Factors Impacting Decommissioning Costs – 13576

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ABSTRACT

The Electric Power Research Institute (EPRI) studied United States experience with decommissioning cost estimates and the factors that impact the actual cost of decommissioning projects. This study gathered available estimated and actual decommissioning costs from eight nuclear power plants in the United States to understand the major components of decommissioning costs. Major costs categories for decommissioning a nuclear power plant are removal costs, radioactive waste costs, staffing costs, and other costs. The technical factors that impact the costs were analyzed based on the plants' decommissioning experiences. Detailed cost breakdowns by major projects and other cost categories from actual power plant decommissioning experiences will be presented. Such information will be useful in planning future decommissioning and designing new plants.

INTRODUCTION

Several nuclear power plants in the United States have decommissioned to reach license termination. Cost information from these completed decommissioning projects is available in license termination reports that have been submitted to the United States Regulatory Commission (U.S. NRC). There are also plants that have not yet reached license termination but are in various states of decommissioning. These plants must provide the U.S. NRC with updates to their decommissioning cost estimates biennially. The cost estimates from the completed and ongoing decommissioning projects provide insights into technical factors that impact cost estimates. The Electric Power Research Institute (EPRI) studied the cost estimates from seven completed decommissioning projects and one ongoing decommissioning project. The results of this study are documented in the EPRI Report: *Decommissioning Experiences and Lessons Learned: Decommissioning Cost.* [1]

The completed decommissioning projects that EPRI studied are Trojan [6, 7, 8], Big Rock Point [9, 10], Maine Yankee [2, 11, 12], Connecticut Yankee [3, 13], Yankee Rowe [14, 15], San Onofre Unit 1 [4], Rancho Seco [5, 16]. The ongoing decommissioning project studied is the Humboldt Bay power plant [17]. The plants studied and their attributes are summarized in Table 1 below. These plants are 6 Pressurized Water Reactors (PWRs) and 2 Boiling Water Reactors (BWRs) ranging from 65 to 1130 MWe.

Table 1 Decommissioning Nuclear Power Plants Included in EPRI Study

Plant	Type	Power Rating (Mwe)	Operating Period	Decommissioning Completed (Expected)
Trojan	PWR	1130	1975-1995	2006
Big Rock Point	BWR	67	1963-1977	2006
Maine Yankee	PWR	860	1973-1996	2005
Connecticut Yankee	PWR	619	1968-1966	2007
Yankee Rowe	PWR	167	1963-1991	2007
San Onofre Unit 1	PWR	410	1968-1992	2008
Rancho Seco	PWR	913	1975-1989	2008
Humboldt Bay	BWR	65	1962-1976	2015 (Expected)

Studying the cost estimates of these plants, it was clear that there is not a standard methodology for categorizing the costs of decommissioning. Also, publically available decommissioning cost information for some plants do not include a breakdown of the costs or the breakdown of costs is considered confidential. As such, this study makes some assumptions related to categorization of costs from the different publically available cost information to allow for common categorization and analysis. If the breakdowns for the costs are not available, the costs were allocated to the categories that were identified during earlier phases of decommissioning. The EPRI study categorized the decommissioning costs into the following major categories:

- Dismantling and Removals of Systems, Structures, and Components (includes decontamination if identified)
- Radioactive Wastes (includes disposal of wastes and includes preparation/transportation of wastes if indentified)
- Staffing (if identified)
- Other costs (includes Final Status Survey and Site Restoration if identified)
- Spent Fuel (includes costs to construct the Independent Spent Fuel Storage Installation (ISFSI), Storage Canister/Cask fabrication, and ISFSI operating cost)

Of these eight plants, three plants did not provide a separate line item for staffing costs – the staffing costs for these three plants were included in other cost categories. This difference is accounted for in further analysis of the costs.

In order to allow for comparative analysis, the costs from the different plant decommissioning projects were escalated to 2008 costs.

The rest of this paper summarizes the results of the study for each of the major categories listed above including some narratives on the technical factors, experiences, and lessons learned associated with each category.

DECOMMISSIONING COST

The total final and estimated decommissioning costs of the eight plants are graphed in Figure 1. Several initial decommissioning cost estimate methodologies use the generating capacity or size of the plant as a metric for estimating decommissioning costs. However, it is apparent from experiences that there is not necessarily a trend between size of the plant and decommissioning costs. There are many other variables that impact the final decommissioning costs including final state of the site, waste disposal site access, waste transportation mode and distance, plant duty factor, and failed fuel history. For example, the highest rated plants, Rancho Seco and Trojan, have the lowest total decommissioning costs. This may be due to the fact that both of these plants operated for less than 10 effective full power year (EFPY) and left many of their buildings standing at the time of license termination.

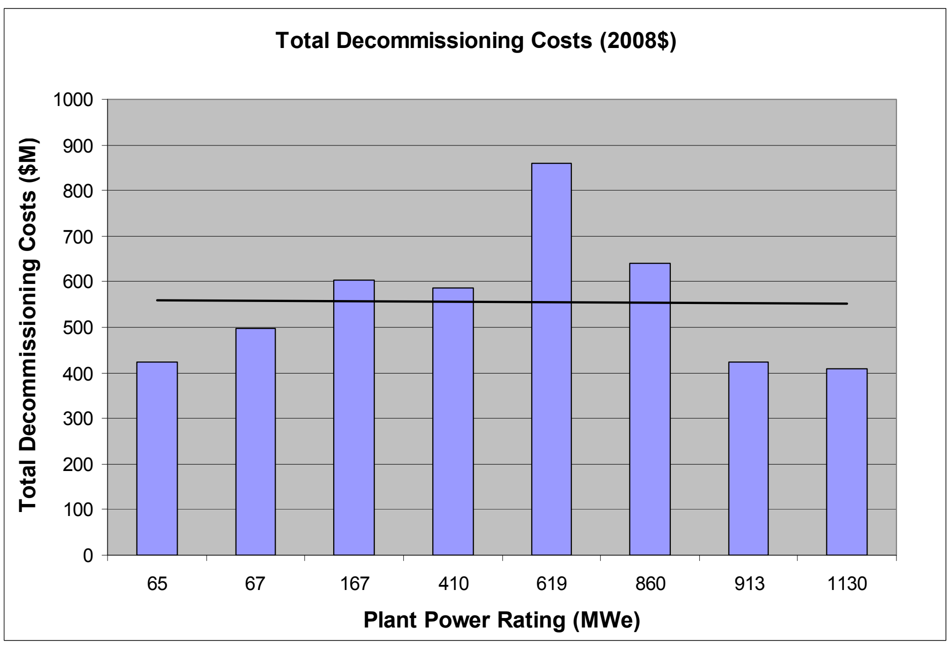

Figure 1 Total Decommissioning Costs

Dismantling and Removals of Systems, Structures, and Components

The first major cost category discussed is the dismantling and removal of systems, structures, and components. Figure 2 provides a depiction of the removal costs versus plant power rating. Figure 3 provides the same information but excludes the three plants that did not provide staffing as a separate line item. This is done because the staffing costs for these three plants would be included in the other cost categories.

As seen in Figure 2, there does not seem to be a trend between plant size and removal costs. Rancho Seco, has very low removal costs. This low removal cost could be due to the fact that Rancho Seco left several buildings standing, had a shorter operating period, and extended SAFSTOR period, and implemented aggressive cost control measures. Figure 4 provides the percentage of removal costs to the total decommissioning costs. Removal costs for the five plants ranged between 19-26% of total decommissioning costs.

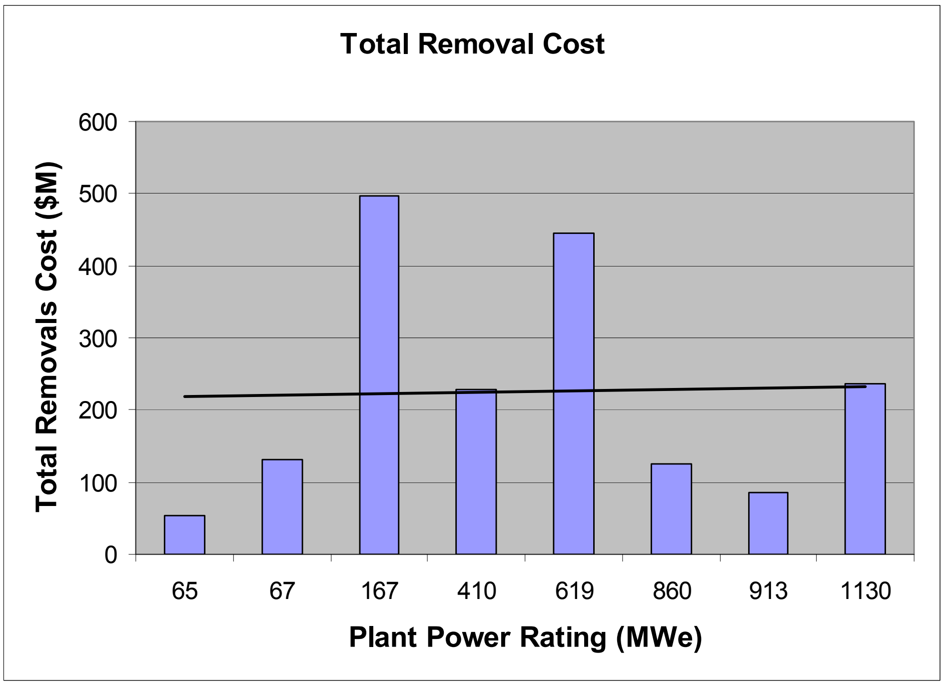

Figure 2 Total Removal Costs

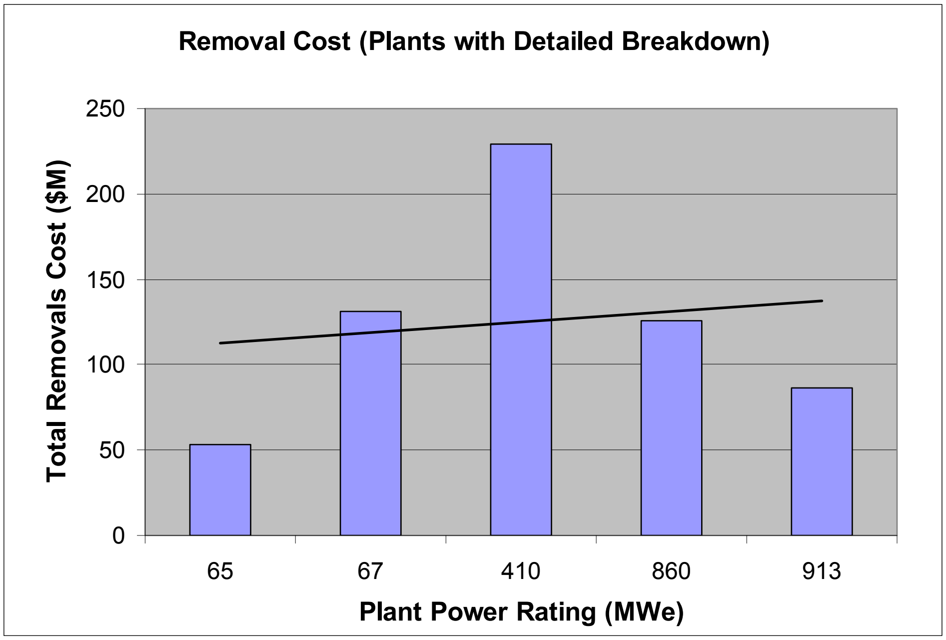

Figure 3 Total Removal Costs for Five Plants

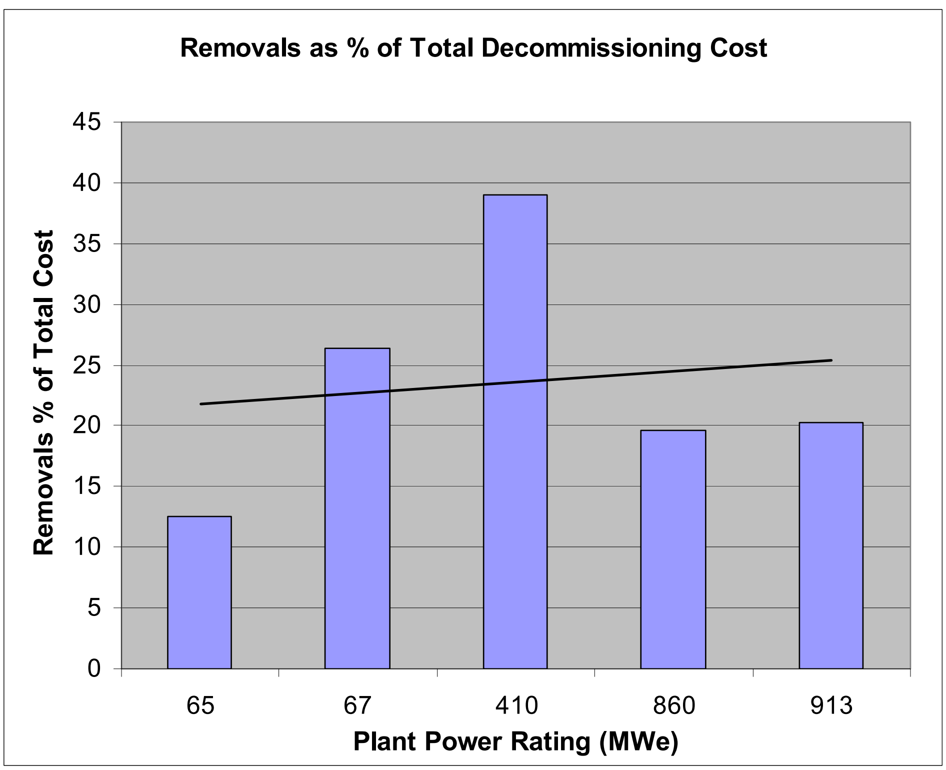

Figure 4 Removal Costs as Percent of Total Decommissioning Cost

Radioactive Waste

Figure 5 provides the total waste costs for each of the eight plants studied. As discussed in the introduction, this category includes the preparation, transportation, and disposal costs for the waste. Plants that disposed of all above grade concrete (Maine Yankee, Connecticut Yankee, and Humboldt Bay) have the higher waste costs. San Onofre Unit 1's low waste cost is partially influenced by the fact that they have not yet disposed of its reactor vessel. Connecticut Yankee's high waste cost is also due to the large soil remediation project they had to undertake to meet site release criteria for soil and groundwater. Figure 6 shows the percentage of waste costs to the total decommissioning costs of each plant. Waste disposal costs ranges from between 17-27% for the plants studied.

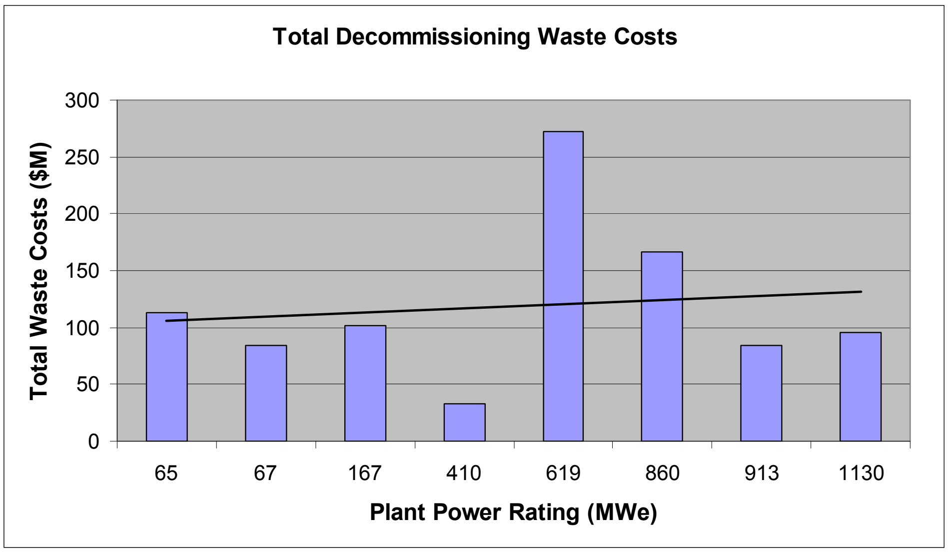

Figure 5 Total Decommissioning Waste Costs

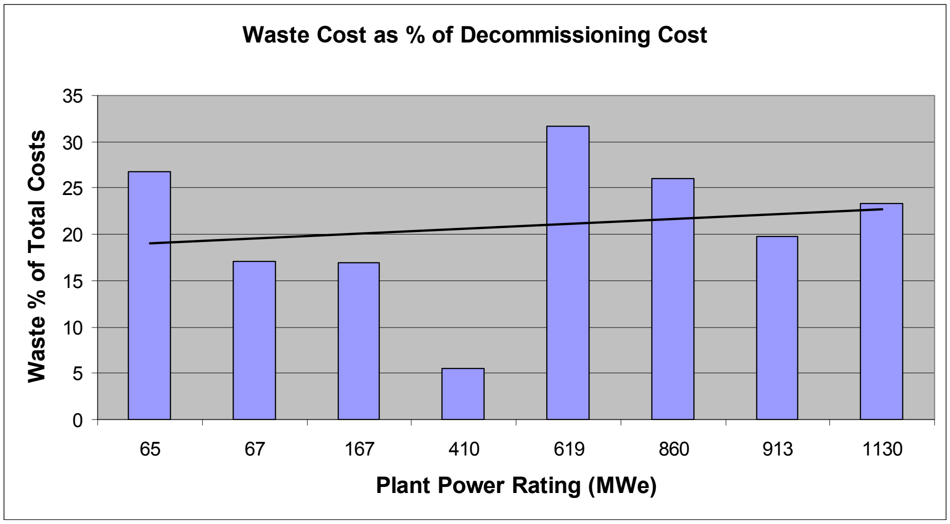

Figure 6 Waste Costs as Percent of Decommissioning Cost

The costs of radioactive waste management can be impacted by the location of the plant (i.e. access to disposal sites and distance to disposal sites) and the discounts negotiated with waste disposal sites for large volumes of waste. Also, lower radioactive wastes (e.g. very low level waste or Class A waste) costs less to dispose of than higher activity wastes. Figure 7 shows the total volumes of radioactive waste shipped (or two be shipped) from each decommissioning plant. Figure 8 provides the waste disposal cost per unit volume (cubic meter) per the total volume shipped. As can be seen from Figure 8, the more waste shipped, the lower the unit volume costs. If the total volume of waste shipped is very low, the higher cost of the disposal of the reactor vessel and internals leads to higher per unit waste costs. With respect to transportation, the availability of rail transportation (via a rail spur that extends to the plant) led to costs savings over truck transportation.

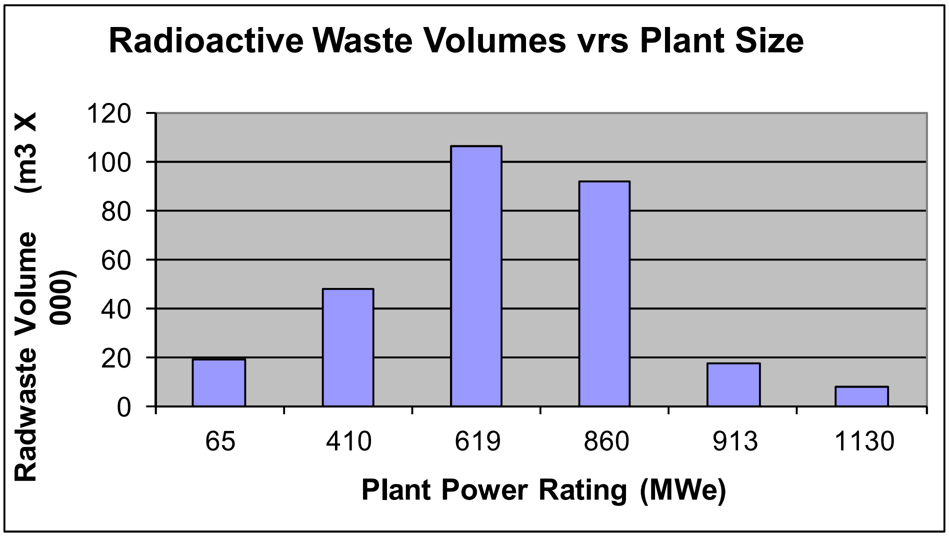

Figure 7 Radioactive Waste Volumes versus Plant Size

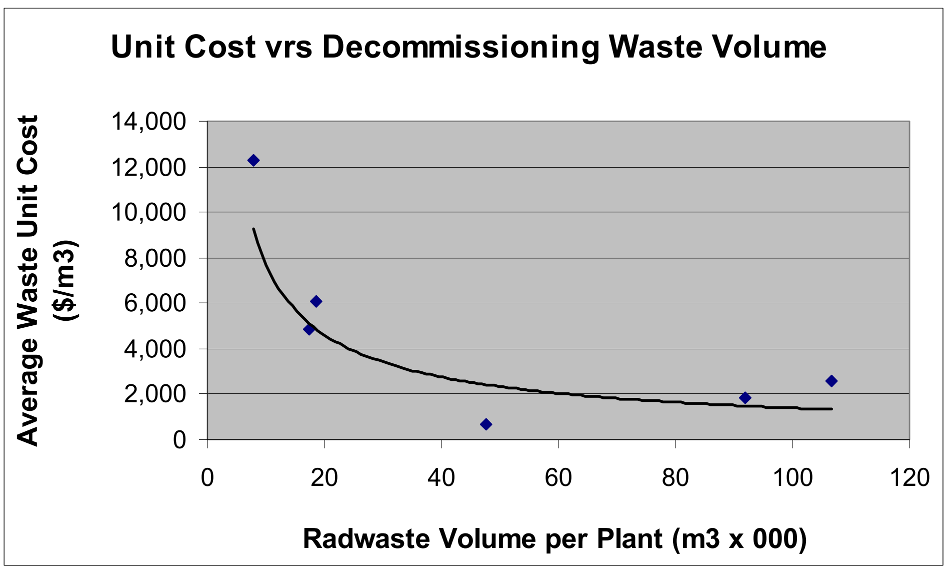

Figure 8 Average Waste Unit Cost versus Decommissioning Waste Volume

Staffing

Figures 9 and 10 provide the staffing cost information for the five plants that provided staffing costs as a separate line item in their decommissioning cost estimates. Figure 9 provides the total staffing costs and Figure 10 provides the percentage of staffing costs to the total decommissioning costs. The noteworthy observation from this data is that staffing costs for these five plants were 29-52% of the total decommissioning costs and is the highest percentage of total decommissioning costs. Staffing costs are tied to the duration of decommissioning. As such, strategies that shorten decommissioning time may reduce staffing costs. This is further discussed in the analysis section below.

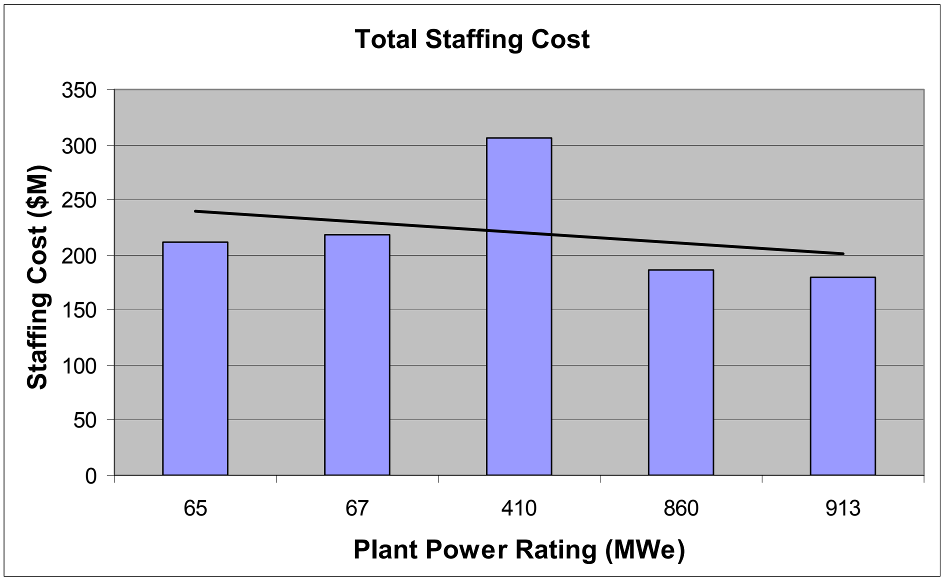

Figure 9 Total Staffing Cost

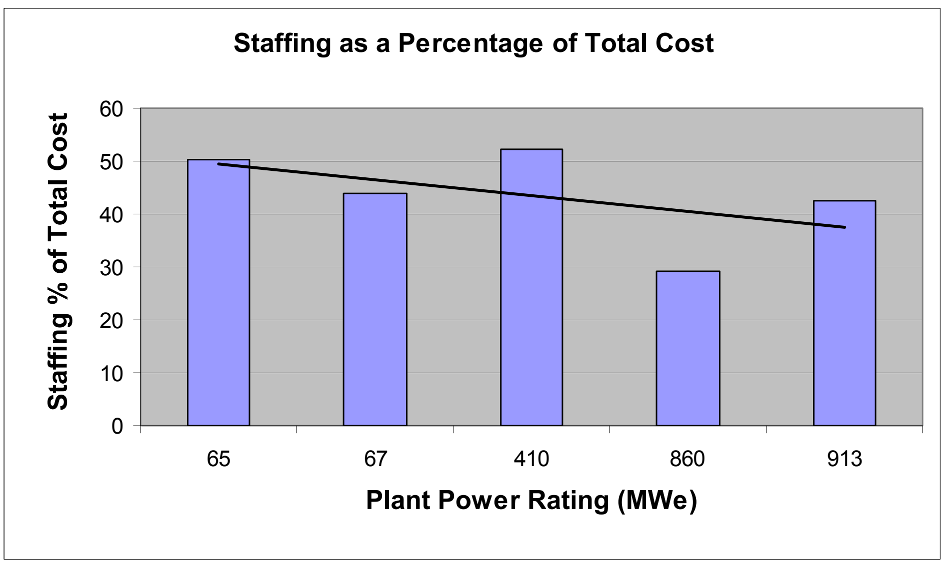

Figure 10 Staffing Cost as a Percent of Total Decommissioning Cost

Final Status Survey and Spent Fuel Management

Figures 11 and 12 show the Final Status Survey (FSS) and spent fuel management costs for the eight plants studied. Both of these cost categories show an increasing trend with increasing plant size.

FSS costs are expected to increase with larger plant sizes (as for newer plant designs) with more building areas to survey. Connecticut Yankee had relatively high FSS costs because of the soil and groundwater monitoring and remediation they needed to conduct to meet site release criteria.

The spent fuel management costs also increase with plant size and generating capacity. Spent fuel management costs include includes costs to construct the Independent Spent Fuel Storage Installation (ISFSI), Storage Canister/Cask fabrication, and ISFSI operating cost. Larger capacity plants would have generated more spent fuel and therefore require a larger ISFSI. Spent fuel management costs also depend on the length of operation of the plant. For example, Yankee Rowe and Connecticut Yankee operated longer than the other plants, leading to a higher generation of spent fuel and higher spent fuel management costs. Trojan and Rancho Seco have relatively low spent fuel management costs because, as discussed before, they operated for less than 10 EFPY.

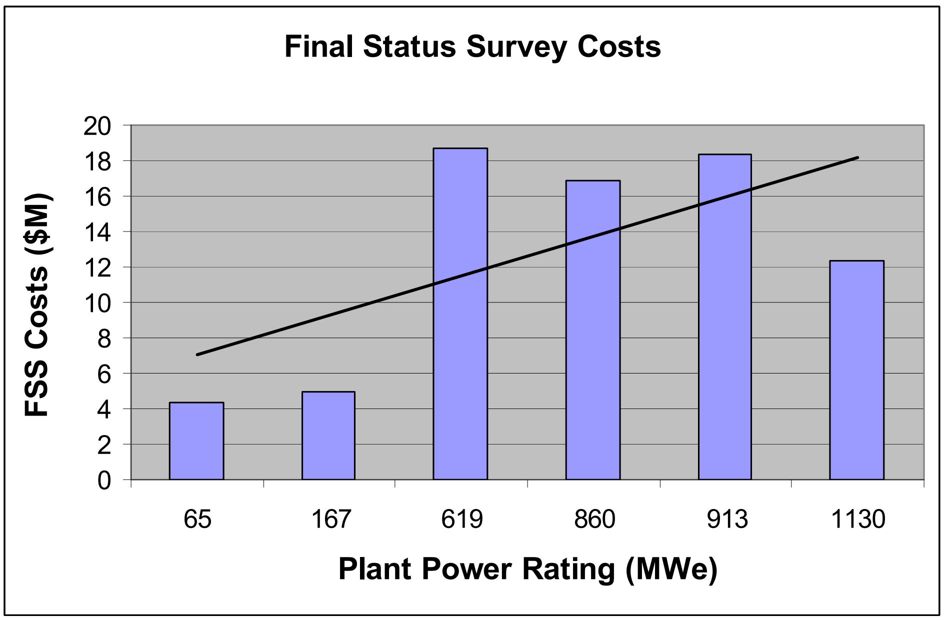

Figure 11 Final Status Survey Cost

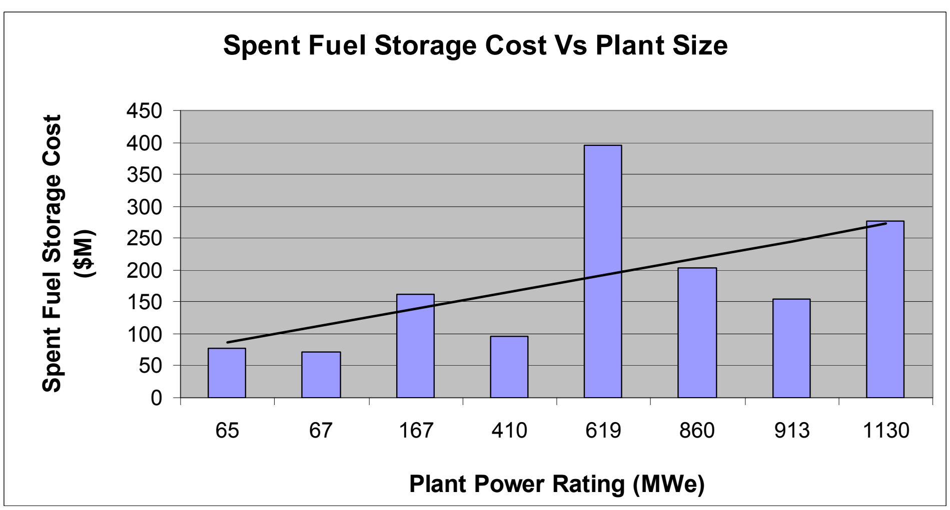

Figure 12 Spent Fuel Storage Cost

ANALYSIS OF TOTAL DECOMMISSIONING COSTS AND COST CATEGORIES

Figure 11 provides the average percentages of each cost category with respect to the total decommissioning costs.

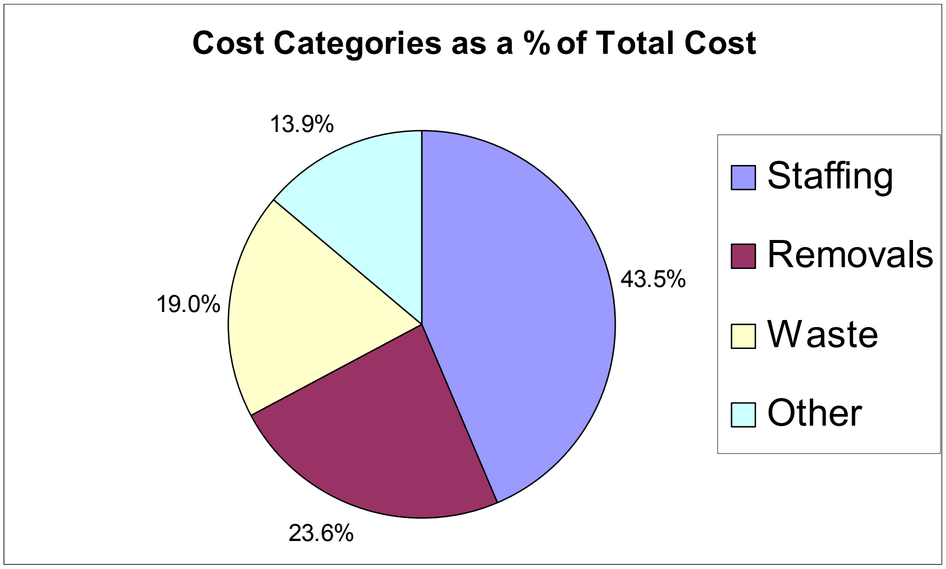

Figure 13 Cost Categories as a Percent of Total Decommissioning Cost

Staffing cost is the highest fraction of total costs when compared to the other cost categories. Staffing is tied to the length of the decommissioning project. As such, strategies that reduce the length of the decommissioning would reduce the staffing costs. For example, the low staffing cost associated with the Rancho Seco plant might be associated with the fact that they left their buildings standing instead of demolishing them. Other time saving (and staff cost saving) strategies implemented by plants include disposing of systems, structures, and components (SSCs) known to be contaminated instead of surveying them for free release, disposing of the concrete inside of the containment liner as radioactive waste, etc. However, the staff costs savings that are gained from such strategies must be balanced against the radioactive wastes costs in consideration of the total decommissioning cost.

Removal costs are the second highest percentage of decommissioning costs. These costs are impacted by the parameters such as the size of the buildings within the radiation controlled areas (RCA), contamination levels, and building radiological release strategies (e.g. whether above ground structures are left standing or demolished). Such parameters may be less amenable to optimization during the decommissioning project, careful management and planning can help control removal costs.

The third highest percentage of decommissioning costs is waste costs. The costs related to generation and disposal of radioactive waste should be balanced with costs related to surveying and releasing structures. The latter are associated with staffing costs as surveying structures can be time consuming. If waste costs are low, then it may be more cost effective to dispose of much of the structures as radwaste instead of surveying and decontaminating these structures for release.

SUMMARY AND CONCLUSIONS

Each nuclear power plant must prepare and update cost estimates for the decommissioning throughout operation, SAFSTOR (if a SAFSTOR period is taken), and active decommissioning. Cost information and the associated technical experiences from the completed and ongoing decommissioning projects can provide insights for planning and optimizing future decommissioning projects. Experiences from the eight plants analyzed in this study reveal that decommissioning costs do not generally trend with plant generating capacity and size. This applies to most of the cost categories except Final Status Survey and spent fuel management costs which do increase with plant generating capacity and size. Of the various decommissioning cost categories staffing costs is the highest fraction of costs, with removal costs and waste costs following as the second and third highest fractions. Staffing cost is tied with decommissioning project duration, so strategies for optimizing decommissioning duration could also reduce staffing costs. However, such strategies must be balanced with removal and waste costs, as some strategies for reducing project duration could increase removal and waste disposal costs.

REFERENCES

The following references were used in the EPRI study summarized in this paper. The full EPRI study is documented in the EPRI Report *Decommissioning Experiences and Lessons Learned: Decommissioning Cost* (2011).

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[9] Big Rock Point License Termination Plan (LTP), Revision 0, April 1, 2003

[10] Case No, U-15611, Before the Michigan Public Services Commission, Application of Consumers Energy Company for Reconciliation of Nuclear Power Plant Decommissioning Revenues and Expenses for the Big Rock Point Nuclear Plant. February 8, 2010.

[11] Maine Yankee License Termination Plan (LTP), Revision 2, August 13, 2001.

[12] Maine Yankee website, www.maineyankee.com

[13] Connecticut Yankee website, www.connyankee.com

[14] Yankee Rowe License Termination Plan (LTP), Revision 1, November 19, 2004.

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[16] Sacramento Municipal Utilities District (SMUD), Rancho Seco Letter to the U.S. NRC: DPG-11-155 Rancho Seco Report on Decommissioning Funding Status. March 29, 2011.

[17] Pacific, Gas, & Electric (PG&E) Letter to the U.S. NRC: HBL-11-003 Decommissioning Funding Report for Humboldt Bay Power Plant Unit 3. March 31, 2011.

ADDITIONAL SOURCES OF INFORMATION

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