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Climate Change Adaptation and Decision Making Support

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Thought Experiment: Which would you rather have, (a) or (b)?

Choice a		Choice b
1a. A gift of 100 DKK	or	1b. A 25% chance to win 500 DKK
2a. A loss of 100 DKK	or	2b. A 75% chance at losing 500 DKK
3a. A gift of 30 DKK	or	3b. 1 in 10,000 chance to win 250,000 DKK
4a. A loss of 30 DKK	or	4b. 1 in 10,000 chance at losing 250,000 DKK
5a. A gain of 100 DKK now	or	5b. A gain of 100 DKK 100 years in the future
6a. A loss of 100 DKK now	or	6b. 10% chance at losing 1000 DKK 100 years in the future
7a. A gain of 1 mil DKK now	or	7b. A gain of 5 mil DKK over the next 100 years
8a. A loss of 1 mil DKK now	or	8b. 1 in 1000 chance to lose 5 billion DKK over the next 100 years

Climate Change Adaptation and Decision Making Support

The Case of Urban flooding

Jay Gregg, Nov 7, 2012

DTU

Outline

1. Adaptation in Context
2. Risk Assessment & Impact Analysis
3. Example: Århus
4. Group Work
5. Economic Assessment of Adaptation
6. Decision Making
7. Group Work

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1. Background- Adaptation in Context

Definitions (IPCC)

- Vulnerability- The propensity or predisposition to be adversely affected.

- Exposure- The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected.

- Resilience- The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

- Adaptive Capacity- the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies.

Impacts

Climate Change Responses

- Mitigation
  - An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC TAR 2001)
  - Actions to reduce the effects of climate change
  - e.g., carbon price, afforestation, etc.
- Adaptation
  - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC TAR 2001)
  - Actions to tolerate the effects of climate change
  - e.g., sea walls, improve storm sewer systems, etc.
- Others?
  - Geo-engineering?
  - Nothing

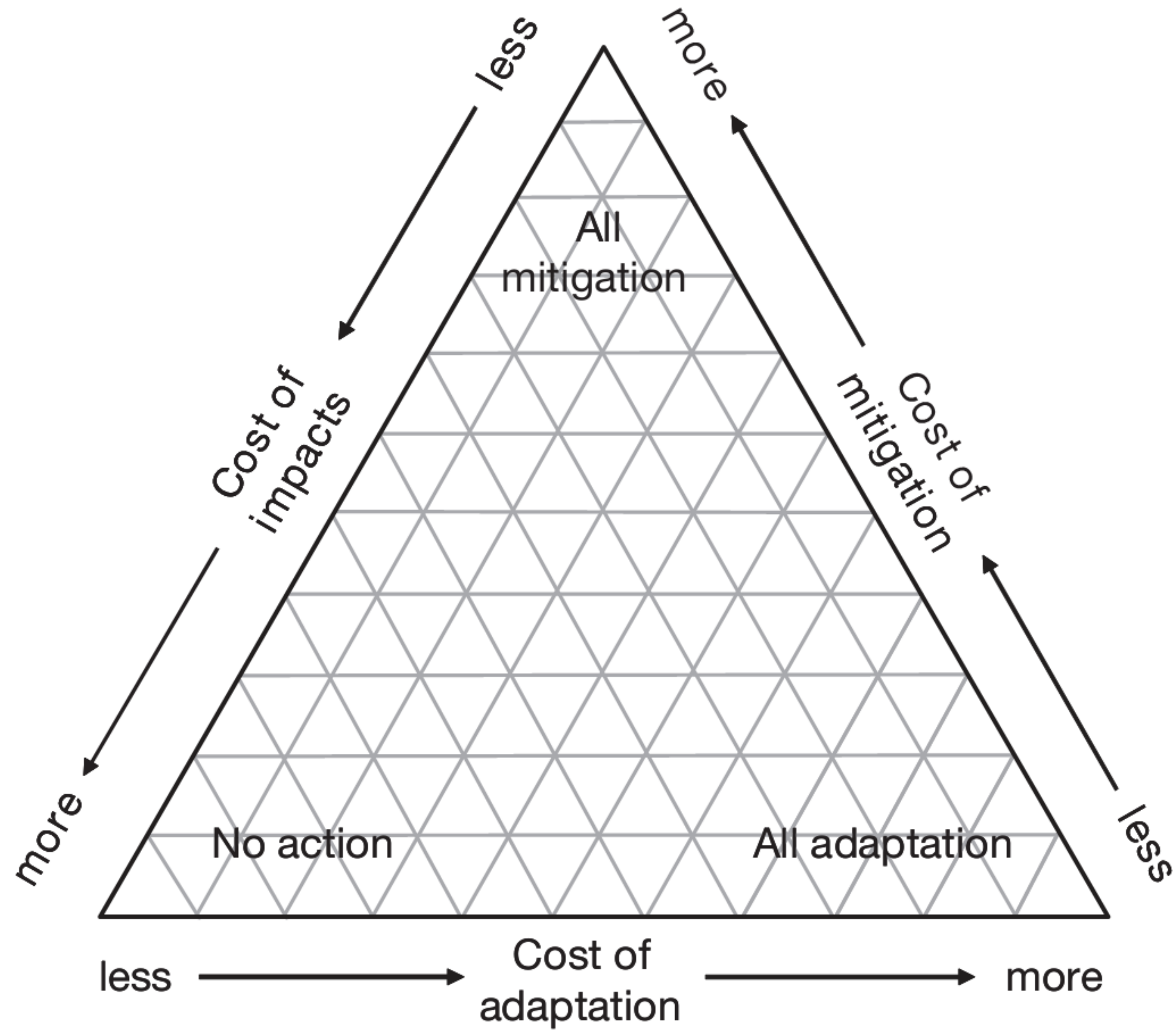
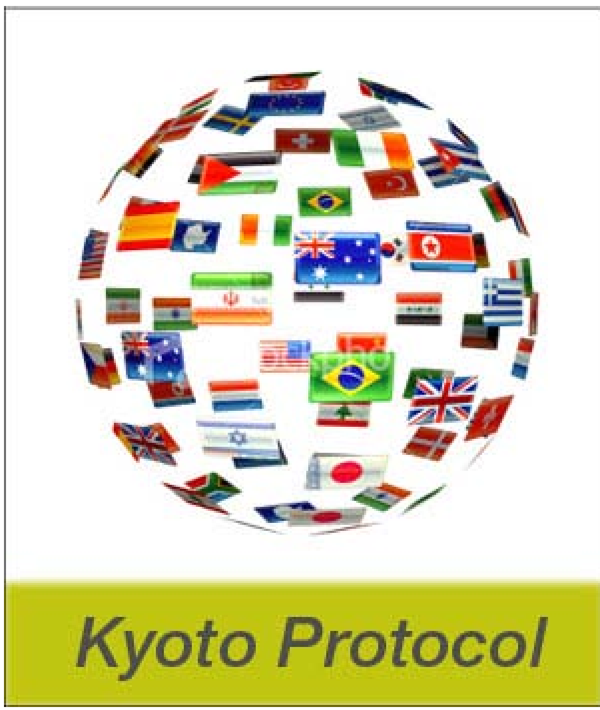


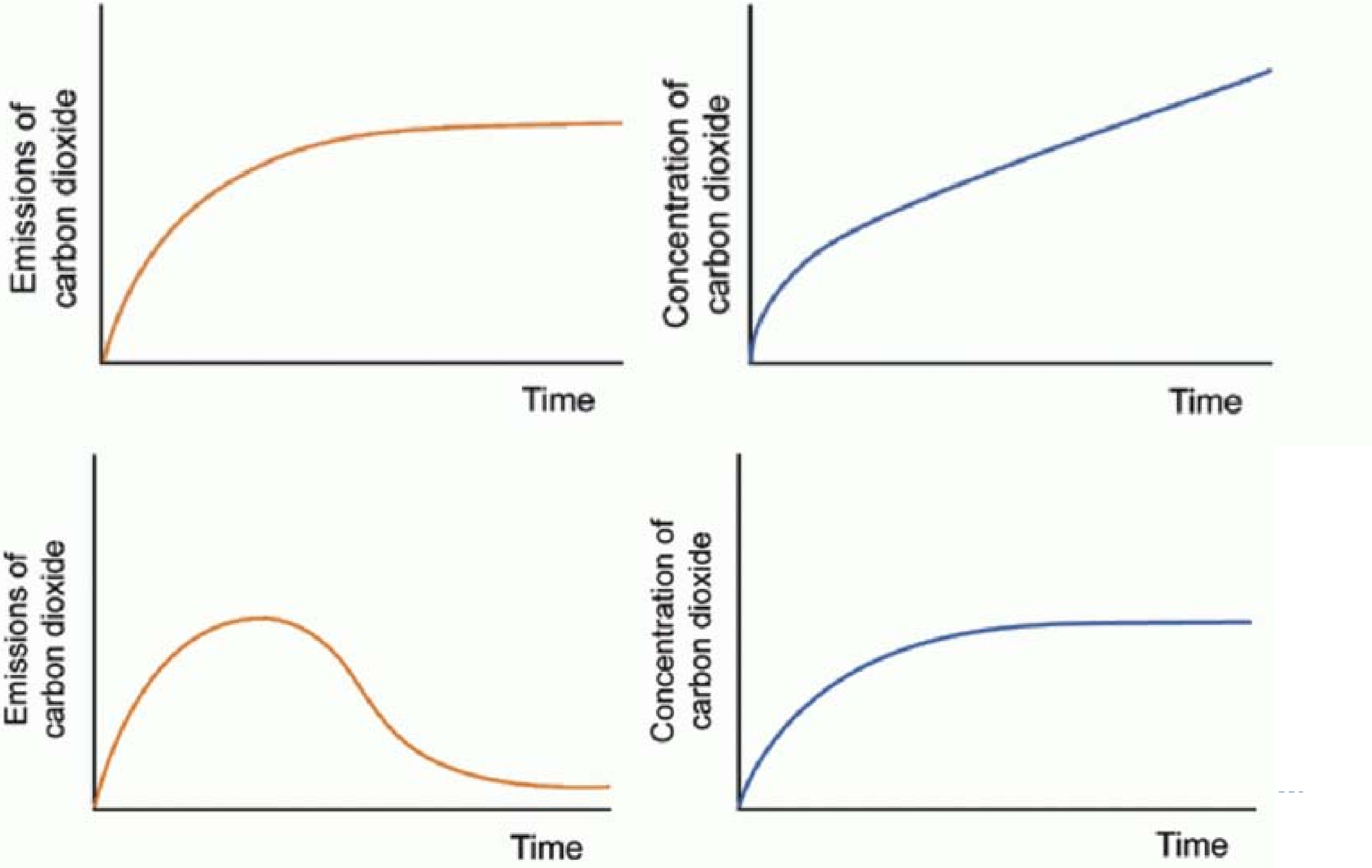
Figure 18.1. *A schematic overview of inter-relationships between adaptation, mitigation and impacts, based on Holdridge's life-zone classification scheme (Holdridge, 1947, 1967; M.L. Parry, personal communication).*

What about Mitigation?

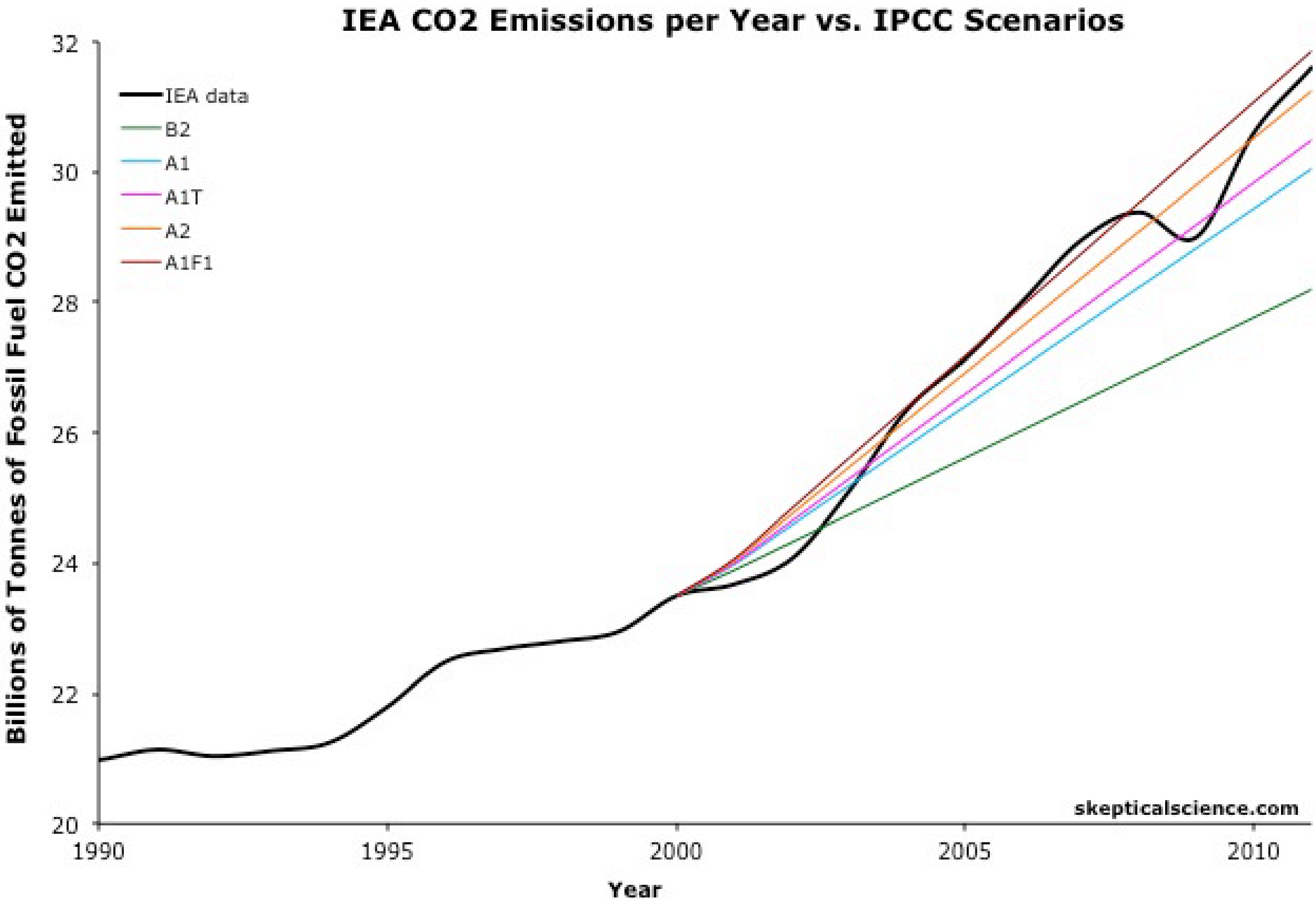
- Seek a global agreement to limit greenhouse gases
- E.g. Kyoto Protocol



The Challenge of Mitigation

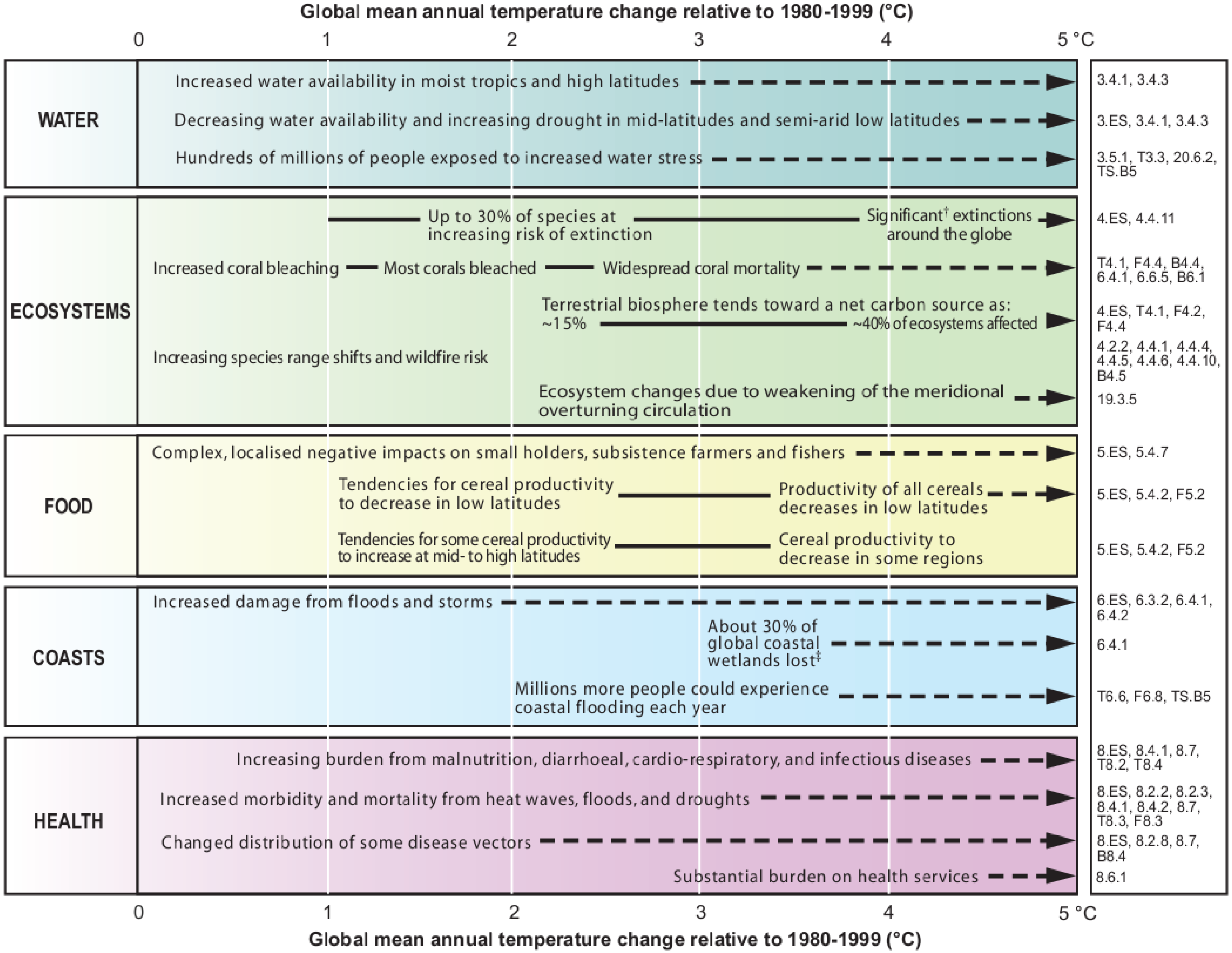


How are we doing?



Key impacts as a function of increasing global average temperature change

(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)



† Significant is defined here as more than 40%.

‡ Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.

Some adaptation is necessary…

- Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.

- Past emissions are estimated to involve some unavoidable warming (about a further 0.6°C by the end of the century relative to 1980-1999) even if atmospheric greenhouse gas concentrations remain at 2000 levels. There are some impacts for which adaptation is the only available and appropriate response.

  -IPCC AR4

More definitions

- anticipatory (or proactive) adaptation: before the impacts of climate change
- reactive adaptation: put in place after the impacts of climate change

- autonomous adaptation: an unconscious response to climatic stimuli, triggered by climate changes
- planned adaptation: resulting from political decisions, and based on an awareness of changing conditions and that actions are necessary to ensure well-being

- private adaptation: initiated by individuals, families or private companies
- public adaptation: initiated and instituted by government at all levels

Mitigation, Adaptation, and Scale

- Adaptation is an investment in private self-insurance to reduce the severity of realized damages. Mitigation is an investment in collective self-protection to reduce the odds that a bad state of nature is realized, and is the sum of all nations' efforts to reduce carbon emissions. Thus adaptation is mainly a private good in which the benefits of reduced severity accrue to one nation, whereas mitigation is a public risk-reduction strategy in which the benefits of reduced risk accrue to all nations. (Hanley et al. ,p 280)

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2. Risk & Impact Assessment

Risk

Risk =

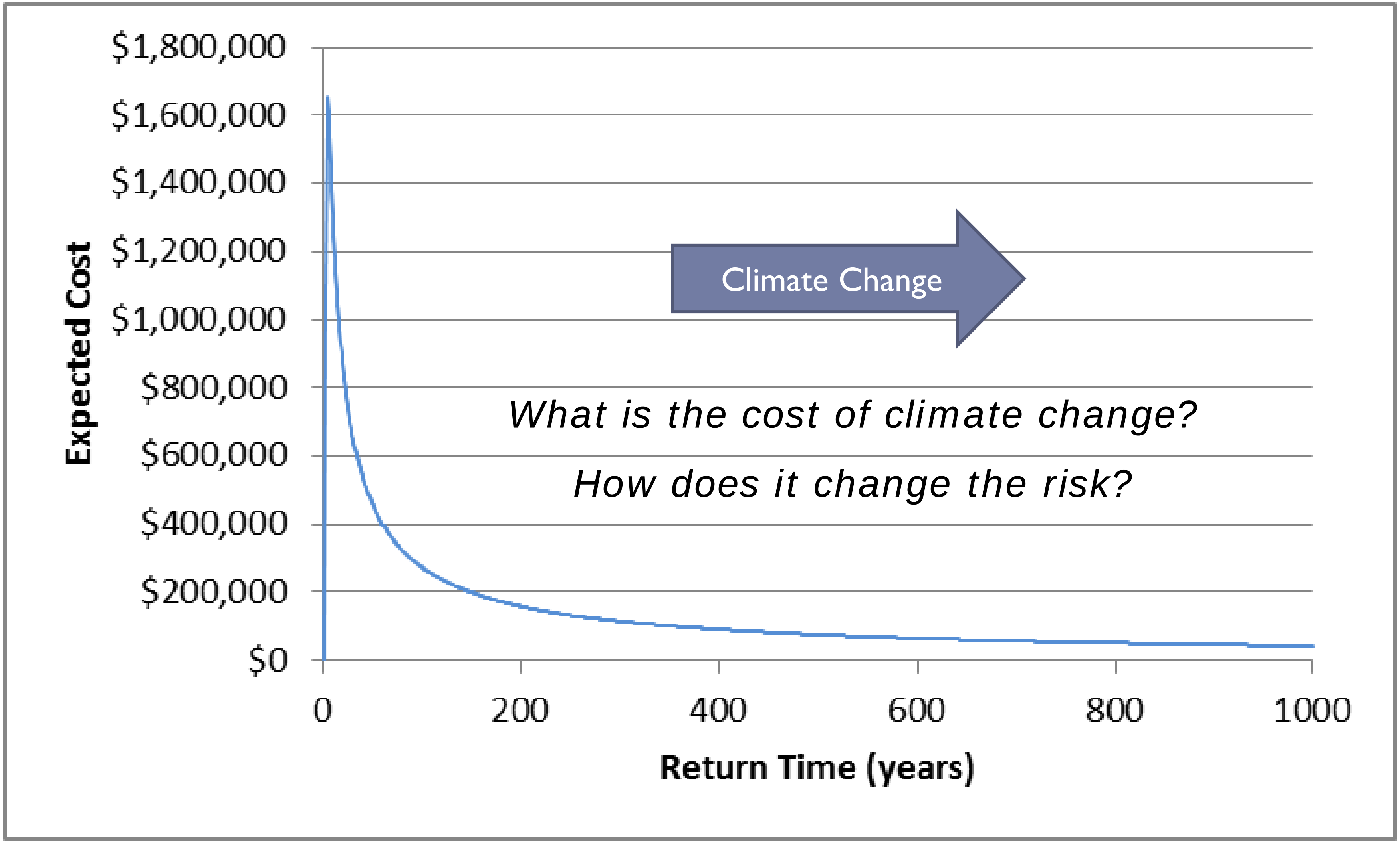
Probability of the impact

x

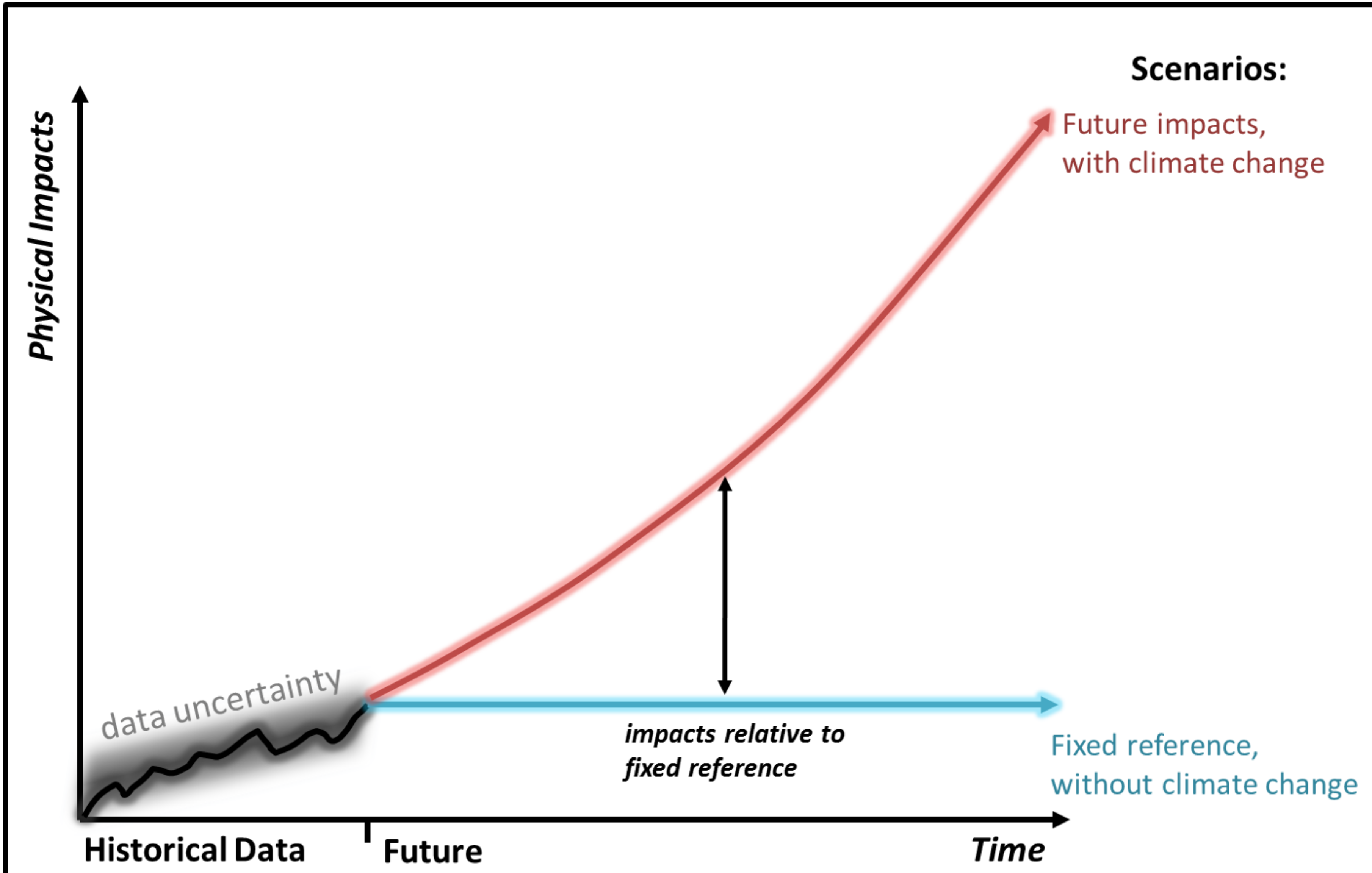
magnitude of the impact

The more severe storms have larger impacts, but they are also less common. As the climate changes, they are expected to become more frequent.

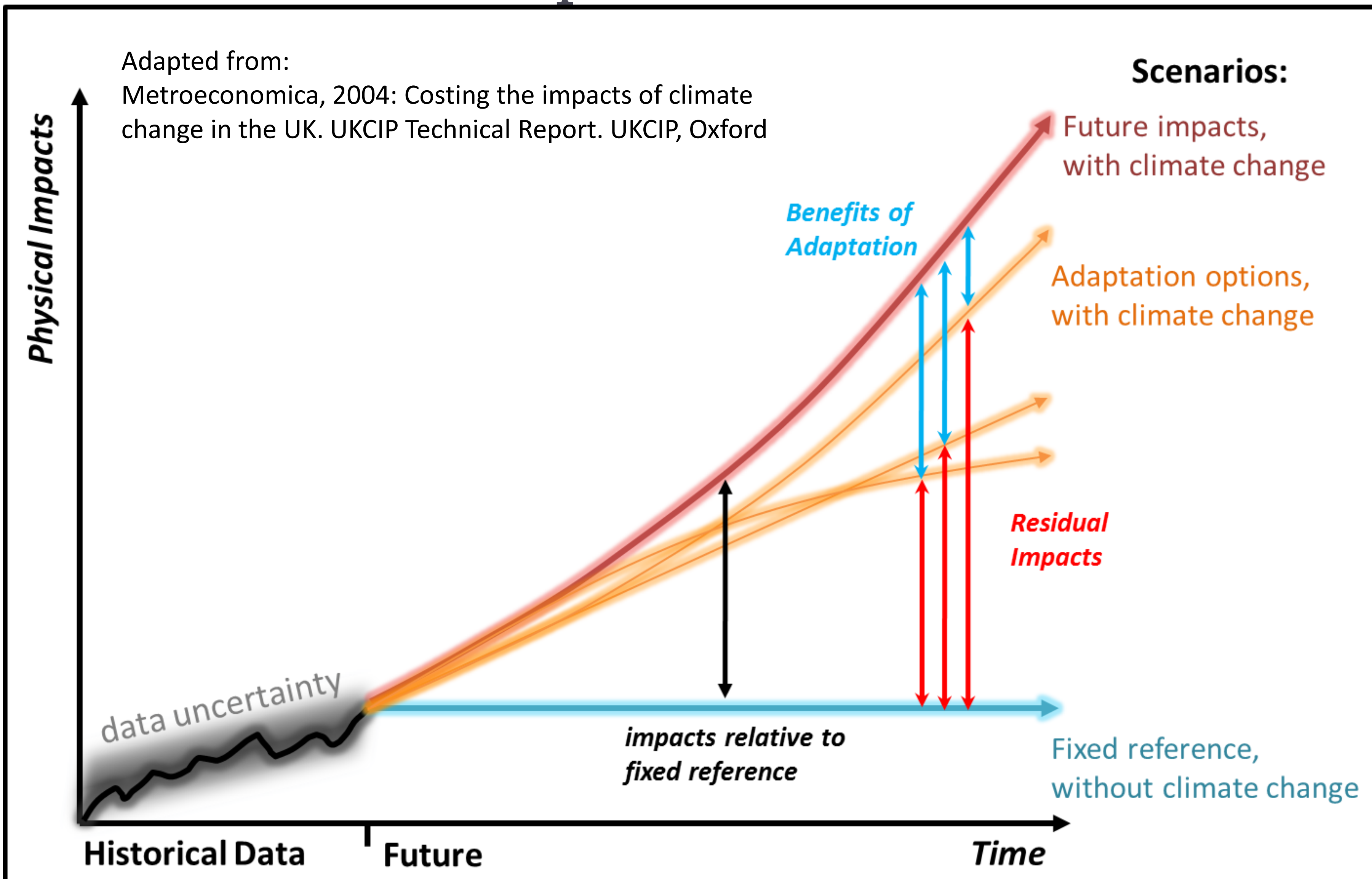
Risk Curve


Expected Cost
$1,800,000
$1,600,000
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
0
200
400
600
800
1000
Return Time (years)
Climate Change
What is the cost of climate change?
How does it change the risk?

Risk & Impact Assessment



”Benefits of Adaptation”



Impact Assessment

- ***Goals***:
  - identify impacted areas
  - highlight key uncertainties
  - inform decision makers on which adaptation options make sense

- Climate change can increase the probability of a number of different impacts

- How do we select the impacts of interest?

- How do we assess these?

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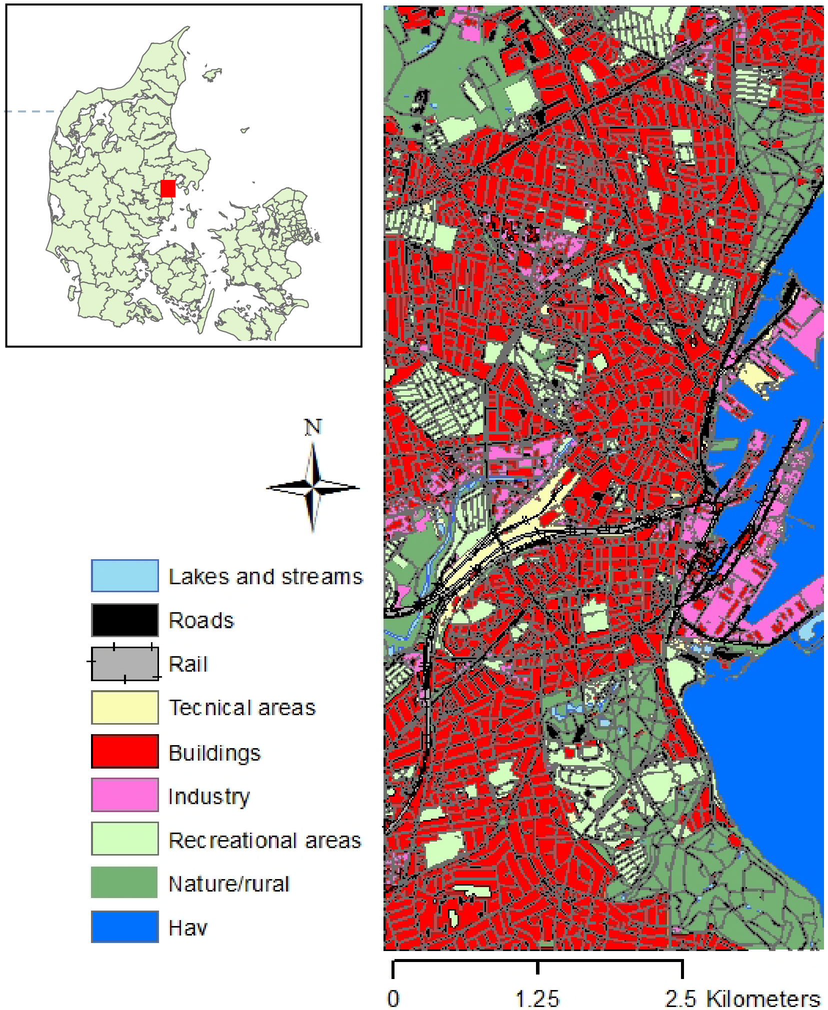
3. Example: Århus

Århus case

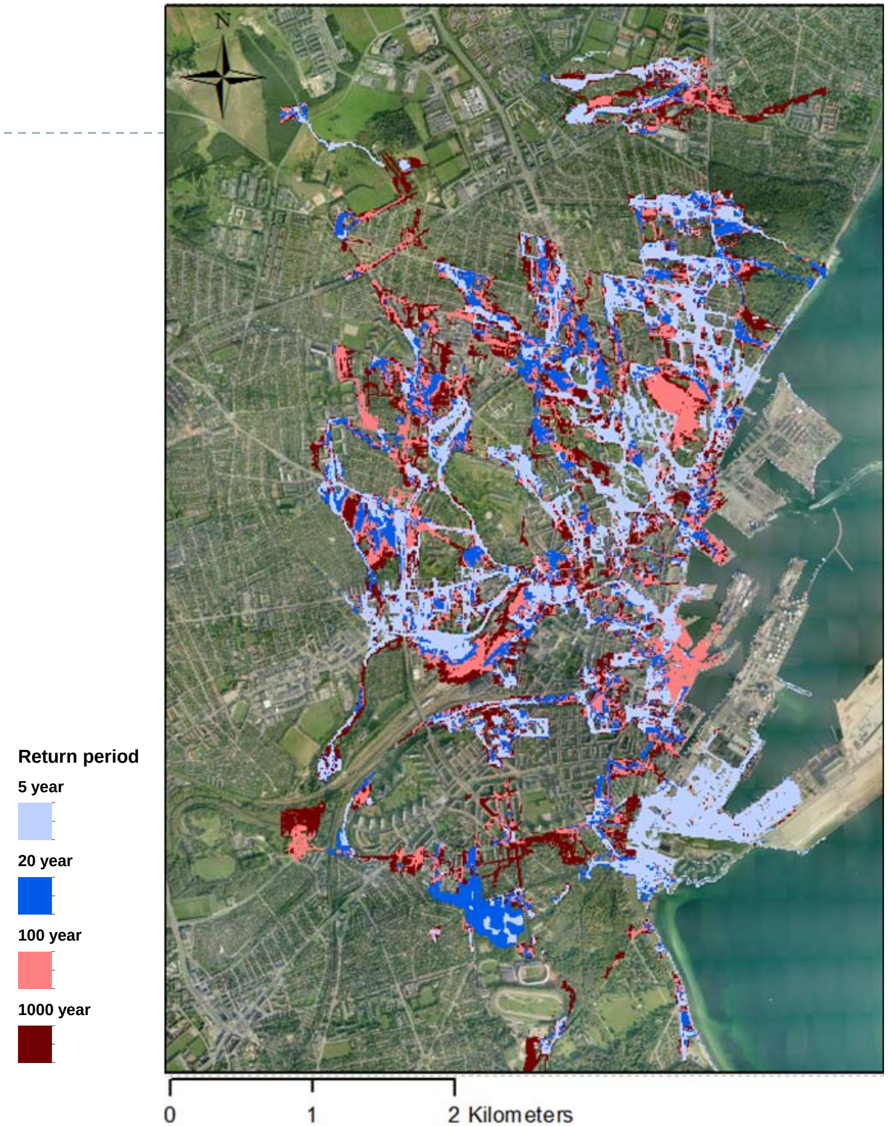
Impacts considered:

- Infrastructure
  - Residential Structures
  - Industry and Commercial
- Transportation
  - Delays
  - Trips avoided
  - Road damage
- Health
  - Injuries and Illness
  - Deaths
- Other
  - Historical & Cultural Value
  - Symbolic & Religious Value

Study area



Flood map

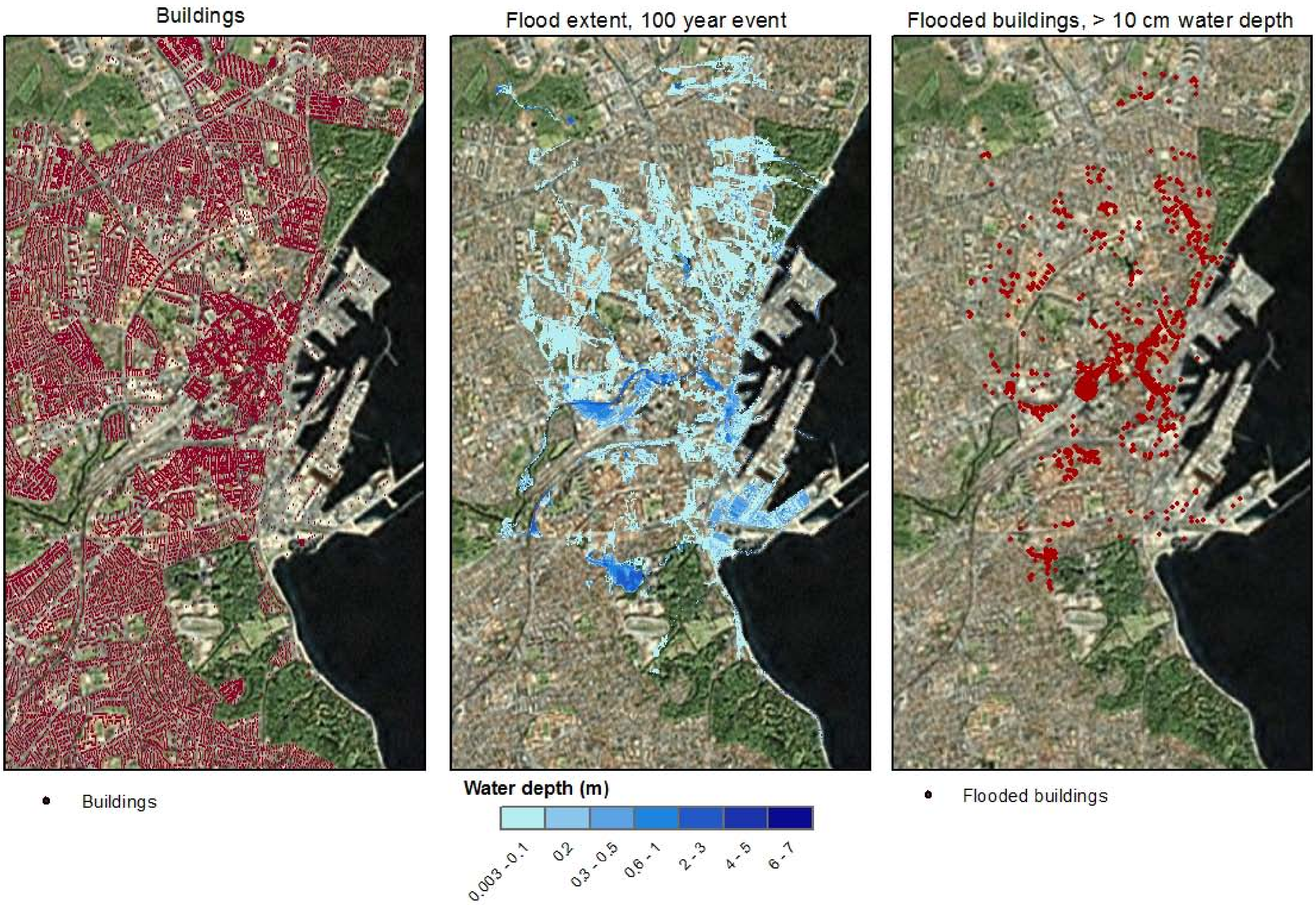


Return period		Flooded area
5 year	=	2,41 km2
20 year	=	3.52 km2
100 year	=	5.01 km2
1000 year	=	6.38 km2

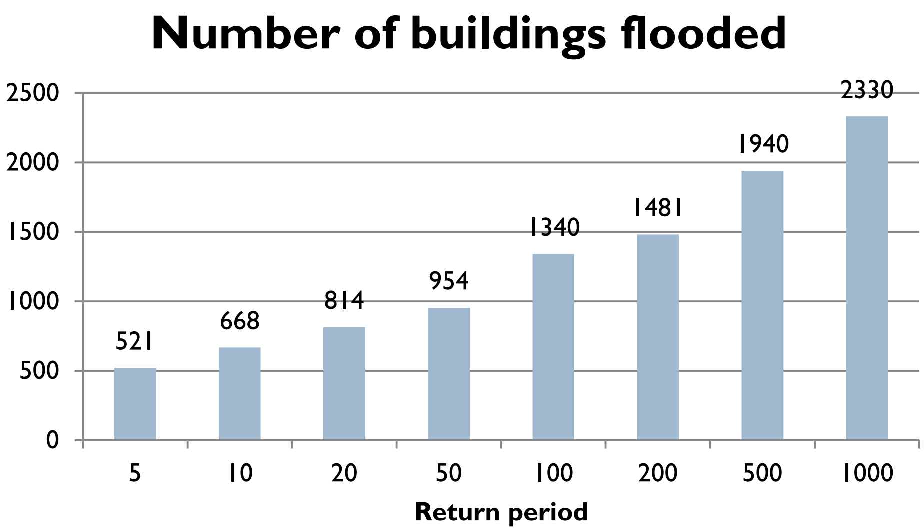
Infrastructure

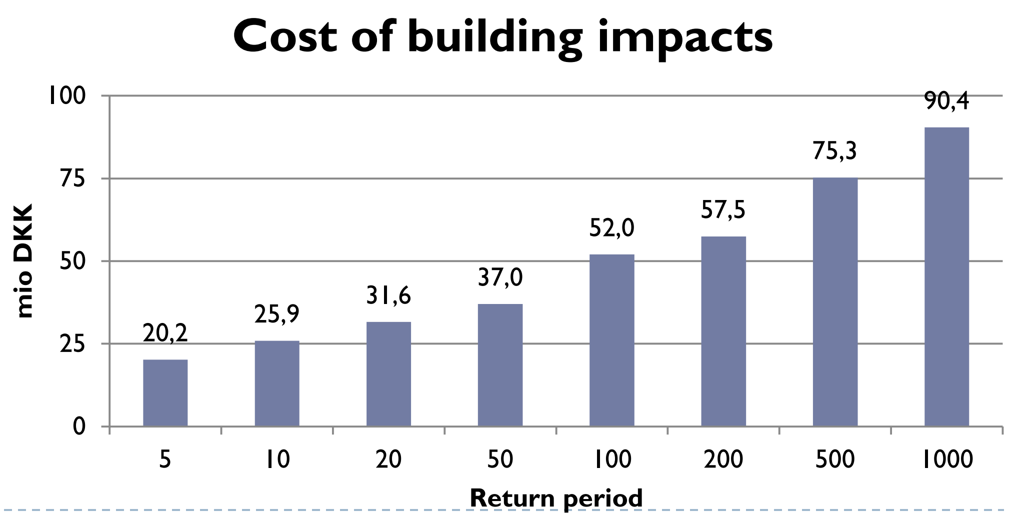
- Method:
  - Use a flood map to locate structures that are inundated with more than 10cm of water
  - Use insurance data from 2011 Copenhagen flood to estimate damage costs
  - Assume similar cost for industrial areas, less the basement/ personal property loss.

Buildings Flooded



Cost of building impacts

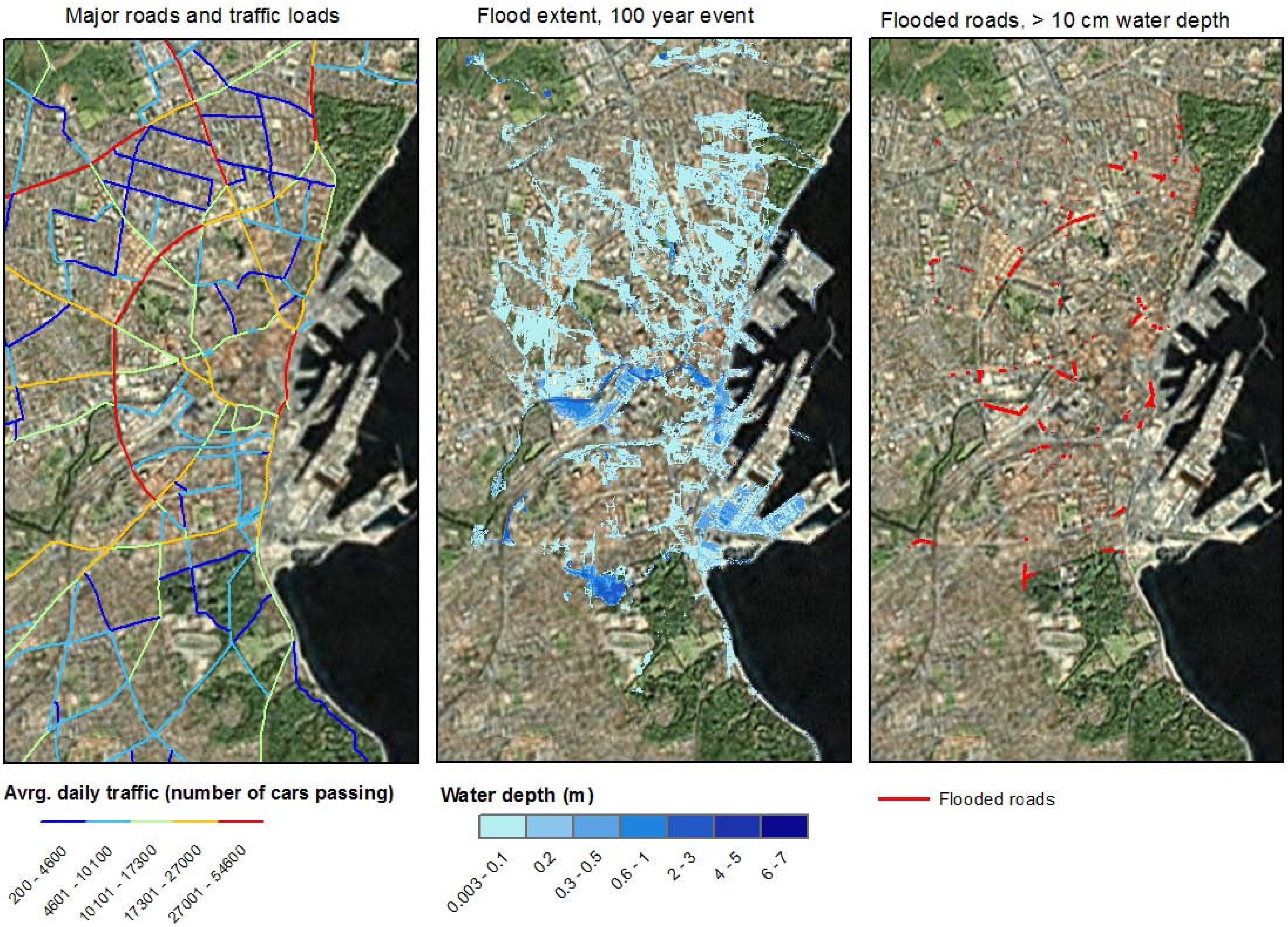




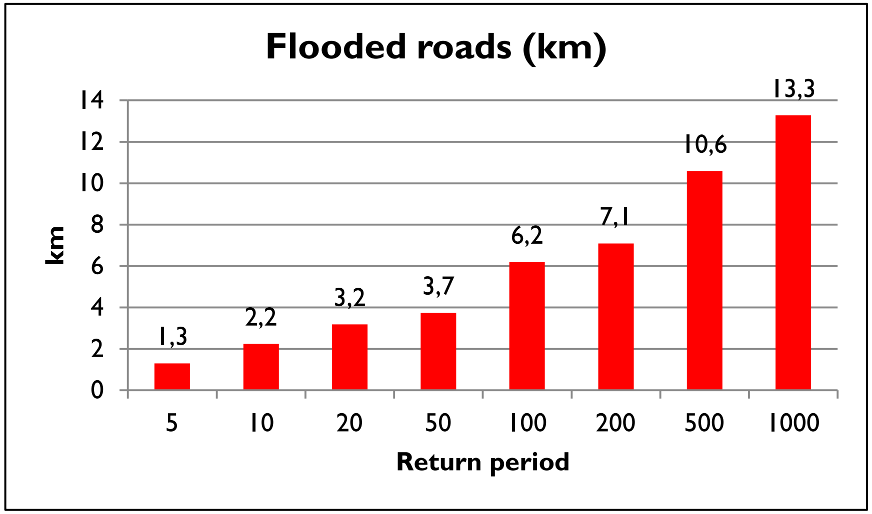
Transportation

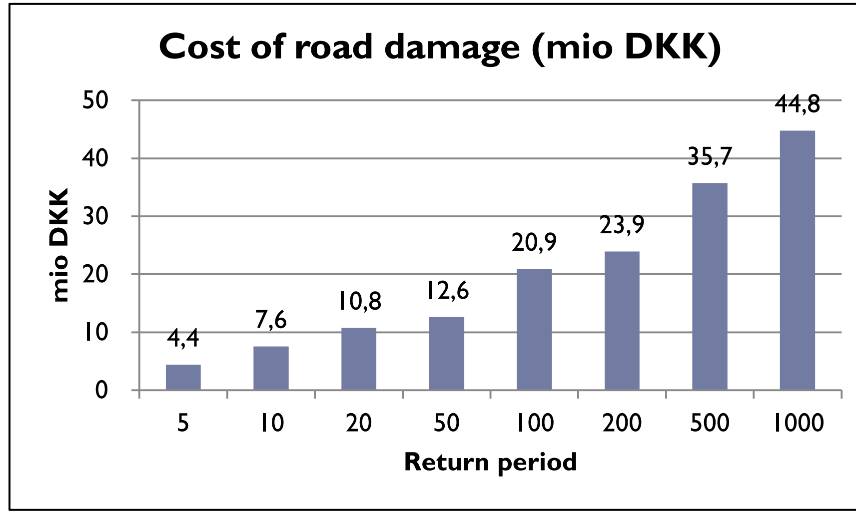
- Method:
  - Delays
    - Use traffic count data from Århus
    - Google traffic maps
    - We assume traffic delay can be approximated by peak traffic versus non-peak. Multiply travel times by this % increase
    - Multiply by average salary
  - Avoided travel
    - We assume that the proportion of transportation network that is flooded (approx. equivalent to % of residential area flooded) represents proportion of people who stay home from work
    - Multiply by average salary
  - Road Damage
    - Function of water depth and peak velocity from GIS map. Cost data from multi-country, multi-study review (Netherlands).

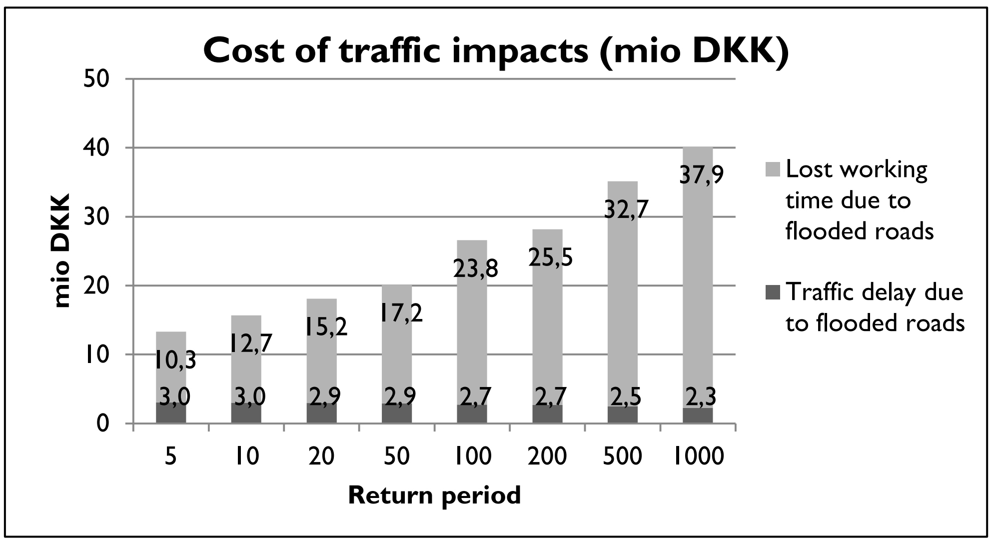
Transportation Flooding



Cost of transportation impacts



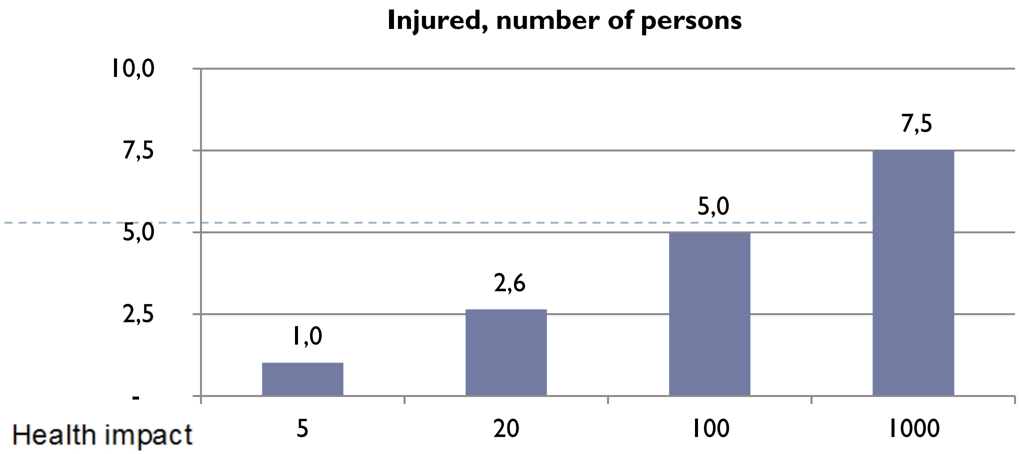


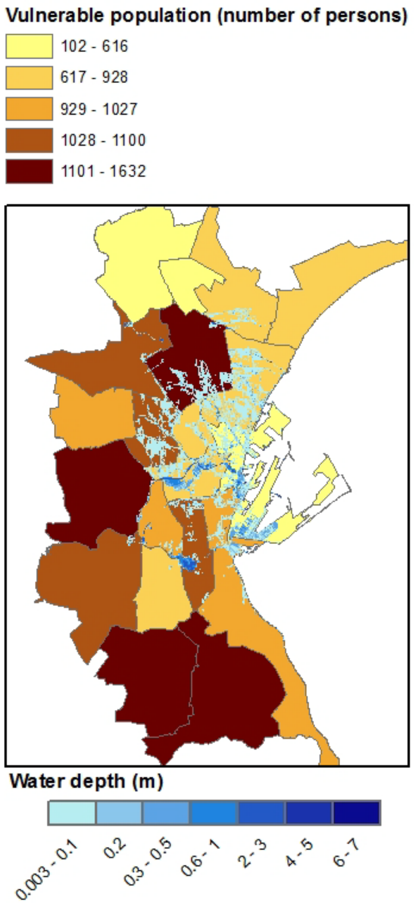


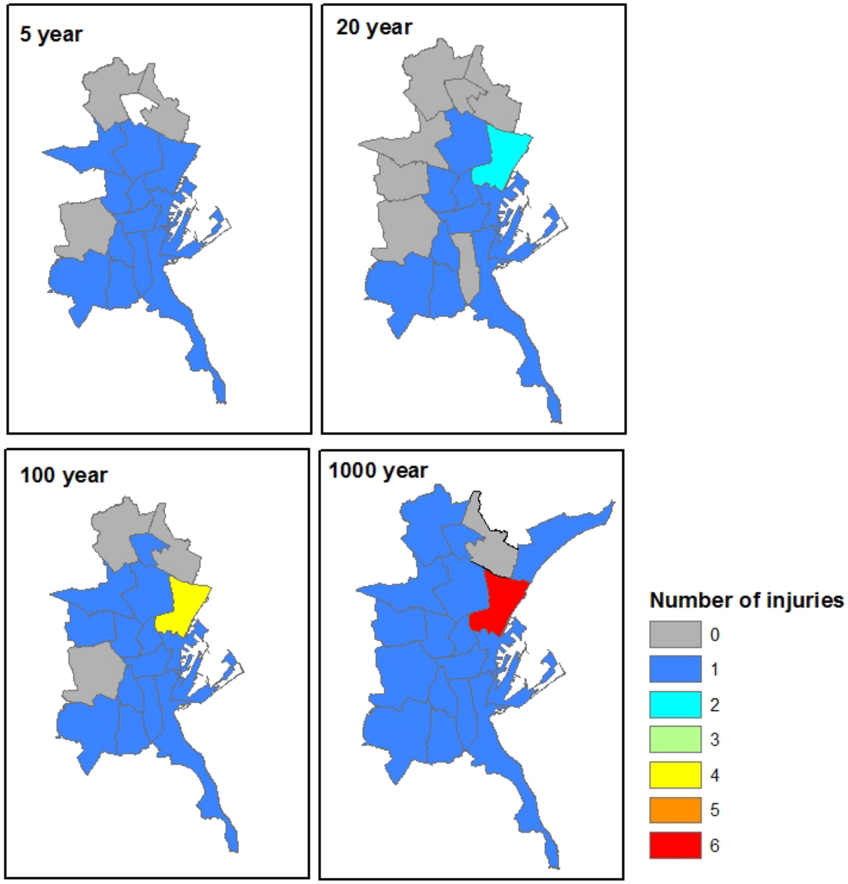
Health

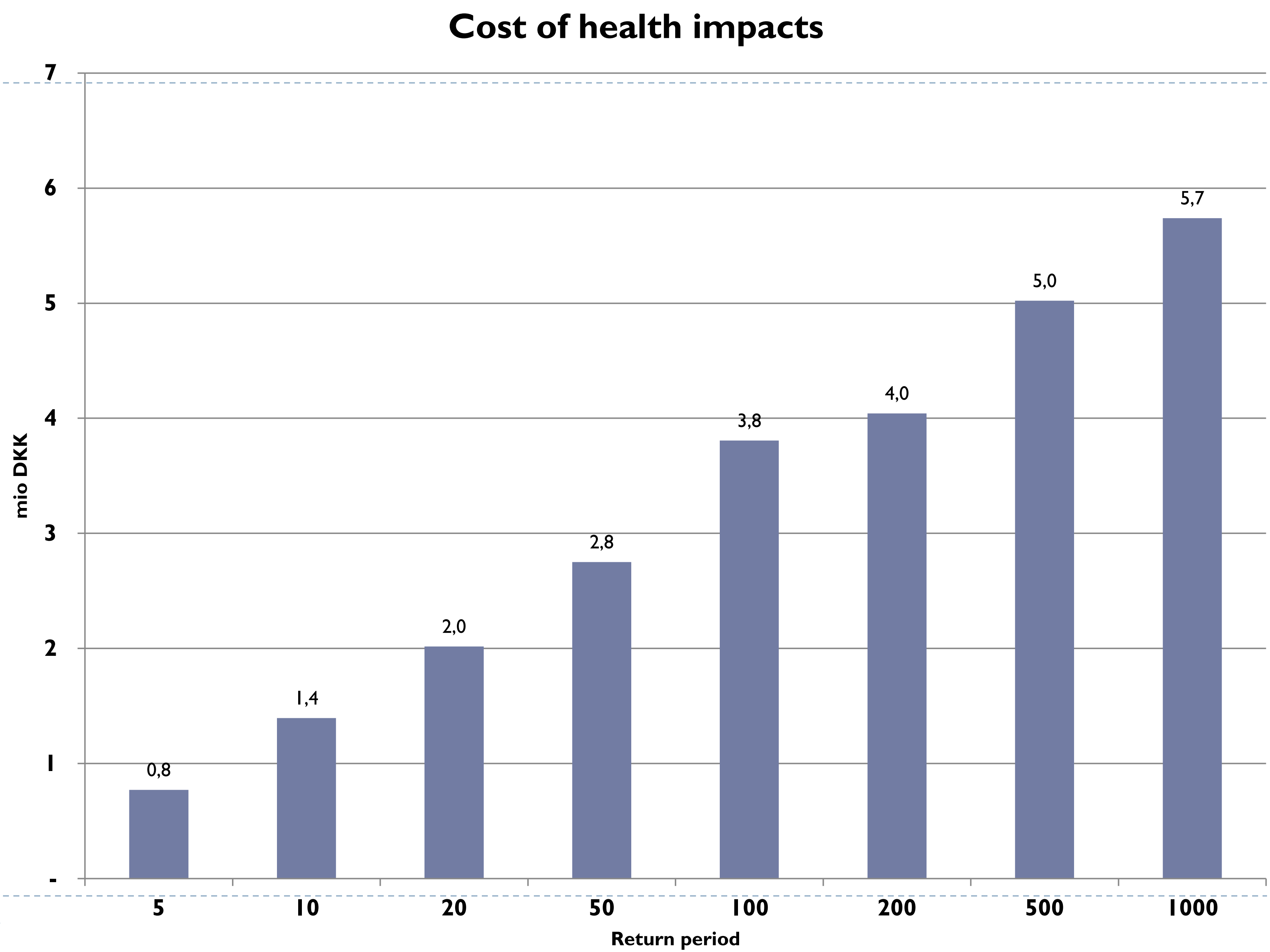
- Number of injured and killed based on a procedure by Penning-Rowsell et al. (2005). Approach employs:
  - water depth,
  - maximum velocity,
  - anticipated debris loads,
  - housing type,
  - warning systems and
  - location of vulnerable population.
- Spatially explicit based on flood map and age specific census map
- Costs estimated from value of a statistical life, adjusted by assuming different severity of injuries

Health Impacts

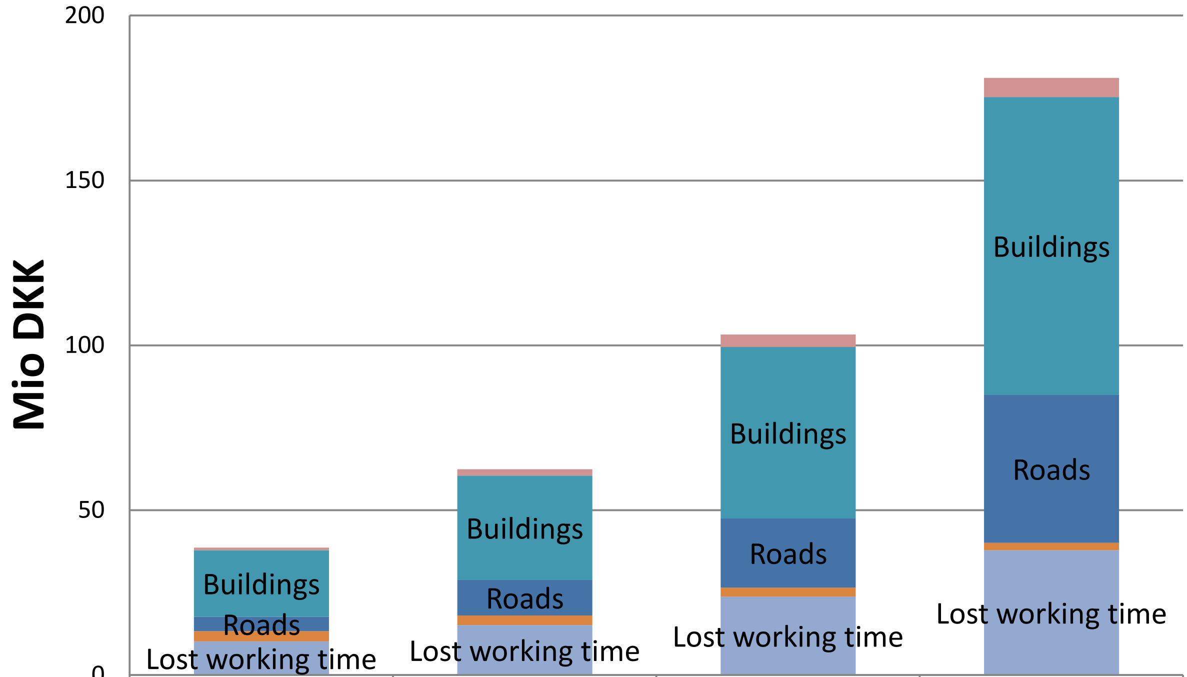







Cost of health impacts
mio DKK
7
6
5
4
3
2
1
-
0,8
1,4
2,0
2,8
3,8
4,0
5,0
5,7
5
10
20
50
100
200
500
1000
Return period

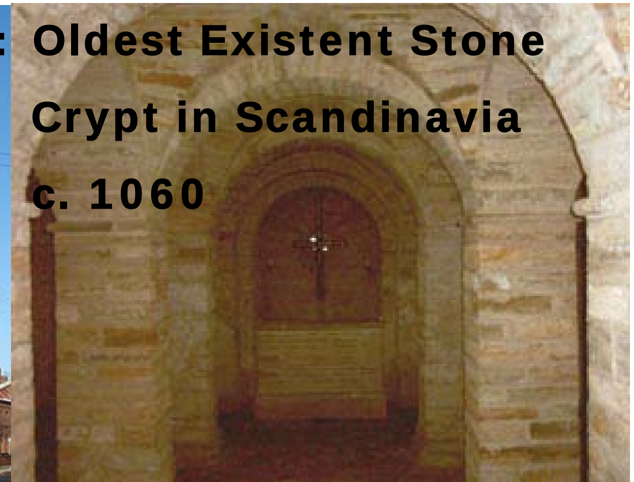
Cost benefit summary



Return period	5	20	100	1000
Health costs	0,8	2,0	3,8	5,7
Buildings	20,2	31,6	52,0	90,4
Roads	4,4	10,8	20,9	44,8
Traffic delay	3,0	2,9	2,7	2,3
Lost working time	10,3	15,2	23,8	37,9

Other Impacts: What are the costs of these?

Von Frue Kirke: Oldest Existent Stone Crypt in Scandinavia c. 1060



Viking Museum: Archaeological Site

Århus Domkirke: Numerous Frescos c. 1300-1500

Baroque Organ: Largest Church Organ in DK

Kindergarten: Very new things

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4. Group Work

- Questions 1 & 2 in the Excel Spreadsheet

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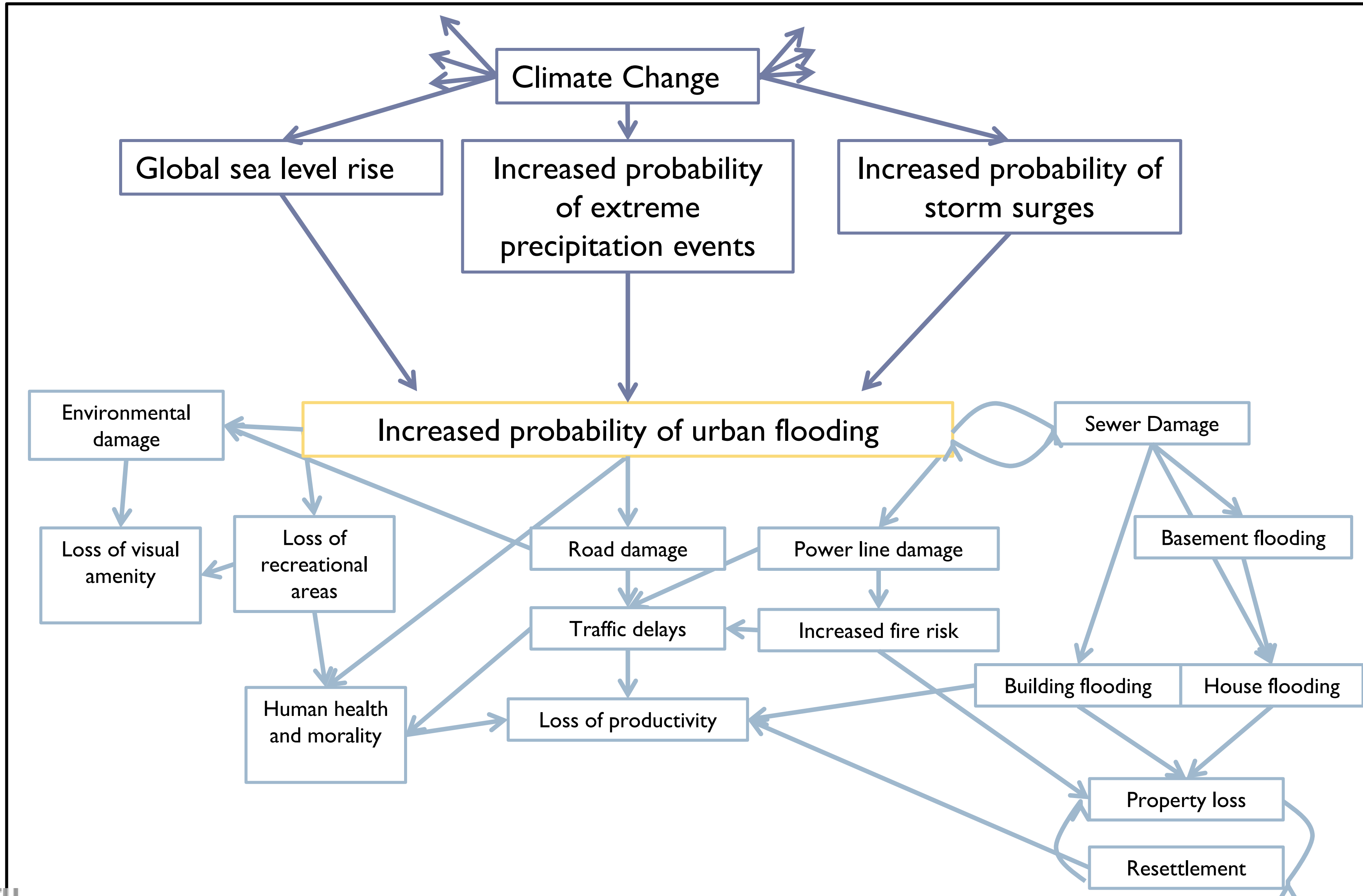
5. Economic Assessment of Adaptation

Identifying Risks and Impacts

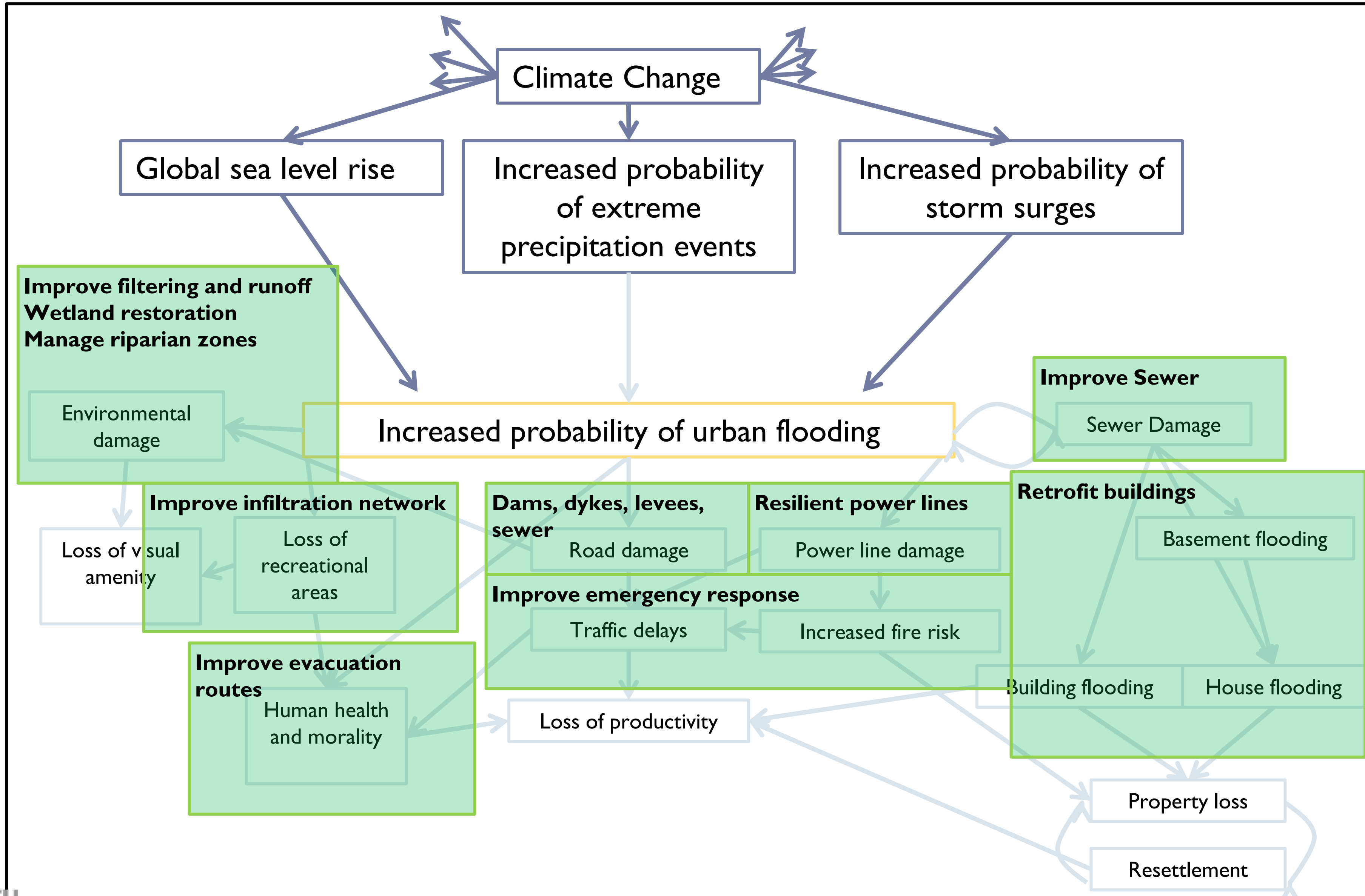
Impact	Physical measure	Direct Cost	Additional Consequences
Flooding of basement in houses	Number of houses and area	Repair	Loss of irreplaceable objects
Erosion of road	Distance of road	Repair	Traffic congestion and delay
Illness from water pollution	Number of person days with sickness	Lost salary, Lost productivity	General loss of wellbeing loss of life
Flooding of local lake	Impacts on life in the lake water level	Clean up, restoration	Esthetic value, loss of recreational area illness
Flooding of unique historical building	Physical character of the building	Repair and replacement	Esthetic values
Traffic delay	Time	Lost salary, Lost productivity	Worker morale, lost time for leisure
Loss of recreational areas	Area inundated	Reparation, clean up, replacement	Lost leisure, visual amenity

etc.

Causal Chain of Impacts



Mapping Adaptation Options



Which Adaptation Options?

- How do the various adaptation options relate to the different damage categories?
  - e.g., expanding sewage pipes may protect more than just buildings
  - e.g., a focus on protecting a church may at the same time be a solution that will protect the adjacent buildings
- Each adaptation option is analyzed in the decision matrix.

Adaptation option	Cost of imple-mentating option *i*	Impact a, given option *i*	Preference factor for impact a	Impact b, given option *i*	Preference factor for impact b	…	Proba-bility of extreme event	Damage
O_1	$C(O_1)$	$a_1 = a \mid O_1$	w_a	$b_1 = b \mid O_1$	w_b	…	$p(x)$	$C(O_1)+p(x)*(w_a*a_1 + w_b* b_1+\ldots)- V(O_0)$
O_2	$C(O_2)$	$a_2 = a \mid O_2$	w_a	$b_2 = b \mid O_2$	w_b	…	$p(x)$	$C(O_2)+p(x)*(w_a*a_2 + w_b* b_2+\ldots)- V(O_0)$
:	:	:	:	:	:	.:.	:	:
O_n	$C(O_n)$	$a_n = a \mid O_n$	w_a	$b_n = b \mid O_n$	w_b	…	$p(x)$	$C(O_n)+p(x)*(w_a*a_n + w_n* b_n+\ldots)- V(O_0)$

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Impact Assessment within the Decision Making Framework

Decision Support Matrix: A systematic way of comparing available choices and options (*rows*) on the basis of a set of criteria (*columns*) associated with each hypothetical outcome

Adaptation option	Cost of implementing option *i*	Impact a, given option *i*	Preference factor for impact a	Impact b, given option *i*	Preference factor for impact b	…	Probability of extreme event	Damage
O_R	0	$a_R = a\|O_R$	w_a	$b_R = b\|O_R$	w_b	…	$p(x_R)$	$V(O_R) = p(x_R)*(w_a*a_R + w_b*b_R+…)$
O_0	0	$a_0 = a\|O_0$	w_a	$b_0 = b\|O_0$	w_b		$p(x)$	$V(O_0) = p(x)*(w_a*a_0 + w_b*b_0+…) - V(O_R)$
O_1	$C(O_1)$	$a_1 = a\|O_1$	w_a	$b_1 = b\|O_1$	w_b	…	$p(x)$	$C(O_1)+p(x)*(w_a*a_1 + w_b*b_1+…)- V(O_0)$
O_2	$C(O_2)$	$a_2 = a\|O_2$	w_a	$b_2 = b\|O_2$	w_b	…	$p(x)$	$C(O_2)+p(x)*(w_a*a_2 + w_b*b_2+…)- V(O_0)$
O_3	$C(O_3)$	$a_3 = a\|O_3$	w_a	$b_3 = b\|O_3$	w_b	…	$p(x)$	$C(O_3)+p(x)*(w_a*a_3 + w_b*b_3+…)- V(O_0)$
:	:	:	:	:	:	.:.	:	:
O_n	$C(O_n)$	$a_n = a\|O_n$	w_a	$b_n = b\|O_n$	w_b	…	$p(x)$	$C(O_n)+p(x)*(w_a*a_n + w_n*b_n+…)- V(O_0)$

from the climate model

← reference scenario, no climate change

← climate change scenario

damage from climate change →

← adaptation options, given climate change scenario

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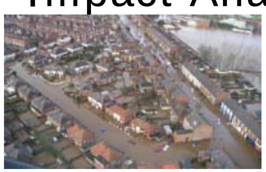
6. Decision Making

Why decision theory?

- The decision-making process isn't a "black box" where calculations are done by scientists and finally presented to decision-makers
  - people make decisions
  - people are influenced by the probabilities, but
  - people have different preferences and values

→ The method and framing of the analysis leading up to the decision-making process needs to take this into account.

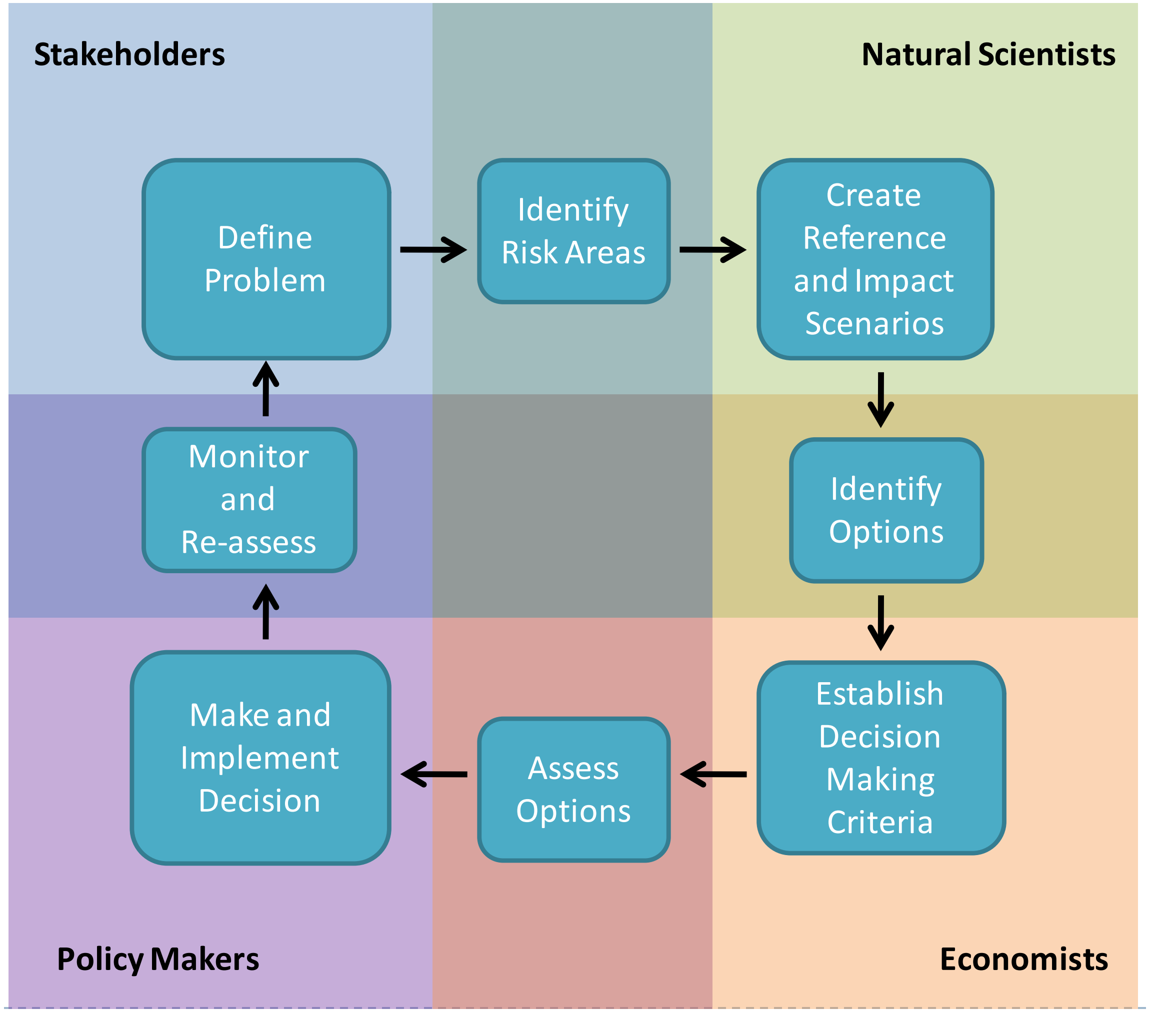
Impact Analysis



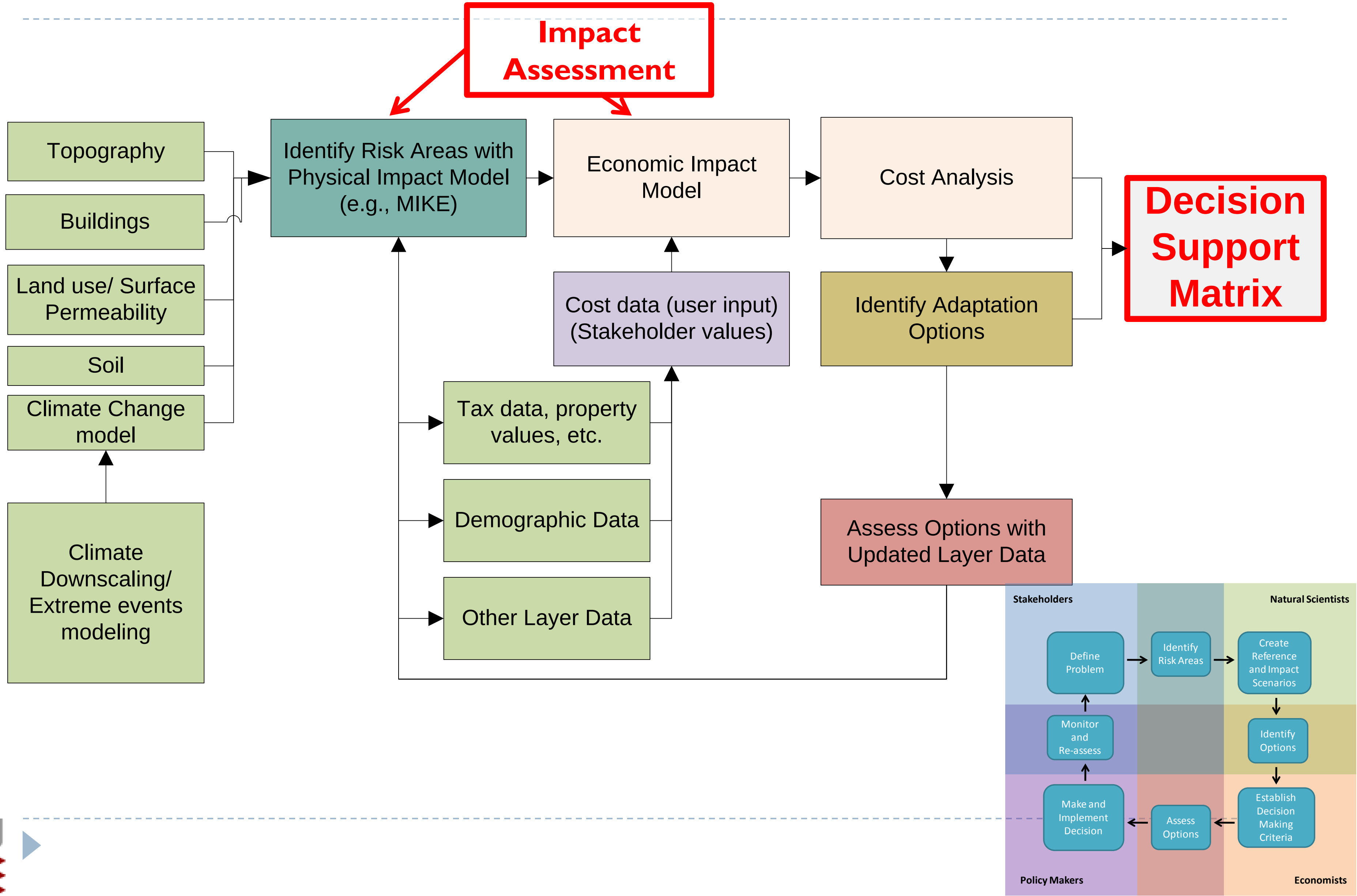
Decision Support Matrix

Decision

Adaptation Strategies and Decision Making: Actors and Process

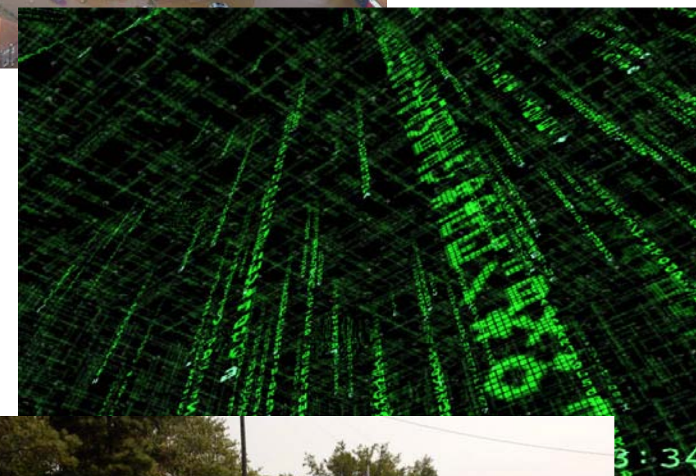


Adaptation Decision Analysis



Decision Making

- Impact Assessment



- Decision Support Matrix
- *Adaptation Decisions are Based Upon*:
  - damage assessments
  - weighting of impacts
  - attitudes toward risk
  - parallel/competing goals with existing and concurrent policies
  - predefined non-negotiable constraints

Theory of Expected Utility

- The dominate approach to decision-making under risk
  ~ Probability-weighted-utility-theory

- With *n outcomes* with *utility u* and *probability p* the decision rule is as follows:

$$Max\ (p_1 \cdot u_1 + p_2 \cdot u_2 + \ldots + p_n \cdot u_n)$$

→changes in probabilities or utility will of course change the choice of preferred action

Hansson (2005): Decision Theory – A Brief Introduction. KTH, Stockholm

Prospect theory: Background

- Developed by psychologists Daniel Kahneman and Amos Tversky in 1979
- More accurate description of preferences compared to expected utility theory
- Describes how people choose between probabilistic alternatives and evaluate potential losses and gains.

→In a sense it takes account of the inconsistency / irrationality in decisions

- e.g. the overweighing of low probabilities

Source: Kahneman & Tversky (1979): Prospect Theory: An Analysis of Decision under Risk. Econometrica.

Prospect theory

1. The certainty effect:

- People underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty

  → leads to *risk aversion* in choices involving sure gain

  → leads to *risk seeking* in choices involving sure losses

2. Isolation effect

- People tend to discard components that are shared by all prospects under consideration

  → leads to *inconsistent preferences* when the same choice is presented in different forms

3. People react to relative changes and not to absolute levels

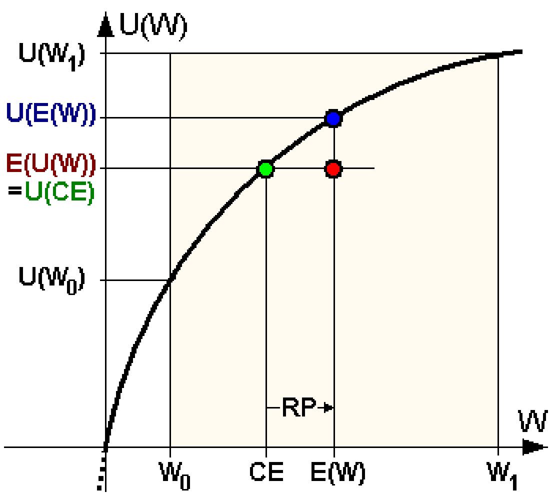
- Who is happier? The man than had 20 mil DKK and gained 2 mil DKK or the man that had nothing and found 1 mil DKK laying on the street?

Source: Kahneman & Tversky (1979): Prospect Theory: An Analysis of Decision under Risk. Econometrica.

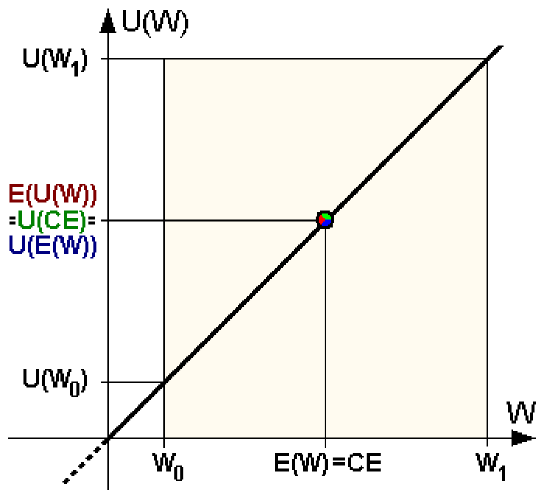
Risk Aversion Factor

- Index value that reflects a risk aversion factor

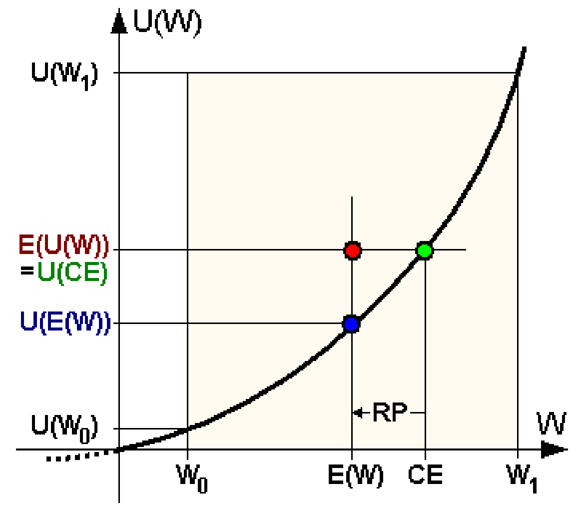
- Different factors are applied to different damage elements or applied in general to the whole function



Risk Averse



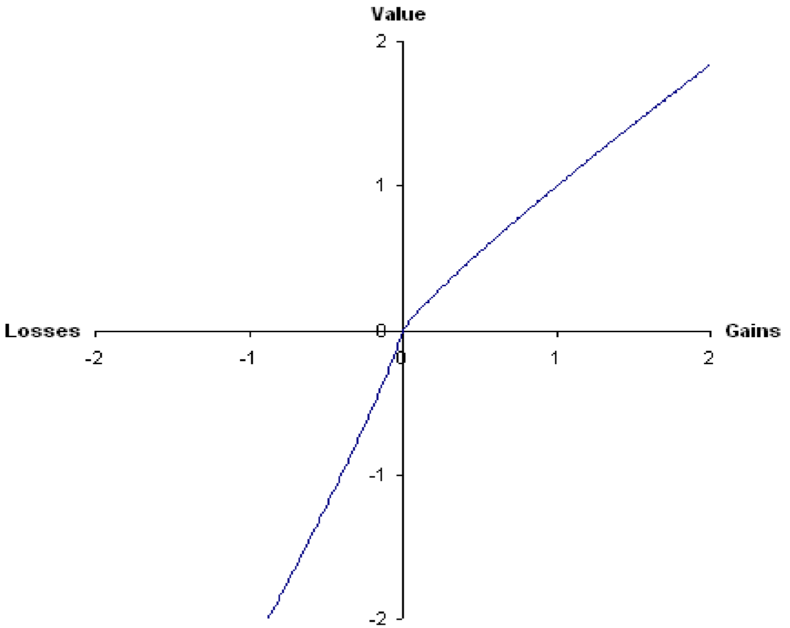
Risk Neutral



Risk Affine

Under prospect theory…

- … value is assigned to gains and losses rather than to final assets
- … the value function is:
  - defined on deviations from a reference point
  - normally concave (f''(x)<0) for gains (= risk aversion)
  - commonly convex (f''(x)>0) for losses (=risk seeking)
  - generally steeper for losses than for gains (=loss aversion)
  - steepest at the reference point



Source: Academy of Behavioural Finance and Economics

Source: Kahneman & Tversky (1979): Prospect Theory: An Analysis of Decision under Risk. Econometrica.

Thought Experiments: Which would you rather have, (a) or (b)?

Choice a	or	Choice b
1a. A gift of 100 DKK	or	1b. A 25% chance to win 500 DKK
2a. A loss of 100 DKK	or	2b. 75% chance at losing 500 DKK
3a. A gift of 30 DKK	or	3b. 1 in 10,000 chance to win 250,000 DKK
4a. A loss of 30 DKK	or	4b. 1 in 10,000 chance at losing 250,000 DKK

Thought Experiments: Which would you rather have, (a) or (b)?

Choices based on Expected Value

Choice a	or	Choice b
1a. A gift of 100 DKK EV=100 DKK	or	1b. A 25% chance to win 500 DKK ✓ EV=125 DKK
2a. A loss of 100 DKK ✓ EV= -100 DKK	or	2b. 75% chance at losing 500 DKK EV= -125 DKK
3a. A gift of 30 DKK ✓ EV= 30 DKK	or	3b. 1 in 10,000 chance to win 250,000 DKK EV= 25 DKK
4a. A loss of 30 DKK EV= -30 DKK	or	4b. 1 in 10,000 chance at losing 250,000 DKK ✓ EV= -25 DKK

Thought Experiments: Which would you rather have, (a) or (b)?

How most people choose!

Choice a	or	Choice b
1a. A gift of 100 DKK Certainty effect: Risk adverse for gains EV=100 DKK	or	1b. A 25% chance to win 500 DKK EV=125 DKK
2a. A loss of 100 DKK EV= -100 DKK	or	2b. 75% chance at losing 500 DKK Certainty effect: Risk affine for losses EV= -125 DKK
3a. A gift of 30 DKK EV= 30 DKK	or	3b. 1 in 10,000 chance to win 250,000 DKK Lottery: Risk affine for large gains EV= 25 DKK
4a. A loss of 30 DKK Insurance: Risk adverse for large losses EV= -30 DKK	or	4b. 1 in 10,000 chance at losing 250,000 DKK EV= -25 DKK

Thought Experiments: Now which would you rather have, (a) or (b)?

Choice a	or	Choice b
1a. A gain of 100 DKK now	or	1b. A gain of 100 DKK 100 years in the future
2a. A loss of 100 DKK now	or	2b. 10% chance at losing 1000 DKK 100 years in the future
3a. A gain of 1 mil DKK now	or	3b. A gain of 5 mil DKK over the next 100 years
4a. A loss of 1 mil DKK now	or	4b. 1 in 1000 chance to lose 5 billion DKK over the next 100 years

Thought Experiments: Now which would you rather have, (a) or (b)?

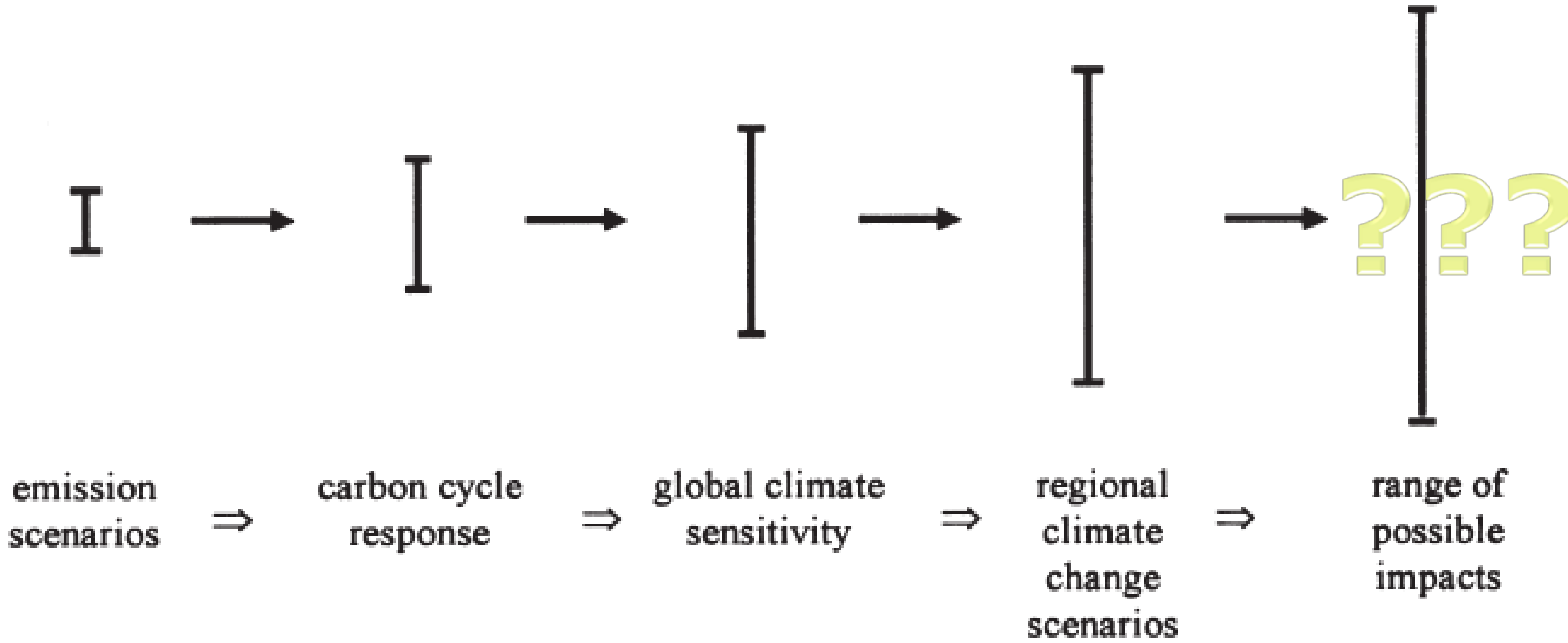
Choice a	or	Choice b
1a. A gain of 100 DKK now	or	1b. A gain of 100 DKK 100 years in the future
2a. A loss of 100 DKK now	or	2b. 10% chance at losing 1000 DKK 100 years in the future
3a. A gain of 1 mil DKK now	or	3b. A gain of 5 mil DKK over the next 100 years
4a. A loss of 1 mil DKK now	or	4b. 1 in 1000 chance to lose 5 billion DKK over the next 100 years

Adaptation Decision Making: Which game are we playing?

- 1. Abatement of future anticipated impacts

- 2. Insurance against current vulnerabilities

Cascade of uncertainty



Schneider et al. (eds.) (2002): Climate Change Policy: A survey

Uncertainty: Århus in the Future

Århus 2009 municipal plan: ***In the next 20 years:***

- +50,000 jobs
- +10,000-15,000 students
- +75,000 population
- The council has made environmental and social sustainability a priority in it vision for the future.

- How does this affect the analysis of future impacts?
- How does this constrain the future decision making criteria?
- What will Århus look like in the future?

The Time Dimension

- How do we represent future hypothetical states and risk in models?
- How do we model future human behavior on a societal level?
- How do we know what future generations will value?

Decision Criteria: Planning for the Future

- What are the extent of impacts and the effectiveness of potential adaptation measures?
- What will the area look like in the future?
- What will we learn in the mean time?
- What will we value?

- Challenges of modeling the future:
  - Is it possible for a model to predict the future of a human system?
  - Is it possible to validate the model by running from a past date to the present?

No!

Differences between modeling physical systems vs. conducting policy analysis

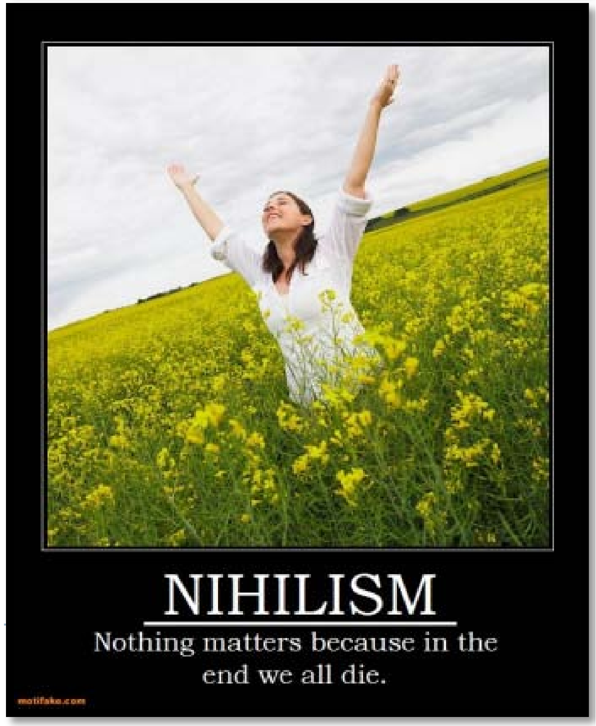
For policy analysis to make sense, we have two philosophical assumptions:

1. Non-Determinism:

   If we assume that whatever is going to happen is already predestined, then policy has no role. We have to assume that policy has the power to change the course we are on.

2. Non-Nihilism:

   We have to assume that some outcomes are better than others and that there exists a criteria for deciding between the different outcomes. If not, policy again would have no purpose because every possible future would be equally desirable.



Who Responsibility is it? Who pays?

- Individual? Autonomous Adaptation…
- Government?

Who is adapting?

- We only care about climate change adaptation because of the human system. If there were no people, it wouldn't matter.
- How do we understand climate change adaptation under the context of future human decisions?
- How should uncertainty and risk be understood in an economic analysis to support decision making?
- How should adaptation be considered in the larger context of responses to climate change, and other needs that require resources from the government?

Conclusions

- The goal of economic analysis of adaptation is to aid in decision making.
- A rigorous approach to cost-benefit analysis can clarify decisions about which adaptation options to implement, and when to implement them.
- How should we effectively incorporate economic discounting and attitudes toward risk (such as the precautionary principle) into adaptation decision making?

Outline

1. Adaptation in Context
2. Risk Assessment & Impact Analysis
3. Example: Århus
4. Group Work
5. Economic Assessment of Adaptation
6. Decision Making
7. Group Work

7. Group Work

- Questions 3 & 4 in the Excel Spreadsheet