Sustainability of nuclear energy with regard to decommissioning and waste management

Staffan Lindskog,
Rolf Sjöblom and
Bea Labor

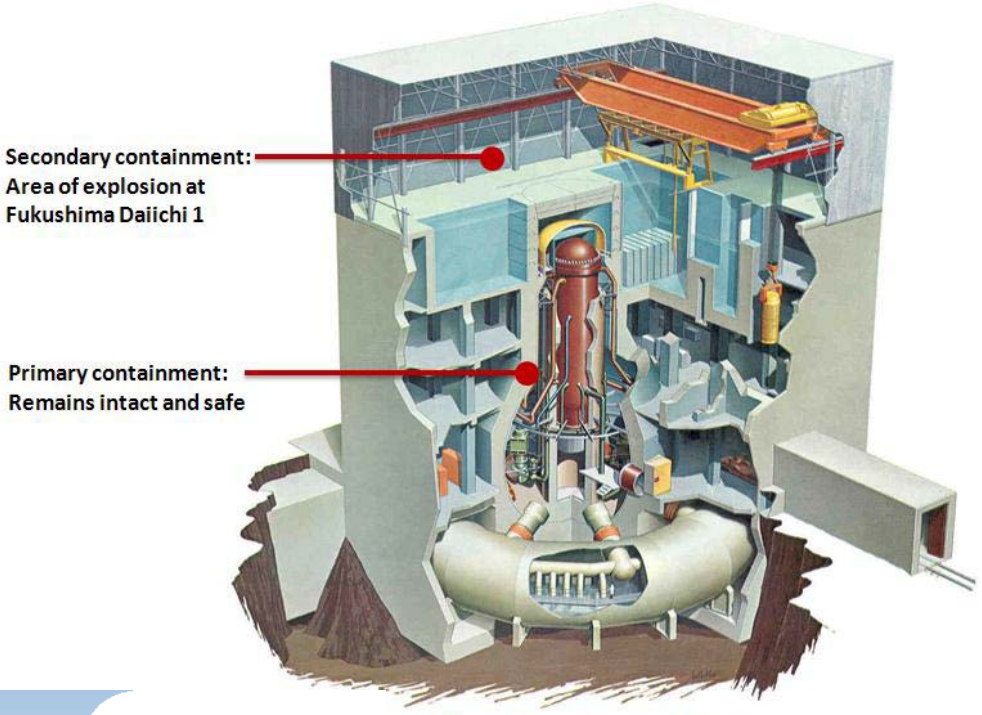
TEKEDO

Swedish Radiation Safety Authority

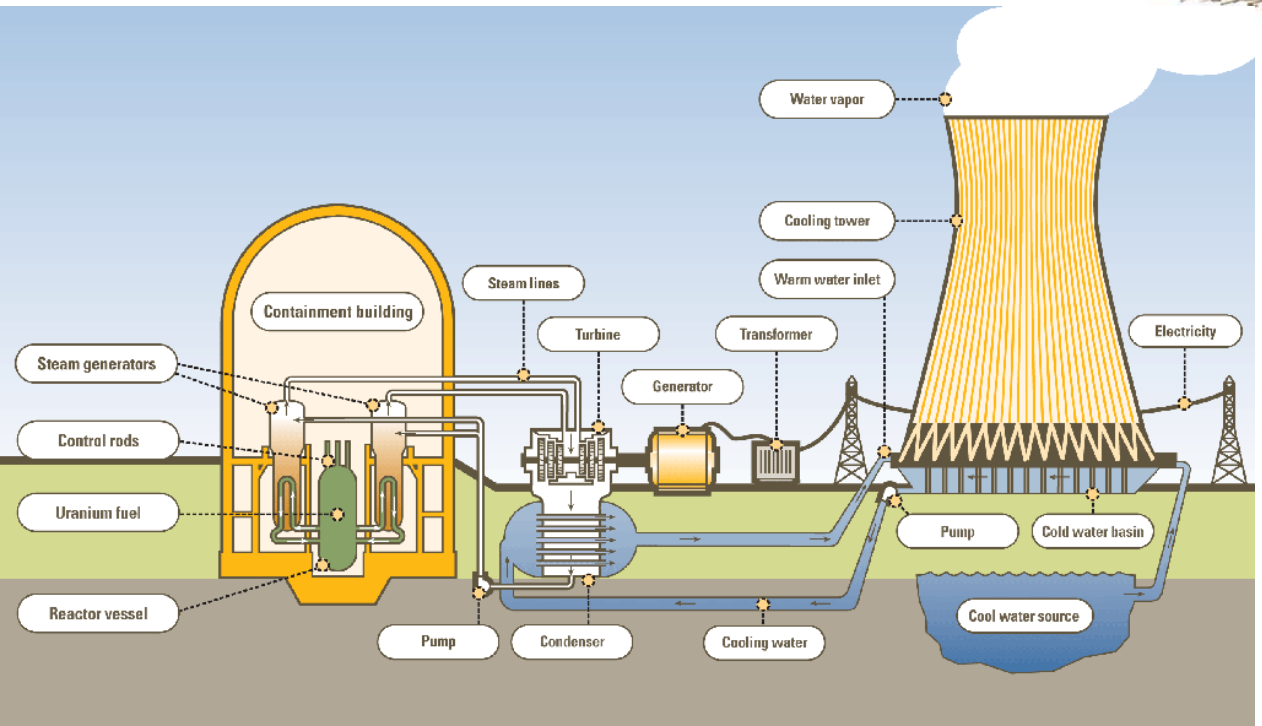
Is nuclear energy really sustainable?

Fukushima reactors in 2011

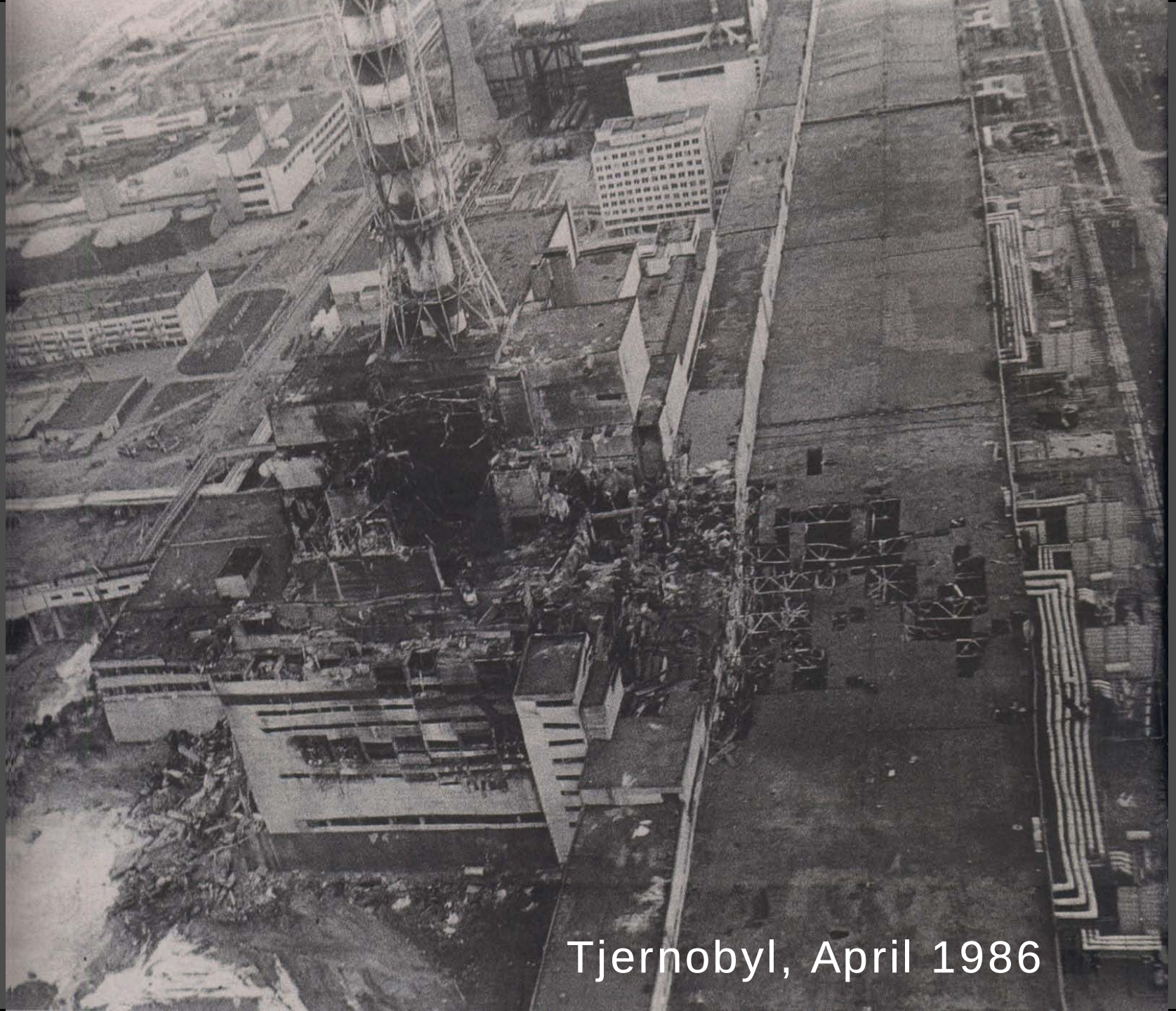
Fukushima reactors in 2011



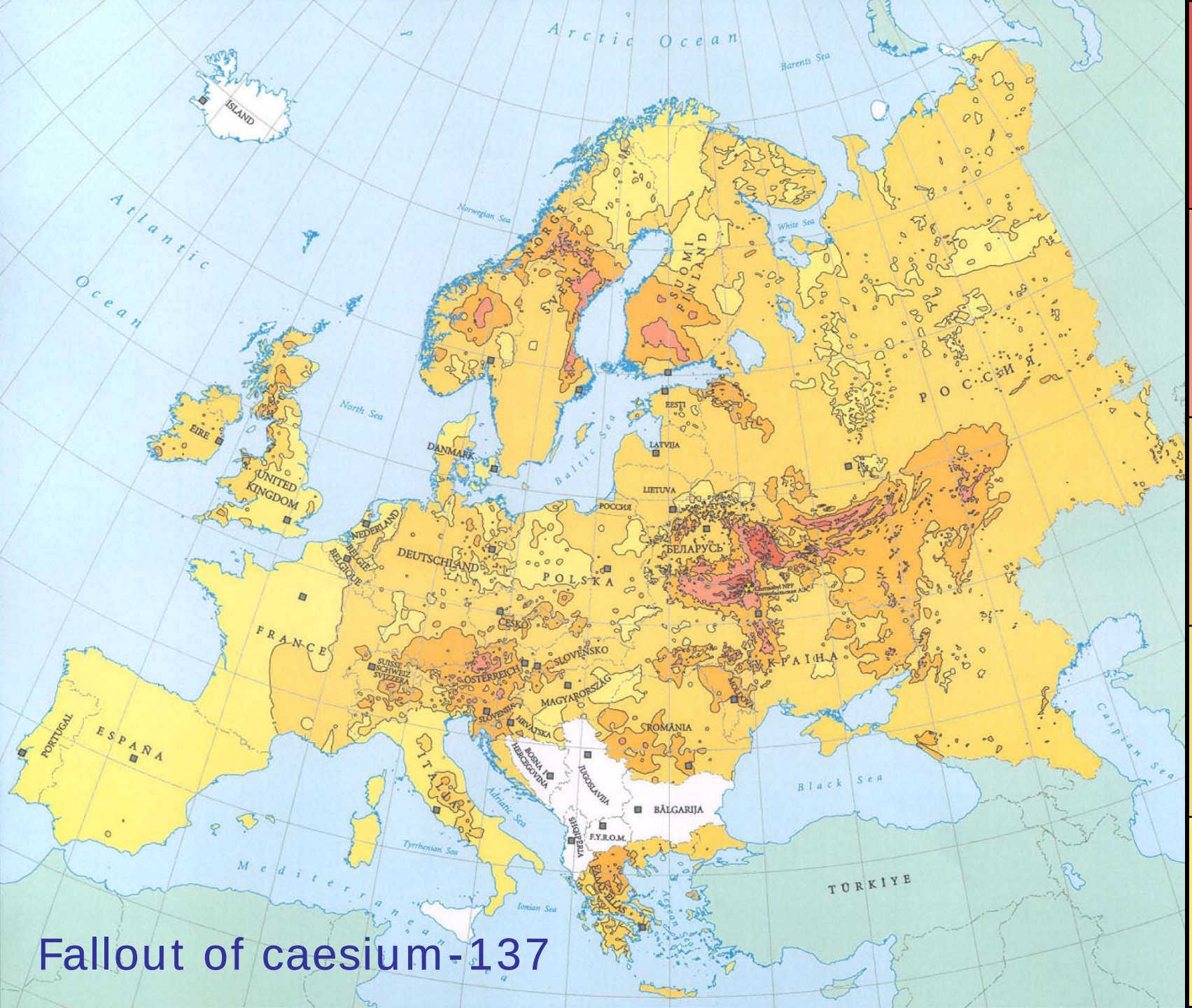
Boiling Water Reactor Design



- BWR = Boiling Water Reactor design



Tjernobyl, April 1986

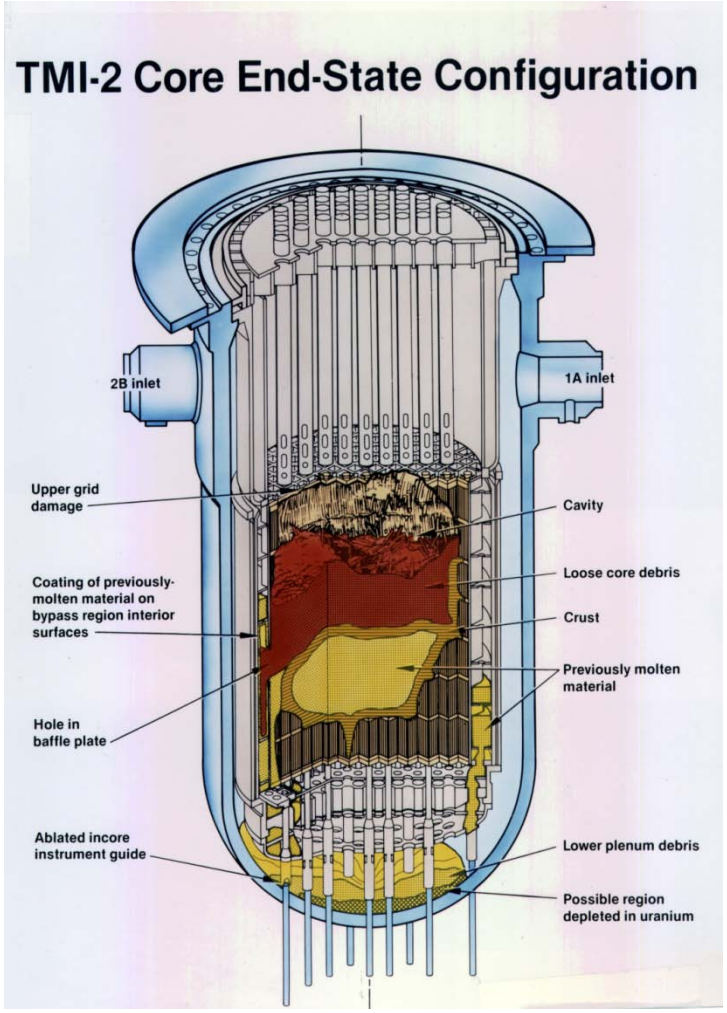


Fallout of caesium-137

185 – 1480 kBq/m²
40 – 185 kBq/m² (Gävle)
10 – 40 kBq/m²
2 – 10 kBq/m² (Syd-sverige)
0 - 2 kBq/m²

The Three Mile Island 2 accident in 1979

- Severely damaged core
- Releases of radioactive water and gasses
- No casualties
- Costs for present ”safe state” ≈ 0,7 G€
- (cost for full decommissioning of a NPP ≈ 0,15 G€)



Sustainability of nuclear power

- Reactor safety / incidence & consequence of accidents
- Decommissioning and waste management
- Availability of nuclear fuel
  - Sustainability of uranium resources
  - Efficiency in the utilization of the uranium - including reprocessing & breeder technology

Purpose: to analyze the sustainability aspects of nuclear power with regard to

- ~~Reactor safety / incidence & consequence of accidents~~
- Decommissioning and waste management
- ~~Availability of nuclear fuel~~
  - ~~Sustainability of uranium resources~~
  - ~~Efficiency in the utilization of the uranium - including reprocessing & breeder technology~~

The structure of this presentation

1. Nuclear liability evaluation and financing in Sweden
2. Sustainabilities and associated methodologies for analysis and comparison
3. Nuclear energy sustainability
4. Results from information searches
5. Results from field studies
6. Concluding remarks

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Is there any legal limit to the potential danger?

- Generally potential danger for health and environment is not prohibited by law
- It is the risk that is limited
- It is the operator that has the full responsibility
- The role of the Authorities is to
  - Instigate proper action
  - Ensure compliance

The Swedish Radiation Safety Authority

- Finance
- RD&D programme review
- Radioactive waste management and disposal
- Radiation protection
- Nuclear facility operational safety
- Non-proliferation

- Research
- Cost – benefit analyses
- Review of plans & cost calculations for decom-missioning of nuclear facilities
- Review of plans and cost calculation for management and disposal of nuclear waste including spent nuclear fuel
- Analyses of level of fee required & proposal of fee to Government
- Disbursement

2 out of a total of 12 modern Swedish NPP:s have been closed

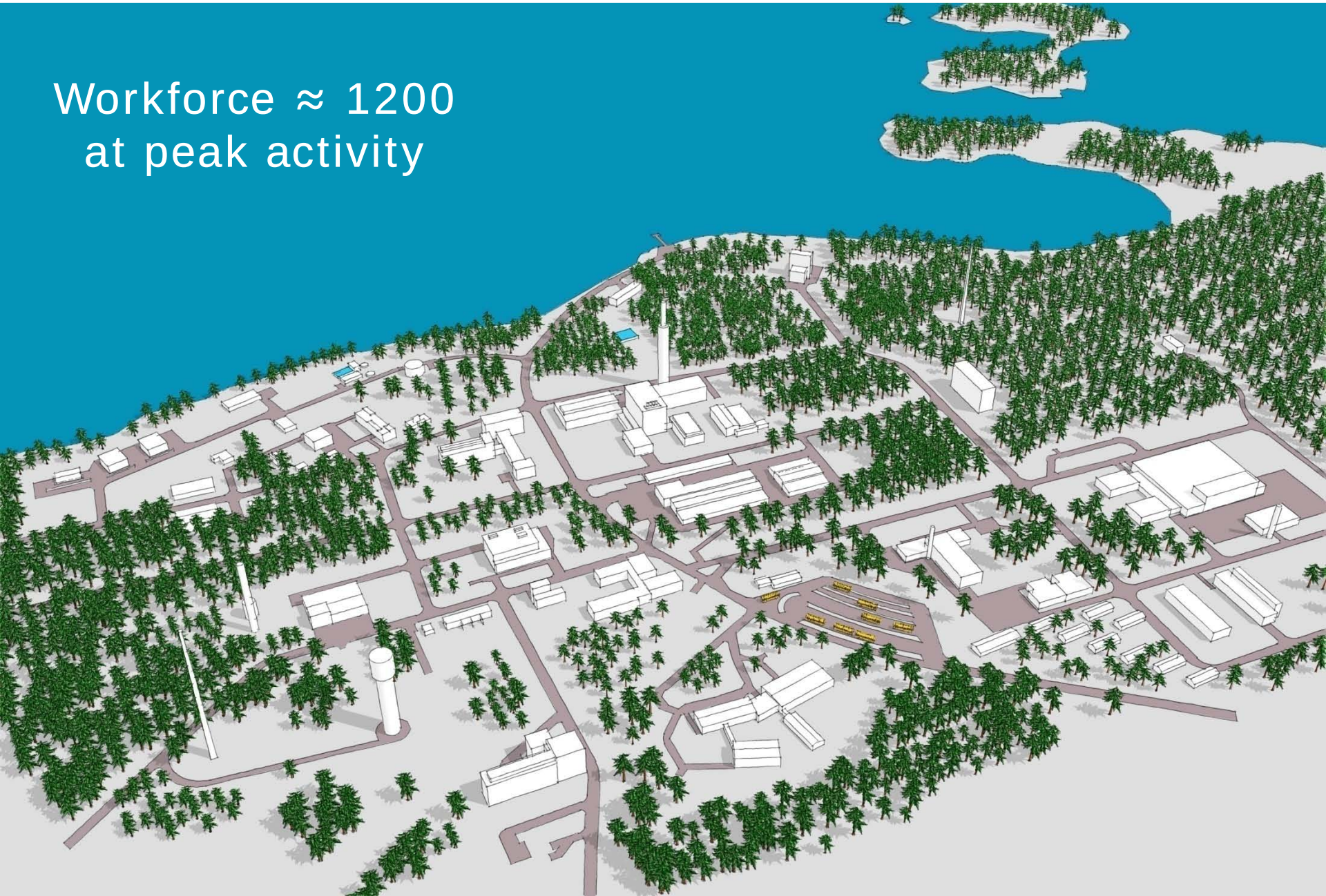
Decommissioning and waste management for Swedish NPPs - compartments for securities and fees to segregated funds

- The anticipated cost
  - Combination of fees and securities (unlimited in time)
- A risk fee to cover the residual risk that the Government takes as the ultimate guardian
  - Securities (unlimited in time)

Swedish NPPs – in addition, to cover “unplanned events”

- Plant owner / operator - securities & unlimited responsibility
- The Swedish Government - guarantee
- Other countries – support in accordance with international agreements

The ”national laboratory” at Studsvik ≈ 1964



The Ågesta nuclear power plant in operation 1963-1973

Sweden one of six countries to build first nuclear power reactors

Swedish uranium mining in the 60’ies – the artificial lake Tranebergssjön

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Definition of sustainability according to the UN Brundtland report from 1987

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Two key concepts of the Brundtland definition

- *the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs*

Are the implementations coherent?

World Nuclear Association implementation

They are "*confident that nuclear power is a 'sustainable development' technology*

- *because its fuel will be available for multiple centuries,*
- *its safety record is superior among major energy sources,*
- *its consumption causes virtually no pollution,*
- *its use preserves valuable fossil resources for future generations,*
- *its costs are competitive and still declining, and*
- *its waste can be securely managed over the long-term"*

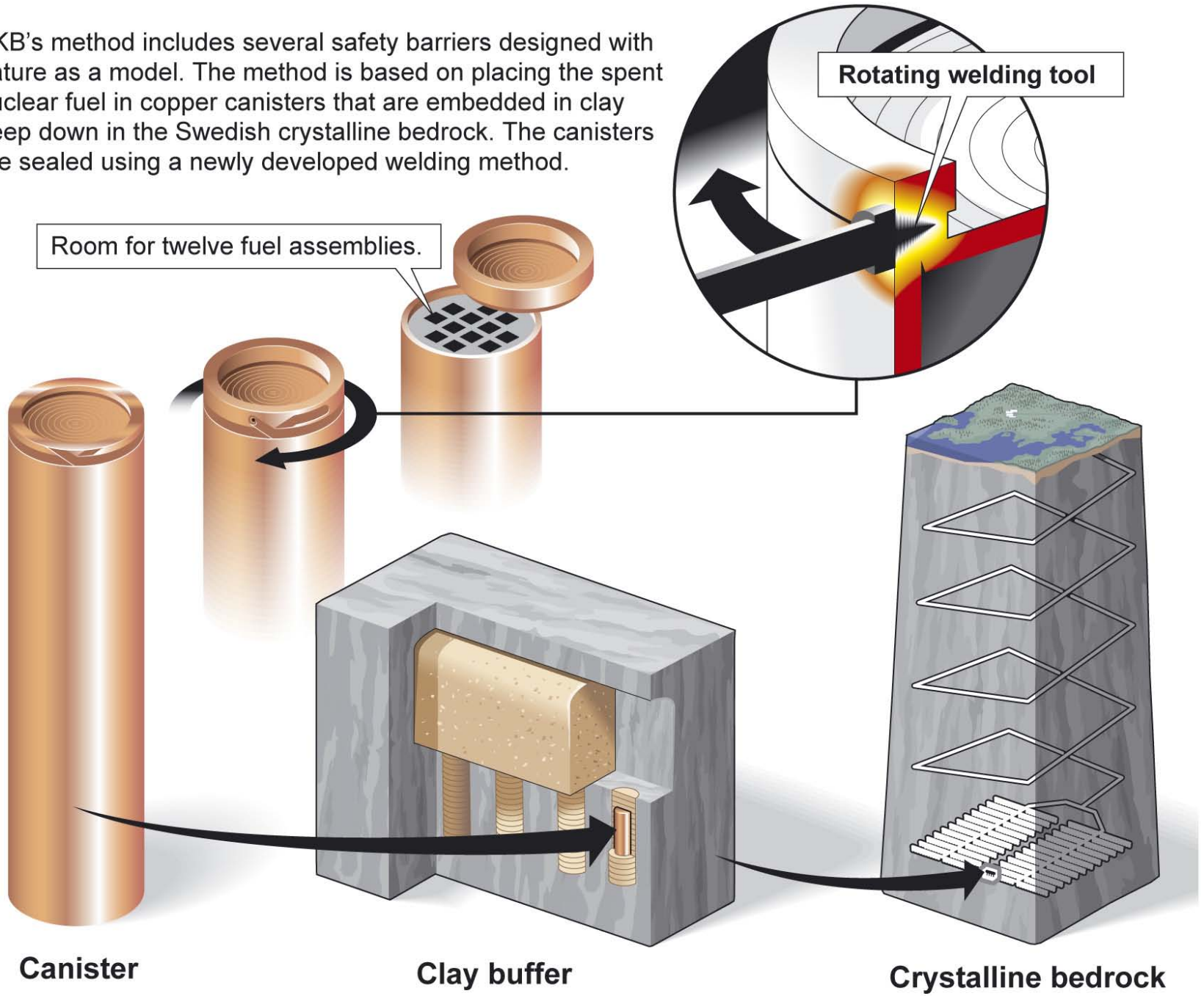
“Its waste can be securely managed over the long-term”

- Must not be interpreted “draconically”
- This far, no country has commissioned any disposal facility for civilian spent nuclear fuel or corresponding waste from reprocessing

Swedish repository for short-lived and low level nuclear waste

Repository for short-lived and low level nuclear waste

SKB's method includes several safety barriers designed with nature as a model. The method is based on placing the spent nuclear fuel in copper canisters that are embedded in clay deep down in the Swedish crystalline bedrock. The canisters are sealed using a newly developed welding method.



Source: SKB

The coal combustion community

considers three pillars of sustainable development

- economic prosperity
- social well-being and
- environmental sustainability

The coal combustion community

makes the following observations:

- "*Coal will play an important role in energy systems that support sustainable development for the foreseeable future*
- *Further improvement in coal's environmental performance will be required ... to reduce greenhouse gas emissions”*

Of course

carbon capture
(carbon dioxide sequestration)
is still at the development stage

It can be concluded that

- the application of the fundamental principles of sustainability is not straightforward, and
- tools for assessment and comparison are needed as well as
- knowledge bases structured in a feasible manner

Tools for systems analyses

- Modern tools for assessment of the functioning of industrial facilities
- have largely been developed in conjunction with the planning and safe operation of advanced industrial facilities
- especially in the chemical and nuclear industries

General considerations in such analyses

- definition of the system, including boundaries
- identification and description of features, events and processes
- identification and studies of scenarios
- comparison (e g for best available technology) based on comparing one type of characteristic at the time, and to make overall assessment thereafter

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Availability of uranium and the efficiency in its utilization

- All contemporary reactors based on uranium
- Ores are low level ⇔ large volumes of tailings to manage
- Presently known sources ⇔ > 100 years
- Might be >> <= new reactor and reprocessing technology

Protection of health and the environment

⇔

costs for decommissioning and waste management

- Easily a couple of orders of magnitude higher than for corresponding buildings with no nuclear activities
- For cases of accidents, easily yet another couple of orders of magnitude higher

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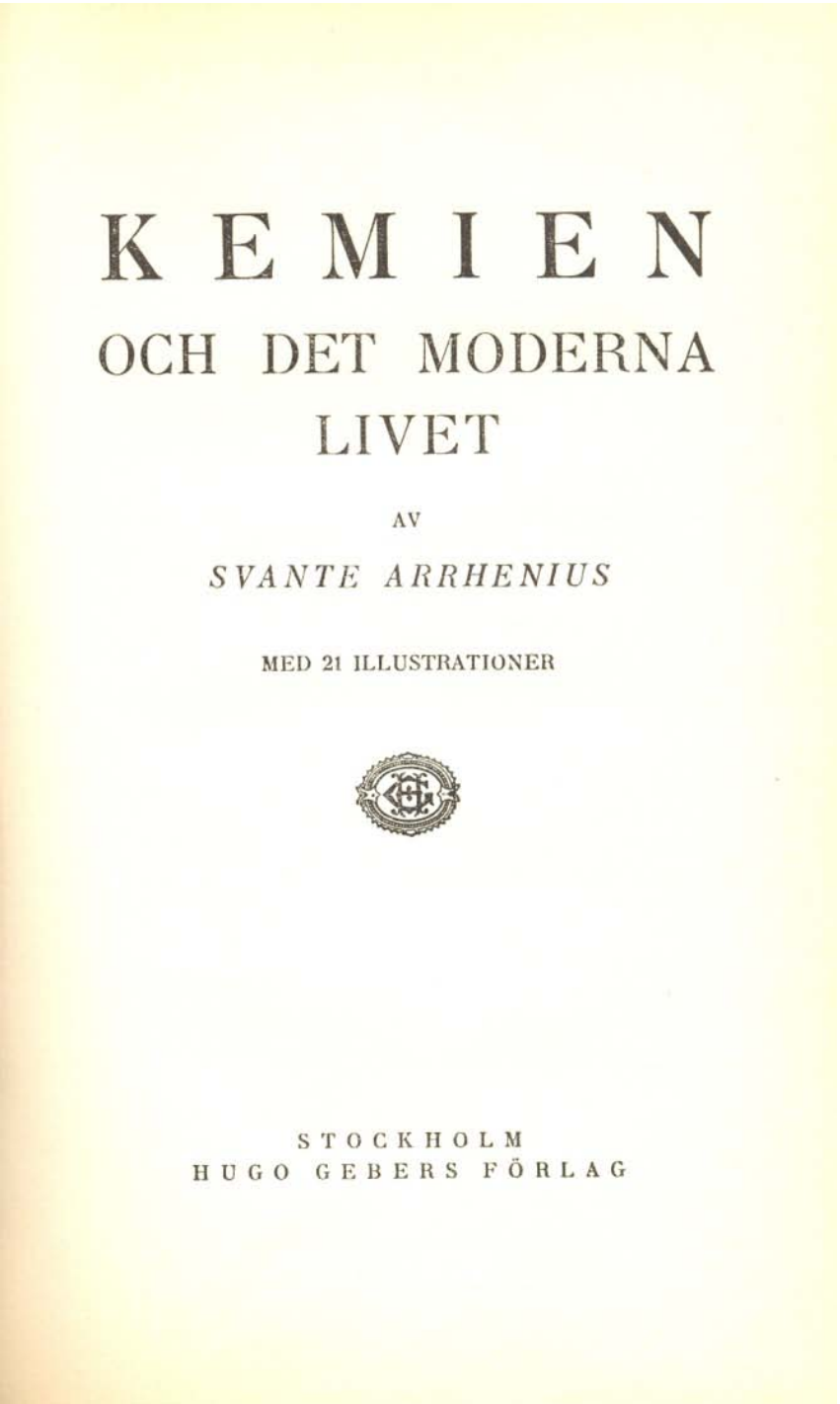
KEMIEN
OCH DET MODERNA LIVET
AV
SVANTE ARRHENIUS
MED 21 ILLUSTRATIONER
STOCKHOLM
HUGO GEBERS FÖRLAG

Greenhouse effect

- Well known since > 100 years
- Swedish scientist Svante Arrhenius
- Also in popular literature
- Dormant for 100 y
- What other issues will catch attention?

- Published in 1896 & in use in Sweden 1897
- 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 respect for waste containing induced radioactivity

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

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

Prerequisites

- Money available at the time when needed
- <= cost estimates now with sufficient precision
- Experience is: numerous large deviances
- Legislation ⇔ precise calculation
- Penal law ⇔ ≤ 6 years prison
- ⇔ good idea to follow standards
- ⇔ good idea to declare uncertainties

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Values and time

- Values have changed strongly in < 100 years (e g no sea dumping now)
- Values of coming generations will be different
- Difficult to assess
- But views of next generation available
- Different culture of communication
- ⇔ interviews pertinent

Experimental

- 1444 persons attending secondary grammar school
- Response rate close to 100 %
- Conducted during 2007 – 2010 in
  - Poland: Gdansk, Lublin, Elblag and Jaworzno (Katowice)
  - Slovakia: Trnava
- Trnava close to nuclear reactors that have been shut down

Preferences found, young generation

- Truly sustainable sources of energy are preferred. Coal has the lowest score.
- Sweden should take care of its own waste.
- Only few people can consider having a final disposal of nuclear waste near to their homes.
- Protection of health and environment are most important for final disposal, but distance from home is also an important consideration.
- Young people feel that unease with the risks together with lack of knowledge are the most important aspects for acceptance of nuclear waste disposal

  while trust for the stakeholders involved and local opportunities are less important.

  Detailed data in the paper.

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Conclusions

- The definitions of sustainability are quite clear
- Analyses have nonetheless been carried out in different ways in different areas of technology
- The results are not coherent
- Consequently, it is necessary to apply methodologies that enable comparisons to be carried out in a more uniform and systematic manner
- Such methods are available from the areas of systems and safety analysis

Sustainability of nuclear power

- The sustainability of nuclear energy is not just a matter of
  - Availability of uranium
  - efficiency in its utilization
- But also of protection of health and the environment
  - now as well as
  - in the future

Appropriate that

- the benefitting generation leaves behind the full technical solutions together with
- all the financial resources needed for adequate protection of health and the environment

Planning for decommissioning

- Treacherous – many lessons learned
- Careful analyses needed:
  - radiological surveying
  - selection of techniques to be used and
  - potential cost raisers
- Timing dictated by needs for financial planning – not technology

Planning for decommissioning

- Imperative to at least learn about the values of the next generation
- And to carefully consider what they share
- Strive for solutions that have a good prognosis to stand the tests of time
- Record keeping and information transfer

Example of historical sustainability awareness

Care about offsprings

- Natural element of human nature
- Natural to leave behind a better basis for existence
- The concern for descendants is not unconditional
- Research suggests that an individual will sacrifice consumption to benefit future generations only if there exists a guarantee that others will do the same
- => bodies are required as ombudsmen for the public to ensure general compliance


Example of offspring in Sweden