RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING IN THE NETHERLANDS

1. NATIONAL AND REGULATORY FRAMEWORK

1.1 National framework

1.1.1 Overview of national policy

One of the leading principles in the Dutch regulation is that the primary responsibility for safety rests with the operator of a facility. This applies equally for protection of the workers, the public and the environment against the effects of radiation, but also for nuclear safety and for the safe management of spent fuel and radioactive waste. The regulatory body has responsibility to ensure that the operators meet the applicable legal and regulatory requirements.

The government policy on spent fuel management acknowledges the primary responsibility for safety of the operators: the decision on whether or not to reprocess spent fuel is in the first place a matter of the operators of the NPP's. In the early days the operators have decided in favour of reprocessing their spent fuel for economic reasons. This decision was endorsed by the government. The operator of the Borssele NPP has recently extended the contract with the reprocessing facility at la Hague, France.

The Netherlands' policy on radioactive waste management is based on a report that was presented to parliament by the Government in 1984. This report covered two areas. The first concerned the long-term interim storage of all radioactive wastes generated in the Netherlands, and the second concerned the Government research strategy for eventual disposal of these wastes.

Consideration of this report led, in regard to the first area, to establishment of the Central Organisation for Radioactive Waste (COVRA) in Borsele, and in regard to the second, to establishment of a research programme on disposal of radioactive waste. Pending the outcome of research on the feasibility of geological disposal, and assurance of political and public acceptance, it was decided to construct an engineered surface-storage facility with sufficient capacity for all the radioactive wastes generated in a period of at least 100 years.

Long term storage

An additional reason why the preferred choice was made in favour of long term storage is the fact that the cumulative waste volume that is actually kept in storage right now is a few thousand m^3 of LILW and just a hundred m^3 of HLW. For such a small volume the construction of a deep geologic disposal facility cannot be justified on economical reasons. The waste volume collected in a period of 100 years is considered to be large enough to make a disposal facility viable. So a period of at least 100 years of storage in buildings is required. This creates at least six positive effects:

- Public acceptance is quite high for long term storage. The general public has more confidence in physical control by today's society than in long-term risk calculations for repositories even when the outcome of the latter is a negligible risk.

- There is a period of 100 years available to allow the money in the capital growth fund to grow to the desired level. This brings the financial burden for today's waste to an acceptable level.

- During the next 100 years an international or regional solution may become available. For most countries the total volume of radioactive waste is small. Co-operation creates financial benefits, could result in a higher safety standard and a more reliable control.

- In the period of 100 years the heat generating waste will cool down to a situation where cooling is no longer required.

- A substantial volume of the waste will decay to a non-radioactive level in 100 years.

- A little bit more than 100 years ago, mankind was not even aware of the existence of radioactivity. In 100 years from now new techniques or management options can become available.

Consequently, it was concluded in the policy report of 1984 that a dedicated solution for the Netherlands is to store the waste in buildings for a period of at least 100 years and to prepare financially, technically and socially the deep disposal during this period in such a way that it can really be implemented after the storage period. Of course at that time society has the freedom of choice between a continuation of the storage for another 100 years or to realise the final disposal.

Disposal

In 1993 the government adopted, and presented to parliament, a position paper on the long-term underground disposal of radioactive and other highly toxic wastes. This forms the basis for further development of a national radioactive waste management policy, which now requires that any underground disposal facility be designed in such a way that each step of the process is reversible. This means that retrieval of waste, if deemed necessary for whatever reason, would always be possible.

The reasons for introducing this concept of retrievability came from considerations of sustainable development. Waste is considered a non-sustainable commodity whose generation should be prevented. If prevention is not possible, the preferred option is to reuse and/or recycle it. If this in turn is not practical at present, disposal of the waste in a retrievable way will enable future generations to make their own decisions about its eventual management. This could include the application of more sustainable management options if such technologies become available. The retrievable emplacement of the waste deep underground would ensure a fail-safe situation in case of neglect or social disruption.

Although waste retrievability allows future generations to make their own choices, it is dependent upon the technical ability and preparedness of society to keep the facility accessible for inspection and monitoring over a long period. It also entails a greater risk of exposure to radiation and requires long-term arrangements for maintenance, data-management, monitoring and supervision. Furthermore, provision of retrievability in disposal deep underground is likely to make the construction and operation more complex and costly.

1.1.2 Overview of relevant institutions

Regulatory body

All activities with radioactive materials (import, transport, use, treatment, storage, disposal), are regulated under the Nuclear Energy Act and in most cases a license is required.

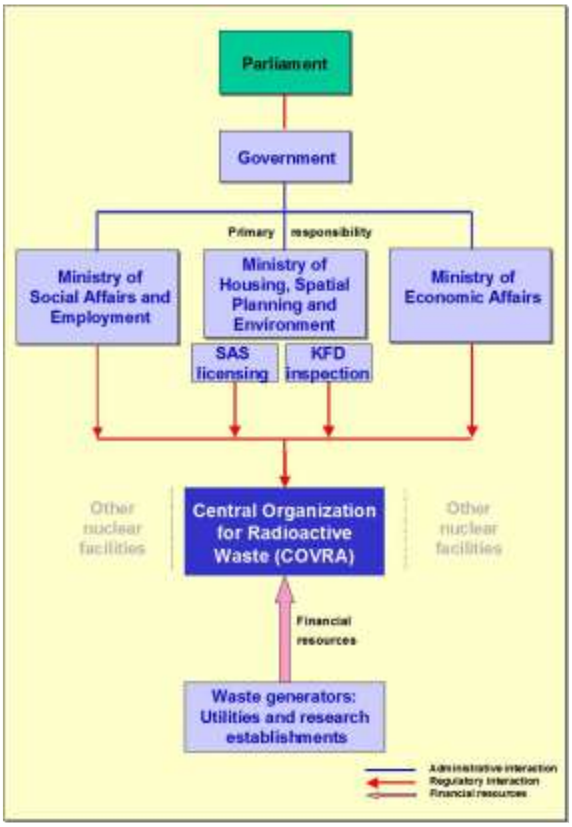

Figure 1. Organization of the regulatory body.

Licensing of nuclear facilities is a joint responsibility of the Directorate for Chemicals, Waste, Radiation Protection (SAS) of the Ministry of Housing, Spatial Planning and Environment (leading), the Ministry of Economic Affairs, and the Ministry of Social Affairs and Employment. For medical applications the ministry of Health, Welfare and Sport is also involved. Inspection of nuclear activities is carried out by the Nuclear Safety Department (KFD) and the Regional Inspection (south-west region) of the VROM Inspection, both part of the Ministry of Housing, Spatial Planning and Environment. An organisational chart is represented in Figure 1.

Waste Management Agency

The Central Organization for Radioactive Waste (COVRA) was established in 1982 and designated in 1987 by a governmental decree as the implementing organization responsible for radioactive waste management in the Netherlands. It was set up as a private company, owned by two nuclear utilities [Dodewaard (30%) and Borssele (30%)], the Energy Research Foundation (ECN, 30%) and the government (10%).

As a result of the liberalisation of the electricity market as well as due to the dim perspectives for new nuclear energy, the decision was made to transfer the ownership of COVRA to the government. As of 15 April 2002 the State is 100% owner of COVRA.

1.2 National, technical regulatory organization(s)

1.2.1 Regulatory function

The Nuclear Regulatory Body in the Netherlands is formed by several entities, of which the most important are SAS and KFD, both from the Ministry of Housing, Spatial Planning and the Environment. These organisations will be described in more detail later in this section.

According to the Nuclear Energy Act, the Ministry of Social Affairs and Employment and the Ministry of Economic Affairs are also part of the Regulatory Body. The Directorate Health and Safety at Work within the Ministry of Social Affairs is responsible for the legal aspects of radiation protection of workers. About one man-year is allocated to this work.

The Directorate-General for Energy (Ministry of Economic Affairs) is responsible for aspects concerning the energy demand and energy supply. About three man-year is devoted to Nuclear Energy Act matters.

Directorate for Chemicals, Waste, Radiation Protection (SAS)

The main task of this Directorate is policy development and legislation in the field of radiation protection and nuclear safety, particularly in relation to the public and the environment. The Directorate is also responsible for licensing of nuclear installations and nuclear transports in general (all procedural aspects), as well as for all aspects of radiation protection and external safety. It has expertise in the following disciplines: radiation protection, nuclear safety, risk assessment, radioactive waste management including disposal and legal and licensing matters. These disciplines are grouped together in the Radiation Protection, Nuclear and Biosafety Division (SNB).

The total professional staff of SAS, assigned to nuclear, waste, radiation and transport safety, including legal support and management is currently about 10 full time staff equivalents. SAS devotes about four man-years per annum to nuclear licensing and safety issues relating to all nuclear facilities.

Nuclear Safety Department (KFD)

The main tasks of the KFD consist of regular inspection of licensees of nuclear facilities, including waste management facilities. It also performs the regulatory review of safety assessments submitted by licensees in connection with license applications or as a result of specific license requirements. The KFD encompasses all major reactor safety, radiation protection, security and safeguards and emergency preparedness disciplines. The core disciplines include mechanical and electrical engineering, metallurgy, reactor technology, safety assessment, quality management and security and safeguards. The basic policy of the KFD is that all core disciplines should be available in-house in order to ensure that the main tasks can be performed. The remaining work is then subcontracted to third parties or technical support organizations.

1.2.2 Organization and resources

The regulatory body is part of the national government and it receives its funds from the regular annual budget, allocated to each of the constituent ministries. This budget is meant to cover the running costs of the organization and expenses to contract research or, if applicable, to outsource some regulatory tasks. Consequently, for SAS the duties mentioned above do not require any specific additional budget, apart from resources to cover the annual contribution to support the work of the National Institute for Public Health and the Environment (RIVM).

Budgetary constraints have prompted the KFD to adopt a restrictive staffing recruitment policy. For areas, not being core activities, in which its competence is not sufficient or where a specific in-depth analysis is needed, the KFD has a budget at its disposal for contracting external specialists.

Although a fee is raised from licensees for obtaining a license, which is commensurate with the potential hazard of the facility or activity, it is not aimed to achieve full cost recovery for the regulatory functions of the regulatory body.

1.3 National implementing organizations

1.3.1 Scope of responsibility

In the policy document of 1984, mentioned before, the government decided to confer the responsibility for the safe management of radioactive waste to a centralized organization, COVRA, the Central Organisation for Radioactive Waste. COVRA operates a facility at the industrial area Vlissingen-Oost in the south-west of the country. The main considerations underlying this decision were:

- the relatively small amounts of radioactive waste being produced in The Netherlands
- waste management requires specialist care, and this is easier to achieve in one central facility.
- financial reasons, since one central facility can be operated at lower cost.

In discharging it responsibilities COVRA has established measures to prevent radioactivity to escape uncontrolled into our environment. In practice this means that radioactive waste is managed according to the ICM principles (Isolate, Control and Monitor).

Nearly all radioactive waste produced in The Netherlands is managed by COVRA. It has a site available of about 25 ha at an industrial area where the conditioning and the long-term storage (at least 100 years) takes place. The facilities for low- and medium-level waste were erected between 1990 and 1992. In 2000 a storage building for the storage of very low level radioactive waste from ore processing industries was commissioned (TENORM waste). The construction of a naturally cooled storage facility for high level waste started in 1999 and has been commissioned in 2003. The construction of a storage facility for depleted uranium started in 2003 and the facility became operational in 2004.

All these different kinds of radioactive waste remain stored in engineered surface facilities for a period of at least 100 years. During this 100 years' storage period consideration will be given to the final destination of the waste. Part of the LILW is expected to have decayed into non-radioactive material and can therefore be managed as such. For the waste that is still radioactive disposal in suitable layers in the deep underground of the Netherlands is the anticipated solution. Alternatively, international solutions may have become available or new management techniques might have been developed.

1.3.2 Organization and resources

COVRA is a small implementing organization consisting of 48 full staff equivalents employed by the end of 2006. Due to an increase in the quantities of radioactive waste offered for conditioning and storage, the year could be concluded with a net positive result.

It is accepted in the Netherlands that financing of radioactive waste management is in conformity with the “polluter pays” principle. Hence, the fees charged by COVRA upon collection of LILW include all direct costs for transport, conditioning and storage as well as financial provisions for the costs of future storage and eventual disposal. COVRA assumes full ownership of the waste, and fees will not be adjusted retrospectively. The part of the fee attributable to costs of future disposal is placed in a capital growth fund. This fund is expected to grow to the necessary level during the 100-year period of interim storage, and its adequacy is analysed periodically.

Appropriate arrangements were made for transfer of the fund at the time of transfer of COVRA ownership to Government, and its previous owners are now discharged from any further liabilities for radioactive waste management. COVRA, and ultimately the State, now has full financial responsibility for the management of radioactive waste in the Netherlands.

2. LEGAL FRAMEWORK

2.1 Primary Legislation and General regulations

The following are the main laws to which nuclear facilities and activities with radioactive substances are subjected:

- the Nuclear Energy Act (1963, as amended 2004); (Kew);
- the Environmental Protection Act (1979, as amended 2002); (Wm);
- General Administrative Law Act (1992, as amended 2003); (Awb).

The basic legislation governing nuclear activities is contained in the Nuclear Energy Act. The Nuclear Energy Act has historically been designed to encourage the use of nuclear energy and techniques with radioactive substances, as well as to lay down rules for protection of the public and workers against the risks. The Act sets out the basic rules on nuclear energy, makes provisions for radiation protection, designates the various competent authorities and outlines their responsibilities.

A number of decrees have also been issued containing additional regulations. The most important of these in relation to the safety aspects of nuclear installations are:

- the Nuclear Installations, Fissionable Materials and Ores Decree (Bkse), and
- the Radiation Protection Decree (Bs).
- the Transport of Fissionable Materials, Ores, and radioactive Substances Decree (Bvser).

The Nuclear Installations, Fissionable Materials and Ores Decree regulates all activities (including licensing) that involve fissionable materials and nuclear facilities. The Radiation Protection Decree regulates the protection of the public and workers against the hazards of all ionising radiation. It also establishes a licensing and notification system for the use of radioactive materials and radiation emitting devices, and prescribes general rules for their use. The Transport of Fissionable Materials, Ores and Radioactive Substances Decree deals with the import, export and inland transport of fissionable materials, ores and radioactive substances by means of a reporting and licensing system.

The Nuclear Energy Act and the above mentioned decrees are in compliance with the relevant Euratom Directive laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. This Directive (96/29/Euratom) is implemented in the relevant Dutch regulations.

The Environmental Protection Act, in conjunction with the Environmental Impact Assessment Decree, stipulates (in compliance with EU Council Directive 97/11/EC; see also the section on Article 8) that an Environmental Impact Assessment must be presented when an application is submitted for a licence for a nuclear installation.

In the case of non-nuclear installations, this Act regulates all environmental issues (e.g. chemical substances, stench and noise); in the case of nuclear installations, the Nuclear Energy Act takes precedence and regulates both the nuclear issues and the conventional environmental issues mentioned before.

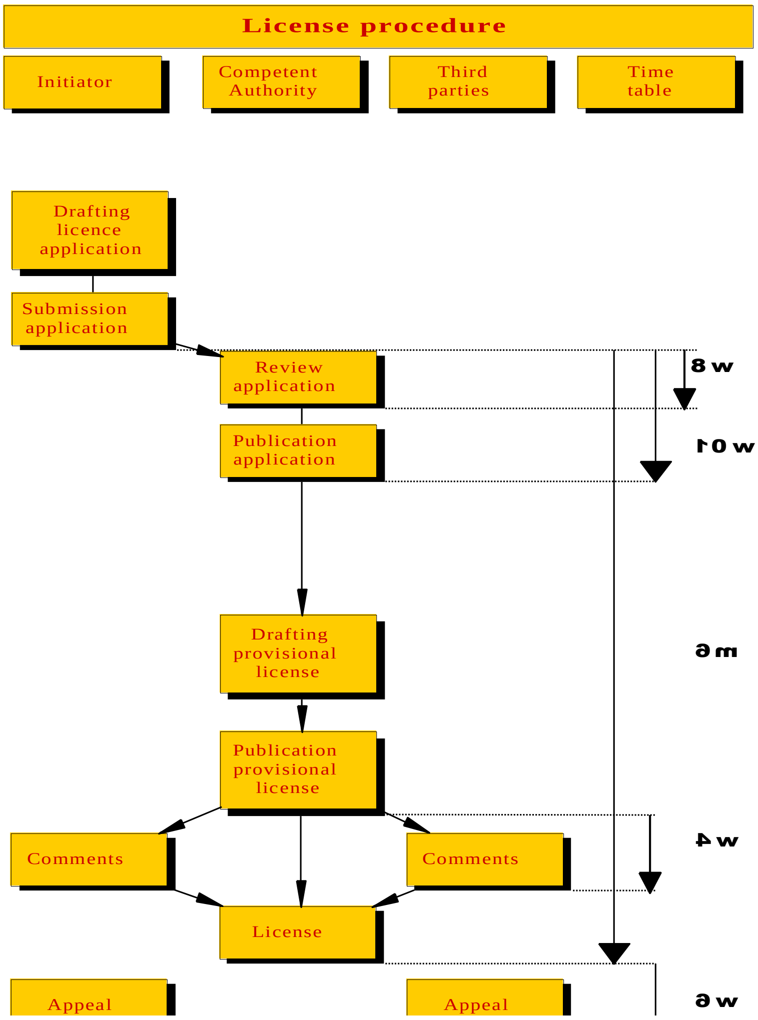

Figure 2. Schematic diagram of the license procedure

The General Administrative Law Act sets out the procedure for obtaining a licence, and also describes the involvement of the general public in this procedure (i.e. providing information and allow for objections and appeals). In principle the discrete steps in the licensing procedure observe a fixed term timetable (see Figure 2). Consequently, in theory there would not be a difference between the licensing procedure of a nuclear power station and that of a small radioactive source. In practice, in the case of complex situations – and a license for construction and operation of a power reactor of for a radioactive waste management facility is usually considered a complex situation – there is a legal provision that allows relaxation for one or more steps. In particular this situation arises when there are many objections against the issue of the license or when an appeal is filed with the high administrative court (State Council).

2.2 Regulations concerning specific activities or facilities

2.2.1 Radioactive waste management

Article 21 of the Nuclear Energy Act provides the basis for a system of more detailed safety regulations for certain categories of facilities or activities. Some of these regulations, which are generally referred to as Nuclear Safety Rules (NVR's), have been developed in the areas of design, operation and quality management of nuclear power plants. These have also been utilised for the design and operation of other nuclear facilities, such as radioactive waste management facilities. However, there are plans to develop dedicated regulations for radioactive waste management.

2.2.2 Decommissioning

So far the decommissioning of nuclear installations is regarded as a special form of modification and is treated in a similar way. In 2002 the Nuclear Installations, Fissionable Materials and Ores Decree (Bkse) was amended to meet the requirements set by Council Directive 96/29/Euratom with regard to the protection of workers and members of the public from the hazards of ionising radiation. The Directive had introduced a new license requirement for the shut-down and decommissioning of nuclear installations. The amendment of Bkse had the effect of incorporating these regulations in Dutch legislation.

Further, pursuant to this amendment of the Bkse, an operator of a new nuclear power plant is already obliged to submit an outline decommissioning plan as part of the documentation when applying for a licence for the design and construction of the plant. This aims to achieve a proper logistical set up for the plant and the right choice of materials for its components, which would make it easier to decommission and dismantle the plant in the future, and would ensure that less radioactive waste is created.

More recent draft modifications of both the Nuclear Energy Act (Kew) and the Bkse aim to introduce more specific regulation on decommissioning. The new article 15g of the Kew requires that an operator of a nuclear facility provides financial security for the later decommissioning of that facility.

In article 22 of the Bkse it is stipulated that for any new build NPP dismantling shall start immediately after closure and that these activities be completed as soon as possible.

Article 23 of the new draft Bkse includes the additional requirement that the decommissioning plan be updated periodically (every 5 years).

The aforementioned draft modifications have still to be approved by the Parliament. It is expected that the proposed changes will be discussed with the Parliament in the first semester of 2008.

It is envisaged to develop more detailed regulation on decommissioning as a publication in the Nuclear Safety Rules (NVR's) series.

2.3 Guidance on implementation

2.3.1 Radioactive waste management

A license for a spent fuel management facility is only granted if the applicant complies with the national requirements and, more in general, with international (IAEA) established safety goals, codes and guides, as well with the international state of the art. Also the applicable parts of the IAEA codes on Design, Operation and Quality Assurance for NPP's must be covered or incorporated in the Safety Report (SR), which is submitted to the regulatory body. A typical example are the requirements against the site specific external hazards, such as military aircraft crashes, external flooding, seismic events and gas cloud explosions.

After obtaining the license but before construction the licensee drafts and submits to the regulatory body the Safety Analysis Report (SAR) and supporting topical reports, which give a detailed description of the facility and present an in-depth analysis of the way in which the facility meets the SR and the international state of the art.

After construction and commissioning of the spent fuel management building the licensee submits the report with description of the as built-facility and the results of the commissioning to the regulatory body for approval before start of the routine operation. Since full compliance is expected with the Safety Report, no formal update of the safety assessment or environmental assessment are foreseen and there will be no need for revision of the Safety Report, which is the basis of the license. However, all the results of the commissioning programme are incorporated in a full update of the detailed SAR.

As IAEA regulations are fairly general and hence lack technical detail, the licensing basis for the HABOG building was based on the French state of the art for SF/HLW storage. As an independent assessment tool for the SAR the USA ANS/ANSI standard 57-9-1992 was utilised.

2.3.2 Decommissioning

The Dodewaard NPP is the only nuclear facility that is currently in a state of decommissioning. It was shut down in 1997 after 28 years of operation. In May 2002 a license was granted to GKN, the operator of the NPP Dodewaard, to bring and keep the plant in a safe enclosure. In July 2005 the phase of safe enclosure was achieved. The safe enclosure period for the NPP Dodewaard is scheduled to last 40 years. In the license applying for this safe enclosure period the operator is required to appoint a radiological expert, who is responsible for all radiation protection issues.

In the case of the Dodewaard NPP the cost of decommissioning was calculated with the programme STILLKO 2, a cost evaluation model, developed by NIS Ingenieurgesellschaft mbH. The STILLKO 2 programme has been used for the calculation of the decommissioning cost of other NPP's in Belgium and Germany. The programme has a structure which comprises the following basic elements:

- a structural plan
- a mass analysis
- an evaluation of working steps
- a time schedule

Although the STILLKO programme is an internationally recognized and widely applied methodology, there was a need to include feed back from practical decommissioning experience. Since it is envisaged that COVRA assumes in due time the responsibility for the decommissioning of the Dodewaard NPP, COVRA has a obvious interest in reliable estimates. It commissioned an additional study using a standardised cost units methodology1, supplemented with practical data. Not unexpectedly, the differences between the two calculations were substantial and further investigations are required to sort out these differences.

[1] A proposed Standardised list of items for costing purposes in the decommissioning of nuclear facilities, Interim technical document, NEA/OECD, 1999

3. WASTE MANAGEMENT STRATEGY AND CURRENT PRACTICE

3.1 Waste classification and quantities

Radioactive waste is defined as: a radioactive material for which no further use, reuse, or recycling is foreseen and which will not be discharged.[2]

Except for radioactive wastes with a half-life less than 100 days, which is allowed to decay at the sites where it has been generated, all radioactive waste produced in the Netherlands is managed by COVRA, the Central Organisation for Radioactive Waste. Long-term storage of all radioactive waste in buildings has been chosen as the preferred national policy. Disposal in suitable geological formations is envisaged in due time. Consequently, classification of the waste is based on practical criteria both derived from the need to limit exposures during the prolonged storage period and from the final disposal route.

Roughly there are three waste categories, namely LILW, HLW (non heat generating) and HLW (heat generating).

No distinction is made between short lived and long lived LILW as defined by the IAEA Safety Guide on Classification.[3] The reason for this is that shallow land burial is not applicable for the Netherlands. All categories of waste will be disposed of in a deep geologic repository in the future. The waste in the storage buildings for LILW is segregated according to the scheme in Table 1.

Category	*Type of radioactivity*
A	Alpha emitters
B	Beta/gamma contaminated waste from nuclear power plants
C	Beta/gamma contaminated waste from producers other than nuclear power plants with a half-life longer than 15 years
D	Beta/gamma contaminated waste from producers other than nuclear power plants with a half-life shorter than 15 years

Table 1. Low- and intermediate-level waste classified by type of radioactivity

3.1.1 Nuclear power plants

HLW, heat generating, is formed by the vitrified waste from reprocessing of spent fuel from the two nuclear power reactors in the Netherlands (Borssele and Dodewaard) and by the spent fuel of the two research reactors (Petten and Delft).

HLW, non-heat generating, is mainly formed by the reprocessing waste other than the vitrified residues. It also includes a small amount of waste from research on reactor fuel and some decommissioning waste.

HLW, heat generating, and HLW, non-heat generating, are stored in separate compartments of the HABOG.

The LILW from nuclear power plants consists of disposable protective clothing, plastics, paper, metals, filters and resins. Resins are conditioned with cement at the power plant to create a stable product, while all other waste is treated and conditioned at the central treatment and storage facility of the Central Organisation for Radioactive Waste (COVRA), located in Borssele. Some 100 m3 of conditioned LILW is generated annually, mainly at the Borssele NPP. Removal of activated components from the Dodewaard NPP currently contributes a small amount to the annual arisings of LILW, but this will stop in near future. Over a period of 100 years, the cumulative amount of LILW will be about 188 000 m3

High-level waste (HLW) arises mainly from reprocessing of spent fuel, and about 10 m3 is produced annually. Over the same period of 100 years, the cumulative amount of HLW, including decommissioning waste, will be about 3200 m3. A breakdown of the cumulative amounts of HLW by origin is represented in Table 1.

Type of HLW by Origin	Volume (m^3)
Heat-generating waste	
- Fuel elements and fissile residues	40
- Vitrified HLW	110
Non heat-generating waste	
- Decommissioning waste	2,000
- Reprocessing waste	850-900
- Other high activity waste	120

Table 2. Cumulative amounts of high-level radioactive waste

3.1.2 Hospitals, research and industry

The LILW arising from the use of radioactive materials in hospitals, research institutions and industry is highly varied. It includes liquids and solid materials such as paper, plastics, metals and glass, but also consists of animal carcasses, laboratory tools or equipment and sealed radioactive sources. All these forms of waste are treated and conditioned at the COVRA central treatment and storage facility. About 100 m3 of such conditioned waste is produced annually.

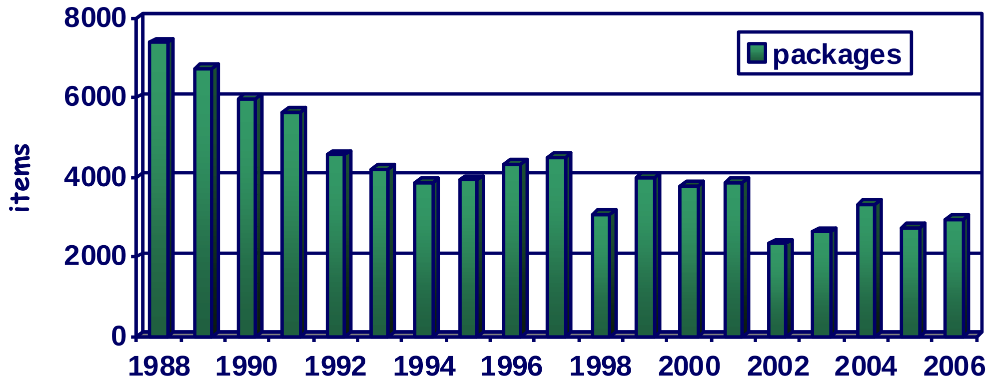

Figure 3. Annual arisings of LILW from hospitals, etc.

3.1.3 TENORM

In addition to the waste described above, relatively large volumes of very low-level radioactive waste is produced during the processing of some metal ores. This waste contains naturally occurring radionuclides whose concentrations have been enhanced by the technical operations involved. Hence it is described as Technically Enhanced Naturally Occurring Radioactive Material (TENORM) waste. This waste is usually generated in the form of a relatively stable product, such as a slag or calcinate, for which no further conditioning is needed. The annual production of such waste is about 1 000 m3.

3.2 Waste management strategy

As stated before, the national policy adopted for the management of radioactive waste is long-term storage. It is envisaged that without a significant extension of the national nuclear power programme, the cumulative amounts of waste are too small to justify the construction of a disposal facility much earlier than about 100 years. This estimate also assumes that all radioactive waste (from LILW to HLW) will eventually be placed in a geological repository in the deep underground. The national strategy to achieve these objectives follows a two tier approach:

- To limit the generation of radioactive waste to the extent possible

- To bring the waste in a robust conditioned form that will last during the envisaged storage period and that is likely to meet the acceptance criteria for a final disposal facility.

3.2.1 Waste minimization

Waste minimization can be achieved in different ways. The preferred method is to prevent the arising of radioactive waste. This method has been very successful in the areas of medical applications and scientific research, where in the last two decades increasingly short-lived radionuclides were used. The resulting radioactive waste was stored on site and could be disposed of as non-radioactive waste after full decay. The effect of this practice is clearly visualized in Figure 3.

Further the amounts of radioactive waste are minimized, if materials with low concentrations of radioactivity are reused or recycled. An example of this is the recycling of residues from industrial processing of raw materials, which contain slightly enhanced levels of natural radioactivity in the construction of roads or other public works. In order to facilitate recycling or reuse of these materials, the 2002 revision of the Radiation Protection Decree (Bs) allows mixing of radioactive residues with non-radioactive residues provided that these are used in the same process.

Also reprocessing of spent fuel from the NPP’s can be considered as recycling resource materials and thus contributing to waste minimisation. In the beginning of the nuclear era in the Netherlands the operators of the two NPP’s Dodewaard and Borssele decided in favour of reprocessing for economic reasons. Uranium prices were relatively high and it was considered that the reprocessed uranium and plutonium could be reused either in fast breeder reactors or as MOX in the more conventional light water reactors. Reuse of resource materials is definitely a way to reduce the amount of waste if not in an absolute sense, then at least relative to the electric output of the process. For a variety of reasons, but principally the low price of uranium ore, fast breeder reactors have not yet been deployed commercially. Reuse of uranium from reprocessing facilities, although not fully competitive with fresh uranium, occurs on a limited scale. The reuse of plutonium as MOX fuel in light water reactors is accepted as a method to reduce the plutonium stocks and is increasing steadily. The utility operating the Borssele plant has arranged for the recycling of its reprocessing products (uranium, plutonium); for the products of future Dodewaard fuel reprocessing, no decisions have been made as yet.

3.2.2 Waste conditioning

Particularly with a view to the long storage period, measures are needed to prevent radioactivity to escape uncontrolled into the environment. In practice this means application of the Isolate, Control and Monitor (ICM) principle to this kind of waste as mentioned in Section 1.3.

This can be done by ensuring that these materials are effectively embedded in concrete (low- and medium level waste) or in glass (high level waste) and isolated from the environment. COVRA achieves this by storing the treated waste in specially designed buildings. All operations, including storage, are carefully controlled by COVRA and monitored by government inspectors.

The storage and treatment buildings are designed to provide protection against possible incidents and accidents, commensurate with the hazards of the materials contained in them. It goes without saying that the storage building for HLW (HABOG) is of a particularly strong design. The concrete walls of the HABOG are 1.7 meters thick. No radiation can get through it. The building is so strong that it resists extreme external influences such as hurricanes, gas explosions, earthquakes and floods. Even the impact of an aircraft crashing onto it will not release any radioactive material. The HABOG is isolated from the environment and is kept under close monitoring and control. In this way safe storage is guaranteed.

3.2.3 Details of the COVRA treatment and storage facility

COVRA operates a centralised facility for management of LILW at Borssele. This facility was built between 1990 and 1992 and includes the following:

- An office building, including an exhibition centre;
- A building for the treatment of LILW;
- Storage buildings for conditioned LILW.
- A building for storage of wastes from ore-processing industries, i.e. TENORM waste.
- A storage building for depleted uranium oxide.

The building for treatment of LILW has buffer-storage areas for the different kinds of waste, and various treatment installations. The treatment installations became operational in 1993, and currently comprise the following:

- Super-compactor;
- Separator for organic/inorganic liquids;
- Dedicated incinerator for biological wastes;
- Dedicated incinerator for organic liquids;
- Shearing and cutting installation;
- Cementation station;
- Wastewater treatment system.

The HABOG storage facility mentioned above was commissioned in 2003. It is a vault-type facility with two separate compartments. One compartment is for storage of drums and other packages containing cemented or compacted fuel element cladding and other HLW. The other compartment is for storage of the heat-generating, vitrified HLW from reprocessing of spent fuel from the NPPs, and of unreprocessed spent fuel from the research reactors. Waste in the first compartment does not require additional cooling, but that in the second compartment does. The vitrified HLW and spent fuel are stacked on 5 levels in vertical, air-cooled storage wells. The storage wells are filled with an inert gas to prevent corrosion of the canisters and are equipped with a double jacket. Cooling-air flows, under natural convection, between the walls of the double jacket, thus avoiding direct contact of the cooling air with spent fuel or vitrified HLW canisters.

3.3 Waste management issues at national level

A major concern to be addressed in forthcoming year is the difficulty to maintain nuclear competence in a situation where the prospects of new nuclear energy are still uncertain. The initial plan to shut-down the NPP Borssele in 2003, followed by a complete phase out of nuclear energy, did not help to improve the situation.

Only recently the government has considered that closure of the NPP Borssele and replacing it with a fossil fuelled plant, could lead to an increase of greenhouse gases and consequently compromise the objectives of the Kyoto protocol. It was decided that, in principle, the NPP could continue operation, contingent on a political agreement with the operator to invest in research on sustainable energy solutions. In 2005 the Parliament approved an extension of the operation of the NPP Borssele until 2033 as well as the agreement between the government and the utility. Later on, the Energy Council recommended to the government that a discussion on new nuclear energy for electricity generation should be commenced at short notice, at least with a view to bridge a transition to a higher use of sustainable energy resources. Both the prolonged operation of Borssele and the increased interest for nuclear energy in general require that qualified personnel be available for a longer period.

The main problems ensuing from this scenario are the following:

- An aging workforce, with the prospect of many experts retiring within five years.
- An insufficient number of graduates with relevant studies from technical universities which could replace the vacancies.

The abovementioned developments have, at least at the level of the Regulatory Body, strengthened the determination to cope in a prudent way with the problem of retaining an adequately broad nuclear competence. So far serious shortcomings have been prevented by:

- Seeking efficiency gains by concentration of functions mainly within VROM.
- Outsourcing certain operational tasks to other national or international institutes.

In 2005 a pilot study was commissioned to make an inventory of the status regarding the organisation, the tasks and the likely developments of the regulatory body in the areas of nuclear and waste safety, nuclear security and safeguards and radiation protection.

A follow-up study started by the end of 2006 focused on the identification of tasks that are considered core activities and should be addressed by the regulatory body and on the best organisational structure to carry out these tasks. In this context the question of the required manpower and quality of the staff will be addressed. Also proposals will be made for those tasks that can be delegated to other organisations or can be performed by (private) organisations under contract. Furthermore the study will focus on the needs of human and financial resources for the next 10 years and will consider different scenarios with regard to the existence or planning of certain nuclear installations.

3.4 Research and development

3.4.1 Research infrastructure

The waning interest for and the limited deployment of nuclear energy for electricity production has affected the available capacity for nuclear and radiation research. The most important institutes which are conduct research in these areas on a regular basis include the following:

- The Nuclear Research and Consulting Group (NRG) in Petten, is the operator of the High Flux Research Reactor, and operates also hot cell laboratories. NRG has extensive expertise in the area of geological disposal of radioactive waste in salt formations.

- The Reactor Institute Delft (RID) operates a research reactor which supports education and research programmes on nuclear physics and reactor operation of the Technical University Delft.

- The National Institute for Public Health and the Environment (RIVM) is a State-owned independent institute specialized in environmental monitoring. It functions as the back-office for radiological information in the event of an emergency, provides projected dose data on the basis of dispersion calculations and monitoring data for the environment, drinking water and foodstuffs.

- The Netherlands Organisation for Applied Scientific Research is a private research foundation which accommodates a department with deep knowledge on the geology of the underground.

3.4.2 Contents of R&D plans

In 2001 the CORA research programme, aimed at demonstrating the technical feasibility of a retrievable underground repository in salt and clay formations, was concluded. The main conclusions of the CORA report were:

- Retrieval of radioactive waste from repositories in salt and clay is technically feasible. The disposal concept envisages the construction of short, horizontal disposal cells each containing one HLW canister.

- Safety criteria can be met. Even in a situation of neglect, the maximum radiation dose that an individual can incur remains far below 10 μSv/year.

- Structural adjustments to the repository design are required to maintain accessibility. This applies particularly to a repository in clay, which needs additional support to prevent borehole convergence and eventual collapse of the disposal drifts.

- Costs are higher than those for a non-retrievable repository, mainly due to maintenance of accessibility of the disposal drifts.

Although it was not included in the terms of reference, the CORA programme also addressed social aspects in a scoping study of local environmental organisations. In particular, it considered the ethical aspects of long-term storage of radioactive waste versus retrievable disposal. Although the results may not be representative of the views of a broader public, including other institutions with social or ideological objectives, some preliminary conclusions could be drawn. The following statements reflect the position of many environmental groups:

Radioactive waste management is strongly associated with the negative image of nuclear power. As such, underground disposal is rejected on ethical grounds since nuclear power is considered unethical and a solution for radioactive waste could revitalise the use of nuclear power.

Permanent control by the government is considered as the least harmful management option, although the possibility of social instability is recognised as a liability for which no solution can be provided.

While it is clear that widely different views exist between stakeholders, this exchange of views can be considered as the start of a dialogue, which is a prerequisite for any solution.

Because the Netherlands has adopted the strategy of storage in dedicated surface facilities for at least 100 years, there is no immediate urgency to select a specific disposal site. However, further research is required to resolve outstanding issues and to be prepared for site selection in case of any change to the current timetable, arising by way of future European directives, for example. The CORA committee recommended validation of some of the results of safety studies, under field conditions, and co-operation with other countries, particularly on joint projects in underground laboratories, is foreseen in this context. As regards other technical aspects, it recommended that attention be given to the requirements for monitoring of retrievable repositories. Non-technical aspects will also be addressed.

Although the Parliament has agreed the proposed research programme and endorsed the budget required for its implentation, it has not started yet due to lack of funds. Presently steps have been taken to investigate the possibility to start the new research programme in the first semester of 2008 as a joint undertaking of the nuclear industry and the government.

3.5 Financing of Radioactive Waste Management

3.5.1 Framework and responsibilities

One of the basic principles governing radioactive waste management and also adhered to in the Netherlands is the polluter pays principle. This principle requires that all costs associated with radioactive waste management are borne by the organisations or institutes responsible for the generation of this waste.

As regards the management of spent fuel and high level waste, the utilities and the operators of research reactors have agreed to jointly build a facility for treatment and long term storage of SF and HLW at the COVRA site. This building (HABOG) was commissioned in 2003 and is now receiving vitrified and other high level waste from reprocessing plants as well as spent fuel from the research reactors. Both the construction costs and the operating costs are borne by the generators of the spent fuel and the waste respectively.

In the frame of transfer of ownership of COVRA from the utilities and the Energy Research Foundation (ECN) to the State, the utilities decided to discharge themselves from any further responsibility for management of the radioactive waste. They made a down payment to COVRA covering the discounted costs for operation and maintenance of the HABOG during the envisaged operational period (~100 years). The other customers for the HABOG pay their share of operational costs by annual instalments.

For LILW there are fixed tariffs for specified categories of radioactive waste which take into account all management costs. Once the transfer of the waste has been accomplished the customer is exempted from further responsibility for the waste. No surcharges can be made to make up for exploitation losses by

COVRA and no waste can be returned to the customers. While the tariffs are annually adjusted with the price index, every five years the tariff structure is evaluated with the aim to reconsider the need for any structural adjustment. However, the utmost restraint is exercised to any proposal for an increase of the tariffs, in order to prevent the temptation of environmentally irresponsible behaviour with the waste by the customer. In the previous period COVRA suffered substantial and structural exploitation losses for the management of LILW which can be partly attributed to a successful implementation of national waste separation and reduction policies. Financial support as a combination of a subsidy and a loan granted by the government, aimed to ensure that COVRA will have a neutral financial result over the period up to 2015.

3.5.2 Status of financing schemes

As mentioned in the previous paragraph, all costs associated with the management of radioactive waste originating from the nuclear facilities are covered by the generators.

The management costs of radioactive waste from smaller users is not fully covered due to the fact that the capital costs of COVRA are based on a larger nuclear programme than the one that actually exists. In the framework of transfer of ownership of COVRA from the utilities to the State in 2002 an arrangement was made with the departing shareholders for this category of radioactive waste, in which they were prepared to bear a fair share in the future management cost of COVRA. Any future losses of COVRA will then be supplemented by the State. This acknowledges the fact that COVRA as a waste management agency has a public utility function.

In 1986 a study was conducted with the aim to estimate the cost for the construction and operation of a repository for radioactive waste in salt formations in the deep underground. It is envisaged that all radioactive waste, LILW and HLW, will be placed in this repository. The total cost was estimated at 1230 M€ of which M€ 820.- for the disposal of HLW (1986 price level). These cost estimates formed the basis for the establishment of financial provisions by the operators of nuclear facilities and have been taken into account in the calculation of the discounted costs as mentioned before. A real interest rate of 3.5% and a discounting period of 130 years was used in the calculations for disposal of HLW.

The cost estimates for a disposal facility are evaluated periodically. The concept of a retrievable facility emerged after 1986 and it was expected that the requirement of retrievability of the waste would have an impact on the cost. The CORA study provided a good opportunity to re-estimate the costs of retrievable disposal, because the technical features had been identified within the scope of the study. On the basis of the technical data in the CORA study the total estimated costs for disposal in rock salt is around € 0.28 billion and in clay € 0.7-1.2 billion for the reference year 1994. There is an estimated € 1.8 million per year on top of this for inspection and maintenance costs. According to the most recent evaluation conducted by COVRA in 2003 of the adequacy of the funds, this would amount to € 1.274 billion. Although it has to be noted that these estimates still contain uncertainties, due to unforeseen variations of the interest rate that affects the build up of the fund capital, the conclusion seems legitimate in stating that, also according to the latest insights, the size of the disposal fund appears to be adequate. Because the policy assumes long-term aboveground storage, a calculation period of 130 years has been taken into account for financing the repository.

4. DECOMMISSIONING STRATEGY AND CURRENT PRACTICE

4.1 Decommissioning strategy

International consensus exists that there are basically three different strategies for the decommissioning of nuclear power stations:

- immediate dismantling within a period of ten years;
- delayed dismantling within 50 years, after bringing the facility in a safe enclosure (SE);
- "in situ" dismantling after a period of SE;

In the EIA for the Dodewaard NPP these three strategies were considered. In principle, the operator of the NPP designates one of these strategies as the preferred alternative on the basis of a decommissioning plan. Since the environmental impact was minute for all strategies considered the operator decided in favour of the least expensive strategy, namely postponed dismantling, with a waiting period of 40 years. Although the government had a slight preference for immediate dismantling for various reasons, no objection was raised against the decision of the operator.

After dismantling of all the structures of the NPP the end-point is:

- Removal of all potentially contaminated structures and installations;
- Proper management of radioactive waste;
- Removal of residual radioactive contamination from the site according to agreed clearance levels. The target is clearance for unrestricted use.

This corresponds with what is generally described as the "green field" situation.

In May 2002 a license was granted to GKN, the operator of the NPP Dodewaard, to bring and keep the plant in a safe enclosure. In July 2005 the stage of safe enclosure was achieved.

Meanwhile, under the influence of strong preference voiced in relevant international documents2 for direct dismantling, a change in the strategic approach occurred. Major considerations for the turnaround included the following:

- The nominal costs are lower because no costs are incurred for the safe enclosure;
- The knowledge and experience of the people who were present during the operational phase in the power plant is still available; dismantling therefore proceeds more efficiently;
- Immediate dismantling has a better image. It shows that the post-operational stage of a nuclear power plant is manageable and that no nuclear legacy for the next generation needs to be passed on, apart from the radioactive waste;

[2] Decommissioning of Facilities using Radioactive Material, IAEA Safety Requirements No. WS-R-5, 2006

- Immediate dismantling offers benefits from the point of view of employment opportunities, because some of the workers can be deployed in the dismantling work;

- Immediate dismantling reduces uncertainties about the condition of the power plant after a long transitional period. This applies to the reliability of electrical equipment such as overhead cranes, and aging and corrosion processes that adversely affect dismantling work.

In the framework of the negotiations with the operator of the NPP Borssele on a life extension until 2033, an agreement was reached on immediate dismantling after closure. This option has been agreed within the scope of the implementation of a sustainability package and has been laid down in a covenant.

4.2 Status of decommissioning projects

The only installation currently under decommissioning is the NPP Dodewaard. The fuel has been removed from the reactor vessel and the spent fuel storage pool and both have been drained and cleaned. The fuel was transferred to Sellafield (UK) for reprocessing. All installations and components have been decontaminated to the extent possible. Radioactive waste arising from these operations was transferred to COVRA. The office buildings and other auxiliary buildings outside the supervised area have been removed. The remaining buildings have been brought in a safe enclosure (see picture). This means that all openings to the outside environment (doors, windows, discharge pipes, electrical ducts etc) have been closed. A new ventilation system which filters and dries the air before it is allowed to enter the safe enclosure aims to prevent corrosion. The safe enclosure phase was achieved in 2005 and is scheduled to end with the start of the dismantling activities in 2045. All items in the safe enclosure are listed in a database, the Dodewaard Inventory System (DIS). The objective of the DIS is to describe in detail all relevant radiological data of the items located in the controlled zone of the NPP. Since the dismantling activities will take place after 40 years, much attention will be given to keep the information in a form that ensures its accessibility by the systems in use at that time.

4.3 Decommissioning issues at national level

There are no particular difficulties of an administrative or a technical nature envisaged in connection with decommissioning activities.

4.4 Research and development

There is no research on decommissioning going on or planned.

4.5 Financing

4.5.1 Framework and responsibilities

Although a strict legal requirement to ensure that adequate funding is available for decommissioning does not exist up to now, there has been a general understanding that the "polluter pays principle" applies. Consequently, the operators of NPP's have made financial reservations for decommissioning on a voluntary basis. These decommissioning funds are managed by the utilities. However, with a view to international developments in this area, it is envisaged to establish a legal basis in the Nuclear Energy Act. This would enable the possibility to impose requirements on the way decommissioning funds are managed.

4.5.2 Status of financing schemes

In connection with decommissioning funds two major aspects have to be considered, namely fund formation and fund management.

Fund formation

In the Netherlands the operators of nuclear power plants reserved and managed finances for decommissioning in a separate decommissioning fund based on discounted decommissioning costs and built up through annual deposits. The basic objectives for fund formation are:

- To ensure that sufficient finances are available when required on the basis of the chosen dismantling strategy, and

- To ensure that the finances are not used for anything but the intended purpose.

Fund management

Once again, the basic objective is to provide sufficient assurance that the funds will be available when required to cover the decommissioning costs. This entails drafting quality requirements for the legal basis of the fund and management of the money it contains. Steps must be taken to ensure the money is not involved in any possible corporate failure/bankruptcy of the licensee. The dismantling funds have so far been managed by the electricity generating companies.

Decommissioning funds are also a subject of interest within the EU. The European Commission recently produced draft recommendations on measures to cover the costs of decommissioning and dismantling nuclear power plants. The main aspects of this are:

- The “user/polluter pays” principle applies;

- The financial resources must cover all aspects related to decommissioning, including radioactive waste management;

- Member states must establish a national supervisory body that monitors the fund's growth;

- Preference is expressed for a ring-fenced external fund, or a fund that is legally separate from the licensee's other assets and liabilities;

- The decommissioning and dismantling cost estimates must be location-specific and made using reliable methods;

- If several estimates have been made, the highest estimate should be chosen;

- The fund can be built up from electricity sales.

The need for international harmonisation in the area of fund formation and fund management is clearly demonstrated in the Netherlands. Discussions between the operator at one hand and COVRA/government at the other hand about the adequacy of the capital in the fund are going on for some years and have not been settled yet. The latest developments indicate that progress towards an agreement is within reach.