ASME Nuclear Facility Decontamination and Decommissioning Handbook, Chapter XX

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XX. Decision Processes for Prompt vs. Delayed Decommissioning

XX.1 Introduction

This chapter describes typical decision processes used in the determination of whether to decommission a nuclear facility essentially immediately after it's mission has been concluded, or whether to delay the decommissioning until some future date. The chapter also discusses the typical information needed for the decision making process, from both economic and non-economic perspectives.

XX.2 Requisite Initial Decisions

A critical assumption before the discussion of decommissioning options is that there has been a formal decision that the nuclear related mission for a facility is permanently over. There are many examples of nuclear facilities where a determination has been made to cease operations for an indeterminate time period, while a decision is made as to the facility's future use. Examples of this include the US DOE Fast Flux Test Facility (Baranowski 1993), commercial nuclear reactor Millstone unit 1, and various national laboratory hot cells. These facilities may be viewed as being in "Hot Standby". In some cases, initial decommissioning studies are performed while a facility is in this mode. A facility in Hot Standby requires essentially the same resources as a facility in operation in order to assure the option for future restart is maintained. This approach is a costly one since no operational benefits are derived from the facility, but near – operating level costs continue to be expended.

Although not a required decision prior to commencement of decommissioning, a prudent decision is determining the ultimate end state of the facility. Substantially different decommissioning approaches may be taken for a facility that will be remediated to "green-field" and reused for residential use, than for one that will be reused in an industrial manner by the original facility owner. These two options, and a spectrum of options in-between are optimally and cost-effectively approached differently. The earlier in the decommissioning process that the end state of a facility is known, the more efficiently and effectively the project will proceed.

XX.3 Overview of Decommissioning Options

The objective of decommissioning is to remove a nuclear or radioactive facility from service and restore the facility to such a condition that there is no unreasonable risk from residual radioactive material remaining at the decommissioned facility to public health or safety or the environment. This includes occupational exposures as well as public exposures from related activities (e.g., transportation of radioactive wastes). For the basis of this chapter, decommissioning activities will be considered primarily those required due to the site's use of radioactive material. It is important to note however, that decommissioning can also include non-radiological contaminants, and that the potentially affected media to remediate may include water, soil and even air emissions. Generally, there are three alternatives used for decommissioning: DECON; SAFSTOR; and ENTOMB, or a combination of these, e.g., partial decommissioning followed by a storage period prior to decommissioning completion. (USNRC 1988). Actions taken under any of these alternatives, or combinations are assumed to provide for a reduction of risk from the radiological and environmental contaminants remaining on site to the occupational workers, the general public and to the environment.

XX.3.1 DECON

DECON is 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 reuse shortly after cessation of operations. For an NRC licensed facility, DECON is the only one of the decommissioning alternatives presented here which leads to termination of any applicable facility radioactive material(s) license(s) and release of the facility and site for reuse shortly after cessation of facility operations. Decommissioning via the DECON approach may take from fairly short time periods for small facilities to up to several years for a large nuclear facilities. Examples of DECON time frames for some facilities are noted below (Boing 2001):

Table XX.1 TIME AND COST ESTIMATES FOR FACILITIES IN D&D

Facility Name	Type	D&D Period	Cost ($)
EBWR	Research reactor	1986-1996	19.6M
Janus	Research reactor	1995-1997	2.1M
Argonne Thermal Source Reactor	Research reactor	1997-1998	614K
CP-5	Research reactor	1991-2000	29.5M
Argonne – Bldg 212 Plutonium Gloveboxes	Gloveboxes	1992-1996	6.9M
Yale University HILAC	Accelerator	Completed 1975	~ 100K
Carnegie-Mellon synchrocyclotron	Synchrocyclotron	Completed mid 1970's	~ 500K
Cambridge Electron Accelerator	Accelerator	Completed mid 1970's	~735K
NUREG-0586 Reference Research Reactor	1 MW_t pool reactor	2 year estimate	1.25M estimate (1986 dollars)
NUREG-0586 Reference Test Reactor	60 MW_t reactor	4 year estimate	24.2M estimate (1986 dollars)

NUREG-0586 notes that the estimated DECON costs for a reactor post-accident were approximately double the costs of a reactor D&D without accident.

The end state of the DECON approach may lead to unrestricted use, the so called '"green field approach" in which the facility may be reused for any purpose including residential or agricultural use. DECON may also lead to an end state of restricted use. In this case, the facility would typically be required to maintain some administrative or engineering controls in place to assure appropriately low risk to the public and the environment is maintained. This is an appropriate approach for facilities that will continue to be used by the facility owner for the extended future. In the cases where facilities have substantial challenges with radioactive waste transportation and/or disposal options, restricted use DECON may be a viable alternative to the SAFSTOR or ENTOMB options.

Because all of the DECON work is completed within a few months or years following shutdown, personnel radiation exposures are generally higher than for other decommissioning alternatives which spread the decommissioning work over longer time periods thus allowing for additional radioactive decay. For example, if the major radionuclide on site was cobalt-60, the radiation exposures using the DECON option are approximately four times higher than if the facility was placed into SAFSTOR for ten years. Similarly, larger commitments of money and waste disposal site space are generally required for DECON in a relatively short time frame compared to the other alternatives.

Thus, the primary advantage of DECON, which is terminating the facility license(s) and making the facility and site available for some other beneficial use, is accomplished at the expense of larger initial commitments of money, personnel radiation exposure, and waste disposal site space than for the other alternatives. Other advantages of DECON include the availability of a work force highly knowledgeable about the facility and the elimination of the need for long-term security, maintenance and surveillance of the facility which would be required for the other decommissioning alternatives.

For governmental facilities, the DECON option is affected by some differing factors than affect the commercial sector. For example, the beneficial reuse of real estate and the time value of money are lesser decision drivers than the costs of ongoing Surveillance and Maintenance (S&M), as well as the costs of maintaining the technical specifications and requirements of the facility to assure operational safety.

In DECON, nonradioactive equipment and structures need not necessarily be torn down or removed as part of a decontamination procedure for termination of the facility license and release for reuse. Once the radioactive facility structures are decontaminated to radioactivity levels permitting reuse of the facility, they may either be put to some other use or demolished at the owner's option.

The following table summarizes the advantages and disadvantages for the DECON option:

Table XX.2 DECON OPTION ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
Facility and site becomes available for earlier reuse	Higher radiation exposure to workers and to the public
Knowledgeable facility workforce available to support project	Larger initial commitment of funds
Reduction in security, surveillance and maintenance costs due to reduced project duration, which would be required for other decommissioning alternatives.	Potentially larger volumes of radioactive wastes generated
Greater certainty about availability of low level	Project complications if site must continue to

radioactive waste burial space	store high-activity radioactive wastes on-site.
Lower project total costs due to non-escalation and less risk of uncertainty	May require use of new (not yet developed) technology
Known regulatory climate	

XX.3.2 SAFSTOR

SAFSTOR is the alternative in which the nuclear facility is placed (prepared for safe storage) and maintained in a condition that allows the nuclear facility to be safely stored (safe storage) and subsequently reused or decontaminated to levels that permit release for reuse (deferred contamination). SAFSTOR consists of a short period of preparation for safe storage (typically up to 2 years for power reactors after final shutdown), a variable safe storage period of continuing care consisting of security, surveillance, and maintenance for a period consistent with the regulations of the applicable facility regulator (e.g., up to 60 years after final shutdown of an NRC licensed power reactor or up to 135 years for a United Kingdom power reactor), and including a short period of deferred decontamination (Bonser 1997). As noted earlier, a key beneficial attribute to the SAFSTOR option is the reduction in personnel radiation exposure from radioactive decay over the storage period. Overall reductions in the hazards or hazard classification for the site also typically occur during SAFSTOR, allowing reductions in S&M costs. Several subcategories of SAFSTOR are possible:

1. Hot/Cold Standby as noted in section XX.2 is an interim state where nuclear facility operations have stopped for an indeterminate period of time. Evaluations as to the facility's operational future and potential end state may be determined during this period. Other facilities may be kept in this mode if the facility mission is currently not needed but may be required in the future (e.g., Nevada Test Site). Operations in hot/cold standby are similar to those conducted during long surveillance and maintenance outages. Protection of the workers, public and environment is maintained through compliance with operational technical specifications and license requirements.

2. Custodial SAFSTOR requires a minimum cleanup and decontamination effort initially, followed by a period of continuing care with the active protection systems (principally the ventilation, waste management and radiation monitoring systems) kept in service throughout the storage period. Full-time onsite surveillance by operating and security forces is required to carry out radiation monitoring to maintain the equipment and to prevent accidental or deliberate intrusion into the facility and the subsequent exposure to radiation or the dispersal of radioactivity beyond the confines of the facility. During this period continued environmental monitoring is required to assure radiological contaminants remain within the confines of the facility. Protection of the workers, public and environment is maintained through compliance with a reduced set of operational technical specifications and license requirements, active systems and some passive barriers.

3. Passive SAFSTOR requires a more comprehensive cleanup and decontamination effort initially, sufficient to permit deactivation of the active protective systems during the continuing care period. The structures are strongly secured and electronic surveillance is provided to detect accidental or deliberate intrusion. Periodic monitoring and maintenance of the integrity of the structures is required. This is needed both to assure the appropriate confinement of radioactive contaminants but also to assure structures maintain their physical integrity over time. More emphasis is placed on engineered controls to protect the worker, public and environment.

4. Hardened SAFSTOR requires comprehensive cleanup and decontamination and the construction of barriers around areas containing significant quantities of radioactivity. These barriers are of sufficient strength to make accidental intrusion impossible and deliberate intrusion extremely difficult. Surveillance requirements are limited to detection of attack upon the barriers, to maintenance of the integrity of the structures, and to infrequent monitoring. This mode requires substantial emphasis on both engineered controls and on institutional controls to assure the protection of the workers, the public and the environment.

All categories of safe storage require some positive action at the conclusion of the period of continuing care to release the property for reuse and terminate the license(s) for radioactive materials. Depending on the nature of the nuclear facility and its operating history, the necessary action can range from a radiation survey that shows that the radioactivity has decayed and the property is releasable, to dismantlement and removal of residual radioactive materials. These latter actions, whatever their scale, are generically identified as deferred decontamination.

SAFSTOR is used as a means to satisfy the requirements for protection of the workforce, the health and safety of the public, and the protection of the environment while minimizing the initial commitments of time, money, occupational radiation exposure, and waste disposal. In addition, SAFSTOR may have some advantage where there are other operational nuclear facilities at the same site, and may also become necessary in other situations if there are obstacles to radioactive waste disposal. Modifications to the facilities are typically limited to those, which ensure the security of the buildings against intruder, and to those required to ensure containment of radioactive, toxic or hazardous materials.

In highly contaminated facilities and/or facilities with large amounts of activation products, there is the potential for incurring larger occupational radiation exposures if complete decontamination is performed immediately after shutdown (DECON). However, as a result of radioactive decay of this contamination, reductions in personnel exposure and simplifications in the complexity of operations can be achieved by deferring major decontamination efforts for a number of years. Also because many of the contamination and activation products present in the facility will have decayed to background levels after a lengthy storage period the volume of material that must be packaged for disposal will be reduced.

The reduced initial effort (and cost) of the preparation of safe storage is tempered somewhat by the need for continuing surveillance and physical security to ensure the protection of the health and safety of the public and environment. Electronic surveillance devices, which are presently available, could be in service fulltime, with off shift readouts in a local law enforcement office or private security agency. These devices, which monitor for intruders, increases in radiation levels, and detection of fires will require periodic checks and maintenance. Maintenance of the facility's structures and an ongoing program of environmental surveillance are also necessary. The duration of the storage and surveillance and dismantlement period can vary from a few years to up to several decades depending on the type of facility and the applicable regulatory requirements.

If the SAFSTOR option is used, the decision on the length of the safe storage period will be made by the facility owner, with the approval of the regulator, based on consideration of factors including desirability of terminating the license, radiation dose and waste volume reductions, availability to waste disposal capacity, and other site specific factors affecting safety, such as presence of other nuclear facilities at the site. SAFSTOR can be an attractive option for keeping an operating license active on the site if the end state use may be a differing form of nuclear facility. This keeps future use options of modifications; new construction or facility upgrades a viable possibility. Similarly, the decision on the extent of decontamination during the period of preparation for safe storage, and the resultant subcategory of SAFSTOR to be used depends upon safety considerations and the planned length of the storage and surveillance period. If for example, Cobalt-60 is the controlling source of occupational exposure, a chemical decontamination campaign achieving a decontamination factor (DF) of 10 (i.e., radioactivity levels reduced to 1/10 of original) will result in approximately the same dose reduction as a decay period of 17 years.

At the end of the period of safe storage, several things will remain to be done before the facility can be released for reuse. In most cases, radioactivity in some areas within the facility will be significantly above levels acceptable for release of the facility, necessitating the removal, packaging and disposal of selected materials at a regulated disposal site. If the safe storage period is sufficiently long, radioactive materials in the facility may have decayed to levels low enough to permit the facility to be released for reuse without additional decontamination. This would not apply in the case of a reactor, if the reactor had been operated long enough to produce significant amounts of long-lived isotopes (e.g., Nickel-59, Niobium-94, or dispersed transuranics).

Deferred decontamination, even for a major facility such as a large power reactor, is a relatively straightforward disassembly job complicated by whatever radioactivity remains. Safe removal and transport of the materials containing the radioactivity to a disposal site are the principal tasks that must be completed.

Further action following termination of the license and release for reuse, such as disassembly of the various non-radioactive systems and demolition of the buildings, would normally be at the owner's discretion. For example, the planned end state for both the Yankee Rowe and Maine Yankee nuclear power plants includes the complete demolition of buildings identified in the facility operating license.

A disadvantage of SAFSTOR is the reduced availability of personnel familiar with the facility operations at the time of deferred decontamination. Good historical records including pictorial records will reduce the additional training time, which might otherwise be required. Other disadvantages include the fact that the site is tied up in less than optimal use for extended time, also regulatory uncertainties in the future, and the continuing need for maintenance, security and surveillance.

A good discussion of the SAFSTOR option for a 200 kW research reactor may be found in the article, "Decommissioning the World's Premier Facility for Radiological Research: The Janus Reactor" (Taboas 2000)

The following table summarizes the advantages and disadvantages for the SAFSTOR option:

Table XX.3 SAFSTOR OPTION ADVANTAGES AND DISADVANTAGES:

Advantages	Disadvantages
Substantial reduction in radioactivity as a result of the decay that occurs during the storage period.	Shortage of personnel familiar with the facility at the time of deferred decontamination and dismantlement
A reduction in worker radiation exposure (as compared to DECON option)	Limited availability for site reuse during SAFSTOR period
A reduction in public radiation exposure (due to fewer radioactive waste shipments as compared to DECON	Uncertainties of availability and costs of low-level radioactive waste storage at the time of

option)	decontamination and dismantlement
A reduction in radioactive waste volumes (compared to DECON option)	Continued need for security, surveillance and maintenance during the SAFSTOR period
Lower annual costs following cessation of operations	Probable higher total project costs due to price escalation during the SAFSTOR period and the intermediate S&M costs.
SAFSTOR period allows more time for development of permanent disposal options such as a high level waste repository	

XX.3.3 ENTOMB

ENTOMB is intended for use where the residual radioactivity will decay to levels permitting release of the facility within reasonable time periods (i.e., within the time period of continued structural integrity of the entombing structure as well as confidence in the reliability of continued radioactivity containment and access restriction, perhaps the on the order of 100 years). An example of this would be a facility dealing solely with Co-60 or tritium. Their relatively short half-lives would allow essentially all of the residual material to decay over the ~ 100 year control period. ENTOMB is also a viable option where long-term barriers are available to prevent exposure to the residual radioactivity. An example of this would be for radioactive contamination emitting only low energy alpha and/or beta particles. However, a few radioactive isotopes found in fuel reprocessing plants, nuclear reactors, fuel storage facilities, and mixed oxide facilities have half-lives well in excess of 100 years and the radioactivity will not decay to levels permitting release of the facilities for reuse within the foreseeable lifetime of any man-made structure. Thus, the basic requirement of continued structural integrity of the entombment cannot be insured for these facilities, and ENTOMB would not be a viable alternative in these circumstances.

On the other hand, if the entombing structure can be expected to last many half-lives of the most objectionable long-lived isotope, then ENTOMB becomes a viable alternative because of the reduced occupational and public exposure to radiation. However, even in these circumstances, one of the difficulties with ENTOMB for a complex structure such as a reactor is that the radioactive materials remaining in the entombed structure would need to be characterized well enough to be sure that they will have decayed to acceptable levels at the end of the surveillance period. If this cannot be done adequately, deferred decontamination would become necessary, which would make ENTOMB more difficult and costly than DECON or SAFSTOR. Some method would have to be provided to demonstrate that the entombed radioactivity will decay to levels permitting release of the property for reuse within the order of 100 years, which would be difficult. ENTOMB does, of course, contribute to the problems associated with increased numbers of sites dedicated for very long periods to the containment of radioactive materials. In some cases, the specific activity of residual transuranics contamination may require entombment due to the unavailability of alternate radioactive waste disposal sites. (SAIC 1982)

A modification of the ENTOMB approach has been taken by the US DOE. In some cases (e.g., Hanford C-Reactor), the facility is placed in a modified ENTOMB state, maintained with robust institutional controls, and the facility status/decommissioning approach reviewed at specified periods (e.g., 25 years). As long as the entombed facility remains structurally sound with the engineering and institutional controls intact, the facility may be safety retained in this mode.

The following table summarizes the advantages and disadvantages of the ENTOMB option:

Table XX.4 ENTOMB OPTION

Advantages	Disadvantages
Reduced cost (as compared to DECON OPTION)	Facility unavailable for reuse
Reduced personnel and public radiation exposure (as compared to DECON OPTION)	Maintains radioactive materials at distributed locations rather than centralized repositories

XX.4 *Economic Inputs to the Decommissioning Decision Process*

In order for an optimum decommissioning decision to be made, a variety of financial and economic data must be obtained. Key economic and financial variables that will be discussed in this chapter include:

- Cost estimates for each potential decommissioning mode chosen;
- Decommissioning funding vehicles, whether a fully funded external sinking fund, or annual budget allocations;
- The effects of project delays (both in timing to begin the project and delays while the project is in progress)
- Projections on escalation rates for key decommissioning costs, (e.g., radioactive waste disposal);
- Projections on growth rates (if any) for decommissioning funds;
- Projections on interest rates (determination of future cost of money); and,
- Evaluation of the variability in these parameters.

Varying one parameter may likely change others, so the preferred decommissioning option from an economic basis will likely be the result of several iterations of the economic models discussed.

XX.4.1 Decommissioning Cost Estimates

Before economic analysis of any decommissioning options may be undertaken, it is imperative to have available a sound cost estimate for immediate decommissioning (DECON). The subject of Decommissioning Cost Estimates and Schedules is discussed in detail in Chapter 12 of this text, Decommissioning Cost Estimates and Schedule, but the approach is briefly summarized below.

Decommissioning a facility should be managed as a complex project. One aspect of classic project management is the management of uncertainty. Complex projects may experience delays on individual or multiple tasks throughout the project life span. It is important to note that although individual delays cannot be anticipated, that for an overall project, the uncertainties or risks may range from 15% to 35%, with a typical average of 25%. This risk or uncertainties should be included in the development of the facility decommissioning cost estimate as noted below.

The basis for the development of decommissioning cost estimates is discussed in detail in "Guidelines for Producing Nuclear Power Plant Decommissioning Cost Estimates", (LaGuardia 1986). Although originally written to develop cost estimates for power reactors, the approach outlined is generally applicable to the development of decommissioning cost estimates for most nuclear facilities.

The cost estimating approach is based on the application of unit cost factors to an accurate inventory of facility equipment. Separate cost elements are obtained for Activity Dependent Costs, Period Dependent Costs, and Collateral Costs. In addition, funding to deal with probable activity risk or uncertainty (sometimes known as contingency costs) should be incorporated into each cost activity. The cost estimating approach for decommissioning is similar to the approach used in initial facility construction.

Activity Dependent Costs vary according to the individual tasks detailed, e.g., the costs to decontaminate, remove, package, ship and process/dispose of 2 meters of 10 cm diameter piping. This cost is then multiplied by the amount of piping matching this description for the inventory of plant equipment. Similar individual cost categories are developed for a broad range of materials for the affected facility.

A large component of decommissioning costs is the cost of labor. Another decision in the process is determining the extent to which facility staff will participate in the project. In many cases, it may be economically preferable to outsource many of the decommissioning project tasks to dedicated, experienced decommissioning organizations.

In the case of governmental projects, the provisions of the Davis-Bacon Act affect the cost of labor for a project. The particular project scope and schedule will affect the extent of work conducted under the provisions of the Act. The Davis-Bacon Act, as amended, requires that each contract over $2,000 to which the United States or the District of Columbia is a party for the construction, alteration, or repair of public buildings or public works shall contain a clause setting forth the minimum wages to be paid to various classes of laborers and mechanics employed under the contract. Under the provisions of the Act, contractors or their subcontractors are to pay workers employed directly upon the site of the work no less than the locally prevailing wages and fringe benefits paid on projects of a similar character. The Davis-Bacon Act directs the Secretary of Labor to determine such local prevailing wage rates.

In addition to the Davis-Bacon Act itself, Congress has added prevailing wage provisions to approximately 60 statutes which assist construction projects through grants, loans, loan guarantees, and insurance. These "related Acts" involve construction in such areas as transportation, housing, air and water pollution reduction, and health. If a construction project is funded or assisted under more than one Federal statute, the Davis-Bacon prevailing wage provisions may apply to the project if any of the applicable statutes requires payment of Davis-Bacon wage rates.

The geographic scope of the Davis-Bacon Act is limited, by its terms, to the 50 States and the District of Columbia. By the same token, the scope of each of the related Acts is determined by the terms of the particular statute under which the Federal assistance is provided. For example, Davis-Bacon prevailing wage provisions would apply to a construction contract located in Guam or the Virgin Islands funded under the Housing and Community Development Act of 1974, even though the Davis-Bacon Act itself does not apply to Federal construction contracts to be performed outside the 50 States and the District of Columbia. Davis-Bacon wage determinations are to be used in accordance with the provisions of Regulations, 29 CFR, Part 1 and Part 5.

Period Dependent Costs vary solely according to the duration of the project. These costs include such items as facility owner/licensee site staff, Decommissioning Operations Contractor (DOC) staff, long-term rental of equipment and others.

Collateral costs are neither Activity Dependent nor Period Dependent. Examples of these costs would be Site Characterization, Licensing Fees by Regulators (if any), Property Taxes and Insurance, Cost of Energy Consumed, and others.

As stated above, it is critical to have a sound cost estimate available for the decommissioning option selected. If possible, any estimates prepared by facility staff should be compared and validated to independently produced estimates. Project tasks/activities with either high individual costs, or high potential variability in costs (e.g., radioactive waste processing and disposal, or stakeholder programs and support) should get particular focus.

XX.4.2 Decommissioning Funding Approaches

The total cost of decommissioning is dependent on the sequence and timing of the various stages of the program. The minimum amounts that are required for reasonable assurance of funds for decommissioning are $105 million for pressurized-water reactors and $135 million for boiling-water reactors. These costs are in 1986 dollars and are adjusted annually, as further specified in the regulations. (USNRC 1988) These are minimum amounts to show reasonable assurance, rather than estimates, of what it would cost to decommission a specific nuclear reactor.

Actual site-specific costs incurred and estimated costs of decommissioning give a better indication of what the decommissioning may cost. The following table reflects actual and anticipated costs for decommissioning of several power reactors in the United States. All of these facilities used the DECON option.

Table XX.5 Summary of Decommissioning Costs for U.S. Power Reactors

Facility Name	Facility Type	Costs *	Comments
Big Rock Point	67 MWe Boiling Water Reactor	$351M (1997)	Ceased operations in 1997 and decommissioning is in progress
Fort St. Vrain	330 MWe High Temperature Gas Cooled Reactor	$189M (1996)	Ceased operations in 1989 and decommissioning completed in 1996
Haddam Neck (Connecticut Yankee)	619 MWe Pressurized Water Reactor	$344M (1996)	Ceased operations in 1996 and decommissioning is in progress. Additional costs of $82M for interim spent fuel management are expected.
Maine Yankee	830 MWe Pressurized Water Reactor	$274M (1997)	Ceased operations in 1997 and decommissioning is in progress. Additional non-radiological remediation costs of $49M for Greenfield costs and $53M for interim spent fuel management is expected.
Millstone 1	660 MWe Boiling Water Reactor	$532M (1999)	Permanent cessation of operations in 1998 and decommissioning in progress
Trojan	1130 MWe Pressurized Water Reactor	$210M (1993)	Ceased operations in 1993 and s decommissioning is in progress. Additional nonradioactive remediation costs of $42M for Greenfield costs and $110M for interim spent fuel management are expected to be incurred
Yankee Rowe	175 MWe Pressurized Water Reactor	$477M (1999)	Ceased operations in 1991 and decommissioning is in progress.

* Year of cost estimate dollars noted in parentheses

Two primary types of funding approaches are used for nuclear facilities. The first approach provides for the accumulation of funds prior to or during operations such that at the anticipated end of operations, that there will be sufficient funds for decommissioning. This approach is typically used for non-governmental licensees. In the case of some governmental licensees, e.g., the Tennessee Valley Authority, the licensee is only required to have a statement of intent containing a cost estimate for decommissioning, and indicating that the funds for decommissioning will be obtained when necessary. Other governmental owners of nuclear facilities (e.g., US DOE) have a legislative mandate to safely decommission the facilities at the end of their mission and to obtain the appropriate funding to accomplish the task.

XX.4.2.1 External Funding Approaches

This funding approach is typically used by non-governmental facility owners and reflects the approaches acceptable to the US NRC. Financial assurance is provided by the following methods:

Prepayment. In this case, at the start of operations, the licensee deposits into an account enough funds to pay the decommissioning costs. The account is segregated from the licensee's other assets and remains outside the licensee's administrative control of cash or liquid assets. Prepayment may be in the form of a trust, escrow account, government fund, certificate of deposit, or deposit of government securities.

External sinking fund. An external sinking fund is a fund established and maintained by setting funds aside periodically into an account segregated from licensee assets and outside the licensee's administrative control. The total amount of these funds would be sufficient to pay decommissioning costs at the time that it is anticipated that the licensee will cease operations. An external sinking fund may be in the form of a trust, escrow account, government fund, certificate of deposit, or deposit of government securities.

Surety method, insurance, or other guarantee method. A surety method may be in the form of a surety bond, letter of credit, or line of credit. Any surety method or insurance used to provide financial assurance must be open-ended, or if written for a specific term, such as 5 years, must be renewed automatically unless, 90 days or more preceding the renewal date, the issuer notifies the NRC, the beneficiary, and the licensee of its intent to not renew. The surety or insurance must also provide that the full face amount be paid to the beneficiary automatically preceding the expiration date 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. In addition, the surety or insurance must be payable to a trust established for decommissioning costs, and the trustee and trust must be acceptable to the NRC. The surety method or insurance must remain in effect until the NRC has terminated the license.

Whichever method of external funding is used, it is crucial that the anticipated costs for decommissioning are fully provided for by the time that decommissioning is expected to begin.

XX.4.2.2 Annual Budgeted Funding Approaches

The decommissioning of large nuclear facilities is typically a multi-year project. Optimum planning, budgeting and scheduling is best performed on a project wide basis. This can be particularly problematic to governmental facility owners. The problems arise due to the usual nature of governmental budget processes. Although governmental agencies appropriately use full duration project planning and budgeting approaches, typical budget cycles vary from 3 – 5 years at maximum. Even with the longer 5-year cycle, reasonable assurance of the level of annual project funding is typically only for a single fiscal year. This factor constrains the decommissioning planner to attempt to break the project into discrete tasks that may be accomplished within a single year. Although this approach provides for steady progress, it is a suboptimal approach for long duration projects and may necessitate larger overall expenditures of funds to accomplish the project.

A recommended decommissioning approach when using this funding vehicle is to budget and appropriate funds on a “front-end” load basis for the project. As soon as the facility end state is determined begin the project and develop the project plan and schedule with a focus on completing all possible work as funding allowed by the obligational authority provides.

XX.4.3 Decommissioning Decision Model

The detail and complexity of the decision making process for decommissioning approach selected should vary directly with the scope and complexity of the facility which will be decommissioned. Other factors, which play into the decision process, are evaluating preferred options based on the residual radioactive contaminants on site (e.g., radiation type, level, transportability, toxicity, potential pathways to the environment, etc.). The stability of the regulatory climate as well as the stability of waste disposal options and costs are also key decision factors. If the facility used or stored Special Nuclear Material (SNM), then additional costs will need to be factored into any ongoing surveillance and maintenance costs in order to maintain appropriate safeguards and/or criticality controls and systems, including any additional security staff. Virtually all sites to be decommissioned however can use similar economic models to select cost viable decommissioning options. The basic process provides for the determination of probable project costs for current year through out-years. Factors taken into account include:

- Funds available for decommissioning today;
- Annual additions to decommissioning fund (if any);
- Annual growth rate of decommissioning fund (if any);
- Decommissioning costs if prompt decommissioning beginning immediately;
- Annual surveillance and maintenance (S&M) costs;
- Annual cost escalation for decommissioning costs and S&M costs; and,

The following table provides a review of the strengths and weaknesses of each of the decommissioning alternatives. This is useful to help demonstrate the inputs that are typically used for decision models.

Table XX.6 SUMMARY OF ADVANTAGES AND DISADVANTAGES FOR ALL THREE DECOMMISSIONING OPTIONS:

DECON OPTION:

Advantages	Disadvantages
Facility and site becomes available for earlier reuse	Higher radiation exposure to workers and to the public
Knowledgeable facility workforce available to support project	Larger initial commitment of funds
Reduction in security, surveillance and maintenance costs due to reduced project duration, which would be required for other decommissioning alternatives.	Potentially larger volumes of radioactive wastes generated
Greater certainty about availability of low level radioactive waste burial space	Project complications if site must continue to store high-activity radioactive wastes on-site.
Lower project total costs due to non-escalation and less risk of uncertainty	May require use of new (not yet developed) technology
Known regulatory climate	

SAFSTOR OPTION:

Advantages	Disadvantages
Substantial reduction in radioactivity as a result of the decay that occurs during the storage period.	Shortage of personnel familiar with the facility at the time of deferred decontamination and dismantlement
A reduction in worker radiation exposure (as compared to DECON option)	Limited availability for site reuse during SAFSTOR period
A reduction in public radiation exposure (due to fewer radioactive waste shipments as compared to DECON option)	Uncertainties of availability and costs of low-level radioactive waste storage at the time of decontamination and dismantlement
A reduction in radioactive waste volumes (compared to DECON option)	Continued need for security, surveillance and maintenance during the SAFSTOR period
Lower annual costs following cessation of operations	Probable higher total project costs due to price escalation during the SAFSTOR period and the intermediate S&M costs.
SAFSTOR period allows more time for development of permanent disposal options such as a high level waste repository	

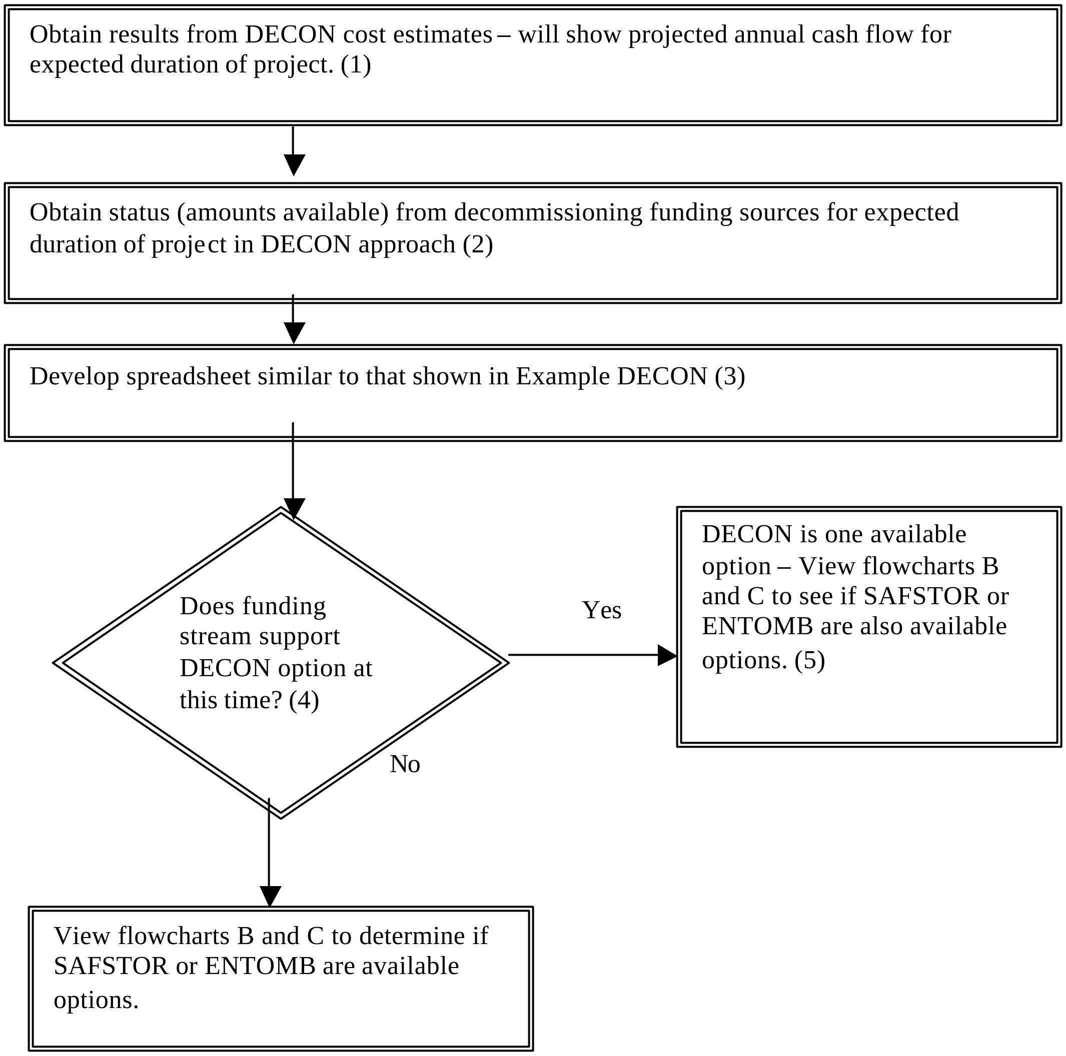
ENTOMB OPTION

Advantages	Disadvantages
Reduced cost (as compared to DECON OPTION)	Reduced availability of reuse for site
Reduced occupational and public radiation exposure (as compared to DECON OPTION)	Maintains radioactive materials at distributed locations rather than centralized repositories

For each of the potential decommissioning options, DECON, SAFSTOR, and ENTOMB, generally similar decision processes are used to determine economic viability of the option. In order to illustrate the decision processes, the following pages provide for each decommissioning option a simplified decision process flow chart, an example spreadsheet model, and discussion to guide the reader through the economic analysis approach for each option.

XX.4.3.1 Sample Economic Model for DECON Option

Figure XX.1 Flowchart for DECON Option



Obtain results from DECON cost estimates – will show projected annual cash flow for expected duration of project. (1)

Obtain status (amounts available) from decommissioning funding sources for expected duration of project in DECON approach (2)

Develop spreadsheet similar to that shown in Example DECON (3)

Does funding stream support DECON option at this time? (4)

DECON is one available option – View flowcharts B and C to see if SAFSTOR or ENTOMB are also available options. (5)

View flowcharts B and C to determine if SAFSTOR or ENTOMB are available options.

1. As stated earlier, the baseline for development of an economic decision model is a sound cost estimate for the DECON option which would start essentially immediately (year 1 for our model). Preferably, this cost estimate would have been site specifically developed and be provided in a format to allow the development of differing "what-if" scenarios via use of computer based spreadsheet software. For the basis of our example, we will assume the cost estimate provides for a four-year project, with annual costs of $8.0M, $12.0M, $16.0M, and $10.0M and the project to begin in "Year 1". No additional detail is provided in our cost estimate on cost breakdown.

2. The decommissioning fund currently contains $22.6M. It is reasonably expected to grow at an annual rate of 5%, and an additional $5M per year is expected to be added to the fund.

3. A spreadsheet should be developed to perform "what-if" scenarios with the economic parameters. The DECON example which follows provides the basic approach used for the discussion of additional decommissioning options. The spreadsheet is set up on an annual basis with available decommissioning funding at top of each annual column. Under it are the various charges that might be considered. In this case the actual DECON costs, and Surveillance and Maintenance (S&M) costs. Since in the example, DECON begins immediately, no S&M charges occur. The funds are increased by the annual addition of $5M, plus the annual growth of 5%.

Figure XX.2 Example Spreadsheet for DECON Option

Flowchart Item	Example Data
1	The 4 year DECON estimate is $8M in year 1, $12M in year 2, $16M in year 3 and $10M in year 4.
2	The current value of the decommissioning fund is $22.6M with annual additions of $5M and an assumed annual growth rate of 5%.

	Present Year	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Fund Value - year start	$22.6	$29.0	$27.3	$21.3	$10.8
S&M costs		$0.0	$0.0	$0.0	$0.0
DECON costs		$8.0	$12.0	$16.0	$10.0
Fund Value - year end	$22.6	$21.0	$15.3	$5.3	$0.8

4. In this case, the decommissioning funding currently available and anticipated over years 1 – 4 provide sufficient revenue to complete the decommissioning. In this example, the total decommissioning cost was $46M over four years.

5. Although DECON is demonstrated to be a viable economic option for this example, it is useful to explore other options as well as this information is typically useful during the non-economic portions of the decision process.

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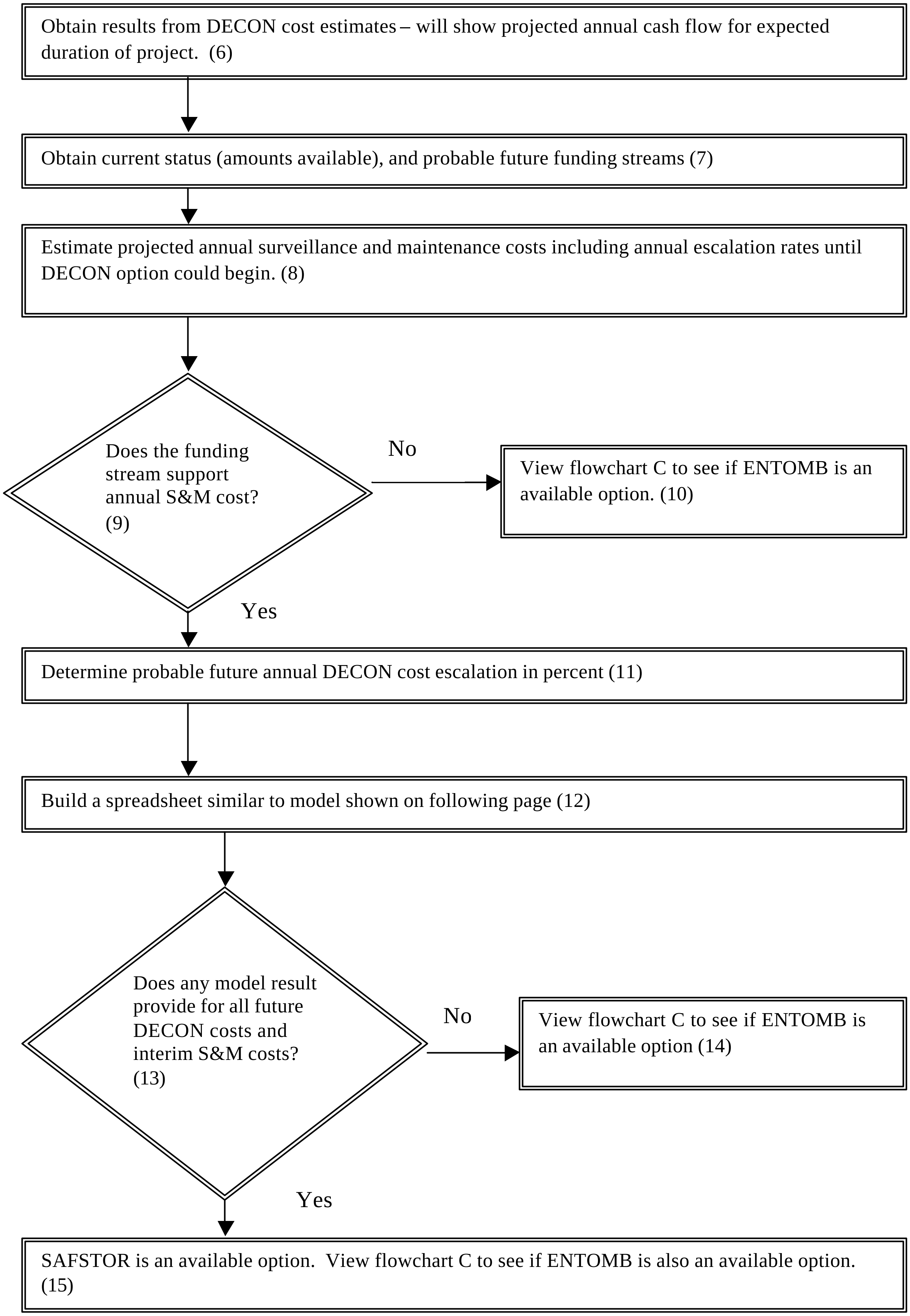
XX.4.3.2 Sample Economic Model for SAFSTOR Option

Figure XX.3 Flowchart for SAFSTOR Option



Obtain results from DECON cost estimates – will show projected annual cash flow for expected duration of project. (6)

Obtain current status (amounts available), and probable future funding streams (7)

Estimate projected annual surveillance and maintenance costs including annual escalation rates until DECON option could begin. (8)

Does the funding stream support annual S&M cost? (9)

View flowchart C to see if ENTOMB is an available option. (10)

Determine probable future annual DECON cost escalation in percent (11)

Build a spreadsheet similar to model shown on following page (12)

Does any model result provide for all future DECON costs and interim S&M costs? (13)

View flowchart C to see if ENTOMB is an available option (14)

SAFSTOR is an available option. View flowchart C to see if ENTOMB is also an available option. (15)

6. As stated earlier, the baseline for development of an economic decision model is a sound cost estimate for the DECON option which would start essentially immediately (year 1 for our model). Preferably, this cost estimate would have been site specifically developed and be provided in a format to allow the development of differing “what-if” scenarios via use of computer based spreadsheet software. For the basis of our example, we will assume the cost estimate provides for a four-year project, with annual costs of $8.0M, $12.0M, $16.0M, and $10.0M and the project to begin in “Year 1”. No additional detail is provided in our cost estimate on cost breakdown.

7. The decommissioning fund currently contains $22.6M. It is reasonably expected to grow at an annual rate of 5%, and an additional $3M per year is expected to be added to the fund.

8. Since SAFSTOR assumes a future decontamination and dismantlement, annual costs for surveillance and maintenance must be accounted for. For this model, S&M costs are assumed to be $0.5M per year and assumed to escalate at an annual 4% rate.

9. As shown in SAFSTOR Example 1 following, the decommissioning funding currently available and anticipated over years 1 – 4 provide sufficient revenue to provide for ongoing S&M costs so ongoing SAFSTOR analysis can continue.

10. If the revenue available to support ongoing S&M costs is insufficient, then the ENTOMB option should be evaluated.

11. Since the decontamination and decommissioning will occur at some future date, the cost estimate provided for the DECON option must have the costs escalated to the future date(s) for potential project start. In the examples, an annual escalation rate of 7% is assumed.

12. Similar to the DECON example, spreadsheets are used to evaluate “what-if “ scenarios for the SAFSTOR option.

13. In the SAFSTOR spreadsheet, three examples are shown. The first one actually is the DECON option with decontamination and dismantlement beginning in year 1. This example demonstrates that the available and future funding is insufficient for this option. The fund value is -$8.2M at the project end. The second example shows active D&D beginning in year 5 and S&M costs occurring in years 1 – 4. This example also is not economically viable as the fund shows a value of - $3.9M at the project end (year 8). The third example with D&D beginning in year 10 however is economically viable with the decommissioning funding completely providing for D&D in years 10 – 13, and the S&M costs in years 1 – 9. For this successful option, the total decommissioning costs (in year of expenditure dollars) rose from $46M in the DECON option to approximately $90M for the SAFSTOR option.

14. If no viable SAFSTOR scenario meets economic parameters, the review the ENTOMB option as this typically provides for the lowest ongoing costs.

15. If SAFSTOR is shown to be economically viable, then it is still prudent to review the ENTOMB decision process.

Figure XX.4 **Example Spreadsheets for SAFSTOR Option**

SAFSTOR Spreadsheet Example 1 – D&D starts year 1 (same as DECON option)

	Present Year	Year 1	Year 2	Year 3	Year 4
Fund Value - year start	$22.6	$26.9	$23.0	$14.7	$1.8
S&M costs		$0.0	$0.0	$0.0	$0.0
DECON costs		$8.0	$12.0	$16.0	$10.0
Fund Value - year end	$22.6	$18.9	$11.0	-$1.3	-$8.2

SAFSTOR Spreadsheet Example 2 – D&D starts in year 5

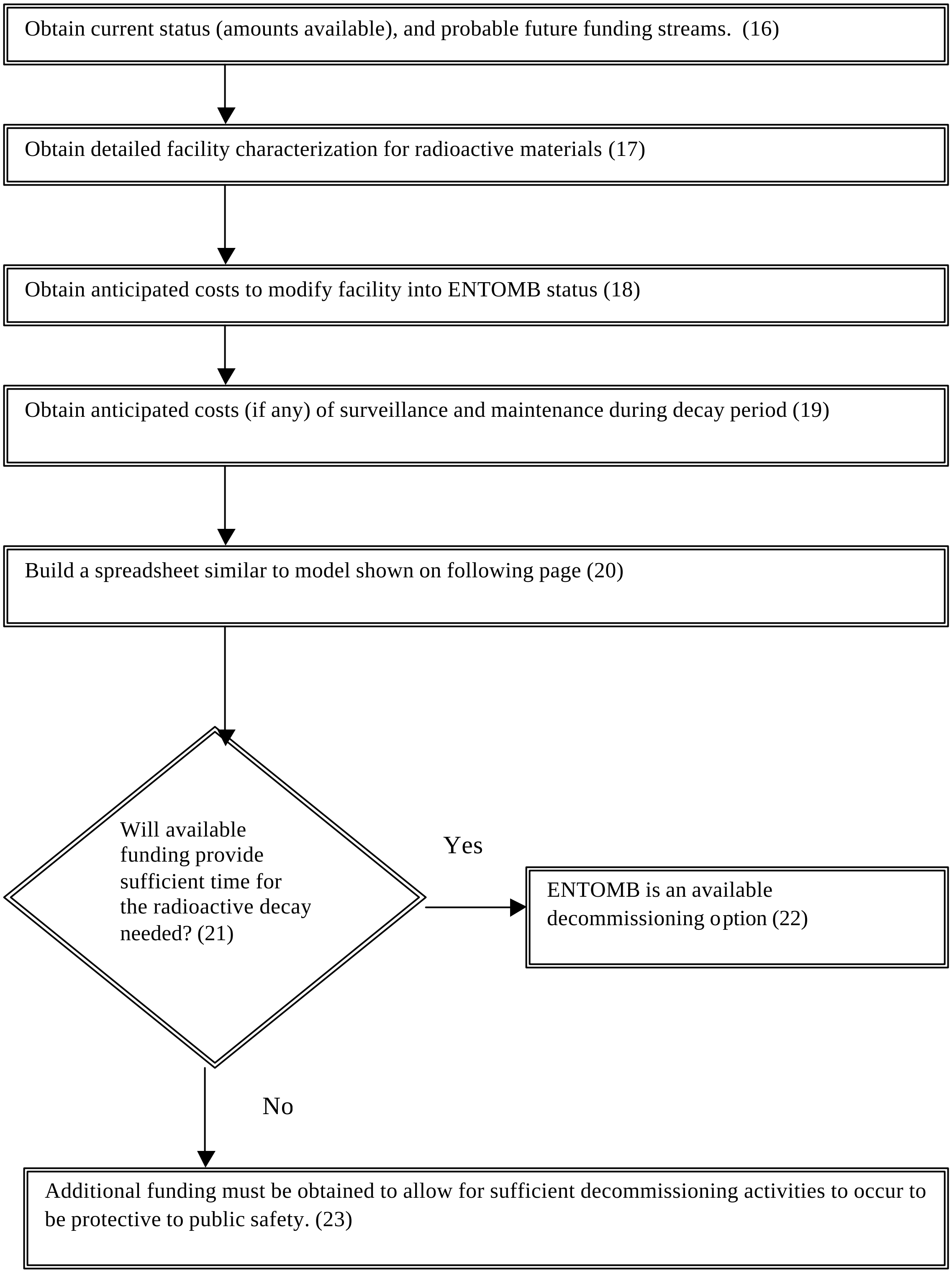
	Present Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Fund Value - year start	$22.6	$26.9	$30.8	$35.0	$39.3	$43.9	$38.2	$26.7	$9.2
S&M costs		$0.5	$0.5	$0.5	$0.6				
DECON costs						$10.5	$15.7	$21.0	$13.1
Fund Value - year end	$22.6	$26.4	$30.3	$34.5	$38.8	$33.4	$22.5	$5.8	-$3.9

SAFSTOR Spreadsheet Example 3 – D&D starts in year 10

	Present Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Fund Value - year start	$22.6	$26.9	$30.8	$35.0	$39.3	$43.9	$48.6	$53.5	$58.7	$64.1	$69.7	$60.9	$43.9	$18.4
S&M costs		$0.5	$0.5	$0.5	$0.6	$0.6	$0.6	$0.6	$0.7	$0.7				
DECON costs											$14.7	$22.1	$29.4	$18.4
Fund Value - year end	$22.6	$26.4	$30.3	$34.5	$38.8	$43.3	$48.0	$52.9	$58.0	$63.4	$55.0	$38.8	$14.5	$0.0

XX.4.3.3 Sample Economic Model for ENTOMB Option

Figure XX.5 Flowchart for ENTOMB Option



16. For our example the decommissioning fund currently contains \$22.6M. It is reasonably expected to grow at an annual rate of 5%, and for this example no additional funding is to be provided

17. Since the basis for the ENTOMB option is for radioactive decay to sufficiently reduce the level of radiological contaminants that the facility can be released, it is imperative to have detailed characterization data for the facility. This major factor to be taken into account in deciding the method and extent of decommissioning is the estimated quantities of particular radionuclides present and the nature of their principal physical and chemical forms. The volume of activated materials and the extent of contaminated materials will also play a part in the selection of a decommissioning option.

18. Some funding is initially necessary to modify components or systems for long-term entombment. In some cases remote monitoring or security equipment is necessary. In this example these modifications are assumed to cost \$10M and the expenses occur in year 1.

19. Some level of surveillance and maintenance may still be needed for a facility using the ENTOMB option, however it is less costly than the S&M costs for SAFSTOR. In this example, S&M costs are assumed to be \$0.2M per year and assumed to escalate at a rate of 4% per year.

20. A spreadsheet similar to the one following should be developed to perform "what-if" scenarios

Figure XX.6 Example Spreadsheet for ENTOMB Option

	Present Year	Year 1	Year 2	Year 3	Year 4	Year 5
Fund Value - year start	\$22.6	\$23.7	\$14.2	\$14.7	\$15.2	\$15.7
S&M costs		\$0.2	\$0.2	\$0.2	\$0.2	\$0.2
ENTOMB costs		\$10.0				
Fund Value - year end	\$22.6	\$13.5	\$14.0	\$14.5	\$15.0	\$15.5

	Year 108	Year 109	Year 110	Year 111
Fund Value – year start	\$50.5	\$39.0	\$26.5	\$12.7
S&M costs	\$13.3	\$13.8	\$14.4	\$15.0
ENTOMB costs				
Fund Value – year end	\$37.2	\$25.2	\$12.1	-\$2.2

21. Based on the results of the radiological characterization, a decay period sufficient to meet the license termination conditions can be calculated. It is also important to determine the reasonable lifetime of the physical structures and components that will remain at the facility during the potential decay period. The available funds must provide for the initial ENTOMB costs and the limited ongoing S&M costs for a protracted period. If structural improvements are needed prior to sufficient radioactive decay, then the funds must provide for this also. If we assume for this example that the necessary radioactive decay will take place over a period of 110 years, then the fund is sufficient. In this case the total costs for the ENTOMB option

is approximately $379M in year of expenditure dollars spent over the 110 year period of decay.

22. In this case ENTOMB provides an economically viable decommissioning option.

23. If insufficient funding is apparently available, the additional resources must be obtained in order to conduct sufficient decommissioning activities at the facility to be protective of the health and safety of the public and the environment.

The spreadsheet examples presented provide the basic approach used for economic analysis of the three decommissioning options of DECON, SAFSTOR, and ENTOMB. The level of detail and complexity of the analysis should be commensurate with the significance and scale of the project being evaluated. At a large or complex facility substantially more variables will be used, and may also include sensitivity or probability distributions for each parameter. Another option for nuclear facilities is the use of specialized decision analysis software. One example specifically developed for power reactors is the "Decommissioning Economics and Risk Advisor (DERAD)" developed by the Electric Power Research Institute. (EPRI 1996)

XX.4.4 Other Factors Affecting Economic Analysis

The prior section addressed the key economic factors for simple analysis of decommissioning options. Two additional factors however may provide substantial input to the economically optimum decommissioning approach selected. These two factors are the determination of the end state or use of the facility, and the need (if any) to provide for interim storage of high activity radioactive wastes and/or spent nuclear fuel.

The end use of a facility should be evaluated in concert with evaluations of potential decommissioning modes. This will help in the selection of the optimum decommissioning approach from both economic and non-economic needs. In many cases a facility undergoing decommissioning is viewed as a liability, however it may also appropriately be viewed as an untapped asset. The following are examples where a decommissioned facility end use provided revenue, or offset otherwise needed expenditures of money. This asset and revenue should be applied to the economic models to develop the decommissioning approach.

- Pathfinder Reactor – Now a natural gas fired electrical generating facility
- Ft. St. Vrain Reactor – Now a natural gas fired electrical generating facility (used existing turbine generator equipment)
- Big Rock Point – Facility is on over 600 acres of what has become prime recreation area
- EBWR (Argonne National Laboratory – East) – Reuse as a waste storage facility

The potential revenues provided by facility reuse and/or the funds not needed due to alternate use of the facility should be added to the economic models.

In the US, the Department of Energy has the ultimate responsibility for the disposal of high level radioactive wastes, including spent nuclear fuel. The DOE is currently unable to provide for this disposal, and the current estimates are that acceptance of this waste will not occur until at least 2010. This fact has caused many facilities to provide for interim storage of these high level wastes on site. Typical practice has been the construction of Interim Spent Fuel Storage Installations (ISFSI) consisting of an engineered concrete pad, and dry cask storage systems for the interim storage of high level wastes.

As noted in Table XX.5 above, costs for spent fuel management ranged from $53M to $110M for commercial power reactors, with the fund totals driven primarily by the amount of spent fuel to be placed into dry casks. Facilities may be able to maintain spent fuel in wet storage (on-site spent fuel pools) at reduced capital costs, but this approach typically requires higher annual surveillance and maintenance costs than dry cask storage systems. Additional discussion on the management and disposition of high level wastes is provided for in Chapter 14, Spent Nuclear Fuel.

Both wet and dry storage modes have respective strengths and weaknesses. The important point is that if the facility in question has high level wastes which must be maintained on-site for an interim period prior to ultimate disposition, the potential costs and storage options need to be evaluated in tandem with the economic evaluations for decommissioning approach.

The use of innovative or advanced technology can have a positive economic impact on a decommissioning project. The use of advanced technology is addressed in Chapter 15, Decommissioning Technologies.

XX.5 Non-Economic Inputs to the Decommissioning Decision Process

In most cases, the decision process for decommissioning approach is not solely driven by the preferred economic alternative for radiological remediation. Non-radiological contamination on the site (if any) can be a key contributor to the decommissioning option selected. Additionally, stakeholder interests provide a valued and necessary input to the decommissioning decision making process.

The issues addressed in this section although identified as “non-economic inputs to the decommissioning decision process”, clearly can impact the economics of the decommissioning decision. The wide variability and applicability of these issues however, do not readily lend themselves to simple economic analysis tools. It is important however to consider these issues in the decision making for the decommissioning option selected.

Although decommissioning is by definition the remediation of radiological contaminants, it is appropriate to also consider potential non-radiological contaminants and their impact to the decommissioning options under consideration.

Another significant non-economic issue is the consideration of stakeholder interests. Stakeholder inputs and participation in the decommissioning decision making process is at least a prudent recommendation, and in many decommissioning projects, stakeholder participation is a legal mandate.

Lastly, this section will discuss other issues for consideration during the decision process for selecting the facility decommissioning option.

XX.5.1 Non-Radiological Remediation

Many regulatory drivers regarding non-radiological remediation exist which may impact the selection of the decommissioning option. Some of these include:

- Resources Conservation and Recovery Act (RCRA), as amended;
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended;
- National Environmental Policy Act (NEPA);
- Federal Facility Compliance Act;
- Clean Air Act, as amended;
- Clean Water Act, as amended;
- Safe Drinking Water Act, as amended;
- Toxic Substances Control Act (TSCA) as amended;
- Atomic Energy Act, as amended;
- Uranium Mill Tailing Radiation Control Act;
- Low-level Waste Policy Act, as amended;
- Nuclear Waste Policy Act, as amended; and,
- Superfund Amendment and Reauthorization Act (SARA), as amended.

A valuable flowchart of environmental considerations for decommissioning is provided in the DOE Decommissioning Resource Manual, Chapter 2, and Appendix C (DOE 1985). Additionally, environmental considerations for decommissioning are further addressed in Chapter 5 of this book, Environmental and Related Requirements.

Although decommissioning is solely an effort for radioactive materials, it is foolish to ignore other potential contaminants in the decision making process. Nuclear facilities of any size should evaluate non-radioactive contaminants as part of their decision-making and decommissioning planning processes. For this evaluation, all media types should be considered (e.g., surface and subsurface soil, surface and subsurface water, adjacent waterways, gaseous effluents and surface solids) along with all possible pathways to the public and the environment (e.g., drinking water, irrigation, agriculture, fish and wildlife, etc.).

Facilities built prior to the 1980’s may likely use asbestos piping insulation or tiling. Although generally remediated already, some PCB containing transformers or other components may still exist. Asbestos and PCBs may also be compounds found in facility paint in addition to the potential of lead. These compounds must be appropriately remediated during the decommissioning process and need to be included in both the cost estimates, and in the decision process. Any chemical processes, which may have been conducted at the facility, are also suspect. U.S. or regional EPA typically regulates these non-radioactive contaminants. The regulatory framework for these contaminants are addressed in chapter 5 of this book, Environmental and Related Requirements and need to be expressly addressed in a facility(s) planning and decision-making.

The early characterization of environmental and radiological contaminants can help determine the level of environmental regulatory impact to the decision process. Also, if environmental impacts are determined to be a factor in the decision process, the earlier in the decommissioning decision process this is determined, the better the potential outcome will be.

An optimum characterization approach for decommissioning includes sufficient early characterization to develop project plans and environmental safety and health plans, followed by a process of iterative characterization and remediation of higher priority hazards throughout the decommissioning process.

XX.5.2 Stakeholder Inputs to Decommissioning Decision Process

Broadly defined, a Stakeholder is “any group or individual who is affected by or who can affect the future of the facility decommissioning program” (USDOE 1997). The previous section addressed the rudiments of economic analysis for decommissioning approaches for nuclear facilities. Seldom however, is such a decision made solely on the economics of the situation.

Throughout the operating life of a nuclear facility, it maintained interactions with a variety of stakeholder groups. The relationship of the facility owner with these stakeholders, whether good or bad, can substantially affect the approach to decommissioning ultimately selected for action by the facility owner.

This section will briefly address key stakeholder groups, interests they may have in the decommissioning approaches available and suggestions for building good stakeholder relationships. Additional discussion on stakeholder interaction is provided for in Chapter 9 of this book, Stakeholder Participation.

Each facility will have a unique set of stakeholders to work with for decommissioning. Some stakeholders will be supportive, some adversarial, and others open to interaction. It is important for the facility owner to interact with the various stakeholders, gather information as to the stakeholder’s interests and intents with respect to the decommissioning process. The facility owner then needs to evaluate the potential impact each stakeholder may have on the decommissioning approach decision.

XX.5.2.1 Local Community

The end of a nuclear facility’s mission and transition into decommissioning can create substantial effects on the local community. This is particularly true in the case of large facilities. Large facilities have historically tended to be built at distances from large metropolitan areas as a safety measure. One result of this however, is that the communities that have sprung up around the nuclear facility rely heavily on the nuclear facility for the communities economic well being. This can be either through direct taxes paid by the facility, or to the economy driven by services and support functions to the nuclear facility. During permanent shutdown the site permanent staff is typically significantly reduced. Many of these individuals may also live in the local community creating additional economic effects. A permanent shutdown can create rapid and dramatic reductions in all of these areas and the ensuing economic ripple effects. When the decommissioning process actually begins (i.e., work begins at the facility) then in some cases it may result in a local economic upturn for the duration of the work as additional personnel conduct the D&D.

Because of these financial impacts, local community opinion will likely be neutral to negative initially, even if the shutdown had been planned and previously announced. In the event of premature shutdowns, the reaction can be even more dramatic.

If the economic impact is put aside, then the next significant concern by the local communities is the decommissioning approach selected. The typical community reaction would be to select the DECON approach as it provides the fastest path toward free release of the facility for alternate uses and the fastest assurance that the site is free from residual radioactive contamination which would require regulation. The community view would likely be to get the facility to a condition in which it could be used to generate revenue again for the community. Another reason that local community opinion would likely favor DECON, is that during the duration of the decommissioning, supplemental staffing is typically required at the facility undergoing decommissioning, and may require a temporary increase in services and support provided by the local community. If DECON is not the decommissioning approach selected, then the facility owner will need to be able to address the local community interest in DECON, and satisfactorily address why it is not the option ultimately selected.

Some facilities supported a group for local community interaction and input during the period the facility operated. Examples of these groups were Community Advisory Panels, or Boards, or Site Specific Advisory Boards. If these communications vehicles existed during operations, they will continue to be a critical asset during the early stages of decommissioning.

XX.5.2.2 Regulatory Groups

As stated at the beginning of this chapter, decommissioning is focused solely on the actions needed to remediate a site for radioactive materials only. In many cases, only one regulatory group has the authority to terminate a facility(s) license upon satisfactory decontamination. Depending upon the facility, in the United States the regulatory group may be the U.S. NRC, U.S. Department of Energy, a State Agency (e.g., Illinois Department of Nuclear Safety or Washington State Department of Ecology), or U.S. EPA (if the facility is listed on the National Priorities List [NPL], then CERCLA also applies).

Although these agencies and others typically work under Memoranda of Understanding to minimize duplication of regulation, it is not always totally effective. A recent example is noted in the ongoing decommissioning of the Maine Yankee nuclear power plant. The unrestricted release criterion for the U.S. NRC is 25 mrem annual total effective dose equivalent through all pathways to the average member of the critical group including As Low As Reasonably Achievable (ALARA) considerations. Based upon much stakeholder interaction and regulatory action by the State of Maine, the criterion established by Maine Yankee is 10 mrem through all pathways with a separate criterion of 4 mrem per year through the groundwater pathway.

A similar overlap occurs between various state/federal agencies that may have duplicative or joint jurisdiction on nuclear materials, hazardous and toxic materials, environmental quality, etc. The interests of each of the applicable agencies must be taken into account in development of a facility decommissioning plan.

Regulatory groups typically will not suggest a specific decommissioning approach. Rather, their focus is to ensure that any approach taken by the facility owner will meet all applicable regulations. As an example, if sufficient non-radioactive contaminants are identified at a facility that remediation would be required, it is unlikely that the EPA would authorize ENTOMB as a viable option without additional remediation of the non-radioactive contaminants. Likewise, if the radioactive contaminants would not decay to unrestricted release criteria over the regulated time frame (currently 60 years for U.S. NRC), then the NRC likewise would not allow ENTOMB to be selected.

XX.5.2.3 Public Interest Groups and Other Stakeholders

There are a variety of public interest groups and other stakeholders whose inputs may also substantially affect the ultimate decommissioning option selected. These may include environmental groups, anti-nuclear groups, tribal nations, labor unions, business or religious groups. These groups may originate locally, nationally or even internationally in some cases.

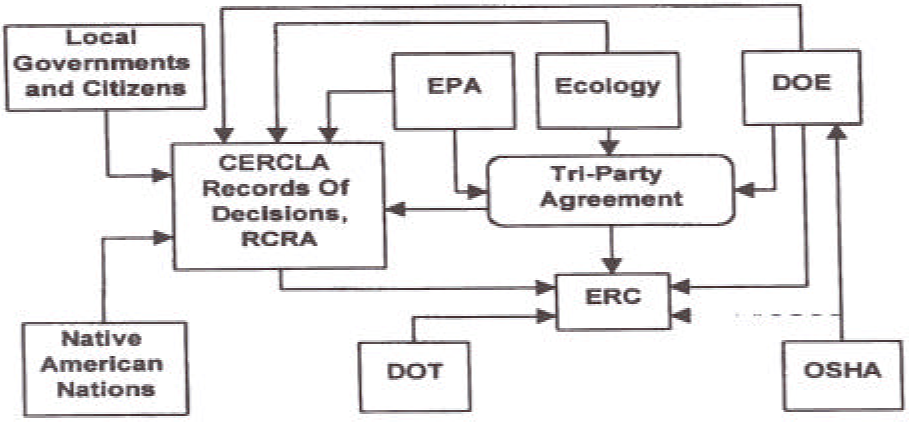
Many of these stakeholders have appropriate concerns on the selection of the decommissioning approach and the future of the facility. Some groups however may only actively participate to provide a vehicle for media attention, regardless of the their specific concerns with respect to the decommissioning decision. In all cases though, it is important to understand the interests and to work with appropriate stakeholders.

A classic example of interaction among many regulators and stakeholder groups regarding decommissioning decisions is presented by the Tri-Party Agreement for the Hanford Site decommissioning and remediation. The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) is an agreement among the US EPA, the Washington State Department of Ecology, and the US DOE for achieving environmental compliance at the Hanford Site with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) including the Superfund Amendments and Reauthorization Act (SARA) remedial action provisions, and with Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal unit regulation and corrective action provisions.

The Tri-Party Agreement 1) defines RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal of achieving regulatory compliance and remediation with enforceable milestones in an aggressive manner. The Tri-Party Agreement was also established with input from the public.

Negotiations to make major changes to the Tri-Party Agreement were conducted in 1993, and a renegotiated agreement was signed by the three agencies in January 1994. Further significant changes were negotiated during 1994 with approval of these changes pending required public involvement activities. In addition to the three primary governmental agencies, many groups and individuals provided input to the development of the Tri-Party agreement and continue to have interests and inputs to the remediation process. The following table shows the simplified structure of the governing regulatory structure of the Tri-Party Agreement. The box labeled ERC refers to the Environmental Restoration Contractor. (Slobodien 1999)

Figure XX.7 Tri-Party Agreement Organization



XX.5.3 Other Non-Economic Inputs to Decision Process

In some cases, additional factors affect the decommissioning option selected. Examples of these include:

- When the facility to be decommissioned is on a still operating site, then questions of operational safety are significant. Will the activities undertaken to decommission the facility affect the safe operation of adjacent structures? If this answer were yes, it would result in a decision preference to the SAFSTOR option until the adjacent facilities were ready for decommissioning.

- The choice of decommissioning options is also strongly influenced by potential uncertainties in low-level waste disposal costs and by concerns over the future availability of low-level waste sites.

All of these “non-economic inputs” are essential to evaluate in concert with the economic evaluations in order for the facility owner to select the optimum decommissioning approach for their facility.

XX.6 Large Facility Experience to Date

The following tables note U.S. Experience in the three decommissioning options:

Table XX.7 Facilities Decommissioning using DECON Option:

Facility	D&D completed
Special Power Excursion Reactor Test (SPERT) Reactors	1970’S – 1980’S
Walter Reed Research Reactor (WRRR)	1972
Air Force Ground Test Reactor	1974
Shield Test and Irradiation Reactor (STIR)	1975
Organic Moderated Reactor Experiment (MORE)	1979
Ames Laboratory Research Reactor	1980
Lynchburg Pool Reactor	1982
Force Northrop Corp. TRIGA Mark F Reactor	1986

Virginia Polytechnic Institute Research Reactor	1988
Westinghouse Nuclear Training Reactor	1988
Michigan State University Research Reactor	1990
Ultra High Temperature Reactor Experiment (UTHREX)	1990
University of California-Berkeley Research Reactor	1991
ARMY Material Research Reactor (AMRR)	1993
University of California-Los Angeles Research Reactor	1993
University of Kansas Research Reactor	1993
Experimental Boiling Water Reactor (EBWR) Facility	1996
Cintichem Reactor	1997
JANUS Reactor	1997
Chicago Pile #5 Research Reactor	2000
Georgia Institute of Technology Research Reactor	Currently In Progress
Haddam Neck Power Station	Currently In Progress
Maine Yankee	Currently In Progress
Trojan	Currently In Progress
University of Washington Research Reactor	Currently In Progress
Yankee Rowe	Currently In Progress

Table XX.8 Facilities Decommissioning using SAFSTOR Option:

Facility	D&D status
Southeast Fast Oxide Reactor (SEFOR)	SAFSTOR ongoing
Saxton Nuclear Experimental Reactor	Decommissioning Currently In Progress
Indian Point 1	SAFSTOR ongoing
Dresden 1	SAFSTOR ongoing
Humboldt Bay 3	SAFSTOR ongoing
Peach Bottom 1	SAFSTOR ongoing
San Onofre 1	SAFSTOR ongoing
Rancho Seco	SAFSTOR ongoing
LaCrosse BWR	SAFSTOR ongoing
Vallecitos BWR	SAFSTOR ongoing
Fermi 1	SAFSTOR ongoing
Zion 1 and 2	SAFSTOR ongoing
Three Mile Island 2	SAFSTOR ongoing

Table XX.9 Facilities Decommissioning using ENTOMB Option:

Facility	D&D status
BONUS	ENTOMB Continues
Hallam	ENTOMB Continues
Piqua	ENTOMB Continues

XX.7 Conclusions and Recommendations

The selection of the decommissioning approach for any nuclear facility is a complex one. Once there is common acceptance of the future use of the facility (or facility end state), the decision process can be simplified by separating key economic inputs from key non-economic inputs. All the inputs can and should be systematically reviewed by the facility owner in order to arrive at the optimum decommissioning solution for the individual facility.

The authors recommend reliance on expert methodology for the development of decommissioning cost estimates for the various options considered. These may be supplemented with in-house estimates but the sole use of in-house cost estimates is ill advised. For federal facilities, the packaging and sequencing of work can have a significant effect on the amount of decontamination work exempt from Davis-Bacon coverage, and therefore on overall project cost.

In conclusion, once a defined facility end state is accepted, and the waste disposal pathway is established, the D&D of a facility may be likened for cost estimating, project management and fiscal controls to the process used during the initial construction of a similar facility.

XX.8 References

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