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

Quantitative Siting Criteria

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Outline

1. Background
2. Case Specification
3. Metric Evaluations
   - Transportation Burden
   - Site Appropriateness
   - Workforce Utilization
   - Consent Basis
   - Site Access
   - Expediency
4. Results

Background - Problems

- Overflowing Spent Nuclear Fuel (SNF) in Reactor Pools
  Solution now: Expensive Dry Casks
- Most Plants are built in the 70s and 80s, facing license renewal or shutdown
  = Decommissioning costs

Motivation

Why not reuse the existing licensed land?
Solve two issues with one solution:

- Save on decommissioning costs
- Permanent Repository so dry casks are no longer needed

Terminology

Borehole Repository

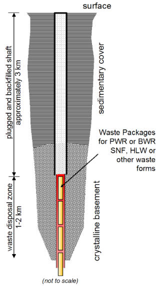

Figure 1: Deep Borehole Schematic [2].

Non-Operating Nuclear Facility

A nuclear power plant facility that is no longer of commercial usage, or no longer produces spent fuel.

Outline

Integrated Design

Non-operating Reactor Site + Borehole Repository

- Save cost on decommissioning (some parts)
- Earn Revenue from hosting repository
- Save cost on repository facility construction with already existing infrastructure
- Communities that benefit from power plants are more likely to be friendly

Why Boreholes?

- Less rigorous geological standard (flexible siting)
- modularity
- Area($30km^2$ for 70,000MTHM)

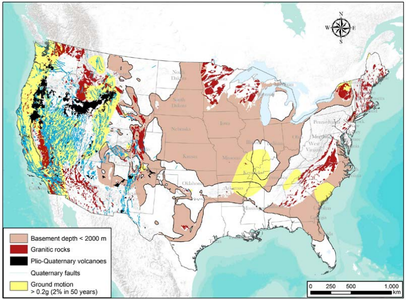

Figure 2: Map of Areas in US with crystalline basement rock at less than 2,000m in depth. Pink areas are suitable for a borehole repository. [9].

Method of Comparison: Case Study

Two cases:

- Reference/Base Case: Yucca Mountain
- Proposed Case: Borehole Repository at Clinton Power Station (Clinton, IL)

Why Clinton?

- Clinton is under risk of shutting down, despite the recent bill that saved it from shutting down. (Inherent economic disadvantage of single - unit reactor site)
- Geological study done for Decatur Carbon Sequestration Project
- Socio-Economic research done in impacts of its shutdown
- Central Location (low MTHM*km value)

6 Quantitative Metrics

- Transportation Burden [$MTHM \cdot km$]: Less SNF to be transported
- Workforce Utilization [$-$]: Pre existing skilled workforce
- Expediency [y]: Faster the removal of SNF, more cost savings
- Consent Basis [$\frac{nuclearMW}{\text{capita}}$]: More familiarity and dependency to nuclear $=$ more likely to be consenting
- Site Access [$-$]: Rail access to the site is essential for beginning operations.
- Site Appropriateness [$-$]: Must be geologically viable.

Stakeholders

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

Evaluation Method

For Each Metric:

$$
\begin{aligned}
\mathrm{NV} &= \frac{x - \mathrm{W}}{\mathrm{B} - \mathrm{W}} && (1)\\
NV &= \text{normalized value for the metric} && (2)\\
x &= \text{considered case value for the metric} && (3)\\
B &= \text{best case value for the metric} && (4)\\
W &= \text{worst case value for the metric} && (5)\\
& && (6)
\end{aligned}
$$

Some are Boolean - either yes or no.

Stakeholder Weights

Weight of metric for each Stakeholder is up to the discretion of evaluator's interpretation. For this paper, the following weight is used:

Table 1: Metrics and Weight for Each Stakeholder

Metric	Federal	State	Local	Utility
Transportation Burden	3	2	1	1
Site Appropriateness	3	2	1	1
Workforce Utilization	3	2	2	2
Consenting Locals	3	2	3	2
Site Access	3	2	1	1
Expediency	3	2	1	3

Outline

Haversine Formula

Calculates the 'great-circle' distance between two coordinate points
* Coordinate data from Wikidata

$$\Phi_1, \Phi_2 = \text{latitude in radians} \tag{7}$$

$$\lambda_1, \lambda_2 = \text{longitude in radians} \tag{8}$$

$$\Delta\lambda = |\lambda_1 - \lambda_2| \tag{9}$$

$$\Delta\Phi = |\Phi_1 - \Phi_2| \tag{10}$$

$$a = \sin^2(\Delta\Phi) + \cos(\Phi_1)\cos(\Phi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right) \tag{11}$$

$$c = 2 \cdot arctan2(\sqrt{a}, \sqrt{1-a}) \tag{12}$$

$$d = (6,371km) \cdot c \tag{13}$$

MTHM*km Calculation

$$b_i = m_i d \tag{14}$$

$$B = \sum_i^N b_i \tag{15}$$

where

$$b_i = \text{spent fuel transport burden from facility i [km]]} \tag{16}$$

$$m_i = \text{mass of spent fuel at facility i [MTHM]} \tag{17}$$

$$B = \text{total spent fuel transport burden [MTHM*km]} \tag{18}$$

$$N = \text{total number of facilities with spent fuel on site.} \tag{19}$$

Transportation Burden

MTHM of waste in each reactor (data from EIA 2011 Survey - GC859 [7])

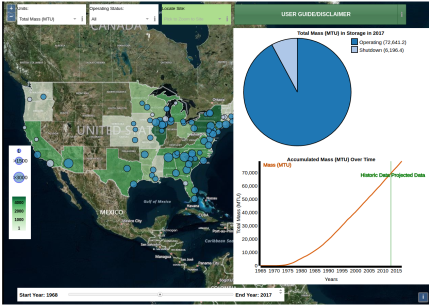

Figure 3: ORNL CURIE map of nuclear waste. This map is based off of the EIA survey data.[14].

MTHM*km For Different Reactors

Table 2: Reactors with relatively small spent fuel transportation burden [$MTHM \cdot km$].

Reactor	State	$MTHM * km$	License Area [km^2]
Clinton	Illinois	**77,352,339**	**57.87**
Dresden	Illinois	**77,663,969**	3.856
Peach Bottom	Pennsylvania	85,563,135	2.509
Indian Point	New York	84,097,374	.967
Yucca Mountain	Nevada	209,575,157	N/A

Table 3: Transportation Burden for Each Case

Case	Transportation Burden [$MTHM \cdot km$]	NV
Yucca	209,575,157	0
Clinton	77,352,339	1

Site Appropriateness

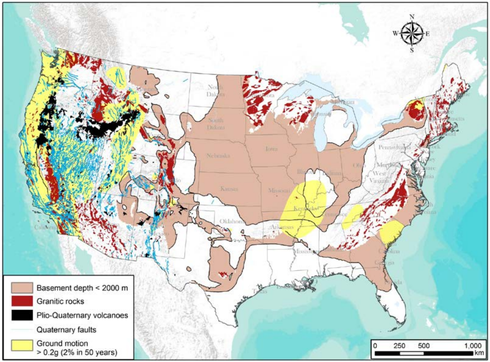

Figure 4: From [15], a map of areas in the US with crystalline basement rock at less than 2000 meters depth. Pink areas suitable for borehole repositories.

Site Appropriateness

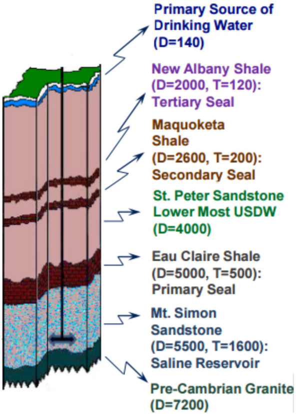

Figure 5: Stratigraphy of the Decatur Region, D is depth in feet. [12].

Table 4: Site Appropriateness for Each Case

Case	Site Appropriateness
Yucca	1
Clinton	1

Workforce Utilization

- Local Talent (nuclear experts)
- Transport, Catering and Lodging services
- 700 employees for Clinton [8]
- Yucca Mountain = $2,000$ - $5,000$ jobs [17]
- The experts are no longer in Yucca after defunding of project.

Table 5: Workforce Utilization for Each Case

Case	Workforce Utilization
Yucca	0
Clinton	1

Consent Basis

- Consent-Basis approach to siting is crucial [1, 6, 11, 9]
- Communities near nuclear facilities are more likely to volunteer [13]
- Clinton Pays $15 million in property taxes [3]
- $54 million payroll to workers [5]
- Shutdown of Clinton would cause 13,000 job losses in 5 years [16]
- Yucca was known as "Screw Nevada Bill" - strong opposition

Consent Basis Metric: NMWPC

Nuclear MW Per Capita (NMWPC)

Table 6: NMWPC values for different states

State	Net Nuclear Capacity (MW)	Census Population	NMWPC (10^{-3})
South Carolina	6,486	4,625,401	1.4
Alabama	5,043	4,780,127	1.05
Vermont	620	625,745	.99
Illinois	11,441	12,831,549	.89
Nevada	0	2,705,000	0
Average Nuclear States	101,167	265,386,569	.38
Average National	101,167	309,300,000	.33

Table 7: NMWPC values for Each Case

Case	NMWPC	NV
Yucca	0	0
Clinton	.89	.635

Site Access

- Railway Access
- Proximity to other power plants
- Illinois Division of Nuclear Safety
- Traversal of Land:
  Yucca : 955 counties, 177 million people [10]

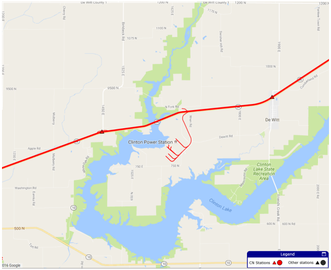

Figure 6: From [4], a map of Clinton Power Station in Clinton,IL with the Canadian National rail passing through.

Site Access

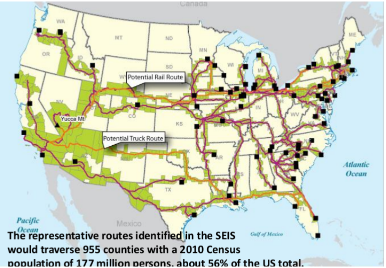

Figure 7: Yucca Mountain Project Estimated Route [10].

Table 8: Site Access for Each Case

Case	Site Access
Yucca	0
Clinton	1

Expediency

- Existing Infrastructure
  Fuel Handling Facility
  Railway
- Quicker Acceptance of SNF = less dry casks built
- 5 years arbitrarily chosen for time of fuel handling facility

Table 9: Expediency in Each Case

Case	Time Saved [y]	NV
Yucca	0	0
Clinton	5	1

Outline

Results

Table 10: Metrics and Weight for Each Stakeholder

Metric	Federal	State	Local	Utility
Transportation Burden	3	2	1	1
Site Appropriateness	3	2	1	1
Workforce Utilization	3	2	2	2
Consenting Locals	3	2	3	2
Site Access	3	2	1	1
Expediency	3	2	1	3
Case I total	3	2	1	1
Case II total	16.9	11.2	7.9	9.2

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