

R2D2P Workshop on Cost Estimates

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Overview of cost calculations and key concepts

R2D2P

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- 1) Requirements and purpose of decommissioning costing**
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1. Requirements and purpose of decommissioning costing

- Decommissioning of nuclear facilities is in general a complex and expensive process of technical and non-technical activities covering the time scale of tens of years. Estimating of parameters of decommissioning is one of the main issues in preparatory and planning phases of decommissioning.
- The main aim of these activities is to prepare files of qualified data like costs, exposure, manpower, personnel / equipment needed, amounts of waste, time schedules, time graphs etc. Based on this qualified data, the decommissioning process can be planned to be accomplished.
 - **safely** with minimal actual and future influence on personnel/environment
 - **economically** according to costs / resources optimized decommissioning option
 - **in due time** according to optimised decommissioning time schedule

1. Requirements and purpose of decommissioning costing

- When selecting a decommissioning strategy, in most cases **several alternative options** are evaluated. One of the important factors influencing a final decision is the **cost** of the different alternatives.
- The **decommissioning costs** should be known already in early stages before starting decommissioning and in the case of new nuclear facilities at the commissioning stage.
- The accuracy of costs estimates should be as best as possible **in total, in its fine structure and in time structure** in order to raise-up the relevant decommissioning fund and to plan the decommissioning activities.
- The term "**decommissioning costing**" refers to decommissioning costs as a pivotal (focal) parameter into which all aspects with impact on decommissioning activities are projected, like strategy, state of the facility, decommissioning infrastructure, social aspects. etc.
- Other parameters like manpower, exposure, amount of waste support the information content of results of decommissioning costing

1. Requirements and purpose of decommissioning costing

Main purposes of decommissioning costing

- **Governmental level:** to inform the government and guide their policy for assuring that decommissioning fund will be available when needed.
- **Facility level:** to determine funding requirements and financial liabilities
- **Planning level:** basis for industrial strategy and decommissioning activity planning

A) Governmental level

The results of decommissioning costing at the highest level should have such a structure and reasoning that the governments/regulator can develop an appropriate **understanding of decommissioning costs** as input to policy and regulation development in order to assume that adequate funds are appropriately collected.

Another important issue of decommissioning costing on the highest or on the international levels is the **comparability** of calculated costs. Without proper **common understanding** of individual cost items, the comparability is hampered.

1. Requirements and purpose of decommissioning costing

B) Facility level

On the facility level, the decommissioning costs are generally based on the agreed decommissioning strategy, and will focus on the **amount of money** necessary, and on the **timeframe** for the spending of the collected fund. Decommissioning cost estimates that are made for this purpose are thus **periodically updated** to reflect the current decommissioning strategy and the actual state of decommissioning technology.

C) Planning level

The results of cost estimates used for **planning** may well be more detailed than those that serve for developing an overall cost envelope for decommissioning funding purposes.

This type of estimates is generally based on a detailed decommissioning strategy and plan, and may be used also a basis for **contracting**, as a starting point for establishing a project baseline for costs and schedule management, and for **cost accounting** and **scheduling purposes** during decommissioning operations.

2. Decommissioning costing methodologies

Principles and types of cost estimates

- **Reliable cost estimating** is one of the most important elements of decommissioning planning. Alternative technologies may be evaluated and compared on their efficiency and effectiveness and measured against a baseline costs as to the feasibility and benefits derived from this technology.
- This principle ensures that the cost consideration is economically sound and practical for funding.
- Through the history of cost estimates, many cost methodologies were developed and the results may differ due to different work scope, labour costs, structure of presented data, etc. The major issue is to understand and explain the differences.
- Experience accumulated shows that a reasonable degree of reliability and accuracy can be achieved by developing the cost estimates bases on a **case-by case site/project specific basis**.

2. Decommissioning costing methodologies

Principles and types of cost estimates

Proper evaluation of decommissioning costs is important for:

- Selection of a decommissioning strategy and activities
- Support to a cost-benefit analysis to ensure that the principle of optimization and reasonably practicable measures are applied
- Estimate of required financial resources for selected strategy
- Preparation of the project schedule, workforce requirements and phased funding needs
- Definition of measures for proper management and maintenance of resources for safe and timely decommissioning
- Establishment of financial mechanisms
- Harmonisation in costing

2. Decommissioning costing methodologies

Involvement of international organisations

- Costing and funding issues were addressed specifically by main international organizations involved in decommissioning: **IAEA, OECD/NEA and European Commission (EC)**.
- There is a general consensus that estimating decommissioning costs and collecting funds for decommissioning of facilities that have used radioactive material is a prerequisite for safe, timely and cost effective decommissioning.
- The cost must be understood in details in order that identical or similar decommissioning activities would be comparable – **what is behind the cost**
- One of the most important results of common effort is the standardised cost structure of decommissioning cost items (**Yellow Book**). This structure can be now identified as the **common platform** for harmonisation in decommissioning costing.
- The directions in which these main organisations proceed, seem to be different but in some aspects complementary.

2. Decommissioning costing methodologies

Involvement of international organisations

OECD/NEA, EC

- The activities of **EC and OECD/NEA** are oriented mostly to **power generating facilities** due to fact that huge amount of finances will be needed for decommissioning project in near future and the finances should be adequately reasoned and appropriately planned.
- The experience in decommissioning in developed countries (USA, Europe) was already accumulated and the decommissioning is now going to be a standard **industrial activity**.
- This is the positive aspect but there is also a negative aspect that the information on costing estimation methodologies and representative data are more and more the subject of **companies' know-how** and less information and data are available due to competition on decommissioning market.

2. Decommissioning costing methodologies

Involvement of international organisations

IAEA

- The activities of IAEA involve the whole spectrum of nuclear facilities and also all aspects of decommissioning.
- Aspects of decommissioning of non power generating facilities like **research reactors** due to their world wide spread in member states have a special position on IAEA activities.
- The experience in decommissioning of research reactors are accumulated in some developed countries and therefore the international activities are needed to support the planning and implementation of decommissioning of research reactors in other countries. Among these issues are the also the aspect of decommissioning costing.

2. Decommissioning costing methodologies

Involvement of international organisations

Review of current activities of main organizations in costing and funding

- The effort of **IAEA** is to address the subject from the standpoint of the diverse social, economic and cultural environments that constitute IAEA membership in order to develop a broader background for decision making process and for implementation of decommissioning projects. The last overview of **decommissioning costs and funding mechanisms** is presented in [**TECDOC 1476 Financial aspects of decommissioning**]. The project for robust **cost estimation for research reactors** was started.
- The **OECD/NEA** developed in the last period an expert working group within the **Working Party on Decommissioning (WPDD)** that address and analyses the main cost drivers in decommissioning costing and tries to define the different types of uncertainties and their treatment in cost estimations, how different cost methodologies analyze the uncertainties and where cost estimates go wrong. The **revision of the Yellow Book** is planned.
- The **European Commission** currently ran (until end of 2008) a project **Coordinated Network on Decommissioning (CND)** that address also the cost aspect in decommissioning with the aim to review the current methods for decommissioning costing, and to promote uniformity and standardisation in cost structure [**Yellow Book**] and costing methods.

2. Decommissioning costing methodologies

Principles and types of cost estimates

- At the preliminary stages of decommissioning costing, the level of details is lower. The final cost estimates used more precise data and methodology and the results are more precise too.
- The basic levels of cost estimates that are used, and which have different level of accuracy, can be identified as follows [**TEDOC 1476**]:
 - **Order/of Magnitude**, accuracy -30% to +50%, no detailed engineering data, use of scaling factors, the scope of the project not well defined
 - **Budgetary Estimate**, accuracy -15% to +30%, the scope of the project has been defined, the detailed engineering not yet applied
 - **Definitive Estimates**. accuracy -5% to +15%, after applying the detailed engineering approach and planning in depth

2. Decommissioning costing methodologies

Features of current costing methodologies

- Current costing methodologies were developed based on experience from decommissioning of nuclear facilities mostly with **standard shutdown properties**. The methodologies could then be used for cost estimates for similar facilities.
- The **unit factors, calculations formulas** and other elements of cost methodologies could be applied after comparison of facilities and relevant corrections for the differences in size, inventory, local factors and other aspects. The quality of results depends on proper adjustment of the methodology for facility conditions.
- One of the general aspects of these traditional methodologies is the fact that the cost structures are in general **different for various projects**. The cost structure of the projects are then less comparable and also less transparent.
- The **project specific approach** and the principle which takes into account the **elementary decommissioning activities**, will help to improve the quality and comparability of cost estimates

2. Decommissioning costing methodologies

Types of costing methodologies

Costs may be estimated in several ways:

- **Bottoms-up** - site specific and most accurate
- **Specific analogy** - based on known cost of an activity in prior estimates
- **Parametric** - based on historical databases of similar systems and structures
- **Cost review and update** - based on previous estimates of same or similar project
- **Expert opinion** - based on consensus of specialists in an iterative process

Bottoms-up estimates are most accurate and preferred because they are based on evaluating of individual **elementary decommissioning activities** (activity based costing methodology) for which the site specific calculation data (unit factors, ...) are developed.

The amount of work estimated for the elementary decommissioning activity, which can be related to the inventory data of the facility, is the base for estimation of costs – **unit factor approach**.

2. Decommissioning costing methodologies WBS

The calculated data of individual decommissioning activities are then grouped into higher levels, so hierarchical structure in the final schedule can be developed.

This principle of constructing the tree structures of decommissioning activities is known as the **work breakdown structure (WBS)**. Using this approach, the decommissioning projects is divided into **discrete and measurable work activities**. The source data at the lowest levels can be **traced and evaluated**.

2. Decommissioning costing methodologies

Steps in costing methodologies

- Practical costing is carried out by identifying all work activities together with their associated labor, material, equipment, and service requirements.
- Subsequently, estimation is made of the costs arising from **each elementary activity** as the discrete and measurable elementary work activity (bottom-up principle) for which unit costs are calculated or estimated - unit factors approach.
- Typical steps of current practice in decommissioning costing are:
 - Definition of cost categories as hands-on activities (depended on amount of inventory), period dependent activities (depended on duration and staff involved), collateral cost and contingency
 - Identification of decommissioning activities for hands-on activities based on the facility inventory
 - Definition of unit factors for ideal working conditions and definition of increase factors under working constraints
 - Definition of period-dependent activities depending on critical path constructed for hands-on activities
 - Collateral costs as the cost for procurement of equipments, payments, costs for special items, etc.,
 - Total cost is the sum of cost for hands-on activities, period dependent activities, collateral cost which is adjusted with the reasoned contingency fro unforeseen items within the scope of the project

[2] **Financial aspects of decommissioning. Report by an expert group. IAEA-TECDOC-1476, IAEA, Nov. 2005**

3. Standardised decommissioning cost structure

Reasons for the Standardised cost structure

- **OECD/NEA, IAEA and EU issued in 1999 the document “A Proposed Standardised List of Costs Items for Decommissioning Purposes” (PSL), which defines the full extent of categories of decommissioning activities for which the costs are to be evaluated and presented.**
- **The reason for issuing this document were inconsistencies in presented costs of various decommissioning projects caused by different extent of activities, technical / local / financial factors, waste management systems, etc. The main purpose of the document is:**
 - **To facilitate communication**
 - **To promote uniformity**
 - **To encourage common usage**
 - **To avoid inconsistency or contradiction of results of costs evaluations**
 - **To be of world wide interests to all decommissioners**

3. Standardised decommissioning cost structure

Content of the standardised cost structure

The **PSL documents** with standardised cost structure is recommended for application in decommissioning costing in general for any nuclear facility. The standardised cost items can be generally used for development of the **cost calculation structures**.

Eleven cost groups were identified in the PSL:

- Pre-decommissioning actions
- Facility shutdown activities
- Procurement of general equipment and material
- Dismantling activities
- Waste treatment and disposal
- Security, surveillance and maintenance
- Site cleanup and landscaping
- Project management, engineering and support
- Research and development
- Fuel
- Other costs

3. Standardised decommissioning cost structure Methods of implementation of the PSL

Implementation of the PSL (Proposed Standardised List ...) into the cost estimating system can be achieved in principle in two ways:

A)

Calculation of costs using the national/project specific cost structure and converting the resulted costs into the PSL structure. This option needs to develop an **additional specific conversion matrix**. Each specific decommissioning cost structure needs its own conversion matrix.

The calculation core is the project specific WBS. This is mostly the current state.

B)

Calculation of costs directly in the standardised cost structure. The project specific WBS is constructed as the upper layer over the items of the standardised calculation structure by their grouping or linking. **No additional conversion matrix is needed.**

Various specific WBS can be constructed using the standardised cost structure as the calculation core. The standardised cost structure can be used as an **universal decommissioning cost calculation structure** which can be used for any nuclear facility.

The quality of cost estimates are directly dependent on the quality of input data used for cost calculation. Following groups of input data can be identified:

■ Facility inventory data

- Data for facility **technology systems**, their location, materials and other parameters with impact on decommissioning
- **Building objects** data, types of materials, building surfaces
- **Radiological data** - dose rate, contamination, activation and nuclide composition

■ General calculation data

- National specific data for labour force, decommissioning technologies data (unit factors), material data, cost data for materials, electricity and technological media, etc,
- Project specific data of the decommissioning infrastructure which include the data of waste management technologies, waste disposal and material release.

■ Specific calculation data

- Calculation item specific data which reflect the local calculation conditions applied in individual calculation items, e.g. increase factors
- Data for definition of period dependent activities – definition of the professions, duration,

Management of waste from decommissioning in current costing methodologies is mostly a **separate cost module**. It covers all activities following the waste generating decommissioning procedures like dismantling, decontamination and demolition. Main technologies are following:

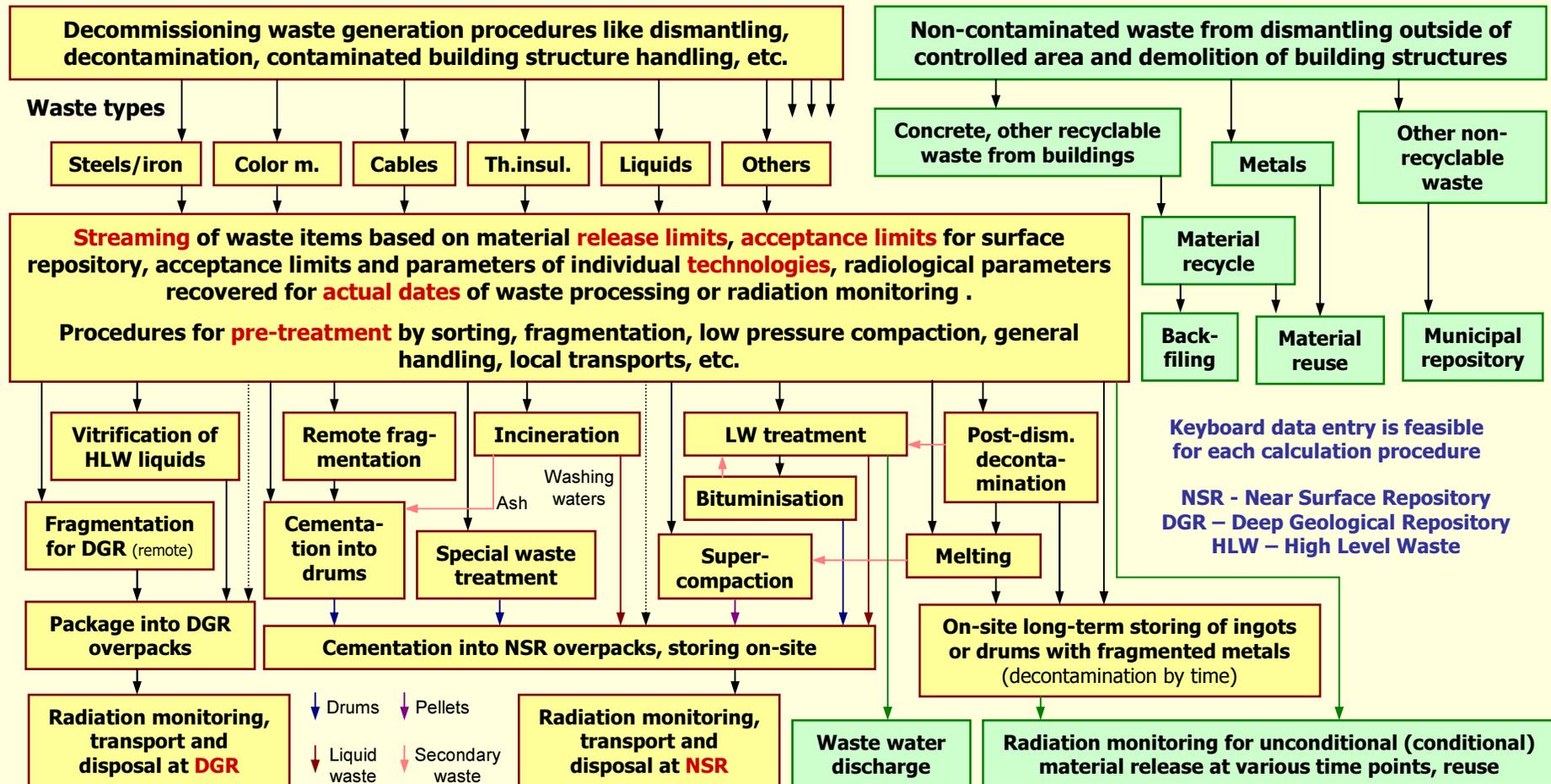
- Waste sorting and material streaming
- Treatment of solid waste – fragmentation, decontamination (wet / dry), melting, super-compacting
- Treatment of liquid waste - evaporation, bituminisation, cementation, vitrification, incineration, cementation
- Packaging into final disposal overpacks
- Long term storing, short term storing
- Final disposal
- Releasing of materials
- Management of non-contaminated materials

If the waste management procedures will be included into the main calculation stream and the inventory and interim material data will be linked, the accuracy of cost calculation can be higher.

5. Waste management in cost estimate process

Example of a waste management scheme used for costing

Review scheme of waste management in OMEGA for decommissioning costing and for general waste management projects optimisation using the keyboard data enter and internal OMEGA tool

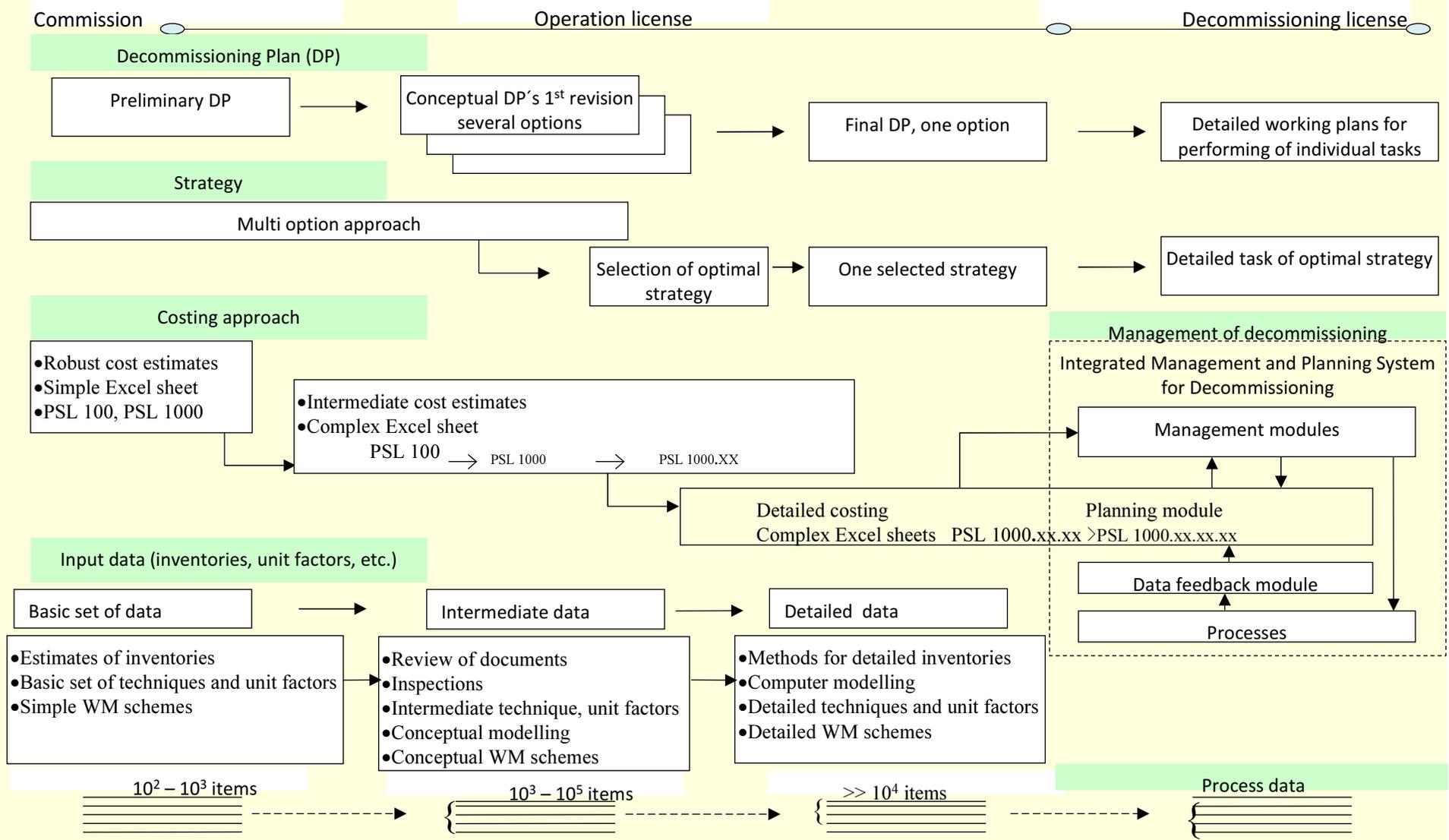


6. Grading aspects in cost estimating

The cost estimating process has several phases starting from preliminary cost estimates up to the detailed cost estimates used for planning of decommissioning. The individual phase can be as follows:

- **Preliminary cost estimates** at the level of order-of-magnitude estimates. This approach is applied in the early phases of preparing the decommissioning during the operating phase of the nuclear facility.
- Cost estimating in the frame of the **decision making process**. The main aim of this phase is to decide for a selected decommissioning option. The selection should be supported by definition, calculation, optimisation and evaluation of such a set of decommissioning options which cover all possible scenarios of decommissioning in the frame of the decommissioning project.
- For selecting the optimal decommissioning option, the principles of **multi-attribute analysis** should be applied. The criteria and weighing factors for selecting the option should be defined. In the process of evaluation, the data as a result of calculation and the subjective opinion of experienced experts are used for selecting the optimal option.
- **Final decommissioning costing** which develop the detailed data for planning of the decommissioning activities. The detailed work with the cost calculation structure and work breakdown structure is the base for this phase.

6. Grading aspects in cost estimating



7. Cost control in decommissioning projects

The factors with main impact on the estimated costs, which causes the differences between the calculated and real costs, may be identified and managed as follows:

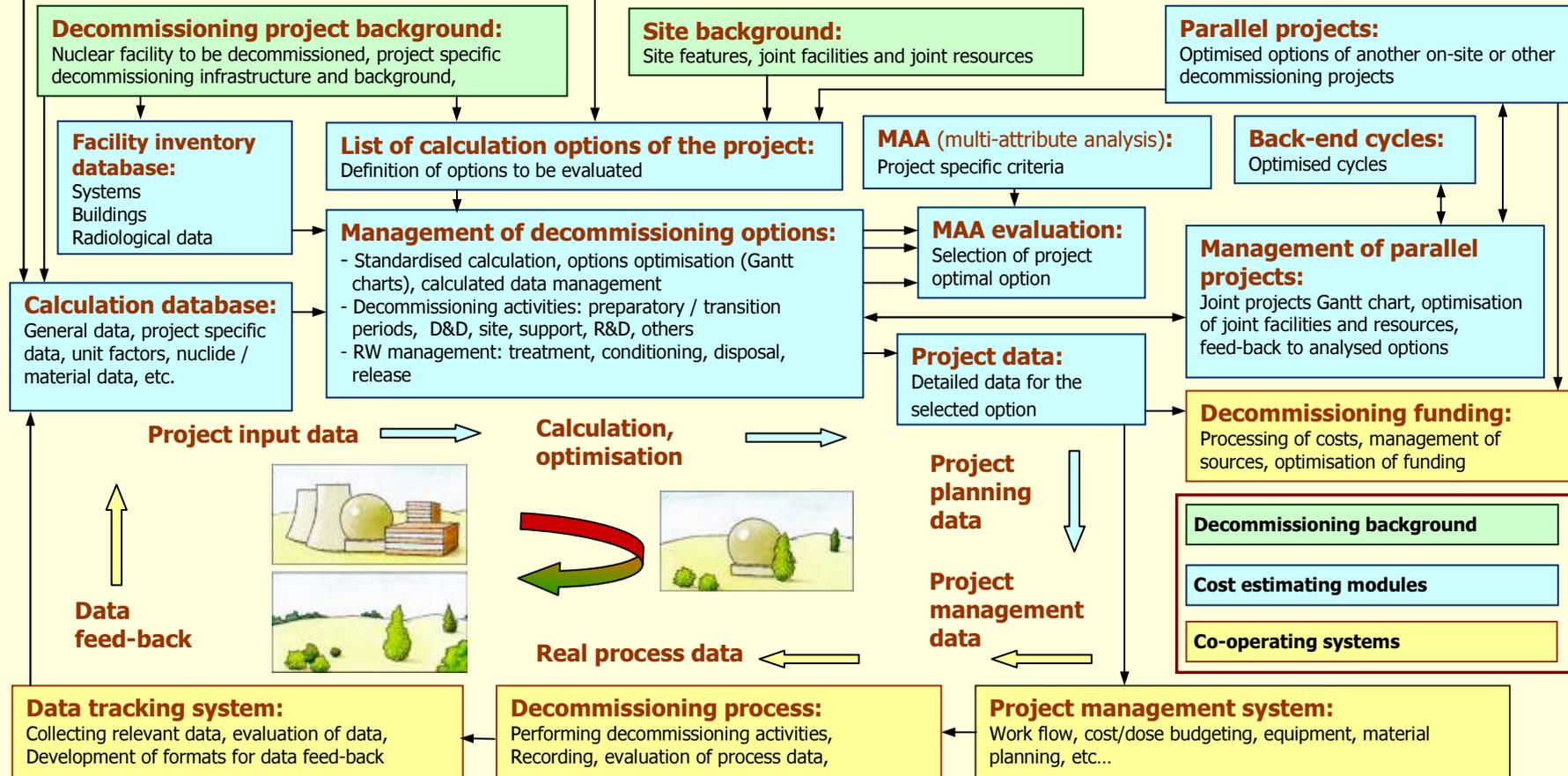
- Changes in scope of the decommissioning project - **parametric studies** can be applied to determine the impact to the project
- Inflation rate – can be managed by periodical re-evaluation
- Discount rate (used to estimate the **net present value** of future costs) – periodical re-evaluation
- **Contingency** (amounts of money for unforeseen cost elements) – proper adjustment for individual items, grading at various levels of costing, activities with higher increase factors,
- Special contingency items – adding extra cost elements for most risk items with significant impact on costs like disposal, regulatory involvement, politics, etc.
- Quality of input data – evaluation of **impact of inaccuracy of input data** on calculated costs by parametric **sensitivity analysis**
- **Data feed-back** from decommissioning process. The input data should be permanently reviewed and upgraded based on data collected from decommissioning activities performed according the plan of the decommissioning project. In this way the accuracy of cost estimation is **permanently improved**.

8. Summary of the cost estimation process Principal scheme

Principal scheme of cost estimate process and decommissioning data flow

Country specific decommissioning infrastructure and decommissioning background:

Legislative aspects, material releasing criteria, RW management technologies, funding aspects, stakeholders involvement, social aspects, D&D technologies available, disposal aspects, site aspects, decommissioning experience, public involvement, etc.



8. Summary of the cost estimation process

Main phases

Individual phases of decommissioning costing are following:

- **Description of the facility related to decommissioning**
 - Study of the facility documentation, history of operation, and other relevant documents, inspection and surveys of the facility, consultation with operational personnel, ...
 - Development of the description of the facility relating to decommissioning
 - Technical description of technologies and buildings
 - Radiological characterisation and description
- **Inventory of the nuclear facility for decommissioning**
 - Technological and building inventory and relevant radiological parameters (contamination, activation, dose rates, nuclide vectors):
 - The inventory at the level of a **feasibility study** can be done as a simple list of inventories
 - The inventory at a **detailed level** with the structure building objects – floors – rooms - individual items in the rooms (technological equipment, building materials, building surfaces)
 - The inventory for the **reactor structures** is developed as separate task including material modelling of the reactor structures and calculation of activation of materials. The inventory structure should correspond to the considered dismantling procedures.

8. Summary of the cost estimation process

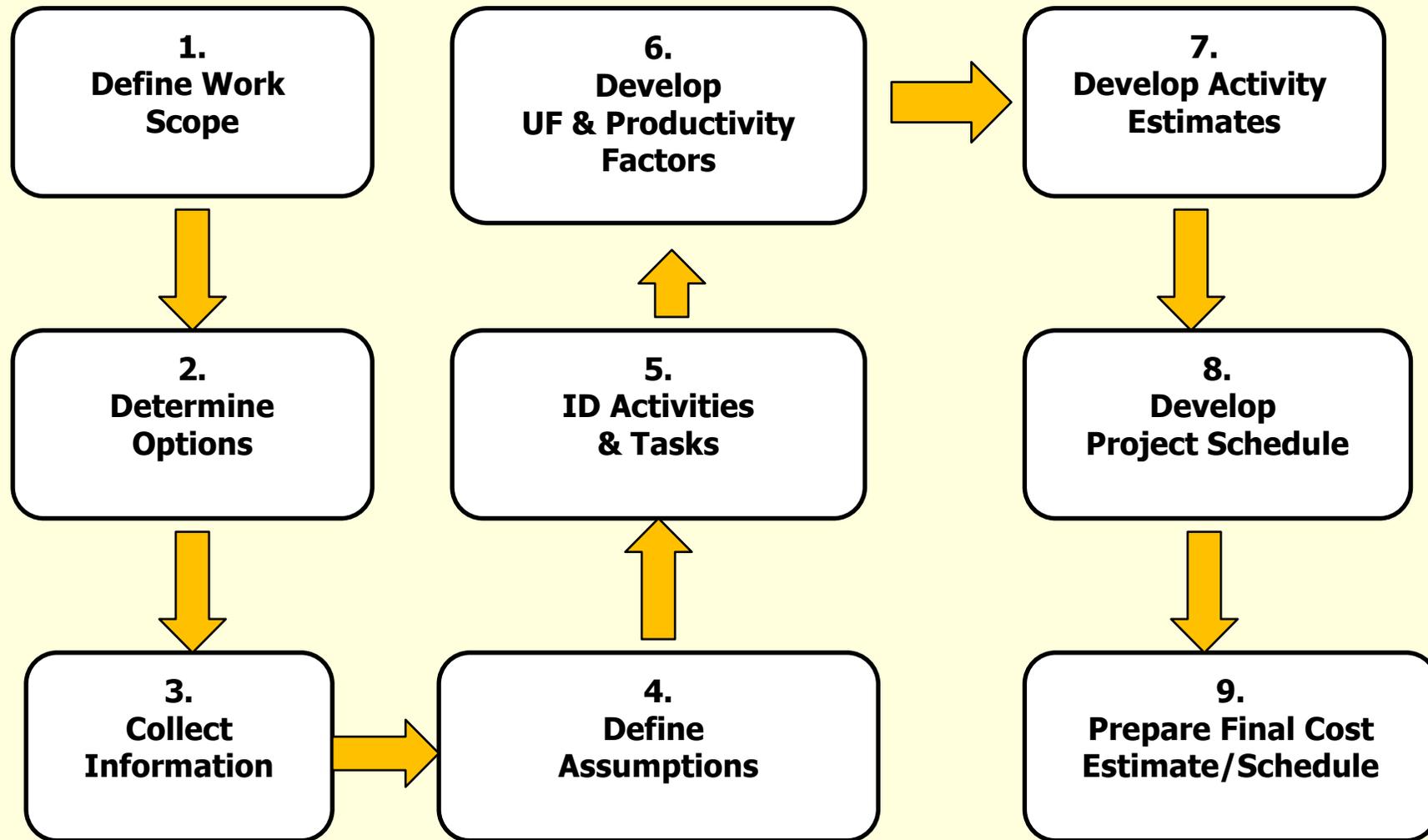
Main phases

- **Decommissioning infrastructure / technologies for the decommissioning project**
 - Review of the actual state in decommissioning related to the project
 - Review of technologies available / recommended for the project
 - Review of unit factors,
 - Development of the database with unit factors and parameters of decommissioning technologies, waste management and general data

- **Decommissioning options**
 - Definition of decommissioning options and their structure
 - Inventory of decommissioning activities
 - Development of the database for period dependent activities and fixed costs
 - Development of the calculation structures for individual options as an interaction of the standardised structure of decommissioning activities and the facility inventory
 - Calculation, optimisation, evaluation of individual options
 - Comparison of options, selection of the optimal option based on multi-attribute analysis
 - Preparation of final data for the selected option

8. Summary of the cost estimation process

Graphical interpretation of basic steps in decommissioning costing process (US approach)



8. Summary of the cost estimation process

Concept of the integrated cost methodology

- The known cost estimating methodologies generally calculate the costs in **several computational modules** and the final data are developed as summing up and processing of results of individual modules.
- The accuracy of calculation cost estimating especially related to waste management and to radioactive decay-dependent decommissioning activities, can be increased by introducing the calculation procedures that implement the **radioactive decay** on an on-line basis and simulate the **real material flow** in decommissioning by appropriate data linking within the calculation process.
- When implementing the standardised cost structure and by implementing the waste management activities into the calculation core, a **compact calculation structure** is created which include all decommissioning activities.
- When using the concept of the work breakdown structure developed as the upper layer over the standardised calculation structure and at the same as the interface to the user, new possibilities are created for **on-line optimisation** of the calculation option by using the standard planning software.
- Compactness of this type of the standardised calculation structure enables the **parametric evaluation** the impact of various input parameters on decommissioning costs.

- Decommissioning costing is a matured methodology which is capable to develop reasoned data for decommissioning planning. The prerequisite is the **sound understanding of individual calculated cost items** (inventory data, calculation methods, structure and meaning of results).
- There is a general need for **common understanding** of cost items and the cost methodology. The differences which remain can be suppressed by implementation of the Proposed Standardised List (**PSL**) of cost items for decommissioning. **Implementation of PSL** in decommissioning costing is highly recommended by the IAEA.
- The PSL structure should be promoted by international organisations, e.g by developing a more detailed guidelines. The initiatives for standardisation in cost estimation methodologies should be supported.
- The decommissioning cost are **manageable** and can be kept closer to the reality by:
 - In the pre-planning phases by **periodical updates**.
 - During performing the activities
 - by revising the baseline estimates. Inflation and the cost items which are sensitive for various parameters influenced from outside of the project, should be re-evaluated.
 - by selecting the proper contract management and by control of the project budget

Basic general recommendations [TECDOC 1476]

- Quality cost estimates and **up-front planning** is critical for economical, safe and in-time decommissioning
- Don't underestimate the value of **assumptions**. Each cost estimates should be site and facility specific. Site specific cost estimates are necessary for near term D&D
- Keep cost estimates **up-to-date** in order the decommissioning could be performed according real status during performing decommissioning
- Don't reinvent, use proven software and expertise
- **Contingency** is an integral part of the cost estimate
- Don't underestimate "soft" costs – engineering, licensing support

8. Conclusions and recommendations

IAEA TECDOC 1476 - General long term planning recommendations

- Prepare a detailed **cost estimate** in a manner that can be **updated periodically** as conditions change (analytical cost estimating systems with **on-line links** to inventory database and database of calculation parameters).
- Prepare a **funding plan** so it can be adjusted periodically.
- Seek and secure approval from regulatory bodies to collect funds for contribution to the trust fund.
- Establish a core group within the organization to follow decommissioning issues throughout the life of the facility.
- Prepare a preliminary **transition plan** to identify the functional personnel and activities needed to transition from operations to decommissioning (operational finance vs. fund).
- Work with regulatory bodies to support them in the development of regulatory actions and rules.
- Maintain an open dialogue with local politicians and the public, and hold public meetings to keep everyone informed on developments affecting the community.

8. Conclusions and recommendations

TECDOC 1476 - Recommendations for cost estimating

- Prepare cost estimates on a **site-specific basis**.
- Review and adapt the EU, OECD and IAEA report, "**A Proposed Standardized List of Items for Costing Purposes in the Decommissioning of Nuclear Installations**" for development of site-specific cost estimates.
- Prepare a **Work Breakdown Structure (WBS)** of the site-specific activities for the facilities to be decommissioned with links to decommissioning plan.
- Address whether spent fuel storage and disposal costs are to be included in decommissioning costs and funding (operational waste?).
- Base the cost estimate and planning on the historical site assessment and **detailed characterization** performed for the facility.
- Address how waste will be transported and disposed in accordance with applicable regulations and identify available disposal facilities.

8. Conclusions and recommendations

Recommendations for cost estimating (cont.)

- Evaluate whether the owner/licensee will self perform the management and implementing of decommissioning or whether a contractor will be used.
- Evaluate the facility shutdown activities and sequencing necessary to prepare the facility for decommissioning.
- Estimate the costs for procurement of general equipment and material.
- Estimate the cost of dismantling the facilities.
- Determine the cost of waste disposition and appropriate alternatives.
- Include the costs for security, surveillance, and maintenance, site remediation and landscaping .
- Include the costs for project management of both the licensee/owner and the contractors, if used.
- Include contingency in the estimate for unexpected costs that are likely to occur.