Broadening the Concepts of Justification and Optimization in Environmental Remediation by Incorporating Sustainability Principles in the Decision-Making Process

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The discovery of radiation and its associated hazards

- Rontgen discovery of X-rays → November 1895
- Becquerel's identification of radioactivity → 1896
- Curie discovers Radium → 1898
  - All these discoveries led to many cases of radiation damage
  - Ignorance about the risks caused numerous injuries
  - Soon it turned out that effects could be lethal
- One year after Rontgen's discovery of X rays, Wolfram Fuchs (1896) gave what is generally recognised as the first protection advice:
  - Make the exposure as short as possible;
  - Do not stand within 12 inches (30 cm) of the X-ray tube; and
  - Coat the skin with Vaseline and leave an extra layer on the most exposed area.
- These form the three basic tenets of reducing exposures from radiation:
  - Time,
  - Distance, and
  - Shielding
- In early 1920s, radiation protection regulations were prepared in several countries,
- It was not until 1925 that the first International Congress of Radiology (ICR) took place and considered establishing international protection standards.

The International Commission on Radiological Protection (ICRP)

- First ICR was held in London in 1925 → most pressing issue was that of quantifying measurements of radiation,
- International Commission on Radiation Units and Measurements (ICRU) was created, although it was then named the ‘International X-ray Unit Committee’.
- The second ICR was held in Stockholm in 1928 and ICRU proposed the adoption of the roentgen unit;
- As a courtesy to the host country, Rolf Sievert was named Chairman
- After the Second World War, the first post-war ICR convened in London in 1950. The ICR was named ICRP. Six sub-committees were established and later on reorganised in 1962:
  - C1: Radiation effects;
  - C2: Internal exposure;
  - C3: External exposure; and
  - C4: Application of recommendations

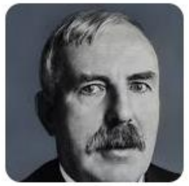
Marie Curie

Antoine Henri Becquerel

Wilhelm Röntgen

Pierre Curie

Lise Meitner



Ernest Rutherford

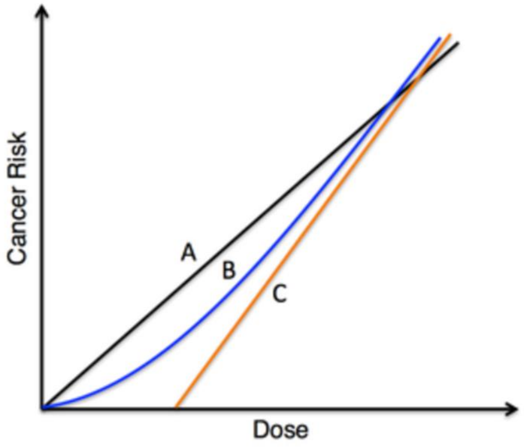
History of Nuclear Safety Regulations (Michael Baumer)

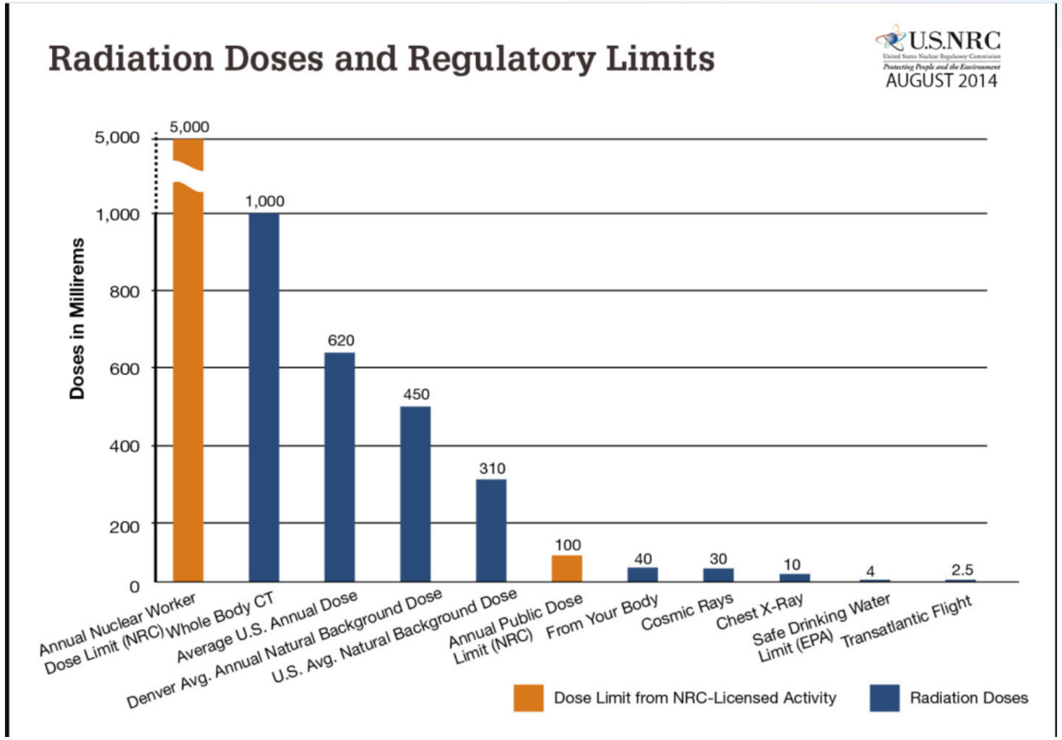
IAEA

- As public understanding of the safety risks of nuclear energy increased, demand for stricter regulations on radiation exposure and control of radioactive material rose.
- In the late 1950s, public debate raged over the danger of fallout from nuclear testing. In response, the Atomic Energy Commission tightened its dose limits in 1961.
- Later in the 1960s, concern flared up again over public radiation exposure from routine operation of nuclear power plants.
- Again, to respond to public criticism, the AEC tightened limits of releases of radioactive material from power plants.
- Since 1974, radiation protection regulations have been created in the USA and enforced on a federal level by the NRC.
- The regulations established the safety protocol known as ALARA

History of Nuclear Safety Regulations – The ALARA Protocol

- Dose-response relationship, particularly at high dose levels, derived from survivors of the atomic bombing,
- Linear relationship between received dose and cancer risk for doses above 100 mSv
- The grounding of ALARA is in the linear-no-threshold hypothesis
- Validity of the LNT model is unclear below doses of 100 mSv and is assumed to be linear for radiation protection purposes
- Detriments (e.g. significant costs) can be incurred if ALARA is applied inappropriately
- ALARA application in many cases is driven by public opinion rather than scientific investigation

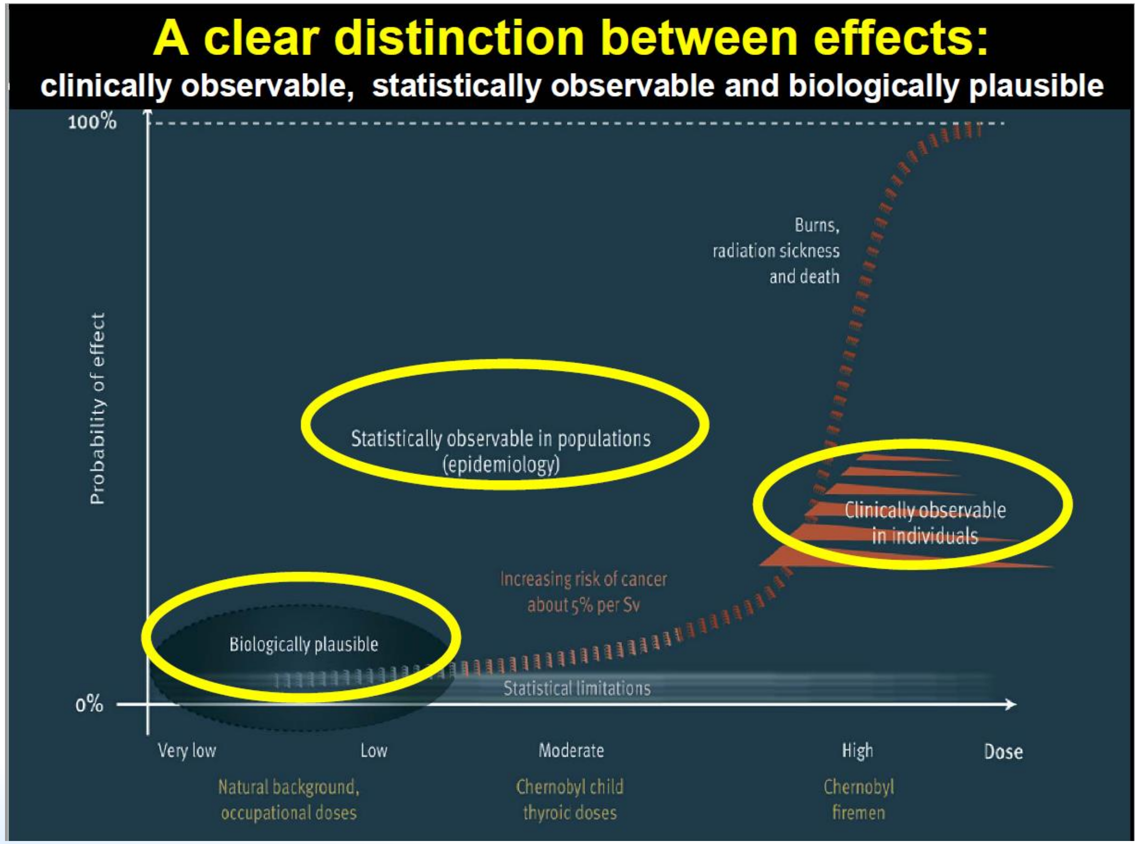


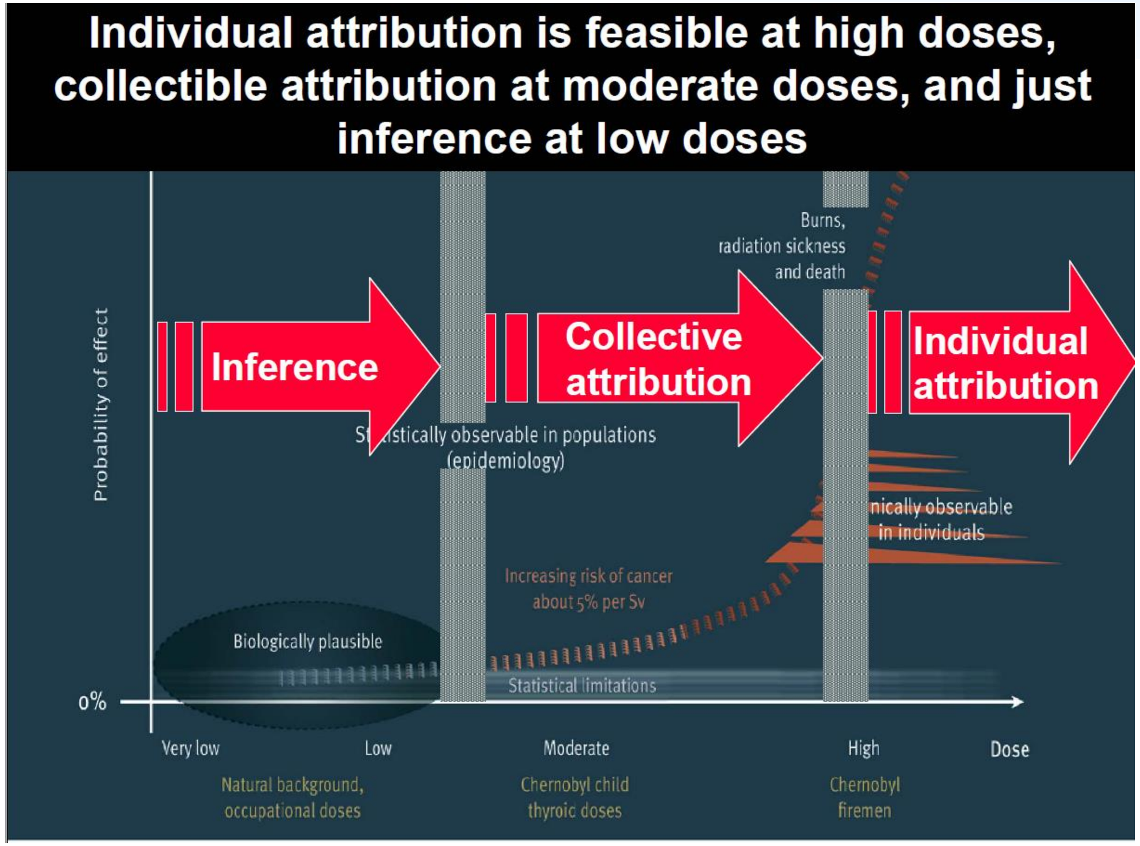


- The LNT model (A), which is the basis of the ALARA protocol, is the most conservative
- Models with sub-linear (B) or threshold (C) response have also been proposed

http://large.stanford.edu/courses/2015/ph241/baumer2/

What Science tells us?





Source: Abel Gonzales (former NSRW-IAEA Director)

The Three Principles of Radiation Protection

- Principle of Justification:
  - Decisions that alter (i.e. introduce, reduce or remove) the radiation exposure situation should, overall, do more good than harm. This means that, by introducing a new radiation source, or by overall reducing existing or emergency exposures, one should achieve sufficient individual or societal benefit to offset any harm including radiation detriment to humans and the environment.
- Optimization:
  - The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, As Low As Reasonably Achievable with economic, societal and environmental factors being taken into account
- Limitation of Dose:
  - The use of controls (in terms of doses) over the exposure of an individual to ensure that the radiation risk is acceptable.

Two types of Exposure Situations

Planned exposure situation

An exposure situation resulting from the deliberate introduction and operation of radiation sources, used for their radioactive properties. For this type of situation, the use of the source is understood, and as such the exposures can be anticipated and controlled from the beginning

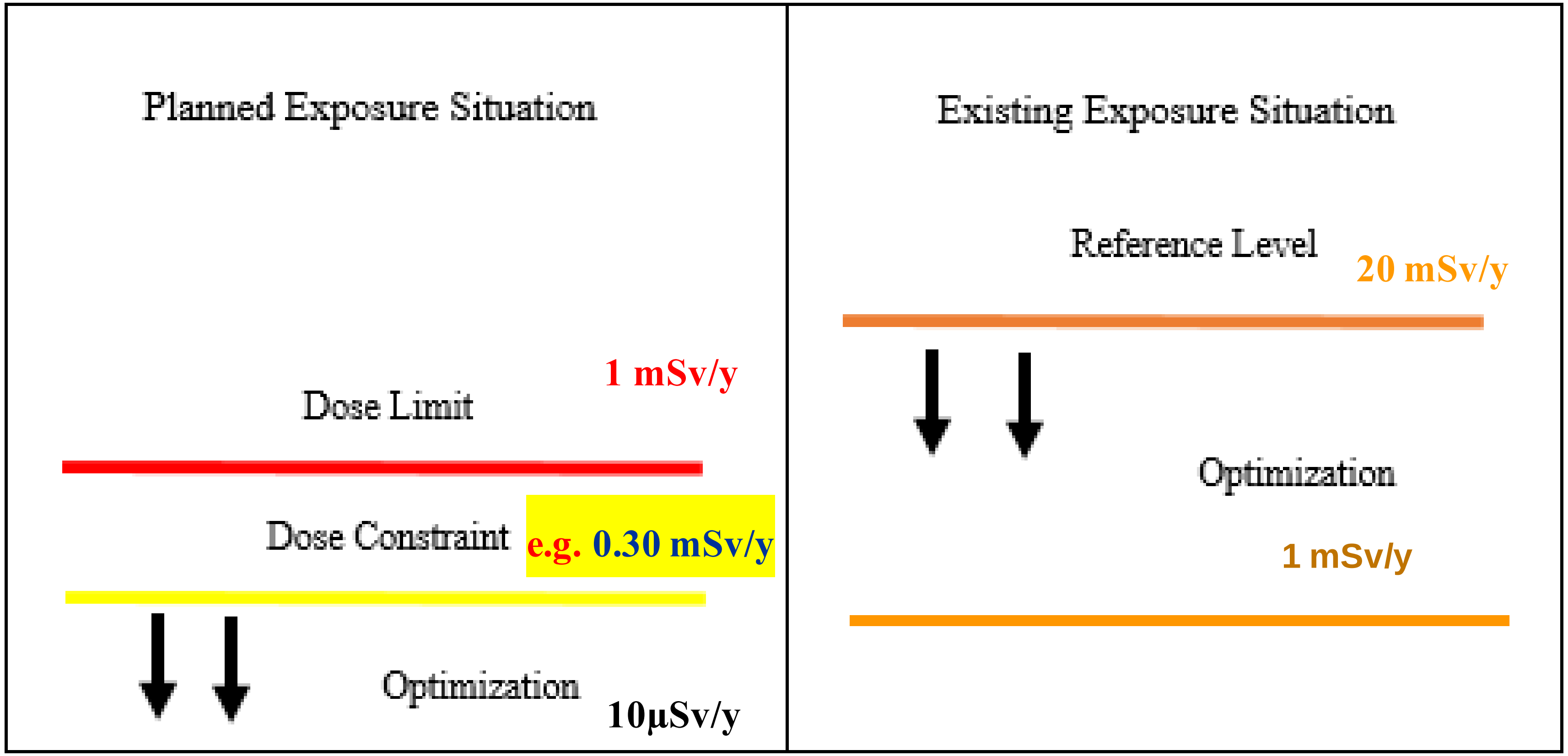
Dose Limit - The value of absorbed, equivalent, or effective dose that is applied to exposure of individuals to prevent the occurrence of radiation-induced tissue reactions or to limit the probability of radiation-related stochastic effects to an acceptable level. Dose limits apply to exposures from regulated sources only; it does not apply to medical and environmental exposure.

Existing Exposure Situation

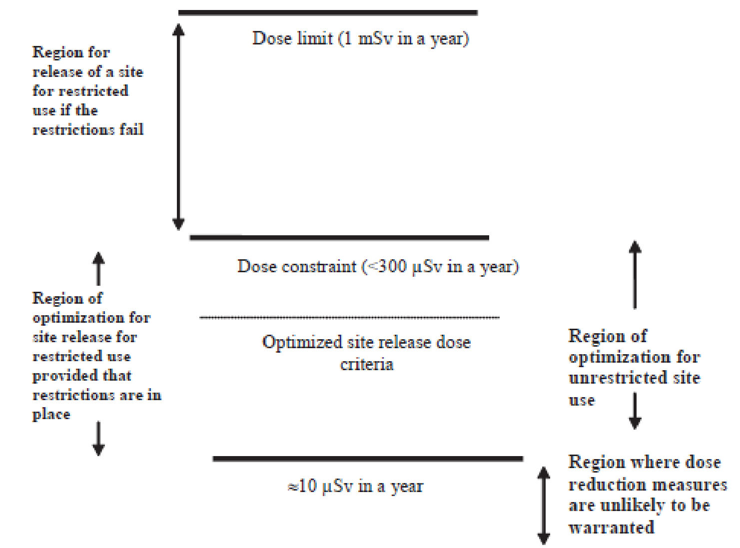
An exposure situation resulting from a source that already exists, with no intention to use the source for its radioactive properties, before a decision to control the resulting exposure is taken. Decisions on the need to control the exposure may be necessary but not urgent. (Adapted from ICRP Publication 138)

Reference level: The value of dose used to drive the optimisation process in existing and emergency exposure situations. The value of a reference level will be selected within the bands recommended by the Commission according to the prevailing circumstances. This selection should consider the actual individual dose distribution, with the objective of identifying those exposures that warrant specific attention and should be reduced as low as reasonably achievable

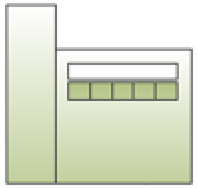
Planned x Existing Exposure Situations



Normal Operation - Planned Exposure Situation



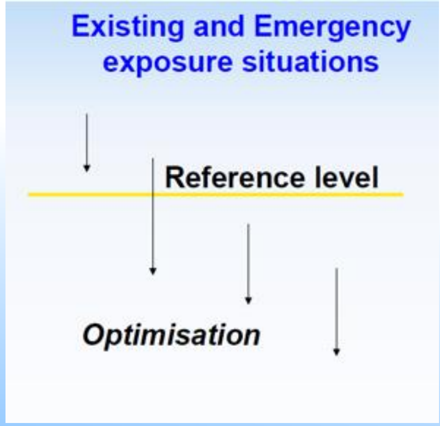
Facility = Installations + Associated Land (soil + GW)



< 1.0 mSv/y

Decommissioning: Planned Exposure Situations ideally to unrestricted use. (“Green Field”).

Accident



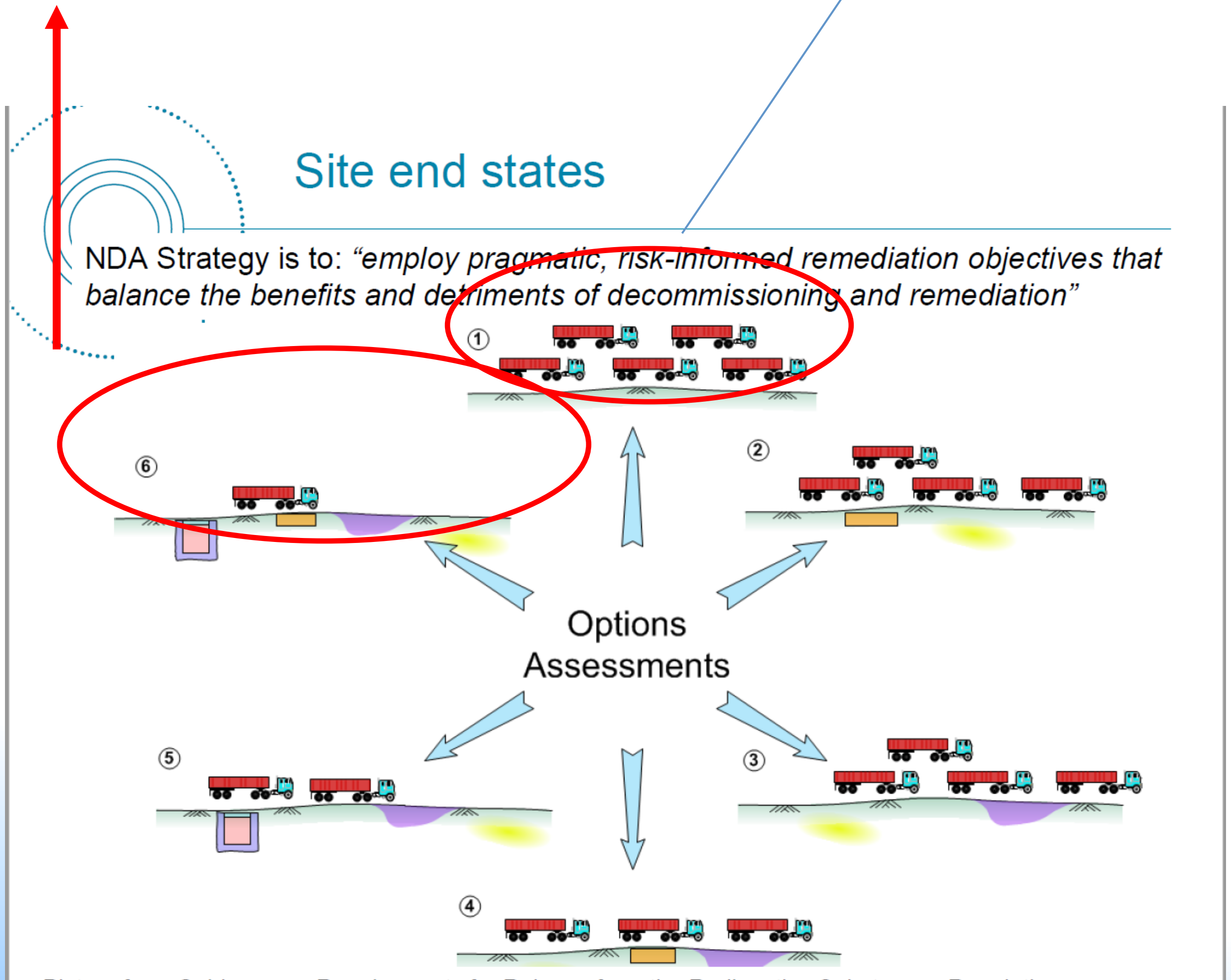
Remediation: Existing Exposure Situation

1 – 20 mSv/y

- **Sustainable ???**

- Disposal can be minimized;
- Lower CO_2 emissions
- Site can have alternative use
- Land use restrictions may be necessary for a period

- Higher CO_2 emissions
- Need for disposal site
- Noise and Nuisance
- Risks to workers and public of extracting and transporting waste
- Materials required for void-filling



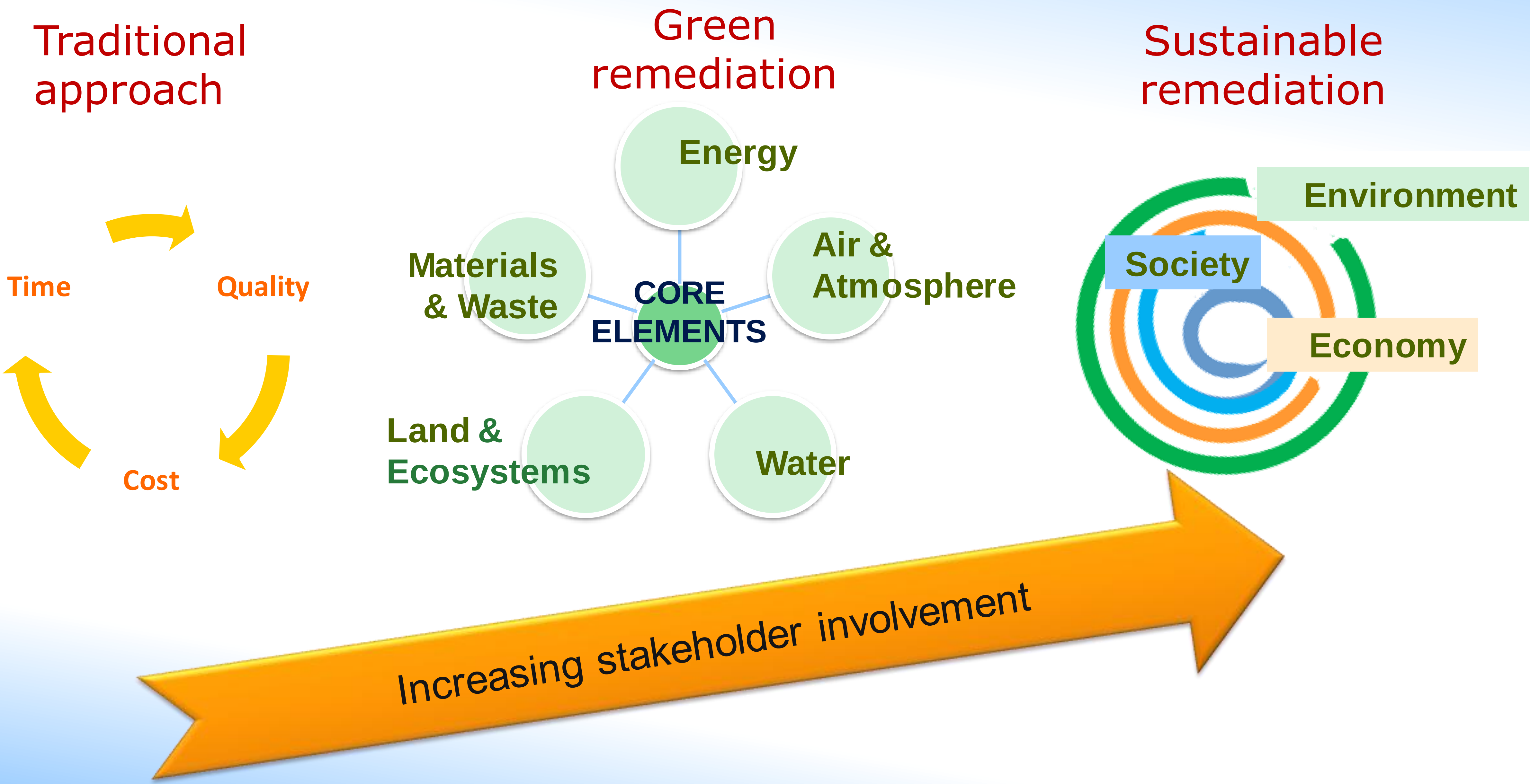
Picture from Guidance on Requirements for Release from the Radioactive Substances Regulations

Gradual Reduction of the footprint

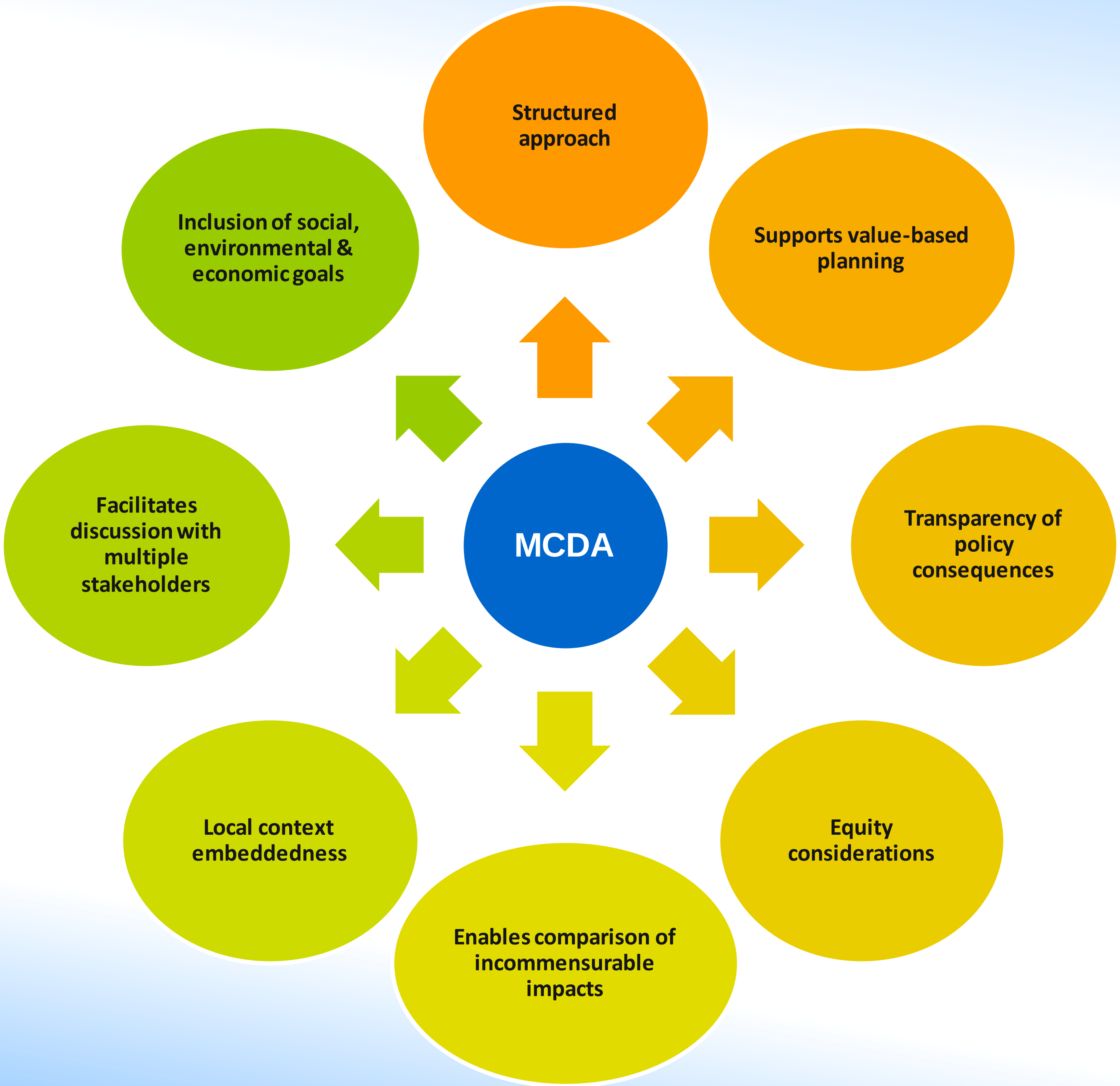
The bottom line

- ALARA protocol has successfully limited the exposure of radiation workers to impressively low levels of around 1 mSv and even less in relation to members of the public
- But in the case of remediation/clean-up of contaminated sites this might not be quite straightforward;
- However, ALARA is perceived incorrectly as requiring environmental releases or residual contamination to be as low as possible not as low as reasonably achievable;
- Let's keep in mind that ALARA also calls for taking into consideration social, and economical aspects, although this part may be less prominent (particularly on public perception)
- The environmental, social and economical dimensions form the pillars of sustainability;
- As a result, sustainability was always implicit in the ALARA principle but was not seen as such;
- So, the question is: how to bring sustainability into decision-making of ALARA?

Sustainable environmental remediation



Transparent, consistent and participatory decisions



Multi-criteria decision analysis (MCDA)

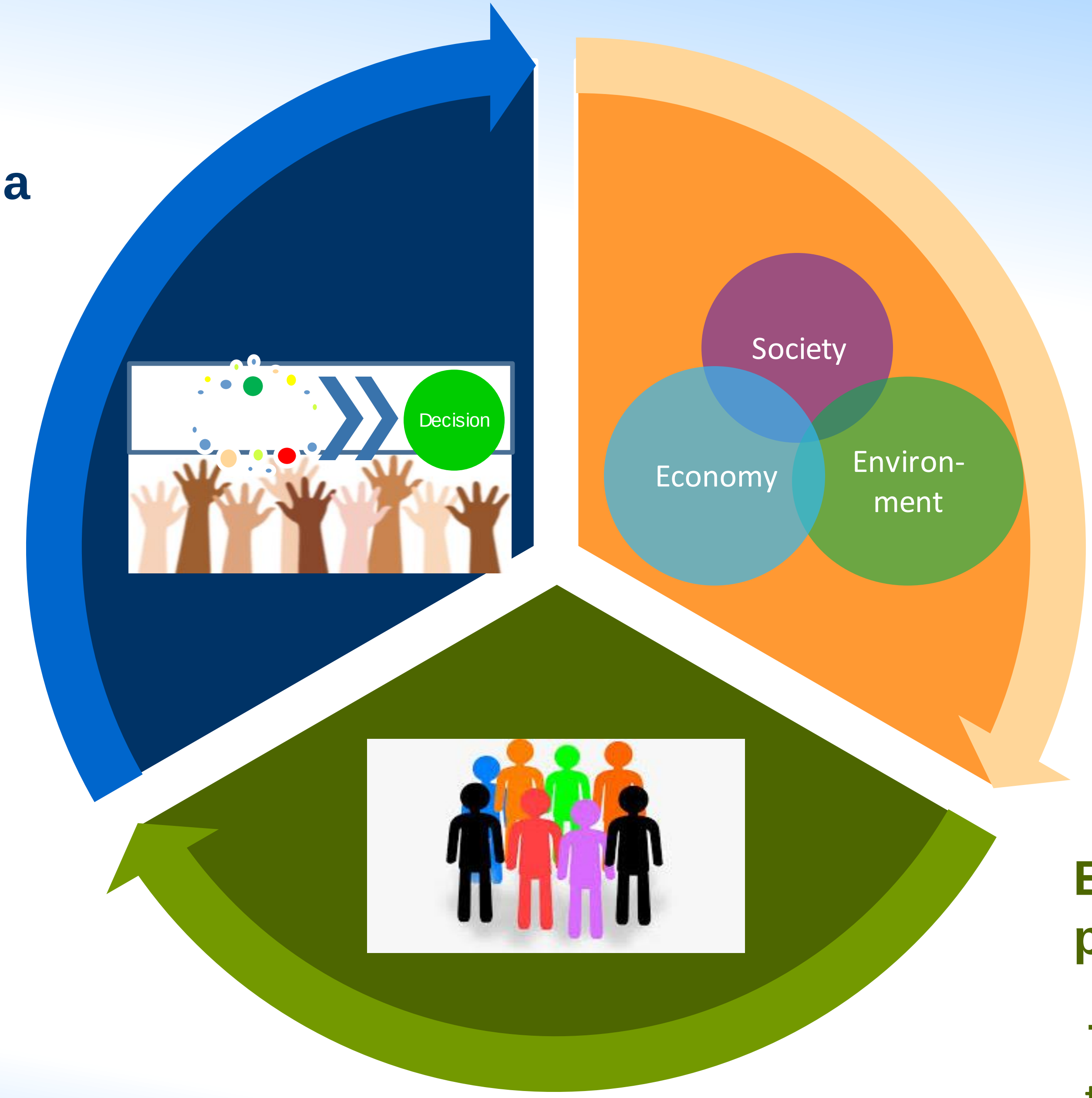
Social multi-criteria evaluation

MAESTRI Project

Framework for social multi-criteria evaluation

→Integration of technical and non-technical factors

→Participatory decision support tools



Evaluation of environmental management (EM) dimensions

→Explicitly including Sustainability Criteria in the Process

Engaging communities of practice

→Validation of framework & tools (case studies)

→Best practice & training

Example of Integrating Sustainability Criteria in Decision-Making

STEP 3 - RATING

Ratings answer the question, "How well does each alternative satisfy the interest?" Use a 'best to worst' ranking or a numeric scale (5=excellent; 4=very good; 3=fair; 2=below average; 1=poor). Rate only 2nd level criterion.

		RATINGS		
1st level criteria	**2nd level criteria**	**Option A**	**Option B**	**Option C**
Social Aspects	Community involvement and community satisfaction	2	2	5
	Radiological exposure	5	3	5
	Ethics and equality	4	4	4
	Endstate land use	2	1	1
Environmental Aspects	Resource use and waste	3	3	3
	Carbon footprint	4	3	2
	Physical and ecological impacts	5	5	5
	Groundwater and surface water	1	2	5
Economical Aspects	Short term costs and benefits	5	5	5
	Longterm costs and benefits	3	1	4
	Employment	4	4	4

Wider benefits of low input remediation

Risk management

Soil improvement

Water resource management

Renewable energy

Biofeedstock

Green infrastructure

Materials re-use

Economic gains, e.g. revenue

Social gains, e.g. amenity

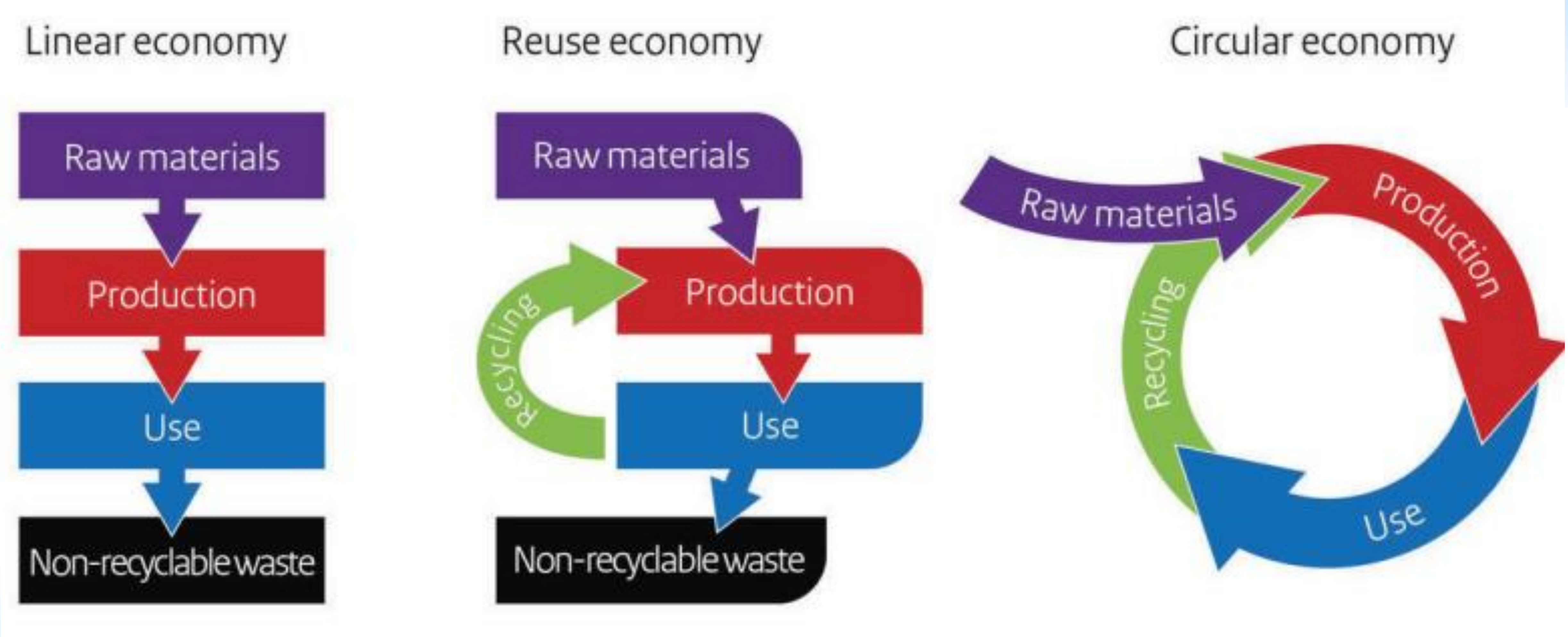
Outside the nuclear area (SURF-UK)

- Sustainable remediation has advanced substantially since its inception in the mid-2000s
- In may jurisdictions, a lack of understanding of sustainable remediation still persists within the regulatory community.
- Further expansion of sustainable remediation into corporate programs might prove difficult in some cases, despite several corporate success stories.
- An inability by remediation professionals to demonstrate the value of sustainable remediation might constrain the process.

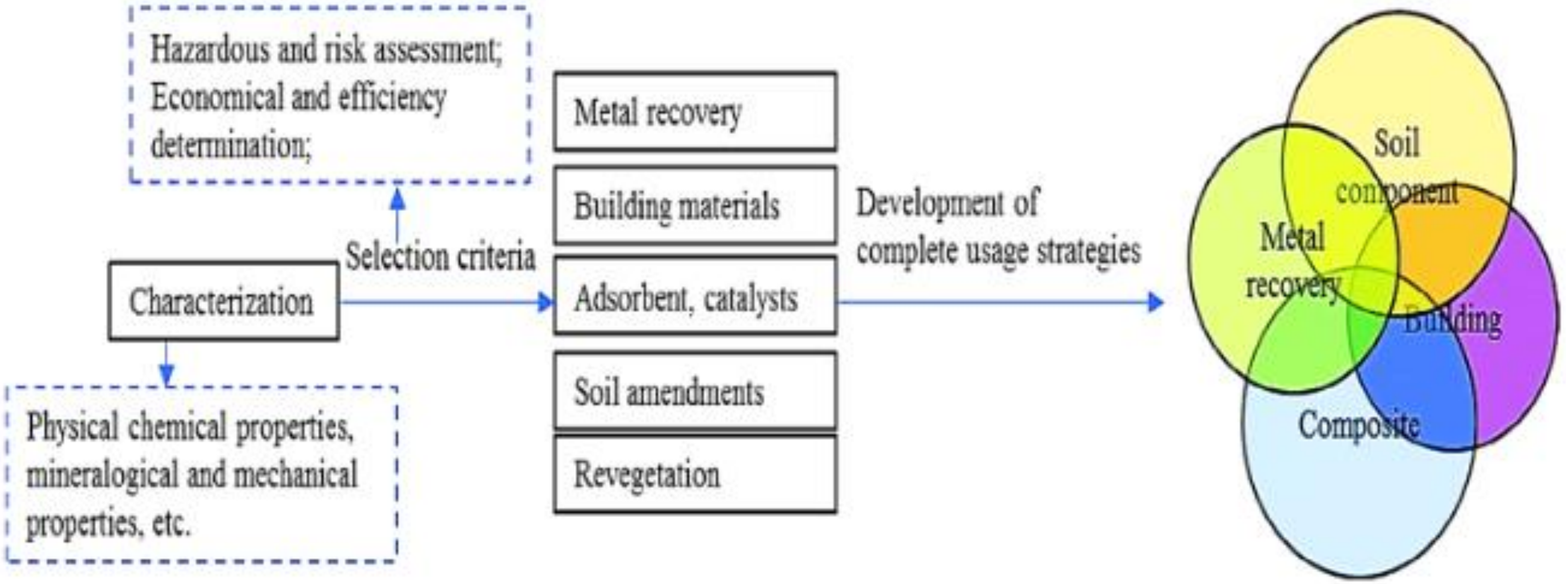
https://www.sustainableremediation.org/surf/guidance-Tools-and-Other-Resources/2019/Favara_et_al-2019-Remediation_Journal.pdf

SOME CONCRETE EXAMPLES

Linear x Circular Economy



Valorisation analysis scheme



Shaker M.A. Qaidi et al. (2022)

Reconversion strategy around the 3 pillars of sustainable development

Economic

Industrial facilities: **~7%**

Agricultural activities: **~50%**

Photovoltaic power plants: **~6%**

Environmental

Ecological lands (hives, ecosystems protection, etc.): **~10%**

Forest lands: **~25%**

Social

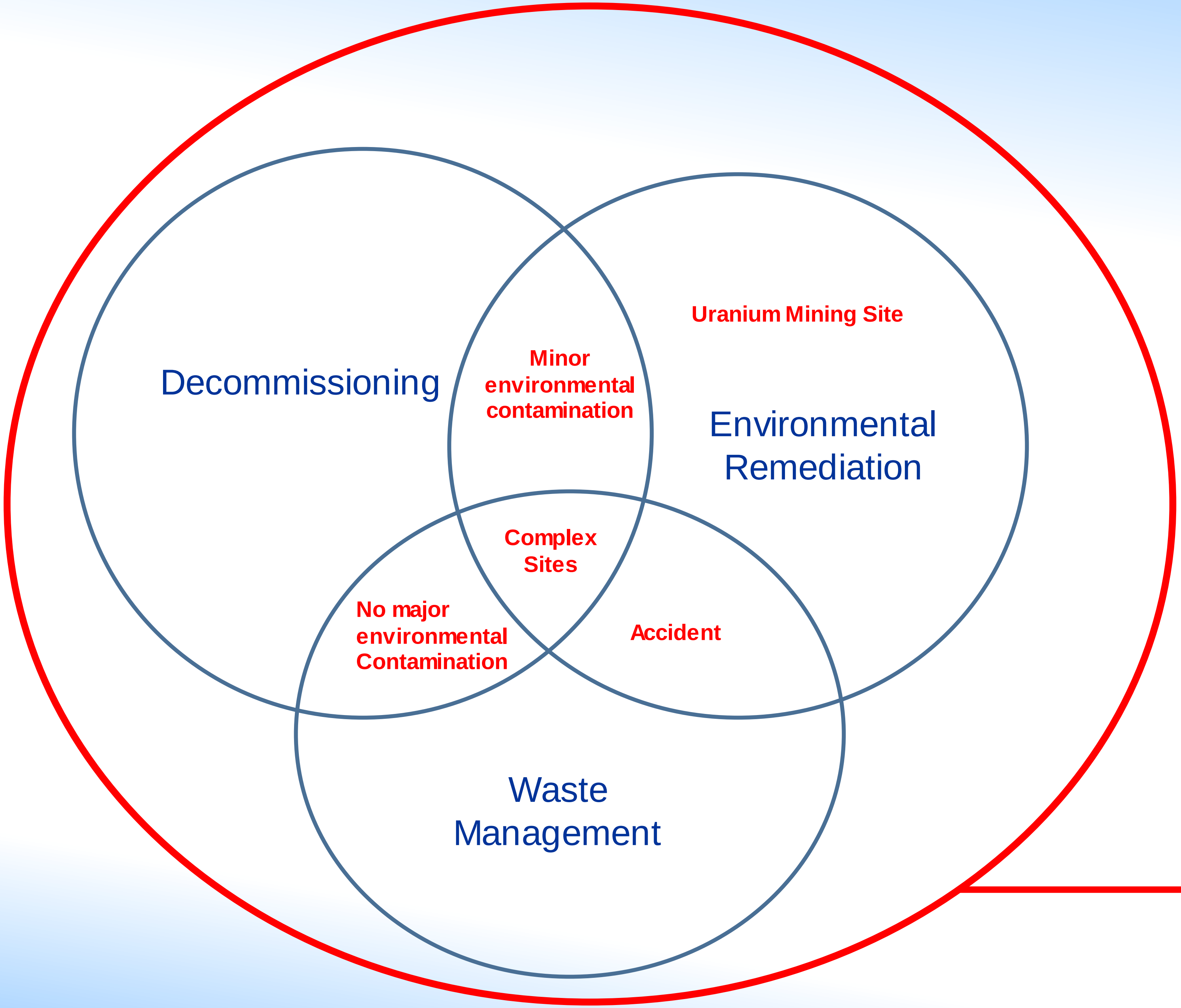
Leisure activities (fishing, hunting, etc.), training areas for firefighters, one-off agreements: **~20%**

Several different reconversions are possible for each site

Source

orano

Finally, Sustainability, yes…



But also, Holistic!!!

In conclusion

Sustainable approach

You should consider using a sustainable approach when you select remediation options.

Sustainable remediation can provide the opportunity to manage unacceptable risks to human health and the environment. If you use a sustainable approach it can help to ensure the:

- benefit of doing the remediation is greater than its impact
- impacts of climate change and extreme weather events are taken into account when selecting the final options

Consider the relative ability of each option to achieve the remedial objectives in a safe and timely manner whilst optimising the environmental, social and economic value of the work.

For further detailed guidance on sustainability see SuRF-UK on the CL:AIRE website.

See also:

- sustainability in LCRM: Before you start
- BS ISO 18504: Soil quality – sustainable remediation.

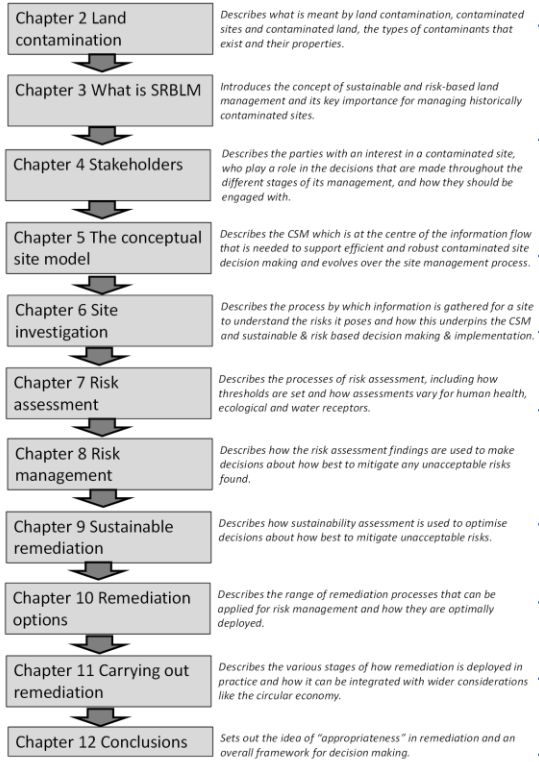
Interested in participating in MAESTRI?

Register at:

- https://nucleus.iaea.org/sites/connect/ENVIRONETpublic/Pages/default.aspx

And Join Environet

Additional Resources - SRBLM Book



- Bardos P. : Sustainable and risk based land management for contaminated sites in practice.
- Supported by FECO-MEE, will be published in English and Chinese in 2024.
- English version *likely* will use Amazon platform @ $9.99
- Single narrative of approx. 250 pages
- Seeking >20 applied sponsored case studies for a "Volume 2"
- ~20 high level operating windows
- Bibliography of approx. 1,000 citations
- Peer reviewed by 20 experts from around the world
- Taken 4 years to produce

IAEA
60 Years
Atoms for Peace and Development

Disclaimer: Some of the messages shared in this presentation does not necessary represent the position of the IAEA

Thank you!