BASE BOTTOM-UP CLIMATE ADAPTATION STRATEGIES FOR EUROPE

Title: **Model catalogue and data exchange plan**

Summary: this deliverable reports the advancements of the work accomplished by WP3 under Sub-Tasks 3.1.1 and 3.1.2. Therefore this deliverable suggests how to identify a common framework in terms of climate and when possible/appropriate impact scenarios for use in the quantitative economic models in WP3 and WP6; defines climate data exchange requirements; critically evaluates the economic modeling frameworks used by BASE research teams identifying where they can be developed and/or consolidated; the need for linkages and gaps between the models; paying particular attention to the disclosure and sharing of the key modeling features. This to build a common understanding of the aggregation level, data needs, units etc. across the models such that an integration strategy of the model work can be agreed upon and its outcomes cross-validated.

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SEVENTH FRAMEWORK PROGRAMME

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Contents

1 Introduction and aims of this document

The final aim of the BASE project is to improve upon the current and still incomplete knowledge on climate change adaptation processes. This requires primarily to enrich the quantitative information on costs and benefits of adaptation strategies/measures, however this also calls for a higher integration, access and use of this information.

This ambitious goal implies, among other things, the development of appropriate methodologies. And, against this background, this deliverable contributes to three specific goals of BASE with a strong methodological content. These are:

Goal 2: Improve current, develop new and integrate methods and tools to assess climate impacts, vulnerability, risks and adaptation policies to stocktake and enrich past and current EU research project outputs.

Goal 4: Assess the effectiveness and full costs and benefits of adaptation strategies to be undertaken at local, regional, and national scales using innovative approaches (mainly by integrating bottom-up knowledge/assessment and top-down dynamics/processes) with particular attention on sectors of high social and economic importance.

Goal 5: Bridge the gap between specific assessments of adaptation measures and top-down implementation of comprehensive and integrated strategies.

Goal 2 will be realized developing in BASE WP3 different modeling tools and approaches to the study of adaptation. At the same time it presents strong interactions with WP6 where the models under WP3 will be applied to accomplish Goal 4, and with WP7 that will ultimately derive policy implications. Indeed the current deliverable shares both methodological considerations and definitions with D6.1. Finally, a key aspect of the work in WP3 and 6 is the integration across the different methodologies and across the modeling work and the analysis developed by BASE case studies. Coupling top-down or partial equilibrium models with large geographical coverage like those in WP3 with insights from case studies will thus allow the fulfillment of Goal 5.

More specifically the current deliverable 3.1 reports the advancements of the work accomplished by WP3 under Sub-Tasks 3.1.1 and 3.1.2.

Sub-Task 3.1.1 aims to identify a common framework in terms of climate and where possible/appropriate impact scenarios for use in the quantitative economic models in WP3 and WP6. It will also provide WP5 case studies with the appropriate downscaling of the climate scenarios. This will ensure a common reference base for comparing efficiency of adaptation policies and measures across sectors, scales and countries. Sub-task 3.1.2 will identify development areas and linkages in quantitative models critically evaluating the economic modeling frameworks to be further developed and tested later in WP3 and to be applied under WP6. The sub-task will identify the areas where the quantitative models will be developed and/or consolidated; it will identify the need for linkages and gaps between these models; pay particular attention to the disclosure and sharing of the key modeling features driving final results and their interpretation to build a common understanding of the aggregation level, data needs, units etc. across the models. This will ensure that an integration strategy of the model work can be agreed upon and its outcomes cross-validated. It is essential that this stage is early in the process to avoid the risk of non-concerted development of different quantitative models at different scales and approaches, so that an integration strategy of the model work can be agreed upon and its outcomes cross-validated.

The aims of this document are accordingly:

- To describe the individual models to be used including:
    - Their hierarchy (framework, incl. relationships)
    - Data needs
    - Where they are used and for what purpose
- To provide a *common grid* for the project on:
    - The use of climate and socio-economic scenarios
    - Definitions (scenarios. Pathways, storylines)
    - Baseline, reference strategies for comparative assessment
    - How to cope with uncertainty in the analysis of case studies and model runs
- To define what WP3 requires and wishes to receive from other WP's
    - List per model what is needed and what is optional but useful

As background, it is worth placing BASE against the recent and ongoing research in the area of climate change impacts and adaptation. A natural precursor of BASE is the FP7 CLIMATECOST project which analysed the cost of long-term mitigation policies and the costs of inaction (the economic effects of climate change) in the EU, but only dealt with the costs and benefits of adaptation to a limited extent. BASE thus complements CLIMATECOST. The links between the two projects are strengthened with respect to the quantitative analysis in BASE relating to the strategic analysis of mitigation and adaptation and the of impacts on agriculture. These quantitative parts apply models also used in CLIMATECOST. Accordingly the two research efforts are directly linked, but the risk of duplications is avoided by using the developments from CLIMATECOST.

The BASE modelling work also connects well with the FP 7 and on-going CLIMSAVE project whose final aim is to develop a user-friendly, interactive web-based tool allowing stakeholders to assess climate change impacts and vulnerabilities for a range of sectors, including agriculture, forests, biodiversity, coasts, water resources and urban development. The quantification of cost effectiveness measures for adaptation conducted in BASE with both top-down and bottom-up approaches can nicely complement CLIMSAVE outputs as well as learn from its communication strategy. Note also that some "impact areas" (e.g. the urban level, agriculture, floods) overlap across the two projects, which can facilitate comparison and cross fertilization. This can be particularly helpful methodologically, as also CLIMSAVE, like BASE, faces the challenge to consistently integrate different scales of investigation.

A third FP7 research project linked with BASE is ToPDAD. It aims to develop state-of-the-art socio-economic methods and tools for an integrated assessment, supporting regional adaptation decision-making in the EU over the 21st century in the sectors of energy, transport, and tourism. ToPDAD is a modeling oriented project, and in addition is covering domains different from those of BASE. In this sense it is a "twin project", that can complement the quantitative assessment of BASE and contribute to widen the informative basis for policy decision making.

In what follows, section 2 introduces WP3 briefly and section 3 describes the main models.

2 Introduction to WP3

In order the fulfil its objectives WP3 proposes to apply different top-down and bottom-up integrated assessment modelling approaches to quantify costs and benefits of adaptation in specific domains – namely: water, agriculture, ecosystems, the urban context and health. Moreover, by adopting a holistic perspective, it investigates complementarity and trade-off between mitigation and adaptation.

Further, WP3 aims at improving existing quantitative tools for a more realistic description of adaptation dynamics.

The specific activities under WP3 are therefore to:

1. Critically evaluate modelling frameworks and contexts currently applied to adaptation;

2. Establish a consolidated quantitative top-down integrated assessment model which builds on previous work but makes some new developments;

3. Establish new developments in quantitative sectoral assessment models (water, agriculture, ecosystems; urban context and health) and their integration into the top-down integrated assessment models; and

4. Develop methodologies to deal with uncertainty and scaling. Uncertainty could be addressed through extensive sensitivity analysis (e.g. related to the scale of climatic impacts, social preferences, different assumptions on adaptation cost and benefits) or through the introduction of stochastic elements.

To guarantee comparability and the possibility to consistently integrate results, all the analyses above will be performed using a common reference climate change scenario. The choice of this common framework and the practical quantification of the associated climatic information (e.g. temperature and precipitation) is also one of the main tasks of WP3.

3 The models in BASE

3.1 Model framework

Within BASE three different type of models are used :

- Economy wide models: describing the consequences of climate change adaptation and mitigation on GDP and other macroeconomic indicators. These types of models describe the interactions within the economy in some detail but are very coarse in spatial resolution. In BASE we use the Ad-Witch model to describe EU-wide economic implications of different climate strategies. On a lower scale we use the IO-model of Univ. Leeds to study cross-sectoral impacts on the regional economy (Urban scale). As input from other models these economy wide models require estimates of damages from climate change and avoided damage and investment costs of climate adaptation.

- Sector models provide the direct (avoided) damages and effects of climate adaptation. Sector models usually have a higher spatial resolution. In BASE we have sector models available for flood and drought damage, health impacts and Environmental flows. As input these models require spatial explicit information on climate effects, its consequences and adaptation measures.

- Decision support tools like PRIMATE, which supports users in assessment of cost and benefits or multi criteria analysis under uncertainty in a multi-stakeholder setting[1].

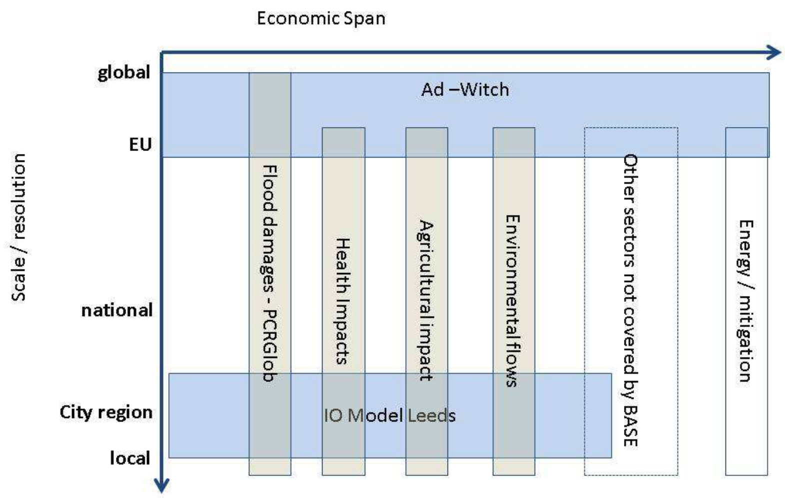


Figure 1 Models within BASE (coloured rectangles) and their relation to each other and scales

As case studies take place at the local to national level there will not be any dataflow from them to the EU scale economy wide model Ad-Witch (see 2.2), which operates only in an aggregated manner. There will be direct data flows, however, to the sectoral models which can help in aggregating data to EU level and thus to Ad-Witch. The following sections describe the models within base as depicted in Figure 1.

3.2 The Ad-Witch model

Aim of the model within BASE

The AD-WITCH model will be developed further within BASE WP3 and applied within BASE WP6. Its aim is to investigate the potential trade off/complementarity between mitigation and adaptation and investigate the implications of this relation. Typical questions are: what is the optimal mix (resources allocated to) between adaptation and mitigation? What is the timing of the two strategies? How are they influenced by social preferences (e.g. discounting), different damages, uncertainty? To do this, costs and benefits of the two strategies, described by reduced-form functions specific to each macro region represented within the model, are contrasted in a dynamic optimization framework. The Ad-WITCH model developments devised within WP3, consist of an improved

[1] PRIMATE will be applied primarily in WP5, where it will be used as a support for decision making on adaptation at the case study level. Nonetheless it has also the potential to assess adaptation options on the large-scale, strategic level and thus in WP6. The description and role of this DSS is thus included in D3.1.

adaptation function (based on more recent data, and potentially on a richer functional specification) and on the introduction of uncertainty.

The work described above, is a natural continuation of the research activity performed within the CLIMATECOST FP7 research project. There, the WITCH model reduced-form climate change damage function was recalibrated using the output from an economic assessment of climate change damages performed with a computable general equilibrium (CGE) model. Inputs to the CGE model were a set of impacts determined by a suite of bottom-up modeling exercises. The rationale for this procedure was to capture in WITCH market adjustments (through prices) and their impacts across different sectors. Accordingly, it could be said that BASE is the completion of CLIMATECOST in the sense that it contributes to the improvement of the “adaptation module” of (AD)-WITCH, allowing the complete re-calibration of the model and, consequently, a brand new analysis based on the best available knowledge.

The work also links well with the FP7 CLIMSAVE project. The top-down strategic assessment of the optimal mix between residual impacts, adaptation and mitigation performed with AD-WITCH can complement/support the more stakeholder bottom-up oriented methodology and results by CLIMSAVE.

Description

AD-WITCH (Bosello et al. 2010, 2013) is an intertemporal, optimal growth model in which forward-looking agents choose the path of investments to maximise a social welfare function subject to a budget constraint. A reduced-form global circulation model links emissions from industrial activities to temperature increase. In turn the temperature increase translates into GDP losses via a reduced-form climate change damage function (Figure 2 left). The model depicts 12 world macro-regions[2] and simulates changes until 2100. It uses a disaggregated representation of the energy system detailed into many energy production technologies.

The model can be solved in two alternative game theoretical settings. The non-cooperative one yields a Nash equilibrium, which does not internalise the environmental externality. The cooperative setting describes a first-best world, in which all externalities are internalised.

More relevant for BASE is the treatment of adaptation. In AD-WITCH, adaptation is modelled as a set of control variables chosen optimally together with all the other controls, namely investments in physical capital, R&D, and energy technologies. The large number of possible adaptive responses has been aggregated into four macro categories: generic and specific adaptive capacity-building, anticipatory and reactive adaptation, organized by a nested sequence of CES functions (Figure 2 **The AD-WITCH model** right). Table 1 summarises the main features of the model.

[2] These are: USA (United States), WEURO (Western Europe), EEURO (Eastern Europe), KOSAU (Korea, South Africa, Australia), CAJANZ (Canada, Japan, New Zealand), TE (Transition Economies), MENA (Middle East and North Africa), SSA (Sub-Saharan Africa), SASIA (South Asia), CHINA (China and Taiwan), EASIA (South East Asia), LACA (Latin America, Mexico and Caribbean). Focus of BASE is the EU. In AD-WITCH WEURO includes: Andorra, Austria, Belgium, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Greenland, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom. EEURO includes: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia

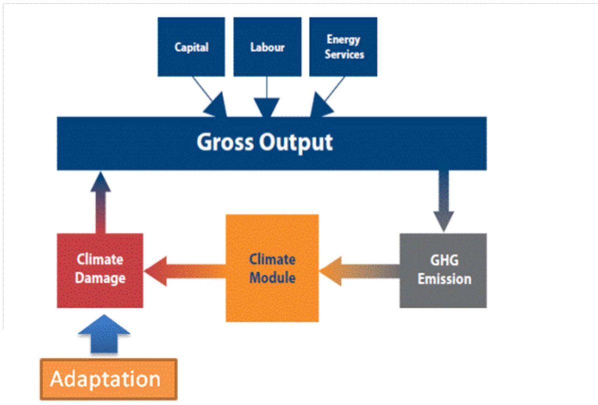
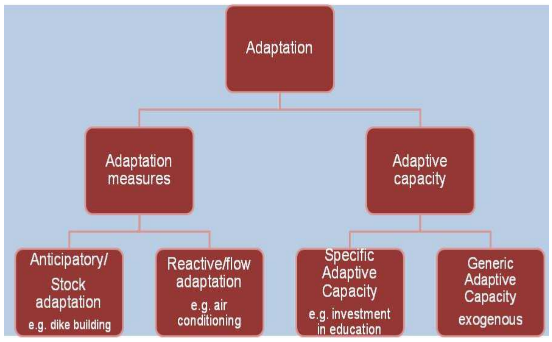
Structure of the AD WITCH model	Adaptation "tree" in the AD-WITCH model
	

Figure 2 The AD-WITCH model

Generic adaptive capacity building captures the link between the status of the development of a region and the final impact of climate change on its economic system. Specific adaptive capacity building accounts for all investments dedicated to facilitate adaptation activities (e.g. improvement of meteorological services, of early warning systems, the development of climate modelling and impact assessment etc.). Anticipatory adaptation gathers all the measures where a stock of defensive capital must already be operational when the damage materialises (e.g. dike building). By contrast, reactive adaptation gathers all actions that are put in place when the climatic impact effectively materialises (e.g. use of air conditioning) to accommodate the damages not avoided by anticipatory adaptation or mitigation.

Table 1. Summary of AD-WITCH model features

Model	Institute	BASE WP	Type	Scenarios /Time scale	Resolution/ scale	Input needed from other partners: type/format	Output:type /format
AD-WITCH	CMCC	WP3, WP6	Top-down IA climate-economic model. Dynamic optimization model	A2 IPCC (can be re-calibrated on different SSPs, until 2100)	12 world macro-region (see footnote 2)	Cost effectiveness of different adaptation measures	Optimal mix (in terms of resource allocation, timing, geographical distribution) between mitigation and adaptation

Data needs and linkages between models within BASE

The AD-WITCH model uses different information to characterize the evolution of the social economic system. The most important are GDP and population growth rates (for their characterization see section 4.3.2), fossil fuel prices, GHG emission levels at the macro-regional level[3]. More relevant for the purpose of BASE is the characterization of cost and effectiveness of adaptation functions. Those currently calibrated into the model are represented in Figure 3.

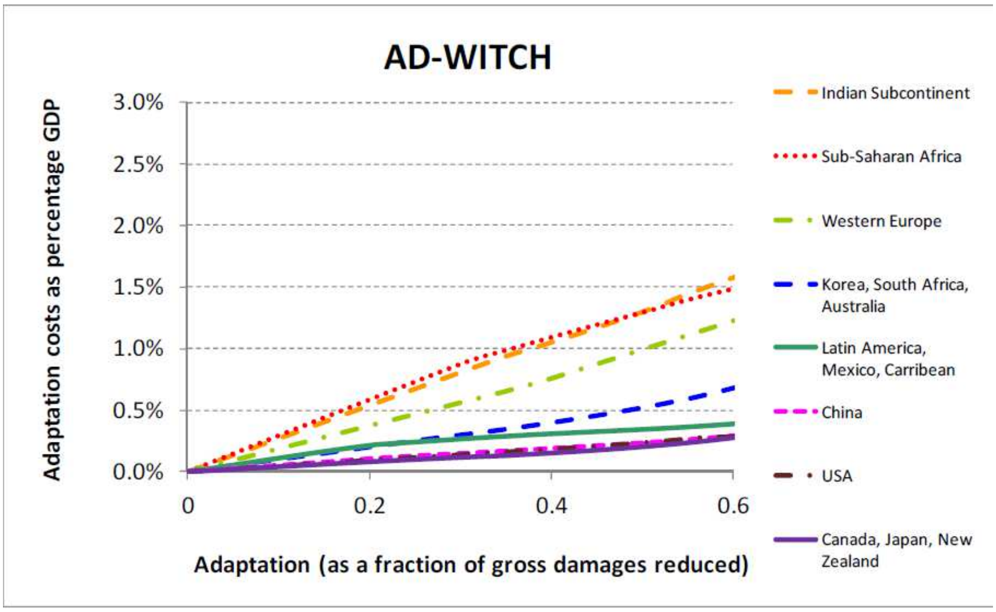


Figure 3 Adaptation cost/effectiveness curves in AD-WITCH

[3] The modeling of the energy-production side is based on detailed information on the investment needed to implement and expand the different generation technologies modeled and of their energy generation capacity.

The present structure uses the functions in Figure 3 which are the net resultant of all the types of adaptation considered by AD-WITCH. The aim within BASE is to improve upon this calibration. To do so it is necessary to gather, for different adaptation types or measures, their cost and effectiveness that will be then aggregated into the AD-WITCH larger adaptation "families" and regions.

As AD-WITCH works with large geo-political aggregates, it is very unlikely that the cases study within BASE, with their site specific features, can provide direct information for the calibration of macro-regional adaptation functions in the model. However sectoral models like Climatecrop (see section 3.4 and 3.5) from UPM, the flood risk model from DELTARES (see section 3.6), as well as the work on health developed by BC3 under BASE WP3, sub task 3.3.3 have the necessary coverage to provide data at the EU level, which can be incorporated into Ad-Witch.

This implies the following steps.

1) Identify the measures, their cost and effectiveness with respect to a specific year or temperature increase (climate change) scenario. While costs need to be expressed in money terms, effectiveness can be expressed by different indicators, e.g. lower money losses, lower number of people affected, lower share of capital or land lost/damaged etc. To give an example, the information can be the following: by spending x$ in coastal protection in region 1 y% of economic losses (or land losses or of people affected) can be avoided in the case of a temperature increase of 2°C.

2) Data on cost and effectiveness of adaptation do not always match the regional resolution of the model. For instance the sectoral models described in section 3.5 are grid-based. This requires therefore upscaling/making consistent this information at a regional detail consistent with AD-WITCH

3) Grouping of different measures into anticipatory and reactive adaptation and adaptive capacity building.

The data needed from BASE partners are thus those related to the first step.

More specifically, Table 2 reports the adaptation measures considered in the AD-WITCH model (together with the reference literature on respective cost and effectiveness) which allowed the calibration of the adaptation functions represented in Figure 3. Table 3 reports the present estimates of adaptation cost and effectiveness used in AD-WITCH and for those sectors also considered within the BASE project, Table 4 reports the information needed to improve upon the current calibration.

Table 2. Adaptation activities whose cost and effectiveness allowed the calibration of adaptation functions in AD-WITCH

Proactive adaptation measures → Modelled as "stock" variable*
✓ Coastal Protection Activities. **Costs:** DIVA model **Effectiveness:** DIVA model ✓ Settlements, Other Infrastructures (Excluding Water) and Ecosystem Protection Activities **Costs:** Nordhaus and Boyer (2000), **Effectiveness:** Nordhaus and Boyer (2000) ✓ Irrigation **Costs**, Kirshen (2007) **Effectiveness** Tan and Shibasaky (2003), Parry et al (2009)
Reactive adaptation measures → Modelled as "flow" variable*
✓ Agricultural Adaptation Practices. **Costs:** Tan and Shibasaky (2003), Parry et al. (2009) **Effectiveness:** Tan and Shibasaki (2003),EEA (2007), Kirshen et al. (2006) ✓ Treatment of Climate-Related Diseases **Costs**, Tol and Dowlatabady (2001) **Effectiveness:** WHO (2008), Nordhaus and Boyer (2000) ✓ Space Heating and Cooling Expenditure. **Costs:** Tol (2002a, 2002b), Bigano et al. (2006), De Cianet al. (2007). **Effectiveness:** Ad hoc assumptions
Generic adaptive capacity → Modelled as an exogenous trend*
✓ Exogenous trend increasing at the rate of total factor productivity
Investment in specific adaptive capacity → Modelled as a "stock" variable*
✓ Investments in specific capacity set to be 1% of world expenditure on education and total R&D in the calibration year. Allocated to regions proportionally to the normalised share of education expenditure over GDP

Source: Bosello et al., (2013)

Note: * Each measure or group of measures has been defined for the 12 AD-WITCH regions. The calibration point for data gathering is related to a 2.5°C temperature increase (or doubling of CO_2 concentration) scenario which in the model occurs in 2070. The 2005-2070 trends in adaptation expenditure are then determined endogenously by the model

Table 3: Adaptation costs and effectiveness, for a doubling of CO_2 concentration. Base for the calibration in the AD-WITCH model

	Water in Agric. (irrigation) (Billion $)	Water in Other Vulnerable Markets (Billion $)	Early Warning Systems (Million $)	Coastal Protection (Billion $)	Settl.mnts (Billion $)	Cooling Expenditure (Billion $)	Disease Treatment Costs (Billion $)	Adapt. R&D (Billion $)	TOTAL (Billion $)	TOTAL (% of GDP)	Effectiveness of adaptation (% of damage reduced)
USA	3.0	1.3	5	3.57	22.1	3.9	1.13	2.92	37.9	0.09	0.18
WEURO	4.7	2.0	5	5.03	56.2	-8.8	-0.68	2.44	60.9	0.18	0.13
EEURO	7.4	3.2	5	0.26	3.2	-0.8	-0.06	0.03	13.2	0.37	0.30
KOSAU	5.9	2.5	5	1.77	5.2	7.7	1.86	0.29	25.3	0.48	0.16
CAJAZ	1.6	0.7	5	2.87	9.8	-7.8	3.02	1.66	11.8	0.09	0.20
TE	10.1	4.3	5	1.66	3.2	0.6	0.13	0.06	20.1	0.28	0.12
MENA	50.7	21.7	5	1.24	3.9	18.6	2.12	0.14	98.5	1.06	0.34
SSA	13.4	5.7	5	2.68	3.9	10.4	0.51	0.01	36.6	0.70	0.21
SASIA	17.0	7.3	5	1.28	19.7	50.7	1.10	0.04	97.1	0.49	0.19
CHINA	3.0	1.3	5	1.26	17.2	45.5	0.29	0.16	68.6	0.20	0.15
EASIA	1.3	0.5	5	4.26	3.9	25.9	4.74	0.04	40.7	0.40	0.18
LACA	4.3	1.8	5	7.75	5.9	2.0	5.72	0.07	27.7	0.13	0.38

Source: Adapted from Bosello et al., (2013)

Table 4: information needed to improve the calibration of cost effectiveness of adaptation in the AD-WITCH model*

	Adaptation measures**					
WEURO (Western Europe),	**Cost of adaptation in Agriculture (through cooperation with UPM and info from the crop model)**: Cost of measures (in absolute value or in % of region GDP) to totally or partially offset negative climate change impacts on crop yields consistent with RCP 4.5 and RCP 8.5. This has to be possibly referenced to different temperature levels. In addition ranges of values (max-min costs) could be important to perform sensitivity analyses and see implications of uncertainty	**Effectiveness of adaptation in agriculture (through cooperation with UPM and info from the crop model)**: % of yield loss that can be avoided applying the chosen mix of adaptation measures. Consistently with the cost section, this has to be possibly referenced to different temperature levels. In addition ranges of values (max-min effectiveness) could be important to perform sensitivity analyses and see implications of uncertainty	**Cost of adaptation in the health sector: (through cooperation with BC3):** Cost of measures (in absolute value or in % of region GDP) to totally or partially offset negative climate change impacts (additional mortality morbidity) of heath related diseases consistent with RCP 4.5 and RCP 8.5. This has to be possibly referenced to different temperature levels In addition ranges of values (max-min costs) could be important to perform sensitivity analyses and model uncertainty	**Effectiveness of adaptation in the heath sector (through cooperation with BC3):** Decreased mortality morbidity (%) that can be accomplished applying the chosen mix of adaptation measures. Consistently with the cost section, this has to be possibly referenced to different temperature levels. In addition ranges of values (max-min effectiveness) could be important to perform sensitivity analyses and model uncertainty	**Cost of adaptation in flood risk prevention (through cooperation with DELTARES and info from the flood risk model):** Cost of measures (in absolute value or in % of region GDP) to totally or partially reduce additional climate change impacts on flood risk consistent with RCP 4.5 and RCP 8.5. This has to be possibly referenced to different temperature levels. In addition ranges of values (max-min costs) could be important to perform sensitivity analyses and model uncertainty	**Effectiveness of adaptation in flood risk prevention (through cooperation with DELTARES and info from the flood risk model):** % of risk reduction (or of damage reduction) that can be accomplished applying the chosen mix of adaptation measures. Consistently with the cost section, this has to be possibly referenced to different temperature levels. In addition ranges of values (max-min effectiveness) could be important to perform sensitivity analyses and model uncertainty
EEURO (Eastern Europe)	As above	As above	As above	As above	As above	As above

*If information were available for other AD-WITCH regions, these could be easily incorporated. Anyway CMCC is performing an independent re-calibration of the model adaptation functions.

**Information on cost and effectiveness of adaptation in the water sector could be available from the hydrological model developed by UPM.

3.3 The IO model to upscale Urban adaptation

Inter-industry input-output analysis can be used in risk analysis and adaptation of climate extreme events because of their ability to reflect the structure of a regional economy in detail and to trace economic interdependence between the regions by calculating indirect effects of disruptions. Disasters can cause physical destruction to built-environment and networks, such as transportation and lifelines, and these damages are called direct losses. Direct losses then lead to interruptions of economic activities, production and/or consumption, and the losses from business interruptions are often called the indirect effects of disaster. Those indirect effects can cascade through the inter-linkage regional and national supply chains. In other words, an effective adaptation measure is implemented at local level, which not only avoids damage to local physical assets and infrastructure, but also protects the disruptions of supply chains. Such benefits can be upscaled beyond impact local to other economic sectors in the city as well as to national and international level.

Aim of the model

Analysis of the urban economy is central to understanding the broad costs and benefits of climate change adaptation. Assessments of the adaptation measures on cities have traditionally been based on on-site and local level of cost-benefit analysis. Since economies are connected, either the costs or the benefits of implementing adaptation measures can be amplified, but also smoothed throughout the wider economic systems (regional/ national/global).

The aims of the input-output model are three-fold

- Adapt the city scale Adaptive Regional Input-Output Model (ARIO) to quantify cost-benefits of adaptation measures for case study cities from a macroeconomic perspective. This will be implemented in WP6
- Linking the city scale ARIO models with national input-output tables (for each case study city) to estimate the cost and benefit of implementing local adaptation measures to the national economy
- Further integrate the national scale ARIO model with the World Input-Output Database (WIOD) to estimate the cost and benefit of implementing local adaptation measures to the EU and other countries' economies.

Method review of macro-economic valuation in risk and adaptation

The following are the most used modelling approaches in disasters impact analysis, their principal advantages and weaknesses.

<u>Input Output model</u>

The Input Output (IO) model, first developed by Wassily Leontief in the 1930's and based in the idea of the circular flow of the economy, presents the complex transactions in an economy in a transparent and simple way. Its main advantages are the possibility of managing the interconnectedness among sectors, agents and regions and make it compatible with engineering models (Cole, 2003; Greenberg et al., 2007; Li et al., 2013; Miller and Blair, 1985; Okuyama, 2009; Rose, 1995, 2004). The information in the model takes into consideration all the production inputs

(Rose, 1995) and is treated in value terms but is sensible to physical changes (Greenberg et al., 2007; Okuyama, 2007). The production technology is implicit in the model (Cole, 2003; Rose, 1995).

Its characteristics make it well-suitable for risk analysis through the use of IO multipliers (Cole, 2003; Okuyama, 2009; Rose, 1995) and can provide distributional analysis (Okuyama, 2009; Rose, 2004). Beyond its rigidities, the adaptability of the model is reflected in extended models that overcome some of the initial disadvantages, mainly in temporal and multiregional directions (Cole, 2003; Okuyama, 2007; Rose, 1995; van der Veen, 2004).

On the other hand, the suitability of the IO model for risk analysis has been criticized for its main constraints. In its basic development it is a static model, based on linear relationships; it also presents rigidity in prices and in input and import substitutions (Cole, 2003; Greenberg et al., 2007; Okuyama, 2007, 2009; Rose, 2004). It is essentially a demand-driven model and does not consider changes in consumer behaviour which make it difficult to take into account changes in productive capacity (Cochrane, 2004; Li et al., 2013).

Computable General Equilibrium (CGE)

Another methodology that has become greatly used in recent decades in this field is the Computable General Equilibrium (CGE) model. Some researchers see this model as an improvement to the IO model, mainly regarding the manageability of supply constraints, price changes, non-linearity, and flexibility in input and import substitutions and maintaining distributional considerations in the analysis (Cochrane, 2004; Okuyama, 2007, 2009; Rose, 2004). The CGE model also deals well with regional effects of an external shock. The treatability of behavioural changes allows the explicit consideration of resilience (Greenberg et al., 2007; Rose, 1995, 2004; van der Veen, 2004).

The main weaknesses of the CGE model are related to the characteristics of natural disaster impacts. This kind of model considers the economy in equilibrium at each step, while it has been argued that after a disaster, imbalances in the economy are present and most of the time persistent[4]. Additionally, the behaviour of agents is not always optimal in these situations (Greenberg et al., 2007; Okuyama, 2007, 2009; Rose, 1995, 2004; van der Veen, 2004). Other weakness in the model is that relevant parameters are user-calibrated (Cochrane, 2004; Greenberg et al., 2007; Rose, 2004). In general terms, CGE estimations are seen as overoptimistic, underestimating total impacts of a natural disaster (Li et al., 2013; Okuyama, 2007).

Econometric models

The main strengths of these models are their rigorous statistical foundations, which make them suitable for forecasting. The time-series data used in these models allows for counterfactual analysis as well as uncertainty incorporation (Cochrane, 2004; Greenberg et al., 2007; Hallegatte and Przyluski, 2010; Li et al., 2013; Okuyama, 2007, 2009).

Despite their advantages, econometric models seem ill-suited for climate impact analysis as their data set does not normally contain information on past climate-related disasters. Additionally, they are usually national scale designed, which make it difficult to use them either for more spatially resolved or macro-regional analysis (Cochrane,

[4] In fact many CGE models do incorporate disequilibrium through market power (imperfect competition) usually in energy markets or neoclassical or involuntary unemployment in the labour market. Nonetheless what we are referring to are those unbalances, persisting mismatches between demand and supply, created by an adverse extreme weather event.

2004; Greenberg et al., 2007; Li et al., 2013; Okuyama, 2007, 2009). Finally they are ill suited to disentangle direct costs from indirect effects on the macroeconomic context (Okuyama, 2007, 2009)

In summary, IO and CGE models have been the most used in risk impact analysis. Estimations from the former are usually seen as the upper bound estimation, while estimations from the latter are usually taken as the lower bound or an optimistic estimation (Okuyama, 2007, 2009; Rose, 2004). However, in practice IO models and extensions have been more widely used in impact analysis (Cole, 2003; Li et al., 2013; Okuyama, 2007; Rose, 2004), mainly due the strengths of the IO model –and extensions- make it suitable to deal with the different aspects involved in the assessment of the economic impact of a natural disaster, i.e. its simplicity and transparency in results, and the manageability of demand change, interconnectedness, affected regions, economy disequilibrium, products substitution, supply-bottlenecks, and recovery length (Cole, 2003; Okuyama, 2007, 2009; Rose, 2004; van der Veen, 2004). Additionally, the potential of IO model promises future developments to improve the accuracy of the natural disaster economic impact analysis (Okuyama, 2007, 2009; Rose, 2004; van der Veen, 2004).

A variant of the Adaptive Regional Input-Output model (ARIO) will be developed to explore the vulnerability of city economy to climatic change induced extreme events (i.e. flood / drought) and quantify the cost-benefit of adaptation measures implementation. The ARIO model will be adjusted for each case study cites according to the features of the city and nature of extreme events that can potentially attack the city.

A city level ARIO will be constructed in the following steps:

- Review of cost-benefit analysis definition in climate change adaptation context.
- Quantify direct cost-benefit of adaptation measures:
    - Marginal abatement cost analysis evaluates the cost of any adaptation measures
    - Event Accounting Matrix (EAM) will be developed to specify initial damage of potential extreme events to case study cities without adaptation measures. The EAM consists of a set of damage functions at the scale of case study regions including direct damages and business interruption. Information on recovery costs after damaging events will be compiled. The physical damage can be seen as ‘direct benefits’ of adaptation measures.
- Measure indirect cost-benefit:
    - Estimate economic cost/benefit triggered by investments in constructing adaptation infrastructures and other spending

Quantify indirect cost/benefit by integrating EAM (damage functions) into the ARIO models. Such cascading impacts can be seen as ‘indirect benefit’ of adaptation measures. The cascading impacts can be measured at city/national/global (e.g. EU) levels.

Data needs and linkages with other models/cases study within BASE

There are two level of data required to upscale the benefit of adaptation in avoiding economic impacts triggered by climate extreme events. The paragraph below summarizes the data needed for the I/O model. The list is indicative. Probably not all the data required will be available from the urban case studies within BASE. When this is the case missing information will be retrieved from other sources which are also reported in Table 5, **Error! Reference source not found.** and Table 6.

Data for evaluation of direct disaster effects

The evaluation of direct physical damages will form the event damage function, which will act as input to estimate the cascaded effects throughout the national and international supply chain.

For each climate disaster various direct effects occur. These can be of physical, economic and social nature. These indicators should be quantifiable. The tables below present examples of such quantifiable direct effects for each type of weather events. When we conduct a selective of case studies by using the ARIO method, we will re-visit this table to produce a case specific direct effects to the study region.

Table 5: data needs for the quantification of direct physical damages (example)

Natural hazard X Type of effect	Type of indicator	Examples of data indicators
Physical	Buildings	Residential buildings and offices
	Transport infrastructure	Roads, rails and ports
	Energy infrastructure	Electricity lines and power plants
Economic	Agriculture	Damage to crops by type of crop and cattle
	Tourism	Loss of tourism
	Firms	Loss of capital stock
Social	Fatalities	Number of fatalities
	Public health	Number of affected people / hospital admissions
	Migration	Change of population composition

For detailed data on damages due to climate disasters, data from the reinsurance company Munich Re (NatCatService) can be used. The database is based on over 200 sources worldwide, including news agencies, insurance companies, international agencies (UN, EU, Red Cross, etc.), scientific sources and weather and warning services. It keeps track of all loss events concerning natural hazards that have resulted in material or human losses. The damage cost of the event is based on costs provided by the insurance industry which are used to estimate overall economics costs.

Data for evaluation of indirect effects

Besides the data related to the direct damages from the extreme events we also need to collect the data for evaluation of indirect effects using our adaptive input-output models.

The next table offers an initial overview of the types of data needs for the quantification indirect damages and losses triggered by extreme events. When we conduct a selective of case studies by using the ARIO method, we will re-visit the data availability (e.g. city level input-output table and trade statistics) in case study region which can be used to assess impact cascading effect.

Table 6 Overview of data needs for the quantification of indirect damages related to the extreme events

	Data indicators	Possible sectoral detail	Possible database
City level	Employment, value added, turnover etc.	NACE 2-digit	Eurostat SBS
	City input output tables	Various depending on country level IO sectoral details	RAEM-EU database
	Export and import of cities	4 transport modes statisics	ETIS-Plus
National / EU level	National supply and use tables	200 commodities and 160 sectors	EXIOBASE
	Employment, value added, turnover etc.	NACE 4-digit 130 sectors	Eurostat SBS
	Inter-country trade statistics	30 sectors	World Input-Output Database
	Gross fixed capital formation	NACE 2-digit and type of asset	Eurostat National Accounts
	Changes in stock		Eurostat National Accounts
	Producer prices	NACE 4-digit	Eurostat short term business statistics
	Consumer prices	COICOP 4-digit	Eurostat

The data needed for the evaluation of indirect effects includes the data necessary for the construction of the modelling tools themselves including for example IO tables from EXIOBASE (200 commodities and 164 sectors) data on inter-regional transport and trade flows from ETIS-Plus project and regional level data from SBS of EuroStat.

3.4 Modelling agriculture

Aim of the model

With this modelling activity we will assess the land productivity changes resulting from different climate scenarios and multiple adaptation pathways. We will develop adaptation scenarios in four dimensions: Local to National and private to public. We will incorporate the local adaptation measures selected in the case-studies. The output will be changes in agricultural productivity maps which can be aggregated to one value in the different EU-27 countries as requested by Ad-Witch.

If requested, the agricultural productivity maps can be made available to the case-study partners.

Description

- ***Crop productivity modelling:*** UPM will focus on the analysis of climate change impacts on EU-27 using the global scale agricultural model Climate-Crop (1300 sites) and a subsequent interpolating at the country scale.
- ***Climate scenarios:*** The agricultural model will be run for a set of climate scenarios (ideally CMIP5, (need to check for availability) otherwise CMIP3) for the time-horizon 2100. To incorporate uncertainty multiple GCMs will be considered with two extreme scenarios: nearly no change and large change (A1B and B1). All will be down-scaled with the EU WATCH dataset.
- ***Adaptation pathways:*** Adaptation strategies and measures will be collected from those case-studies focussing on agriculture. The adaptation measures will be aggregated and integrated in the European model to assess potential benefits under different climate scenarios. A Cost Benefit analysis of different adaptation options could be assessed in different case studies. A policy analysis of tradeoffs between adaptation (1 or 2 adaptation policy scenarios) and mitigation could be developed at the EU-27 level.
- ***End-product:*** The results will be European agricultural productivity maps for different climate scenarios and adaptation paths. These will be aggregated to two overall values of productivity changes: changes in nitrogen leaching (diffuse pollution), and changes in irrigation demands. The irrigation component will be linked to the water availability modelling. The final set of maps will be adjusted as required by Ad-Witch.

Data needs and linkages with other models/cases study within BASE

Adaptation measures from the case-studies will be aggregated and integrated in the European scale model therefore the following information is needed:

- Overview of local adaptation pathways + individual adaptation measures;
- Estimated implementation costs of adaptation measures;
- Estimated economic climate extreme loss for current climate and future climate for different adaptation strategies;

- Reference period, scenarios and time-horizon considered;

3.5 Modelling water availability

Aim of the model

With this modelling activity we will assess water availability resulting from different climate scenarios and multiple adaptation pathways. We will incorporate the local adaptation measures selected in the case-studies. The output will be water availability maps which can be aggregated to one value at the river basin scale and to one value at the EU-27 countries scale as requested by Ad-Witch.

If requested water availability maps can be made available to the case-study partners.

Description

- ***Water availability modelling:*** UPM will calculate water availability under climate change on river basins using the European scale WAPA model (460 subbasins). The Water Availability and Policy Assessment model (WAPA, Garrote et al., 2011) links water supply, demand and management and is used to analyse policy options. The model computes water availability and reliability as a result of implementing climate or policy scenarios. WAPA is used to compute water availability and demand-reliability curves, which provide a simple way to evaluate water availability under different policy and climate change scenarios. The model has been applied to evaluate economic decisions of drought policy and water policy in the Mediterranean. Here it will be extended to the EU27-wide area.

- ***Climate scenarios:*** The hydrological model and flood routine model will be run for a set of climate scenarios (ideally CMIP5, (need to check for availability) otherwise CMIP3) for the time-horizon 2100. To incorporate uncertainty multiple GCMs will be considered and two extreme scenarios: nearly no change and large change (A1B and B1). All will be down-scaled with the EU WATCH dataset.

- ***Adaptation pathways:*** Adaptation strategies and measures will be collected from those case-studies focussing on water resources. The adaptation measures will be aggregated and integrated in the European model to assess potential benefits (water for environmental flow requirements) under different climate scenarios.

- ***End-product:*** The results will be European water availability maps for different climate scenarios and adaptation paths. These will be aggregated to several overall values of water availability changes: for agriculture, for domestic use and environmental flow requirements. The final set of maps will be adjusted as required by Ad-Witch.

Data needs and linkages with other models/cases study within BASE

For adaptation measures from the case-studies to be aggregated and integrated into the European scale model following information is needed:

- Overview of local adaptation pathways + individual adaptation measures;
- Estimated implementation- and environmental costs of adaptation measures;
- Estimated economic climate extreme loss for current climate and future climate for different adaptation strategies;
- Reference period, scenarios and time-horizon considered;

3.6 Modelling hydrology and flood risks across Europe

Aim of the model

With this modelling activity we will assess the impacts resulting from river floods under different climate change scenarios and multiple adaptation pathways. Impacts and risks will be estimated using a European scale model. The case studies will be used to compare the results of the European model and local models, in order to improve the European model, and better understand differences and uncertainties, and their causes, in flood risk estimates at the European and national/local scales. This will allow BASE to draw conclusions on the quality and value of the models, for applications and decisions. We will also consider whether it is possible to incorporate local adaptation measures selected in case-studies. The output will be flood damage maps which can be aggregated to one economic loss value for northern and one value for southern Europe as requested by AD-WITCH.

Flood inundation maps can be made available to the case-study partners on request, in the required extent and format.

Description

The modelling framework is built up of four main components , centred around hydrology the hazard (flood event), and risk (combination of hazard and exposure, resulting in potential impacts) (Figure 4):

1. Hydrological assessment (hydrology, and routing);
2. Flood hazard mapping;
3. Impact assessment to determine flood risk, using local exposure and vulnerability data;
4. Flood risk assessment.

Also indicated is the exchange of data and comparison of information with local case studies; using local flood hazard and where possible flood impact information. Data exchange is not limited to information on river flooding; also information on low flows will be provided, as the model can also provide information on other hydrological changes in. The latter is particularly useful for studying drought impacts in the different case studies.

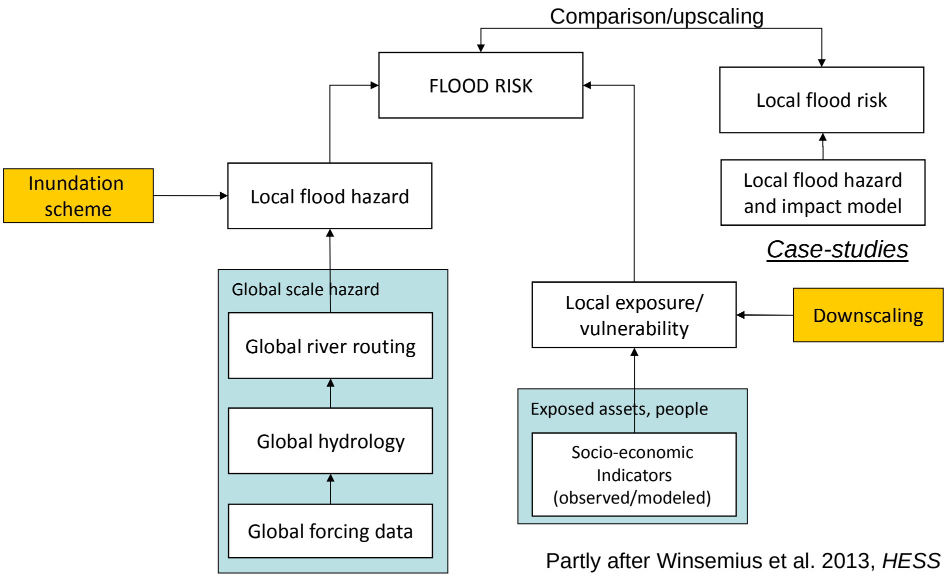


Figure 4: Set-up of the hydrological and impact modelling framework

Using the flood hazard maps, an assessment will be made of flood impacts. Using basic datasets on population distribution in Europe,

- ***Hydrological modelling:*** The hydrological assessment involves the assessment of the water balance for the entire Europe through a hydrological model at the global scale (Winsemius et al., 2013). Deltares will focus on the analysis of climate change impacts on river flood risk using the European scale hydrological model PCR-GLOBWB (0.5 degrees resolution). The output of the model is fed into a routing scheme, to account for river flow accumulation. Using an inundation scheme these outputs can be used to map the flood hazard, at a scale of 1x1 km. Note that the hydrological model outputs can also be used to construct other datasets, such as low flows, or annual total runoff etc., to be used in the case studies.

- ***Flood hazard maps:*** Flood maps will be produced on a resolution of 90x90m, in order to provide meaningful information for case study applications. These maps will be provided for different estimated return periods. Also, this information will used in the application of the impact model.

- ***Impact model:*** The flood hazard maps at 90m resolution are used to calculate impacts. These impacts consist of a number of metrics, including:
    - Area and economic activity (e.g. via GDP) affected, based on outline of the extent of flooded area for country, region or case study area;

- Number of people affected, based on intersection of population data for baseline and scenarios intersected with the flood extent maps.
- Expected monetary losses for several land-use types/economic sectors. Using information on land-use and/or exposed assets and depth-damage functions, estimates of direct monetary losses will be made for several different land-use, object and sector types.

A number of steps will be carried out as part of WP6, in order to arrive at the required coupling of models and output datasets.

- ***Climate scenarios:*** The hydrological model and flood routine model will be run for a set of climate scenarios (ideally CMIP5, (need to check for availability) otherwise CMIP3) for the time-horizon 2100. To incorporate uncertainty multiple GCMs will be considered and two extreme scenarios: nearly no change and large change (A1B and B1). All will be down-scaled with the EU WATCH dataset.
- ***Projections of socio-economic change*** (see also sections 4.3 below)***:*** Scenarios will be applied for changes in population; economic growth (both based on IPCC Shared Socio-Economic Pathway (SSP) scenario's). We will apply here SSPs 2 and 5. As SSP and RCP scenarios are independent, different sets of SSP and RCP climate projection scenario's combination are possible, resulting in low, medium and high projected impacts; see matrix below.

	RCP 4.5	RCP 8.5
SSP5	Medium impact	High impact
SSP2	Low impact	Medium impact

- ***Adaptation pathways:*** Adaptation strategies and measures will be collected from those case-studies focussing on floods (see below). The adaptation measures will be aggregated and integrated in the European model to assess potential costs of adaptation, as well as monetary and non-monetary benefits under different climate and socio-economic scenarios.

- ***End-product:*** The results will be European flood and economic loss information, including maps, for different climate scenarios and adaptation paths. These will be aggregated to two overall values of economic costs and benefits resulting from flood risk; one for southern and one for northern Europe as required by AD-WITCH. Also, we will provide monthly flow data, to be used in other models, such as the water availability model WAPA (see above).

Data needs and linkages with other models/cases study within BASE

The European flood risk model, that includes estimates for flood risk, that is developed for top-down assessment as described above, is a stand-alone model, which produces flood risk estimates for entire Europe. Below, we describe the links in two directions between the case studies and the European model. Second, we describe the case studies we intend to cooperate closely with, and provide information on the anticipated information exchange.

The data exchange and interaction with some of the case studies will be an iterative process, where hypotheses on for instance effectiveness of certain adaptation measures will be tested at the two levels (case study and European levels).

Further data and information exchange between the hydrological model, other sectoral models developed in WP3, and the economic model AD-WITCH will be described below as well.

Data and information exchange: from the European flood risk model to the case studies

For the case studies, we can provide, up to a certain return period:

1) Flood hazard maps (inundation depth and extent);
2) Area affected;
3) Number of people affected;
4) Expected monetary losses for several land-use types/economic sectors;
5) Avoided losses and residual losses after flood protection measures (adaptation).

This information can be varied according to different scenarios for:

- Climate change: four RCP scenarios; basis information as agreed is provided for RCPs 4.0 and 8.5;
- Population change and economic growth according to SSPs 2 and 5.

Data and information exchange: from the case studies to the European flood risk model

For this analysis in first instance we do not require information from the case studies. However, we foresee three types of linking with the case studies. The first concerns the feeding of local information into the European flood risk model, the second is a comparison with other national/local studies, and the third concerns the adaptation plans developed in the cases, to inform the European level adaptation strategies.

1) Exchange and comparison of outcomes from the top-down model, to local/regional models, by using

   a. Local flood hazard maps: this information can be used as validation material for the European flood risk model.

   b. National flood hazard maps; developed for the European Commission, as part of the requirements under the EU Floods Directive.

   c. Flood risk (economic or other impacts) estimated on the basis of hazard maps and exposed people and assets; coming from previous studies carried out by the BASE project partners, or form other local or national studies.

2) Exchange and incorporation of local information and datasets from the case study on: Exposed assets: geographical information on location and value of exposed assets, such as population, buildings, infrastructure, agriculture, and other economic activities. These data can be used to make a second analysis of impacts, and to compare differences between the European-wide and local impact assessments.

3) Exchange of adaptation plans developed in the cases, to inform the European level adaptation strategies. This includes the analysis and possibly the extension of locally developed adaptation plans to other European areas. Adaptation measures from the case-studies will be aggregated and integrated in the European scale model therefore the following information is needed:

   a. Overview of local adaptation pathways and individual adaptation measures;

   b. Estimated implementation costs of adaptation measures, both at the case study level (where information is available. In addition, review of material available at the national level would be very worthwhile as well;

   c. The reference period, scenarios and time-horizon considered;

The case studies identified which we intend to work with are identified in the table below, and the information exchange is summarised.

Table 7. Links between hydrological model and case studies

Country	Case name	Team	Zone	Impact	Data and information from hydro model to case	Data and information from case to hydro model
Germany	Jena	UFZ	River basin/city	Flooding	Flood inundation maps; monetary losses; people affected	Flood extent maps for different return periods; information on potential flood impacts (monetised)
Finland	Kalajoki river	SYKE	River basin	Flooding	Flood inundation maps; monetary losses; people affected	Flood extent maps for different return periods; information on potential flood impacts (monetised)
Spain, Portugal	Tagus river	UPM	River basin	Water scarcity	Flow timeseries (including low flow)	To be defined
Czech Republic	Prague	CVGZ	City	Flooding	Flood inundation maps; monetary losses; people affected	To be defined
Spain	Bilbao, Zaragoza (tbc)	BC3	River basin	Flooding	Flood inundation maps; monetary losses; people affected	To be defined
Vietnam	Mekong	Deltares	River basin	Flooding	Flood inundation maps; monetary losses; people affected	To be defined

Data and information exchange from the Flood Risk model to AD-WITCH

From the top-down flood risk assessment, we are able to provide the following information to the AD-WITCH model, on impact costs and adaptation costs:

1) Impact costs: What we can provide, however, is information on expected annual flood losses, under different climate change scenario's (in fact all 4 RCP scenario's), as well as residual and avoided losses when adaptation (flood risk reduction/ adaptation) is implemented.

2) Adaptation costs: the top-down flood risk assessment with also consider adaptation responses, in particular flood risk reduction measures. These will consist of flood prevention, such as dike systems, but may also include retention (flood wave reduction), but also local measures such as adjusted building codes for flood damage reduction (to be further developed in D3.4). The costing aspect of these measures at the European scale will be a challenge. Some rules of thumb however, and costing information available from The Netherlands and other countries, can serve as a basis. We can assess costs of dike development for instance. But for the rest this costing information is likely to be rather limited.

3.7 Modelling environmental flows

Aim of the model

The aim of the model is to assess for different scenarios (and strategies) the resulting alteration in river hydrological regime. Time series of simulation results will be further processed into ecologically-relevant flow statistics.

Description

Key is the post-processing of flow time series. Different possibilities for this post-processing are available based on previous research, and can be further adjusted to specific project needs.

At the case level, more specific assessment can be made of main ecosystem features and services and the major flow parameters relevant for these features and services.

Data needs and linkages with other models/cases study within BASE

The main data needs consist of multiyear time series of discharges for a reference situation and the situation under different scenarios and strategies. At the case level, data on ecosystem services and species, their requirements with respect to discharge, or monitoring data for different hydrological situations would be nice to have.

3.8 Estimating health risks across Europe

Aim of the approach

The approach to modelling at European/broader global level for health is to improve on existing coverage of the adaptation cost curve within the AD-WITCH model. This will enable better outcomes in terms of policy analysis, while the outputs may also be used as inputs for case studies involving health in WP4/5. The latter will be the case for studies where there is no investigation of the impact of climate change using e.g. historical analogues or statistical methods to isolate the location specific impact of changes in climate risk.

Description

Optimising the level of adaptation for health requires knowledge on the shape of the total health impact cost, which is a balance between residual damages and the cost of adaptation. The Figure below gives a simplified overview, with some illustrative interventions. The objective is to minimise total health impact costs. However, there are a number of issues that need to be faced in developing appropriate adaptation policy for health. These include:

- Uncertainty over the climate change impact, and hence uncertainty over the damages (and residual damages) to health;
- Uncertainty over the future health adaptation costs – with learning likely to make costs in the future lower;
- The crucial role of discounting – as shown by the Stern report and others, discounting has a major role to play in the appropriate definition of policy; and
- The influence of non-climate change related drivers for future health (e.g. demographic change, pollution, health care systems).

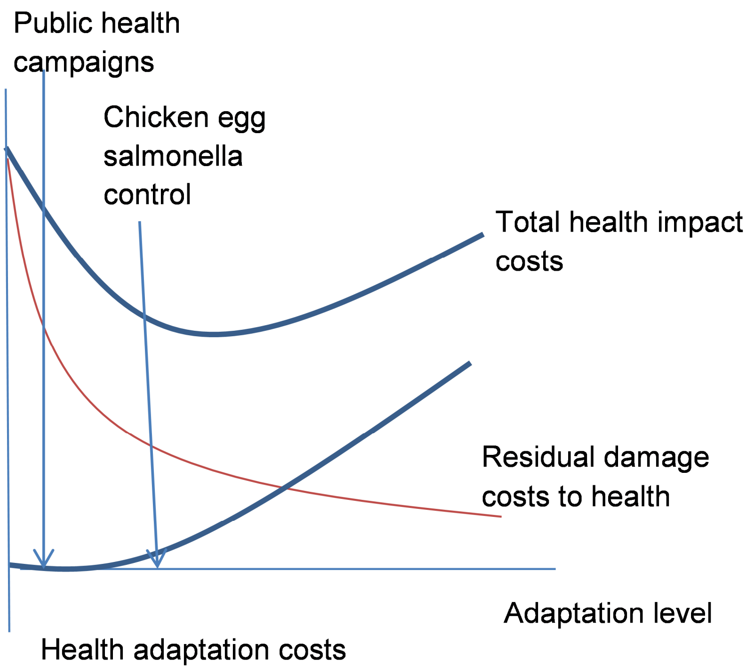


Figure 5: Optimal level of adaptation (adapted from Patt et al, 2010)

In order to move towards a better understanding of the optimum level of adaptation in health, the steps we plan to undertake are the following:

- To identify climate-change based health impacts/risks relevant at EU level and dose-response relationship or similar, and calculate the total additional burden of disease by health outcome.
- To identify preventive and reactive measures for each selected health risk.
- To identify costs and effectiveness of each measure (per case or death or DALY avoided, depending on the data available).
- To adjust the cost estimates of the measures in a format that is compatible with AD-WITCH (see next section) or to undertake new extrapolations with the participation of stakeholders when necessary.

In order to be able to estimate a cost adaptation curve with AD-WITCH, it will be necessary to identify and calculate different levels of adaptation (e.g. 100% risk reduction with return to the baseline risk, 50%, etc) for different scenarios of temperature increase (+ 1°C, + 2°C, etc).

Final selection of health outcomes will depend on the data available on impact quantification, costs and effectiveness of measures. A number of research projects will be reviewed providing information on costs of health adaptation at EU level. The review will also, if necessary, draw on costs of health interventions estimated outside the climate change and adaptation context, if programmed to achieve a certain reduction in the burden of climate-related diseases. The types of measures used for prevention and treatment of disease are technically the same in both contexts so that these studies can provide some indications of what would be the cost in a context of adaptation.

Data needs and linkages with other models/cases study within BASE

In terms of identifying the health impacts in Europe, we need access to relevant scenarios for the direct climate change impacts (for each health impact, the climatic variable(s) concerned may vary). This will include as a minimum mean temperature and precipitation – but factors such as flood risk, changes in risk of extreme events (e.g. storms, heatwaves) would also be helpful to have at hand.

Socioeconomic scenarios will be important – notably scenarios for population at NUTS 2 level if possible and for demographic change at the same scale.

We will collect the results of relevant health studies, and as an example, output the results in a matrix as shown below. This will feed the delivery of adaptation cost curves for the health sector and may help case studies considering health in identifying secondary literature estimates of costs or benefits and appropriate dose-response or relative risk data if case study specific analysis is not possible.

In terms of the Deltares flood risk model, we will need to:

a. Harmonise any applicable health related valuation (e.g. consistent valuation of the health outcomes);

b. Identify health relevant options included in the flood risk model;

c. Develop a data exchange plan with Deltares to ensure consistency.

The information on adaptation costs has to follow a specified format to enter the AD-WITCH model, as specified in Table 8 below.

Table 8: Adaptation Cost and Health Impact Assessment Summary of Studies

Data	**Description**
Health outcome	Heat stresses, VBD, WBD, deaths/injuries from flooding.
Health Impact/risk	Relative risk or dose-response for specific temperature increase and yearly based (ex. RR for cardio-vascular mortality, in year 2030, for different scenario or temperature increase: unmitigated scenario,

	stabilization at 759 ppm CO2 equivalent at 2210, etc, Ebi 2008), which enables to calculate the excess cases of diseases in a future year.
Cost effectiveness	Cost per avoided case, death, DALY, yearly based.
Total cost adaptation	For one specified year (future) and a number of scenarios of temperature increase. This information is calculated from the two above measures (health risks and cost effectiveness). Ideally provided as range estimates and for different levels of adaptation.
Geographical region	Eastern and Western Europe (see footnote 2).

Considering the limited existing literature on costs of adaptation, in the process of gathering data for the AD-WITCH model, two cases may occur:

- The cost is available from the existing literature, but not in the format required. In this case it is necessary as a first step to proceed to an adjustment of these estimates in order to make them compatible for the AD-WITCH model. There may be the need for a geographical, temporal or scenario (temperature increase) adjustment. The studies reviewed could, in fact, refer to different geographical grouping of countries not compatible with or different from those used in AD-WITCH, or it could happen that different studies provide estimates for different scenarios (of temperature increase) which will require some kind of homogenization. Availability of projections of relative risk (estimated increase in risk of the disease per unit increase in exposure, McMichael 2004) for different health outcomes, geographical regions and temperature increase is crucial in this respect.

- The cost is not available in the literature. In this case it will be necessary to proceed to some extrapolation in order to infer existing knowledge coming from different geographical areas (for example outside Europe) to an European context or for primary collection of cost data in a limited number of cases where this is possible and necessary.

Two or more scenarios can be considered for different levels of adaptation and risk reduction, as well as for different scenarios of temperature increase. The additional health risk can be reduced back to the baseline (100% of the impact reduced) or of a certain proportion, with a final impact higher than in the baseline but lower than with no adaptation. The computation will be different depending on how we consider preventive and reactive measures in the assessment. The main question is whether reactive measures should be classified as adaptation or residual impacts of climate change. In addition, if adaptation includes only preventive measures, it should be discussed whether and when a scenario with a 100% risk reduction is realistic or not – this may also require some stakeholder engagement to evaluate potential ranges of effectiveness of such actions.

3.9 Tool for assessment of strategies

Aim of the PRIMATE decision support tool within BASE

The decision support tool PRIMATE (interactive software for Probabilistic Multi-Attribute Evaluation) will be available in BASE to support the evaluation, i.e. prioritization of alternative adaptation options by means of Cost-benefit analysis (CBA) and/or participatory Multicriteria analysis (MCA). The primary use of PRIMATE in BASE will be in WP5, where PRIMATE is used by BASE partners for supporting decision making by the means of CBA and MCA at the project level in their case studies.[5] Case study owner will be trained for this bottom-up evaluation of adaptation options with PRIMATE on a training workshop on the 27-28th of November 2013. Besides this bottom-up application in WP5, PRIMATE has the potential to be used also in WP6 for an evaluation of adaptation options on the large-scale, strategic level. I.e. currently UFZ and DELTARES are discussing if PRIMATE can be also used to evaluate adaptation pathways on the macro scale. For this purpose results from the different models described under 3.4-3.9 could be used as evaluation criteria in PRIMATE.

Description

PRIMATE allows for the comparative assessment of alternative adaptation measures by means of CBA and/or participatory MCA. In the context of climate change adaptation the tool has primarily been used to carry out MCAs as in most cases multiple criteria had to be considered simultaneously and monetary valuation of relevant benefits has generally proven to be nonviable.

The aim of the CBA is to indicate whether an adaptation option is efficient, i.e. provides a higher net benefit than the baseline alternative (no adaptation-option). When comparing several adaptation measures with the baseline option PRIMATE identifies the most efficient alternative on the basis of the net benefits calculated.

The MCA module in PRIMATE is based on the outranking concept PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluations), which performs a pairwise comparison of all alternatives identified across all evaluation criteria selected counting arguments “in favour” and “against” each option.

PRIMATE allows for the simultaneous and explicit consideration of the varying preferences of different decision makers and/or stakeholders involved in the decision making process. Uncertainties in the criterion values can be considered by using a Monte Carlo simulation approach (Stochastic PROMETHEE II), i.e. several PROMETHEE analyses are performed for a random sample of criterion values within a range to be defined. The effects of the varying preferences and the uncertainty ranges of the criterion values are documented in the final results.

The results of the MCA are presented in PRIMATE in various ways. This includes not only the overall performance of an alternative considering all criteria and preferences but also its strengths or weaknesses with regard to specific

[5] For further information on the use of PRIMATE for economic assessments at case study level see D4.1 chapters 4.5, 4.6 and 4.10. The tool and handbook is available at https://emdesk.eu/cms/?p=334&hash=fYWQ7bGF0ZXN0OzIzNzMzZG93bmxv6

criteria or decision makers' preferences. This enhances the transparency of the decision making process and facilitates the identification of compromise solutions.

An overview of the different steps of PRIMATE and its application for a climate change adaptation project is given on the Poster on the next page. For more detailed information on the various steps of the PROMETHEE-approach with several references to its implementation in PRIMATE see Meyer (2007, especially p.24-26).

For a guided tour offering comprehensive information on the methodical foundations of PRIMATE as well as practical advice for its use see Drechsler (2004).

Data needs and linkages with other models/cases study

The use of PRIMATE requires the identification of *adaptation options* to be compared.

A set of *evaluation criteria* has to be defined. In BASE this could be on the one hand the costs of a certain adaptation option or pathway, and, on the other hand its benefits, e.g. economic, social and ecological benefit criteria (e.g. annual average flood damage avoided, coming from the flood risk model, annual average drought damage avoided, coming from the water scarcity model, health effects avoided, coming from the health model, effects on ecological flows, coming from the ecological flow model, etc.)

The *preference functions* (indifference threshold, threshold of strict preference, shape of the preference function) for each decision maker and every criterion have to be specified (for details see Drechsler 2004, p.3, p.18-19).

The *weight* of every criterion has to be determined by each decision maker in accordance with its relative importance. Data on the *performance* of the alternatives with regard to each evaluation criterion has to be collected. For the evaluation of adaptation pathways in BASE this performance of the different criteria could potentially be provided from the different models (see above, e.g. annual average flood damage avoided, coming from the flood risk model, annual average drought damage avoided, coming from the water scarcity model, health effects avoided, coming from the health model, effects on ecological flows, coming from the ecological flow model, etc.).

There a few options to include *participatory elements* in the evaluation process when using the CBA module (e.g. selection of cost categories to be included, selection of adaptation options to be compared), but the MCA module offers some participatory elements as stakeholders need to express their preferences with regard to the different evaluation criteria (*preference functions*) and have to assign *weights* to the criteria representing their relative importance in the decision making process.

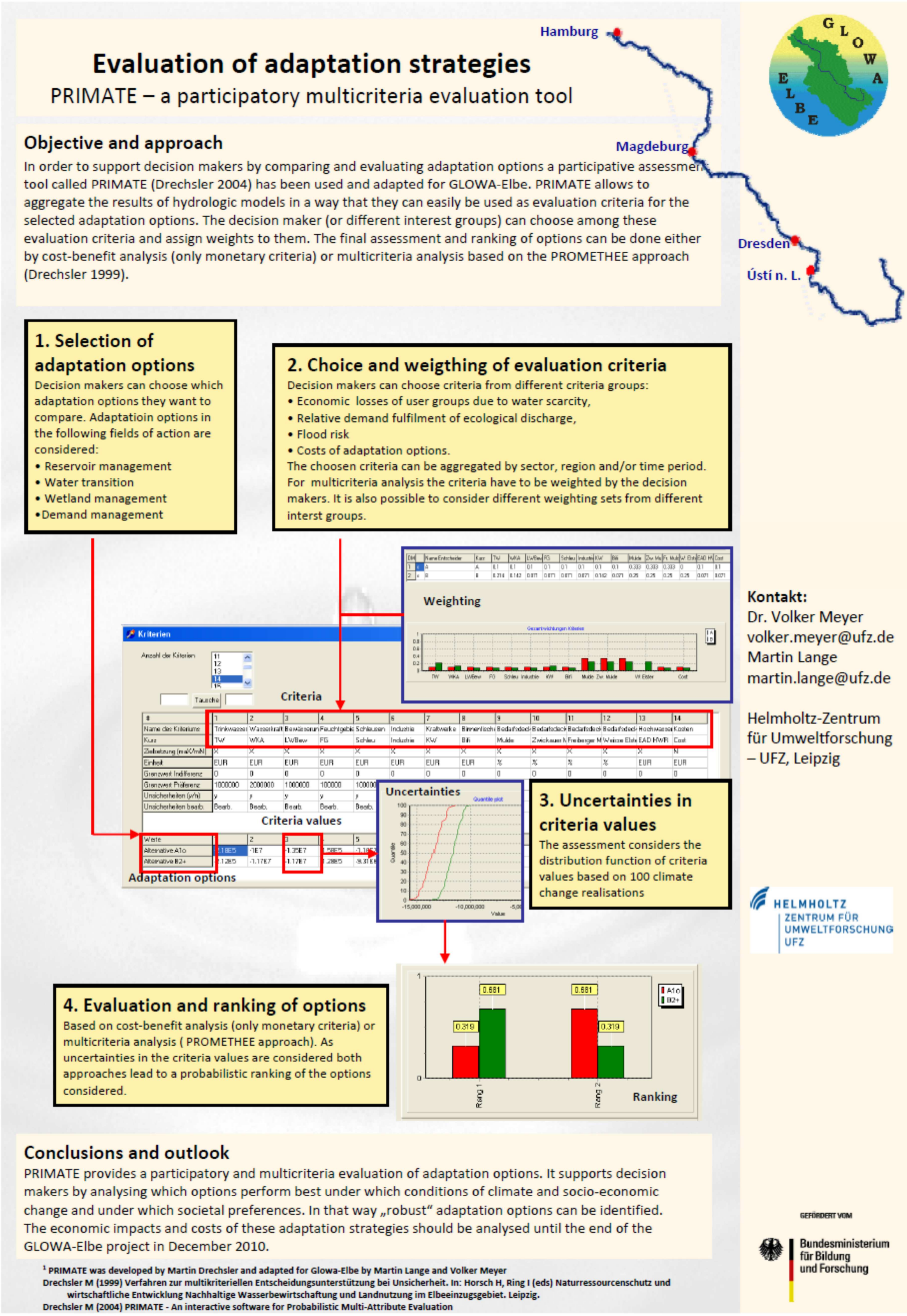


Figure 6: PRIMATE tool characteristics

4 A common grid for BASE

4.1 Introduction

The BASE project needs to come up with improved estimates of full cost and benefits of adaptation to climate change upscaled and integrated nto sectors at EU-level. This upscaling and integration is the main challenge of WP6.

There have been many studies done before to estimate the costs of adaptation against climate change. Climate Cost has made a review of the studies done to identify gaps and potential needs in the climate adaptation cost estimate research area. Below a summary of the main observations derived from the 7th FWP Climate Cost Study (Hunt and Watkiss, 2011).

- **Availability of information**: There is limited coverage of impacts and adaptation costs across sectors (majority of studies have been done for the coastal zone and flooding), and of adaptation strategies (often only hard engineering solutions are considered and no behavioural changes). Cost estimates are incomplete and there is an uneven distribution of available information over countries (the most comprehensive national adaptation cost assessments have been done in the Netherlands, Sweden and the UK).

- **Comparability**: Adaptation cost assessments vary heavily in methodology and approaches; the use of different metrics, time periods, assumptions with regards to changing socio-economic conditions and with regard to a proper reference strategy: often at a local level the current backlog of investment needs and normal investment replacement cycles are included in adaptation costs and the marginal additional costs for climate change are rarely split from those induced by socio-economic change. These differences make it challenging to compare various assessment studies and to draw generalized conclusions.

- **Scalability**: Assessments either deliver aggregated representation of impacts and adaptation based on integrated assessment models that provide insufficient detail for national or sub-national adaptation planning or sector specific results neglecting economy wide effects. Insufficient model resolution and availability of ground data make it difficult to validate and calibrate assessment models.

4.2 Definitions[6]

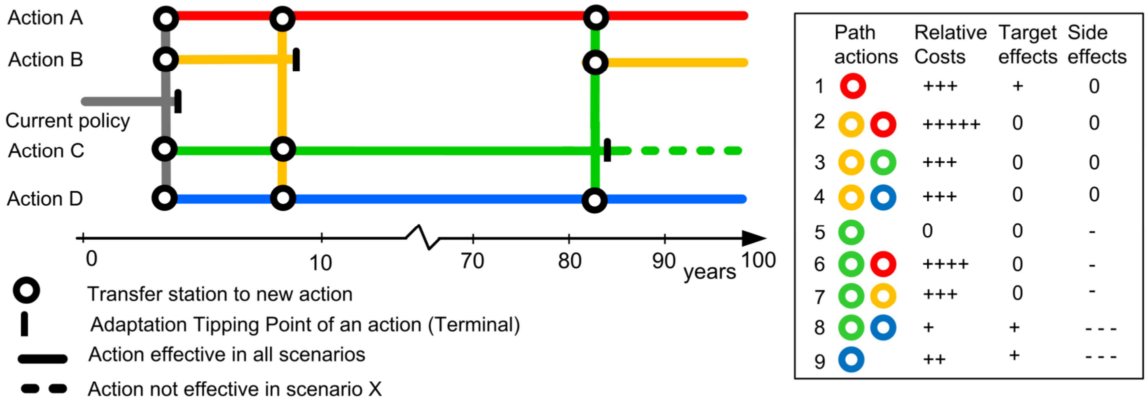
Within the BASE project there are some essential concepts and wording used that need to be understood similarly across the people involved in the project. Here we provide some practical definitions.

One central approach within BASE is to define adaptation strategies by means of adaptation pathways (Haasnoot et al. 2012, 2013).

An *adaptation pathway* consists of a sequence of adaptation actions to achieve targets under changing climate and socio-economic conditions. Usually these pathways are used in the context of policy planning, i.e. ***planned adaptation***. Actions may also involve stimulation and enhancement of ***autonomous adaptation*** the response of individual stakeholders to external changes and (sectorial) policy. Adaptation pathways may be considered as part of an adaptation ***plan*** in which coping with uncertainty is considered important. Central to the adaptation pathways

[6] This section is common to D6.1

concept are ***adaptation tipping points*** (Kwadijk et al., 2010), which are the conditions under which an action no longer meets the clearly a-priori specified objectives. After reaching a tipping point, additional actions are needed to reach the defined objectives. As a result, a pathway emerges. An ***adaptation pathways map*** presents an overview of relevant pathways and policy options after an adaptation tipping point. A scorecard can present the costs, the extent to which policy goals are achieved, and potential side effects of the pathways. In combination with signposts, that can be monitored to indicate whether implementation of actions is needed, decision makers can make an informed decision about short term actions, while keeping options open to adapt, if necessary.



Adaptation Pathways Map **Scorecard pathways**

Source: Haasnoot et al, (2013).

Note: In the map, starting from the current situation, objectives begin to be missed after four years: an adaptation tipping point is reached. Following the grey lines of the current policy, one can see that there are four options. Actions A and D should be able to achieve the objectives for the next 100 years in all climate scenarios. If Action B is chosen after the first four years, a tipping point is reached within about five years; a shift to one of the other three actions will then be needed to achieve the targets (follow the orange lines to a transfer station). If Action C is chosen after the first four years, a shift to Action A, B, or D will be needed in the case of Scenario X as in this scenario the performance of this actions was unacceptable after approximately 85 years (follow the solid green lines). In all other scenarios, the objectives will be achieved for the next 100 years (the dashed green line).

Figure 7 Graphical depiction of adaptation pathway.

Other definitions used within BASE include:

Scenarios: are coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present and future developments, which can serve as a basis for action (Van Notten, 2005). For BASE scenarios are climate change and socio-economic projections describing a range of plausible external contexts for the system considered in the case studies and model exercises. These scenarios are only very indirectly influenced by adaptation within the considered system and sectors and are thus policy-free. Scenarios are used within Base as a means to evaluate impacts of climate and socio-economic changes and the performance of adaptation actions and pathways, and as a context for developing story lines.

Storyline: a narrative of a plausible future including climate change, socio-economic developments and adaptation pathways. These storylines tell the combined logical story of external developments and sectorial responses.

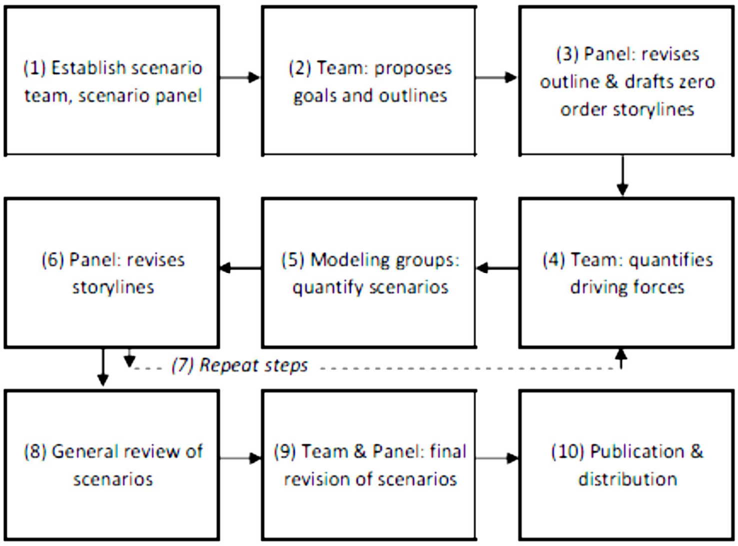


Figure 8 Overview of SAS (Story And Simulation) approach to scenario development as applied in the SCENES project (Duel and Meijer, 2011).

The Storyline And Simulation (SAS) approach (Alcamo, 2001) has been adopted in the SCENES project to develop pan-European water scenarios. The SAS approach accounts for all steps considered essential to develop scenarios at a single scale (see Figure 8). Important steps include the establishment of a scenario panel and scenario team (1-2); construction of storylines (3) that are quantified and revised (4-6). BASE in turn will adopt this approach. BASE storylines will be made using a stakeholder panel. The scenarios, adaptation pathways and modeling results will be the most important input to these storylines.

Upscaling: We define upscaling as an activity in which information on a lower spatial scale is translated into information at a higher spatial scale. This information on a lower spatial scale is scattered sparsely in space and often highly context specific. A certain representativity for a broader context or larger area of similar characteristics is required for scalability. In the context of BASE, and more specifically WP6, the information to be upscaled is gathered from the case studies and consists of adaptation pathways and its characteristics, costs of impacts and adaptation, and adaptation benefits. As an example; the benefits of a certain flood risk reduction action, studied in detail at the local scale for a specific catchment, can be translated by using the models developed and applied in BASE, to the European scale, for catchments where a similar measure is supposed to be relevant.

BASE sectors: The BASE project has the aim to consider adaptation in sectors of major economic importance. These sectors are defined in a very practical manner to group research questions and activities. For the case studies six clusters are defined distinguishing between ‘human settlements and infrastructure’, ‘agriculture and forestry’, ’coastal zones’, ‘human health’, ‘water resources management’, ‘biodiversity and ecosystems’. In addition there is the need to comply with impacts of climate change and sea level rise, like heat waves, pests, droughts and floods and cross-sectorial economic effects. These impacts are partly covered by the models that are developed under WP3 (with models for water availability, agriculture and riverine floods). Within WP4 and WP5 cross referencing tables have been developed to link impacts to major sectors in cases. A simplified version derived from this is depicted in Table 9.

Table 9. Case clusters and impacts

	Impact from		
Case cluster	*Sea level rise*	*Precipitation/Evaporation*	*Temperature*
Human settlements and infrastructure	coastal flooding coastal erosion	flooding from extreme rainfall riverine flooding soil erosion other extreme events (storm, snow)	extreme temperatures
Coastal zones	coastal flooding coastal erosion		
Biodiversity and ecosystems	salinization	water scarcity / droughts	Temperature shifts
Human health	flooding	Flooding	Extreme temperatures Vector and food borne diseases
Water management	flooding	Flooding, water scarcity / droughts	
Agriculture and Forestry		Droughts	Temperature shifts

Within BASE economic evaluation of costs and benefits of climate change adaptation for sectors is one of the central aims. The terminology on cost types sometimes differs in the literature and among different communities (see e.g. Parker et al., 1987; Smith and Ward, 1998; Heinz Center, 2000; Wilhite, 2000; Thieken et al. 2010, Meyer et al. 2013). For BASE it is important to work with a set of definitions that apply for the broad set of sectors, case studies and models involved.

Baseline: In order to be able to ultimately assess costs and benefits of climate adaption it is necessary to have a common baseline strategy next to adaptation strategies for economic assessment. There are basically two main ways to choose a reference strategy: i) Starting from a reference year there is ***no further adaptation***. This will result into a large need for adaptation. ii) Policy and management is continuing business as usual (***BUA***). For example regular flood- and drought risk management is carried through. This may imply increasing costs to cope with climate change. In terms of pathways there is however no change of strategy. In addition to above mentioned strategies, that refer to planned adaptation there is the always autonomous adaptation of individual stakeholders, which also involve societal costs. In BASE we choose to use the BUA strategy as baseline strategy against which cost and benefits are assessed. For autonomous adaptation additional assumptions have to be made.

Costs: All negative effects of an adaptation option compared to a baseline option, which is usually the "business-as-usual"-option. The most important cost components are

- Investment costs to implement a certain adaptation measure. Transaction costs, i.e. costs associated with the design and implementation of measures are part of it.
- Running costs, operation and maintenance costs
- But also negative side-effects, possible negative effects in another sector, such as negative environmental and social effects of the measures. I.e. building a dike reduces flood risk but could also have negative impacts on floodplain ecosystems or on the spatial quality of a city front.

Benefits: All positive effects of an adaptation option compared to a baseline option, which is usually the "business-as-usual"-option. The most important benefit components are:

- Avoided damages (at buildings, yields, insured persons, environment, treatment costs in health care)
- Positive side benefits (possibly for other BASE sectors) such as change of recreational function, tourism change of potential for development, change of biodiversity and ecosystem services , change of values of goods or land

If possible, costs and benefits should be expressed in monetary terms as annual average damage avoided (reduced risk due to the adaptation measures). However, intangible effects, such as social and environmental impacts, are not easily measurable in monetary terms. Methods exist to include them in a CBA, which try to monetise effects by means of valuation approaches such as contingent valuation, choice modelling, hedonic pricing, travel cost approach or replacement cost approach. Most often however they can be included in non-monetary terms in a multi criteria analysis.

Direct damage: Assessments of the climate extreme impacts (e.g. flooding) have focused on the initial impact on people and assets. These initial estimates, so-called 'direct damage', are useful both in understanding the immediate implications of damage, and in marshalling the pools of capital and supplies required for re-building after an event.

Indirect damage: Since different economies (at different regional scale) as well as societies are coupled, any damage occurred in the impacted region (e.g. transport disruption, utilities out-of-function) can be propagated throughout the regional, national, and international supply chains due to. The cost of damage beyond the impacted region can be referred as 'indirect damage'.

Economy wide effects: These are different from indirect damages even though often confused. They refer to the final economic effects (either costs or gains) expressed in terms of GDP or of monetized welfare that materialize once all the market adjustments in the economy took place. Economy wide effects thus include the feedback that the macro-economic context exert at the micro (single market) level.

Mainstreaming: it is that process according to which climate change, climate change impacts, risks and policies (strategies/measures) aiming at addressing them are included in (latu sensu) development planning. Mainstreaming climate change adaptation can therefore ensure that development programs and policies are not at odds with climate risks both now and in the future.

4.3 Common framework on climate and socio-economic scenarios

One of the aims of D3.1 is to provide a common framework within the BASE project to allow comparability and consistency across the analyses performed by case studies and by bottom-up and top-down modeling exercises. According to BASE purposes, this common framework should regard the climatic and social economic dimensions. In principle the old IPCC SRES scenarios (Nakicenovic et al. 2000) could serve to the purpose. They contain information both on climate change variables (temperature, precipitation, sea-level rise etc.) and on underlying social economic developments. Therefore, each SRES scenario is also associated to a well-defined development of social economic variables, like GDP, population, but also fossil fuel prices.

However these scenarios are somewhat outdated. The more recent scenario building process developed by the IPCC (van Vuuren et al. 2012) devises a set of “4 Representative Concentration Pathways (RCPs)” corresponding to different GHG emissions, concentration and radiative forcing scenarios. This set of new scenarios has been defined for the Fifth Assessment Report of the IPCC and used for climate change projections in Working Group 1 (IPCC 2013). In parallel Shared Social Economic Pathways (SSPs) are being developed by social scientists (Moss et al 2011, O’Neil et al. 2012) detailing social economic future development for the world economic system that can be linked then to RCPs.

Given the decision of the BASE consortium, to be up to date and policy relevant, it is thus necessary to refer to this new information set rather than to use the old IPCC SRES scenarios. Next sessions briefly summarize the main features of both RCPs and SSPs.

4.3.1 The Representative concentration Pathways

Table 10 describes first the different CO2 equivalent concentrations that the four RCPs propose. They range from a minimum of the RCP2.6 which is more or less consistent with a global effort to keep temperature increase below the 2°C within the century, to the very high concentration of RCP 8.5. There are many studies that are associating RCPs to temperature increases. Figure 9 and Table 11 report for instance the results by Rogelj et al. (2012). As can be seen, in terms of temperature signal, RCP 6 and 8.5 would be consistent with a warming of 2.6-3.7 and 4.0-6.1 °C by the end of the century, respectively. Therefore they are also the RCPs which will imply the highest adaptation effort.

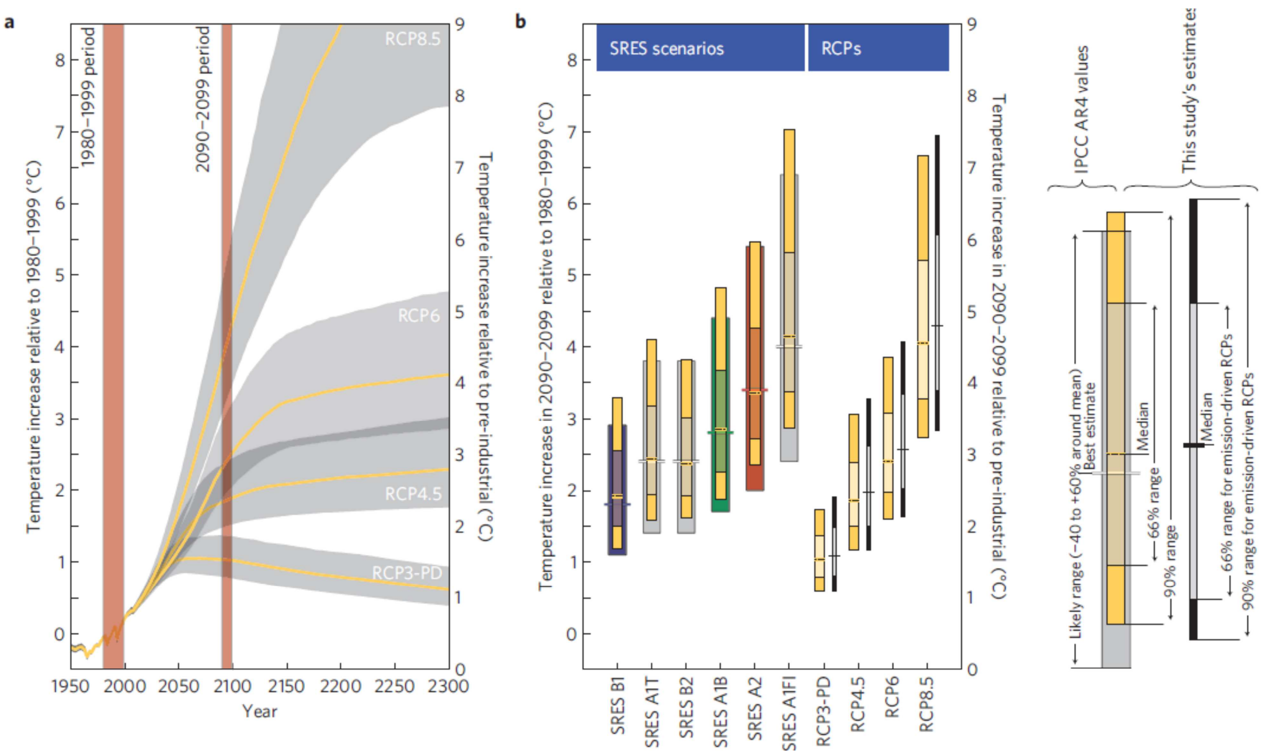
Just to give an overview of potential impacts associated, Figure 10 reports WITCH estimated relation between temperature increases and regional GDP losses, which (very) indirectly may also indicate how much could be worth spending or needed to be spent, in adaptation.

Table 10. RCP description

	Description[a]	Publication—IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO_2 eq) by 2100.	(Riahi et al. 2007)—MESSAGE
RCP6	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO_2 eq) at stabilization after 2100	(Fujino et al. 2006; Hijioka et al. 2008)—AIM
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 (~650 ppm CO_2 eq) at stabilization after 2100	(Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009)—GCAM
RCP2.6	Peak in radiative forcing at ~3 W/m^2 (~490 ppm CO_2 eq) before 2100 and then decline (the selected pathway declines to 2.6 W/m^2 by 2100).	(Van Vuuren et al., 2007a; van Vuuren et al. 2006)—IMAGE

[a] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m^2 relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents

Source: Van Vuuren et al. (2011)



Source: Rogelj et al. (2012)

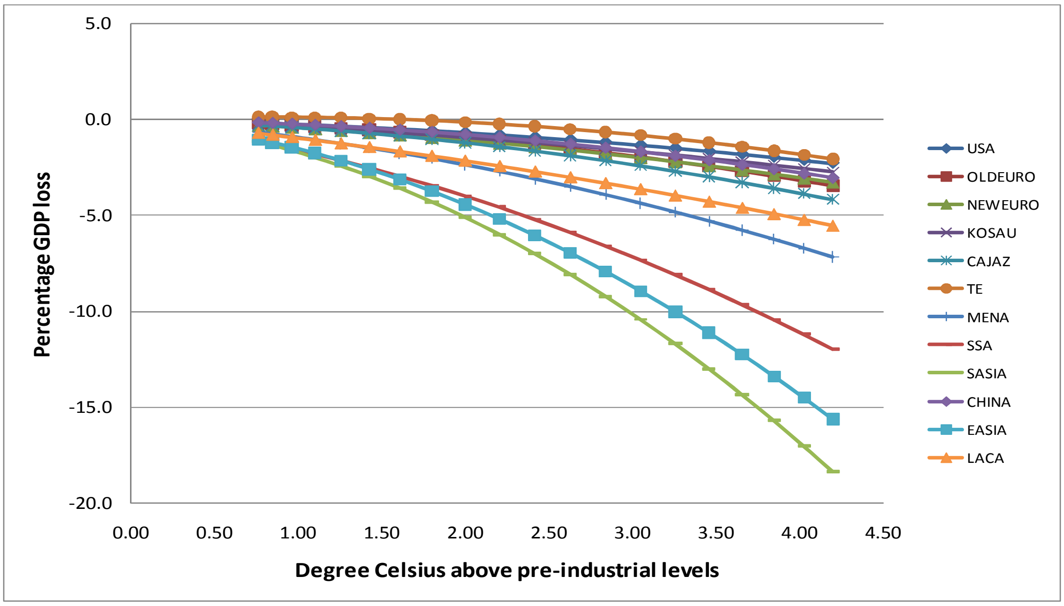
Figure 9. RCPs and temperature increases

Table 11. Probabilistic estimates of temperature increase above pre-industrial levels based on representative ECS distribution for the six SRES marker scenarios and the four RCPs

Scenario	Temperature increase above pre-industrial (°C)					
	2090–2099 period		2100		2300	
IPCC AR4	Best estimate	Likely range	Median	66% range	Median	66% range
SRES B1	2.3	1.6–3.4	-	-	-	-
SRES A1T	2.9	1.9–4.3	-	-	-	-
SRES B2	2.9	1.9–4.3	-	-	-	-
SRES A1B	3.2	2.2–4.9	-	-	-	-
SRES A2	3.9	2.5–5.9	-	-	-	-
SRES A1FI	4.5	2.9–6.9	-	-	-	-
This study	Median	66% range	Median	66% range	Median	66% range
SRES B1	2.4	2.0–3.1	2.5	2.0–3.2	-	-
SRES A1T	2.9	2.5–3.7	3.0	2.5–3.8	-	-
SRES B2	2.9	2.4–3.5	3.0	2.6–3.7	-	-
SRES A1B	3.4	2.8–4.2	3.5	2.9–4.4	-	-
SRES A2	3.9	3.2–4.8	4.2	3.5–5.2	-	-
SRES A1FI	4.7	3.9–5.8	5.0	4.1–6.2	-	-
RCP3-PD	1.5	1.3–1.9	1.5	1.3–1.9	1.1	0.9–1.5
RCP4.5	2.4	2.0–2.9	2.4	2.0–3.0	2.8	2.3–3.5
RCP6	2.9	2.5–3.6	3.0	2.6–3.7	4.1	3.4–5.3
RCP8.5	4.6	3.8–5.7	4.9	4.0–6.1	10.0	7.9–14.1

Note that estimates in AR4 were given relative to 1980–1999. The 'likely range' denotes the 'greater than 66%' probability range as suggested by the IPCC (ref. 12). The '66% range' labels denote the 66% range as such. RCP results are from concentration-driven runs. Results for emission-driven RCP runs are provided in Supplementary Table S3.

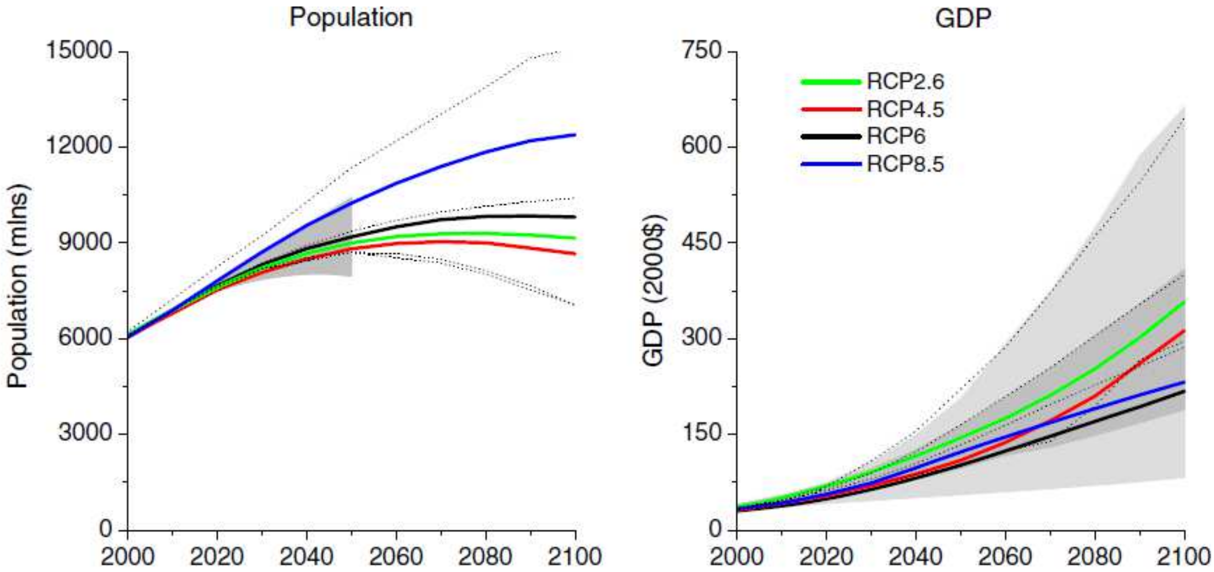
Source: Rogelj et al. (2012)



Source: WITCH model

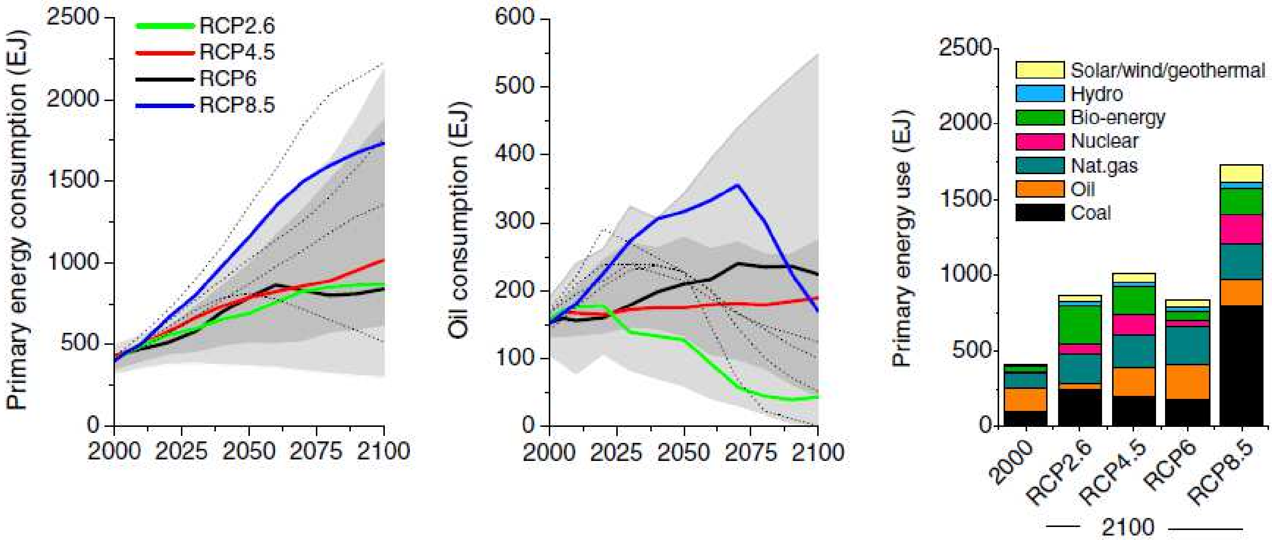
Figure 10. Relation between regional climate change impacts and temperature

There are also some social-economic characterization of the RCPs. RCPs themselves provide these information as e.g. in Figure 11 and Figure 12.



Source: Van Vuuren et al. (2011)

Figure 11. Social economic drivers for RCPs (a)



Source: Van Vuuren et al. (2011)

Figure 12. Social economic drivers for RCPs (b)

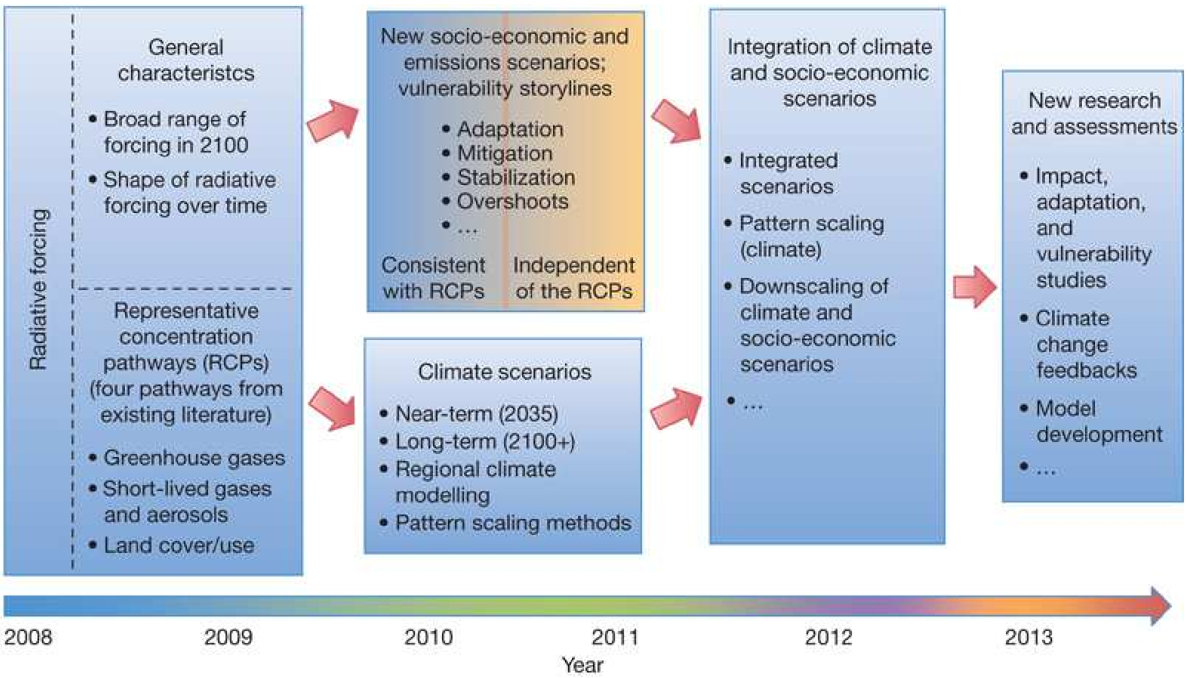
It is interesting to note, looking at Figure 11, that the RCP with the highest economic growth is not the one with the highest emission and therefore CO2 concentration. This to say that the “quality” of development is important. In RCP

2.6 indeed energy consumption, especially that based on oil declines while bioenergy experiences the strongest increase. In parallel, population growth is the lowest across all the RCPs.

In parallel, social economic scientists are developing the so called Shared Social Economic Pathways (SSPs).

4.3.2 Shared Social Economic Pathways

The SSPs are part of a new framework that the climate change research community has adopted to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation (Figure 13). They are supposed to be either linked, but also independent of the RCPs. Anyway, the process of linking RCPs with SSPs has not yet started, even though some preliminary attempts in this direction have been made.



Source: Moss et al. (2010)

Figure 13. The "new" IPCC scenario building process

The SSPs framework is built around a matrix that combines climate forcing on one axis (as represented by the Representative Forcing Pathways) and socio-economic conditions on the other. Together, these two axes describe situations in which mitigation, adaptation and residual climate damage can be evaluated.

The associated narratives describe the main characteristics of the SSPs future development pathways. They are briefly summarized below. (For more detail visit: https://secure.iiasa.ac.at/web-apps/ene/SspDb/static/download/ssp_suplementary%20text.pdf).

SSP1 - Sustainability: This is a world making relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. Elements that contribute to this are a rapid development of low-income countries, a reduction of inequality (globally and within economies), rapid technology development, and a high level of awareness regarding environmental degradation. Rapid economic growth in low-income countries reduces the number of people below the poverty line. The world is characterized by an open, globalized economy, with relatively rapid technological change directed toward environmentally friendly processes, including clean energy technologies and yield-enhancing technologies for land. Consumption is oriented towards low material growth and energy intensity, with a relatively low level of consumption of animal products. Investments in high levels of education coincide with low population growth. Concurrently, governance and institutions facilitate achieving development goals and problem solving. The Millennium Development Goals are achieved within the next decade or two, resulting in educated populations with access to safe water, improved sanitation and medical care. Other factors that reduce vulnerability to climate and other global changes include, for example, the successful implementation of stringent policies to control air pollutants and rapid shifts toward universal access to clean and modern energy in the developing world.

SSP 2 - Middle of the Road (or Dynamics as Usual, or Current Trends Continue, or Continuation, or Muddling Through): In this world, trends typical of recent decades continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. Development of low-income countries proceeds unevenly, with some countries making relatively good progress while others are left behind. Most economies are politically stable with partially functioning and globally connected markets. A limited number of comparatively weak global institutions exist. Per-capita income levels grow at a medium pace on the global average, with slowly converging income levels between developing and industrialized countries. Intra-regional income distributions improve slightly with increasing national income, but disparities remain high in some regions. Educational investments are not high enough to rapidly slow population growth, particularly in low-income countries. Achievement of the Millennium Development Goals is delayed by several decades, leaving populations without access to safe water, improved sanitation, medical care. Similarly, there is only intermediate success in addressing air pollution or improving energy access for the poor as well as other factors that reduce vulnerability to climate and other global changes.

SSP 3 - Fragmentation (or Fragmented World): The world is separated into regions characterized by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. Regional blocks of countries have re-emerged with little coordination between them. This is a world failing to achieve global development goals, and with little progress in reducing resource intensity, fossil fuel dependency, or addressing local environmental concerns such as air pollution. Countries focus on achieving energy and food security goals within their own region. The world has de-globalized, and international trade, including energy resource and agricultural markets, is severely restricted. Little international cooperation and low investments in technology development and education slow down economic growth in high-, middle-, and low-income regions. Population growth in this scenario is high as a result of the education and economic trends. Growth in urban areas in low-income countries is often in unplanned settlements. Unmitigated emissions are relatively high, driven by high population growth, use of local energy resources and slow technological change in the energy sector. Governance and institutions show weakness and a lack of cooperation and consensus; effective leadership and capacities for problem solving are lacking. Investments in human capital are low and inequality is high. A regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity. Policies are oriented towards security, including barriers to trade.

SSP 4 - Inequality (or Unequal World, or Divided World): This pathway envisions a highly unequal world both within and across countries. A relatively small, rich global elite is responsible for much of the emissions, while a larger, poorer group contributes little to emissions and is vulnerable to impacts of climate change, in industrialized as well as in developing countries. In this world, global energy corporations use investments in R&D as hedging strategy against potential resource scarcity or climate policy, developing (and applying) low-cost alternative technologies. Mitigation challenges are therefore low due to some combination of low reference emissions and/or high latent capacity to mitigate. Governance and globalization are effective for and controlled by the elite, but are ineffective for most of the population. Challenges to adaptation are high due to relatively low income and low human capital among the poorer population, and ineffective institutions.

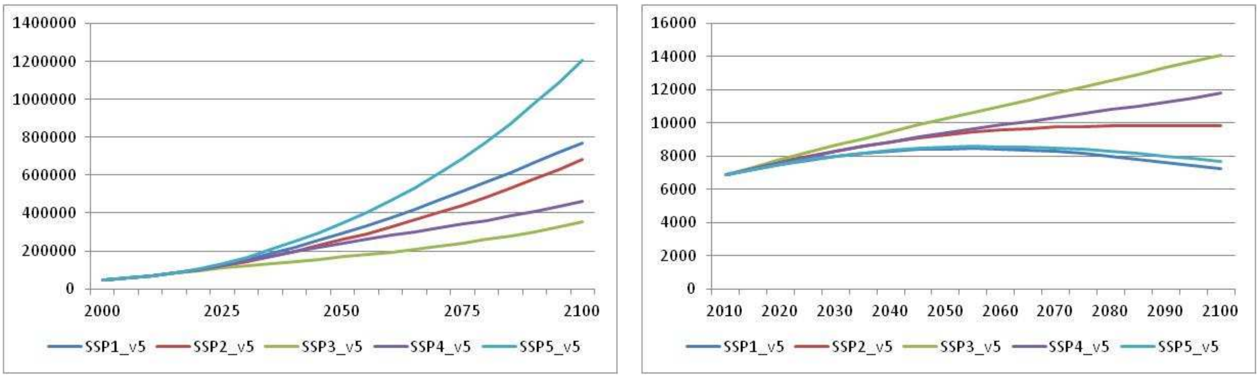
SSP 5: Conventional Development (or Conventional Development First): This world stresses conventional development oriented toward economic growth as the solution to social and economic problems through the pursuit of enlightened self interest. The preference for rapid conventional development leads to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation. Lower socio-environmental challenges to adaptation result from attainment of human development goals, robust economic growth, highly engineered infrastructure with redundancy to minimize disruptions from extreme events, and highly managed ecosystems.

As usual, these storylines (an example in Figure 14) are qualitative and offer, on purpose, great flexibility in their quantitative characterization. Different modeling tools can thus be used to develop quantifications of these storylines, including factors like population, economic development, land use and energy use.

Currently (in the IIASA link https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=welcome), the database includes projections for:

- population by age, sex, and education;
- urbanization;
- economic development (GDP)

For each SSP a single population and urbanization scenarios is provided, developed by IIASA and NCAR respectively. For GDP, three alternative interpretations of the SSPs have been developed by the OECD, IIASA, and PIK.

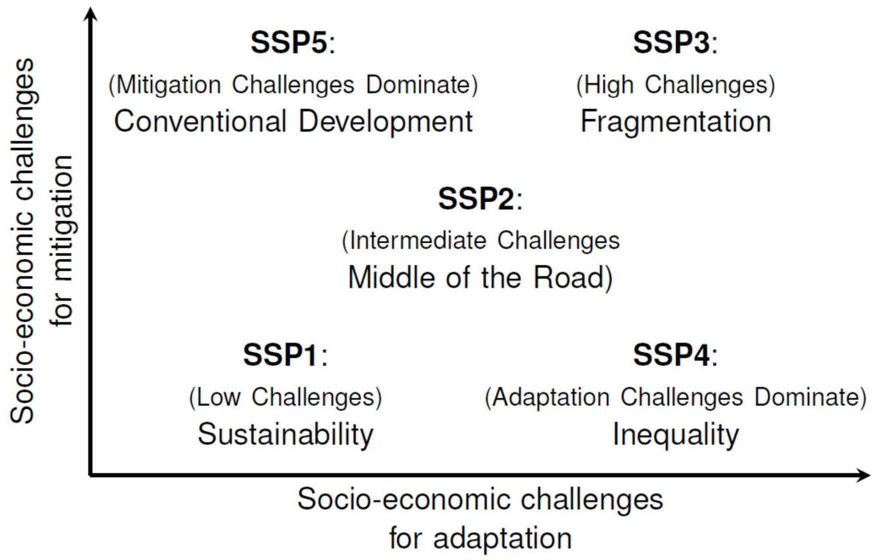


Source: direct download from: https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=welcome

Figure 14. World GDP, OECD source, US$ billion (left) and population, IIASA source, million, (right) in the SSPs

As said, the process of linking SSPs to RCPs is under way. However, albeit considering the great flexibility and also subjectivity in this exercise some general indications on possible correspondences can be derived.

For instance a scenario like SSP1 with its sustainability concerns and technological progress towards the decarbonization of energy system is hard to reconcile with a 4-6°C increase by the end of the century characterizing the RCP8.5. Figure 15 exemplifies, qualitatively, the different challenges for mitigation and adaptation polices related to SSPs.



Source: O'Neill et al. (2012)

Figure 15 Climate change policy challenges in the different SSPs

Summarizing, SSP2 (the “middle of the road scenario”) is broadly consistent with RCP 4.5, while both SSP5 and SSP3 with RCP 8.5. SSP3 presents also high challenges for adaptation as the “fragmentation” devised reduces international support and lowers adaptive capacity. However for the sake of the BASE project it is not a contradiction to assume that the high emissions and consequent climate change damages consistent with SSP5 will also pose substantial adaptation challenges.

The final choice of the BASE consortium is to use as social-economic references SSP2 and SSP5 and to associate them respectively to RCP4.5 and RCP8.5. SSP2 represents a sort of “business as usual” that can allow to characterize adaptation needs and challenges in a world were both social-economic and environmental concerns evolve following “current trends”. SSP5 is a world with high emissions where climate change policies are unable to limit increases in CO2 concentration and temperature. These two scenarios are obviously the most interesting for the analysis of adaptation. In particular, SSP5 is expected to quantify the cost of inaction in mitigation policy not only in terms of higher damages, but especially of higher adaptation expenditure. The choice of the SSP-RCP couplets, is thus motivated by scientific interest and relevance for the questions BASE tries to answer. By no means BASE endorses the view that SSP2 or SSP5, are unavoidable, more likely or “preferred” development paths, and that no effort should be made to avoid the associated high emission paths. In particular, the consortium considers that RCP2.6 and the potentially associated SSP1 as “desirable”, but this combination is also that with the lowest adaptation challenges and accordingly somewhat less relevant to a project aiming at investigating cost and benefit of adaptation.

4.4 Reference strategies for comparative assessment

In order to be able to assess costs and benefits of climate adaptation fully it is necessary to have a common baseline strategy next to adaptation strategies for economic assessment. It should be clear what is the adaptation gap to be bridged.

Different levels might be distinguished:

1. Starting from the reference year 2015 there is no further adaptation. This will yield a large adaptation gap
2. Policy and management is continuing business as usual (bau). For example regular flood- and drought risk management is carried through. This may imply increasing costs to cope with climate change. In terms of pathways there is no change of strategy.

In addition to above mentioned levels, that refer to planned adaptation there is the always autonomous adaptation of individual stakeholders, which also involve societal costs.

In BASE it should be made clear at all time (in case and model studies) to what baseline strategy cost and benefits are assessed: including business as usual or not, including autonomous adaptation or not.

4.5 Including uncertainty

There are different areas of climate policy that are affected by/originating from uncertainty. There is first uncertainty about climate pressures, namely, the same emission path can originate different temperature increases depending on climate sensitivity. There is then uncertainty about "physical" impacts of climate change; that is: the same temperature increase scenario can originate different impacts - on e.g. water availability, crop yields, sea-level rise etc. - due to the uncertain responses by the environmental system. Third there is uncertainty about "social economic" impacts originated from the different reactions of social economic systems to environmental pressures. The uncertainty about costs and effectiveness of mitigation and adaptation policies falls within this last area. To complete the picture, there is finally uncertainty on the decision making preferences. This pertains to the choice of different equity criteria intertemporally (discounting) or intratemporally (equity weighting) to frame the decision process.

Except for the last source of uncertainty, and independently upon where uncertainty originates, it can derive from two motivations: imperfect knowledge of the phenomenon, which in principle can be reduced as long as information improves, and intrinsic stochasticity of the phenomenon, which is not reducible.

Uncertainty can be dealt with different techniques. The part related to climatic pressures can be captured by considering different climate change scenarios and/or envelopes of circulation models to "quantify" a given climate scenario. This would imply that sectoral impact models (e.g. crop models, flood models within BASE) will have to quantify impacts, and thus adaptation, for a set of different climate change shocks. Sectoral models may also add, on top of this, their impact uncertainty, which will further amplify the ranges of possible outcomes.

The treatment of this kind of knowledge about future outcomes from climate change and from adaptation actions has not been well treated in the literature to date. The key aspect is to ensure that the ranking of options fully reflects the state of knowledge about impacts and adaptation measures. One way to partly address this is to apply an option value to future knowledge, so an action taken today that leaves open the possibility to take more than one direction at some date in the future is worth more than an action that limits future options or makes it more expensive to change direction. The adaptation pathway structure outlined above allows such options values to be incorporated into the decision-making process of calculating the benefit-cost ratios of different actions as long as probabilities can be defined for different pathways. It is not immediately clear how it can be translated into the top down frameworks such as Ad-Witch in a real practical way but we will examine these issues and see what tractable formulations can be applied in that context.

Another way to represent uncertainty is to add a risk premium to each impact, based on the range of possible outcomes. This reflects society's aversion to the fact that the damage associated with climate change are uncertain. Estimates of the premium can be derived from preference elicitation with stakeholders, or it can be estimated using expected utility functions with risk parameters that have been applied in a social context (e.g. decisions about levels of flood protection or decisions relating to individual savings). In both cases the risk premium can be added to the cost of the damages and, in the case of adaptation measures to the cost of adaptation when the net outcome after undertaking the adaptation measure is uncertain. Such premiums can change the ranking of different actions: if one action reduces the range of negative net outcomes significantly but is more expensive it may be preferred to another which is cheap but leaves the range of net outcomes very wide.

Estimating the range of uncertainty can be made based on the steps outlined above, where the temperature uncertainty feeds into that of physical impacts, which in turn feeds into that of socio-economic impacts. Given the multiplicative nature of each of the cascading uncertainties one can show that the final range of outcomes will tend toward a log-normal distribution where the geometric mean and standard deviation are functions of the means and standard deviations at each step of the process for which estimates can be obtained from databases and from expert judgment (Rabl and Spadaro, 1999). The method has been applied to deriving uncertain bounds for air pollution damages.

In this work package we will work with both methods of representing uncertainty and will develop assessment of adaptation options which show how the relative ranking can change when account is taken of the risk premiums (with different parameter values) and of future knowledge through option values.

4.6 The exchange of climatic data

Within the scope of BASE D3.1, Sub-Task 3.1.1, CMCC has to provide information on different RCPs with different levels of spatial resolution. If this is higher than 25 sq Km grid, statistical downscaling will be used.

The process of delivering climatic data requests from partners proved to be complex, as it was not immediately straightforward, at least in the initial project phases, what exact information were necessary. However now the list of climate data is complete and reported in an excel spreadsheet (annex 1) attached to this document. The process of delivering the information is thus starting.

4.7 Social economic data

An excel spreadsheet accompanying this document (annex 2) contains the social economic data referring to SSP2 and SSP5 providing country-level information on population, GDP and urbanization.

5 Conclusions

The final aim of the BASE project is eventually to improve upon the current and still incomplete knowledge on climate change adaptation processes. This requires primarily to enrich the quantitative information on costs and benefits of adaptation strategies/measures, however this also calls for a higher integration, access and use of this information.

This ambitious goal implies, among other things, the development of appropriate methodologies. And, against this background, this deliverable contributes to three specific goals of BASE with a strong methodological content. These are:

Goal 2: Improve current, develop new and integrate methods and tools to assess climate impacts, vulnerability, risks and adaptation policies to stocktake and enrich past and current EU research project outputs.

Goal 4: Assess the effectiveness and full costs and benefits of adaptation strategies to be undertaken at local, regional, and national scales using innovative approaches (mainly by integrating bottom-up knowledge/assessment and top-down dynamics/processes) with particular attention on sectors of high social and economic importance.

Goal 5: Bridge the gap between specific assessments of adaptation measures and top-down implementation of comprehensive and integrated strategies.

Goal 2 will be realized developing in BASE WP3 different modeling tools and approaches to the study of adaptation. It presents strong interactions with WP6 where the models under WP3 will be applied to accomplish Goal 4, and with WP7 that will ultimately derive policy implications. Indeed the current deliverable shares some methodological considerations with D6.1. Finally, a key aspect of the work in WP3 and 6 is the integration across the different methodologies and across the modeling work and the analysis developed by BASE case studies. Coupling top-down or partial equilibrium models with large geographical coverage like those in WP3 with insights from case studies will thus allow the fulfillment of Goal 5.

More specifically this document:

(a) describes the individual models developed under WP3 and that will be applied in WP6. Within BASE, different kinds of tools will be used. The dynamic optimization AD-WITCH model, will be used to describe the interaction between climate change damages, adaptation and mitigation and their effects on GDP and other macroeconomic indicators. It is very coarse in spatial resolution. On a lower scale the IO-model of Univ. Leeds will be used to study cross-sectoral impacts on the regional economy (Urban scale). Sector models with high spatial resolution will provide the direct (avoided) damages and effects of climate adaptation for flood and drought damage, health impacts and environmental flows. The decision support tools PRIMATE, will assist users in assessment of cost and benefits or multi criteria analysis under uncertainty in a multi-stakeholder setting

(b) Provides a *common grid* for the project. To be up to date and policy relevant, the decision of BASE is to refer to the climatic and socio-economic information currently released during the new scenario building process developed by the IPCC. These are contained in the Representative Concentration Pathways (RCPs) (Van Vuuren et al. 2011) and in the Shared Social-economic Pathways (SSPs) (O'Neill et al. 2012) exercises. More specifically, the analysis will focus on the RCP 8.5 and 4.5 climate scenarios. The former assumes high temperature increases (median +4.9°C in 2100 compared with preindustrial level) and thus high adaptation challenges; the latter a more moderate, but still non negligible temperature increase (median +2.9°C in 2100 compared with preindustrial level). The social economic development paths more consistent with these climatic futures are respectively SSP5 and the business as usual SSP2. Sub-Task 3.1.1, includes also information provision on the chosen RCPs with different levels of spatial resolution.

(C) Set the process to deliver high resolution climatic data to BASE partners. The process of delivering climatic data requests from partners proved to be complex, as it was not immediately straightforward, at least in the initial project phases, what exact information were necessary. However now the list of climate data is complete and reported in an excel spreadsheet (annex 1) attached to this document. The process of delivering the information is thus starting.

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