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OPINION

Is Yucca Mountain a long-term solution for disposing of US spent nuclear fuel and high-level radioactive waste?

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Abstract

On 26 January 2012, the Blue Ribbon Commission on America's Nuclear Future released a report addressing, amongst other matters, options for the managing and disposal of high-level waste and spent fuel. The Blue Ribbon Commission was not chartered as a siting commission. Accordingly, it did not evaluate Yucca Mountain or any other location as a potential site for the storage or disposal of spent nuclear fuel and high-level waste. Nevertheless, if the Commission's recommendations are followed, it is clear that any future proposals to develop a repository at Yucca Mountain would require an extended period of consultation with local communities, tribes and the State of Nevada. Furthermore, there would be a need to develop generally applicable regulations for disposal of spent fuel and high-level radioactive waste, so that the Yucca Mountain site could be properly compared with alternative sites that would be expected to be identified in the initial phase of the site-selection process. Based on what is now known of the conditions existing at Yucca Mountain and the large number of safety, environmental and legal issues that have been raised in relation to the DOE Licence Application, it is suggested that it would be imprudent to include Yucca Mountain in a list of candidate sites for future evaluation in a consent-based process for site selection. Even if there were a desire at the local, tribal and state levels to act as hosts for such a repository, there would be enormous difficulties in attempting to develop an adequate post-closure safety case for such a facility, and in showing why this unsaturated environment should be preferred over other geological contexts that exist in the USA and that are more akin to those being studied and developed in other countries.

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1. The Report of the Blue Ribbon Commission

Two years ago, the US Secretary of Energy charged the Blue Ribbon Commission on America's Nuclear Future with reviewing policies for managing the back end of the nuclear fuel cycle and recommending a new plan. On 26 January 2012, the Commission fulfilled its duties with the release of a report [1] that includes recommendations covering topics such as the approach to siting future nuclear waste management facilities, the transport and storage of spent fuel and high-level waste, options for waste disposal, institutional arrangements for managing spent nuclear fuel and high-level wastes, reactor and fuel cycle technologies, and international considerations. The report also includes recommendations regarding critical changes needed in the handling of nuclear waste fees and of the Nuclear Waste Fund.

With respect to the existing waste management programme in the USA, the Blue Ribbon Commission report is forthright. That policy, which tied the entire US high-level waste management programme to the fate of the Yucca Mountain site, is described as having been troubled for decades and now to be almost entirely broken down. The report recommends a new approach that involves development of one or more geological repositories as the preferred option for disposal of spent nuclear fuel and high-level waste, coupled with the development of one or more consolidated interim storage facilities. In this new approach, site selection would be through a consent-based process involving local, tribal and state levels of government. Specifically, the Commission considers that the potential host community, tribe, and state would have had to consent to be considered for a waste site, with full knowledge of the relevant safety standards and siting criteria. Further, the host state and affected tribal and local governments would have had to agree to the terms of site study and what was to be built prior to the submission of a licence application. When studies were complete, a licence application would be prepared, and the Commission believes the host state and affected tribal and local governments should be given the opportunity to sign off on it before submittal. After that time, the state and other units of government would only be allowed to opt out 'for cause'—such as bad faith on the part of the facility operator. This process is in strong contrast with the approach through which the Yucca Mountain site was selected. That process was initiated through the Nuclear Waste Policy Act (NWPA) of 1982 which provided for the selection of two repository sites and led, in 1986, to the Energy Secretary making the recommendation that the Hanford site in Washington State, Deaf Smith County in Texas, and Yucca Mountain in Nevada should be subject to detailed site characterisation as leading candidates for the first permanent high-level geologic waste repository. However, faced with a deteriorating political situation and growing recognition that the original timelines set out in the NWPA and the associated cost assumptions were unrealistic, Congress revisited the issue of nuclear waste management in 1987. The resulting NWPA Amendments Act of 1987 halted then ongoing research in crystalline rock of the type found in the Midwest and along the Atlantic coast, cancelled the second repository programme, nullified the selection of Oak Ridge, Tennessee as a potential interim waste storage site, and designated Yucca Mountain as the sole site to be considered for a permanent geologic repository. The decision was widely viewed as political and it provoked strong opposition in Nevada, where the 1987 legislation came to be known as the 'Screw Nevada' bill [1].

Anger at the politically motivated selection of Yucca Mountain in 1987 was increased by a new approach to regulation of Yucca Mountain imposed by Congress and subsequently adopted by the US Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC). This has resulted in there currently being two sets of federal regulatory standards for high-level radioactive waste disposal facilities—one set that was developed specifically for Yucca Mountain and another, earlier set that would, under current law, apply to all other sites. As the Commission comments [1, section 10.3], while there may be advantages to

developing standards and requirements that recognise the specific features and characteristics of a particular site, experience with Yucca Mountain indicates that this approach can create suspicions that regulations are being tailored to make a pre-selected site 'work'. The Commission considers that generally applicable regulations are more likely to earn public confidence and that a generic standard will also support the efficient consideration of multiple sites. The difficulties arising when standards are developed in a site-specific context is well illustrated by the chequered history of standards developed for Yucca Mountain. The process, which was initiated by the Energy Policy Act of 1992, involved a study by the National Academy of Sciences, multiple lawsuits, and another court remand that required EPA to reconsider certain provisions it had initially proposed. Thus, it was not completed until 2008 for the EPA rule and 2009 for the associated NRC rule, and still resulted in standards that were regarded, by some parties, as biased in favour of the Department of Energy's (DOE's) Yucca Mountain licencing case.

What then of the current status of Yucca Mountain as a potential location for the disposal of US commercial and naval spent fuel and high-level waste? The Blue Ribbon Commission makes it clear that it was not chartered as a siting commission. Accordingly, it did not evaluate Yucca Mountain or any other location as a potential site for the storage or disposal of spent nuclear fuel and high-level waste, nor did it take a position on the Administration's request to withdraw the licence application (a request that remains subject to legal challenge). Nevertheless, if the Commission's recommendations are followed, it is clear that any future proposals to develop a repository at Yucca Mountain would require an extended period of consultation with local communities, tribes and the State of Nevada. Furthermore, there would be a need to develop generally applicable regulations for disposal of spent fuel and high-level radioactive waste, so that the Yucca Mountain site could be properly compared with alternative sites that would be expected to be identified in the initial phase of the site-selection process.

2. The technical adequacy of Yucca Mountain

How would Yucca Mountain fare in such an evaluation, taking into account the expectations that have developed as to the requirements that should be placed on the performance of such a disposal facility? Worldwide, there is broad agreement that deep geological disposal is the preferred option for spent fuel and high-level waste disposal, with the intent being that the geological environment will provide long-term protection of the waste packages from degradation, and will limit the transport of radionuclides to the human environment in the event of container failure. Thus, for example, in Sweden and Finland, the proposal is to dispose of spent fuel in copper canisters in a geological environment in which significant degradation of the packages would not be expected on a timescale of one million years or longer (see, e.g. [2]). Typically, a suitable environment for deep disposal would display properties such as long-term (millions of years) geological stability, low groundwater content and flow at repository depths, stable geochemical or hydrochemical conditions at depth, mainly described by a reducing environment and a composition controlled by equilibrium between water and rock-forming minerals, and good engineering properties that readily allow construction and operation of the repository [3].

In contrast, the relatively young and volcanically active geological environment at Yucca Mountain does not contribute positively to the protection of the waste packages against degradation and would do little to limit the transport of radionuclides from those packages once they had degraded. Thus, the DOE has to argue for the long-term safety of the proposed facility based on projection of the performance of complex engineered materials and structures over

timescales of thousands to tens of thousands of years [4][2]. In contrast, the materials that they rely on have been used for engineering purposes only for, at most, a few decades. Furthermore, although resistant to degradation in some contexts, it has been demonstrated experimentally that these materials would not maintain their physical integrity in the environment that would be present in a repository at Yucca Mountain [5, see NEV-SAFETY-106][3].

A fundamental problem with the proposed Yucca Mountain facility is that it is positioned above the water table in a location where infiltrating water would be rendered corrosively aggressive to the waste containers by the water–rock reactions that would occur at the high temperatures projected in the vicinity of the repository. No other country is proposing to locate a spent fuel or high-level waste repository above the water table [3, section 4.6], so the coupled hydro-thermo-geochemical problems that arise are unique to the Yucca Mountain context and are not being addressed by research and development activities elsewhere in the world. Safety analyses conducted by the DOE have shown that without the additional protection of titanium drip shields (see below) disposal of waste packages of the proposed design at Yucca Mountain would give rise to radiation doses to members of the local population far in excess of the Federal Standard set for a Yucca Mountain repository by the EPA to protect public health. Furthermore, this situation is projected to occur within a few hundred years of repository closure, since groundwater transit times are short and the DOE takes no credit for waste canister performance in its safety assessment.

Faced with this fundamental obstacle to demonstrating the safety of the proposed repository, the DOE Licence Application [4] introduced an additional design feature. It posited the existence of titanium alloy ‘drip shields’, one 5 ton drip shield over each of the 11 500 waste packages, to ward off the corrosion-promoting water. However, these extremely expensive drip shields are not part of the current waste installation plan, but are intended to be installed by a yet-to-be-designed, remote-controlled robotic mechanism about one hundred years after the wastes have been emplaced. Taking account of the high temperature (above boiling point), high radiation, physically degraded environment that would exist at that time, it seems unlikely that efficient and comprehensive installation of the drip shields could be achieved, even if the political will to undertake that installation could be relied upon. It is surely not acceptable to base public safety on such a technically risky and politically uncertain proposition.

The problems in developing a safety case for Yucca Mountain have arisen essentially from selection of an inappropriate site and an invalid disposal concept. Although located in a desert region, the unsaturated rock at Yucca Mountain contains large quantities of water that can percolate rapidly downward to the saturated zone, where it is then carried away horizontally towards the residential and agricultural area of Amargosa Valley. The downward seeping water would enter the hot, oxidising environment of the waste tunnels and there promote rapid waste package corrosion, waste dissolution and the migration of radionuclides to a major aquifer and hence to Amargosa Valley, contaminating groundwater resources there to an unacceptable degree. No other country is considering a repository attaining temperatures as high as those proposed at Yucca Mountain. Nor are other proposed repositories located in unsaturated, oxidising environments where reliance has to be placed entirely on the predicted performance of complex engineered materials and structures to achieve safety.

[2] See also: First Update to the Yucca Mountain Repository License Application (LA) for Construction Authorisation transmitted from the Office of Civilian Radioactive Waste Management, Department of Energy to the Office of Nuclear Material Safety and Safeguards, US Nuclear Regulatory Commission, February 2009.

[3] Individual contentions within this document are supported by references to underlying documents that were placed on the Licensing Support Network and are available from the State of Nevada Agency for Nuclear Projects, www.state.nv.us/nucwaste/. Responses to this Petition by DOE and NRC are also available, as is a rebuttal of those responses by the State of Nevada.

This heavy reliance on a single engineered barrier is inconsistent with international standards, because those standards include the requirement that the design should incorporate multiple barriers that act in concert, initially to contain the radionuclides, therefore allowing them to decay, and then to limit their releases to the accessible environment. A combination of engineered and geological barriers is generally known as a multi-barrier system and the IAEA considers that the geological formation in which the waste is emplaced, referred to as the 'host rock', generally constitutes the most important isolation barrier [3, Section 2.1], where isolation includes both protection of the engineered system from degradation and limitation of the migration of radionuclides if any degradation of that engineered system does occur. This concept of multiple barriers acting in concert is similar to the defence-in-depth approach that is a basic feature of nuclear power reactor safety as regulated by the NRC. Defence-in-depth does not exist in the proposed Yucca Mountain repository design, as compliance with Federal Safety Standards depends critically on the installation and performance of the drip shields, neither of which can be assured at the time of licencing.

The foregoing general objections apply even if the results of calculations presented by the DOE in the Yucca Mountain Licence Application [4] are accepted. However, the scientific and technical bases of these calculations are open to question. Three independent panels of NRC judges comprised of lawyers and scientists have accepted contentions from intervening parties that the Licence Application raises approximately 300 significant safety, environmental and legal issues that would have to be fully adjudicated and satisfactorily resolved in a sequence of oral hearings before any licence could be issued. These issues include [5]:

- The appropriate representation of future climate in the area.
- The selection of models to characterise water flow.
- The chemical composition of the water that would contact the drip shields (if installed) and waste packages.
- The corrosion resistance and failure mechanisms of drip shields and waste packages.
- The sorption of radionuclides to minerals in the rock.
- The behaviour of radionuclides in the biosphere.

Further issues relate to vulnerabilities of surface facilities to military aircraft crashes and the overall vulnerability of the site to future volcanic events [5].

The unprecedented number, scope and technical depth of the admitted contentions relating to these issues suggests that, taken together, they could not all reasonably be expected to be resolved in favour of the proposed repository. In addition, even the evaluation of these issues through a sequence of hearings could be expected to be a very protracted undertaking, and would be likely to imply considerable expenditure of resources in performing additional scientific and technical studies to resolve the matters under dispute. Indeed, some of the matters raised could only be resolved by new field studies or by the development of complex new computational models. To date, some nine billion dollars have been expended in investigating the Yucca Mountain site and in developing a grossly inadequate licence application that the US Administration is seeking to withdraw. Therefore, it is suggested that it would be imprudent to include Yucca Mountain in a list of candidate sites for future evaluation in a consent-based process for site selection. Even if there were a desire at the local, tribal and state levels to act as hosts for such a repository, there would be enormous difficulties in attempting to develop an adequate post-closure safety case for such a facility, and in showing why this unsaturated environment should be preferred over other geological contexts that exist in the USA and that are more akin to those being studied and developed in other countries.

References

[1] Blue Ribbon Commission on America's Nuclear Future 2012 *Report to the Secretary of Energy* January 2012, available from www.brc.gov

[2] Svensk Kärnbränslehantering AB 2011 Long-term safety for the final repository for spent nuclear fuel at Forsmark *Main Report of the SR-Site Project Volumes I to III* (Stockholm: Swedish Nuclear Fuel and Waste Management Co.) SKB Report TR-11-01

[3] International Atomic Energy Agency 2003 *Scientific and Technical Basis for the Geological Disposal of Radioactive Wastes, IAEA Technical Reports Series No.* 413 (Vienna: International Atomic Energy Agency)

[4] US Department of Energy, Office of Civilian Radioactive Waste Management 2008 *Yucca Mountain Repository License Application, DOE/RW-0573* Rev. 0, June 2008

[5] State of Nevada 2008 *Petition to Intervene as a Full Party in the matter of US Department of Energy (High Level Waste Repository), Docket No. 63-001, December 2008*