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DECOMMISSIONING ISSUES RELATING TO GALENA'S PROPOSED LICENSING OF A 4S REACTOR-BASED POWER GENERATION FACILITY

Prepared for the City of Galena, Alaska

DECOMMISSIONING PLANNING

I Executive Summary

This paper discusses the major issues associated with the decommissioning a 10 MWe 4S Nuclear Reactor Based Power Generation Facility (NPF) deployed at a site in the vicinity of Galena, Alaska. While a discussion of the decommissioning of a nuclear facility may seem premature prior to the construction of the facility, Nuclear Regulatory Commission ("NRC") regulations require that licensees adequately plan for decommissioning as part of the facility licensing process.

Planning for the decommissioning of the Galena 4S NPF involves three major areas: (1) selecting the appropriate methods for decommissioning the facility at the end of its useful life, disposing of the spent fuel and other radioactive waste, and returning the site to a decontaminated condition; (2) estimating the cost of decommissioning the plant at the end of its useful life; and (3) establishing an appropriate mechanism for funding the estimated decommissioning costs.

This paper addresses these three areas by first discussing the disposal of the spent nuclear fuel, the primary radioactive sodium coolant, the reactor vessel, and other radioactive waste at the end of the nominal reactor fuel life of 30 years, including strategies for the shipment of the reactor vessel offsite after removal of the spent fuel from the vessel. The paper then provides estimates of the approximate costs of decommissioning the facility and reducing residual radioactivity so that the site can be released for industrial use, allowing for termination of the NRC license for the facility. Finally, the paper describes potential methods for providing assurance in accordance with NRC requirements that sufficient funds will be available to pay for the decontamination, decommissioning and other costs to terminate the license.

II BACKGROUND

A. The City of Galena

The City of Galena, Alaska (Galena) is a small community (pop. 700) located in west-central Alaska, along the banks of the Yukon River. The closest communities to Galena (within 100 air miles or less) are Koyukuk (pop. 100) approximately 30 miles to the west, Nulato (pop. 330), approximately 40 miles to the west, Kaltag (pop. 230), approximately 60 miles to the west, Ruby (pop. 190) approximately 50 miles to the east, and Huslia (pop. 300), approximately 70 miles to the northeast. The nearest major population center is Fairbanks (pop. 30,500), 270 miles to the east.[1]

Galena has no roads linking it to the rest of the state. A former United States Air Force base, now known as the Edward J. Pitka Sr. airport, is located 1.5 miles west of the city.

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[1] U.S. Census Bureau, 2000 Census data, available online at http://www.census.gov/popest/cities/tables/SUB-EST2004-04-02.csv.

The main runway of the airport (runway 7-25) is 7,254 feet long, and is capable of handling heavy transport type air traffic. The airport is the primary access point into and out of the Galena area, and operates year-round. The Yukon River serves as the major heavy transportation resource during the unfrozen summer months. Galena serves as an educational and cultural center for the region. There are many public use and commercial buildings in the area of the airport and the city itself including schools, workshops, and municipal buildings. Homes are predominately located around the "New Town" area, 1.5 miles east of the airport.

B. The Galena Power Supply

Galena has no connection to an outside power grid. The city currently depends on diesel generators for its electric power supply. Galena experiences long, severe winters (winter low temperatures may reach –50°C (-60°F) or below and temperatures below -40°C (-40°F) are common). The lack of low cost year-round heavy transport into Galena requires the city to maintain large diesel fuel tanks in order to meet energy demand. The escalating price of fuel and the associated costs of fuel transportation, storage, and financing make the cost of electricity prohibitively high to Galena residents. These economic issues, coupled with environmental pollution concerns, make it prudent for Galena to explore alternative ways to meet its energy needs.[2]

C. The Galena 4S Project

In 2004, Galena received presentations from Toshiba Corporation (Toshiba) on a "Super-Safe, Small and Simple" (4S) Nuclear Based Power Generation Facility. The 4S reactor was developed jointly by Toshiba and the Central Research Institute of Electric Power Industry (CRIEPI) of Japan.[3] Following those presentations, Galena secured the preparation of a U.S. Department of Energy (DOE) sponsored study on ways to meet Galena's power requirements.[4] The study included analyses of the thermal and electric load profiles for Galena, technologies available to meet those loads (the technologies evaluated in detail were enhanced diesel power, coal, and a 4S NPF, which were determined to be the only viable alternatives), the environmental and regulatory issues associated with each of these technologies, and the overall economics of each energy option. The DOE study concluded that the 4S NPF is the best economic and environmental choice for Galena.

On December 14, 2004, the Galena City Council passed a resolution calling for the deployment of a 4S NPF in the community. The resolution stated, among other things, that: "It is in the public interest to pursue the siting of a Toshiba 4S nuclear battery in

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[2] Adams Atomic Engines, Inc., Atomic Insights, "Nuclear Power for Galena, Alaska" (March 2005), available online at http://www.atomicinsights.com/AI_03-20-05print.html.

[3] See, e.g., http://www.uaf.edu/aetdl/Presentations.htm.

[4] Robert E. Chaney et al., "Galena Electric Power- A Situational Analysis" (DE- AM26-99FT40575) (December 2004). Science Applications International Corporation (SAIC) coordinated the study, in which the University of Alaska and Idaho National Engineering and Environmental Laboratory participated.

Galena." The council further directed the City Manager to "establish a process and timeline leading to evaluations, industrial partners, and financial and contractual arrangements necessary to bring the economic and environmental benefits of the 4S to Galena."

Since the passing of the resolution, Galena has been investigating the regulatory and economic feasibility of locating a 10 MWe 4S NPF in Galena. In parallel, Toshiba has been developing a preliminary design document (PSID) to submit to the U.S. Nuclear Regulatory Commission (NRC) for its review.[5]

In order to move the siting evaluation process forward and open lines of communication with various stakeholders and the NRC, Galena has commissioned a set of white papers that discuss important aspects of the small nuclear power facility project including a General Overview, Nuclear Liability and Insurance, Emergency Planning, Physical Security, Decommissioning, Containment, and Seismic Isolation. This paper is part of the white paper series.

D. Features of the 4S Reactor

The 4S is a small, liquid metal cooled nuclear reactor. Liquid metal reactors (LMRs) have been operated successfully worldwide and have been used in the United States at test facilities, with over 300 reactor years of operational experience. The small, advanced design of the 4S has several operational and safety advantages, particularly for remote location deployment, when compared to the large light-water commercial nuclear power plants currently operating in the United States. The peak thermal output of a 10 MWe 4S reactor is approximately 30MW thermal (MWt), which is a small fraction of the power output of a standard sized commercial reactor. Important features of the design of the 4S include:

- Modular construction, which reduces costs and construction time
- Nuclear systems that are installed below grade, resulting in safety and security benefits
- Liquid sodium coolant, which does not react with core internals or piping
- Reactor coolant that is not highly pressurized, which minimizes stresses on the plant systems
- Passive safety systems that do not depend on emergency power to function
- Negative reactivity temperature coefficients, including coolant void reactivity, which slow down the reaction rates in the core as temperatures rise, preventing an over-temperature condition.
- Air-cooled reactor vessel, steam generator and condenser; no condenser coolant water, intake structures, or continuous outside water supply are required
- 30-year core life and fuel cycle, which avoids the need to refuel, eliminates fuel storage, and minimizes fuel handling concerns

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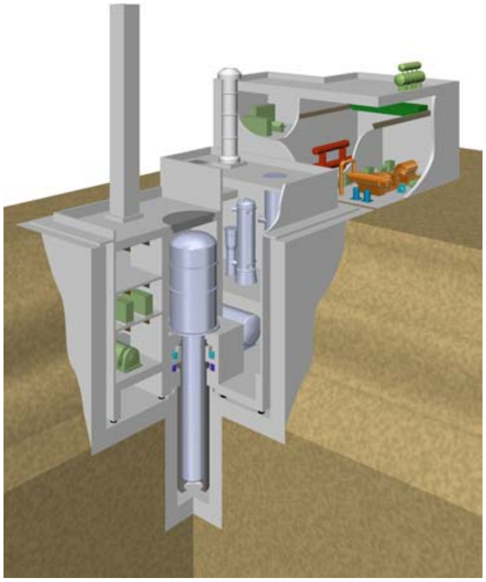
[5] "Galena Project Officials Gear Up for Pre-Application Activities," Inside NRC, February 6, 2006.

- Capability of load following (i.e., matching the reactor power level to the external electrical power demand) without mechanical operation of the reactor control system
- Continuous containment of all radioactive materials within the reactor module throughout the life of the plant.

These unique features are among those that provide the 4S reactor system with significant benefits in operational capability, physical security, and protection of public safety. Many of the systems that increase cost, raise safety concerns, and pose potential security hazards at current plants (such as use of numerous mechanical pumps and valves, the need for a spent fuel pool, and the reliance upon high and low pressure water injection systems) have been eliminated in the design of the 4S. While the 4S reactor system does raise some new issues, such as the need to deal with highly reactive liquid sodium and potential accident scenarios involving sodium-water interaction, these issues have been addressed in the 4S system design and in past LMR facilities. On balance, the licensing of a 4S NPF should be a relatively straightforward process, provided that good communications are maintained between all parties involved and there is a timely flow of complete and accurate technical information.

With respect to decommissioning, the small size of the 4S NPF and its design, which limits the presence of radioactive materials to the reactor module, will minimize the volume of radioactive material that eventually requires disposal. The figure to the right is a 3D rendition of the 4S power generation facility. It depicts the reactor building (lower left), which is below grade, and the turbine generator building (upper right). To put the small size of this facility in perspective, the overall dimensions of the below ground and above ground structures are approximately 190 feet long and 90 feet wide, and can be accommodated in less than ½ acre of land.



The reactor building (also referred to as the nuclear island) houses the reactor module (lowest left corner of figure), the steam generator (slightly higher and to the right of the reactor module), and other vital safety equipment. As can be seen in the figure, the reactor module is located in its own below grade silo-like reinforced concrete structure. The heavy reinforced concrete cap on the top of the reactor module encloses the reactor assembly and core and provides the only access to the nuclear fuel within the reactor.

The major components enclosing the reactor assembly and core are the reactor vessel, the containment guard vessel, and the guard vessel closure head (the heavily reinforced concrete cap on top of the reactor module). The containment guard vessel surrounds the reactor vessel and ensures that the core will not be uncovered and core cooling can be accomplished even if the reactor vessel leaks. The reactor vessel is the container and support for the reactor core, the primary sodium coolant (radioactive), and the primary sodium intermediate heat exchanger structures.

The primary heat transport system (PHTS) through which the primary sodium coolant flows is wholly contained within the sealed reactor vessel. The sodium, which is made radioactive by direct contact with the core, is heated before flowing through two intermediate heat exchangers (IHXs). The IHXs, which are located within the reactor vessel, cool the primary loop sodium as they heat the secondary loop sodium (non-radioactive) that circulates through the intermediate heat transport system (IHTS). All radioactive materials in the 4S are limited to the PHTS and the fuel, both of which are wholly contained within the reactor vessel. No radioactive materials are ever removed from 4S reactor vessel throughout its 30-year life.

The ITHS transports heat from the primary system to the steam generator (SG) where it produces steam that drives convention steam turbine equipment. The IHTS is comprised of a piped loop thermally coupled to the primary system by the IHXs located in the reactor vessel and to the SG located in the SG compartment. The sodium that is circulated through the IHTS to transfer the heat from the primary system to the SG system is non-radioactive. The non-radioactive IHTS sodium entering the shell side of the SG heats the water on the tube side to produce steam, which drives a steam turbine located within the turbine generator building. The steam is cooled and condensed by the main condenser, which is also located with the turbine generator building. The condensed water is re-circulated through the SG system to repeat the process.

The 4S reactor shutdown heat removal systems consist of main condenser cooling, an intermediate reactor cooling auxiliary system (IRACS) for the SG, and the safety related reactor vessel auxiliary cooling system (RVACS), which removes heat directly from the reactor. Except for the RVACS, none of the components for these systems will be exposed to radioactive materials during the course of normal plant operations.

The above features of the 4S design and related features of the design are discussed at greater detail in the overview white paper[6] prepared as part of this series of white papers.

E. White Paper Objectives

The "white papers" in this series are part of an effort underwritten by the State of Alaska to provide "expert legal and technical analysis for [a] proposed mini-nuclear plant" at Galena. The objectives of the papers are threefold: (1) to discuss some of the more important issues that will need to be addressed by the NRC in its consideration of applications for an early site permit (ESP) and a combined construction/operating license (COL) for a 4S NPF located in Galena; (2) to identify approaches for handling issues to ensure that the overall cost of operating a 4S NPF in Galena is competitive with

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[6] Overview of Galena's Proposed Approach to Licensing a 4S Reactor-Based Power Generation Facility (Overview White Paper).

alternative electric power generation methods; and (3) to increase the awareness of government officials and the general public regarding the process for obtaining authorization from the NRC to construct and operate a 4S NPF in Galena. The main purpose of this specific white paper is to identify and introduce the considerations associated with decommissioning a 4S NPF, and to perform a preliminary analysis of those considerations, providing a rough estimate of the cost of decommissioning a 4S NPF located in Galena, Alaska based on currently available information.

Ultimately, Galena must determine if proceeding with the licensing and construction of a 4S NPF is economically justified. These papers are intended to assist the City in making that determination.

III Relevant Law

Decommissioning requirements for entities that possess Part 50 licenses are spread throughout Title 10 of the Code of Federal Regulations (CFR).[7] However, the three most significant sections regarding this topic are 10 C.F.R. §§ 50.33(k), 50.75 and 50.82. 10 C.F.R. § 50.75 requires that licensees provide assurance that adequate funds will be available at the end of facility life to cover all costs related to decommissioning the radiation-contaminated portion of the facility and sets forth several options for demonstrating funding assurance, depending on the type of entity that holds the facility operating license.

Section 50.82 concerns the actions that must be taken by a licensee to accomplish the actual decommissioning of the facility. The NRC defines decommissioning as removing a facility from service and reducing residual radioactivity to the point that the reactor site can be released in either a restricted or unrestricted condition.[8] This regulation requires that decommissioning of power reactor facilities be completed within 60 years of permanent shutdown.[9] Within two years of shutdown, the licensee must submit a post-shutdown decommissioning activities report ("PSDAR"), containing a description of planned decommissioning activities and a schedule for their completion.[10] The PSDAR is subject to public comment, and no significant decommissioning activities may begin until at least 60 days following the NRC's receipt of the document.[11] Section 50.82 further stipulates that licensees must implement their NRC-approved decommissioning

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[7] A 4S NPF at Galena will be licensed under the provisions of 10 C.F.R. Part 52. However, 10 C.F.R. § 52.77 directs that the application for a construction/operating license for a new reactor include addressing the matters set forth in 10 C.F.R. § 50.33, one of which is decommissioning funding. See 10 C.F.R. § 50.33(k)(1). More generally, 10 C.F.R. § 52.83 directs that, unless provided otherwise in 10 C.F.R. Part 52, the provisions in 10 C.F.R. Part 50 apply to Part 52 reactors. Proposed amendments to Part 52 will not change the applicability of relevant Part 50 provisions but will incorporate them explicitly into the amended Part 52. See 71 Fed. Reg.12782 (2006).

[8] 10 C.F.R. § 50.2.

[9] 10 C.F.R. § 50.82(a)(3).

[10] 10 C.F.R. § 50.82(a)(4).

[11] Id.

plans set forth in the PSDAR, and specifies allowable uses of decommissioning funds.[12] Final license termination cannot occur until the NRC is satisfied that all remaining decommissioning activities will be carried out in the manner prescribed in the license termination plan, which must be submitted at least two years prior to the date of license termination.[13]

Finally, under 10 C.F.R. § 50.33(k), a license applicant for a power reactor must demonstrate that it will provide decommissioning funding that meets the requirements set forth in § 50.75, which specifies the funding assurance mechanisms that are acceptable to the NRC. This paper discusses in Section IV.E, infra, the various options that will be available to the Galena NPF applicant/licensee for satisfying the NRC's decommissioning funding requirements.

IV Analysis

The 4S reactor is designed to have a 30-year life cycle (which coincides with the design life of the core and the refueling cycle). Before the 30-year mark passes, a decision will have to be made in regards to the future of the Galena 4S NPF. While the facility could be shut down and decommissioned at the end of the initial core service life, the preferred option will probably be to apply for a renewal of the facility operating license from the NRC. The renewal sought at that time will most likely extend the life of the plant for 30 years by analyzing and replacing necessary components of the reactor core, refueling the core, and refurbishing the existing balance of plant (BOP) facilities. Because most of the components associated with a 4S NPF have a design life of 60 years or more, in addition to the significant industry experience in extending the operational life of power plants, extending the operating life at the end of the first 30 years of operation should be a relatively straightforward process. Extending the plant operating life to 60 total years provides several advantages, as it not only decreases the capital costs of the facility by doubling the effective life, but it also significantly reduces the cost of decommissioning relative to the amount of power generated. Such an approach also increases the amount of time over which the funds needed for decommissioning are collected, as well as the time that they are assumed to accumulate under NRC decommissioning fund financial assurance regulations.[14]

Regardless of whether its service life is extended, the 4S NPF will eventually be decommissioned, and the site restored in accordance with applicable Federal, State, and local regulations. The analysis section discusses various decommissioning methods in order to cover regulations as defined in the relevant law section above. The information presented below is meant to outline the decommissioning process, from initial financing

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[12] 10 C.F.R. § 50.82(a)(7) and (8).

[13] 10 C.F.R. § 50.82(9).

[14] License renewal is an option being currently utilized by the owners of many nuclear power plants in the United States. Extensions of the operating licenses of over twenty facilities have already been approved to date by the NRC.

to eventual closure, and presents options in order to initiate dialog between the NRC, the City of Galena, and other concerned parties.

A. Decommissioning Overview

Two main decommissioning options are likely to be initially considered for the Galena 4S NPF: 1) entombment of the below grade nuclear island including the reactor, so that the buried portion of the facility is left in place and permanently isolated from the surrounding environment; and 2) complete removal and disposal offsite of all plant facilities. These two options were evaluated for the Fast Flux Test Facility (FFTF), a sodium cooled reactor much larger than the 4S that operated at DOE's Hanford site during the 1980s and is now being decommissioned. These two broad approaches are not exclusive, however, and represent the extremes of options that might be considered. The possibility exists for intermediary strategies that combine portions of the two approaches, such as the removal of nuclear facilities and equipment followed by the demolishment and entombment of the non-radioactive portions of the facility onsite as construction debris.

Developing an appropriate estimate of decommissioning costs is necessary because such an estimate will be used to demonstrate compliance with the NRC requirement that financial assurance for decommissioning funding be established as part of the license application. The regulations in 10 C.F.R. § 50.75(c) provide formulae for establishing the minimum funding that must be guaranteed by an applicant or licensee for purposes of decommissioning, but those formulae apply only to large light water reactors ("LWRs") and are useful in the context of a 4S NPF only for comparison purposes. Therefore, as discussed further in Section IV E below, a comprehensive site-specific analysis of the decommissioning costs of a 4S NPF sited at Galena will be required as part of the license application for the facility.

This paper focuses mainly on the technical, economic, and regulatory requirements associated with decommissioning the radiological contaminated portions of a 4S NPF as required by NRC regulations. If Galena chooses to dispose of non-radiological contaminated buildings or structures whose decommissioning is not required by the NRC, the costs of such disposal will need to be estimated separately and will be comparable to the costs of demolishing conventional commercial buildings or structures. For informational purposes, rough estimates of the cost of decommissioning the non-radiological portions of the plant are included below.

B. Analysis of Decommissioning Options

1. Entombment

The entombment of the reactor building and other below grade facilities is probably not a viable option for the Galena 4S NPF. Though technically feasible, the environmental, social, and political ramifications of reactor entombment near the town of Galena will require extensive scrutiny and will likely encounter significant opposition. Because the combined cost of engineering a proper long-term entombment, overcoming the projected opposition, and dealing with the associated regulatory uncertainty is very high, entombment is not discussed further in this white paper.

2. Removal

The removal option is based on the dismantlement and the removal from the site of the 4S radiological and non-radiological facilities. Given this framework, uncertainties remain with respect to the disposal paths of two major components: the reactor pressure vessel and the cold traps**.** Cold traps are cooling modules used to purify the molten sodium coolant by filtering out impurities, which crystallize on them The reactor vessel and the cold traps are expected to contain the most significant radiological hazards, and disposing of them may result in large cost impacts which will have to be researched further.

This paper addresses some removal options and presents a range of cost estimates that have been developed, based on currently available information, to account for the disposal of the reactor and the cold traps as well as cost savings/avoidance possibilities. Subsequent detailed studies of decommissioning options may identify alternative approaches that are both technically and economically preferable to the approach assumed in this paper.

3. Decommissioning by Complete Removal of Radiological and Non-Radiological Facilities

One approach to decommissioning is to completely remove all radiological and non-radiological systems, structures and components of the power generation facility from the site. The result is a restoration of the site to a near-initial condition. The analysis of this option is based on prior experience with the decommissioning of the Fast Flux Test Facility (FFTF) located at Hanford, Washington and other deactivation and decommissioning (D&D) experiences of the international liquid metal reactor community.

a. Reactor Spent Fuel Removal and Disposal

Upon the initiation of decommissioning activities, the first task will be to remove the fuel from the reactor core. Fuel removal will be accomplished by utilizing a process similar to fuel loading, except in the opposite sequence. The spent fuel will be removed and drawn into a transfer cask with a built-in grapple and an external drive, or similar equipment. In preparation for final shipment, the spent fuel will then be transferred to "T-3" type shipping casks, which are casks qualified to handle sodium-wetted fuel assemblies.

For purposes of this study, it is assumed that the spent fuel casks will be transported to the Idaho National Laboratory ("INL") for cleaning and storage of the fuel until the fuel is transferred to its ultimate disposal site.[15] Whether the operator of the Galena 4S NPF will be responsible for this transfer, or it will be accomplished by the Department of Energy (DOE) under the terms of a disposal contract, is unclear at this time. It is further assumed that all of the 4S spent nuclear fuel (SNF) will be disposable at a nationally developed commercial high-level radioactive waste disposal facility such as Yucca Mountain or an alternative equivalent disposal facility. The assumption that disposal in a federally-developed repository will be possible is consistent with the NRC's "Waste Confidence Rule,"[16] which provides that "there is reasonable assurance that at least one mined geologic repository will be available within the first quarter of the twenty-first century and sufficient repository capacity will be available within 30 years beyond the licensed" operating life "of any reactor to dispose of the . . . spent fuel" generated by the reactor.

Under the contractual arrangement currently in place between commercial utilities and the Department of Energy, entered into under the Nuclear Waste Policy Act (NPWA), all costs associated with the eventual disposal of SNF are to be covered by payment of an ongoing 1 mill ($0.001) per kilowatt-hour charge on the sale of nuclear generated power. The licensee of a Galena 4S NPF will enter into a similar Standard Contract[17] with DOE for the disposal of SNF generated by the Galena nuclear facility. Under the provisions of the Standard Contract, DOE will be obligated to take title to the SNF at the Galena site, provide transportation casks at the Galena site into which the SNF will be loaded, and pay for transporting the loaded casks from the Galena site to the disposal facility.

Under such an arrangement, no SNF disposal costs should be borne by the Galena 4S licensee other than removal of the SNF from the reactor vessel and loading the SNF into transportation casks provided by DOE. However, the cost estimate set forth below in this paper conservatively provides that the licensee will be responsible for the costs of temporarily storing the SNF (including the costs for the casks), pending its acceptance by DOE for ultimate disposal,[18] and also for the costs of cleaning the SNF to remove sodium contamination.[19] As discussed above, it is assumed that the SNF will be cleaned and

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[15] The ability to clean and store spent fuel at the INL will need to be confirmed by Galena.

[16] 10 C.F.R. § 51.23

[17] See 10 C.F.R. § 961.11 (the Standard Contract between DOE and the utilities providing for the disposal of spent nuclear fuel).

[18] Under both the NWPA and DOE's contracts with the utilities, DOE was obligated to begin picking fuel up from the utilities in 1998. However, DOE has not yet done so, because of the delays in the proposed Yucca Mountain facility, and numerous lawsuits have been brought by the utilities seeking damages from DOE for breach of its contractual obligations, including the costs of temporarily storing the spent nuclear fuel pending disposal by DOE. Presumably, by the time the Galena 4S facility were decommissioned, some 60 plus years from now, a disposal facility will be in place and DOE will take title to the spent fuel at the Galena site for its ultimate disposal, as discussed in the text above, such that temporary storage of the spent fuel pending disposal will not be necessary.

[19] To our knowledge, no waste acceptance criteria have been established for the disposal of sodium contaminated fuel. Therefore, this analysis conservatively assumes that the 4S SNF will have to be cleaned to remove residual sodium prior to placement in a permanent repository. However, discussions should be held with the NRC and DOE to ensure that there is an understanding of the residual level of sodium that will be acceptable for disposal at a permanent repository.

temporarily stored at INL pending acceptance by DOE for disposal. Therefore, under this conservative assumption, the licensee will also be responsible for the cost of transporting the spent fuel to INL. The cost estimate for this phase of decommissioning is thus based on the following assumptions:

- The same mechanism used to initially load the fuel into the reactor will be used to unload fuel and transfer it to a transportation cask. This device is portable and can be rented from Toshiba;
- Access to the reactor head requires removal of the top part of the containment dome;
- Two T-3 sodium-qualified casks can accommodate all 18 fuel assemblies in the 4S core. The loaded casks will be stored onsite at Galena within the double-fenced security fence for approximately a year until they are readied for shipment (along with the reactor and sodium; see subsection (i) below). Consistent with the conservative assumption that DOE will not accept the spent fuel directly from the Galena site, the loaded casks will be transferred by dedicated barge and ocean-going vessel to Hanford and then placed on a dedicated train for transfer to INL. More information regarding the assumptions associated with shipment of all of the material from the Galena site is discussed in subsection (i) below.
- The fuel will be cleaned of its sodium residue and stored at INL pending ultimate disposal by DOE.

The cost elements associated with reactor defueling operations are shown in Table 1 of the Reference Document, Appendix A, under the heading “Fuel Removal.” Estimated INL costs associated with fuel cleanup and subsequent storage pending disposal are shown in Table 1 under the heading “Waste Management and Disposal”.

b. Primary sodium drain and disposal

Subsequent to fuel removal, the bulk primary sodium will have to be removed from the reactor vessel. This will be done by inserting a pump into the reactor vessel from an existing port in the reactor head and pumping the sodium into shielded tanks, where it will be allowed to cool and solidify before shipment. This sodium will be highly radioactive, and will require special handling and shipment precautions.

Based on INL’s plan to accept FFTF primary and secondary sodium, this paper assumes that the Galena 4S NPF drained sodium will be shipped to INL. The intended disposal path for the sodium will be to first react the sodium with water to form NaOH, and then ship the NaOH to the Waste Treatment Plant (WTP) at Hanford, where it will be processed.

The shielded tanks containing the drained primary sodium will also be shipped to Hanford, Washington by dedicated barge and ocean-going vessel and then placed on a dedicated train for transfer to INL. This transportation is more fully discussed in subsection (i) below.

c. Primary sodium wetted component cleanup

In a 4S reactor, the vessel and its internals are exposed to primary liquid sodium, which leaves a radioactive residue on the components. The removal of primary sodium residue and contamination from these components will be accomplished by reacting residual sodium collected in the system as well as sodium-contaminated surfaces with wet nitrogen gas steam, followed by a water rinse. The cost estimates assume that cleaned components will meet the waste acceptance criteria at an appropriate low-level radioactive waste (LLW) disposal facility.

d. Secondary sodium drain and disposal

The secondary sodium and the components in the secondary loop will not be expected to contain radiological contamination. It is therefore anticipated that these materials could be recycled into other uses or reclaimed as salvage without undergoing radiological decontamination. However, in order to bound operating and decommissioning uncertainties, this paper conservatively assumes that the sodium and other components utilized in the secondary loop will contain some minimal radiological contamination such that they will need to be disposed of as low level radioactive waste (LLW).

Sodium from the secondary loop will be pumped out of the secondary loop by inserting a pipe into the system and drawing the sodium from the entire loop into a sodium tank. No special radiological precautions will be needed to handle the sodium after it is removed from the secondary loop since its level of radioactivity, if any, should be insignificant.

The secondary sodium cold trap will be removed and suitably isolated, and, consistent with the above assumption that secondary components will need to be disposed of as LLW, will be placed within the reactor before the reactor is grouted.

As in the case of the 4S primary sodium, solidified secondary sodium will be shipped via the Hanford site to INL for processing and subsequently shipped to a waste disposal facility similar to the WTP.

e. Major sodium-wetted component/piping disposal

Consistent with the conservative assumption that secondary components will need to be disposed of as LLW, the cleanup and removal of sodium residue from sodium-wetted secondary components will be accomplished in a manner similar to that for the primary sodium wetted components as described in subsection (c) above. The major sodium-wetted components that will be cleaned of sodium residue and be packaged individually and transported for disposal as LLW are:

- Steam Generator
- Sodium-water reaction products dump tank
- Sodium drain tank

- Piping

f. Reactor Vessel disposal

Burns and Roe Enterprises, Inc. (BREI) was involved with the removal of the reactor for the Trojan One-Piece Reactor Vessel and Internals (RVAIR) Project[20] as well as the Shippingport Decommissioning Project. These experiences were utilized by BREI to develop the methodology and estimate the costs for removing the FFTF reactor/guard vessel.[21] The combined experience from these projects provides valuable insights into the actions that will be required for the removal of the reactor vessel from a 4S reactor.

Removal of the 4S reactor and the containment vessel will be comprised of the following steps: preparation of the reactor vessel, grouting, inlet and secondary sodium piping detachment, and removal of the reactor vessel from the reactor building. Each of these are discussed in additional detail below.

(i) Preparation of the reactor vessel

The reactor vessel and the intermediate heat exchanger (IHX) will be drained and cleaned using the sodium cleanup methodologies discussed above, leaving behind residual sodium with a currently unknown level of radioactivity that cannot be removed with the cleaning media.

Several electrical, instrumentation, drive mechanisms and other components will have to be disconnected from the reactor top to permit vertical lifting of the reactor/containment vessel. This step should be conducted in the same fashion as the original installation of the reactor in the reactor building, but in reverse.

Assumptions associated with this process include the following:

- The reactor internals, including reflector, flux monitors, IHXs and primary electromagnetic pumps, will be left in place and disposed along with the reactor.
- The primary cold trap will be isolated (by means to be determined) and left in place within the reactor for disposal. (As an option, removal of the cold trap from the reactor and its shipment to INL in a T-3 cask for processing has been evaluated and discussed as part of the range of estimates in Table 3).

(ii) Grouting

The reactor vessel will then be grouted in order to provide shielding from its radioactive internal components. Grouting will be accomplished by utilizing access ports that are present in the reactor head. Lightweight grout of appropriate density will be poured into

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[20] Rollin' up the River: Trojan's Last Voyage, Nuclear News, October 1999.

[21] BREI Report, Independent Cost Estimate of the Fast Flux Test Facility (FFTF) Closure Project at Hanford, Richland, Washington, September 2003.

to the lower section of the reactor and allowed to cure. The core region of the reactor (height 6 to 7 ft) will then be filled with either regular concrete (density ~2.35 g/cm^3) or high-density concrete, depending on shielding requirements. This concrete will be allowed to cure/harden before pouring lightweight concrete in the top region of the reactor. Regular density concrete will also be added to the annulus between the reactor vessel and the containment vessel through several locations around the periphery for additional shielding. The radiological dose at the containment vessel surface will then be evaluated to ascertain if any additional shielding was required, and, if so, such shielding will be installed at that time. It is likely that additional local shielding will be required, particularly in the vicinity of the cold trap located within the reactor vessel**.**

Based on the relative size and structure of the 4S reactor, the 4S reactor with the IHXs, containment vessel and grout is estimated to weigh less than 500 tons. Thus, a five hundred ton lifting device will need to be deployed at the site.

After grouting the space between the reactor and the containment vessel, radiation will be reduced such that it will be possible to access the reactor cavity area for clearing interferences from the lift.

(iii) Inlet and Outlet Secondary Sodium Piping Detachment

The inlet and outlet pipes will be severed close to the external face of the containment vessel, effectively detaching the reactor vessel from the surrounding structure. A portion of the cut will be through grout. The dose rate in this area will be low enough to permit semi-remote cutting and sealing.

(iv) Removal of the Reactor Vessel from the Reactor Containment Building

The upper part of the reactor vessel will be removed through the reactor building access hatch during the fuel removal operations, and will not be reinstalled. The reactor building hatch will remain in service, however, and will remain closed unless lifting access is required in the reactor building.

The lifting device will most likely be mounted to a lifting beam mounted on the reactor main support structure. As the reactor assembly is lifted out of the reactor compartment and through the open containment dome, surface radiation measurements will be taken and final localized shielding (i.e., welded plate) will be added as required before lifting the reactor vessel to the operating level. Once removed from the building, the entire reactor vessel will be placed onto a crawler for transfer to a barge for shipment.

g. Shipment of Spent Fuel, Reactor Vessel and Sodium

After removal from the reactor vessel, the unloaded spent fuel will be stored in the T-3 casks in the nuclear island buildings within the double security fence. The fuel and the drained sodium will be stored onsite until the reactor vessel is grouted and removed from the reactor building. It is assumed that the transport of the spent fuel (consistent with the conservative assumption in subsection (a) above that DOE will not accept the spent fuel for disposal directly at the Galena site), reactor vessel and the solidified sodium will be accomplished through a single shipment from Galena to a coastal port in Alaska. These three components will then be shipped on a single dedicated ship to a Northwest U.S. port, and then to the Department of Energy facility in Hanford, Washington. Once transferred to Hanford, the sodium tanks and spent fuel will most likely be moved by dedicated train to the INL in Idaho Falls, Idaho. In summary, the following transportation arrangements will be required:

- Barge transport from Galena to a coastal port in Alaska
- Dedicated transport by ship to the US west coast
- Ship/barge transport to Hanford, Washington
- Railroad transport (of spent fuel, sodium and cold trap) to Idaho Falls, Idaho.

h. Potential Balance of Plant Decontamination Activities

The NRC is only concerned with the decontamination and decommissioning of radiation-contaminated areas. Therefore, decommissioning of the rest of the plant will be optional to the owner (and State regulatory authorities). The estimated costs associated with decontamination and decommissioning of the balance of a 4S NPF are presented here so as to provide a complete analysis of the costs of potential decommissioning activities. To develop this estimate, the simplified methodology developed by Kaiser Hill for decommissioning cost estimation was used. This methodology is derived from Kaiser Hill's extensive D&D experience and the data they have compiled from the completion of D&D work at DOE sites, including the Rocky Flats project. This methodology is described in detail in Appendix B.

The main activities associated with balance of plant will include deactivation and demolition. It is assumed that the debris could be used for fill at the site. The estimated cost of performing these activities for a 4S reactor in Galena, Alaska is $3 million, as shown in Table 1 of Reference Document Appendix A.

i. Additional Assumptions

In addition to the specific assumptions stated above, the following assumptions apply to the estimate of decommissioning costs for a 4S reactor in Galena, Alaska:

- A qualified LLW site will be established in Alaska. LLW such as concrete and steel debris removed from the 4S facility will be sent to such disposal site.

- Reactor removal and transport operations will only occur during the summer when the river is passable. Access to barge transport will be required and is assumed to be available.

- A grout batch plant will be available at the Galena site. The costs associated with the batch plant are not included in this estimate.

- As a part of the base estimate (Tables 1 and 2 in Appendix A), it is assumed that the primary cold trap could be isolated (so that it will not react with the steam-nitrogen media used to clean up sodium-wetted surfaces within the reactor) and will be left in the reactor vessel and grouted. However, leaving the primary cold trap grouted within the reactor vessel will impose a certain challenge from the perspective of 4S decommissioning because it could not meet waste acceptance criteria at any current LLW disposal site. (This does not mean that an acceptable LLW disposal facility will not be available at the time a 4S NPF is decommissioned.) To account for this uncertainty, the cost of removing the primary cold trap from the reactor vessel and shipment of the cold trap in a T-3 cask to INL for processing has been estimated and included in the range of estimates in Table 3 of Appendix A. Removal of the cold trap and the associated costs is based upon the experience gained with decommissioning the FFTF, where the primary and secondary cold traps were sent to INL for processing. This action added a significant (~$25 million) cost to decommissioning FFTF, and a similar proportional amount is provided in Table 3 of Appendix A for the Galena 4S NPF.

j. Expected End of Life Waste Quantities

An estimate of the significant waste products at the end of a 4S reactor 30-year life is provided below, as well as in Appendix A of the Reference Document. The table also identifies the potential category of each of these waste products and their anticipated disposal path. The disposal paths are based upon those identified for the decommissioning waste from the FFTF facility. Some issues will have to be resolved regarding the disposal path of some components, as discussed above.

Waste	Quantity	Category	Disposal Site	Remarks
Fuel Assemblies	18	MHLW	INL/YMP	
Reactor & Containment including internals	1	Class C	Hanford	Issues would remain with respect to meeting Hanford WAC
Primary cold trap	1		Hanford	Isolated and located within the grouted and shielded reactor
Reflector Assembly	1		Hanford	Located within the grouted and shielded reactor
Secondary cold trap	1		Hanford	Located within the grouted and shielded reactor
IHX	1		Hanford	Located within the

				grouted and shielded reactor
Primary EM Pumps	2		Hanford	Located within the grouted and shielded reactor
Steam Generator	1	LLW	Hanford/NTS	
Containment dome	1	LLW	Envirocare/NTS	
NI Rubble	3,630 cu yd	LLW	Alaskan site	
BOP Rubble		Clean	Use as fill at site	
Primary sodium	600 gal	Hazardous	INL/WTP	INL to process it to NaOH; Subsequent shipment to WTP or similar facility for use in their process

Table 1 Expected Major Waste Quantities at 30 Years (Consistent with the Base Cost Estimate in Reference Document Appendix A, Table 1)

Abbreviations:
IHX- Intermediate Heat Exchanger
INL- Idaho National Laboratory
LLW- Low-level Waste
MHLW- Mixed High Level Waste
NI- Nuclear Island
NTS- Nevada Test Site
WTP-Waste Treatment Plant

C. Summary of Decommissioning Costs

The base cost estimates for the decontamination, and decommissioning activities discussed above are as follows:

ACTIVITY	**COST ESTIMATE**
Fuel Removal	$5,000,000
Primary Sodium Removal	$2,650,000
Removal of Secondary Sodium and of Secondary System Cold Trap	$1,070,000
Reactor/Containment Vessel Grouting, Removal and Disposal	$7,140,000
Nuclear Island Deactivation, Decommissioning, and Rubble Disposal	9,351,000
Balance of Plant Deactivation, Decommissioning, and Rubble Disposal	$3,000,000
Transportation to and Waste Processing and Storage at INL	9,150,000
SUBTOTAL OF ABOVE	$37,361,000
Project Management (estimated at 15% of above subtotal)	$5,604,000
Operations, Maintenance & Security (estimated at 5% of above subtotal)	$1,868,000
TOTAL	$44,833,000

TABLE 2 – BASE DECOMMISSIONING COST ESTIMATE[22]

This base estimate is conservative in several respects. First, it assumes that the licensee will need to supply the transportation casks for the spent fuel, pay for the transportation of the spent fuel casks to INL, and pay for cleaning and storage of the fuel at INL. Currently, DOE is obligated under the Standard Contract to take title to the spent fuel for its ultimate disposal at the Galena site and to provide the casks into which the fuel is to be loaded at the site. The cost estimates for these activities exceed $3.5 million.

Second, the cost estimate assumes that the secondary loop sodium will become contaminated during operation or decommissioning, requiring the treatment of the secondary loop sodium as LLW. This is in reality very conservative, as the 4S is designed to preclude radioactive contamination of the secondary loop sodium and components outside the reactor vessel. The decontamination and decommissioning cost

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[22] Table 1 (above) is compiled from information available in “Decommissioning Issues Relating to Galena’sS Proposed Licensing of a 4S Reactor-Based Power Generation Facility – Reference Document” Appendix A, Table 1.

estimates therefore include amounts for removal of the secondary system sodium, including removal of sodium residues from secondary system components, and for transporting and processing secondary sodium as LLW at INL. The cost estimates for these activities exceed $5.5 million.

Third, the base estimate includes costs in excess of $6 million for decontaminating the reactor building and disposal of its rubble as LLW. The 4S is designed to limit radioactive contamination to the reactor module, and so we can expect that if the design performs as expected, these structures could be decommissioned in a similar fashion as the balance of plant structures at significantly reduced costs.

Excluding these significant conservatisms will reduce the base estimate on the order of 25% or more, to $33 million or less, which will provide a lower bound estimate based on currently available information.

To capture uncertainty that might increase the base cost estimate, Table 3 of Appendix A[23] identifies additional decommissioning and decontamination activities and their costs should radiological contamination of the Galena 4S facility require decontamination beyond that assumed in the base case. This upper bound estimate assumes the removal and disposal of all of the concrete below the operating floor of the reactor building, as well as removal of the primary sodium cold trap, and includes transport to INL in a T-3 cask for waste processing. This upper bound of the cost is estimated at $53 million.[24]

10 C.F.R. § 50.75(c)(1) provides a table to be used for calculating the minimum funding (in January 1986 dollars) required to demonstrate reasonable assurance of funds for decommissioning BWR and PWR reactors by power level, P (in MWt). This table is intended to establish the minimum amount of funding that a licensee must demonstrate to be available for decommissioning purposes in January 1986 dollars, which are escalated per 10 CFR 50.75(c)(2), but does not necessarily reflect the actual cost of decommissioning at a specific facility. The amounts explicitly do not consider any costs other than those activities necessary for terminating the facility license, i.e., the table excludes costs associated with the removal and storage of spent fuel or of non-radioactive structures and materials not necessary to terminate the license.[25] The amount of funding required by this regulation for BWRs and PWRs is as follows:

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[23] "Decommissioning Issues Relating to Galena's Proposed Licensing of a 4S Reactor-Based Power Generation Facility – Reference Document" Appendix A, Table 3.

[24] *Id.*

[25] 10 CFR 50.75(c)(1).

For a PWR:	greater than or equal to 3400 MWt	$105M
	between 1200 MWt and 3400 MWt (For a PWR of less than 1200 MWt, use P=1200 MWt)	$(75+0.0088P)
For a BWR:	greater than or equal to 3400 MWt	$135M
	between 1200 MWt and 3400 MWt (For a BWR of less than 1200 MWt, use P=1200 MWt)	$(104+0.009P)

TABLE 3 – MINIMUM DECOMMISSIONING FUNDING REQUIRED BY 10 C,F,R, § 50.75(c)(1)

These estimates were based on generic reactor decommissioning studies done by Battelle Pacific Northwest Laboratory as part of the Commission's initial rulemaking for establishing decommissioning funding assurance requirements.[26]

A few points worth noting in connection with the above table are:

- The minimum amount of funding for a 1200 MWt PWR (40 times larger than the proposed Galena 4S) or less will be $85.6 million in 1986 dollars, and the minimum amount of funding for a 1200 MWt BWR (40 times larger than the proposed Galena 4S) or less will be approximately $115 million in 1986 dollars.
- The formula thus requires significantly greater funding on a per MWt for a smaller plant than it does for a larger plant, reflecting that fixed decommissioning costs are high compared to variable costs related to size of the reactor.
- In line with this expectation, the per MWt cost estimate for decommissioning the 4S developed in this paper are considerably higher when compared to per MWt decommissioning costs/funding requirements for the much larger LWRs shown in the table above, even taking into account the differences in the estimation process (i.e., the inclusion of many costs in the 4S estimate developed above that were excluded from the cost estimates upon which the funding requirements in the table are based).

D. Potential Funding Strategies

NRC regulations in 10 C.F.R § 50.33(k)(1) require an applicant for a license to operate a nuclear reactor to prepare a report in accordance with 10 C.F.R. § 50.75, indicating how the applicant will provide reasonable assurance that funds will be available to decommission the facility at the end of its useful life. (10 C.F.R. § 50.75 describes the NRC requirements for assuring the availability of decommissioning funding and specifies the methods for providing this assurance that are available to different types of licensees.)

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[26] 53 Fed. Reg. 24,019, 24,027-28 (1988). In 1993, the Commission had additional studies performed which estimated the cost of decommissioning a large PWR and BWR at about $125 million and $160 million respectively in 1993 dollars, an increase of $20 million and $25 million, respectively, from the 1986 cost estimates. These estimates were lower than the 1986 estimates escalated in accordance with 10 CFR 50.75(c)(2).

More detailed guidance is provided in NUREG-1577, Rev. 1, Standard Review Plan on Power Reactor Licensee Final Qualifications and Decommissioning Funding Assurance, and Regulatory Guide 1.159, Rev. 1, Assuring Availability of Funds for Decommissioning Nuclear Reactors. The method chosen by a licensee for providing financial assurance of the availability of sufficient funds for all decommissioning activities at the facility's end of life is significant, as it can affect the funding level required to be available at the outset of plant operations.

The regulations spell out specific requirements for determining the amount of decommissioning funding required for PWR or BWR power reactors (which will not encompass the Galena 4S NPF) in 10 C.F.R. §§ 50.75(b) and (c). These provisions allow this cost estimate for PWRs and BWRs to be based either on a site-specific facility analysis of the expected costs associated with decommissioning, or the use of "minimum amounts" of funding contained in § 50.75(c), and shown in Table 3 above. A PWR or BWR power reactor facility is not allowed to provide funding assurance less than the amounts contained in § 50.75(c), but may only increase this amount of funding assurance if a site-specific estimate indicates that the actual costs will be higher. 10 C.F.R. § 50.75(d) provides the requirements for determining the amount of decommissioning funding required for "a non-power reactor applicant" which is defined by 10 C.F.R. § 50.2 as a research or test reactor licensed under 10 C.F.R. §§ 50.21(c) or 50.22 for research and development would. Non-power reactors are required under 10 C.F.R. § 50.75(d) to base the amount of decommissioning funding on a site-specific cost estimate for the facility. None of the reactor types specified by these regulations will encompass a 4S NPF.

10 C.F.R. § 50.75 contains no provisions that are directed specifically to the amount of decommissioning funding that needs to be maintained by a power reactor that is not a PWR or BWR. Because no minimum amount of decommissioning funding is prescribed by 10 C.F.R. § 50.75 for power reactors that are not PWRs or BWRs, a reasonable interpretation of the regulation is that other power reactors must provide a site specific cost estimate to establish the amount of decommission funding to be required for the facility. A preliminary estimate of the decommissioning costs for the 4S NPF is outlined above.

The method for providing decommissioning funding for a facility depends on the nature of the entity that holds the license for the facility. There are three types of entities that may eventually become the operating license holder of a 4S reactor in Galena: a regulated entity, an unregulated entity, or a government entity. Under NRC nomenclature, a regulated entity is a licensee that recovers, either directly or indirectly, the estimated total cost of decommissioning through rates established by "cost of service" or similar ratemaking regulation, or through a non-bypassable charge. Non-bypassable charges are those charges imposed over an established time period by a Government authority that affected persons or entities are required to pay to cover costs associated with the decommissioning of a nuclear power plant. Such charges include, but are not limited to, wire charges, stranded cost charges, transition charges, exit fees, other similar charges, or the securitized proceeds of a revenue stream.[27] An unregulated entity is any non-governmental entity that does not recover the total cost of decommissioning using one or more of these methods, often referred to as a "merchant plant." NRC regulations also allow for a licensee to be a federal entity, such as the Department of Energy. Federal entities which are power reactor licensees are given an additional method of decommissioning fund assurance, available only to them. Because a federal licensee is unlikely for a Galena facility, this option will not be discussed further.

1. Regulated Entity

There are a number of options contained in 10 CFR § 50.75 for a regulated entity to provide decommissioning fund financial assurance. The majority of these methods are identical to the methods available to an unregulated entity, such as prepayment, parental guarantee, and contractual commitments. The most significant option that is only available to a regulated entity, however, is the establishment and exclusive use of an external sinking fund. Because the exclusive use of an external sinking fund provides distinct advantages to a regulated licensee, it is the preferred method for this type of entity and is the only option that will be discussed for regulated entities.

a. External Sinking Fund

A regulated entity may use an external sinking fund exclusively to provide financial assurance; no additional method of financial assurance is required.[28] Under this method, a fund is established into which payments are periodically deposited. The amount of the payment is calculated by dividing the decommissioning funding assurance amount by the total number of years over which payments will be made into the fund. Use of the external sinking fund allows the entity to provide an initial payment, and then periodically contribute to the fund with payments over the operating life of the plant. The amount of the periodic payment is a function of the ultimate amount of funding determined to be necessary, the number of years over which payments will be made into the fund, and the assumed real annual rate of return on the fund over its life.

10 C.F.R. § 50.75(e)(1)(ii) provides that a regulated entity may assume a real rate of return on the fund of 2% over its life, or may credit a higher percentage if the licensee is authorized to do so by its rate-setting authority. The decommissioning estimate established for a facility in Galena will include a period of safe storage, thus the assumed rate of return may be credited through the period of operation, safe storage, final dismantlement, and license termination. The total period of time over which the fund could assume to accumulate returns could thus be on the order of 50 – 100 years. With

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[27] 10 C.F.R. § 50.75(e)(1)(ii)(A) and (B).

[28] Any *significant* (i.e., greater than 20%) portion of sales that are *not* regulated must be guaranteed using the guidelines described for an Unregulated Entity (i.e., an additional form of financial assurance other than an external sinking fund must be provided). Provided at least 80% of an entity's sales are regulated, the NRC allows for an external sinking fund to be used as the exclusive means of financial assurance.

such a long period of growth, a relatively small periodic payment will be necessary to fully satisfy the requirements for funding assurance.

b. Other Financial Assurance Options

All of the options available to an unregulated entity (e.g., prepayment, financial guarantee, and contractual commitments, discussed below) are also available to a regulated entity. None of these other options, however, will offer a regulated entity the advantages provided by an external sinking fund.

2. Unregulated Entity

For an unregulated entity, an external sinking fund cannot be the exclusive method of providing financial assurance. Therefore, if a sinking fund is used, one of the other methods specified in § 50.75 for funding assurance must also be used.

a. Prepayment

The first option for providing financial assurance discussed in § 50.75 is prepayment of the obligation. While this option is available to regulated utilities as well, there are no incentives for a regulated entity to select this option. As in the case of an external sinking fund, the amount of the prepayment can be reduced assuming a 2% real rate of return over the life of the fund, and a regulated entity can credit a greater amount if authorized to do so by its rate-setting authority. Also similar to the external sinking fund, the time period over which the fund can be assumed to continue to earn this rate of return, provided the decommissioning plan includes a period of safe storage, is the period through operation, safe storage, final dismantlement, and license termination. Again, depending on the life of the plant and assumptions regarding the time required for decommissioning activities, this compounding period could be between 50 and 100 years.

b. External Sinking Fund

This option is the same as for a regulated entity, except that an unregulated entity cannot use an external sinking fund as the sole method of providing financial assurance; one or more of the other available options must be used in conjunction with the external sinking fund. In other words, at least one additional method of funding assurance must be designated and, at the time of license application, this method will have to be sufficient to cover the full amount of the funding assurance required. As money was subsequently placed in the external sinking fund, this alternative method of funding assurance could be correspondingly reduced. In addition, since an unregulated entity has no “rate setting authority,” the maximum real rate of return that can be assumed over the life of the sinking fund is 2%.

c. Financial Guarantee

Another option available to both regulated and unregulated entities is to provide some sort of financial guarantee that the funds will be paid. Section 50.75 suggests three methods by which such a guarantee may be provided: a surety method, insurance, or other guarantee method; a parental guarantee; or, a self-guarantee.

(i) Surety method, insurance or other financial guarantee

A surety method may be in the form of a surety bond, letter of credit, or line of credit. Insurance will be provided under commercial decommissioning insurance policies. The beneficiary of the surety agreement or insurance policy must be a trust established exclusively for covering decommissioning costs. The surety method or insurance must be open-ended, or, if written for a specified term, such as 5 years, must be renewed automatically, unless 90 days or more prior to the renewal day the issuer notifies the NRC, the beneficiary, and the licensee of its intention not to renew. The surety or insurance must also provide that the full face amount will be paid to the beneficiary automatically prior to the expiration without proof of forfeiture if the licensee fails to provide a replacement acceptable to the NRC within 30 days after receipt of notification of cancellation. The trustee and trust must be acceptable to the NRC. An acceptable trustee includes an appropriate State or Federal government agency or an entity that has the authority to act as a trustee and whose trust operations are regulated and examined by a Federal or State agency.

(ii) Parental Guarantee

A parental guarantee must also be open-ended or automatically renewed. If the guarantee is not renewed, the licensee must give notice 90 days prior to expiration of the guarantee and the full amount of the guarantee must be paid to an acceptable trust, which is established exclusively for the purpose of covering decommissioning costs.

10 C.F.R. § 50.75 requires that the parent company must meet at least one of two financial tests described in 10 C.F.R. Part 30, Appendix A in order for the parental guarantee to qualify as an acceptable method of financial assurance. These two tests can be summarized as follows:

Test 1: Parent Company must have:

- Two of the following three ratios: A ratio of total liabilities to net worth less than 2.0; a ratio of the sum of net income plus depreciation, depletion, and amortization to total liabilities greater than 0.1; and a ratio of current assets to current liabilities greater than 1.5; and
- Net working capital and tangible net worth each at least six times the amount of decommissioning funds being assured by a parent company guarantee, excluding the net book value of the nuclear unit; and
- Tangible net worth of at least $10 million; and
- Assets located in the United States amounting to at least six times the amount of decommissioning funds being assured by a parent company guarantee.

Test 2: Parent Company must have:

- A current rating for its most recent bond issuance of AAA, AA, A, or BBB as issued by Standard and Poor's or AAA, AA, A, or BAA as issued by Moody's; and

- Tangible net worth each at least six times the amount of decommissioning funds being assured by a parent company guarantee, excluding the net book value of the nuclear unit; and
- Tangible net worth of at least $10 million; and
- Assets located in the United States amounting to at least six times the amount of decommissioning funds being assured by a parent company guarantee.

(iii) Self-Guarantee

A licensee may self-insure the availability of decommissioning funds, provided the licensee meets the appropriate financial test. However, a self-guarantee may not be used as a means of providing financial assurance if the applicant or licensee has a parent company holding majority control of voting stock of the company seeking the license. If a licensee is a commercial company that issues bonds, they must meet the test contained in Appendix C to 10 C.F.R. Part 30. If the licensee is a commercial company that does not issue bonds, they must meet the test contained in Appendix D to 10 C.F.R. Part 30. Finally, if the licensee is a university or a hospital, they must meet the test contained in Appendix E to 10 C.F.R. Part 30. Because the eventual licensee of a reactor in Galena is unlikely to be either a university or a hospital, the test contained in Appendix E will not be discussed further. The other tests are summarized as follows:

Test To Be Used By Commercial Companies That Issue Bonds – company must have:

- Tangible net worth at least 10 times the amount of decommissioning funds being assured by a self guarantee, excluding the net book value of the nuclear unit.
- Assets located in the United States amounting to at least 10 times the amount of decommissioning funds being assured by a self guarantee.
- A current rating for its most recent bond issuance of AAA, AA, or A as issued by Standard and Poors (S&P), or Aaa, Aa, or A as issued by Moodys.
- The company must have at least one class of equity securities registered under the Securities Exchange Act of 1934.
- The company's independent certified public accountant must have compared the data used by the company in the financial test that is derived from the independently audited, yearend financial statements for the latest fiscal year, with the amounts in such financial statement. In addition, the licensee must inform the NRC within 90 days of any matters coming to the attention of the auditor that cause the auditor to believe that the data specified in the financial test should be adjusted and that the company no longer passes the test.
- After the initial financial test, the company must repeat passage of the test within 90 days after the close of each succeeding fiscal year.

Test To Be Used By Commercial Companies That Do Not Issue Bonds – company must have:

- Tangible net worth greater than $10 million, or at least 10 times the total current decommissioning cost estimate (or the current amount required if certification is used), whichever is greater, for all decommissioning activities for which the company is responsible.

- Assets located in the United States amounting to at least 90 percent of total assets or at least 10 times the total current decommissioning cost estimate (or the current amount required if certification is used) for all decommissioning activities for which the company is responsible.
- A ratio of cash flow divided by total liabilities greater than 0.15 and a ratio of total liabilities divided by net worth less than 1.5.
- The company's independent certified public accountant must have compared the data used by the company in the financial test, which is required to be derived from the independently audited year end financial statement based on United States generally accepted accounting practices for the latest fiscal year, with the amounts in such financial statement. In addition, the licensee must inform the NRC within 90 days of any matters that may cause the auditor to believe that the data specified in the financial test should be adjusted and that the company no longer passes the test.
- After the initial financial test, the company must repeat passage of the test within 90 days after the close of each succeeding fiscal year. If the licensee no longer meets the financial test requirements, the licensee must provide alternative financial assurance within 120 days after the end of the fiscal year.

d. Contractual commitments (i.e., electrical purchase contracts)

Both regulated and unregulated licensees also have the option of demonstrating the existence of contractual commitments that are sufficient to assure the NRC that the licensee will be able to meet its financial commitments to adequately funding decommissioning costs. This option also has several requirements, including:

- The total amount of the contractual obligations over the duration of the contract(s) must provide the licensee's total share of uncollected funds estimated to be needed for decommissioning under applicable regulations.
- To be acceptable, terms of the contract(s) must include provisions that the electricity buyer(s) will pay for the decommissioning obligations specified in the contract(s), notwithstanding the operational status either of the licensed power reactor to which the contract(s) pertains or *force majeure* provisions.
- All proceeds from the contract(s) for decommissioning funding must be deposited to an external sinking fund.
- The NRC reserves the right to evaluate the terms of any contract(s) and the financial qualifications of the contracting entity(ies) offered as assurance for decommissioning funding.

e. Combination of Methods

Finally, the regulations in 10 C.F.R. § 50.75 allow licensees to use a combination of the above methods, or “any other method,” to provide decommissioning funding assurance, as long as the method provides “assurance of decommissioning funding equivalent to that provided by the mechanisms” described above.

3. Analysis of Decommissioning Funding Options

As explained above, if the entity that is eventually licensed as the operator of a Galena 4S NPF is a regulated utility, an external sinking fund should be selected as the method of providing fund assurance. This method presents the lowest initial financial obligation and allows for spreading the obligation over the longest term. While other funding assurance options will be available, there will be no economic reason for selecting them.

If the Galena licensee is unregulated, use of an external sinking fund is also recommended, although it cannot be used exclusively. As explained, in this case the external sinking fund can only be used to reduce over time the amount of funding assurance provided by other funding assurance options. Consequently, an initial funding option must be identified that is sufficient to satisfy the entire funding assurance obligation, properly adjusted for natural compounding over the expected collection period to the extent applicable. This alternative funding option could then be reduced over time as the amount of the external sinking fund increased.

Prepayment of the obligation, even considering the allowance for the time value of money, will not be an attractive option. The amount of initial funding required to satisfy this option will greatly increase the initial construction costs of the facility without conferring any tangible benefits.

The nature of the Galena NPF project makes it unlikely that either a parent company guarantee or a self-guaranty will be available as an option. For these options to exist, the licensee of the facility will have to be large enough to satisfy the “tests” identified and the economics of operating the facility will have to justify the commitment of funds required. Given that the facility will generate less than one-hundredth of the power generated by a typical nuclear facility and the exclusive nature of the customer base, a company that could meet these requirements will probably not elect to accept this financial obligation.

10 C.F.R. § 50.75 does provide options, in addition to an external sinking fund, that may be economically reasonable to pursue in the case of a Galena 4S NPF. In particular, reliance on contractual commitments will be particularly appropriate for the licensee of a 4S reactor in Galena since Galena is an isolated user and alternative sources of electricity are not available. Thus, power purchase agreements between the city and the licensee will be very reliable. In addition, because the 4S reactor is designed to operate for 30 years with little interaction, a long-term purchase contract between the city and the licensee should be obtainable, resulting in a stable source of financial assurance. Using contractual commitments in combination with an external sinking fund will therefore be the recommended approach for an unregulated licensee to meet the requirements of providing decommissioning fund financial assurance. In order for such contractual obligations to satisfy NRC requirements, the contracts will be required to contain a clause guaranteeing the payment of the decommissioning cost of the facility even if the facility were to cease generating electricity.

Other options might also prove attractive. As discussed, 10 C.F.R. § 50.75 allows for a combination of methods to be used or the use of "any other method" that the NRC determines satisfies the intent of the requirement. A method that may be particularly relevant to the Galena situation will be to use a guarantee from the State of Alaska in combination with the above methods. The concept will be to initially identify the amount of financial assurance required, and then include this required amount in the contracted rates for the service life of the facility. As the electricity is sold, funds collected to satisfy the funding assurance obligation will be deposited into an external sinking fund. To satisfy the initial financial obligation, the State of Alaska will guarantee that if the facility failed to operate for the full service life, any deficit in the fund will be paid by the State. Thus, the State's obligation to the decommissioning fund will only be contingent and will decrease over time. Assuming the facility operated for its entire design service life, the State will have no funding obligation.

V Conclusions

Based on similar decommissioning projects already performed and the expected characteristics of a 4S reactor, this white paper estimates that the deactivation, decontamination and decommissioning of a 4S reactor at the Galena site can be performed at the end of the plant's operating life at an approximate cost of between $33 and $53 million in 2006 dollars. While a more detailed analysis of the factors discussed in this paper will be required, this paper provides an estimate of the range of expected costs based up prior industry experience.

This analysis also concludes that certain technical and financial issues will need to be resolved before decommissioning a 4S NPF sited at Galena. While a currently identified disposal path exists for most of the wastes, the disposal of the reactor vessel and cold trap will require additional scrutiny. Additionally, while DOE is required under the NWPA to accept the spent nuclear fuel at the individual reactor sites for ultimate disposal at a national geologic repository, DOE has not yet begun to accept such fuel. Both the spent fuel issues as well as an appropriate disposal path for the reactor vessel and cold trap should, however, be well delineated by the time the Galena 4S is decommissioned (30 to 60 years from now).

VI Recommendations

Because of the potential concerns over entombing the reactor in place, as well as the limited alternative options, it is recommended that the chosen decommissioning path be the complete removal of all radiological material followed by the on-site demolition of the BOP facilities to industrial zoning standards. In order to take advantage of the benefits of spreading the estimated earnings of investments, it is recommended (and fully anticipated) that this approach will include a life extension at the 30 year mark (to 60 years) as well as a period of on-site storage for certain nuclear related components.

The ability to implement the plan discussed in this white paper assumes that both the SNF and the contaminated components will be sent to INL first, via Hanford, for cleaning and/or storage prior to their shipment to a permanent waste repository. Galena should hold early discussions with the NRC and with DOE regarding the eventual disposal of the 4S NPF SNF, including obtaining assurances that the SNF will be accepted by DOE for disposal at any commercial HLW disposal facility that is eventually developed and determining the degree of sodium removal that will be required for such SNF to be accepted by DOE for disposal. Integral to these discussions with DOE will be the potential execution of a disposal contract, similar to 10 CFR 961.11, Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste. Galena will also need to confirm with INL and with Hanford that those facilities will be available for the handling and processing of the Galena 4S NPF contaminated materials. Galena should further explore the ultimate disposal path for the reactor vessel and cold trap, which could affect the decommissioning cost estimates provided in this paper.

The base assumption for many of the cost estimates developed in this paper is that a 4S NPF placed in Galena will be utilized for the design life of a single load of fuel, 30 years. However, the other components associated with such a facility will have a design life of 60 years or more. Therefore, similar to the action being taken by many nuclear power generators in the United States, a 4S NPF could be refueled and utilized for a second 30-year term. Based on the significant benefits of extended plant operations, it is recommended that the life of the 4S reactor be extended to 60 years.

Regarding provision of decommissioning fund assurance, the recommended approach depends on the nature of the eventual holder of the operating license for the facility. If the entity is a regulated utility, an external sinking fund should be selected as the method of providing fund assurance. This method presents the lowest initial financial obligation and allows for spreading the obligation over the longest term.

If the entity is unregulated, use of an external sinking fund is also recommended, although it cannot be used exclusively. Using contractual commitments in combination with an external sinking fund will therefore be the recommended approach for an unregulated licensee to meet the requirements of providing decommissioning fund financial assurance. The State of Alaska could also provide a funding guarantee that will probably result in no actual funding obligations.