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The Royal Academy
of Engineering

Review of options for acceleration of geological disposal

Department of Energy and Climate Change

March 2012

Introduction

1. In June 2011, the Minister of State for Energy asked the Radioactive Waste Management Directorate (RWMD), part of the Nuclear Decommissioning Authority (NDA), to conduct a review of the implementation plan for the geological disposal facility (GDF) with the ambition of seeing first waste emplacement being brought forward from 2040 to 2029, with consequent possibilities for acceleration of subsequent emplacements of high-level waste (HLW) and spent fuels.
2. In January 2012, the Royal Academy of Engineering was approached by the Department of Energy and Climate Change (DECC) to provide a review of the NDA options published in December 2011. The Academy, with DECC, agreed an approach whereby a review panel of senior engineers with relevant expertise would be formed and would review the options for acceleration from an engineering perspective. Members of the review panel were:

Sir John Armit CBE FREng (Chair)
Norman Haste OBE FREng
Dr Dame Sue Ion DBE FREng
Professor Hywel Thomas FREng
Professor Paul Younger FREng

Secretarial support was provided by Richard Ploszek, Senior Policy Advisor at the Royal Academy of Engineering.

3. In addition to wide-ranging discussion among the panel members of the issues raised within the options, a joint meeting was held between the panel, DECC and NDA officials and arrangements were made for any queries from the panel to be fielded by experts within NDA and DECC.
4. In conducting this review, the review panel has necessarily been limited to the assessment of the engineering implications (risks and opportunities) of the three scenarios which incorporate a number of specific options and the rigour of the conclusions. In terms of the engineering of the GDF, the panel was of the opinion that planning considerations (as opposed to engineering programme considerations), the Committee on Radioactive Waste Management (CoRWM) proposed voluntarism process (adopted by government) and local community engagement were all part of the engineering delivery of the entire project. The deliverability of the scenarios and the options within them was considered in terms of the normal engineering and project management risks they presented, but the political risks of announcing firm delivery dates ahead of the start of such a major and long-duration engineering project are not assessed in this review.

Terms of Reference

5. The full terms of reference are included in Annex A. The key elements of the Academy review can be summarised as follows.

The peer review should assess the work carried out to date by the NDA on options for accelerating the programme, in particular on options for bringing forward first waste emplacement in a geological disposal facility from 2040 to 2029. It should include views on the robustness of the process the NDA has followed in developing and assessing a long list of options, evaluate the risks and opportunities identified and consider the analysis and conclusions presented in the report.

6. As such, this review was concerned with the potential for accelerating the creation of the repository but not with the technical issues/opportunities of encapsulation of the different types of waste.
7. The review panel did not examine detailed information on the process the NDA followed in developing the long list of options, but has been able to consider the robustness of the output. In this context, the treatment of engineering risks associated with acceleration (announcement of earlier completion dates ahead of project initiation and final project specification) in the options can be assessed and are indicative of the robustness of the processes used to determine them.

General findings

8. The panel accepted that there are clear and agreed processes within the overall process of 'voluntarism' that, in light of the history of GDF development should not be ignored, avoided or rushed. There are expectations of how long community engagement could take but that it is, by definition, it is an open-ended process. The process of voluntarism was proposed by CoRWM and has been adopted by government. To create a repository, a fundamental criterion is community acceptance. This acceptance has been a key factor in other countries which are ahead of the UK in developing GDFs, such as Sweden and Finland. It could well be helpful for the local volunteer communities in the UK to share experiences with the communities which are more advanced in other countries, albeit communities and projects may be potentially different and the review panel understands that funding for some such visits has been, and continues to be, available. Exchange visits might be a valuable endeavour in this regard. This could help build confidence and enable UK communities to come to decisions more quickly and with more information available to them.
9. The review panel noted that there is clearly a determination within the NDA to avoid the problems experienced by Nirex, but at the same time Nirex should not be allowed to create a shadow of concern over the NDA. The NDA should be frank and open about the Nirex issues with stakeholders, and use this candour to create an air of confidence in the NDA approach.
10. Early delivery of a GDF on a set date relies critically on the programme starting on time. Early progress clearly depends on the communities already in the process being prepared to take decisions about proceeding to the next stage. There is considerable preparation to be done prior to engineering works beginning and an early priority should be to ensure that, during the remainder of 2012, every opportunity is taken to encourage acceptance by the stakeholders for investigation to proceed to the next stage. If there is a realistic possibility of further communities making an expression of interest, these options should also be pursued as efficiently as possible. The NDA should have a focused approach to all possible risks and advantages which can be managed in this period.
11. In the opinion of the review panel, options for acceleration of the programme are warranted on a number of grounds:
 - a) Work to reduce timescales in the baseline programme will, in the absence of a decision to bring forward emplacement of waste, create more scope for flexibility in the programme and significantly increase the probability of delivery of the project to time and to budget. In terms of government definitions, every effort should be made in the optimisation of the programme

regardless of decisions over acceleration (announcing earlier dates for first emplacement).

- b) Speeding up of the critical phases of the programme create the option of allowing volunteer communities to take decisions ahead of schedule, and/or to do so with more confidence and on the basis of a better information base.
- c) Although acceleration (of the programme) can introduce some construction risks where progression is made without all of the information that could possibly be available, the acceleration itself can be planned to allow time for engineering solutions to be sought. It is in any case impossible to completely and infallibly characterise the rock mass at proposed gallery depth, and issues concerning unanticipated permeable fractures and the like will have to be managed by engineering interventions (such as high-pressure grouting). Hence, the additional risk of proceeding with some elements of the GDF programme earlier than the baseline case is not large.

12. The review panel concluded that the risks arising from acceleration of the programme break down into four categories:

- a) Financial risks: those that involve extra expenditure but do not necessarily affect programme timing.
- b) Regulatory risks: those that involve new safety cases to be made that will require regulatory oversight with consequent risk of rejection or delay.
- c) Programme risks: where unforeseen circumstances produce knock-on delays in the programme risking late delivery.
- d) Skills and resources risks: where particular skilled workers or regulators are not available in the numbers required at critical points in the programme. This also applies to critical resources, such as specialised pieces of equipment and/or materials.

Site identification

13. It was clear to the review panel that there will never be an absolutely 'perfect site' from a geological/hydrogeological perspective; however, the panel holds the view that engineering solutions are available to ensure creation of a 'fit for purpose' GDF at the finally chosen site (above and below ground) within the range of feasible (hydro)geological conditions. The NDA's proposed options for acceleration will have little or no effect on the eventually chosen site, and contingencies to deal with variations in exact site conditions need to be maintained independently of decisions on acceleration of the announced programme dates.

14. It was also clear to the review panel that while the engineering and timing of scenarios one and two were feasible (see paragraph 33 for the panel's views on the borehole technologies used in option three), specific site conditions would have an impact on the ability of the project team to deliver the project on time and to budget. Some, but not all, of the implications presented by specific sites will be discoverable before a specific site is chosen, so there is little advantage in putting off decisions to rebaseline the programme until a preferred site is positively identified. As added insurance that an accelerated programme could be delivered, it was the view of the panel that other volunteer communities should continue to be sought around the UK (accepting current political sensitivities surrounding engagement with Scottish communities) so as to provide the widest possible choice of sites.

15. While accepting that community decision timeframes might not be brought forward, the panel concluded that there is merit in proceeding with stage four (site identification and assessment) as efficiently as possible. If the baseline programme allows five years for completion of site identification and assessment, there is no engineering reason why this could not be accelerated, using available geological survey data (and data from work previously conducted in the Cumbria region and other Nirex investigations if appropriate), and creating the option of an earlier community decision based on all available information.
16. The five-year horizon for stage four is not dictated by engineering requirements.
17. Depending on environmental permits and planning permissions, some geophysical investigations which do not cause significant impact could be brought forward into stage four if site identification can be accelerated. Although there may be a desire not to commit money and resources to geophysical investigations until after community decisions have been made, if community agreement can be achieved to allow this work to come forward without prejudicing community commitment to the next stage, it makes sense to do so and carries only a small downside risk of some investigation work and expense being wasted.

Site investigation

18. The panel considered that there were no major geological or hydrogeological risks over and above the baseline case in the three scenarios put forward by the NDA. In engineering terms (excluding regulatory and planning risks), all options within the three scenarios concerning site investigation are credible and robust.
19. Within stage five, the review panel considered that it would be sensible to proceed with exploratory boreholes in parallel with further geophysical investigations. The view of the panel was that for a less sensitive project, the first few boreholes would be sunk on a 'best guess' basis in order to obtain as much information on rock characterisation as quickly as possible. Bearing in mind that environmental and planning concerns may lead to the absolutely optimal borehole sites not being made available, the additional risk of using an element of 'best guess' based on a partial dataset of geophysical information does not increase programme risk as much as might be initially thought. This approach should be considered. A 'best guess' approach to early borehole sighting would naturally be to place boreholes where they have the least possibility of interfering with a 'best guess' vault layout to reduce the risk rendering a suitable rock volume unusable. As even a meticulously planned exploratory borehole programme cannot fully characterise the rock volume at depth, the review panel considered there was also a residual risk of planned boreholes rendering rock volumes unusable that later turn out to have been optimal, so the additional risk a 'best guess' approach for early boreholes was not as large as might otherwise be expected.
20. Sinking of early boreholes ahead of full geophysical information carries a risk of potentially requiring a small number of extra boreholes to be sunk. This does not pose a programme risk as the time required to drill to a 650m depth in hard rock is only of the order of a month or so. Of more concern might be the ongoing availability of rigs and skilled drilling operatives in a constrained market with many other calls on the drilling operators' time.

Construction phase

21. The review panel was of the view that the timelines expressed in the baseline case were very conservative (with significantly more time devoted to the decision-making processes than might be expected in a purely commercial project) and that, with good project management techniques, there was scope to optimise the programme in its current form, without adopting new scenarios. It was felt that the currently accepted timelines were not dictated by engineering requirements alone.
22. The methods of achieving acceleration in scenarios one and two are all technically feasible, in terms of the engineering involved, with little downside risk.
23. The acceleration proposals in scenario three are technically feasible with the exception of the deep borehole approach in scenario three will require considerable further research and development, and by its very nature carries construction risks which inevitably make it a higher-risk option compared to the underground tunnelling approaches. This is because in such deep boreholes the likelihood of wall instability damaging casing and causing access problems is rather unpredictable. The benefits could, however, be considerable and continued research and development, possibly with other countries is recommended. The panel understands that there is still interest in deep borehole disposal in the USA, driven by the possibility that a centralised GDF may not be politically achievable, leaving individual states to find their own GDF solutions.
24. Shallow-level repositories only carry a consents risk, not a practical risk. In Belgium, consents have been granted. Given the nature of the geology in potential sites the risk of subsequent investigations resulting in the need for a second site away from the initial shallow repository is low and unlikely to be advanced as a reason not to commence work on a high-level waste repository at greater depth. Equally bringing forward the opportunity to create a HLW facility in parallel with SILW and LLW is not a high risk approach.
25. Acceleration will put pressure on the regulatory bodies and it will be necessary to recognise this challenge at an early date and take steps to ensure resource levels in these bodies do not become a constraint. Because of current demographic profiles and general pressures on numbers (in staff terms), there is a real danger of regulatory bodies losing experienced staff through retirement and struggling to recruit new staff with commensurate experience and knowledge. The Office of Nuclear Regulation (ONR) has recognised that its past demographic presented a problem with its long-term ability to fulfil its regulatory duties and has been working to address this.

Scenario one

26. The review panel agreed with the NDA analysis that the site characterisation programme could be accelerated by bringing the sinking of exploratory boreholes forward to occur in parallel with geophysical investigations. In the opinion of the review panel, it would be unlikely that 'optimal' borehole sites could be identified with significantly more certainty should the borehole investigation be carried out in series with geophysical investigations, so an element of 'best guess' judgement in the siting of boreholes introduces little additional risk. The panel considered that, although the small risk of requiring the sinking of additional exploratory boreholes exists, the possibility of this, if acknowledged early in the environmental permissioning process, should not present significant risk

(assuming a 'programme' of borehole investigations is sought rather than permissioning individual boreholes). The panel warned that even the most comprehensive programme of borehole investigations cannot entirely characterise the rock formation of interest at depth, only reduce uncertainties. It is entirely possible that the actual conditions discovered at depth vary from the picture presented by borehole investigations but the amount of information obtained (as opposed to data) from sinking additional boreholes hits the law of diminishing returns quickly.

27. The further acceleration of the borehole investigations by commencing geophysical investigations towards the end of stage four rather than stage five also seemed to make sense in terms of the engineering programme. The panel concluded that the availability of more and better information earlier in the programme would be seen as a benefit to community engagement.
28. Acceleration options for emplacement of HLW and AGR spent fuel in scenario one do not significantly impact on the acceleration of the date, from 2040 to 2036, for first emplacement of shielded ILW. However, revisions to the baseline programme that can reduce handling and movement requirements for these wastes should be pursued regardless of acceleration of first emplacement considerations.

Scenario two

29. The main element of change to the baseline case in scenario two allowing the bringing forward of first emplacement of ILW to 2029 appears to be the splitting of permissioning and disposal of certain types of HLW and ILW, with some changes to the handling, packing and storage of certain waste types.
30. Although thought by the review panel to be technically feasible, the use of a shallow-level vault for shielded ILW and LLW is potentially a side issue in terms of delivering an earlier date for first emplacement of waste. The important point is that it is an entirely separate vault regardless of depth. The panel was aware of work in Belgium to go forward with a GDF design incorporating a shallower vault for emplacement of SILW and LLW, so concluded that this option presented insignificant additional technical risk and low additional regulatory risk with significant learning available from the Belgian experience.
31. Wrapped up with the splitting of permissioning and emplacement of the different categories of waste are significant changes to the emplacement of HLW without a disposal overpack, relying, in the safety case, on the existing stainless steel canister and vitrification. These options, if acceptable, significantly bring forward the possible emplacement of HLW, but have no impact, in themselves, on the date for first emplacement of SILW and LLW. The review panel considered that these options were interesting, but, with the limited time available for the review, made it difficult to assess the acceleration potential of the stages approach to site characterisation in isolation. It may be that the staged characterisation option can be de-risked in regulatory terms without changes to the emplacement of higher level wastes.
32. By splitting and staging the site characterisation and permissioning arrangements for the two vaults, there is a risk of receiving clearance for the SILW/LLW vault, but not the higher-level wastes vault. The review panel considered this to be risk that needed to be considered, but concluded that the site investigation and

exploratory boreholes processes were likely to flag up the majority of possible issues which might lead to this situation well in advance of construction starting.

Scenario three

33. The review panel agreed that the potential use of deep borehole disposal of higher-level wastes could reduce the overall footprint of the GDF quite considerably and that there is international interest in continuing development of this option as an alternative to mined geological disposal. Although the technology of deep boreholes is advancing rapidly, with R&D being driven by the oil and gas industry, the current state of technology would not make this an attractive option today. The risks of wall instability in any particular borehole are too large to meet strict safety case requirements at this time.
34. As the main drive for an accelerated programme appears to be to bring the date for first emplacement of waste forward from 2040 to 2029 and the deep borehole option affects only higher level wastes to be emplaced later, this scenario does not seem to warrant further investigation at this time.

Conclusions

35. In terms of the engineering required, the Academy panel believed that all three acceleration scenarios could be built in the timescales proposed. However, although technically feasible as an engineering concept, the panel does not believe that the deep borehole option in scenario three should be pursued without further significant research and development of the concept. It currently presents the highest engineering risk of technical failure as well as very significant risk of failing safety case and regulatory tests. It also brings into question the retrievability of deposited waste and should not go forward at this stage as a credible option. In engineering terms, both scenarios one and two could be taken to the next stage of detailed analysis.
36. The review panel concluded that scenario one carried the lowest safety case and regulatory risk. In terms of examining the options presented within the scenarios, there could be room for reducing safety case and regulatory risks in scenario two. In particular, elements of splitting of permissioning for separate high- and intermediate-level waste vaults included in scenario two could be worth further examination in isolation of options to change the handling, encapsulation and emplacement of higher-level wastes.
37. The five-year horizon for stage four is not dictated by engineering requirements.
38. Successful delivery of an accelerated programme will require a highly finessed programme management approach which convinces communities by its professionalism, transparency and willingness to listen to community concerns. Strong leadership for such a complex programme will create confidence in government and in the community and need not take a dictatorial approach with community stakeholders.
39. Every aspect of this programme must be manned by the highest quality personnel, be they managers, geoscientists, engineers, communicators, psychologists, political analysts or lobbyists. All have a part to play but not in too forceful a manner which might be perceived as arrogant. It is also important not to give the impression that acceleration is driven simply by cost-cutting or programme management preferences. This does not mean that the programme

management team should not be using a clear milestone-driven approach with mutual success reflected in a series of short-term, six-month targets.

40. In summary this is a management challenge; the technology is proven and learning can be taken from other countries which are ahead with their programmes. In this respect it is likely that potential host communities will continue to benefit from exchanging ideas and experiences with host communities in other countries, and continued facilitation of such visits is recommended.
41. Throughout, consistent clear senior level political support, ideally on a cross party basis, will be essential. At this stage the various construction projections are such as to not cause cost differences that affect a decision to go for acceleration. Terms of course such as 'acceleration' may be emotive and advancing delivery to create early solid and economic benefits may be better.

Annex A - Terms of Reference

Peer review of Geological Disposal: Review of options for accelerating implementation of the geological disposal programme.

Terms of Reference

1. The Department of Energy and Climate Change (DECC) is seeking independent peer review of the Nuclear Decommissioning Authority's report, Geological Disposal: Review of options for accelerating implementation of the geological disposal programme, published in December 2011.
2. The peer review should assess the work carried out to date by the NDA on options for accelerating the programme, in particular on options for bringing forward first waste emplacement in a geological disposal facility from 2040 to 2029. It should include views on the robustness of the process the NDA have followed in developing and assessing a long list of options, evaluate the risks and opportunities identified and consider the analysis and conclusions presented in the report.
3. The results of the peer review process should be presented to the department by 22 March 2012.

Production of the Report

1. The Royal Academy of Engineering will be required to submit a single written report to Government presenting the views and conclusions of the Panel by 22 March 2012.
2. In support of the production of the Report, DECC and NDA will provide the Academy with relevant background briefing material and further information, as requested by the Panel.
3. It is anticipated that the Panel will convene a meeting to discuss and agree its conclusions.
4. During the course of the Panel's work it may be helpful for panel members to put questions to the NDA in the run-up to the meeting and such dialogue should be facilitated by the Academy, as required.
5. The Academy should also ensure that the NDA is invited to the panel meeting to take questions and provide supplementary information, as necessary.
6. Copies of the final draft report will be submitted to DECC and NDA in advance for checking for factual accuracy.

Role of the Chair

1. The chair of the Panel will be responsible for ensuring throughout the review process that the panel understands and agrees how their discussions will be presented in the final report.
2. The chair will be co-responsible with the Academy for ensuring that the review keeps to the Terms of Reference for the peer review.

Use of the Report

1. The report will be submitted to Ministers in line with their request for a peer review of the NDA's report.

Confidentiality

1. DECC requires that the Academy maintains confidentiality about the proceedings of the panel until the peer review is published and maintains confidentiality about proceedings not captured in the published report; and that the Academy direct the panel members to likewise maintain confidentiality.

Department of Energy and Climate Change
February 2012