BASQUE CENTRE FOR CLIMATE CHANGE
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Adaptation to Climate Change Assessing Costs and Evaluating Policy Measures

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Definition

- Adaptation: Policies, practices, and projects with the effect of moderating damages and/or realizing opportunities associated with climate change.

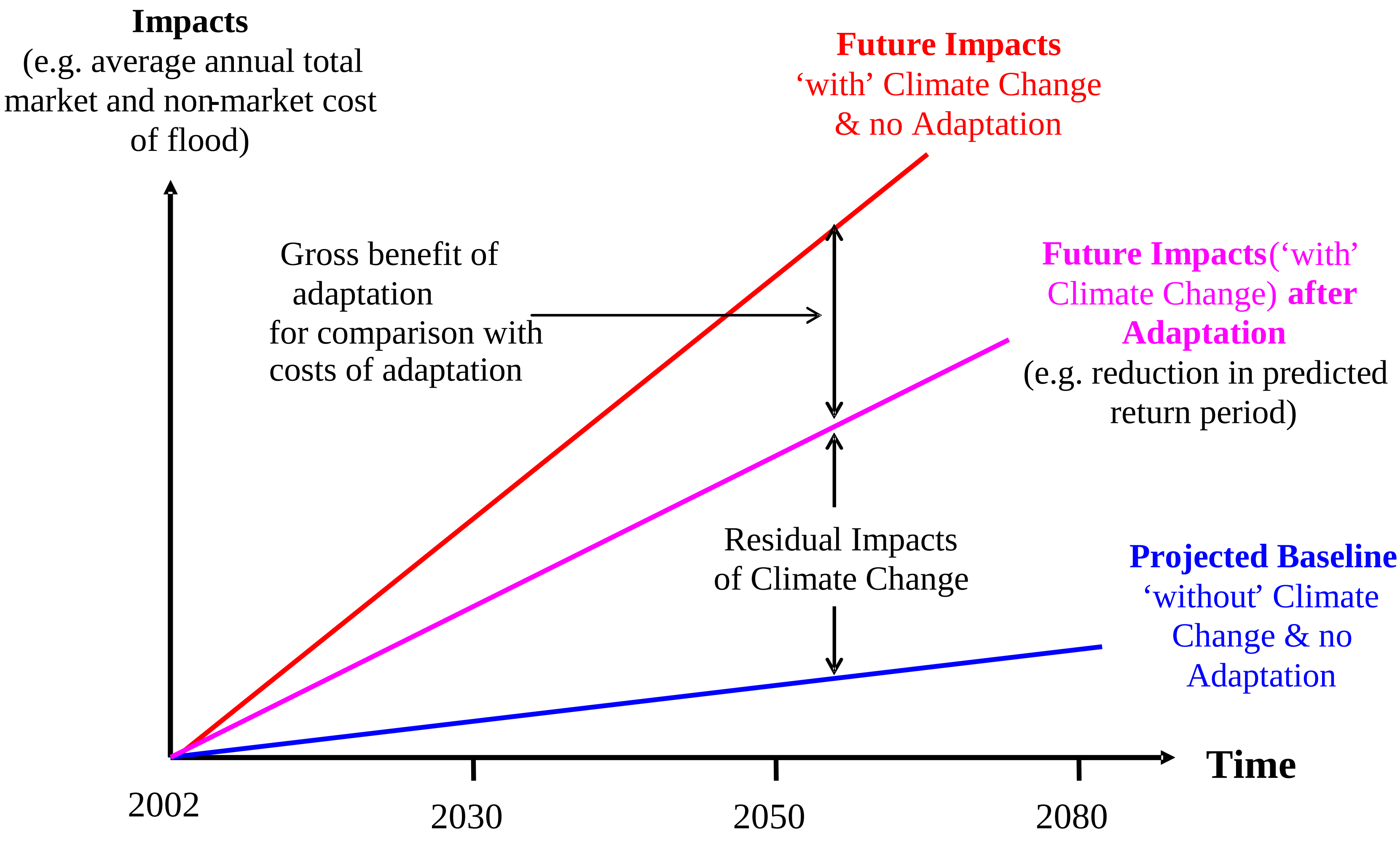
- Autonomous Adaptation: Adaptation that does not constitute a conscious response to climate stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems

- Planned Adaptation: Adaptation that is the result of a deliberate policy decision based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state

Other Issues

- Anticipatory Adaptation
- Reactive Adaptation
- Long term Adaptation Vs Short Term Measures
- Geographical Scale (local, regional, national)
- Functions: legislative, regulatory, technical, advisory, educational, behavioral.

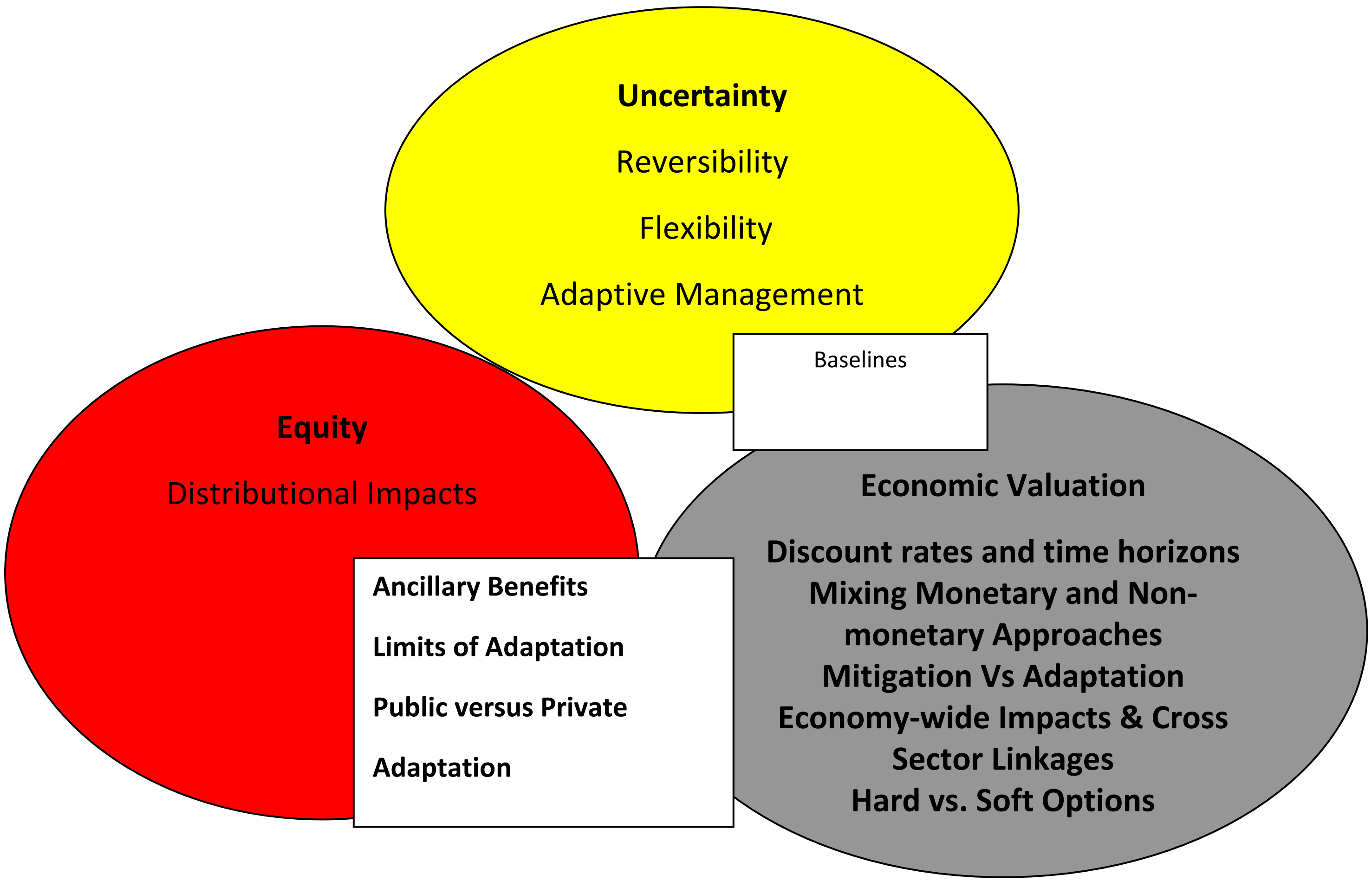
Basic Issues



The Ideal Evaluation and Its Problems

- We estimate the benefits of the measures relative to the baseline and the impacts line
- We estimate the costs of the measures
- We select those that have the highest net benefits.
- Problems with this:
  - Uncertainty
  - Dynamic nature of the baselines etc.
  - Lack of knowledge
  - Benefits are very complex to estimate in money terms
  - Impacts will depend on amount of mitigation

Methodological Themes



A Lot of Uncertainty to Contend With!

- For a 2^{o}C increase the decrease in water availability is estimated at 20-30%, the declines in crop yields in tropical regions at 5-10% and 15-40% of species are said to be facing extinction (Parry et al. 2007). These wide ranges become even larger when different emissions scenarios and different modelled projections of temperature change are taken into account.
- To the uncertainty of the magnitude of the physical impacts, we have to add the uncertainties associated with the valuation of the impacts.
- In addition to the uncertainties described above we also have to take account of the incomplete coverage of climate change itself, as well as the risks and impacts in the literature. See next figure.

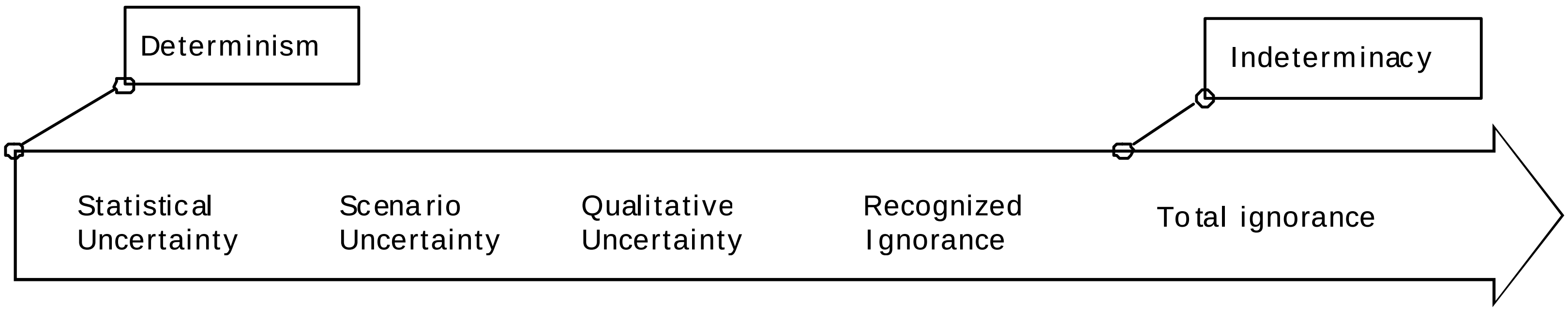
	Market	Non-Market	Socially contingent
Projection **e.g. temperature and sea level rise**	Limit of coverage of many studies		None
Bounded **e.g. precipitation and extremes**	Limits of coverage for most studies	None	None
Major change **e.g. major tipping points**	One or two studies	None	None

Defining Uncertainty

- "An expression of the degree to which a value (e.g., the future state of the *climate system*) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain *projections* of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts.", IPCC, 2007
- Different kinds of uncertainty:
  - Epistemic: due to imperfect knowledge
  - Ontological: due to inherent variability, can be quantified but not eliminated
  - Ambiguity: arises multiple ways of understanding or interpreting a system.

Level and Sources of Uncertainty

Level of Uncertainty



Sources of Uncertainty

The *sources of uncertainty* can be divided into uncertainties on *input data*; *model uncertainty*; *context uncertainty;* and *uncertainty due to multiple knowledge frames*, reflecting that different persons may have different perceptions of what the main problems are, what is at stake, which goals should be achieved, etc. The simultaneous presence of multiple frames of reference to understand a certain phenomenon may cause ambiguity.

Uncertainty and Climate Change

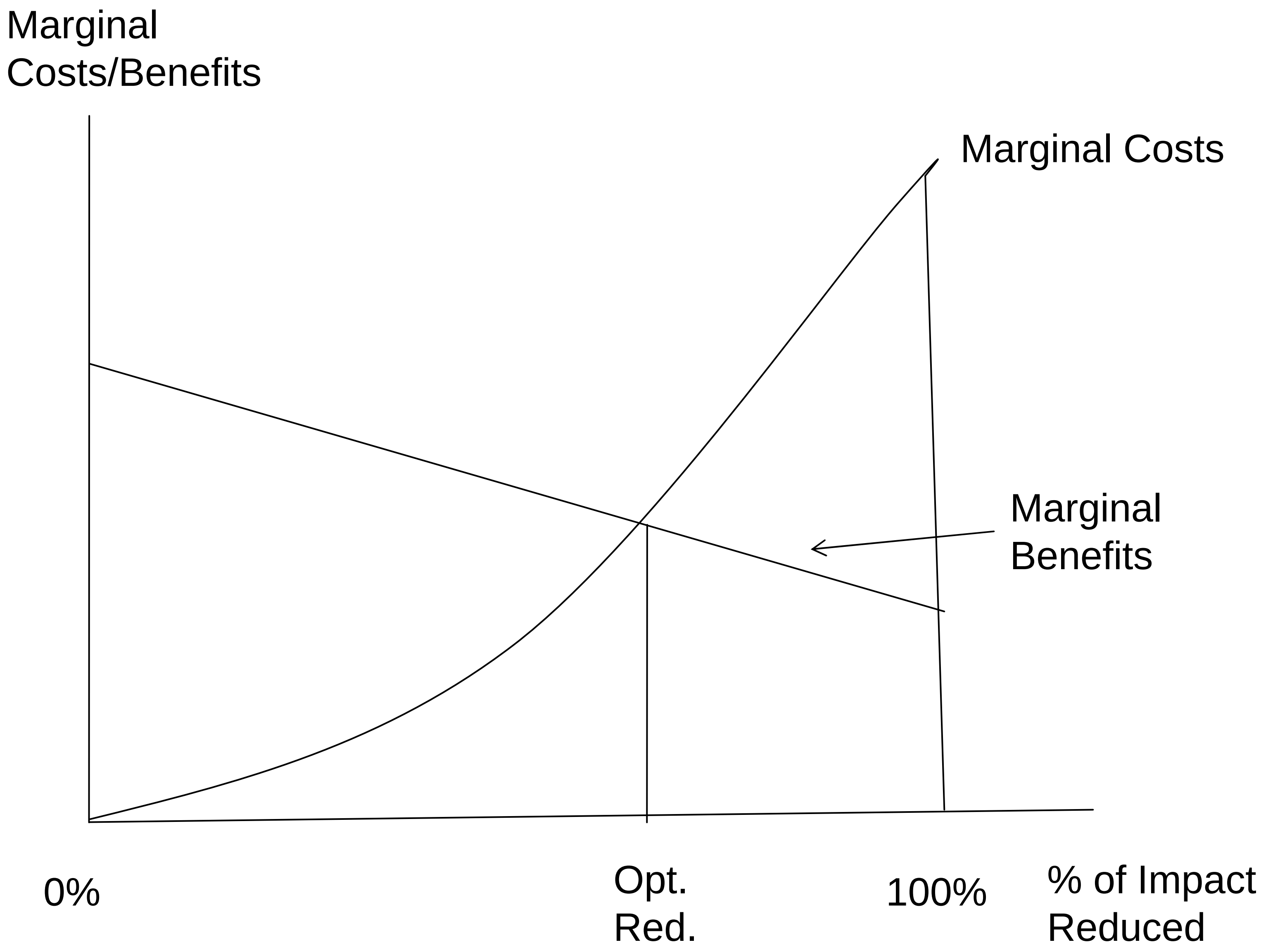
- With climate change we have a cascade of uncertainty, from emissions scenarios and socioeconomic scenarios, to climate projections models, to systems impacts (water, sea level rise etc.) to adaptation measures.
- In the case of climate change all three types are present but, at the present time epistemic uncertainty is pervasive at all steps of the decision-making frame. Ontological uncertainty is especially important in the climate models, in the downscaling measures and in characterising the adaptation measures. Finally ambiguity is most serious in defining the socio-economic scenarios and in characterising the socioeconomic impacts and adaptation measures.
- This makes use of benefit cost analysis in evaluation adaptation options difficult in some case (we discuss this later).

Adaptation Costs & Residual Damages: Alternative View

- There is also a view that adaptation costs should be the measured as the full costs of compensation for the damage done due to climate change.
- In other words they would argue that the residual damages should be included in any adaptation package.
- What is presented in practical estimates is typically a mixture of the two: individual studies find it hard to define adaptation cleanly in many cases and simply report total damages.
- Key point: even if one takes the view that ‘adaptation’ means compensation for all damages it is very important to know what the costs of appropriate actions are and what residual damages should be accepted so that the right policies can be put in place.

Issues That Arise

- Adaptation Deficit
  - In many countries level and quality of infrastructure is very poor and this is the cause of the high damages caused by climate change. If the level and quality can be improved over time damages from climate will be less (e.g. flooding). How much of this increase in investment should we attribute to climate adaptation and how much to development?
  - Risks in combining development with adaptation into one strategy (specific adaptation issues will get less importance).
- Residual Damages
  - It may not pay to go for zero residual damages. Marginal costs of removing all damages rise and marginal benefits fall. That is why it makes sense not to plan for full protection against consequences of climate change.


Marginal
Costs/Benefits
Marginal Costs
Marginal
Benefits
0%
Opt.
Red.
100%
% of Impact
Reduced

Baselines

- Define what would happen in the absence of climate change.
- Clearly an element of judgment as we are looking forward 20 or more years.
- For example most developing countries will have improved public health by then. This has to be allowed for
- Given uncertainties, some researchers have proposed using multiple baselines and then selecting measures that fulfil the requirements of stakeholders under a range of possible outcomes.

Reversibility, Flexibility and Adaptive Management

- Adaptation measures must be designed so they can be modified in the light of new information.
- One way to incorporate such an approach is through the use of option values in the cost benefit or cost effectiveness analysis.
- So if the scheme you propose has the option of being modified you attach a value to that option.
- Can be useful for projects with very long lifetimes.
- Guidance on how to use option values in this context have been provided in the UK but practical applications are very rare. (Thames Estuary Study in the UK used them)

Example of Option values

Consider the case where there are two options for protecting a coastal area against sea level rise. The first is to build a sea wall to protect against a one meter rise by 2030. The second is to build a wall that protects against a one meter rise but also includes stronger foundations such that the wall could be raised to protect against a two meter rise should that be discovered to be necessary in 2030. We assume that the higher wall will only be built in 2030 if it is found to be necessary in the second option and that we will know for certain whether it is required by 2030.

The trade-off is between incurring a higher cost now for the option of being able to protect against a higher risk in the future.   The cost of a simple wall now is 100, while the more flexible wall is 130. If the simple wall is put up the benefits with a one meter rise are 200, but if the seal level rise is 2 meters, we will be forced into a retreat (it will be too late to put up a protective barrier when we get to know about the 2 meter rise) and there will be a loss of 200. With the flexible wall this second eventuality is avoided, but at an additional cost of 50.

Data for the Option Value Example

	Period 1		Period 2			Probability of 2 M Rise	Expected Value
	Costs	Benefits	PV of Costs	PV of Benefits			
				1m Rise	2M Rise		
Option 1	100	0	0	200	-150	5%	82.5
Option 2	130	0	50	200	200	5%	67.5
Option 1	100	0	0	200	-150	10%	65.0
Option 2	130	0	50	200	200	10%	65.0
Option 1	100	0	0	200	-150	15%	47.5
Option 2	130	0	50	200	200	15%	62.5
Option 1	100	0	0	200	-150	25%	12.5
Option 2	130	0	50	200	200	25%	57.5

The comparison hinges on what the probability is of a 2 meter rise.

Ancillary Benefits

- Many adaptation actions have other benefits than simply to reduce the impacts of climate change:
  - Reduce vulnerability to other risks
  - Reduce exposure to local pollutants
- Where possible such benefits should be included in any cost benefit analysis.
- Problem is sometimes one of measuring them.
- Often ancillary benefits favour the poor and vulnerable and should be given greater weight for that reason.

Issues That Arise

- Distributional Impacts
  - Many impacts of climate change affect the vulnerable (elderly, poor, those with health impairments). Hence we cannot look only at net benefits in deciding on policies. We must take account of distributional factors.
- Valuation of Impacts
  - We cannot value all impacts in terms that are acceptable to policy makers. E.g. increased deaths? Losses of biodiversity? Loss of cultural assets? In such cases we need to combine monetary valuations of some impacts with other indicators of value that are not monetary. Involves using techniques such as multi-criteria.
- Changes in Risks
  - We can value changes in risks of negative events but this needs sophisticated methods of valuation. We cannot just take expected damages as an indicator of loss or gain.

Simplifications

- Divide the impacts and measures by sector
  - Health
  - Sea Level Rise
  - Freshwater Systems
  - Extreme Events
  - Infrastructure
  - Agriculture
  - Ecosystems
  - Other sectors (tourism)
- There will be overlaps but these can be addressed as they arise.

Health

- Climate change will have a wide range of implications to human health. These include thermal-related morbidity and mortality due to extreme temperatures, effects associated with air pollution, impacts of extreme weather events, malnutrition, water-borne (e.g. diarrhea, cholera, typhoid), food-borne (e.g. *Salmonella*) and vector-borne diseases (e.g. malaria, dengue). The highest impacts are expected in developing countries, resulting in increased mortality, morbidity and suffering.
- A useful metric of impacts is DALYS or VOLYS. Projects are accepted if the cost per DALY or VOLY is less than an agreed amount.
- Used in health planning and familiar to policy makers.
- We would exclude deaths from extreme events and treat them separately.
- Distributional issues are of great importance here.
- Data on relative risks are still quite uncertain.
- Baseline important – vector borne diseases decline with development!

Sea Level Rise (SLR)

- With sea level rise the impacts are largely in terms of loss of the services of land. Estimates of loss of services under climate change have been made; in fact this is one of the better quantified areas of impacts.
- Adaptation measures can reduce this loss of services and the benefits are then measured in terms of the cost per ha. of the adaptation measures relative to the increase in services per ha. as a result of the measures. As a point of departure we can take land prices as a measure of the discounted present value of future land services.
- Options can be described as: Retreat, Accommodate and Protect.
- The Dynamic Interactive Vulnerability Assessment (DIVA) tool has been used widely used to calculate the costs for coastal protection. It covers impacts from flood and storm damage, wetland loss, erosion and saltwater intrusion. The adaptation measures include mainly coastal protection and beach nourishment. Hence it is very engineering oriented. Some specific features such as cyclones are not covered.

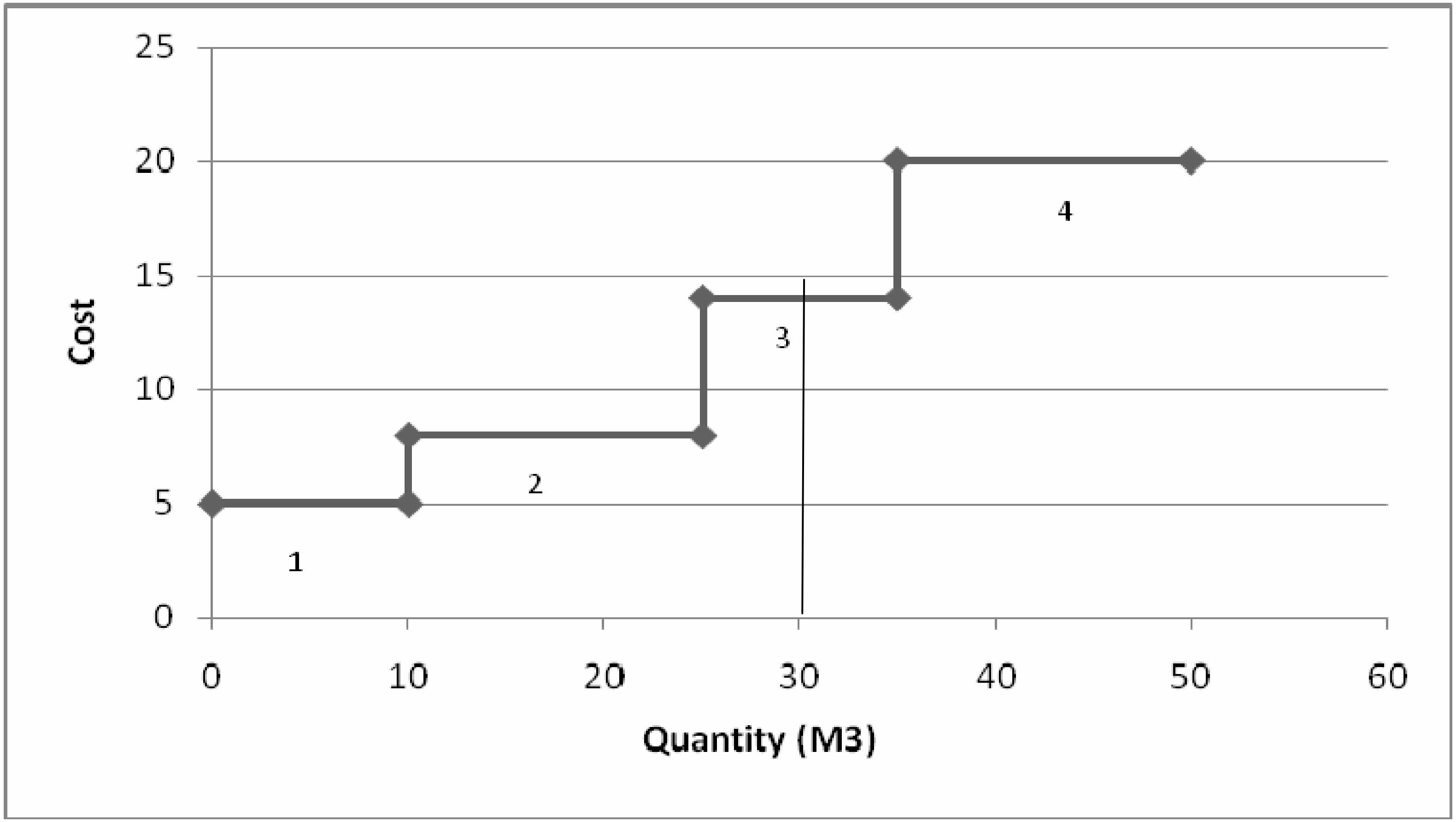
Sea Level Rise (SLR)

- *Some services of land are not captured in land prices.* These could be significant if externalities are not captured in the market valuations. In such cases additional values of land have to be added to the market value, based on non-market valuations.
- All this suggests that model results need to be complemented by additional measures based on assessment of soft options and inclusion of phenomena not covered by SLR.
- And there are distributional impacts in poor countries where SLR can affect livelihoods of poor people. Here decisions may need to compare alternative livelihoods and ensure full compensation.
- Some examples such as the Thames estuary use options analysis and exploit the fact that we can delay decisions about major investments till 2050. Then we concentrate on low cost options now and revisit the major investment decision later.

Freshwater Systems

- The impacts of climate change on freshwater systems are mainly due to the observed and projected increases in temperature, sea level and precipitation variability. An increase in the ratio of winter to annual flows, and possibly the reduction in low flows caused by decreased glacier extent or snow water storage, is predicted. Sea-level rise will extend areas of salinisation of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. Increased precipitation intensity and variability is projected to increase the risks of flooding and droughts in many areas of the world.
- The analysis of adaptation measures has to be carried out at the river basin level. Projections are available of water demand and supply going forward 30 years and possibly longer. Against this one can make estimates of changes in supply resulting from climatic impacts. This will create (in most cases) a gap between demand and supply relative to the baseline situation. The proposal is to rank different measures to fill this gap, based on the cost per cubic meter of water provided. Robustness analysis has to be applied to make sure we choose the best option!

Ranking Measures for Water



Extreme Events

- Extreme events almost certainly will merit some adaptation measures.
- The impacts are best characterized in terms of increased frequency of such events, causing loss of life and damage to property.
- Actions can be taken to reduce the frequencies to the baseline level and/or to reduce the consequences for the events so that damages are no more than at the baseline level. An example of the former could be raising protection barriers, while an example of the latter would be relocating individuals and increasing protection for property.
- We propose that adaptation measures should be such as to keep the expected losses from extreme events at a level that reflects societal risk. This bypasses the benefit cost decision-making methodology but it may be justified on the grounds that public concern for losses from extreme events is sufficiently high for us to adopt an absolute standard.
- It also avoids the problem of valuing loss of life.

Extreme Events: Issues

- *Allowance must be made for autonomous adaptation*. Given the increased risks of flooding, for example, individuals will choose to relocate and take personal measures in response.
- If, however, public investments offer protection that assumes no autonomous adaptation, the overall costs of responding to the change in risk will be much higher than it would be if proper account was taken for behavioural changes at the individual level. Part of the adjustment individuals and companies will make will be in response to higher insurance premiums, or even refusal by insurance companies to offer protection against some events in certain locations. If the government measures consist of essentially underwriting the risks that the private sector will not cover, the costs of meeting a given "expected consequence" target could be very high.

Infrastructure

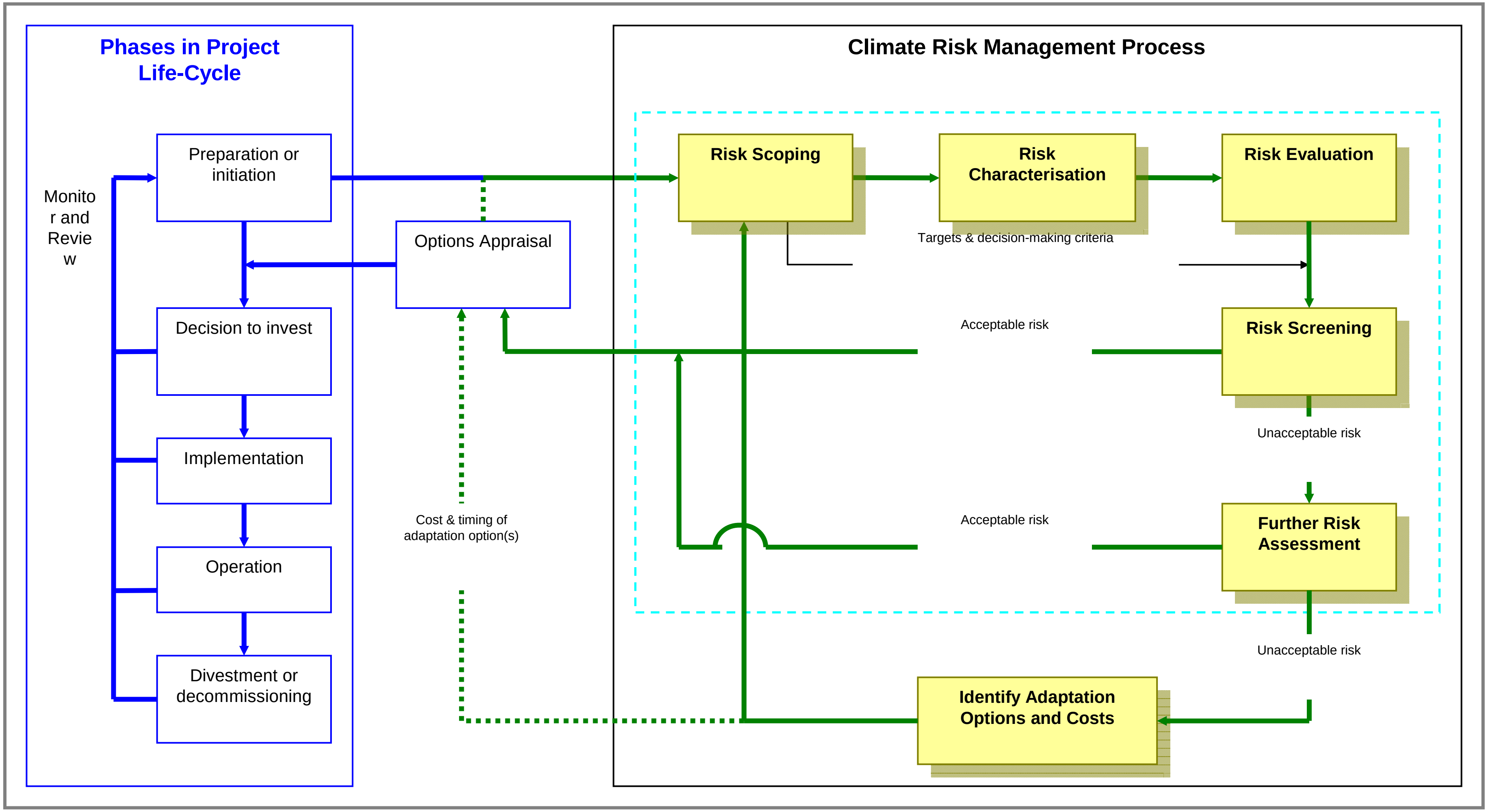
- Long lead times

Sector	Time Scale (years)	Exposure
Water (dams etc.)	30-200	+++
Land Use Planning	>100	+++
Coastline and flood defenses	>50	+++
Building & Housing	30-150	++
Transport (roads Railways, bridges)	30-200	+
Urbanism	>100	+
Energy (e.g. cooling systems)	20-70	+

Infrastructure

- Climate change will change the design of infrastructure investments.
- “Climate proofing” future investments will therefore be a major requirement in the design of investments in roads, rail systems, hydropower plants and so on.
- The analysis of proposed climate risk management process for development projects is shown in Figure on next slide; this process is based on standard approaches to charactering and managing risk (DETR, 2000).
- Essentially the project is evaluated for the climate risk. If the risk is deemed acceptable the options are appraised as before. If, however, the risk is considered unacceptable further modifications are made until the risk is reduced to an acceptable level, at the least cost possible. There is no general metric that can be applied here; the rule is defined in terms of acceptable risk and the use of a least cost analysis to identify the measures to meet that risk.
- Applications have been made via UKCIP to railway investments in Scotland.

Framework for Managing Climate Variability at Project Level



Agriculture

- Climate change can influence agriculture in a number of ways:
  - 1) plants (crop and forage growth and water needs are altered);
  - 2) soil fertility, moisture supply and land competition;
  - 3) performance and carrying capacity of animals and feed supply;
  - 4) water supply for irrigation (availability, run-off, non-agricultural competition);
  - 5) pests (prevalence of insects, weeds and diseases due for instance to lack of a substantial freeze);
  - 6) Fires due to warmer and drier conditions;
  - 7) extreme events, as they influence production conditions, destroy trees or crops, drown livestock and alter water supplies;
  - 8) other effects such as the alteration of market prices due to different regional effects of climate change, alteration in insurance availability and costs and potential migration movements due to hunger and food insecurity (e.g. inundation of agricultural land due to sea-level rise).

Agriculture

- Given the very high level of autonomous adaptation in this sector, as well as the important role that markets and trade will play in transmitting impacts in one geographic region to another, it is necessary to evaluate this sector differently from others. Economy-wide models are essential for the analysis and have been used extensively for this purpose.
- These models can provide estimates of expected changes in value added from agriculture as a result of climate change, taking account of climatic, allocative and terms of trade effects. The aim of adaptation measures could then be to improve the value added to selected groups of individuals (both producers and consumers). An evaluation of such measures necessarily requires working through some such models to see who gains and who loses, after account is taken of market linkages.

Base Case in 2060 With No Climate Change

- Population will go to 10.2bn. from 6.1bn. Today
- Trade in agriculture will be liberalized gradually by 50% by 2020
- There will be moderate world economic growth: 3.0% p.a. now falling to 1.1% p.a. over the period 2040 – 2060.
- Crop yields will increase: 0.7% p.a. for the world, 0.9% p.a. for developing countries and 0.6% p.a. for developed countries.
- Result is cereal production (wheat, rice, maize and soyabean, (~85% of traded grains and legumes) would equal 3,286 mmt (world), 1,149 mmt (developed) and 1,836 mmt (developing). Today (2008) it is around 2,180 mmt, so increase is 50%.
- Cereals price fall in the no CC case after 2020, continuing the trend of last 100 years.
- The impact of climate change is estimated to be in the following range: decline of 1-7% (world), decline of 9-11% (developing) and decline of 3% to possible increase of 11% for developed countries. This is with no adaptation.

Impact of Adaptation in Case of No Mitigation of GHGs

- Two levels of adaptation are considered:
  - Level 1 which has only minor changes in planting dates, additional application of water to crops under irrigation and changes in crop varieties to currently available, better suited varieties.
  - Level 2, large shifts in planting dates, increased fertilizer application, development of new varieties and installation of irrigation systems
- Results are as follows:
  - With level 1 adaptation developed countries production goes up 4-14% over reference case. However, developing countries change little (decline is still 9 to 12%). Global production now remains same as with no CC, or declines by 5%.
  - With level 2 adaptation developed countries production goes up 2-12% over reference case. Developing countries now have a decline in the range of 5 to 6%. Global production now declines by around 1-2% or increases by that amount.

Estimation of Adaptation Costs

- Expenditures required to ensure no loss of income or livelihoods as a result of CC. These may take the form of:
  - Support through irrigation
  - Support through adoption of changed practices
  - Alternative livelihoods.
- We must do this on a dynamic baseline and taking account of autonomous adaptation.
- Expenditures on R&D to develop resilient varieties etc.
- Upper bound is to estimate the damage caused by CC and assume that compensating this will be necessary to ensure no loss of income. But such a cost estimate is not additive to costs of a programme of planned adaptation.

Ecosystems and Biodiversity

- Valuation in monetary terms here is very difficult. Yet impacts of CC are expected to be significant and irreversible in many cases.
- Measures being considered include: increasing connectivity through corridors, mitigating threats from invasive species, fragmentation, translocate species, increase reserves etc.
- The assessment of measures has to be relative to set targets for mitigating impacts of climate change. These targets have to be defined in physical terms and measures have to be judged in terms of the costs of achieving these targets. At the global level targets include:
  - increase in protected areas (10% to meet CC challenges),
  - Number of species conserved as a result of different measures.

Coverage of Sectoral Estimates of Costs & Benefits

Sector	Coverage	Cost estimates	Benefit estimates
Coastal zones	Comprehensive – covers most coastlines	√	√
Agriculture	Comprehensive – covers most crops and growing regions	–	√
Water	Isolated case studies in specific river basins	√	√
Energy (Demand for space cooling and heating)	Primarily North America	√	√
Infrastructure	Cross-cutting issue – covered partly in coastal zones and water resources. Also isolated studies of infrastructure in permafrost areas.	√	–
Health	Very limited	√	–
Tourism	Very limited – winter tourism	√	–

Other Issues

- Cross sectoral impacts (e.g. Sea level rise, ecosystem services) have to be addressed.
- Priorities across sectors may need to be established. (may need Delphic methods)
- Uncertainties will decline over time and we should design measures so that new data can be incorporated to improve the adaptation strategy

	SLR	Freshwater	Extreme Events	Agriculture	Ecosystems	Infra structure
Health	Loss of life and injury, indirect effects (disease outbreaks)	Water resources, levels and quality affecting waterborne diseases	Loss of life and injury, indirect effects (disease outbreaks)	Food availability potentially affecting malnutrition	Provisioning services (fisheries, marine) affecting food availability	Reduced performance or delivery of water supply and sanitation services
SLR		Saltwater intrusion reduced available water in coastal areas	Combined effects of SLR and storm surge – effects across categories	Land-use change and availability for agriculture. Effects on aquaculture	Reduction in coastal ecosystems (mangroves) reducing flood protection	Changes in design and location of coastal infrastructure
Fresh Water			Contamination of water sources from extreme, water quality effects	Changes in water demand for irrigation	Changes in water run-off, water filtration, from changes to ecosystems	Changes in water demand for infrastructure
Eco Systems						Lost protection from ecosystems affecting exposure risk

Examples of Adaptation Options

Sector	Example	No Regret	Reversible	Safety Margins	Reduced Horizon
Agricul-ture	Crop Insurance	+	+		
	Irrigation	+	-	+	
	Short Rotation Forestry	-	-		-
	Resistant Crops	++			
Coastal Zones	Sea Walls	+	-	+	
	Easy to Retrofit Defenses		+	+	+
	Enhanced Drainage Systems	+	-	+	
	Restrictive Land Use Planning	+	+	+	
	Insurance & Warning Schemes	++	+		
	Relocation	-	-		
	Creation of risk analysis	+	+		

Examples of Adaptation Options

Sector	Example	No Regret	Reversible	Safety Margins	Reduced Horizon
Health	Air Conditioning		+		
And	Improved Building Standards	+	-	+	
Housing	R&D on Vector Control	+	-		
	Improvement in public health	++			
Water	Loss Reduction	++			
Resources	Demand Control & Water Reuse	++	+		
	New Reservoirs		-	+	
	Desalination and Water Trans.	+	-	+	
Human	Climate proofing new buildings	+			
Settlement	Climate proofing old buildings	+	-		
	Improve urban infrastructures	+	-	+	
	Early warning systems	++	+		

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QUESTIONS

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