AREVA

Statement of

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Committee on Science and Technology

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Mr. Chairman and members of the Committee:

My name is Alan Hanson, and I am Executive Vice President, Technology and Used Fuel Management, of AREVA NC Inc.

I appreciate this opportunity to testify before you today on advanced technology for nuclear fuel recycling.

AREVA Inc. is an American corporation headquartered in Maryland with more than 6,000 employees in over 40 locations across 20 U.S. states. Last year, our U.S. operations generated revenues of $2.5 billion—12 percent of which was derived from U.S. exports. We are part of a global family of AREVA companies with 75,000 employees worldwide offering proven energy solutions for emissions-free power generation and electricity transmission and distribution. We are proud to be the leading supplier of products and services to the worldwide nuclear industry, and we are the only company in the world to operate in all aspects of the nuclear fuel cycle.

AREVA designs, engineers and builds the newest generation of commercial nuclear plants and provides reactor services, replacement components and fuel to the world's nuclear utilities. We offer our expertise to help meet America's environmental management needs and have been a longtime partner with the U.S. Department of Energy on numerous important projects. Relevant to today's testimony is the fact that AREVA operates the largest and most successful used fuel treatment and recycling plants in the world.

As I read the Committee invitation, you have requested information in five subject areas:

(1) Explore the risks and benefits associated with the recycling of used nuclear fuel;
(2) Discuss the research, development and demonstration needs at the Federal level as the U.S. reviews its nuclear waste management strategy;
(3) Describe AREVA's strategy for management of used nuclear fuel, including the technologies deployed for establishing a closed fuel cycle;

(4) Discuss the environmental impacts of recycling and the safety measures AREVA has adopted to address concerns about nuclear proliferation; and
(5) Recommend any research, development and demonstration needs that could make nuclear waste recycling safer, more efficient and/or cost effective.

What I hope to accomplish today is to address each of these requests in the testimony that follows.

Benefits and Criticisms Associated With Recycling

The main benefits associated with the recycling of used nuclear fuel can be summarized as follows:

- Recycling makes waste management easier.
- Recycling provides strategic flexibility and confidence for the long term.
- Recycling saves natural resources.
- Recycling is a path to burning plutonium, thereby reducing proliferation concerns.

Recycling makes waste management easier. Recycling used nuclear fuel reduces the volume of high-level waste to be disposed of in a final repository.

Only 4 percent of used fuel content is high-level waste. When such waste is *vitrified*, or specially-packed into a highly compact glass-like waste form for final storage, and added to the volume of compacted structural waste and high-level process waste, the total volume necessary for final disposal is 75 percent less than the volume required if the used fuel is disposed directly in a repository.

The volume required in the repository is further reduced if the vitrified waste is allowed to "cool" in interim storage for some decades before actual emplacement in a repository. This is due to the thermal load issue. For example, if vitrified waste is stored for 70 years of cooling before emplacement, the volume reduction factor would double. And volume requirements could be even further reduced when future technologies such as transmutation are available for deployment.

High-level waste volume reduction is a crucial benefit of recycling as it allows maximum use of a geological repository, a rare and precious asset. When a high-level waste repository eventually opens in the U.S., one would want to make optimal use of every cubic unit of emplacement. Licensing of such a facility is long, and public acceptance is very sensitive. It is difficult to envisage today an attempt to license multiple geological repositories in the U.S. It is already difficult enough just to license the first one.

It is worth noticing that today the quantity of used fuel already discharged from U.S. reactors is very significant, approximately 60,000 metric tons. If Yucca Mountain were to open in the next decade, the amount of fuel available for emplacement would already completely fill the repository's legal capacity, leaving no place to dispose newly-generated waste. Furthermore, about 2,000 metric tons of used fuel is discharged every year by the U.S. commercial nuclear reactor fleet of 104 reactors. Even if no more reactors were to be built in the U.S., an additional 20,000 metric tons of used fuel would accumulate every decade the U.S. waits.

The main contributor to the long-term radioactive toxicity of used nuclear fuel is plutonium for the first several hundreds of thousands of years, then minor actinides and uranium become predominant. Consequently, extracting plutonium and uranium from the waste for final disposal significantly reduces the waste's toxicity, by a factor of about 90 percent.

Recycling provides a highly safe, resistant and well-characterized waste form. Vitrified waste is a very robust matrix against dissolution by water, as strong as volcanic rock. It has been proven scientifically that after 100,000 years only 1 percent of its mass would be lost by leaching in water, and it would require more than 10 million years to completely dissolve in water. It is important to recognize that after 10,000 years, the radioactivity of a vitrified waste package is reduced down to that of natural uranium ore due to the natural decay of the radioactive atoms contained therein. Such robust characteristics of the waste form facilitate the long-term safety demonstration of the repository and consequently simplify the licensing process.

Recycling provides strategic flexibility and confidence for the long term. Vitrified waste packages are no longer subject to International Atomic Energy Agency safeguards, as almost all of the fissile material, uranium and plutonium, has been removed to manufacture recycled fuel. Consequently waste from recycling can be safely and cost-effectively interim-stored in simple, compact and low-cost facilities.

Recycling provides a credible and reliable nuclear waste management option consisting of storing the vitrified waste for an extended period of time waiting for a geological repository to be ready and approved. Long-term interim storage of waste from recycling is easier and safer than interim storage of used fuel without recycling. Vitrified waste from 40 years of operation of the French nuclear reactor fleet, currently 54 power reactors, resides in a single building with a footprint that is less than two American football fields.

Recycling saves natural resources. Uranium recovered from recycling, also known as "RepU," represents about 95 percent of the mass of light water reactor used fuel with a residual U^{235} enrichment level of 0.8 percent to 0.9 percent, higher than natural uranium ore.

Re-enrichment and recycling of RepU is performed by several utilities throughout the world. With the current and forecasted costs of nuclear fuel sourced from natural uranium, RepU becomes a secondary source that is quite attractive. Today, customers are asking AREVA to provide them with 100 percent recycling of their RepU. AREVA is making investments to ensure 100 percent RepU re-enrichment and RepU fuel fabrication by 2015.

Recycling RepU allows savings of 15 percent of natural uranium resources. Recycling plutonium into *mixed oxide*, or MOX, fuel allows about 12 percent of natural uranium savings. Recycling both recovered uranium and plutonium leads to a total savings of at least 27 percent of natural uranium resources.

The amount of U.S. commercial used nuclear fuel accumulated by 2010, 60,000 metric tons, if recycled represents the energy equivalent of eight years of nuclear fuel supply for today's entire U.S. nuclear reactor fleet. Energy recovery potential is, therefore, significant and enhances energy security.

Recycling is a path to burning plutonium, thereby reducing proliferation concerns. Recycling plutonium in MOX fuel consumes roughly one-third of the plutonium through single recycling and significantly alters the isotopic composition of the remaining plutonium, thus severely degrading its potential weapons attractiveness.

Burning plutonium in MOX fuel is the path that has been selected by the National Nuclear Security Administration to dispose U.S. weapons-grade plutonium declared in excess. With the assistance of AREVA, a MOX fuel fabrication facility is currently being constructed at the DOE Savannah River Site in South Carolina, and it is on track to start production of the first MOX fuel by 2016.

In contrast to the benefits described above, the criticisms of spent fuel recycling focus mainly on the following points:

- Non-proliferation
- Cost
- Volume of waste generated

Non-proliferation. In recent years, a few countries have sought to acquire nuclear weapons for reasons of national security, national power or national prestige. Their basic motivations were political. It is very important to note such countries never intended to use nuclear technology to produce a single kilowatt-hour of electricity. Meanwhile, the vast majority of countries in the world continue to seek ways to produce electricity on an efficient, competitive, sustainable, peaceful and responsible basis. They have no interest in developing or accessing sensitive nuclear technologies when it does not make economic sense for them and as long as security of supply is guaranteed for them.

There are ways and means to control the spread of material and technologies, mainly through the limitation of the number of facilities in the world and providing strong guarantees of supply to dissuade most countries from developing their own uranium enrichment or reprocessing capabilities.

There is a fundamental question of policy which should be important to this Committee:

> Would a decision by the U.S. to recycle its used fuel and close the nuclear fuel cycle contribute to proliferation, or would it do the opposite and contribute to non-proliferation?

Let us examine the case for proliferation by diversion. Today we do not know if recycling in the U.S. would be carried out by a government entity or a commercial firm. If by a government entity, the diversion scenario is not relevant since the Federal government already has a stockpile of weapons-grade plutonium and, therefore, has no use for less-effective reactor-grade plutonium. Since the U.S. government has demonstrated an ability to prevent diversion of its weapons material, there is no reason to believe it could not prevent diversion of material recovered from used fuel by the same means. If recycling is done by a commercial entity, the government could impose its own safeguards in addition to IAEA safeguards to prevent diversion.

What about theft of weapons-usable material? The same logic applies as for diversion. The Federal government has been successful at protecting its own stockpile of weapons-grade material, so there is no reason to believe that it cannot adequately protect less attractive reactor-grade materials.

If diversion or theft of plutonium can be prevented by extensive national and international safeguards and physical protection, then there remains only one reason for the U.S. to forego recycling and that is to avoid setting an example that might be followed by the rest of the world. This is the ostensible reason why the U.S. turned its back on recycling three decades ago. But that U.S. policy did not prevent Britain, France, Japan or Russia from building domestic recycling facilities, nor will it prevent China from following suit.

Notice that the only countries to build such facilities are those with a sizeable amount of used fuel that makes it economically justifiable to do so. Other countries which chose to recycle elected to purchase the service rather than build their own facilities. This is similar to the model for enrichment espoused by U.S. policy, *i.e.* there is sufficient capacity and robust supply assurances that can make proliferation of expensive enrichment facilities unattractive. I would argue that the same logic can be applied to recycling and that a U.S. decision to offer such a service could prevent many countries from building indigenous facilities, thereby enhancing the non-proliferation regime.

Cost. In 2006, The Boston Consulting Group (BCG) performed a study with input from AREVA that showed that the economics of recycling as compared to direct disposal are comparable, within 10 percent difference. The reasons are the following:

- The cost of uranium has significantly increased in the past years, which increases the value of recycled fuel.
- The projected total life cycle cost of a geological repository is high, which provides high value for each cubic unit of emplacement saved due to recycling.
- A large recycling facility, about 2,500 metric tons per year capacity, provides significant cost savings through economies of scale.

Today, the conclusions of the BCG report are even truer as the long-term forecast for uranium cost is going up and the cost of the Yucca Mountain repository has also significantly increased.

Of course, any study depends upon the assumptions made, and other studies using different assumptions have produced results different from those of BCG. Of note, however, is a respectable study by the Congressional Budget Office (CBO) which concluded that costs for recycling would be somewhat higher then projected by BCG. However, the cost for management of the back-end of the fuel cycle is such a small part of the total cost of electricity produced that nuclear power would remain competitive even using the CBO estimates. The impact of recycling on the cost of electricity is between 0.1 and 0.2 cents per kilowatt-hour when the production cost of nuclear electricity is around 2 cents per kilowatt-hour.

Volume of waste generated. Recycling used fuel generates two types of waste streams classified according to their ultimate disposal pathway: surface disposal and underground, or geologic, disposal, the latter being orders of magnitude more complex, more expensive and more sensitive to implement as the focus of public acceptance issues is concerned. When comparing solid waste figures between the option to directly dispose used fuel or to recycle it, it is therefore fundamental to distinguish between those two types of waste.

As pointed out previously, the volume of material destined for the high-level waste repository is reduced by at least 75 percent through recycling. Some critics of recycling point out that there is a price to be paid for recycling which is an increased volume of low-level waste destined for near-surface disposal. Based on AREVA's experience, the projected increase in low-level waste to be disposed in near-surface facilities were the U.S. to recycle would approximate only 2.5 percent of the volume of such waste that is disposed annually in the U.S.

Federal Research, Development and Demonstration

While industry can be relied on to carry out research and development on topics that are of near-term commercial interest, it is unrealistic to expect any industry to expend research funds on basic science or on topics with a very uncertain or a long-term payoff. It is these latter types of research which must be primarily a Federal priority.

To its credit, the U.S. Department of Energy has for years devoted resources to the Advanced Fuel Cycle Initiative (AFCI). Such research should continue, but it should not focus solely on unattainable goals.

AFCI has often seemed to be a search for the non-existent "proliferation-proof" fuel cycle. It is important to understand that the laws of chemistry and physics preclude the existence of such a utopian fuel cycle. Any technology that allows the separation and/or the concentration of fissionable atoms has the potential for misuse. That is why the sensitive fuel cycle activities associated with enrichment and recycling must be adequately safeguarded and physically protected.

Even the search for a so-called "proliferation-resistant" fuel cycle may be a fruitless effort. To date, it appears that there is not a great deal of difference in proliferation resistance between any of the conceivable, realistic fuel cycles. An undue focus on self-protecting fuel forms could well lead to a nuclear fuel type which does not meet necessary standards for safety and economic efficiency. In this case, we should not expect to find a technological solution, a proliferation-resistant fuel cycle, for an inherently political problem, the proliferation of nuclear weapons. This problem demands political solutions, and technology should focus on giving political leaders the tools to accomplish their objectives, primarily enhanced safeguards systems and physical protection measures.

AREVA's Used Fuel Management Strategy

When nuclear fuel is discharged from a commercial reactor, it is actually not "spent." There is still a significant amount of fissile material remaining in used fuel—we call it *used* fuel instead of spent fuel for this very reason—still capable of providing at least 25 percent more energy. But this energy cannot be delivered in the conventional nuclear reactor because the fuel is progressively accumulating fission products; it is polluted by the "ashes" resulting from the fission reaction. Many byproducts of the fission of uranium atoms are neutron absorbers. And such absorptions reduce the population of neutrons available to induce new fission reactions. Then the fission reaction can no longer be sustained appropriately or cost-effectively.

This is when recycling comes into play. Recycling consists of separating the "ashes" from the reusable material, recovering the valuable material, uranium and plutonium, and manufacturing fresh new fuel out of it.

In terms of mass, 95 percent of used fuel contents is composed of reusable uranium, 1 percent is reusable plutonium, and the remaining 4 percent is actual waste which contains practically no remaining fissile material nor any energy value for the current and near-future generation of reactors. Recovered uranium is re-enriched and used to fabricate fresh new fuel, where the fissile material is U^{235}. Recovered plutonium is blended with depleted uranium to fabricate MOX, or mixed oxide, fuel, where the fissile materials are Pu^{239} and Pu^{241}.

The 4 percent of actual waste is then specially packed through vitrification in order to provide a safe waste form with a very long-term stability. The vitrified waste is the package that is bound for disposal in a geological repository, together with the metallic structures of the fuel bundle.

AREVA today uses an aqueous process to recover the uranium and plutonium. It is an updated version of the PUREX process invented in the U.S. Future AREVA facilities will benefit from lessons learned and continuous improvement of our technology. The main features of new plants would be:

- Implementation of the new enhanced COEX™ process where no pure plutonium is separated anywhere in the facility, as a replacement for today's PUREX process.
- Co-location of treatment and fuel fabrication plants to avoid transportation of intermediate nuclear material outside of the facilities.
- Overall enhanced safeguards systems and "safeguards by design" approaches.

This is what is available and possible today and in the near to medium future. Current research is focusing on future processes capable to further extract material from the "ashes" that could be burned in a new generation of fast neutron spectrum reactors. In such next generation, Generation IV reactors, more atoms and more isotopes become fissionable because the fast neutrons produced are of much higher energy. Moreover, the long-lived actinides, which heavily drive the requirements for confinement in geological disposal, could be broken into shorter live atoms which, in theory, could lead to a dramatic reduction of the volume required to dispose remaining waste in a geological repository.

This is a very long-term story, probably 50 to 60 years before the first commercial operation. Of course, one could choose to wait for Generation IV recycling technologies, but the price to be paid for waiting is an enormous increase in world inventories of plutonium in used fuel and an enormous waste of energy potential if the used fuel is irretrievably disposed. It is also contrary to sustainable development principles under which we promise our children not to burden them with the legacy of our consumption.

Environmental Impacts and Nuclear Security

Protection of workers and of the environment is at the highest of AREVA's priorities. The environmental impact of our La Hague treatment operations remains below the natural background radiation level. The maximum potential impact on the most highly-exposed sectors of the public remains 100 times less than the natural radioactivity level. The natural background exposure at La Hague is about 2.4 millisieverts per year. The highest local exposure to farmers or fishermen is less than 0.02 millisieverts per year, which is equivalent to the exposure received by a passenger during one New York to Paris trans-Atlantic flight.

AREVA La Hague performs systematic and in-depth monitoring of the environment in the air, on land (*e.g.*, surface water, grass and milk) and at sea (*e.g.*, coastal waters, fish and seaweed) around the site. A host of measurements are taken; around 23,000 samples are taken every year, and 70,000 analyses are made every year under the scrutiny of independent authorities who also perform their own sampling and analyses.

AREVA takes very seriously its responsibility to minimize the risk of proliferation of sensitive nuclear facilities and materials. We believe that the spread of recycling and uranium enrichment technologies should be limited. At the recent Carnegie Endowment for International Peace meeting held in Washington, AREVA Chief Executive Officer Anne Lauvergeon stated emphatically that at this time there are only two countries to which AREVA would export its recycling technologies: the U.S. and China.

Strong guarantees of supply should dissuade the vast majority of countries from developing their own capabilities for recycling and enrichment. Industry support and a commercial model ensuring competition, profitability and reliability are necessary in this regard. Existence of a few competitors will provide the guarantee of continuous supplies at reasonable prices. Large-scale profitable facilities and industries are therefore an important asset. Long-term contracts can ensure credibility and sustainability of commitments.

France has developed a model under which it can accept used fuel to recycle in its domestic facilities, burn recovered plutonium in its reactors and return the waste to the country where the fuel was used to produce energy. Other countries may choose to retain the high-level waste and dispose of it along with their domestic waste in the future. In either case, there is no proliferation threat from the vitrified products of recycling.

New recycling plants in the world should incorporate enhanced non-proliferation and security features such as the COEX™ process with no pure separated plutonium, co-location of treatment and fuel fabrication plants to avoid intermediate nuclear material transportation, and robust safeguards systems and "safeguards by design" approaches.

The Future of Safe and Efficient Recycling

While AREVA takes pride in the successful operation of its recycling complex centered at the La Hague and MELOX facilities, we are convinced that further improvements can be made. In fact, continuous improvements have been made in France over the previous three decades based on research and development. Much of what has been learned was incorporated into the design of the Japanese recycling treatment plant at Rokkasho-mura. Future plants wherever they are located should take advantage of the advanced safeguards procedures built into the Rokkasho-mura facility and should also implement advanced technology such as COEX™, which does not separate pure plutonium.

In addition, AREVA believes that there are other areas for research, development and demonstration. Offsite doses are highly dependent on specific locations, as are the allowable levels of gaseous and liquid discharges. Research, development and demonstration should be concentrated on reducing the minimal gaseous and liquid discharges that arise from current processing technologies. The capture, packaging and disposal of gases and liquids are areas ripe for research. At the same time, such research should focus on the cost-benefit analysis of limiting discharges while assuring that worker dose rates are not inappropriately increased.

In the long-term, and especially in conjunction with the future implementation of Generation IV reactor technologies, electro-metallurgical separations may become a useful technology. Such separations technology has not yet reached the level of maturity found today with aqueous processing. This is another area suitable for research at the U.S. national laboratories because of the long-term time horizon for widespread commercial implementation.

Finally, further Federal research, development and demonstration should be devoted to advanced safeguards technologies such as advanced instrumentation that will allow near-real time material accountancy. The development of that technology would contribute significantly to enhancing the assurance that sensitive materials are not being diverted.

Mr. Chairman and members of the Committee, I appreciate having this opportunity to join you today. I am delighted that our lawmakers have taken an interest in advanced technology for nuclear fuel recycling. A used fuel recycling facility should be built in the U.S. in the near future in order not to postpone the waste management issue once again and for America to regain global leadership.

A nuclear renaissance is undeniably happening around the world. Britain, France, China, Japan and Russia have already built or are developing recycling capabilities. America was the first to develop this technology, we were the first to send a man to the moon, and it is time for America to take the lead again. AREVA would be pleased to cooperate with the U.S. Department of Energy to further research, development and demonstration on recycling.

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Alan Hanson was appointed Executive Vice President, Technology and Used Fuel Management, of AREVA NC Inc. in 2005. He was formerly President and Chief Executive Officer of AREVA subsidiary Transnuclear, Inc., which he first joined in 1985. He continues his responsibilities there as a Director of the company.

Dr. Hanson began his career in 1975 with the Nuclear Services Division of Yankee Atomic Electric Company. In 1979, he joined the International Atomic Energy Agency in Vienna, Austria, where he served first as Coordinator of the International Spent Fuel Management Program and later as Policy Analyst with responsibilities for safeguards and non-proliferation policies.

Dr. Hanson completed his undergraduate studies in mechanical engineering at Stanford University and earned a Ph.D. in nuclear engineering from the Massachusetts Institute of Technology. He is a member of the American Nuclear Society and the American Society of Mechanical Engineers.