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Technical workshop
Dynamic nuclear fuel cycle

Economic Appraisal of The Schedules of High Level Radioactive Waste Repositories

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PLAN

1. Problem definition
2. Constraints influencing the DGR implementation schedule
3. Economic appraisal of different DGR schedules
4. Conclusion and Perspectives

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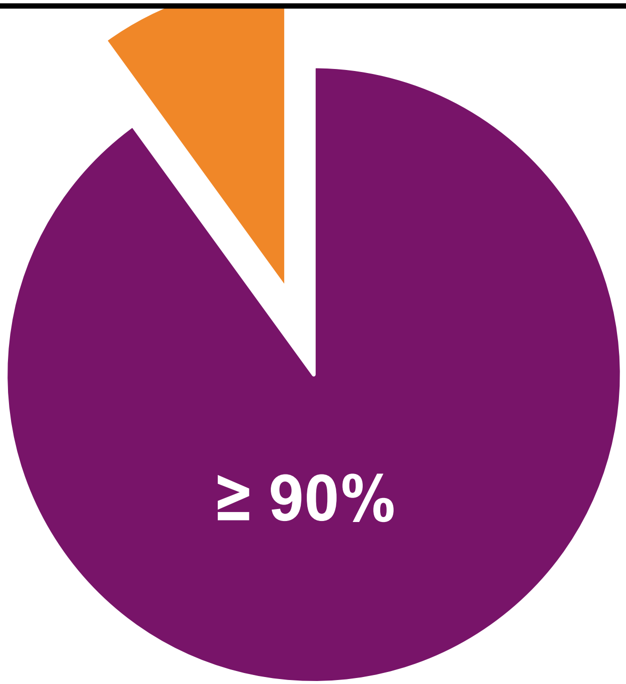
Problem Definition

WORLD RADIOACTIVE WASTE MANAGEMENT

≤ 10% in volume, **long lived intermediate level and high level waste**, accounts for over **95%** of the total radioactivity produced => Being stored in spent fuel ponds and interim storage facilities while waiting for a definitive disposal option.



≥ 90 % in volume**, low level and short-lived intermediate waste**, is being disposed of safely in near-surface repositories.

PROBLEM DEFINITION

- **Solution :** International convergence on the **Deep Geological Repository** (DGR) for the high level waste management.

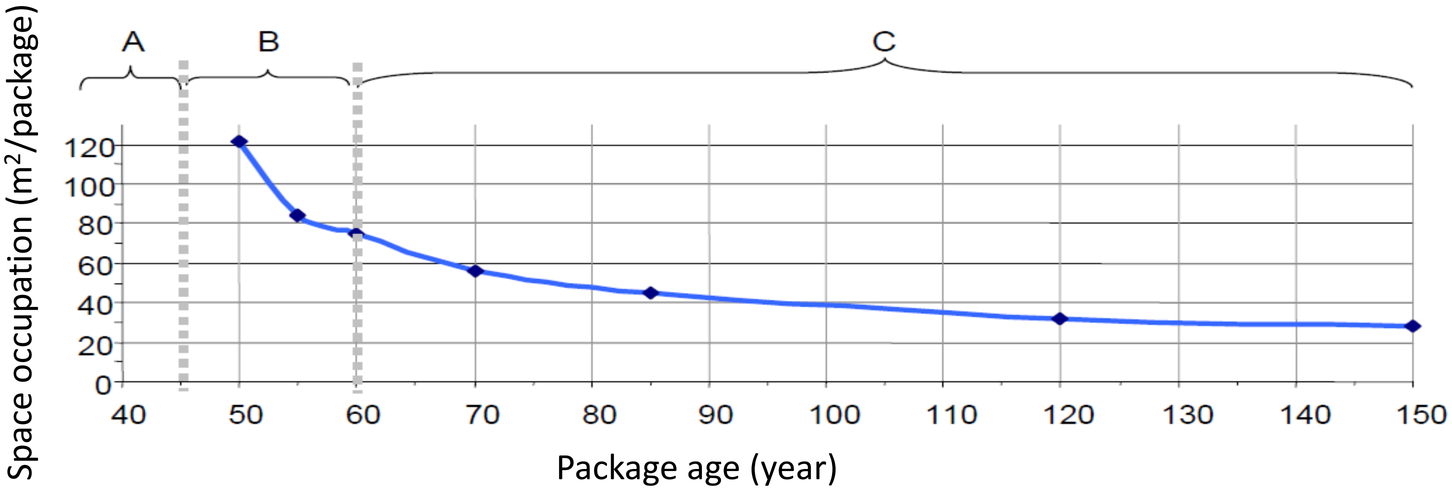
- **Arguments:**

« Rapid or Immediate » Disposal	Delayed Disposal
▫ Demonstrate that all steps of nuclear activity are controlled. ▫ Relieve future generations from the waste management burden. ▫ High reliability in term of project financing.	▫ Radioactivity decay ▫ Discounting effect ▫ Make sure of the waste ultimate nature and technical solutions. ▫ Economies of scale

Economic Assessment of Different Schedules of DGR Implementation ?

Constraints influencing the DGR timing decision

WASTE THERMICS AND RADIOACTIVITY DECAY

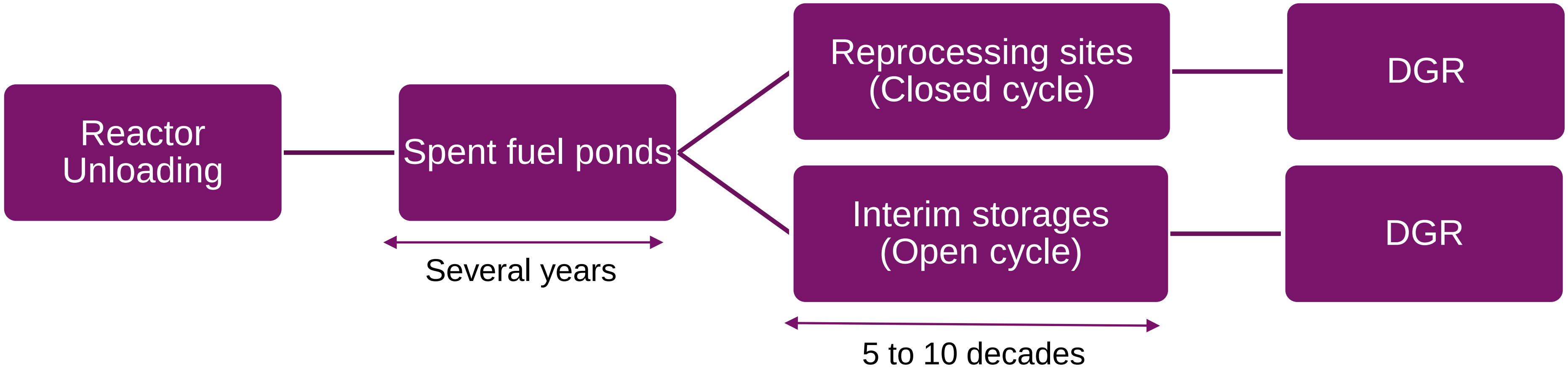


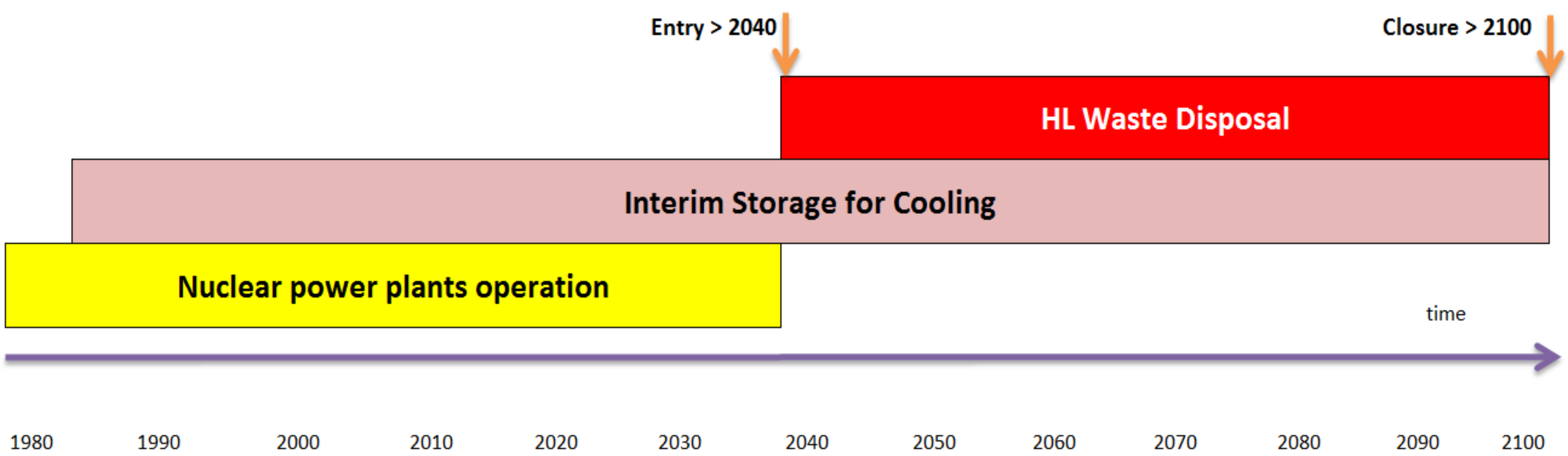
A: Technical impossibility (<45 years); B: Excellent package age sensitivity (45-60 years); C: Lower sensitivity (>60 years)

Influence of cooling duration on package space occupation (French concept – clay formation)

- HLW packages need cooling for several decades before disposal for reducing the waste heat production.
- HLW packages are then spaced each other in the disposal to respect the geology thermal constraints (e.g. 90 °C limit in a clay formation in France).
- The longer the cooling period, the more the residual thermal power is reduced, which gives the possibility to design the more compact hence cheaper repository.

WASTE FLOW MANAGEMENT





POLITICAL AND SOCIAL ASPECTS

- Political decisions (law, decree, …)
- National back-end strategy (direct disposal or reprocessing)
- National energy strategy (nuclear phasing out, developing, …)
- Financial resources
- Regional and international guidance
- Stakeholder responsibilities
- Public acceptance
- ….

Economic Appraisal of Different DGR Schedules

TIME VALUE IN ECONOMIC ANALYSIS

- **Regret Mini-Max/MiniMin/Maximax** adapted in the case of unmeasurable uncertainties.

- **Internal rate of return of the project**: A rate that makes the net present value of all cash flows from a particular project equal to zero. The higher a project's internal rate of return (than the interest rate), the more desirable it is to undertake the project.

- **Rate of return of household savings**: If this rate is lower than the internal rate of return of the project, the investment will be financed by the sacrifice of present consumption.

- **Discount rate** helps to deduce the current value of a future expense and to calculate the net present value of a long-term project.

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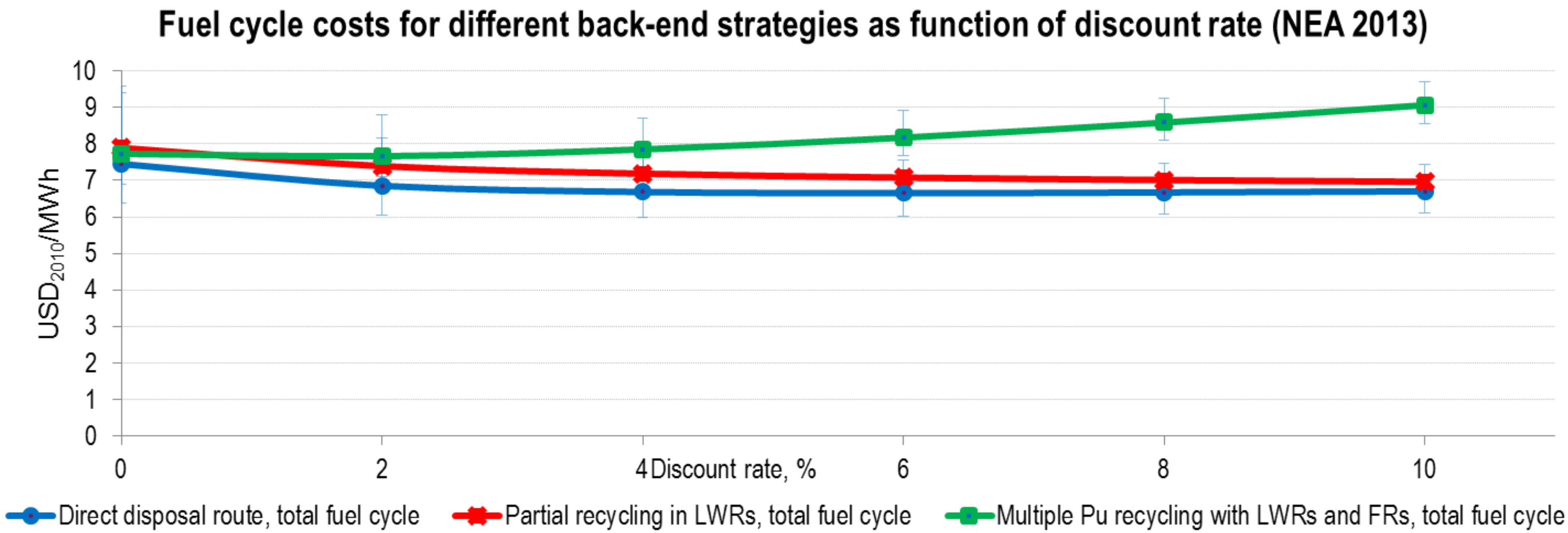
DISCOUNT RATE – ORDER OF MAGNITUDE

- The **French ministerial order** of February 2007 related to the securing of funding for nuclear expenses : **2.7%** (last updated).
- **ANDRA** uses a discount rate of de 3.5% including inflation, or **1.7%** (real rate).
- **French nuclear operators** have chosen a rate of roughly **2.9 %**.
- Department of Energy, **US** : **3%**
- **Spain**: **1.5%**
- **UK** : **2.2% to 3%** according to provision timing.
- **Sweden** : **2.5% to 3.25%** according to provision timing.

=> **Calculations are performed with different discount rates (from 0% to 5%, updated to 2016).**

INPUT DATA

- **The economics of the back-end of the nuclear fuel cycle, NEA (2013)**
  - **Direct disposal**, where the fuel is used once and is then regarded as waste to be disposed of.
  - **Partial recycling**, where the spent fuel is reprocessed to recover unused uranium and plutonium for recycling in light water reactor.
  - **Multiple plutonium recycling**, single MOX and REPUOX recycling in LWRs and multiple plutonium recycling in fast reactors.



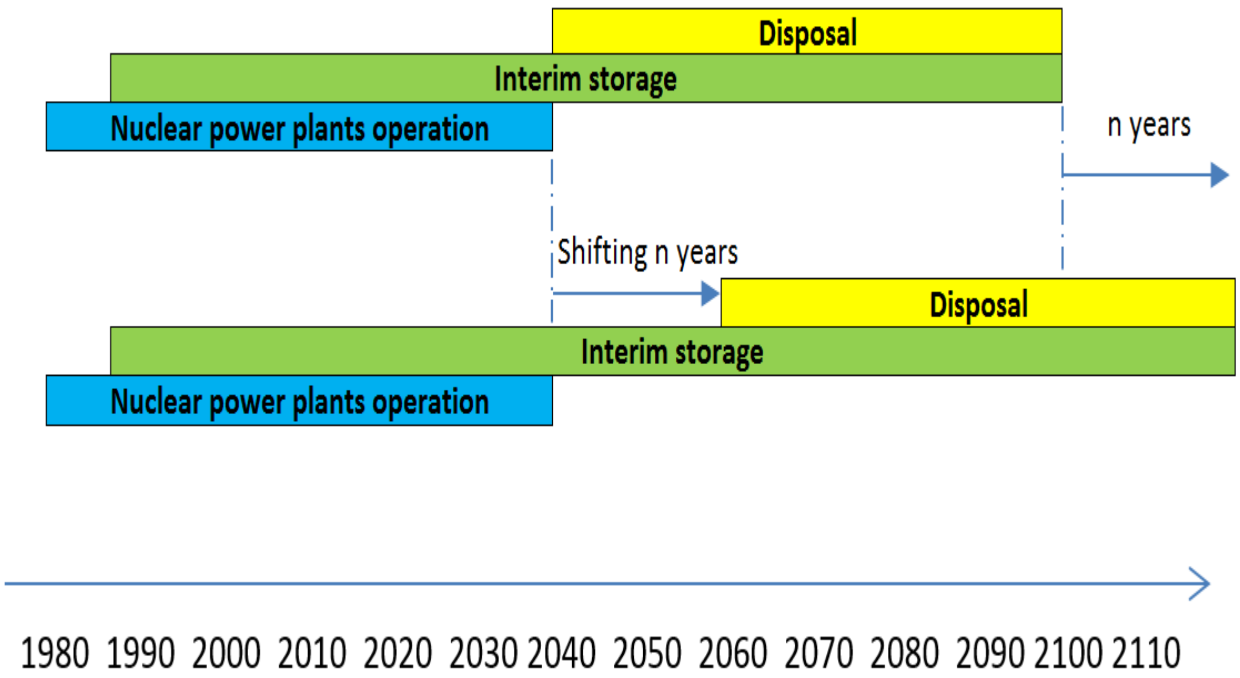
ASSUMPTIONS FOR A GENERIC CASE

- **Direct disposal** : SNF is stored for at least 60 years; then it is encapsulated and finally disposed in the deep geological repository.
- The total waste inventory to be disposed of is **30 000 tHM** produced by a **fleet of LWRs operating between 1980 and 2040**.
- The **encapsulation facility** and the **deep geological repository** are put in place at the same time. They are planned to **start in 2040** and to **end in 2100**.
- **Stable and continued R&D activities** (research, local integration) until the DGR implementation (progressive reprogramming steps).
- All cost values are expressed in **$M\$_{2010}$** and are levelized to **2016**.

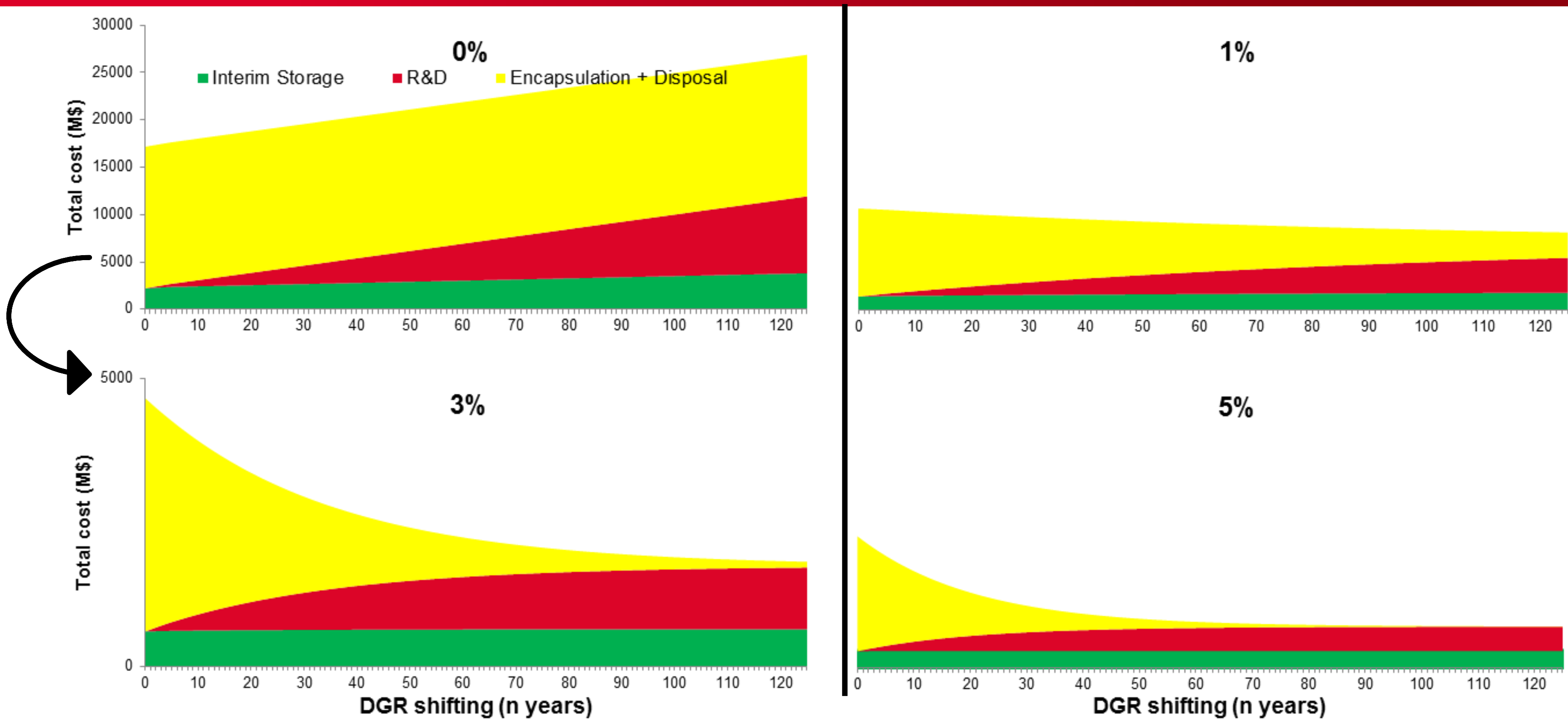
FIRST ANALYSIS : EFFECTS OF RESCHEDULING THE DEPLOYMENT OF A DGR WITH THE SAME INITIAL OPERATIONAL PERIOD

Reference scenario

Shifted scenario with rigid temporal profile



FIRST ANALYSIS RESULTS

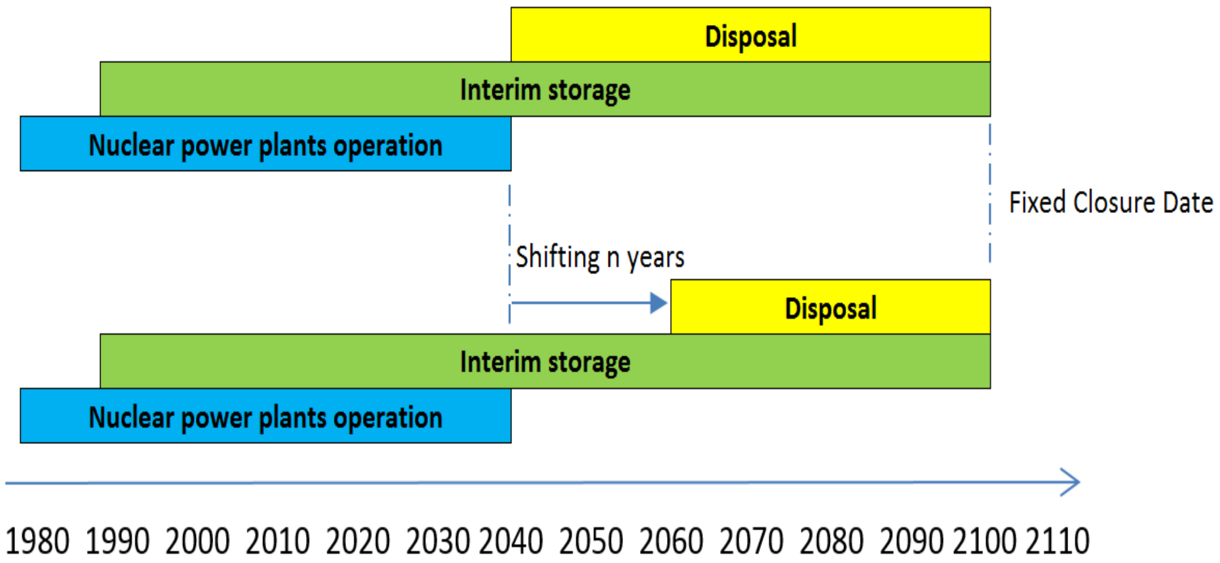


- With "usual" discount rates, no economic interest to dispose of quickly the waste.
- Countries who have chosen the "immediate" disposal are willing to accept the higher costs for quickly solving the problem and relieving future generations from such burden.
- These overcosts can reach roughly a factor of 3 with the rate of 5% or even 8 if deciding not to carry out any R&D activity and local support programs.

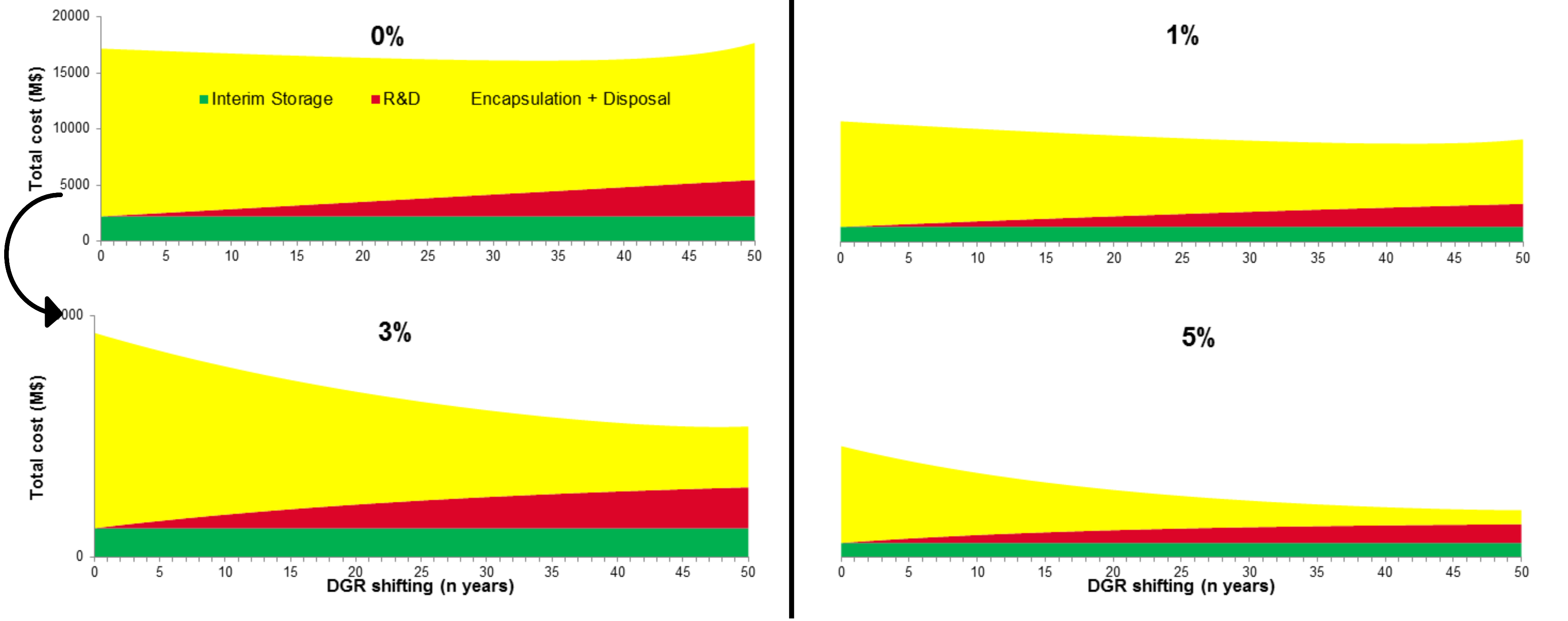
SECOND ANALYSIS : EFFECTS OF RESCHEDULING THE DEPLOYMENT OF A DGR WITH THE INITIAL CLOSURE DATE

Reference scenario

Shifted scenario with fixed closure date



SECOND ANALYSIS RESULTS



- The “optimal” solution is to dispose of 30000 tHM (the total waste inventory for a generic case) during roughly 15 years with the flow of 2000 tHM/year.
- But, the results need to be confirmed with engineering studies for a more accurate estimate on the investment augmentation as function of waste flow.

Conclusion and Perspectives

CONCLUSION AND PERSPECTIVE

- With “usual” discount rates (≥1%), it is more economically favorable to extend the interim storage of SNF/HLW than to dispose of the waste immediately.
- It is further supported by the radioactivity decay.
- But some countries are willing to accept higher costs for quickly solving the waste problem.
- High flow disposal is more economically preferable.
- The economies of scale are important for the DGR : 10 identical disposal of 3000 tHM is far expensive than one unique disposal of 30000 tHM (10*6.3b$ >> 9b$); but public opposition of receiving other waste.

Further study:

- Integrating other factors in the model : social value of “immediate” disposal, accidental risks of prolonged storages or during disposal operation, …
- Taking into account other aspects : technological progress, energy context, economic growth, changes in social acceptance,…

Thank you for your attention

Annexe

DISCOUNT RATE FOR DGR PROJECT

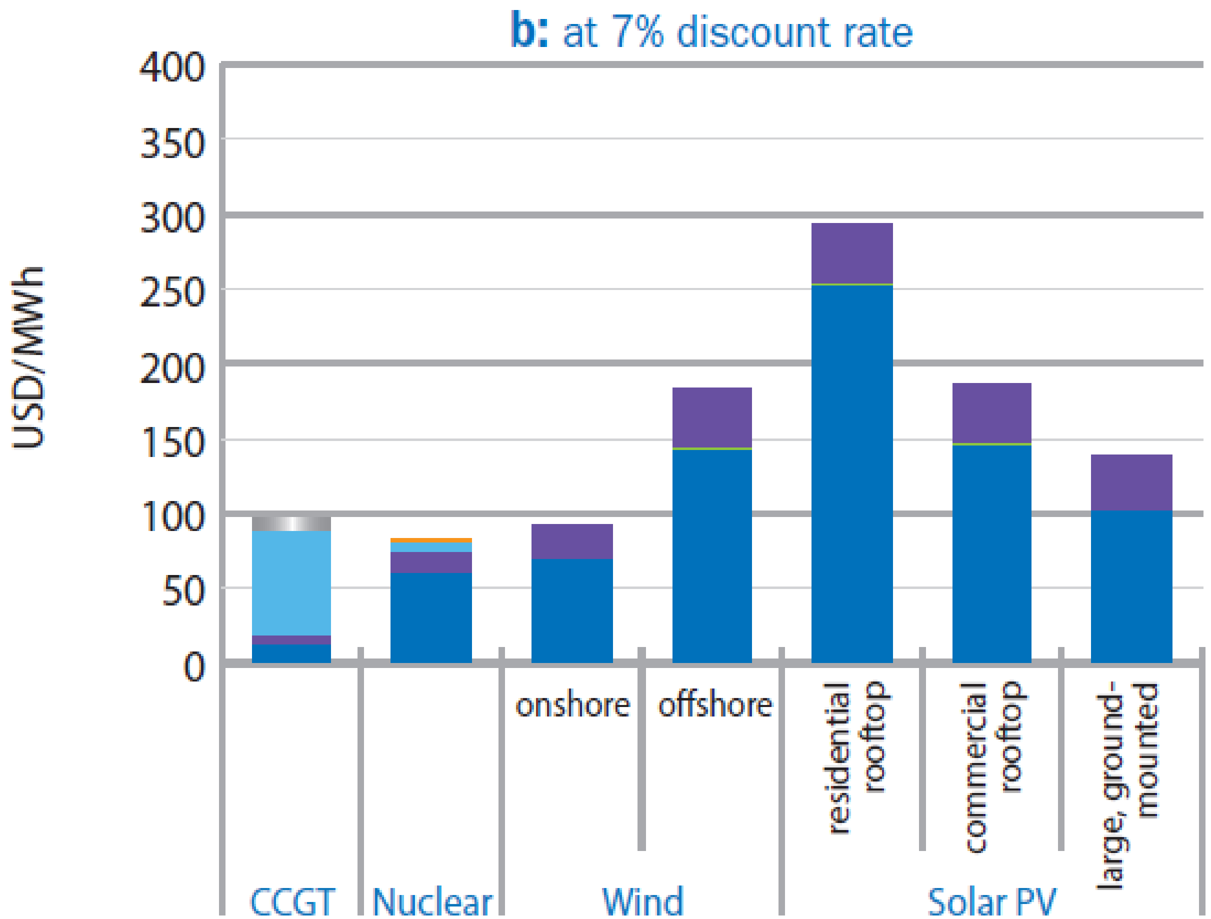
- Long operation period of the DGR : the price of health and that of environment would definitely increase. = > Low discount rate.

- Uncertainties and risks on the estimated cash flow => reduce the discount rate.

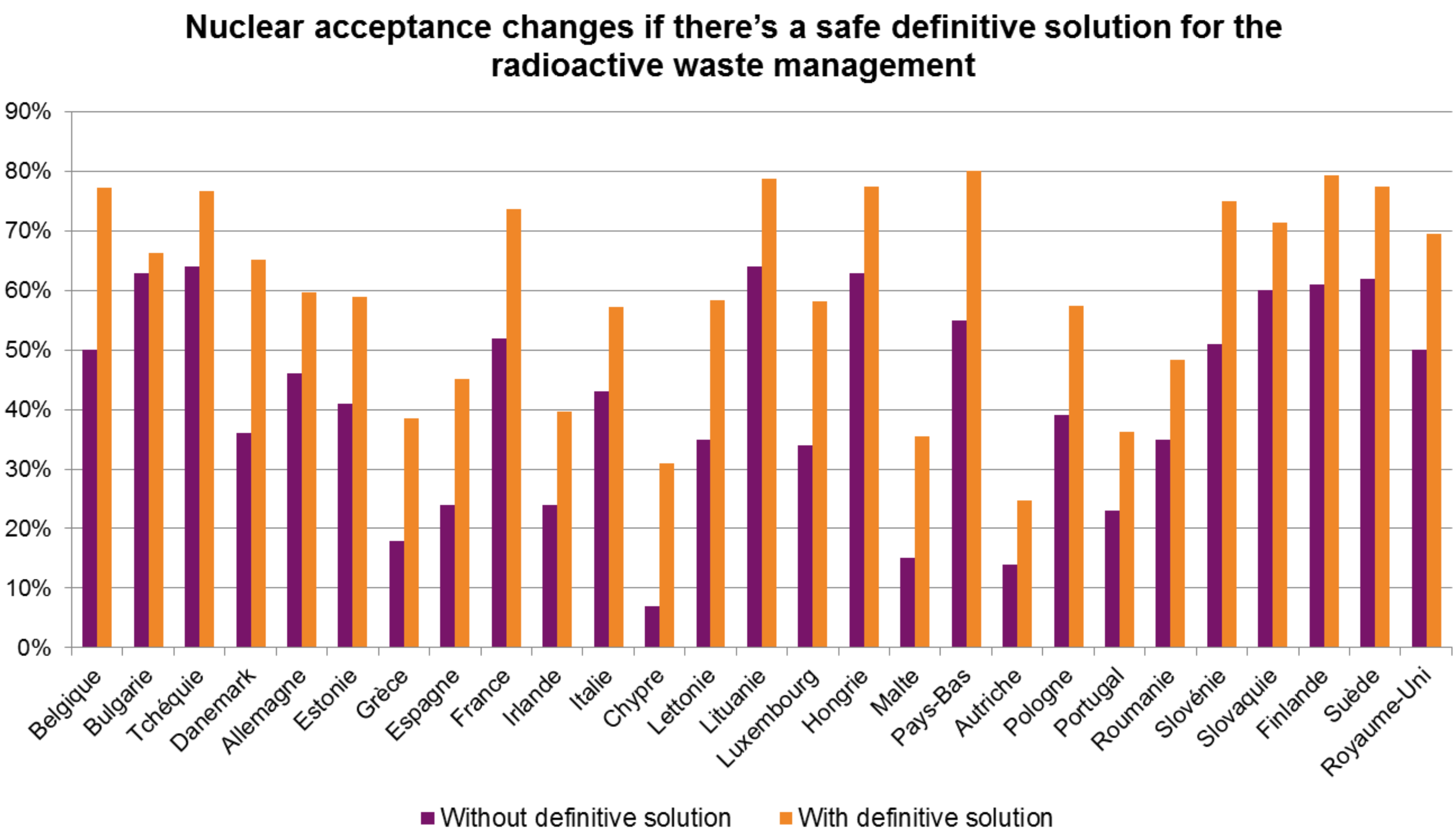
- The project cash flows are always negative. => lower the discount rate.

- The disposal project is regulated by law. However, the only microeconomic assessment with the usual rates would not validate, at first sight, a decision to dispose of the radioactive waste compared to a simple interim storage. Thus, the willingness to make a solution having no burden on future generations induces to choose a very low or zero rate in the disposal program for having a coherent time schedule with the law.

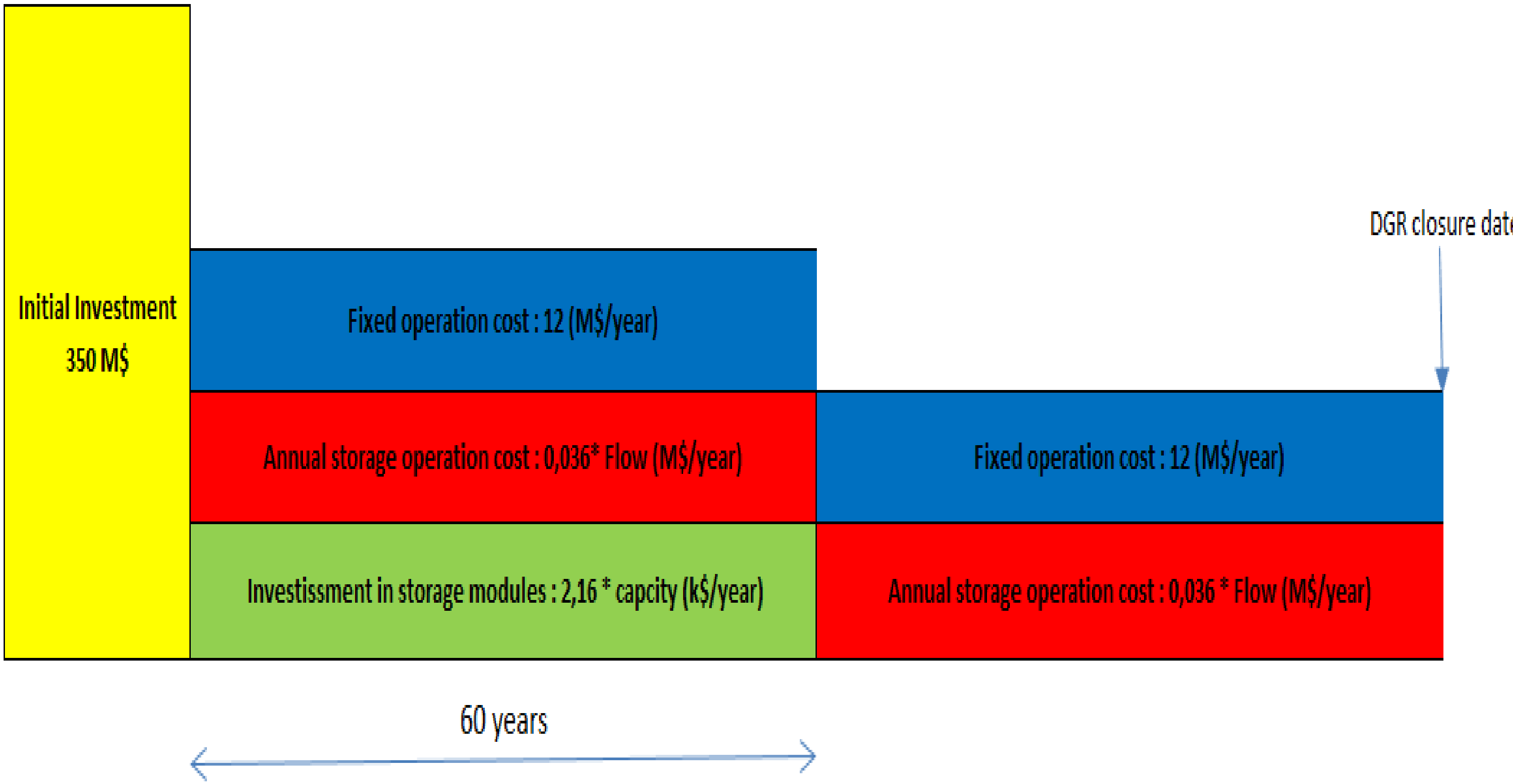
ELECTRICITY LEVELIZED COSTS



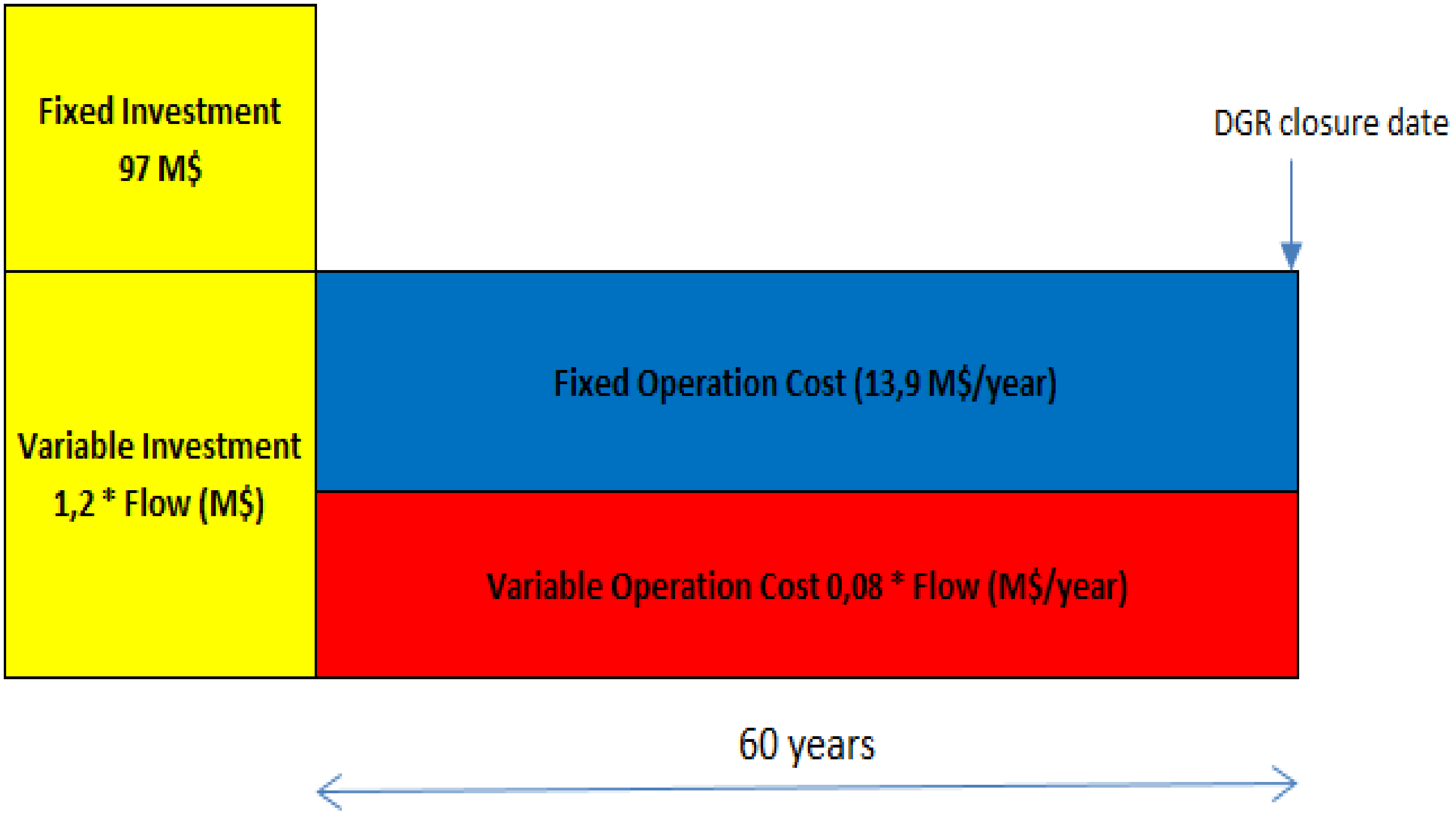
SOCIAL VALUE OF DGR



INTERIM STORAGE COST



SNF ENCAPSULATION COST



DISPOSAL COST