



Recycling: Essential Element of a Sustainable Nuclear Fuel Cycle

EXECUTIVE SUMMARY

AREVA has successfully and profitably operated commercial nuclear fuel recycling facilities for more than three decades. The demonstrated safety and environmental record of these facilities makes them a model for used-fuel management that continues to be adopted internationally. AREVA's experience demonstrates that deployment of proven state-of-the-art recycling technology is cost competitive, simplifies waste management, and conserves natural resources. In addition, recycling used fuel boosts public acceptance of nuclear energy while retaining sufficient flexibility to incorporate longer-term technology developments such as Generation IV reactors.

The energy remaining in used nuclear fuel is a strategic resource, and we can reuse 96 percent of its energy content using proven technology. AREVA's technology enables the recovery of this valuable energy resource, increasing domestic energy security and saving 25 percent of natural uranium resources. The amount of used fuel stored at U.S. plant sites could power today's entire U.S. reactor fleet for six years. With recycling, we could reduce by 75 percent the volume of high-level waste (HLW) slated for disposal in a repository. As the experience with the Yucca Mountain project demonstrated, repository space is a rare and precious asset. In addition, AREVA's recycling technology uses a specialized vitrification process that produces a simple, stable, durable waste form optimized for storage and geological disposal.

AREVA's facility design for the United States employs new technologies and engineering improvements, including the COEX™ process, which confers additional nonproliferation benefits by ensuring that no pure plutonium is separated at any point within the plant.

Detailed studies show that deploying AREVA's recycling technology would increase our nation's energy security, create jobs and investment, and improve public acceptance of nuclear energy, but would not increase electricity costs. Local public support for a recycling center is likely to prove a significant factor in the ability to gain acceptance for proposed interim used fuel storage facilities.

There are exciting areas of research into emerging nuclear energy technologies, and this advanced research must proceed. However, many decades will pass before these technologies are ready for commercial deployment. Meanwhile, the United States has a pressing obligation to address a large – and growing – used fuel backlog. Deploying state-of-the-art recycling technology is an important first step in developing a viable integrated fuel cycle strategy. This would support our existing reactor fleet, while retaining the flexibility to pursue additional R&D on advanced fuel cycles.

It is crucial that the Nuclear Regulatory Commission continue developing a regulatory framework for deploying commercial recycling facilities. Congress and the Administration must likewise chart a strategic course for sustainable fuel cycle management. This national policy commitment must recognize used nuclear fuel as a resource, not a waste, and facilitate the consolidation and recycling of this resource, continue R&D, and develop a national repository. Executing this policy requires an entity, such as a Federal Corporation (FedCorp), that it is broadly chartered, appropriately capitalized, insulated from political volatility, and capable of sustaining long-term projects.

RECYCLING: ESSENTIAL ELEMENT OF A SUSTAINABLE FUEL CYCLE

INTRODUCTION

For more than two decades, the United States has focused on a single path for disposition of used nuclear fuel (UNF) – direct disposal – precluding serious consideration of other options. AREVA supports an integrated approach that includes interim consolidated storage as an initial phase of used fuel treatment and recycling centers, followed ultimately by permanent disposal.

Leveraging the best of industry expertise and the National Labs, the United States has the unique opportunity to chart a fresh course toward a sustainable nuclear fuel cycle infrastructure for low-carbon domestic energy production. Constructing state-of-the-art facilities to extract the energy value from used nuclear fuel and reduce demands placed on geologic disposal facilities will be a driver of research, innovation, and employment.

Our current system is broken, but a better way exists today. Today more than 60,000 metric tons is stored at America's nuclear plant sites, and over 2,000 metric tons of used fuel is produced each year. Recycling used nuclear fuel has a long, successful, and secure history, and provides a pathway to public confidence for industry and government in the United States.

RECYCLING TECHNOLOGY

Used nuclear fuel – a strategic resource or waste form? The United States continues struggling with this question, with some recent studies suggesting that decades more of research and development at a cost of billions of dollars are still required to answer this question. This perspective fails to recognize that other countries with large and growing nuclear sectors have successfully addressed this question in advance and as a matter of policy.

In fact, the more than 60,000 metric tons of used nuclear fuel stored at America's plants are not waste, but, instead, 60,000 metric tons of a recyclable resource. When nuclear fuel is discharged from a commercial reactor, it is not "spent." A significant amount of fissile material remains in used fuel that can provide 25 percent more energy.

This is when recycling comes into play. Recycling consists of separating the waste material from the reusable material – uranium and plutonium – and manufacturing fresh new fuel. In terms of mass, 96 percent of the content of the used fuel is reusable. The remaining 4 percent is high-level waste (HLW), which contains practically no remaining fissile material and no energy value for the current and near-term generation of reactors.

Recovered uranium is re-enriched and used to fabricate fresh new fuel for commercial reactors. Recovered plutonium is blended with depleted uranium to fabricate mixed-oxide (MOX) fuel for commercial reactors. MOX fuel has been used safely and effectively since the 1970s, and has been loaded in 40 reactors located in five countries. The HLW is stabilized in an engineered waste form by vitrification to provide a simple, stable, durable waste form suitable for an eventual geological disposal.

Through its deployments internationally, the recycling process invented in the U.S. has benefited from decades of lessons-learned and continuous improvements in technology. A new recycling facility in the United States would not simply replicate facilities from France, Japan or the United Kingdom, but rather would employ state-of-the-art technologies and processes, including:

- Implementation of an enhanced COEX™ (Coextraction) process where no pure plutonium is separated anywhere in the facility.
- Co-location of treatment and fuel fabrication plants to avoid transportation of intermediate nuclear material outside of the facilities.
- Overall enhanced protection systems and design approaches.
- Flexibility in design to allow deployment of advanced separations processes, when such processes are developed and commercially industrialized, supporting fully closing the fuel cycle.

There are significant benefits to implementing recycling technology, which simplifies waste management and has great potential to impact the way in which used fuel is disposed and stored.

KEY BENEFITS OF RECYCLING

Recycling reduces the burden on a geologic repository.

Recycling used nuclear fuel significantly reduces the volume of HLW to be disposed of in a final geologic repository. Only 4% of used fuel content is HLW. 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% less than the volume required if the used fuel is disposed directly in a repository. Depending on the repository geology, 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.

HLW volume reduction is a crucial benefit of recycling as it allows maximum use of a geologic repository, which has proven to be a rare and precious asset. When a HLW repository eventually opens in the U.S., one would want to make optimal use of every cubic unit of emplacement.

Under the DOE’s medium energy growth scenarios, accumulation of used fuel in a once-through cycle would total 150,000 metric tons by 2050. Licensing of a geological repository is long, and public acceptance is very sensitive. It is difficult to envisage today an attempt to license multiple geological repositories in the United States, given the dramatic uncertainty that has surrounded the attempt at licensing of the first one at Yucca Mountain, Nevada. Recycling can significantly delay and potentially eliminate any requirement for additional repositories.

Recycling reduces toxicity.

The main contributors to the long-term radioactive toxicity of used nuclear fuel are plutonium and uranium. Consequently, extracting these materials from the used fuel significantly reduces the toxicity of the final waste form. The main contributor to the long-term radioactive toxicity of used nuclear fuel is plutonium for the first several hundreds of thousands of years, at which point 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 produces simple, stable, durable, and standardized waste forms.

Vitrified waste from recycling provides a highly safe, resistant and well-characterized waste form, and 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. The vitrification process results in a waste form with long-term stability that can be safely and cost-effectively stored in simple, compact and low-cost facilities as a reliable interim waste management option.

Recycling contributes to energy security.

Because 96 percent of the content of the used fuel is reusable energy, AREVA's technology enables the recovery of valuable energy resources, providing for greater domestic energy security. In fact, if recycled, the 60,000 metric tons of U.S. commercial used nuclear fuel represents the energy equivalent of at least six years of nuclear fuel supply for today's entire U.S. nuclear reactor fleet. If the U.S. were to recycle the 2,000 metric tons of used fuel generated annually, it would be equivalent to the total projected U.S. imports of liquefied natural gas in 2010.

Further, the availability of recycled fuel provides a tool for the nuclear energy sector to protect against potential rises in uranium prices by providing recycled fuel whose production cost is independent of uranium prices.

Recycling saves natural resources.

Uranium recovered from recycling represents about 95 percent of the mass of light water reactor used fuel with a residual U-235 enrichment level of approximately 0.9 percent, higher than natural uranium ore. Re-enrichment and recycling of recycled uranium (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 recycled uranium. AREVA is making investments to ensure 100 percent recycled uranium re-enrichment and RepU fuel fabrication by 2015. Recycling both recovered uranium and plutonium leads to a total savings of at least 25 percent of natural uranium resources.

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. This provides a credible and reliable interim nuclear waste management option for the extended period of time necessary for a geologic repository to be approved and available.

Recycling is a path to burning plutonium, thereby supporting non-proliferation efforts.

Recycling plutonium in MOX fuel consumes roughly one-third of the plutonium through a 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 2017.

Recycling supports an international non-proliferation framework.

AREVA takes very seriously its responsibility to minimize proliferation risks of sensitive nuclear facilities and materials. 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. 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 – as long as security of supply is guaranteed for them.

There is a fundamental question of policy that must be assessed against facts and history: 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 a strong international non-proliferation paradigm? 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 generated by commercial recycling. Any recycling facility built in the U.S. would meet all the necessary NRC requirements for safeguards and security.

Since 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 or India from following suit.

Notice that the only countries to build recycling 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, which seeks sufficient capacity and robust supply assurances designed to make proliferation of expensive enrichment facilities unattractive. That same logic should be applied to recycling. Developing a capacity that would allow the U.S. the flexibility to offer services for used fuel would also serve to prevent many countries from building indigenous facilities, thereby enhancing the non-proliferation regime.

Hundreds of additional reactors are projected to be operating by 2030. The U.S. must lead in establishing a responsible framework that advances the desire for peaceful nuclear energy, while also protecting against the spread of sensitive materials and technologies.

An effective non-proliferation paradigm should focus on providing incentives that make nuclear energy economical in exchange for commitments that make it secure. Such an approach would allow the world community to focus scrutiny on nation-states who rebuff cost-effective, secure nuclear energy in favor of costly technologies that could lead to the proliferation of nuclear weapons.

For the United States to effectively lead in meeting such a challenge internationally, a policy shift will need to occur at home.

INTEGRATED USED FUEL MANAGEMENT STRATEGY

Implementation of near-term recycling using proven commercial technology coupled with research on advanced fuel cycles is the appropriate path to effective management of the U.S. fuel cycle. This approach would:

- Limit the continuing accumulation of used fuel backlogs
- Utilize the residual energy value of the used nuclear fuel
- Restore credibility in fuel cycle management by demonstrating progress through the deployment of safe and proven solutions in the U.S.
- Support the nuclear renaissance and its contribution to a low-carbon economy
- Re-establish an industrial skilled workforce and the hands-on expertise that are critical to the successful implementation of any used fuel management solution

Industry and the DOE/National Labs must play a critical role in developing the near-term and long-term technology developments, respectively, and policymakers would be wise to adopt approaches designed to leverage the expertise and experience of all parties.

Deployment of a scalable, commercial recycling facility needed in the United States.

This approach would allow the U.S. to develop the industrial skills and expertise essential to a safe and secure fuel cycle solution. Such practical expertise will maximize the chances for long-term success and reduce the risk that taxpayer/ratepayer dollars are wasted in the pursuit of solutions that are unable to be implemented. Beginning with a scalable pilot facility would allow for the expansion of additional capacity that is based on market needs, and allows incorporation of advanced technologies, when mature. Such a facility could also serve the function of an interim storage facility for receipt and storage of used fuel from commercial power plants.

From a technological perspective, this recycling approach is the only solution available in the near to medium future.

Federal research and development efforts should align with integrated strategy.

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 first-of-a-kind systems that should be developed by the Federal Government to meet the requirements of a national policy for closing the fuel cycle.

There are exciting areas of research into emerging nuclear energy technologies. This advanced research must proceed, but it should not focus on unattainable goals, such as the search for a 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.

To date, it appears that there is not a great deal of difference in proliferation risks between any of the conceivable, realistic fuel cycles. Therefore, we should not expect to find a technological solution – a proliferation-proof fuel cycle – for an inherently political problem. Technology should focus on giving political leaders the tools to accomplish their objectives, primarily enhanced safeguards systems and physical protection measures.

Advanced fuel cycles (including Generation IV reactors) and the perils of “Leapfrogging.”

Current research includes future processes capable of further material extraction from the waste that could be burned in a new generation of fast reactors. In such next generation reactors, the long-lived actinides, which heavily drive the requirements for confinement in geological disposal, could be broken into shorter-lived atoms which, in theory, could lead to a dramatic reduction of the volume of remaining waste required to be disposed in a geological repository. This is a very long-term story and is many decades from commercial operation.

The United States has a pressing obligation to address our large, and growing, used fuel backlog. Because such advanced concepts are decades from deployment, waiting for the commercialization of “leapfrog” technologies is a commitment to further fuel cycle risk and uncertainty. Without a solid framework of proven technology and a skilled and experienced workforce, reliance on a “leapfrog” technology is likely to reduce the chances of successful deployment on an industrial scale. Deployment of current, state-of-the-art recycling technologies in an upgradeable pilot facility should be the first step in an integrated strategy that supports our light water reactor fleet while retaining the flexibility to support continued research and development of advanced separations technology and advanced fuel cycles.

SOCIAL AND ECONOMIC CONSIDERATIONS

Recycling costs must be quantified in full context.

Cost is driven by several factors, including the cost of uranium – which drives the market value of recycled fuel; the projected total life cycle cost of a geological repository – which determines the value of HLW volume reductions from recycling; and the degree to which economies of scale are achieved by a large recycling facility.

In 2006, The Boston Consulting Group (BCG) performed a study with input from AREVA that showed the economics of recycling as compared to direct disposal are comparable, within 10 percent difference. Of course, any study depends upon the assumptions made, and other studies using different assumptions have produced results different from those of BCG. However, any evaluation of recycling costs must include optimization realized for the geological repository, credits for the recycled fuel and reductions in federal liabilities associated with removing used nuclear fuel from utility sites, along with a recognition of key intangible benefits, such as fuel cycle and resource sustainability, contributions to international non-proliferation efforts, and the ability to assure broader public confidence in the management of the backend of the nuclear fuel cycle.

Current dynamics are delivering no value with escalating costs.

Several additional factors should be noted in assessing the economics and benefits of used fuel recycling. First, cost estimates of the once-through disposal strategy had significantly increased – to \$96 billion in 2007 dollars – even before the potential lost costs from termination of Yucca Mountain. As repository costs

escalate, so too does the value in HLW volume reduction services from recycling. Second, with the DOE's continued inability to meet its contractual obligations to accept commercial used fuel, taxpayer-funded liability costs are predicted to reach at least \$13.1 billion by 2021. If the DOE remains unable to meet its obligations by 2021, these estimated liabilities will increase by roughly \$500 million annually.

Recycling delivers major economic development, creating thousands of skilled jobs.

Deployment of recycling capabilities would be a significant investment in the future energy infrastructure of the United States. Such infrastructure would be considerable in scale, creating approximately 50,000 jobs. This includes up to 18,000 direct jobs during construction for the initial pilot scale facility and 5,000 steady direct jobs during 50+ years of operation. The impact on the surrounding community and host state would be even greater, with an estimated 30,000 indirect jobs created in the wider economy.

These economic development incentives would ensure that local communities and states compete for the right to host facilities – rather than resist them – and provide political certainty to the process as it moves forward. Without the economic development benefits of a recycling center, it is difficult to envisage the public support necessary for successful consolidation of material at interim storage sites.

Private capital should be leveraged for recycling infrastructure.

With appropriate national policy commitments, private capital can be harnessed to finance recycling infrastructure. However, it is unrealistic to expect that industry will invest private capital in anything but proven technologies. To leverage the commercial sector funding, deployment should focus on currently available, proven technologies that have the certainty of long-term policy assurances.

Extensive environmental monitoring and transparency are imperative.

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 continuous, 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.

FEDERAL ACTIONS

The current U.S. policy framework is of another era.

The once-through fuel cycle is not consistent with the expansive U.S. reactor fleet, extension of plant licenses, and the addition of new generation nuclear capacity. More nuclear power means more used fuel. Our legacy policy was designed decades ago in a different context, where declining outputs of used fuel

were anticipated. Policy modernization in the U.S. is crucial to restoring public confidence in nuclear energy and assuring U.S. leadership in the successful global management of used fuel.

In order to restore public confidence, we must move beyond current policy paralysis and chart a path that enables an integrated used fuel management solution, with options for recycling, interim storage and disposal, that minimizes waste volume and toxicity, increases fuel supplies, reduces proliferation risks, and maintains long-term flexibility to incorporate new technologies.

A national policy commitment is needed.

To ensure public acceptance of recycling as a key option of an integrated strategy for a sustainable fuel management, U.S. policy should affirmatively support the recycling of used nuclear fuel to advance energy independence, maximize the energy potential of nuclear fuel, and reduce the volume and toxicity of HLW destined for a permanent geologic repository. Execution of such a policy commitment should reside within a Federal Corporation (FedCorp) structure better insulated from political volatility than the Department of Energy. It is increasingly clear that industry will need a more credible and stable back-end management structure in order to make major long-term capital investments. Such a structure would provide a more holistic and cost-effective approach to the full scope of backend infrastructure and management.

The FedCorp should be policy and technology neutral, and have responsibility for material from the reactor site through ultimate disposal. Industry and ratepayers are owed value for their continuing payments to the Nuclear Waste Fund (NWF), and the FedCorp must have access to the NWF and be accountable for making expenditures consistent with that fund's purpose and sound economics. A FedCorp would provide for fiscal predictability, avoiding a budget process characterized by insufficient and unsteady appropriations that are a significant risk to the financing of long-term construction projects.

A stable regulatory framework is needed to support licensing of recycling facilities.

Finally, another area where federal action is needed to enable the option of recycling is on the regulatory front. Today, there is no regulatory framework to support licensing of commercial recycling facilities in the U.S. The NRC should work in parallel to continue development of a regulatory framework that allows for licensing and commercial deployment of such facilities.

CONCLUSION

Now is the time to move forward decisively and to restore public credibility in used fuel management. Used fuel recycling provides the ability to economically reduce high level waste (HLW) volume and radioactive toxicity while recovering valuable domestic energy resources – and it delivers a compelling answer to questions about the ability of industry and government to effectively manage nuclear waste.

A scalable used fuel recycling facility should be built in the U.S. in the near future to restore confidence in America's ability to solve problems and to meet our obligations to our children and grandchildren. America was the first to develop this technology, and it is time for America to reclaim global leadership.

ABOUT AREVA

AREVA provides its customers with solutions for low-carbon power generation in North America and all over the world. As the leader in nuclear energy and a significant, growing player in the renewable energies sector, AREVA combines U.S. and Canadian leadership, access to worldwide expertise and a proven track record of performance. Sustainable development is a core component of AREVA's strategy. Its more the 5,000 U.S. and Canadian employees work every day to make AREVA a responsible industrial player helping to supply ever cleaner, safer and more economical energy to the greatest number of people. AREVA Inc. is headquartered in Bethesda, Maryland.

We are part of a global family of AREVA companies offering proven energy solutions for low carbon power generation. 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. In conclusion, it is essential to note that AREVA operates the largest and most successful used fuel treatment and recycling plants in the world.