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A framework for a new generation of socioeconomic scenarios for climate change impact, adaptation, vulnerability, and mitigation research

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55 **1 Introduction and Overview**

56 Climate change is projected to impact human and natural systems, with differential
57 consequences across regions, sectors, and time. The magnitude and extent of future impacts
58 will depend on the response of the Earth system to atmospheric composition; the effectiveness
59 of mitigation and adaptation options to avoid, prepare for, and respond to impacts; and on
60 development pathways, including changes in demographics, economies, technologies, and
61 policies. Scenarios can be used to explore and evaluate the extensive uncertainties in each of
62 these. The term *scenario* describes a comprehensive description of the future of the human-
63 climate system, including quantitative and qualitative information. This can be distinguished
64 from the term *pathway* that describes scenario components such as atmospheric concentration
65 or development indicators

66 Acronyms

67	CM = Climate Modeling community
68	CMIP3 = Climate Model Intercomparison Project 3
69	CMIP5 = Climate Model Intercomparison Project 5
70	IAM = Integrated Assessment Modeling community
71	IAV = Impacts, Adaptation, and Vulnerability community ¹
72	RCP = Representative Concentration Pathways
73	SPA = Shared climate Policy Assumptions
74	SSP = Shared Socioeconomic reference Pathways

75 The roadmap of the new scenario process was laid out in Moss et al. (2008) and summarized in
76 Moss et al. (2010). The process consists of preparatory, parallel, and integration phases that
77 involve the CM, IAM, and IAV communities. The new scenarios will provide quantitative and
78 qualitative narrative descriptions of socioeconomic reference conditions that underlie
79 challenges to mitigation and adaptation, and combine those with projections of future
80 emissions and climate change, and with mitigation and adaptation policies. They will provide a
81 framework for underpinning, creating, and comparing sectoral and regional narratives.

82 In the *preparatory phase*, IAM teams at IIASA, JGCRI-PNNL, PBL, and NIES produced four
83 **Representative Concentration Pathways (RCPs)** for use in the Climate Model Intercomparison
84 Project 5 (CMIP5). The RCPs were created to jumpstart the analysis process. They were crafted
85 with the climate modeling community as the principal user group (Moss, et al., 2010). There
86 are four RCPs, each defined in terms of its radiative forcing in the year 2100 and direction of
87 change (van Vuuren et al., 2011a).

88

89

¹ Past IPCC assessments used the acronym IAV, though usage among researchers in the field varies, with VIA, AVI and AIV often adopted as alternatives. This report retains IAV for consistency with previous reports, but takes no position on the most appropriate formulation, which in any case would not be expected to influence the scenario framework described.

90 *Table 1.1: Representative Concentration Pathways in the Year 2100*

	Radiative forcing	CO ₂ equivalent concentration	Rate of change in radiative forcing
RCP 8.5	8.5 W/m ²	1350 ppm	Rising
RCP 6.0	6.0 W/m ²	850 ppm	Stabilizing
RCP 4.5	4.5 W/m ²	650 ppm	Stabilizing
RCP 2.6	2.6 W/m ²	450 ppm	Declining

91 The RCPs provide information that is essential input to climate models, including emissions of
 92 greenhouse gases and short-lived species at ½ degree by ½ degree grid scale, and land use and
 93 land cover. As stand alone products, the RCPs have limited usefulness to other research
 94 communities. First and foremost, they were selected with the sole purpose of providing data to
 95 climate models, taking into consideration the limitations in climate models differentiating levels
 96 of radiative forcing. They lack associated socioeconomic and ecological data. They were
 97 developed using idealized assumptions about policy instruments and the timing of participation
 98 by the international community.

99 Therefore, there is a need to develop socioeconomic and climate impact scenarios that draw on
 100 the RCPs and associated climate change projections in the scenario process. Referencing the
 101 RCP and climate change projections has two potential benefits; they would facilitate
 102 comparison across research results in the CM, IAM, and IAV communities, and facilitate use of
 103 new climate modeling results in conjunction with IAV research.

104 The *parallel phase* has several components. Within CMIP5, CM teams are using the RCPs as an
 105 input for model ensemble projections of future climate change. These projections will form the
 106 backbone of the IPCC's Working Group I assessment of future climate change in the 5th
 107 Assessment Report (AR5). The IAM community has begun exploring new socioeconomic
 108 scenarios and producing so-called RCP replications that study the range of socioeconomic
 109 scenarios leading to the various RCP radiative forcing levels. In the meantime, IAV analyses
 110 based on existing emission scenarios (SRES) and climate projections (CMIP3) continue.

111 In the *integration phase*, consistent climate and socioeconomic scenarios will inform IAM and
 112 IAV studies. For example, IAV researchers can use the new scenarios to project impacts, to
 113 explore the extent to which adaptation and mitigation could reduce projected impacts, and to
 114 estimate the costs of action and inaction. Also, mitigation researchers can use the global
 115 scenarios as “boundary conditions” to assess the cost and effectiveness of local mitigation
 116 measures, such as land-use planning in cities or changes in regional energy systems.

117 These scenarios need to supply quantitative and qualitative narrative descriptions of potential
 118 socioeconomic and ecosystem reference conditions that underlie challenges to mitigation and
 119 adaptation. And they have to be flexible enough to provide a framework for comparison within
 120 which regional or local studies of adaptation and vulnerability could build their own narratives.
 121 The defining socioeconomic conditions of these scenarios have been designated **Shared**
 122 **Socioeconomic reference Pathways (SSPs)**.

123 This document presents a conceptual framework for developing new scenarios using a matrix
 124 approach. This approach provides the landscape within which a particular scenario can be

125 located based on the state of human societies (SSPs); the degree of anthropogenic interference
126 with the climate system (measured in terms of radiative forcing as e.g. described in the RCPs);
127 the state of the atmosphere and climate (CMIP5 and other projections); and shared climate
128 policy assumptions. The resultant scenarios can be used for individual research projects and for
129 integrated assessments of mitigation, adaptation, and residual climate impacts.

130 **1.1 Outline of key features of the new scenarios**

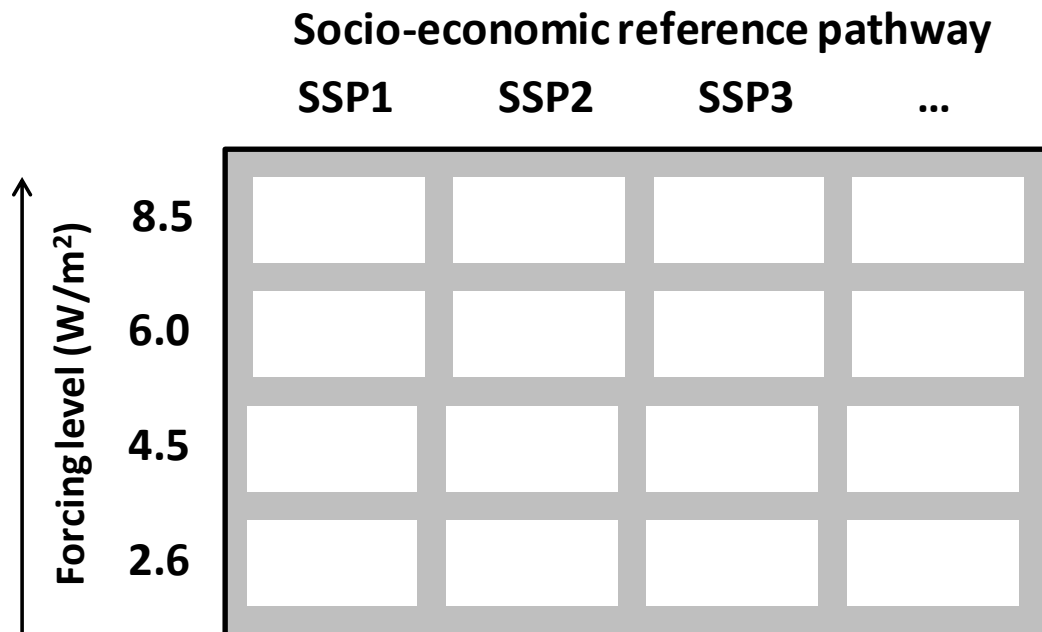
131 The scenario matrix approach and its underlying concepts are described in Section 2.

132 The SSPs define the state of human and natural societies at a macro scale and have two
133 elements: a narrative storyline and a set of quantified measures that define the high-level state
134 of society as it evolves over the 21st century under the assumption of no significant climate
135 feedback on the SSP. This assumption allows the SSP to be formulated independently of a
136 climate change projection. In reality, SSPs may be affected by climate change, which can be
137 taken into account when combining SSPs with climate change projections to generate a
138 socioeconomic-climate reference scenario. In the absence of climate policies, the SSPs may lead
139 to different climate forcing in the reference case and to different changes in climate. See
140 Section 3 for a conceptualization of the SSPs.

141 Two axes of the scenario matrix are the SSPs and radiative forcing levels (see Figure 1). Each
142 combination of an SSP and a radiative forcing level defines a family of macro-scale scenarios.
143 Because the RCP level provides only a rudimentary specification of mitigation policy
144 characteristics, and very little information on adaptation policies, a third axis embeds RCPs in
145 **Shared climate Policy Assumptions (SPAs)** that include additional information on mitigation and
146 adaptation policies, e.g. global and sectoral coverage of greenhouse gas reduction regimes, and
147 the aggressiveness of adaptation in different world regions. Obviously, there can be more than
148 one SPA for a given radiative forcing level. For any combination of SSP, RCP, and SPA, there will
149 be a number of possible climate change projections that are associated with a different model
150 of the physical climate system, adding another dimension to each cell. See Section 4 for a
151 discussion of SPAs.

152 Not every cell of the scenario matrix need be populated. For example, an SSP that is defined
153 such that population growth decreases rapidly and renewable energy costs are quickly reduced
154 may be inconsistent with radiative forcing reaching 8.5 Wm^{-2} in 2100. However, scenarios
155 associated with lower radiative forcing can be populated assuming appropriate levels of
156 mitigation. The degree of global climate mitigation stringency is inversely related to the level of
157 radiative forcing in the year 2100: the wider the gap between baseline forcing and an RCP level,
158 the more effort will be required to close it. Thus, by definition, smaller radiative forcing in 2100
159 implies greater mitigation stringency.

160



161

162 *Figure 1.1: The scenario matrix architecture: confronting different future levels of climate*
 163 *forcing with different socio-economic reference assumptions described by SSPs. See Section 2*
 164 *for details.*

165 Main modes of analysis will be to explore (a) the implications of increasingly stringent mitigation
 166 within any one SSP, e.g. an analysis based on scenarios within one column; (b) the implications
 167 of different climate policy assumptions, e.g. increasing adaptation aggressiveness for a given
 168 RCP and SSP combination; and (c) the implications of various SSPs within any one category of
 169 radiative forcing, e.g. an analysis based on scenarios within one row. There also can be analyses
 170 within any one cell (or collection of cells) to examine the implications of using different climate,
 171 mitigation, or impact models within an SSP/RCP combination.

172 1.2 Scenarios in previous assessments

173 Global change scenarios widely used include those of the Special Report on Emissions Scenarios
 174 (SRES), the scenarios developed for the Millennium Ecosystem Assessment, and the GEO-4
 175 scenarios.

176 The SRES set of scenarios was developed to represent the range of driving forces and emissions
 177 in the scenario literature, to reflect current understanding about underlying uncertainties
 178 (Nakicenovic, 2000). The scenarios were based on an extensive assessment of driving forces
 179 and emissions in the scenario literature, alternative modeling approaches, and a process that
 180 solicited wide participation and feedback. Four narrative storylines were developed to
 181 consistently describe the relationships between emission driving forces and their evolution,
 182 with each storyline representing different demographic, social, economic, technological, and
 183 environmental development pathways. The scenarios cover a wide range of the main
 184 demographic, economic, and technological driving forces of GHG and sulfur emissions. For each
 185 storyline, several different scenarios were developed using different modeling approaches to

186 examine the range of outcomes arising from models that use similar assumptions about driving
 187 forces. Contrary to the new scenarios described here, the SRES scenarios assumed no
 188 specifically targeted climate mitigation and adaptation policies and measures. In subsequent
 189 studies and assessments, such extensions to the original SRES set were explored extensively.

190 The Millennium Ecosystem Assessment (MEA) was a large assessment of the current status,
 191 present trends, and longer-term challenges to the world's ecosystems, including climate change
 192 and other sources of stress. The MEA sought to assess changes in ecosystems in terms of the
 193 services they provide to people and the effects of ecosystem change on human well-being; and
 194 to identify and assess methods to mitigate and respond to ecosystem change. Scenarios to
 195 2050, with more limited projections to 2100, were developed in an iterative process, including
 196 consultations with potential scenario users and experts (Carpenter, 2005). Two basic
 197 dimensions of uncertainty in long-term ecosystem stresses were identified: globalization
 198 (continuation and acceleration of present global integration trends, versus reversal of these
 199 trends to increasing separation and isolation of nations and regions) and whether responses to
 200 increasing ecosystem stresses are predominantly reactive – waiting until evidence of
 201 deterioration and loss of services is clear – or predominantly proactive, taking protective
 202 measures in advance of their clear need. The extreme values of each of these dimensions
 203 yielded four scenarios, summarized in table 1.3.

204 *Table 1.3: The Millennium Ecosystem Assessment scenarios.*

ECOSYSTEM MANAGEMENT	WORLD DEVELOPMENT	
	Global	Regional
Reactive	Global Orchestration	Order from Strength
Proactive	TechnoGarden	Adapting Mosaic

205
206

207 The GEO-4 conceptual framework is based on the drivers-pressures-state-impacts-responses
 208 (DPSIR) concept that reflects the key components of the complex chain of cause-and- effect
 209 relationships that characterize the interactions between society and environment at all spatial
 210 scales, from global to local (Agard et al., 2007). Environmental changes are induced by drivers
 211 and caused by pressures, and also affect each other. Responses include measures by society for
 212 mitigating and adapting to environmental changes. Through the GEO-4 scenario exercise,
 213 stakeholders explored the interplay between some of the environmental issues in atmosphere,
 214 land, water and biodiversity. The scenarios were based on assumptions related to institutional
 215 and socio-political effectiveness, demographics, economic demand, trade and markets, scientific
 216 and technological innovation, value-systems, and social and individual choices, and highlighted
 217 areas of uncertainty in the coming decades. The main scenarios are:

- 218 • Markets First: the private sector, with active government support, pursues
 219 maximum economic growth as the best path to improve the environment and
 220 human well-being for all.

- 221 • Policy First: the government sector, with active private- and civic-sector support,
222 implements strong policies intended to improve the environment and human well-
223 being, while still emphasizing economic development.
- 224 • Security First: the government sector and the private sector vie for control in efforts
225 to improve, or at least maintain, human well-being for mainly the rich and
226 powerful in society.
- 227 • Sustainability First: the civic, government and private sectors work collaboratively to
228 improve the environment and human well-being for all, with a strong emphasis on
229 equity.

230 **2 The scenario framework: main concepts**

231 **2.1 Criteria for a new scenario framework**

232 The CM, IAM, and IAV communities use scenarios in different ways and for different purposes.
233 Therefore, their requirements for scenarios differ, including relative emphases on scenario
234 elements and approaches. At the same time, the communities use each other's results and
235 insights, and they collaborate in research and scientific assessment activities, such as the
236 Intergovernmental Panel on Climate Change (IPCC), with its working groups corresponding to
237 the three major research communities. Policy relevant questions for research and assessment
238 include the interactions among and trade-offs between adaptation and mitigation responses,
239 and options to deal more effectively with the challenge of understanding multiple stresses.
240 There is a clear benefit from scientific and policy perspectives if a subset of scenarios provides a
241 connecting and integrative thread across the three communities. There also is clear benefit to
242 being able to synthesize across studies of climate modeling, impacts, adaptation and mitigation
243 options, and co-benefits to, for example, estimate costs of action and inaction under different
244 scenarios. The scenarios discussed in this paper are designed to serve these purposes.

245 Projections of future impacts, adaptation, and vulnerability, need qualitative and quantitative
246 information on climate (change) and the status of the exposed system (to assess its sensitivity
247 and adaptive capacity, which strongly depend on socioeconomic conditions). Scenarios in IAM
248 models mostly concentrate on mitigation, primarily related to the technological implications of
249 different stabilization targets and their associated costs. Taken together, these suggest that key
250 factors in the interaction between the different disciplines include:

- 251 • The level of climate change and associated impacts;
252 • Trends in human development in relation to drivers of climate change, the ability to
253 mitigate greenhouse gas emissions, and the ability to adapt to climate change.

254 A useful scenario framework would predominantly include these two elements. Other design
255 criteria can be derived from the intended purposes of the scenarios (Van Vuuren et al., 2011b;
256 Kriegler et al., 2011):

- 257 1. **Limited number:** The set of scenarios should be as small as possible, consistent with
258 other scenario design criteria.

- 259 2. **Comprehensive.** The framework needs to cover sufficiently different future
260 development to represent a plausible range of assumptions and thus represent relevant
261 uncertainties.
- 262 3. **Comparability.** The scenario set should make it possible for some research knowledge
263 generated in one community to be compared with information generated in another.
- 264 4. **Relate adaptation, mitigation, and climate impacts.** The scenarios should provide a
265 means of synthesizing information from the three climate research communities in a way
266 that highlights the similarities and differences among alternative potential climate
267 futures, and that allows estimation of associated costs.
- 268 5. **Multiscale.** The storylines should provide enough explicit information on the aggregated
269 scale to be clearly distinguishable also at finer scales. Similarly, storylines and scenarios
270 should embrace near-term and long-term future conditions; the former providing
271 linkages to ongoing trends and planning horizons, and the latter accommodating
272 plausible large-scale divergences in key driving factors.
- 273 6. **Structured but flexible.** The scenario set should provide enough structure to facilitate
274 consistency, and offer context and calibration points for IAV and mitigation analyses, but
275 also offer flexibility for defining relevant details.

276 2.2 The scenario matrix approach

277 2.2.1. Need for new socioeconomic scenarios

278 The emission scenarios underlying the RCPs provide a consistent combination of socioeconomic
279 parameters, such as population, income, energy use, land use, emissions and climate. However,
280 as shown by Van Vuuren et al. (2011b), as a set these scenarios do not match another important
281 criterion, e.g. a wide coverage of the literature. In that context, it should be noted that the
282 emission scenarios were selected from the literature on the basis of their joint coverage of a
283 wide radiative forcing range. The socioeconomic parameters are based on specific assumptions
284 of each individual team and for most RCPs represent medium assumptions. There is no logical
285 story behind the assumptions of the RCP set as a whole.

286 This raises the question as to whether it is possible to combine different socioeconomic
287 scenarios and forcing levels. The SRES-report (Nakicenovic et al., 2000) found that for each
288 forcing level, multiple emission pathways can be identified. More recently, Van Vuuren et al.
289 (2011b) confirmed that very little correlation exists between the population and economic
290 assumptions of climate policy scenarios and the forcing levels. In other words, for a given set of
291 such socioeconomic boundary conditions, it is possible to project a very wide but credible range
292 of future emissions, radiative forcing, and climate. Similarly, a given emissions pathway may be
293 reached under a wide variety of socioeconomic boundary conditions.

294 2.2.2. The scenario matrix approach as an overall organizing principle

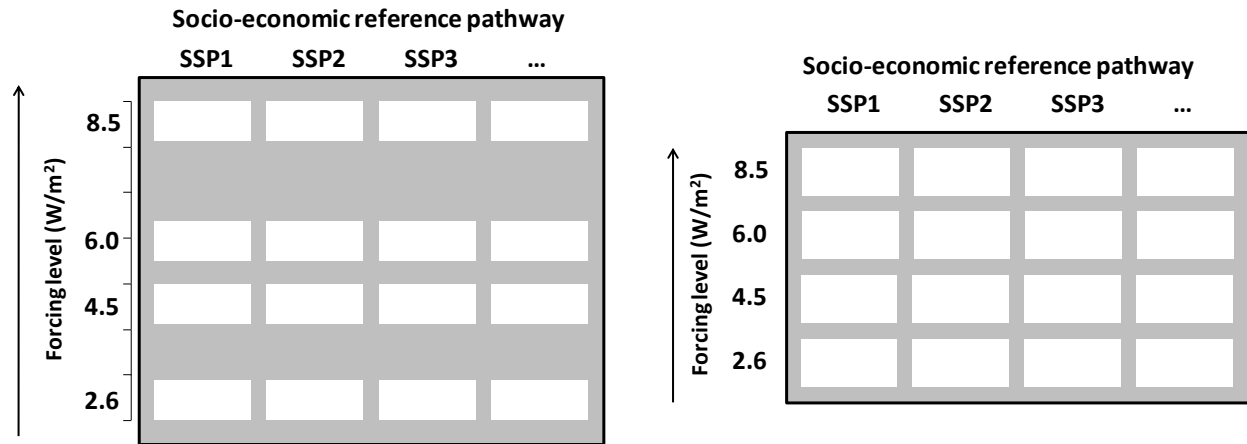
295 The scenario matrix approach is based on two crucial elements: radiative forcing level (as an
296 organizing variable for climate change); and the socioeconomic assumptions underlying the
297 scenarios.

298 Assumptions about socioeconomic development are important ‘drivers’ of scenarios, including
299 the scenario narrative, and qualitative and quantitative assumptions about broad development
300 patterns for major world regions. A scenario combines these assumptions with a quantitative
301 dynamic analysis in a model. Therefore, scenarios include assumptions and derived
302 quantifications of additional socioeconomic indicators relating to energy or land use (or if
303 additional models are used, parameters such as health). Model assumptions and the model
304 output parameters can be relevant for IAM and IAV analysis. To group scenarios, a minimum set
305 of assumptions should (to some degree) be shared among all scenarios in a group. This
306 minimum set ensures some amount of consistency. The elements of the socioeconomic
307 reference scenario that are shared among all possible manifestations in a column of the
308 scenario matrix form a **Shared Socioeconomic reference Pathway** or **SSP**. For the purpose of
309 the SSP within the scenario matrix, we explicitly assume that in their original form they do not
310 include climate policy and that these assumptions are not influenced by climate change. As
311 such they form a reference that defines the columns of the matrix in Figure 1.

312 The primary objective of the SSPs is to provide sufficient information and context for defining
313 development pathways that can be used as a starting point for IAM and IAV analyses, at the
314 same time differing significantly in the challenges to mitigation and adaptation. The SSPs thus
315 comprise a set of narratives and quantitative information on the drivers of how the future might
316 unfold. The quantitative information from that scenario will include an internally consistent set
317 of input assumptions that can be used directly by different types of models for the development
318 of reference scenarios. The SSPs are discussed further in Section 3.

319 In Figure 2.1, the SSPs form the horizontal axis in the scenario matrix and the RCPs form the
320 vertical axis (Moss et al., 2010). This is a natural choice because radiative forcing constitutes the
321 most useful interface between the IAM (translating emissions drivers to forcing) and CM
322 communities (translating forcing to climate change). The CM community is conducting multiple
323 modeling experiments to investigate the climate response to the RCPs. It should be noted that,
324 in fact, the radiative forcing axis is continuous, which means that scenarios (in particular those
325 without explicit climate targets) could end up at places along this axis that do not correspond to
326 a specific RCP. How the climate projections from the RCPs can be used with these scenarios
327 needs further elaboration.

328 One column of the matrix thus contains scenarios constructed from the family of socioeconomic
329 reference pathways and the radiative forcing levels of the RCPs. The elements of an SSP can
330 change when moving from a reference to a policy scenario as a result of climate change and
331 climate policy (adaptation or mitigation). This does not limit the ability to separate the RCP and
332 SSP dimensions because all scenarios within a column refer to a single reference SSP.



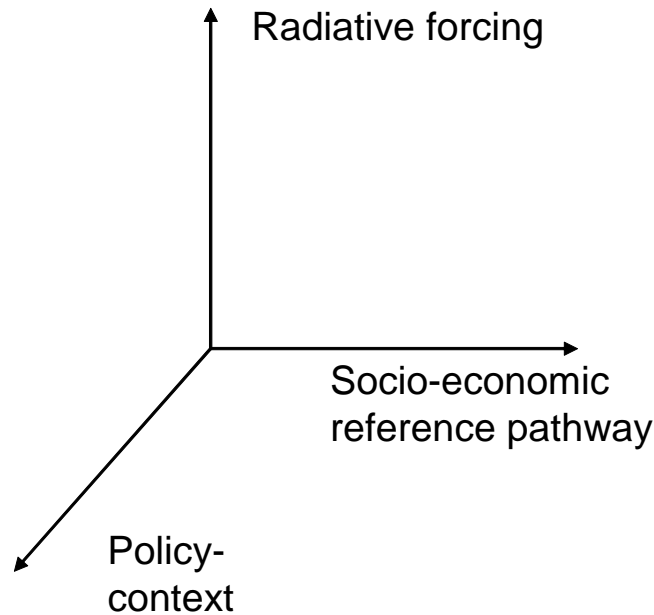
333

334 *Figure 2.1: The scenario matrix architecture: confronting different future levels of climate*
 335 *forcing with different socioeconomic reference assumptions described by SSPs. The number of*
 336 *SSPs has been chosen for illustrative purposes. The forcing levels are chosen to correspond to the*
 337 *forcing level reached by the RCPs. The left-hand panel shows the matrix with equidistant vertical*
 338 *axis, illustrating the relative position of the RCPs on the forcing scale. The right-hand panel*
 339 *shows a simplified version of the matrix that is used throughout this report.*

340 2.2.3 Common policy assumptions

341 A series of additional assumptions are needed about adaptation and/or mitigation policies to
 342 derive a policy scenario consistent with a given combination of an RCP and an SSP. Examples
 343 are cooperative vs. non-cooperative action and sectoral flexibility in using the least cost
 344 mitigation options, and adaptation preparedness in different world regions; the effectiveness
 345 and costs of mitigation and adaptation depend on these assumptions. Analogous to the
 346 socioeconomic reference assumptions, another dimension of the matrix architecture is a set of
 347 **Shared climate Policy Assumptions (SPA)** that characterize the types of climate policies. In
 348 practice, each research team will make its own assumptions about climate policies to reach a
 349 given RCP. The SPAs will be an attempt to categorize the key elements of those assumptions
 350 beyond the RCP level. In a scenario with climate policy (in particular mitigation), some scenario
 351 elements (like energy use and land use, or GDP size and sectoral composition) are bound to
 352 differ from the reference scenario; these may include elements of the SSP. In the mitigation
 353 example, the new model output GDP replaces the SSP assumption.

354 Climate policy scenarios are derived by combining an SSP and SPA (e.g. a set of climate policies
 355 designed to achieve a given RCP level), and, possibly, climate change projections. Because GDP
 356 and other variables would be affected by the climate policies and climate change impacts,
 357 model outputs would replace reference SSP assumptions when and where they were
 358 significantly different. Climate policy scenarios generally include assumptions about
 359 adaptation, framed by the SSP narrative and the assumed SPA characteristics. The analysis of
 360 mitigation policies may be conducted without explicitly taking climate change projections into
 361 account.



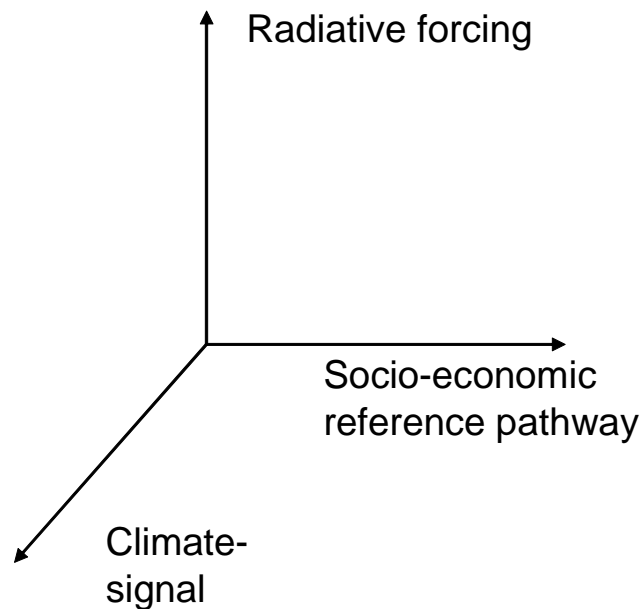
362

363 *Figure 2.2: The policy context may still vary within a SSP. Therefore, the policy context can be*
364 *defined as an additional axis to explore in scenario analysis. Note it is not implied that the*
365 *forcing level and the policy context, nor the policy context and the SSP, are uncorrelated.*

366 2.3.4 The climate dimension

367 The vertical axis in the scenario framework is defined in terms of RCPs, i.e. the level of radiative
368 forcing. As explained above, the choice is made for practical reasons (RCPs form the connecting
369 element between IAM and CM models; radiative forcing targets are commonly used across IAM
370 model analysis). It should be noted that climate impacts may differ strongly even within a
371 certain radiative forcing level. Global mean temperature change is not directly determined by
372 forcing level alone; factors such as climate sensitivity and the pattern of climate change play a
373 key role. Climate impacts are usually a result of more than temperature change alone. For
374 example, precipitation, radiation, wind, and humidity can have important effects on society and
375 natural systems. Impacts also depend critically on the timing, pattern, frequency, duration, and
376 intensity of weather events, especially extreme events. As shown by several studies, including
377 Arnell et al. (2011), for instance, the same level of climate change defined in terms of change in
378 global mean temperature may result in very different changes in the risk of water scarcity as a
379 function of the direction, magnitude, and pattern of changes in precipitation and their interplay
380 with population density. Thus, projections obtained from a single climate model for a given RCP
381 level might indicate changes in climate that contrast greatly from projections from another
382 climate model for the same forcing. Therefore, there are additional uncertainties to account for
383 in deploying this scenario framework. For near-term scenarios, in which pathways of
384 concentrations vary little across different RCPs, it is the climate model uncertainty (especially
385 the representation of natural variability of climate) that dominates projections of future climate.
386 The importance for climate of the concentration pathway on which the world has embarked,
387 described by the RCPs, only becomes apparent when the RCPs diverge in the second half of the
388 21st century.

389



390

391 *Figure 2.3: The uncertainty in the climate signal as a function of the forcing level plays out as an*
 392 *additional axis to explore in scenario analysis. Note it is not implied that the climate signal and*
 393 *forcing level are uncorrelated.*

394 **2.3 The scenario matrix approach in relation to IAM and IAV analysis**

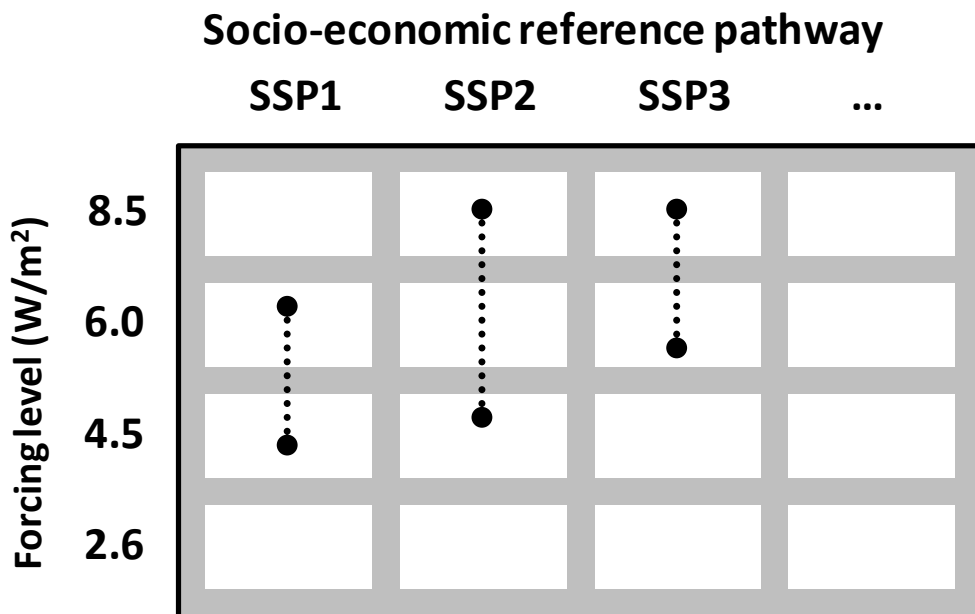
395 An important feature of the scenario matrix is that its individual cells describe the interplay
 396 between adaptation and mitigation and the resulting residual climate impacts. Using the matrix
 397 as an organizing principle allows research to explore a wide range of relevant combinations
 398 between contributing factors.

399 The scenario matrix architecture can be used in different ways for scientific and policy analyses.
 400 For instance, impact, adaptation, or vulnerability analysts could compare consequences under
 401 the same climate scenario (RCP driven) across all socioeconomic scenarios (along a row: “what
 402 is the effect of future socioeconomic conditions on the impacts of a given climate change”). Or,
 403 they could compare consequences under a given socioeconomic scenario with different degrees
 404 of climate change (down a column: “how do the impacts of climate change in a given future
 405 world vary with the magnitude of change”). An assessment of the effects of mitigation and
 406 adaptation compares consequences down a column; an assessment of the effect of future
 407 socioeconomic conditions on the effectiveness and costs of a suite of mitigation and adaptation
 408 measures would compare the differences between columns. A comprehensive analysis covers
 409 all cells, calculating for example adaptation costs, mitigation costs, and residual damages in each
 410 cell. This is explored in a little more detail below.

411 *How do the impacts of climate change and climate policy in a given future vary with the*
 412 *magnitude of change?*

413 Scenarios without climate policy (reference scenarios) may end up at different places along the
 414 radiative forcing axis. Further, as illustrated in Figure 2.4, models can interpret an SSP in

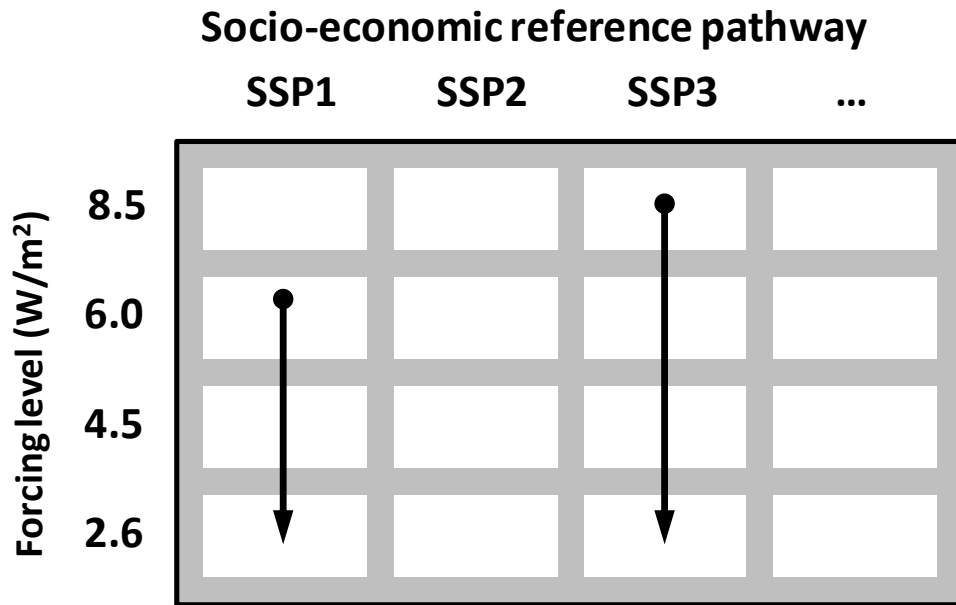
415 different ways. In this example, at the same time, on average SSP3 may have higher radiative
 416 forcing levels than SSP1.



417
 418 *Figure 2.4: The scenario matrix architecture and possible reference scenario forcing (the lines*
 419 *indicate the uncertainty due to the different possible interpretations of the SSPs by different*
 420 *model teams).*

421 Mitigation policy can move the climate forcing from one cell to another within a given column,
 422 Figure 2.5. The mix of policies that are necessary vary between columns and between cells in a
 423 column. The framework therefore allows the coherent analysis of the effects of climate policy.

424 It is also possible to analyze the costs of mitigation and/or adaptation along the RCP axis, Figure
 425 2.6. For example, one could compare a consistent set of reference and climate policy scenarios
 426 in terms of abatement costs, changes in total and sectoral GDP, trade, emissions of different
 427 gases, etc. to assess the cost of mitigation policy. The scenario matrix architecture facilitates
 428 the consistent evaluation of the costs of mitigation, adaptation, and residual climate damages.
 429 The results would depend on different choices for the SPAs. Conducting this experiment using
 430 several reference scenarios or different models provides a sensitivity analysis of how robust the
 431 policy is to different reference world evolutions.



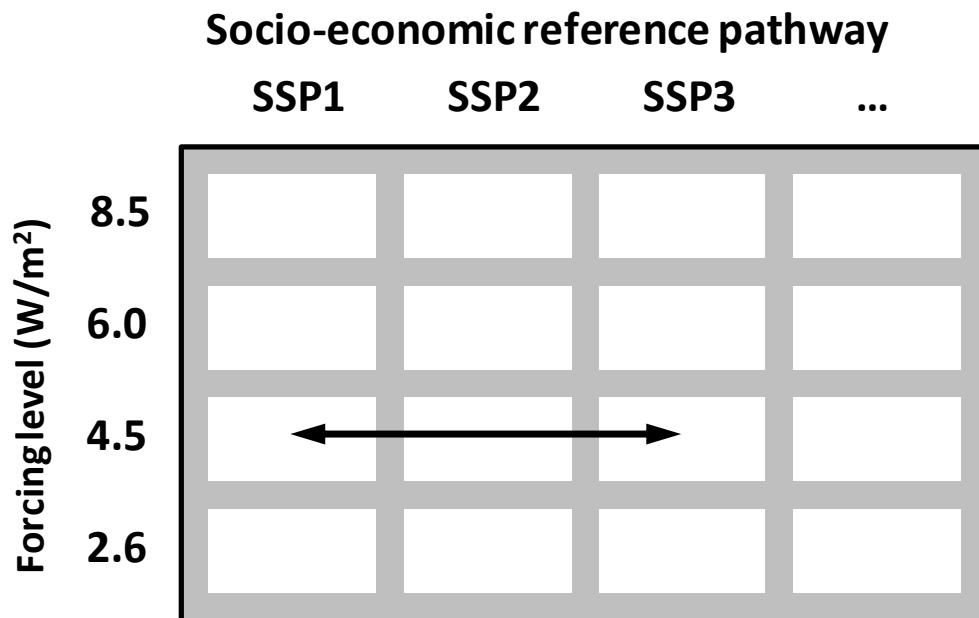
432

433 *Figure 2.5: The scenario matrix architecture can be used to explore the costs and benefits of*
 434 *mitigation action for a certain socioeconomic reference assumption described by an SSP.*

435

436 *What is the effect of future socioeconomic conditions on the impacts of a certain degree of*
 437 *climate change?*

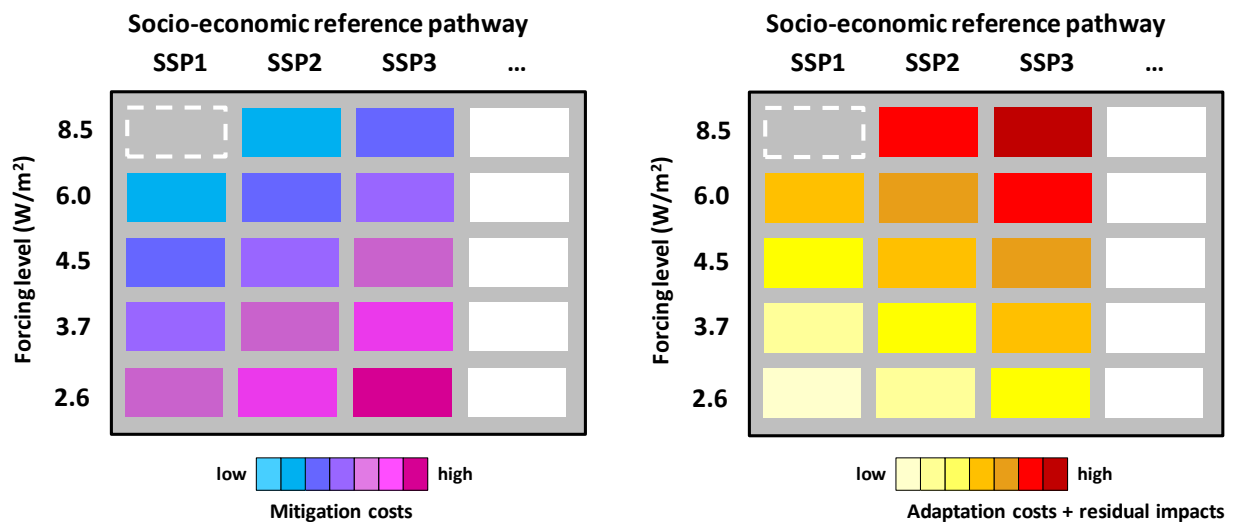
438 The presence of several different SSPs allows one to explore the consequences of different SSPs
 439 on climate impacts, but also on the effectiveness of climate policy.



440

441 *Figure 2.6: Comparing results along one row of the scenario matrix show how mitigation,*
 442 *adaptation, and remaining climate impacts play out under different socioeconomic futures.*

443 Figure 2.7 summarizes the two dimensions of climate change and climate policy analysis using
 444 the scenario matrix approach. The range of radiative forcings in the reference case will vary
 445 with SSP, and there may be SSPs for which very high forcings such as RCP8.5 will not be obtained
 446 even in the reference case. Similarly, the challenges to mitigation and adaptation will vary with
 447 SSP, so that different levels of mitigation costs, adaptation effectiveness, and residual climate
 448 damages will be obtained for a given RCP level in different SSPs. These effects can be explored
 449 by a comparison of studies bridging different cells across the columns and rows of the matrix. A
 450 fully integrated analysis of impacts, adaptation, vulnerability, and mitigation would include
 451 feedbacks to the initial (exogenous) boundary conditions presented by the SSP. For example, it
 452 may be the case that impacts, adaptation, and mitigation reduce (or increase) GDP or alter
 453 population movements, initially assumed exogenous for all cells in a column. The “output” GDP
 454 or population distribution would then be different for each cell in a column (because the
 455 climate change is different and climate policies have been introduced).



456

457 *Figure 2.7: Illustrative indications of how climate policy costs and residual impacts may vary*
 458 *across the cells of the matrix. The empty box (dashed lines) illustrates that not all combinations*
 459 *of forcing levels and SSPs may be consistent. The 3.7 W/m² level was added to illustrate that*
 460 *this is an important forcing level for policy-makers.*

461 It should be noted that it seems preferable to include 3.7 W/m² in a set of preferred scenarios
 462 because this forcing level is an important part of ongoing policy-making activities. Analyses of
 463 the mitigation and adaptation implication of this forcing level could be informative for policy-
 464 makers.

465 2.4 Different ways to use the scenario matrix architecture

466 There are different ways in which the scenario matrix architecture can be used for further
 467 scenario analysis:

- 468 • The scenario matrix as a heuristic tool: the matrix may help to classify existing scenarios
- 469 and new scenarios developed by different modeling groups.
- 470 • The scenario matrix as basis for new scenario development, including the use of

471 markers: scenarios may also be developed explicitly based on the matrix using available
472 storylines and marker scenarios.

473 **2.4.1 The matrix as heuristic tool**

474 One important use of the matrix structure is as a heuristic tool. The matrix offers an
475 opportunity to classify typical examples of combinations of factors that are crucial for
476 adaptation and mitigation from the literature. By locating published studies in different cells of
477 the matrix, these studies can more readily be compared and evaluated, as illustrated in the
478 following examples.

479 Example 1: Different studies have estimated the costs of mitigation policy using baselines where
480 the capacity of mitigation varied. For instance, some scenarios included high technology
481 development and global cooperation, while other scenarios assumed technology development
482 was low and global cooperation was lacking. Classifying scenarios from the literature within the
483 matrix would allow researchers to account for these differences and only compare scenarios
484 with similar assumptions. Remaining uncertainties would obviously still result in a range of
485 possible outcomes within a cell.

486 Example 2: Various studies estimated the impacts of and adaptation costs for flooding. These
487 studies used different assumptions about adaptive capacity and levels of climate change. Again,
488 the matrix can help to classify studies in a common way and provide a framework of
489 communication across various communities.

490 To achieve this purpose, criteria need to be established whether a scenario aligns with SSP1,
491 SSP2, or SSPn, and/or with different forcing levels. Categories of scenarios are available in the
492 literature (Raskin et al., 2005; Van Vuuren et al., 2011b; Rounsevell and Metzger, 2010). Box 2.1
493 discusses an attempt by van Vuuren et al. (2011b) to identify scenario archetypes or families in
494 the literature across different assessments.

495

Box 2.1: Classification of existing scenarios from GEAs

Over the last 10 years, a large number of global environmental assessment studies have been published that include scenario projections. Comparison of these studies shows there is a limited set of scenario families based on the same explorative storylines that form the basis of many scenarios used in different environmental assessments. Mapping these scenarios within these families allow a more easy comparison across different assessments. The fact that many assessments can be positioned within these scenario families gives some confidence in their relevance. At the same time, it is also noticeable that several recent assessments focused on simple policy-scenarios as variants to a single baseline.

The six scenario families that can be observed are: 1) economic-technological optimism/conventional markets scenarios; 2) reformed market scenarios; 3) global sustainability scenarios; 4) regional competition/regional markets scenarios; 5) regional sustainable development scenarios; and 6) business-as-usual/intermediate scenarios. Table 3 summarizes

the main characteristics of these scenario families.

Table 3. Key assumptions in different ‘scenario families’

	Economic optimism	Reformed Markets	Global SD	Regional competition	Regional SD	Business as Usual
Economic development	very rapid	Rapid	ranging from slow to rapid	slow	ranging from mid to rapid	medium (globalisation)
Population growth	Low	Low	Low	high	medium	medium
Technology development	Rapid	Rapid	ranging from mid to rapid	slow	ranging from slow to rapid	medium
Main objectives	economic growth	various goals	global sustainability	security	local sustainability	not defined
Environmental protection	reactive	both reactive and proactive	proactive	reactive	proactive	both reactive and proactive
Trade	globalisation	globalisation	globalisation	trade barriers	trade barriers	weak globalisation
Policies and institutions	policies create open markets	policies reduce market failures	strong global governance	strong national governments	local steering; local actors	mixed

Note: This table summarises key assumptions in very general terms. Where differences within a set of scenario families exist, broad ranges are indicated.

496

497 **2.4.2. Use of marker scenarios**

498 The scenario framework can also be explicitly used to develop new scenarios. For this purpose,
 499 one would need to define elements for each SSP/radiative forcing combination that would guide
 500 new development. There is a trade-off between harmonization and providing flexibility. Any
 501 new scenario framework should provide flexibility and not over-specify scenarios. Reasons for
 502 this include the need to communicate existing uncertainties, to allow for different approaches,
 503 to avoid constraints on research directions, and to provide an opportunity for a wide research
 504 community to participate in scenario analysis. At the same time, however, the scenarios also
 505 have a function to organize information (acts as a thread to the communities), which benefits
 506 from some form of standardization.

507 In this context, we propose the following steps.

- 508 • The basic SSPs include a minimum set of qualitative and semi-quantitative
- 509 descriptions (see Section 3) allowing for a great flexibility in interpretation of the
- 510 underlying narratives, including a preferred range for basic quantitative indicators
- 511 and key model input assumptions such as population and income.
- 512 • The scientific community should be encouraged to submit scenarios to populate the
- 513 different cells within the framework based on simple criteria that define the
- 514 columns/cells.

- 515 • Define specific “marker” scenarios that are considered illustrative of the type of
516 scenarios within the framework (similar to what was done for SRES). These markers
517 or illustrative scenarios are not the only possible quantification of a SSP (or SPA), but
518 will preferably be used in most analyses as a basis for comparison, in addition to
519 using other scenarios from a specific element in the framework. In the definition of
520 the markers, it can be decided the degree to which parameters are specified – and
521 how much is left as choice for individual analysts.

522 ***2.4.3 Uncertainty in climate policy and climate impact***

523 A similar discussion exists regarding the specification of the climate projections along the RCP
524 axis. At the very least, there is a need to indicate clearly how future climate and its
525 uncertainties have been characterized using different climate models, as the use of different
526 climate models may lead to very different results. The methods by which climate uncertainties
527 associated with similar levels of radiative forcing are to be addressed by IAV and other analysts
528 remain to be determined, and it is important that further guidance be provided on how to
529 handle these important choices (e.g. by clearly identifying the characteristics of different CM
530 model runs).

531 **3 Defining the Shared Socioeconomic Pathways (SSPs)**

532 **3.1 Introduction**

533 As discussed in Section 2, the intent of this process is the development of scenarios based on
534 combinations of climate model projections, socioeconomic conditions, and assumptions about
535 climate policies (including a no policy reference). Narratives and qualitative and quantitative
536 assumptions about broad development patterns for major world regions, relevant to impacts,
537 adaptation, and mitigation, define the SSPs. These assumptions include common inputs
538 required by integrated assessment and impact models, but not typical model outputs such as
539 greenhouse gas emissions. It is desirable to develop a set of scenarios that present a broad
540 range of possible development pathways; with reference scenarios based on SSPs and
541 assumptions of no (new) climate policy, and policy scenarios based on SSPs combined with
542 assumptions about climate policies for reaching a given RCP level.

543 This section discusses the framework for defining the content of SSPs. We first discuss the logic
544 used to define the space of possible futures that the set of SSPs is intended to span, and the
545 relation of this space to the scenario matrix architecture. We then discuss the dimensions of
546 socioeconomic systems that might be used to specify particular SSPs, including demographic,
547 economic, institutional, and other dimensions. We distinguish two variants of SSPs – basic vs.
548 extended – that provide different levels of detail about future development pathways. Finally,
549 we provide an illustration of the SSP concept by revisiting the choices made in the Special
550 Report on Emissions Scenarios (SRES), and showing how they relate to the concepts contained
551 in this framework paper.

3.2 The logic behind the definition of the SSPs

As discussed in Section 2, one of the key aims of the scenario matrix architecture is to facilitate research and assessment that can characterize the range of uncertainty in mitigation efforts required to achieve particular radiative forcing pathways, in adaptation efforts that could be undertaken to prepare for and respond to the climate change associated with those pathways, and in residual impacts. These outcomes will depend on assumptions regarding future socioeconomic conditions. To encompass a wide range of possible development pathways, the SSPs are defined along two axes: socioeconomic challenges to mitigation, and socioeconomic challenges to adaptation (Figure 3.1).

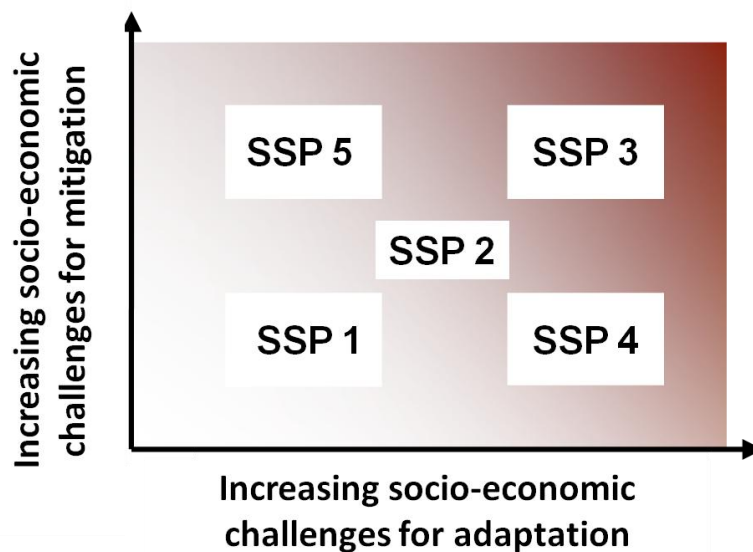


Figure 3.1: The scenario space to be spanned by SSPs.

Challenges to mitigation for the purpose of defining SSPs do not include the mitigation target itself, which is implied by the SPAs and the RCP forcing level. Rather, these challenges are defined by factors that would make the mitigation task easier or harder for any given target. For example, in the matrix architecture, a target would be defined by the radiative forcing pathway defining the rows of the matrix, while the challenges to mitigation would be defined by the nature of the SSPs in the columns of the matrix.

Socioeconomic challenges to mitigation are defined as consisting of: (1) factors that tend to lead to high reference emissions in the absence of climate policy because, all else equal, higher reference emissions makes that mitigation task larger; and (2) factors that would tend to reduce the inherent mitigative capacity of a society. High reference emissions could be generated in a large number of ways, with possible contributions from high population growth rates, rapid economic growth, energy intensive economic systems, carbon intensive energy supplies, etc. More fundamental processes could drive each of these factors, such as technological and social changes that include (autonomous) energy efficiency improvements, fossil fuel availability, and dietary choices. Not all factors need operate in the same direction in order to produce high (or low) reference emissions. For example, neither high population growth nor high economic

579 growth on its own is necessarily associated with high reference emissions in existing scenarios
580 (van Vuuren et al., 2011b). However, combinations of these drivers acting together can be
581 expected to lead to high emissions in a reference case. An SSP would include assumptions
582 about particular combinations of emissions drivers.. There is a tension between having an
583 outcome (such as high or low reference emissions) when designing an SSP in order to occupy a
584 particular part of the scenario space depicted in Figure 3.1, and avoiding the specification of
585 outcomes. Model outcomes such as emissions should be part of scenarios based on SSPs,
586 rather than part of SSPs themselves, which emphasize development pathways and drivers. It is
587 likely that some iteration between the design of SSPs, and the development of scenarios based
588 on them, will be necessary before the set of SSPs and reference scenarios is developed that
589 most effectively spans the space of future outcomes.

590 Factors that tend to influence the mitigative capacity of a society include the range of viable
591 technological options, national and international institutions for policy making, the availability
592 of financial resources necessary to support mitigation activities, stocks of human and social
593 capital, and political will (Yohe, 2001; Winkler et al., 2007; Klein et al., 2007). High (or low)
594 mitigative capacity can result from one or more of these factors, and need not involve all factors
595 influencing capacity in the same direction. It also may be the case that key determinants of
596 mitigative capacity, including the capacity for technological change in energy systems, overlap
597 significantly with determinants of reference emissions, making these two components of
598 challenges to mitigation closely related. Because internal consistency is important, it will limit
599 the freedom to ‘pick and choose’ from ranges for each individual factor enhancing or limiting
600 mitigative capacity.

601 Socioeconomic challenges to adaptation are defined as societal conditions that, by making
602 adaptation more difficult, increase the risks associated with any given climate change scenario.
603 Climate change risks arise from the combination of climate hazards, who or what is exposed to
604 those hazards, and the associated vulnerability, whether it is geographic, socioeconomic,
605 cultural, etc.² Within the scenario matrix architecture, the component of climate change risk
606 due to climate hazards is reflected in climate model projections based on the RCPs, and

² The definitions of hazard are similar across research communities, as are definitions of who or what is at risk (including physical, socioeconomic, and ecological components). However, vulnerability is defined differently. The AR4 defined vulnerability as consisting of exposure to climate change hazards, sensitivity of socioeconomic or ecological systems to them, and the adaptive capacity of these systems (AR4; Fuessel & Klein, 2006; Fuessel, 2007). This definition describes a future state that takes into account efforts to reduce sensitivity (e.g. coastal vulnerability to sea level rise at some future date would take into consideration the extent to which coastal defenses would be augmented). A complicating factor for the purposes of defining socioeconomic challenges to adaptation is that this definition includes the nature of the climate hazard itself, which should be excluded from SSPs. Thus, using the AR4 definition, challenges to adaptation are socioeconomic elements of exposure, sensitivity, and adaptive capacity. Many impact sectors and the disaster risk community view vulnerability differently, focusing on describing current and future internal characteristics of socioeconomic or ecological systems that increase (decrease) the susceptibility to harm. Vulnerability, then, is a description of the socio-ecological elements of exposure, and the factors leading to increased/decreased susceptibility to that exposure, including past adaptation efforts. In this perspective, adaptive capacity describes the socio-ecological potential for decreasing future vulnerability, assuming that potential is deployed. These different perspectives lead to similar determinants of the risks of the possible magnitude and extent of future impacts to a given degree of climate change: socioeconomic elements of exposure, sensitivity to that exposure, and adaptive capacity.

607 therefore should not be contained in the SSPs. The remaining components of risk are inherent
608 to human-environment systems potentially exposed to those hazards, and therefore are
609 appropriately included in the SSPs. Adaptation effectiveness, in the absence of specific
610 adaptation policies, is a function of existing autonomous adaptation or that could be expected
611 to develop without external intervention, which in turn is affected by the severity of the climate
612 change, sensitivity to its potential impacts, and the adaptive capacity to deploy coping
613 measures. The socioeconomic driving factors that influence future adaptation effectiveness are
614 described in each SSP.

615 Exposure is the presence of people, livelihoods, infrastructure, ecosystem services and
616 resources, and economic, social, and cultural assets in places that could be adversely affected by
617 a climate hazard. For example, a population that is concentrated near a coastline has
618 potentially high exposure to the impacts of sea level rise, while one that is heavily concentrated
619 in urban areas has potentially high exposure to urban heat waves. Sensitivity indicates the
620 responsiveness of socioeconomic systems to a given amount of climate change; it can be
621 described by an exposure-response relationship (Fuessel and Klein, 2006). If coastal populations
622 live in poorly constructed housing, for example, they would be more sensitive to the increased
623 storm surges associated with sea level rise compared to a population living in better-constructed
624 buildings. Likewise, an urban population that has higher proportions of elderly residents, or
625 that lacks widespread air conditioning, would be more sensitive to urban heat waves.

626 Adaptive capacity indicates the ability of a society to adjust to climate change in order
627 ameliorate its consequences or to take advantage of opportunities. Factors that influence this
628 capacity include the availability of viable technological options for adaptation, the effectiveness
629 of relevant institutions (such as agricultural research and development, markets for goods
630 affected by climate change, forest management organizations, etc.), and the availability of
631 resources, including their distribution across the population (Klein et al., 2007; Yohe & Tol, 2002;
632 Hallegatte et al., 2011). For example, a well functioning public health system would increase the
633 capacity of a society to ameliorate health impacts of heat waves, while well functioning food
634 markets and institutions for agricultural research and development would increase the capacity
635 to ameliorate consequences of climate change for agriculture, including the possibility of taking
636 advantage of outcomes such as lengthening growing seasons and higher CO₂ concentrations
637 that could be beneficial to some crops.

638 It is also important to note that measures of adaptive capacity alone do not necessarily define
639 the ability of society to adjust to climate change; different social factors such as awareness,
640 attitudes, empowerment, and political will may constrain the deployment and effectiveness of
641 adaptive measures.

642 Figure 3.1 shows five SSPs occupying different combinations of challenges to mitigation and
643 adaptation, spanning a wide range of possible development pathways. SSP 1 in the lower left
644 corner, for example, indicates a future in which challenges to both mitigation and adaptation are
645 low. By contrast, SSP 3 indicates a future in which challenges to both are high. The number and
646 location of these SSPs are for illustrative purposes because the most appropriate number and
647 characterization of the SSPs remain to be decided by the scientific community.

648 To keep the number of scenarios manageable, it will be necessary to simplify the complexity of

649 drivers of mitigative and adaptive capacity. Indeed, the world can have a low capacity to
650 mitigate for many – unrelated – reasons (e.g. low institutional capacity or high availability of
651 low-price fossil fuels). The same is true for adaptive capacity (e.g. low institutional capacity or
652 slow reduction of extreme poverty in developing countries). In an initial phase and to avoid
653 over-constraining research groups, it may be useful to keep open the options for specifying the
654 challenges to mitigation and adaptation for a particular SSP.

655 An important question is whether some of the locations in this scenario space are a higher
656 priority to explore than others, and if so, for which purpose. For example, SSPs 1-3, lying along
657 the diagonal from the lower left to upper right, represent futures in which socioeconomic
658 challenges to mitigation co-vary with challenges to adaptation. In contrast, SSPs 4 and 5
659 indicate futures in which challenges are high to either mitigation, or to adaptation, but not both.
660 It is possible that the drivers of these challenges are more likely to co-vary, which would favor
661 focusing on the SSPs along the diagonal, but this question remains to be explored. In many
662 cases, the determinants of mitigative and adaptive capacity are similar and can be
663 conceptualized as a more general “response capacity” (Klein et al., 2007; Tompkins & Adger,
664 2005). For example, human and social capital are important determinants for both. On the
665 other hand, these capacities need not share the same determinants (Hallegatte et al., 2011),
666 and furthermore the challenges to mitigation and adaptation as conceptualized here include not
667 just response capacity, but also other elements of development pathways such as those that
668 would lead to high reference emissions or to high levels of sensitivity to climate change.

669 A further consideration is that the SSP should set the boundary conditions within which regional
670 and sectoral variation could occur. For example, some pathways might envision response
671 capacities that are low in some parts of the world and high in others, or that transition from one
672 state to another over time. An additional consideration is that some futures may not be the
673 most plausible outcomes, but nonetheless may be equally (or even more) important to explore
674 given their potential consequences.

675 Finally, it is important to consider, to the extent possible, the plausibility of SSPs against the
676 backdrop of climate change that they potentially imply in the reference case. Particularly with
677 regard to SSP3, the plausibility of a simultaneous combination of high reference emissions
678 (reflecting a challenge to mitigation and correspondingly strong climate change signal) and high
679 climate damages given the large challenges to adaptation can be questioned, but not excluded a
680 priori. It may require assuming strong lock-ins in the energy sector, ineffective governance
681 structures, and only a moderate (or even negative) impact of climate damages on emissions
682 (e.g. because adaptation is done using highly energy consuming options like desalinization, air
683 conditioning, and increased-input agriculture). A full plausibility check closing the loop from
684 emission drivers to climate damages will only be possible after combining the socioeconomic
685 reference scenarios based on the SSPs with climate impact assessments that would also draw on
686 the SSPs. The feedback of climate change onto the SSPs can only be addressed in a preliminary
687 and qualitative manner during the time of SSP construction. However, even if futures such as
688 SSP3 may not turn out to be the most plausible, their investigation will be highly relevant for
689 developing a deeper understanding of the interplay between mitigation, adaptation, and
690 residual climate impacts.

691 3.3 Dimensions of the SSPs

692 Although the SSPs are differentiated on the basis of socioeconomic challenges to adaptation and
693 to mitigation, they are characterized by a series of determinants of these outcomes (regarding,
694 e.g. population, economic development, technologies, preferences). Some of these dimensions
695 will be expressed in narrative terms, while others will be quantitative in line with the underlying
696 narrative. The process of constructing and evaluating SSP candidate proposals will inform the
697 detailed descriptions of the dimensions of an SSP. Here we restrict ourselves to defining the
698 characteristics that an SSP will need to exhibit.

699 An SSP comprises the assumptions about the main determinants of the global scale
700 socioeconomic reference development in the 21st century. SSPs have the following key
701 characteristics:

- 702 1. A focus on the description of global and long-term trends.
- 703 2. A narrative of future global development that provides a point of reference for
704 elaboration of global assumptions that also are relevant for local- and regional-scale
705 scenarios.
- 706 3. Incorporation of information typically used as input assumptions by integrated
707 assessment models of the global energy-economy-land use system, or by global scale
708 climate impact models of different economic sectors. At a minimum, this includes
709 assumptions about future demographics, economic development, and degree of global
710 integration. Such assumptions will likely involve quantitative pathways for population
711 and economic growth.
- 712 4. Qualitative and quantitative content sufficient to distinguish SSPs from each other in
713 terms of their challenges to mitigation and adaptation.
- 714 5. Clear distinction from a single or best-guess socioeconomic reference scenario. An SSP
715 should restrict itself to key determinants of future global development and not comprise
716 the full manifestation of the future development as captured in a scenario. As a practical
717 guideline, an SSP should not include variables that constitute standard output of
718 integrated assessment models (such as the precise mix of technologies used in the
719 energy sector).
- 720 6. Restriction to assumptions that do not include new policies and measures directly
721 motivated by climate change, or their effect on other variables. An SSP refers to
722 socioeconomic reference development of a world without future climate policy. The
723 dividing line between climate policies and other policies can sometimes be difficult to
724 draw; useful approaches are discussed in Section 4, including how to treat currently
725 implemented climate policy measures. If these policy measures are significant enough
726 to affect observed global trends, they would need to be included in the reference
727 assumptions.

728 Based on these characteristics of an SSP, a number of possible dimensions have been suggested
729 to be included:

- 730 • Demographics
- 731 ○ Population total and age structure

- 732 ○ Urban vs. rural populations, and urban forms
- 733 ● Economic Development
 - 734 ○ Global and regional GDP, or trends in productivity
 - 735 ○ Regional, national, and sub-national distribution of GDP, including economic
 - 736 catch-up by developing countries
 - 737 ○ Sectoral structure of national economies. In particular, share of agriculture, and
 - 738 agricultural land productivity
 - 739 ○ Share of population in extreme poverty
 - 740 ○ Nature of international trade
- 741 ● Welfare
 - 742 ○ Human development
 - 743 ○ Educational attainment
 - 744 ○ Health
- 745 ● Ecological factors
- 746 ● Resources
 - 747 ○ Fossil fuel resources and renewable energy potentials
 - 748 ○ Other key resources, such as phosphates, fresh water etc.
- 749 ● Institutions and Governance
 - 750 ○ Existence, type and effectiveness of national/regional/global institutions in
 - 751 particular sectors
- 752 ● Technological development
 - 753 ○ Type (e.g. slow, rapid, transformational) and direction (e.g. environmental,
 - 754 efficiency, productivity improving) of technological progress
 - 755 ○ Diffusion of innovation in particular sectors, e.g. energy supply, distribution and
 - 756 demand, industry, transport, agriculture
- 757 ● Broader societal factors
 - 758 ○ Attitudes to environment/sustainability/equity
 - 759 ○ Globalization of life styles (including diets)
- 760 ● Policies
 - 761 ○ Non-climate policies could also be an important dimension of SSPs. These
 - 762 include development policies, technology policies, urban planning and
 - 763 transportation policies, energy security policies, and environmental policies to
 - 764 protect air, soil and water quality, for example. It is possible that SSPs could be
 - 765 specified partly in terms of policy objectives, such as strong welfare-improving
 - 766 goals, rather than specific policy targets or measures.

767 3.4 “Basic” vs. “Extended” SSPs

768 The development of SSPs is proposed to take place in two stages. A first stage would define
769 “basic” SSPs with the minimum detail and comprehensiveness required to distinguish SSPs
770 along the axes described in Section 3.2 and to provide useful input to populate model settings
771 and parameters. A second stage would develop “extended” SSPs would build on the basic SSPs
772 greater detail on qualitative and/or quantitative information for sectoral and regional analyses.

773 The two primary motivations for this two-stage approach are practicality and flexibility. A
774 minimum set of assumptions can be defined more quickly and therefore can be available for use
775 sooner, increasing the possibilities for carrying out analyses based on the new SSPs that could
776 be assessed as part of the AR5. Basic SSPs offer the possibility for early “hands-on”
777 experimentation by a wide range of researchers on extending the basic SSPs in various
778 dimensions. These extensions could be motivated by a number of different needs.

- 779 • Experience with developing scenarios based on basic SSPs, including reference,
780 climate policy, and climate change scenarios, may lead to a need for additional
781 information by particular models (or types of models) that is not contained in the
782 basic SSP. This information could include more detail on consumption patterns
783 (convergence, diet, etc.), income distributions, non-climate related policies, specific
784 development strategies, etc.
- 785 • Application of basic SSPs in regional and local contexts will likely lead to new
786 demands for information that will make the SSPs more useful for decision-makers.
787 One can view basic SSPs as describing “boundary conditions” that provide the
788 framing for more complex assumptions for regions or sectors, including additional
789 elements of narratives, which could then become part of extended SSPs.
- 790 • Extended SSPs could take into account sub-optimality and imperfections in the
791 socioeconomic scenarios (2nd-best worlds). Some models will be able to produce
792 scenarios in which significant sub-optimality exist (e.g. large unemployment,
793 market-power in the energy sector, insufficient funding for infrastructure
794 development).

795 A large number of extended SSPs can be constructed for any given basic SSP. A hierarchical
796 structure comprising a small number of basic SSPs, each associated with a family of extended
797 SSPs, may be useful for several purposes:

- 798 – *Structured uncertainty analysis*: The family of extended SSPs should reflect the range of
799 assumptions that are consistent with a given basic SSP, and that are requested as
800 additional inputs for the construction of socioeconomic reference scenarios, e.g. in
801 integrated assessment models or in sectoral and regional studies. It thus can help to
802 explain the range of socioeconomic reference scenarios that can be associated with a
803 basic SSP. When combining the family of extended SSPs with climate policy assumptions,
804 it can also help to investigate the robustness of the climate policy scenarios across the
805 SSP family.
- 806 – *Distinguishing different types of socioeconomic reference assumptions*: Combining SSPs
807 with SPAs and RCPprep will transform the quantitative reference pathways in the SSP to
808 their associated pathways in a climate policy situation. Two types of SSP variables may
809 be distinguished for assessing the sensitivity of climate policy scenarios across the full
810 range of the scenario matrix. Variables that vary much less with climate policy (for a
811 given SSP) than with SSP (for a given climate policy), and variables for which this does
812 not hold. It is an open question whether basic SSPs will be dominated by variables of the
813 former type (e.g. population and income) and extended SSPs will take up variables of the
814 latter type (e.g. energy and land use). However, if the construction and investigation of

815 basic and extended SSPs revealed this property, it would add value to the concept of
816 distinguishing a basic SSP and its associated family of extended SSPs.

817 A possible drawback to the development of a large number of extended SSPs is that it could blur
818 the distinction between SSPs and scenarios. To the degree that extended SSPs become
819 associated with individual model interpretations of an SSP, this distinction becomes less clear.
820 An alternative would be to aim for the development of a small number of extended SSPs for
821 each basic SSP, each of which extended the basic SSP in somewhat different directions, but
822 remained broad enough to support the development of a large number of scenarios based on
823 each extended SSP.

824 The development of basic and extended SSPs does not preclude producing revised versions of
825 either. After a period of time, assumptions in even the basic SSPs may become outdated or for
826 other reasons require revision; at that time, a second generation of SSPs could be produced.

827 **3.5 Initial Specification of SSPs**

828 The IPCC Special Report on Emissions Scenarios (SRES) is an example of the types of information
829 that are likely to be useful to include in SSPs. For example, the overarching narratives of the
830 SSPs would provide the frame for distinguishing alternative possible futures. The SRES
831 developed four families of socioeconomic futures spanned by the dimension of globalized vs.
832 regionalized development and economic vs. environmental orientation. Box 1 reproduces the
833 description of the narratives from the Summary for Policy Makers of the SRES.

Box 1: Short summary of scenario narratives in the Special Report on Emissions Scenarios (copied from the SPM - Summary for Policy Makers):

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).
- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.
- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

834

835 A similar specification of narratives for the SSPs will be needed in an early phase of SSP
836 construction. The narratives should be chosen such that they cover the space of socioeconomic
837 challenges to mitigation and adaptation (Section 3.2). Box 2 is an illustration of a starting point
838 for such narratives. It is important to note that we are not advocating for a specific number or
839 content of SSPs. The objective of this paper is to suggesting a framework for the construction of
840 new socioeconomic scenarios. The actual formulation of the SSPs and corresponding scenarios
841 are to be a community activity following circulation of this paper (see Section 5).

Box 2: Illustrative example of narratives underlying the SSPs depicted in Figure 3.1:

SSP 1, in which the world is reasonably well suited to both mitigate and adapt, could be one in which development proceeds at a reasonably high pace, inequalities are lessened, technological change is rapid and directed toward environmentally friendly processes, including lower carbon energy sources and high productivity of land. An analogue could be the SRES B1 scenario.

SSP 3, with large challenges to both mitigation and adaptation, could be a world in which unmitigated emissions are high due to moderate economic growth, a rapidly growing population, and slow technological change in the energy sector, making mitigation difficult (as, for example, in SRES A2). Investments in human capital are low, 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.

SSP2 would be an intermediate case between SSP1 and SSP3, where future dynamics could follow historical trends similar to e.g. SRES B2 scenario.










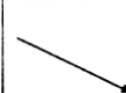




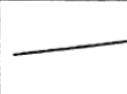



























SSP 4, in which mitigation might be relatively manageable while adaptation would be difficult and vulnerability high, could describe a mixed world, with relatively rapid technological development in low carbon energy sources in key emitting regions, leading to relatively large mitigative capacity in places where it mattered most to global emissions. However, in other regions development proceeds slowly, inequality remains high, and economies are relatively isolated, leaving these regions highly vulnerable to climate change with limited adaptive capacity.

SSP 5 as a world with large challenges to mitigation but reasonably well equipped to adapt, could be one in which, in the absence of climate policies, energy demand is high and most of this demand is met with carbon-based fuels (perhaps similar to the SRES A1FI scenario). Investments in alternative energy technologies are low, and there are few readily available options for mitigation. Nonetheless, economic development is relatively rapid and itself is driven by high investments in human capital. Improved human capital also produces a more equitable distribution of resources, stronger institutions, and slower population growth, leading to a less vulnerable world better able to adapt to climate impacts.

842
843 Associated with such narrative starting points, trend diagrams for various SSP elements can help
844 sketch out the major dimensions of development pathways for a given SSP, and their differences
845 across SSPs. Figure 3.2 shows an example of such a diagram describing storylines underlying
846 scenarios developed to explore the possibilities and challenges related to global sustainability
847 transitions (Gallopín et al., 1997; NRC, 1999). Combinations of such trends would need to be
848 developed through a collaborative process including experts in integrated assessment modeling,
849 impacts and adaptation, and other relevant disciplines, with care taken to ensure the internal
850 consistency of pathways taken as a group, keeping in mind the intended part of the space of
851 future challenges to adaptation and mitigation to be covered.

Figure 3.2: Illustrative patterns of change in elements of archetypal global scenarios developed in Gallopín et al. (1997) and assessed by the US National Research Council (1999).

852

Class Variant	 Population	 Economy	 Environment	 Equity	 Technology	 Conflict
Conventional Worlds Scenario						
<i>Reference</i>						
<i>Policy Reform</i>						
Barbarization Scenario						
<i>Breakdown</i>						
<i>Fortress world</i>						
Great Transitions Scenario						
<i>Eco-communalism</i>						
<i>New sustainability paradigm</i>						

853

854 Further decisions will be needed about which types of information should be qualitative and
 855 which quantitative, within an SSP. The desired degree of freedom to allow for adequate
 856 coverage of relevant uncertainties will have to be balanced against a practically unbounded
 857 cloud of outcomes ascribed to a certain SSP and overlapping largely with other SSPs. The list of
 858 possible elements in Section 3.3 provides a starting point for these considerations. While it is
 859 likely that broad features of demographic and economic development futures should be
 860 included in quantitative form, many choices remain regarding the assumptions to be made in
 861 other areas.

862 **4 Defining the Shared Socioeconomic Pathways (SSPs)**

863 **4.1 Introduction**

864 This section discusses information that can be part of climate policy assumptions; analysts
 865 developing climate mitigation and adaptations scenarios routinely make such assumptions.
 866 Because they often have a strong influence on the scenario, it is desirable to characterize their
 867 key dimensions in the same way as socioeconomic reference assumptions are summarized in
 868 the SSPs.

869 Climate policies have two major components: ambition of the climate policy, which is useful to
870 compare results; and actions to promote and support adaptation to the impacts of climate
871 change associated with a particular degree of climate change for a RCP forcing. These policies
872 are explicitly define in a Shared climate Policy Assumptions (SPA).

873 In terms of mitigation, this package should contain three different types of information (Kriegler,
874 et al. 2011).

875 1. “First, the SPA should state the global “ambition” of policies, i.e. the policy targets in
876 terms of emission reduction or in terms of stabilization concentration. For instance, a
877 possible SPA ambition is the introduction of policies aiming at a stabilization of CO₂
878 concentration at 450 ppm or of global temperature stabilization at 2°C above its
879 pre-industrial level. This ambition determines the RCP with which the scenario will be
880 consistent.

881 2. “Second, the SPA should state the “policy and measures” introduced to reach the target:
882 carbon tax, energy tax, international trading scheme, R&D subsidy, norms and
883 regulation, etc.

884 3. “Third, a SPA should include the “implementation limits and obstacles” that are
885 considered. Examples of generic climate policy assumptions include domestic action on
886 the basis of current ambitions, global coordination on 2 degree or 3 degree stabilization,
887 etc. An SPA may consider an idealized case of all world countries implementing a carbon
888 tax at the same date, or a fragmented international regime with different or zero carbon
889 prices in different regions; it may also exclude or include sub-optimalities in the
890 implementation of policies (e.g., loopholes in regulations). While specification of a
891 limited number of such policy scenarios could be difficult to agree on, it could also
892 provide substantial insight into the robustness of alternative policy designs.” (Kriegler, et
893 al., 2011, P. 21)

894 Even though the ambition of climate policy is sufficient to define in which matrix cell the
895 scenario will be, the other types of information are necessary to insure that it is possible to
896 make appropriate comparisons across models or research groups exploring that combination of
897 SSP and radiative forcing limit, which can facilitate comparison across research results and allow
898 for an estimation of model-related uncertainty.

899 The character of policies that are taken to adapt to climate change could be defined along
900 similar lines. First, different levels of ambition in limiting residual climate damages for given
901 levels of climate forcing may be defined, e.g. in terms of development indicators that should not
902 be jeopardized by climate change. Second, information relevant for policy and measures may
903 include information on global scale factors influencing the availability, viability, and
904 effectiveness of adaptation actions at national and local scales, such as enhanced provision of
905 clean water; enhanced and geographically expanded healthcare provision for infectious
906 diseases; and enhanced investments in coastal defenses.

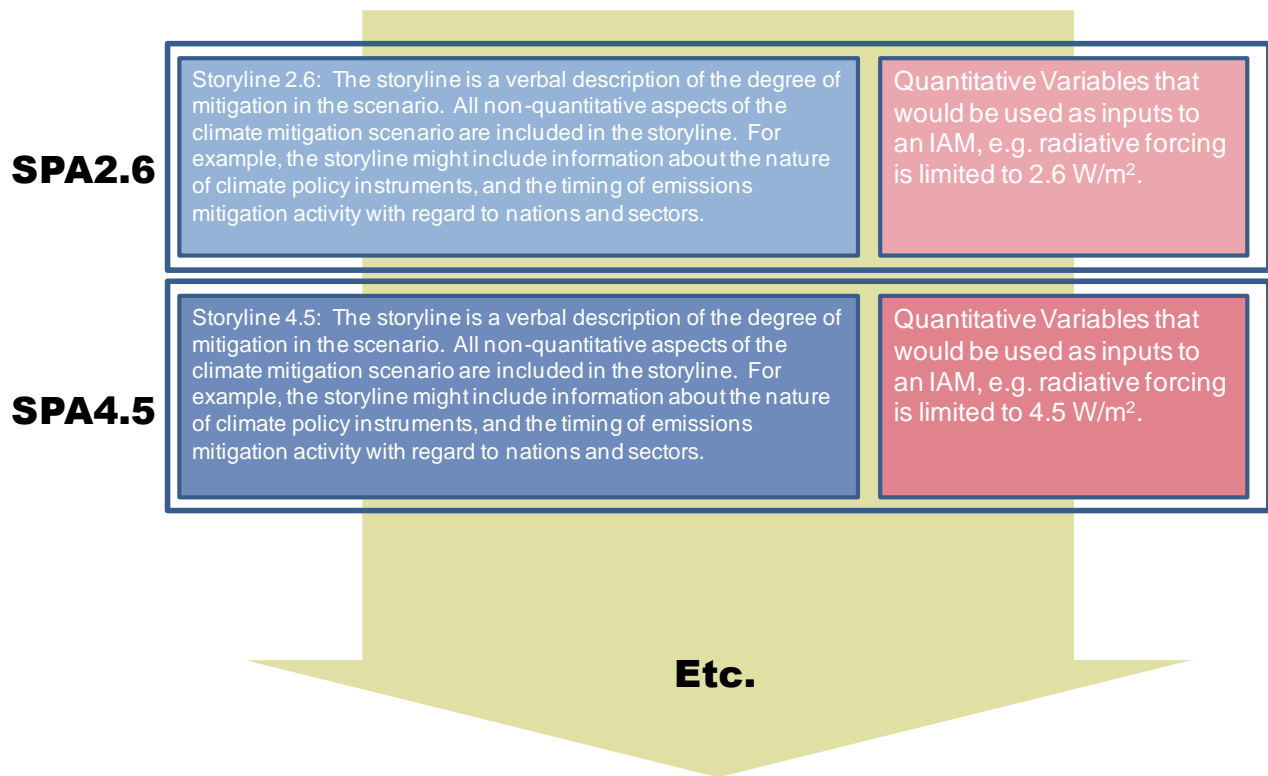
907 In such instances, the dividing line between policies responding to climate change (part of an
908 SPA) and development policies not directly driven by climate change (part of an SSP) will be
909 sometimes difficult to draw. This will have to be decided on a case-by-case basis. For example,

910 an important consideration in an SSP is the degree to which countries participate in
911 globalization, for example the degree to which world markets for agriculture goods are
912 functioning—are they free market or highly regulated? (This is similar to the global versus local
913 scale axis of the SRES.) But, also the role of temporal and spatial equity concerns are expected
914 to set priorities and weigh alternative policy actions. This orientation will be included in the
915 SSPs and will frame the policies articulated in a SPA package; such as ease of technology transfer
916 and time required to provide universal access to safe water and improved sanitation.

917 The SPA package itself may include, for example, the availability of adaptation options (e.g.
918 more efficient irrigation techniques or water recycling technologies), and the availability of
919 various amounts of international support for adaptation in developing countries. The range of
920 options can be increased through investments in environmental observations, data collection,
921 research and development, etc.

922 **4.2 Elements of shared climate policy assumptions**

923 Shared climate Policy Assumptions (SPAs) contain qualitative and quantitative information. The
924 **quantitative information** consists of information such as the criteria determining emissions
925 mitigation. In principle information about explicit emissions mitigation could be described in
926 any number of ways. The mitigative stringency could be described in terms of a level of climate
927 change, e.g. transient global mean surface temperature at a given date. They could also be
928 described in terms of a limit to radiative forcing in a specific year, e.g. 2100 and side conditions
929 on the rate of change of radiative forcing. Reaching such targets will require the implementation
930 of policy instruments, e.g. a global or differentiated carbon-equivalent tax. Alternatively, a
931 carbon tax or other instruments may be envisaged without specifying climate a climate target
932 explicitly.



933

934

935 Focusing on radiative forcing as the target level for mitigation allows the climate policy scenarios
 936 to be prescribed so as to coincide with the RCPs. How close they should follow the RCP
 937 trajectories over time, or in selected target years, is to be considered in the process.

938 The quantitative portion of the scenarios could include assumptions of the relative prices of
 939 non-CO₂ greenhouse gases and greenhouse gas emissions from different sectors. It could also
 940 assume different timing for mitigation by region, the magnitude of initial emissions prices when
 941 a region first begins emissions mitigation, rules for the allocation of permits in cap-and-trade
 942 regimes, and/or carbon values for terrestrial carbon in regions with climate emissions mitigation
 943 policies.

944 **The narrative or storyline portion of the SPAs** include information that describes the world of
 945 climate policies and their evolution over time and across space. It could contain information
 946 about the nature of climate policies—preferences for fiscal as opposed to regulatory policies, as
 947 well as the timing and application of policies. For example, it could assume the nature of
 948 policies to mitigate fossil fuel CO₂ emissions as well as the nature of policies to address land-use
 949 change emissions and non-CO₂ greenhouse gases. It could assume different timing of
 950 participation of regions and nations in emissions mitigation regimes as for example considered
 951 in EMF22 (Clarke, et al. 2009; see also Knopf et al., 2011, Figure 6). It should also include R&D,
 952 development, and institutional policies that are implemented to support adaptation, such as the
 953 implementation of a technology transfer agreement at the international scale or an
 954 international insurance scheme.

955 The narrative portion of the SPAs should contain information that is instructive to both the

956 integrated assessment modeler trying to develop a scenario, and an IAV researcher trying to
957 understand the nature of the climate policy world co-developing even as climate impacts and
958 adaptation to climate change are transpiring.

959 **4.3 Combining SPAs and SSPs**

960 Climate policy assumptions provide information about (new) climate policies that is excluded
961 from SSPs by their definition as socioeconomic reference assumptions. The dividing line
962 between assumptions on (new) climate policies to be included in SPAs and other policies to be
963 included in SSPs will be difficult to draw in many cases, particularly when it comes to land use
964 and energy policies. It will prove very hard, if not impossible, to establish a convention that
965 would define the climate-relatedness of a policy unambiguously in all instances. We expect that
966 any such convention would evolve over time during the construction and testing of SSPs and
967 SPAs, and their use for the development of socioeconomic scenarios. And it would always be
968 incomplete, as the nature of a policy will have to be judged on a case-by-case basis.

969 Nevertheless, it is possible to provide some general guidelines for distinguishing a climate policy
970 that belongs in the SPA and a non-climate policy that belongs in the SSP:

971 A climate policy is a policy that would not have been implemented if there was no
972 concern about climate change. Any policy that directly constrains or taxes the emissions
973 of greenhouse gases, or that supports greenhouse gas removal or reduction
974 technologies, falls into this category.

975 In contrast, most development policies such as improving energy access, urban planning,
976 infrastructure, health services, and education are motivated in their own right, and thus
977 are not climate policies. Those policies are part of the socioeconomic reference scenario,
978 and their outline should be included in the SSPs. Such policies may, of course, affect
979 climate policies, or be affected by them, but this does not prevent their inclusion in SSPs.
980 It would only mean that care must be taken when combining SPAs with SSPs to ensure
981 consistency of the full policy package.

982 In addition, development policy assumptions in the SSPs may have to be adjusted when being
983 combined with an SPA. However, this also holds true for other variables in the SSPs, such as
984 land and energy use patterns that will be affected by climate policy.

985 There are also borderline cases due to the fact that policies are often derived from multiple
986 objectives and serve multiple purposes. Is a renewable portfolio standard motivated by
987 concerns about climate change or energy security? Does increased disaster preparedness stem
988 from a concern about the increased frequency or magnitude of such disasters in a changing
989 climate, or does it stem from the objective to decrease the vulnerability of the society to
990 present climate variability? Such cases cannot fully be decided, and one may have to resort to
991 ad hoc judgments on a case-by-case basis. The main point is that it is important that the
992 relevant policy assumptions underlying the socioeconomic reference and climate policy
993 scenarios are clearly allocated to either an SSP or a SPA.

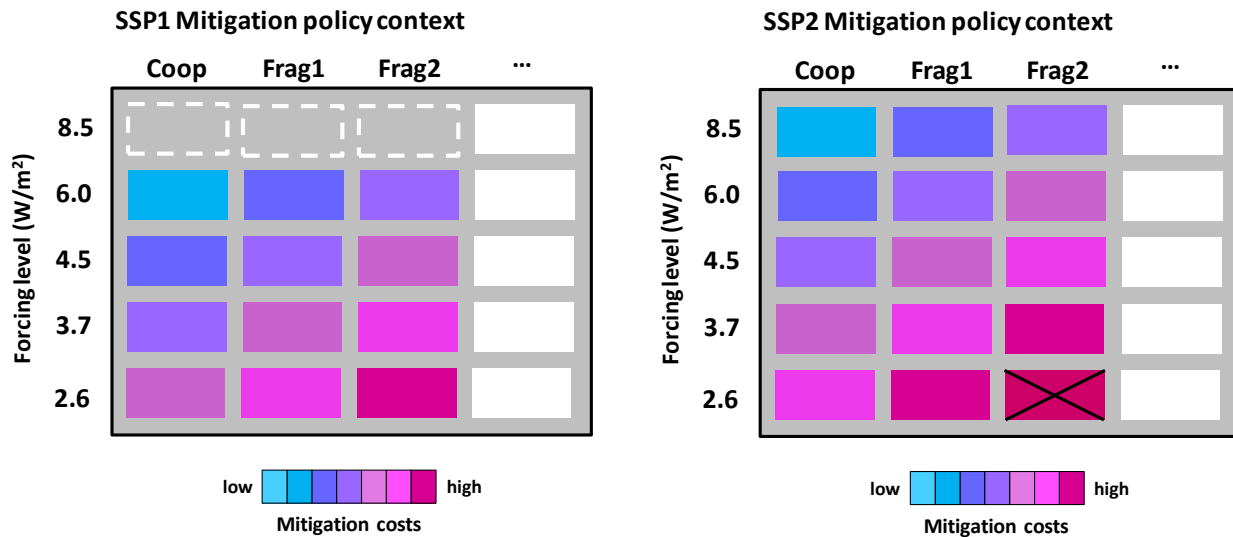
994 One of the most difficult issues may be how to deal with climate policies and measures that are
995 already implemented and affect the socioeconomic development on a larger scale. The price on

996 greenhouse gas emissions in Europe, imposed directly via the European Emissions Trading
997 System (EU ETS), or implicitly via sectoral measures aiming to reach the targets under the Kyoto
998 Protocol, are a case in point. If such implemented climate policy measures are excluded from
999 the socioeconomic reference scenario, it would have already diverged from reality. In order to
1000 avoid this, existing climate policies should be part of the reference case. This immediately raises
1001 the new questions of what is an existing climate policy (measures in effect like the EU ETS; or a
1002 policy foreseeing future measures that is coded into law like the EU Climate and Energy
1003 Package)? And how should such policies be projected into the future in the reference case?
1004 Ideally, this should be done in a way reflecting the present expectations of market and non-
1005 market actors, but those will be hard to discern and characterize. In the framework paper, we
1006 cannot do more than flag this issue. The definition of "reference climate policy" or "climate
1007 policy as usual" assumptions will be a subject of active discussion during the construction and
1008 testing of SSPs and SPAs, and their use in the development of socioeconomic scenarios.

1009 When combining SSPs and SPAs to derive a socioeconomic climate policy scenario, care needs to
1010 be taken that their combination is consistent. First, SSPs will contain reference assumptions that
1011 are affected by climate policies, and those would need to be adjusted to take into account the
1012 information in the SPA. Second, some reference assumptions in an SSP, e.g. development
1013 policies, will have implications for climate policy and those assumptions in the SPA would need
1014 to be adjusted as well. Finally, the overall narrative in an SSP and the qualitative assumptions in
1015 a SPA would need to be broadly consistent. For example, a narrative describing a regionalized
1016 development in a fragmented world can hardly be paired with the assumption of a global
1017 carbon market. It therefore will be the case that not all SPAs can be combined with all SSPs.

1018 **4.4 Extensions of the SPA Concept**

1019 The proposed scenario matrix architecture is designed to generate scenarios that have utility in
1020 that they allow important comparative and integrative analyses to be performed across all CM,
1021 IAM, and IAV communities. The scenarios described in this framework are suitable to be
1022 combined with climate model projections for the purpose of informing IAV researchers about
1023 the nature of the world as it might evolve over the course of the next century. The explicit
1024 introduction of a climate policy dimension as captured in the SPAs offers the flexibility to
1025 explore adaptation and mitigation policies for different combinations of SSP, RCP and associated
1026 climate change projections. For example, Figure 4-1 shows the combination of RCPs with SPAs
1027 describing different levels of adaptation actions for a given SSP. See also the conceptualization
1028 of mitigation SPAs in a scenario matrix setting in Knopf et al. (2011; Figure 6).



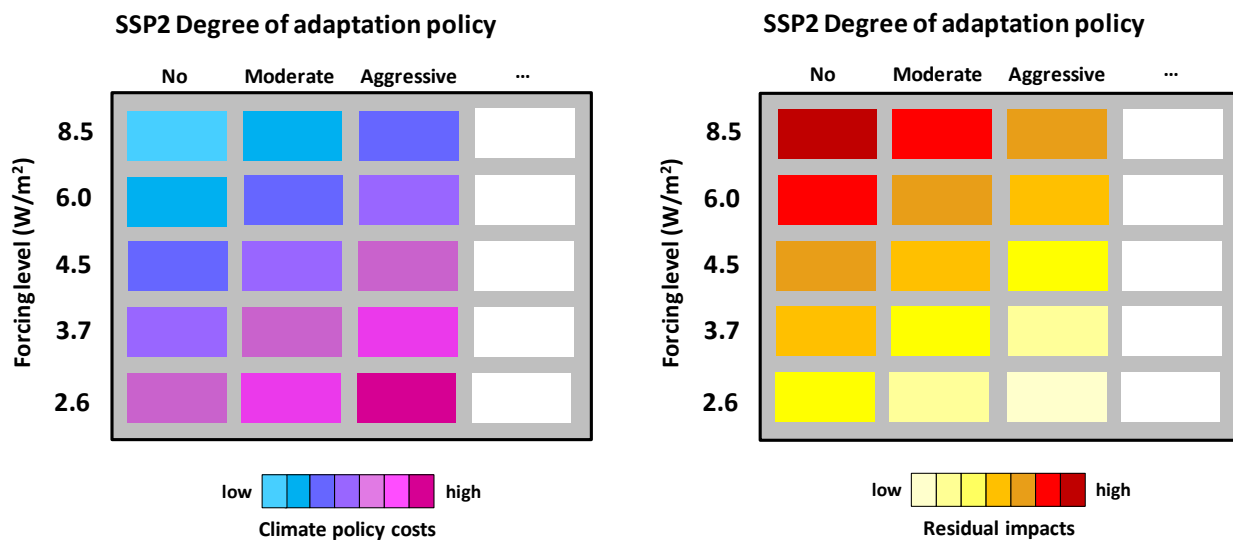
1029

Figure 4-1: A policy axis can be added to the matrix architecture to explore how the costs of mitigation policy depend on assumptions regarding the form of mitigation action. Here, the costs assuming cooperative action (Coop) are compared to policies with different degrees of fragmented participation (Frag1 and Frag2), for SSP1 and SSP2. Some targets cannot be achieved with fragmented participation (indicated by the crosses).

1030

The full SPA will include a consistent set of assumptions on mitigation and adaptation policies (see Figure 4-2).

1031



1032

Figure 4-2: The degree of adaptation policy can also be explored within the matrix architecture. Here, adaptation policy is varied from no adaption policy to moderate to aggressive adaptation. The matrix allows for the comparison of the costs and benefits of the policy. The shading for climate policy costs is provided for illustrative purposes only and may change under different assumptions for the interaction of mitigation and adaptation policies.

1033

1034 **5 Scenario Process Overview & Timeline**

1035 **5.1 Status of the new scenario process**

1036 Integrated assessment modeling (IAM) teams at IIASA, JGCRI-PNNL, PBL and NIES produced four
1037 Representative Concentration Pathways (RCPs) for use in the Climate Model Intercomparison
1038 Project 5 (CMIP5). The RCPs reach radiative forcing levels of 2.6, 4.5, 6.5 and 8.5 W/m²,
1039 respectively, in 2100, and were extended to 2300 based on stylized assumptions (van Vuuren et
1040 al., 2011a). CMIP5, currently underway, will use the RCPs as an input to produce model
1041 ensemble projections of future climate change. These projections will be assessed in the IPCC's
1042 Working Group I contribution to the 5th Assessment Report (AR5). The Program for Climate
1043 Model Diagnosis and Intercomparison (PCMDI) is making the climate model runs available, as
1044 they are ready. Model runs available by the end of 2011 and integrated into the quality-
1045 controlled CMIP5 database will be assessed by the IPCC in its 5th Assessment Report.

1046 At the same time, IAV projections continue based on existing emission scenarios (SRES) and
1047 climate projections (CMIP3). The IAM community has begun to explore new mitigation
1048 scenarios, e.g. in the context of several model comparison activities such as the Asian Modeling
1049 Exercise, the Energy Modeling Forum's Project 24 on mitigation technology, and the EU AMPERE
1050 project. Individual IAM teams are producing RCP replications, where they study the range of
1051 socioeconomic scenarios leading to the various RCP radiative forcing levels.

1052 The construction of SSPs for use by the IAM and IAV communities still needs to be tackled. The
1053 following sections outline the steps and timeline needed to produce an operational set of new
1054 socioeconomic scenarios incorporating the SSPs. Such a scenario set will facilitate the third
1055 phase of the new scenario process, the integration phase. In this phase, consistent climate and
1056 socioeconomic scenario information should be employed in IAM and IAV studies.

1057 **5.2 Contribution to the IPCC 5th Assessment Report and beyond**

1058 A major stakeholder in the new scenario process is the IPCC with its upcoming 5th Assessment
1059 Report (AR5). IPCC author teams in the three working groups (WGs) are facing the challenge of
1060 evaluating a very large number of studies from the IAM, IAV, and CM communities, and
1061 producing an internally consistent assessment that can be meaningfully synthesized across the
1062 WGs. Producing information on mitigation, adaptation, and residual climate impacts for a range
1063 of climate change outcomes using similar assumptions and across similar temporal and spatial
1064 scales will be critical information of relevance for climate policy makers. For this, the IPCC will
1065 need a consistent set of climate and socioeconomic scenarios.

1066 The table lays out the timeline of the IPCC's 5th Assessment Cycle. There is considerable overlap
1067 between the development of new scenarios and the AR5. Ideally, SSPs and new socioeconomic
1068 scenarios need to be available quickly to allow the scientific community enough lead time for
1069 meeting the AR5 cut-off dates for eligible publications. Realistically, new socioeconomic
1070 scenarios might not become fully available before early 2012 (see timeline below). This is
1071 shortly after the 2nd LA meeting of WG II and around the time of the 2nd LA meeting of WG III.
1072 Scenarios that are not available by this time will likely not be assessed in the AR5. There is

1073 considerable time pressure to produce the new socioeconomic scenarios, and do so without
 1074 compromising the process. It is expected that much of the literature assessed in the AR5 will be
 1075 based on previous scenario sets such as SRES and CMIP3.

1076 Even though there may not be many new socioeconomic reference and climate policy scenarios
 1077 available for AR5, the scenario matrix approach can prove very useful for assessing the work
 1078 based on previous scenario sets (see Section 2 for a discussion of the scenario matrix as a
 1079 heuristic tool). Benchmarking studies comparing the new scenarios with, e.g., the SRES
 1080 scenarios would help to inform a mapping of research using previous scenarios with the
 1081 scenario matrix. Such a mapping would allow the assessment to use the scenario process as a
 1082 heuristic tool to group the existing scenario literature.

1083

	WG I	WG II	WG III
1st LA Meeting	8-11 November 2010	11-14 January 2011	12-15 July 2011
2nd LA Meeting	18-22 July 2011	12-15 December 2011	19-23 March 2012
First Order Draft (FOD)	16 December 2011	11 May 2012	22 June 2012
3rd LA Meeting	16-20 April 2012	22-26 October 2012	5-9 November 2012
Cut-off date for submission of publications	31 July 2012	31 January 2013	11 March 2013
Second Order Draft (SOD)	5 October 2012	1 March 2013	11 March 2013
4th LA Meeting	14-19 January 2013	15-17 July 2013	15-19 July 2013
Cut-off date for acceptance of publications	15 March 2013	31 August 2013	28 October 2013
Final government distribution	7 June 2013	28 October 2013	13 December 2013
Final plenary Approval	23-26 September 2013	17-21 March 2014	7-11 April 2014

1084 The IPCC 5th assessment report will not be the endpoint of the new scenario process. Rather, it
 1085 may serve a catalyst for a new round of climate change scenario development that will continue
 1086 beyond the publication of the AR5, and produce scenarios that are likely to be relevant for the
 1087 period until 2020 - much as SRES has been relevant for the previous decade. It is important to
 1088 allow the socioeconomic scenario development sufficient time to reach a level of sophistication
 1089 and integration of IAM, IAV, and CM perspectives that would constitute a major step forward.
 1090 The timeline of the scenario process should be able to accommodate both objectives - to
 1091 produce a tangible outcome for the AR5 in the near term, and to move the next generation of
 1092 climate change scenarios to a new level in the long term.

1093 **5.3 Milestones for developing new socioeconomic scenarios**

1094 A series of steps and processes will be needed to develop a set of socioeconomic scenarios for
 1095 use in the IAM and IAV communities.

- 1096 – **Draft framework paper.** The draft framework paper will be widely circulated to the
1097 scientific community, commented upon, revised by the writing team, and finalized. This
1098 process will help build support for the socioeconomic scenario process and harmonize
1099 conceptual approaches to producing compatible and consistent scenarios. It is
1100 recommended that a small panel of review editors oversee the review process. The
1101 review panel would work together with the framework paper writing team to ensure
1102 that an appropriate process is put in place to adequately take into account the
1103 community response in the revision process.
- 1104 – **Initial proposals and testing of basic SSPs.** The formulation of initial proposals for basic
1105 SSPs, comprising socioeconomic reference assumptions, can begin in parallel with
1106 circulation of the first draft of the framework paper. The community could initiate the
1107 process of socioeconomic scenario development and the identification of basic SSPs.
1108 However, before identifying the subset of basic SSPs that will constitute the columns of
1109 the SSP-RCP scenario matrix, it is important to test them in integrated assessment
1110 models and IAV analyses. The testing phase will begin with the construction of SSP
1111 proposals and may involve preliminary socioeconomic scenario development, including
1112 IAM reference scenarios with a basic SSP core, socioeconomic scenarios, and climate
1113 policy assumptions that establish different RCP levels.
- 1114 – **Preliminary selection of basic SSPs.** Based on the results of the testing phase, a
1115 preliminary set of basic SSPs for the scenario matrix may be selected at the workshop on
1116 socioeconomic pathways for climate change research in Boulder, Colorado (3-4
1117 November 2011). This workshop will seek broad participation of the IAM and IAV
1118 community. The selected preliminary set of basic SSPs should be published in a special
1119 issue of a scientific journal. It is anticipated that the basic SSPs may be revised as the
1120 development of socioeconomic scenarios matures (see next item).
- 1121 – **SSP extensions and socioeconomic reference and policy scenario development.** After
1122 the preliminary basic SSPs are determined, the IAM and IAV communities will continue
1123 to work on extending the basic SSPs with relevant socioeconomic reference
1124 assumptions. Such extended SSPs may include additional quantitative information on
1125 e.g. urbanization, poverty, etc., and richer narratives including regional perspectives.
1126 Initial discussion of priorities for SSP extensions will take place at the workshop in
1127 Boulder, Colorado. The investigation of extended SSPs will involve an iterative process
1128 between the formulation of the extended SSPs, the development of socioeconomic
1129 reference and climate policy scenarios, a further refinement of extended SSPs, and
1130 potential revision of basic SSPs based on a periodic evaluation of what socioeconomic
1131 information has proven useful to include. This process of socioeconomic reference and
1132 climate policy scenario development will likely proceed over several years. It will aim to
1133 produce a set of scenarios that will inform climate policy analysis in the years extending
1134 beyond the IPCC AR5 assessment cycle.
- 1135 – **Illustrative socioeconomic reference and climate policy scenarios.** During the period of
1136 SSP extensions, a larger number of socioeconomic reference and climate policy
1137 scenarios will be constructed. Although the process will continue for years, it is
1138 desirable to identify a subset of illustrative socioeconomic scenarios filling the RCP-SSP
1139 matrix at an early stage. Such early illustrative scenarios could still be taken up by a

1140 subset of studies prepared for AR5. The decision on illustrative scenarios would ideally
 1141 be taken together with a decision on the preliminary set of basic SSPs at the Boulder
 1142 workshop in November 2011.
 1143 – **Analysis of development implications of mitigation and adaptation:** Mitigation and
 1144 adaptation policies will have implications for socioeconomic development. Further
 1145 work, including scenario work, will be needed to fully understand the socioeconomic
 1146 implications of climate policies.

1147 **5.4 Timeline for finalizing the framework paper**

August 2011	Circulation of the draft framework paper to the scientific community. It is desired to establish a review panel to collect the community response and oversee the revision of the framework paper.
16 September 2011	Deadline for submitting feedback, comments, and suggestions for revisions to the review panel.
By end of October 2011	Authors produce revised framework paper with guidance from the review panel, taking into account the review comments and the initial experience gained from the construction of the SSPs.

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1149 **5.5 Near-term timeline for the development of new socioeconomic scenarios**

July - Dec 2011	Initial SSP testing phase. Initial SSPs will be developed and tested in IAM and IAV analyses
7 Oct 2011	Scenario and SSP workshop of the IAMC scenario subgroup to discuss and compare scenario proposals of IAM teams.
from Fall 2011	Socioeconomic scenario development phase. Open call to the community to conduct IAM and IAV analyses building on the basic SSPs for developing extended versions of the SSPs, and socioeconomic reference and climate policy scenarios. This process is likely to continue over several years, and may be reviewed at the time of completion of the AR5 assessment cycle.
3-4 Nov 2011	Workshop on socioeconomic pathways for climate change research at Boulder, Colorado. The workshop will facilitate the implementation of the socioeconomic scenario development phase and ideally select a preliminary set of basic SSPs and illustrative scenarios for use in AR5.
Feb-Apr 2012	Publication of the data of the illustrative socioeconomic scenarios for AR5. These illustrative scenarios are solely dedicated for a small subset of IAV and IAM analyses with the goal of informing the AR5.
First half of 2012	Preparation of a special issue on basic SSPs in a scientific journal.

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