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# On the precision in cost estimation and the associated consequences for the planning for decommissioning of a nuclear power plant – - an explorative approach

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## This presentation

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- Cost estimation methodology, in general
- Cost calculation in nuclear decommissioning
- Conclusions

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## Polluter pays principe in the Swedish Environmental code

"*Persons who pursue or have pursued an activity or taken a measure that causes damage or detriment to the environment shall be responsible, until such time as the damage or detriment ceases, for remedying it to the extent deemed reasonable …".*

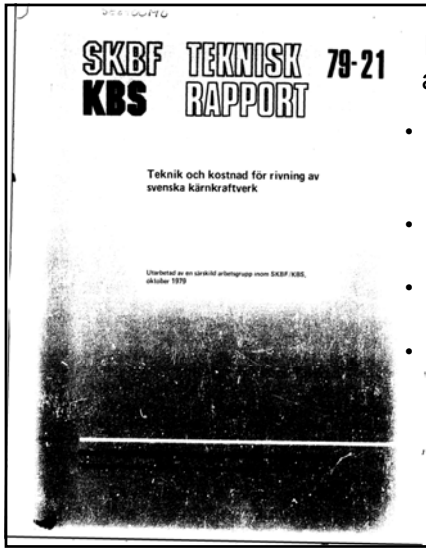
Since there is no limit in time, a liability will exist as long as remediation has not been completed

## Prerequisite for nuclear power

- Protection of health and the environment - now and in the future

=> Money available at the time when it is needed

<= Cost estimates with sufficient precision - to be made now for decommissioning to take place perhaps after several decades




## A long journey

- Between the first controlled nuclear chain reaction in 1942
- And the first IAEA meeting on decommissioning in 1975

in which the Swedish delegation stated the following:

"*The current approach to decommissioning studies is to convene a specialist team with back-up resources to* ***deal with situations as they arise***"




## But the Swedes didn't actually drag their feet

- First study of NPP decommissioning & associated cost in 1979
- B1 / O2 reference units 600 MW each
- Cost (including waste) = 10 – 15 % of new plant
- Cost estimate
  - 500 MSEK at 1979 level
  - 1550 MSEK at 2011 level
  - 164 M€ at 2011 level
  - 237 M$ at 2011 level

## Decommissioning cost calculations, one of the reactors at Barsebäck

| | SKB 1979 | SKB 2004 [1] | TLG [1] |
|---|---|---|---|
| MSEK 1979 | 500 | | |
| MSEK 2004 | | 802 | |
| MSEK 2005 | | | 1632 |
| MSEK 2011 [2] | 1550 | 894 | 1812 |
| M€ 2011 | 164 | 94 | 190 |
| M$ 2011 | 237 | 136 | 276 |

1. Differences between TLG and SKB/Westinghouse discussed/explained in SKB R-09-55
2. Swedish consumer price index used for calculation

## IAEA 1975 decommissioning report

- Decommissioning is technically feasible
- Cost calculations are important for obligations to society & acceptance
- Need to establish standard method(s) with
  - Standardized itemisation, and
  - Unit cost factors
  - Potential cost raisers such as decontamination costs separate
- Open exchange of
  - Technology used
  - Costing information
  - Collective dose

## Questions to be illuminated

- Why are there substantial differences between different cost estimates?
- What is a reasonable level of ambition for such cost calculations that are made primarily for the purpose of assuring adequate financing?
- What decommissioning cost estimation strategies are pertinent for the purposes of
  - Financial planning?
  - Execution of decommissioning operations?

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## Cost estimation methodology

- AACE International (Association for the Advancement of Cost Engineering)
  - Has been instrumental in the development of cost estimation methodology
  - Founded in 1956
- Response to need of chemical and other industries
- The need is different at different stages of planning for a new facility

## At least three stages can be identified (IAEA-TECDOC-1476 from the year 2005)

- ***Order-of-Magnitude Estimate***: One without detailed engineering data. Expected level of accuracy ***-30% to +50%.***
- ***Budgetary Estimate***: One based on the use of flow sheets, layouts and equipment details. Expected level of accuracy ***-15% to +30%.***
- ***Definitive Estimate***: One where the details of the project have been prepared and its scope and depth are well defined. Expected level of accuracy ***-5% to +15%.***

## Techniques for estimation of cost From *decommissioning handbook*

- ***Bottom-up.*** Quantities derived from e g drawings are multiplied with per unit costs from previous facilities.
- ***Specific analogy***. As bottom-up but with adjustments to account for differences in relative complexity of performance e t c
- ***Parametric.*** Historical databases and statistical analyses => cost equations / cost estimating relationships

## Method versus stage, in general

| | |
|---|---|
| Order of magnitude<br>-30 % to + 50 % | Parametric technique<br>others possible |
| Budgetary estimate<br>-15 % to + 30 % | All possible |
| Definite estimate<br>-5 % to + 15 % | Bottom-up technique<br>others possible |

## Strongly maintained by AACE International

- A cost figure has no meaning unless it is associated with the pertinent uncertainty

## Discovered in the 1970's

- Summations based on data from previously constructed facilities give
  - Precise results at late stages
  - Poor results at early stages
- This lead to the introduction of *parametric cost estimating* suitable especially for early stages

C. Peter Rapier:
*Toolmaking for Better Conceptual Estimates,*
AACE Transactions, 1977

***However, the facts of life are that very few companies value and maximize use of their feedback. Fewer still do anything in the way of casting their cost data into a useful form for application on future estimates. What happens is that, to get credibility into their conceptual estimates, companies resort to making preliminary designs and takeoffs to develop the estimate. Then after doing all that, they still lack faith in the results because the project has not really been designed yet. They know from experience there will be many changes to the details before the design is completed. This is a waste of engineering energy.***

## Discovered in the 1970's, cont

- *Parametric cost estimating* utilises
  - existence of numerical relations between "system attributes" (e g a sub-system) and cost
  - relations not necessarily linear
- *Parametric cost estimating* implies / requires
  - That existing data must be sufficiently abundant to allow mathematical/statistical analysis (typically several completed facilities)
  - That existing data from completed facilities must be thoroughly analysed
  - That analysis of a plant at early stage of planning becomes simple, in comparison with other methods

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## Nuclear decommissioning

- Almost exclusively bottom-up
- Reasons include
  - Facilities exist and all items can readily be identified
  - Initially, the number of facilities decommissioned was low, thus making statistical analysis difficult
  - Focus on imminent decommissioning, less on assurance of financial resources in distant future (at least initially / / special situation in the US: NRC *vs* GAO)

## Deviations / agreement between plants, and between calculated and incurred costs

- OECD/NEA 1991 "*Decommissioning of nuclear facilities; an analysis of the variability of decommissioning cost estimates*"
  - Conclusion: Numbers should vary between different reactors
- OECD/NEA 2003: "*Decommissioning of nuclear facilities; Policies, Strategies and Costs*"
  - Conclusion: increased precision by bottom-up with
    - Improved items list
    - Improved scope and other cost raisers

## Last five years plus of international meetings

- Many sessions on lessons learned in decommissioning
- Few presentations on uncertainty in cost calculations
- Maintained by LaGuardia - founder of and affiliated to TLG Services - that agreement between calculated and incurred costs are
  - 8,8 % for Maine Yankee (880MWe PWR), and
  - About 6 % for Big Rock point (60MWe BWR)

  Paper also explains when calculations go wrong (NEA International workshop, Rome, 2004)

## Public Utilities Commission of the State of California

- Had found lack of transparency and comparability of the decommissioning cost estimates provided for Commission review
- The commission therefore ordered an independent Panel of decommissioning experts to review cost estimates
- Report on March 1st, 2011
- Commission decision on July 14th, 2011

## Examples of Panel Conclusions 1

- any conclusions about future decommissioning costs "*involve a significant amount of informed speculation about events that will only be fully understood in the future…and which may resemble historical events to a greater or lesser degree as circumstances change*."

## Examples of Panel Conclusions 2

- the Panel found substantial barriers to comparing prior decommissioning experiences because reported estimates and costs from around the country are not always public, or even similar in what activities are included and the information disclosed

## Examples of Panel Conclusions 3

- With the exception of Rancho Seco, all actual costs appear to exceed estimated costs by varying margins, e.g., Connecticut Yankee exceeded estimates by 82% and SONGS 1 by 32.5%.
- However, the Panel presented these results more as indications than actual factual findings due to the challenges of comparison.

## Examples of Panel Conclusions 4

- As noted above, there were numerous problems in obtaining accurate and comparable figures.
- For example, some information is withheld as proprietary, public records can be incomplete, and estimates may not include identical activities or may even omit key elements such as site restoration.

## Examples of Panel Conclusions 5

- Eight items were identified that account for 99.4% of the cost difference between SONGS 2 and 3, and Diablo Canyon 1 and 2.
- By a large margin, the assumed site condition at the end of decommissioning is the primary difference between the estimates

## Examples of Panel Conclusions 6

- Historical experience in the U.S. has provided no consensus on the best way to decommission a nuclear plant because every site has different challenges, technology is improving, and new ideas are borne from experience.

## Examples of Panel Conclusions 7

- The Panel was asked to develop a common format for decommissioning cost estimates that would result in greater transparency and comparability.
- However, the fact that cost estimators use proprietary and substantially different decommissioning cost models to develop their estimates, combined with the unique aspects of decommissioning SONGS, make a common cost model impractical.

## Examples of Panel Conclusions 8

- The panel found a key error that reduced the Palo Verde estimate by about half.
- It took a lot of digging by the Panel and SCE to figure out that a double counting of waste volume had occurred.

EU report: Comparison among different decommissioning funds methodologies for nuclear installations

- Starting from the definition of "decommissioning" it is almost impossible (or only with an enormous input of time resources which is an inefficient exercise) to compare and assess the financial risks and consequences of the applied decommissioning funding systems in all European countries.

EU report: Comparison among different decommissioning funds methodologies for nuclear installations, continued

- "*Three main problems exist:*
  - *The definition in each country only covers a specific, in most cases a limited range of decommissioning activities. Such an environment favours the emerging of under funded situations.*
  - *In addition, even provisions for the same range are not comparable as they are based on country specific accounting treatments.*
  - *And third, the basis (assumptions) of cost calculation is not always disclosed.*"

Openness & information exchange required for review and public insight

- It is virtually impossible to validate an estimate without the details of how the estimate was prepared.
- At best, a comparison can be made of the total estimated cost to the actual cost with no attempt to correlate individual cost drivers.
- Often, the cost and schedule tracking system used during decommissioning is not correlated to the cost estimate structure, so direct comparisons are impossible.

LaGuardia at NEA International workshop, Rome, 2004

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## Relevance for Sweden

- The Barsebäck experience of deviating cost estimates is hardly unique in an international perspective
- => Warranted to look for
  - Generic factors as well as
  - Barsebäck specific factors

  In order to improve cost calculations
- And especially to attempt to find what may be pertinent for cost calculations for the purpose of adequate fees and funds

## Scope

- Differences in scope is frequently put forward as the main reason for deviances
- Scope is understood in a different way by different parties
  - Professional cost estimators do frequently not provide overall uncertainty figures. Instead, they exclude this, that and the other here and there in their reports.
  - Plant owners and Authorities expect that the estimates of the total cost refer to – just that - what is actually the total cost

## Cost raisers

- Nordic co-operation under the auspices of the Nordic Nuclear Safety Research
- The following main categories were identified to highly influence cost and uncertainty
  - Radiological surveying
  - Method selection
  - Specific features that might be identified through hazard identification methodologies

## Need for and use of information

- Almost impossible for an Authority to inspect if proprietory constraints
  - Limited public insight
  - Limited feedback on performance
- Access to data from limited number of NPP:s
  - Not so detrimental for use of bottom-up techniques
  - Discourages or invalidates use of parametric techniques

## Bottom-up methodology

- Easy and straightforward to apply in the sense that the facility exists and can readily be mapped
- Treacherous in the sense that the per unit entities may be uncertain. This includes:
  - Radiological situation (survey for the purpose of decommissioning ≠ that for the purpose of operation)
  - Special features
  - End state prerequisites
- Bottom-up feasible ⇔ all such features are included and their influence on the total uncertainty are known

## Parametric methodology

- Murphy & Hickery ”*Parametric Cost Estimates for an International Competitive Edge*” presented at WM’05:
  - Developed for and tested on nuclear research and technology development facilities
  - ”Reasonable expectations” … ”fall within 10 % when compared to actual cost data”
  - Belived to be possible to improve
- Appear not to have been tested on NPP:s
  - (except for scaling linearly with electric power output which is not sufficiently accurate)

## Very simple parametric method

Let the total calculated cost be given by

$$K^0 = \sum_i p_i$$

Where
$K^0$ = the total calculated cost
p = cost item, och
i = index for cost item

An adjustment to total actual incurred total cost can be written

$$K^v - K^0 = s \sum_i w_i p_i$$

Where
$K^v$ = the total actual incurred cost
$w_i$ = weight factor
S = scale factor

Weight factors are derived by expert judgment.
They are given e g the values 1, 2, 4 or 8

## Very simple parametric method, continued

The scale factor can then be determined by

$$s = (K^v - K^0) / \sum_i w_i p_i$$

An adjusted value for the total cost can now be obtained by using the equation

$$K^{adjusted} = \sum_i (1 + s w_i) p_i$$

Where
s and $w_i$ refer to a similar plant with known costs
$p_i$ refers to the plant for which the improved calculation is intended

## What precision is warranted for calculations for financial funding?

- Sufficiently precise in order for polluter pays principle to be respected
- But uncertainty can be managed by securities
- Reasonable to have more comprehensive cost bases for decommissioning operations
- The requirements are different:
  - Operations require bases & cost structures to be used for procurement
  - Financial funding adequacy requires reasonably conservative total cost

## Financial funding adequacy

- Parametric methodology might be preferable – at least in part
  - Might be applied with less effort on a number of facilities as compared to bottom-up
  - Might enable adequate precision (e g ± 15 %)
  - Precision might depend mainly on definition of scope & cost raisers rather than methodology
  - Might be feasible now that a relatively large number of NPP:s have been decommissioned
  - Requires that data can be shared

## Comments on Barsebäck

- Validation with regard to already decommissioned facilities should to be continued
- Important to focus on uncertainties and to identify and to quantify those that contribute the most
- Important to analyse possibilities for better methodology, especially for long-term predictions
- Different methodologies for cost estimations need to be studied and their relative merits evaluated

## Comments on Barsebäck, cont

- Such information can be used in comparisons between the Swedish and Finnish reactors, and especially between those of ASEA/ATOM design
- Studies on Oskarshamn 2 should be included
- Plant owners and Authorities should assess what exchange of information serves their interests the best with regard to
  - Efficiency of cost calculations for different purposes
  - Public insight
- The result should be communicated to those who perform calculations services as a given prerequisite for orders

Thank you
for your atention