Advancing Technology for Nuclear Energy

Prepared Testimony
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Hearing on A National Assessment of Energy Policies – Significant Achievements since the 1970s and an Examination of U.S. Energy Policies and Goals in the Coming Decades

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Mr. Chairman, Senator Alexander, and members of the Subcommittee, I am Eric Loewen, Chief Consulting Engineer of Advanced Plants at GE Hitachi Nuclear Energy. Thank you for the opportunity to testify before you today. As you look at energy policy over the past 40 years, I have been asked to help you look forward – to look at the next generation of nuclear technology – the technology that will help the U.S. achieve energy independence, create new jobs and move toward a low carbon future.

Headquartered in Wilmington, North Carolina, GE Hitachi Nuclear Energy (GEH) is a world-class enterprise with a highly skilled workforce and global infrastructure dedicated to serving the nuclear industry. We are proud of our record of accomplishments that spans more than five decades; our nuclear alliance is recognized as the world's foremost developer of boiling water reactors, robust fuel cycle products and highly valued nuclear plant services. Combining deep-rooted experience with fresh insight, we provide light water plant operators with responsive reactor services to support safe, efficient and reliable operation.

The nation has already begun to witness the success of the recent federal polices designed to bring about a renaissance of the nuclear industry in the United States. Today, with the incentives of the Energy Policy Act of 2005 in effect, the design and even some basic construction have begun on the next generation of light water reactors in the U.S. Public support for clean, reliable nuclear energy is at record high levels. We have an opportunity to increase the percentage of electricity produced by nuclear plants above the current twenty percent.

My testimony today will give you an overview of how nuclear technology has developed over the past 40 years, the current state of technology in the U.S. and the rest of the world, and perspectives on where the technology might go in the 40 years to come.

Overview of the Development of Nuclear Technology

U.S. leadership in nuclear energy started in 1951 at the National Reactor Test Station near Arco, Idaho. This sodium-cooled reactor produced enough electricity to light four light bulbs. Interestingly, a study done for President Harry Truman in 1952 made a "relatively pessimistic" assessment of nuclear power and actually called for research instead in solar energy. President Eisenhower's call for "Atoms for Peace" one year later, however, led to the initial indication that the federal government would be a strong partner in the development of civilian nuclear energy. Atomic Energy Act of 1954 removed barriers to nuclear energy development by the private sector. The stated purpose of the 1954 Act was to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes, although nuclear materials remained under government control. The new law for the first time permitted private industry to build and operate nuclear plants on their own initiative, and not just as government contractors. GE, the first company to take advantage of this opportunity, built a reactor in Vallecitos, CA – the first commercially funded reactor in the U.S. to provide power to the grid.

In 1955, an early concept of a boiling water reactor developed by Argonne National Laboratory powered a city – Arco, ID – the first such use of nuclear power in the world. This U.S. technical leadership lead to the first generation of commercial nuclear power plants (GEN I), some of which are still in operation. The world's first commercial nuclear power plant opened in England in 1956; the first plant in the U.S. came a year later in Pennsylvania. Availability of adequate funding to provide compensation in the very unlikely event of a nuclear or radiological incident was addressed through the passage of the Price-Anderson Act in 1957.

GE commercialized Argonne's concept of the boiling water reactor by first building a small commercial reactor at our GE facility in Vallecitos, CA, followed by the larger commercial boiling water reactors at the Dresden unit in Illinois, the KRB unit in Europe and the Tsuruga plant in Japan. GE management proceeded in the confident expectation that it could develop the Boiling Water Reactor (BWR) technology and have a commercially competitive product by the 1960s.

The construction of Generation II reactors followed in the early 1960s and represent the 104 nuclear power plants operating in the U.S. today. Of the GEN II reactors in the U.S. today, 34% are BWR designs and 66% are pressurized water reactors (PWR). The power output of U.S. GEN II reactors ranges from 482 to 1,300 MWe. In the early 1960s, these were built as "turnkey projects" to overcome the reluctance of utilities to assume the uncertain risk of building nuclear plants. By the mid 1960s, the industry had evolved to the point where architect engineers and constructors contracted directly with owners and turnkey plants were no longer offered.

During the 1960's, U.S. light water reactor (both BWR and PWR) technology also became established in the world nuclear market, with large orders in Western Europe and Japan. The light-water reactor became the world's technology standard, outstripping the British gas-cooled reactor and Canadian heavy-water reactor technologies by wide margins.

From the construction and operating experience of the GEN II reactors, design improvements were made by industry, and the U.S. government improved the Nuclear Regulatory Commission's licensing processes. The Energy Policy Act of 1992 authorized the one step licensing process known better in the industry as "Part 52."

GE submitted its GEN III design, the Advanced Boiling Water Reactor (ABWR) to the NRC in 1987 and received design certification in 1997. To date, no certified GEN III reactor has yet been built in the U.S. There are currently four ABWRs operating in Japan and work will soon be complete on construction of two additional ABWRs in Japan and two in Taiwan.

The year 1992 was the high water mark for U.S. nuclear power plant installed capacity. The technical successes were enormous. We now have in operation nuclear power plants with a generating capacity greater than the total U.S. electrical capacity installed in 1940, and the plants have a superb safety record. The technical issues that the industry has been able to resolve are far greater than those that remain to be solved. Yet no new plants were started. Why? One significant reason is the substantial financial risks due to the large capital investment required and uncertainties about cost and schedule on new reactor designs.

The Energy Policy Act of 2005 responded to these financial risks by authorizing loan guarantees for carbon free technologies such as nuclear power plants, tax incentives for first movers, and risk insurance during the construction phase. This promise of these policies became reality when President Obama announced in February that the Department of Energy has offered conditional commitments for a total of $8.33 billion in loan guarantees for the construction and operation of two new nuclear reactors at a plant in Burke, Georgia. This project is expected to be the first new nuclear power plant to break ground in the U.S. in nearly three decades.

It is important to note that, despite the fact that the U.S. has not built any new plants in recent years, U.S.-developed light-water reactor technology has become the world standard. Japan, Germany, France, Italy, Spain, Sweden, and Switzerland have all adopted our light-water reactor design for their nuclear programs.

GEH submitted the next advancement in technology its GEN III+ design, the economic simplified boiling water reactor (ESBWR), to the NRC for design certification under Part 52 in 2005, and is expecting final certification in September 2011. This effort was supported by the DOE Nuclear Energy Office through the Nuclear Power 2010 program.

Looking forward to the next generation of nuclear plant design, in 2000, the U.S. organized the world technical community to look at GEN IV reactors in order to improve safety, and address waste issues, and reduce cost and proliferation concerns. This international effort screened over 100 different reactor concepts to identify six plausible designs for continued study. Three of the six GEN IV reactor concepts could be used for nuclear fuel recycling.

Recycling: What is it?

The next area for U.S. innovative leadership in nuclear energy is the commercialization of full-recycling technology.

There are three basic options for used fuel management: the 3 Rs – Repository, Reprocessing or Recycling. Let me provide an overview of each:

> **Repository** - Underground storage for used nuclear fuel from the GEN I and GEN II fleet, where it needs to be stored for at least 1,000,000 years.
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> **Reprocessing** – Takes GEN I and GEN II used nuclear fuel for the separation of plutonium using an aqueous-acid system and organic solvents. The recovered plutonium is used in GEN II reactors. The wastes, fission products and high-heat-load transuranics (also known as actinides) are incorporated into glass requiring safe storage for at least 10,000 years. Reprocessing is done currently in the U.K. and France, and soon will be in Japan.
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> **Recycling** – Takes GEN I – GEN III used nuclear fuel and separates the usable uranium and transuranics using a molten salt bath and electricity. The recovered uranium and transuranics are then used as fuel for GEN IV reactors, thereby generating electricity from nuclear waste. The remaining fission products wastes are placed into a rock (ceramic) and chunk of metal (a metallic alloy of Zr or Fe) requiring safe storage for just a few hundred years. Because no pure plutonium is extracted, the proliferation risks are eliminated. The U.S. uses a form of this approach currently in treating spent fuel at the Idaho National Laboratory. We call this process "full-recycling."

GE and now GEH have supported investigation of the full-recycling approach initially called the Integral Fast Reactor concept, which was funded under DOE's Advanced Liquid Metal Reactor program for ten years and by the Global Nuclear Energy Partnership for the past three years. What does it take to recycle? A Generation IV reactor.

Generation IV Reactor: What is it?

Perhaps the greatest promise of the next generation reactor is the ability to recycle used fuel from today's light water reactors.

The GEN IV reactor that I am most familiar with is the PRISM, a Sodium Fast Reactor or "SFR" under development since 1981. The PRISM is America's sodium-cooled reactor, developed jointly by nine U.S. companies under the leadership of GE. The reactor recycles used nuclear fuel, generates electricity and incorporates the lessons learned from the development of earlier reactors.

Following is a brief overview of how the technology works. First, the recycled elements (uranium and transuranics) from today's light water reactors are fabricated into a metallic reactor fuel, which is submerged in liquid sodium. During operation the recycled material fissions (i.e. splits in half) releases energy, and is removed by the flow of sodium and ultimately turned into electricity. The unique element in this recycling reactor is the sodium coolant, which allows nuclear interactions at higher energies so that full-recycling can occur. This cannot occur in a water-cooled GEN II or GEN III reactor where nuclear reactions occur at lower energies.

The sodium-cooled GEN IV reactor is designed with passive safety features. These include passive reactor shutdown, passive shutdown heat removal (requires no human or automatic systems), and passive reactor cavity cooling (improves safety and reduces cost). The sodium-cooled GEN IV reactor supports a sustainable and flexible fuel cycle to consume transuranic elements within the fuel as it generates electricity.

Key milestones and attributes associated with this technology include:

- EBR-II is a sodium test reactor with 30 years of successful operation at the Argonne National Laboratory, which provides a significant base of technical data;
- The Energy Policy Act of 1992 authorized the building of a sodium-cooled recycling reactor;
- The 2002 DOE GEN IV Roadmap rated the sodium-cooled reactor ahead of the other five GEN IV concepts;
- Most recently the Global Nuclear Energy Partnership, with four industrial teams including GEH, all agreed that a sodium-cooled reactor was needed to fully recycle all the transuranics in used nuclear fuel;
- A GEN IV sodium-cooled reactor vessel can be fabricated in the U.S. today; and
- This technology uses small modular reactors suitable for smaller electrical grids.

Earlier this year, President Obama directed the Secretary of Energy to establish the Blue Ribbon Commission on America's Nuclear Future to make recommendations for developing a safe, long-term solution to managing the Nation's used nuclear fuel and nuclear waste. The highly respected members of the Commission have already started their work and will provide a final report to the President within the next two years. GEH has requested an opportunity to engage with the Commission to discuss the benefits of full-recycling and the establishment of recycling centers. Some of the benefits of recycling that we will outline include:

- Reducing the required storage time of used nuclear fuel by over 99.99%, from greater than 1 million years to several hundred years;
- Using the current U.S. inventory of 60,000 metric tons of used nuclear fuel to meet the electricity generation demands of the United States for over 100 years if recycled within a high energy GEN IV reactor (using 2008 U.S. electricity generation data); and
- Using the U.S. inventory of depleted uranium that is discarded during the enrichment process that has the potential to meet the electricity generation demands of the United States for over 900 years if recycled within a sodium-cooled GEN IV reactor (using 2008 U.S. electricity generation data.

While GEH believes the PRISM is an excellent technology, we acknowledge that it is not the only technology and will encourage the Commission to embrace the concept of recycling rather than endorse a particular technology. GEH supports establishing advanced recycling centers in the regions where the reactors stand and where consumers have paid into the Nuclear Waste Fund.

Toward a New GEN IV Policy

GE has worked with the U.S. government to develop civilian nuclear power technology since the beginning of the U.S. nuclear program. There was extraordinary creativity in fashioning novel arrangements to meet the demands of nuclear development; Congress established the Joint Committee on Atomic Energy, and industry established standards and professional societies such as the American Nuclear Society to support those standards. These government/private sector approaches represented triumphs of pragmatism over ideology and of substance over form.

Over the past decade, Congress has been responsive and creative in supporting the national laboratories and universities as they investigate the sustainable nuclear fuel cycle. This focus on education and research has played a significant role in the large increase of graduates in nuclear related fields, and must continue so that the industry is prepared for the future.

Our current challenges (waste solutions and plutonium disposition) and opportunities for low carbon electricity call for policymakers to take a fresh look at how to fast track the building of sodium-cooled recycling reactors.

GEH believes that in order to sustain long-term development of full-recycling, the U.S. must learn from our foreign allies (U.K., France, and Japan) regarding best practices from the modified open fuel cycle approach (reprocessing). But we must also stand on our own in support of an even more innovative full-recycling technology.

It is critical to recognize that the U.S. is falling behind in developing innovative nuclear technologies. China and India are in the process of building sodium-cooled GEN IV reactors, which are expected to be the drivers in their development of sustainable nuclear fuel cycles. Without a similar long-term policy, the U.S. can expect to place third, at best in the near future.

Before I conclude my remarks, I want to shift gears a little and mention an additional innovative nuclear technology that GEH is pursuing in the U.S. – Global Laser Enrichment. This new method of enriching uranium for peaceful purposes is being developed in the U.S. under strict oversight by the NRC and the Department of Energy. If the testing of the GLE technology continues to return the positive results we have seen thus far, we will soon build the first commercial facility in Wilmington, NC, adding hundreds of high paying jobs and providing our U.S. customers with a competitively priced, domestic supply of enriched fuel for their power plants.

Summary of Recommendations

The advanced nuclear power technology developed at GEH is a vital part of GE's clean energy portfolio. The world needs the innovative energy technology solutions America has to offer, and America needs them too.

Safe, reliable base-load electricity generated without producing greenhouse gas emissions is needed to meet the heavy demands of industrial and residential users. Congress and the public have endorsed the expansion of nuclear power in the United States, understanding the energy independence and job growth potential of this low-carbon power generation technology. The helpful provisions in the Energy Policy Act of 2005, including loan guarantees have helped set the stage for a nuclear power renaissance.

We must continue the great tradition of the government and private sectors working in partnership to enable nuclear energy to grow. Our recommendations for this Committee for investments in an abundant and responsible long-term energy supply, for weapons plutonium disposition and for addressing used nuclear fuel using full-recycling are to support:

- Competitively awarded industry-led licensing project(s) for sodium-cooled recycling reactor(s).
- Reenergize the domestic manufacturing and sodium research and development base by competitively awarding the manufacture and siting of two GEN IV sodium recycling reactor vessels to support the licensing project.
- Expand the weapons disposition program to include converting weapons material into fuel for disposition in a sodium-cooled recycling reactor.
- Funding the President's budget request for the nuclear energy programs including an additional $36 billion in loan guarantees, Reactor Concepts R&D, Fuel Cycle R&D and the Nuclear Energy Enabling Technology program.

The nation faces a choice today: should we continue down the same path that we have been on for the last thirty years with a repository-only solution, should we take the path of our allies and adopt reprocessing, or should we lead nuclear innovation with full-recycling? By building a sodium-cooled recycling project, we can lead the transformation to full-recycling, use a previously untapped energy source, and provide another path for weapons plutonium disposition.

Thank you. This concludes my formal statement. I would be pleased to answer any questions you may have at this time.