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KVU – Handling of Norwegian Spent Fuel and other Radioactive Waste

Radioactive waste inventory in Norway, Task 1

Tommi Huutoniemi

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Abstract

This report presents an assessment of the Norwegian inventory of radioactive waste. The purpose is that the inventory assessment should provide data that can be used in an assessment on the requirements of future storage and disposal facilities for Norwegian radioactive waste.

This report is one of the technical reports in the KVU process regarding a possible new interim storage facility for spent nuclear fuel and other radioactive waste.

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List of abbreviations

ABA	Avfallsbehandlingsanlegg (Kjeller)
HBWR	Halden boiling water reactor (Halden)
IFE	Institutt för Energiteknikk
ILW	Intermediate Level Waste
IXR	Ion exchange resin
JEEP-II	JEEP-II reactor (Kjeller)
KLDRA	Kombinert lager og deponi for lav- og middels radioaktivt avfall (Himdalen)
KVU	Konseptvalgsutredning
LILW	Low and Intermediate Level Waste
LLW	Low Level Waste
NORM	Naturally occurring radioactive material
NMAT	Materials testing department (Kjeller)
URA	Uranrenseanlegg (Kjeller)

1 Introduction

This report presents an assessment of the Norwegian radioactive waste inventory, and focuses on volume and nuclide inventory.

This report is one of the technical reports in the KVU process regarding a possible new interim storage facility for spent nuclear fuel and other radioactive waste.

The information has been gathered by site visits, through databases and published materials, and through direct communication with IFE.

2 Waste management in Norway

This chapter presents the types of waste that form the majority of the present Norwegian waste inventory. A brief explanation of its handling and packaging steps are given. While new waste streams will arise in the coming years, such as decommissioning wastes, these are expected to follow the same basic waste types to a large degree.

2.1 Spent fuel

Spent fuel management is the subject of another report in the project scope, and is therefore not further discussed here.

2.2 Spent ion exchange resin

Ion exchange resin typically consists of organic material such as polystyrene divinylbenzene co-polymer, and is used in treatment of contaminated liquids. Through the resins ability to exchange ions, it is able to collect the radioactive ions from the liquid and retain them on the organic material.

The activity level in ion exchange resin varies greatly depending on where it has been used.

Typically a density of 0.7 tons/m^3 is used.

2.2.1 HBWR ion exchange resin, primary circuits

HBWR primary ion exchange resin is transported to Kjeller using a special 130 liter transport package. The contents are emptied through the package bottom into two tanks (2 m^3 each) outside the radwaste building at Kjeller. Up to 50 liters of water is added in order to flush the remaining resin into the tanks.

When enough has been gathered for further treatment, resin is pumped in batches into a dosage tank of 28 liters. Excess water is pumped away to a boiler (see below) and more resin is added until the 28 liter tank is full of resin. The 28 liters of resin is poured into a 50 liter lead container which has been cement embedded in a 210 liter drum. Cement is added so that the contents in the 50 liter container is solidified.

2.2.2 HBWR ion exchange resin, other circuits

HBWR also conditions some lower level ion exchange resin in concrete boxes with 10 cm concrete walls in which the resin is cement embedded. The amount of resin is approximately 100 liters. This waste type is conditioned at HBWR and is only transported to Kjeller for storage while waiting for transport to Himdalen.

2.2.3 Jeep-II ion exchange resin

Jeep-II ion exchange resin is emptied into 110 liter drums which have been concrete embedded in 210 liter drums. Up to 2/3 of the 110 liter drum is filled with resin. The package is then transported to the radwaste department where the remaining volume in the inner drum is filled with cement and vermiculite, thereby resulting in a solid waste form.

2.3 Liquid wastes

Liquid waste is generated mainly at hospitals and research institutions, or as a byproduct in other waste treatment. It may range from essentially contaminated water to e.g. organic compounds such as oils.

2.3.1 Excess water from ion exchange resin management

The excess water generated during handling of HBWR ion exchange resin from primary circuits is pumped to a boiler in which a part of the water is boiled off. The steam goes to the tanks where normal low level water waste is stored before being pumped and discharged into Nitelva. The remaining water is poured into a 210 liter drum. The drum is put on a vibrating table and filled with cement. Afterwards it is set aside for curing, thereby resulting in a solid waste form.

2.3.2 Other liquid waste

Low level liquid waste from hospitals, universities etc., is poured into a 210 liter drum which has a polyethylene liner in it. If not filled, the drum is stored waiting for more liquid. When 135 liters of liquid have been collected in the drum, it is out in a vibrating table and filled with cement. Afterwards it is set aside for curing, thereby resulting in a solid waste form.

2.4 Compressible waste

This waste form consist of compressible waste such as clothing, plastics, cardboard, paper etc. While the material composition and density varies, it may be assumed to consist of approximately 50 % plastics and 50 % cellulosic materials, with a total density of approximately 0.1 tons/m^3.

While the treatment is similar from all waste producers, the packaging for HBWR compressible waste is different from that of other producers. Therefore HBWR compressible waste is not mixed with similar waste from other producers.

This waste form is usually transported in 210 liter drums to the treatment facility at the IFE radwaste department at Kjeller. The contents is emptied into a glove box where it is sorted into grindable and non grindable fractions. The grindable fraction is dropped into a grinder, while the non-grindable bypasses it. Both streams are collected in a glove box below where it is scooped down into a drum (generally another 210 liter drum, but for HBWR waste into a 110 liter drum that is cement embedded in a 210 liter drum).

The drum is positioned below a compactor, which compacts the waste into the drum. Generally, the compaction is about a factor of 5−7. More waste is put in the drum and compacted, etc. until the whole drum is full.

The reason for keeping Halden waste separate is that it may be alpha contaminated. If there is e.g. metallic waste included by mistake, the compactor might cause this waste item to rupture the drum and spread alpha contamination – hence the double drum setup for Halden waste.

The above indicates that after compression an approximate density of 0.5 tons/m^3 may be assumed.

2.5 Uncompressible waste

This waste form consist of general uncompressible waste, such as metallic components, electronics, glass, concrete etc. It is common to assume an average density of approximately 1 tons/m^3 for such wastes.

For uncompressible waste where external radiation is of low concern, it is usually packaged in steel boxes (outer dimensions 210x135x111 cm). The waste producers package the waste into boxes at the generating facility.

Uncompressible waste where external radiation is of concern is mainly packaged in concrete boxes with either 10 cm or 20 cm walls (outer dimensions 80x120x100 cm). If needed, a lead liner can also be put inside the concrete box for further radiation shielding. The waste producers package the waste into boxes at the generating facility. After filling, the waste producer top fills the box with concrete.

If there are smaller amounts of waste that cannot wait for a full concrete box, there are various forms of 210 liter drums with embedded lead containers inside that may be used instead.

2.6 Spent sealed sources

Sealed sources consist of small radioactive sources used for a variety of applications, such as for medical therapy or in smoke detectors for home usage.

Depending on the application and the specific nuclide(s) in the source, the activity of such sources varies by many orders of magnitude. For this reason, some sources are contained in heavily shielded containers, while others may be handled manually with no shielding.

2.6.1 Sealed sources where external radiation is of concern

The sealed source together with its casing (shielding) is put in a 210 liter drum. Several such casings are put in the drum, leading to a large voidage. This voidage is filled with smoke detector sources.

In some cases high level sources are removed from their casing and put in a 60 liter lead container which is embedded in a 210 liter drum.

2.6.2 Sealed sources where external radiation is of less concern

This category consists mainly of smoke detector sources. If there is no drum where they can be put as void filling, they are put in their own 210 liter drum. Usually there will be something else that is heavy that is also put into the drum as to prevent floating when the 210 liter drum is subsequently embedded in Himdalen.

Some low level sources are disposed of together with other waste forms in their respective packaging.

3 Estimation of waste amounts

This chapter presents an estimate of the number of waste packages, and thereby the total amount of radioactive waste existing, or that may be expected to be generated in Norway. NORM waste from the oil and gas industry is, however, excluded as they fall outside of the project scope.

It should be noted that it is quite common that two sets of volume measurements are used when discussing waste volumes. First and foremost the actual package volume is used, expressed in metric units. Secondly, it is common to relate waste volumes into amounts of standard containers. In Norway, this second measurement is drum equivalents, i.e. the number of 210 liter drums that would be generated if the waste was packaged in such drums. It should be noted that this relates to outer volume and is therefore not directly scalable to the volume of un-packaged waste. As an example, if 50 liters of waste is packaged in a 50 liter container which has been embedded in a 210 liter container, the volume of this waste is considered to be 1 drum equivalent. If, on the other hand, 100 liters of waste is packaged in a 100 liter container which has been embedded in a 210 liter drum, the volume of this waste is also considered to be 1 drum equivalent.

3.1 Existing packages in Himdalen

IFE operates a combined intermediate storage and disposal facility, KLDRA, at Himdalen. This facility consists of four halls (rock caverns), of which there are three halls for disposal and one hall for intermediate storage. Presently it is, however, assumed that the intermediate storage hall will be converted into a disposal hall.

As of the end of 2013, the KLDRA facility contains an amount of waste as given in Table 3-1 below.

Table 3-1
Current (end of 2013) status of KLDRA volume.

Hall	Current purpose	Drum eq. disposed	Drum eq. left
1	Intermediate storage	166	2 334
2	Disposal	375	2 125
3	Disposal	2 500	0
4	Disposal	2 500	0

In total there are 5 541 drum equivalents stored or disposed at the KLDRA combined storage and disposal facility at the end of 2013. If the interim storage hall is converted to a disposal hall, there are in total 4 459 drum eq. of space left.

3.2 Spent fuel

Based on data received from IFE, the following amounts of spent fuel is reported at different Norwegian storage locations in the summer of 2014, see Table 3-2 below.

Table 3-2
Amount of spent fuel at various storage locations in Norway in 2014.

Location	Oxide fuel, Al cladding (kg)	Oxide fuel, Zr cladding (kg)	Metallic fuel (kg)
Halden			
HBWR-Core		396	
HBWR-Pool		645	
Halden-Törrlager		1 841	6 725
Halden-Brenselbasseng		1 320	
Kjeller			
JEEP 2-Core	222		
JEEP 2-Lagerbrönn	215		
Met. Lab. 2	1 158	614	
JEEP 1-Stavbrönn	100*		3 130
Total	**1 695**	**4 816**	**9 855**

* It is not clear how the mass is distributed between Al and Zr clad fuel.

The above data do not include volume since it is currently not known what type of container that is to be used when the waste is packaged.

Furthermore, approximately 125 kg/year is expected to be generated from the two Norwegian reactors until operations cease. This is distributed as approximately 80 kg/year from HBWR and 45 kg/year from JEEP-II.

3.3 Operational waste from IFE facilities

IFE operates reactors as well as fuels and materials research facilities in Norway. These facilities individually generate operational waste, but during treatment they are in some cases mixed with either other IFE waste, or sometimes with waste from other producers.

3.3.1 HBWR operational waste

The HBWR reactor is the main waste producer among IFE's facilities. Based on records of waste production during the last decade, an annual average of waste production has been compiled, as given in Table 3-3 below [D243].

Table 3-3
Annual average waste from the HBWR reactor, by packaging type.

	Concrete boxes	Steel boxes	Drums with compressible waste	Drums with primary circuit ion exchange resin
Annual avg.	6	4	35 pre-treat 14 post-treat	250 liters
Annual avg. (in drum eq.)	12	16	35 pre-treat 14 post-treat	9

For the amount of primary ion exchange resin, records indicate that 4 998 liters of ion exchange resin has been transported to Kjeller during the past 20 years. Assuming 28 liters of resin per drum after treatment, this would correspond to an annual generation rate of 9 drums.

For drums with compressible waste, a compression factor of 5 has been assumed. Waste is, however, compressed in 110 liter drums which means that effectively only a compression of approximately 2.5 is reached.

3.3.2 NMAT operational waste

NMAT is the department that does fuel R&D and fabrication, as well as does post-irradiation examination and testing of spent fuels and materials for IFE.

While only limited information has been gathered, based on data from 2010−2013 the annual generation of operational waste from NMAT has been calculated as given in Table 3-4 below [D224].

Table 3-4
Annual average waste from the NMAT, by packaging type.

	Drum un-shielded	Drum 5 cm concrete	Drum 10 cm concrete	Drum 3 cm lead	Drum 6 cm lead	Concrete box	Steel box
Annual avg. (number of containers)	18 pre-treat 4 post-treat	3	1	1	0,5	0,5	1
Annual avg. (in drum eq.)	18 pre-treat 4 post-treat	3	1	1	0,5	1	4

3.3.3 Operational waste from other IFE facilities

No specific data have been received regarding waste from other IFE producers than HBWR and NMAT. IFE does, however, state that an average amount of 80 drum equivalents is generated by IFE per year (based on 2009−2013) [D362].

If it is assumed that the *drums* from HBWR and *unshielded drums* from NMAT contain compressible waste which during treatment is reduced to 18 drum eq., the number of drum equivalents from other IFE producers' amounts to approximately 15. This has not been possible to distribute on waste types.

3.4 Operational waste from external producers

The amount of waste from external producers, such as industry, hospitals, etc., varies from year to year. Based on the last few years, the amount has been as given in Table 3-5 [D362]. Additional data have not been received. Due to updating of legislation in 2009 it is possible that the relatively large volumes of waste 2009−2011 are due to waste producers transporting waste that was awaiting the legislation update. The available data are, however, not enough to validate this.

Table 3-5
Annual waste amount from other producers.

Year	Waste from external producers (approximate drum eq.)
2009	130
2010	100
2011	130
2012	60
2013	70

Based on the above, an average of approximately 100 drum equivalents is assumed.

It is currently expected that an annual production of approximately 10 drum equivalents of waste will arise from planned new operations [D362]. It is, however, not accounted for separately in order to account for other operations ceasing, etc.

All waste is expected to be packaged in 210 liter drums.

3.5 Other stored waste

Apart from operational waste from the producers, some uranium and thorium waste is stored at Kjeller. Based on [D048], the amount of this wastes is given in Table 3-6 below.

Table 3-6
Other stored waste at Kjeller (kg).

	Enriched U	Natural U	Depleted U	Th
Shielding from industry/medical			420	
Solidified U from URA		1 210		
From waste manufacturing	532	2 141	42	55
Total	**532**	**3 351**	**462**	**55**

No detailed database over the waste packages has been received, but it is reported that solidified U from URA is stored in 110 liter drums which are concrete embedded in 210 liter drums. There are 21 such packages.

The other waste is reportedly stored in approximately 500 containers of approximate height 20−30 cm and a diameter of 10−12 cm.

3.6 Decommissioning waste

Decommissioning of facilities generate wastes that are largely comparable to that of operational waste from a packaging point of view.

This section presents data from IFE's decommissioning studies of the various IFE facilities. Since the amount of detail varies between the studies, the corresponding information in the sub chapters below also varies.

It should be noted that independent decommissioning studies are performed in the KVU project. At the time of writing this report these studies are, however, not finalized and therefore not used as source material for this section.

3.6.1 HBWR decommissioning waste

Decommissioning waste from HBWR, based on [D065], is presented in Table 3-7. It should be noted that packaging type is not given in the reference, but has been assumed here. This assumption has been made in order to correspond to existing packages for purpose of simplifying the assessment. As an example, the reactor internals are assumed to be packaged in concrete boxes, while a more likely scenario is that they will be packaged in some form of thick steel or lead shielded steel box during the actual decommissioning.

Note also that it is common to consider the possibility to dispose of large components intact without segmentation and packaging. This only applicable to such components where the outer part forms an effective barrier against spreading contamination present in the inside, e.g. some heat exchangers. Due to the disposal system at KLDRA this is, however, unlikely to be applicable for the Norwegian decommissioning program.

Table 3-7
Expected HBWR decommissioning waste amount.

Waste stream	Volume (m^3)	Drum eq.	Assumed packaging
Reactor tank	11	100	Concrete box
Reactor internals	4	36	Concrete box
Primary systems	46	836	Concrete box
Experiment loops	14	127	Concrete box
Stored metallic waste	35	318	Steel box
Concrete waste	157	952	Steel box
Ventilation	30	273	Steel box
Other activated from decom	20	182	Concrete box
Other from decom	20	182	Drums
Total	**337**	**3 007**	

3.6.2 JEEP-II decommissioning waste

Decommissioning waste from JEEP-II, based on [D061], is presented in Table 3-8. It should be noted that packaging type is not given in the reference, but has been assumed here.

Note also that it is common to consider the possibility to dispose of large components intact without segmentation and packaging. This only applicable to such components where the outer part forms an effective barrier against spreading contamination present in the inside, e.g. some heat exchangers. Due to the disposal system at KLDRA this is, however, unlikely to be applicable for the Norwegian decommissioning program.

Table 3-8
Expected JEEP-II decommissioning waste amount.

Waste stream	Volume (m^3)	Drum eq.	Assumed packaging
Steel from thermal shield	2.4	40	Concrete boxes
Other metal	7.2	65	Concrete boxes
Concrete	80	730	Partly concrete boxes, Steel boxes
Secondary waste	4	35	Steel boxes
Total	**93.6**	**870**	

3.6.3 Fuel labs at Kjeller decommissioning

Decommissioning waste from the fuel laboratories at Kjeller, based on [D059], is presented in Table 3-9.

Table 3-9
Expected fuel lab decommissioning waste amount.

Container code	Type	Gross vol. (m^3)	Net vol. (m^3)	Shielding	No.	Drum eq.
A1	Drum	0.22	0.06	4cm conc. + 6 cm lead	10	10
A2	Drum	0.22	0.06	7cm conc. + 3cm lead	21	21
A3	Drum	0.22	0.06	10cm conc.	55	55
B	Drum	0.22	0.11	5cm conc.	382	191
C	Drum	0.22	0.21	None	239	120
D	Concrete box	1	0.13	20cm conc.	30	60
E	Concrete box	1	0.36	10cm conc.	50	100
S	Steel box	3	3	None	123	492
Total					**910**	**1 049**

3.6.4 Radwaste building decommissioning waste

Decommissioning waste from the IFE radwaste building (Uranrense-anlegg, URA, and Avfallsbehandlingsanlegg, ABA, based on [D064], is presented in Table 3-10.

Table 3-10
Expected radwaste building decommissioning waste amount.

Building part	Package type	Drum eq.
URA 012	Steel box	10
URA 010	Steel box	8
URA 102	Steel box	20
URA 103	Tanks, Steel box	4
URA 004	Steel box	8
URA 107	Tanks, Steel box	12
ABA Lagertanker	Drums	5
ABA Indamperanlegg	Drums, Steel box	8
ABA Gammel ionebyttersilo	Steel box	6
ABA Presse/kvern	Steel box	8
ABA Ionebytteranlegg	Drums, Tanks, Steel box	121
ABA Forbrenningsanlegg	N/A	0
ABA Lab 107	Steel box	10
Total		**220**

3.6.5 Sum of decommissioning waste

In Table 3-11 below, a summary of the decommissioning waste is presented.

Table 3-11
Summary of decommissioning waste as given in IFE decommissioning plans.

Facility	**Decommissioning waste volume (drum eq.)**
HBWR	3 007
JEEP-II	870
Fuel labs	1049
Radwaste building	220
Total	**5 146**

4 Nuclide inventory

In this chapter the reported nuclide inventory in generated and expected waste is presented. The data is mainly based on data gathered from the radwaste department's database regarding the waste throughput, as well as from published documents such as decommissioning reports.

These data are often given with a limited number of nuclides. It is also presented in a way that is difficult to verify independently. The presented data should therefore be considered as uncertain. Furthermore, this report combines data from several sources and distributes them over different waste streams, which leads to further uncertainties.

Such uncertainties are taken into account in subsequent reports in the KVU.

4.1 Expected annual nuclide inventory addition

Table 4-1 presents an estimate of the nuclide inventory in annually generated operational wastes in Norway. It is based on an average value in waste transported to the radwaste department between the years 2004−2013 [IFE, 2014]. The data include waste from IFE facilities as well as from external generators such as industry, hospitals etc. It should be noted that the presented data are based on the waste generators data, which may not specify all nuclides. The extracted information does not include nuclides with half-lives shorter than 2 years.

Table 4-1
Annual activity inventory in Norwegian radioactive waste passing through the IFE radwaste department.

Nuclide	Half-life (y)	External producer (Bq/y)	IFE HBWR (Bq/y)	IFE Jeep-II (Bq/y)	IFE NMAT (Bq/y)	IFE Others (Bq/y)	Total (Bq/y)
H-3	1.23E+01	3.4E+11	3.7E+12	4.4E+11	0.0E+00	3.4E+11	4.8E+12
C-14	5.70E+03	1.2E+09	0.0E+00	0.0E+00	0.0E+00	5.1E+07	1.3E+09
Cl-36	3.01E+05	4.2E+06	0.0E+00	0.0E+00	0.0E+00	4.5E+05	4.6E+06
K-40	1.25E+09	0.0E+00	0.0E+00	3.5E+03	0.0E+00	0.0E+00	3.5E+03
Co-60	5.27E+00	4.1E+10	2.8E+11	2.4E+10	5.0E+09	2.6E+10	3.8E+11
Ni-63	1.00E+02	7.7E+09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E+09
Kr-85	1.08E+01	3.0E+10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+10
Sr-90	2.88E+01	4.5E+08	1.7E+10	0.0E+00	4.7E+09	8.0E+09	3.0E+10
Tc-99	2.11E+05	3.3E+07	0.0E+00	0.0E+00	0.0E+00	3.0E+06	3.6E+07
I-129	1.57E+07	3.9E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.9E+06
Ba-133	1.05E+01	1.4E+09	0.0E+00	3.0E+07	0.0E+00	4.3E+06	1.4E+09
Cs-137	3.02E+01	2.5E+11	1.1E+12	7.9E+10	7.1E+09	4.5E+10	1.5E+12
Eu-152	1.35E+01	1.2E+06	1.8E+08	0.0E+00	8.9E+07	3.9E+03	2.7E+08
Eu-154	8.59E+00	0.0E+00	2.0E+03	0.0E+00	2.0E+08	0.0E+00	2.0E+08
Pb-210	2.22E+01	6.6E+03	0.0E+00	0.0E+00	0.0E+00	1.7E+03	8.3E+03
Ra-226	1.60E+03	9.3E+07	0.0E+00	0.0E+00	0.0E+00	4.1E+09	4.2E+09
Ac-227	2.18E+01	1.8E+08	0.0E+00	9.8E+03	0.0E+00	1.9E+07	2.0E+08
Ra-228	5.75E+00	1.4E+03	0.0E+00	0.0E+00	0.0E+00	2.2E+06	2.2E+06
Th-232	1.41E+10	3.3E+07	0.0E+00	3.5E+03	9.1E+03	4.5E+07	7.8E+07
U-234	2.46E+05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E+05	5.0E+05
U-235	7.04E+08	0.0E+00	0.0E+00	0.0E+00	4.1E+05	3.8E+04	4.4E+05
U-238	4.47E+09	3.6E+06	0.0E+00	1.2E+03	5.7E+05	1.6E+09	1.6E+09
Pu-238	8.77E+01	0.0E+00	0.0E+00	0.0E+00	8.0E+04	1.3E+04	9.2E+04
Pu-239	2.41E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+07	3.0E+07
Am-241	4.32E+02	7.1E+10	0.0E+00	0.0E+00	1.6E+09	4.2E+11	5.0E+11
Cm-244	1.81E+01	3.2E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E+08

4.2 Future decommissioning waste

This section presents the decommissioning activity inventory as presented in decommissioning studies.

4.2.1 HBWR decommissioning

Table 4-2 presents the nuclide inventory data in HBWR decommissioning wastes as presented in [D065]. It should be noted that the categorization of waste is not the same as in Table 3-7.

Table 4-2
Decommissioning inventory HBWR.

	Reactor tank material	Shield circuit	Control rods and experimental rigs in core	Bioshield (<1.7 m from tank)	Primary circuit surf.cont	Primary circuit (old) surf.cont	Exp circuit surf.cont	Shield circuit surf.cont	Ion exchange resin	Total
H-3				5.40E+06					7.20E+12	7.20E+12
C-14	2.30E+08	5.70E+07	2.20E+11							2.20E+11
Si-32	6.00E+04	4.30E+03	8.80E+05							9.44E+05
Fe-55	4.50E+16	1.20E+16	3.30E+16	1.90E+12						9.00E+16
Co-60	5.90E+15	1.60E+15	1.10E+16	4.00E+12	4.50E+10	9.10E+10	1.40E+10	2.50E+06	1.10E+12	1.85E+16
Ni-59	3.60E+11	9.70E+10	4.00E+13	2.80E+09						4.05E+13
Ni-63	3.60E+13	9.30E+12	5.00E+15	2.70E+11						5.05E+15
Sr-90									2.00E+10	2.00E+10
Zr-93			3.90E+10							3.90E+10
Nb-93m	6.10E+09	1.50E+09	2.00E+11							2.08E+11
Mo-93	9.10E+09	2.30E+09	3.20E+11							3.31E+11
Tc-99	5.90E+08	1.50E+08	2.00E+10							2.07E+10
Ag-110m			2.60E+16							2.60E+16
Cd-109			3.60E+13							3.60E+13
Sn-121m	8.80E+09	2.20E+09	8.10E+10							9.20E+10
Sb-125		9.00E+10	4.40E+12							4.49E+12
Te-125m		2.10E+10	1.00E+12							1.02E+12
Cs-134				1.50E+10						1.50E+10
Cs-137					6.50E+09	1.30E+10	2.00E+09	0.00E+00	4.90E+12	4.92E+12
Sm-151				1.20E+10						1.20E+10
Eu-152				4.60E+12						4.60E+12
Eu-154				3.60E+11						3.60E+11
Eu-155				6.40E+09						6.40E+09

4.2.2 JEEP-II decommissioning

Table 4-3 presents the nuclide inventory data in JEEP-II decommissioning wastes as presented in [D061]. It should be noted that the categorization of waste is not the same as in Table 3-8.

Table 4-3
Decommissioning inventory JEEP-II[1].

	Activated metal	**Activated concrete**	**Contaminated metal**	**Other wastes**	**Total**
Co-60	3.0E+12	6.0E+11	1.0E+10	1.0E+09	3.6E+12
Eu-152		1.5E+12			1.5E+12

4.2.3 Fuel labs at Kjeller decommissioning

Table 4-4 presents the nuclide inventory data in fuel lab decommissioning wastes as presented in [D059].

1 Note that the reported nuclide inventory is very limited. Key nuclides such as Cs-137 and other fission products are not reported in [D061] but are expected in the actual waste. The levels are, however, expected to be far below that of HBWR and are therefore not estimated separately here.

Table 4-4
Decommissioning inventory fuel lab.

Nuclide	Total
Co-60	6.08E+10
Sr-90	2.96E+11
Cs-134	2.31E+11
Cs-137	4.06E+11
Eu-154	2.39E+10
U-233	3.55E+01
U-234	4.99E+06
U-235	9.41E+04
U-236	1.09E+06
U-238	6.73E+05
Pu-238	1.74E+10
Pu-239	1.09E+09
Pu-240	4.20E+09
Pu-241	5.42E+11
Pu-242	1.16E+07
Am-241	1.16E+09

4.2.4 Radwaste building decommissioning

Table 4-5 presents the nuclide inventory data in radwaste building (Uranrenseanlegg, URA, and Avfallsbehandlingsanlegg, ABA) decommissioning wastes as presented in [D064].

Table 4-5
Decommissioning inventory radwaste building.

Building part	Co-60	Cs-137	U-238
URA 012	1.0E+07	5.0E+07	1.0E+06
URA 010	0.0E+00	0.0E+00	1.0E+05
URA 102	1.0E+07	1.0E+07	1.0E+06
URA 103	1.0E+04	1.0E+04	1.0E+05
URA 004	1.0E+05	1.0E+05	1.0E+06
URA 107	1.0E+06	1.0E+06	1.0E+05
ABA Lagertanker	3.7E+05	7.0E+04	0.0E+00
ABA Indamper-anlegg	5.0E+09	5.0E+09	1.0E+06
ABA Gammel ionebytter-silo	1.2E+07	1.2E+07	1.0E+04
ABA Presse/kvern	5.0E+04	5.0E+04	0.0E+00
ABA Ionebytter-anlegg	5.2E+09	2.0E+10	0.0E+00
ABA Forbrennings-anlegg	1.1E+05	0.0E+00	0.0E+00
ABA Lab 107	1.0E+06	1.0E+05	1.0E+06
Total	1.0E+10	2.5E+10	5.3E+06

4.2.5 Sum of decommissioning wastes

In Table 4-6 below, a summary of the decommissioning waste inventory is given.

Table 4-6
Sum of decommissioning inventory (Bq).

	HBWR	JEEP-II	Fuel labs	Radwaste building	Total
H-3	7.2E+12				7.2E+12
C-14	2.2E+11				2.2E+11
Si-32	9.4E+05				9.4E+05
Fe-55	9.0E+16				9.0E+16
Co-60	1.9E+16	3.6E+12	6.1E+10	1.0E+10	1.9E+16
Ni-59	4.1E+13				4.1E+13
Ni-63	5.1E+15				5.1E+15
Sr-90	2.0E+10		3.0E+11		3.2E+11
Zr-93	3.9E+10				3.9E+10
Nb-93m	2.1E+11				2.1E+11
Mo-93	3.3E+11				3.3E+11
Tc-99	2.1E+10				2.1E+10
Ag-110m	2.6E+16				2.6E+16
Cd-109	3.6E+13				3.6E+13
Sn-121m	9.2E+10				9.2E+10
Sb-125	4.5E+12				4.5E+12
Te-125m	1.0E+12				1.0E+12
Cs-134	1.5E+10		2.3E+11		2.5E+11
Cs-137	4.9E+12		4.1E+11	2.5E+10	5.4E+12
Sm-151	1.2E+10				1.2E+10
Eu-152	4.6E+12	1.5E+12			6.1E+12
Eu-154	3.6E+11		2.4E+10		3.8E+11
Eu-155	6.4E+09				6.4E+09
U-233			3.6E+01		3.6E+01
U-234			5.0E+06		5.0E+06
U-235			9.4E+04		9.4E+04
U-236			1.1E+06		1.1E+06
U-238			6.7E+05	5.3E+06	6.0E+06
Pu-238			1.7E+10		1.7E+10
Pu-239			1.1E+09		1.1E+09
Pu-240			4.2E+09		4.2E+09
Pu-241			5.4E+11		5.4E+11
Pu-242			1.2E+07		1.2E+07
Am-241			1.2E+09		1.2E+09

4.3 Spent fuel

The spent fuel nuclide inventory, as given in Table 4-7 below, is based mainly on [D047], in which specific activities have been calculated for a number of nuclides in standard elements of JEEP-II (3. 5% enrichment, 17 500 MWd/tU) and HBWR fuel (6 % enrichment, 30 000 MWd/tU).

Only long-lived nuclides have been included. [D047] is not specific on the assumptions used, e.g. calculation date, but due to the long-lived nature of the waste, the short-lived nuclides are of less interest.

Table 4-7
Specific activity for standard JEEP-II and HBWR fuel [D047].

Nuclide	T½ (y)	Spec.act (TBq/kg)	JEEP-II fuel g/tonneU	JEEP-II fuel Bq/tonneU	HBWR fuel g/tonneU	HBWR fuel Bq/tonneU
Sr-90	2.88E+01	5.06E+03	3.68E+02	1.86E+15	6.56E+02	3.32E+15
Zr-93	1.53E+06	9.21E-02	4.26E+02	3.92E+10	7.36E+02	6.78E+10
Tc-99	2.11E+05	6.27E-01	4.56E+02	2.86E+11	7.75E+02	4.86E+11
Pd-107	6.50E+06	1.89E-02	4.60E+01	8.68E+08	7.10E+01	1.34E+09
I-129	1.57E+07	6.49E-03	8.30E+01	5.38E+08	1.41E+02	9.15E+08
Cs-135	2.30E+06	4.23E-02	3.51E+02	1.49E+10	2.97E+02	1.26E+10
Cs-137	3.02E+01	3.18E+03	6.36E+02	2.02E+15	1.11E+03	3.52E+15
U-233	1.59E+05	2.30E-01	5.00E-04	1.15E+05	1.00E-03	2.30E+05
U-234	2.46E+05	2.30E-01	2.30E+02	5.30E+10	3.76E+02	8.66E+10
U-235	7.04E+08	8.00E-05	1.67E+04	1.34E+09	2.76E+04	2.21E+09
U-236	2.34E+07	2.39E-03	2.86E+03	6.83E+09	5.19E+03	1.24E+10
U-238	4.47E+09	1.24E-05	9.58E+05	1.19E+10	9.31E+05	1.16E+10
Np-237	2.14E+06	2.60E-02	7.50E+01	1.95E+09	1.49E+02	3.88E+09
Pu-238	8.77E+01	6.34E+02	1.00E+01	6.34E+12	2.10E+01	1.33E+13
Pu-239	2.41E+04	2.30E+00	3.04E+03	6.97E+12	3.13E+03	7.17E+12
Pu-240	6.56E+03	8.40E+00	6.84E+02	5.74E+12	9.99E+02	8.39E+12
Pu-241	1.43E+01	3.83E+03	2.03E+02	7.76E+14	3.65E+02	1.40E+15
Pu-242	3.73E+05	1.46E-01	3.20E+01	4.66E+09	7.30E+01	1.06E+10
Am-241	4.32E+02	1.27E+02	1.30E+01	1.65E+12	8.00E+00	1.02E+12

Since data are only available for standard JEEP-II and HBWR fuel respectively, the whole Kjeller inventory (6.3 tonnes) is assumed to correspond to JEEP-II fuel, and the whole HBWR inventory (10.4 tonnes) to HBWR fuel. The whole weight is assumed to correspond to uranium. It should, however, be noted that these assumptions lead to an overestimate since historical waste had a burn-up of only a fraction of today's values. This overestimate has not been quantified, and therefore the below nuclide inventory should be regarded as a conservative estimate for dimensioning purposes.

This leads to the following assessment of the spent fuel nuclide inventory in Norway, as given in Table 4-8 below.

Table 4-8
Assessment of nuclide inventory in stored spent fuel.

Nuclide	Activity, stored JEEP2 fuel (5.4 tonnes*)	Activity, stored HBWR fuel (10.9 tonnes*)
Sr-90	1.01E+16	3.62E+16
Zr-93	2.13E+11	7.41E+11
Tc-99	1.56E+12	5.31E+12
Pd-107	4.72E+09	1.46E+10
I-129	2.93E+09	9.99E+09
Cs-135	8.08E+10	1.37E+11
Cs-137	1.10E+16	3.85E+16
U-233	6.26E+05	2.52E+06
U-234	2.88E+11	9.46E+11
U-235	7.27E+09	2.41E+10
U-236	3.72E+10	1.36E+11
U-238	6.48E+10	1.27E+11
Np-237	1.06E+10	4.24E+10
Pu-238	3.45E+13	1.45E+14
Pu-239	3.79E+13	7.84E+13
Pu-240	3.12E+13	9.17E+13
Pu-241	4.22E+15	1.53E+16
Pu-242	2.54E+10	1.16E+11
Am-241	8.98E+12	1.11E+13

* Note that this is a conservative overestimate since older spent fuel has a significantly lower burn-up than newer spent fuel.

Due to continuing operation of the two reactors the assessed inventory will increase annually according to Table 4-9 below.

Table 4-9
Annual nuclide inventory addition from spent fuel.

Nuclide	Annually generated nuclide inventory JEEP-II fuel (45 kg)	Annually generated nuclide inventory HBWR fuel (85 kg)
Sr-90	8.37E+13	2.65E+14
Zr-93	1.77E+09	5.42E+09
Tc-99	1.29E+10	3.89E+10
Pd-107	3.90E+07	1.07E+08
I-129	2.42E+07	7.32E+07
Cs-135	6.68E+08	1.01E+09
Cs-137	9.10E+13	2.82E+14
U-233	5.18E+03	1.84E+04
U-234	2.38E+09	6.93E+09
U-235	6.02E+07	1.77E+08
U-236	3.08E+08	9.93E+08
U-238	5.36E+08	9.27E+08
Np-237	8.79E+07	3.10E+08
Pu-238	2.85E+11	1.06E+12
Pu-239	3.13E+11	5.74E+11
Pu-240	2.58E+11	6.71E+11
Pu-241	3.49E+13	1.12E+14
Pu-242	2.10E+08	8.51E+08
Am-241	7.43E+10	8.13E+10

4.4 Other stored wastes

While the data given is not specific on factors such as enrichment, physical form etc., in order to make an assessment it has been assumed that all the mass given in Table 3-6 is uranium and thorium respectively.

The following assumptions, based on [D364], are made regarding the nuclide inventory.

Table 4-10
Data for natural uranium [D364].

	U-234	U-235	U-238
Fraction weight (%)	0.005	0.7	99.3
Fraction activity (%)	48.9	2.2	48.9
Specific activity Bq/kg U	1.2E+07	5.7E+05	1.2E+07

Table 4-11
Data for uranium with enrichment 3.5% [D364].

	U-234	U-235	U-238
Fraction weight (%)	0.03	3.5	96.47
Fraction activity (%)	81.8	3.4	14.7
Specific activity Bq/kg U	6.7E+07	2.8E+06	1.2E+07

Table 4-12
Data for depleted uranium (depletion from natural uranium enriched to 3.5 %) [D364].

	U-234	U-235	U-238
Fraction weight (%)	0.0009	0.2	99.8
Fraction activity (%)	14.2	1.1	84.7
Specific activity Bq/kg U	2.0E+06	1.6E+05	1.2E+7

Thorium is assumed to consist only of Th-232 with a specific activity of 4.1E+06 Bq/kg.

The above, combined with mass according to Table 3-6 leads to a nuclide inventory (excluding progeny) as given in Table 4-13 below.

Table 4-13
Nuclide inventory in other stored waste at Kjeller (Bq).

	U-234	U-235	U-238	Th-232
Shielding from industry/medical	8.4E+08	6.7E+07	5.0E+09	0.0E+00
Solidified U from URA	1.5E+10	6.9E+08	1.5E+10	0.0E+00
From waste manufacturing	6.1E+10	2.7E+09	3.3E+10	2.3E+08
Total	**7.7E+10**	**3.5E+09**	**5.2E+10**	**2.3E+08**

5 Base scenario for the inventory assessment

This chapter presents a first estimate of the Norwegian radioactive waste inventory based on the characteristics and data presented in the previous chapters. Due to the lack of quantified and verifiable data this assessment is uncertain.

5.1 Fuel

No assessment of packaged fuel has been made in this reports since that is the subject matter of other reports within the project. Instead, the results from Chapter 4 is reproduced here.

The amount of waste and its nuclide inventory is presented in Table 5-1. As discussed in Section 4.3 this estimate is a conservative overestimate.

Table 5-1
Assessment of nuclide inventory in stored spent fuel.

Nuclide	Activity stored JEEP2 fuel (5.4 tonnes*)	Activity stored HBWR fuel (10.9 tonnes*)
Sr-90	1.01E+16	3.62E+16
Zr-93	2.13E+11	7.41E+11
Tc-99	1.56E+12	5.31E+12
Pd-107	4.72E+09	1.46E+10
I-129	2.93E+09	9.99E+09
Cs-135	8.08E+10	1.37E+11
Cs-137	1.10E+16	3.85E+16
U-233	6.26E+05	2.52E+06
U-234	2.88E+11	9.46E+11
U-235	7.27E+09	2.41E+10
U-236	3.72E+10	1.36E+11
U-238	6.48E+10	1.27E+11
Np-237	1.06E+10	4.24E+10
Pu-238	3.45E+13	1.45E+14
Pu-239	3.79E+13	7.84E+13
Pu-240	3.12E+13	9.17E+13
Pu-241	4.22E+15	1.53E+16
Pu-242	2.54E+10	1.16E+11
Am-241	8.98E+12	1.11E+13

* Note that this is a conservative overestimate since older spent fuel has a significantly lower burn-up than newer spent fuel.

As long as the reactors continue operations comparable to that of the past, the inventory assessment will increase annually according to Table 5-2 below.

Table 5-2
Annual nuclide inventory addition from spent fuel.

Nuclide	Annually generated nuclide inventory JEEP2 fuel (45 kg)	Annually generated nuclide inventory HBWR fuel (85 kg)
Sr-90	8.37E+13	2.65E+14
Zr-93	1.77E+09	5.42E+09
Tc-99	1.29E+10	3.89E+10
Pd-107	3.90E+07	1.07E+08
I-129	2.42E+07	7.32E+07
Cs-135	6.68E+08	1.01E+09
Cs-137	9.10E+13	2.82E+14
U-233	5.18E+03	1.84E+04
U-234	2.38E+09	6.93E+09
U-235	6.02E+07	1.77E+08
U-236	3.08E+08	9.93E+08
U-238	5.36E+08	9.27E+08
Np-237	8.79E+07	3.10E+08
Pu-238	2.85E+11	1.06E+12
Pu-239	3.13E+11	5.74E+11
Pu-240	2.58E+11	6.71E+11
Pu-241	3.49E+13	1.12E+14
Pu-242	2.10E+08	8.51E+08
Am-241	7.43E+10	8.13E+10

5.2 Other stored wastes

Since no package database has been received for this waste stream, it is assumed that the waste, excluding solidified uranium from URA, is evenly distributed on the packages according to their mass distribution. This simplification is made since the density varies between the materials.

However, since it may also reasonably be assumed that the depleted uranium is in a more bulky form, its bulk density may be similar to that of the natural and enriched uranium. For these reasons, it is assumed that shielding from industry/medical is packaged in 50 small containers, while the waste from manufacturing is in 450 small containers.

The data is presented in Table 5-3 below. It is not known if, and if so, how, the smaller containers will be packaged at disposal. For these reasons the number of drum equivalents is not given here.

Table 5-3
Package specific activity for other stored waste.

	Shielding from industry/medical	**Solidified U from URA**	**From waste manufacturing**
Package type	Small containers	Drums	Small containers
Number of packages	50	21	450
Number of drum eq.	N/A	21	N/A
	Activity per package (Bq/package)		
U-234	1.7E+07	6.9E+08	1.4E+08
U-235	1.3E+06	3.3E+07	6.0E+06
U-238	1.0E+08	6.9E+08	7.2E+07
Th-232	0.0E+00	0.0E+00	5.0E+05

5.3 Operational waste

Operational wastes consists of waste forms generated during normal operation of Norwegian waste generating facilities and operations.

5.3.1 IFE waste

Due to the lack of data regarding nuclide contents on a package specific level, a coarse method to estimate such an inventory has been made. This is mainly based on the total annual reported generation rates of HBWR and NMAT.

From [D065] it is possible to estimate the fraction of activity that is present in ion exchange resin since both the annual produced volume as well as the HBWR annual nuclide inventory is known. By matching the specific activity to that reported for the decommissioning ion exchange resin, it can be concluded that approximately 90 % of the annual HBWR nuclide inventory may be assumed to be in this stream.

While circumstantial, examinations of transport documentation on a non-statistical sample has indicated that concrete boxes from HBWR contain an activity inventory in the range of 50−100 GBq, Steel boxes one to a few GBq, and general waste drums 20−100 MBq.

The nuclides on which the above values are based (Cr-51, Co-58, Co-60, Nb-95, Cs-137, Ce-144) do not match those reported in the annual HBWR inventory. It is still possible to use these approximate values for the nuclides that are reported. H-3, however, is excluded in the correlation due to its dominant activity level while at the same time not being reported in the transport data.

If the higher end of the above ranges are combined with the annual inventory from HBWR in table 4-1, it can be concluded that if ~10 % of the nuclide inventory is assumed to contaminate wastes in concrete boxes, ~1 % in steel boxes, ~0.25 % in drums, respectively, the result is an activity concentration in the correct range for all waste streams.

The above leads to a general assessment that the annual activity inventory from HBWR is distributed approximately according to table 5-4 below.

Table 5-4
Assumptions for the assessment of HBWR waste.

Waste stream	**Fraction of annual generated HBWR activity inventory**	**Number of packages per year**	**Number of drum eq. per year**
Ion exchange resin	90 %	9 (210-liter drums)	9
Concrete boxes	10 %	6	12
Steel boxes	1 %	4	16
Drums	0.25 %	35/14 (pre-/post-treatment)	35/14 (pre-/post-treatment)

Since no waste stream specific data have been gathered regarding NMAT-waste, the same specific activity per waste stream is assumed for similar waste packages (unshielded drums, concrete boxes and steel boxes) from NMAT. In addition, however, the NMAT-specific inventory from Table 4-1 is assumed to be added to the concrete boxes.

Table 5-5
Assumptions for the assessment of NMAT waste.

Waste stream	Method to determine activity inventory	Number of packages per year	Number of drum eq. per year
Concrete boxes	Specific activity as HBWR concrete boxes + NMAT-specific activity	0,5	1
Steel boxes	Specific activity as HBWR steel boxes	0,5	2
Drums	Specific activity as HBWR drums	18/3 (pre-/post-treatment)	18/3 (pre-/post-treatment)

The above assessment leaves approximately 5 drum equivalents of NMAT waste as well as approximately 15 drum equivalents of other IFE waste in order to reach the full 80 drum equivalents produced per year by IFE. For these waste drums, the remaining annual IFE generated activity is assumed to be evenly distributed. It should be noted that many such drums are likely to contain only specific sealed sources, perhaps even of only a single nuclide. Due to the lack of data all remaining activity is, however, assumed to be evenly distributed.

The resulting distribution on IFE waste is presented in Table 5-6 below.

Table 5-6
Package specific activity for IFE waste streams.

Waste stream	HBWR IXR	HBWR concrete box	HBWR steel box	HBWR drum	NMAT concrete box	NMAT Steel box	NMAT drum	Rest	Sum
Number of packages/y	9	6	4	14	0.5	0.5	3	30	60
Number of drum eq./y	9	12	16	14	1	2	3	30	80
					Activity per package (Bq/package)				
H-3	3.7E+11	6.1E+10	9.1E+09	6.5E+08	6.1E+10	9.1E+09	6.5E+08	2.3E+10	4.4E+12
C-14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+06	5.1E+07
Cl-36	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E+04	4.5E+05
K-40	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+02	3.5E+03
Co-60	2.8E+10	4.7E+09	7.0E+08	5.0E+07	9.7E+09	7.0E+08	5.0E+07	1.5E+09	3.3E+11
Ni-63	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	1.7E+09	2.9E+08	4.3E+07	3.1E+06	5.0E+09	4.3E+07	3.1E+06	3.3E+08	3.0E+10
Tc-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+05	3.0E+06
I-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+06	3.4E+07
Cs-137	1.1E+11	1.9E+10	2.8E+09	2.0E+08	2.6E+10	2.8E+09	2.0E+08	3.4E+09	1.3E+12
Eu-152	1.8E+07	2.9E+06	4.4E+05	3.1E+04	9.2E+07	4.4E+05	3.1E+04	1.4E+06	2.7E+08
Eu-154	2.0E+02	3.3E+01	5.0E+00	3.6E-01	2.0E+08	5.0E+00	3.6E-01	3.4E+06	2.0E+08
Pb-210	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.7E+01	1.7E+03
Ra-226	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E+08	4.1E+09
Ac-227	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.4E+05	1.9E+07
Ra-228	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.3E+04	2.2E+06
Th-232	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E+03	0.0E+00	0.0E+00	1.5E+06	4.5E+07
U-234	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+04	5.0E+05
U-235	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.1E+05	0.0E+00	0.0E+00	8.0E+03	4.4E+05
U-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.7E+05	0.0E+00	0.0E+00	5.4E+07	1.6E+09
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.0E+04	0.0E+00	0.0E+00	1.8E+03	9.2E+04
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+06	3.0E+07
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E+09	0.0E+00	0.0E+00	1.4E+10	4.3E+11
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

5.3.2 Operational waste from external producers

As noted in Section 3.4 it is assessed that approximately 100 drums of external waste is generated in Norway each year. Due to the lack of data for specific waste packages in this stream, the full annual nuclide inventory from external producers in Table 4-1 is assumed to be evenly distributed on these drums. It should, however, be noted that many such drums are likely to contain only specific sealed sources, perhaps even of only a single nuclide. Due to the lack of data all activity is, however, assumed to be evenly distributed. This data is presented in Table 5-7 below.

Table 5-7
Package specific activity for external waste streams.

Waste stream	External waste in drums
No. of packages/y	100
No. of drum equivalents/y	100
Activity per package(Bq/package)	
H-3	3.4E+09
C-14	1.2E+07
Cl-36	4.2E+04
Co-60	4.1E+08
Ni-63	7.7E+07
Kr-85	3.0E+08
Sr-90	4.5E+06
Tc-99	3.3E+05
I-129	3.9E+04
Ba-133	1.4E+07
Cs-137	2.5E+09
Eu-152	1.2E+04
Pb-210	6.6E+01
Ra-226	9.3E+05
Ac-227	1.8E+06
Ra-228	1.4E+01
Th-232	3.3E+05
U-238	3.6E+04
Am-241	7.1E+08
Cm-244	3.2E+06

5.4 Decommissioning waste

5.4.1 HBWR decommissioning waste

Information on both the decommissioning nuclide inventory as well as the expected amount of packages have been given in Tables 3-7 and 4-2. It is, however, noted that these two tables do not contain a mutual categorization. For this reason, the approach presented in Table 5-8 is used in determining the inventory per package.

Table 5-8
Approach to determine package specific HBWR decommissioning waste activity.

Waste category from Table 4-2	Category for packaging in Table 3-7	Assumed package type	Number of packages if correlated to drum equivalents	Number of drum equivalents
Reactor tank material	Reactor tank	Concrete box	50	100
Shield circuit + Primary circuit	Primary systems	Concrete box	418	836
Control rods and exp. rigs in core	Reactor internals	Concrete box	18	36
Bioshield	Concrete waste	Concrete box	476	952
Exp. circuit	Experimental loops	Steel box	32	127
Ion exchange resin	Other contaminated waste (parts of)	HBWR Ion exchange drum	29	29

This does leave some waste where the categories of the activity inventory (Table 3-7) and the packaging inventory (Table 4-2) cannot easily be connected. This amounts to 926 drum equivalent which are assumed to be distributed evenly on concrete boxes (230) as well as steel boxes (115) and are assumed to be contaminated similarly to the corresponding package types in the operational waste.

The above leads to an assessment as given in Table 5-9 below.

Table 5-9
Nuclide inventory for HBWR decommissioning waste packages.

	Reactor tank material	Shield circuit + Primary circuit	Control rods and exp. rigs in core	Bio-shield	Exp. circuit	Ion exchange resin	Other waste	Other waste
Package type	Concrete box	Concrete box	Concrete box	Concrete box	Steel box	IXR drum	Concrete box	Steel box
Number of packages	50	418	18	476	32	29	230	115
Number of drum eq.	100	836	36	952	128	29	460	460
	Activity per package (Bq/package)							
H-3	0.0E+00	0.0E+00	0.0E+00	1.1E+04	0.0E+00	2.5E+11	6.1E+10	9.1E+09
C-14	4.6E+06	1.4E+05	1.2E+10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Si-32	1.2E+03	1.0E+01	4.9E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Fe-55	9.0E+14	2.9E+13	1.8E+15	4.0E+09	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Co-60	1.2E+14	3.8E+12	6.1E+14	8.4E+09	4.4E+08	3.8E+10	4.7E+09	7.0E+08
Ni-59	7.2E+09	2.3E+08	2.2E+12	5.9E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ni-63	7.2E+11	2.2E+10	2.8E+14	5.7E+08	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.9E+08	2.9E+08	4.3E+07
Zr-93	0.0E+00	0.0E+00	2.2E+09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-93m	1.2E+08	3.6E+06	1.1E+10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Mo-93	1.8E+08	5.5E+06	1.8E+10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Tc-99	1.2E+07	3.6E+05	1.1E+09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ag-110m	0.0E+00	0.0E+00	1.4E+15	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cd-109	0.0E+00	0.0E+00	2.0E+12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sn-121m	1.8E+08	5.3E+06	4.5E+09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	0.0E+00	2.2E+08	2.4E+11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-125m	0.0E+00	5.0E+07	5.6E+10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	0.0E+00	0.0E+00	0.0E+00	3.2E+07	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	0.0E+00	4.7E+07	0.0E+00	0.0E+00	6.3E+07	1.7E+11	1.9E+10	2.8E+09
Sm-151	0.0E+00	0.0E+00	0.0E+00	2.5E+07	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-152	0.0E+00	0.0E+00	0.0E+00	9.7E+09	0.0E+00	0.0E+00	2.9E+06	4.4E+05
Eu-154	0.0E+00	0.0E+00	0.0E+00	7.6E+08	0.0E+00	0.0E+00	3.3E+01	5.0E+00
Eu-155	0.0E+00	0.0E+00	0.0E+00	1.3E+07	0.0E+00	0.0E+00	0.0E+00	0.0E+00

5.4.2 Jeep-II decommissioning waste

Distributing the activity from Table 4-3 on the waste in Table 3-8 gives a package specific inventory as presented in Table 5-10 below.

Table 5-10
Activity per package for JEEP-II decommissioning waste.

	Activated metal	Activated concrete	Contaminated metal	Other wastes
Package type	Concrete box	Concrete box	Steel box	Steel box
No packages	20	365	16.25	8.75
No drum eq.	40	730	65	35
	Activity per package (Bq/package)			
Co-60	1.50E+11	1.64E+09	6.15E+08	1.14E+08
Eu-152	0.00E+00	4.11E+09	0.00E+00	0.00E+00

5.4.3 Fuel lab decommissioning waste

Using data in [D059] results in a package specific inventory as given in Table 5-11 below.

Table 5-11
Activity per package for fuel lab decommissioning waste.

Package type	Drum (A1)	Drum (A2)	Drum (A3)	Drum (B) after compaction	Drum (C) after compaction	Concrete box (D)	Concrete box (E)	Steel box
Number of packages	10	21	55	382	239	30	50	123
No drum eq.	10	21	55	191	119.5	60	100	492
				Activity per package (Bq/package)				
Co-60	7.68E+08	3.84E+08	1.15E+08	3.84E+07	3.86E+06	2.30E+08	2.30E+08	3.84E+07
Sr-90	3.74E+09	1.87E+09	5.61E+08	1.87E+08	1.88E+07	1.12E+09	1.12E+09	1.87E+08
Cs-134	2.92E+09	1.46E+09	4.38E+08	1.46E+08	1.46E+07	8.75E+08	8.75E+08	1.46E+08
Cs-137	5.13E+09	2.56E+09	7.69E+08	2.56E+08	2.57E+07	1.54E+09	1.54E+09	2.56E+08
Eu-154	3.02E+08	1.51E+08	4.53E+07	1.51E+07	1.52E+06	9.06E+07	9.06E+07	1.51E+07
U-233	4.48E-01	2.24E-01	6.73E-02	2.24E-02	2.25E-03	1.35E-01	1.35E-01	2.24E-02
U-234	6.30E+04	3.15E+04	9.45E+03	3.15E+03	3.16E+02	1.89E+04	1.89E+04	3.15E+03
U-235	1.19E+03	5.94E+02	1.78E+02	5.94E+01	5.97E+00	3.57E+02	3.57E+02	5.94E+01
U-236	1.38E+04	6.88E+03	2.06E+03	6.88E+02	6.91E+01	4.13E+03	4.13E+03	6.88E+02
U-238	8.50E+03	4.25E+03	1.27E+03	4.25E+02	4.27E+01	2.55E+03	2.55E+03	4.25E+02
Pu-238	2.20E+08	1.10E+08	3.30E+07	1.10E+07	1.10E+06	6.59E+07	6.59E+07	1.10E+07
Pu-239	1.38E+07	6.88E+06	2.06E+06	6.88E+05	6.91E+04	4.13E+06	4.13E+06	6.88E+05
Pu-240	5.30E+07	2.65E+07	7.96E+06	2.65E+06	2.66E+05	1.59E+07	1.59E+07	2.65E+06
Pu-241	6.85E+09	3.42E+09	1.03E+09	3.42E+08	3.44E+07	2.05E+09	2.05E+09	3.42E+08
Pu-242	1.47E+05	7.33E+04	2.20E+04	7.33E+03	7.36E+02	4.40E+04	4.40E+04	7.33E+03
Am-241	1.47E+07	7.33E+06	2.20E+06	7.33E+05	7.36E+04	4.40E+06	4.40E+06	7.33E+05

5.4.4 Radwaste building decommissioning waste

Using data in [D064] results in a package specific inventory as given in Table 5-12 below.

Table 5-12
Activity per package for Radwaste building decommissioning waste (Bq/package).

Building/Room	Package type	No packages	No. drum eq.	Co-60 (Bq/package)	Cs-137 (Bq/package)	U-238 (Bq/package)
012	Steel box	2.5	10	4.00E+06	2.00E+07	4.00E+05
010	Steel box	2	8	0.00E+00	0.00E+00	5.00E+04
102	Steel box	5	20	2.00E+06	2.00E+06	2.00E+05
103B	Steel box	1	4	1.00E+04	1.00E+04	1.00E+05
004	Steel box	2	8	5.00E+04	5.00E+04	5.00E+05
107	Steel box	3	12	3.33E+05	3.33E+05	3.33E+04
Lagertanker	Drums	5	5	7.40E+04	1.40E+04	0.00E+00
Inndamperanlegg	Drums	8	8	6.28E+08	6.28E+08	1.25E+05
Gammel ionebyttersilo	Steel box	1.5	6	8.00E+06	8.00E+06	6.67E+03
Presse/kvern	Steel box	2	8	2.50E+04	2.50E+04	0.00E+00
Ionebytteranlegg	Steel box	30.25	121	1.70E+08	6.68E+08	0.00E+00
Forbrennings-anlegg	N/A	N/A	0	0.00E+00	0.00E+00	0.00E+00
Lab 107	Steel box	2.5	10	4.00E+05	4.00E+04	4.00E+05
Lab 106	N/A	N/A	0	0.00E+00	0.00E+00	0.00E+00

Note: Some streams have several types of packages, but for simplicity it has been assumed that each stream is only packaged into one type as above.

5.5 Prognosis for future waste arisings

5.5.1 Fuel

In Figure 5-1, the amount of existing fuel together with the expected waste arising (125 kg/y) is presented. It should be noted that while highly unlikely, the prognosis uses this waste arising number for a time period of 100 years.

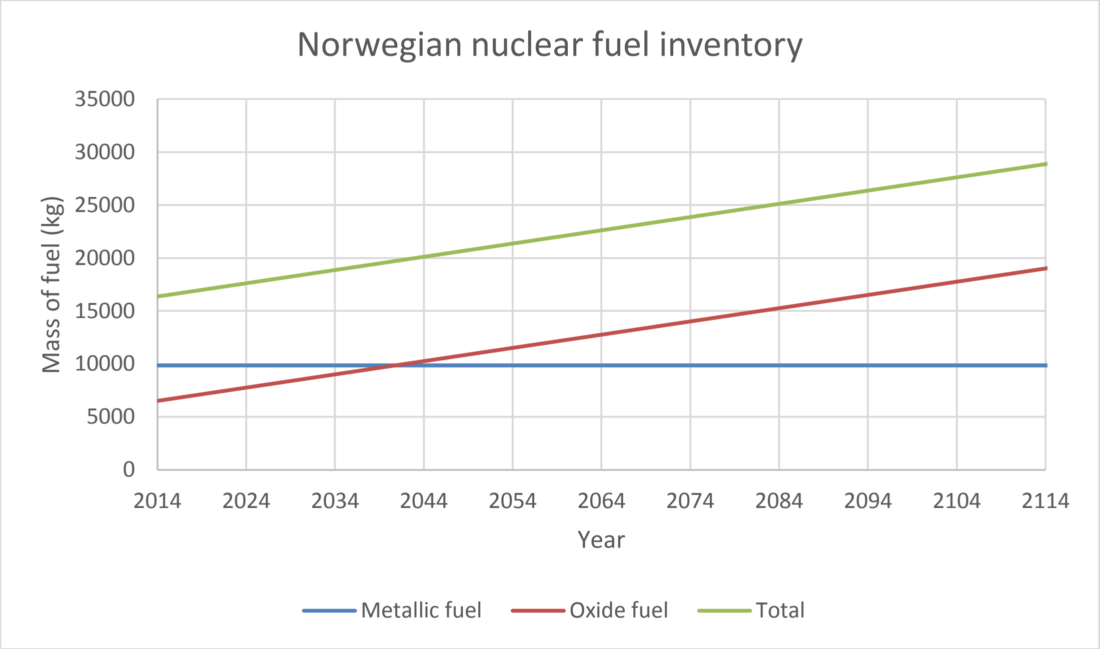

Figure 5-1
Existing and prognosis for Norwegian nuclear fuel inventory.

5.5.2 Other waste

In Figure 5-2, a prognosis for non-fuel waste is given. It should be noted that the waste amount is relative to year 2013, i.e. waste disposed before 2013 is not included, but is discounted in the available volume at Himdalen.

It is also of interest to note that if future decommissioning waste is taken into consideration, the current repository at Himdalen does not have enough free volume to dispose the full waste volume, not even at the present date. The deficiency increases each year as additional operational waste is generated.

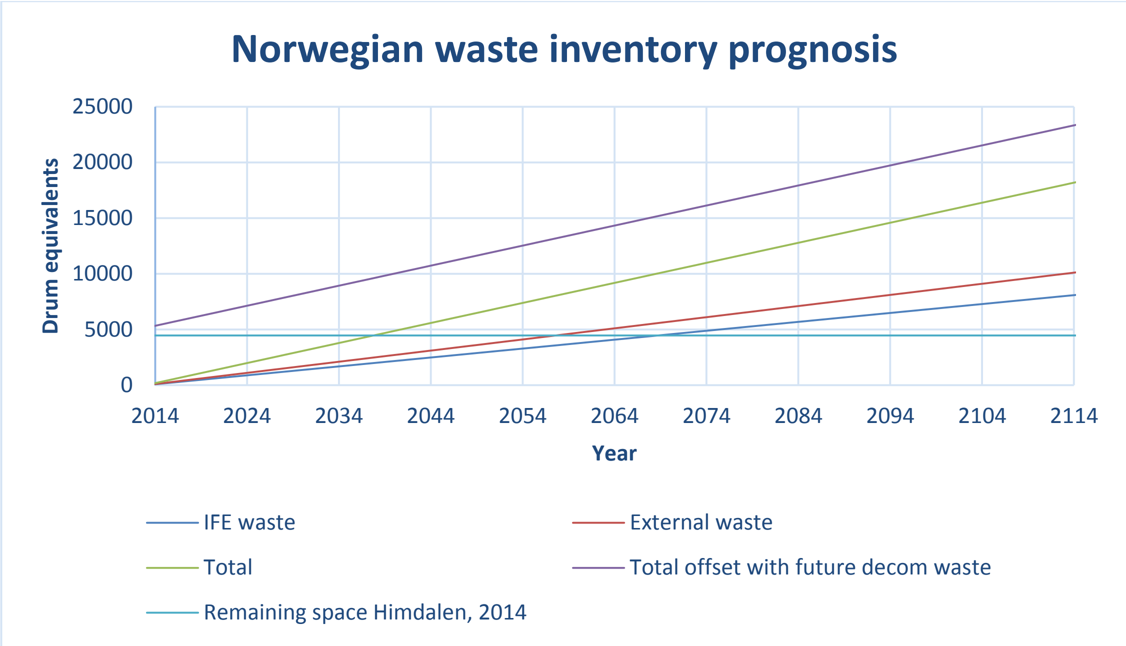

Figure 5-2
Prognosis for low- and intermediate level waste in Norway relative to levels of 2013.

5.6 Dose rate and category assessment

A coarse assessment of dose rates and waste categories for the different waste package types discussed in this report has been made and is presented in Table 5-13 below.

The dose rate assessment has been made using the Microshield software package and coarse models of the waste when possible. For specific waste streams, such as sealed sources, no dose rate assessment has been made since the internal packaging varies, e.g. sources which have the potential to lead to high external dose rates are most likely kept and disposed in their protective casing.

The models used are simple, and the results should be interpreted as coarse estimates.

Concrete boxes have been modelled as cubes with a side length of 70 cm, with an additional 10 or 20 cm concrete wall. The waste has been modelled as iron with an average density of 1 g/cm^3.

Steel boxes have been modelled as cubes with a side length of 150 cm, with an additional 3 mm steel (iron) wall. The waste has been modelled as iron with an average density of 1 g/cm^3.

Drums are modelled as 90 cm high cylinders with a radius of 30 cm, with an additional 1 mm steel (iron) wall. For some waste forms the drum model is modified by including other inner cylindrical objects as described above. In all cases these inner containers are assumed to be of equal height as that of the drum itself. This has no big effect on the dose rate calculated at the side of the drum at mid-height. The waste has been modelled as carbon with an average density of 0.5 g/cm^3.

It has not been possible to determine neither the categorization with regards to activity (Low/Intermediate/High) nor short-/long-lived (SL/LL) waste based on a quantitative approach. This is due both to a lack of clear definitions, as well as a variable list of nuclides reported for the different waste streams. Instead, an estimate has been made where e.g. activated metal and waste with a stated significant content of transuranic elements or other long-lived isotopes has been set as long-lived. This is also true for most wastes from NMAT and the fuel labs which may be assumed to be contaminated by TRU and uranium isotopes.

Similarly, the differentiation between low- and intermediate level waste has been made based on the estimated package dose rate, where the distinction is made at 2 mSv/h.

Table 5-13
Dose rate assessment for packages in the various waste streams.

Waste stream	Packaging	Co-60 (Bq/package)	Cs-137 (Bq/package)	Model	Dose rate estimate (mSv/h)	Estimate SL/LL	Estimated activity category L/I/H
Fuel							
Spent fuel	N/A	N/A	N/A	N/A	N/A	LL	H
Stored waste							
Shielding from industry/medical	Small containers	0	0	Pb-210 and Bi-214. With activities same as the highest of U-234 and U-238. 210 liter drum. 0.5 g/cc carbon	1	LL	L
Solidified U from URA	210 liter drums	0	0	Pb-210 and Bi-214. With activities same as the highest of U-234 and U-238. 210 liter drum. 0.5 g/cc carbon	1	LL	L
From waste manufacturing	Small containers	0	0	Pb-210 and Bi-214. With activities same as the highest of U-234 and U-238. 210 liter drum. 0.5 g/cc carbon	1	LL	L
Operational waste							
HBWR IXR	IXR drum	2.80E+10	1.10E+11	20 cm radius inner drum. 3 cm lead. 7 cm concrete. Waste is set as water 0.13 g/cc and concrete 2.35 g/cc	2	SL	I
HBWR concrete box	Concrete box 10 cm	4.70E+09	1.90E+10	Concrete box 10 cm	2	SL	I
HBWR steel box	Steel box	7.00E+08	2.80E+09	Steel box	0.2	SL	L
HBWR drum	210 liter drum	5.00E+07	2.00E+08	210 liter drum. 0.5 g/cc carbon	0.2	SL	L
NMAT concrete box	Concrete box 10 cm	9.70E+09	2.60E+10	Concrete box 10 cm	3	LL	I
NMAT steel box	Steel box	7.00E+08	2.80E+09	Steel box	0.2	LL	L
NMAT drum	210 liter drum	5.00E+07	2.00E+08	210 liter drum. 0.5 g/cc carbon	0.2	LL	L
Other IFE waste	210 liter drum	1.50E+09	3.40E+09	N/A	0.1 (estimate)	Varies	Varies
Op. waste from external producers	210 liter drum	4.10E+08	2.50E+09	N/A	0.1 (estimate)	Varies	Varies
HBWR decom waste							
Reactor tank material	N/A	1.20E+14	0	N/A	In the order of Sv/h	LL	I
Shield circuit + primary circuit	N/A	3.80E+12	4.70E+07	N/A	In the order of Sv/h	LL	I
Control rods and exp. rigs in core	N/A	6.10E+14		N/A	In the order of Sv/h	LL	I
Bioshield	Concrete box 10 cm	8.40E+09		Concrete box 10 cm	2	LL	I

Waste stream	**Packaging**	**Co-60 (Bq/package)**	**Cs-137 (Bq/package)**	**Model**	**Dose rate estimate (mSv/h)**	**Estimate SL/LL**	**Estimated activity category L/I/H**
Exp. circuit	Steel box	4.40E+08	6.30E+07	Steel box	0.1	SL	L
IXR	IXR drum	3.80E+10	1.70E+11	20 cm radius inner drum. 3 cm lead. 7 cm concrete. Waste is set as water 0.13 g/cc and concrete 2.35 g/cc	2	SL	I
Other waste in concrete boxes	Concrete box 10 cm	4.70E+09	1.90E+10	Concrete box 10 cm	2	SL	I
Other waste in steel boxes	Steel box	7.00E+08	2.80E+09	Steel box	0.2	SL	L
JEEP-II decom waste							
Activated metal	Concrete box 20 cm	1.50E+11		Concrete box 20 cm	9	LL	I
Activated concrete	Concrete box 10 cm	1.64E+09		Concrete box 10 cm	0.5	LL	L
Contaminated metal	Steel box	6.15E+08		Steel box	0.1	SL	L
Other wastes	Steel box	1.14E+08		Steel box	0.01	SL	L
Fuel lab decom waste							
Drum A1	210 liter drum	7.68E+08	5.13E+09	20 cm radius inner drum. 6 cm lead. 4 cm concrete	3.00E-02	LL	L
Drum A2	210 liter drum	3.84E+08	2.56E+09	20 cm radius inner drum. 3 cm lead. 7 cm concrete	8.00E-02	LL	L
Drum A3	210 liter drum	1.15E+08	7.69E+08	20 cm radius inner drum. 10 cm concrete	2.00E-01	LL	L
Drum B	210 liter drum	3.84E+07	2.56E+08	25 cm radius inner drum. 5 cm concrete	0.1	LL	L
Drum C	210 liter drum	3.86E+06	2.57E+07	30 cm radius inner drum	2.00E-02	LL	L
Concrete box D	Concrete box 10 cm	2.30E+08	1.54E+09	Concrete box 10 cm	0.1	LL	L
Concrete box E	Concrete box 10 cm	2.30E+08	1.54E+09	Concrete box 10 cm	0.1	LL	L
Steel box	Steel box	3.84E+07	2.56E+08	Steel box	1.00E-02	LL	L
Radwaste building decom waste							
Steel box from 012	Steel box	4.00E+06	2.00E+07	Steel box	1.00E-03	LL	L
Steel box from 010	Steel box	0	0	Steel box	0	LL	L
Steel box from 102	Steel box	2.00E+06	2.00E+06	Steel box	4.00E-04	LL	L
Steel box from 103B	Steel box	1.00E+04	1.00E+04	Steel box	2.00E-06	LL	L
Steel box from 004	Steel box	5.00E+04	5.00E+04	Steel box	1.00E-05	LL	L
Steel box from 107	Steel box	3.33E+05	3.33E+05	Steel box	7.00E-05	LL	L
Drums lagertankar	210 liter drum	7.40E+04	1.40E+04	210 liter drum. 0.5 g/cc carbon	2.00E-04	SL	L
Drums inndamperanlegg	210 liter drum	6.28E+08	6.28E+08	210 liter drum. 0.5 g/cc carbon	2	LL	I
Steel box from gammel ionebyttersilo	Steel box	8.00E+06	8.00E+06	Steel box	2.00E-03	LL	L
Steel box from presse/kvarn	Steel box	2.50E+04	2.50E+04	Steel box	5.00E-06	SL	L
Steel box from ionebytteranlegg	Steel box	1.70E+08	6.68E+08	Steel box	5.00E-02	SL	L
Steel box from Lab 107	Steel box	4.00E+05	4.00E+04	Steel box	6.00E-05	LL	L

6 Discussion

6.1 Data uncertainties

This report has presented inventory data that have been gathered at site visits, through databases, published materials and discussions with operators.

As has been pointed out in the previous chapters, there is a lack of accessible detailed information regarding some aspects of the waste. The lack of data stems partly from uncertainties in the source terms in themselves, and partly in how such information is produced and used in the Norwegian waste management system.

Furthermore, this report has made several assumptions in deriving parameters based on the input, further increasing the uncertainties in the data presented, e.g. nuclide inventories.

The main goal of this report has been to provide an overview of waste and a basic set of standard waste package properties that may be used to define a first set of requirements for a future storage and disposal facility for Norwegian radioactive waste.

The level of detail in the data is judged to be sufficient at this stage.

6.2 Available volume at KLDRA

It is of interest to note that the data in this report indicates a deficiency in the available disposal volume in the Norwegian LILW-management and disposal system. Indeed, already today the combined reported waste volumes from the future decommissioning projects exceed the available disposal volume, and the discrepancy increases each year as additional operational waste is generated within the country. For this reason, the conclusion that can be drawn from the data is that additional LILW disposal space is likely to be needed, either in a new facility or through extension of existing sites. It is, however, possible to decrease the waste volumes generated by e.g. sending waste for treatment (free release, melting, incineration etc.) at specialized facilities, see below. Several such facilities are operational in Europe.

6.3 Parallel studies

In parallel to this project, an independent study has been made regarding future decommissioning waste amounts from the Norwegian decom-missioning program, [Huutoniemi et.al., 2014].The study has, based on experience from other facilities and evaluation of component databases, resulted in an estimate of the amount of primary waste. Three different waste treatment strategies are then evaluated resulting in three estimates of the final waste amount for disposal. The strategies are:

- Direct disposal, where waste is packaged and sent for disposal without any significant effort to reduce the waste amount.
- Recycling off-site, where a significant portion of the waste is sent to specialized treatment facilities for waste and/or volume reduction (decontamination, melting, incineration etc.).
- Recycling on-site, where efforts towards waste and volume reduction are made at the site of decommissioning (decontamination).

The resulting waste amount for the three strategies are given in Table 6-1 below.

Table 6-1
Waste disposal volume depending on the waste management strategy used in the Norwegian decommissioning program based on [Lidar et.al., 2014].

	Number of drum equivalents for disposal	**Percentage compared to direct disposal (model a)**
Model a, direct disposal	7 815	100 %
Model b, recycling off-site	4 435	57 %
Model c, recycling on-site	7 040	90 %

It should be noted that there is a large difference between the total decommissioning waste amount presented in Section 3.6.5, i.e. 5 146 drum equivalents, and the most comparable amount in Table 6-1 (model c, recycling on-site). Indeed, the data stated by IFE in the decommissioning plans are more similar to that of the independent assessment for off-site recycling. Since the decommissioning plans by IFE do not take off-site recycling into account, it is clear that there are differences in assumptions.

The main difference is thought to be in assumptions regarding the possibility for on-site free release. The independent assessment has been more cautious in assumptions regarding the possibility to perform on-site recycling. This is partly based on international experience from decommissioning projects where the logistics as well as the amount of information available in the process has been overestimated, leading to actual reduced values of material released than initially planned. It has, however, not been possible to make a thorough comparison between the parameters in the two studies, and consequently an assessment of which one is more reliable.

The data presented in the current report have been based on IFE's reported data since they are official documents supporting IFE's license. This also improves traceability. The difference between the studies does, however, indicate that there may be additional concern that the available volume at the KLDRA facility is not enough for disposal of the Norwegian radioactive waste inventory. It also shows the potential in volume reduction if a waste treatment strategy is chosen. Note, however, that the minimum waste volume (off-site recycling) is still approximately equal to the available KLDRA volume at the time of writing. Since operational waste continues to be generated until decommissioning starts, the available volume for decommissioning waste will be reduced.

6.4 Ownership of waste

This report has not discussed the ownership issue regarding the Norwegian radioactive waste inventory. Instead, it has been assumed that all, or a vast majority, of the operational waste is owned by IFE as it is the legal entity tasked with operation of the facilities producing the majority of the waste. Furthermore, external waste is treated by IFE as a licensed entity, implying ownership by IFE as well.

Ownership of some of the waste, e.g. nuclear fuel, could potentially be transferred to a third party as part of a reprocessing deal. This material would then no longer be classified as waste, but may lead to some reprocessing waste being transferred back to the sender.

Future waste could potentially have another owner if that owner is awarded a license to conduct nuclear or waste management operations. This could for example be an operator of a future nuclear facility, a holder of a license to manage sealed sources, or a third party which is responsible for decommissioning etc. There are, however, currently no plans for such operations.

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8 Revision record

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