Nuclear Hydrogen Initiative

Office of Nuclear Energy, Science and Technology
U. S. Department of Energy

October 2004

Goal of the Nuclear Hydrogen Initiative

The goal of the Nuclear Hydrogen Initiative is to demonstrate the economic, commercial-scale production of hydrogen using nuclear energy. If successful, this research could lead to a large-scale, emission-free, domestic hydrogen production capability to fuel a future hydrogen economy.

Why Use Nuclear Energy to Produce Hydrogen?

Hydrogen offers significant promise as a future energy technology, particularly for the transportation sector. The use of hydrogen in transportation will reduce U.S. dependence on foreign sources of petroleum, enhancing our national security. Significant progress in hydrogen combustion engines and fuels cells is making transportation by hydrogen a reality.

The primary challenge to the increased use of hydrogen as part of the Nation's overall energy infrastructure is the cost associated with its production, storage and delivery. Hydrogen is the most common element in the universe and can be produced from readily available sources such as methane and water. However, existing hydrogen production methods are either inefficient or produce greenhouse gases. Nuclear energy has the potential to efficiently produce large quantities of hydrogen without producing greenhouse gases and hence, to play a significant role in hydrogen production.

Developing an Integrated Hydrogen Program

The President's Hydrogen Fuel Initiative is a new research and development effort to reverse America's growing dependence on foreign oil and expand the availability of clean, abundant energy. Hydrogen is produced today on an industrial scale in the petrochemical industry by a process of steam reforming, using natural gas as both source material and heat source.

Nuclear heat, supplied to a hydrogen-producing thermochemical or high-temperature electrolysis plant through an intermediate heat exchanger, promises high efficiency and avoids the use of carbon fuels. Using very-high-temperature advanced reactors, such as Generation IV gas-cooled or molten salt-cooled reactors, nuclear energy can produce hydrogen in very large quantities consistently over long periods of time without emitting greenhouse gases or other harmful air emissions.

Significant research and development (R&D) will be required in order to complete a commercial-scale demonstration. The hydrogen production system and heat transfer components, such as intermediate heat exchangers, will require the evaluation and development of high-temperature, corrosion-resistant materials.

The Office of Nuclear Energy, Science and Technology (NE) has developed a Nuclear Hydrogen R&D plan, which defines the objectives and goals of the Nuclear Hydrogen Initiative and identifies the R&D required to deploy the most promising technologies.

As part of the President's Hydrogen Fuel Initiative, the Nuclear Hydrogen Initiative is being implemented in close cooperation with programs in other DOE offices that are conducting hydrogen R&D -- the Offices of Energy Efficiency and Renewable Energy, Fossil Energy, and Science. This cooperation eliminates redundancy while ensuring that R&D is complimentary. NE has also established substantial cooperation in this area with its international research partners.

Program Highlights

The Nuclear Hydrogen Initiative addresses the need for greater utilization of our energy resources by developing energy conversion systems to economically produce hydrogen for use in our national transportation system.

Program milestones include:

- FY 2007: Begin operation of integrated laboratory-scale thermochemical and high-temperature electrolysis hydrogen production systems.
- FY 2009: Select technologies to be demonstrated in the pilot-scale hydrogen production experiment.
- FY 2011: Begin operation of a pilot-scale hydrogen production system.
- FY 2013: Complete the final design of a commercial-scale nuclear hydrogen production system.

- FY 2017: Complete construction and checkout of the nuclear hydrogen demonstration facility and initiate demonstration of commercial-scale hydrogen production.

FY 2003 Accomplishments:

- A Nuclear Hydrogen R&D Plan was developed that defined and prioritized the necessary R&D to develop, design and construct hydrogen production facilities.

FY 2004 Accomplishments:

- Completed final designs for the baseline thermochemical and high-temperature electrolysis laboratory-scale systems.
- Prepared report identifying materials requirements for baseline hydrogen production processes.
- Prepared report identifying potential applications for membranes in nuclear-compatible hydrogen production processes.
- Identified infrastructure requirements for the pilot plant demonstration of hydrogen production processes.

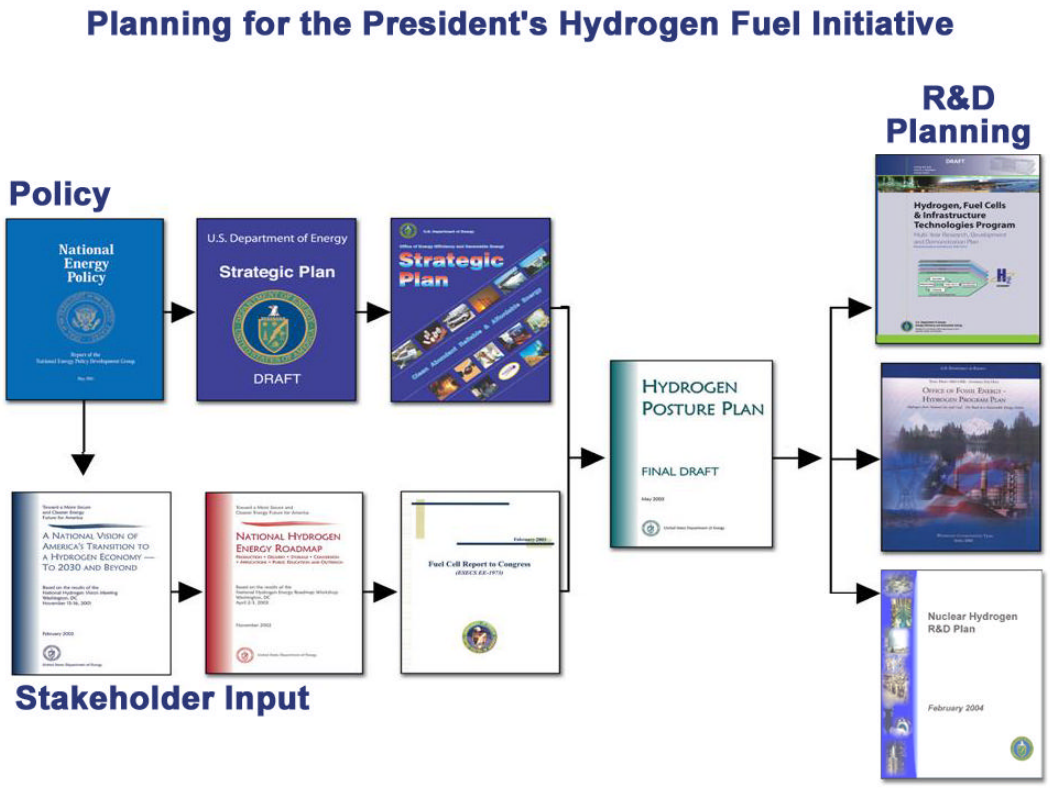
FY 2005 Planned Accomplishments:

- Complete conceptual design and begin preliminary design for the baseline thermochemical and high-temperature electrolysis pilot plants.

Program Budget
Nuclear Hydrogen Initiative
($ in Millions)

FY 2003 Adj. Approp.	FY 2004 Adj. Approp.	FY 2005 Request
$2.0*	$6.2	$9.0

**$2M included in Nuclear Energy Technologies budget for R&D on nuclear hydrogen production technologies.*



Visit our web site: *nuclear.gov*

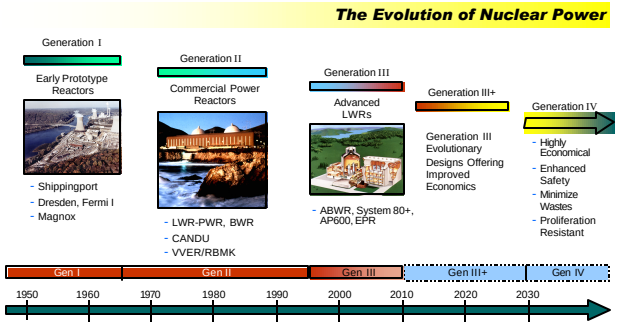
Generation IV Nuclear Energy Systems Initiative

Office of Nuclear Energy, Science and Technology
U. S. Department of Energy

October 2004

What is Generation IV?

Today there are 441 nuclear power reactors in operation in 31 countries around the world. Generating electricity for nearly 1 billion people, they account for approximately 17 percent of worldwide electricity generation and provide half or more of the electricity in a number of industrialized countries. Another 32 are presently under construction overseas. Nuclear power has an excellent operating record and generates electricity in a reliable, environmentally safe, and affordable manner without emitting noxious gases into the atmosphere.



Concerns over energy resource availability, climate change, air quality, and energy security suggest an important role for nuclear power in future energy supplies. While the current Generation II and III nuclear power plant designs provide an economically and publicly acceptable electricity supply in many markets, further advances in nuclear energy system design can broaden the opportunities for the use of nuclear energy. To explore these opportunities, the U.S. Department of Energy's Office of Nuclear Energy, Science and Technology has engaged governments, industry, and the research community worldwide in a wide-ranging discussion on the development of next-generation nuclear energy systems known as **"**Generation IV**"**.

Generation IV International Forum (GIF)

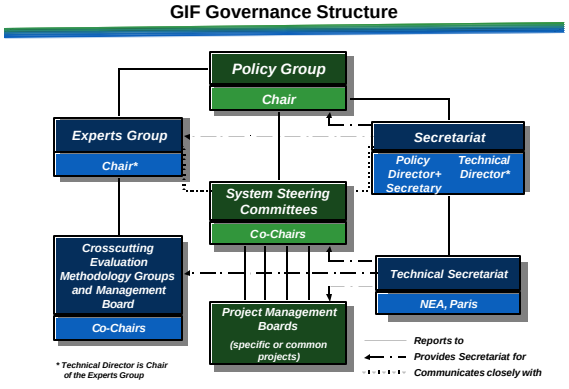
The objective of the U.S. Generation IV Nuclear Energy Systems Initiative is to develop and demonstrate advanced nuclear energy systems that meet future needs for safe, sustainable, environmentally responsible, economical, proliferation-resistant and physically secure energy. Under U.S. DOE leadership, this initiative has led a group of ten countries (Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom, and the United States) and Euratom to jointly plan the fulfillment of this objective. In 2002, the Generation IV International Forum (GIF) was chartered, establishing a Policy Group as the highest policy-making organ, an Experts Group as the technical advisory organ, and a Secretariat to administer and coordinate GIF activities. In 2003, the GIF, together with the Department's Nuclear Energy

Technology Goals

Generation IV nuclear energy systems will:

- Provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.
- Minimize and manage their nuclear waste and notably reduce the long term stewardship burden in the future, thereby improving protection for the public health and the environment.
- Increase the assurance that they are a very unattractive and least desirable route for diversion or theft of weapons-usable materials.
- Excel in safety and reliability.
- Have a very low likelihood and degree of reactor core damage.
- Eliminate the need for offsite emergency response.
- Have a clear life-cycle cost advantage over other energy sources.
- Have a level of financial risk comparable to other energy projects.

Research Advisory Committee, issued *A Technology Roadmap for Generation IV Nuclear Energy Systems*. Based on the *Roadmap*, GIF countries are jointly preparing collaborative R&D programs to develop and demonstrate candidate concepts.

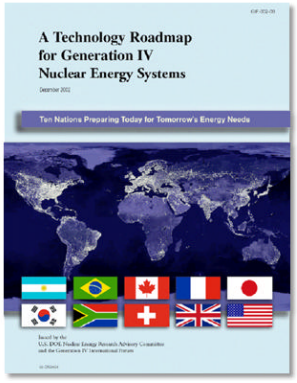


Generation IV Technology Roadmap

A Technology Roadmap for Generation IV Nuclear Energy Systems documents a comprehensive evaluation of nuclear energy concepts and selects the most promising ones as candidates for next-generation nuclear energy system concepts. For these concepts, detailed R&D plans were developed for establishing technical and commercial viability, demonstration and, potentially, commercialization. More than 100 experts from twelve countries and international organizations collaborated to complete the *Roadmap* over a period of two years. The *Roadmap* was submitted to Congress, followed by the *U.S. Generation IV Implementation Strategy*, which provides the strategy for implementing the Generation IV program in the United States.

International Collaboration on Generation IV Systems

The Department seeks to leverage its research investments in Generation IV concepts with research funding from



http://gen-iv.ne.doe.gov

interested members of the GIF. In FY 2004, the GIF countries, including the United States, began formulating joint R&D plans based on the *Roadmap*. The GIF countries began the formulation of multilateral agreements to enable the planned R&D collaboration and established a governance structure involving System Steering Committees and Project Management Boards. The United States is currently working closely with France, Japan, Korea, South Africa, and the United Kingdom through the GIF to establish a multinational research program to develop the technologies needed to support the design and construction of next-generation, very-high-temperature, gas-cooled reactors. In the meantime, R&D was initiated on several Generation IV reactor concepts under existing bilateral I-NERI agreements. These concepts include the Gas-Cooled and Lead-Cooled Fast Reactor Systems, the Supercritical-Water-Cooled Reactor, and the Very-High-Temperature Reactor (VHTR).

U.S. Generation IV Priorities

While the Department is supporting research on several reactor concepts, priority is being given to a system that matches VHTR technology with advanced hydrogen and electricity generation capabilities. This technology is known as the Next Generation Nuclear Plant (NGNP). The special emphasis on the NGNP reflects its potential for economically and safely producing electricity and hydrogen without emitting greenhouse gasses. Within the Department's FY 2005 budget request of $30.5 million for the Generation IV program, $19.3 million is budgeted for the NGNP effort. FY 2005 NGNP activities will be focused primarily on research and development activities associated with fuels and structural materials for high-temperature, high-radiation service conditions and continuing concept design activities initiated in FY 2004.

The Department is exploring the possibility of moving forward with a new reactor development project to take the Next Generation Nuclear Plant and associated hydrogen production technologies from concept to technology demonstration. A range of options with regard to such a technology is being explored, which options will be narrowed as the research effort proceeds.

Research and development for the other Generation IV systems will focus on establishing technical and economic viability, and the resulting core and fuel designs and materials requirements.

FY 2003 Accomplishments:

- Submitted *A Technology Roadmap for Generation IV Nuclear Energy Systems* to Congress.
- Established NGNP functions and requirements.
- Initiated R&D on six Generation IV concepts.
- Developed the NGNP reference point design.
- Submitted *U.S. Generation IV Implementation Strategy* to Congress.

FY 2004 Accomplishments:

- Completed the independent technical review of NGNP technologies.
- Defined NGNP procurement strategy and issued a draft for public comments.
- Developed NGNP fuel particles and compacts including quality control approaches.
- Recovered approval for the NGNP Mission Need Statement.
- Completed plans for high-temperature materials irradiation testing.

FY 2005 Planned Accomplishments:

- Initiate university R&D activities directed toward Generation IV reactor development.
- Award Cooperative Agreement with NGNP Project Integrator.
- Issue pre-conceptual design solicitation.
- Initiate radiation testing of NGNP fuel.
- Initiate NGNP materials testing.

Program Budget
Generation IV
($ in Millions)

FY 2003 Adj. Approp.	FY 2004 Adj. Approp.	FY 2005 Request
$10.6[1]	$22.9[1]	$27.5[1]

[1]*Does not include International Nuclear Energy Research Initiative funding*

Nuclear Power 2010

Office of Nuclear Energy, Science and Technology
U. S. Department of Energy

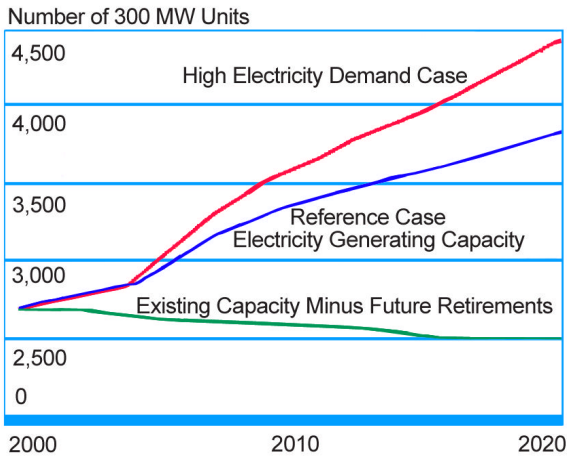
October 2004

Nuclear Power 2010 — Overview

New baseload nuclear generating capacity is required to support the *National Energy Policy (NEP)* objectives of enhancing U.S. energy supply diversity and energy security. The Nuclear Power 2010 program, unveiled by the Secretary on February 14, 2002, is a joint government/industry cost-shared effort to identify sites for new nuclear power plants, develop and bring to market advanced nuclear plant technologies, evaluate the business case for building new nuclear power plants, and demonstrate untested regulatory processes leading to an industry decision in the next few years to seek Nuclear Regulatory Commission (NRC) approval to build and operate at least one new advanced nuclear power plant in the United States. The Department is actively engaged with the industry to address the issues affecting future expansion of nuclear generation. The *Strategic Plan for Light Water Reactor Research and Development* was jointly issued by the Department and the electric utility industry in February 2004 that describes the goals and objectives of this cooperative government and industry approach.

Background

Electricity demand in the United States is expected to grow sharply in the 21st century requiring new generation capacity. Forecasts indicate that the country will need about 335,000 megawatts of new generating capacity by 2025. If electricity demand continues to grow at the rates experienced in recent years, even more generating capacity will be needed. This growth would require building between 1,000 to 1,200 new power plants over the next two decades. This averages to building and commissioning 50 to 60 new power plants per year.



Source: NEP

Nuclear power plants generate 20 percent of the electricity produced in this country; however, all recent electric-generating capacity additions and projected future additions are primarily fueled by natural gas. To help meet our growing demand for new baseload electricity generation, the *NEP* has recommended expanding the role of nuclear energy as a major component of our Nation's energy picture. Despite the excellent performance of current nuclear plants and decisions by power plant owners to seek license renewal and power uprates, no new plant has been ordered in this country for more than 25 years. The Department believes that an over reliance on a single fuel source, like natural gas, is a potential vulnerability to the long-term security of our Nation's energy supply and new nuclear plants must be built in the next decade to address increasing concerns over air quality and to ease the pressures on natural gas supply.

The recent publication by the University of Chicago titled, *The Economic Future Of Nuclear Power*, shows great promise for the future of nuclear power. The principal findings of the Chicago study demonstrate that future nuclear power plants in the United States can be competitive with coal and gas fired technologies. Whereas the levelized cost of electricity for coal is $33 to $41 per MWh and $35 to $45 per MWh for gas-fired production, the cost from new nuclear plants would be $31 to $46 per MWh once early plant costs are absorbed.

Program Activities for the Deployment of Nuclear Power

The Nuclear Power 2010 program is focused on reducing the technical, regulatory and institutional barriers to deployment of new nuclear power plants. Nuclear Power 2010 activities are based on expert recommendations documented in *A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010*, and the *Business Case for New Nuclear Power Plants* in the United States.

The technology focus of the Nuclear Power 2010 program is on Generation III+ advanced light water reactor designs which offer advancements in safety and economics over current nuclear plant designs and the nuclear plant designs certified by NRC in the 1990's. To enable the deployment of new Generation III+ nuclear power plants in the United States in the relatively near-term, it is essential to demonstrate the untested Federal regulatory and licensing processes for the siting, construction, and operation of new nuclear plants. The Department, utilizing competitive procurement processes, conducts program activities in cost-share cooperation with industry to address such issues. The Department has initiated cooperative projects with industry to obtain NRC approval of three sites for construction of new nuclear power plants under the Early Site Permit (ESP) process, and to develop application preparation guidance for the combined Construction and Operating License (COL) and to resolve generic COL regulatory issues. The COL process is a "one-step" licensing process by which nuclear plant public health and safety concerns are resolved prior to commencement of construction, and NRC approves and issues a license to build and operate a new nuclear power plant.

In November 2003, the Department issued a solicitation inviting proposals from teams led by power generation companies to initiate New Nuclear Plant Licensing Demonstration Projects to demonstrate the COL process. The Department has received proposals from three consortia representing eight domestic and one international power generation companies, and four advanced reactor technology suppliers. The nine power generation companies responding to the solicitation operate 63 of the 103 U.S. commercial nuclear power plants. Although no company has yet announced a decision to build a plant, these companies are conducting detailed technical and economic evaluations necessary to support a corporate decision on constructing a new nuclear power plant.

FY 2003-2004 Accomplishments

- Three ESP applications were submitted by power generation companies to NRC for review and approval in September and October 2003. The ESP project focus in FY 2004 was on resolution of site-specific issues arising from NRC review of the three ESP applications. Successful resolution of these issues will lead to issuance of ESPs in FY 2006 making three NRC approved sites available in Virginia, Illinois and Mississippi for construction of new nuclear power plants.
- Completed a nuclear construction technology assessment that independently evaluated the schedule and construction methods of advanced nuclear plant designs. This assessment provides important technical and economic data to the power generation companies to support reactor technology selection for the next nuclear power plant to be built in the United States.
- Awarded an interagency agreement to TVA for the Advanced Boiling Water Reactor (ABWR) Cost/ Schedule/COL project at the Bellefonte Site.

FY 2005 Planned Activities

- Continue the ESP demonstration projects by supporting resolution of site-specific issues arising from the NRC review of the ESP applications. Draft and Final NRC Safety Evaluation Reports and Environmental Impact Statements are projected to be completed in FY 2005.
- Complete the TVA site suitability study potentially making another site available in Alabama for building new nuclear plants. Additionally, the cost and schedule evaluation by the TVA -led team for building a two-unit ABWR at the Bellefonte Site will be completed. Results of these studies will be used by the power company to make decisions on proceeding with a COL application to construct a new nuclear power plant.
- Complete the Texas Gulf Coast Nuclear Power Plant Feasibility Study initiated in FY 2004. This study will prepare the business and technical case for constructing a privately financed nuclear power plant to serve the needs of the general public and industry end-users in the Texas Gulf Coast region.
- Continue the industry cost-shared project initiated in FY 2003 to develop generic guidance for the COL application preparation and to resolve generic COL regulatory issues. A draft guidance document will be completed and provided to the NRC for review.
- Initiate the New Nuclear Plant Licensing Demonstration Projects with Dominion and NuStart Energy. The Dominion project could lead to a license to build and operate an Atomic Energy of Canada, Ltd (AECL) Advanced CANDU Reactor (ACR-700). The NuStart Energy consortium will evaluate the Westinghouse Advanced Passive Pressurized Water Reactor (AP-1000) and the General Electric Economic Simplified Boiling Water Reactor (ESBWR). The consortium plans to select a final reactor technology and a site by 2007. If a nuclear power plant order results from this work, a new nuclear power plant could be in operation as early as 2014.

Program Budget
Nuclear Power 2010[1]
($ in Millions)

FY 2003 Appropriation	FY 2004 Appropriation	FY 2005 Request
$31.6	$19.4	$10.2

[1]*Funding provided in the Nuclear Energy Technologies Appropriation*

Visit our web site: nuclear.gov