NUCLEAR 21®
PERSPECTIVE FOR YOUR DECISIONS

COST/RISK-OPTIMISED DECISIONEERING IN NUCLEAR ENERGY

DECISIONEERING

Gent-Paris-London

www.nuclear-21.net

WE ARE NUCLEAR-21

An independent expert cabinet providing bankable decision support driving policy, strategy, technology and business development towards optimised nuclear-based solutions

OUR SERVICES AIM TO

Identify and analyse the challenges our customers face in developing and using nuclear science- & technology-based solutions

Enrich policy, strategy, technology and business options

Support our customers in their policy, strategy, technology and business development activities

Recommend decisions based on proven, sector-specific expertise and quantitative, best practice methodologies

Broker solutions-focused international partnerships

Ensure compliance with national and international requirements and regulations

A Comprehensive Expertise(d) Core Team

Our Core Team are experienced senior experts driving towards making a difference in the nuclear sector together with our customers

An International Reach

Our long-standing collaborative work with top-notch experts in various organisations worldwide maintains and secures our up-to-date best-practice based methodologies, tools and services

Scalability According To Your Needs

Our agile Core Team scales up with selected experts locally and globally whenever customer assignments require

THE FOUR ASPECTS OF OUR SERVICE OFFER ARE CENTRED AROUND OUR CUSTOMERS' NEEDS

1. Policy and Business Intelligence

technology, policy and business integration
technology reviews
competition analysis
market assessments
economic and financial risk assessments
innovation process development
partnering and funding options

2. Optioneering and Designing Strategies

policies and frameworks
comprehensive plans
provide validated market & business scenario models
design enabling strategies
risk-assessment of decisional options
partnering and sourcing project funding
due diligence and intellectual property analysis
international technology transfer and process industrialisation
knowledge management and expert sourcing

3. Decisioneering

modelling and simulation of policy, strategy and business options
future developments projection
baseline studies
Financial performance verification
Documentation and communication of critical decisions
accompanying due diligence processes

4. Optimising Implementation

project initiation & guidance
project funding & partnering support
project operationalisation
process and project evaluations
performance benchmarking
business development & commercial offer support
support to win new markets

NUCLEAR ENERGY IN A FINANCIALLY RISKY ENERGY MARKET

THE ENERGY MARKET HAS BECOME INCREASINGLY UNCERTAIN DESPITE LONG-TERM TRENDS TOWARDS INCREASING ELECTRIFICATION AND SUSTAINABLE ENERGY MIXES

Geopolitical developments with an increasing energy security focus during the coming decades

Socio-political uncertainties regarding energy policies and their sustainability

Technical-economic performance challenges given an (apparently) increasing competitiveness of renewable energy sources

Ecological uncertainties related to unclear progress globally towards tangible decarbonisation of the energy mix

Programmatic risks regarding the timing of socio-politically acceptable waste management strategies

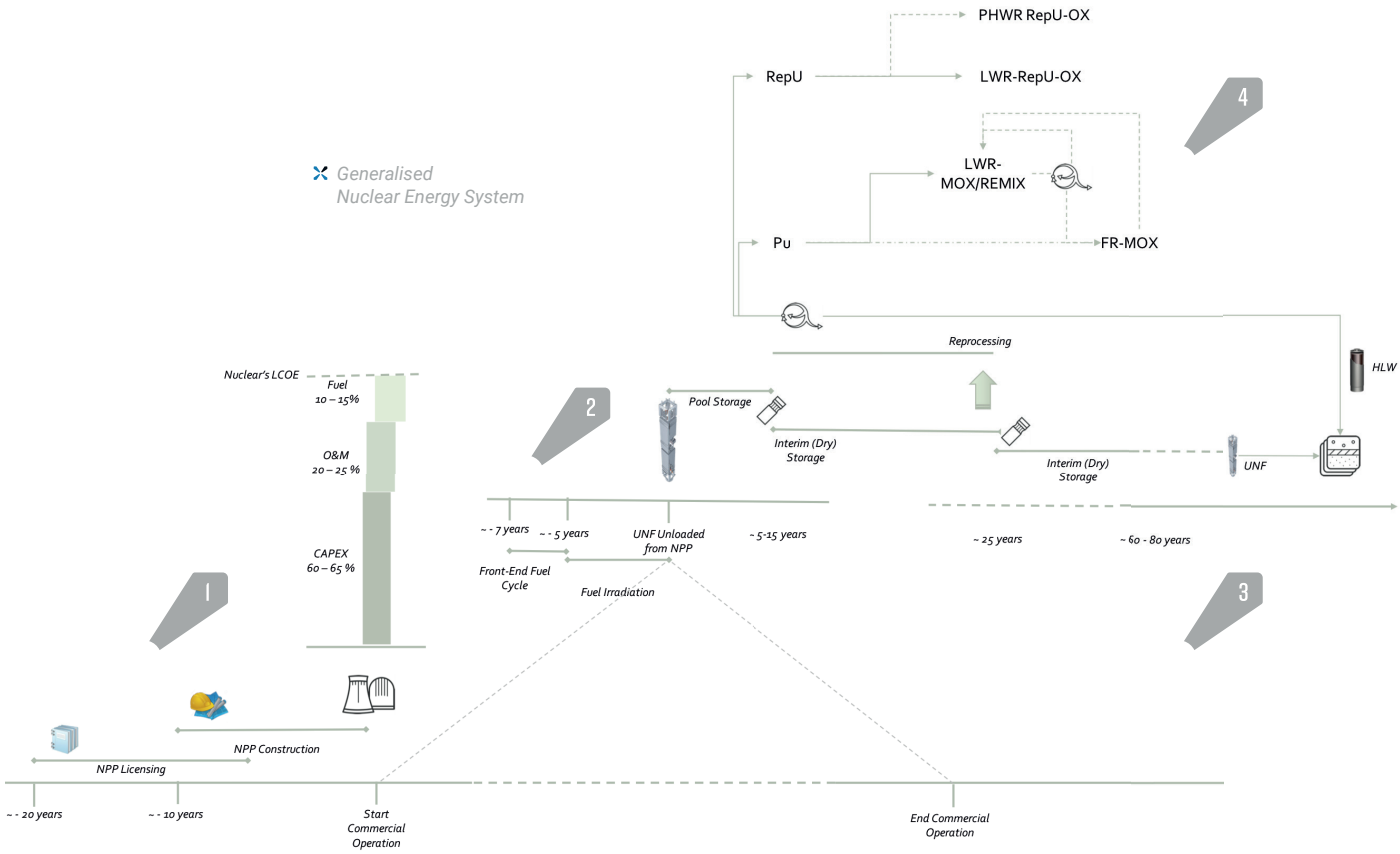
NUCLEAR ENERGY CAN PLAY A MORE PROMINENT ROLE IF IT CAN MEET THE NEEDS OF THE MODERN ENERGY MARKET, PARTICULARLY BY AGAIN BECOMING A BANKABLE ENERGY OPTION.

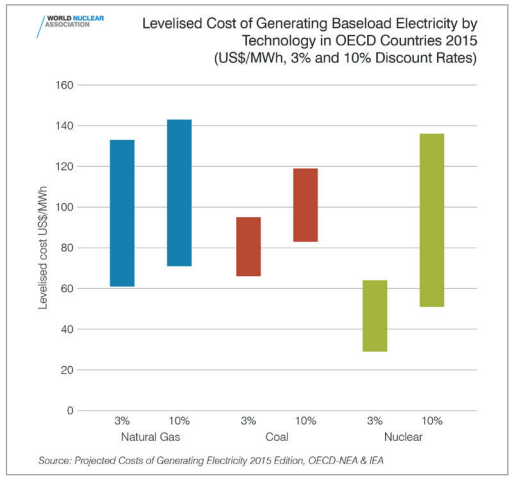
“HOW CAN WE DERISK NEUTRONS IN AN ELECTRON MARKET?”

Luc Van Den Durpel

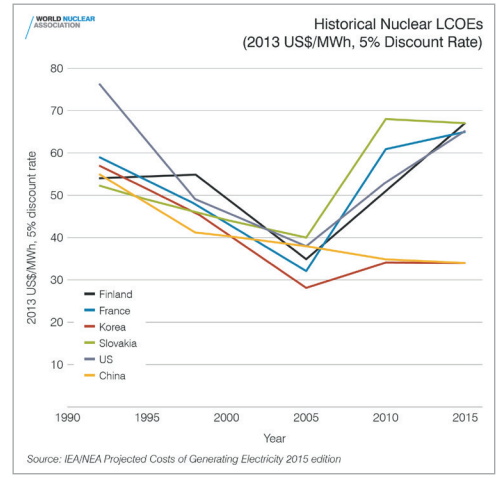
COST/RISKS CHALLENGES TOWARDS IMPROVED BANKABILITY FOR NUCLEAR ENERGY SYSTEMS

A Nuclear Energy System (NES) covers at least a century of activities and is exposed to various cost and timing uncertainties translating into financial risks for various stakeholders





Typical Net-Present-Value (NPV) analysis indicates that nuclear energy is competitive



But there are challenges for new-build NPPs stemming from supply chain and project-management uncertainties

1 Financial Risks For Nuclear Power Plants (NPP)

- NPP Technology Development
- NPP Market Competitiveness
- NPP Licensing Processes
- NPP Construction / Project Mgt
- NPP Socio-Political Acceptance
- Energy Market Competitiveness
- Nuclear Waste Management

2 Financial Risks for the Fuel Cycle Front End

- A worldwide uranium and enrichment supply market with peculiar pricing mechanisms
- Fuel Technology Development
- Fuel Qualification & Licensing

3 Financial Risks for UNF & Waste Management

- Investment decisions on UNF-management facilities
- Uncertain costs and timing of final Geological Disposal Facility
- Uncertain safety performance of the interim stored UNF
- Security requirements interim stored UNF
- Damaged UNF management
- Socio-political acceptance of ever increasing UNF inventories
- Transport of UNF
- Regulatory changes to UNF management

4 Financial Risks of Closed Fuel Cycles

- Economic value of UNF recycling
- Advanced NPP & Fuel development
- Socio-political acceptance of reprocessing
- Uncertain costs and timing of GDF for HLW and recycled UNFs

HOW CAN ONE MAKE DECISIONS IN UNCERTAIN FUTURES?

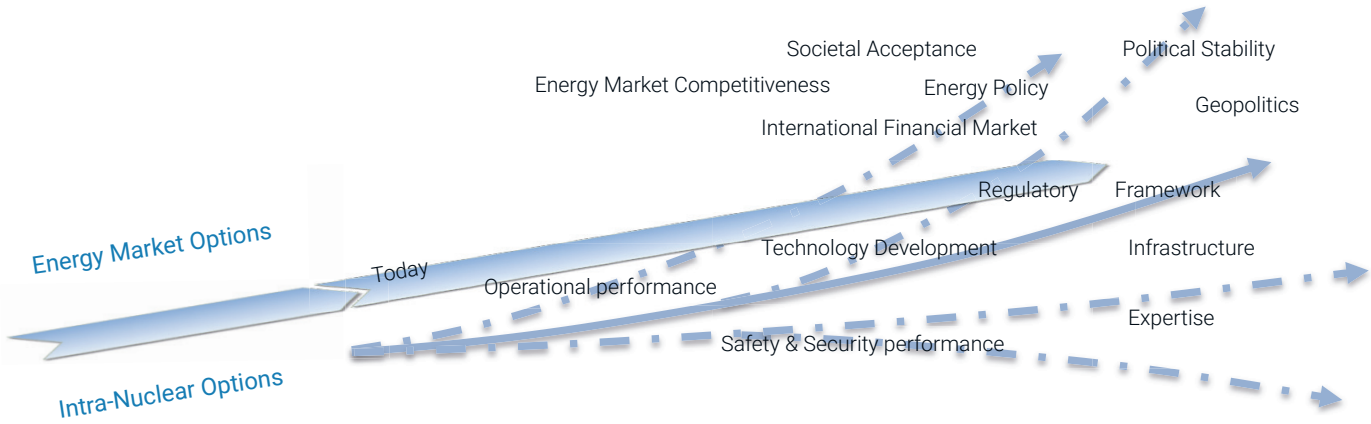
CLASSICAL METHODOLOGIES AS NET PRESENT VALUE (NPV) OR DISCOUNTED CASH FLOW (DCF) DO NOT PROVIDE ANSWERS ON IMPORTANT DECISIONAL QUESTIONS IN UNCERTAIN SITUATIONS, E.G.:

- When is the best moment to make a decision
- At that moment, which will be the best decision to execute?
- what is the value in keeping an option open?
- what is the most robust decisional strategy?
- what is the affordable value of future decisional flexiblity?
- what is the optimal investment portfolio in uncertain futures?

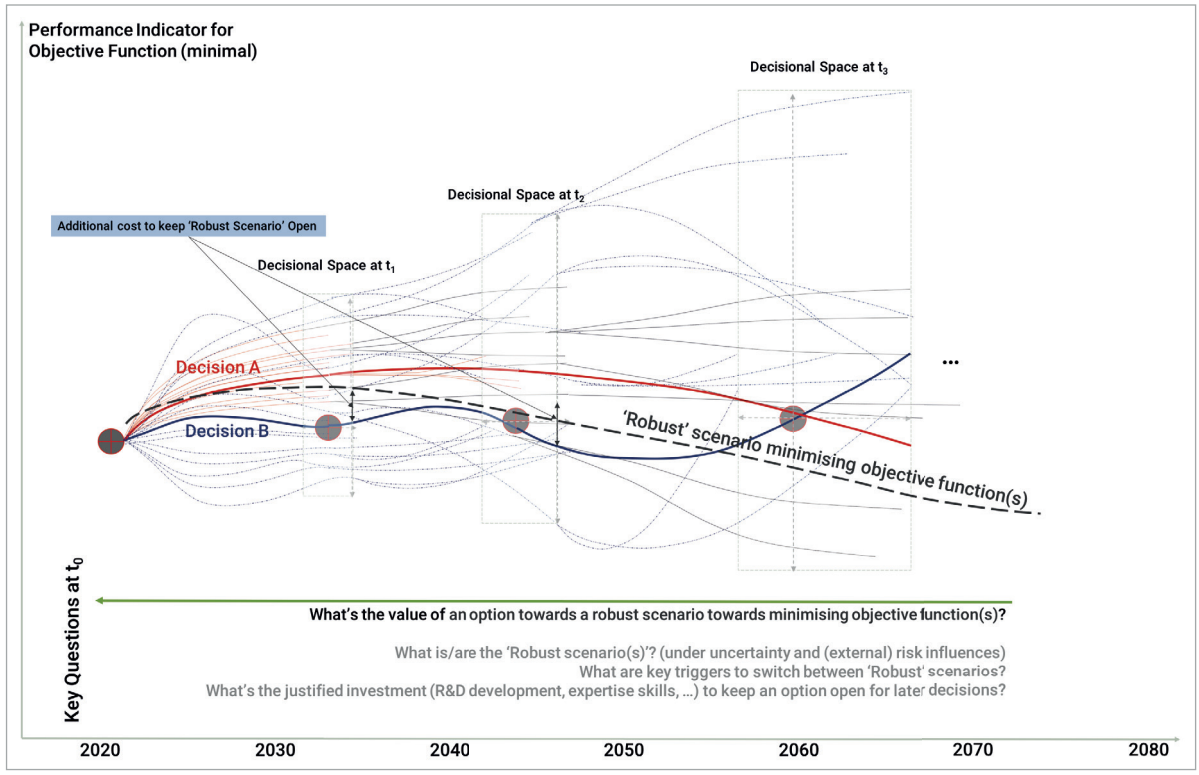
Flexibility brings increasing market and business value:

- Longer-term policy and business strategies can be segmented into flexible options
- Flexible options can later be matched to the future market context.

WE FACE MULTI-VARIATE UNCERTAINTIES IN DECISIONEERING ON NUCLEAR ENERGY OPTIONS



THE COMPLEXITY OF DECISION-MAKING IN (NUCLEAR) ENERGY SYSTEMS STRATEGIES



OUR DECISIONEERING METHODOLOGY

Decision Tree Analysis

Risk analysis of decisional branches and tipping-points analysis

Options Portfolio Analysis

Multi-Variate Cost/Risk Segmentation of Options

Optioneering

Describing and modeling the foreseeable and feasible options

Decisional Strategy Performance

Analysis of robustness of decisional strategy and defining decisional moments and options

- Multi-variate characterisation of the decisional options
- Identify and investigate innovative options
- Identify and structure decision tree
- Identification and characterisation of uncertainties
- Scenario analysis projecting decisional impacts
- Real options valuation of decisional branches and hedging actions
- Multi-variate performance analysis of options
- Sensitivity analysis on key parameters and identification of decisional threshold markers

OUR DECISIONEERING METHODOLOGIES WITHIN ONE TOOLBOX

NUCLEAR ENERGY SYSTEM STRATEGIES ASSESSMENT TOOLBOX

NESSAT provides

1. Up-to-date past, present and future nuclear reactor and fuel cycle information on global, regional, country and/or utility/NPP-level

2. Projection of future deployment scenarios for NPP-fleet and associated fuel cycle facilities and options
   - Technical-economic analysis of nuclear reactor park and/or fuel cycle options
   - A library of deployment scenarios from Business-As-Usual to transition scenarios towards more advanced nuclear energy system options

3. Analysis of the technology-to-business potential by
   - Market analysis and projection of market trends
   - Impact analysis of technology innovation

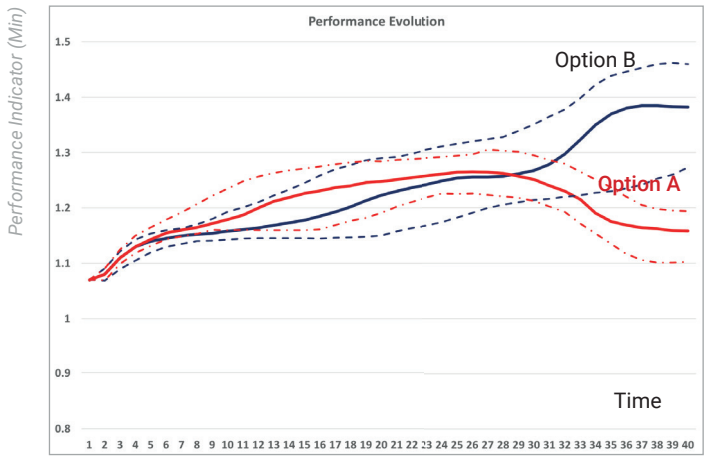
4. Options value assessment allowing the user to
   - Value decisional flexibility in nuclear reactor fleet and/or fuel cycle options deployment
   - Optimise cost and risk exposure by assessing options and taking optimal decisions

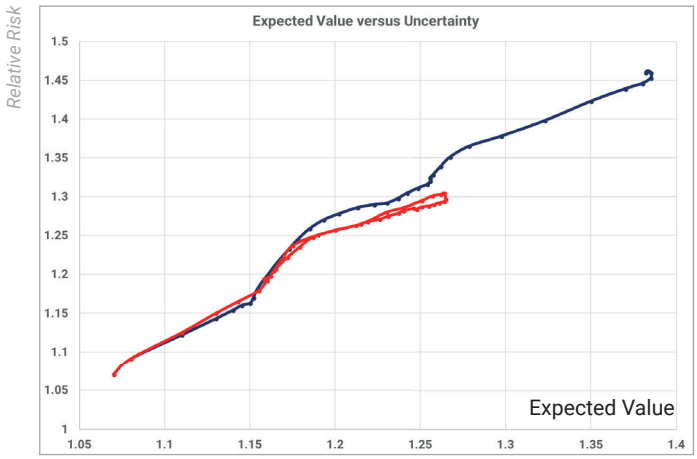
A REAL CASE EXAMPLE

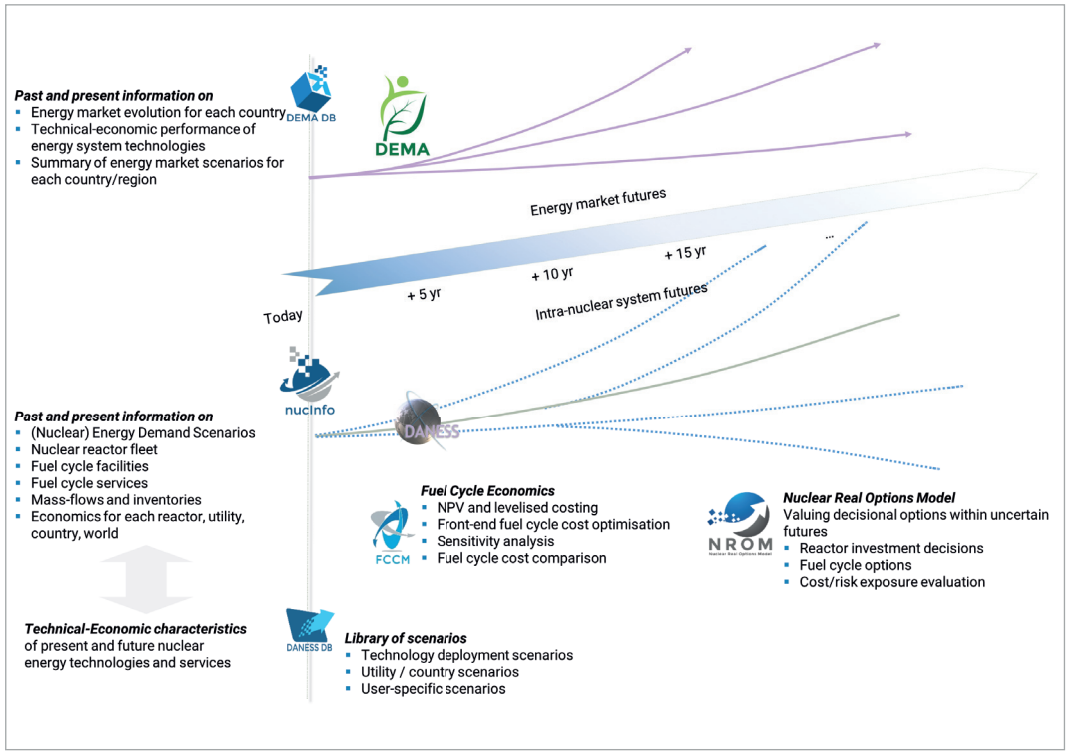
Two fuel cycle decisional options A and B differ in performance over time.

- Option B appears to be the best option but comes with higher uncertainty over time
- Option A seems to become the best option but comes with a higher cost in the beginning

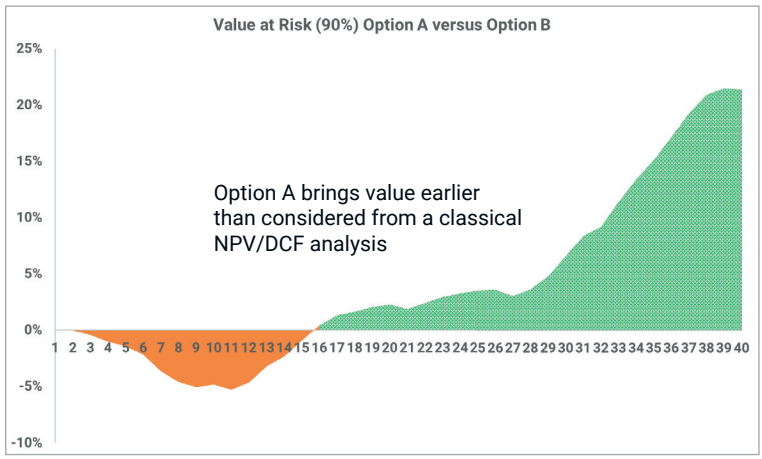
When is the best moment to switch from B to A and what is the value for keeping Option A open?







"DERISKING NEUTRONS" MEANS PROVIDING SAFE, SECURE AND COST/RISK-OPTIMISED SOLUTIONS



USED NUCLEAR FUEL MANAGEMENT DECISIONEERING

The management of Used Nuclear Fuel (UNF) is increasingly a financial risk for UNF owners given:

- A general 'wait-and-see' approach leading to delays in the execution of ultimate UNF-management options;
- Ageing Nuclear Power Plants (NPP) with possible stranding of UNF at non-operational NPP-sites;
- (extended) Long-term interim storage of UNF may increase security and safety risks;

But also by a changing and uncertain environment:

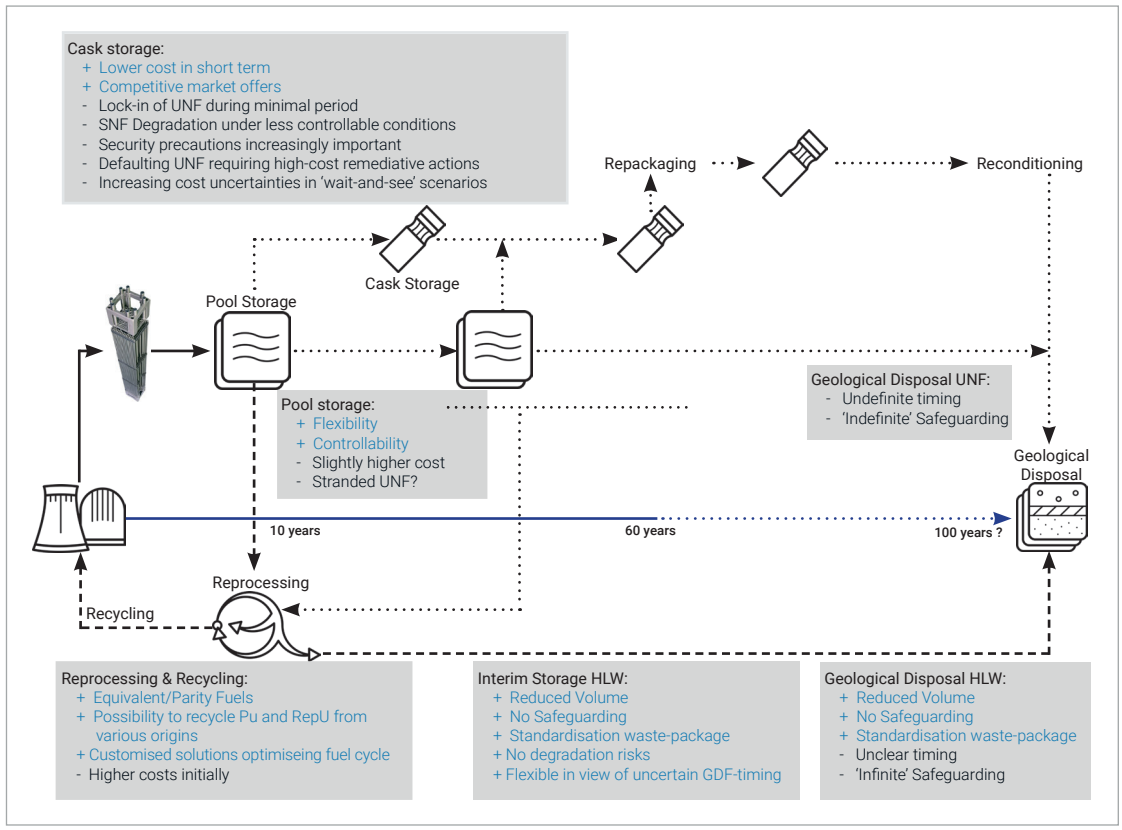
- Socio-political acceptance of UNF-storage
- Financial market rating and governmental review of provision-fund terms
- Regulatory changes

A TYPICAL QUESTION: SHOULD WE REPROCESS UNF OR NOT?

Classical NPV/DCF-analysis do not capture these uncertainties in decisional branching and do not assess the hedging values of various UNF-management options

UNF may be reprocessed at various points in time after discharge, the central question being:

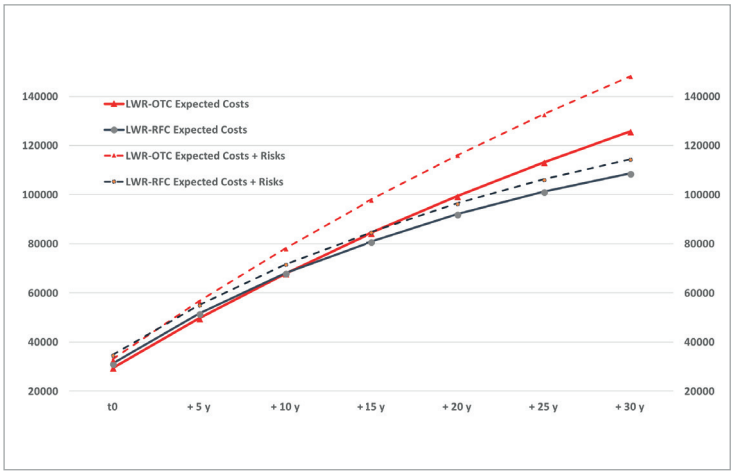
"Is there an ideal time to reprocess, given future uncertainties in UNF-management?"



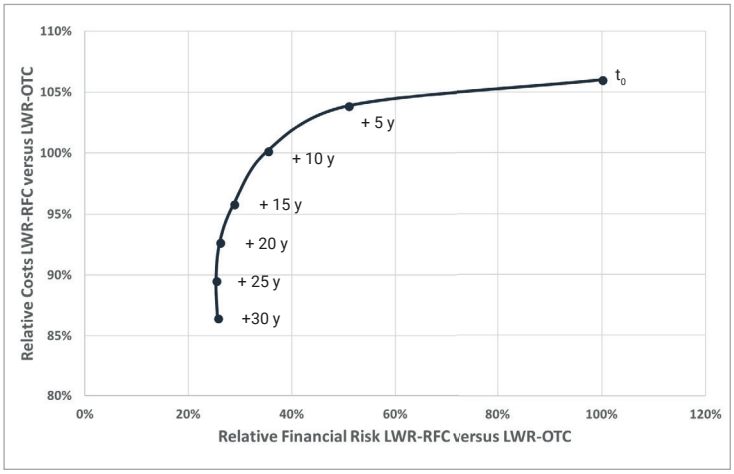
COMPARISON OF NPV/DCF AND REAL OPTIONS VALUE (ROV)

The OECD/NEA study "the Economics of the Back-End of the Nuclear Fuel Cycle" (2013) applied the classical NPV/DCF-analysis to compare the Once-Through Fuel Cycle (OFC) with the plutonium mono-recycling Fuel Cycle (RFC) but did not account for uncertainties in the costs and timing of back-end UNF-management operations.

MORE ADVANCED FINANCIAL RISK ASSESSMENT METHODOLOGIES, SUCH AS REAL OPTIONS VALUATION (ROV), PROVIDE INSIGHTS INTO HOW VARIOUS STAKEHOLDERS MAY REDUCE THEIR COST/RISK-EXPOSURE OVER TIME AND PROVIDE INSIGHTS ON WHEN TO EXECUTE WHICH OPTION



Applying uncertainty values from NEA-study, the expected costs and associated uncertainty range for costs are essentially governed by GDF cost and timing uncertainties



While ROV provides at the same results as NPV/DCF-analysis (i.e. 8 % in favour of LWR-OTC), the increasing uncertainty with time provides increasing value to LWR-RFC from 10 years after discharge with low costs than LWR-OTC and significantly lower future financial risks

COST/RISK-OPTIMISED DECISIONEERING ON USED NUCLEAR FUEL

The multi-variate decisional environment of UNF management demands more advanced cost/risk-assessment methodologies allowing to:

- UNF-management options
- Value the flexibility required in uncertain futures
- Optimise the cost/risk-exposure for UNF owners to control their financial risk exposure

this is achievable by

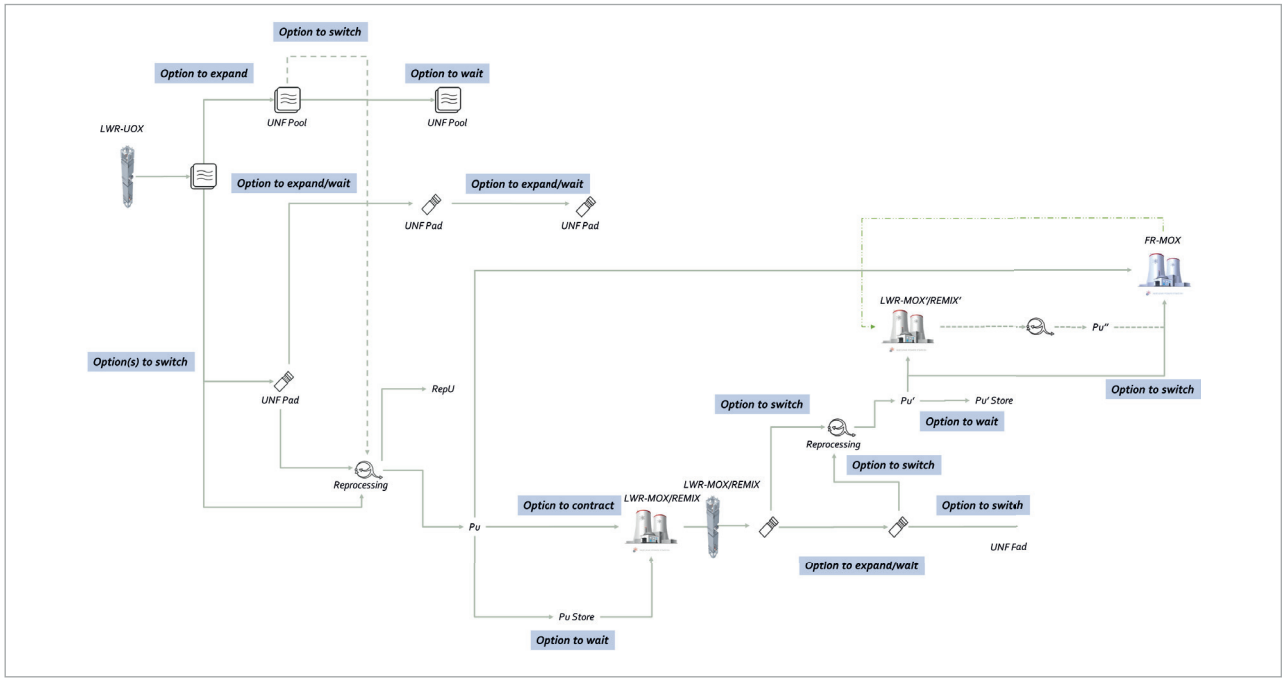
- Segmenting the UNF-inventory according to its cost/risk-profile
- Projecting the optimised contractualisation roadmap for UNF-management services
- "what-if?" analysis for new UNF-management developments and decisional impacts
- Analysing pricing strategies for UNF-management strategies

As such, our Cost/Risk-Optimised Decisioneering methodology allows us to:

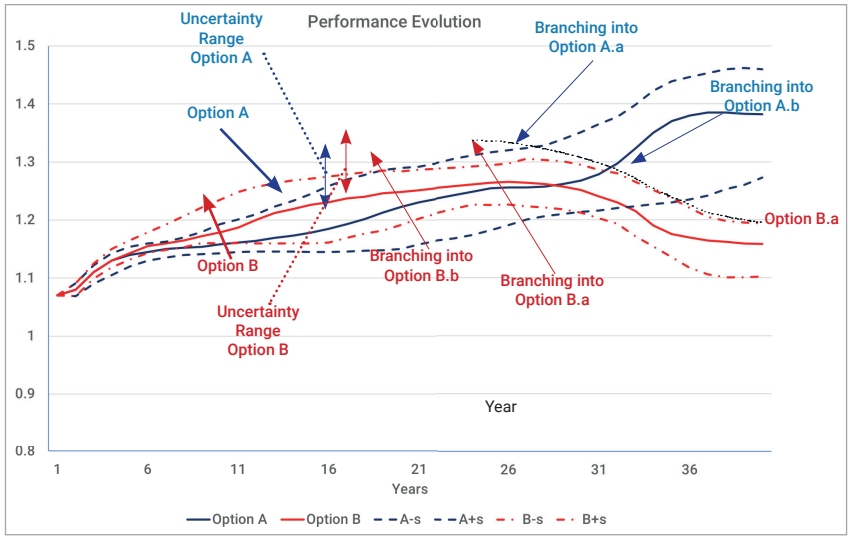
- Project the decisional strategies for UNF
- Determine the value of possible actionsto optimise cost/risk-exposure
- Identify the decisional conditions towards optimised UNF-management options
- Inform stakeholders and leverage towards improved understanding of the decisional framework

GENERIC EXAMPLE

A typical LWR-UNF batch faces multiple decisional options during the decades after discharge with our cost/risk methodology determining the hedging value in view of future uncertainties and valuing flexibility from keeping future options open

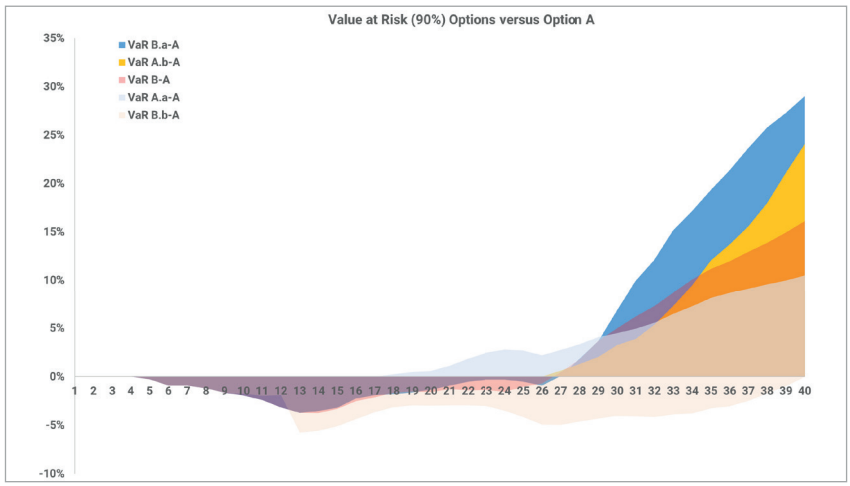


THE FUEL CYCLE BACK END PRESENTS A VARIETY OF VALUE-ADDING OPTIONS BRINGING THE FLEXIBILITY TO MITIGATE UNCERTAIN RISKS



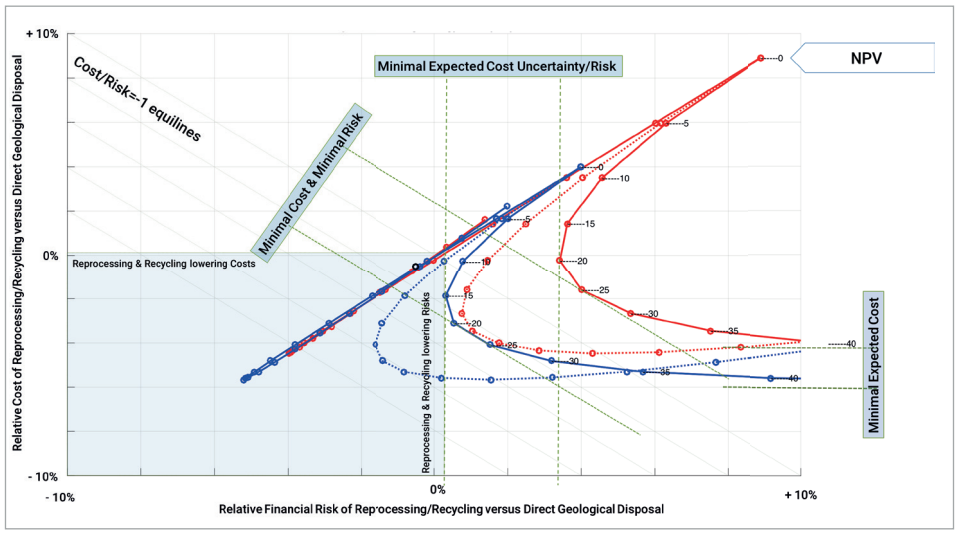
A generic example maps the performance evolution of 6 different decisional scenarios in the back-end of the fuel cycle, i.e.:

- Two main scenarios A and B branch at different moments into A.a / A.b and B.a / B.b respectively;
- This results in different performance evolutions over time
  Main question:
  "Which option should be executed and when to minimise cost/risk-exposure?"



The Value-at-Risk (VaR) analysis concludes that:

- Option A should be executed till year 16 and then to switch to
- Option A.a till year 28, where continuation of A.a or switching to B, A.b or particularly B.a would be beneficial



The Cost/Risk-decisioneering methodology allows UNF owners to optimise their cost/risk exposure by balancing their cost and risk exposure against their financial performance rating (example, RFC versus OTF fuel cycle choice)

OUR DECISIONEERING METHODOLOGY IS APPLICABLE IN VARIOUS UNCERTAIN DECISIONAL SITUATIONS

While the cost/risk-decisioneering methodology is particularly well-suited for for spent nuclear fuel management decisioneering, it is universally applicable. Other applications include: to, e.g.:

- market analysis in uncertain market futures
- valuation of technology developments in investment analysis
- pricing analysis in portfolio optimisation
- risk analysis allowing market segmentation

These are applicable in various domains, e.g.:

Energy markets

- Market analysis to compare various technology options

Nuclear Power Plant investments

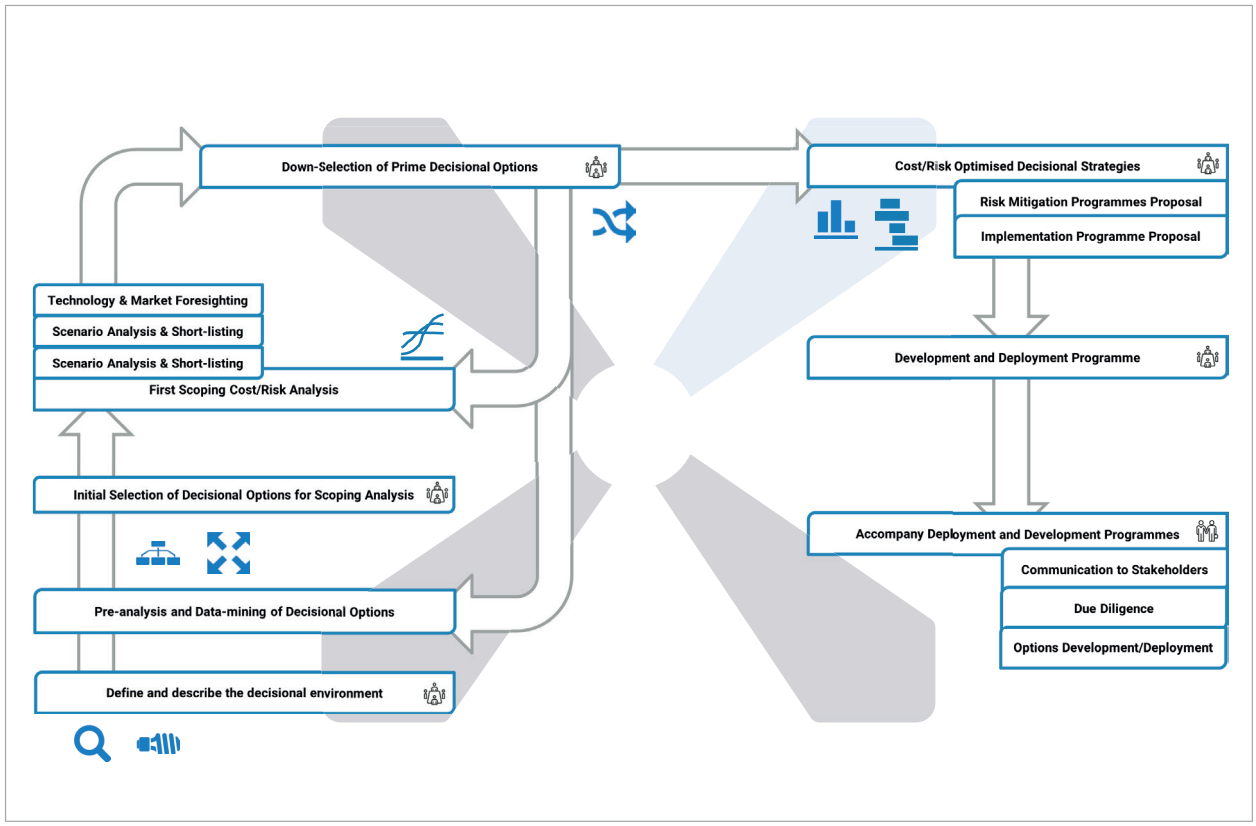
- Various large plants versus smaller/modular reactors

Waste management

- Decommissioning and waste policies & strategies

in short, **our methodology is applicable in any decisioneering situation where future uncertainty needs to be valued in today's decision-making, where costs and risks need to be optimised and matched to investors' risk appetite**

A TYPICAL APPLICATION APPROACH IN FOUR PHASES



A typical cost/risk-decisioneering project:

- is a highly interactive process with the customer ensuring in-depth understanding and integration of policy, strategy, technology and business market environments;
- Involves four main phases
    - Mapping the decisional environment and analysing the decisional options and strategies
    - Interactive decisional scenario analysis and assessment of decisional criteria detailing the cost/risk-optimised decisional strategies;
    - Down-selecting to the most robust decisional strategies and enabling development & deployment programmes;
    - Optionally, accompanying our customers in those development and deployment programmes with regular updating and verification of decisional strategy

DECISIONEERING

NOTES

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