# Management of recyclable fissile and fertile materials

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**The possibility of recycling fuel is a very attractive – and nearly unique – feature of nuclear energy systems. The fissile and fertile materials contained in spent nuclear fuels and enrichment plant tails, for example, may be retrieved and re-used to provide additional energy. Doing so also reduces the amount and radiotoxicity of waste that will ultimately need to be sent to repositories.**

While recycling spent nuclear fuel becomes increasingly attractive in the context of renewed interest for nuclear energy and of sustainable development goals, extended interim storage and direct disposal of recyclable materials remain the favoured options by many countries. The recyclable materials which are not intended to be re-used may be disposed of in a safe way, guaranteeing their isolation from the biosphere over very long periods of time until they become harmless for humans and the environment.

The NEA study[1] on recyclable fissile and fertile materials was carried out in order to review technical, strategic and policy issues raised by the management of such materials, and to provide insights into the opportunities and challenges offered by alternative options. The materials considered include: spent fuel; depleted uranium from enrichment plant tails; separated uranium and plutonium from commercial reprocessing plants; ex-military materials (highly enriched uranium and plutonium) declared excess to national security by the Russian Federation and the United States; and thorium inventories.

This article is based on the study's analyses, findings and conclusions. It provides an overview of the quantities and potential energetic value of recyclable materials available worldwide. The main advantages and drawbacks of the two management options that may be adopted are also described.

## Inventories of recyclable materials

Existing inventories of recyclable fissile and fertile material represent a potential energy source important enough to be of significance in a long-term policy perspective, and more recyclable materials are arising continuously. The operation of the current fleet of nuclear power plants results in some 10 000 tonnes of spent fuel per year.

Table 1 gives an overview of the amounts of separated recyclable materials in stock worldwide at the end of 2005 and provides estimates of their potential value in terms of fuel supply. It shows that the present stockpile of recyclable materials represents almost 4 000 reactor-years worth of fuel

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Table 1. **Inventory of separated recyclable materials**

| Source | Quantity (tHM) | Natural U equiv. ($10^3$ tU) | Reactor-years of supply * |
|---|---|---|---|
| Ex-military highly enriched uranium (HEU) | 230 | 70 | 420 |
| Ex-military plutonium | 70 | 15 | 90 |
| Plutonium | 320 | 60 | 380 |
| Reprocessed uranium | 45 000 | 50 | 300 |
| Enrichment tails | 1 600 000 | 450 | 2 650 |

** Based on a 1000 MWe LWR operating at 80% load factor.*

with existing reactor technology. In other words, recycling the entire inventory of separated materials in reactors currently in operation would provide them with an additional 10 years of fuel supply, increasing by more than 10% the 85 years of supply offered by identified uranium resources.[2]

The enrichment plant tails represent by far the largest potential energy content, but their exploitation would require extensive re-enrichment capacity which is not industrially available today. Furthermore, the economic viability of this option might be questionable with current technologies and at present natural uranium prices, even after recent spot price increases.

The inventories included in Table 1 do not include spent fuels accumulated in interim storage facilities which would require reprocessing prior to their eventual recycling. If all accumulated spent fuel were to be reprocessed, some 1 700 tonnes of plutonium and 190 000 tonnes of natural uranium equivalent would be made available for fuelling nuclear power plants, representing around seven and a half years of supply for the fleet currently in operation.

## Management options

There are two options for the management of recyclable materials: final disposal and recycling. Both options will ultimately require final waste repositories, but the approach chosen will have a drastic impact on the size and commissioning date of the required repositories. Long-term storage is not a viable alternative; it is an interim measure that allows postponing a final decision.

The inventories of materials that are not being processed in nuclear fuel cycle facilities are stored in different physical and chemical forms on various sites. In all OECD countries, stringent regulations and norms are in place regarding the transport, storage and processing of those materials, ensuring that radiological impacts to health and the environment are as low as reasonably achievable.

The disposal of recyclable materials, including spent fuel, can be achieved in a safe and economically viable way with currently available technologies. While no spent fuel has been packaged for final disposal yet, approaches which exist or are under development for low-level, intermediate-level and high-level waste will be considered for suitability in spent fuel disposal applications. Regarding disposal, there is a general consensus that geological disposal offers a reliable and safe solution for present and future generations at affordable costs. Projects under development in several countries should lead to the commissioning of repositories within one or two decades.

In countries which are not considering the recycling option, timely disposal of recyclable materials is a relevant solution to avoid long-term storage burdens and costs, and to eliminate future financial liabilities associated with extended interim storage. On the other hand, final disposal of potentially valuable materials may be considered a "non-sustainable" option by some stakeholders. Therefore, current approaches tend to favour retrievable solutions that would eventually allow recycling if and when it becomes the preferred solution.

All options will ultimately require the disposal of radioactive waste, but some alternatives reduce the volumes and radiotoxicity of waste more than others. Repository designs and sizes should be adapted to the options chosen.

Recycling fissile and fertile materials can significantly increase the energy content extracted from natural uranium and thorium, extend the lifetime of nuclear fuel resources and enhance the sustainability of nuclear energy. When the recycling option is adopted, its main goals are generally a better utilisation of the energy content of natural resources and a reduction of the volumes and radiotoxicity of waste. Recycling fissile and fertile materials provides additional fuel resources and decreases the amount of plutonium and minor actinides to be disposed of, thereby reducing the long-term stewardship of radioactive waste.

A few examples illustrate the wide range of opportunities offered by alternative recycling options. The reprocessing of spent fuel from current light water reactors (LWRs) followed by recycling of uranium and plutonium in those reactors can reduce the specific, per kWh, fresh uranium consumption of existing nuclear energy systems by 50%. Advanced systems based on fast neutron reactors, on the other hand, could multiply by more than 50 the energy produced per tonne of natural uranium consumed.

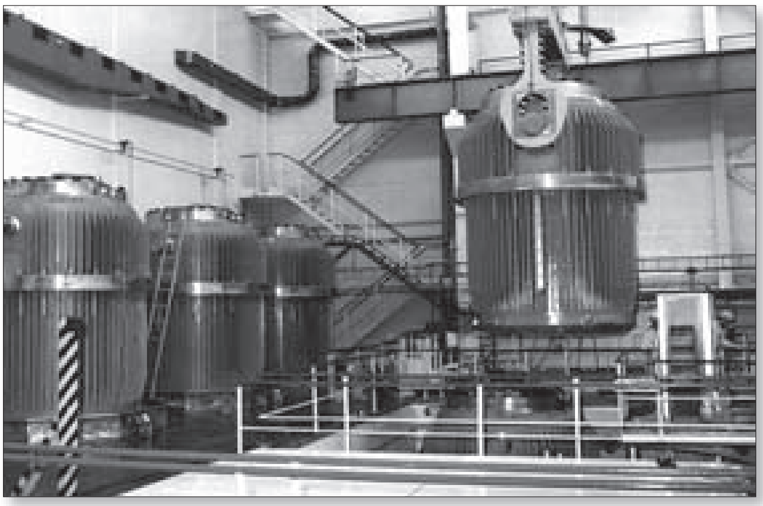
The efficiency of recycling depends on the mix of nuclear energy systems used and on the timing of their deployment. A major finding from the analysis of alternative options for the management of recyclable materials is that the amount of energy retrieved is highly sensitive not only to reactor types and the fuel cycle schemes chosen, but also to the timing of their deployment. The most efficient strategies are likely to involve nuclear systems capable of using various materials in a synergetic manner (e.g., plutonium and depleted uranium in fast neutron reactors). Transition scenarios from once-through to fully closed fuel cycles deserve thorough analyses in order to identify the best strategies, taking into account the size and development rate of the national, regional and/or global nuclear fleet.

Regarding the minimisation of waste volumes and radiotoxicity – a major issue for nuclear energy deployment in a long-term, sustainable development perspective – recycling provides significant benefits. It postpones the need for final disposal of high-level waste and, more importantly, reduces the amount and radiotoxicity of waste to be disposed of, especially if advanced systems designed for partitioning and transmutation of minor actinides are included in the nuclear power fleet.

## Issues, challenges and opportunities

All strategies to manage recyclable materials require the implementation of strict measures to ensure adequate levels of safety, radiological protection, proliferation resistance and physical protection. The legal and regulatory regimes in place in OECD countries provide robust frameworks in this regard.

How much waste will ultimately need to be sent to repositories?



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There is significant industrial experience in several countries on various steps of the alternative options (recycling some fissile materials, mainly plutonium, for example), and experts are confident that all recyclable fissile and fertile materials can be managed in a safe and reliable manner. Existing technologies already enable the partial exploitation of the energy content of recyclable materials. For example, the retrievable energy content of depleted uranium inventories using current technologies is very high, exceeding the energy content retrievable from plutonium inventories used in nuclear energy systems of the present generation. However, industrial enrichment capabilities would need to be adapted in order to process depleted uranium stockpiles.

The energy content that may be recovered from recyclable fissile and fertile materials would vary dramatically depending on the recycling options chosen and the strategies adopted for their implementation. Energy content could be multiplied by 2 to more than 50 times, as described above.

At the policy level, international co-operation is essential to address some of the issues raised by the management of recyclable fissile and fertile materials, which are difficult to tackle on a national level, especially for countries with limited nuclear energy infrastructures. Collaboration between countries could help to provide solutions which are optimised from a global perspective and facilitate the implementation of adequate infrastructures which would not otherwise be viable at the national level.

The management of recyclable fissile and fertile materials requires infrastructures and facilities that are unlikely to be technically and economically viable in all countries where nuclear power plants are or will be operated. The implementation of multinational, regional and/or international facilities could provide a broader range of options to all countries, including those with small- or medium-size nuclear power programmes.

Research and development programmes undertaken in many countries aim at enhancing the technological performance, safety and economics of disposal and recycling options. Joining strengths within international R&D endeavours offers effective means to develop advanced technologies adapted to the social, environmental and economic requirements of future generations.

## Concluding remarks

Inventories of recyclable fissile and fertile materials represent a large potential energy resource which could help countries relying on nuclear energy to enhance their security of supply while reducing greenhouse gas emissions from their energy sector at affordable costs. A thorough review of management options available to store, re-use or dispose of recyclable materials demonstrates that a range of technically, environmentally and economically viable solutions are in place or being developed for all materials.

There is no single option that is optimal in all cases, but there is a broad range of solutions from which to chose according to each specific case and taking into account the priorities of policy makers. These solutions need to be integrated into long-term national energy policies and to include prospective views on the evolution of the role of nuclear systems in global energy supply.

The best option for the management of recyclable materials will depend on such factors as the specific situation of the owners of the materials, the national energy policy of the country concerned, the size and characteristics of its nuclear fleet, the availability of a repository, the nuclear industry infrastructure available and the national regulatory framework.

The assessment of alternative options for the management of recyclable materials should be based on a multi-criteria analysis taking into account economic, environmental and social factors in the overall context of national energy policies. Issues such as security of energy supply, stewardship burden imposed on future generations and proliferation resistance have a much larger impact on the assessment of alternatives than variations in the fuel cycle cost, which in any case represents today less than 20% of the total cost of electricity generated by nuclear power plants.

A prerequisite to decision making in this field is to identify irreversible measures which would foreclose the choice of other options at a later date. Generally, reversibility is a desirable characteristic as it keeps the possibility of re-considering options in the future open, as well as taking advantage of technology progress and changes in the socio-economic landscape. ■

### References

1. NEA (2007), *Management of Recyclable Fissile and Fertile Materials*, OECD, Paris.
2. NEA and IAEA (2006), *Uranium 2005: Resources, Production and Demand*, OECD, Paris.