Benefits of Siting a Borehole Repository on Non-Operating Nuclear Facility

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INTRODUCTION

This work evaluates a potential solution for two pressing matters in the viability of nuclear energy: spent fuel disposal and power plants that no longer operate. The potential benefits of siting a borehole repository at a shut-down nuclear power plant facility are analyzed from the perspective of myriad stakeholders. Preliminary results indicate that integrated siting will make economic use of the shut-down power plant, take advantage of spent fuel handling infrastructure at those sites, help to empty the crowded spent fuel storage pools at nearby reactors, and will do so at sites more likely to have consenting communities.

Motivation

The proposed integrated siting strategy takes advantage of three technical benefits of borehole repository designs: modularity, broad geological suitability, and footprint efficiency. Modularity enables regional repositories to scale in size according to the local spent fuel burden. Additionally, the necessary geological characteristics required for borehole disposal, crystalline basement rocks at $2,000m - 5,000m$ deep, are relatively common in stable continental regions [?]. Finally, the surface footprint requirements of a borehole repository are comparable to the available footprint of a nuclear power reactor site, with only $30km^2$ required for the total spent nuclear fuel (SNF) amount proposed for Yucca Mountain [?].

Integrated siting also has potential economic benefits. One significant cost inherent to borehole repository concepts is the repacking of spent fuel assemblies into smaller-diameter waste canisters. However, siting a repository at a non-operating power plant facility, especially one with a dry-cask storage site, will take advantage of already existing infrastructure and local human talent for spent fuel handling and packaging. Many candidate non-operating reactor sites, such as those mapped in Figure 1 may be appropriate for integrated siting if they are located above crystalline basement formations and include dry cask packaging facilities.

Preliminary work [?] indicates integrated siting is appealing to many stakeholder groups. For example, a consent-based approval process may be feasible because communities local to power plants may be uniquely receptive to the incentives of hosting a repository.

METHODOLOGY

This work will evaluate the potential impacts of integrated siting from the perspective of 5 stakeholders:

- the federal government,
- the state government,
- the local government,
- the local community,
- and the owner of the non-operating plant.

Preliminary work [?] suggests that integrated siting will reduce costs, construction, time (both for construction and licensing), transportation distances, and resistence from the local community. The present work will compare the proposal along these axes to a base case: a standalone borehole repository at a similar location to that of Yucca Mountain. Quantification of those stakeholder benefits will be undertaken for two different regions of the US in addition to the base case.

Unique parameters are quantified using simple calculations from easily accessible data. The goal of this paper is to quantify different metrics in numbers in order to clarify siting methodology.

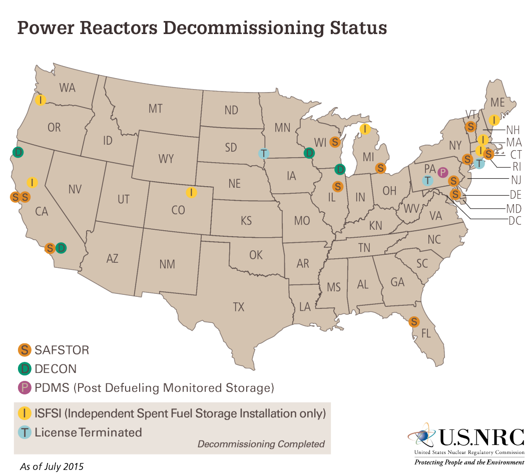

Fig. 1. Non-operating facilities status [?].

ACKNOWLEDGMENTS

This material is based upon work supported by Program in Arms Control & Domestic and International Security (ACDIS). Preliminary work was conducted in collaboration with the Independent Student Research Group (ISRG) within the Department of Nuclear, Plasma, and Radiological Engineering (NPRE). The authors are accordingly grateful for guidance by Prof. Clifford Singer.

CASE DEFINITION AND SPECIFICATIONS

This paper sets the proposed case to building a 70,000 metric ton of heavy metal (MTHM) capacity borehole repository at the Clinton Power Plant in Illinois. The base case is to build a standalone borehole repository at a location similar to that of Yucca Mountain with the same capacity. The borehole design follows the Sandia Report Reference Design and Operations for Deep Borehole Radioactive Waste [**?**]. However,the difference in design of borehole will not contribute directly to the analysis for the design is the same for both case. The design will affect the necessary repacking facility to repack the individual rods into a emplacement canister.

Proposed Case Methodology and Definition

In order to minimize transport cost, a central location is preferred. An elementary analysis on the transportation of spent fuel is done by calculating the total amount of waste multiplied by the distance it has to travel (in units of MTHM*km) using the Havershine formula. First, the coordinates of each power plant is obtained by scraping public data [wikipedia?]

The distance between each storage site (i.e. reactors and Independent Spent Fuel Storage Installation (ISFSI)) is calculated by using the havershine formula on the geographical coordinates of the sites.

$$\Phi_1, \Phi_2 = latitude\ values\ in\ radians$$
$$\lambda_1, \lambda_2 = longitude\ values\ in\ radians$$
$$\Delta\lambda, \Delta\Phi = difference\ between\ two\ values\ in\ radians$$
$$a = sin^2(\Delta\Phi) + cos(\Phi_1)cos(\Phi_2)sin^2(\frac{\Delta\lambda}{2})$$
$$c = 2 * atan2(\sqrt{a}, \sqrt{1-a})$$
$$d = (6,371km)c$$

This distance value is multiplied by the MTHM that needs to be transported. The spent fuel inventory data is from the GC-859 survey data from the U.S. Energy Information Administration (EIA) and the Centralized Used Fuel Resource for Information Exchange (CURIE) website. From the list of 74 reactors, several candidates with the smallest MTHM*Km value is listed below:

TABLE I. Reactors with relatively small MTHM*Km value

Reactor	State	$MTHM * km$	License Area [km^2]
Clinton	Illinois	**77,352,339**	**57.87**
Peach Bottom	Pennsylvania	85,563,135	2.509
Indian Point	New York	84,097,374	.967
Dresden	Illinois	**77,663,969**	3.856

The Clinton Power Plant is chosen as the site for the proposed case due to its low $MTHM * km^2$ value and substantially large license area.[**?**] Considering that only $30km^2$ is required for all the total SNF amount, the licensed area at Clinton power plant allows more than enough space to site a borehole repository, which avoids possible conflicts with the community from purchasing and utilizing more land.

The proposed case requires a great amount of cooperation from the utility that owns the Clinton power plant, Exelon Corporation. Currently, Exelon has no incentive to cooperate, for they do not pay for storage of spent fuel, due to the 2004 settlement with the Department of Justice.Also, Exelon currently owes approximately a billion dollars to the Nuclear Waste Fund (NWF), (gaining interest at U.S. Treasury bond rate) when a repository is completed [**?**] Exelon has an incentive to cooperate, since it will earn profit throughout the construction and operation of the repository at its power plant, as well as to utilize the unused land mass in a lucrative manner. Also, Exelon would not have to pay for operation or construction, since it is the government's responsibility to dispose nuclear spent fuel [**?**].

The figure below demonstrates the geologic fitness of the proposed site, where a crystalline basement lies at a depth of less than 2,000 meters.

Also, from the Decatur Carbon Sequestration Project, there is ample data on the stratigraphy of the Decatur region, which is less than 50 miles south of the Clinton power plant.

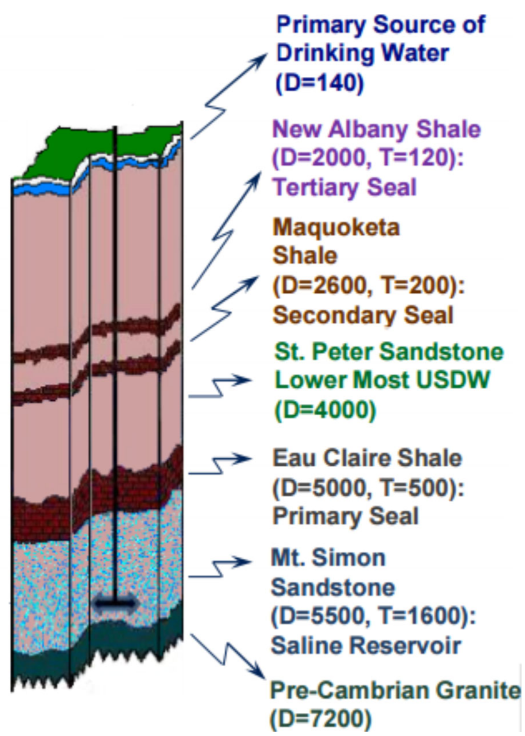

Fig. 2. Stratigraphy of the Decatur Region [**?**].

Base Case Methodology and Definition

The base case is presented in order to demonstrate the cost savings and efficiencies that arise from the proposed case. The base case mimics the Yucca Mountain Project but is a borehole-type repository. Costs include new licensing and processing facility for repacking the spent fuel assemblies.

INCENTIVES TO VARIOUS STAKEHOLDERS

Prior to discussing the benefits of the proposed case over the base case, the list of stakeholders and their incentives are listed below, with a number indicating the magnitude of the importance of the incentive.

TABLE II. Incentive Criterion and Weight for Each Stakeholder

	Federal	State	Local	Utility	Environmental
Job Creation		1	3	1	
Transport[$MTHM * km$]	2	1	2		2
No Need for new treatment license	2			1	
No Need for additional land purchase	3	2	3		2
Emptying Spent Fuel Storage Pools	3			3	
Net Cost	3			3	
No New Above-Ground Facility Construction	3			3	2

Job Creation

Building a spent nuclear fuel repository is no easy task. It is a task that requires numerous experts and labourers. Also, operating and maintaining a nuclear power plant requires numerous experts and labourers. In case of the proposed case, the Clinton Power Station has approximately 700 employees living in nearby counties with an additional several hundred contractors during fuel outages.[**?**] The existing skilled workers and local talent for maintenance, transport and catering services can be utilized without bringing a whole new group of workers to the area. [**?**].

The base case does produce more jobs, since it needs additional constructions such as the repackaging infrastructure. It is estimated that jobs created during the construction was between 3,200 to 4,000 [**?**]. However, the job creation may not be as appreciated greatly by the local community than that of the proposed case.

Additionally, an estimate by the Illinois State University on fracking the New Albany Shale in southern Illinois estimated that such a project can create 1,000-47,000 jobs [**?**]. Translating the workforce to central Illinois and the borehole project should create somewhere in the low and medium estimate, which is about 10,000 jobs.

Thus, the void created by the shutdown of the Clinton plant can be, though not completely, filled by the new construction of a borehole repository. The construction will prioritize local hires as an incentive to ease local opposition on repository siting. Employment during the operation of Yucca Mountain was estimated to range from 2,000 to 5,000 jobs, [**?**] which means that the borehole repository would at leaste require half of the workforce for the same capacity.

Transport

Transport of radioactive material is a difficult matter, and poses one of the greatest problems in siting a repository. The proposed case, according to the crude analysis, has the least amount of required transportation of spent fuel. Also, it is conveniently located near the Canadian National rail line [**?**].

Conversely, siting the base case will have a $km * MTHM$ value of $209,575,157 km * MTHM$, which is approximately 2.7 times more than that of the proposed case. Also,

No Need for a New Treatment License

No Need for Additional Land Purchase

The proposed case has a licensed land area of approximately $58km^2$ and $20km^2$ cooling heat sink, the Clinton Lake, with only $.6km^2$ being used for the facility. [**?**] This leaves enough room left for a 70,000 MTHM borehole repository without additional land purchase from the public.

However, the base case also does not require land purchase, for the land near Yucca Mountain is part of the Nevada Test Site.

In this aspect, the

Emptying Spent Fuel Storage Pools

Net Cost

The proposed case has a larger advantage over the base case in the sense that there are already existing facility in regards to spent fuel handling and worker lodging and catering services. It is assumed, for the sake of argument, half of the construction cost of the repacking facility in the base case is used to expand the existing facility in the proposed case.

No New Above-Ground Facility Construction

The proposed case, being a once-operating nuclear power plant, has the facility to repack the spent fuel assemblies into a disposal cask. However, this facility needs to be upgraded to handle a large influx of spent fuel assemblies, and should be preferably automatic, to minimize worker exposure. The transported spent fuel assemblies are repacked and inspected at the upgraded facility, and is sent to the emplacement tubes for final disposal. Not having to build a new above-ground facility should greatly increase the public perception, for it seems like there's minimal impact.

The base case requires a new above-ground facility, which not only costs a great amount, but also will be considered problematic to the public's eye.

RESULTS AND DISCUSSION

Given the current circumstances, a repository is crucial for the survival of nuclear power. By selecting a power plant in a central location with lot of licensed land, a repository with sizeable capacity can be built cheaper, more efficiently, and in a consent-based manner with the local community.