Decision-making when uncertainty and reversibility matter

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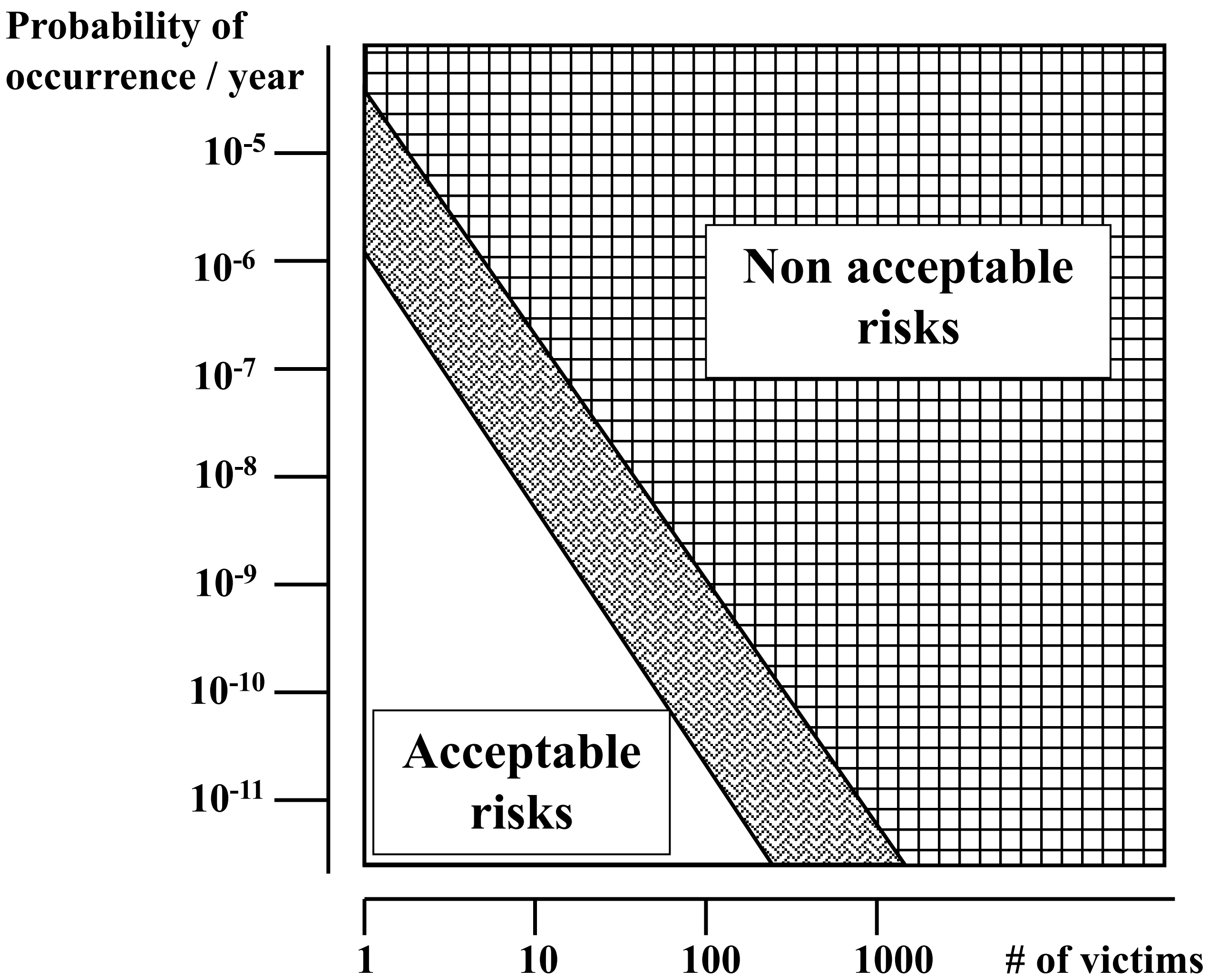
Overview

- Risk concept in environmental economics & policy
- Risk preference in decision-making
- IPCC position on hazards ✣ risks
- Dealing with societal risks
- Decision context
- Revocability & Reversibility
- Applied decision-making
- Conclusions

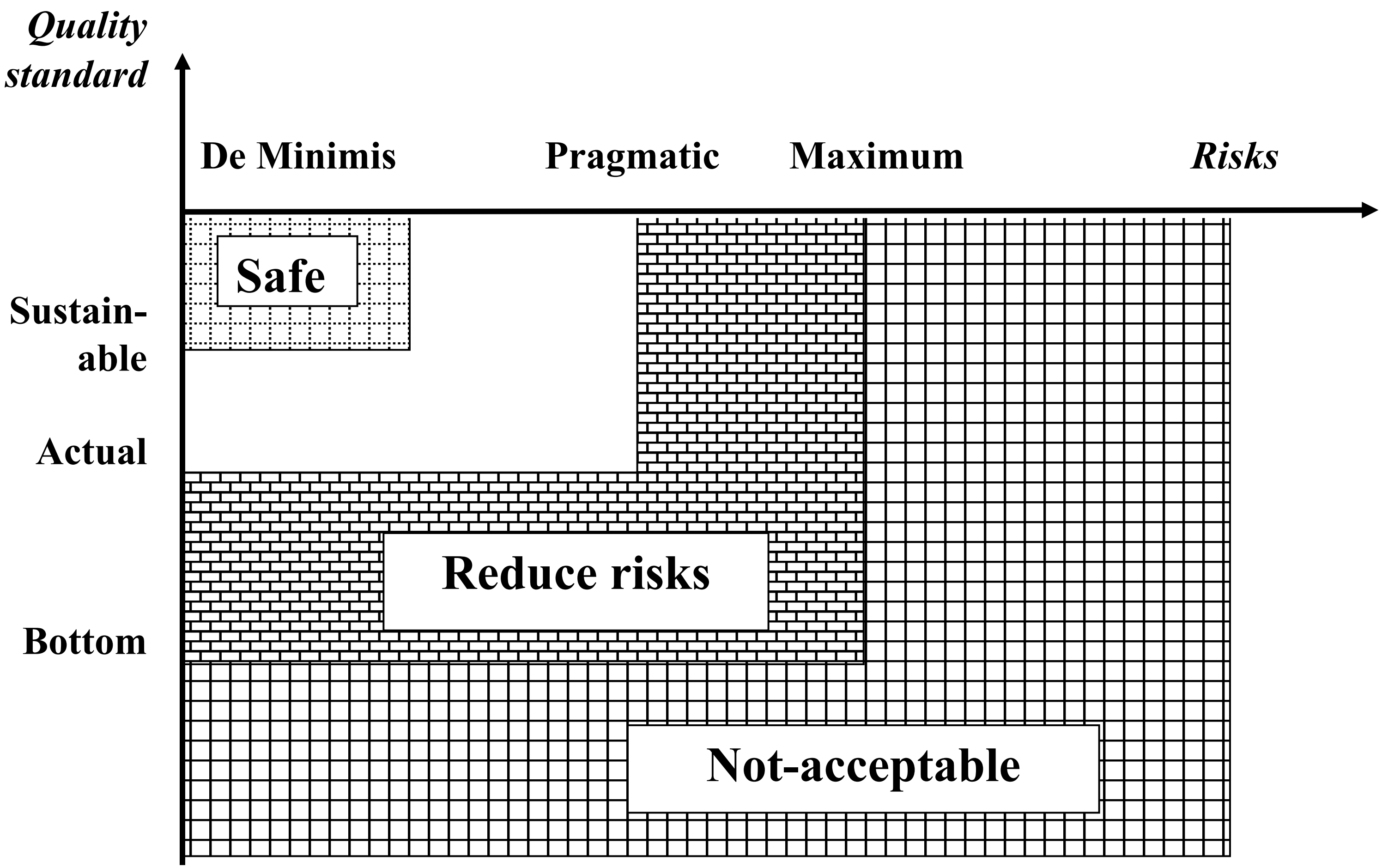
Societally Accepted Risks (=Probability x Outcome)



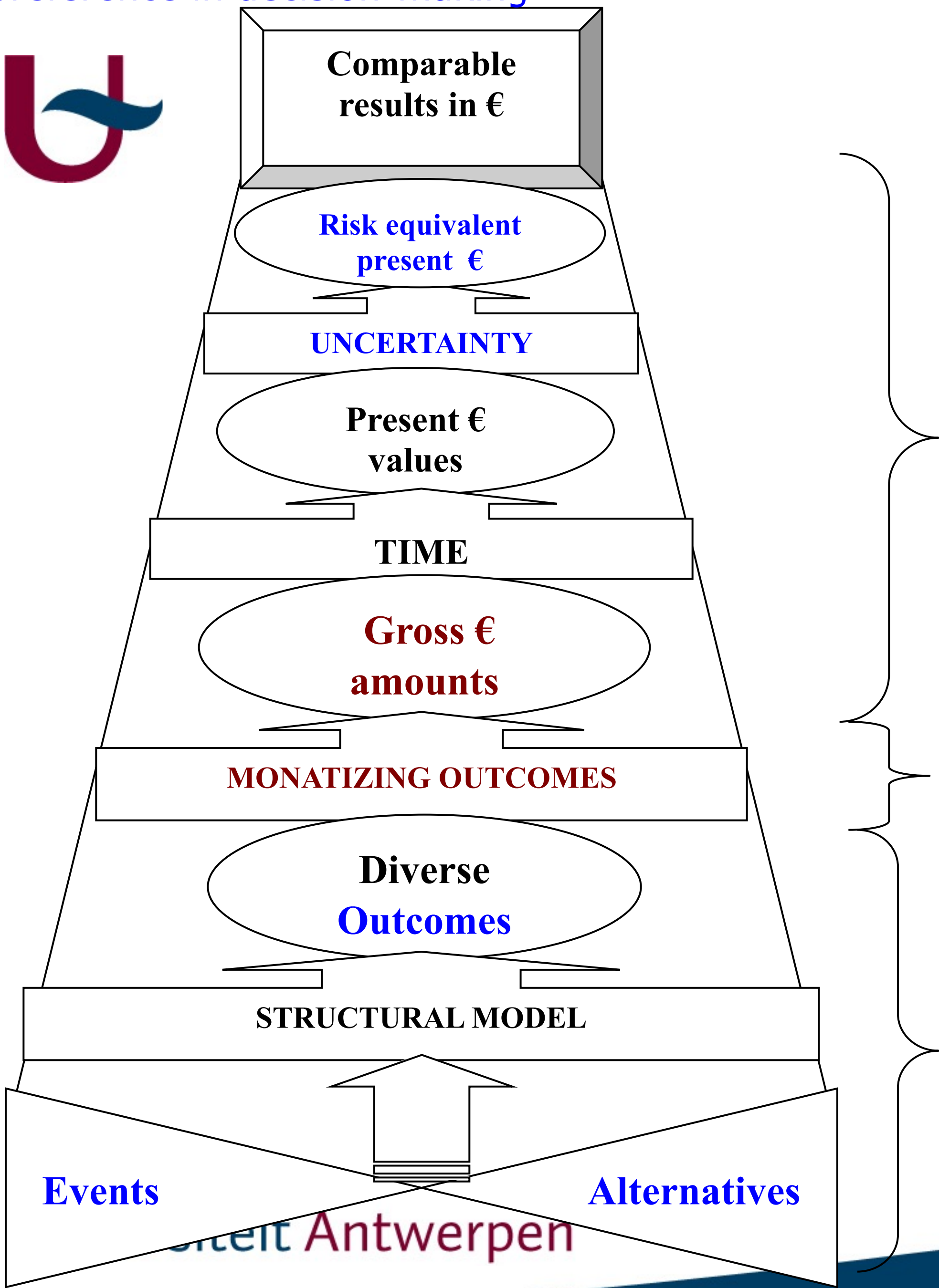
Environmental Quality Standards

- **Sustainability goals**
  - **Natural references and background values**
  - **Respect for intrinsic values (≠ instrumental values)**
  - **Risk averse safety buffers (precaution)**
- **Actual Targets**
  - **Best Available Technology (BAT) (Abatement)**
  - **Critical Loads (Damage)**
  - **Economic cost-benefit (Abatement/Damage)**
- **Bottom lines, tresholds**
  - **Intervention triggers**
  - **Banning of products, activities**

Link Quality Standards & Risks



Decision Stair



2 %

18 %

80 %

Effort shares

Attitudes towards uncertainty

Uncertainty destabilizes many: 'guess' instead of 'think'

⇔ only rational Boolean algebra solves probability questions
e.g.: all probabilities are conditional; $0 \leq P_i \leq 1$; $\Sigma_i P_i = 1$ = universum of possible outcomes

Bayes rule: prior prob. + new information ➔ posterior prob.

Lottery [component of risk analysis]:

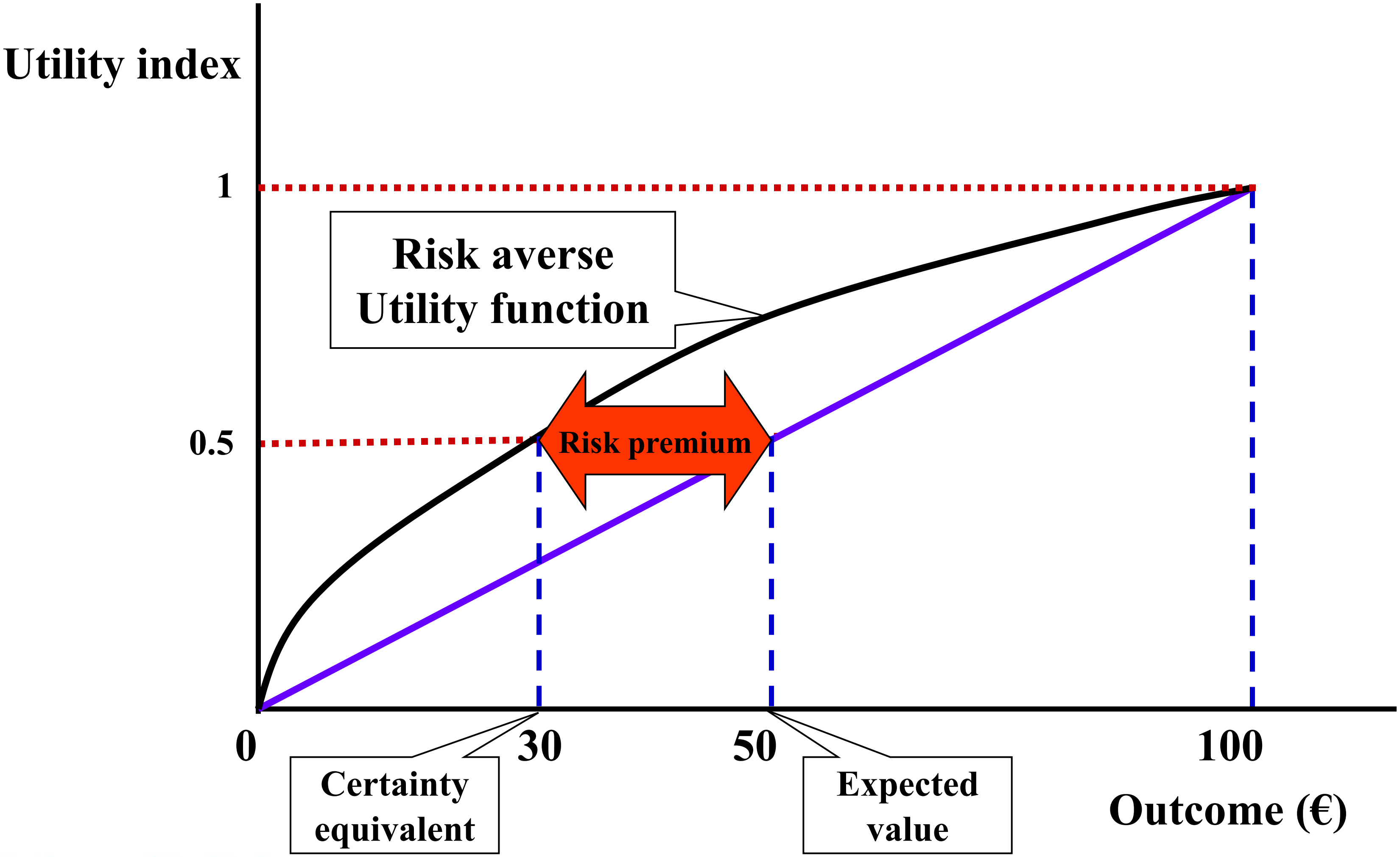
- **Outcomes O_i**
- **Probabilities P_i**
- **Expected Value = $\Sigma_i P_i \times O_i$**

People differ in attitude towards risks:

risk averse … risk neutral … risk prone/enjoying

- **> specific 'risk utility functions'**
  ≈ willingness to pay a premium to avoid risks

Utility function & risk premium

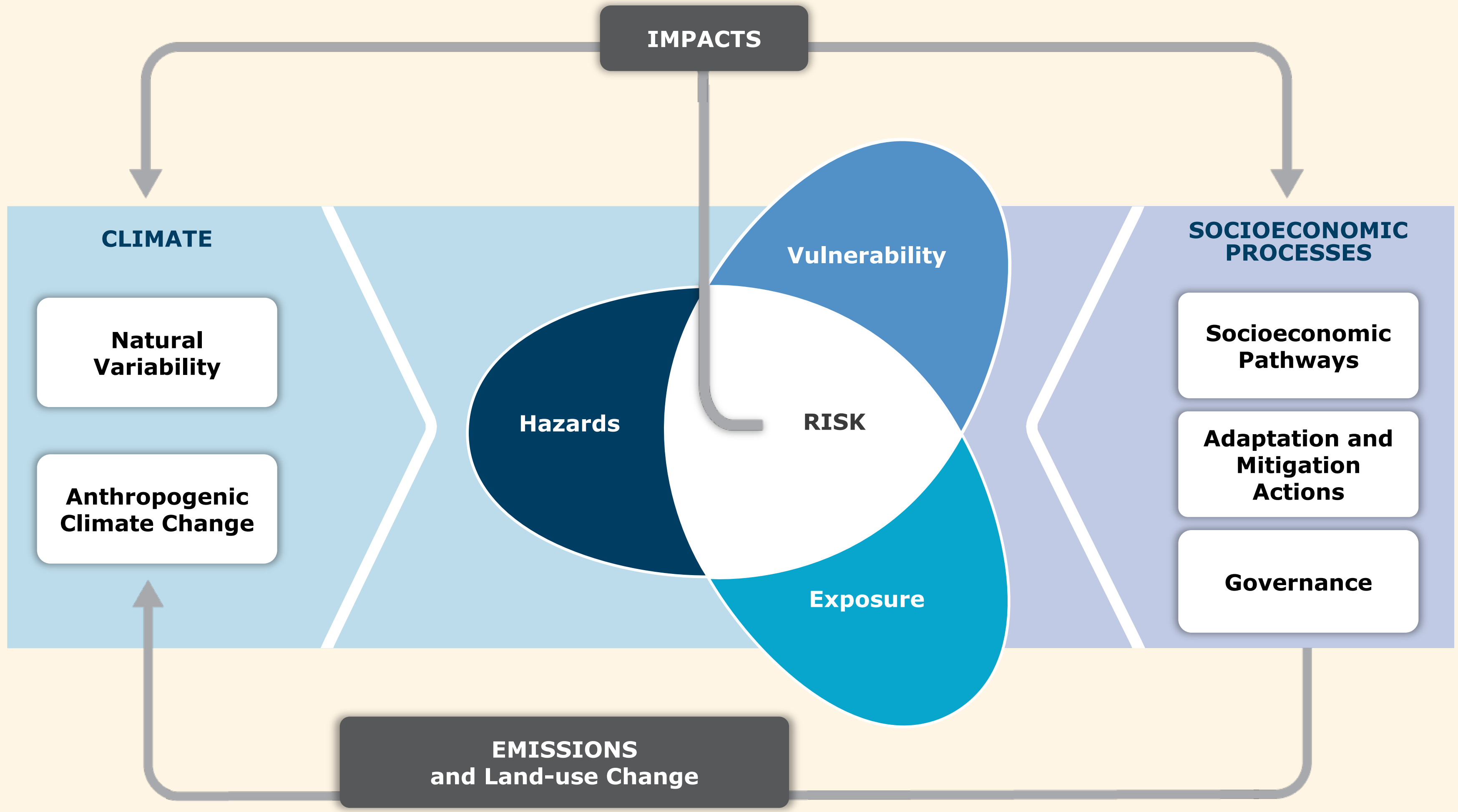


IPCC (SR1.5C, 2018): Risk definition

Risk:

- **The potential for adverse consequences from a climate-related hazard for human and natural systems, resulting from the interactions between hazard and the vulnerability and exposure of the affected system.**
- **Risk integrates the likelihood of exposure to a hazard and the magnitude of its impact.**
- **Risk also can describe the potential for adverse consequences of adaptation or mitigation responses to climate change.**

IPCC AR5 WG2 (2014): Climate Change Risks



Risk analysis – weighing - acceptance

1) Risk analysis: technical task

- Proper studies require mastering of …
  - space & time
  - uncertainty, ignorance
  - (ir)reversibility
  - plurality, conditionality

- Many studies: myopia, bias
  - Studying fictituous situations
  - Focus (exclusively) on human morbidity/mortality
  - Dependent on worldviews, assumptions, preferences
  - Over-reliance on aggregates/averages

2) Risk weighing is a personal matter

3) Risk acceptance is a societal process

Societal aggregation of risks

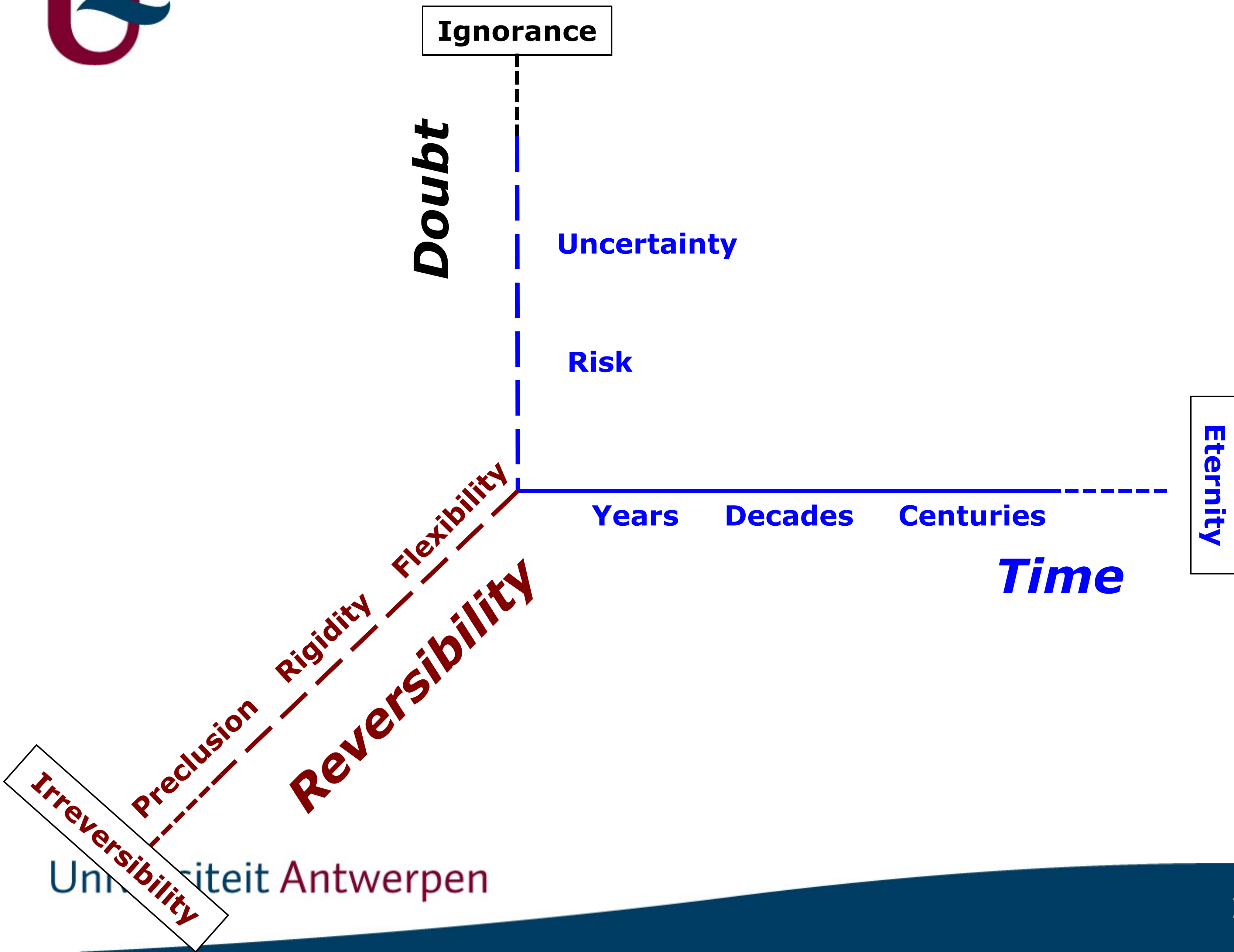
1. Normative, top-down approach via
PRECAUTIONARY PRINCIPLE

- **Particular activities are precluded, reduced, because of incomprehensibility of issues, consequences, …**
- **Sustainability assessments provide necessary information in practical cases**
- **Beware of abuse: covering-up NIMBY ⇔ principle only valid when comprehensively applied on full-size problems**

2. *Positive, bottom-up via*
INSURANCES

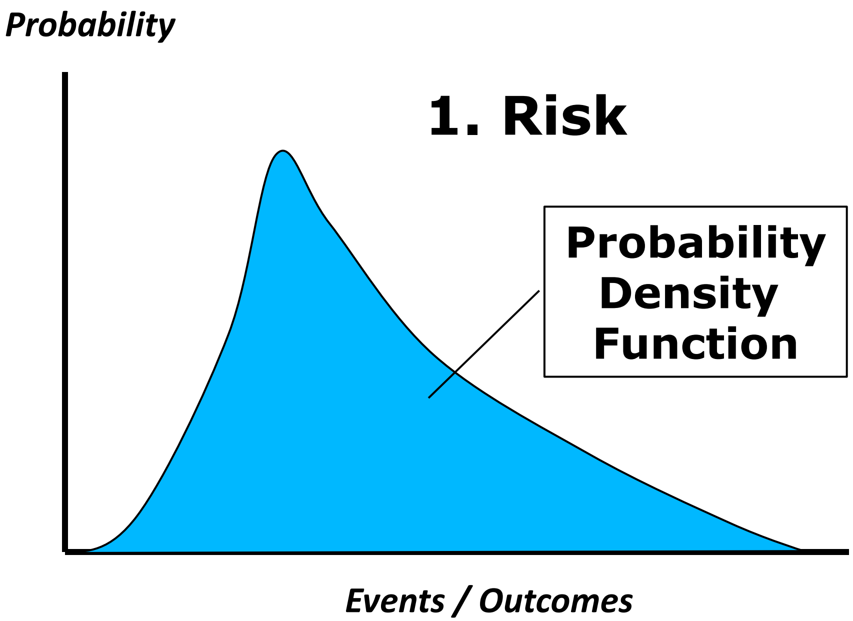
- **Principle of 'insurance premium':**
  > Now pay a premium for later compensation of probable costs
  > Now forgo benefits from hazardous activities, for precluding probable high future costs
- **Specialized companies up to global re-insurers manage risk portfolios**
- **Voluntary or Obligatory insurance? Obligatory when one's activity may cause (irreversible) huge damage to (many) others**

Comprehensive Decision context



Context DOUBT: 3 degrees

1. Risk



2. Uncertainty

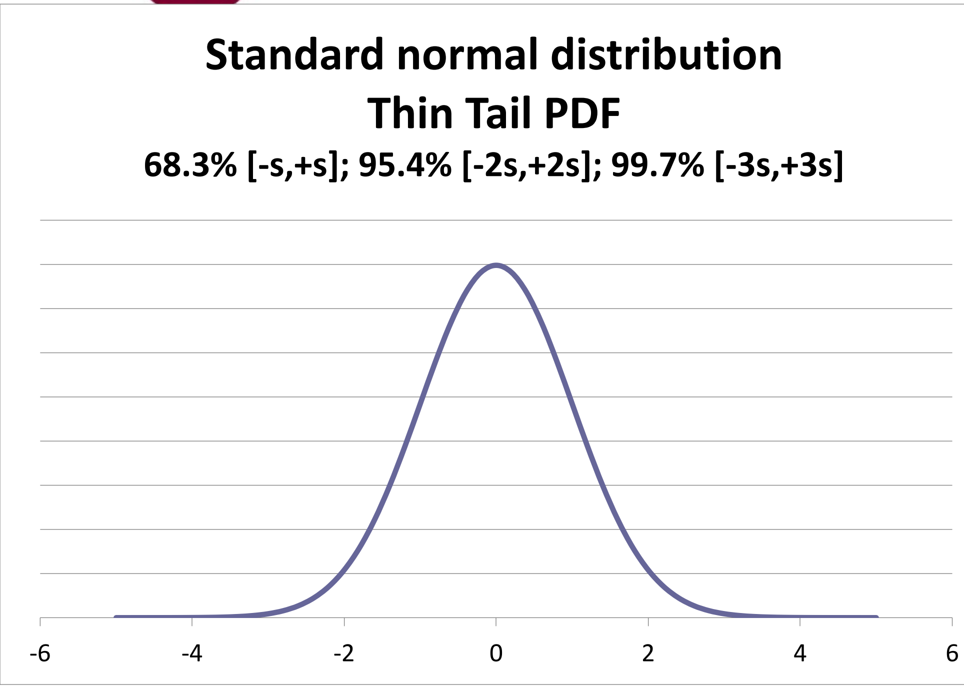
Unknown Probabilities

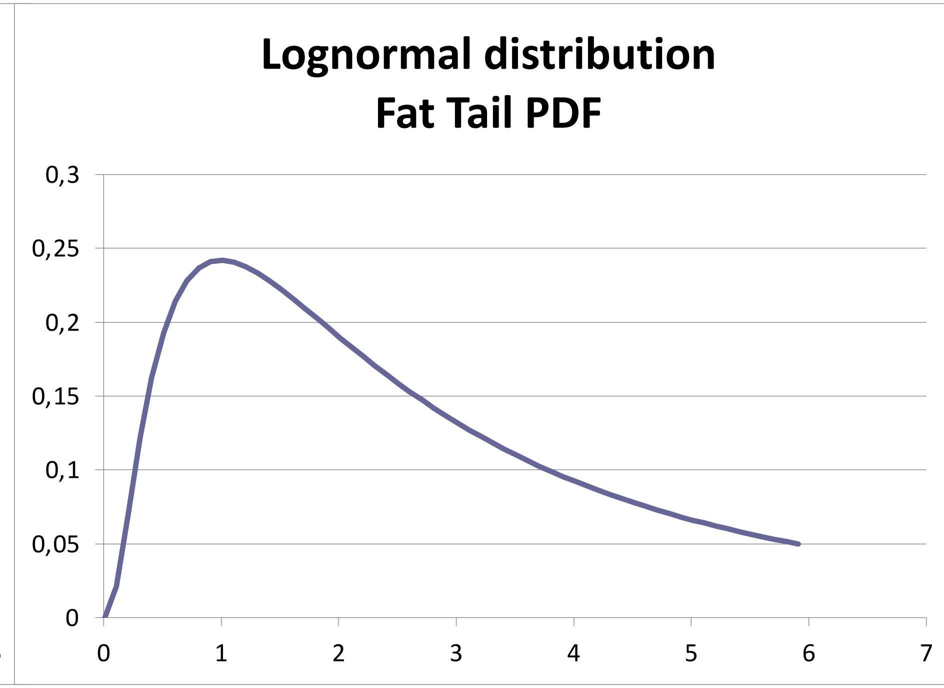
Ambiguous events / outcomes

3. Ignorance

Known Unknowns
Unknown Unknowns

Probability Density Functions (PDF)





Cost-Benefit Analysis of Integrated Assessment Models

Truncate PDF or finite discrete-point PDF = Exclude extreme events

Weitzman (2009) develops "Fat-Tailed Logic" = combination of

- **PDFs with non-negligible tail probabilities (e.g., lognormal PDF)**
- **Disutility-damage of high temperatures: assumed cubic form**
- **Discount rate low (close to zero)**
- **Recognize elevated GHG stocks + inertia + irreversible climate changes**

Very large present discounted damages + correct policy to avoid fat tails

Uncertainty Matrix (Stirling, 2010)

Knowledge about possibilities

Knowledge about probabilities	Unproblematic	Problematic
Unproblematic	**Risk**	**Ambiguity**
Problematic	**Uncertainty**	**Ignorance**

Possibilities encompass
Events / Alternatives

Levels of doubt

Risk

- **Possible outcomes can be assessed**
- **Probabilities linked to outcomes also assessed**
- **Conditional decision-making methods applicable**

Uncertainty

- **Outcomes assumed known; ambiguity may exist**
- **Probabilities mostly subjective**
- **Participative deliberation for proper scope & diversity**

Ignorance (Stirling, 2010)

- **Known Unknowns / Unknown Unknowns**
- **Monitoring & Surveillance**
- **Reversibility of effects**
- **Flexibility of commitments**
- **Adaptability, resilience**
- **Robustness, diversity**

Apply more plural and conditional methods for science advice

Reversibility

Defining reversibility

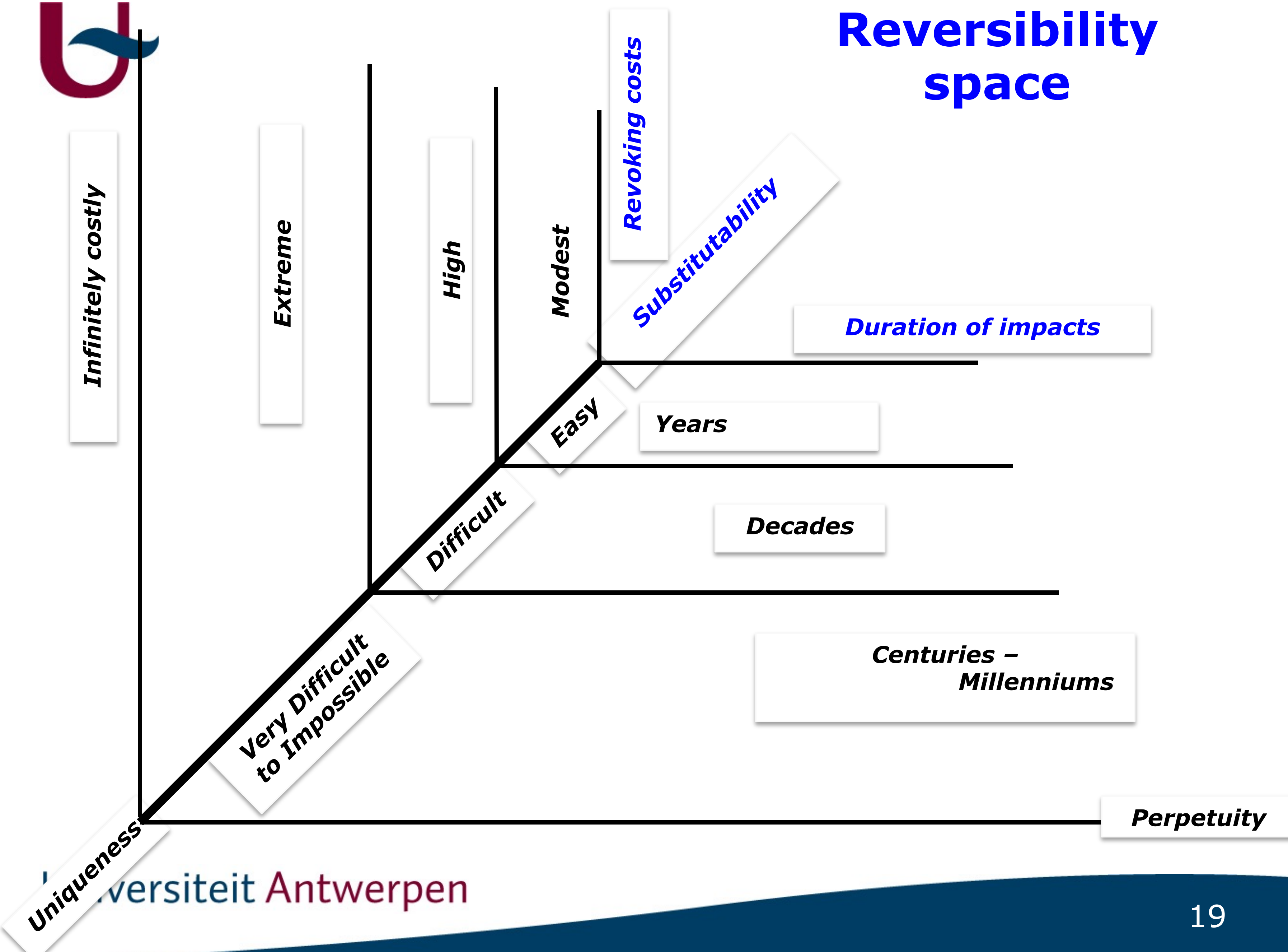
- **Scientific definition, generally adopted is lacking**
- **Literal deductions (such as 'possibility to return to a previous or initial state') trivialize the concept**
  - **Return in time is never feasible**
  - **The 'state' of something (subject, object, system, person) is characterized by its 'identity' / 'functionality'**

Proposed definition

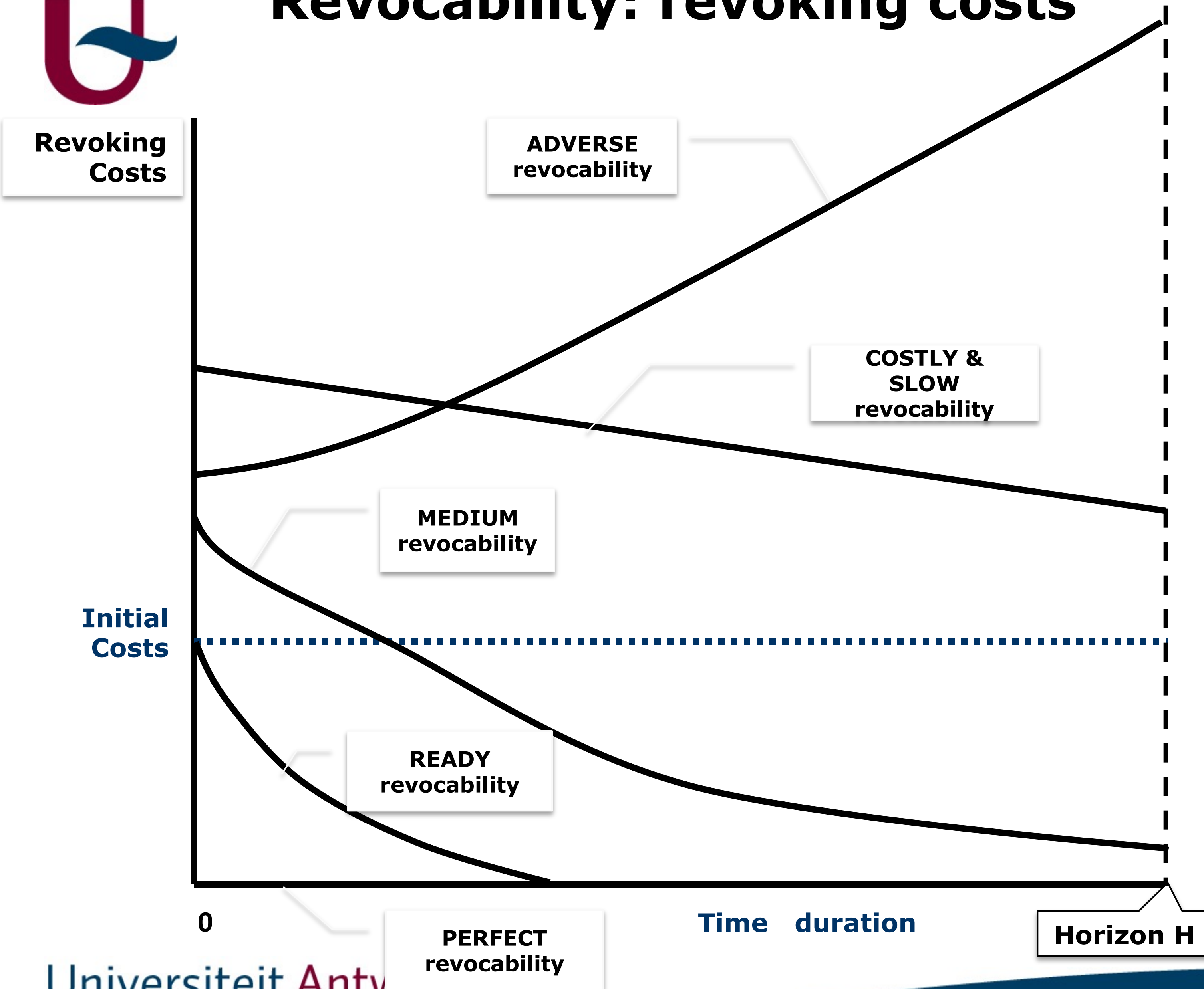
- **Reversibility is the ability to maintain and to restore the functional performance of a system *(= interconnected set of elements coherently organized in a way that achieves something)***
  - **Ability: qualified by 'at affordable costs within a reasonable time'**
  - **Maintain and restore (⇔ revert) ≈ resilience**
  - **Functional performance ⇔ identity**

Hence: 'irreversibility' when the functional performance of a unique identity breaks down

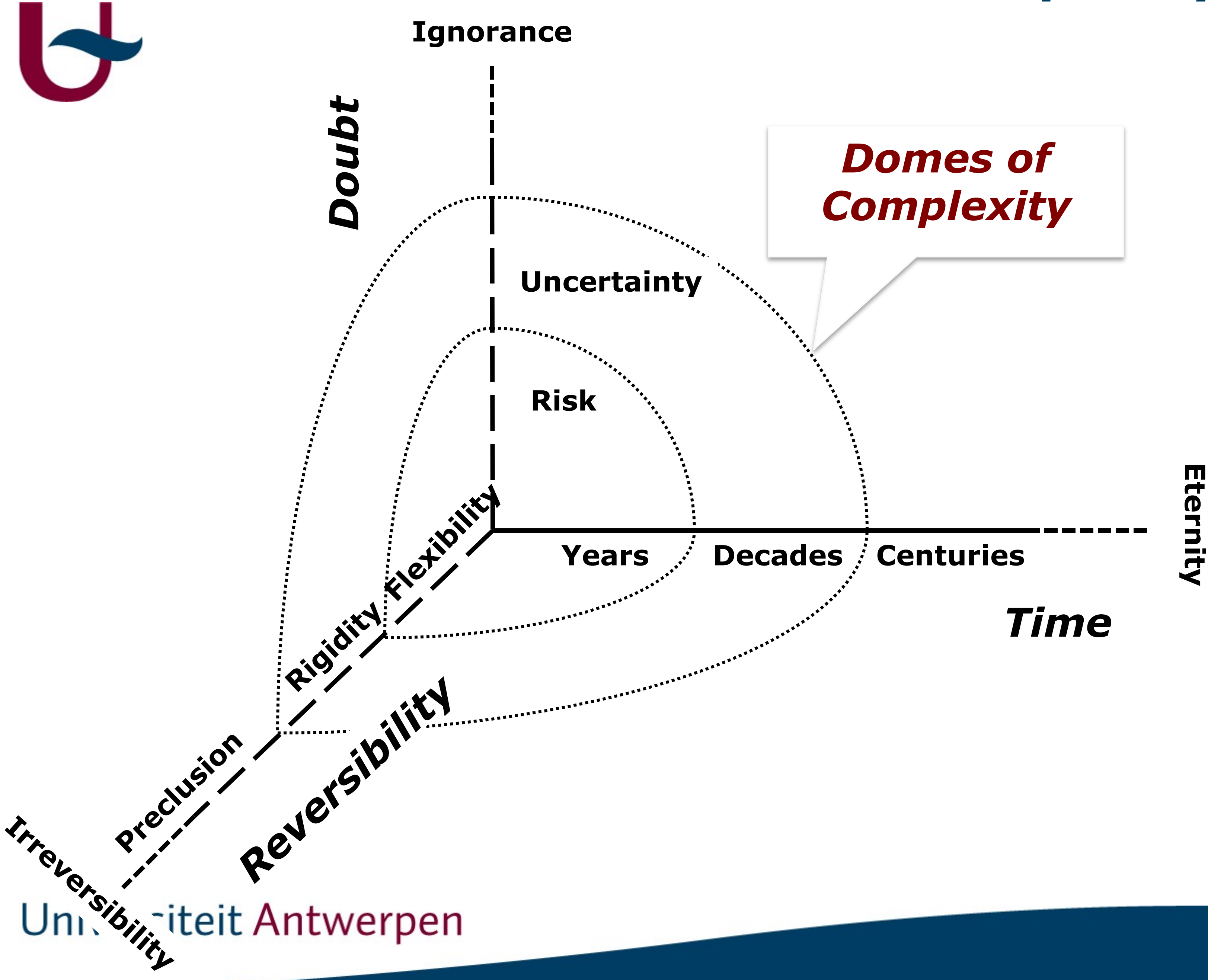
Reversibility space



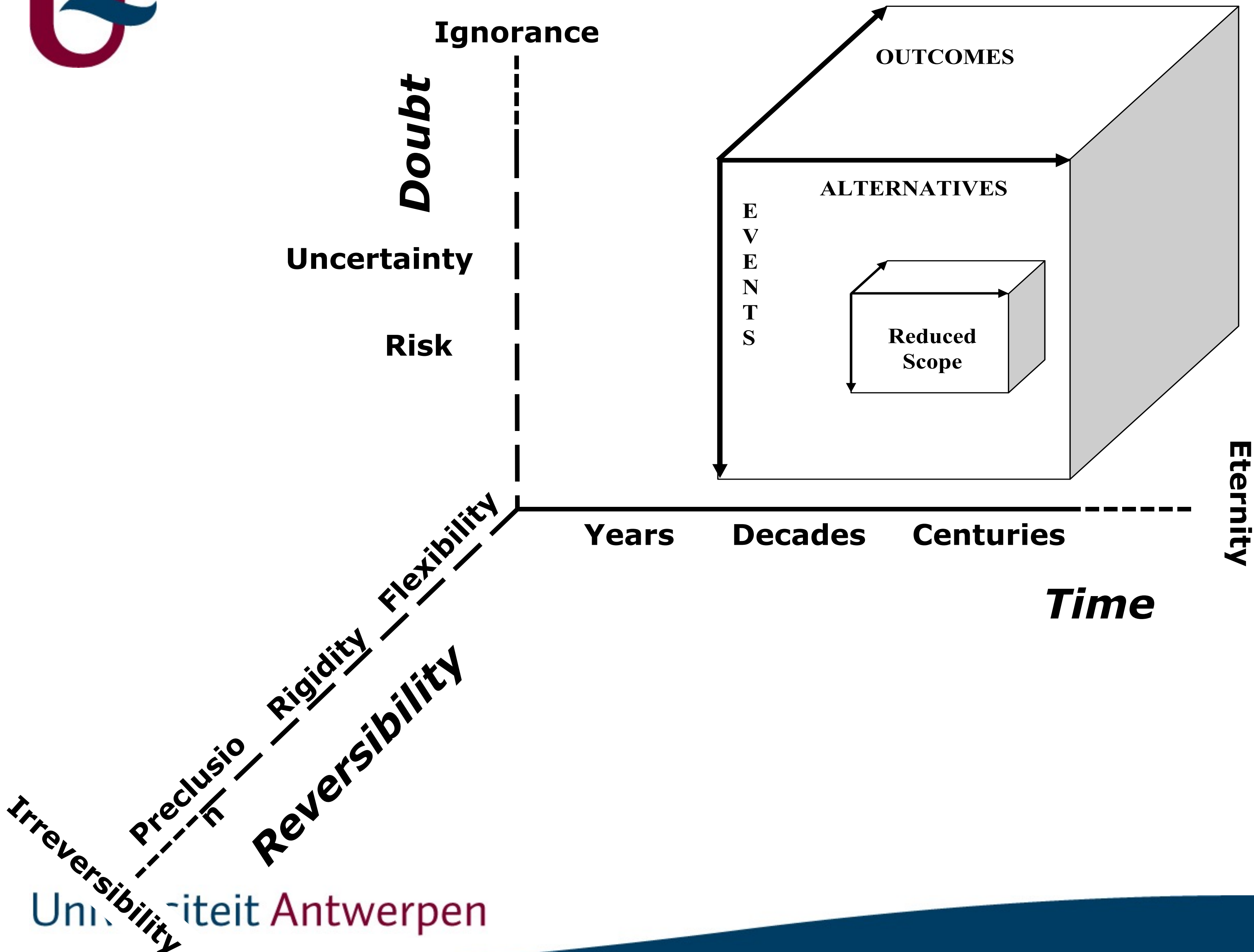
Revocability: revoking costs



Context complexity



Decision object-cube in decision context



Applied Approaches

- **Risk Analysis by probability calculus**
- **Good decision = based on rational use of all information available ≠ good outcome (partly decided by fortune)**

- **Analytical schemes**
  - **Static analysis**
    - **Filling the decision matrices**
    - **First hand and problems of limited scope and horizon**
  - **Dynamic, time-sequential analysis**
    - **Tedious, only for important, intricate decisions**
    - **'Wait and Learn' ⇔ 'Choose or Lose' situations**

- **Precautionary approach: humans accept limits and abstain from particular paths, choices**
  - **Ignorance omnipresent**
  - **Time horizons beyond imagination**
  - **Irreversibility looming**

Static approach: (opportunity) loss tables

		Alternatives			
Events	Probabilities	***A1***	***A2***	**…**	***Am***
G1	P1	V1,1	V1,2	…	V1,m
G2	P2	V2,1	V2,2	…	V2,m
…	…	…	…	…	…
Gk	Pk	Vk,1	Vk,2	…	Vk,m
Criterion					
MiniMax	Minimum of	Max.{Vi,1}	Max.{Vi,2}	…	Max.{Vi,m}
Expected value	Minimum of	Σ Pi x Vi,1	Σ Pi x Vi,2		Σ Pi x Vi,m

Legend

- **Not under control: k Events Gi with related Probabilities Pi**
- **Under control: m Alternatives (actions, strategies) Aj**
- **Outcomes of Event . Alternative combinations : k.m Values (+/-) Vi,j**
- **Decision criteria: MiniMax (of negative Values, e.g. # deaths); Expected Value**

Dynamic approach: case study data

Decision about the conversion of 100ha nature land in industrial area. In a two-period frame, one decides about the conversion shares in two phases S_1, S_2 and $S_1 + S_2 \leq 1$. Conversion of nature to industry is poorly revocable, or S_1 stands through future phases.

DATA:

Assessed probabilities and outcomes for 100% conversion

Period 1 (now): decide on S_1 where $0 \leq S_1 \leq 1$

- **Convert 100%: + 100 M€ certain economic value in period 1**
- **Wait: 0 €**

Period 2 (future): decide on S_2 where $S_2 \leq 1 - S_1$

- **Positive value of 100% conversion: + 300 M€ with P= 0.6**
- **Negative value of 100% conversion: - 400 M€ with P= 0.4**

Dynamic approach: case study analysis

Standard approach:

- **Calculate expected value in phase 2 of 100% conversion:**

(0.6).(300 M€) + (0.4).(-400 M€)=

180 M€ - 160 M€ =

+20 M€

- **Add the 'certain' economic value of +100 M€ in phase 1**

= total expected benefit +120 M€

RECOMMENDATION: convert 100% in first period

HOWEVER: Is the standard scenario approach right?

NO! because not using all available information

Dynamic approach: 'Wait & Learn' case

Phase 1 decision determines options open in period 2

Phase 2 reveals either the bad (-400 M€) or the good case (+300 M€) becoming real

- **In the bad case, S is as small as possible, however S_1 stands**
- **In the good case, S is maximized to 1, with $S_2 = 1 - S_1$.**
- **The benefit function to maximize:**

  (+100 M€){S1} + (0.4).(-400 M€){S1} + (0.6).(+300 M€){1}

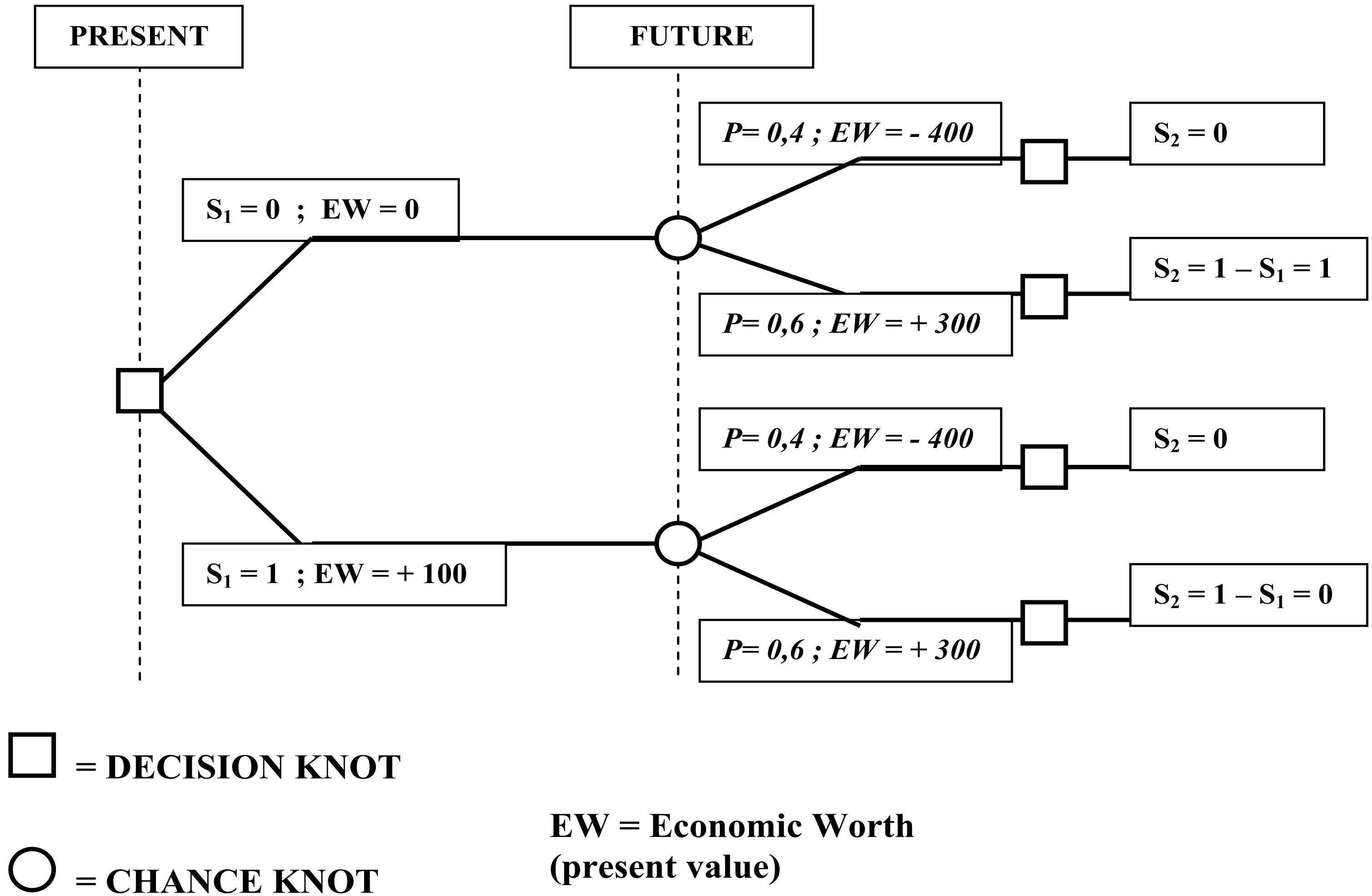
  = [+100 M€ + (0.4).(-400 M€)]{S1} + 180 M€

  = [-60 M€]{S1} + 180 M€

The benefit is maximum if $S_1 = 0$

Conversion is postponed in period 1, to keep the choice option open for period 2.
Uncertainty + Irrevocability are properly processed in this 'Wait & Learn' case

Dynamic Approach: decision tree



EW = Economic Worth (present value)

Irrevocable Decisions 'Choose or Lose'
Energy Performance Endowment of Buildings

Based on:

Verbruggen, A., 2012. Financial Appraisal of Efficiency Investments: Why the good may be the worst enemy of the best. Energy Efficiency 5, 571-582

Buildings Directive 2010/31/EU

Art.4 § 1: Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels

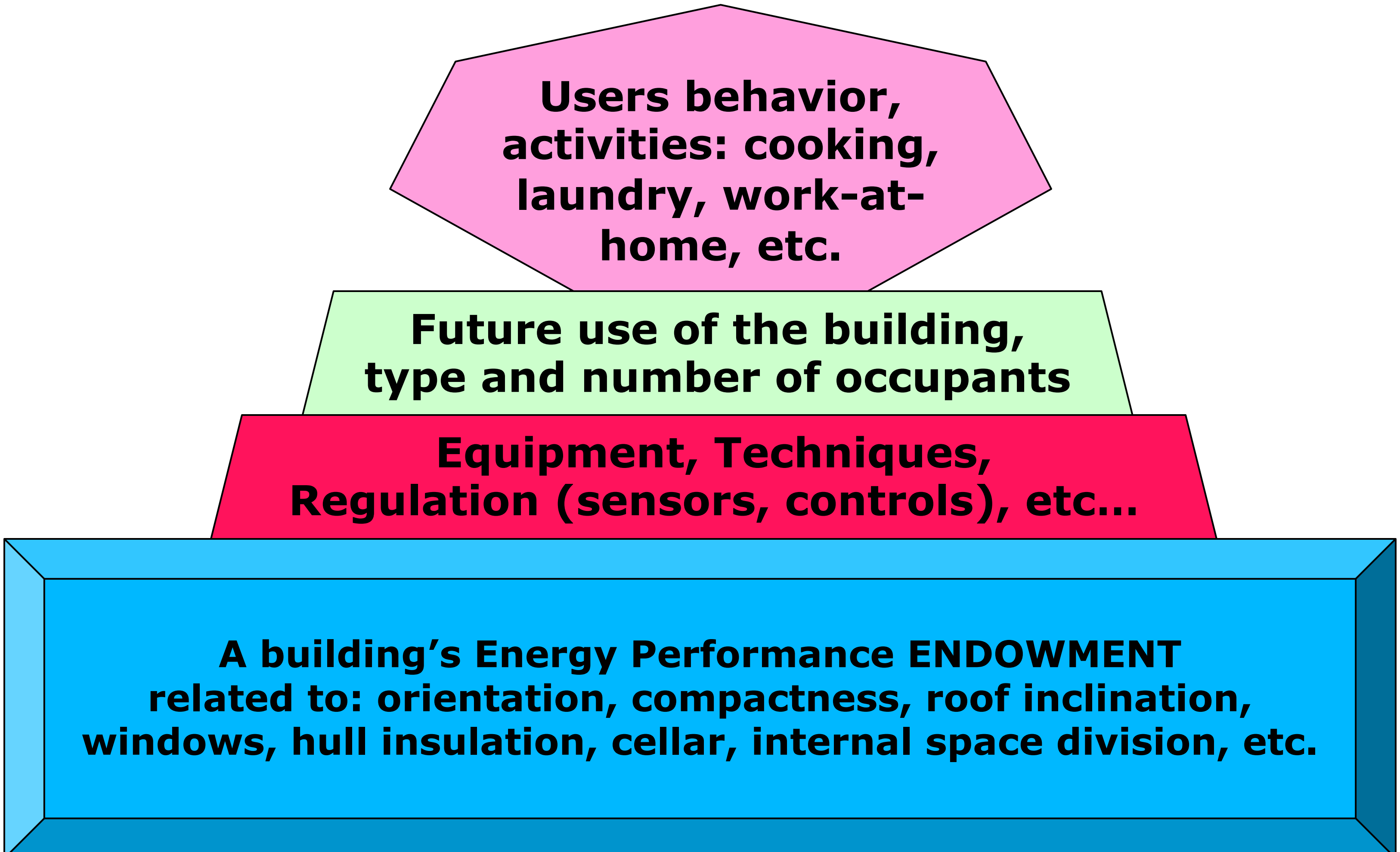
Art.2 § 14: cost-optimal = lowest cost during the estimated lifecycle

Art.5 : Announced framework for 'Calculation of cost-optimal levels of minimum energy performance requirements'

'COST-OPTIMAL ENERGY PERFORMANCE' is CRUCIAL

But UNANSWERED by EU

Factors influencing building energy use



Deciding on building constructions

Constructing a building is a definite commitment of resources, implying irrevocability

- **Revocability of investment depends on revoking costs**
- **Distinguish Physical / Financial revocability**

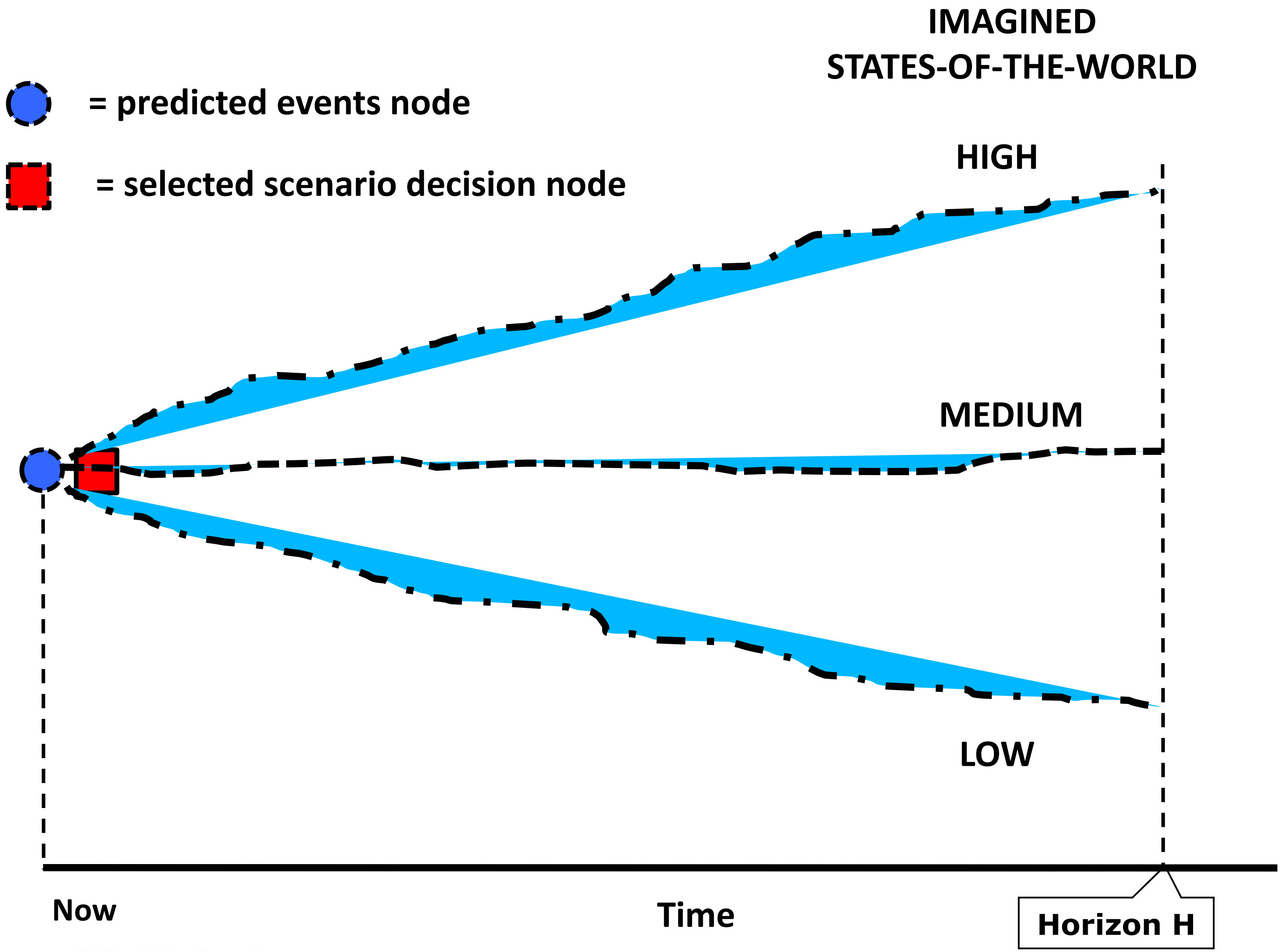
A building investment:

- **Physical revocability is costly**
- **Financial revocable if liquid sales/renting markets exist**

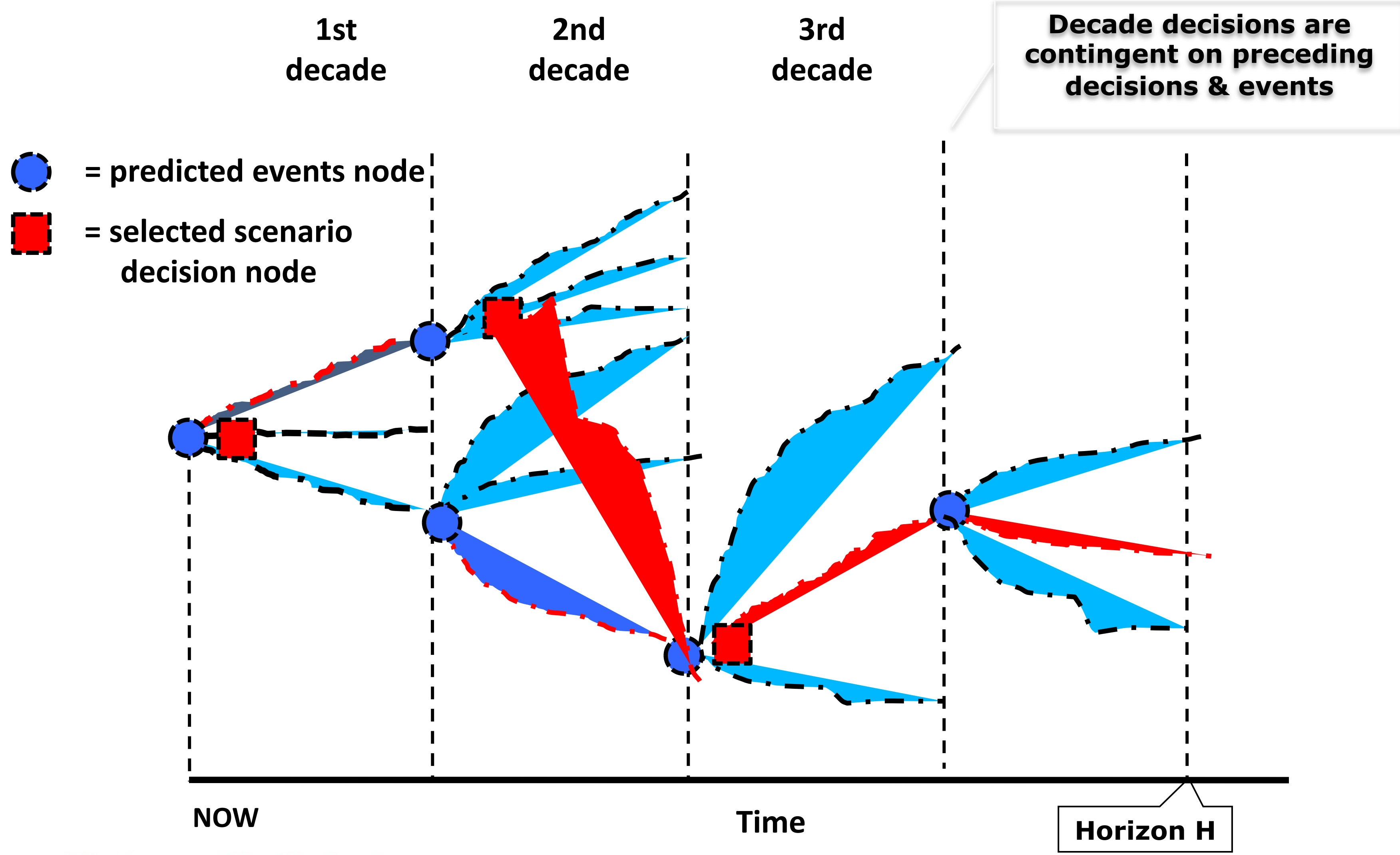
Energy Performance Endowment (EPE)
not separable of physical construction, i.e. costly revocable

Many drivers trigger constructions' timing & features
Energy performance is a secondary, weak driver

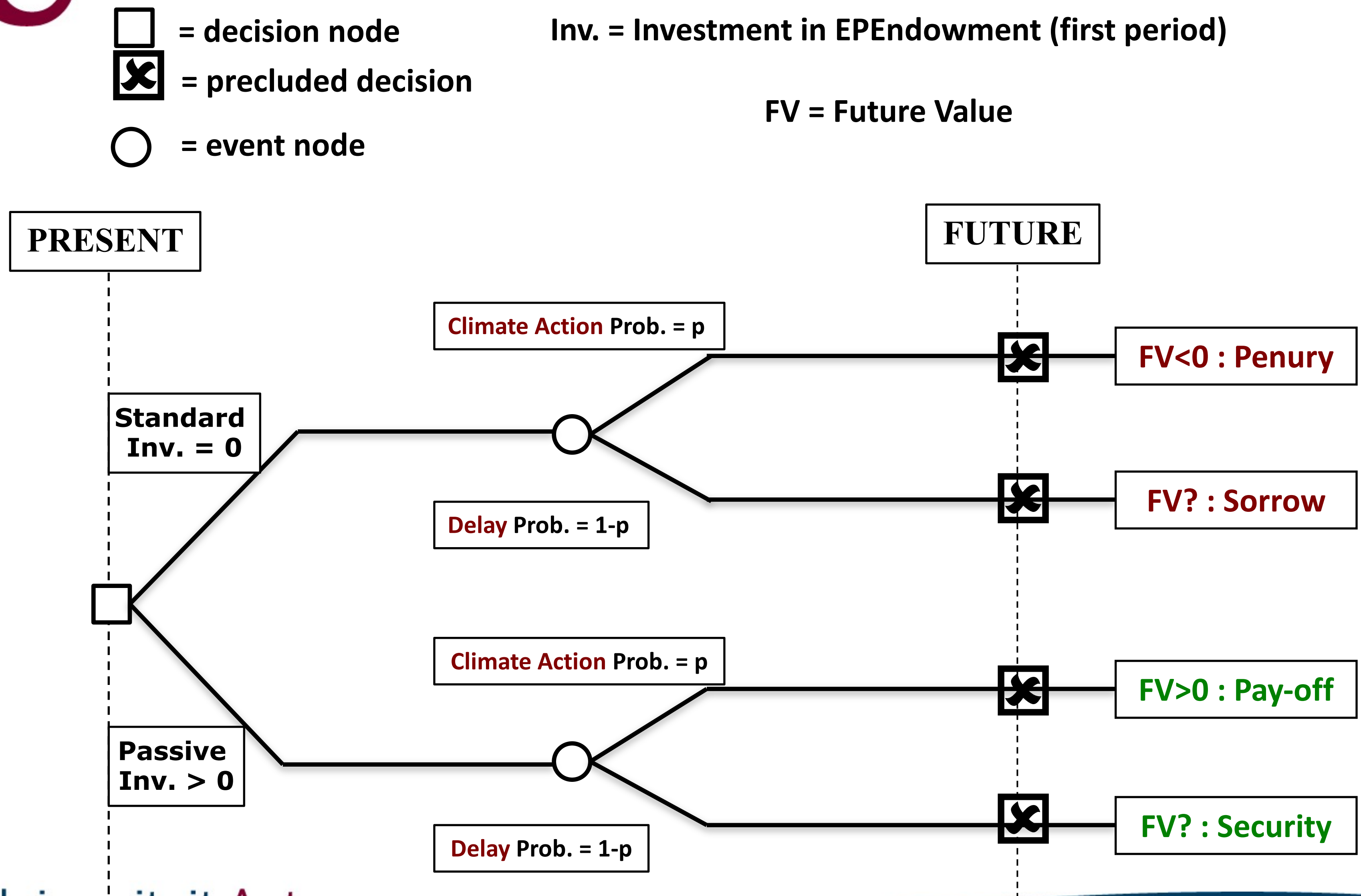
Predicting the future by SCENARIOS



Exploring the future SEQUENTIALLY



Sequential decision-making: CHOOSE or LOSE
Example CLIMATE ACTION versus DELAY



Conclusion on Building Investment

- **Cost-optimal: crucial concept in Buildings Directive, but not developed – unclear**
- **Life-cycle appraisal: static, expected value method;**
  - **finds averages, not the optimal frontiers**
- **Energy Performance Endowment: not or costly revocable**
  - ✓ **Appraisal requires right scientific methods**
- **Recommendations**
  - ✓ **Identify & weigh all benefits of sustainable buildings**
  - ✓ **Avoid preclusion of necessary future solutions**
  - ✓ **The good may be the worst enemy of the best**
  - ✓ **The borderline (envelope)> middle-of-the-river quagmire**
  - ✓ **Choose now the best passive^{+++} or Lose**

Who wants to be a loser?

Conclusions on Cost-Benefit Analysis (CBA)

CBA is the most applied approach in policy.
However, but do-able in non-complex context domes :

- **Doubt limited to risk (+ some subjective probabilities)**
- **Reversibility in the flexibility range (+ some rigidity)**
- **Time within an individual professional life-span (max. 50 years)**

Beyond the inner complexity dome, CBA becomes fuzzy

Beyond the second dome, CBA is counter-productive

Other decision mechanisms are needed, with e.g.

- **Foresight studies**
- **Democratic deliberation**
- **Multiple, diverse, revocable initiatives, enhancing resilience**

CBA studies are often manipulated and subject of stalemating

For example: Stern Review (2006), heavily criticized by W. Nordhaus (Economics Nobel Prize, 2018) because of applied discount rate