Climate Policy
Toward Carbon Reduction and Greener Cities Adaptation

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Outline of the presentation

- **Introduction**
- **Case study examples**
  - Deep geothermal energy extraction (economic criterion)
  - Deep geothermal energy extraction (economic and environmental criteria)
  - Transport infrastructure (railway)
- **Ongoing projects**
  - Transport infrastructure (tunneling the Antwerp ringroad)
  - Sustainable management of the deep subsurface

Introduction

- **Prof. Dr. Tine Compernolle**
- **Research group EnvEcon @UAntwerp**
- **Royal Belgian Institute of Natural Sciences**

→Interdisciplinary research

→Transdisciplinary research?

- Involving policy makers/stakeholders

Introduction

- Dr. Thomas Machiels
- Dr. Roel Nagy
- Spiros Gkousis

Introduction

- **Context of climate change**
- **Limited resource availability**

→Transition to a low-carbon, circular economy

→A just transition

→ Need for new technologies

→ Investment are irreversible and characterized by multiple sources of uncertainty. There is flexibility in the decision making process

→ Evaluation should involve an economic, environmental and social dimension

The decision to invest under uncertainty

A case study example

deep geothermal energy development

Real options-like approach

Technical uncertainty stimulates investment

Example: geothermal energy extraction

→ a two-period case

→ the time at which you have learned, is predefined.

Geothermal energy extraction

Multiple sources of uncertainty

- Market uncertainty: energy prices
- Geological uncertainty (= technical uncertainty)

Experts:

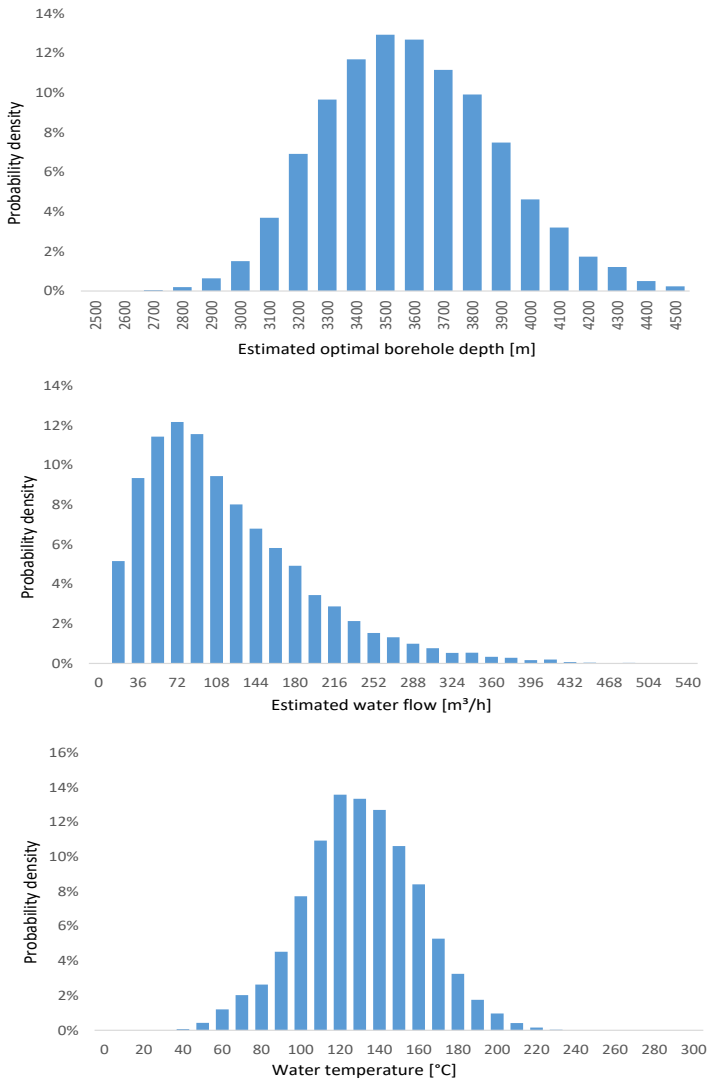
independent, academic background, well acquainted with deep geology in BE, not directly involved in the setting up of the methodology and processing of results.

Inquiry:

2 reservoirs targeted (Campine Basin and Mons basin)

The reservoir concept is described by the probability distributions for 10 parameters:

- the geotechnical failure of the reservoir,
- depth,
- total thickness,
- productive thickness,
- the geothermal gradient,
- transmissivity,
- flow rate,
- effective porosity,
- the distance between doublets and the wells.



Probability distributions of the estimated values for borehole depth, water flow and temperature resulting from the expert questionnaires (for the Balmatt site).

Geothermal energy extraction

Stage-gate-system

- Exploration phase
- Development phase

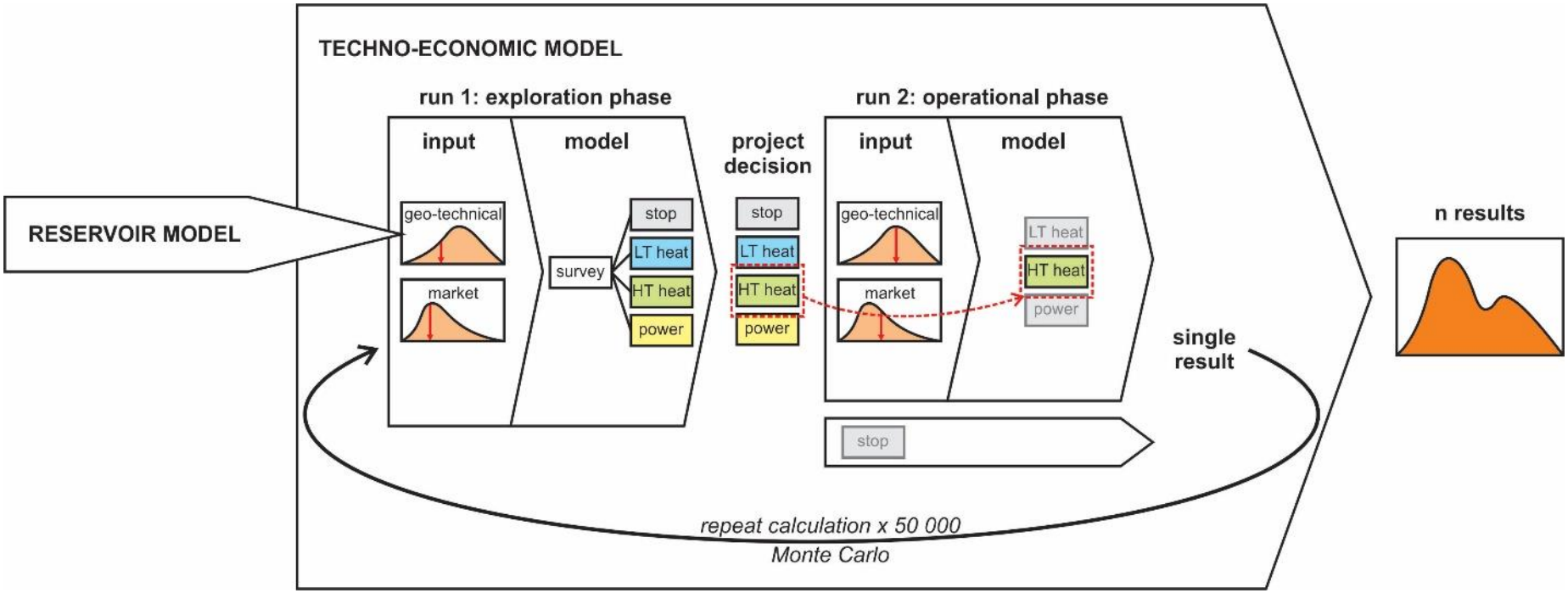
Geological uncertainty resolves

Flexibility after learning:

- The option to abandon the project
- If development: choice in different types of geothermal development

NPV analysis + Monte Carlo simulation

Geothermal energy extraction



Geothermal energy extraction

	Probability	NPV
(1) Abandon project	45.27%	-€ 6,447,272
(2) LT Heat	0.10%	-€ 6,121,965
NPV<0	0.09%	
NPV>0	0.01%	
(3) HT Heat	54.63%	€ 6,780,975
NPV<0	19.55%	
NPV>0	35.08%	
(4) Binary power plant	0.00%	€ 0.00
NPV<0	0.00%	
NPV>0	0.00%	
Expected average project value		€ 779,896

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Expected average project value		€ 779,896

Learning

Value with learning + flexibility

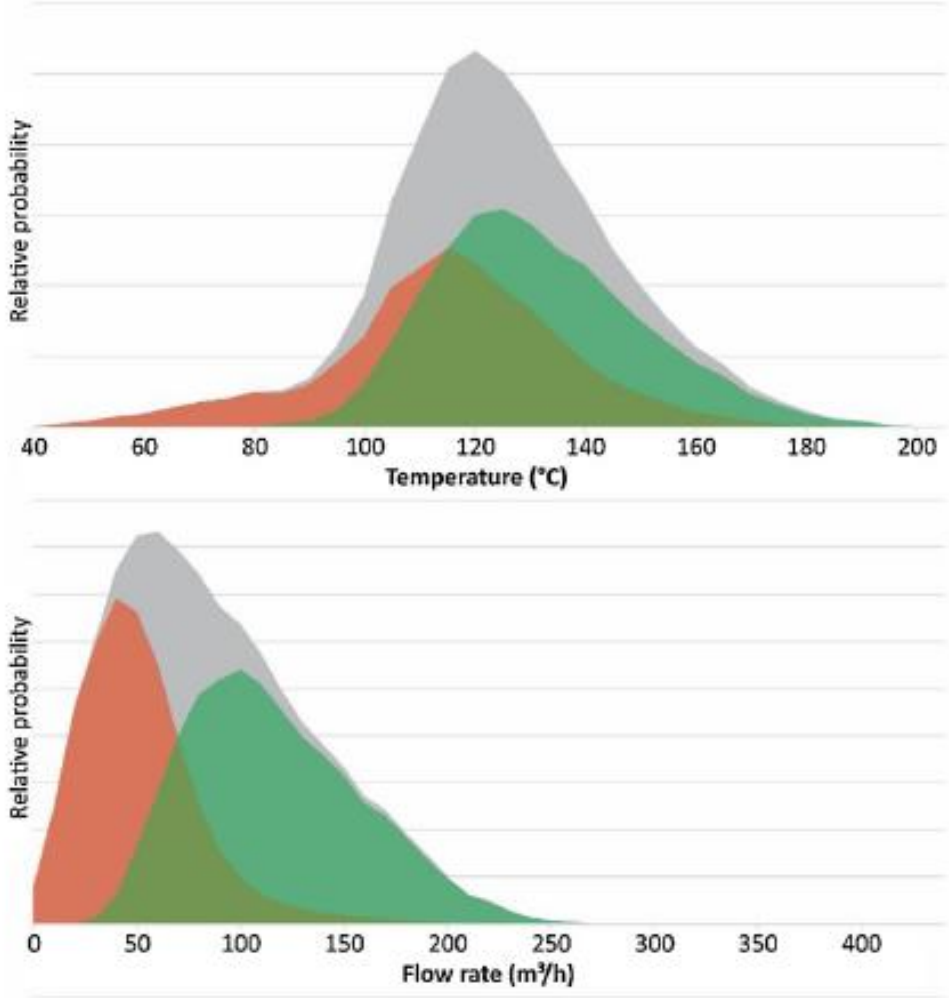
(3) HT Heat	54.63%	€ 6,780,975
NPV<0	19.55%	
NPV>0	35.08%	

Value without learning and flexibility

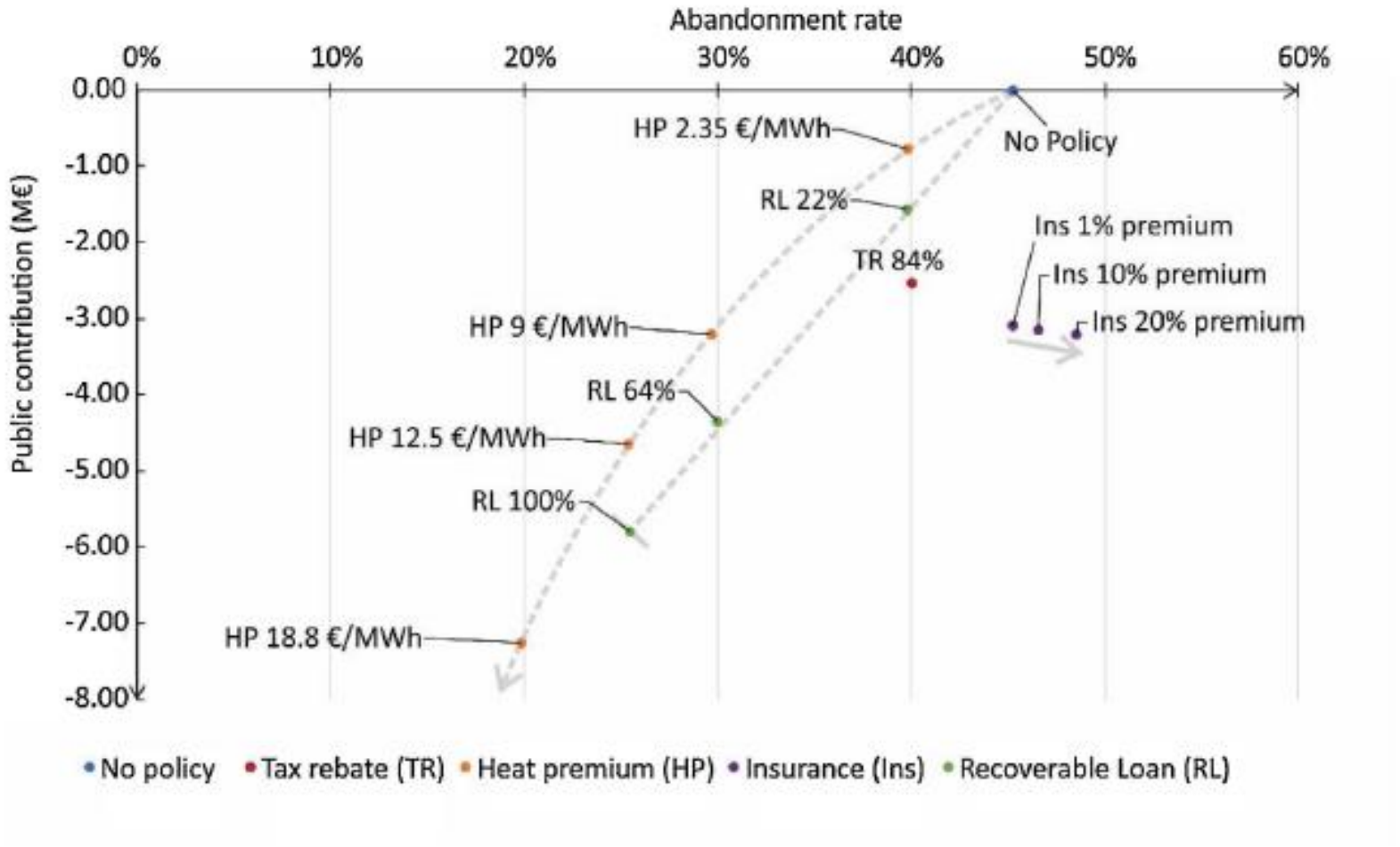
(3) HT Heat	100%	€ -2,2887,482	⟷	€ 779,896
NPV<0	64.5%			
NPV>0	35.5%			

Geothermal energy extraction

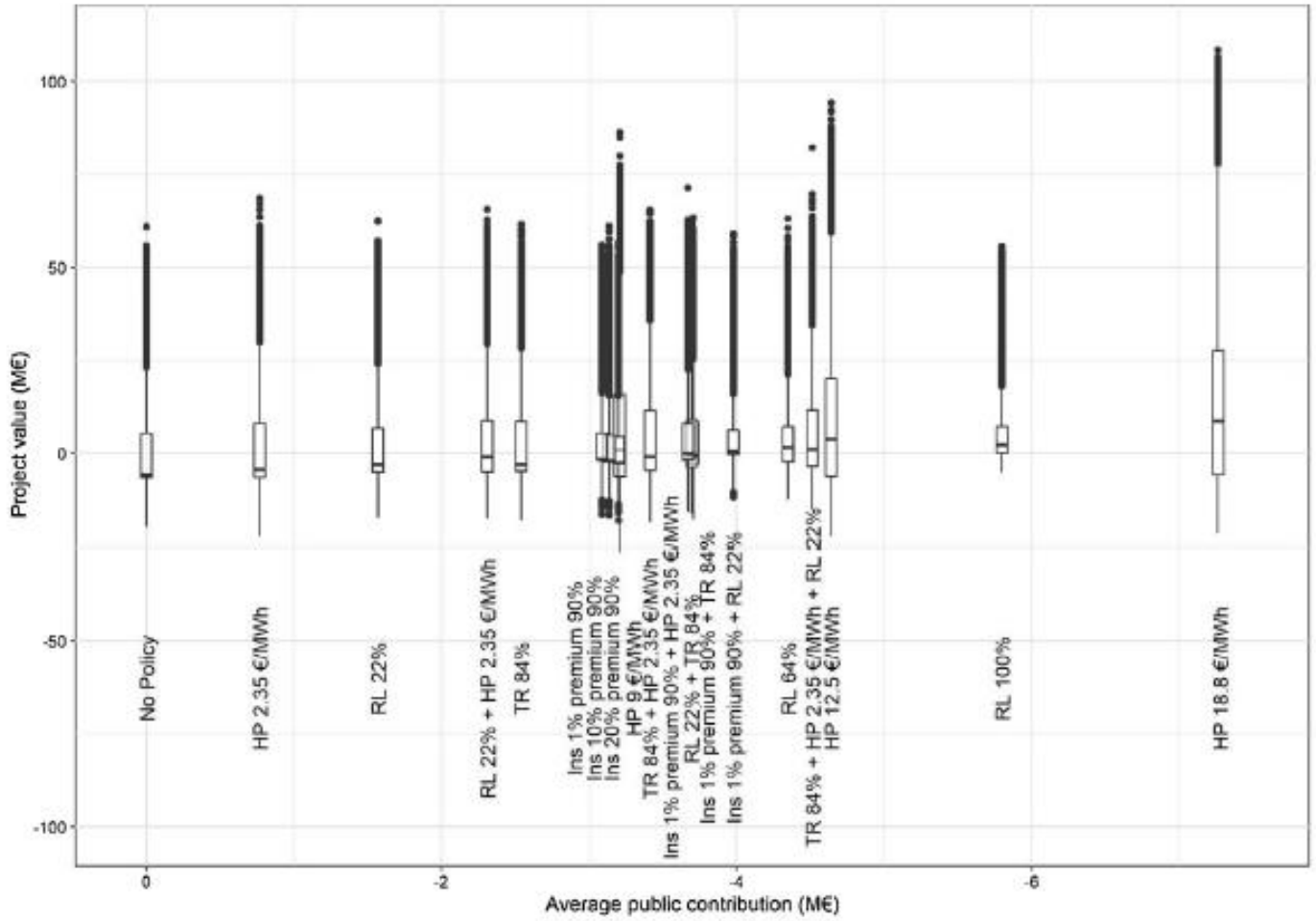
Fig. 3. Distribution of the stochastic values for reservoir temperature (grey, total), and of the projects that are either abandoned (red) or activated (green).



Policy implications



Policy implications



plot diagrams of the project values for the single and combined policy instruments, ranked according to their associated public cost. If the upper whiskers are pared to the No Policy case, windfall profits occur.

The decision to invest under uncertainty

A case study example

deep geothermal energy development

Environmental and economic criteria

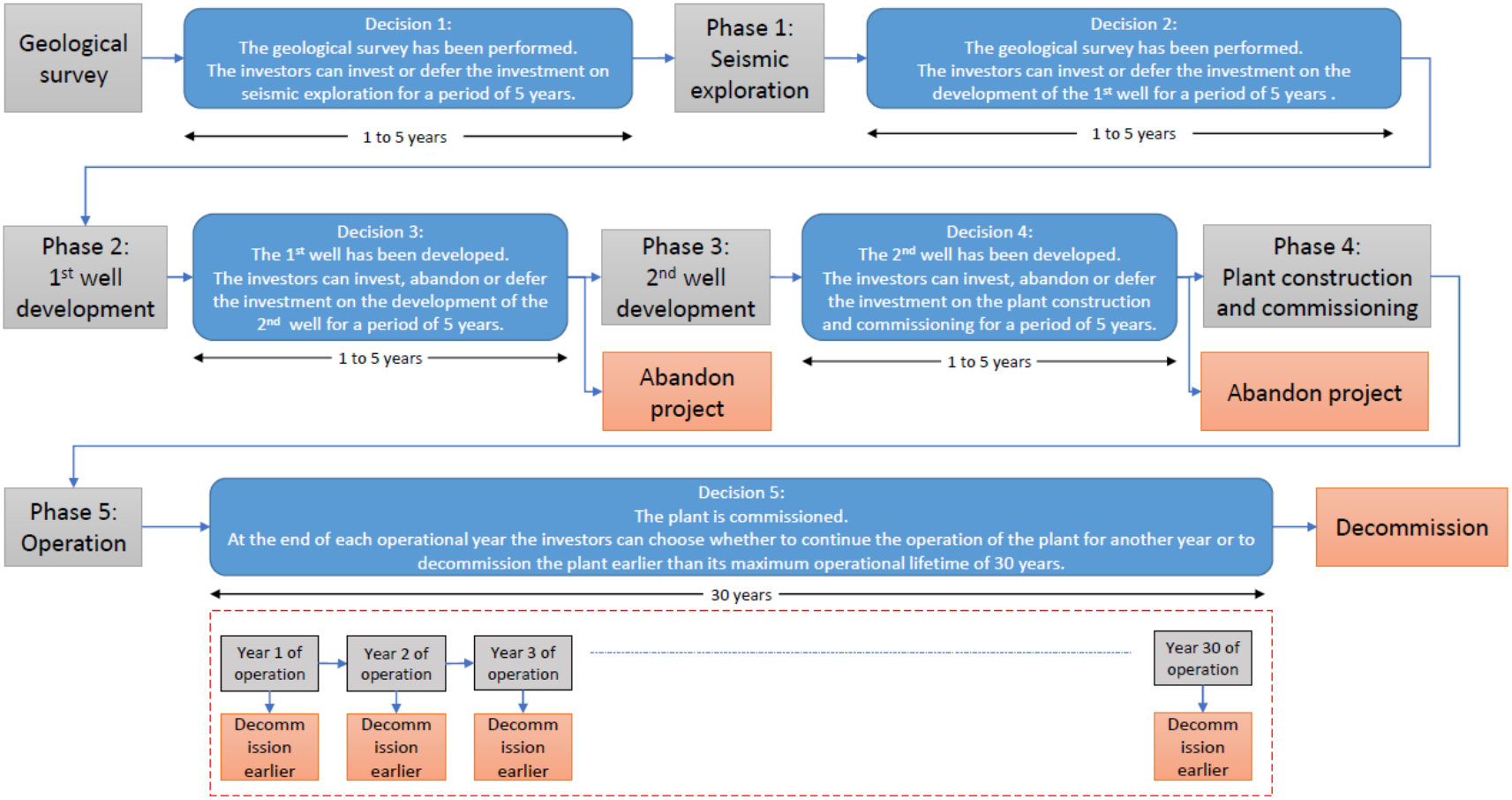
Integrating Environmental LCA and Techno-economic assessment

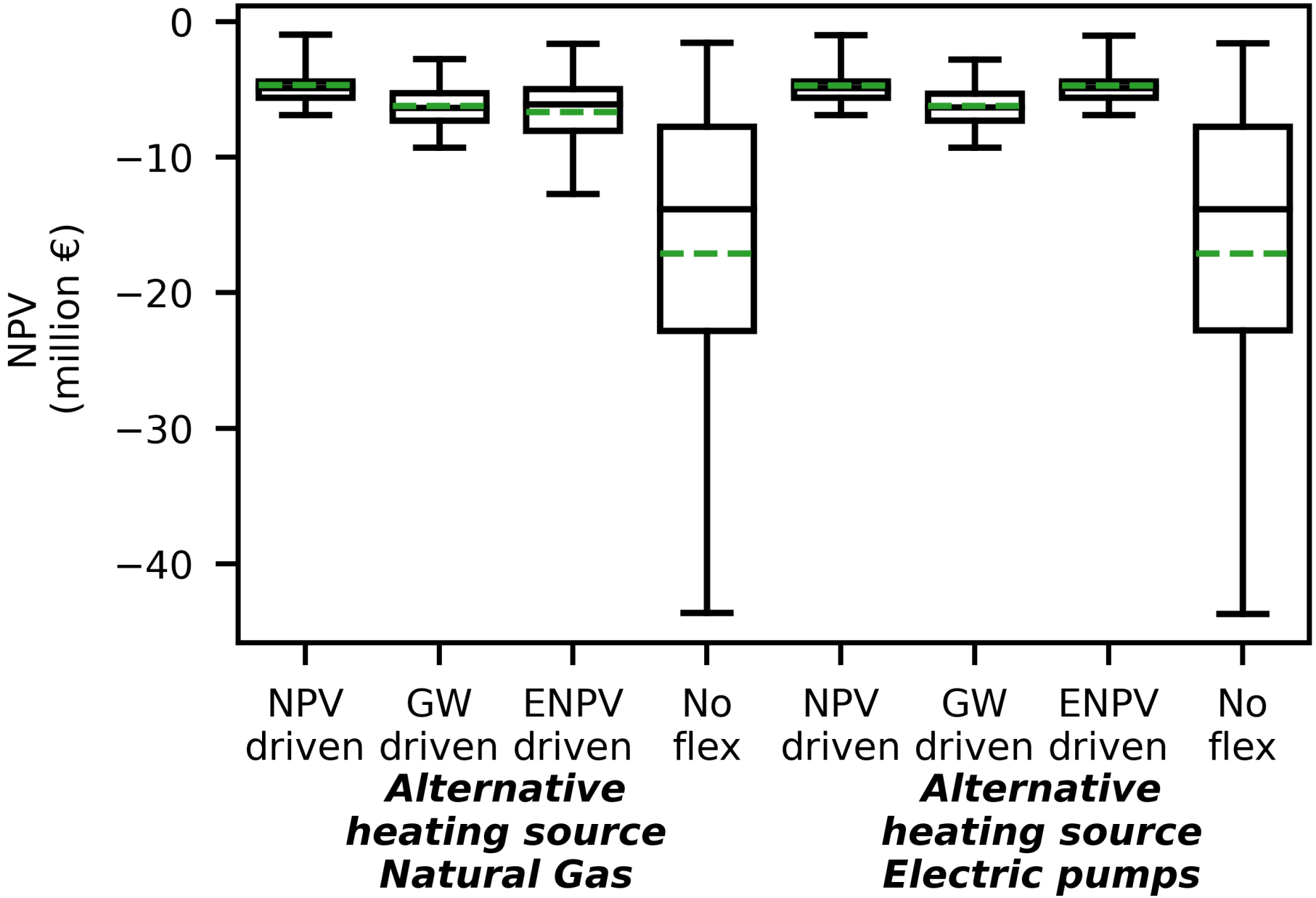
Least square Monte Carlo algorithm by Longstaff and Schwartz

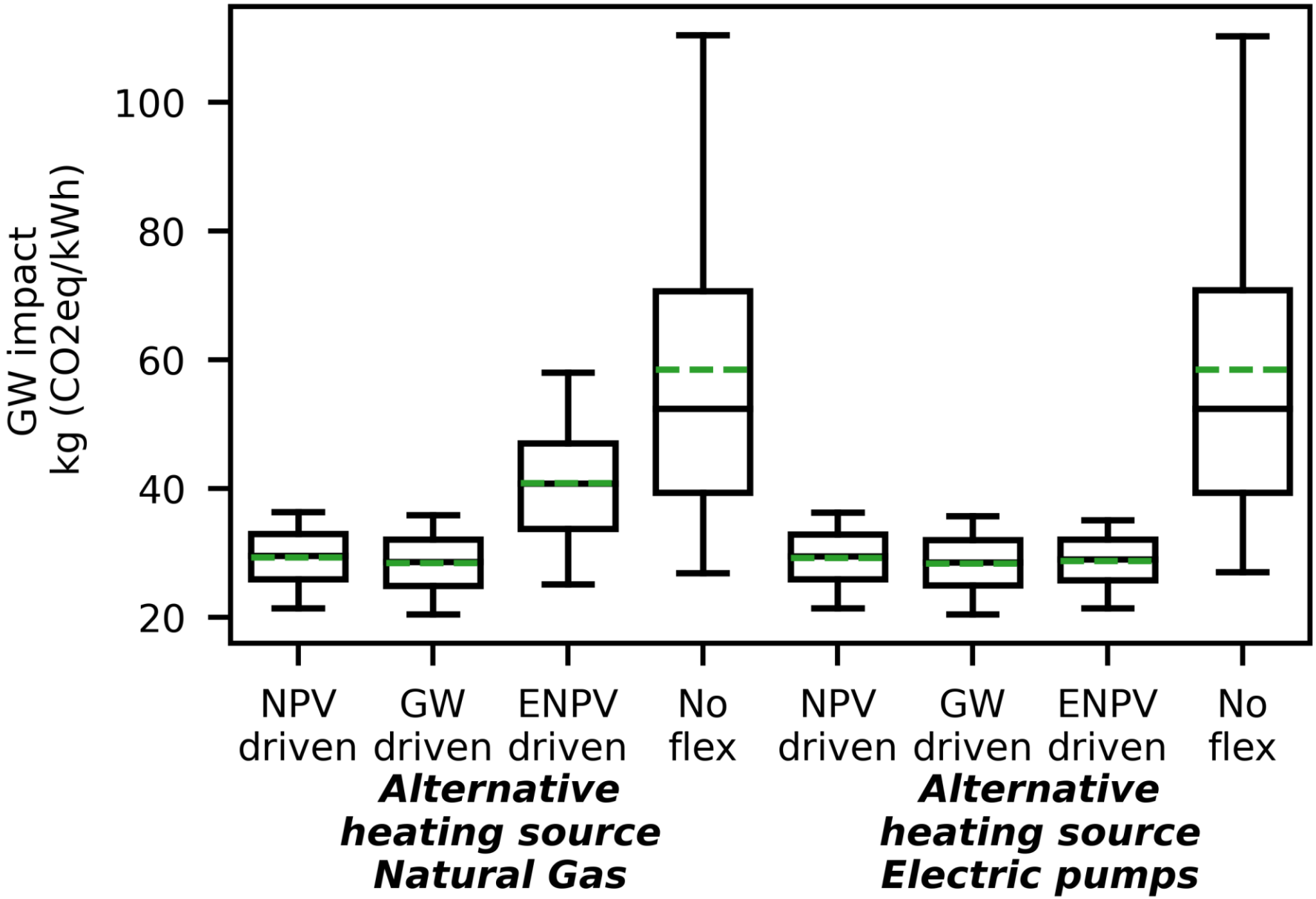
- To account for an environmental criterion in addition to the economic value criterion

→ To minimize the global warming impact of the investigated system

Integrating Environmental LCA and Techno-economic assessment




0
−10
−20
−30
−40
NPV
(million €)
NPV driven
GW driven
ENPV driven
No flex
NPV driven
GW driven
ENPV driven
No flex
Alternative heating source Natural Gas
Alternative heating source Electric pumps


GW impact
kg (CO2eq/kWh)
100
80
60
40
20
NPV driven
GW driven
ENPV driven
No flex
NPV driven
GW driven
ENPV driven
No flex
Alternative heating source Natural Gas
Alternative heating source Electric pumps

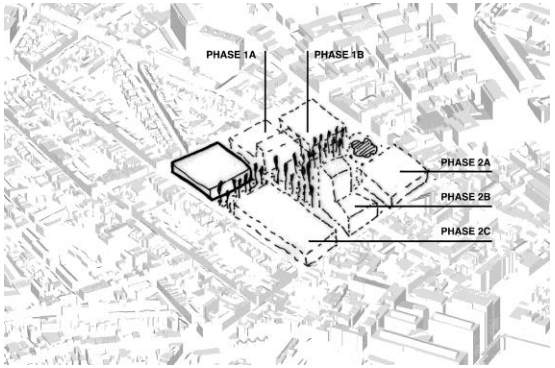
The decision to invest under uncertainty

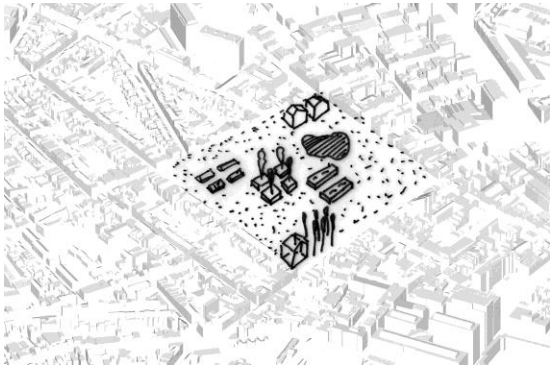
A case study example

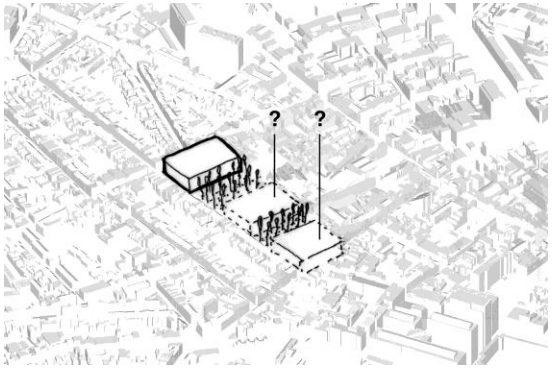
Investment in railway infrastructure

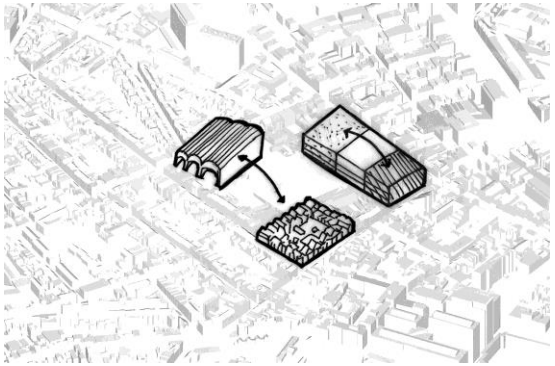
Stakeholder involvement

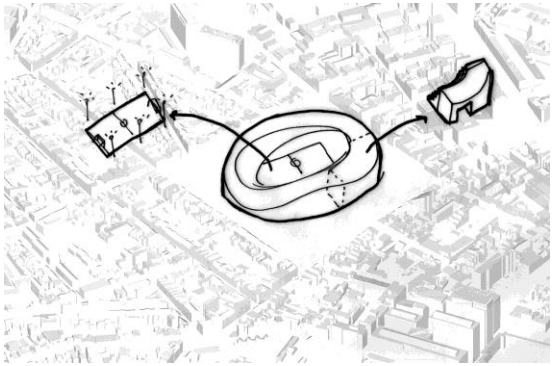
Real options in urban planning





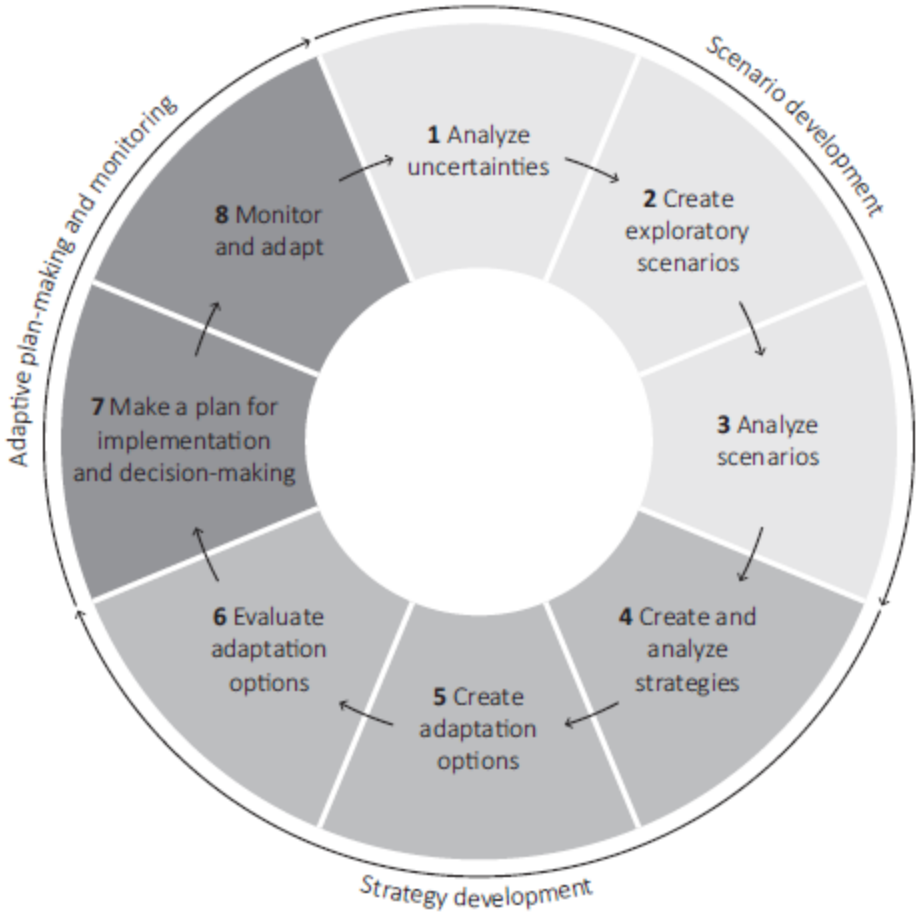




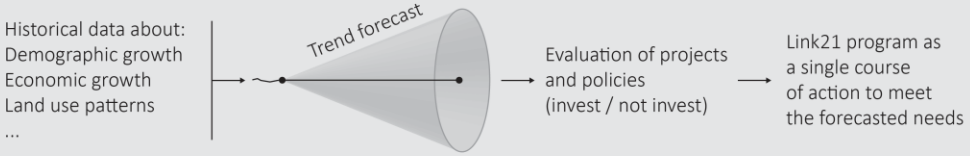


Investment in railway infrastructure

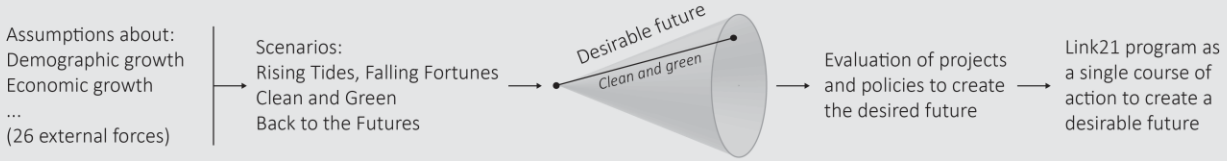
- **A qualitative real options approach**



PREDICT-AND-PLAN. Planning for a most likely future

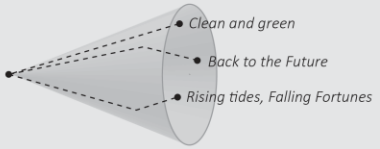


CONVENTIONAL SCENARIO PLANNING (NORMATIVE). Planning for a desirable future



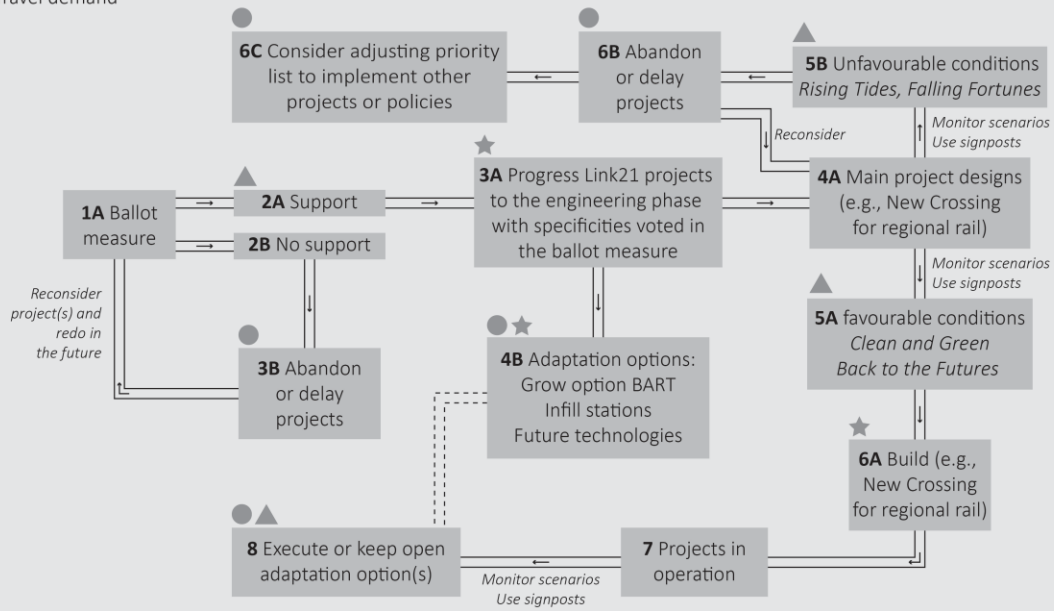
ADAPTIVE PLANNING WITH EXPLORATORY SCENARIOS AND REAL OPTIONS

Planning for multiple possible futures (Step 7. Link21 example)

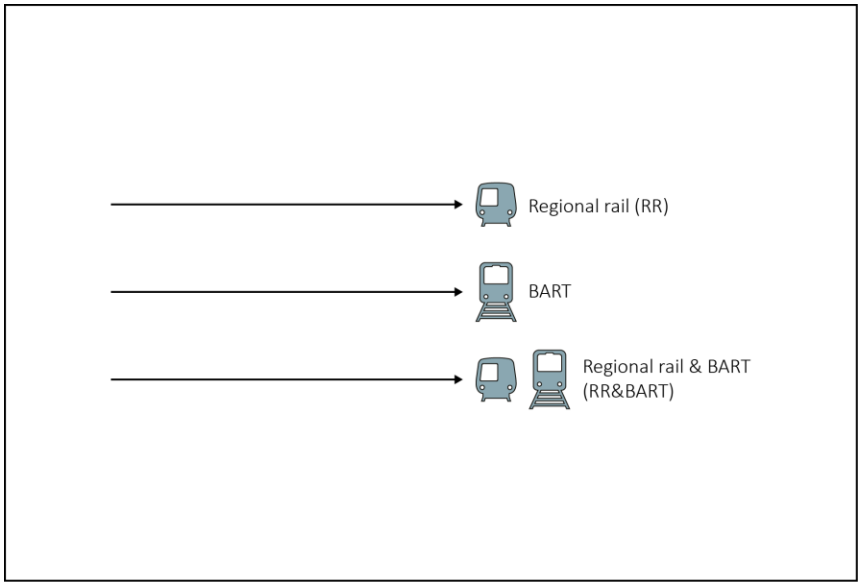


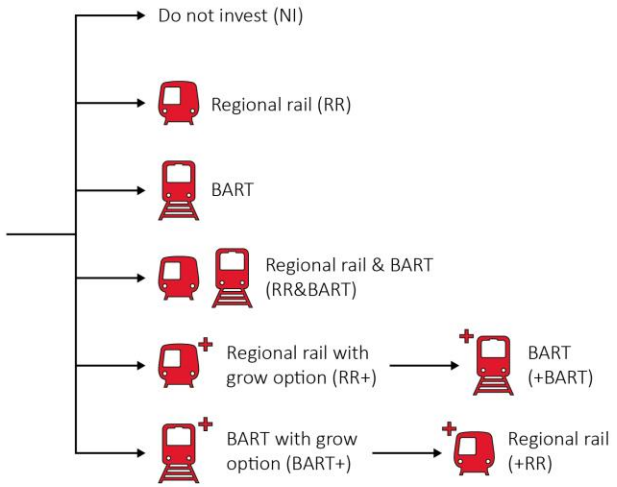
▲ *Conditions/scenarios* ● *Adaptation option* ★ *Project investment decision*

Societal support
Funding
Travel demand



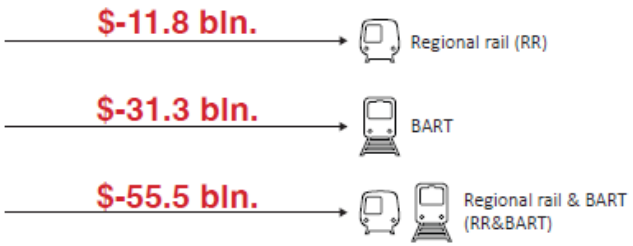
Investment in railway infrastructure





Investment in railway infrastructure

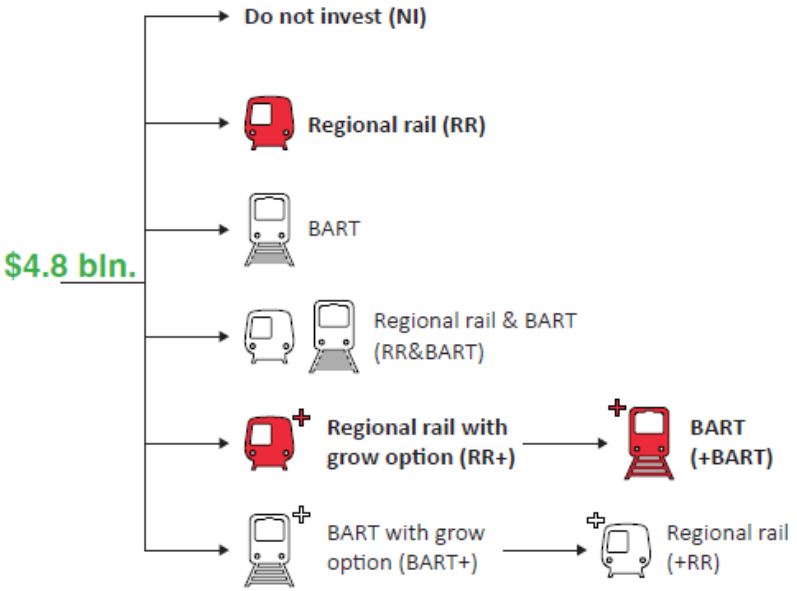
Predict-and-plan



Real option value = $16.9 bln.

The **value of flexibility** is the difference between the project values of a project with and without flexibility

Decision tree with real options

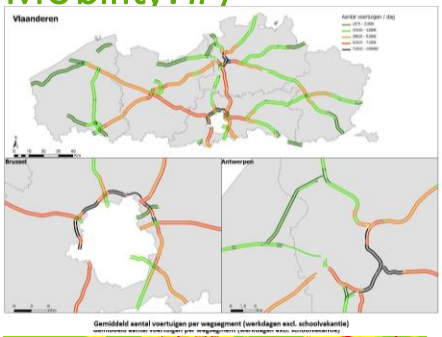


The decision to invest under uncertainty

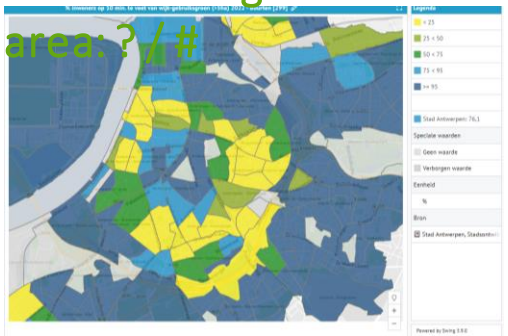
Ongoing projects

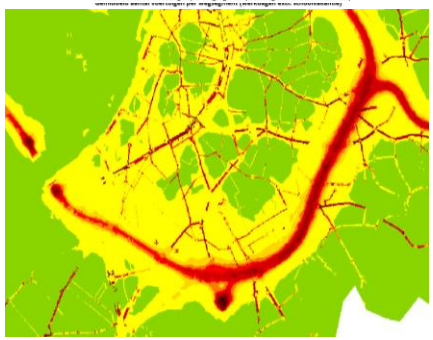
The ‘Future Alliance’ in Antwerpen : a compromise between mobility and liveability

Mobility: # /

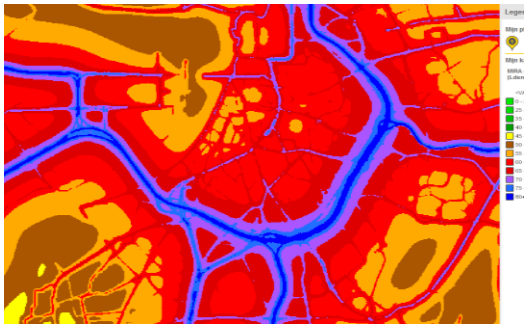


Provision of green area: ? / #





Air quality: # / €



Noise: # / €

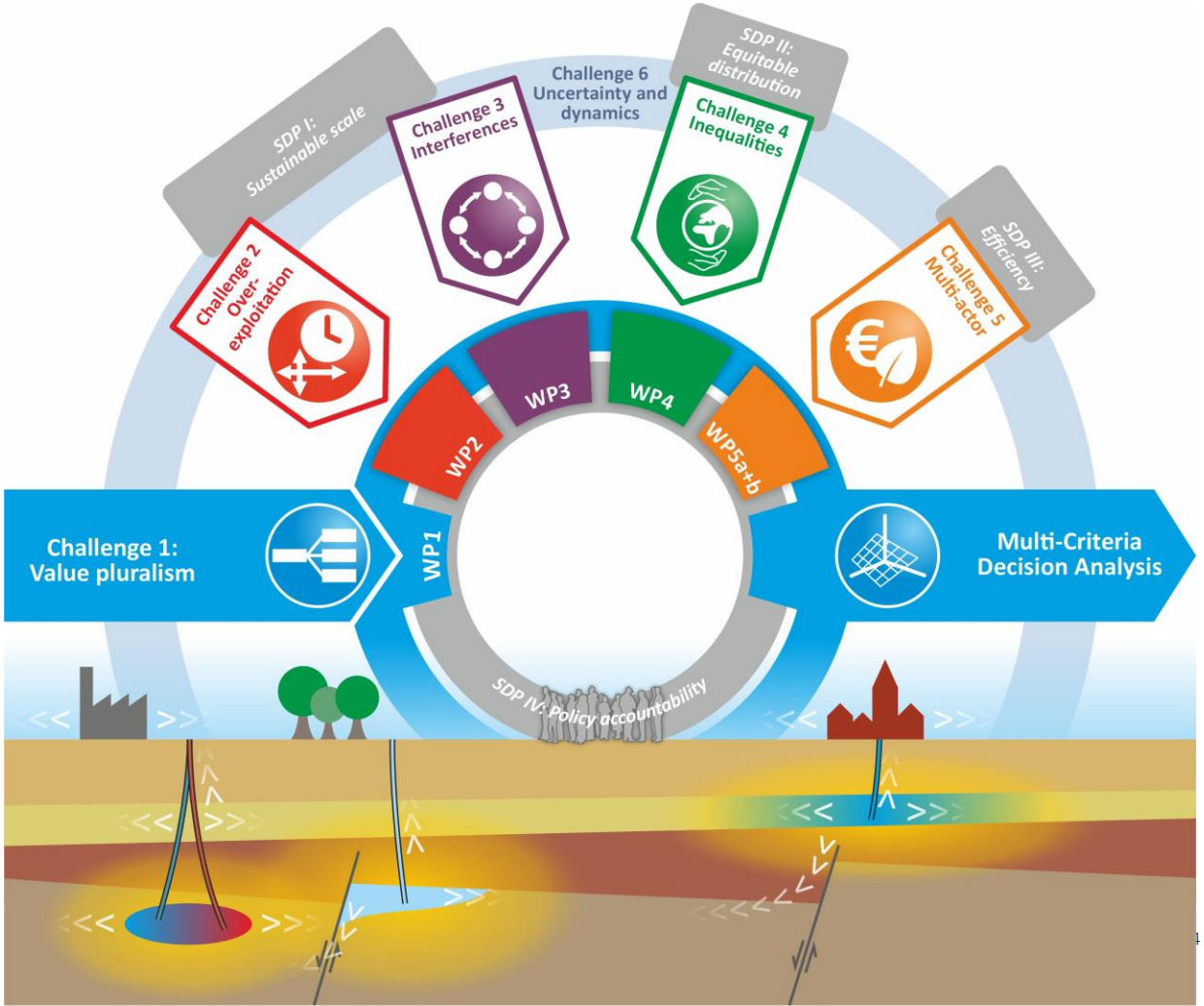
Spatial quality: ? / #

Sources:
Mobility: Vlaams verkeerscentrum (2021)
Provision of green area: Stad Antwerpen (2021)
Air quality & Noise : Vlaamse Milieumaatschappij (2018)
Spatial quality: AG Vespa (2015)

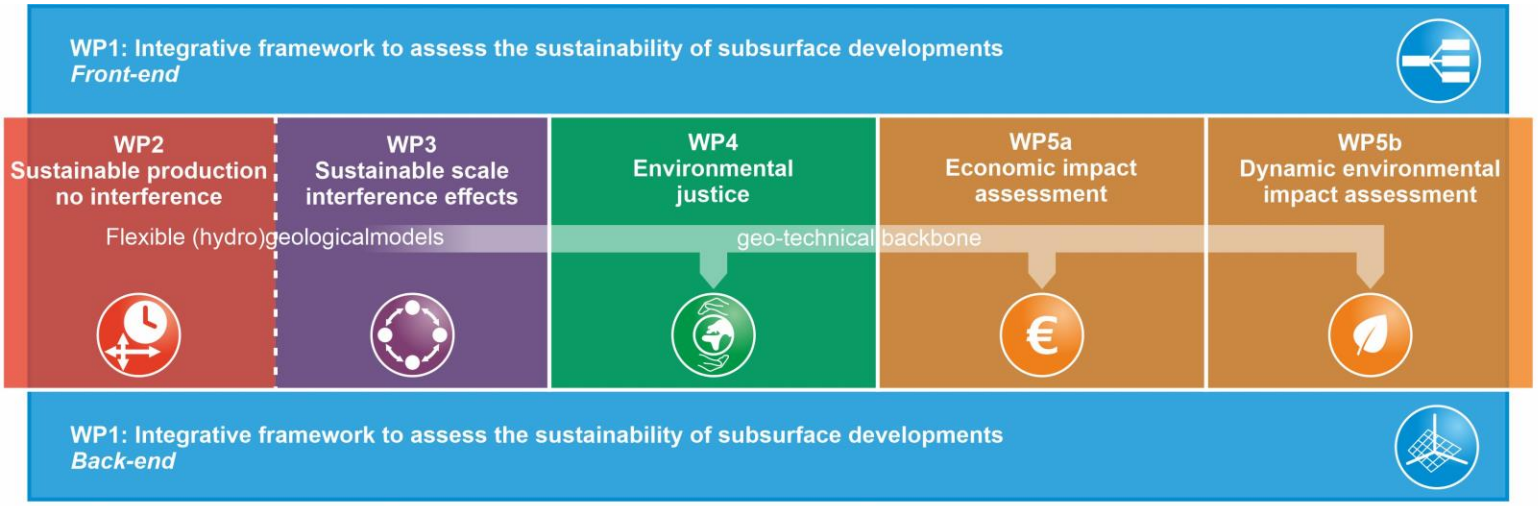
Tunneling the Antwerp ringroad

- Stakeholder involvement
  - Uncertainty avoidance
  - Focus on social cost benefit analysis
- Lack of data → scenario analysis
- Flexibility?

Dynamic integrated assessment methods for the sustainable development of the deep subsurface (DIAMONDS)



Dynamic integrated assessment methods for the sustainable development of the deep subsurface (DIAMONDS)



Linking to the objectives

- O1: to understand what sustainable management of geological resources involves and how to measure it
- O2: to develop flexible (hydro)geological models to determine hydrogeological threshold values for the identified sustainability indicators
- O3: to determine the social impacts of subsurface utilization, considering tenets of environmental justice
- O4: to detemine the economic impacts of subsurface utilization in time, taking into account different development options
- O5: to determine the changes in environmental impact resulting from subsurface utilization, taking into account the time at which these impacts occur
- O6: to integrate the calculated environmental and economic values together with hydrogeological values into a multi-dimensional decision support framework

Conclusion

- **Real options analysis can support policy making**
  - By evaluating different policy measures and investigate the impact on the decision to invest
  - By integrating multiple criteria in the decision analysis
  - Bringing real options-thinking to the practice field is a challenge

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