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ECONOMIC APPRAISAL OF DEPLOYMENT SCHEDULES FOR HIGH LEVEL RADIOACTIVE WASTE REPOSITORY IN FRANCE

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PRESENTATION OUTLINE

1. **Problem Definition and Study Objectives**

2. **Economic Appraisal of Different Deployment Schedules for Deep Geological Repository**

3. **Conclusion**

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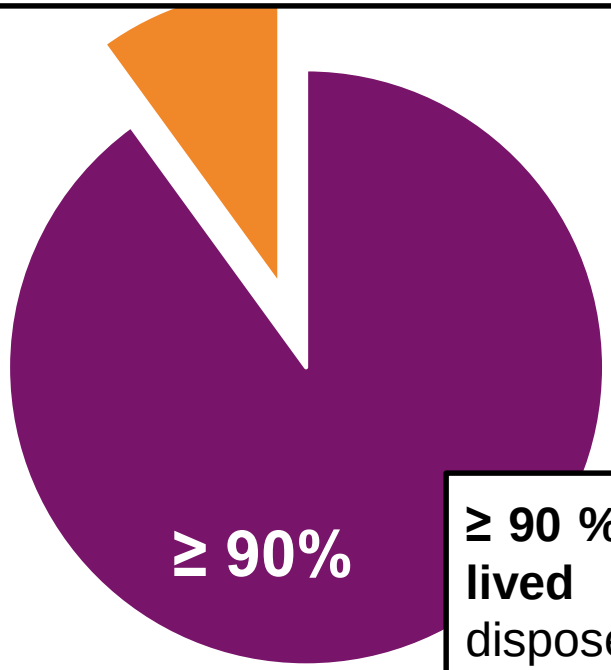
Problem Definition and Study Objectives

RADIOACTIVE WASTE MANAGEMENT IN FRANCE

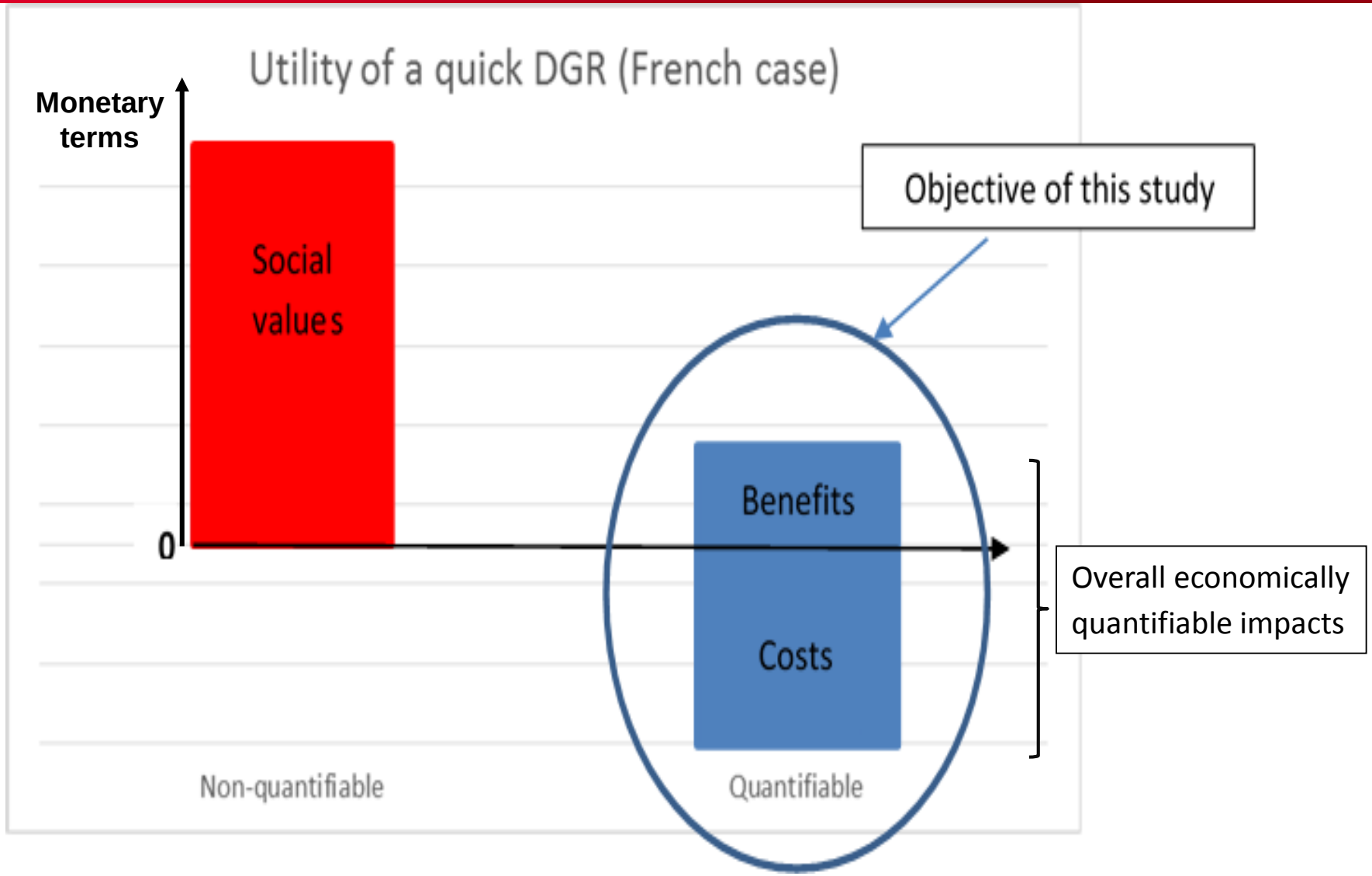
≤ 10% in volume, **long lived intermediate level and high level waste**, over **95%** of the radioactivity => **Waiting** for a definitive disposal option : **Deep Geological Repository (DGR).**



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

DGR IMPLEMENTATION – SOCIAL AND POLITICAL ISSUE

FRANCE'S PLANNING ACT OF 2006



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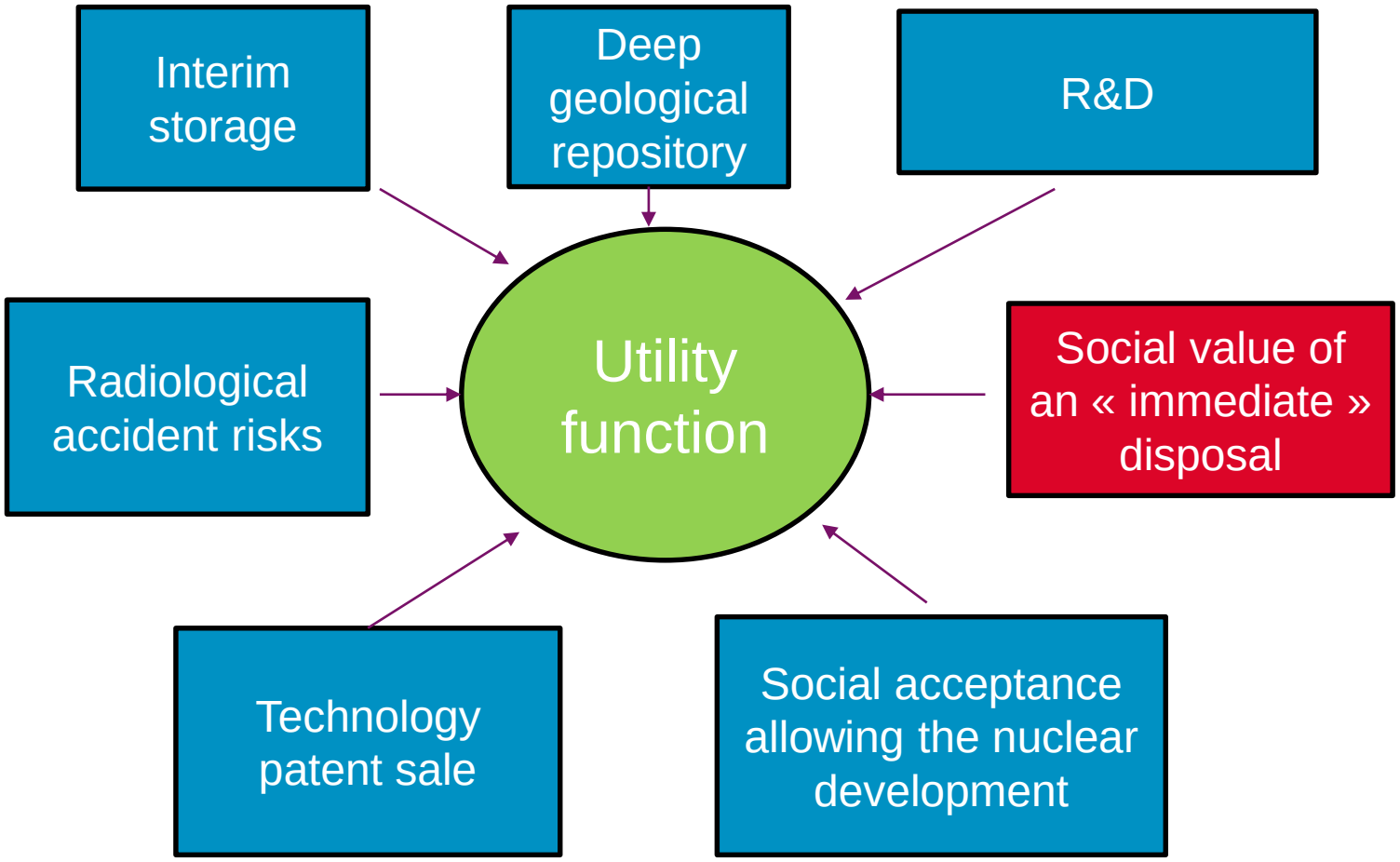
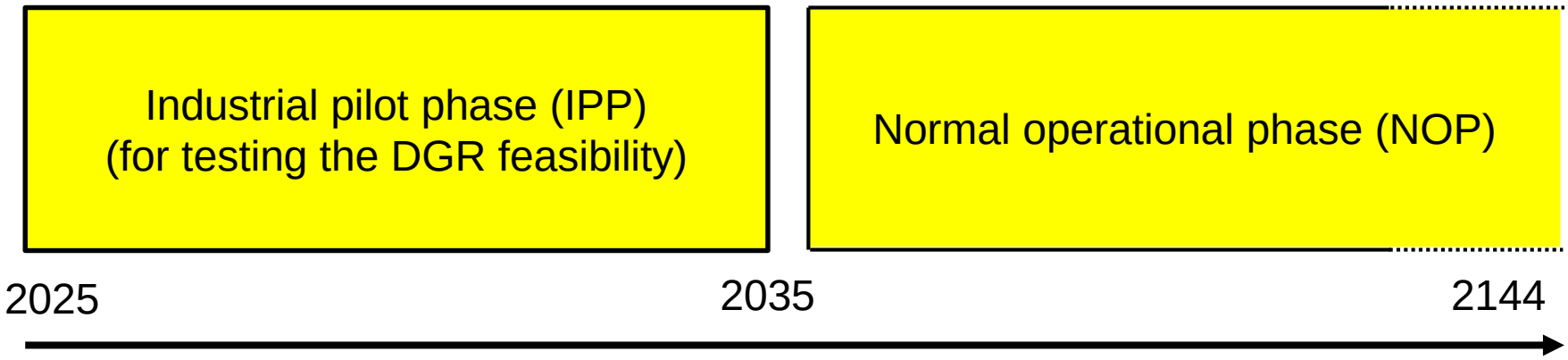
Economic Appraisal of Different Deployment Schedules for DGR

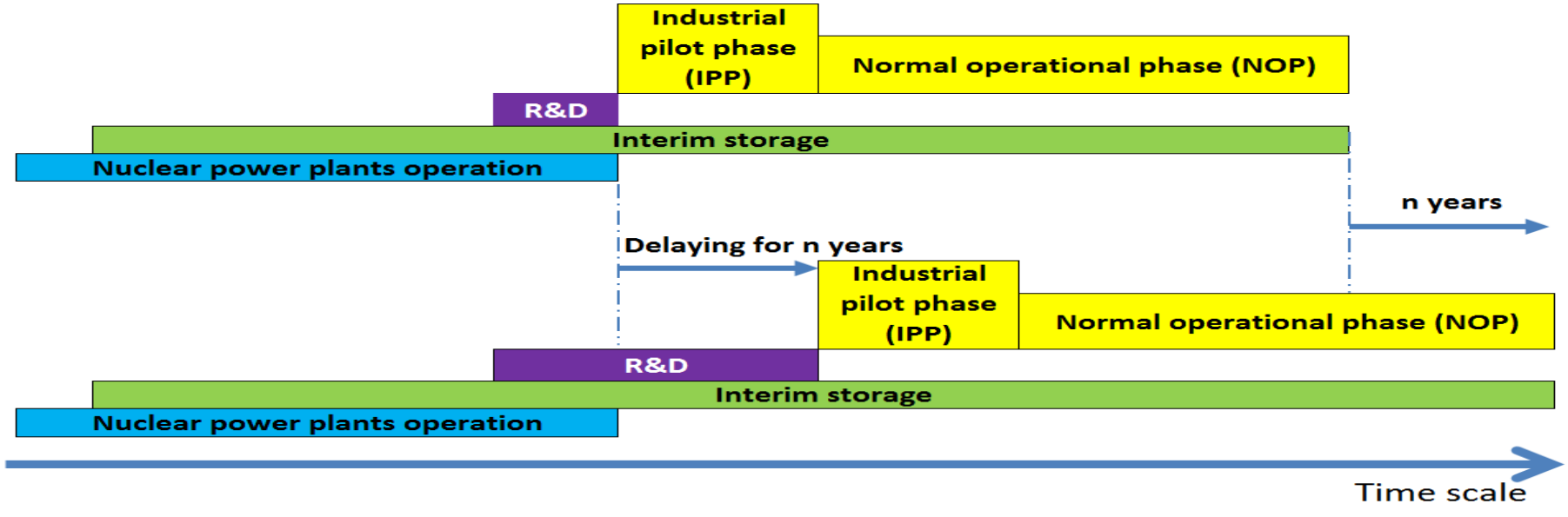
METHODOLOGY : UTILITY FUNCTION



PLANNED SCHEDULE OF CIGÉO PROJECT



1ST CALCULATION : ANALYTICAL FUNCTION 1/2

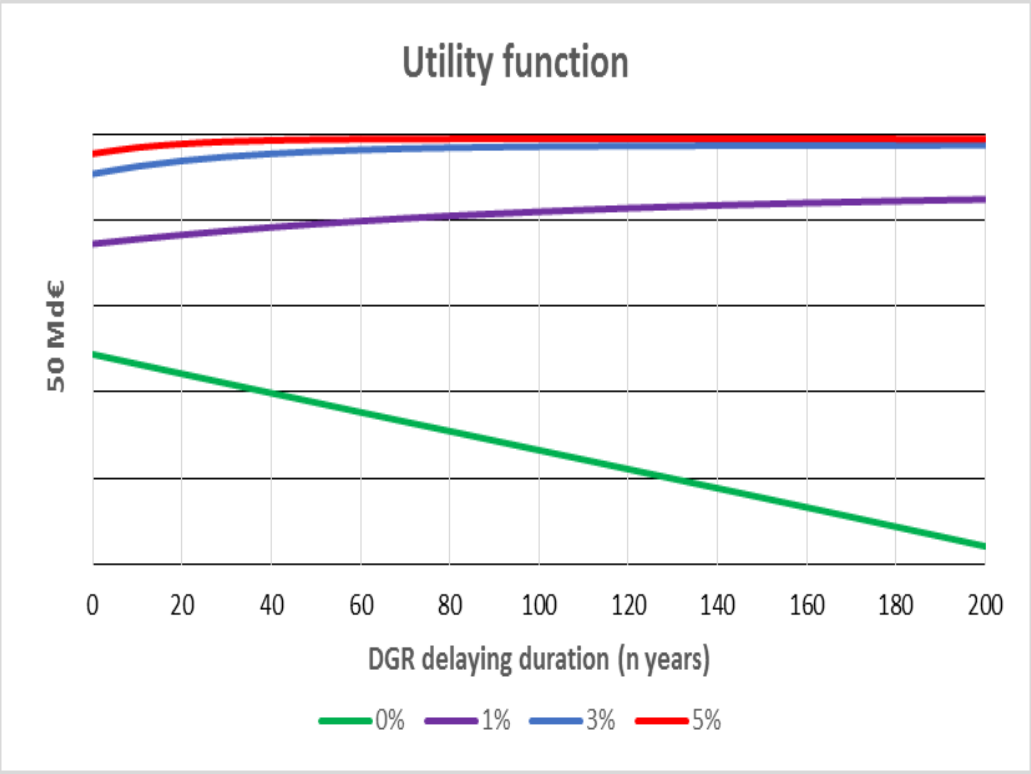


In case of project delay :

1) Permanent storage until DGR closes => **Interim storage cost** ↑
2) Research activities until DGR opens => **R&D** ↑
3) **Disposal cost** ↘
4) **Profit of technology patent sale** ↘
5) **Cost of radiological accident in storage** ↑
6) **Cost of radiological accident during DGR exploitation**

1ST CALCULATION : ANALYTICAL FUNCTION 2/2

$$F(n) = \sum Benefits - \sum Costs$$



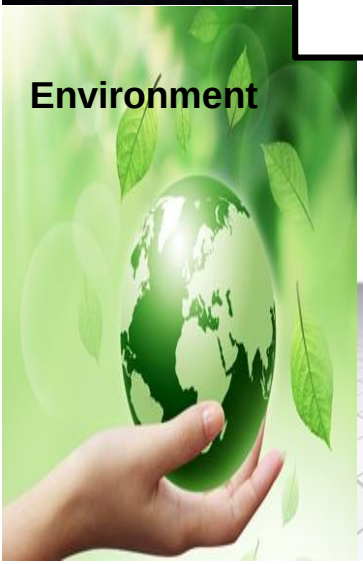
Utility function of DGR implementation with different discount rates

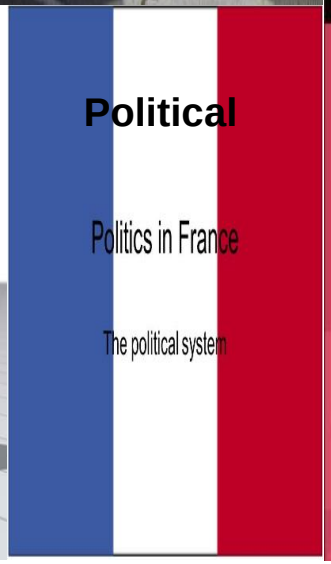
- In gross values, the utility function will decrease if the DGR implementation is postponed.
- With "usual" discount rates (≥1%), the utility function is increasing according to the DGR delaying duration.

=> There would be no economic interest in disposing of the waste immediately.

RW MANAGEMENT & NUCLEAR DEVELOPMENT

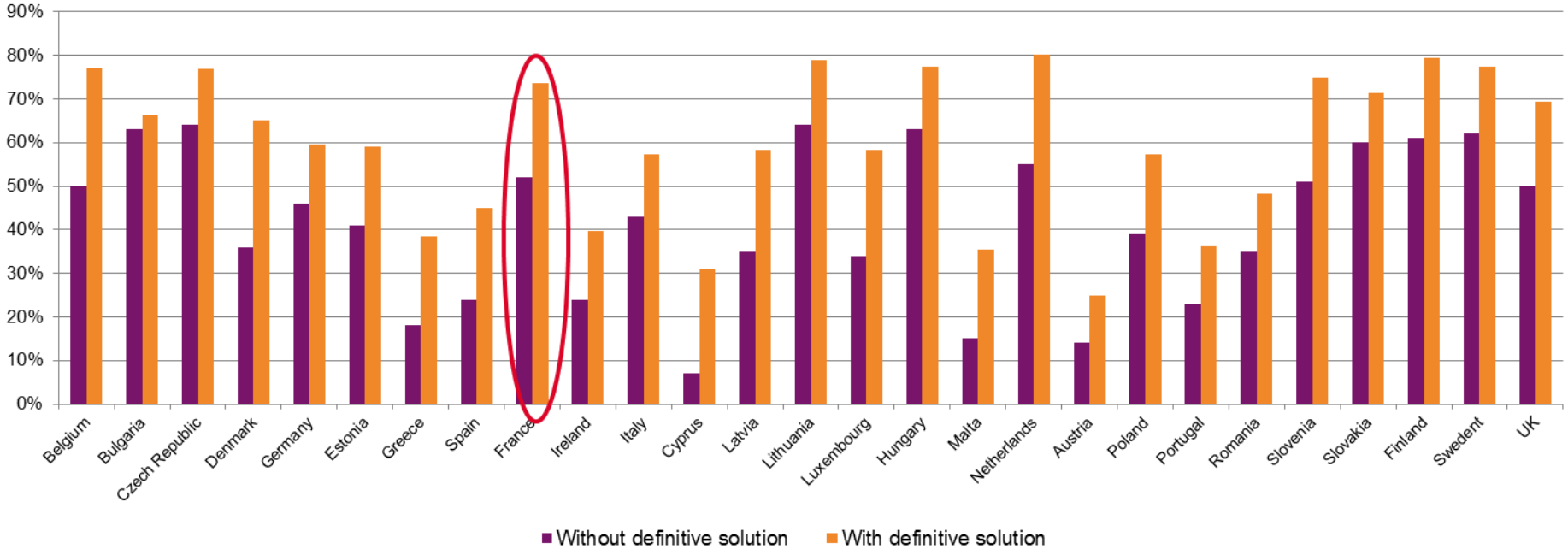
Nuclear





PUBLIC OPINION ON NUCLEAR DEVELOPMENT

Opinion modification if there was a permanent and safe solution for the management of radioactive waste (Eurobarometer 2008)



- 50% of favorable opinions doesn't guarantee the possibility of the nuclear power plant renewal.
- 75% ensure on the other hand this possibility.

NUCLEAR OPPOSITION IN CASE OF PILOT PHASE DELAY ?

- **Hypothesis**: Higher nuclear opposition in case of pilot phase delay.

⇒ Other technologies will be used for electricity generation.

⇒ Electricity production cost ↗

⇒ The loss **L** resulting from the replacement of nuclear energy with renewable in case of DGR implementation delay.

⇒ $L \in d$, with $d = Renewable - Nuclear$ (€/MWh)

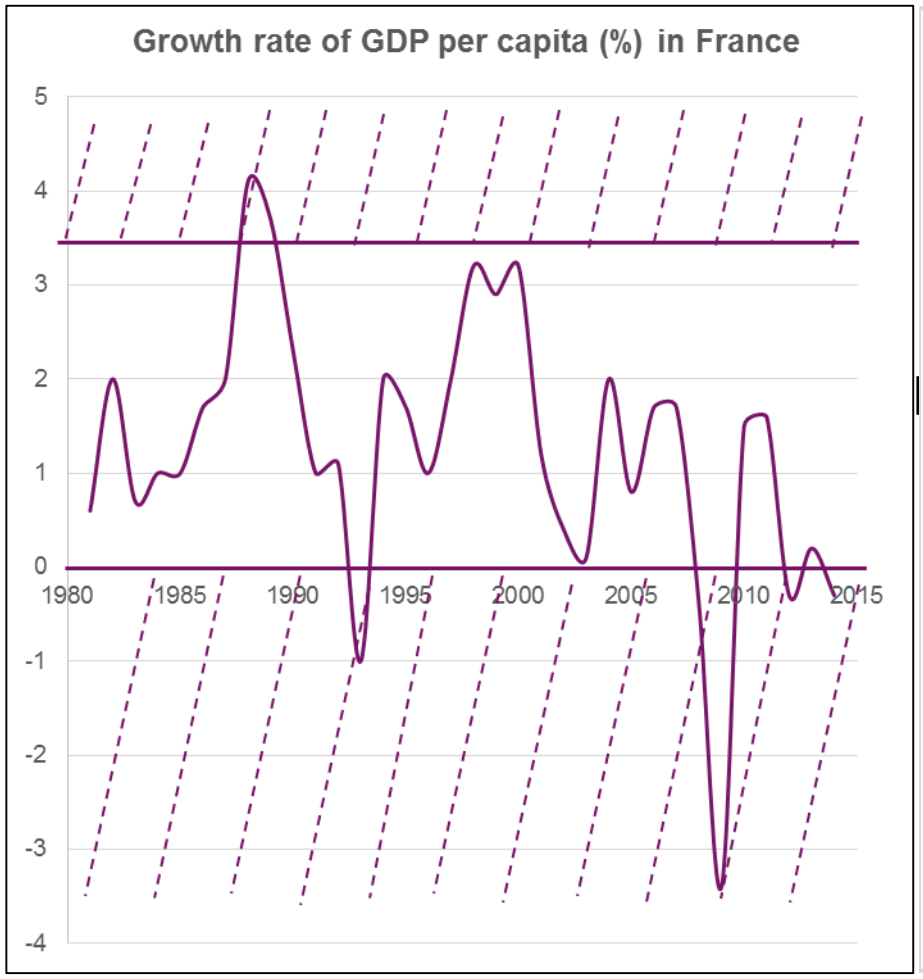
A NEW ELEMENT => DGR UTILITY FUNCTION

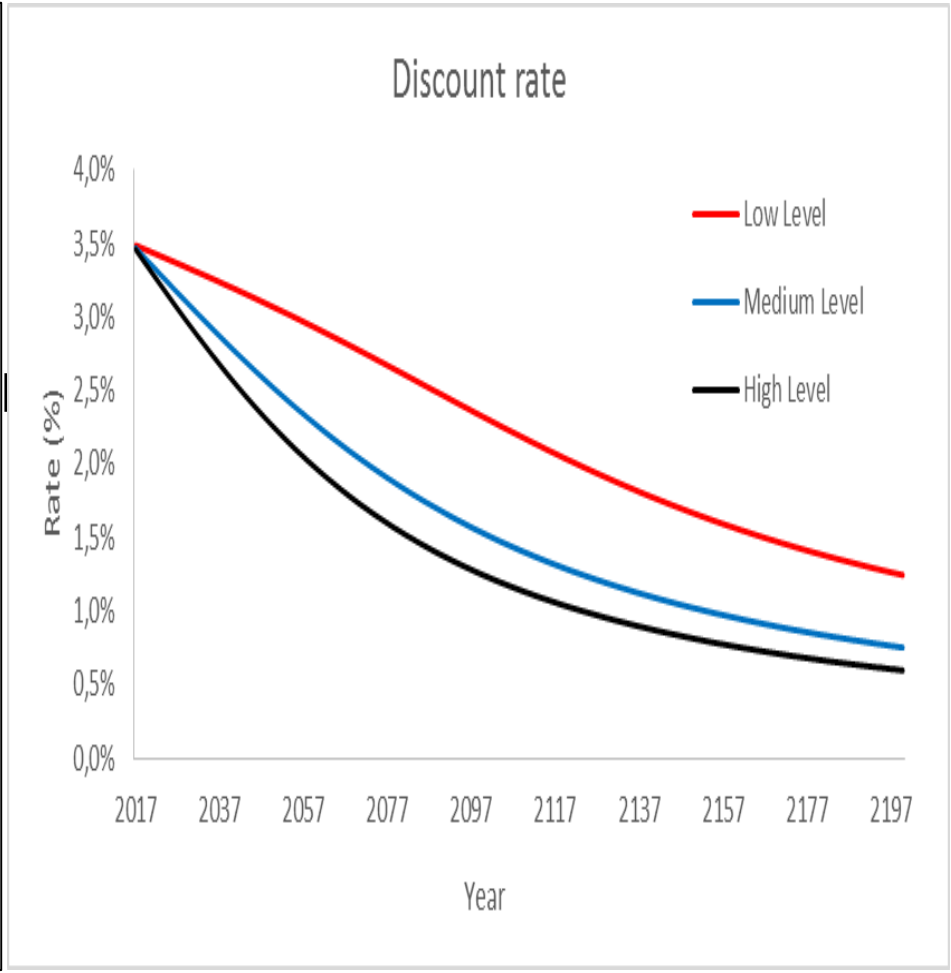
$$F(n) = \sum Benefits - \sum Costs - \boldsymbol{L}$$

- With "usual" discount rates, when $d \geq 1$ €/MWh , the utility function is decreasing $\left(\frac{dF}{dn} < 0\right)$ => It is preferable to maintain the industrial pilot phase implementation for retaining the nuclear option.

- However, there will always be an economic advantage in postponing the normal operational phase.

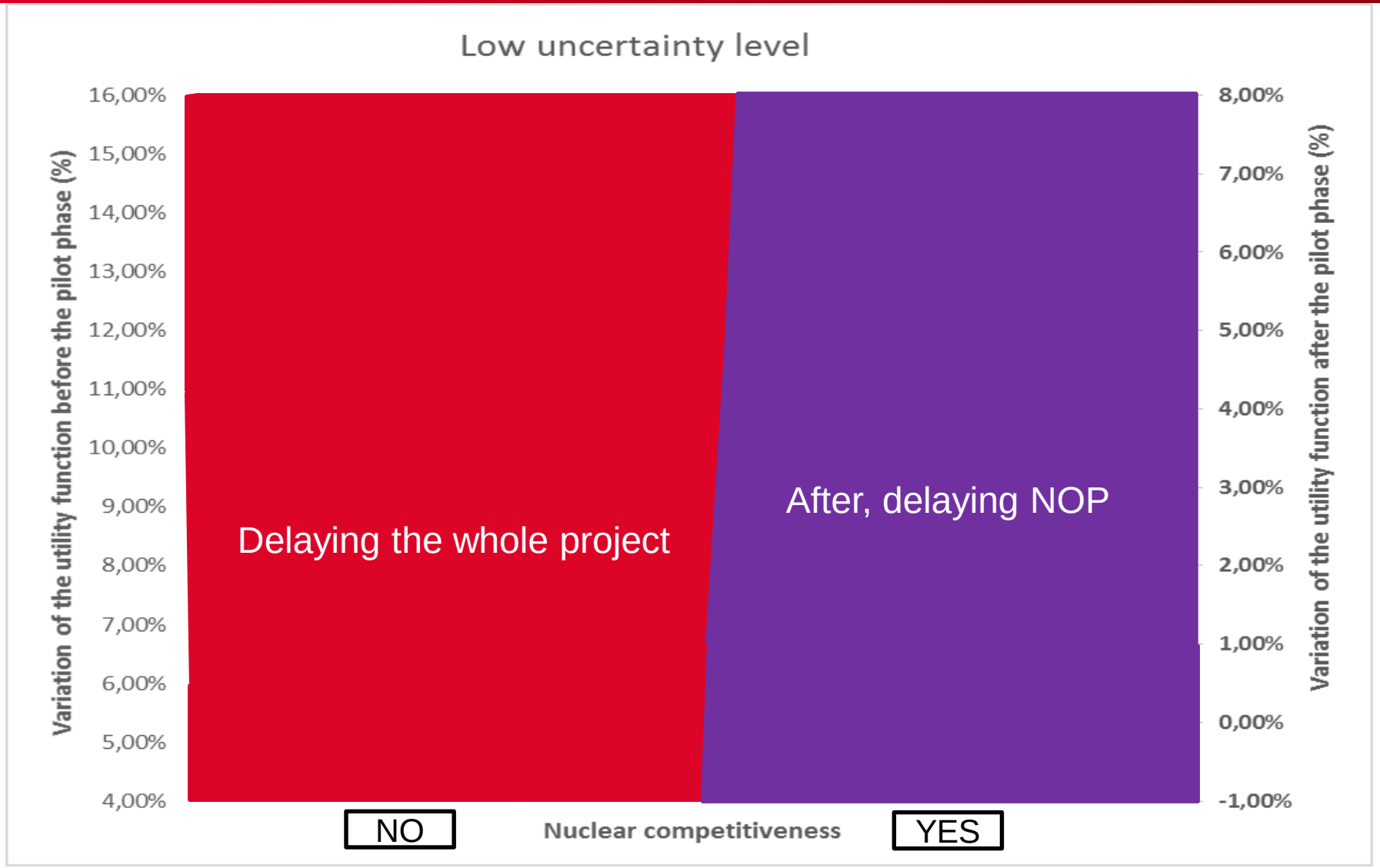
DIFFERENT PROSPECTS FOR LONG TERM ECONOMY





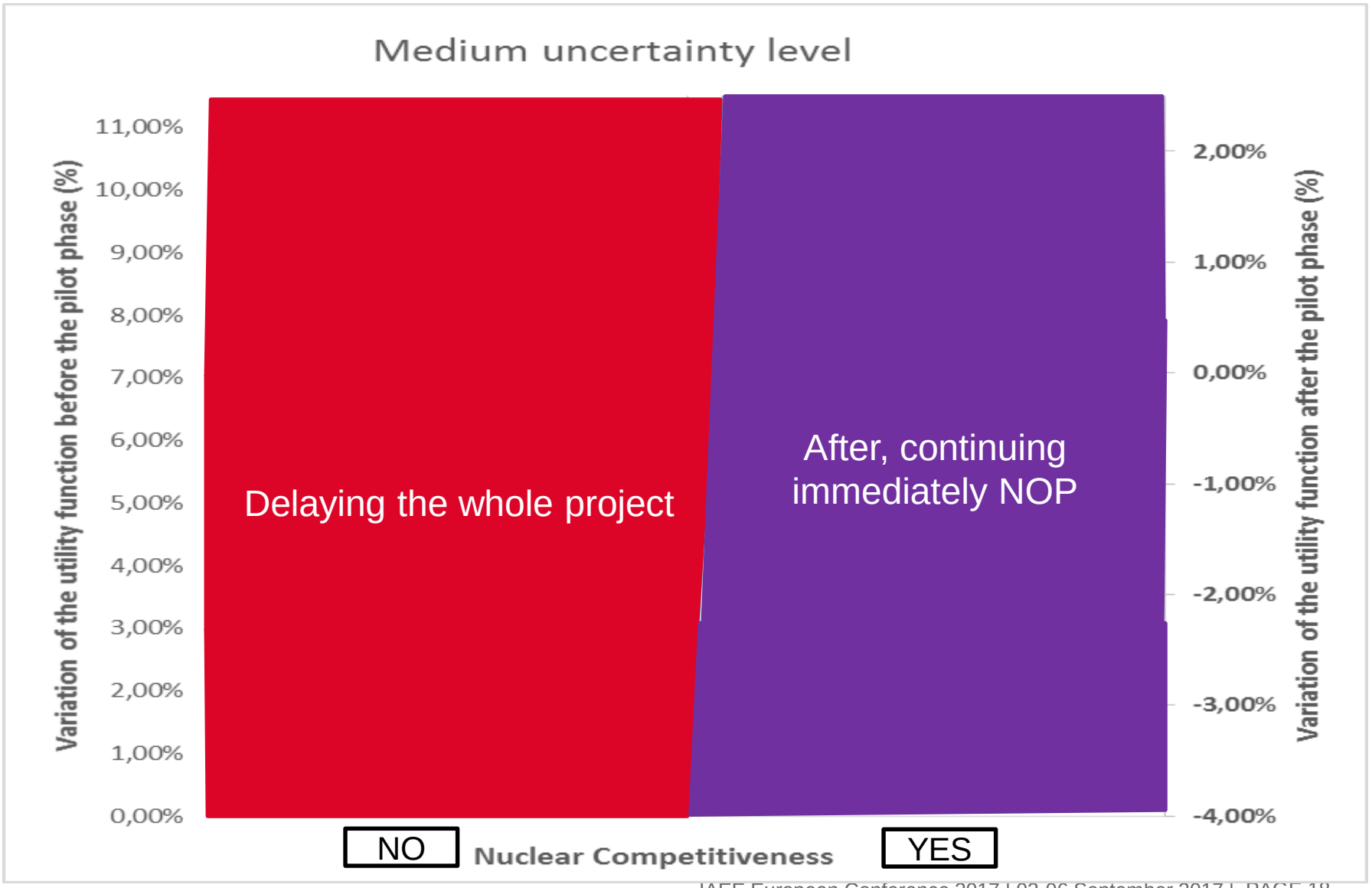
DETAILED ANALYSIS OF 5 YEAR DELAYING 1/3

LOW LEVEL OF UNCERTAINTY IN THE LONG-TERM. (DISCOUNT RATE DOESN'T DECREASE TOO QUICKLY.)



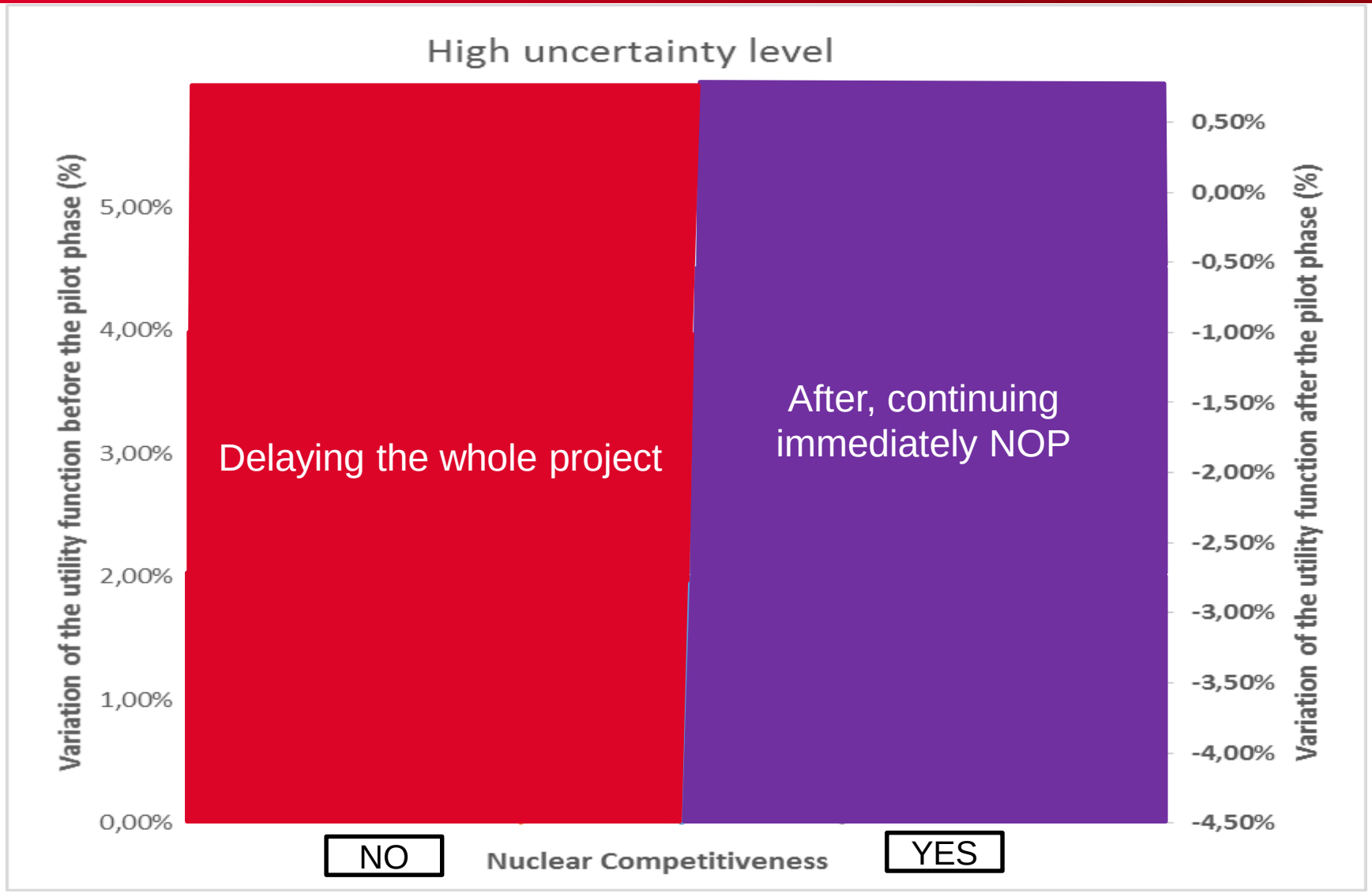
DETAILED ANALYSIS OF 5 YEAR DELAYING 2/3

MEDIUM LEVEL OF UNCERTAINTY IN THE LONG-TERM. (DISCOUNT RATE DECREASES QUITE QUICKLY.)



DETAILED ANALYSIS OF 5 YEAR DELAYING 3/3

HIGH LEVEL OF UNCERTAINTY IN THE LONG-TERM. (DISCOUNT RATE DECREASES QUICKLY.)



CONCLUSION

CONCLUSION

- In many countries, **DGR implementation schedule is fixed by political choices. Our study intends to put a new light (economics) on the consequences of these choices.**
- **The quick implementation of** the so-called French **"industrial pilot phase"** has a direct social value, as it **could be a favorable condition for maintaining the nuclear option.**
- After the industrial pilot phase, **the more the long run future appears as uncertain, the more we should maintain the effort for completing a non-stop disposal.**
- **Some other social values** procured by DGR **certainly exist. Even if we have serious doubts on the possibility to measure these other items** (risk perception, care vs the next generations, …), **we are convinced that new work is needed to better consider and assess the DGR deployment schedule.**

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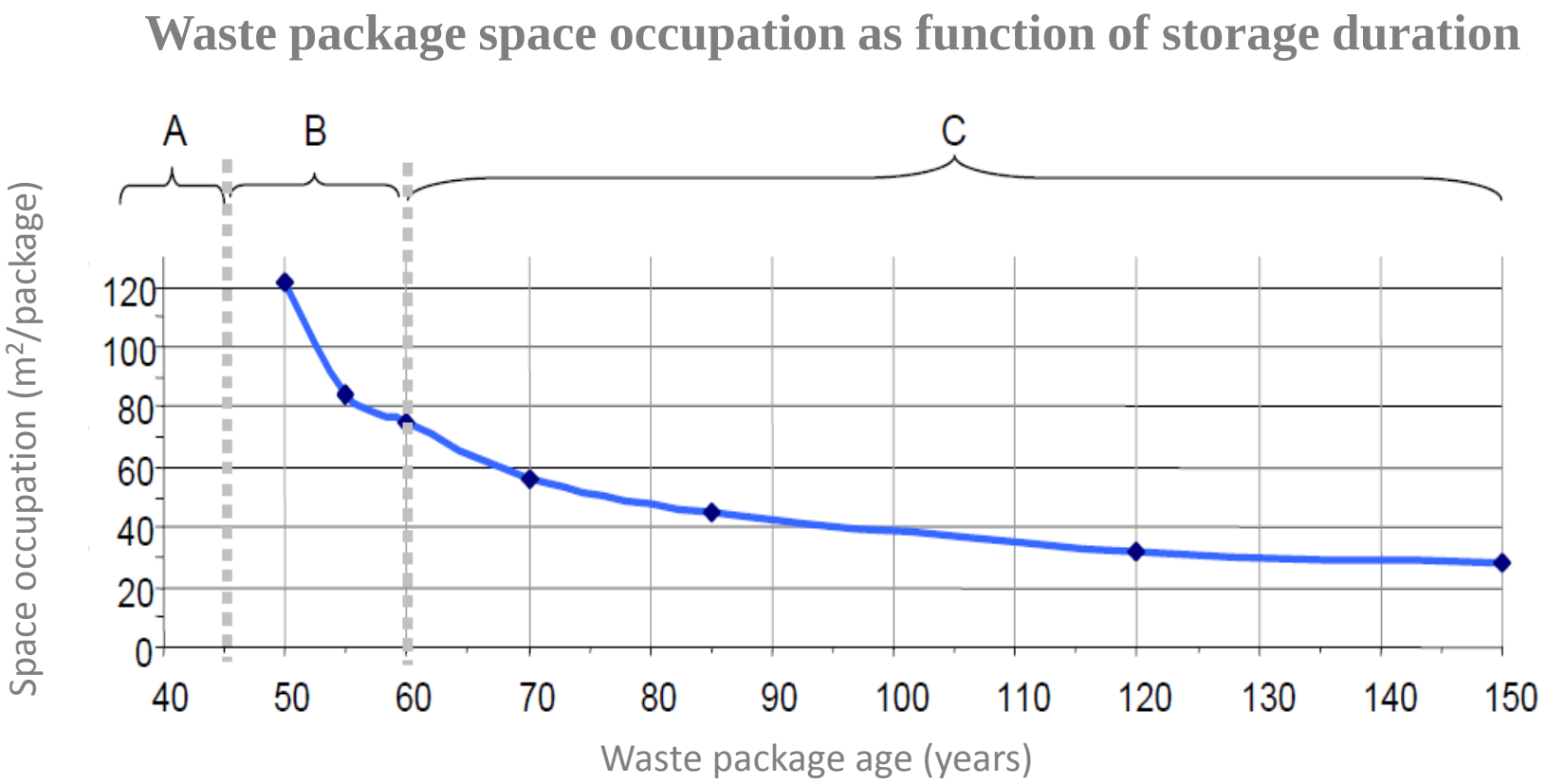
Thank you for listening

Annexe

EFFECT OF WASTE THERMAL DECAY



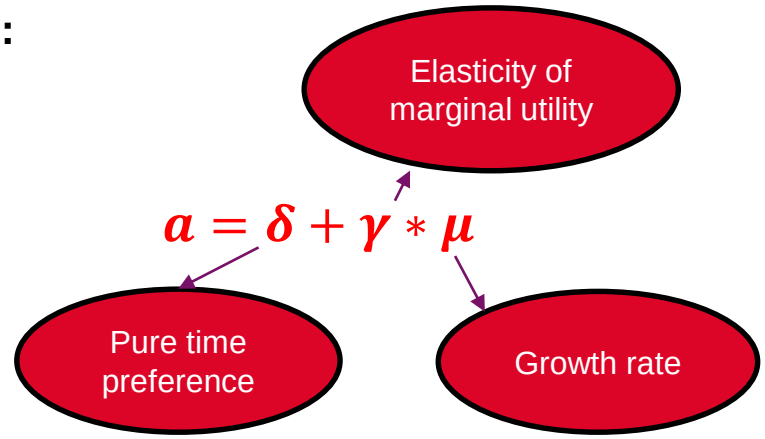
A: Technical impossibility (<45 years); B: Excellent package age sensibility (45-60 years); C: Lower sensibility (>60 years)

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.

2ND CALCULATION : QUANTITATIVE FUNCTION 2/4
DISCOUNT RATE DETERMINATION

- **Most-used formula :**



- **For long-terme issues :** $a_t = -\frac{1}{t} ln[\sum_{i=1}^{n} p_i * e^{-(\delta+\gamma\mu_i)t}]$ **(Ref Lebègue)**
  - **Pure time preference** ⇨ Fixing **$\delta = 0$** : no priority is given to the present generation and neither to our «grand-children».
  - **Elasticity of marginal utility =>** $\gamma = 2$ (Gollier).
  - μ_i**: growth rate,** p_i **: probability**

1ST CALCULATION : ANALYTICAL FUNCTION DISCOUNT RATE – ORDER OF MAGNITUDE

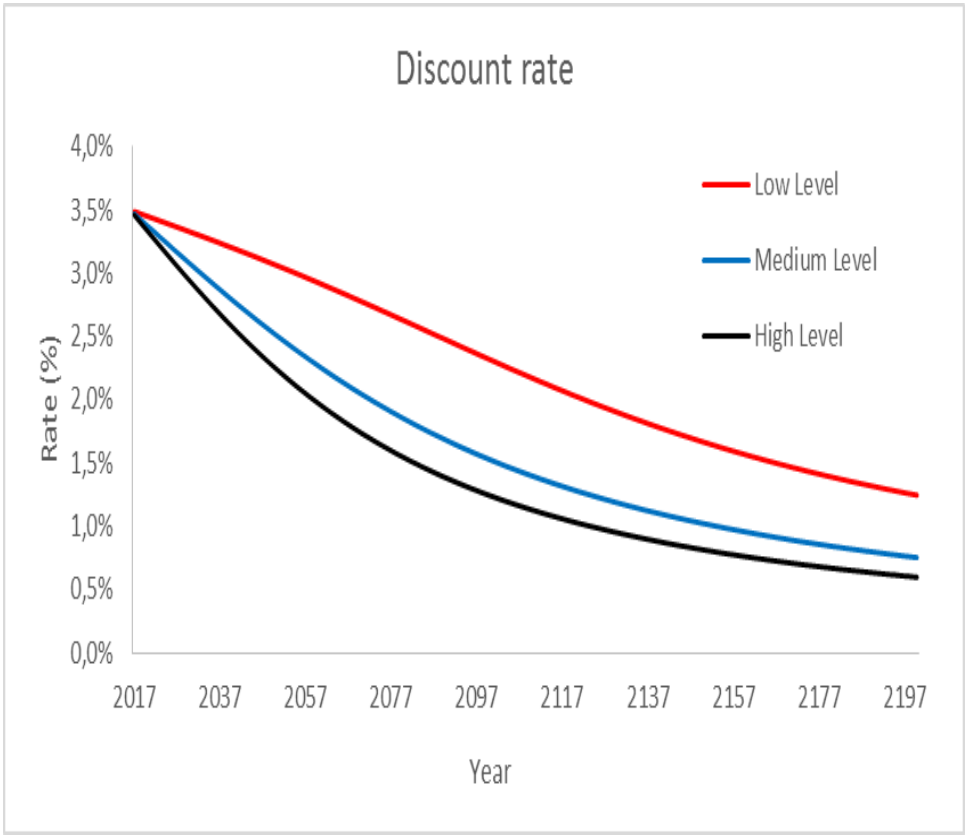
- The **French ministerial order** of February 2007 related to the securing of funding for nuclear expenses : **2.7%** (last updated).
- **ANDRA** uses a discount rate of 3.5% including inflation, or **1.7%** (real rate).
- **French nuclear operators** have chosen a rate of roughly **2.9 %**.
- Department of Energy, **USA** : **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).**

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.

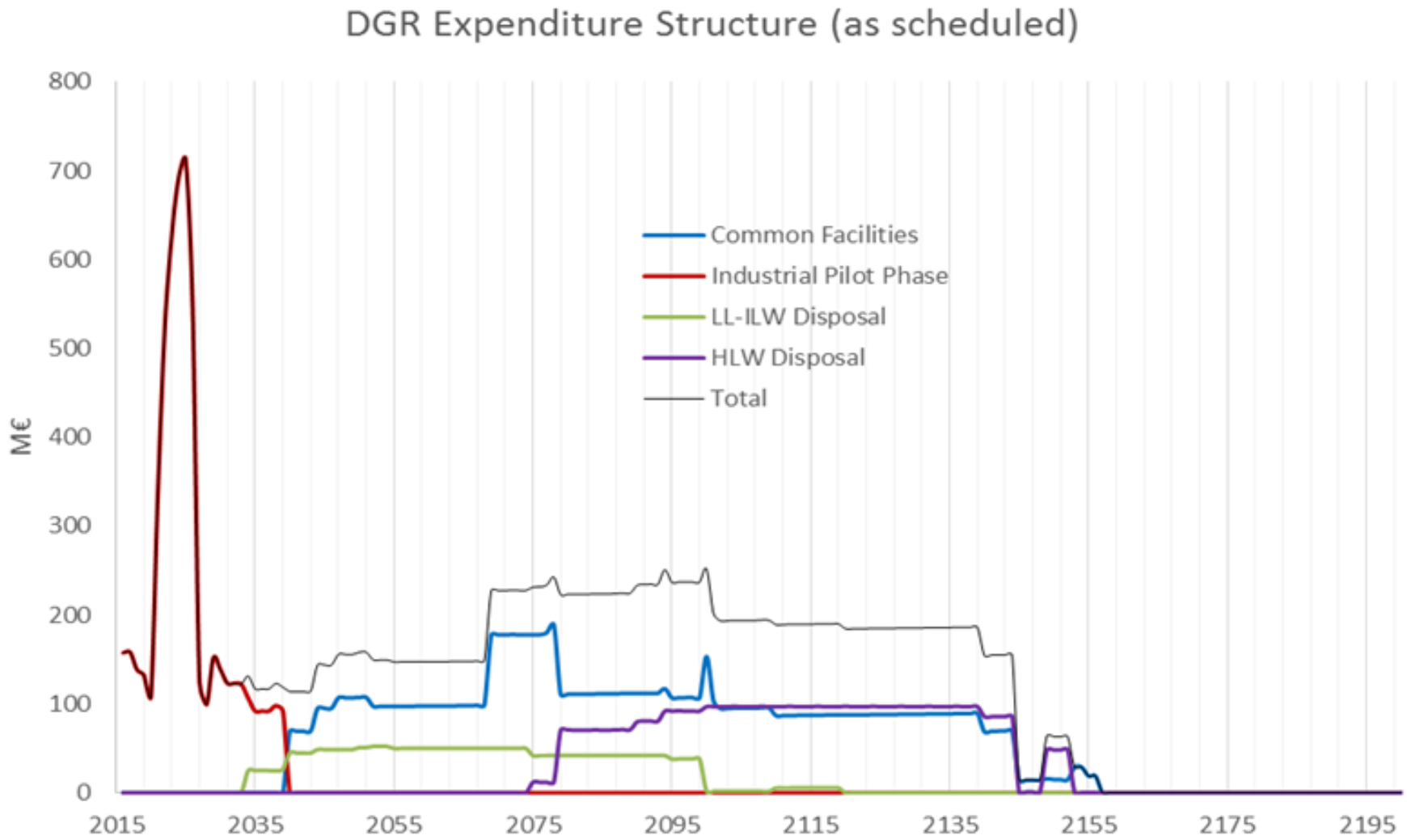
2ND CALCULATION : QUANTITATIVE FUNCTION 3/3
DISCOUNT RATE DETERMINATION



In case of high level of uncertainty, the discount rate will decrease faster in long-term.

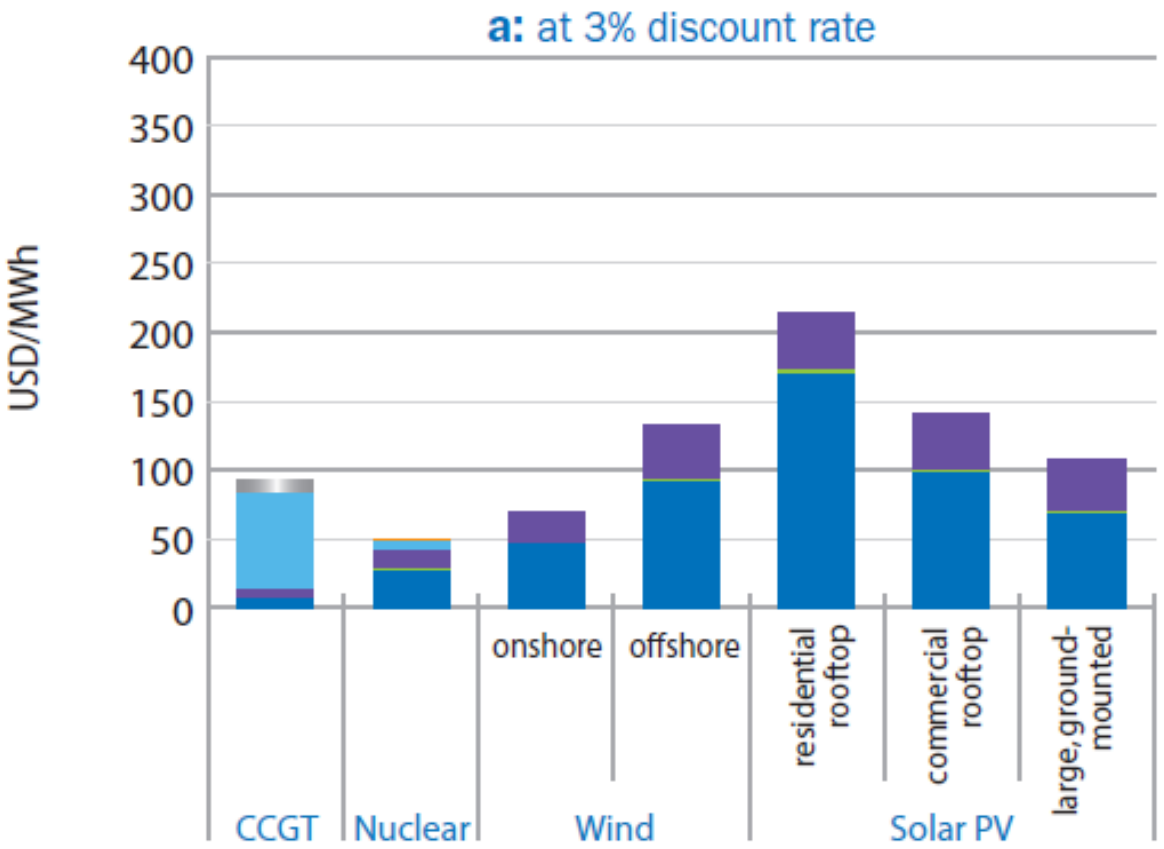
The more efforts must be made in the present if there is little certainty about the future growth.

DGR EXPENDITURE STRUCTURE

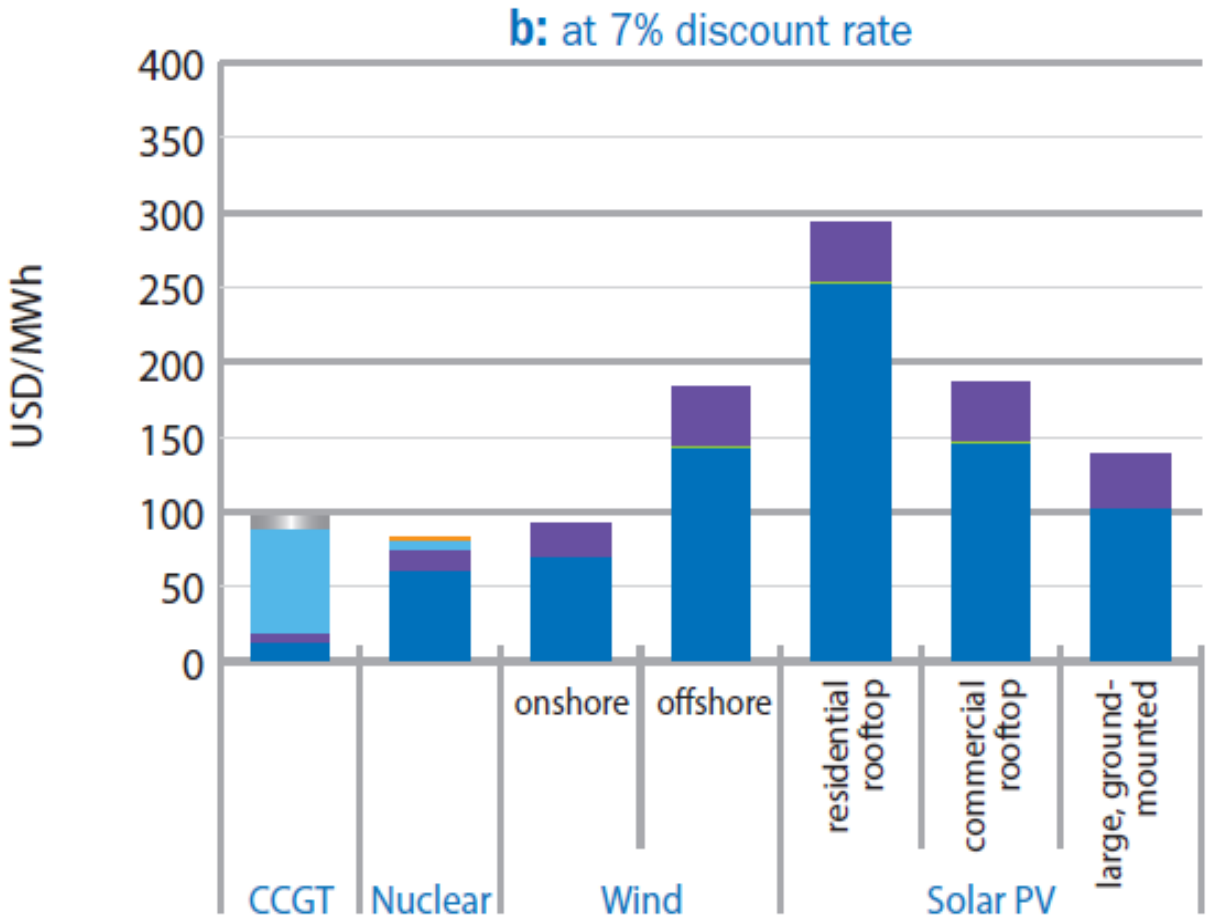


ELECTRICITY LEVELIZED COSTS 1/3

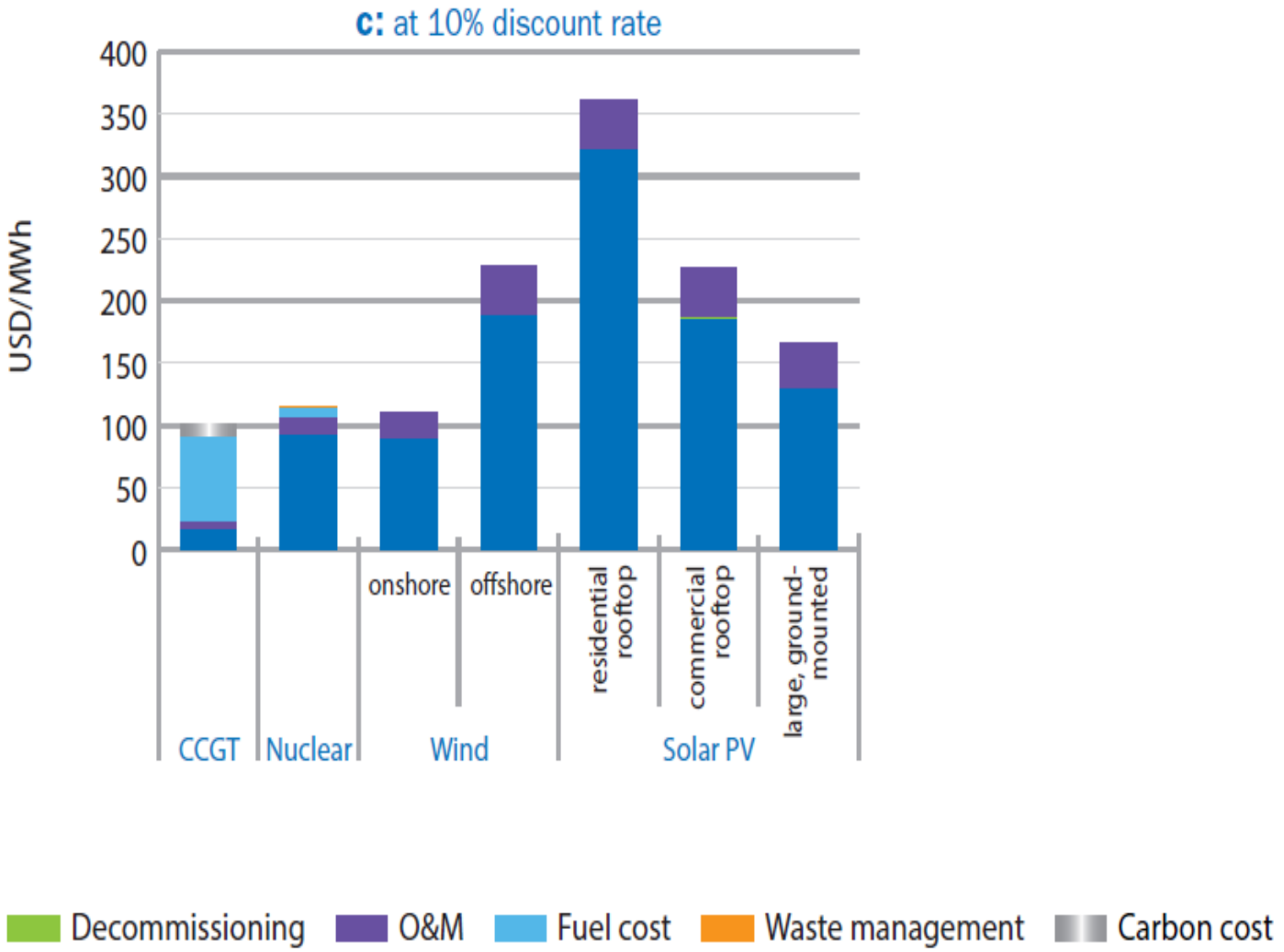
Figure 4.5: Levelised cost of electricity – France



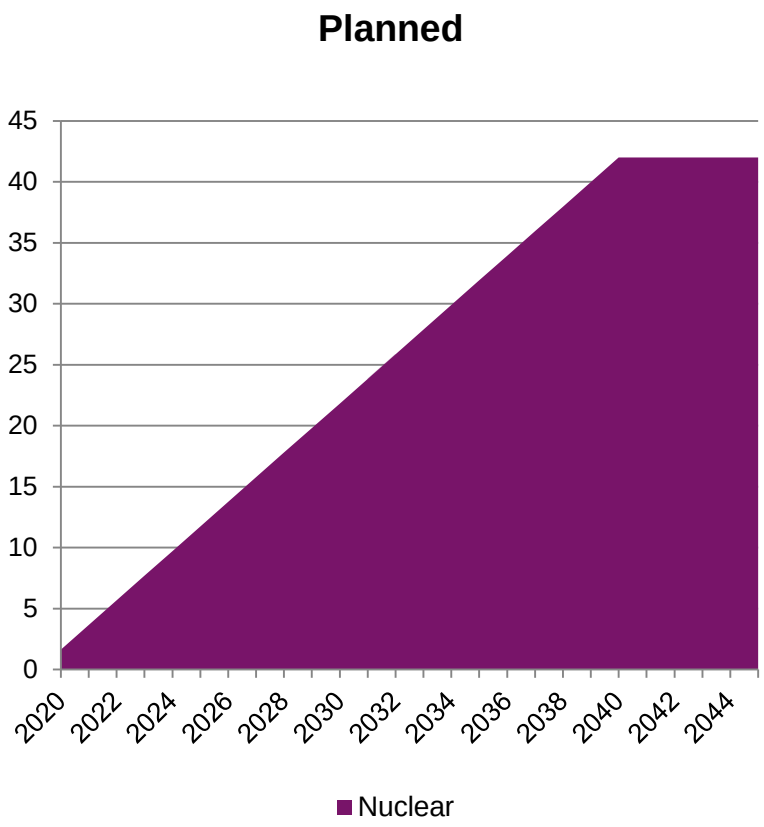
ELECTRICITY LEVELIZED COSTS 2/3

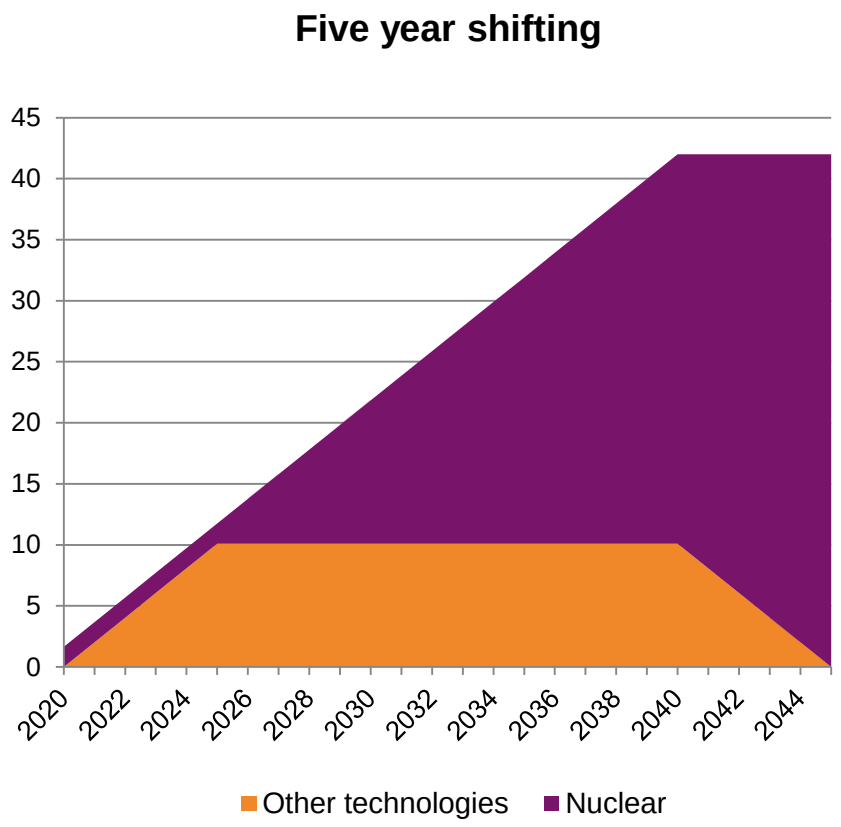


ELECTRICITY LEVELIZED COSTS 3/3



INFLUENCE ON THE NUCLEAR PLANT RENEWAL





1ST CALCULATION : ANALYTICAL FUNCTION

- Set up an analytical utility function by supposing that :
  - **The whole project would be translated** in case of the DGR rescheduling. ,
  - **The discount rate is constant** during the period in question.
- Calculate the derivative of the function according to the disposal start-up date and search for the optimum point.

2ND CALCULATION : QUANTITATIVE FUNCTION

- **The discount rate decreases over time for evaluating long-term issues.**

- **Practical approach** :
  - Turn away towards a quantitative evaluation,
  - Compute the variations of each cost/benefit item depending on different DGR implementation schedules :
    - Compare the utility function in case of the planned and shifted schedules,
    - The 5-year interval is chosen in case of the disposal shifting.

DETAILED ANALYSIS OF THE RESULTS

- Depending on different scenarios of the discount rate evolution, we will propose three decision fields:

  (1) There is an economic interest in delaying the whole disposal project ($\Delta F_{before-IPP}(5) > 0$) (in red).

  (2) The industrial pilot phase (IPP) should be started as scheduled to maintain the nuclear energy option ($\Delta F_{before-IPP}(5) < 0$), but the normal operational phase (NOP) should be postponed ($\Delta F_{after-IPP}(5) > 0$) (in blue).

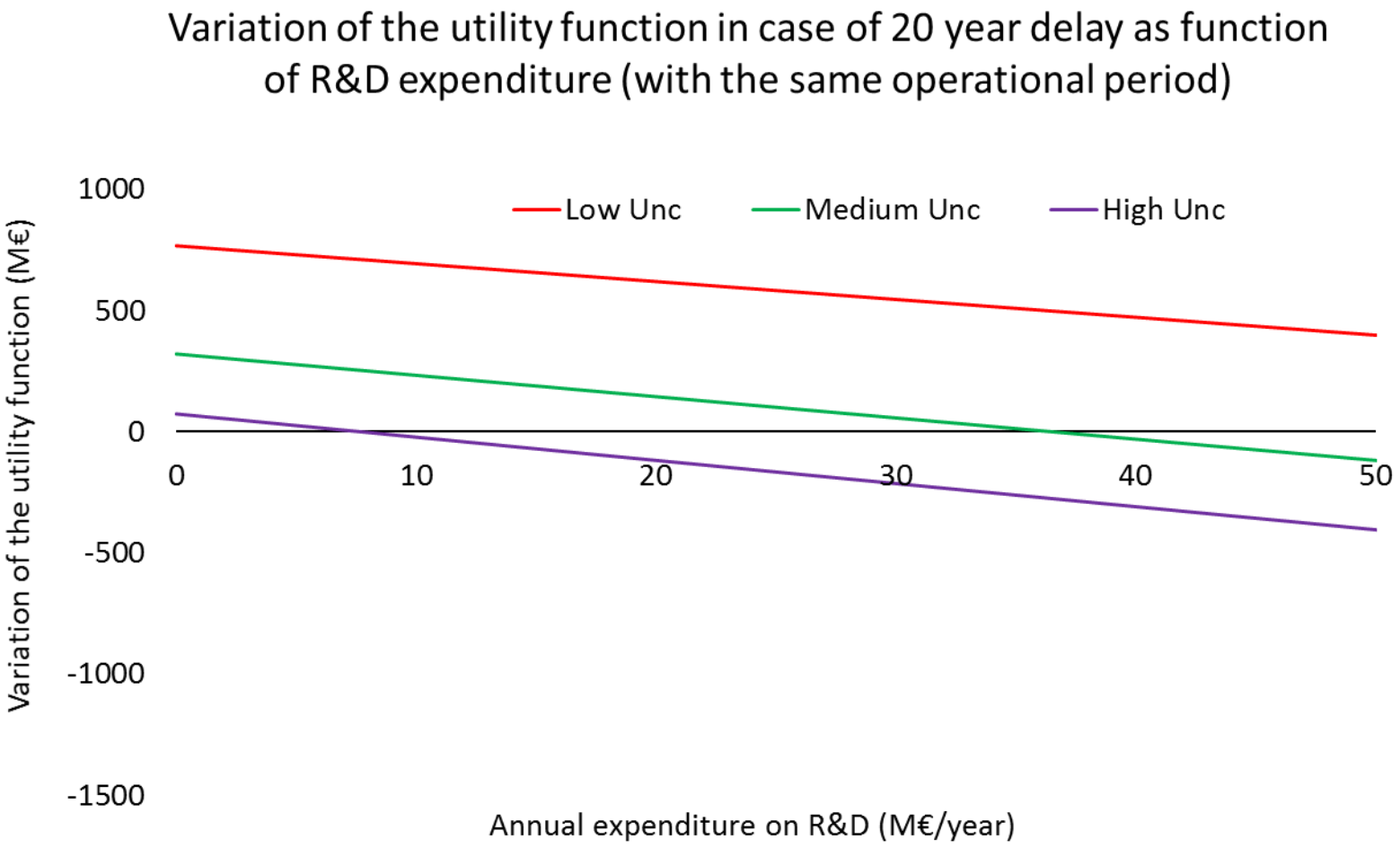
  (3) "Immediate" DGR implementation ($\Delta F_{before-IPP}(5) < 0$ and ($\Delta F_{after-IPP}(5) < 0$) (in green).

- Given the uncertainties on different cost/benefit items (storage, DGR, R&D, etc.), the variations of the DGR utility function are illustrated by **Gaussian curves.**

UNCERTAINTY REGARDING MODEL PARAMETERS

Parameters	Minimum value	Maximum value	Central value	Unity
Industrial pilot phase cost (IPP)	4	8,5	5,5	b€
Normal operational phase cost (NOP)	15	25	20	b€
Accident probability (DGR)	0,00001	0,0001	0,00001	$Year^{-1}$
Storage Cost	*0,75	*2	*1	Coeff
Accident probability (Storage)	0,00001	0,0001	0,00001	$Year^{-1}$
R&D	25	100	50	M€/an
Gain from the patent sale	0	500	250	M€

20 YEAR DELAY (WITH THE SAME OPERATIONAL PERIOD)



20 YEAR DELAY (MAINTAINING THE INITIAL CLOSURE DATE)

Variation of the utility function in case of 20 year delay as function of R&D expenditure (maintaining the initial closure date)