SKB International Report 173

Joint Top Down Review of Potential Benefits of transferring Swedish technology for geological disposal to the UK

Prepared for Radioactive Waste Management Limited by SKB International AB, Sweden, in close co-operation with RWM

Final Report

August 2014

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Executive summary

Radioactive Waste Management Limited (RWM) in the UK is considering how it could further enhance confidence, and potentially reduce costs and timescales of implementation of a Geological Disposal Facility (GDF) by the transfer of technology from overseas programmes that are more advanced. As a first step, it has entered into discussions with SKB who submitted in March 2011 licence applications for an encapsulation facility and a geological disposal facility in Sweden. RWM is also considering technology transfer[1] with other organisations who are planning to implement disposal facilities in other geological settings. However, the advanced state of SKB's programme makes it an appropriate starting point for quantifying the potential benefits of technology transfer.

RWM commissioned this study as part of an ongoing policy commitment to build upon international progress and experience with geological disposal programmes.

The benefits of technology transfer have been explored and discussed in previous studies and are mainly related to the significant value in enhancing confidence in the safety of geological disposal.

This study is based upon a previous work that examined how the SKB licence applications that were completed and submitted in March 2011 can have benefits to a GDF in the UK. The aim of this study was to quantify the cost benefits and potential savings that could ultimately be achieved by technology transfer. The output is an estimate of the high level cost saving potential.

There have been many initiatives to compare the costs of national GDF programmes but the differences in national inventory and the allocation of roles and responsibilities for decommissioning and disposal make meaningful comparisons very difficult. Therefore to examine the potential cost savings of technology transfer it was necessary to recognise some of the key differences in the organisational remits, approaches to compiling costs and country specific requirements. The study therefore focussed on the:

- (i) costs that could be avoided within the UK programme by using technology already developed and how this compared to the potential cost of purchasing the SKB technology and the cost of adaptation. This would typically take the form of development costs not the capital costs, which would be considered as unavoidable.
- (ii) near-term benefits i.e. the benefit of transferring the technology developed by SKB that underpins the licence application for a GDF in Sweden.

For the purposes of the cost review it was necessary to assume that a UK GDF would be implemented based on SKB technology at a site for which this is applicable for UK heat generating radioactive wastes.

Based upon a high level analysis of costs the estimate of the potential cost saving to the UK GDF programme from the possible use of technology transfer from the SKB programme is as follows:

1. SKB has identified £1 billion of technology developed to support the licence applications for the Swedish final repository and the encapsulation plant for spent nuclear fuel.
2. RWM has identified around £1.6 billion of UK GDF avoidable costs of which approximately £500 million (30%) (2010 money value) could potentially be removed by obtaining the SKB developed technology.
3. The costs incurred by SKB to develop the technology are understandably higher than the RWM cost estimate of potentially avoidable costs that could be avoided by obtaining SKB technology

[1] It should be noted that the word "technology" is used in a broad sense in this context. In addition to pure technology, e.g. for investigations and constructions it includes all the background knowledge needed for designing a GDF and for performing an adequate safety assessment to the level that a licence application can be made and that construction and operation can begin.

as:

- SKB technology was developed on the basis of a first of a kind project and includes significant costs for demonstration facilities (such as the Äspö HRL, Canister and Bentonite Laboratories). RWM technology will be developed from a more mature platform of GDF technology now available from significant progress internationally. This removes the need for RWM to incur costs of the magnitude of SKB.
- The SKB technology includes transport and encapsulation plant technology. These items are not included in the RWM costs as they are the responsibility of waste owners. It is however to be expected that RWM will need a certain amount of knowledge even within technology areas which are not within RWM responsibility but still part of, or closely related to, RWM's disposal system.

4. SKB has estimated that approximately 90% of the SKB technology could be applicable to UK GDF development in a higher strength rock.

   Although the SKB technology is primarily for spent fuel disposal, much of the knowledge will also be applicable to other waste disposal, in particular HLW and nuclear materials, but also for ILW and LLW if disposed in a GDF. The value of this component has not been assessed in this study.

5. RWM would need to adapt any technology to the UK programme needs. The SKB resources for such adaptation have been estimated by SKB to about £32 million. In addition similar resources would be needed from within RWM, corresponding to approximately £24 million. Therefore the total adaptation costs for a joint SKB/RWM adaptation team would be approximately £55 million (approximately 10% of the technology costs).

6. If RWM could obtain the SKB technology for half the cost that SKB has spent developing the technology, no significant costs could be removed from the RWM costs. Instead, the value to RWM would be in terms of the significant value of reducing risk and building confidence.

7. If RWM could obtain the technology for an assumed 10% of the cost to SKB then once adaptation costs have been taken into account, RWM could potentially save up to £350 million of development costs (£500m – (£100m + £55m)).

8. SKB suggests that to make a business case for technology transfer a pricing factor of 10% < F < 50% should be explored.

9. Key areas where SKB technology could potentially remove RWM costs are in the areas of:

Engineered Barrier Systems	£210 million
Spent Fuel	£70 million
Site Characterisation	£90 million
Safety Analysis	£70 million

10. A high level analysis of the impact of discounting suggests that this would equate to a discounted cost of approximately £205 million.

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1 Introduction

Radioactive Waste Management Limited in the UK is considering how it could enhance confidence, and potentially reduce the costs and timescales of implementation of a Geological Disposal Facility (GDF) by the transfer of technology from overseas programmes that are more advanced. As a first step, it has entered into discussions with SKB who submitted in March 2011 licence applications for an encapsulation facility and a geological disposal facility in Sweden. Radioactive Waste Management Limited is also considering technology transfer with other organisations who are planning to implement disposal facilities in other geological settings. However, the advanced state of SKB's programme makes it an appropriate starting point for quantifying the potential benefits of technology transfer.

RWM commissioned this study as part of an ongoing policy commitment to build upon international progress and experience with overseas geological disposal programmes.

1.1 Background

In 2011 Nuclear Decommissioning Authority Radioactive Waste Management Directorate (NDA RWMD, the predecessor of RWM prior to April 2014) commissioned a study to understand what information and technology are available now to improve confidence in the safety of geological disposal and what key information and data could be used to inform future concept selection work (as illustrated in Figure 1). An overarching aim of the study was to provide authoritative quantification of potential benefits in terms of timescales, cost and any other benefits such as reduction in programme or project risk connected with the potential use by NDA RWMD of imported technology.

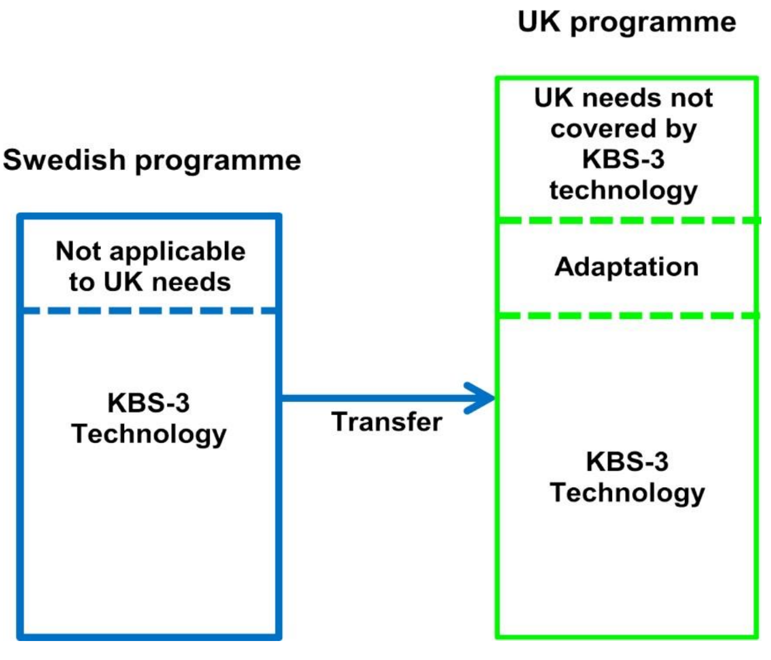

Figure 1: Schematic illustration of KBS-3 technology transfer.

A systematic review, was carried out and the output was reported in [SKB International, 2012, or "R157"] The study concluded that it is SKB's opinion that for spent nuclear fuel (SNF) and high-level waste (HLW):

- 80%-90% of the KBS-3 technology would be applicable to a UK GDF programme at a site with higher strength host rock.
- 60% of the KBS-3 technology would be applicable to a UK GDF programme at a site with lower strength sedimentary host rock.

- 20%-30% of the KBS-3 technology would be applicable to a UK GDF programme at a site with an evaporite host rock.

Much of the knowledge would also be applicable for disposal of intermediate-level waste (ILW) and low-level waste (LLW) disposal in a GDF.

SKB's licence applications, and the KBS-3 technology on which they are based, have been subject to international peer review, including the positive views from the independent Nuclear Energy Agency review reported in June 2012 [NEA, 2012] and are currently being reviewed by the regulatory authorities in Sweden. This, coupled with the analysis of applicability, provides confidence that the UK GDF programme could benefit significantly from technology transfer. The benefits would include:

- Improved confidence in the UK programme.
- Potential reduction in programme risk.
- Potential cost and programme savings.

[R 157] set out to define and quantify the potential benefits of technology transfer in terms of both cost and time. The cost of the technology developed by SKB so far for licensing review in Sweden is SEK 12.7 billion (approximately £1.15 billion). SKB expects this to rise to £1.5 billion to the start of construction. The continued development to industrialise the technology is expected to take this figure to SEK 21.2 billion (approximately £1.9 billion).

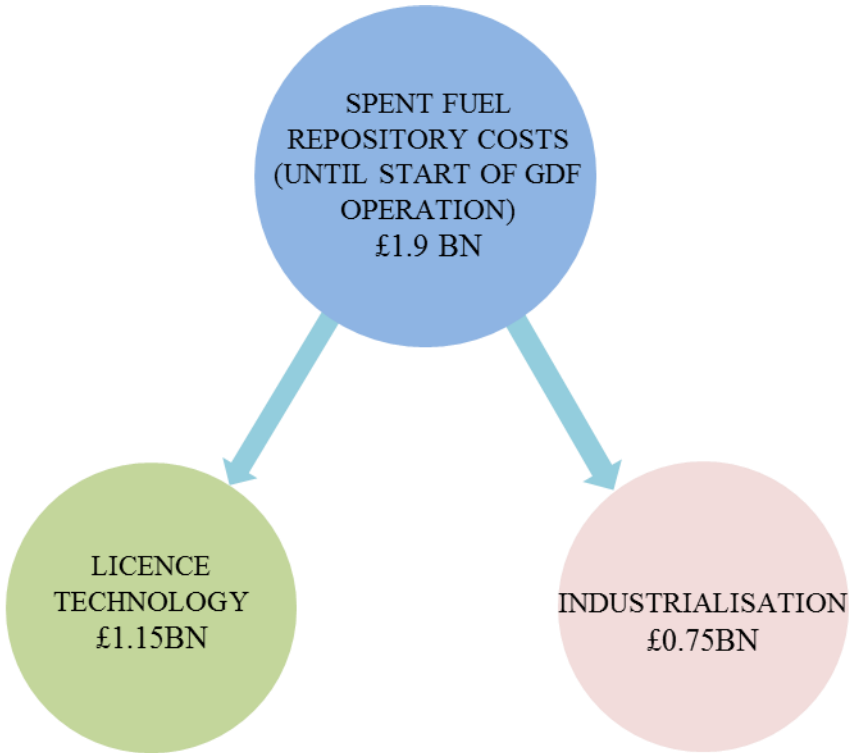

Figure 2: *Distribution of total costs for the Swedish spent fuel repository. Estimates are based on SKB's cost calculations (Plan Reports[SKB 2010, 2013]). The amounts are presented in 2010 money value.*

In SKB's view the net savings to RWM by employing the KBS-3 technology compared with developing its own technology will depend on several factors, including RWM's costs to import the technology compared to potential cost increases due to more comprehensive requirements and processes that could be expected if the same development was initiated today.

The previous work, [R157] also reported that SKB has spent between 18 and 27 years developing key parts of the KBS-3 technology. Differences in the UK and SKB programmes make it difficult to estimate the time savings in the UK programme as a result of technology transfer The importance of acceptance also means that activities relating to engaging with stakeholders delivering site selection dictate the pace and duration of a GDF programme.

Report [R157] stated SKB's overall view that the UK programme could benefit significantly from technology transfer at the different stages of the UK programme. However SKB International is not in a position to assess the potential cost saving or value to the UK GDF programme of the SKB technology. Hence it was concluded that in order to progress this initiative three areas were identified for further joint consideration:

I. Development of the options for technology transfer to further understand the commercial implications.

II. Review of potential benefits against NDA RWMD's programme and cost estimates to improve understanding of the financial benefits to the UK.

III. Review of the detailed technology transfer proposals that have been developed as part of the study and agreement of appropriate action for each stage of the UK programme.

This report summarises a joint study by SKB International and RWM to address item II above.

Due to the differences in the programmes within each country this joint review compares costs at a high level in order to achieve the following outcomes:

1. A high level figure for the potential cost savings to the RWM GDF programme of technology transfer from the SKB programme.
2. The main caveats and high level assumptions on which the cost saving is based.
3. The key technology areas for consideration of technology transfer.
4. A statement on the licence arrangement and fee for use of the SKB technology.
5. A discussion on the range of potential benefits depending upon the use by the UK of technology from SKB.

2 Objective and assumptions

2.1 Objective

There have been many initiatives to compare the costs of national programmes but the differences in national inventory and the allocation of roles and responsibilities for decommissioning and disposal make meaningful comparisons difficult.

Therefore to examine the potential cost savings of technology transfer it was necessary to recognise some of the key differences in the organisational remits and country specific requirements. The study therefore focussed on the:

(i) costs within the UK programme that could potentially be reduced or removed by use of existing technology and how this compared to the potential cost of purchasing the SKB technology and the cost of adaptation.
(ii) near-term i.e. the benefit of transferring the technology developed by SKB that underpins the licence application for a GDF in Sweden.

The objective of the study is to determine a joint understanding of the basis and assumptions behind the different parameters in the following formula in order to quantify a high level estimated figure of the value and potential cost benefit (B) to RWM of technology transfer from SKB.

B = RWM relevant costs against which savings can be compared – (Cost of applicable technology from SKB + Cost of adapting the technology)

The aim is to achieve the following outcomes:

1. A high level estimate for the potential cost savings to the RWM GDF programme of technology transfer from the SKB programme (with reference to published GDF cost estimates).
2. The main caveats and high level assumptions on which the cost saving is based
3. The key technology areas for consideration of technology transfer
4. A statement on the licence arrangement and fee for use of the SKB technology
5. A discussion on the range of potential benefits depending upon the use by the UK of technology from SKB.

The key objective is a high level quantified estimate of the potential cost benefit of technology transfer (TT) to RWM.

2.2 Assumptions

The main differences between the programmes in both Sweden and the UK were identified in the previous study [R157] and include:

Host rock

RWM is considering three potential host rock environments [NDA 2010]:

1. **Higher strength rock**, similar to the hard crystalline rock environments in Sweden and Finland
2. **Lower strength sedimentary rock**, typically argillaceous, clay type environment, such as in France and Switzerland
3. **Evaporites**, typically salt, such as in Germany and USA.

For the purpose of this study the cost figures for higher strength host rock were used.

Inventory

The SKB licence application presents the case for disposal of Spent Nuclear Fuel.

RWM must consider all higher activity radioactive wastes including High Level Waste, Spent Nuclear Fuel, Plutonium and Uranium as well as intermediate level waste (ILW) and low level waste (LLW) not suitable for near-surface disposal [NDA 2010].

Regulatory Framework

Both countries must adhere to the same international conventions and European Union Directives and Safety Standards. Both have separate safety and environmental legislation bodies. However the regulatory requirements and licensing procedures are different and must be addressed by the implementing body applying for the licence.

Study Assumptions

Due to country specific requirements and differences between the organisations a number of assumptions were needed in order to conduct the cost review. These are set out in the following list.

1. A GDF is assumed to be implemented at a higher strength rock host environment in the UK for which KBS-3 is applicable.
2. KBS-3 is considered applicable to UK wastes and materials packaged in copper canisters.
3. The UK inventory to be placed in copper canisters is assumed to be:
    a. HLW
    b. Spent Fuel (that is for direct disposal)
    c. Pu (for disposal)
    d. Highly enriched uranium (for disposal)
4. The number of canisters to be emplaced is 8,800.
5. The throughput and size of facilities is based on 8,800 canisters, 1 per day, 200 max per year, i.e. the same throughput is assumed for the design of both the UK and SKB facilities.
6. Although not a feature of the UK programme the SKB experimental facilities are an integral part of the technology available and applicable to the UK programme (taking into account the above assumptions) and therefore the SKB technology costs include:
    a. Äspö HRL
    b. Bentonite Laboratory
    c. Canister Laboratory
    d. Prototype equipment
    e. Demonstration trials
7. The UK waste is assumed to arrive at the GDF packaged inside a copper canister and ready for disposal. I.e. although the following costs are included in the SKB technology costs, it is acknowledged that they are excluded from RWM costs:
    a. Copper canister costs (including inserts)
    b. Canister factory cost
    c. Encapsulation plant costs

    Although these costs are not part of this comparison, it can be expected that RWM will have to acquire certain knowledge about the long term behaviour of the copper canister and how this is guaranteed through the activities to be performed during canister fabrication and encapsulation. Such knowledge is also part of the technology that can be provided by SKB.
8. The findings of SKB International Report R157 are to be used for the purpose of this study i.e.

   a. 80–90% of the technology developed by SKB is assumed to be applicable to the UK reference concept for a higher strength rock, mainly for disposal of HLW, SF, and Pu, but also to a certain extent for disposal of ILW and LLW in a GDF.
   b. SKB has spent approximately £1 billion up to the point of submitting the licence application.
   c. SKB expects this to rise to £1.5 billion to the point to allow the start of construction.
   d. Construction costs are not included in either of these figures (i.e. the unavoidable costs).
   e. These figures are mainly for research, development & demonstration (RD&D), prototype and demonstration facilities needed for a successful GDF programme to gain the necessary approvals (avoidable costs, based on applicability to the UK).
9. ILW/LLW costs are to be separated at the outset for the RWM costs. However, much of the knowledge included in the geotechnical components of the KBS-3 technology is also applicable to ILW/LLW disposal in a GDF.
10. Adaptation to UK conditions: the SKB adaptation costs are calculated from the resource figures in [R157] and SKB man hour rates are applied. RWM will assume the same level of resources as SKB have estimated for joint adaptation. The RWM resource will be multiplied by the RWM rates as necessary to get the RWM adaptation costs.
11. The same currency conversion figure used in [R157] will be used to maintain an audit trail for the figures but it is recognised that they are subject to fluctuation.
12. The study will be based on non-discounted figures at the price level of 2010. No adjustment is made for future escalation.
13. The UK cost review is based on the estimate undertaken at 2012 money values and the potential saving has been calculated at 2010 money values based on an assumed 2% de-escalation in order to provide a consistent basis for analysis of RWM and SKB cost estimates.

Comment

It must also be re-iterated that the SKB costs presented to date quantify actual costs of KBS-3 development up to licence application. This is not an estimate but is based upon evidence of the costs incurred by an implementer of developing this technology to a point considered fit for purpose to support the licence applications. As a result, the SKB costs represent actual costs of the technology that SKB has available as the basis for technology transfer.

It should be noted that the word “technology” is used in a broader sense in this context. In addition to pure technology, e.g. for investigations and constructions it includes all the background knowledge needed for designing a GDF and for performing an adequate safety assessment to the level that a licence application can be made and that construction and operation can begin.

SKB is willing to make technology available through SKB International[2] to prevent duplication of work by other waste management programmes and implementing organisations.

An important component of SKB’s progress as a leading implementer has been the development, construction and use of facilities as part of the RD&D programme. Such facilities have also been an essential part of working with stakeholders to gain acceptance and as such are valued by the communities as they attract visitors and business to the local areas.

It is also important to note that although previous studies [R157] identified a high percentage of the of the SKB technology to be applicable to the UK programme this does not equate to the percentage of the UK programme that can be considered complete. The aim of this study is to explore the potential benefits to the UK programme from transfer of the applicable SKB technology.

[2] SKB International is a fully owned subsidiary of SKB with the task to market SKB knowledge and experiences on the international market.

3 Method and approach

The potential cost benefit for RWM was estimated through a joint SKB and RWM study. This was based on high level analysis of the applicability of SKB technology set out in the earlier study [R157]. The starting point was the UK (£12 billion [NDA 2013a]) and Swedish (SEK 12.7 billion [R157]) cost estimates (undiscounted) for implementing geological disposal in respective countries.

Scope

SKB set out the eight main technology areas in [R157] and these were used as the basis for setting out the scope of the technology available as follows:

1. System analysis
2. Encapsulation
3. Geological repository facility
4. Site characterisation and site selection
5. Transportation and logistics
6. Long-term safety assessment
7. Environmental impact assessment
8. Nuclear licence application

Area 3 above (Geological repository facility) covers a wide range of technical detail and hence it was necessary to take the scope description to the next level of the work breakdown structure, thus dividing it further to cover the following headings:

3.1 Facility description

3.2 Spent Fuel

3.3 Canister

3.4 Rock construction and openings

3.5 Buffer

3.6 Backfill

3.7 Plug in deposition tunnel

3.8 Closure

During the course of the study, the sub-groups within Technology area 3 have been rearranged to facilitate comparison with the RWM cost figures. This means that 3.2 and 3.3 have been merged into a unit called “SF” (Spent Fuel), and 3.4–3.8 have been merged into a unit called EBS (Engineered Barrier Systems).

Cost analysis

The following formula was agreed at the outset of the study and sets out the logic for the assessment of the costs and the approach to the study:

> B = RWM relevant costs against which savings can be compared – (Cost of applicable technology from SKB + Cost of adapting the technology)

RWM relevant costs against which savings can be compared

These costs were estimated by RWM based on the information summarised in Section 4 of this report and the earlier joint study [R157].

Cost of applicable technology from SKB

This was estimated by SKB based on the incurred costs for the KBS-3 technology [R157] multiplied by a pricing factor F.

Cost of adapting the technology

This cost was based on the applicability of the KBS-3 technology as set out in [R157] and described in Section 5 of this report. The cost includes:

1. SKB staff to support the adaptation of the KBS-3 technology to a UK context, and;
2. the work that RWM will need to do to support the import and adaptation of the KBS-3 technology to the UK GDF programme.

4 RWM cost assumptions for the top down study

The estimated cost of the geological disposal programme is published in the NDA Annual Report and Accounts (ARAC) [NDA 2013a]. The potential cost savings identified in this report have been derived from the 2012/13 ARAC, as shown in Figure 3. The estimated cost of disposing of separated uranium and plutonium has been added to the cost presented in the ARAC.

For comparison with costs reported in [R157], RWM potential cost savings are presented in 2010 monetary values. A 2% reduction from the 2012/13 cost estimate has been assumed.

RWM costs exclude the cost of waste encapsulation and the cost of transport of wastes to the geological disposal facility; these are the responsibility of the waste owner in the UK programme.

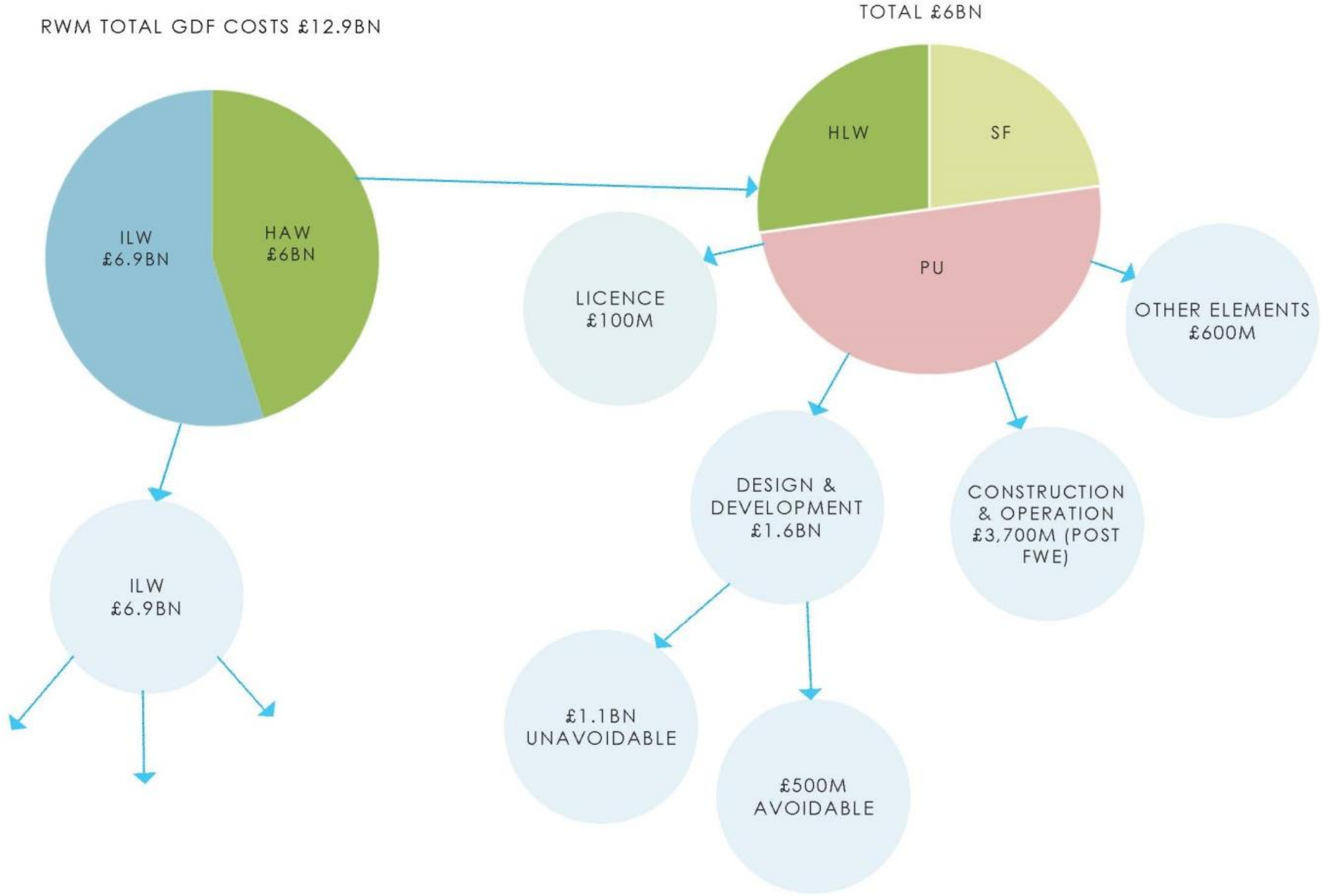

Figure 3: *Overview of UK GDF cost analysis based on [NDA 2013a].*

The RWM programme is divided into 5 phases:

- Preparatory studies £138 million
- Site investigation £1,245 million
- New construction £5,568 million
- Operation £5,322 million
- Closure £646 million
- Total £12,919 million

The cost of construction and operation is considered unavoidable. In addition, staff costs and maintaining a competent organisation are considered unavoidable.

The areas for potential cost savings that have been identified are predominantly to be found in the group avoidable costs and include costs allocated to external resource (i.e. contractor support) to carry out research and develop designs.

An assessment of the potential RWM cost savings is made in Section 7.

5 Adaptation

In addition to gaining access to the technology it is acknowledged that this will need to be developed to meet the specific needs of the UK programme. In order to take full opportunity of the value of the technology this cannot be done in isolation from those who have developed the technology. There is knowledge about the development that resides with those experts who have developed the technology. In order to mitigate risk, a joint RWM and SKB team of experts, those who have developed the technology and those who know the requirements of the new application, must be involved. Hence it has been identified that there will be a cost for this resource and this is referred to as the “Adaptation costs” in this study.

The SKB resources that would be available for this purpose were estimated in the study reported in [R157].

The total figure estimated at this time for the adaptation costs associated with the SKB resources is £32 million. The cost assumes 1,600 working hours per year. The rate applied is SEK 1,600/hour as it is foreseen that only SKB experts with a comparably high degree of experience will be working with technology transfer.

The RWM adaptation cost assumes the same time allocation that was identified in [R157] for SKB adaptation; assuming that SKB and RWM would work together to understand the application of SKB technology to the UK situation. The cost assumes 1,600 working hours per year and a rate of £106.89 / hour. Hence the RWM adaptation cost is identified as £24 million.

6 SKB costs and pricing statement

6.1 Introduction

SKB developed the KBS-3 technology to advance the Swedish programme, the aim was not to make any commercial gain. However as the programme has developed there is much international interest. SKB International developed a strategy in 2008/09 to explore the issue of transferring the SKB technology to other waste management organisations. The strategy was to move towards a delivery organisation able to provide demonstrable benefits and assistance and deliver key aspects to other implementers based upon the SKB available technology. The intention was to explore the potential value of the SKB technology to other organisations. As this work has developed it has become clear that this is not a straightforward task, it depends on many factors, some of which are only known to the receiving organisation e.g. the needs and scope of any transfer and the potential value to another country's programme.

6.2 Value of technology transfer

The main conclusions of [R157] were that in the short term the main benefits to the UK programme are in terms of the potential to increase confidence in geological disposal by the use of examples, lessons learned and data, as well as information and experimental evidence from the SKB programme that underpins the licence applications made by SKB in 2011. The pedigree of the concept having been subject to extensive peer review and regulatory scrutiny is an important factor that adds value. Another important factor is that key parts of the technology have been established reducing the first of a kind risk with such a major project. This is value added over and above any capital and resource costs incurred.

Such benefits are difficult to quantify so the study was restricted to look at the facts of the SKB investment already made and the applicability of this available technology to the UK programme.

6.3 Costs and pricing

The cost of the applicable technology from SKB = the SKB investment cost adjusted by a pricing factor (F) which has been defined for the purposes of this study.

Due to the sensitivities of discussing price this early in the process; without a full understanding of what is needed by RWM, or of what can be provided by SKB, the factor F is provided only for the purposes of this joint top down study.

It should be stressed that; RWM is not asking for a price to buy the SKB technology in 2014, nor is SKB providing a definitive price at this time for the SKB technology.

SKB International's initial views are that the pricing factor F should include consideration of the following:

- SKB investment in the technology
- Potential number of users of the technology
- Degree of shared rights to the technology

There is a high applicability of this technology (80%–90%) at a site with a higher strength host rock (hard rock site), mainly for disposal of HLW, SF and Pu, but also for disposal of ILW and LLW in a GDF.

6.3.1 SKB investment in the technology

[R157] identified that to the point of submitting the licence applications in 2011 the cost of SKB investment in this technology has been of the order of SEK 12.7 bn (approximately £1.15bn) with the investment value expected to rise to £1.5bn in order to industrialise the process for start of construction.

6.3.2 Potential number of users of the technology

SKB has a long term interest in increasing the credibility in geological disposal and in particular the KBS-3 system. The open and transparent approach of the work of SKB to date has been necessary in developing this technology for a 'first of a kind' application and has led to the work being extensively reviewed. SKB is supportive of other waste management organisations using its technology and facilities in order to increase:

- the credibility of the technology,
- the confidence that it can be implemented successfully; and
- the bank of knowledge and competent supply chain available to the user.

Many countries reference the work of SKB and countries such as Canada and the UK have gone so far as to state that KBS-3 is a reference concept used mainly for illustrative purposes. At the moment it is only Posiva in Finland who have used the KBS-3 method as part of their permission and licensing process.

6.3.3 Degree of shared rights to the technology

The KBS-3 technology has been developed predominately by SKB. Since the mid 1980's Posiva of Finland has co-operated through a joint working programme and made a contribution in terms of co-operation with both resources and funds to the successful development of this technology. This would need to be taken into account when distributing any income from any sale of the KBS-3 technology. This would potentially vary depending on the area of technology and the contribution of Posiva to its development. This paper does not include any further discussion of such consideration (as this is a matter for SKB and Posiva). For the purposes of this study SKB and Posiva are to be viewed as a joint single developer and user of this technology.

6.3.4 Other pricing considerations

Factors regarding the intended use of the technology are also important considerations and potential uses could include:

- Benchmarking, an alternative for comparison involving use of SKB published information.
- Adaptation and use (implementation) with SKB involvement.
- Ownership for further development not necessarily with SKB involvement (RWM may wish to compete for the adaptation task).

Previous studies have considered the options of SKB's role in terms of involvement, responsibility and risk. The following options were identified in [R157]:

Option 1: Licence for transfer of documentation and consulting support (to ensure understanding of application).

Option 2: Close co-operation between NDA RWMD and SKB towards a UK solution.

Option 3: SKB provides the KBS-3 technology adapted to the UK needs (SKB delivers solutions).

None of these options involve SKB supply of facilities to the UK or operation of the facilities in the UK. The middle option is the stated preferred option of SKB as it is mutually attractive with active use of SKB experts and facilities and ability to mitigate any risks and liability.

6.3.5 Current status

Taking the three bullet points made in the introduction in Section 1 as follows:

Improved confidence: Countries such as Canada and the UK have KBS-3 as a stated reference concept in their published documents; however no decision has been made on the selected concept at any potential site. The use of a concept in this way has a value in terms of building confidence that geological disposal can be implemented. The ‘value’ of the SKB technology in building confidence is difficult to assess at this time (the short term).

Reduction in programme risk: SKB facilities and RD&D can be used to reduce the costs of experimental facilities and the need for significant expenditure in siting and establishing full scale demonstration tests to build the competence in the relevant technologies. The existence, acceptance and support for the SKB demonstration facilities make this a potentially valuable asset. SKB, with the support of the local community and academic community has made investments to enable such facilities to be available to other parties. This is an area that may realise potential tangible benefits in the short to medium term. However until the need from RWM for such facility has been established it is not possible to quantify the potential cost and time savings, this will depend upon the RWM RD&D programme and strategy.

Potential cost and programme savings: This is the point that the joint top down study sets out to quantify. In order to make progress the SKB investment costs identified above and described in [R157] are to be used for the calculation. Using the earlier assumption that SKB and Posiva are considered as a single body, at this time, there would be two potential users should the UK wish to use the technology.

6.3.6 Discussion and conclusion on pricing

There are too many unknown aspects of technology transfer in terms of:

- The scope of the technology transfer.
- The intended use of the SKB technology by RWM.
- The risks and responsibilities of SKB in transferring the technology.
- The ongoing role of SKB in support of any transfer.

Based upon the factors considered above a pricing factor based on two potential users would suggest a pricing factor of around 50%. However it could decrease should there be more potential users. On the other hand should a value be put on factors such as improved confidence and reduction in programme risk then the factor could increase.

For the purposes of this study a range for the Pricing Factor ‘F’ was used of 10%-50%.

7 Identification of potential RWM cost savings

Table 3 below shows the estimated costs that could be potentially avoided through technology transfer. The main areas where significant potential savings have been identified are:

- Engineered barrier systems – £210 million
- Spent fuel – £70 million
- Site characterisation – £90 million
- Safety analysis – £70 million

These areas identify the basis for further discussion of work packages to take forward in the future.

The analysis of potential cost savings was based on the analysis of applicability of the KBS-3 technology to the UK programme presented in the earlier study [R157]. The RWM cost estimate for elements considered in the Technology Transfer are based on the assumed manpower and external supply chain costs to undertake the R&D, and engineering. These estimates have been taken into account in the consideration of the reduction that could be possible as a result of technology transfer.

Cost estimates have been quoted in the table to 5 significant figures due to adjustments such as money value conversions and does not imply a level of accuracy.

The potential cost savings identified in this section does not include savings incurred through the reduction in programme risks and enhanced confidence and acceptance of an already implemented technology.

Table 3: Potential RWM savings associated with technology scope areas

1 System analysis		**£6.756m** The overview of alternative systems for spent nuclear fuel is highly applicable as a background for the evaluation of options for disposal of spent nuclear fuel, HLW, plutonium and uranium. It is assumed that 5% of the estimated cost associated with preparatory studies could be saved. This is based on current level of progress and UK specific considerations for waste and the siting process.
2 Encapsulation		0 Encapsulation is the responsibility of waste owners in the UK.
3 Geological repository facility		
Facility description		0 Facility description not identified separately in UK.
Spent Fuel	Description of spent nuclear fuel	£68.538m It is assumed that costs of external resource in research and design could be saved through technology transfer to develop the understanding of long-term evolution and behaviour of spent fuel under repository conditions and models and data required to support the safety case. Costs associated with understanding the waste package for disposal and developing waste package specifications are identified here.
Spent Fuel	Description of canister	0 Canister development costs are the responsibility of waste owners in the UK.
Total, Spent Fuel		**£68.538m**
Engineered Barrier Systems	Description of underground openings	£81.838m It is assumed that a proportion of the costs associated with research and design external resource and project management can be saved through technology transfer. This mainly covers the work required to develop the design (including excavation and construction technique) and the understanding of long-term evolution, rock processes, radionuclide transport in the geosphere, models and data to support the safety case. This scope area is part of the EBS technology.
Engineered Barrier Systems	Description of buffer	£40.919m The KBS-3 backfill design and production processes can be fully used with minor adaption to UK conditions, The assessment of post-

		closure processes has to be adapted to groundwater properties at the selected site. It is assumed that a proportion of the costs associated with research and design external resource and project management can be saved through technology transfer through the need not to develop all the technology needed for backfill to support design (i.e. the requirements, design, fabrication and installation of backfill) and safety case (i.e. developing an understanding of long-term evolution of the backfill, radionuclide transport in the backfill, processes that could impact performance and models and data). This scope area is part of the EBS technology.
	Description of backfill	£40.919m It is assumed that a proportion of the costs associated with research and design external resource and project management can be saved through technology transfer through the need not to develop all the technology needed for backfill to support design (i.e. the requirements, design, fabrication and installation of backfill) and safety case (i.e. developing an understanding of long-term evolution of the backfill, radionuclide transport in the backfill, processes that could impact performance and models and data). This scope area is part of the EBS technology.
	Description of plug in deposition tunnels	£40.919m It is assumed that a proportion of the costs associated with research and design external resource and project management can be saved through technology transfer through the need not to develop all the technology needed for plugs for the deposition tunnel to support design (i.e. the requirements, design, fabrication and installation of plugs) and safety case (i.e. developing an understanding of long-term evolution of the plugs and the processes that could impact performance). This scope area is part of the EBS technology.
	Description of closure	£2.749m It is assumed that costs of external resource in research and design for closure could be saved through technology transfer through the need to not develop all the technology required to develop the closure requirements, design (including fabrication and installation and safety case (i.e. developing an understanding of long-term evolution of the GDF closure, the processes that could impact performance, models and data).
Total Engineered Barrier Systems		**£207.344m**
4 Site characterisation		**£90.139m** It has been assumed that 50% of the cost of research and design external resource could be avoidable through technology transfer.
5 Transport and logistics		0 Transport is the responsibility of waste owners in the UK.
6 Long-term safety assessment		**£68.538m** It is assumed that the cost of external resource in research and design could be saved through technology transfer (i.e. by drawing on the SKB work undertaken to identify disposal system requirement, prepare the production line reports[3] and adaption of relevant aspects of safety assessment methodology).
7 EIA		**£26.562m** It is assumed that the cost of external resource in research and design and a proportion of external resource supporting regulatory submissions could be saved through technology transfer.
8 Licence application		**£33.663m** It is assumed that a proportion of the cost of external resource supporting regulatory submissions and a proportion of project management costs could be saved through technology transfer.
TOTAL		**£501.541m**

[3] The aim of production reports is to *verify* that the chosen design complies with the design requirements.

As the potential costs occur over the lifetime of a long term project (i.e. approximately 125 years), a high-level analysis has been performed of the impact of cost discounting. The RWM costs are based on the NDA project controls procedure which uses a 2.2% discount rate. On this basis the discounted value of costs avoided by obtaining SKB technology have been estimated by RWM as approximately £205 million.

8 Value of co-operation and technology transfer

Technology transfer in the field geological disposal is closely related to increased co-operation between the parties involved. During the course of this study it has been established that the value of co-operation is not a simple case of discussing and identifying cost savings. The value of co-operation, particularly during the early stages of a geological disposal programme are more in terms of increasing the credibility of the technology with stakeholders by reference to demonstration facilities and the evidence available through work in other countries. The added value is also in terms of providing the opportunity to build and develop competence using available facilities and the associated infrastructure. The drivers for RWM in maintaining co-operation with the Swedish waste management organisation are summarised as follows:

- To improve confidence in the UK programme by providing access to SKB staff and facilities to support the demonstration that geological disposal is being implemented successfully overseas.
- To utilise the existing body of knowledge available from the Swedish programme to aid in the development of a geological disposal solution appropriate for the UK and provide a basis for future transfer of technology.
- To secure value for money for the UK tax payer by capturing and applying lessons learnt from the implementation of geological disposal in Sweden.
- To provide RWM staff with opportunities to add value to the Swedish programme by contributing to underground rock laboratory experiments or working within a geological disposal environment.
- To provide development opportunities for RWM staff.

The main drivers for SKB International on behalf of SKB in maintaining co-operation with the UK waste management organisation are summarised as follows:

- To promote international credibility of geological disposal.
- To make the SKB facilities at Oskarshamn, such as the Äspö URL available to overseas organisations (as part of the Added Value Programme which aims to support the local communities that host SKB's encapsulation plant and geological disposal facility).
- To protect the use of SKB information by others.
- To reduce the risks of communication and mis-information about the SKB work programme.
- To save cost and time for other waste management organisations.
- To provide opportunities for SKB staff and contractors who have gathered expertise but who are no longer fully utilised as the SKB programme has advanced.

8.1 Key technology areas

A number of areas have been highlighted for further development where there could be significant cost savings as well as a value in competence building and transfer of validated tests and models. These are summarised as follows:

Key Technology Areas for consideration for potential Technology Transfer:

- Engineered Barrier Systems, including areas of interest such as bentonite, backfill, construction of opening and construction tests in Äspö etc.
- Spent Fuel including SKB work in the canister lab and on corrosion etc. as well as aspects from the canister development that the implementer must lead.
- Site Investigation, an area where SKB has developed technology, that is not the subject of continued development, as SKB has passed this stage, but where RWM could explore the

principles of technology transfer and adaptation such as using SKB borehole sealing technology as a platform for development of large borehole sealing designs.

- Safety Assessment, this is an area where SKB has vast experience but where the UK would need to take the lead for the specific permissions needed for the UK regulatory framework.

8.2 Implementation

Overall, the risks to the schedule and cost of a SNF disposal programme are less related to the technology but more relevant to stakeholder acceptance and political decision-making, which of course are intimately connected. The acceptability in turn depends heavily on the trustworthiness of the responsible waste management organisation and the credibility of its plans. SKB's experience is that trust is built on scientific and technical professionalism combined with honest, open and transparent communication with the stakeholders.

This means, in the context of technology transfer, that a solid science-based technology is a necessary minimum but not a sufficient prerequisite for a successful disposal programme. The technology needs to be coupled with high quality management and a long-term stakeholder and decision-maker communication programme to develop confidence in the technology and in the implementing organisation.

In summary, a transfer of SKB technology could provide not only direct cost and schedule benefits related to the technology itself but, equally important, a cost and schedule risk reduction due to a significant contribution to 'transfer of confidence'. SKB has a successful track record not only from the Swedish programme but also from an advanced transfer of the KBS-3 technology to Finland, based on very close co-operation with Posiva. As a result there is in Finland a parliamentary decision both on a site and on the use of the KBS-3 technology.

In 2013 NDA RWMD set out the approach being followed to develop a strategy for technology transfer [NDA 2013a]. The plan identified that at the current stage it is appropriate for RWMD to build its knowledge base of available technology and its understanding of the maturity of the available technology such that it can make informed decisions about transferring the technology at the appropriate point in the implementation programme. Technology transfer is intended to reduce risks through the use of tested techniques and through the transfer of confidence, leading to a reduction in public acceptance risks. There will, however, be risks associated with technology transfer, hence the approach recognises the need to manage and mitigate risks with each progressive stage of technology transfer [NDA 2013b].

Both SKB and RWMD are committed to future co-operation. A Joint Strategy Paper for co-operation between SKB and NDA RWMD was therefore set out in 2013. The document set out the drivers for co-operation and highlighted a number of issues including the need to establish a 5 year programme outlining the potential SKB input based upon RWMD programme needs.

In order to prepare for a more structured approach to the areas of potential co-operation, the 5 year programme has been developed through a series of meetings and workshops involving senior representatives and department heads from RWMD. The resulting programme was the output from a joint workshop and has been reviewed by RWM Heads of Department responsible for delivery of the UK GDF programme. The 5 year programme is structured around a framework of RWM milestones where RWMD require information and input from the SKB programme and now identifies 40 activities for future co-operation, showing the potential SKB input to RWMD milestones and activities.

SKB has found that the basis for co-operation is an understanding of the respective work programmes and the process for implementation which is unique to each country. This provides the context for co-operation.

The 5 year programme forms the basis for taking this forward and exploring the possibilities for SKB technology to best support the RWMD Technical programme [NDA 2013c] and successively identify components of technology transfer.

9 Concluding statement

1. SKB has identified £1 billion of technology developed to support the licence applications for the Swedish final repository and the encapsulation plant for spent nuclear fuel.
2. RWM has identified around £1.6 billion of UK GDF avoidable costs of which approximately £500 million (30%) could be potentially removed by obtaining the SKB developed technology.
3. SKB technology was developed on the basis of a first of a kind project and includes significant costs for demonstration facilities (such as the Äspö HRL, Canister and Bentonite Labs). RWM technology will be developed from a more mature platform of GDF technology now available from significant progress internationally. This removes the need for RWM to incur costs of the magnitude of SKB for spent fuel.
4. The SKB technology includes transport and encapsulation plant technology. These items are not included in the RWM costs as they are the responsibility of waste owners in the UK programme. It is however to be expected that RWM will need a certain amount of knowledge even within technology areas which are not within RWM responsibility but still part of, or closely related to, RWM's disposal system.
5. It is therefore noted that differences would be expected between the SKB incurred costs and the RWM cost estimate.
6. SKB have estimated that approximately 90% of the SKB technology could be applicable to RWM GDF development in a higher strength rock.

   Although the SKB technology is primarily for spent fuel disposal, much of the knowledge will also be applicable to other waste disposal, in particular HLW and nuclear materials, but also for ILW and LLW if disposed in a GDF. The value of this component has not been assessed in this study.
7. RWM would need to adapt any technology to the UK programme needs. The SKB resources for such adaptation have been estimated by SKB to be about £32 million. In addition similar resources would be needed from within RWM, corresponding to approximately £24 million. Therefore the total adaptation costs for a joint SKB/RWM adaptation team would be approximately £55 million.
8. If RWM could obtain the SKB technology for half the cost that SKB has spent developing the technology (a pricing factor F of 50%) no significant costs could be removed from the RWM costs. Instead, the value to RWM would be in terms of the significant value of reducing risk and building confidence.
9. If RWM could obtain the technology for an assumed 10% of the cost to SKB then once adaptation costs have been taken into account, RWM could potentially save up to £350 million of development costs (£500m – (£100m + £55m)).
10. SKB suggest that to make a business case for technology transfer a pricing factor of 10% < F < 50% should be explored.
11. Key areas where SKB technology could potentially remove RWM costs are in the areas of:

Engineered Barrier Systems	£210 million
Spent Fuel	£70 million
Site Characterisation	£90 million
Safety Analysis	£70 million

12. A high level analysis of the impact of discounting suggests that this would equate to a discounted cost of approximately £205 million.

10 References

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