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# **Financial Aspects of a Decommissioning Project**

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- The objectives of a decommissioning cost estimates are:
  - to indicate the cost required to complete a decommissioning project;
  - to determine the yearly budgets covering the expenditures;
  - to allow further definition of the funding mechanisms;
  - to make sure that sufficient funding is or will be available for the completion of the decommissioning project;
  - to optimize the dismantling sequence and timing and therefore minimizing the total decommissioning cost. <sup>3</sup>

## Elements of decommissioning costs: Statements from previous studies

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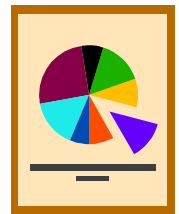
- Different costing methods have different data requirements;
- Some uncertainty is inevitable in all estimates of future costs, and no costing method is generally superior to others in this respect;
- Decommissioning cost estimates as published worldwide today show relatively large variations;
- The main important reasons of differences in cost estimates are:
  - the scope of the calculation;
  - the boundary conditions;
  - the decommissioning timing;
  - the waste management system;
  - the administrative factors (e.g. labour rates and legal system);
  - the financial (discount rate) factors.

## Elements of decommissioning costs: Standardised list of cost items



<http://www.nea.fr/html/rwm/reports/1999/costlist.pdf>

- The "standardised list" of IAEA/EC/NEA proposed eleven cost groups:
  - 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 site support
  - Research and development
  - Fuel
  - Other costs
- The list is then further broken down into tasks and subtasks.



## Elements of decommissioning costs: Inventory

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- decommissioning costs depend on the complexity of the nuclear installation, its physical and radiological inventory and local factors
- the draw up of an inventory is necessary for decommissioning cost estimate;
- 3 parts in an inventory:
  - Inventory of infrastructure and equipment
  - Inventory of radioactive waste (already present)
  - Inventory of nuclear material

# Elements of decommissioning costs: Inventory of infrastructure/equipment



|   |            |                          |                           |                 |   |   |                    |                                   |
|---|------------|--------------------------|---------------------------|-----------------|---|---|--------------------|-----------------------------------|
| Inventory id  |            |                          |                           |                 |   |   |                    |                                   |
| Installation  | Building   | Zone                     | Local                     | Circuit         | Category  | Sub-Category  | Description        |                                   |
| Material  | Mass<br>kg | Volume<br>m <sup>3</sup> | Surface<br>m <sup>2</sup> | Thickness<br>mm | contamin<br>$\beta\gamma$<br>Bq/cm <sup>2</sup> | contamin<br>$\alpha\beta\gamma$<br>Bq/cm <sup>2</sup> | activation<br>Bq/g | dose-<br>rate<br>$\mu\text{Sv/h}$ |
| contamin.   | X1         | -                        | X2                        | X3              | X4  | X5  | -                  | X6                                |
| activation  | Y1         | Y2                       | -                         | Y3              | -   | -   | Y4                 | Y5                                |
| Waste stream id.<br>List of nuclides and activities |            |                          |                           |                 |   |   |                    |                                   |

# Elements of decommissioning costs: Inventory of radwaste



| Inventory id |                          |                    |         |                      |       |                        |   |
|--------------|--------------------------|--------------------|---------|----------------------|-------|------------------------|---|
| Installation | Building                 | Zone               |         |                      |       |                        |   |
| Waste type   | Volume<br>m <sup>3</sup> | Waste stream       | density | Chemical composition |       | Radionuclide Inventory |   |
|              |                          |                    |         | Material             | %Mass | nuclide                | Bq/t  |
| XYZ-A0       | X1                       | SCK-<br>BU-<br>XYZ | min     | M1                   | %M1   | N1                     | A <sub>min</sub><br>A <sub>aver</sub><br>A <sub>max</sub> |
|              |                          |                    | average | M2                   | %M2   | N2                     | A <sub>min</sub><br>A <sub>aver</sub><br>A <sub>max</sub> |
|              |                          |                    | max     | M3                   | %M3   | N3                     | A <sub>min</sub><br>A <sub>aver</sub><br>A <sub>max</sub> |
|              |                          |                    |         | 8                    |       |                        | A <sub>min</sub><br>A <sub>aver</sub><br>A <sub>max</sub> |



Cost estimate is a mix of 4 types of costs:

- **costs based on detailed studies** are recommended for the cost evaluation of work packages requiring large engineering studies, preparation works and/or the use of special decommissioning techniques; (*e.g. RPV dismantling*)
- **work volume dependent costs** are associated with dismantling, decontamination, waste packaging, transport and disposal of components. These costs can be easily estimated using the unit costs methodology; (*e.g. piping*)
- **time dependent costs** are associated with on-site management, administration, routine maintenance, safety, security, insurances, taxes and fees to Authorities and Regulatory Bodies.
- **specific costs** are the costs for investments (*i.e.* decommissioning tools, dismantling and decontamination workshops, radiological survey, etc.), R&D, training of personnel, fees for the licensing process, contingencies, etc.

# Elements of decommissioning costs: Methodologies and techniques



Each cost is made up of 6 components *i.e.*:

- **labour costs** (including the workers salary, the allowances and the direct overhead costs);
- **services** (e.g. costs for work subcontracted outside the project);
- **expenses** (consumables for decommissioning tools, protective clothes, electricity, heating, telephone and water supplies, etc.);
- **investment costs** (under the form of a capital or capital rental or hiring cost in the case of unit costs methodology);
- **secondary waste** covering the waste produced by a decommissioning technique;
- **contingency** (cost to cover incomplete design or documentation, modification in the legal framework, changes in the market condition, tools/equipment breakdown, late delivery of supplies/equipment and adverse weather conditions)..





The cost is given by:

$$C_{\text{task/comp.}} = C_{\text{Lab.}} + C_{\text{Serv.}} + C_{\text{Exp.}} + C_{\text{Invest.}} + C_{\text{Sec.Waste}} + C_{\text{Conting}}$$

With

$$C_{\text{Labour}} = T_N \cdot \delta \cdot \text{HR}_{\text{OT}} \cdot (1 + \text{OC}) / \eta$$

$$C_{\text{Oher Cost}} = T_N \cdot \delta \cdot \text{HRS} \quad (\text{in case of time dependent cost) or,}$$

$$C_{\text{Oher Cost}} = Q \cdot \text{UC}_Q \quad (\text{in case of volume dependent cost})$$

- $T_N$  is the duration of the intervention in normal conditions;
- $\delta$  is a coefficient (generally  $>1$ ) accounting for the difficulty;
- $\text{HROT}$  is the Hourly Rate of the specific Intervention Team (IT);
- $\text{OC}$  is the Overhead Cost;
- $\eta$  is the ratio between the effective working hours and the total working hours;
- $\text{HRS}$  is the Hourly Rate of the specific service;
- $Q$  is the quantity;
- $\text{UC}_Q$  is the unit cost for a specific task<sub>1,r</sub>.



- Contingency rate depends on:

- the knowledge of the nuclear facility;
- the decommissioning techniques;
- the expected evolution of the boundary conditions

| <u>Activity Category</u>                       | <u>Contingency, %</u> |
|--|-----------------------|
| Engineering                                    | 15                    |
| Utility and DOC Costs                          | 15                    |
| Decontamination                                | 50                    |
| Contaminated Component Removal                 | 25                    |
| Contaminated Concrete Removal                  | 25                    |
| Steam Generator/Pressurizer/Circ. Pump Removal | 25                    |
| Reactor Removal                                | 75                    |
| Reactor Packaging                              | 25                    |
| Reactor Shipping                               | 25                    |
| Reactor Burial                                 | 50                    |
| Conventional Radwaste Packaging                | 10                    |
| Conventional Radwaste Shipping                 | 15                    |
| Conventional Radwaste Burial                   | 25                    |
| Clean Component Removal                        | 15                    |
| Supplies/Consumables                           | 25                    |

*(From TLG study)*



The most common estimating techniques are:

- **the *bottom-up technique*** *i.e.* the subdivision of the work in discrete tasks allowing to complete the decommissioning operation; for each discrete task a cost estimate is made;
- **the *comparison technique*** *i.e.* the deduction of the cost for the decommissioning of a specific component from the previous decommissioning of a similar component; if required, the cost can be adjusted to account for differences in radiological conditions, complexity and accessibility;
- **the *parametric technique*** *i.e.* the use of a model based on key driver parameters deduced from previous decommissioning experiences;
- **the *expert opinion technique*** *i.e.* several experts are iteratively consulted until a consensus cost estimate is reached.

# Elements of decommissioning costs: Influencing factors



- Decommissioning cost estimates are influenced by :
  - **Political factors;**
  - **Social factors;**
  - **Economical factors;**
  - **Technical factors.**



## Elements of decommissioning costs: Influencing factors: Political fact.

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- Legislation for conventional and the nuclear safety requirements i.e. the protection of the workers, the public and the environment:
  - Collective and specific yearly dose;
  - the criteria for free release of material;
  - Criteria for the discharge of gaseous and liquid effluents;
- the availability of 3 types of disposal facilities:
  - a site for the burial of very low radioactive waste (see France); or the possibility to free release materials
  - a near-surface disposal facility for short lived nuclides bearing waste;
  - a geological disposal facility for long lived waste and high level waste
- Open or close cycle for the back-end of spent fuel

## Elements of decommissioning costs: Influencing factors: Social fact.

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- Decision-making process is influenced by the local social and economical condition. It concerns:
  - the degree of outsourcing;
  - the employment of former plant employees;
  - the use of new or high technologies;
  - the choice of an immediate or a deferred dismantling strategy.
- The involvement of stakeholders, from the Authorities and Regulatory Bodies to the public is rising from year to year.

## Elements of decommissioning costs: Influencing factors: Economical fact.

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- Decommissioning projects are stretched over a long period of time, in particular in the case of a deferred dismantling.
- Each cost component (labour costs, service costs, expenses, investment costs, expenses, waste costs) has its own inflation rate over the decommissioning period.
- The calculation of the yearly budget (in current value) has to take into account the specific inflation rate of each cost component.

## Elements of decommissioning costs: Influencing factors: Technical fact.

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- Knowledge of the installation at the moment of the final shutdown is very important. It concerns:
  - physical and radiological inventory
  - the overall state of the infrastructure and equipment.
- Waste Acceptance Criteria and waste management costs will influence the techniques to be used in order to optimize the decommissioning costs e.g:
  - the use of large waste packages
  - the extensive use of decontamination techniques to face the waste cost escalation
- Management of nuclear site containing several facilities of the same types
- Evolution of the D&D techniques and their performances

# Elements of decommissioning costs: Influencing factors: Practical experiences

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- Decrease of the free release level by a factor 10 generates roughly the following increases:
  - $\pm 5\%$  of the cost estimates;
  - $\pm 17\%$  of the waste volume;
  - $\pm 7\%$  of the doses.
- For the Biblis reactor, the comparison of the studies 1977 and 1991 leads to the following observations:
  - the aggregate decommissioning cost estimate increases in a similar way as the inflation; (*i.e. no dramatic changes*)
  - in 1991 the waste cost represented 18,5 % of the aggregate cost instead of only 6,5 % in 1977;
  - in 1991 the management (including licensing) cost represented 33,5 % of the aggregate cost instead of only 6,5 % in 1977;
  - a decrease of the dismantling costs by a factor 2.

## Elements of decommissioning costs: Scheduling of a decommissioning cost



Scheduling of a decommissioning cost is also based on:

- draw-up of the planning corresponding to the decommissioning strategy
- yearly budgets from the “overnight” cost estimate are defined in constant money value;
- yearly budgets are then converted in current money value taking into account the specific escalation rate of each cost component (labour, waste, investments and expenses)
- discount rate technique may be applied to calculate the decommissioning cost in net present value



A step approach is recommended. The steps are:

- gather all the as-built drawings, construction records and operation records to allow the set-up of a detailed physical and radiological inventory;
- definition of the boundary conditions e.g.:
  - free release limits
  - discharge criteria for gaseous and liquid effluents
  - final objectives (e.g.: green field or restricted reuse)
  - availability of disposal sites for the various categories of produced waste
- select the main decommissioning strategy
- define the waste management strategy
- set-up a planning detailed into work packages, tasks and subtasks

**This process gives as result the overall project duration, the critical path and the yearly detailed budgets in constant money value.**



- Financing schemes fall into the following categories:
  - those that rely on a levy on electricity generation;
  - those that rely on funds from the Licensee;
  - those that rely on State or Government funding (historical legacy).

## How to secure the funds ?

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- The fund can be secured:
  - before the start-up of the nuclear installation;
  - by yearly provisions over the lifetime of the installation;
  - by yearly budget allowances covering the decommissioning expenditures; (*case of historical liabilities*)
  - by yearly payment of an insurance fee.

Where can the fund be secured?

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- In specific account within the operator's accounts
- In a separate bank account
- At the Government (case of levy or tax on the electricity)
- In a separate dedicated fund managed by Government agency
- Through an insurance (then including some risk fee)

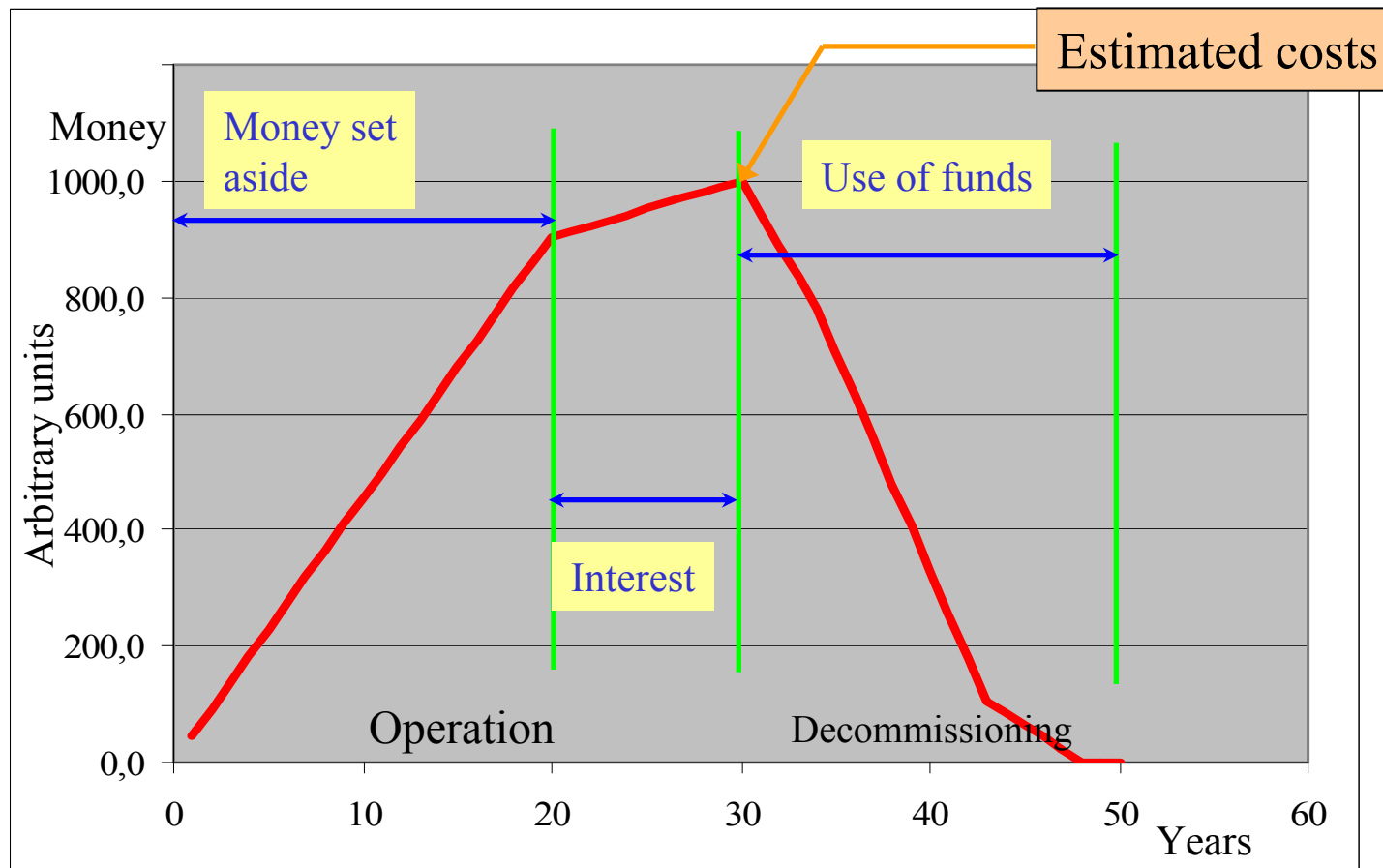
## Financing mechanisms: some specific topics

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- The financing scheme must ensure that sufficient money will (always) be available at the time of shut down.
- It is important to ensure a regular reassessment of costs. (*see further*)
- Discount rate techniques are often used to decrease the present liability.

# Example of a typical funding mechanism





## Discounting: How does it work ?

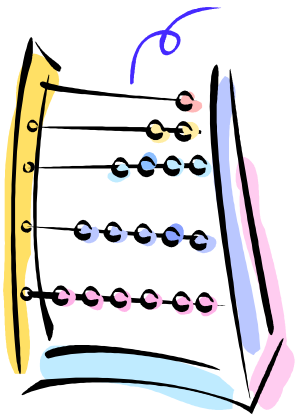
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- A simplified formula:

$$B = A * \frac{(1+a)^T}{(1+i)^T}$$

Where:

- B= net present value
- A= future amount
- T= time in years
- i= nominal interest rate
- a= inflation rate



## Discounting: How does it work ?

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- Sometimes the formula is still more simplified by defining a “real” interest rate  $r$  as

$$r = \frac{(1+i)}{(1+a)} - 1$$

## Example of an annuity calculation

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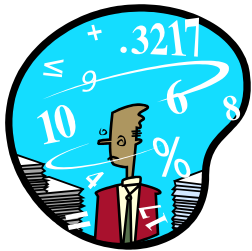


- Let us assume that the operator has to set money aside during 20 years for having the needed amount after 30 years
- If  $r$  is the “real” interest rate, and  $A$  the calculated amount to obtain after 30 years,
- Then, 20 years after start-up the amount to reach is:

$$C = \frac{A}{(1+r)^{10}}$$

## Example of an annuity calculation (continued)

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- The annuities are thus calculated as follows:

$$a = \frac{r}{(1+r)^{20}-1} \times C$$

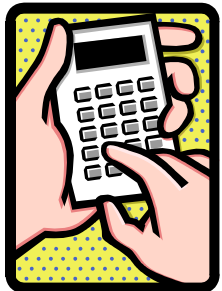
# To better understand: the evolution of the provisions



| Year    | Provision constituted | Calculation Year N |                | Cumulated provision  |
|---------|-----------------------|--------------------|----------------|----------------------|
|         |                       | annuity            | interest       |                      |
| Year 1  | -                     | a                  | -              | $A1 = a$             |
| Year 2  | A1                    | a                  | $A1 \times r$  | $A2 = A1(1+r) + a$   |
| Year 3  | A2                    | a                  | $A2 \times r$  | $A3 = A2(1+r) + a$   |
| ...     | ...                   | ...                | ...            | ...                  |
| Year 20 | A19                   | a                  | $A19 \times r$ | $A20 = A19(1+r) + a$ |
| Year 21 | A20                   | a                  | $A20 \times r$ | $A21 = A20(1+r) + a$ |
| ...     | ...                   | ...                | ...            | ...                  |
| Year 30 | A29                   | a                  | $A29 \times r$ | $A30 = A29(1+r) + a$ |

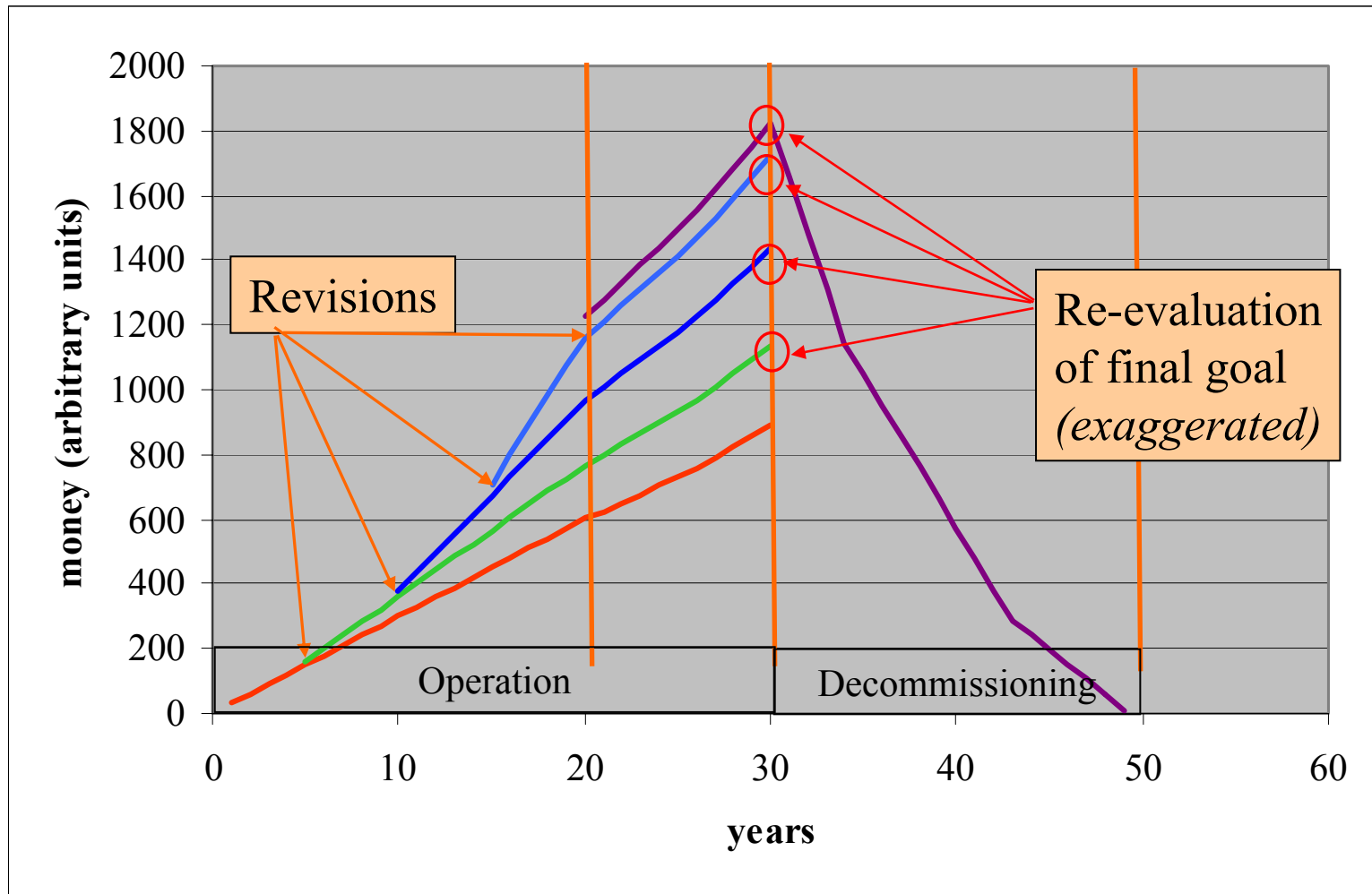
## To take account of the inflation rate variations

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- The variation of the inflation rate is then reviewed regularly by adapting the “goal”  $A$  as follows:  
$$A_{\text{adapt}} = A_{\text{const}} \times (1+a)^{30}$$
- But often the complete amount is reviewed (or even **re-evaluated**) and the whole calculation is started again

# Example (*exaggerated*) of the review process



# Review or re-estimate the costs WHY ?

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- Changes in inflation rates (see before)
- Discount rates (or interest rate) changes
- Waste management costs escalation (often higher than inflation)
- Advances in technology (e.g. robotics, measurement methods, etc.)
- Changes of safety rules and regulations (e.g. clearance criteria, dose limits, classical safety, etc.)