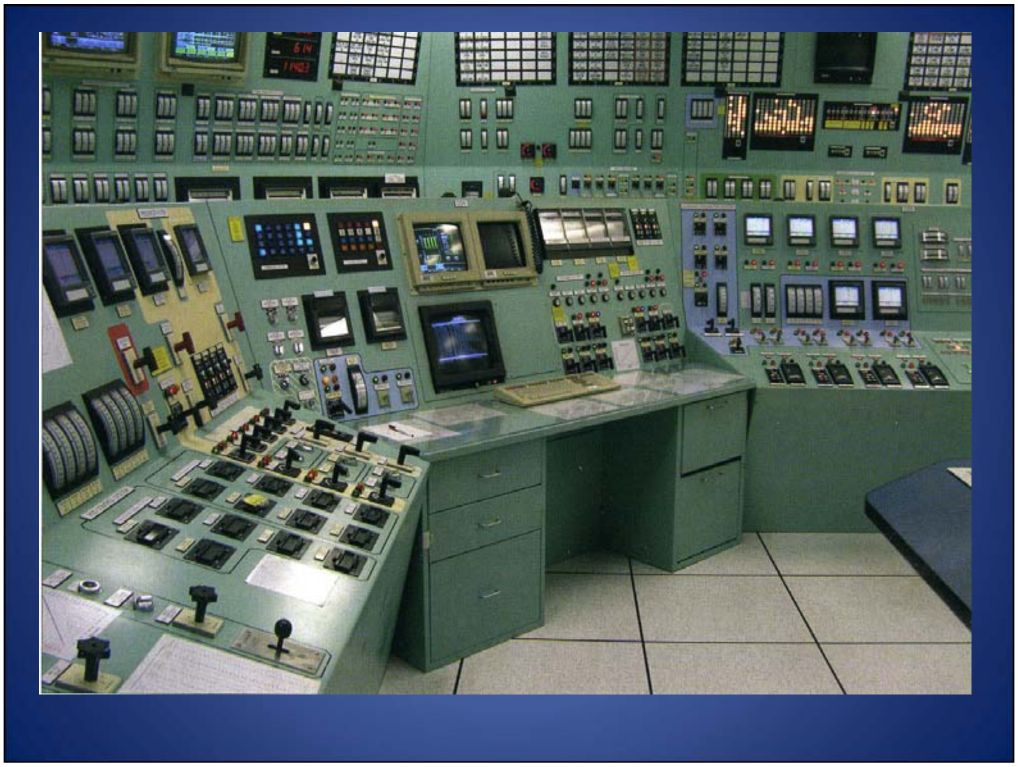
Other than the relatively few professionals who have been exploring nuclear waste management, little is known by the general public that decades of research have seen a considerable growth in the understanding of the science associated with this subject. This volume, edited by Murakami and Ewing, is but one of many written proceedings from frequent conferences held by the Materials Research Society. It is an international effort.



This graph, published by the Nuclear Energy Institute, displays public attitudes about nuclear power plants for the past 25 years. The recent, rather dramatic, increase of those favoring nuclear energy is likely due to growing concerns about carbon dioxide emissions from fossil fuels, and perhaps the recognition that future electric automobiles will need large quantities of electricity from a grid that is powered by fossil-free sources.



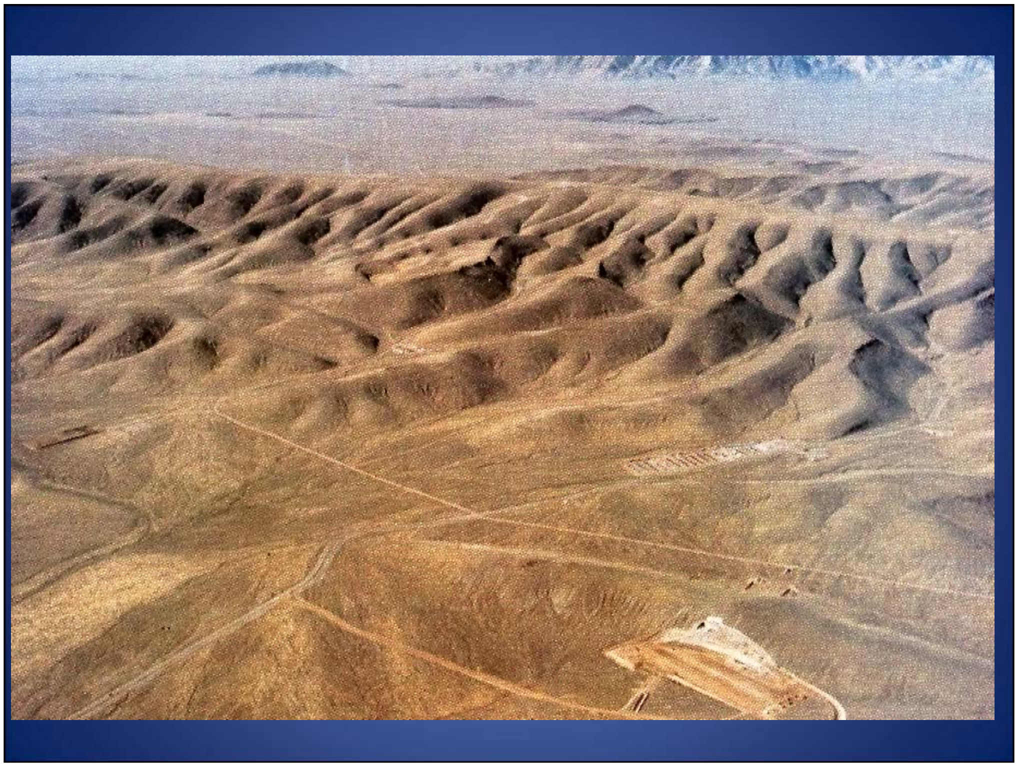
This pie chart from the Nuclear Energy Institute demonstrates the importance of nuclear energy in generating emission-free electrical power. Other renewable energy sources are composed largely of hydroelectric plants, with but a small contribution from solar and wind sources.



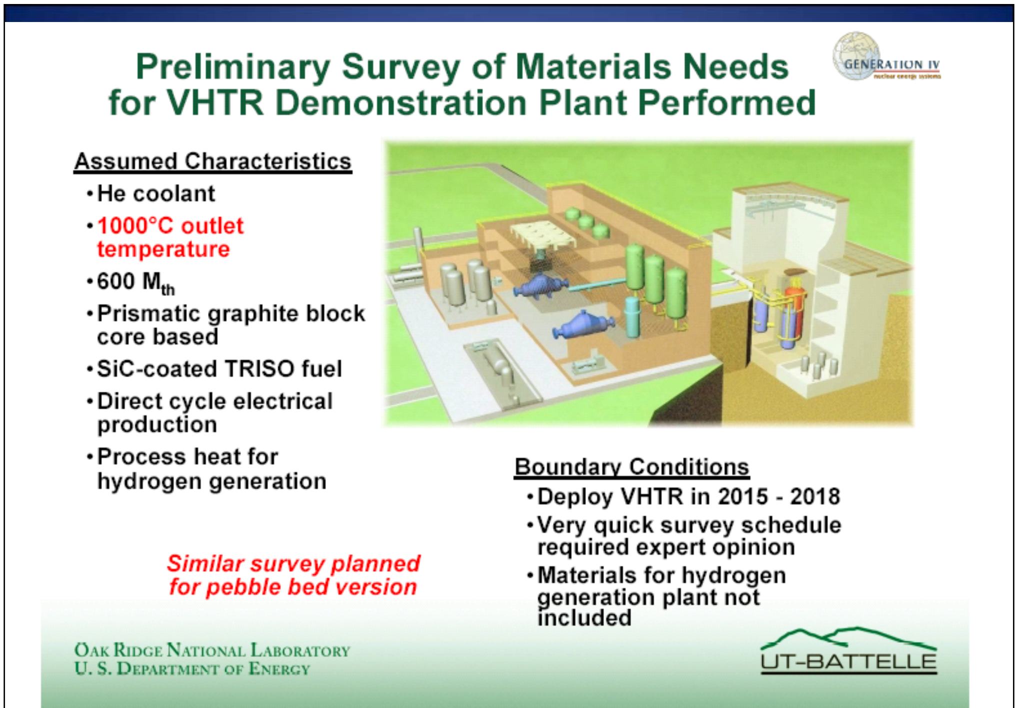
This photograph of a U.S. Light Water Reactor control room was taken in the 1980s, when computerized information and control were just blossoming A 1979 photo of the Three Mile Island control room showed no obvious sign of computers, a large number of dial telephones, and numerous electro-mechanical controls. Real-time information from the reactor to the operarator was quite limited).

A modern reactor control room provides the operators an abundance of graphical and visual information, not available in earlier systems. Such features, in addition to the modern training facilities now available, helps to explain why the U.S. power stations today are over 90% efficient (i.e., the Capacity Factors have roughly doubled). Capacity factors for wind and solar plants are dramatically less (ca. 30 to 35% for wind turbines and in the 24% range for solar PV).

This virtual reality control room was created for our Second Life version of the French Areva EPR (European Pressurized-water Reactor). This model power plant, being erected in Finland and in France, will produce 1600 MWe from a single reactor; because of its several safety features, it is identified as a Generation III+ plant. (Charts are taken from illustrations by Dr. Cliff Po, president and CEO of PCTrans).



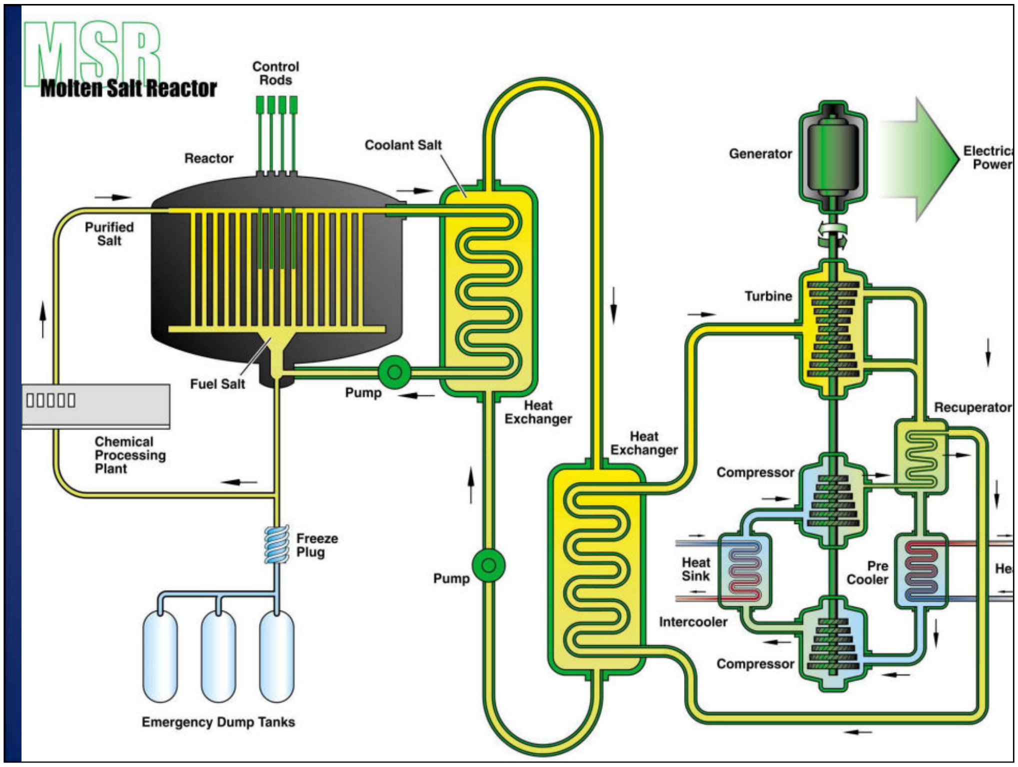
This aerial view of Yucca Mountain, located within the Nevada Test Site ca. 100 miles north-west of Las Vegas, NV, looks westward towards Death Valley. Billions of dollars have been spent exploring its suitability as a permanent disposal site for spent commercial reactor fuel elements, currently stored at or near the reactor sites. Objections from the State of Nevada have been extensive, and the Obama Administration has called a hault to the plan while other prospects for the treatment and disposal of nuclear used fuel are to be investigated.



Bill Corwin, Director National Gen IV Materials Technology Program Oak Ridge National Laboratory
"Materials for Very-High-Temperature Reactor" Presented at CEA, Saclay (Saclay, France) May 28, 2003

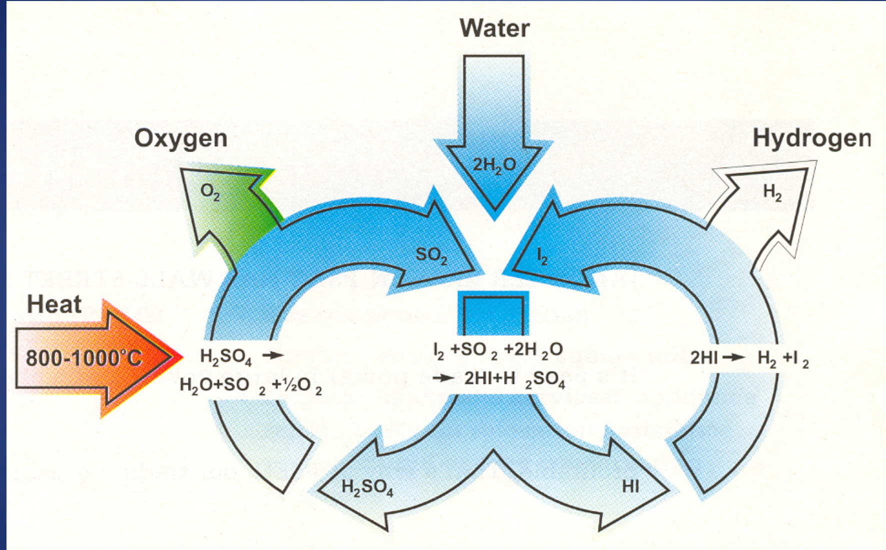
The public (and students in particular) know little of the thinking that has been directed at the future of nuclear energy and its prospects for yet safer and cleaner power. One such vision is that of the Very High Temperature Reactor (VHTR) that would use helium as a coolant and would operate with higher thermodynamic efficiency. The higher temperatures are suitable for thermochemical decomposition of water into hydrogen and oxygen. Hydrogen has been considered a prospect for replacing fossil fuels for many applications, and produces only water as the byproduct. One large nuclear power plant (ca. 1 GWe) could generate enough hydrogen, when combined with fuel-cell powered automobiles, to free one million autos from gasoline consumption. This slide, originating at the Oak Ridge National Laboratory, outlines the need for materials development for such a plant.

This photo depicts a collection of "TRISO" nuclear fuel elements in a Pebble Bed Modular Reactor. Each "pebble" is a collection of thousands of smaller spheres consisting of a core of nuclear fuel (e.g., uranium) surrounded by coatings of pyrolytic carbon, porous carbon, and silicon carbide; the pebbles observed here are about the size of a billiard ball. Such a plant is under construction in South Africa.



Another Generation IV reactor concept is depicted here, the Molten Salt Reactor. Again, higher efficiencies are to be gained from high temperature reactors in which water (used in the common water-cooled reactors of today) has been replaced

by a different type coolant, which also may contain the dissolved fuel (e.g., UF4). More details are available through the NEI or Wikipedia.



Iodine-sulfur process for thermochemical production of H_2 (Source: ORNL)

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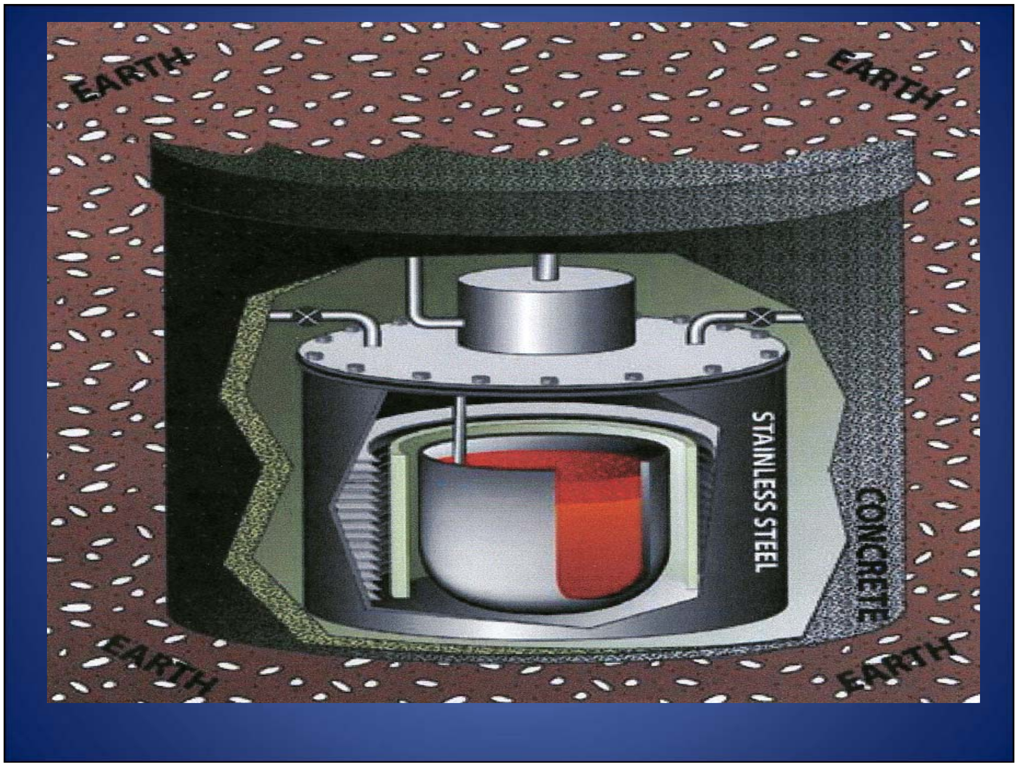
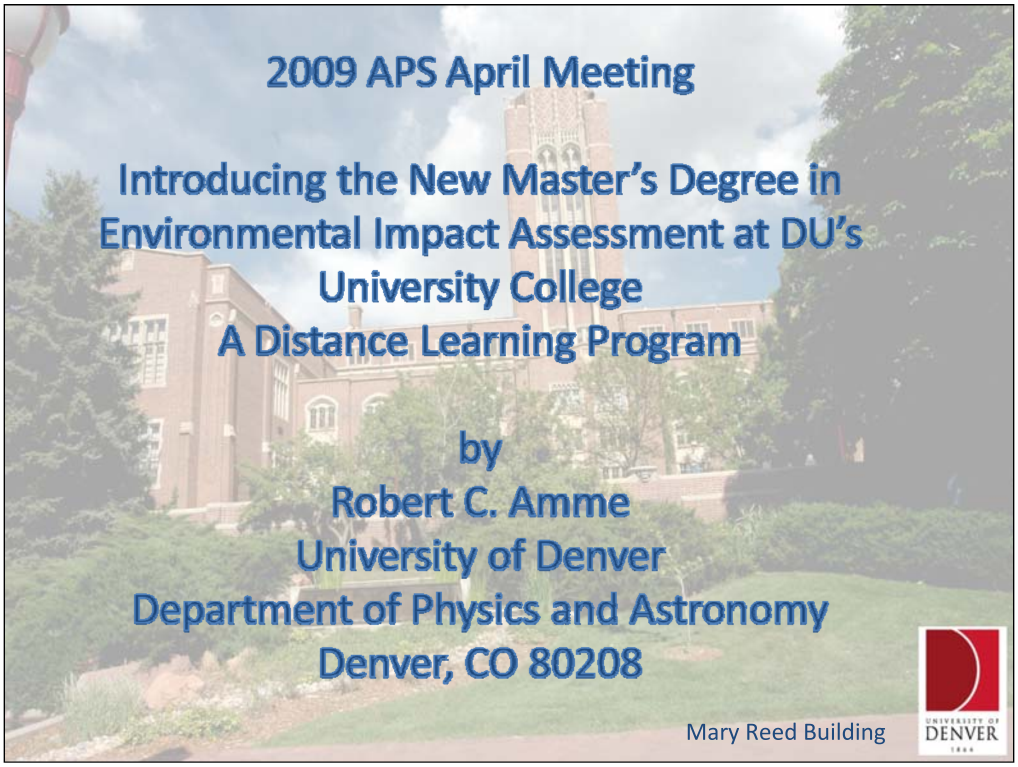
The process shown here is but one means of generating hydrogen with the use of a high-temperature reactor. Here, chemical catalysts H2SO4 and HI are used to produce hydrogen and oxygen from water.



A new candidate for nuclear power is the “mini-reactor”. Shown here is an artistic representation of the “Hyperion” version, invented by Otis Peterson of the Los Alamos National Laboratory. The unit can be shipped by truck, has no moving parts, and requires no operator. It produces ca. 70 MW of thermal energy (27 to 30 MWe), enough to power over 20,000 homes. It is inherently safe and proliferation-resistant. After five years, the unit can be refueled (uranium hydride).



At the June, 2008 meeting of the American Nuclear Society in Anaheim, we introduced a new Master of Applied Science degree at the University of Denver, which now being taught online. The program was initiated by a grant from the Nuclear Regulatory Commission, in an effort to stimulate graduates in environmental science and related disciplines to become knowledgeable in the areas of nuclear power and nuclear materials, subjects in which there is a significant shortage of experience to meet future needs.

Environmental Impact Assessment Course Titles

Course Number	Title
EIS 4.1	Land and Visual Resources with ArcGIS
EIS 4.2	Historical and Cultural Resources
EIS 4.3	Geology and Soils
EIS 4.4	Air Quality and Noise
EIS 4.5	Ecological Resources
EIS 4.6	Socioeconomics and Infrastructure
EIS 4.7	Water Resources: Ground Water and Surface
EIS 4.8	Environmental Law: Government policy and regulatory guidance
EIS 4.9	Transportation
EIS 4.10	Nuclear Waste Management
EIS 4.11	Public and Occupational Health and Safety from Nonradiological and Radiological Toxic Pollutants
EIS 4.12	Environmental Restoration
EIS 4.13	Nuclear Power Plant Systems

Courses designed to meet future needs in environmental impact assessments that must deal with radioactive and special materials. Graduates should be able to participate in the development of EIS (Environmental Impact Statements), as well as in their evaluation. Emphasis in the courses 4.8 through 4.13 is on nuclear installations, radioactive materials transportation and safety, and environmental laws and regulations relating to these subjects.

Environmental Law - Government policy and regulatory guidance (4.8)

- The role of the Nuclear Regulatory Commission will be examined, as well as the process of and requirements related to licensing for construction, operations, use of nuclear materials, and transportation
- In this regard, students will learn about NEPA and its impact on licensing issues. Reactor safety and radioactivity will also be considered. With regard to the latter, some of the issues to be explored are: (1) low-level waste; (2) high-level waste; (3) transportation; and (4) decommissioning.
- Throughout the course, pertinent parts of 10 Code of Federal Regulations §§51-171 will be examined and analyzed.

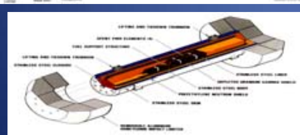
EPM 4200 – Environmental Protection Law

- Coverage includes: National Environmental Policy Act (NEPA), Clean Air Act (CAA), Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Emergency Planning and Community Right-to-Know Act (EPCRA), Occupational Safety and Health Act (OSHA), natural resource laws, ecological laws, and related toxic substance laws. It provides an overview of the legal system and the roles of Congress, the President, executive agencies, states, and courts in shaping environmental laws.

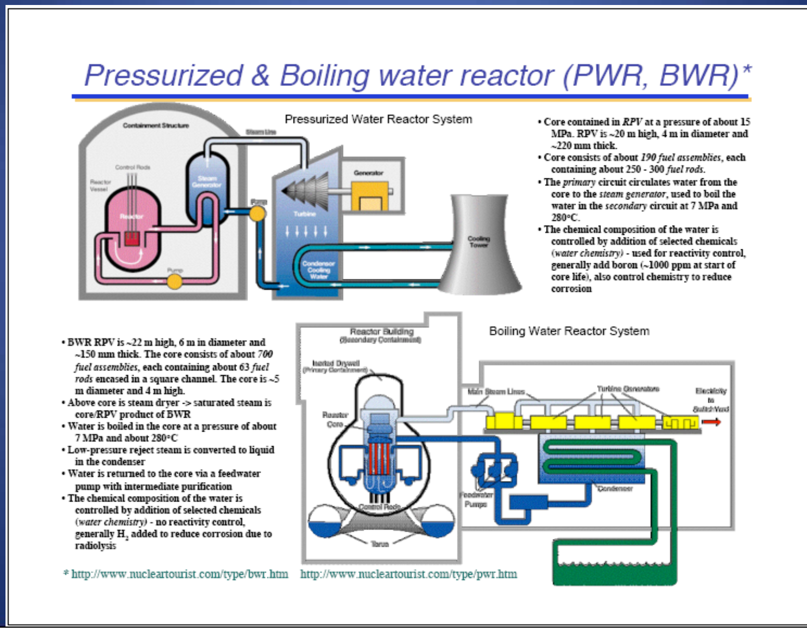
Highlights of the course EIS 4.8 covering Environmental Law, with emphasis on radioactive materials and nuclear reactors.

Transportation (4.9)

- The scope of this module is the impact of transportation on human and environmental risk assessment, including the primary methods and routes used to transport to a specific site, affected employees, commercial shipments, hazardous and radioactive material shipments, transportation packaging, transportation accidents, and onsite and offsite traffic volumes. The subjects in this module also include an overview of analytical methods used for the risk assessment (such as computer models), and important assessment assumptions. In addition to aid in the understanding and interpretation of the results, the principles of uncertainty analysis will be given, and how to interpret the uncertainties in the results that could affect the comparisons of alternative routes and modes.



Nuclear Power Plant Systems
Week 3 (4.13)



Nuclear Waste Management (4.10)

- Basic nuclear and radiation Physics (interaction of radiation with matter)
- Measuring Radiation (Radiation Detection Instruments and Laboratory experiments related to radiation properties, shielding and radionuclide characterization, in lab and field)
- Sources of Radioactive wastes (nuclear fuel cycle)
- Waste treatment technology
- Waste disposal technology
- Safety and environmental assessments of waste treatment and disposal

- EPM 4322 Radioactive Waste Management – Health risk assessments from radioactive contaminated soil.

Nuclear Physics Experiments in Second Life in Support of Nuclear Waste Management Course

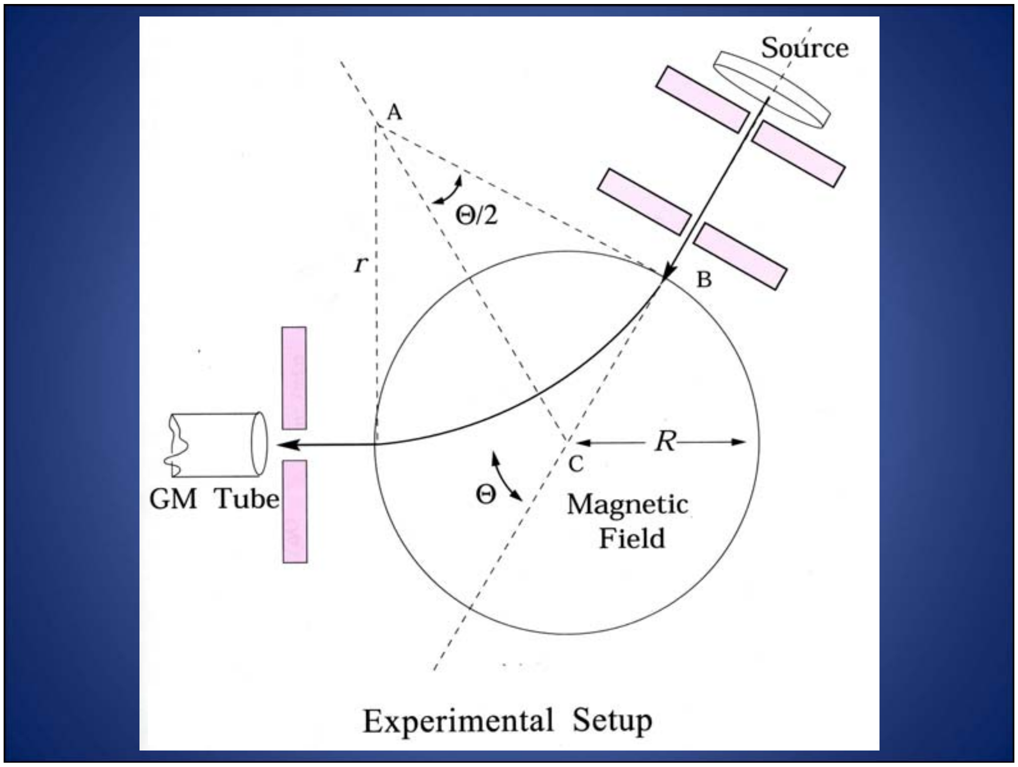
- Absorption of Ionizing Radiation
- Neutron Activation of Heavy Metals and Measurement of Radioactive Half-Lives
- Energy Spectrum of a Beta Radiation Source
- Gamma Ray Spectroscopy

We have constructed a virtual nuclear physics laboratory in “Second Life”, an online, 3-D, virtual world. The lab is accessible by any “avatar” (a virtual being representing the online student) who can navigate in the Second Life environment and (with the help of lab instructions supplied by the instructor over the web) carry out nuclear experiments just as do on-campus students. In this manner, students gain a “hands-on” experience even though they may be far away from the University. The student needs only a reasonably capable computer and access to the web. Details are provided in the August 2008 issue of Nuclear News, p.26, which can be found on-line. The University possesses three “islands” in Second Life; they are named Science School I, II, and III, respectively, and are a part of an “archipelago” of nearly 60 islands in Second Life referred to collectively as Scilands. They are committed to the teaching and learning of scientific subjects, and include NASA, NOAA, IBM, the Exploratorium, JPL, and a host of colleges and universities. There is no cost to the avatar for visiting any site in Second Life.

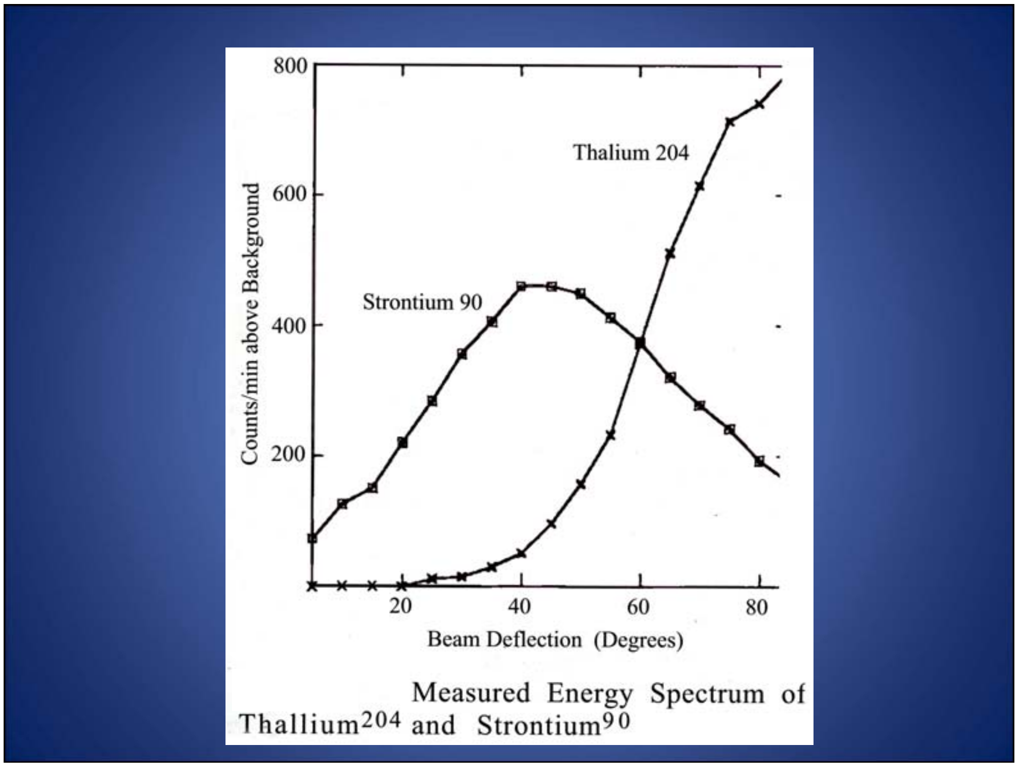
The laboratory we have constructed is a part of the island Science School II, on which we have created a virtual version of the 1600 MWe Areva nuclear power reactor; a video taken inside the reactor facility accompanies this presentation, and may be found on YouTube: http://www.YouTube.com/watch?v=ZXTvAecRfqM. The laboratory is seen in this video, with the apparatus required to perform the above-named experiments (Aimee Weber Studios participated in the construction). The National Physical Laboratory (UK) is a partner in this endeavor.

The virtual Nuclear Physics Laboratory is located in the Office building on the Areva plant site, Science School II. Here we see a photograph of our virtual neutron howitzer (the familiar Nuclear-Chicago product), taken in the Second Life lab. The student avatar uses the howitzer to activate metal foils which are used along with a virtual Geiger-Mueller system to measure half-lives.

(The avatars are expected to wear virtual film badges as they work around the howitzer, as in actual life.)



This diagram is familiar to those who have used the student beta spectrometer (Daedalon Corp). Our lab includes a virtual reproduction of the associated apparatus.



The data collected by the student avatar resembles this energy spectrum (provided by Daedalon). The data sets vary in accordance with the Poisson distribution.

Students in the course EIS 4.13, Nuclear Plant Systems, may also visit a virtual version of a research reactor (General Atomics TRIGA reactor), still under construction.

The nuclear fuel cycle (as outlined on the above chart) includes the in situ mining of uranium. The in situ method is illustrated in the model above and is a part of the curriculum that includes Second Life.