SPENT FUEL MANAGEMENT AND WASTE MINIMIZATION IN FRANCE AND THE WORLD

J.P. Giraud and J. Pijselman
COGEMA (France)

ABSTRACT

Together with nuclear reactor safety, a satisfying answer to the nuclear waste issue is a major condition for a sustainable development of nuclear power worldwide.

This paper will review the various and contrasted attitudes that have developed in the main nuclear countries for spent fuel and waste management, including legislative situations, regulations and industrial developments.

The first part devoted to the French situation is more detailed as it addresses the reprocessing industry status, the plutonium recycling activities, the waste minimization and disposal program, and includes a few remarks on the environmental impact of the reprocessing, recycling strategy.

Then, the spent fuel and nuclear waste programs in the other countries of the European Community are briefly described: Germany, Great Britain, Belgium. The Netherlands, Spain, as well as Switzerland.

Understandably, the US situation is only briefly evoked, as are those of Canada and Sweden. Eastern Europe countries and Russia ask at this time more questions than they offer answers.

In Asia, Korea and Taiwan will have to decide their strategies in the coming years, while Japan is strongly engaged in the complete closure of its nuclear fuel cycle. A comprehensive program is engaged with the objective of a determined continuation into the next century.

The lesson learned from this overview is that in each country, the spent fuel and waste management policy is an initial part of the overall nuclear development strategy, and a strong signal of the willingness to pursue a long term nuclear energy program.

INTRODUCTION

As we approach the turn of the century, societal demands are increasingly complex. They often seem both justified and, at the same time, inconsistent. More precisely, how can we at the same time satisfy the demands of independence and security, the claims for full employment and quality of life, the requests for economic development and protection of the environment? Energy, as the driving force of the development of our societies, has been and remains at the center of such contradictory requirements. And nuclear energy, which has emerged after World War II and was presented as the magic answer to the world energy hunger, indeed involves its own difficulties, that need a responsible attitude and a proper strategy. Today, contestation groups mount strong challenges, based on diverse grounds such as economy, ecology, nonproliferation, technological risks... Although the industry has experienced a few negative events that give rise (especially in non-technical quarters) to some doubt, we know very well that extremely positive technological progress has been made.

Where are we now? Are we in a position to appreciate the entire spectrum of the undertaking of nuclear energy, including how best to manage irradiated fuel after it has been discharged from the reactor? What criteria must we impose on ourselves to protect the environment and the safety of future generations?

As a mature industry, we have to take upon ourselves the responsibilities to properly manage the spent fuel and the waste arising from the production of nuclear electricity.

My presentation today will offer an overview on various spent fuel and waste management programs in the world, and first the strategy that we follow in France regarding nuclear fuel recycling and waste minimization.

FRANCE

It is always easiest to begin addressing an issue by reference to experience. For me, the most familiar experience is in the French program. So I will start with a brief review of spent fuel and waste management in France.

Nuclear energy is at the center of France national energy program, supplying close to 75% of the country's electricity. 52 PWR's generated a total of 311 Terawatt hours in 1991; five more units in advanced stages of construction will raise the installed generating capacity to over 64 Gigawatt electric by 1998.

In fact, France is second only to the United States in terms of nuclear electricity, and as such, we are deeply convinced of our duties and responsibilities with an exemplary program to show as a reference for other countries.

We believe that a secure nuclear program includes appropriate, definitive solutions for the back-end of the fuel cycle. We believe that these solutions are found in reprocessing and recycling. A consensus has been gained and preserved in our country as six successive Governments have consistently followed this commitment that EdF, the French utility, has always endorsed.

The Reprocessing Industry Status

Reprocessing is an industry that works. Commercial spent fuel has been reprocessed at La Hague since 1966, starting with GCR fuel and followed by increased quantities of LWR fuels from the growing French nuclear program and from foreign clients.

COGEMA converted in 1981 its La Hague facilities into a major LWR fuel reprocessing complex with a total capacity which will be capable of servicing 70 to 80 large reactors. The UP3 plant, with a capacity of 800 metric tons of uranium per year, successfully started in 1990, while the existing plant UP2, upgraded also to 800 metric tons of uranium per year, is scheduled for start-up in 1994, to serve both the French utility EdF and the foreign customers of Japan, Germany, Belgium, the Netherlands and Switzerland. At La Hague, substantial spent *fuel interim* storage in pools serves as a buffer for fuels shipped by the customers and awaiting reprocessing. The UP3 plant is ramping up according to schedule, with 350 metric tons of uranium reprocessed in 1991, 450 metric tons of uranium in 1992, 600 metric tons of uranium scheduled in 1993 and nominal capacity to be achieved in the 1994-1995 time frame.

The design fuel burn-up for the plant was 43,000 Megawatt day per metric ton of uranium ; minor adjustments will allow reprocessing of fuels with burn-ups in excess of 50,000 Megawatt day per metric ton of uranium. MOX fuel can be reprocessed in the La Hague plant, as was demonstrated a few weeks ago with a very significant amount of MOX fuel from German reactors.

Every criterion for evaluation of plant performance is being met:

- plutonium quality: better than required for MOX fuel fabrication;
- waste volume : below 1.4 m^3 per ton of uranium for high level and TRU waste, and a program leading in 2000 to 0.5 m^3 per ton of uranium ;
- personnel exposure: 100 times below allowable dose;
- effluents release: 10 to 15 times below release limit.

Plutonium Recycling Activities

The feasibility of recycling plutonium in reactors was demonstrated as early as the late 50's in the US and in the 60's in Europe. In France, sixteen of the 900 MWe PWRs were prelicensed for MOX fuel, thereby starting full plutonium recycling in LWRs. Plutonium use in Fast Breeder Reactors remains a main objective, clearly pursued in Japan for instance where the FBR development program is under progress. In France, the future activity of the Superphenix reactor is now under review for the various potential uses of such facility.

Present MOX fuel fabrication plants include the Belgonucleaire plant at Dessel and the COGEMA facility at Cadarache.

In 1990, the French Government issued a ministerial Order for the creation of the MELOX plant. This plant, devoted to MOX fuel manufacturing, with a nominal capacity of 120 metric tons per year, is under construction at Marcoule, and will come in operation in 1995. Optimized to process massive quantities of 17 x 17 PWR MOX fuel, MELOX will be also capable of manufacturing all types of fuels for LWR's.

Globally, the MOX fuel fabrication capacities will be consistent with the quantities of plutonium made available by the commercial reprocessing facilities in operation or under construction.

Waste Minimization and Disposal

The key for safe disposal of nuclear waste is, first, a proper partitioning, with a specific use of each of the resulting products. Today, reprocessing isolates almost completely the main long-lived radionuclide plutonium, which is burnt in LWRs through MOX recycling. Other actinides will be separated when needed, such as Neptunium for instance.

The French waste management policy is to minimize waste volumes and activities and to condition on-line the wastes from reprocessing in a solid form suitable for ultimate disposal. Thus, for the La Hague plants, the vast majority of alpha, beta, gamma activities (HLW) ends up in a small volume of glass, and hulls and end pieces are embedded in cement.

Through reprocessing, the technical capability is available 1) today for a proper waste management system over a long period of time (containment, storage, disposal), 2) for further actions (up to the year 2000) on waste volume reduction and toxicity reduction (hulls compaction, technological waste incineration, organic residue conditioning, 3) for the future, an extended elimination of the largest part of long-live elements. The waste minimization program of COGEMA, which stands as an integral part of our reprocessing policy, is such that the volume of all wastes from reprocessing will be smaller than the volume of the irradiated fuel that might be directly disposed. The first nuclear waste legislation in France, governing construction of underground laboratories to study long-lived radioactive wastes disposal and related waste management research was adopted by the Parliament and promulgated a year ago. This Law prohibits the final disposal in France of foreign-origin waste. Negotiations with candidate sites and site selection for the underground laboratories will be undertaken by the Waste Negotiator who has been nominated in December 1992. Vitrified HLW is currently being stored for cooling down in vaults located at the reprocessing sites, where there is 40 years of storage capacity.

In discussing the Waste Act, the Parliamentary office asked for a continuation of the research program on reprocessing and waste management. As a result, three programs are now underway: a major program on deep geologic disposal, including the construction of two demonstration underground laboratories and their operations; a second research program on improved waste conditioning; a third program on advanced reprocessing (actinide partitioning and transmutation) is investigated under the so-called SPIN project.

Environmental Impact

In assessing the environmental impact of reprocessing, it is interesting to draw comparisons between the nuclear option and the coal option. Nuclear power plants and coal-fired plants both generate effluents whose release to the environment must be minimized. In the case of coal combustion, the effluent consists of SO2 and NOx emissions which are cleaned with desulfurization and denitrification removal systems, while nuclear combustion generates fission products whose release to the environment in gaseous, liquid or solid from must be minimized; in a closer nuclear fuel cycle, this is accomplished by vitrification of the high-level waste and geologic disposal.

Comparative studies have been performed of the relative costs of environmental protection for the nuclear and coal options: the "back-end of the coal fuel cycle" is twice to three times as costly as the back-end of the nuclear fuel cycle. Moreover, the sheer volume of waste generated by coal-fired plants, in absolute terms, far exceeds the volumes of nuclear-generated waste and is much more toxic to the environment.

THE EUROPEAN COMMUNITY

Now that I have completed a brief overview of the French program, I move to these programs close to home: the other programs in the European Community.

Germany

Controversy regarding nuclear energy has led to a de facto moratorium of the German power program, pending a new atomic Law which could be issued in the near future, and whose options will depend on the then relevant federal political majorities, when and if they are able to develop a consensus. Recommendations for substantial use of coal and gas as resources for energy production are promoted by the antinuclear forces, in spite of unanswered questions regarding CO2, green effect, cost of desulfuration,... In the field of spent fuel and waste management, the presently valid atomic Law requires a "6 year Entsorgungsvorsorge-Nachweis" (utilities have to prove 6 years in advance how and where they will treat their spent fuel) which so far can only be satisfied with reprocessing contracts. German utilities send their spent fuel to France (COGEMA) and Great Britain (BNFL). The reprocessing products have to be recycled. Plutonium in MOX fuels is currently used in some German reactors, but the MOX fabrication plant in Hanau is still awaiting authorization from the Land of Hesse. Residues will be shipped back in a couple of years. An interim storage facility has been built at Gorleben for vitrified high level waste and also for low level waste. For HLW final disposal, the Gorleben salt dome is under investigation as a candidate site, while the Konrad mine is being explored for low level and intermediate level waste.

Great Britain

While benefitting from natural resources (gas and coal), Great Britain has an important nuclear program. With a large reprocessing experience gained in GCR fuel, BNFL is now completing a large LWR reprocessing facility at Sellafield. The THORP plant will start to process its foreign clients spent fuel, together with the domestic spent fuel, in a few months. Regarding its domestic program, Great Britain is engaged in a complete uranium and plutonium recycling policy, while the final disposal question is being examined with a view to geologic disposal, likely to be sited at Sellafield.

Belgium, The Netherlands, Switzerland

These countries are committed for their spent fuel management to reprocessing through contracts with COGEMA and BNFL, and they are engaged to some degree in plutonium recycling in LWRs. Belgium for instance was the first to put MOX fuel in a LWR reactor, 30 years ago.

Spain

The Vandellos GCR fuel is being reprocessed by COGEMA. For the LWR spent fuel, the current policy is to implement a centralized interim storage facility, in order to take time for a definitive back-end decision. This is coherent with the present Spanish nuclear program moratorium. Should this program restart, the question of the completion of the nuclear fuel cycle will arise again.

NORTH AMERICA

USA

The United States is the world's most "nuclear" country, with 100 GWe installed and 110 reactors. But no new unit has been built by the US industry in the last 15 years. Although there are many factors contributing to this situation (such as lengthy delays resulting from regulatory and judicial intervention by opponents of nuclear energy), solving the "waste problem" is one of the most often-cited hurdles to a revitalized nuclear industry. In other words, the industry finds itself stymied due in large part to uncertainties (real or perceived) regarding the feasibility and economy of the back-end of the cycle.

In the US, the need for self reliance (or "energy independence") does not seem to be as much of a driving force as it is in some other countries. This difference in public perception seems to exist even in the face of US reliance on imports for about 40% of its oil supply. Of course, the US does occupy the pre-eminent position in international politics and commerce, and has abundant natural resources not available to most other countries.

I will not recall here all the milestones of the debate in the USA regarding spent fuel management, which include the Carter Administration's ban on domestic reprocessing, the HLW Policy Act establishment of a fee (currently 1 mil/kWh, or about $500 M per year) to support development of the MRS and repository, and the 1987 Amendment to the Act that established the requirement for characterization of a single geologic repository at Yucca Mountain.

- By the end of 1992, DOE had spent over $ 1.2 billion for site characterization at Yucca Mountain, and had awarded a major M&O contract for MRS design and engineering.
- According to the most recent declarations, meeting the 1998 rendezvous for accepting spent fuel from the utilities needs the definition of a specific site specifications in the very next months.
- Precisely, the MRS siting process (or any alternative to the MRS) appears to be the critical step of the whole spent fuel and waste management program in the US, and I can only offer our encouragement for the actions in progress, that will be described in the next presentations of this Conference.
- We in Europe are anxious to better understand the global philosophy behind the program and the inflexions to be brought by the new Clinton administration. A total of 100,000 metric tons of spent fuel will have to be disposed of in the early years of next century, meaning that some 1000 metric tons of plutonium will have to be buried, unless some treatment is set up to use such plutonium and other long lived radionuclides.

So, we can be only happy to see that an ambitious R&D program has been started regarding P/T (Partition of long lived elements within the spent fuel and their Transmutation). The question is: will the US, after having been the first country to master the reprocessing technology almost 50 years ago, make a come back in this industry, to develop an "advanced" version?

- The other key programs needed for a smooth development of the nuclear industry in the US include low level waste treatment, storage and disposal facilities development, and the remediation and environmental restoration actions. We will have several sessions on these important matters by speakers with outstanding credentials.

Canada

CANADA is engaged in a large nuclear energy program through the specific CANDU system based on natural uranium use. Consequently, very large quantities of spent fuel are produced: up to 35,000 metric tons cumulated by the year 2000. The current spent fuel management policy takes into account the poor energetic value of the CANDU spent fuel, favoring direct disposal after interim storage.

Sweden

Following the nuclear progressive phase-out program voted in 1980, the Swedish authorities decided to shift their back-end policy from reprocessing/recycling to direct disposal, and implemented a thorough R&D program in spent fuel conditioning and geological disposal. During a 40 year interim period, spent fuel is to be stored in the CLAB underground facility at Oskarshamm, while low level waste is being stored at Forsmark. Today, the Government, the industry and a large part of the population may reconsider the abandonment of nuclear power, as no other domestic and environmentally acceptable energy source appears as a credible alternative.

Eastern Europe

The Eastern European countries which have to face a critical economic and financial transition, must address a new issue in their nuclear power program, namely the interruption of Russian services related to spent fuel disposal. Ukraine, the Czech Republic, Slovakia, Hungary and Bulgaria are now logically considering interim spent fuel storage in dedicated facilities, in order to resolve short-term at-reactor difficulties, and to buy some time before making decisions for definitive solutions. International organizations and the European Community are becoming increasingly involved in these countries' nuclear waste programs.

For Russia, which is considering a major restart of its nuclear power program, closing the fuel cycle remains the basic policy, even if the reprocessing and recycling facilities at Krasnoïsarsk and Tcheliabinsk must overcome serious safety and environmental problems, and their related financial problems.

ASIA

Korea and Taiwan

I will now address two countries in Asia strongly relying on nuclear energy as they are, like JAPAN, lacking fossil energy resources and are currently developing rapidly. KOREA and TAIWAN have relatively large nuclear programs and are presently among the few countries pursuing construction of NPPs. By the turn of the century, KOREA will have close to 5000 metric tons of spent fuel, and TAIWAN 2500 metric tons, to be taken care of.

In KOREA, options for spent fuel management remain open; the nuclear authorities and the utility are presently examining various ways of fuel recycling, including the dual use of their heavy water reactors and their LWRs and the possible recycling of plutonium in MOX fuel. In the meantime a centralized spent fuel storage away from reactors (AFR) will be constructed. Regarding low level waste, KOREA should restart soon a siting process for storage and disposal. In TAIWAN, recycling is an answer that is considered for the mid to long term. Interim storage of spent fuel will give time for definitive decisions to be taken when all aspects, including political and regulatory are solved.

These two countries present a specific political sensitivity which leads them to demonstrate their dedication to a peaceful use of nuclear energy.

Japan

I would like to end my world tour by what we consider as an example case, Japan. The world's second most important industrial country after the USA has no natural energy resources. Consequently, Japan is forging ahead with its progressive, comprehensive long term nuclear power program that includes deployment of fast breeder reactors in the year 2020's and 2030's, and a complete mastering of the nuclear fuel cycle, with the construction and operation of reprocessing and recycling facilities. The main impetus behind Japan's decision to close the fuel cycle, by reprocessing its spent fuel and recycling plutonium and recovered uranium, is to reduce the country's dependence on foreign energy resources. The promotion of plutonium use in LWRs and ATRs in the 90's will form the solid basis and industrial experience for later utilization in FBRs, the leading power reactors in Japan in the next century. After the Tokai Mura reprocessing first unit, the second step is the construction and operation of the Japan Nuclear Fuel Limited (JNFL) facility, Japan's first private reprocessing plant, which will have an annual capacity of 800 metric tons. Sited at Rokkasho Mura (Aomori Prefecture), the plan is scheduled to begin storing spent fuel in 1995 and start reprocessing in 2001. Transfer of foreign technology is now underway, mainly from FRANCE.

Japan has long-term reprocessing contracts with the European reprocessing firms BNFL and COGEMA for more than 5,000 metric tons of fuel to be reprocessed. COGEMA has already started to reprocess part of the 2,800 metric tons of Japanese fuel in the La Hague UP3 facility. The 2,500 metric tons committed to BNFL are scheduled to be processed from 1993 to 2002 as a part of the baseload charge of the THORP plant. The quantities of plutonium owned by the Japanese utilities and generated by these reprocessing operations shall be transported back to Japan for recycling in LWRs as MOX fuel, and in ATRs and FBRs reactors presently operated or under construction. A shipment of Pu oxide has been carried out at the end of 1992. Later, plutonium will be fabricated into MOX fuel in Europe and then shipped back. Demonstration programs of MOX fuel irradiation in both PWR and BWR are carried out, preparing an industrial utilization in the second half of the 90's.

As part of the reprocessing operations, high level wastes are vitrified. An interim storage facility for vitrified high level waste is currently being constructed at Rokkasho Mura and will receive its first canister of glass (returned *from France*) by end of 1994. After a 50-year storage, they will be permanently disposed of in a geologic repository to be established under government responsibility.

On the same site of Rokkasho Mura, JNFL is operating since the end of 1992 a LLW near surface storage facility. All the LLW generated in Japan, or in Europe through the reprocessing contracts with BNFL and COGEMA, will be stored there.

A vast R&D program is also implemented to separate and transmute the TRU wastes (transuranic or actinides). The so-called OMEGA project began in 1989 and will be pursued over the next 10 years. In parallel, R&D on FBR fuel reprocessing is implemented.

The Rokkasho Mura plant will not be large enough to absorb the Japanese production of spent fuel (1100 metric tons per year in 2000). Thus, a second private reprocessing plant is scheduled in Japan with a start-up around the year 2010.

The Japanese are now completing their nuclear fuel cycle, in particular by recycling plutonium and reprocessed uranium.

As reprocessing contracts (domestic or foreign contracts) do not cover for the time being all the needs of the utilities, and as the recycling capacities are still limited, it is likely that a dry interim buffer storage of spent fuels could be considered during the transitional period.

CONCLUSION

As we have seen in this overview, every country has its own approach based upon rational, and also irrational criteria, to these complex issues. Strong economic, industrial, commercial and political considerations are involved, while different philosophies conflict under the cover of the magic word of "ecology".

What might be the ecological approach to "proper management" of nuclear spent fuel and waste? Of course, we could discuss at length the meaning of "proper management" as it is perceived in various countries, depending upon national habits, cultures and in particular the relations between the public and the bodies and administrations in charge of such questions. A reasonable understanding of the expression might be "taking care of the radioactive materials in such a way that the public health is not threatened, neither now nor in the future, and the environment is not spoiled". But this leaves room for interpretations and questions such as: how long in the future should we project to protect the biosphere from radioactive releases, and of course how completely should we reduce the activity released in order to have no impact on health? We know that "radical" answers to those questions are given by the antinuclear people : nuclear waste must be isolated from the biosphere <u>forever</u>, and the isolation must be <u>complete.</u> As reasonable, scientifically educated people, we know well that such conditions are as strictly impossible to meet as it would be to reduce to zero the probability of any type of occurrence.

Now, I will try to summarize how we understand the strategies developed by the various nuclear countries that we have described in this overview:

- Recycling is not favored in countries, like US and Canada, where the need for energy economy is not perceived as so immediate, because of their vast domestic resources. This is also more or less the case of Sweden which had banned its nuclear power program, on the grounds of ecological consideration. It must be noticed that such attitude can develop without risks in an atmosphere of general welfare. When recycling of Pu is rejected on the emotional grounds of proliferation of nuclear weapons, reprocessing is banned for the benefit of a direct disposal technology which does not yet exist.
- Several countries embarked on nuclear programs, in Asia and in Europe, have not yet made their decision for their ultimate spent fuel management, and they buy time through spent fuel interim storage.
- Reprocessing and recycling is the strategy followed by Russia which relies upon a solid experience in that field and could intend to emerge as an industrial operator. It will be of the utmost importance to monitor the quality of this program.
- Recycling of energy materials contained in spent fuel is favored and implemented by the countries most devoted to a long-term nuclear power program like France and Japan. They need independent resources and they believe that recycling through reprocessing is the optimum answer to the management of residual waste in terms of volume reduction and protection of environment. Most of the European countries are devoted to such strategy, even if in Germany, contestation is developing under the cover of nonproliferation and environmental objectives.

To conclude, we believe that a responsible course of action in front of these challenges includes three tasks:

- Implement satisfactory, industrially proven and economically acceptable technologies instead of waiting for future advanced, ideal, solutions... that next generation(s) would (hopefully) discover.
- Make people understand that in fact, with fuel recycling, the nuclear industry has been able to solve its waste problems better than many other industries, and that the impact on the environment is already at an excellent low level.
- Stay active in further technical improvements, based on current industrial performances and experience, capable to meet future more stringent conditions.