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The Shared Socioeconomic Pathways (SSPs) and their extension and use in impact, adaptation and vulnerability studies[1]

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Abstract

Recently, a new set of future pathways of societal development have been developed for use in climate and global change research. These Shared Socioeconomic Pathways (SSPs) describe five alternative outcomes for trends in demographics, economics, technological development, lifestyles, governance, and other societal factors. The SSPs consist of qualitative narratives of future development and quantitative projections of key elements including national level population growth and educational composition, urbanization, and economic growth. They describe futures that are intended to span uncertainty in two dimensions: challenges that societal conditions would present to adaptation to climate change, and challenges they would present to mitigation of climate change. In this way, integrated analyses of climate change mitigation, adaptation and impacts that draw on the SSPs could explore uncertainty and sensitivities of outcomes to societal conditions. The SSPs currently serve as the basis for developing scenarios of future land use and emissions of greenhouse gas emissions using integrated assessment models (IAMs). In addition, they are being employed in analyses of climate change impacts, adaptation, and vulnerability (IAV). While the SSPs contain a wide range of information on possible future trends in societal development, a number of additional types of outcomes have been identified that would greatly facilitate IAV studies. These include both qualitative and quantitative information at the local or regional level, spatially explicit projections of population, and sub-national income distribution. This paper describes the nature of the five SSPs and describes efforts underway to extend the SSPs to provide additional information for IAV studies. It also assesses early use of the SSPs in IAV analyses, including studies of water scarcity, flood risk, food security, and human health. Preliminary results of these studies confirm that IAV outcomes are very sensitive to future societal conditions, in some cases moreso than to climate change outcomes themselves.

Introduction and background: The scenario framework

Long-term global scenarios have played a key role in climate change analysis for more than 20 years. While other approaches to characterizing the future exist, alternative scenarios are an important method for exploring uncertainty in future societal and climate conditions. Scenarios of global development focus on the uncertainty in future societal conditions, describing societal futures that can

[1] This paper draws heavily on O'Neill et al., 2014, 2015; KC and Lutz, 2014; Jiang and O'Neill, 2015; Dellink et al., 2015.

be combined with climate change projections and climate policy assumptions to produce integrated scenarios to explore mitigation, adaptation and residual climate impacts in a consistent framework.

A process is under way in the climate change research community to develop a new set of integrated scenarios describing future climate, societal, and environmental change (Moss et al., 2010). This process started with the development of representative concentration pathways (RCPs) that describe a set of alternative trajectories for the atmospheric concentrations of key greenhouse gases(Van Vuuren et al., 2011). Based on these, climate modelers produced a number of simulations of possible future climates over the 21st century (Taylor et al., 2012). In parallel, other researchers produced a new set of alternative pathways of future societal development, described as shared socioeconomic pathways (SSPs), and using integrated assessment models (IAMs) to produce scenarios of future emissions and land use change based on them. An integration phase of this project has begun, in which the climate simulations are brought together with SSP-based societal futures to carry out integrated analysis of impacts and of possible mitigation or adaptation responses.

This paper describes the development and content of the SSPs. It also sketches recent and ongoing work that is extending the SSPs to better address specific issues at the regional or sectoral level, as well as first applications of the SSPs to IAV-related topics. Other papers in this session describe the development of IAM scenarios of emissions and land use based on the SSPs (van Vuuren), providing detail especially on the treatment of land use (Calvin).

The SSPs were developed over the last several years as a joint community effort and describe global developments that together would lead to different challenges for mitigation and adaptation to climate change. A conceptual framework for the SSPs and how they could be used with climate simulations to carry out integrated research was developed first (Kriegler et al., 2014; O'Neill et al., 2014; van Vuuren et al., 2014). The content of the SSPs themselves was developed next (Riahi et al., 2016). These comprise five alternative narratives that describe the main characteristics of the pathways in qualitative terms (O'Neill et al., 2015) as well as quantitative descriptions for key elements including population (KC and Lutz, 2014), economic growth (Dellink et al., 2015), and urbanization (Jiang and O'Neill, 2015).

SSP conceptual framework

As described above, the SSPs are one component of a larger framework to facilitate the production of integrated scenarios based on combinations of climate model projections, socioeconomic conditions, and assumptions about climate policies. A key aim of these integrated scenarios is to facilitate research and assessment across a number of research communities that can characterize the range of uncertainty in mitigation efforts required to achieve particular climate outcomes and in adaptation efforts that could be undertaken to prepare for and respond to the climate changes and impacts associated with those pathways. Many impact and mitigation studies, ranging from global analyses to those that focus on specific regions, sectors, or aspects of climate change, use scenarios either as the basis of their approach or to provide key context information to a more detailed analysis. The new integrated scenarios will provide this information, and the framework will allow analysts to assess a

wide range of individual studies by grouping them according to common assumptions they make about socioeconomic conditions or climate change outcomes.

Within the conceptual framework for integrated scenarios, the SSPs are designed to span a relevant range of uncertainty in societal futures. Unlike most global scenario exercises, the relevant uncertainty space that the SSPs are intended to span is defined primarily by the nature of the outcomes, rather than the inputs or elements that lead to these outcomes (O'Neill et al., 2014). As such, the design process begins with identifying a particular outcome and then identifies the key elements of society that could determine this outcome. This approach is typically associated with backcasting, where an end state is already in mind as the pathways are being developed, although not necessarily assuming that these states are all desirable. Such a backcasting scenario approach has proven effective in focusing on those areas of the uncertainty space that are most important in choosing among alternative options. Although the domain of application of climate change scenarios includes a large range of specific decision-making situations, they generally cover options to mitigate or adapt to climate change. Therefore, the SSP outcomes are specific combinations of socioeconomic challenges to mitigation and socioeconomic challenges to adaptation (Fig. 1). That is, the SSPs are intended to describe worlds in which societal trends result in making mitigation of, or adaptation to, climate change harder or easier, without explicitly considering climate change itself.

The framing of SSPs in terms of challenges facilitates research based on the SSPs that collectively can characterize a range of uncertainty in the mitigation required to achieve a given climate outcome, or the adaptation possibilities associated with that outcome. Development of such a research base, and its assessment, is a key goal of the scenario process. Thus, the SSPs are not meant primarily as a direct communication tool for climate policy advice, but rather as a tool to enable the research community to produce effective assessments for climate policy makers. In addition, the SSP framing will facilitate improved understanding of the determinants of challenges to mitigation and to adaptation. The SSPs are developed based on the best current hypotheses about which elements of societal development pathways are the most important determinants of these challenges. Use of the SSPs in impact, adaptation and mitigation studies will test those hypotheses and lead to learning that can be used in future iterations of SSP development.

The SSPs describe plausible alternative trends in the evolution of society and natural systems over the 21st century at the level of the world and large world regions. They consist of two elements: a narrative storyline and a set of quantified measures of development. SSPs are “reference” pathways in that they assume no climate change or climate impacts, and no new climate policies (Kriegler et al., 2012). The choice to define SSPs in this way was made in order to serve a methodological purpose. The ultimate goal of the overall scenario process is to produce integrated scenarios that will indeed include socioeconomic and environmental conditions as affected by both climate change and climate policy. As described in section 1, evaluating climate change impacts on society and the consequences of alternative policy approaches are key goals of the scenario framework. SSPs are a step along the way toward these goals. The intention is that by not incorporating such effects, SSPs can be more easily used by other researchers across a broad set of studies to evaluate how varying levels of climate change and types of policies affect on the “reference” socioeconomic and environmental conditions described in the

SSPs. Because SSPs do not include the effects of climate change and climate policy, they may not describe plausible assumptions for the future, but this is an intentional component of the design.

In addition, the set of quantitative elements included in SSPs does not extend to outcomes such as emissions and land use that are typically calculated by integrated assessment models, or to outcomes of impact models such as effects on agriculture. SSPs include quantifications of factors that are considered drivers of such outcomes such as population growth and economic growth, but quantification of the consequences of these drivers is left to scenarios that will be produced based on the SSPs. It is for this reason that the scenario framework distinguishes between "pathways," which describe one component (such as RCPsor SSPs) of integrated scenarios, and "scenarios" themselves, which combine pathways with other information such as emissions, climate projections and policy assumptions to produce integrated descriptions of future climate and human system development. It is these scenarios, rather than the SSPs themselves, that would be used to do analysis such as comparing outcomes in a policy scenario with outcomes in a reference (no-policy) scenario.

SSP Narratives

The general purpose of narratives of societal development in climate change scenarios is to provide broad descriptions of future conditions that are relevant for both the analysis of emissions drivers and mitigation strategies, and the analysis of societal vulnerability to climate change, climate impacts and potential adaptation measures. To this end, narratives aim to convey a basic ''storyline'' that can guide the specification of further elements of the scenario, including quantitative elements such as population and economic growth patterns. A narrative of global development should also be able to guide regional and sectoral extensions of the scenarios, including the formulation of regional narratives that fit within the overall global picture. Finally, narratives should be sufficiently generic to allow useful coverage of the space of relevant futures by representing much broader categories of possible development pathways. This distinguishes narratives underlying climate change scenarios from much richer storylines that are sometimes used in decision-making contexts to illustrate the consequences of specific courses of action.

As noted earlier, the current scenario framework calls for the SSPs, and therefore the narratives, to portray worlds that have varying challenges to mitigation and to adaptation. These challenges refer to characteristics of society, not to the amount of climate change or the stringency of the mitigation policy (factors that are not included in SSPs). Thus, the narratives were constructed from socioeconomic and environmental (but non-climate) elements judged to be important determinants of these challenges. While much is known about these determinants, there is still substantial uncertainty (O'Neill et al., 2014), particularly regarding determinants of the challenges to adaptation (Rothman et al., 2014; Schweizer and O'Neill, 2014).

Taken together, these considerations implied a method for development of the SSPs that iterated between desired characteristics of the full narratives and identification of specific narrative elements and assumptions. Content for the SSPs was developed in a variety of approaches, essentially through expert judgment with a wide variety of experts from the IAM, IAV, development, futures studies, and

vulnerability and risk research communities providing input through a series of dedicated meetings. A first meeting resulted in the adoption of a set of incipient SSP narratives that were further developed at a subsequent meeting through broader discussion of the drafts and initial quantifications of key drivers. An author group was formed to revise the narratives in light of feedback and to produce a paper documenting them and their production.

Lists of potential narrative elements considered to be important determinants of challenges to mitigation or adaptation were generated through expert discussions at the meetings described above, as well as through formal (Schweizer and O'Neill, 2014) and informal expert elicitation. Ultimately, variables in six broad categories were considered to be important to represent in the SSPs: demographics, human development, economy and lifestyle, policies and institutions (excluding climate policies), technology, and environment and natural resources. This list is not meant to be exhaustive, but to provide sufficient guidance for developing basic narratives that – depending on future research needs – can be further adapted and extended. Principal determinants of challenges to mitigation, for example, include determinants of energy and land use, technological progress, and international policy institutions. In the case of challenges to adaptation, institutional factors, future inequality and poverty as well as possible attainment or failure in achieving different development objectives play a critical role.

It was decided to develop five SSPs to span the challenges space, necessitating five different narratives (Fig. 1). Four of the narratives (SSP1, SSP3, SSP4, SSP5) describe the various combinations of high or low challenges to adaptation and mitigation, all of which were considered plausible enough to warrant SSP development. A fifth narrative (SSP2) described moderate challenges of both kinds and is intended to represent a future in which development trends are not extreme in either of the dimensions, but rather follow middle-of-the-road pathways relative to the span of plausible outcomes for each element. The central case is not meant to be more likely than any of the other storylines or pathways. In fact, historical development of GHG emissions has often followed trajectories close to the upper bound of the range of earlier emissions scenarios, such as those from SRES (Nakicenovic et al., 2000). Including a central case was also intended to ensure that the pathways fill the challenges space and that the other four SSPs not drift toward the middle space, which might otherwise be perceived as not well covered.

Summaries of the SSP narratives are provided in an appendix to this paper, and full versions can be found in O'Neill et al. (2015). Titles and 1-2 sentence descriptions of each SSP are:

SSP1: Sustainability—Taking the green road

The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries.

SSP2: Middle of the road

The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns.

SSP3: Regional rivalry—A rocky road

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues.

SSP4: Inequality—A road divided

Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries.

SSP5: Fossil-fueled development—Taking the highway

Driven by the economic success of industrialized and emerging economies, this world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development.

SSP Quantitative Elements

As noted above, SSP narratives included descriptions of trends in development of variables in six broad categories. For three of those categories (demographic, human development, and economy and lifestyle) quantitative projections were developed as part of the SSPs. Table 1 summarizes the qualitative trends for the four types of projections produced: population growth (and its determinants), urbanization, education, and economic growth.

Population projections (KC and Lutz, 2014) were developed by the Wittgenstein Centre for Demography and Global Human Capital based on assumptions judged to be consistent with the narratives, defined in a collaborative effort of the international Integrated Assessment Modeling community. The medium scenario follows a scenario produced as part of a major new projection effort by the Wittgenstein Centre involving over 550 experts from around the world (Lutz et al., 2014). In terms of total world population size the trajectories resulting from the five SSPs stay very close to each other until around 2030 and by the middle of the century a visible differentiation is apparent, with the range between the highest (SSP3) and the lowest (SSP1) trajectories spanning 1.5 billion. The range opens up much more by the end of the century, with SSP3 reaching 12.6 billion and SSP1 falling to 6.9 billion which is lower than today's world population.

The education projections (KC and Lutz, 2014) also span a wide range of outcomes, although share some similarities. In all cases the absolute number of people with secondary or tertiary education increases over the coming decades. This is a trend that is already pre-programmed in today's education structures where almost universally the younger age groups are better educated than the older ones. Under SSP1 and SSP5 the global proportion of people with higher education will increase dramatically and the global mean years of schooling (Mean Years of Schooling in Table 2) of the total adult population will already by 2050 reach 12 years, which is about the current level in Europe. Even under the medium SSP2 scenario the global Mean Years of Schooling will reach 11.2 years by mid-century. But SSP3 and SSP4 draw a much more pessimistic picture that is based on the assumption of a stagnation of the increase in school enrollment. In both cases the average education of the world population will even decline slightly

during the second half of the century, following a minor increase in the nearer future due to the above described momentum.

Regarding urbanization, the world continues to urbanize in each of the SSPs relative to its current level of 50.4% urban, but outcomes vary widely (Jiang and O'Neill, 2015). Urbanization is fast in SSPs 1, 4, and 5, reaching 92% (or nearly so) by the end of the century. In contrast, urbanization is slow in SSP3, reaching only 60% by the end of century, while in SSP2 the outcome lies between these two, at 79%.

Global GDP levels by the end of the century vary substantially across SSPs (Dellink et al., 2015). The range of global GDP levels at the end of the century varies from around 280 trillion USD in SSP3 to more than 1000 trillion USD in SSP5. This pattern is similar for income (i.e. per capita GDP) levels. SSP5, with its narrative focused on "conventional" economic development, projects a global GDP increase by 2100 of more than 15-fold the 2010 level. In this scenario growth rates of income remain above 2% per annum throughout the century, leading to a 14-fold increase of income by 2100. SSPs 3 and 4, which represent the scenarios with lowest levels of international co-operation and trade, are at the bottom of the range. They both see marked reductions in global growth of income to 0.5% and 0.7% per annum, respectively. The drop in global growth starts almost immediately in SSP3 while it is more gradual in SSP4, which first follows the growth pattern of the SSP2 scenario. SSP3 in particular shows very low growth in income (a bit more than doubling in income levels over the century), following the assumptions of low growth rates for the economic drivers. SSPs 1 and 2 have intermediate growth rates. In the first decades, SSP1 presents higher growth at global level as it assumes a quicker convergence. Given the higher population projections in SSP2, income levels diverge more than absolute GDP levels between SSP1 and SSP2.

SSP Extensions and Applications to IAV Studies

The narratives and quantitative elements presented here are part of ''basic SSPs''; that is, they contain enough information to sketch alternative development pathways that are plausible and that enable them to be located in a particular area of the challenges space. However, for many applications, ''extended SSPs'' are likely to be required, which would contain additional, more detailed information for particular regions, sectors, or variables (van Ruijven et al., 2014) or that would be enhanced according to specific needs. For example, scenario analyses that focus on a particular national or subnational region, or on a particular sector (such as water, health, or agriculture), will likely benefit from extending these narratives and their associated quantitative assumptions (Ebi, 2014). Extended SSPs could use assumptions that are consistent with the basic SSPs, but that support modeling and analysis that goes beyond the key variables provided in the basic SSPs.

Global spatial population projections have recently been completed as a quantitative demographic extension of the SSPs (Jones and O'Neill, submitted). In addition, efforts are underway to develop projections of sub-national income distribution consistent with the SSPs (Rozenberg and Hallegatte). Regional scenario-based studies have extended the SSPs to inform analyses of the southeastern US (Absar and Preston, 2015), climate impacts in Europe (Kok et al.), and food security in Africa (AgMIP) and other locations (CGIAR).

The SSPs have also been used in large research projects carrying out global and regional scale applications to climate impact studies. The BRACE study (Benefits of Reduced Anthropogenic Climate changE) is drawing on SSPs to evaluate how sensitive impacts across two different climate scenarios are to socioeconomic conditions. They have also been used in the QUEST-GSI project, and are being used in combination with climate simulations based on the RCPs to investigate impacts on agriculture (AgMIP Global Economic Modeling). Finally, SSP-based IAM scenarios are providing the basis for a new round of climate model simulations to update and expand on the RCPs, as part of the Couple Model Intercomparison Project Phase 6 (CMIP6) (O'Neill et al., submitted).

Individual studies have also begin to appear which draw on both the SSPs and CMIP5 simulations of the RCPs have already begun to appear (e.g., Alfieri et al., 2015; Arnell et al., 2014; Biewald et al., 2015; Dong et al., 2015; Hejazi et al., 2015).

Conclusions

The SSPs are one part of a larger framework for scenario development, representing reference conditions that do not include elements that will be the objects of study of the overall framework, namely emissions, land use, climate change, its impacts, and climate policy responses. As a consequence, the SSPs should be seen as hypothetical development pathways that serve as a starting point for developing integrated scenarios of the future, rather than as plausible scenarios themselves. Combined with the scenario matrix architecture, the SSPs provide a flexible tool for climate change research. They are designed to span a wide range of futures measured by the challenges those futures represent to mitigation and to adaptation, the two primary responses to climate change. They can be applied as boundary conditions to studies in more specific geographical or sectoral contexts, narratives can be extended to suit the needs of specific studies, and additional quantitative information can be added as needed. In addition, SSPs are only examples of the kinds of socioeconomic futures that can produce particular challenges to adaptation and mitigation. To explore uncertainty in ways these challenges might be achieved, SSP variants should be developed, or even entirely new pathways that produce challenges in fundamentally new ways. Employing this framework to develop SSPs will require the participation of researchers from many different communities, with collaboration between the IAM and IAV communities being particularly important.

Figures

Figure 1: Five SSPs located in a space defined by challenges to mitigation and adaptation (O'Neill et al., 2015).

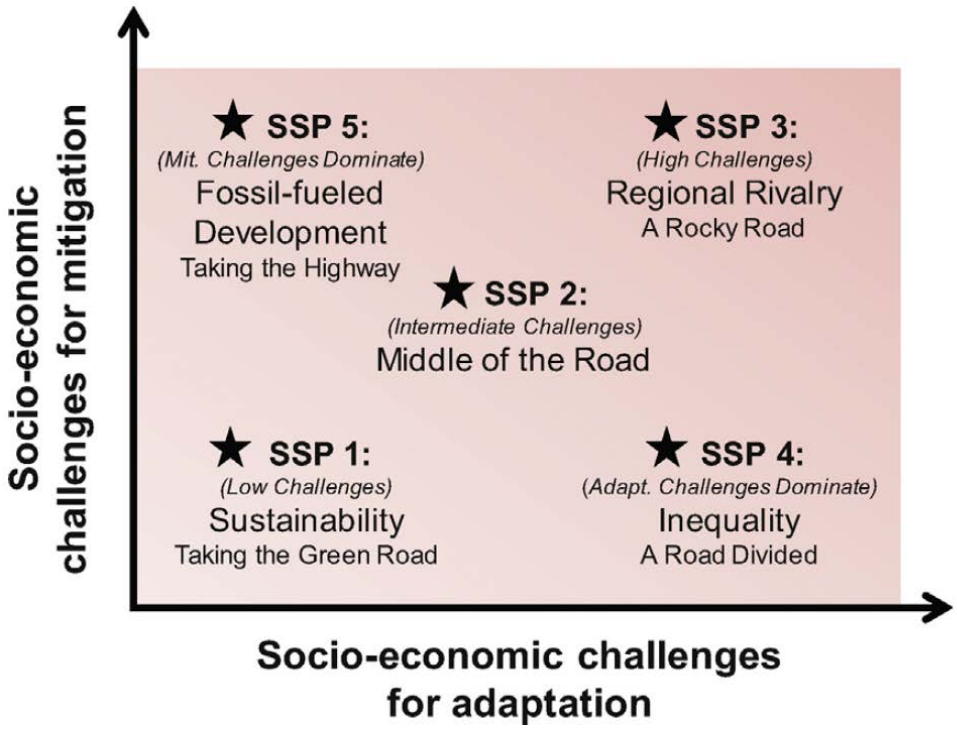

Table 1: Summary of assumptions regarding Demographic, Human Development, and Economy & Lifestyle elements of SSPs for which quantitative outcomes have been developed. Country groupings referred to in table entries are based on the World Bank definition of low-income (LIC), medium-income (MIC) and high-income (HIC) countries.

SSP element	SSP1			SSP2			SSP3			SSP4			SSP5		
	Country Fertility Groupings for demographic elements														
	High Fert.	Low Fert.	Rich-OECD	High Fert.	Low Fert.	Rich-OECD	High Fert.	Low Fert.	Rich-OECD	High Fert.	Low Fert.	Rich-OECD	High Fert.	Low Fert.	Rich-OECD
Demographics															
Population															
Growth	Relatively low			Medium			High		Low	Relatively high		Low	Relatively low		
Fertility	Low	Low	Med	Medium			High	High	Low	High	Low	Low	Low	Low	High
Mortality	Low			Medium			High			High	Med	Med	Low		
Migration	Medium			Medium						Medium			High		
Urbanization															
Level	High			Medium			Low			High	High	Med	High		
Type	Well managed			Continuation of historical patterns			Poorly managed			Mixed across and within cities			Better mgmt. over time, some sprawl		
Human development															
Education	High			Medium			Low			V.low/ uneq.	Low/ uneq.	Med/ uneq.	High		
Economy & Lifestyle															
Growth (pc)	High in LICs, MICs; medium in HICs			Medium, uneven			Slow			Low in LICs, medium in other countries			High		

Appendix: SSP Narrative Summaries[2]

SSP1: Sustainability—Taking the green road The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Increasing evidence of and accounting for the social, cultural, and economic costs of environmental degradation and inequality drive this shift. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and interna-tional organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading to a relatively low population. Beginning with current high-income countries, the emphasis on economic growth shifts toward a broader emphasis on human well-being, even at the expense of somewhat slower economic growth over the longer term. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Investment in environmental technology and changes in tax structures lead to improved resource efficiency, reducing overall energy and resource use and improving environmental conditions over the longer term. Increased investment, financial incentives and changing perceptions make renewable energy more attractive. Consumption is oriented toward low material growth and lower resource and energy intensity. The combination of directed development of environmentally friendly technolo-gies, a favorable outlook for renewable energy, institutions that can facilitate international cooperation, and relatively low energy demand results in relatively low challenges to mitigation. At the same time, the improvements in human well-being, along with strong and flexible global, regional, and national institutions imply low challenges to adaptation.

SSP2: Middle of the road The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Most economies are politically stable. Globally connected markets function imperfectly. Global and national institutions work toward but make slow progress in achieving sustainable development goals, including im-proved living conditions and access to education, safe water, and health care. Technological development proceeds apace, but without fundamental breakthroughs. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Even though fossil fuel dependency decreases slowly, there is no reluctance to use unconventional fossil resources. Global population growth is moderate and levels off in the second half of the century as a consequence of completion of the demographic transition. However, education invest-ments are not high enough to accelerate the transition to low fertility rates in low-income countries and to rapidly slow population growth. This growth, along with income inequality that persists or improves only slowly, continuing societal stratification, and limited social cohesion, maintain challenges to reducing vulnerability to societal and environmental changes and constrain significant advances in sustainable development. These moderate development trends leave the world, on average, facing moderate challenges to mitigation and adaptation, but with significant heterogeneities across and within countries.

[2] From O'Neill et al., 2015.

SSP3: Regional rivalry—A rocky road A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. This trend is reinforced by the limited number of comparatively weak global institutions, with uneven coordination and cooperation for addressing environmental and other global concerns. Policies shift over time to become increasingly oriented toward national and regional security issues, including barriers to trade, particularly in the energy resource and agricultural markets. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development, and in several regions move toward more authoritarian forms of government with highly regulated economies. Investments in education and technological devel-opment decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time, especially in developing countries. There are pockets of extreme poverty alongside pockets of moderate wealth, with many countries struggling to maintain living standards and provide access to safe water, improved sanitation, and health care for disadvantaged populations. A low international priority for addressing environmental concerns leads to strong envi-ronmental degradation in some regions. The combination of impeded development and limited environmental concern results in poor progress toward sustainability. Population growth is low in industrialized and high in developing countries. Growing resource intensity and fossil fuel depen-dency along with difficulty in achieving international coopera-tion and slow technological change imply high challenges to mitigation. The limited progress on human development, slow income growth, and lack of effective institutions, especially those that can act across regions, implies high challenges to adaptation for many groups in all regions.

SSP4: Inequality—A road divided Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that is well educated and contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy. Power becomes more concentrated in a relatively small political and business elite, even in democratic societies, while vulnerable groups have little representation in national and global institutions. Economic growth is moderate in industrialized and middle-income countries, while low income countries lag behind, in many cases struggling to provide adequate access to water, sanitation and health care for the poor. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. Uncertainty in the fossil fuel markets lead to underinvestment in new resources in many regions of the world. Energy companies hedge against price fluctuations partly through diversifying their energy sources, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas. The combination of some development of low carbon supply options and expertise, and a well-integrated international political and business class capable of acting quickly and decisively, implies low challenges to mitigation. Challenges to adaptation are high for the substantial proportions of populations at low levels of development and with limited access to effective institutions for coping with economic or environmental stresses.

SSP5: Fossil-fueled development—Taking the highway Driven by the economic success of industrialized and emerging economies, this world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated, with interventions focused on main-taining competition and removing institutional barriers to the participation of disadvantaged population groups. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary. While local environmental impacts are addressed effectively by technolog-ical solutions, there is relatively little effort to avoid potential global environmental impacts due to a perceived tradeoff with progress on economic development. Global population peaks and declines in the 21st century. Though fertility declines rapidly in developing countries, fertility levels in high income countries are relatively high (at or above replacement level) due to optimistic economic outlooks. International mobility is increased by gradually opening up labor markets as income disparities decrease. The strong reliance on fossil fuels and the lack of global environmental concern result in potentially high challenges to mitigation. The attainment of human develop-ment goals, robust economic growth, and highly engineered infrastructure results in relatively low challenges to adapta-tion to any potential climate change for all but a few.

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