DECOMMISSIONING COST ANALYSIS

for the

CALLAWAY ENERGY CENTER

prepared for

Ameren Missouri

prepared by

TLG Services, Inc.
Bridgewater, Connecticut

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No.	Date	Item Revised	Reason for Revision
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EXECUTIVE SUMMARY

This report presents estimates of the cost to decommission the Callaway Energy Center (Callaway) for the selected decommissioning alternatives and scenarios following the scheduled cessation of plant operations. The estimates are designed to provide Ameren Missouri with sufficient information to assess its financial obligations, as they pertain to the eventual decommissioning of the nuclear unit.

The analysis relies upon site-specific, technical information from an evaluation prepared in 2011,[1] updated to reflect current assumptions pertaining to the disposition of the nuclear unit and relevant industry experience in undertaking such projects. The analysis is not a comprehensive engineering evaluation, but estimates prepared in advance of the detailed planning required to execute the decommissioning of the nuclear unit. It may also not reflect the actual plan to decommission Callaway; the plan may differ from the assumptions made in this analysis based on facts that exist at the time of decommissioning.

The costs to decommission Callaway for the base scenarios (current license expiration date) are presented at the end of this section. Costs are reported in 2014 dollars and include monies anticipated to be spent for radiological remediation and operating license termination, spent fuel management, and site restoration activities.

A complete discussion of the assumptions relied upon in this analysis is provided in Section 3, along with schedules of annual expenditures for the base scenarios. A sequence of significant project activities is provided in Section 4 with a timeline for each scenario. Detailed cost reports used to generate the summary tables contained within this document are provided in the appendices along with the costs for the additional scenarios.

Consistent with the 2011 analysis, the current cost estimates assume that the shutdown of the nuclear unit is a scheduled and pre-planned event (e.g., there is no delay in transitioning the plant and workforce from operations or in obtaining regulatory relief from operating requirements, etc.). The estimates include the continued operation of the fuel handling building as an interim wet fuel storage facility for approximately five and one-half years after operations cease. During this time period, it is assumed that the spent fuel residing in the pool will be transferred to an independent spent fuel storage installation (ISFSI) located on the site. The ISFSI will remain operational until the Department of Energy (DOE) is able to

1 "Decommissioning Cost Analysis for the Callaway Energy Center," Document No. A22-1644-001, Rev. 0, TLG Services, Inc., August 2011

complete the transfer of the fuel to a federal facility (e.g., a monitored retrievable storage facility).

Alternatives and Regulations

The ultimate objective of the decommissioning process is to reduce the inventory of contaminated and activated material so that the license can be terminated. The Nuclear Regulatory Commission (NRC or Commission) provided initial decommissioning requirements in its rule adopted on June 27, 1988.[2] In this rule, the NRC set forth financial criteria for decommissioning licensed nuclear power facilities. The regulations addressed planning needs, timing, funding methods, and environmental review requirements for decommissioning. The rule also defined three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB.

> DECON is defined as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."[3]
>
> SAFSTOR is defined as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."[4] Decommissioning is to be completed within 60 years, although longer time periods will be considered when necessary to protect public health and safety.
>
> ENTOMB is defined as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property."[5] As with the SAFSTOR alternative, decommissioning is currently required to

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2 U.S. Code of Federal Regulations, Title 10, Parts 30, 40, 50, 51, 70 and 72 "General Requirements for Decommissioning Nuclear Facilities," Nuclear Regulatory Commission, Federal Register Volume 53, Number 123 (p 24018 et seq.), June 27, 1988

3 Ibid. Page FR24022, Column 3

4 Ibid.

5 Ibid. Page FR24023, Column 2

be completed within 60 years, although longer time periods will also be considered when necessary to protect public health and safety.

The 60-year restriction has limited the practicality for the ENTOMB alternative at commercial reactors that generate significant amounts of long-lived radioactive material. In 1997, the Commission directed its staff to re-evaluate this alternative and identify the technical requirements and regulatory actions that would be necessary for entombment to become a viable option. The resulting evaluation provided several recommendations; however, rulemaking has been deferred pending the completion of additional research studies, for example, on engineered barriers.

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process.[6] The amendments allow for greater public participation and better define the transition process from operations to decommissioning. Regulatory Guide 1.184,[7] issued in July 2000, further described the methods and procedures acceptable to the NRC staff for implementing the requirements of the 1996 revised rule relating to the initial activities and major phases of the decommissioning process. The costs and schedules presented in this analysis follow the general guidance and processes described in the amended regulations. The format and content of the estimates is also consistent with the recommendations of Regulatory Guide 1.202,[8] issued in February 2005.

Decommissioning Scenarios

Multiple decommissioning scenarios were evaluated for the Callaway nuclear unit. The scenarios selected are representative of alternatives currently available to the owner. The DECON and SAFSTOR alternatives were evaluated for both a 40-year and 60-year operating license since the application for license renewal is still in review. Two disposal options were also evaluated: recycling and direct disposal. Recycling is presented as the base option and considers the off-site processing of plant

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6 U.S. Code of Federal Regulations, Title 10, Parts 2, 50, and 51, "Decommissioning of Nuclear Power Reactors," Nuclear Regulatory Commission, Federal Register Volume 61, (p 39278 et seq.), July 29, 1996

7 "Decommissioning of Nuclear Power Reactors," Regulatory Guide 1.184, Nuclear Regulatory Commission, July 2000

8 "Standard Format and Content of Decommissioning Cost Estimates of Decommissioning Cost Estimates for Nuclear Power Reactors," Regulatory Guide 1.202, U.S. Nuclear Regulatory Commission, February 2005

equipment and commodities with low levels of radiological contamination and/or material suspected to be contaminated for volume reduction prior to disposal. The direct disposal option assumes that all contaminated and suspect material is packaged at the site for disposal at a regulated disposal facility. The scenarios are summarized as follows.

Alternative	Plant Operating Life (years)	Low-Level Radioactive Waste Options	Cost Summaries and/or Detailed Estimates
DECON	40	Recycling	Sections 3, 6, Appendix C
		Direct Disposal	Appendix E
SAFSTOR	40	Recycling	Sections 3, 6, Appendix D
		Direct Disposal	Appendix F
DECON	60	Recycling	Appendix G
SAFSTOR	60	Recycling	Appendix H

Methodology

The methodology used to develop the estimates described within this document follows the basic approach originally presented in the cost estimating guidelines[9] developed by the Atomic Industrial Forum (now Nuclear Energy Institute). This reference describes a unit factor method for determining decommissioning activity costs. The unit factors used in this analysis incorporate site-specific costs and the latest available information on worker productivity in decommissioning.

An activity duration critical path is used to determine the total decommissioning program schedule. The schedule is relied upon in calculating the carrying costs, which include program management, administration, field engineering, equipment rental, and support services, such as quality control and security.

Contingency

Consistent with cost estimating practice, contingencies are applied to the decontamination and dismantling costs developed as "specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur."[10] The cost

9 T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," AIF/NESP-036, May 1986

10 Project and Cost Engineers' Handbook, Second Edition, American Association of Cost Engineers, Marcel Dekker, Inc., New York, New York, p. 239

elements in the estimates are based on ideal conditions; therefore, the types of unforeseeable events that are almost certain to occur in decommissioning, based on industry experience, are addressed through a percentage contingency applied on a line-item basis. This contingency factor is a nearly universal element in all large-scale construction and demolition projects. It should be noted that contingency, as used in this analysis, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the station.

Contingency funds are expected to be fully expended throughout the program. As such, inclusion of contingency is necessary to provide assurance that sufficient funding will be available to accomplish the intended tasks.

Low-Level Radioactive Waste Disposal

The contaminated and activated material generated in the decontamination and dismantling of a commercial nuclear reactor is classified as low-level (radioactive) waste, although not all of the material is suitable for "shallow-land" disposal. With the passage of the "Low-Level Radioactive Waste Policy Act" in 1980,[11] and its Amendments of 1985,[12] the states became ultimately responsible for the disposition of low-level radioactive waste generated within their own borders.

With the exception of Texas, no new compact facilities have been successfully sited, licensed, and constructed. The Texas Compact disposal facility is now operational and waste is being accepted from generators within the Compact by the operator, Waste Control Specialists (WCS). The facility is also able to accept limited quantities of non-Compact waste.

Disposition of the various waste streams produced by the decommissioning process considered all options and services currently available to Ameren Missouri. The majority of the low-level radioactive waste designated for controlled disposal (Class A[13]) can be sent to Energy*Solutions*' facility in Clive, Utah. Therefore, disposal costs for Class A waste were based upon Ameren Missouri's Utilities Service Alliance agreement with Energy*Solutions*. This facility is not licensed to receive the higher activity portion (Classes B and C) of the decommissioning waste stream.

The WCS facility is able to receive the Class B and C waste. As such, for this analysis, Class B and C waste was assumed to be shipped to the WCS facility for disposal. Disposal costs were based upon Ameren Missouri's current agreement with WCS.

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11 "Low-Level Radioactive Waste Policy Act of 1980," Public Law 96-573, 1980

12 "Low-Level Radioactive Waste Policy Amendments Act of 1985," Public Law 99-240, 1986

13 Waste is classified in accordance with U.S. Code of Federal Regulations, Title 10, Part 61.55

The dismantling of the components residing closest to the reactor core generates radioactive waste that may be considered unsuitable for shallow-land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. However, to date, the federal government has not identified a cost for disposing of GTCC or a schedule for acceptance.

For purposes of this analysis only, the GTCC radioactive waste is assumed to be packaged and disposed of in a similar manner as high-level waste and at a cost equivalent to that envisioned for the spent fuel. The GTCC is packaged in the same canisters used for spent fuel and either stored on site or shipped directly to a DOE facility as it is generated (depending upon the timing of the decommissioning and whether the spent fuel has been removed from the site prior to the start of decommissioning).

A significant portion of the waste material generated during decommissioning may only be potentially contaminated by radioactive materials. This material can be analyzed on site or shipped off site to licensed facilities for further analysis, for processing and/or for conditioning/recovery. Reduction in the volume of low-level radioactive waste requiring disposal in a licensed low-level radioactive waste disposal facility can be accomplished through a variety of methods, including analyses and surveys or decontamination to eliminate the portion of waste that does not require disposal as radioactive waste, compaction, incineration or metal melt. The estimates for the base case scenarios reflect the savings from waste recovery/volume reduction.

<u>High-Level Radioactive Waste Management</u>

Congress passed the "Nuclear Waste Policy Act"[14] (NWPA) in 1982, assigning the federal government's long-standing responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the DOE. The DOE was to begin accepting spent fuel by January 31, 1998; however, to date no progress in the removal of spent fuel from commercial generating sites has been made.

Today, the country is at an impasse on high-level waste disposal, even with the License Application for a geologic repository submitted by the DOE to the NRC in

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14 "Nuclear Waste Policy Act of 1982 and Amendments," DOE's Office of Civilian Radioactive Management, 1982

2008. As a result, generators have initiated legal action against the DOE in an attempt to obtain compensation for DOE's breach of contract.

In June 2011, Ameren Missouri and the DOE reached an agreement on a settlement. The terms include payment to Ameren Missouri for spent fuel storage and related costs through 2010, and thereafter, annual payment of such costs after they are incurred.

At shutdown, the spent fuel pool is expected to contain freshly discharged assemblies (from the most recent refueling cycles) as well as the final reactor core. Over the following five and one-half years the assemblies are packaged into multipurpose canisters for transfer to the ISFSI. It is assumed that this period provides the necessary cooling for the final core to meet the dry storage system's requirements for decay heat.

The NRC requires that licensees establish a program to manage and provide funding for the management of all irradiated fuel at the reactor site until title of the fuel is transferred to the Secretary of Energy, pursuant to 10 CFR Part 50.54(bb).[15] The post-shutdown costs incurred to satisfy this requirement include the isolation and continued operation of the spent fuel pool and the ISFSI during the five and one-half years following the cessation of plant operations.

Costs are included within the decommissioning estimates for offloading the pool. These costs include the acquisition of the dry storage system modules (multipurpose canisters and shielded overpacks. ISFSI operations, once the fuel has been off-loaded from the pool and until such time that the transfer of fuel to the DOE can be completed, are expected to be fully reimbursable and therefore not addressed in this study. The eventual decommissioning of the ISFSI is also not included.

Relocation of the spent fuel from the pool to the ISFSI will allow Ameren Missouri to proceed with decommissioning (or safe-storage preparations) in the shortest time possible.

Site Restoration

Immediate dismantling of site structures (once the facilities are decontaminated) is clearly the most appropriate and cost-effective option. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed. The cost to dismantle site structures with a work force already mobilized on site is more efficient than if the process is deferred.

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15 U.S. Code of Federal Regulations, Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," Subpart 54 (bb), "Conditions of Licenses"

Site facilities quickly degrade without maintenance, adding additional expense and creating potential hazards to the public and the demolition work force.

Consequently, this study assumes that site structures are removed to a nominal depth of three feet below the local grade level wherever possible. The site is then to be graded and stabilized.

Summary

The costs to decommission Callaway assume the removal of all contaminated and activated plant components and structural materials such that the owner may then have unrestricted use of the site with no further requirements for an operating license. Low-level radioactive waste, other than GTCC waste, is sent to a commercial processor for treatment/conditioning or to a controlled disposal facility.

Decommissioning is accomplished within the 60-year period required by current NRC regulations. Regardless of the timing of the decommissioning activities, the estimates assume the eventual removal of all the contaminated and activated plant components and structural materials, such that the facility operator may then have unrestricted use of the site with no further requirement for an operating license.

The decommissioning scenarios are described in Section 2. The assumptions are presented in Section 3, along with schedules of annual expenditures for the base scenario. The major cost contributors are identified in Section 6, with detailed activity costs, waste volumes, and associated manpower requirements delineated in the appendices to this report. The major cost components are also identified in the cost summary provided at the end of this section.

The cost elements in the estimates are assigned to one of three subcategories: NRC License Termination, Spent Fuel Management, and Site Restoration. The subcategory "NRC License Termination" is used to accumulate costs that are consistent with "decommissioning" as defined by the NRC in its financial assurance regulations (i.e., 10 CFR Part 50.75). The cost reported for this subcategory is generally sufficient to terminate the unit's operating license, recognizing that there may be some additional cost impact from spent fuel management.

The "Spent Fuel Management" subcategory contains costs associated with the transfer of the spent fuel to the ISFSI as well as the operation of the spent fuel pool until such time that the transfer is complete.

"Site Restoration" is used to capture costs associated with the dismantling and demolition of buildings and facilities demonstrated to be free from contamination. This includes structures never exposed to radioactive materials, as well as those facilities that have been decontaminated to appropriate levels. Structures are removed to a depth of three feet and backfilled to conform to local grade.

It should be noted that the costs assigned to these subcategories are allocations. Delegation of cost elements is for the purposes of comparison (e.g., with NRC financial guidelines) or to permit specific financial treatment (e.g., Asset Retirement Obligation determinations). In reality, there can be considerable interaction between the activities in the three subcategories. For example, an owner may decide to remove non-contaminated structures early in the project to improve access to highly contaminated facilities or plant components. In these instances, the non-contaminated removal costs could be reassigned from Site Restoration to an NRC License Termination support activity. However, in general, the allocations represent a reasonable accounting of those costs that can be expected to be incurred for the specific subcomponents of the total estimated program cost, if executed as described.

As noted within this document, the estimates were developed and costs are presented in 2014 dollars. As such, the estimates do not reflect the escalation of costs (due to inflationary and market forces) over the remaining operating life of the reactor or during the decommissioning period.

For the purposes of this analysis, the costs presented in the following tables reflect plant decommissioning at the expiration of its current license (2024) and the use of off-site low-level radioactive waste processing to minimize the volume designated for controlled disposal. Costs for the other identified scenarios (including those for a 60-year operating life) are presented in the appendices (E through H).

DECON COST SUMMARY
40-YEAR PLANT OPERATING LIFE
LOW-LEVEL RADIOACTIVE WASTE OFF-SITE PROCESSING
DECOMMISSIONING COST ELEMENTS
(thousands of 2014 dollars)

Cost Element	Cost
Decontamination	18,461
Removal	173,424
Packaging	27,586
Transportation	15,934
Waste Disposal	92,986
Off-site Waste Processing	25,790
Program Management [1]	302,704
Security	69,772
Corporate Allocations	9,273
Spent Fuel Pool Isolation	12,434
Spent Fuel Management - Direct Costs [2]	29,564
Insurance and Regulatory Fees	13,592
Energy	11,386
Characterization and Licensing Surveys	24,124
Property Taxes	2,595
Miscellaneous Equipment	6,956
Total [3]	836,582

Cost Element	Cost
License Termination	692,622
Spent Fuel Management	29,564
Site Restoration	114,396
Total [3]	836,582

[1] Includes engineering costs

[2] Direct costs only. Excludes program management costs (staffing) but includes costs for spent fuel loading/ spent fuel pool O&M and Emergency Planning fees

[3] Columns may not add due to rounding

SAFSTOR COST SUMMARY
40-YEAR PLANT OPERATING LIFE
LOW-LEVEL RADIOACTIVE WASTE OFF-SITE PROCESSING
DECOMMISSIONING COST ELEMENTS
(thousands of 2014 dollars)

Cost Element	Cost
Decontamination	16,533
Removal	174,946
Packaging	23,969
Transportation	13,139
Waste Disposal	71,244
Off-site Waste Processing	28,471
Program Management [1]	394,922
Security	155,033
Corporate Allocations	9,891
Spent Fuel Pool Isolation	12,434
Spent Fuel Management [2]	29,564
Insurance and Regulatory Fees	73,348
Energy	23,204
Characterization and Licensing Surveys	24,327
Property Taxes	18,943
Miscellaneous Equipment	21,784
Total [3]	1,091,753

Cost Element	Cost
License Termination	887,947
Spent Fuel Management [4]	89,388
Site Restoration	114,417
Total [3]	1,091,753

[1] Includes engineering costs

[2] Direct costs only. Excludes program management costs (staffing) but includes costs for spent fuel loading/spent fuel pool O&M and Emergency Planning fees

[3] Columns may not add due to rounding

[4] Includes percentage of Period 2a (dormancy) plant operating costs until spent fuel pool is emptied, in addition to the direct costs.

1. INTRODUCTION

This report presents estimates of the costs to decommission the Callaway Energy Center (Callaway) for the selected decommissioning alternatives and scenarios following the scheduled cessation of plant operations. The estimates are designed to provide Ameren Missouri with sufficient information to assess its financial obligations, as they pertain to the eventual decommissioning of the nuclear unit.

The analysis relies upon site-specific, technical information from an evaluation prepared in 2011,[1] updated to reflect current assumptions pertaining to the disposition of the nuclear unit and relevant industry experience in undertaking such projects. The analysis is not a comprehensive engineering evaluation, but estimates prepared in advance of the detailed planning required to execute the decommissioning of the nuclear unit. It may also not reflect the actual plan to decommission Callaway; the plan may differ from the assumptions made in this analysis based on facts that exist at the time of decommissioning.

1.1 OBJECTIVES OF STUDY

The objectives of this study were to prepare comprehensive estimates of the costs to decommission Callaway, to provide a sequence or schedule for the associated activities, and to develop waste stream projections from the decontamination and dismantling activities.

An operating license was issued for Callaway in 1984 for a 40 year operating period. The current license expires at midnight on October 18, 2024. On December 19, 2011, Ameren Missouri submitted a request for renewal of the operating license for an additional period of 20 years. The application is current under review by the Nuclear Regulatory Commission (NRC).

For the purposes of this analysis, the base case reflects plant decommissioning at the expiration of its current license (2024) and the use of off-site low-level radioactive waste processing to minimize the volume designated for controlled disposal.

1.2 SITE DESCRIPTION

The nuclear unit is located in Callaway County, Missouri, approximately 80 miles west of the St. Louis metropolitan area. The nearest population center is Jefferson City, 25 miles west-southwest of the plant site. The station is an 1,171 MWe (net design electrical rating) pressurized water reactor with supporting facilities.

Westinghouse Electric Company designed the nuclear steam supply system (NSSS). The NSSS consists of a pressurized water reactor with four independent primary coolant loops, each of which contains a reactor coolant pump and a steam generator. An electrically heated pressurizer and connecting piping complete the system. The NSSS is rated at a thermal power level of 3,579 MWt (3,565 MWt reactor core plus 14 MWt for reactor coolant pumps), with a corresponding turbine-generator gross output of 1284 MWe. The system is housed within a containment structure, a pre-stressed, post-tensioned concrete structure with cylindrical wall, a hemispherical dome, and a flat foundation slab. The wall and dome form a pre-stressed post-tensioned system. The inside surface of the structure is covered with a carbon steel liner, providing a leak tight membrane.

A power conversion system converts heat produced in the reactor to electrical energy. This system converts the thermal energy of the steam into mechanical shaft power and then into electrical energy. The turbine-generator is a tandem-compound, six-flow, four element, 1800-rpm unit. The unit consists of one high pressure and three low-pressure turbine elements driving a directly coupled generator. The turbine is operated in a closed feedwater cycle that condenses the steam; the feedwater is returned to the steam generators. Heat rejected in the main condensers is removed by the circulating water system.

The circulating water system supplies cooling water to the main condenser, condensing the steam exhausted from the turbine. Cooling for the condenser circulating water system is supplied by a large natural draft cooling tower. Makeup water for the cooling tower is drawn from the Missouri River.

1.3 REGULATORY GUIDANCE

The Nuclear Regulatory Commission (NRC or Commission) provided initial decommissioning requirements in its rule "General Requirements for Decommissioning Nuclear Facilities," issued in June 1988.[2] This rule set forth financial criteria for decommissioning licensed nuclear power facilities. The regulation addressed decommissioning planning needs, timing, funding methods, and environmental review requirements. The intent of the rule was to ensure that decommissioning would be accomplished in a safe and timely manner and that adequate funds would be available for this purpose. Subsequent to the rule, the NRC issued Regulatory Guide 1.159, "Assuring the Availability of Funds for Decommissioning Nuclear Reactors,"[3] which provided additional guidance to the licensees of nuclear facilities on the financial methods acceptable to the NRC staff for complying with the requirements of the rule. The regulatory guide addressed the funding requirements and provided guidance on the content and form of the financial assurance mechanisms indicated in the rule.

The rule defined three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB. The DECON alternative assumes that any contaminated or activated portion of the plant's systems, structures and facilities are removed or decontaminated to levels that permit the site to be released for unrestricted use shortly after the cessation of plant operations. The rule also placed limits on the time allowed to complete the decommissioning process. For SAFSTOR, the process is restricted in overall duration to 60 years, unless it can be shown that a longer duration is necessary to protect public health and safety. The guidelines for ENTOMB are similar, providing the NRC with both sufficient leverage and flexibility to ensure that these deferred options are only used in situations where it is reasonable and consistent with the definition of decommissioning. At the conclusion of a 60-year dormancy period (or longer for ENTOMB if the NRC approves such a case), the site would still require significant remediation to meet the unrestricted release limits for license termination.

The ENTOMB alternative has not been viewed as a viable option for power reactors due to the significant time required to isolate the long-lived radionuclides for decay to permissible levels. However, with rulemaking permitting the controlled release of a site,[4] the NRC has re-evaluated this alternative. The resulting feasibility study, based upon an assessment by Pacific Northwest National Laboratory, concluded that the method did have conditional merit for some, if not most reactors. However, the staff also found that additional rulemaking would be needed before this option could be treated as a generic alternative. The NRC had considered rulemaking to alter the 60-year time for completing decommissioning and to clarify the use of engineered barriers for reactor entombments.[5]

The NRC's staff has recommended that rulemaking be deferred, based upon several factors, e.g., no licensee has committed to pursuing the entombment option, and the NRC's current priorities, at least until after the additional research studies are complete. The Commission concurred with the staff's recommendation.

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants.[6] When the decommissioning regulations were adopted in 1988, it was assumed that the majority of licensees would decommission at the end of the facility's operating licensed life. Since that time, several licensees permanently and prematurely ceased operations. Exemptions from certain operating requirements were required once the reactor was defueled to facilitate the decommissioning. Each case was handled individually, without clearly defined generic requirements. The NRC amended the decommissioning regulations in 1996 to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The amendments allow for greater public participation and better define the transition process from operations to decommissioning.

Under the revised regulations, licensees will submit written certification to the NRC within 30 days after the decision to cease operations. Certification will also be required once the fuel is permanently removed from the reactor vessel. Submittal of these notices will entitle the licensee to a fee reduction and eliminate the obligation to follow certain requirements needed only during operation of the reactor. Within two years of submitting notice of permanent cessation of operations, the licensee is required to submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. The PSDAR describes the planned decommissioning activities, the associated sequence and schedule, and an estimate of expected costs. Prior to completing decommissioning, the licensee is required to submit an application to the NRC to terminate the license, which will include a license termination plan (LTP).

1.3.1 High-Level Radioactive Waste Management

Congress passed the "Nuclear Waste Policy Act"[7] (NWPA) in 1982, assigning the federal government's long-standing responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the U.S. Department of Energy (DOE). The DOE was to begin accepting spent fuel by January 31, 1998; however, to date no progress in the removal of spent fuel from commercial generating sites has been made.

Today, the country is at an impasse on high-level waste disposal, even with the License Application for a geologic repository submitted by the DOE to the NRC in 2008. As a result, generators have initiated legal action against the DOE in an attempt to obtain compensation for DOE's breach of contract.

In June 2011, Ameren Missouri and the DOE reached an agreement on a settlement. The terms include payment to Ameren Missouri for spent fuel storage and related costs through 2010, and thereafter, annual payment of such costs after they are incurred.

At shutdown, the spent fuel pool is expected to contain freshly discharged assemblies (from the most recent refueling cycles) as well as the final reactor core. Over the following five and one-half years the assemblies are packaged into multipurpose canisters for transfer to the ISFSI. It is assumed that this period provides the necessary cooling for the final core to meet the dry storage system's requirements for decay heat.

The NRC requires that licensees establish a program to manage and provide funding for the management of all irradiated fuel at the reactor site until title of the fuel is transferred to the Secretary of Energy, pursuant to 10 CFR Part 50.54(bb).[8] The post-shutdown costs incurred to satisfy this requirement include the isolation and continued operation of the spent fuel pool and the ISFSI during the five and one-half years following the cessation of plant operations.

Costs are included within the decommissioning estimates for offloading the pool. These costs include the acquisition of the dry storage system modules (multipurpose canisters and shielded overpacks. ISFSI operations once the fuel has been off-loaded from the pool and until such time that the transfer of fuel to the DOE can be completed, are expected to be fully reimbursable and therefore not addressed in this study. The eventual decommissioning of the ISFSI is also not included.

Relocation of the spent fuel from the pool to the ISFSI will allow Ameren Missouri to proceed with decommissioning (or safe-storage preparations) in the shortest time possible.

1.3.2 Low-Level Radioactive Waste Disposal

The contaminated and activated material generated in the decontamination and dismantling of a commercial nuclear reactor is classified as low-level (radioactive) waste, although not all of the material is suitable for "shallow-land" disposal. With the passage of the "Low-Level Radioactive Waste Policy Act" in 1980,[9] and its Amendments of 1985,[10] the states became ultimately responsible for the disposition of low-level radioactive waste generated within their own borders.

With the exception of Texas, no new compact facilities have been successfully sited, licensed, and constructed. The Texas Compact disposal facility is now operational and waste is being accepted from generators within the Compact by the operator, Waste Control Specialists (WCS). The facility is also able to accept limited quantities of non-Compact waste.

Disposition of the various waste streams produced by the decommissioning process considered all options and services currently available to Ameren Missouri. The majority of the low-level radioactive waste designated for controlled disposal (Class A[11]) can be sent to Energy*Solutions*' facility in Clive, Utah. Therefore, disposal costs for Class A waste were based upon Ameren Missouri's Utilities Service Alliance agreement with Energy*Solutions*. This facility is not licensed to receive the higher activity portion (Classes B and C) of the decommissioning waste stream.

The WCS facility is able to receive the Class B and C waste. As such, for this analysis, Class B and C waste was assumed to be shipped to the WCS facility for disposal. Disposal costs were based upon Ameren Missouri's current agreement with WCS.

The dismantling of the components residing closest to the reactor core generates radioactive waste that may be considered unsuitable for shallow-land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. However, to date, the federal government has not identified a cost for disposing of GTCC or a schedule for acceptance.

For purposes of this analysis only, the GTCC radioactive waste is assumed to be packaged and disposed of in a similar manner as high-level waste and at a cost equivalent to that envisioned for the spent fuel. The GTCC is packaged in the same canisters used for spent fuel and either stored on site or shipped directly to a DOE facility as it is generated (depending upon the timing of the decommissioning and whether the spent fuel has been removed from the site prior to the start of decommissioning).

A significant portion of the waste material generated during decommissioning may only be potentially contaminated by radioactive materials. This material can be analyzed on site or shipped off site to licensed facilities for further analysis, for processing and/or for conditioning/recovery. Reduction in the volume of low-level radioactive waste requiring disposal in a licensed low-level radioactive waste disposal facility can be accomplished through a variety of methods, including analyses and surveys or decontamination to eliminate the portion of waste that does not require disposal as radioactive waste, compaction, incineration or metal melt. The estimates for the base case scenarios reflect the savings from waste recovery/volume reduction.

1.3.3 Radiological Criteria for License Termination

In 1997, the NRC published Subpart E, "Radiological Criteria for License Termination,"[12] amending 10 CFR Part 20. This subpart provides radiological criteria for releasing a facility for unrestricted use. The regulation states that the site can be released for unrestricted use if radioactivity levels are such that the average member of a critical group would not receive a Total Effective Dose Equivalent (TEDE) in excess of 25 millirem per year, and provided that residual radioactivity has been reduced to levels that are As Low As Reasonably Achievable (ALARA). The decommissioning estimates assume that the Callaway site will be remediated to a residual level consistent with the NRC-prescribed level.

It should be noted that the NRC and the Environmental Protection Agency (EPA) differ on the amount of residual radioactivity considered acceptable in site remediation. The EPA has two limits that apply to radioactive materials. An EPA limit of 15 millirem per year is derived from criteria established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund).[13] An additional and separate limit of 4 millirem per year, as defined in 40 CFR §141.16, is applied to drinking water.[14]

On October 9, 2002, the NRC signed an agreement with the EPA on the radiological decommissioning and decontamination of NRC-licensed sites. The Memorandum of Understanding (MOU)[15] provides that EPA will defer exercise of authority under CERCLA for the majority of facilities decommissioned under NRC authority. The MOU also includes provisions for NRC and EPA consultation for certain sites when, at the time of license termination, (1) groundwater contamination exceeds EPA-permitted levels; (2) NRC contemplates restricted release of the site; and/or (3) residual radioactive soil concentrations exceed levels defined in the MOU.

The MOU does not impose any new requirements on NRC licensees and should reduce the involvement of the EPA with NRC licensees who are decommissioning. Most sites are expected to meet the NRC criteria for unrestricted use, and the NRC believes that only a few sites will have groundwater or soil contamination in excess of the levels specified in the MOU that trigger consultation with the EPA. However, if there are other hazardous materials on the site, the EPA may be involved in the cleanup. As such, the possibility of dual regulation remains for certain licensees. The present study does not include any costs for this occurrence.