ECONADAPT

The Economics of Adaptation

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Multi-scale integration and synthesis of scenarios and adaptation narratives

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To find out more about the ECONADAPT project, please visit the web-site: www.econadapt.eu

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1 Introduction

ECONADAPT is an EC FP7 research project whose purpose is to support adaptation planning through building the knowledge base on the economics of adaptation to climate change and converting this into practical information for decision makers. An important activity in WP1 was foreseen to be the development of socio-economic and climate scenarios that would serve to contextualise identification of adaptation options in the various other WPs, particularly in the case studies. Very similar to the process to develop new global scenarios, activities took place in parallel, with socio-economic and climate scenarios being developed separately, to be integrated mostly through impact models. This Deliverable brings together and synthesises the various scenario activities.

1.1 Deviation from original title and content

During the construction of the Description of Work of ECONADAPT and during the early phases of the project, it was foreseen that foresight-related activities and in particular the development of socio-economic scenarios to contextualise adaptations and adaptation narratives would be a crucial part of the project. As discussed in Deliverable 1.3, however, we refrained from development of socio-economic scenarios and coupled scenario-related activities in WP 1. Similarly, the case study work did not focus on scenarios or adaptation narratives. With these changes, a synthesis of undertaken activities is less comprehensive than originally envisioned. This Deliverable will therefore also include a more methodological assessment of the integration of SSPs and Representative Concentration Pathways (RCPs) (see Deliverable 1.3) and will use the case of the workshop on the future of the Common Agricultural Policy, in which integrated scenarios were used. Section 3 and 4 will provide an overview of the climate and socio-economic scenarios as developed and/or used in ECONADAPT. Section 5 will provide an overview of the conceptual and methodological steps that need to be taken to develop integrated climate and socio-economic scenarios. Section 6 will sketch the set-up of an integrated scenario development process based on conclusions drawn in Section 3 and 4.

2 Climate scenarios in ECONADAPT

2.1 Overview of use of climate scenarios in the case studies

This Chapter provides a short overview and synthesis of Deliverable 1.4, which documented the climate scenarios used in all case studies. Although it was agreed that there was no need to ensure consistency, all case studies used the Representative Concentration Pathways (RCPs) as climate scenarios and outputs from CMIP5 General Circulation Models (GCMs) and/or CORDEX Regional Climate Models (RCMs). Thus, there was a widespread agreement on the RCPs as the most recent and most useful starting point for climate scenarios. Table 1 provides an overview of the RCPs and climate models that have been used in the various case studies.

Table 1. Overview of use of RCPs and climate models (GCMs and RCMs) in the various case studies in ECONADAPT.

Case study	RCP				Climate Model			Selection criteria for choice of model runs
	2.6	4.5	6.0	8.5	GCM	RCM	Comb.	
WP6 Bilbao		x		x	5	4	11	Central scenario based on most representative changes in extreme rainfall in SW Europe
WP6 Czech Republic	(x)	x		x	5	4	14	N/A
WP7 Policy Impact Assessment	x	x	x	x	5		N/A	Selection of 5 models made by ISI-MIP fast track
WP8 Macro-economic effects	x			x	5		N/A	Mean global temperature for RCP8.5 (5/25/50/75/95% quantiles)
WP9 International Development Support (Rwanda and Zanzibar)		x		x	10	4	18	N/A

The following conclusions stand out:

- There is (very) widespread consensus on the use of RCPs, GCMs and RCMs. Decisions are strongly influenced by the availability of existing global (CMIP5) and regional (CORDEX) data, as well as the ISIMIP efforts on impact models, particularly the ISIMIP Fast Track.
- All case studies used RCP4.5 and RCP8.5 as two main emission scenarios. Most also include RCP2.6; RCP6.0 was barely used. In terms of global temperature change, RCP4.5 and RCP8.5 almost overlap (see Figure 5), which makes RCP6.0 redundant. The choice of RCP was strongly constrained by the availability of model runs (e.g., CORDEX has focused on downscaling RCP4.5 and RCP8.5).

- Some of the case studies were able to use all available ensemble members. Where it was necessary to select a smaller number of model runs for analysis, the selection criteria were tailored to the case study, .e.g. based on “extreme rainfall” for Spain and mean global temperature for macro-economic effects.

2.2 Conclusions and recommendations

This section draws on an Insight document on 'Sourcing and using climate information for adaptation economics' by Clare Goodess and others.

Availability of data from the ISIMIP – the Impact Model Inter-comparison Project - facilitated data provision for impact estimation within ECONADAPT. Yet, the needs of the adaptation community are partly different: When discussing adaptation measures, there is a much greater focus on the current climate and also on capturing uncertainty of future climate projections: the latter includes a move beyond multi-model ensembles to include more comprehensive scenario and climate uncertainty (including deep uncertainty) as well as specific metrics to allow the application of decision making under uncertainty methods. Finally, key to successful adaptation is often in understanding the extreme, low-probability, high impact events, i.e. the "tails of the distribution" rather than global mean temperature. We recommend to devote more effort to examining the enormous amount of climate change models and data available through the lens of the adaptation community's needs and aims.

3 Socio-Economic Scenarios in ECONADAPT

As explained in Deliverable 1.3, the actual development of socio-economic scenarios in ECONADAPT was very limited. Most WPs used either the socio-economic assumptions underlying the RCPs or the SSP database to parameterise their models. With the expansion of the database with results from the IAMs and the impact models, this will certainly continue to be a main source of information for the modelling community. We revisit two means by which socio-economic scenario development in ECONADAPT was undertaken; a survey of use across all WPs and a stakeholder workshop on the future of the Common Agricultural Policy. Both are described in more detail in Deliverable 1.3.

3.1 Use of scenarios in the case studies

Towards the end of the project, a survey was designed and conducted with a number of questions focusing on the use of scenarios within ECONADAPT. Key persons from each WP were asked to complete the survey. In this way, an overview of the use of scenarios across the project could be obtained. Table 2 shows some of the results of the survey.

Table 2. Summary of survey results.

WP	**What type of scenarios?**	**What existing scenarios are you aware of relevant for ECONADAPT?**	**What scenarios did you use?**	**How did you use scenarios?**
WP1	Qualitative	CLIMSAVE scenarios; SSPs and RCPs; OECD scenarios	Various SSP x RCP combinations	Qualitative context for adaptation options and assessment of CAP changes
WP2	Quantitative scenarios	CLIMSAVE scenarios	three quantitative scenarios Scenario A: Stable preferences; Scenario B: Green preferences; Scenario C: Materialistic preferences	Assessment of future WTP
WP3	Quantitative emission scenarios, mostly related to CORDEX	First IPCC SRES, now RCPs.	The CORDEX simulations use the RCP scenarios, mainly RCP 4.5 and RCP8.5	CORDEX and RCPs, we do not particularly care about socio-economic scenarios
WP4 and WP5	Quantitative model input	SSPs and RCPs	SSPs, made consistent with global climate change assessment	SSP assumptions (SSP2) were used as model input
WP6	Quantitative model output	SSP and RCP are state-of-the-art	15 climate models forced with three RCPs (2.6; 4.5; 8.5) 3 RCP x SSP combinations: SSP1 and RCP2.6 SSP3 and RCP4.5 SSP5 and RCP8.5	Climate model output and GDP projections from SSP database
WP7	Quantitative model input and qualitative storylines related to policy measures.	SSP scenarios. ISIMIP scenarios	Various SSPs and Impact models	a.Two approaches: 1. deterministic scenario-by-scenario analysis 2. Integrated modelling and policy robustness b. stochastic scenarios of crop yield shocks c. alternative scenarios of new CAP policy measures in GLOBIOM d. risk management model
WP8	- Quantitative scenarios - OECD projections - Output from impact models - Policy scenarios	SSPs for the socioeconomic drivers and several sets of scenarios related to RCPs for different impact models.	The AgMIP output of five crop models for all RCPs and the DIVA scenarios for sea level rise. ICES model and we base our reference scenario on SSP2	SSP assumptions (SSP2) were used as model input
WP10	n.a.	SSPs and RCPs and scenarios for socio-economic indicators	n.a.	n.a.

In terms of choice of socio-economic scenarios, the following can be concluded:

- Some WPs used the RCPs as starting point to derive socio-economic scenarios. As argued above, this is not the intended use of the RCPs. Yet, given that the SSPs were not completed at the start of ECONADAPT, it is an understandable and scientifically defendable use. Yet, for future endeavours, it should be avoided.
- Some WPs used the SSPs as starting point for socio-economic scenario development. All SSPs were used, with recurring use of SSP1 (sustainable future), SSP3 (breakdown of society), and SSP5 (maximising emissions), with SSP2 sometimes serving as reference scenario.
- WP2 developed its own set of three socio-economic scenarios
- In all WPs, the focus was on using the socio-economic scenarios as input to models. SSPs were mostly used by extracting data from the SSP database. Similarly, socio-economic settings based on the RCPs were mostly data on population growth and land use change.
- Qualitative scenarios were developed in WP2 and WP7 (CAP workshop, see below)
- RCPs were leading in the choice for socio-economic scenarios. For example, high-emission climate scenarios (RCP8.5) were linked to the SSP with the highest potential for emissions and thus the use of SSP5; low-emission climate scenarios (RCP2.6) were linked to the SSP with lowest potential for emissions and the use of SSP1. The selection was based on CMIP5 data, which largely overlaps with the Tier 1 choices of Scenario MIP for CMIP6 (see Figure 4).

3.2 Choice of SSPs in the CAP workshop

A European stakeholder workshop was held on June 1st 2015, in Brussels, with participants from a variety of (policy) backgrounds and levels of expertise. The scenarios used in the workshop were integrated outlooks until 2100 as developed through the EU FP7 Programs CLIMSAVE and IMPRESSIONS. An initial set of 4 SSPs (SSP1,3,4,5) and 2 RCPs (RCP4.5 and RCP8.5) was put forward in those project as a core set to be further developed and discussed by stakeholders in IMPRESSIONS. In the context of this workshop, a smaller subset of two combinations of the European Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs) were selected to maximize scenario diversity and plausibility. The scenarios are described in detail in Deliverable 1.3, here we elaborate on the choice for SSP.

Similar to the conclusion drawn above, the choice for the most useful socio-economic scenario was, in the first instance, based on the choice of RCP. As most other scenario activities in ECONADAPT, the aim was at including two RCPs (4.5 and 8.5) because of their availability for both GCMs and RCMs, as well as the fact that a relatively low and very high emission level is included, which serves the subsequent discussions on adaptations. The latter makes RCP2.6 less useful. The two RCPs were then matched with two SSPs, using the logic from Table 4, also maximising the differences in terms of socio-economic development. We decided to use a utopian, sustainable future as described by SSP1 and a dystopian, materialistic regionalising world as described by SSP3. Note that Table 4 lists the combination RCP8.5 and SSP3 as impossible, while the Tier 1 of Scenario MIP matched SSP3 with RCP7.0 and not with RCP8.5. The impossibility of generating sufficient emissions to reach 8.5 W/m2 was a recent insight. Future research by the IAMs has to show to what extent very high emissions can be obtained by socio-economic scenarios other than SSP5.

3.3 Conclusions and recommendations

Socio-economic scenario development has been relatively limited within ECONADAPT, and mostly through the use of the SSP database. Conclusions on the use of socio-economic scenarios have been elaborated in Deliverable 1.3. Specific in the context of this Deliverable, it can be concluded that the RCPs and climate scenarios (and related climate change impacts) have been leading in the selection of socio-economic scenarios, serving mostly as model input. As such, a similar conclusion as for the climate scenarios seems valid: the influence of the climate change impact community on the choice for socio-economic scenarios is very large, while the needs of the adaptation community are partly very different.

The choice for socio-economic scenarios is almost entirely dominated by the emissions that are generated by the scenarios. Although other aspects are described in the (global) SSP narratives, they are not used when discussing adaptation options. The potential of the framework of the SSPs with its scenarios that are constructed around the challenges to mitigation and adaptation are underused. SSP1 should be seen as a scenario with high potential for adaptation and could thus be compared with SSP3 with its high challenges for adaption. Thus, we recommend the selection of scenarios based on the (differentiating) role they could play in the discussions on adaptation and mitigation policies, rather than based on their emissions.

4 Concepts of development and integration of SSPs and RCPs

This Chapter builds on and draws from Section 1.5 in Deliverable 1.3. Here, the focus is on the process of developing compartmentalised scenarios that are subsequently integrated and synthesised. For a more introductory explanation of what the Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs) are and why they were selected for use in ECONADAPT, we refer to Deliverable 1.3.

4.1 An introduction to the new global scenarios

Over the last years, the climate change research community has established a new generation of global scenarios. It encompasses a new scenario framework (Moss et al., 2010; Ebi et al., 2014; Kriegler E et al., 2014; O'Neill et al., 2014; van Vuuren et al., 2014), Shared Socio-economic Pathways (SSPs), (Kriegler et al., 2012, Kriegler E et al., 2014; O'Neill et al., 2014, Riahi et al., 2016; O'Neill et al., in press), Representative Concentration Pathways (RCPs) (van Vuuren et al., 2011), associated climate change (CMIP5, Taylor et al., 2012) and climate impact projections (e.g. ISI-MIP; Warszawski et al., 2014).

4.2 From a sequential to a parallel process

The SSP x RCP scenarios are constructed based on a so-called "parallel process", contrary to the sequential approach that was used to develop the IPCC SRES scenarios (see Figure 1). There are important reasons for changing the overall approach to scenario development. Firstly, it sped up the overall process as working in parallel allows for different activities to take place at the same time. In particular, the step of running the climate models (CMs) was slow and inhibited the impact modellers from starting their work. Although a practical consideration, it was essential in the success of the new global scenarios. Secondly, and more fundamentally, it opened the possibility of relating multiple different emission levels to a single socio-economic future outlook. In the SRES scenarios, a socio-economic outlook (e.g. B2 or A1) resulted in a single level of emissions, at least initially. This decoupling of socio-economic changes and levels of emission was a conceptual improvement.

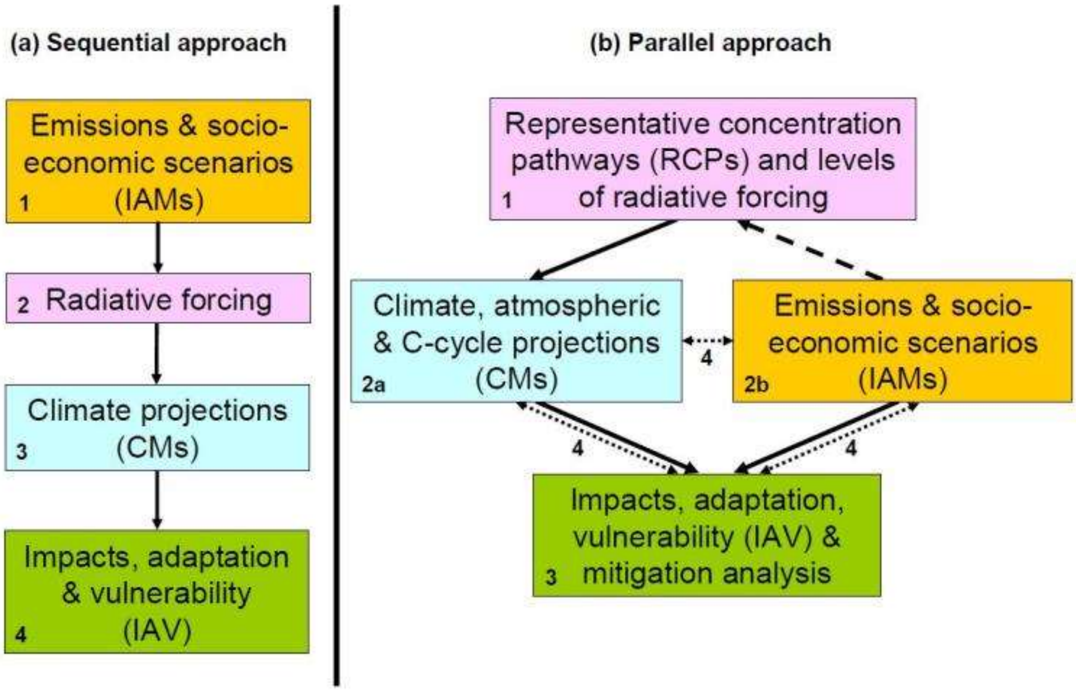

Figure 1. The difference between the sequential approach as employed to develop the IPCC SRES scenarios and the parallel approach used to develop the SSP x RCP scenarios.

Figure 2 presents the parallel process highlighting the position of the RCPs and SSPs, and serves to explain the steps that were taken:

1. Four Representative Concentration Pathways were selected based on the range of emission scenarios in the published literature. It is important to note that they serve as an initial set of scenarios to get the climate modelling efforts started early in the process. They are representative for the range of emissions, not for the range of socio-economic circumstances that explain the emission levels, hence it small lettering in Figure 2.

2a. Climate model runs and constructing ensembles to quantify climate change in terms of, among others, temperature and precipitation change

2b. Simultaneously, new socio-economic scenarios were constructed and quantified: the five Shared Socio-economic Pathways.

3a. The SSPs serve as model input to a range of Integrated Assessment Models that explore the range of emissions that an SSP can encompass

3b. The SSPs simultaneously serve as context for projections of climate change impacts, adaptation, and vulnerability research

Eventually, the circle is closed and now resembles the parallel approach with SSPs feeding into IAMs, that parametrise CMs that are used to model climate change impacts. These all together then contextualise discussions on adaptation options.

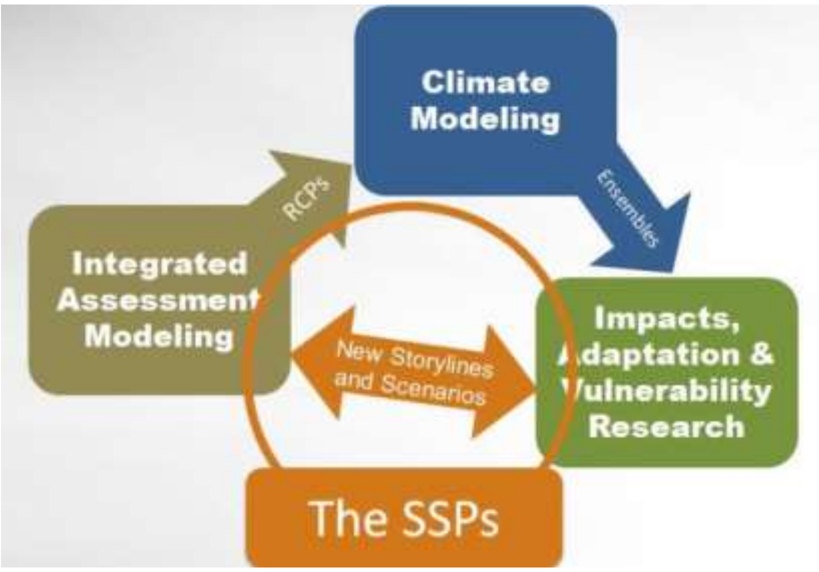

Figure 2. The parallel process of the RCP x SSP scenarios, highlighting the role of the SSPs and RCPs.

Opting for a parallel approach has some potential disadvantages. Firstly and most importantly, the RCPs were selected years before the completion of the SSPs. It was crucial to provide input for the climate modelling community, but left part of the impact modelling community as well as the IAM modellers in need of new socio-economic futures.
As a result, the socio-economic assumptions used to generate the RCPs were, mistakenly but understandably, used as socio-economic scenarios. While each single RCP is based on an internally consistent set of socioeconomic assumptions, the four RCPs together cannot be treated as a set with consistent internal socioeconomic logic. For example, RCP8.5 cannot be used as a no-climate-policy socioeconomic reference scenario for the other RCPs because RCP8.5's socioeconomic, technology, and biophysical assumptions differ from those of the other RCPs. Secondly, the initial disconnection between the RCPs and SSPs left the question which combinations were going to be possible, likely, interesting, etc. to explore unanswered. It is not until the recent publication of a special issue of Global Environmental Change that the IAMs provide insights in what levels of emissions are compatible with the various SSPs. This is further analysed in the next section.

4.3 The RCP x SSP matrix

To assess the characteristics of combinations of SSPs and RCPs, they are often shown in a matrix that also includes the third dimension of the new global scenarios, the Shared Climate Policy Assumptions (SPAs); see Table 3. To illustrate this difficulty of combining them, Figure 3 shows early explorations of all combinations of SSPs and RCPs (note: before the SSPs were developed and with five RCPs), in terms of the potential mitigation and adaptation costs. Here, only one combination was deemed impossible (SSP1 and RCP8.5). The figure indicates, for example, how low emission scenarios (RCP2.6) in a sustainable future (SSP1) have very low adaptation costs, with these costs increase with societies becoming less proactive in dealing with climate-related issues such as land use or (international) collaboration.

Table 3. Scenario development approach showing the connection between Representative Concentration Pathways (RCPs), Shared Socioeconomic Pathways (SSPs) and Shared Policy Assumptions (SPAs) in the new global scenarios.

RCP (W/m^2)	**SSPs**				
	SSP1	**SSP2**	**SSP3**	**SSP4**	**SSP5**
2.6					
4.5	SPA				
6.0					
8.5					

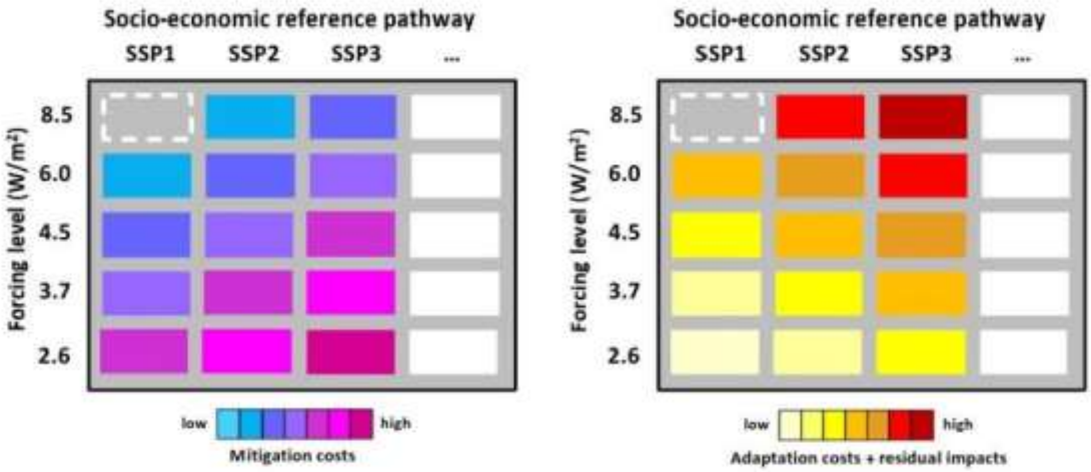

Figure 3. Potential mitigation and adaptation costs in combinations of SSPs and RCPs.

Figure 4 shows how this potential is being explored. Firstly, there are now five SSPs and 7 RCPs that are being considered. The increase in the number of RCPs is based on the results of the SSP runs with the various IAMs. It showed, for example, that the maximum emissions from SSP3 are 7.0 W/m2. Also, after the Paris Agreement, RCP1.9 was added to include a scenario of less than 2 degrees warming. Most importantly, however, Figure 4 shows that out of 35 possible combinations, at global level 24 are deemed possible, while only 8 will be explored in Tier 1 and Tier 2.

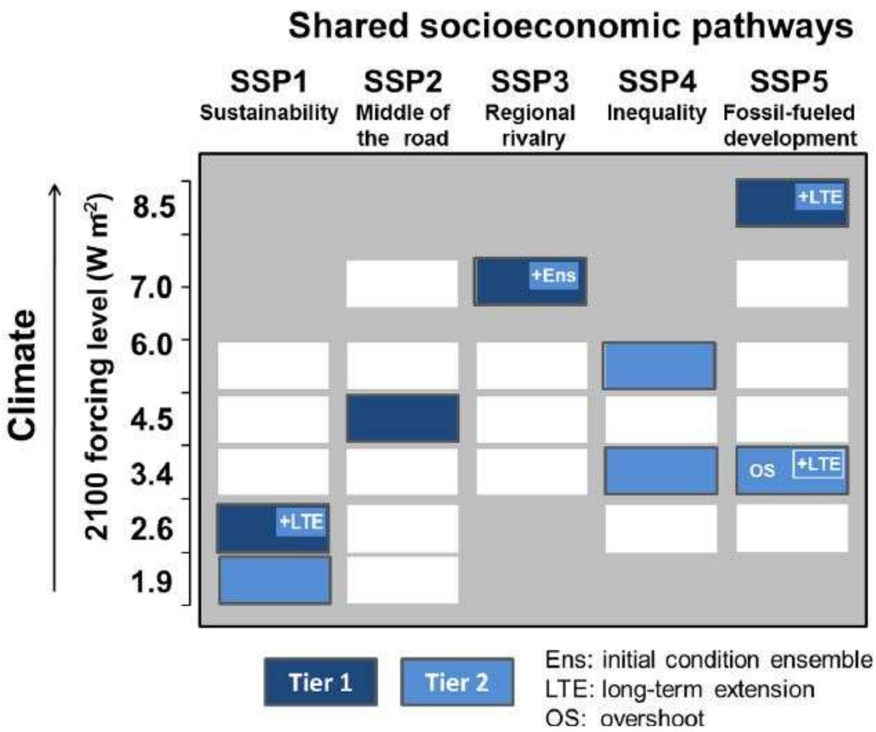

Figure 4. RCP x SSP scenario matrix with dark blue cells indicating scenarios that will serve as the basis for climate model projections in Tier 1 of Scenario MIP for CMIP6; light blue cells indicate scenarios in Tier 2.

In short, the state-of-the-art of the global community in developing integrated scenarios has progressed from using the RCPs and conceptualising RCP x SSP combinations to exploring a small subset of combinations in Scenario MIP.

4.4 Multi-scale considerations

Climate scenarios

There is an enormous amount of work related to the downscaling of global climate information. Climate models are in the first instance global. RCPs are used as input in General Circulation Models (GCMs) that provide a physically-based consistent projection for multiple variables related to climate change. There are a large number of GCMs that are commonly run in ensembles to provide a range of outputs. These models can be downscaled in two different ways. Firstly, there are about 10 Regional Climate Models (RCMs) that use the input of the GCMs in a nested approach. The advantage is that the physical base is maintained, but the RCPs are more limited. A second approach is Empirical Statistical Downscaling (ESD) that has the potential to provide information at point location for any variable, but there is the need to assume that statistical relationships hold in the future.

Socio-economic scenarios

There is an almost equal amount of work devoted to the downscaling and upscaling of socio-economic scenarios. There are socio-economic scenarios at all scales, including global, continental, national, and local. The global SSPs have explicitly been developed as basic set of socio-economic scenarios to be "extended" to other sectors and other spatial and temporal scales. Most work has been devoted to downscaling global scenarios, but upscaling by using and categorising the wealth of local scenarios is becoming increasingly important. Often, global narrative information is "translated" into model input at a lower scale, which can be upscaled. Multi-scale scenario development is the state-of-the-art in most foresight endeavours.

RCP x SSP considerations

Many of the discussions on the plausibility and possibility of the various RCP x SSP combinations were on the global scale, or at sub-global scales that strived for compatibility with global developments, such as Europe or the United States. The majority of the scenario studies, however, do not depend on a strong top-down process. Scenario development is more bottom-up, driven by more local socio-economic changes, while contextualised by global climate changes. When regarding Table 4 and Table 5, a large number of RCP x SSP combinations are simply impossible at the global level. For example, socio-economic trends in the dystopian scenario SSP3 are such that emissions cannot reach 8.5 W/m2 because of widespread poverty, economic recession, and lack of resources. Similarly, the utopian future sketched in SSP1 with its high education, low population growth, global cooperation and technological advances is unlikely to reach more than 6.0 W/m2.

Yet, at the sub-global level these direct and strong links between socio-economic developments and emissions do not exist. For Europe, for example, one might assume emissions to continue in BRICS countries and thus considering a combination of high emissions and SSP1. More importantly, combinations that are impossible at the global level range among the most interesting, challenging, and useful ones at sub-global scales. To single out two:

1. RCP8.5 x SSP1, depicting a utopian future with extremely high emissions. At global level RCP8.5 is only (barely) possible in combination with maximum fossil fuel use in SSP5. At sub-global level a scenario with high adaptation challenges but a society that is maximally ready to deal with those challenging is a very useful combination to consider when discussing adaptation options under most enabling conditions.

2. RCP2.6 x SSP3, depicting a dystopian future with extremely low emissions. At global level this seems only possible in SSP1 and SSP4 (assuming a green global elite). At sub-global level, it is challenging to aim at high mitigation and adaptation in a scenario with poor socio-economic prospects and failing governance structures, requiring new and innovative solutions.

Table 4. Likelihood of global integrated scenarios. The RCP x SSP matrix with an indication of impossible combinations and an estimate of the likelihood for possible combinations at global level provided by the IMPRESSIONS Scenario Team experts (Kok et al., 2015)

RCP (W/m^2)	SSPs			
	SSP1	**SSP3**	**SSP4**	**SSP5**
2.6	Very likely	**Impossible**	More likely than not	Very unlikely
4.5	Likely	Likely	Likely	More likely than not
7.0	**Impossible**	Likely	**Impossible**	Very likely
8.5	**Impossible**	**Impossible**	**Impossible**	Likely

Table 5. Credibility and degree of challenge of sub-global integrated scenarios. The RCP x SSP matrix with an indication of how credible and challenging the combinations are at a sub-global level (Kok et al, 2015).

RCP (W/m^2)	SSPs			
	SSP1	**SSP3**	**SSP4**	**SSP5**
2.6	Credible but not challenging	Low credibility, but very challenging	Interesting, challenging and potentially credible	Very challenging but not credible
4.5	Credible and somewhat challenging	Credible but less challenging	Credible but less challenging	Interesting, challenging, and potentially credible
7.0	Challenging and interesting but low credibility	Credible but less challenging	Less credible but interesting	Credible and somewhat challenging
8.5	Very challenging and interesting, but not credible	Interesting but not very challenging	Not credible and low challenges	Credible but not very challenging

4.5 The Shared Climate Policy Assumptions

A last component of the new global scenarios are the so-called Shared Climate Policy Assumptions (SPAs). The SSPs are supposed to be describing socio-economic trends as well as policy assumptions in other sectors (e.g. energy, water, food, etc.), but without any indication on climate policies, either mitigation or adaptation. These are supposed to be covered by the SPAs. To date, the climate change community has not explicitly addressed what the SPAs should include and what they should not, and how to deal with policies that are not climate, but have strong impacts on emissions (e.g. energy or land use). Particularly mitigation policies within any SSP will determine the range of emissions that are possible against a certain socio-economic backdrop.

4.6 From RCP and SSP to model input and output

With the choice for RCPs, SSPs, and RCP x SSP combinations, the conceptually most important step has been taken. Yet, equally important is the more practical choice to transform narrative information (SSP) or Watts per square meter (RCP) to useful information that can be modelled.

Choice of climate model (GCM and RCM)
Climate change models translate emissions to dynamics in Temperature and precipitation. Although depending on season, region, and variables of interest, there are indications that the scenario uncertainty (difference due to difference in forcing level) is *less* than the model uncertainty (differences because choice of model), particularly in the “shorter” time horizon until 2100. Figure 5 shows the overlap between RCPs that is complete until 2050 and only partly different until 2100. It is not until examining even longer temporal outlooks that scenario uncertainty starts dominating and the choice of model is less important. Particularly for RCP8.5, there is a huge and fundamental model uncertainty. Note that this is only measured against 1 single, global indicator: average mean temperature. When examining differences across space, for precipitation, or for extreme events, there is much less agreement between climate models. Without wanting to enter in the debate of the (dis)agreement between GCMs, it is clear that the model choice is at least equally crucial as the choice of RCPs.

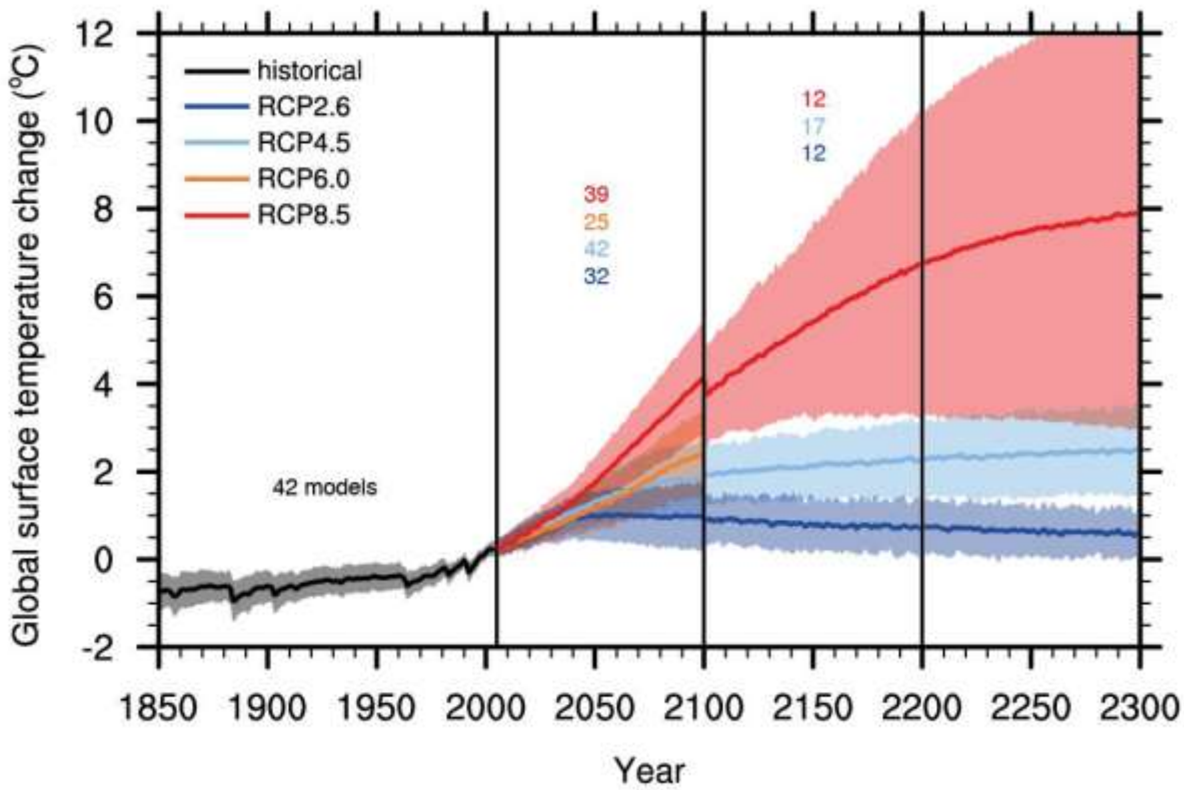

Figure 5. Global average temperature change under the various RCPs with an indication of model uncertainty.

Example from the IMPRESSIONS project

Table 6 shows the temperature changes resulting from a climate scenario selection procedure that was followed in another EU-funded project, IMPRESSIONS, a project on "high-end" scenarios. In this procedure, first, five GCMs were selected based on scientific acceptance and average temperature increase that was projected under two RCPs. Given that IMPRESSIONS is on high-end scenarios, we picked the HadGEM2-ES model as GCM and RCA4 as RCM to project temperature and precipitation changes when communicating with stakeholders. Note that the online Integrated Assessment Platform developed with IMPRESSIONS uses all five of the selected pairs of global/European models, while off-line modelling efforts include results of 20+ GCMs/RCMs in ensemble runs.

Table 6. Overview of average temperature changes until 2100 for five selected GCMs and matching RCMs for Europe.

Selected GCM	Global ΔT		**Selected RCM**	Europe ΔT	
	RCP8.5	RCP4.5		RCP8.5	RCP4.5
HadGEM2-ES	4.19	2.35	**RCA4**	4.28	2.15
CanESM2	4.06	2.11	**CanRCM4**	4.26	2.44
IPSL-CM5A-MR	4.01	2.05	**WRF**	4.02	2.34
MPI-ESM-LR	3.22	1.46	**CCLM4**	3.07	1.42
GFDL-ESM2M	2.39	1.07	**RCA4**	2.86	1.46

Choice of demographic and economic model

Two of the main model variables that need to be quantified based on the SSPs, for most if not all integrated assessment and (socio-economic) impact models are population growth and GDP development. Although the spread of uncertainty appears to be not as large as for climate models, choice of demographic projection and GDP development are important steps to take, and the uncertainty may be exacerbated across different world regions. The SSP database (https://tntcat.iisasa.ac.at/SspDb) offers data on population and GDP for every country in the world and for every year until 2100 for all five SSPs. Population estimates are provided by IIASA and NCAR, while GDP projections are given by PIK, IIASA, and OECD, with substantial differences. Current studies seem to favour the OECD projections of GDP and IIASA projections of populations. Work has started on probabilistic approaches and ensemble runs.

4.7 Conclusions relevant for synthesis in ECONADAPT

- The new global scenarios, the RCP x SSPs, follow a parallel process in which socio-economic scenario development and emission scenarios are (initially) decoupled. This offers opportunities but also present difficulties when contextualising adaptation policies.

- At global level, the recent IAM model runs have shown which combinations are (im)possible, with interesting insights: Very high emission levels (RCP8.5) are difficult to reach; very low emission levels are possible, but also very difficult to achieve.

- At sub-global level, globally impossible combinations are particularly interesting to explore.

- Model choice to translate emissions to climate change and socio-economic dynamics to model essential model inputs such as population growth is at least as important as the choice for RCP x SSP combination.

- In short, scenario development and use in future adaptation projects should make use of knowledge being gathered by the global climate change community, but should not be limited to global boundary conditions given in the SSP database but explore/develop wider adaptation narratives.

5 Towards integration of climate scenarios, socio-economic scenarios and adaptation narratives

This Chapter presents a methodology by which the global RCPs and SSPs can be used as they were originally intended and described (see Figure 2 and Table 4). It can be seen as a two-step process, where first the RCPs and SSPs are combined into integrated scenarios that can be subsequently used to contextualise discussion on adaptation options. These two steps are described separately below in the following sections.

5.1 Practical steps to select and integrate

There are a number of concrete steps that could be followed to integrated RCPs and SSPs, and to use the product to assess the adaptation options:

1. **Select climate change scenarios:**

- *Select relevant RCPs* for the aim of the project, to maximise usefulness of the RCPs. Particularly important are the recent results of the global IAMs that are starting to redefine the ranges of emissions that can be related to the different SSPs. Options that were deemed possible and relevant (e.g. SSP3 x RCP8.5) are now being questioned, at least at global level.
- *Select relevant climate change indicators.* Assess the needs of stakeholders and other users: what type of output needs to be produced?
- *Select relevant GCMs and RCMs, and downscaling method.* It is crucial to assess the needs of the adaptation community to select the most relevant models or downscaling method, in order to be able to produce climate change scenarios that have the correct temporal, spatial, and thematic resolution.

  Product: set of quantitative, spatially explicit climate change scenarios.

2. **Select socio-economic scenarios:**
   Select relevant SSPs for the aim of the project. Particularly important is the information in the SSPs related to technology, governance systems, degree of globalisation, education, etc. in order to capture those aspects that will influence which adaptation options can most easily be implemented in a particular socio-economic future.

- *Select relevant socio-economic (demographic, etc.) models.* Mostly, the SSP database is used, but arguably there might be other models that are more suitable, particularly when studies are not global.
- *Select relevant downscaling method.* When developing case-study scenarios, the choice of downscaling method will determine whether you will have a strong top-down process with case-study scenarios that resemble the global starting point, or whether you will have a bottom-up process that has a strongly local identity, which

might deviate strongly from the global SSPs. Both are possible and have advantages and disadvantages

Product: set of qualitative and quantitative, multi-scale socio-economic scenarios

3. **Combine/integrate RCPs and SSPs**

- *Determine which combinations of RCP x SSP* are most useful to further explore, given the needs of the adaptation community. This could include globally plausible combinations, but also globally impossible but sub-globally interesting sets of RCPs and SSPs.
- *Integrate RCPs and SSPs.* There are multiple ways by which this can be done. Most common in climate change research, and also employed in ECONADAPT, is to integrate RCPs and SSPs when applying impact models. These will produce integrated impacts that can be used to assess adaptation options. Less common is an integration before models are applied. In the CAP workshop, we presented stakeholders with an integrated future of socio-economic and climate change, based on which adaptation options were discussed before models were applied.

Product: sets of qualitative and quantitative, spatially explicit, integrated scenarios.

4. **Develop adaptation narratives**

- *Discuss adaptation options* and/or mitigation options and/or their trade-offs in the context of the integrated scenarios, and given certain targets. These loosely connected options should be consolidated in adaptation narratives that capture the logic of taking certain options at a certain moment in time, given the socio-economic context of that moment.
- *Assess robustness of adaptation narratives* across scenarios, and determine elements that might be successful in all of the integrated scenarios.

Product: set of “no-regret adaptation policies” that could be implemented independently from which scenario will play out.

In ECONADAPT, the use of socio-economic scenarios was limited to the input of (impact) models. This allowed for the development of adaptation options, against adverse impacts as projected by the impact models. It would also allow for an assessment of the adaptation options needed under different impacts and an assessment of the robustness of certain adaptation options. It did not, however, allow for the development of (integrated) adaptation narratives and integrated assessment of what adaptations are feasible, or trade-offs with mitigation.

5.2 Towards high-quality future climate information: credibility, legitimacy, and saliency

Besides the practical steps and reasons to develop integrated scenarios, there is a more fundamental issue in the aim for high-quality climate information and scenarios. It has been proposed to measure the quality of scenarios (and climate information) by their credibility, legitimacy, and saliency. In general, there is a tendency for the physical climate science community to focus on credibility, whereas when involving stakeholders (including policy makers) particularly salience is important. Future climate information can only be of the highest quality possible, when it is credible, legitimate, and salient, which thus calls for the integration of biophysical modelling and stakeholder involvement.

As hinted to in Deliverable 1.3, the so-called Story-And-Simulation approach has been put forward as a means to develop scenarios in an iterative procedure between stakeholders and modellers. This would allow for salient scenarios as stakeholders first develop socio-economic scenarios and help determine the research questions to the extent possible, which are thus useful. It would also allow for credible scenarios, as the state-of-the-art models are used to project climate change and its impact. By combining both, it would increase legitimacy as different user groups are involved in the construction of the scenarios.

The approach taken in ECONADAPT has taken all aspects into account, but by using existing scenarios and thus excluding stakeholders from scenario development, legitimacy of the scenarios might be endangered. As this is the context within which adaptation options are discussed, it might also jeopardise those results. In the very least, legitimacy and saliency of the resulting scenarios can be improved.

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