Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research

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Meeting Report

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1. Contents

1. Introduction

The Boulder workshop on socio-economic development pathways was one element of a series of meetings facilitating a community-wide process for developing new scenarios for use in climate change research and assessment.

The climate change research community is pursuing development of a new framework for the creation and use of scenarios to improve interdisciplinary analysis and assessment of climate change, its impacts, and response options. This process, as formulated at the IPCC Workshop on Scenarios in Noordwijkerhout, Netherlands, in 2007, includes a set of forcing pathways, known as the Representative Concentration Pathways (RCPs), to be combined with alternative socio-economic development pathways (Moss et al., 2008, 2010). Development of RCPs has been completed and these pathways are now documented in a special issue of *Climatic Change* (van Vuuren et al., 2011), and climate model simulations based on them are well under way as part of the CMIP5 exercise (Taylor et al., 2011).

Over the past two years, researchers have turned to the task of developing socio-economic development pathways, and a series of meetings has been held to facilitate progress and synthesize approaches. A joint IPCC-NAS workshop in Washington, DC, in 2010 explored the needs for socioeconomic and environmental futures that could be used with climate scenarios (NRC, 2010) and served as a stimulus for a number of proposed frameworks within which such scenarios could be developed (van Vuuren et al., 2012; Kriegler et al., 2010). An IPCC Workshop on Socioeconomic Scenarios held in Berlin in November 2010 brought together researchers from the integrated assessment modeling (IAM); impacts, adaptation and vulnerability (IAV); and climate modeling (CM) communities to consider the task and led to adoption of a unified framework for the development of a small set of Shared Socio-economic Pathways (SSPs) and their use in conjunction with the RCPs and associated climate model simulations for the development and assessment of integrated research. A framework paper (Arnell et al., 2011) was subsequently produced, and is in preparation for submission to a peer-reviewed journal.

In the meantime, efforts on developing the content of the socio-economic pathways themselves continued. At a meeting in Chongwon City, South Korea, in July 2011, researchers came together to compare notes on experiments with new pathways as implemented in IA models, conceptual development related to SSPs, and application to IAV analysis. The integrated assessment modeling community held a follow up meeting in October 2011 to further compare model experiments based on potential SSPs.

In early November, 2011, the Boulder meeting was held with the joint purpose of adopting a basic set of narratives for the SSPs and laying out priorities for further activities. The meeting should therefore be seen as one important step in a longer term process that involved substantial previous work, and anticipates further progress to be made. In this report, we provide in section 2 an outline of the meeting itself, including its specific goals and general content, and in section 3 a summary of the meeting outcomes. These include the identification of key elements of SSPs that should be included in order to make them most useful to IAM and IAV analysis, the basic narratives for each of five SSPs adopted at the meeting (with the possibility held open of a sixth SSP), needs for a longer-term process of development and use of the SSPs, and key actions that should be taken over the shorter term to carry the process forward.

2. Outline of the meeting

2.1. Meeting goals

The goals of this workshop were to agree on the general nature of a set of basic socioeconomic development pathways, and to prioritize new work on developing extended versions of these pathways that would improve their usefulness for evaluating mitigation strategies, adaptation options, and residual impacts. In addition, the meeting further explored how such socioeconomic development pathways can be used in conjunction with climate model simulations to generate integrated scenarios useful for carrying out climate change research.

The scientific steering committee developed a set of desired decisions to be reached through this workshop, which were presented in the introductory session and categorized as those decisions that were considered essential to make in order to keep the overall scenario development process on track, those that would be desirable (but not essential) to make, and those that should not be made at this meeting:

Essential:

- Zero-order narratives for minimum set of basic SSPs
- Qualitative descriptions of quantitative SSP elements
- Initial distinction between elements in basic vs. extended SSPs
- Process for carrying out further development of SSPs and model simulations based on them

Desirable

- Zero-order narratives for <u>full</u> set of basic SSPs
- Prioritization of needs for development of extended SSPs
- Identification of key issues related to use of climate simulations with SSPs

Not to be decided

- Specific content for extended SSPs

2.2. Meeting format and overview of agenda

The meeting brought together 65 researchers (including two participating remotely) involved in the development or use of scenarios from a variety of research fields (see Appendix I). About one-third of participants were from the field of integrated assessment modeling (IAM), another third that could be broadly categorized as involved in the assessment of impacts, adaptation, and vulnerability (IAV), and a third were from other research communities such as climate modeling (CM), policy studies, future studies, or various aspects of development.

The meeting agenda (Appendix II) included a mixture of presentations, breakout group discussions, and plenary discussions.[1] On Day 1, presentations included an introductory session on the overall scenario framework, a session on proposals for SSP narratives or approaches to developing them, and a session on IAM experiments that had been carried out based on preliminary conceptualizations of SSPs. The day concluded with a set of four breakout groups that each addressed the same set of goals:

- Develop minimal sketches of proposed narratives for each SSP (or as many as possible)
- Identify which aspects of the proposed SSPs are intended to determine the challenges to mitigation and to adaptation
- Identify areas of agreement and disagreement, or where multiple possibilities exist

Day 2 began with reports from the breakout groups on proposed SSPs, and initial plenary discussion of commonalities and differences among proposals. That was followed by a morning session of presentations from a variety of perspectives on elements of SSPs that should be given high priority for inclusion, and an afternoon session presenting specific proposals for quantitative elements of SSPs such as population, GDP, urbanization, and other socioeconomic characteristics. The day concluded with a second set of breakout group discussions aimed at synthesizing SSP proposals into single narratives for each SSP that could be proposed for adoption the following day, and laying out a set of needs for a longer-term process of SSP development and use.

Day 3 began with a session of forward-looking presentations on issues related to the integration of SSPs with RCPs and associated climate simulations, including topics such as progress on climate model simulations based on RCPs, land use, short-lived emissions, and the prospects for use of pattern scaling in conjunction with climate modeling results. It was followed by a concluding plenary session in which proposed SSP narratives from the Day 2 breakout groups were presented, discussed, and adopted. In addition, needs for short-term and longer-term steps for further development of the SSPs, IAM scenarios based on them, and their use in IAV studies were presented and discussed.

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[1] Presentations are available on the meeting website at http://www.isp.ucar.edu/socio-economic-pathways.

3. Meeting outcomes

There were four key types of outcomes from the meeting, each discussed in turn in the sections below. First, key elements of SSPs were identified, along with a preliminary sense of which elements were likely important for inclusion in basic SSPs, and which might be better suited to more extended versions. Second, basic narratives for each of five SSPs were developed, along with qualitative indications (direction and magnitude) of trends in key elements. The possibility of a sixth SSP was also proposed, and its possible development left for future consideration. Third, a set of longer-term needs for development of extended SSPs and their use in IAV analyses, particularly at the local scale, were identified. And finally, a set of shorter-term needs (those likely to be necessary over the next ~12 months, a timeline relevant to the IPCC Fifth Assessment Report) were proposed, with some limited discussion of key priorities.

3.1. Key elements of SSPs

SSPs include both a qualitative component in the form of a narrative on global development (see Section 3.2) and a quantitative component that includes numerical pathways for certain variables that are particularly useful to have in quantitative form for use in other studies (Arnell et al., 2011). By "elements" of SSPs, we mean a set of variables, processes, or components of human-environment systems that provide the building blocks for constructing both the qualitative and quantitative aspects of SSPs.

Several presentations and discussion at the meeting contributed to the identification of elements that were considered "key," that is, of high priority for inclusion in SSPs. The key elements of an SSP aim to characterize a global socio-economic future for the 21st century as a reference for climate change analysis. It is therefore particularly important that the key elements are sufficient to differentiate SSPs from one another in terms of the socio-economic challenges they would present to mitigation and adaptation. Presentations included results of a formal survey of experts regarding the most important elements of SSPs, as well as examples of priority needs from mitigation and IAV studies including the Agricultural Model Intercomparison and Improvement Project (AgMIP), the World Water Scenarios, and from the perspectives of decision analysts and vulnerability and adaptation assessments. In addition, proposed quantifications of population, educational attainment, and urbanization were presented, along with examples of model-based scenarios employing or generating quantitative indicators such as the Human Development Index.

The question of which variables should be part of basic SSPs, and which should be part of an extension of SSPs was left largely open, to be addressed in a next phase of SSP development. There was a shared sense that basic SSPs should contain enough information to provide a broad, basic description of the global socio-economic future over the 21st century that was sufficient to differentiate them in terms of the socio-economic challenges they would present to mitigation and adaptation, and that would allow integrated assessment models to produce meaningful reference scenarios associated with the SSPs.

The list below summarizes the elements identified in presentations and subsequent discussions, using a set of categories developed in one of the breakout groups. Such a collection of elements would provide sufficient information for a broad characterization of SSPs across the relevant space for climate policy analysis.

Population and human resources: Population growth, fertility & mortality, age and gender structure, spatial distribution, migration, urbanization, education

Economic development: growth of per capita income, across-country income distribution, within-country income distribution, economic (sector) structure, employment, international trade, globalization

Human development: poverty, energy access, food security, public health and health care access, equality and social cohesion, human development index

Technology: R&D investment, pace of technological development, state of physical infrastructure, energy sector: direction of technological development in the supply sector, energy intensity, carbon intensity, technology transfer, technology availability

Lifestyles: Consumption patterns, diet, values

Environment and natural resources: fossil resource use, natural resource use, land use, agricultural productivity, environmental pollution, water availability, soil fertility

Policies and institutions: International cooperation, global power structures, environmental policy orientation, effectiveness of institutions, quality of governance, availability of insurance

3.2. Narratives and elements for Basic SSPs

Narratives were developed and agreed upon for basic versions of five SSPs, illustrated in Figure 1 within the space of socio-economic challenges to mitigation and adaptation outcomes that the SSPs are intended to span (Arnell et al., 2011).[2] This space can in principle contain a very large number of socio-economic pathways that would represent various combinations of challenges to mitigation and adaptation.[3] The SSPs are intended to be single pathways that are representative of the types of socio-economic pathways that could occupy particular domains within the overall space. The short titles for each SSP shown in the figure are derived from suggestions at the

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[2] Socio-economic challenges to mitigation do not include the stringency of the policy target, but rather socio-economic factors that, for any given target, would make it more difficult to reduce emissions. Similarly, challenges to adaptation do not include the degree of climate change experienced, but rather socio-economic factors that, for any given climate change, would make adaptation more difficult. Thus the SSPs overall do not include climate change or climate policy. Scenarios that study the effect of climate change or of climate policies can be developed based on the SSPs as a shared reference case.

[3] SSPs are intended to span this space of challenges to mitigation and adaptation so that analyses based on them, when considered as a set, will be able to characterize the uncertainty in the implications for mitigation or for adaptation for a given climate change pathway, for example those based on the Representative Concentration Pathways (RCPs) (Arnell et al., 2011).

meeting, but have been further modified for brevity and clarity. Other options proposed at the meeting are included in the text below. The narratives provided in this section were either largely written at the meeting itself (SSP 5), or were written after the meeting by the chairs and rapporteurs of the breakout groups that developed them based on the discussion and presentations at the meeting (SSPs 1-4). Each narrative has a Summary and a Full Version, and an associated table of qualitative assumptions for all SSPs about direction and magnitude of trends in SSP elements is provided in Appendix III.

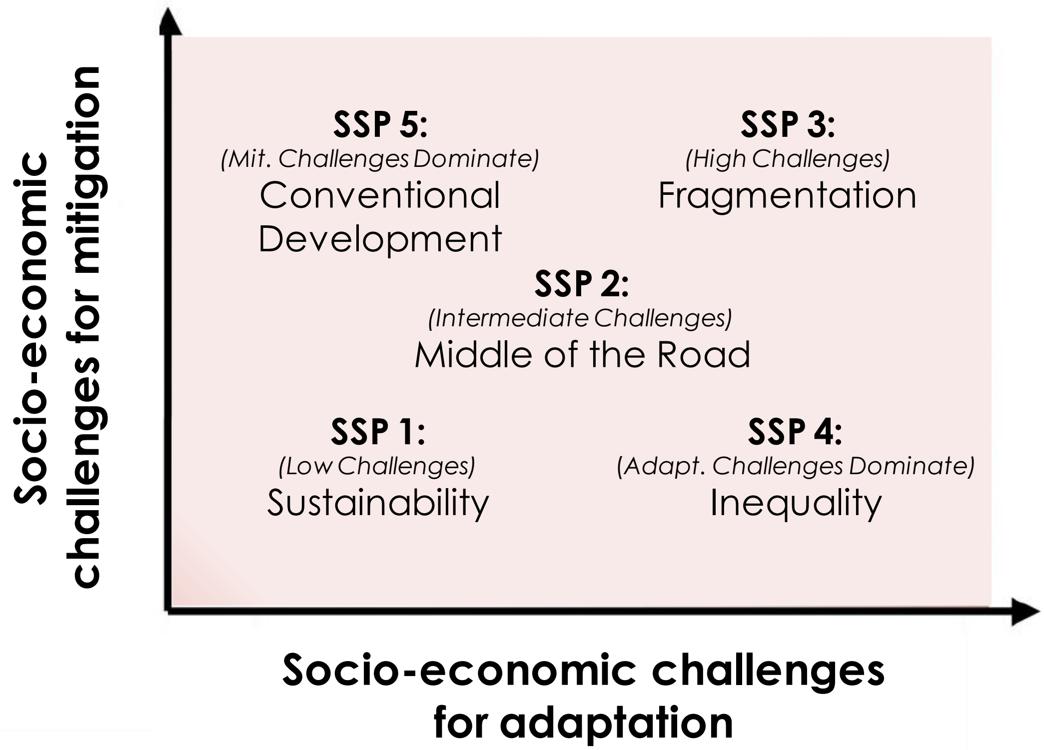

Figure 1: Five SSPs for which basic narratives were developed at the Boulder meeting. A sixth SSP that would be an alternative interpretation of SSP2 was proposed and discussed but not further developed.

3.2.1. SSP 1: Sustainability

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

Full Version: This is a world making relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. Elements that contribute to this are a rapid development of low-income countries, a reduction of inequality(globally and within economies), rapid technology development, and a high level of awareness regarding environmental degradation. Rapid economic growth in developing countries with high employment levels reduces the number of people below the poverty line. This is accompanied by well-managed urbanization, particularly in low- and middle-income countries. Medium economic growth in high-income countries provides sufficient growth to support strong investment in research and development. The world is characterized by an open, globalized economy – in which countries cooperate to achieve common development and environmental goals. This facilitates rapid technological change and technology transfer, leading to universal access to modern and clean energy for all. Increased income equity lowers societal stratification in low- and high-income countries. Standards of living converge internationally and within countries, while maintaining high levels of diversity that confer resilience to societal and environmental changes. Technology development is directed toward environmentally friendly processes, including clean energy technologies and high productivity of land. Natural resources are used efficiently, with high awareness of the environmental consequences of choices. There is a reluctance to use non-conventional fossil fuels. The service sector grows relatively quickly. Consumption is oriented towards low material growth and energy intensity, with a relatively low level of consumption of animal products.

Concurrently, governance and institutions facilitate achieving social, environmental, and economic development goals and problem solving. The Millennium Development Goals are achieved within the next decade or two, resulting in educated populations with access to safe water, improved sanitation, medical care, and other factors that reduce vulnerability to climate and other global changes. In addition, rapid declines in pollutant emissions reduce adverse impacts on human health and the ecosystem. All these changes together result in a relatively rapid decline in fertility and mortality in less-developed countries, and in medium fertility in more-developed countries. Migration is at intermediate levels. Although increasing integration of labour markets allows people to move around more freely, improved regional livelihoods, a renewed emphasis on regional production, and rapidly converging income levels reduce migration incentives.

3.2.2. SSP 2: Middle of the Road (or Dynamics as Usual, or Current Trends Continue, or Continuation, or Muddling Through)

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

Full Version: In this world, trends typical of recent decades continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. Some international cooperation and investments in technology development and transfer support moderate economic growth in low-income countries, with slower economic growth in high-income countries. Technology development proceeds in industrialized countries, but is not shared with low-income countries. There is evidence of degradation of the environment.

Development of low-income countries proceeds unevenly, with some countries making relatively good progress while others are left behind. Urbanization follows a similar pattern, with some countries moving towards more planned settlements as they develop and some seeing increases in unplanned settlements. Population growth is moderate, with higher growth in low-income countries. Most economies are politically stable with partially functioning and globally connected markets. A limited number of comparatively weak global institutions exist. Globalization trends continue slowly, although trade barriers in primary energy, agricultural and capital markets remain. The flow of information and global access to markets are rather well regulated in most countries, with the exception of least developed countries, some resource producing countries and islands of protectionism. Per-capita income levels grow at a medium pace on the global average, with slowly converging income levels between developing and industrialized countries. Intra-regional income distributions improve slightly with increasing national income, but disparities remain high in some regions with high income disparities today.

Education investments are not high enough to rapidly slow population growth, particularly in low-income countries.

Unmitigated emissions are moderately high, driven by population growth, use of local energy resources, and moderate technological change in the energy sector. Driven by security concerns, there is no reluctance to use unconventional energy resources. While local environmental concerns, such as air quality, ranks high on the agenda of many countries, implementation lags behind the ambitions. Globally this leads to an intermediate pathway for pollutant emissions.

Achievement of the Millennium Development Goals is delayed by several decades, leaving populations without access to safe water, improved sanitation, medical care, and other factors that reduce vulnerability to climate and other global changes.

3.2.3. SSP 3: Fragmentation (or Fragmented World)

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

Full Version: The world is separated into regions characterized by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. Regional blocks of countries have re-emerged with little coordination between them. This is a world failing to achieve global development goals, and with little progress in reducing resource intensity and fossil fuel dependency. Countries focus on achieving energy and food security goals within their own region. Little international cooperation and low investments into technology development and education slow down economic growth in low- and high-income regions. Growth in urban areas in low-income countries is often in unplanned settlements. Population growth is high as a result of the education and economic trends. Unmitigated emissions are relatively high as well, driven by high population growth, use of local energy resources and slow technological change in the energy sector. There is serious degradation of the environment, including high levels of pollutant emissions with severe impacts for human health and the ecosystem. Driven by security concerns, there is no reluctance to use unconventional energy resources. A regionalized world leads to reduced flows of trade and technology transfer.

Fertility rates are high in less developed countries, resulting in stalled demographic transitions; fertility rates are medium in more developed countries. Mortality rates also are high, with many children dying from preventable diseases (malnutrition, diarrheal disease, malaria). The Millennium Development Goals are not achieved or are achieved much later than planned, resulting in poorly educated populations with many people without access to safe water, improved sanitation, medical care, and other factors that affect vulnerability to climate and other global changes. Development proceeds slowly, with high inequalities within and across countries.

Disadvantaged populations continue to move to unplanned settlements around large urban areas, often in places that are particularly vulnerable to weather and climate events.

Governance and institutions are relatively weak, with poor cooperation and consensus. In addition, effective leadership and capacities for problem solving are lacking. Investments in research and development and in human capital are low. Institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity. Policies are oriented towards security.

3.2.4. SSP 4: Inequality (or Unequal World, or Divided World)

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

Full Version: This pathway envisions a highly unequal world, both within and across countries. A relatively small, rich global elite is responsible for much of the emissions and is able to mitigate at low cost. This elite also emerges in developing countries, and is highly globally connected and mobile. The larger, poorer part of the population contributes little to emissions, but is vulnerable to the impacts of climate change. This vulnerable group exists in both developing and industrialized countries, and is concentrated in rural areas and large mega-cities. Those mega-cities with a large fraction of relatively poor and less educated people lack the capacity to protect themselves from extreme weather events. Access to high quality education, health services and family planning is also limited, leading to high population growth in low-income countries. In industrialized countries, economic uncertainty for most of the population leads to relatively low fertility and low population growth. Urbanization is high, induced by the large income differences, but takes place in an unorganized way that leads to large slums in developing countries.

In economic terms, this is a mixed world: as inequality increases within all regions, it is not clear beforehand how the diverging growth rates would aggregate to averages. Economic growth is probably medium/high in industrialized countries, low-income countries have low economic growth (though at the same time a rapidly rising elite) and middle-income income countries have medium growth, also driven by the increasingly rich elite groups.

This is a world with low social cohesion. Poor people have the hope, and sometimes the opportunity, to become a member of the elite, but are mostly trapped in their conditions. Governance is dominated by regulatory capture: the government works for the elite, by the elite. Challenges to adaptation are high due to the relatively low incomes and education of large proportions of the population in all regions, as well as to poorly functioning institutions for all but the elite, and lack of investment in reducing vulnerability.

With respect to energy and emissions, a main characteristic is that global elite emits very much, but is capable of changing its patterns, whereas the poor do not emit that much and, hence, there is hardly any transformation needed for them. Actions are taken to control local pollution only in the interests of the elite, likely to live largely in urban areas. As an example, power production could be moved out of city areas to reduce urban air pollution, while there would be little regard for the environmental consequences of land use in rural areas. Overall air pollution levels would thus remain relatively high compared to other SSPs.

In this world, global energy corporations use investments in R&D as a hedging strategy against perceived or potential resource scarcity and the option that climate policy will be imposed. Their main aim is to remain global players in energy supply, also under changing circumstances. This leads to the development of low-cost renewables, CCS-ready power plants and energy-efficient technology. Some of these technologies, like energy efficiency or renewables, may be applied without climate policy, as a response to resource scarcity. Hence, the mitigation challenges are low due to some combination of 1) low reference emissions and/or 2) a high latent capacity to mitigate.

A typical example of hedging against resource scarcity could be a strong push for bio-energy by global energy corporations. In the absence of sustainability regulations, large energy corporations would acquire the necessary land-resources in developing countries to grow energy-crops, while reducing options for adaptation for local communities and for nature conservation.

Another example of a typical climate measure under this pathway could be geo-engineering, where the elite decide on this measure without concern for the potential negative effects for others. This would only be plausible, however, if the elite were able to insulate themselves against the detrimental effects of these measures.

Land ownership is unevenly distributed and land use management is also left to the global elite. Productive areas of the world would be dominated by industrialized agriculture and monocultural production. Crop yields would be typically high in large-scale industrial farming, but low for small-scale farming. Food trade is global, but access to markets is limited, increasing vulnerability for non-connected population groups.

3.2.5. SSP 5: Conventional Development (or Conventional Development First)

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

Full Version: The world is developing rapidly powered by cheap fossil energy. There is a strong push for development in developing countries which follow the fossil and resource intensive development model of the industrialized countries. This is aided by strong globalization and high levels of international trade allowing for specialization of countries. A global “development first” agenda is enforced leading to the eradication of extreme poverty and universal access to education, safe drinking water and modern energy before mid century. Development policies emphasize education and health, leading to a strong build up of human and social capacity in developing countries. Regional governance improves in parallel, leading to effective governance structures (low level of corruption, rule of law) across the globe by mid century. Due to the rapid development, social cohesion strengthened, including larger gender equality.

As a result, per capita incomes in developing countries increase rapidly with strong convergence of inter- and intra-regional income distributions. At the same time industrialized countries continue their focus on economic growth aided by consumerism and resource intensive status consumptions, including – inter alia – a preference for individual mobility, meat rich diets, and tourism and recreation. Developing countries rapidly adopt these consumption patterns. The gross world product at the end of the century is very high, with a continued large role of the manufacturing sector. Global population peaks and declines in the 21st century. High international mobility enables high migration rates from poorer to wealthier countries , buffering the effect of aging populations in industrialized countries. All regions urbanize rapidly and saturate at very high urbanization rates. City planning is based on robustness principles. It includes significant urban sprawl.

Investments in technological innovation are very high, with a focus on increasing labor productivity, fossil energy supply, and managing the natural environment. With the help of technological progress, fossil resource extraction is being maximized at low costs, and local externalities of fossil energy production (e.g. health effects) are well controlled. Due to the strong reliance on fossil energy, alternative energy sources are not actively pursued. This is re-enforced by high discount rates posing additional barriers on capital intensive investments in the energy supply and end use sectors. Massive infrastructure investments are undertaken to strengthen resistance against environmental perturbations including climate variability and climate change. This is complemented by high disaster preparedness.

Environmental consciousness exists on the local scale, and is focused on end-of-pipe engineering solutions for local environmental problems, such as air pollution. Air quality is thus improving pervasively and rapidly throughout the world. Agro-ecosystems are highly managed building on strong technological progress in the agricultural sector. Land use management is generally very resource intensive including water system management. Action on global environmental problems is hampered by high discount rates and a development-first paradigm that assumes there are high opportunity costs of global environmental action.

3.2.6. SSP Element Summary

A subset of SSP elements is summarized in a set of tables in Appendix III. These tables include brief descriptions of elements, or indications of qualitative trends in elements, associated with each SSP based on its narrative. The tables use groupings of elements similar to those presented in section 3.1, although some categories have been combined. Not all elements listed in section 3.1 are included in the tables, but rather only those that were addressed in some way in the narratives. Not all elements have descriptions for all SSPs. In some cases, such as diet in SSPs 2-4, this was because that particular element was not of special importance to the SSP; in other cases, such as for urbanization levels in SSPs 1-3, it was because the narrative was incomplete and does not yet contain judgments for that element. In a next phase of SSP development, both narratives and these table summaries of SSP elements will need to be filled out.

3.3. SSPs as part of a longer-term process

In a number of presentations during the meeting, and in a breakout group on Day 2 explicitly devoted to the topic, participants discussed the role of SSPs in a longer-term process of integrated climate change research and assessment. This section summarizes conclusions.

Building the next generation of long-term global socio-economic scenarios will require meeting two often-competing long-term challenges: (i) scenarios will have to support integrated research on both climate mitigation and impacts, and (ii) they will have to provide information for people making decisions. Moreover, the scenarios are also intended to be useful to two very different groups of users: on the one hand, researchers working at the global or local scale; on the other hand, decision-makers at the national or local level.

Meeting this diverse array of needs will require not only well designed global scenarios, but also methods for extending them and using them in conjunction with other approaches. In addition, the SSPs themselves should be dynamic and evolve over time. While there is a need driven largely by the IPCC AR5 to develop a first generation of narratives and SSPs over the very short term, it will be useful to build simultaneously a process to develop future generations of SSPs. Indeed, SSPs should be used as inputs for the next generation of RCPs and ESM simulations, and an iterative process should be instituted so that scenarios from IAMs and ESMs converge and can eventually be used by the three communities at the same time (climate impacts, vulnerability, mitigation).

To address these challenges, the group identified two important tasks that should be carried out in parallel (see Fig. 2):

- Development of a guidance note on how to use the first generation of SSPs, in particular to facilitate the use of SSPs by scholars working at local scale and the involvement of these researchers in the SSP development process.
- Construction of a multi-model database of scenarios based on the SSP framework for use in research that requires a larger number of scenarios than provided by the first generation SSPs and as a basis to build the next generation of SSPs.

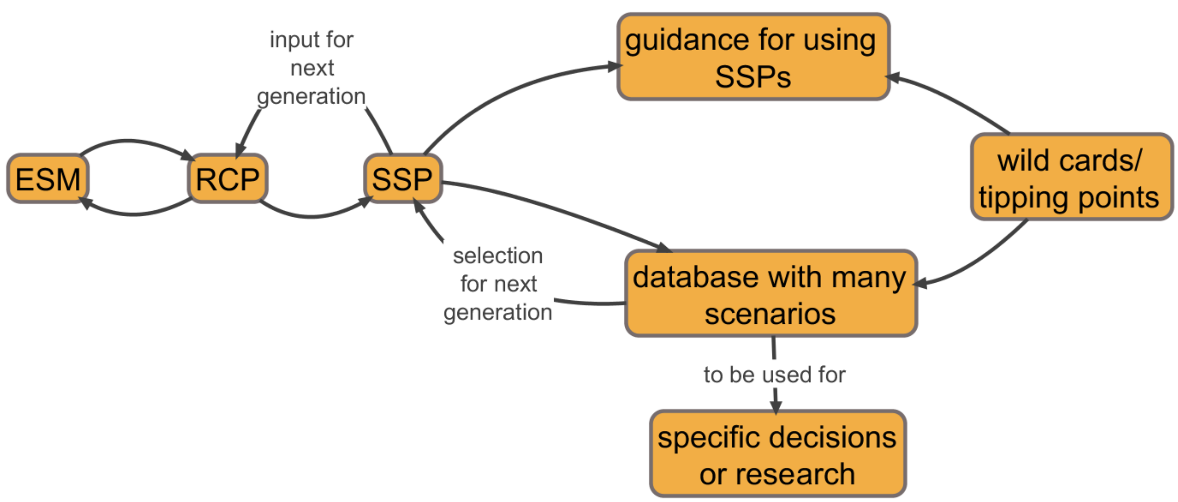

Figure 2: The future of scenario-building

3.3.1. Guidance on the use of SSPs for local analyses

Many scholars working at local level do not use global scenarios but might do so if such scenarios could better meet their needs. A "guidance product" on how to use SSPs for local analysis would help overcome this obstacle. This product should address ways in which global scenarios and local analyses, and short- and long-term dynamics, can inform each other. There are implications not only for ways of using long-term global scenarios in local analyses, but also in how global scenarios can best be designed with these uses in mind.

For example, SSPs must provide enough information for local studies to link global patterns to local issues. In some cases this might involve providing relevant variables, such as those related to global trade or foreign direct investments. In other cases it would involve downscaling information to the local level. However, for many applications downscaling should not be automatic and deterministic, but rather allow assumptions in global scenarios to act as framing or boundary conditions, allowing flexibility at the local level. For example, in a global scenario that assumes general conditions of good governance, the local scenario should be able to assume that local governance does not function well if such an assumption is useful for the purpose at hand. It may be useful to avoid the term "downscaling" in order to emphasize the difference between a flexible and a more deterministic approach.

For other local applications, such as the assessment of health and environmental impacts of air pollution, automatic downscaling of SSP scenarios may be a very useful and appropriate approach. Generally, requirements on the SSPs to provide local information will thus differ, and depend on the IAV methods that are applied for the local scale analysis. Requirements for air-pollution assumptions in the SSPs were discussed in some detail. Two specific needs were identified: 1) sufficient spread in assumptions, in order to explore a wide range of pollutant emissions across the SSPs, and 2) sufficient spatial and sectoral detail for atmospheric chemistry and dispersion modeling, which is necessary to explore climate and health implications of SSP-based scenarios. The former is particularly important, given that RCPs explore only middle of the road pathways for pollutant emissions. The latter detail might not be part of basic or extended SSPs, but will be important information that SSP-based scenarios should provide, in order to make them as relevant as possible for impacts assessments of local climate and air pollution.

For global scenarios to be most effective at providing boundary conditions that can be flexibly applied at the local scale, they must strike a balance between usefully constraining the space of possible future conditions without being over-prescriptive. Achieving this balance would be aided by a particular focus in SSPs on larger-scale qualitative development trends, which could be translated into multiple local versions of the SSP that allow for flexibility in the local manifestation of global trends.

In addition, experience gained with local analyses that use global scenarios should then be integrated into the iterative scenario development process in order to improve global scenarios. Similarly, this process must capture lessons learned about links between long-term dynamics included in global scenarios and short-term dynamics that are typically more important in local decisions contexts. Designing the process of scenario development and use to allow for this learning over time is especially important.

A number or proposals were made for types of activities that might contribute to furthering the connections between global scenarios and local analyses, including:

> Collect information on actual processes on the ground, to review how people use existing scenarios, including the SRES scenarios.
>
> Write a literature review on the connection between local vulnerability studies and global trends as represented in scenarios, and include recommendations and techniques from vulnerability communities.
>
> Produce a special issue on how to use SSPs at local scale, based on a number of different case studies, including local adaptation and local mitigation studies (e.g., drawing on existing work in California, the Mekong Delta, Paris):

3.3.2. A scenario database

The set of five SSPs defined as part of this meeting will be useful but will not meet all needs. In many cases, users either need to be able to select from a large number of scenarios, or to use a large number of scenarios directly in their analyses. Building a database of scenarios would help meet this need. Such a database could expand on existing database initiatives in the IPCC WG3 community. It should include as many scenarios as possible, based on multiple models, modeling groups, and model parameter sets in order to best capture uncertainty. This database would include multiple alternative scenarios based on each of the SSPs, and scenarios that are based on socio-economic pathways different from the 5 SSPs. It might be particularly useful to include scenarios with global shocks that might include “wild cards” or “tipping points” (e.g., global recession, conflicts).

A specific research topic would then be to develop methodologies to select which scenarios are most appropriate for a given decision. This topic is already relevant to the SSP process itself, as evidenced by the task of developing indicators for socio-economic challenges to adaptation and to mitigation, the two concepts that define the SSP space to be spanned. The meeting highlighted the difficulty in selecting these indicators, and that different issues are likely to require different indicators.

The database would not replace the need for a few “archetypical” socio-economic pathways such as the SSPs, which serve to explore the space of possible futures, organize/coordinate/integrate local research, and communicate findings. However, it would not only serve the needs of users at the local level, but would also be a useful input in the process of developing the next generation of SSPs. Some meeting participants plan to propose an activity that would initiate development of such a database.

3.4. Recommended next steps

This section describes some next steps that were identified at the Workshop concerning the specification, development and delivery of socioeconomic scenarios in the near-term, defined as roughly the next year (calendar year 2012). As well as being essential early actions in a longer-term process of scenario development (see Section 3.3), the steps can also be regarded as priority items for delivering useful inputs to the IPCC Fifth Assessment Report (AR5). To fulfill the latter goal, any analysis or application of new scenarios needs to have been completed by January 2013 (the Working Group II and III deadlines for submission to peer-reviewed journals). The steps require active participation by researchers worldwide, including urgent co-operation between representatives of the IAV, IAM and (to a lesser extent) CM communities. The subsections below outline some of the priority near-term goals identified by the IAV and IAM communities, and then consider a joint process and recommended actions required to achieve these goals.

3.4.1. Near-term considerations for the IAV community

The IAV research community is expected to be a significant user of new scenarios in the coming years. However, up to now the involvement of IAV researchers in the process of scenario development has been piecemeal, and their engagement with the IAM and CM communities extremely limited. While there may be some research groups, especially those working with impact models at the global or continental scales, that are familiar with and in a position to adopt and apply new scenarios rapidly, the majority of IAV researchers are clearly not so well positioned.

A survey of IAV researchers reported at the workshop revealed general difficulty in coming to terms with the complexity of the scenario architecture. There was also a worry expressed that the new scenarios are framed too narrowly, relating to climate policy goals of mitigation and adaptation that are familiar to the IAM community, but failing adequately to address contextual issues associated with broader goals of sustainable development as well as the socioeconomic context of future climate change impacts, both of specific interest to many IAV researchers. A third key observation concerned making new scenarios accessible to a wide range of users and suitable for analysis with or without the use of models.

These concerns of the IAV community have a strong bearing on how they are likely to prioritize the immediate and near-term actions required for the development and provision of new scenarios. With specific reference to the IPCC AR5, two types of potential use of new scenarios can be envisaged: for research and for assessment. The former type involves those researchers wishing to apply scenarios immediately in IAV studies that may become eligible for evaluation in the AR5. Their needs pertain to the selection and application of appropriate scenarios for a given IAV theme, regional specification and time horizon. The latter type involves authors and reviewers (including governments) who are involved in the IPCC assessment. They may wish to make use of the new scenarios as a framework and context for considering relevant published literature reporting on studies of future climate change impacts, adaptation and vulnerability. Few of these studies will have been based on the new scenarios.

3.4.2. Near-term considerations for the IAM community

The IAM research community is expected to contribute significantly to the development and use of scenarios based on SSPs over the coming years. In particular, it faces a short-term task over the next 6-12 months to develop an initial round of quantitative, SSP-based scenarios that can serve as a basis for further research, particularly at finer spatial and temporal scales, in the IAM and IAV communities. Developing these scenarios will require a number of tasks, described in more detail below, including further development of the SSP narrative, quantification of key SSP elements used as inputs to IAMs, and a process for developing, harmonizing, vetting, and documenting the scenarios. The role of particular institutions, including the Integrated Assessment Modeling Consortium and its Scientific Working Group on Scenarios, will be vital although specific steps remain to be clarified. Looking beyond the next 6-12 months, a process for stimulating and facilitating the development of extended SSPs will be important, in order to produce scenarios with more comprehensive and detailed information in particular to better inform IAM and IAV studies carried out at local and regional levels.

3.4.3. Priority actions

The following is a suggested list of priority actions for the IAV and IAM communities (to be initiated during the coming year) that were put forward at the Workshop:

<u>Fully developed basic SSPs.</u> The narratives and qualitative descriptions of SSP elements agreed to at this meeting provide a solid foundation for a full set of basic SSPs, but are not complete. Narratives need further development, the utility of the SSPs as a set (for example, whether a wide range of uncertainty in SSP elements is covered) needs to be ascertained, and quantification of a subset of elements, including population, GDP per capita growth rates, and urbanization needs to be completed. This set of basic SSPs can then serve as the basis for IAM scenarios and for initial IAV analyses. Over a longer time horizon, these basic SSPs can be extended to provide additional narrative detail, further quantitative elements including spatial variables, and possibly alternative variants.

<u>Simplified taxonomy</u>. In order to make the SSPs and RCPs understandable and accessible to the broadest possible audience, the detailed model-oriented structure needs an overlay that offers a simple, intuitively understandable approach that can be used for initial heuristics. Users can then access successive layers of detail, as required. In particular, the overlay could comprise clear and simple descriptors of the SSPs that indicate their qualitative differences in a few well chosen words. In addition, a clearer, more specific version of the axes of the SSP space (socio-economic challenges to mitigation and adaptation) could be developed that is complementary to the original. A wide range of climate change research disciplines should be represented in this simplification process, including many types of IAV research.

Quantitative SSP-based scenarios. SSPs provide reference socio-economic development pathways, but full-fledged scenarios require IAM and IAV modeling based on the SSPs. A high priority is development of an initial set of quantitative scenarios developed with IAMs based on the SSPs, for reference climate change outcomes as well as mitigation outcomes matched to RCP forcing levels. One of the central near-term issues to resolve ahead of the AR5 relates to the choice of socioeconomic variables to include in a basic set to be produced by the IAM community. It is essential that potential users and providers conduct an urgent dialogue so that user needs can be matched to reasonable expectations of IAM delivery. One suggestion is to formulate a joint "handshake document" between IAV and IAM representatives similar to that prepared by IAM and CM representatives in specifying the RCPs. In shortlisting specific variables of interest, it is also important to distinguish between socioeconomic drivers of impacts and drivers of adaptation and mitigation response capacities.

Phased delivery of scenarios. Ahead of the AR5 it is only realistic to expect that a set of basic quantitative SSPs can be generated by the IAM community in the time available. Those IAV researchers wishing to apply scenarios based on SSPs in quantitative studies during 2012 should urgently state their minimum requirements for the types of variables and their spatial resolution, so that IAM groups can assess the feasibility of generating these in a first phase of IAM simulations. Following an exchange of results and experiences between the different research communities (CM, IAV, IAM) more detailed scenarios will be prepared later (e.g. at higher resolution, for additional variables, with different policy assumptions). This iterative approach will require the active engagement of IAV researchers to ensure that the extended scenario set is salient, credible and legitimate for a range of IAV purposes.

Storylines amenable to regional interpretation. Currently, the narratives associated with the five SSPs are mainly global or refer to major country groupings (e.g. developed, middle income, developing). In some cases there is explicit mention of other notable disparities, such as between trends in urban versus rural development, or within-region contrasts between rich and poor. IAV and IAM researchers may make use of narratives to infer qualitative trends in those factors that have not been quantified by models. Thus, it is essential that the basic storylines offer sufficient utility for interpretation in IAV and IAM studies at global and regional scales. Development of guidance notes on methods of interpreting SSP narratives for use in IAV and IAM assessment would be a very welcome accompaniment to the storylines.

Prioritisation of scenarios. For the purposes of IAV assessment, it may be unnecessary or infeasible to adopt all five SSPs in order to capture key dimensions of uncertainty in future socioeconomic conditions. Combining these with climate scenarios for different RCP forcings adds complexity to the choices. Hence, some prioritization of scenarios may be desirable (while recognizing that different studies may emphasize socioeconomic sensitivities that are particular to different SSPs). This might take the form of a ranking of the five SSPs. Over time, a large number of quantitative scenarios are expected to be produced that characterize each of the future worlds represented by the SSPs, including different assumptions about climate policy. This proliferation of scenarios will offer a rich choice for analysts to draw on, but will also demand further prioritization of scenarios (e.g. by selecting "marker" or “representative” scenarios as single representatives of future worlds for which there are multiple alternative scenarios available).

Multiple time horizons. The quantitative elements of SSPs will be made available as time series of values throughout the 21st century (some may even extend beyond 2100, though their utility for IAV analysis is questionable). Some IAV analysts employ models that operate in transient mode, and can readily adopt such scenario time series. However, a majority of analysts focus on specific time horizons in the future, characteristically selecting from near-, mid- and long-term options. For the AR5, a time horizon out to 2035 has already been selected for high resolution global modelling and decadal forecasting and might be an appropriate near-term end point. A second date in mid-century (e.g. 2055) and a third at 2100 might be logical choices for common scenario end points to facilitate intercomparison of scenario-based studies. Whether the scenario data are applied as period averages or representing single years is a matter for further consideration by IAV analysts.

Matching SSPs to RCPs and climate change projections. One of the most common questions posed by researchers wishing to apply new scenarios in IAV studies concerns the mutually consistent matching of RCP-based climate projections with socioeconomic scenarios (SSPs). This pairing is not straightforward, for several reasons. First, it is probable that there will be discrepancies in radiative forcing between a given shared socioeconomic pathway (SSP), which represents a reference pathway without any assumed mitigation policy, and the four preselected RCPs. Adjustment (scaling) of the RCP-based climates will therefore likely be required to produce climate outcomes consistent with SSP-based reference pathways. Some of the advantages and potential pitfalls of applying scaling techniques to climate projections were raised at the Workshop in the presentation by Tebaldi. Second, climate policy scenarios based on the SSPs can be tailored to reproduce RCP forcing levels, but differences in land use patterns between RCPs and the SSP based climate policy scenarios will remain. It is an open question how these differences can be best reconciled when combining such scenarios with an RCP based climate change projection for IAV analysis. Third, for a near-term time horizon there may be little difference in the climate response to different RCPs, which could help to limit the number of scenarios adopted (though some regional disparities can occur due to differing near-term changes in land use or aerosol forcing between RCPs). Thus, for example, it might be opportune to prioritize the RCP 4.5 scenario for near-term considerations, as this has been adopted for decadal forecasting and fine resolution climate simulations out to 2035. Fourth, for each RCP, multiple (ensemble) projections of climate are being produced as part of the CMIP-5 exercise. Decisions will be required on how to select from the numerous climate model outputs (including downscaled information from CORDEX and other sources), in order to represent model-derived climate uncertainties in IAV studies in combination with socioeconomic uncertainties.

Relating new scenarios to existing scenarios. Realistically, the overwhelming majority of publications reporting scenario-based studies as an input to the AR5 process will have adopted existing scenarios. These may be of climate change (e.g. commonly from the CMIP-3 set of global models and their derivatives), environmental change (e.g. CO_2 concentrations or global sea-level scenarios), or socioeconomic scenarios (e.g. regional, national or local "bottom-up" scenarios as well as SRES, MA and other global scenarios). Both for research and assessment purposes, it will be essential for the IAV and IAM communities to be provided with some means of interpreting results from existing scenarios in relation to the new scenarios. For instance, some IAV researchers are already using RCP-based climate projections in combination with SRES-based socioeconomic scenarios. Similarly, AR5 authors will need to be advised on how to interpret results from impact studies assuming SRES climates (e.g. B1, A1B or A2) in relation to climates described by RCP simulations reported by WG I for the AR5. Participants at the Workshop attempted a preliminary mapping of some of the more commonly used scenarios onto the emerging SSP and RCP framework. However, more work on this topic is necessary to make such a mapping operational.

IAV testbed. If IAV research groups can be identified that are motivated to apply new scenarios in their work, some kind of iterative process can be envisaged, whereby potential users are presented with prototype information from preliminary scenarios, encouraged to apply such information, and then report back their experiences and needs. An example of early engagement with the IAV community was presented at the Workshop by Shinichiro Fujimori of the AIM integrated modelling group. SSPs generated by AIM have been introduced to researchers in Japan who are modelling climate change impacts and adaptation in agriculture, water resources and coastal/river infrastructure, through a series of IAV workshops. A second example is the Agricultural Model Improvement and Intercomparison Project (AgMIP), presented by John Antle, which is one of a number of ongoing IAV model intercomparison projects worldwide. Aside from their central task of testing and comparing both crop and economic models, AgMIP researchers are also interested in applying SSPs alongside RCPs in some climate change impact modelling exercises in different parts of the world. They have already begun to develop sector-specific socioeconomic scenarios, labelled Representative Agricultural Pathways (RAPs), which cover variables of importance for agriculture (e.g., GDP, population, trade policy, farm size, regional development, agricultural technology). Finally, a third group of IAV researchers that are interested in applying the SSPs is the Inter-sectoral Impact Model Intercomparison Project (ISI-MIP). All these examples illustrate the potential for initiating IAV testbed studies that can inform the scenario development process, while also feeding in some early results to the AR5.

Guidance. The design of the scenarios draws on extensive experience from previous scenario-building exercises while seeking to fulfill new and greater demands for information. In the minds of some of the IAV community surveyed prior to the Workshop, this has resulted in a scenario architecture that appears forbiddingly complex. The need for simplification, improved transparency and prioritisation of scenarios has been touched upon elsewhere in this list of priority actions. However, for effective communication, dissemination, uptake and adoption of the scenarios, it is crucial that potential users be provided with easily accessible guidance documents and tutorial assistance. Some of the topics for which guidance could be especially valuable to IAV researchers include:

- New scenarios for IAV research – general guidance describing the new scenarios, the process of scenario development, main scenario components, where they can be found, how they relate to previous scenarios (e.g. IS92, SRES, MA), why they are relevant for IAV studies, and how they might be applied in such studies (with cross-references to more specialist guidance)
- SSP storylines and their interpretation for IAV studies
- Matching RCPs to SSPs and climate change projections for IAV analysis
- Downscaling quantitative socioeconomic scenarios
- Reconciling top-down and bottom-up approaches to scenario development for IAV research
- Scenario internal consistency – guidance on how causal relationships between key socioeconomic variables are represented in IAMs (e.g. education vs. population; GDP vs. access to clean water), presentation of some of the more robust empirical algorithms relating variables as well as qualitative narratives of these, suggestions on transferability of global algorithms to regional scales for use in IAV
- Sources of new scenarios and associated reference socioeconomic, climate and environmental information

There are already efforts underway to produce guidance on the application of scenarios in general (though not for SSPs in particular) for IAV and related research in various international, regional and national agencies. General guidelines on scenario development and application and specific guidance on climate scenario downscaling and on sea-level scenarios have been developed by the IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) and are already available at the IPCC Data Distribution Centre (DDC)[4]. There are also plans for the DDC to identify and link to regional and national agencies offering support and guidance for scenario use. Furthermore, pages recently added to the DDC provide a description of the new scenarios process, as well as links to sources of data and further information.

3.4.4. Priority coordination tasks

The many priority items detailed in the above list suggest some urgent co-ordination tasks for the IAV community itself and in conjunction with other communities. Some tasks that were raised at the Workshop include:

[4] http://www.ipcc-data.org/

Establishment of an IAV sub-group on scenarios, to represent the global IAV community in dealings with other communities engaged in climate change research. In the longer-term, this would logically be organised under the auspices of UNEP's PROVIA (Programme of Research on Climate Change Vulnerability, Impacts and Adaptation), which has already identified socioeconomic scenario development as a priority topic in its 2011-2012 workplan. In the short-term, it may be necessary to form an *ad hoc* interim international IAV committee comprising persons who have demonstrated community leadership during the recent new scenario process.

Formation of a joint IAM/IAV committee to facilitate and coordinate the development and application of climate change scenarios in the IAM and IAV communities. This includes the coordination of SSP development between the IAM and IAV communities and designing a long term IAV-IAM agenda for further development and application of the new scenario framework. It could also serve as a platform to discuss data needs and transfer of priority basic SSPs to IAV researchers wishing to undertake new studies and specifications of scenario descriptions needed by authors and other contributors to the IPCC AR5. IAV representatives on this committee could be drawn from the IAV scenario sub-group (above), but also include some IAV practitioners representing key themes or sectors. IAM representatives could be drawn from the Scientific Working Group on Scenarios of the Integrated Assessment Modeling Consortium.

Documentation of the process and timetable of scenario development, testing and provision for IAV/IAM researchers and distribution to AR5 authors at Lead Author Meetings, via IAV/IAM email networks and through the IPCC DDC

Provision of more general scenario information to the research community, for instance via international conferences, PROVIA, the IAMC, national IPCC contact points and the IPCC DDC

Delivery of data, supporting documentation and guidance material via the SSP data and scenario library, IPCC DDC, national/regional delivery portals, PROVIA, and the IAMC.

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5. Appendixes

5.1. Appendix I: List of Participants

Aaheim, Hans Asbjørn	CICERO Centre for International Climate and Environmental Research Oslo
Akimoto, Keigo	Research Institute of Innovative Technology for the Earth (RITE)
Antle, John M.	Oregon State University
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Beringer, Tim	Potsdam Institute for Climate Impact Research
Birkmann, Joern	UNU-EHS
Carter, Timothy	Finnish Environment Institute, SYKE
Cohen, Stewart	Environment Canada
Cosgrove, William	UNESCO-WWAP World Water Scenarios
Drummond, Mark	US Geological Survey
Ebi, Kristie	WGII TSU
Edenhofer, Ottmar	WGIII Co-Chair
Edmonds, James	JGCRI/PNNL
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Eom, Jiyong	Joint Global Change Research Institute
Feddema, Johan	University of Kansas
Fujimori, Shinichiro	National Institute for Environmental Studies
Gallopín, Gilberto Carlos	WWAP
Garschagen, Matthias	United Nations University
Guivarch, Celine	Cired
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Hayden, Mary	NCAR
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Hughes, Barry	Pardee Center, Univ of Denver
Jiang, Leiwen	National Center for Atmospheric Research
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Rozenberg, Julie	CIRED
Saxon, Earl	FHI360
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Travis, William Riebsame	University of Colorado
Van Ruijven, Bas J	NCAR
Van Vuuren, Detlef	PBL
Wilbanks, Thomas J.	Oak Ridge National Laboratory
Zwickel, Timm	IPCC Technical Support Unit - Working Group III

5.2. Appendix II: Meeting Agenda

The Nature and Use of New Socioeconomic Pathways for Climate Change Research

Day 1: Wednesday, November 2 Location: FOOTHILLS LAB2

8:30-8:40 **Welcome**
Peter Backlund (NCAR)

8:40-9:00 **Introduction and meeting goals**
Brian O'Neill (NCAR)

The Scenario Matrix Architecture Chair: Jae Edmonds
Overview of the scenario architecture as described in the Framework Paper. What are Shared Socioeconomic Pathways (SSPs)? Why are they useful? What are their key elements? How do they differ from scenarios?

9:00-9:30 Overview of the background document: *A framework for a new generation of socioeconomic scenarios*
Elmar Kriegler (PIK)

9:30-10:00 Discussion

10:00-10:30 *Coffee break*

Narratives for Shared Socioeconomic Pathways (SSPs) Chair: Tim Carter
Proposals regarding SSP narratives or approaches to narratives. What aspects of these narratives determine the level of challenges to adaptation and mitigation? Are there commonalities or key differences across proposals?

10:30-10:50 Overview of narratives in integrated assessment model SSP experiments
Keywan Riahi (IIASA)

10:50-11:10 Key aspects of narratives from an impacts perspective
Tom Wilbanks (ORNL)

11:10-11:30 Internally consistent combinations of narrative elements
Vanessa Schweizer (NCAR)

11:30-11:50 A scenario elicitation methodology to map the space of possible future mitigative and adaptive capacity
Julie Rozenberg (CIRED)

11:50-12:30 Discussion

12:30-1:30 *Lunch*

Integrated Assessment Model SSP experiments Chair: Stephane Hallegatte
Report on IAM experiments, illustrating how SSPs have been interpreted in models, and highlighting insights and open questions for SSP narratives, and for scenarios based on them.

1:30-1:50 Report from the AIM group

	Shinichiro Fujimori (NIES)
1:50-2:10	Report from the GCAM group Jae Edmonds (PNNL)
2:10-2:30	Report from the IMAGE group Detlef van Vuuren (PBL)
2:30-2:50	Report from the MESSAGE group Keywan Riahi (IIASA)
2:50-3:10	Report from the REMIND group Elmar Kriegler (PIK)
3:10-3:45	Discussion

3:45-4:15 *Coffee break*

4:15-6:15 **Breakout groups**

Groups will consider the set of SSPs as a whole and work toward zero-order narratives. Begin to consider elements that could be part of extended SSPs vs basic SSPs.

6:30-8:30 **Reception at the Marriott**

Day 2: Thursday, November 3 Location: MESA LAB

8:30-9:30 **Breakout Group Reports to Plenary Chair: Brian O'Neill**

Reports from each breakout group: bullet points of key aspects of zero order narratives, areas of agreement/disagreement, aspects that might be useful for extended (vs. basic) SSPs

9:30-10:30 **Priority elements of SSPs Chair: Kris Ebi**

Perspectives from various scenario users and developers on elements considered most important to include in SSPs in order to characterize challenges to adaptation/mitigation. Views should also include thoughts on what should be in basic vs extended distinctions.

9:30-9:50	Expert elicitation of key determinants of mitigation/adaptation challenges Vanessa Schweizer (NCAR)
9:50-10:10	Representative agricultural pathways John Antle (Oregon State University)
10:10-10:30	Discussion

10:30-11:00 *Coffee break*

11:00-11:20	Advancing the development of socioeconomic scenarios through the lens of vulnerability and adaptive capacity Joern Birkmann (UNU)
11:20-11:40	Drivers of water stress in the World Water Scenarios Gilberto Gallopin (World Water Scenarios Project)
11:40-12:00	Scenarios as vulnerabilities of proposed policies Rob Lempert (RAND)
12:00-12:30	Discussion

12:30-1:30 *Lunch*

Quantitative elements of SSPs Chair: Keywan Riahi
Proposals for quantitative elements of SSPs such as population, GDP, urbanization, and other socioeconomic characteristics that would be important to characterizing challenges to adaptation and mitigation.

1:30-1:50	Urbanization, education and the Human Development Index as components of SSPs Brian O'Neill (NCAR)
1:50-2:10	International Futures (IFs) as a source of richer socioeconomic development pathways for adaptation and mitigation analyses Dale Rothman (Univ. Denver)
2:10-2:30	New urbanization projections for use in socioeconomic scenario development Leiwen Jiang (NCAR)
2:30-2:50	Consistent global population and education scenarios and a link to GDP Wolfgang Lutz (IIASA)
2:50-3:15	Discussion
3:15-3:45	*Coffee break*
3:45-4:00	**Instructions for breakout groups Chair: Brian O'Neill** Summary of progress on SSPs and unresolved issues Tim Carter
4:00-5:30	**Breakout groups** Revisit SSP narratives and elements of basic vs extended SSPs; discuss possible quantitative elements of SSPs including IA and IAV model inputs.
5:30-6:30	**Breakout Group Reports to Plenary**
6:30-8:30	**Reception at Mesa Lab**

Day 3: Friday, November 4 Location: MESA LAB

8:30-8:40	**Introduction to Day 3**
	Climate and ecosystem topics Chair: Linda Mearns
8:40-9:00	Update on RCP-based climate simulations as part of CMIP5 Jerry Meehl (NCAR)
9:00-9:20	An overview of pattern scaling, its strengths and limitations, and a first look at CMIP5 patterns Claudia Tebaldi (NCAR)
9:20-9:40	Emissions of short lived species in the RCPs, and needs for the SSPs Jean-Francois Lamarque (NCAR)
9:40-10:00	Land use in the RCPs, and needs for the SSPs Peter Lawrence (NCAR)
10:00-10:30	Discussion

10:30-11	*Coffee break*
11:00-1:00	**Plenary: Conclusions and process discussion**
1:00	**Meeting adjourned**

5.3. Appendix III: SSP Element Tables

Plain text: Assumptions about elements taken directly from Boulder meeting breakout group presentations. Italics: Assumptions added after the meeting based on breakout group discussions.

	SSP 1			SSP 2			SSP 3			SSP 4			SSP 5		
	Country Income Groupings														
SSP Element	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
Demographics															
Population															
Growth		*Relatively low*			*Medium*			*Relatively high*			*Mixed*			Peak and decline	
Fertility	Low	Low	Medium		Medium		High		Medium	High	Low/ Medium		*Low/ Medium*	*Low*	*Replace-ment*
Mortality		Low			Medium			High		*High*	*Medium*	*Medium*		*Low*	
Migration		Medium			Medium			Low			*Low*			High	
Urbanization															
Level										High	High/ Medium	Medium		High	
Type		Planned		Mixed				Unplanned		Unplanned				Well planned, possibly sprawl	
Education		High			Medium			Low		Low/ unequal	Medium/ unequal	Medium/ unequal		High	

	SSP 1			SSP 2			SSP 3			SSP 4			SSP 5		
	Country Income Groupings														
SSP Element	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
Economy & Lifestyles															
Growth (per cap)	Medium		Fast	Medium		Slow	Slow			Low	Medium	Medium/ High	High		
Structure	Rapid service sector growth												Limited shift toward services, high demand for mnfd prdts		
Inequality							High (within/across country not specified)								
Across regions	Convergence, but retaining diversity									High			Convergence to high levels		
Within country	Becoming more equitable, less stratification									High			Becoming more equitable, less stratification		
Intl. Trade							Barriers to trade			*Unclear/not specified*			High, with regional specialization in production		
Globalization													High		
Consumption	Low growth in material consumption			material intensive consumption			material intensive consumption			Elites: high consumption lifestyles; Rest: low consumption, low mobility			Materialism, consumerism. Focus on status consumption, including tourism, recreation, mobility.		
Diet	Low meat consumption												High meat consumption		
Policies & Institutions															
Intl Cooperation	High level of political will									*High in favor of global elite and corporations, low otherwise*			High, based on national interests		
Envtl Policy	Environmental protection; *stringent, effective air quality policies*			*Intermediate policies and progress on air quality*			*Little regard for air quality*			*Focus on local environment where elites live, mainly urban; geographically mixed air quality policies*			Focus on local environment, little concern with global problem; *strong and pervasive air quality policies*		
Policy Orientation	Toward sustainable development						Toward security			*Toward the benefit of the elite*			Toward development, free markets, human capacity building		
Institutions							Ineffective			Effective for elite, not for the rest of society			Effective		

SSP Element	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
	Country Income Groupings				
	Low / Med / High	Low / Med / High	Low / Med / High	Low / Med / High	Low / Med / High
Technology					
Development	Rapid	*Medium?*	Slow	*Rapid in industries controlled by large corporations*	Rapid
Transfer	Rapid	*Medium?*	*Slow*	Little transfer within countries to poorer populations	Rapid
Energy Tech Change	Directed away from fossils; rapid low carbon tech change; reluctance to use unconventional fossils	*Balanced across fuels?*	Slow low-carbon tech change; no reluctance to use unconventional fossils; security concerns; low fossil fuel price	*Fast tech change in low-C supply or mitigation options such as CCS; hedge by corporations against fossil resource scarcity and/or mitigation policy*	tech change biased toward fossil fuels; high discount rates impose barriers on energy and resource efficiency improvements.
Carbon Intensity				*Ambiguous; low-C supply could penetrate in baseline or be available for mitigation when necessary*	High
Energy Intensity				*Unclear*	High
Environment & Natural Resources					
Fossil Constraints				*Perception (and possibly reality) of strong constraints*	None for coal and gas, possible for oil
Environment			Serious degradation		Highly engineered
Land Use			High	*Probably low, given high ag productivity*	High demand for land due to consumption patterns
Agriculture				Ag productivity high for large scale industrial farming, low for small-scale farming	Highly managed, resource and water intensive (possibly including desalinization). Rapid increase in productivity.

5.4. Appendix IV: Background Materials

Background papers to IPCC Scenarios Workshop, Berlin, November 2010

Developing new scenarios as a common thread for future climate research by Detlef van Vuuren, Keywan Riahi, Richard Moss, Jae Edmonds, Allison Thomson, Nebosja Nakicenovic, Tom Kram, Frans Berkhout, Rob Swart, Anthony Janetos, Steve Rose and Nigel Arnell. Now in press at Global Environmental Change.

Socio-economic Scenario Development for Clmiate Change Analysis WORKING PAPER by Elmar Kriegler, Brian O'Neill, Stephane Hallegatte, Tom Kram, Robert Lempert, Richard Moss, and Thomas Wilbanks.

The next generation of scenarios for climate change research and assessment, Nature 463, 747-756, 2011. Richard H. Moss, Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, Seita Emori, Mikiko Kainuma, Tom Kram, Gerald A. Meehl, John F. B. Mitchell, Nebojsa Nakicenovic, Keywan Riahi, Steven J. Smith, Ronald J. Stouffer, Allison M. Thomson, John P. Weyant & Thomas J. Wilbanks.

Background on Representative Concentration Pathways

Special issue of Climatic Change on the Representative Concentration Pathways

Projection and prediction: Mapping the road ahead. Nature Climate Change 1, 352–353. O'Neill, B.C., Schweizer, V. 2011.

Papers on related topics

Building world narratives for climate change impact, adaptation and vulnerability analyses, Nature Climate Change 1, 151–155. Hallegatte, S., Przyluski, V., Vogt-Schilb, A. 2011.