DEM 2008
Decommissioning Challenges: an Industrial Reality?
Sept. 28 to Oct. 2, 2008 - Avignon, France

Regulation evolution in Sweden with emphasis on financial aspects of decommissioning

Staffan Lindskog ***and*** ***Rolf Sjöblom***

SKi

Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

TEKEDO

THEME

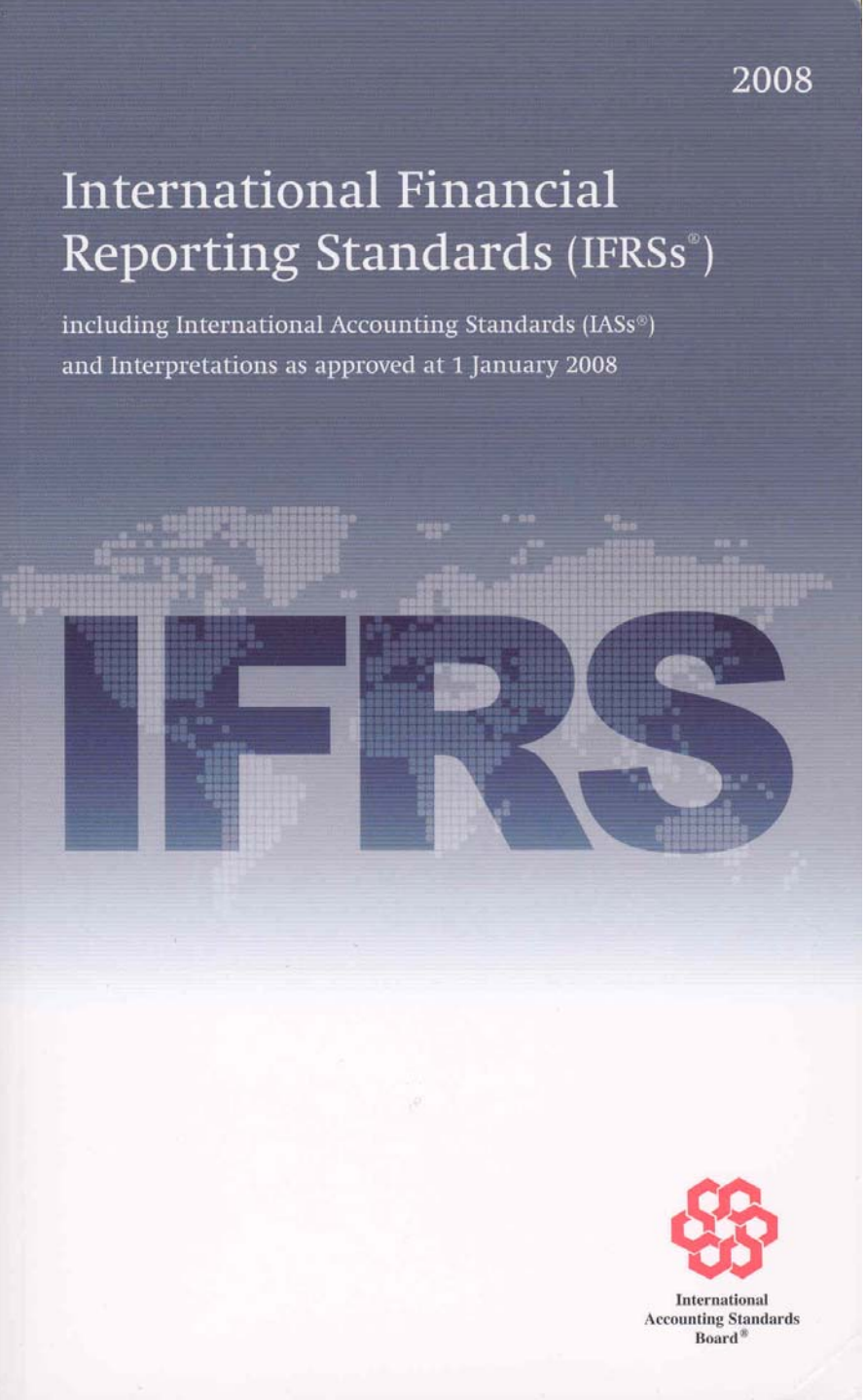
Principle	The polluter pays (subsidarity prinsiple)
Corollary	It is those who benefit from e g nuclear electricity generation that should pay all the future costs for decommissioning and waste management
Implications	1. Cost must be estimated 2. Appropriate funds accumulated 3. Money available when needed

EUROPEAN UNION RECOMMENDATION

on the management of financial resources for the decommissioning of nuclear installations, spent fuel and radioactive waste

Brussels, 24 October 2006. C(2006)3672

- *a segregated fund with appropriate controls on use is the preferred option for all nuclear installations*
- *a clear recommendation to this effect is made for new installations*
- *as regards the estimation of decommissioning costs, … the Commission recommends a prudent calculation of costs based on appropriate risk management criteria and external supervision*
- *experience shows that exchange of information between national experts concerning the various approaches to and financial arrangements for decommissioning and waste management is an excellent way of facilitating a common response to safety challenges*



IFRS *International Financial Reporting Standards*

IAS *International Accounting Standards*

- Stringent requirements on assessing and securing assets for liabilities (financial accruals)
- Precise calculations are to be presented each year
- In case estimation is difficult, various scenarios should be considered and a weighed average presented

IN SWEDEN

Law (SFS 2006:647) on certain financial actions for the management of residues from nuclear activities	Law (SFS 1988:1597) on financing of the management of certain radioactive waste e t c
Nuclear power plants	older nuclear research facilities
Fee on nuclear electricity	Fee on nuclear electricity
Open end	Closed in 2010
Securities at 2 levels	No securities

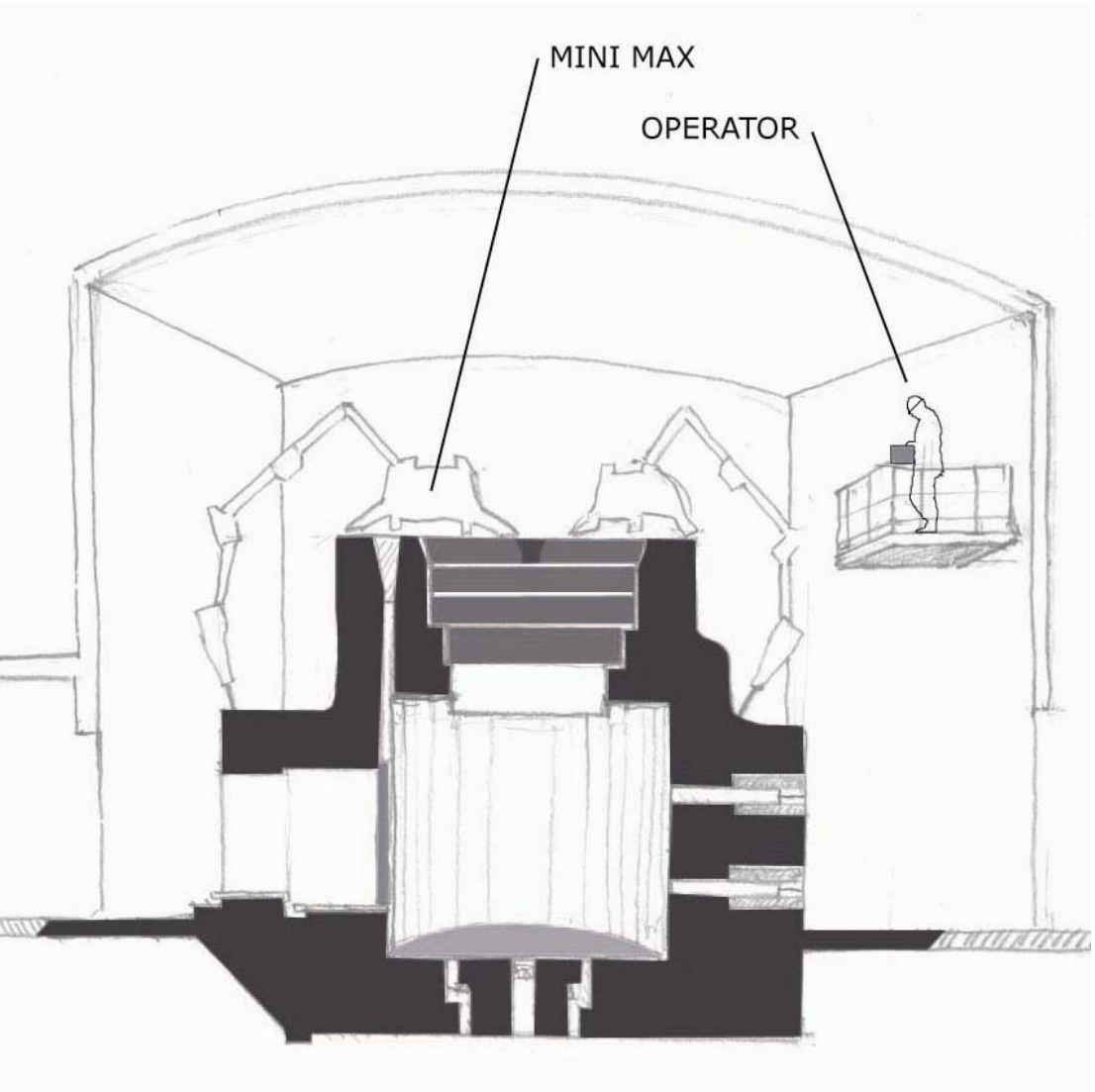
ABOUT SWEDEN

- One of six pioneering countries in nuclear technology development
- Has the highest per capita nuclear electricity generation in the world
- Comprehensive programme for research & development and facility construction & operation for decommissioning and waste management
- Allocation of assets to cover future costs since ≈ 30 years

THIS PRESENTATION

- Historical background
- Regulatory evolution
- Cost estimation prerequisites
  - Chemical plants e t c
  - Special cases
  - Decommissioning of nuclear facilities
- Recent and ongoing Authority activities
- Closing of the fund for older research facilities

THE FIRST SWEDISH REACTOR



- Commissioned in 1954
- Heavy water
- Natural or slightly enriched uranium metal fuel
- Research purposes
- Decommissioned during 1979 - 1983

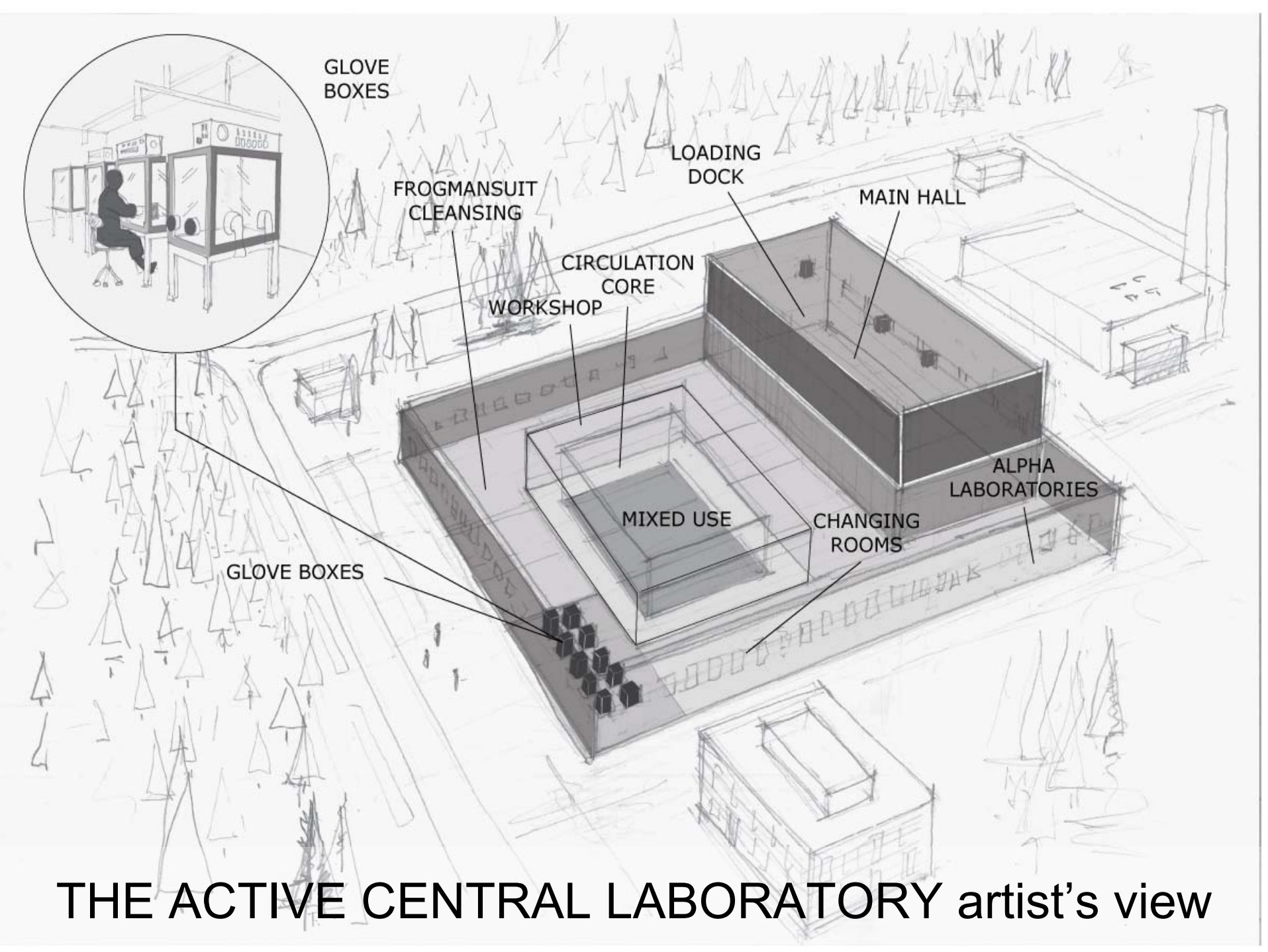
”THE SWEDISH APPROACH” until around 1970

- Heavy water & natural uranium
- Reprocessing (in collaboration with IFA / IFE in Norway)
- Uranium mining and beneficiation
- Tank type reactors (not pipe type like CANDU)

⇨ Nuclear power reactors:

  - The Ågesta reactor outside Stockholm, operated during 1963 – 1973
  - The Marviken reactor outside Norrköping, constructed during late sixties, never commissioned

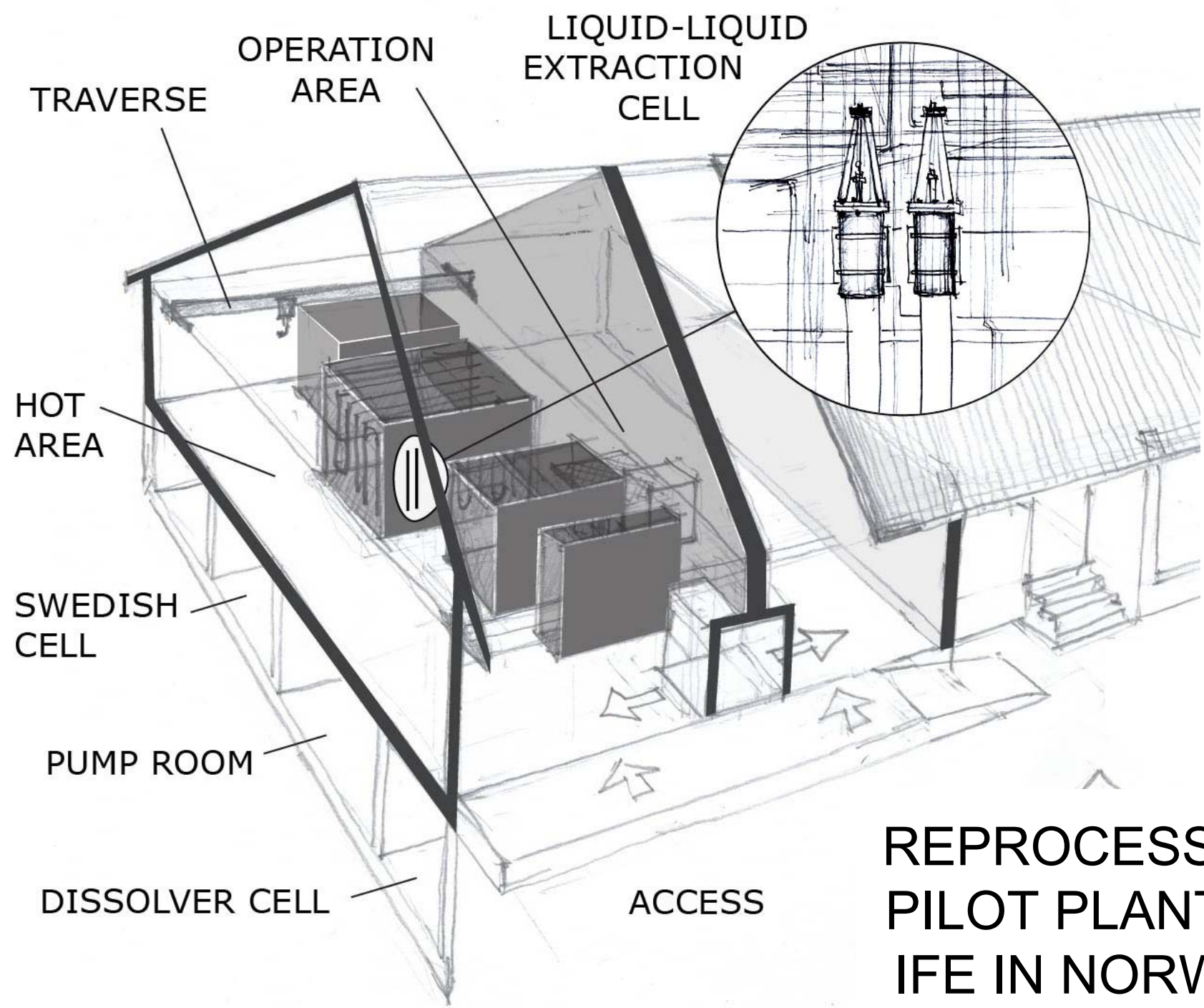
- Implementation by AB Atomenergi at Studsvik



THE ACTIVE CENTRAL LABORATORY artist's view

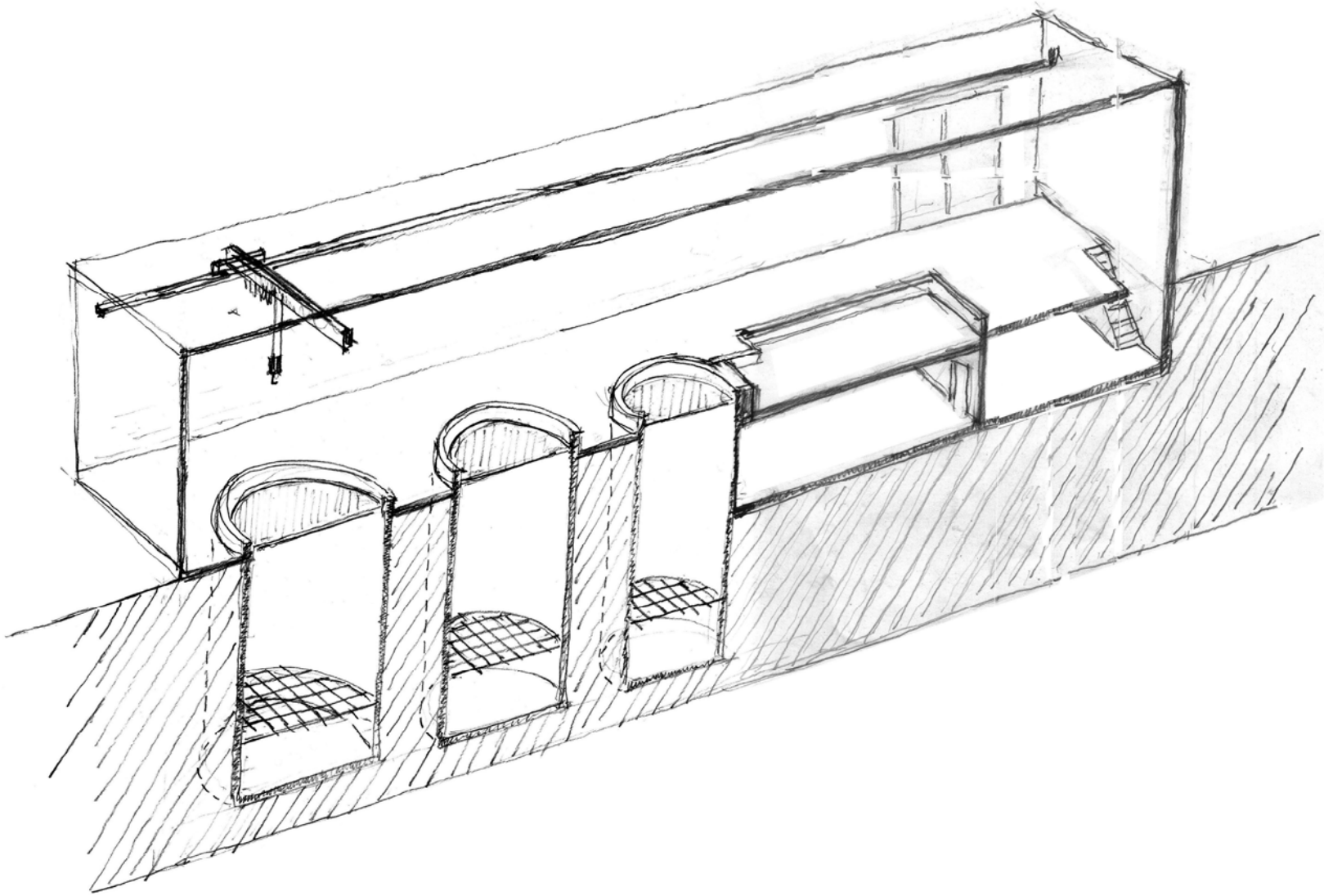
ACTIVE CENTRAL LABORATORIES (ACL)

- Built 1959 – 1963
- Decommissioned 1998 – 2006
- Floor area 14 200 square metres
- Laboratory scale reprocessing and preparation of mixed oxide fuel
- The main hall was intended for a mixed oxide fuel pilot plant
  but no such plant was ever built

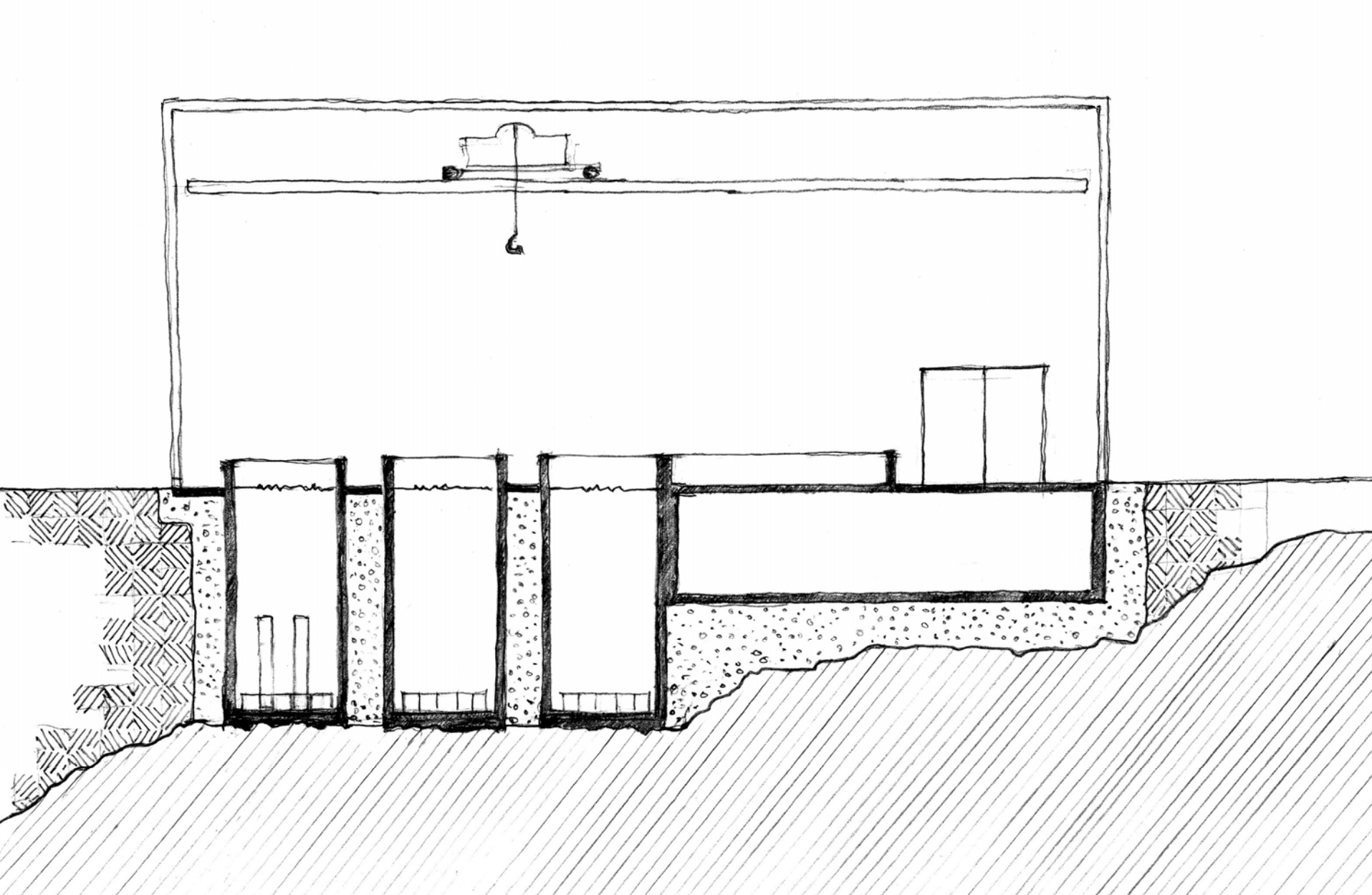


REPROCESSING PILOT PLANT AT IFE IN NORWAY

POOLS FOR FUEL STORAGE

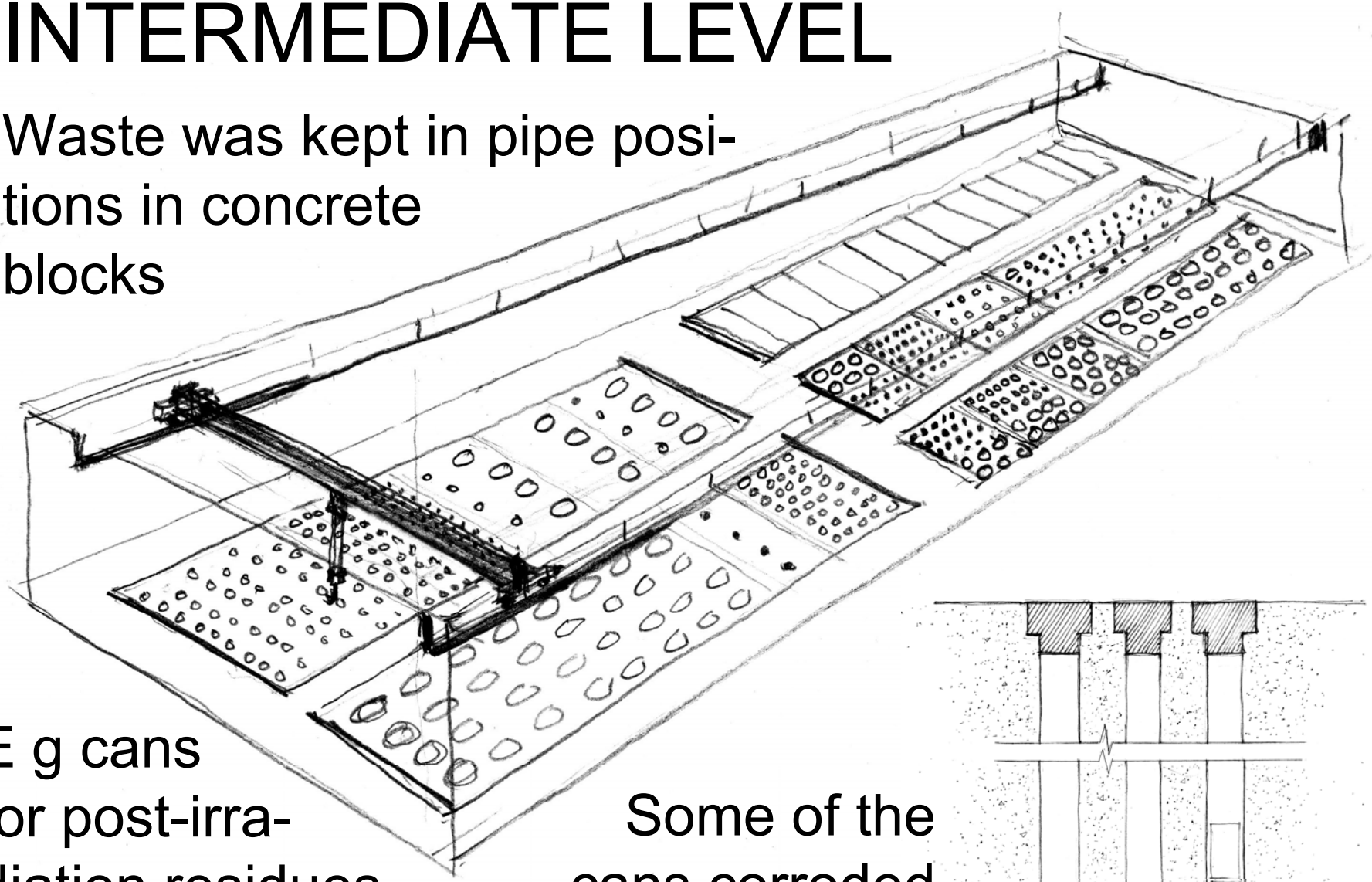


POOLS FOR FUEL STORAGE



STORAGE FOR OLDER INTERMEDIATE LEVEL

Waste was kept in pipe positions in concrete blocks



E g cans for post-irradiation residues

Some of the cans corroded

OTHER FACILITIES

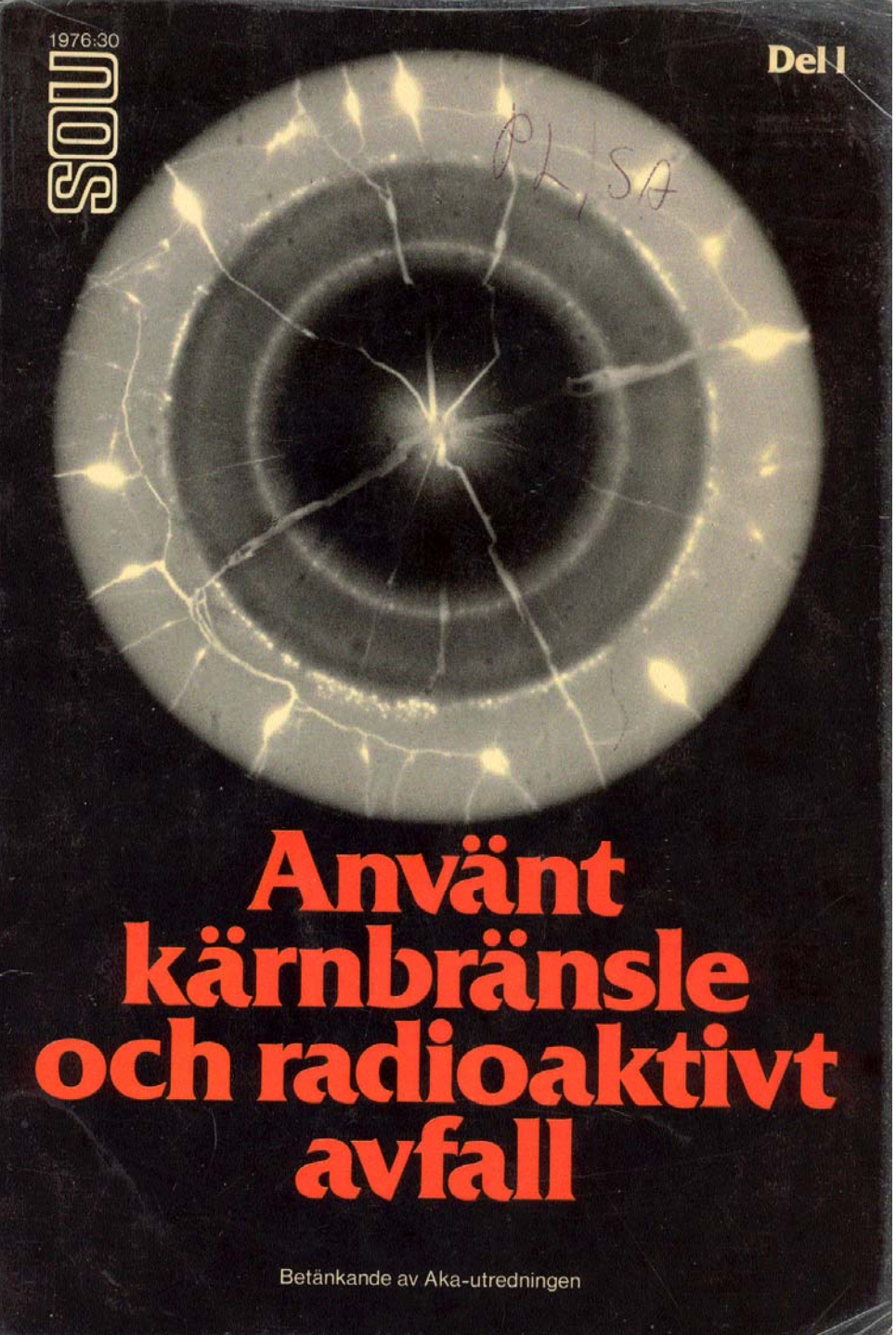
- The Ågesta heavy water reactor – 65 MW
  - Natural or slightly uranium
  - 10 MW electricity generation
  - 55 MW district heating
  - In operation during 1963 - 1974
- The R2 light water research reactor
  - Enriched (≈ 20 %) uranium fuel
  - In operation during 1961 – 2005
- Hot cell laboratory
  - Commissioned in 1961
  - Still in operation

NUCLEAR POWER PROGRAMME AFTER 1970

- 12 Modern light water power reactors
  - Commissioned during 1972 – 1985
  - 9 Boiling Water Reactors – BWR:s
  - 3 Pressureized Water Reactors – PWR:s
  - 2 of the BWR:s have been shut down for political reasons
- Central pool store for spent fuel – CLAB
- Repository for low level waste in crystalline rock – SFR
- Implementation by nuclear power companies

EARLY WASTE MANAGEMENT

- 2 out of 517 reports published by AB Atomenergi during 1956 – 1977 deal with radioactive waste
- Sea dumping of most of the low level waste generated before the year 1969
- Research on ”*nuclear power safety and environment issues*” was started in 1972
- Budget for 1972 – 1973 was 13 M€ at the price level of today



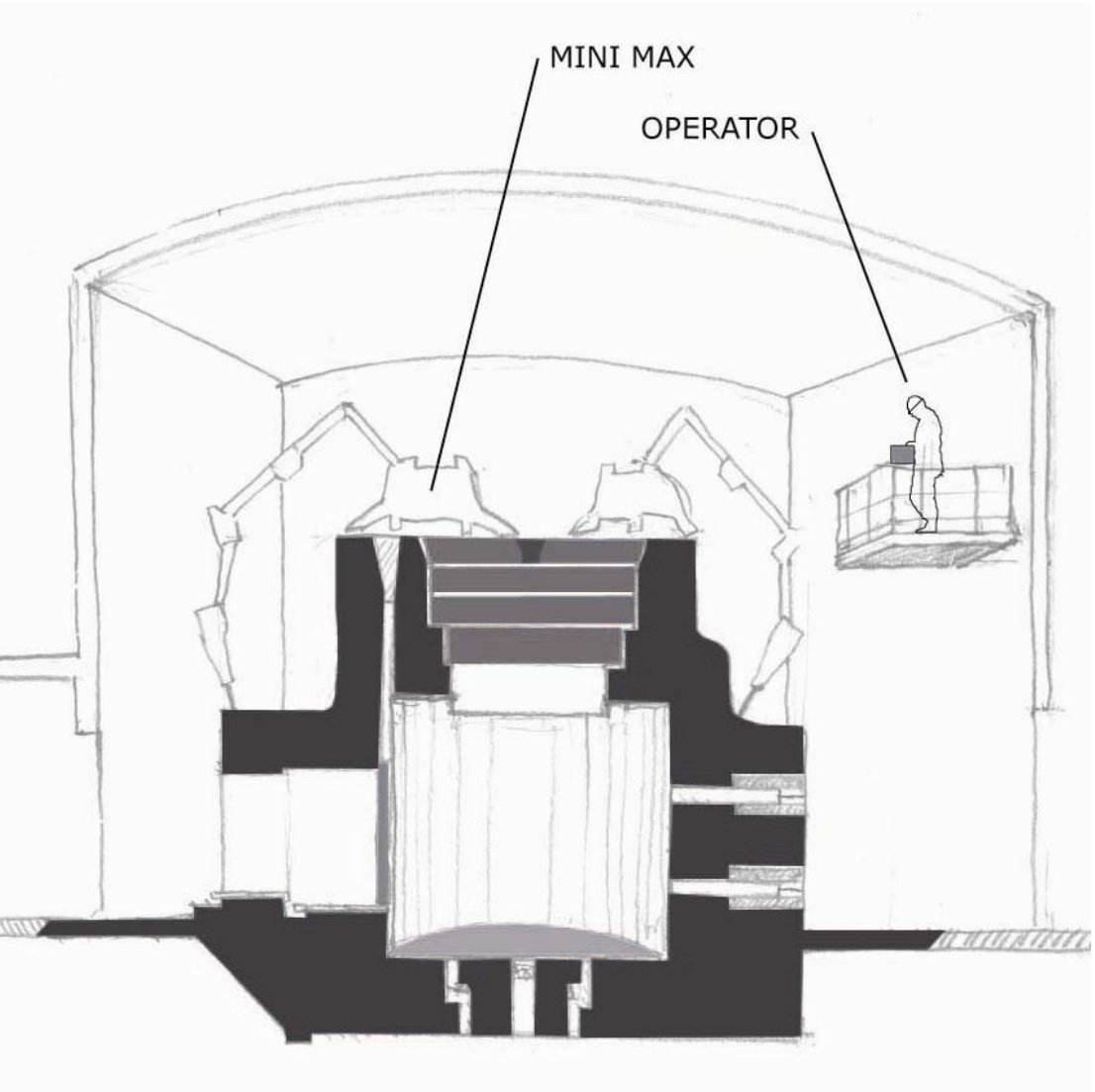
THE AKA PUBLIC ENQUIRY 1973 - 1976

- State-of-the-art on spent nuclear fuel and radioactive waste
- Part of the planning process for the modern light water reactor programme
- AKA proposed:
  - *Research*: Programme Council for Radioactive Waste (PRAV)
  - *Finance*: Costs to be carried by the nuclear utilities

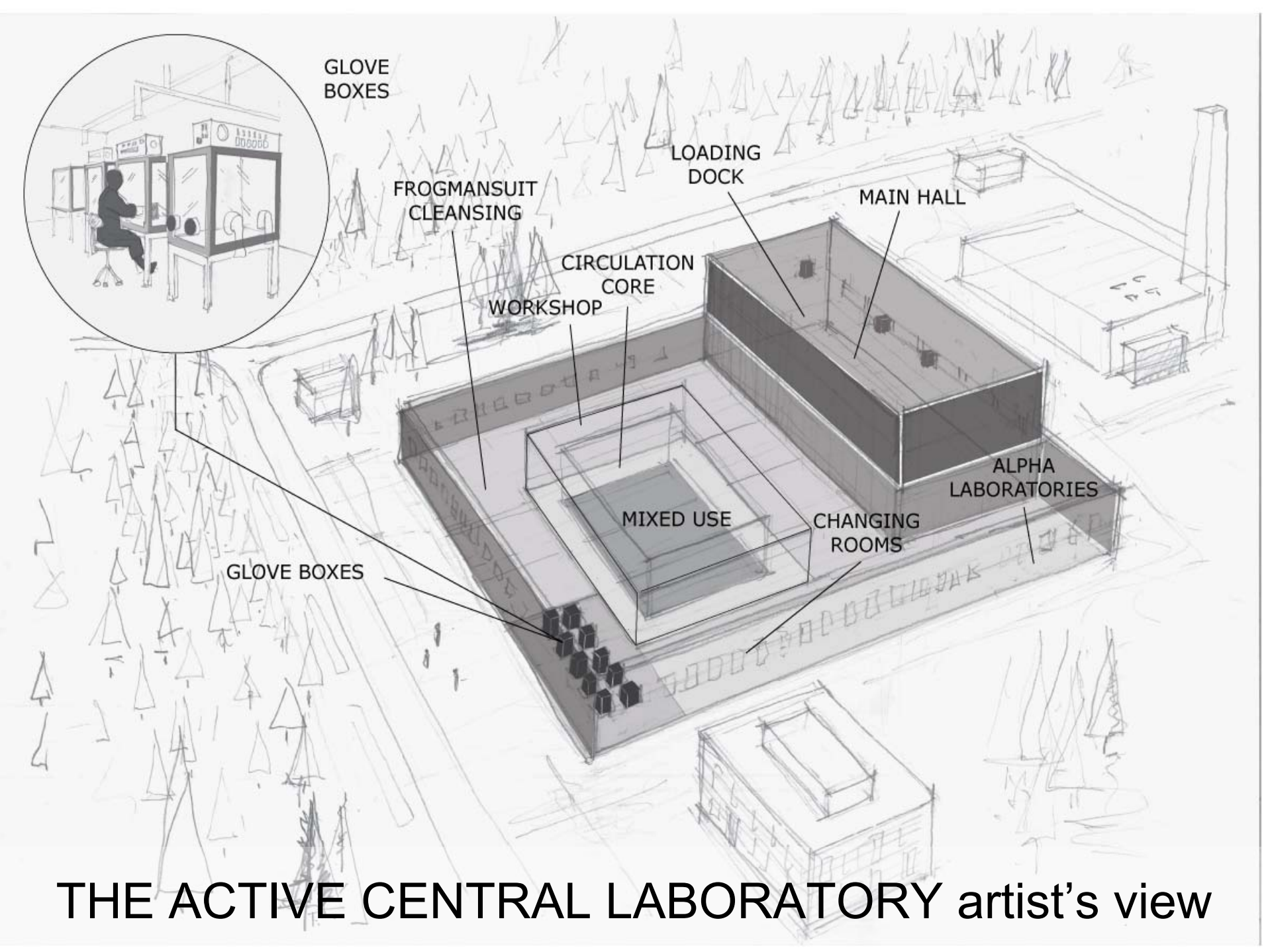
DECOMMISSIONING OF OLDER RESEARCH FACILITIES

- None of the 517 reports published by AB Atomenergi during 1956 – 1977 deals with decommissioning
- The AKA investigation has a section on decommissioning
- Detailed survey of the Ågesta reactor for the purpose of preparing for decommissioning was assessed to be unwarranted <= little value of the results
- A number of practical actions were taken, however, at a cost of ≈ 30 manyears

DECOMMISSIONING OF THE R1 REACTOR



- Operated during 1964 - 1970
- Decommissioned during 1979 – 1983
- Higher dose rate and total exposure than prognosis
- Remote work by modified timber handling machine improved efficiency
- Project completed on time and within budget



THE ACTIVE CENTRAL LABORATORY artist's view

ACTIVE CENTRAL LABORATORIES (ACL)

- Built 1959 – 1963
- Decommissioned 1998 – 2006
- Substantial differences between cost calculations at different stages
- Final cost a few times higher than initially estimated <=
  - High alpha to gamma ratios
  - Varying level of contamination <= different uses of different parts of the facility

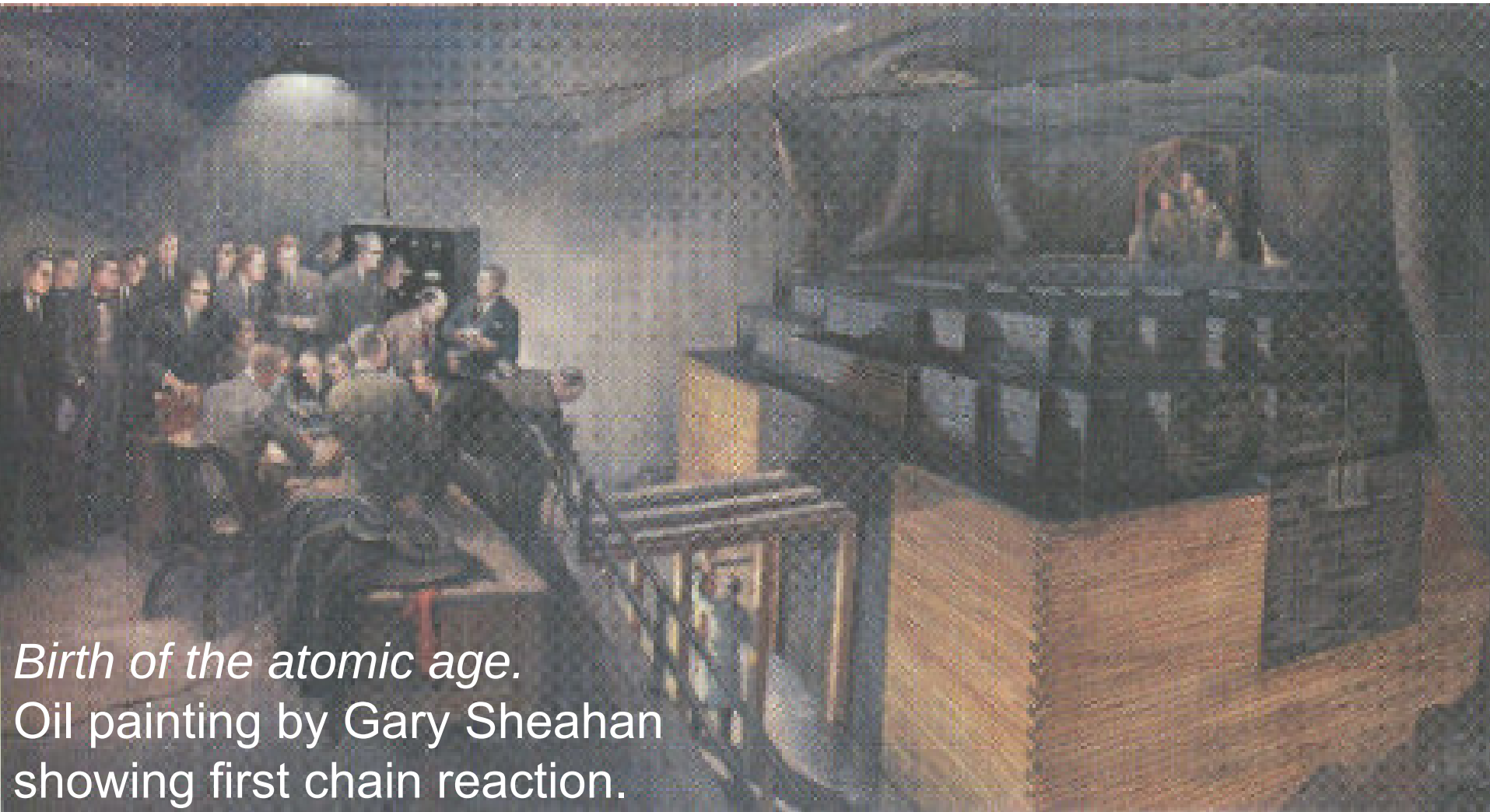
STUDY TOUR IN THE US IN 1957

- *Of course waste should be sunk into the sea*
- *It is infantile even to consider releasing waste into the sea*
- *The waste problem will have a decisive impact on the profitability of nuclear energy*
- *There is no problem with the waste*
- *We can inflict damages for generations to come*
- *Our present practice is fully adequate*

- Published in 1996 & in use in Sweden 1997
- Great benefits in medicine (diagonsis & cancer treatment)
- Severe delayed cancer effects (e g luminous paint)

=> When nuclear fission & chain reactions had been discovered around 1940

- Relatively good handle on radiation protection
- Little experience of waste containing induced radioactivity



Birth of the atomic age.
Oil painting by Gary Sheahan showing first chain reaction.

SHIFT IN PARADIGM IN THE 1970'IES

Approximate cost in G€	During 1955 - 1975	From 1975
Development of new nuclear technology	1,55	≈ 0
Waste management research	≈ 0	1,90

EXPERIENCE ON DECOMMISSIONING

- Waste generated during operation => experience
- Decommissioning carried out after shut down ≠ experience
- Increased attention during last 10 – 15 years
- Frequent disagreement between prognosis and outcome for cost, dose and time
- System of finance presupposes reliable estimates already at early stages

IN 1981: RESPONSIBILITY FOR WASTE RESEARCH E T C TO SKB

- SKB = Swedish Nuclear Fuel and Waste Management Company
- Owned by the nuclear utilities
- Responsible for
  - Research
  - Construction
  - Operation
  - Cost estimates

IN 1981: RESPONSIBILITY FOR SYSTEM OF FINANCE TO NAK

- NAK succeeded by SKN and SKI
- Presently duty of SSM = Swedish Radiation Safety Authority
- SSM duties:
  - Review cost estimates
  - Propose fee to the Government
  - Oversee disbursements

DEVELOPMENT OF THE SYSTEM OF FINANCE

1976 AKA proposed that all costs for waste management and decommissioning , including research should be paid by the nuclear power utilities

1977 The Government concluded that

- auditing standards imply that waste management and decommissioning are liabilities in annual reports
- Corresponding allocation of assets should be accumulated
- Such allocation should not generate taxation

1978: GOVERNMENT PUBLIC INVESTIGATION ON A SYSTEM OF FINANCE => LAW IN 1981

- The costs for the management of the spent nuclear fuel and for decommissioning is to be covered by fees on the nuclear electricity
- Fees are to be paid and low risk assets are to be accumulated in funds
- The owners of the facilities in question are responsible for actually carrying out the various tasks and actions needed
- The Government has the long term responsibility for the waste (presumably after closure of the disposal facilities)

THE OLDER RESEARCH FACILITIES

- Were not included in the 1981 systems for research etc and financing
- Instead they were included in a law in 1988 <= the older facilities were a prerequisite for the existing nuclear power production
- Studsvik AB (successor of AB Atomenergi) was owned 100 % by the Government at the time
- In the early 1990'ies Studsvik became a public company
- Same oversight as for NPP fund
- But no corresponding RD&D programme
- Final storage in the SKB facilities

THE FUND FOR OLDER RESEARCH FACILITIES

- No securities
- To be closed by the year 2010
- => cost calculations must be carried out with a high precision even at early stages since otherwise
  - The funds will be insufficient (overtaxation), or
  - The funds will be superfluous

CONVENTIONAL COST CALCULATIONS – ORDINARY CASES

- Several stages for chemical plant or similar
- First stage order of magnitude based on previous data for similar facilities together with scaling in size – error ± 30 %
- Last stage detailed estimate based on drawings, specifications & quotations – error ± 5 %

CONVENTIONAL COST CALCULATIONS – SPECIAL CASES

1. Cost overruns are more common than the opposite.
2. Cost overruns are higher for odd and unusual projects.
3. Cost overruns are higher in percent for small projects.
4. Cost overruns are higher for longer times between decision on budget and incurred cost.
5. There is a positive correlation between cost overruns and other types of deviations from plans (e g delays).
6. Cost overruns are higher for new and advanced technology.
7. Estimators, and especially entrepreneurs, tend to underestimate costs and schedules.
8. Projects for which the costs are underestimated have a higher probability of being conducted than those for which the costs are not underestimated.
9. Cost overruns are more common in certain organizations than others.
10. Cost overruns are not always smaller today than 50 – 100 years ago.

COST CALCULATIONS – NUCLEAR RESEARCH FACILITIES

- Several of previous points for special cases apply
- Most of the costs accociated with the facility being nuclear
- Most of the overruns accociated with the facility being nuclear
- SKI initiative to Nordic co-operation to find reasons & remedies

IMPORTANT FACTORS FOR PLANNING & COST ESTIMATES

- Follow IAEA and OECD/NEA recommendations and similar
- Find information from other similar facilities
- Carry out radiological characterization for the purpose of decommissioning (usually substantially more extensive than that which is required for operation)
- Carry out an appropriate technology selection with preparedness and flexibility to change methods when warranted
- Carry out a risk identification / risk assessment type of analysis to find and evaluate “cost raisers”

CONCLUSIONS OF NORDIC WORK

- Nuclear research facilities are very different from nuclear power plants and cannot be dealt with in the same manner.
- Costs for decommissioning of nuclear research facilities are among the most difficult ones to estimate
- If great care is taken (cf above), a precision of ± 15 percent might, nonetheless, be attainable in many cases even at early stages.
- More or less concealed circumstances may easily increase this uncertainty a few or even several times.
- Comparison with incurred costs for similar facilities is essential.
- The characterization (radiological and otherwise) must be carried out in sufficient detail in order for data on incurred costs for similar facilities to be fully utilized.

DELIVERABLES FROM NORDIC WORK

- A compilation of best practice with emphasis on radiological characterization, method selec-tion, financial risk analysis and calculation methodology.
- A compilation of examples of decommissioning projects, one from each of the participating countries.
- A compilation of a knowledge base from the various pieces of information that have been submitted for sharing.
- Plant visits.
- Networking to facilitate informal contacts.

PRESENT TRENDS

- New requirements as well as improved and stricter enforcements of existing ones
- Data on incurred costs for decommissioning of nuclear facilities are being accumulated in continuously improved forms for comparison.
- Methodologies for calculation and comparison are being extended from large modern facilities to small odd older research facilities
- The general development in the area of environmental liabilities
- efficient means to meet these expectations and requirements include active learning processes with information exchange and openness

CLOSING OF THE STUDSVIK FUND

- Sweden is probably the first country to face the finalization of the accumulation of fees to a fund in the near future
- Being first requires special caution since there has been noone around earlier to discover any pitfalls.

CLOSING OF THE STUDSVIK FUND

QUESTION	Do the precision of the historical cost calculations correspond to the assumptions underlying the closing of a fund?
ANSWER	A small number of specific items have had an unexpectedly high influence on the total cost for older research facilities

CLOSING OF THE STUDSVIK FUND

QUESTION Is the uncertainty margin in concordance with the assumptions underlying the closing of a fund?

ANSWER Under investigation – we do not know

CLOSING OF THE STUDSVIK FUND

The nuclear utilities	Have paid the fees to the fund
The Government	May keep any superfluous funds
AB SVAFO + Studsvik Nuclear AB (part of Studsvik AB)	May have to compensate and pay for any deficiencies in the funding
Ranstad Industricentrum AB	

COMMENTS

- It is possible that any lack of correspondence between calculated and incurred costs will evidence itself only after a few decades
- The present plans call for the disposal of the long-lived waste from Studsvik during 2040-2050
- It can be expected, however, that any such mismatch will only be more difficult to resolve with time.
- It is therefore important that the practical limits for the reliability of cost calculations be explored and that the results be
  - utilized in the present cost calculations and
  - related to the present legislation and its underlying assumptions.

TREND PATTERNS

1890’ies Discovery of X-rays & immediate utilization	1930’ies and on Adequate radiation protection measures
1940’ies Discovery of controlled chain reactions & immediate utilization	1970’ies and on Adequate measures for induced radioactivity, for waste from operation
	1990’ies and on Adequate measures for induced radioactivity, decommissioning & financing

COMMENTS

- Important to realize that we do not have experience of finalising environmental liabilities over long times (a few decades) ⇔ REQUIRES STRONG AWARENESS
- In the planning and execution of this work it is important to take advantage of the lesson of the past on the importance of using ones imagination in combination with good science and technology in order to manage that which is remote in space and time.