

Interim Report

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Towards Innovative Solutions through Integrative Futures Analysis - *Preliminary qualitative scenarios*

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Abstract

This report presents preliminary results of developing qualitative global water scenarios. The water scenarios are developed to be consistent with the underlying Shared Socio-Economic Pathways (SSPs). In this way different stakeholders in different contexts (climate, water) can be presented with consistent set of scenarios avoiding confusion and increasing policy impact. Water scenarios are based on the conceptual framework that has been developed specifically for this effort. The framework provides clear representation of important dimensions in the areas of Nature, Economy and Society and Water dimensions that are embedded in them. These critical dimensions are used to describe future changes in a consistent way for all scenarios. Three scenarios are presented based on SSP1, SSP2 and SSP3 respectively. Hydro-economic classes are introduced to further differentiate within scenarios based on economic and water conditions for specific regions and/or countries. In the process of building these preliminary water scenarios assumptions that are presented in this report, the number of challenges have been met. In the conclusions section these challenges are summarized and possible ways of tackling them are described.

About the Authors

William Cosgrove

William (Bill) Cosgrove joined IIASA's Water (WAT) Program as a Senior Research Scholar in March 2012. His initial work has been related to the integration of the next phases of a world water scenarios project into IIASA's Water Program.

Cosgrove received his B.Eng. and M.Eng. (sanitary engineering) and Honorary Doctorate of Science from McGill University and is an Honorary Fellow of UNESCO-IHE. He has followed other graduate courses in economics, management and cross-cultural studies at McGill and Georgetown Universities and the Harvard Business School. He is Manager of the World Water Scenarios Project of the UN World Water Assessment Program, a member of the Calouste Gulbenkian Foundation Think Tank on Water and the Future of Humanity, and of several professional associations including the Association of Professional Futurists.

Guenther Fischer

Professor DI Günther Fischer is a senior researcher in land use systems of the Food and Water thematic area at IIASA. He also holds the position of adjunct professor in the Department of Geography at the University of Maryland, USA. His main fields of research are mathematical modeling of ecological-economic systems, econometrics, optimization, applied multi-criteria decision analysis, integrated systems and policy analysis, spatial agro-ecosystems modeling, and climate change impacts and adaptation. He participated in the development of IIASA's world food systems model and was a key contributor to several major food and agricultural studies: On welfare implications of trade liberalization in agriculture; on poverty and hunger; on biofuels and food security; on the climate-water-food-energy-ecosystem nexus; and on climate change and world agriculture. He is collaborating with the United Nations Food and Agriculture Organization (FAO) on the development and application of the Agro-Ecological Zones methodology and has contributed to major FAO agricultural perspective studies, to IPCC assessment reports, the Millennium Ecosystem Assessment, WSSD Johannesburg Report Climate Change and Agricultural Vulnerability.

Professor Fischer is recognized as one of 23 IIASA scientists that have contributed to the large body of IPCC reports. The Nobel Peace Prize (2007) was awarded to the Intergovernmental Panel on Climate Change (IPCC) and Al Gore for "their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."

Martina Flörke

Dr. Martina Flörke is a senior researcher at the Center for Environmental Systems Research (CESR) at the University of Kassel in Germany and is, since 2011, heading the GRID-Water group. Her research focuses on model development, especially with a view to water use, and project management. All of her research interests are related to global change, climate change and water resources; The impact of global change on freshwater

resources: Where are the hotspots and where will they be in the future?; Climate change and its impact on the energy sector.; Indicator development.; Further model improvements and developments of WaterGAP model(s).; Temporal dynamics of different water use sectors: past - present - future.; Urbanisation and water use.; Vulnerability and adaptation strategies.

Since the beginning of the WFaS Initiative Dr. Flörke has been actively involved in the development of its research.

Eva Hizsnyik

Eva Hizsnyik joined IIASA's former Land Use Change and Agriculture (LUC) Program, now Ecosystems Services and Management (ESM) Program, as a Research Scholar in 2003. She holds a master's degree in economics, and has been dealing with socioeconomic aspects of global environmental change for several years. Her current responsibilities include data mining, updating and harmonizing databases for various ongoing research projects, and estimating and analyzing possible socioeconomic impacts of land use and land cover change.

Piotr Magnuszewski

Piotr Magnuszewski has a background in mathematics (MSc) and physics (PhD). He later gained experience in the area of complexity science. He is presently working in the Water and the Risk, Policy and Vulnerability (RPV) Program of IIASA. He is furthermore co-founder and managing director of the ISIS Academy/Centre for Systems Solutions.

Dr. Magnuszewski has been working for many years as a systems modeler, professional trainer, facilitator and researcher. He is particularly involved in linking theory and practice, science and policy, knowledge and action through diverse systems and knowledge management tools. He has been applying and teaching systems tools with diverse groups of scientists, NGOs, businesses and administration in many countries.

Dr. Magnuszewski was engaged in many international projects on resilience adaptive management of complex socio-ecological systems. In this context he facilitated multi-party collaboration. He also developed and applied, in a participatory way, a range of system dynamics models. He designed and applied many simulation and role-playing games as research and educational tools. He is author of many research and educational publications.

Claudia Pahl-Wostl

Claudia Pahl-Wostl is professor for resources management, an endowed chair of the German Environmental Foundation, at the Institute for Environmental Systems Research in Osnabrück, Germany.

She is an internationally well known expert in adaptive management, water governance and participatory integrated assessment and agent based modelling. Before moving to USF Claudia Pahl-Wostl worked for more than ten years in the field of mathematical modelling, integrated assessment and human ecology at the Swiss Federal Institute for

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Angelika Scherzer

Ms. Angelika Scherzer is the program assistant for the IIASA Water program, where she fulfills program coordination activities. Ms. Scherzer has more than ten years of working experience in international organizations and NGOs in Austria and abroad, including developing countries. In her positions she coordinated the implementation of projects and programs dedicated to poverty reduction, food security, agricultural development, migration, return and reintegration as well as peacebuilding and advocacy for the concerns of less and least developed countries. Ms. Scherzer holds a Masters degree in International Relations & Development Studies from the University of East Anglia, a postgraduate diploma in International Development Studies from the Polytechnic University of Catalonia and an undergraduate degree in Business Administration from the International Business College in Vienna.

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Dr. Andrew Segrave is Scientific Researcher and the KWR Watercycle Research Institute. He spearheads scientific futures studies at KWR Watercycle Research Institute. As coordinator responsible for the thematic research on trends and future perspectives for the Joint Water Sector Research Programme of the Dutch water companies, Andrew also has much experience at applying methods for horizon scanning and strategic planning in practice. His work and active contribution to the WFaS Initiative has been substantial to the development of this and other reports.

Geza Toth

Geza Toth has been a research affiliate with IIASA since 2007. He served as the Program Officer of IIASA's Greenhouse Gas Initiative and as a Research Assistant with the Atmospheric Pollution and Economic Development (APD) Program, working within the Policy Assessment Framework between 2007 and 2010. He then moved to IIASA's Ecosystems Services and Management (ESM) Program, specializing in mitigation strategies for land-based systems, including agriculture and forestry. In his last position at IIASA he was affiliated with IIASA's flagship activity, the Water Futures and Solutions Initiative (WFaS), where after an initial period devoted to program coordination- he carries out his own research activities on pilot case studies and real world implications of systems analysis.

Currently he is Project Developer at *Ferrero Trading Lux S.A.* and maintains a guest research contract at IIASA.

Sylvia Tramberend

Sylvia Tramberend is a research scholar in IIASA's interdisciplinary and policy oriented research focused in the food and water thematic area. Since joining the Land Use Change and Agriculture Program in 1997 (Ecosystems Services and Management Program as of

2011), she has contributed to research in systems analysis of agriculture, land use change and ecosystem studies. In 1994, Dr. Tramberend participated in IIASA's Young Summer Scientists Program, after which she continued working as a research scholar with the Program "Regional Material Balance Approaches to Long-Term Environmental Planning".

Her responsibilities as a land use and GIS expert have included the development of large spatial databases serving the modeling and analysis needs in the areas of food-environment-bioenergy-water linkages, food-system analysis, land use and water scenarios and environmental transition. She was involved in Agro-Ecological Zones Methodology assessments for agricultural development planning, worked on several assessments of biofuels and food security, and the mobilization of resources for the bio-economy. In sustainable consumption research she has been a principal investigator in analysis tracing embodied land use and deforestation in agricultural and forestry products from primary production to final utilization. The geographic focus of her research has been both global and regional (e.g. Europe, China, and Brazil).

Michelle van Vliet

Michelle T.H. van Vliet is a Postdoctoral Research Scholar with IIASA's Water (WAT) Program. She is participating in the World Water Scenarios Project and focusses on the 'water-energy nexus' (i.e. complex linkages among water and energy security) under future climate and socio-economic changes. Global and regional water assessments of water resources and cross-sectoral water uses are performed with the aim to develop management strategies for sustainable water, food and energy supply under future climate and socio-economic changes.

Since January 2013, she has been working as a postdoctoral researcher both at IIASA and at Wageningen University, the Netherlands.

David Wiberg

David Wiberg is the Acting Director of IIASA's Water Program and is managing the Water Futures and Solutions Initiative (WFaS), applying systems analysis to build and explore with stakeholders consistent scenarios of the freshwater system across scales and sectors, and exploring the synergies and tradeoffs of intervention options in order to inform decisions focused on more effective and robust water management.

Dr. Wiberg received a degree in physics, with an economics minor, from Gustavus Adolphus College and master's and PhD degrees in civil engineering, water resource engineering and management, from the University of Colorado, Boulder. He designed river basin management software as a consultant for the Bureau of Reclamation, US DOI, and also consulted with the EPA and DOE in the USA. In 1997 he started working with IIASA in the Land-Use Change and Agriculture program, assessing the impact of land use and climate changes on basin water resource availability, demand, required storage capacity, development costs and management options, as well as helping develop the Harmonized World Soil Database and Global Agro-Ecological zoning methodologies and assessments. He consulted concurrently for the World Water Assessment Program and the Dialogue for Water and Climate, and is now helping to launch IIASA's Water

Program and the Water Futures and Solutions Initiative, incorporating water science into IIASA's integrated assessments. Dr. Wiberg's primary fields of interest are efficient and sustainable water management strategies, water modeling and the development of decision support tools, and climate change impact assessments.

Paul Yillia

Paul T. Yillia (Dr. techn.) joined the Water (WAT) Program at IIASA in November 2012 to support research on the Water-Energy Nexus and the World Water Scenarios Project. Previously, he was a research and teaching assistant at the Vienna University of Technology, Institute for Water Quality, Resources and Waste Management, where he accomplished joint research and transnational exchange of knowledge and skills on water science and technology, especially in developing countries and countries in transition. Prior to this, Dr. Yillia undertook various assignments in the Netherlands with UNESCO-IHE Institute for Water Education and Cap-Net (Capacity Building Network for Integrated Water Resources Management), with progressive responsibility in training materials development, research, education and partnership in the water sector. He was also lecturer and research fellow on aquatic systems at the University of Sierra Leone and has undertaken various capacity building responsibilities within the framework of development co-operation in several countries in sub-Saharan Africa.

With a mixed background in applied science, Dr. Yillia has a range of research interests in the water sector, from natural and induced processes and applications in aquatic systems to water quality implications on human health and the environment. His research and publication record covers a range of topics, including water resources evaluation and planning, water-related health risk assessment and catchment vulnerability assessment and management.

Deirdre Zeller

Ms. Deirdre Zeller was formerly associated with IIASA as program assistant for the Water program.

1. Introduction

Scenario planning, also called scenario thinking or scenario analysis, is a strategic planning method that some organizations use to make flexible long-term plans. Scenarios enable improved decision-making. Insightful analysis, structural thinking and challenging outlooks are central elements to good scenarios. These, in turn, allow for more objective and robust responses to current and future needs.

Philippe van Notten (Notten, P. van, 2006) defines scenarios as: consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments, which can serve as a basis for action.

Decision makers can use scenarios to think about the uncertain aspects of the future that worry them most – or to discover the aspects about which they should be concerned – and to explore ways in which these might unfold. Because there is no single answer to such enquires, scenario builders create sets of scenarios. These scenarios all address the same important questions and all include those aspects of the future that are likely to persist, but each one describes a different way in which the uncertain aspects could play out.

Good scenarios are ones that explore the possible, not just the probable – providing a relevant challenge to the conventional wisdom of their users, and helping them prepare for the major changes ahead. They will provide a useful context for debate, leading to better policy and strategy, and a shared understanding of, and commitment to actions.

This report presents preliminary qualitative water scenarios based on three Shared Socio-Economic Pathways (SSPs) – see Figure 1. Information about the scenario process and the SSP framework can be found in Moss et al. (2010), Arnell et al. (2011), van Vuuren et al. (2012) and Kriegler et al. (2012).

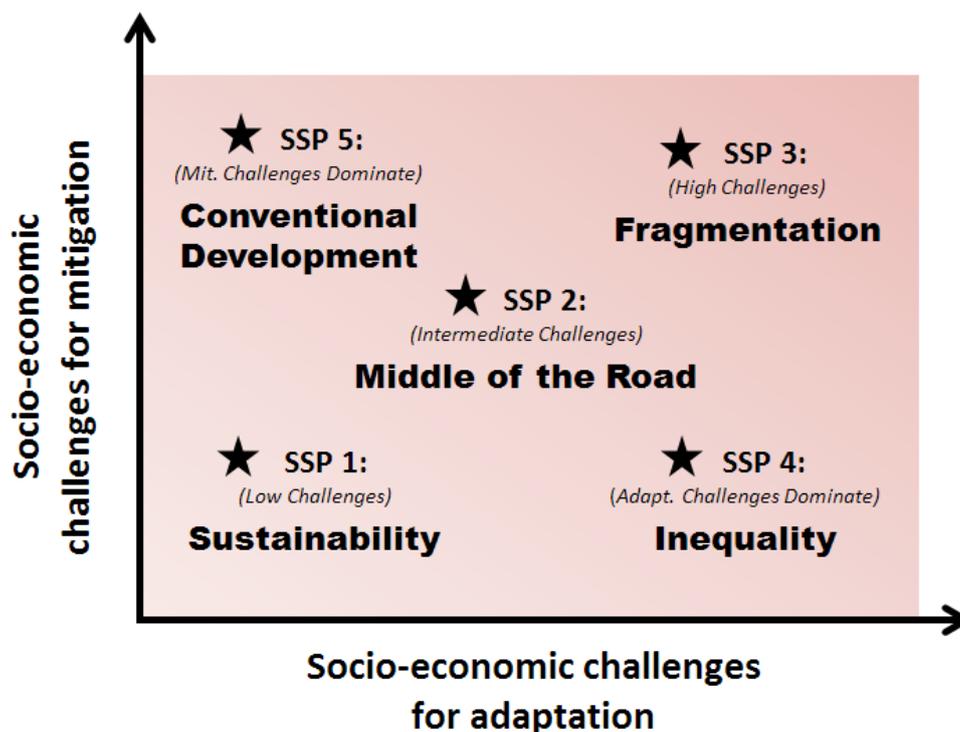


Figure 1. Internal logic of SSPs

Water scenarios are built on the conceptual framework developed specifically for this effort – see Figure 2.

The conceptual framework captures both specific sectors (Nature, Economy and Society) as well as relationships between them including feedback loops.

While not all of these relationships have been quantified yet, they are already represented in the framework, providing clear qualitative view and progress direction for quantitative efforts. Although water is presented as a separate module in the 2-dimensional diagram it is actually embedded in the environmental, social and economic dimensions. Similarly, Options (or solution options) are not coming from outside but within the other framework dimensions. Well-being dimensions including water security provide targets that effectiveness of solution options can be measured against.

In the water scenarios presented in this report the conceptual framework and its dimensions are used to consistently describe how selected futures are different along those dimensions. All future changes are clearly attributed to one of the dimensions within broader sectors/categories of Nature, Economy, Society, Water and Well-being. In this way all scenarios can be compared against each other.

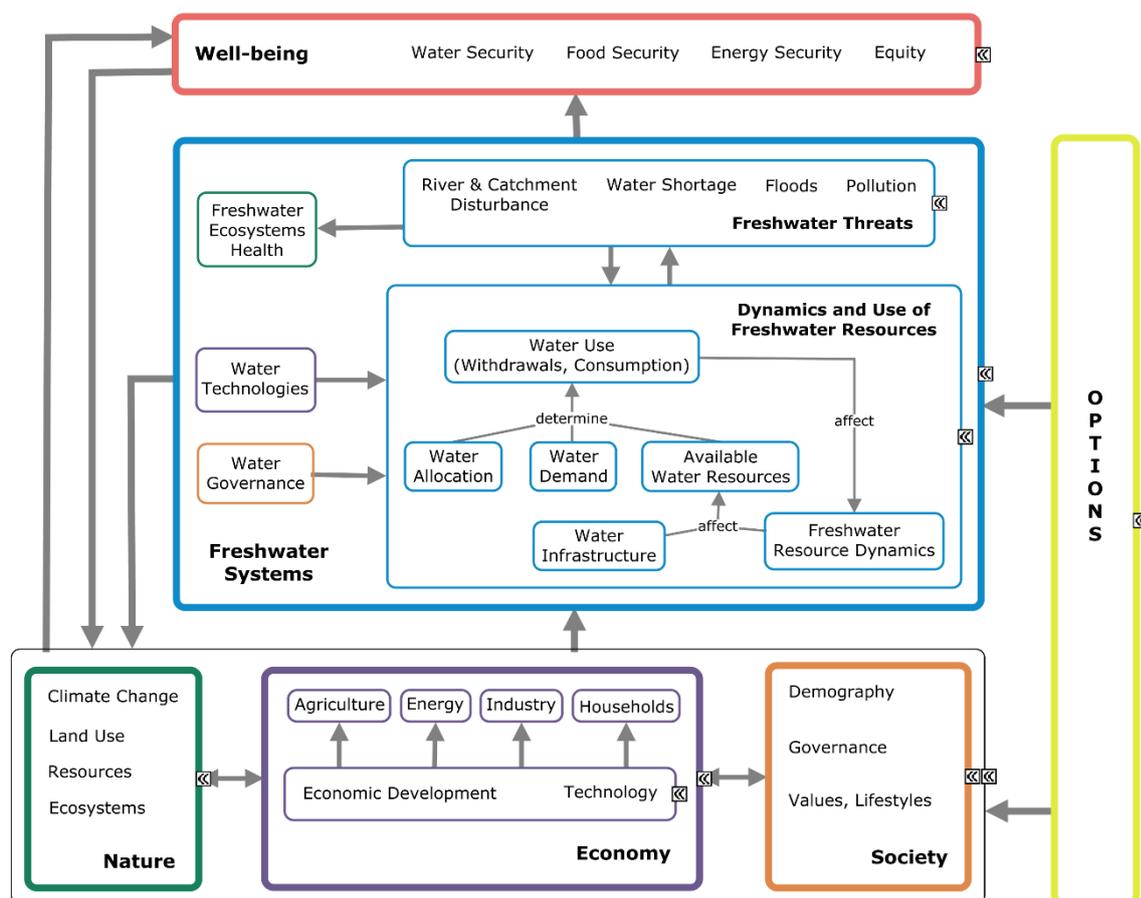


Figure 2. Conceptual framework for developing water scenarios

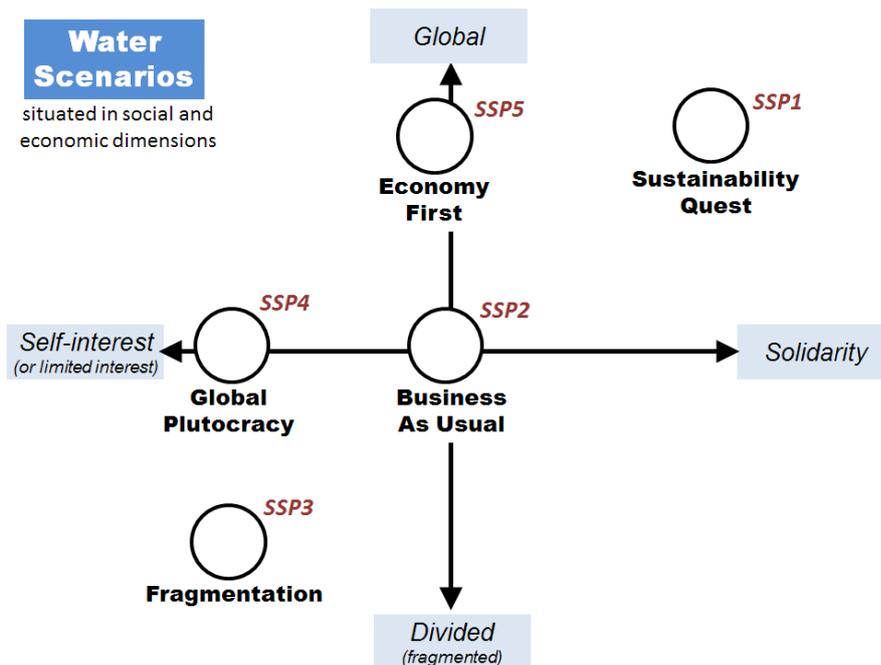


Figure 3. Main axes for water scenarios linked with the SSPs.

The original axis of SSPs (Figure 1) are specific to climate scenarios and may not be a good starting point for developing water scenarios. Because of this we propose alternative axes that are more familiar for anyone acquainted with previous global scenarios efforts such as Millennium Ecosystem Assessment, GEO-4, IPCC SRES, OECD Environmental Outlook (van Vuuren et al 2012). The horizontal axis represents the difference between the world where solidarity is an important concern that is not only discussed but also implemented influencing political and economic outcomes. The vertical axis represents the difference between unified and divided world. In the globalized world important problems are tackled to a large extent internationally, in a divided world different regions and countries are focusing on their own specific solutions, not coordinated with other countries and regions.

Developing global scenarios is always a challenge because of diversity of trajectories that specific regions and countries are following. In order to tackle this challenge the hydro-economic classes have been defined (Tramberend S., Fischer G., 2015, *in publication*) that create a possibility to further diversify future storylines in the specific scenarios based on economic and water conditions.

Following Grey's approach (Grey et.al, 2013) to consider water security in a risk framework entails quantifying economic capacity and, often closely related, viable institutions for managing watersheds on the one hand and the prevailing natural conditions affecting the hydrology of water systems and water use on the other hand. Both dimensions, socio-economics and hydrological complexity are in principle quantifiable using appropriate proxies.

For each country two normalized compound indicators are calculated to describe:

- (i) the economic-socio-institutional coping capacity,
- (ii) the hydrological complexity.

Each of these compound indicator is computed from a number of component indicators, including:

Economic-Institutional coping capacity:

- i. GDP per capita (purchasing power parity corrected) as a measure of economic strength and financial resources that could be invested in risk management; and
- ii. The Corruption Perception Index (CPI) indicator as a measure of institutional capacity to adopt good governance principles (efficiency, effectiveness, transparency, accountability, inclusiveness, rule of law) in governance and management of risks.

Hydrological complexity:

- i. Total renewable water resources per capita as a measure of water availability
- ii. Ratio of total water withdrawal to total renewable water resources availability as a proxy for relative intensity of water use
- iii. The coefficient of variation over 30 years of monthly runoff as a proxy for both inter- and intra-annual variability of water resources
- iv. The share of external (from outside national boundaries) to total renewable water resources as a measure for the dependency of external water resources

For developing water scenario assumptions it is useful to group the countries into a few classes. In the WFaS ‘fast-track’ analysis it has been decided to divide the space of hydro-economic development challenges into four quadrants (Figure 4). For simplicity these are termed: HE-1 (water secure, poor); HE-2 (water secure, rich); HE-3 (water stress, rich); HE-4 (water stress, poor).

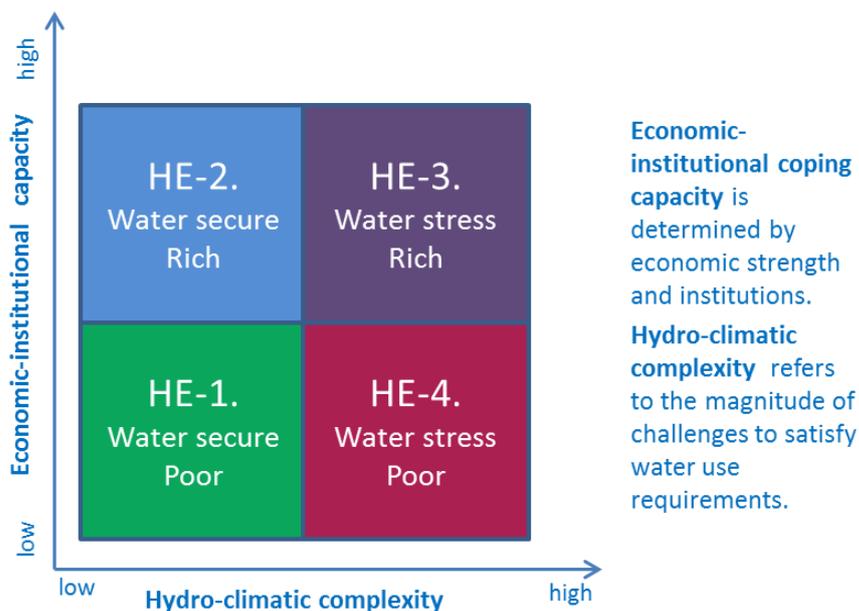


Figure 4. “Hydro-Economic” quadrants for human-natural water development challenges

Hydro-economic classes provide an opportunity to represent divergent tendencies in the world that is characterized by dominant trends. This variability is important to represent and account for because different regional and national conditions may require different types of policies and solutions to be developed and applied. The scenarios with these branches based on hydro-economic classes are presented conceptually on Figure 5.

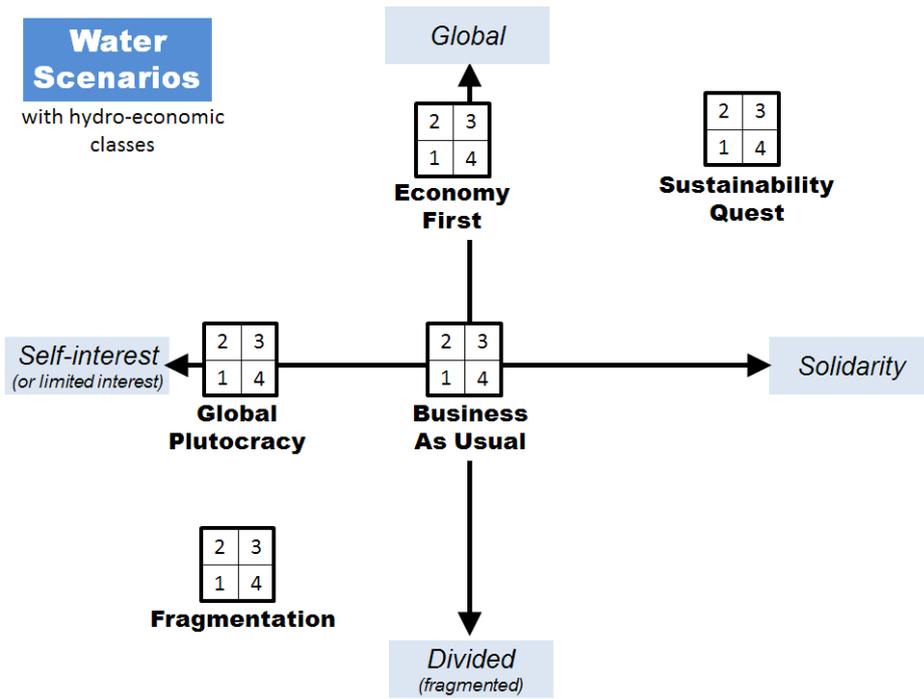
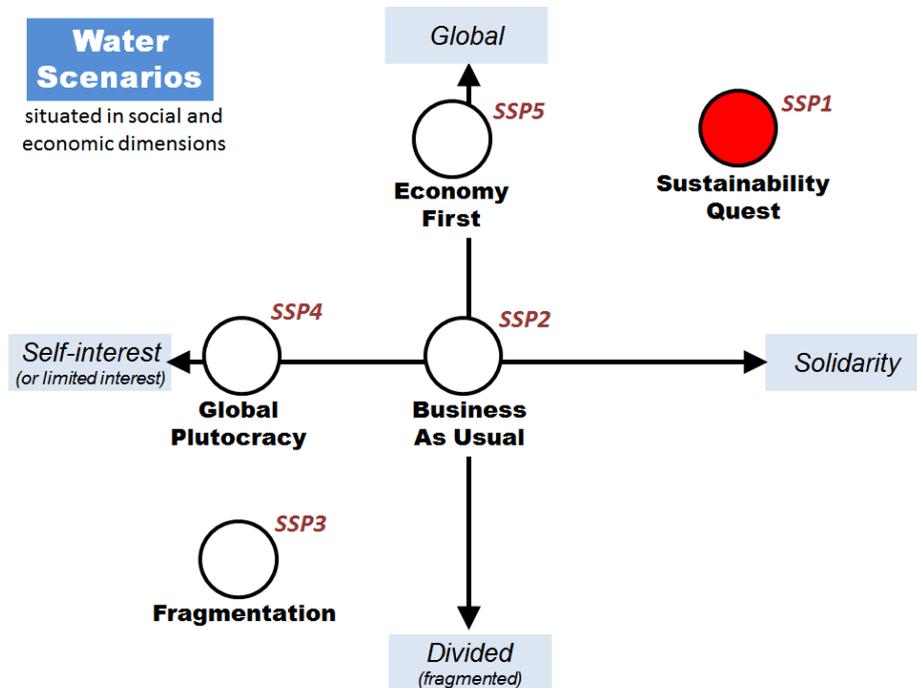


Figure 5. Representation of water scenarios with hydro-economic classes

2. Preliminary Qualitative Scenarios

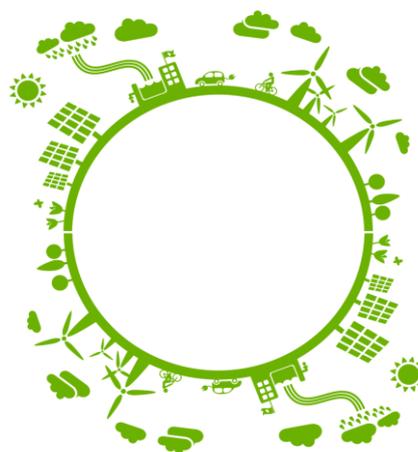
2.1. SCENARIO 1: Sustainability Quest

Analysis based on SSP 1



2.1.1 Summary of Scenario 1

The world shifts gradually but dramatically toward a more sustainable path, emphasizing more inclusive human development that respects perceived environmental limits. Sustainable development goals are set with well-defined targets. The role of water in achieving most of them is recognized. Increasing evidence of and accounting for the social, cultural, and economic costs of inequity and environmental degradation facilitate progress towards the targets. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and international organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading towards a lower population. Beginning with current high-income countries, concerns with economic growth shift toward a focus on human well-being, even at the expense of somewhat slower growth over the longer term. Consumption is oriented towards low material growth and lower resource and energy intensity. In response to changed perceptions, tax incentives encourage increased investment, lower unit costs, and increase the proportion of renewable energy resources with smaller water footprints. Through better forecasting of precipitation and access to it through



low-cost information technology farmers increase their food production. Water efficient irrigation systems are subsidized by governments with focused aid from donors. Early warning systems use these forecasts to reduce risks of damage from floods. Technological development with agricultural, energy and urban applications combined with strong and flexible national and regional institutions and institutions that favor international cooperation and trade together make it possible through water security to move towards human well-being and environmental sustainability.

2.1.2 Analysis under Scenario 1

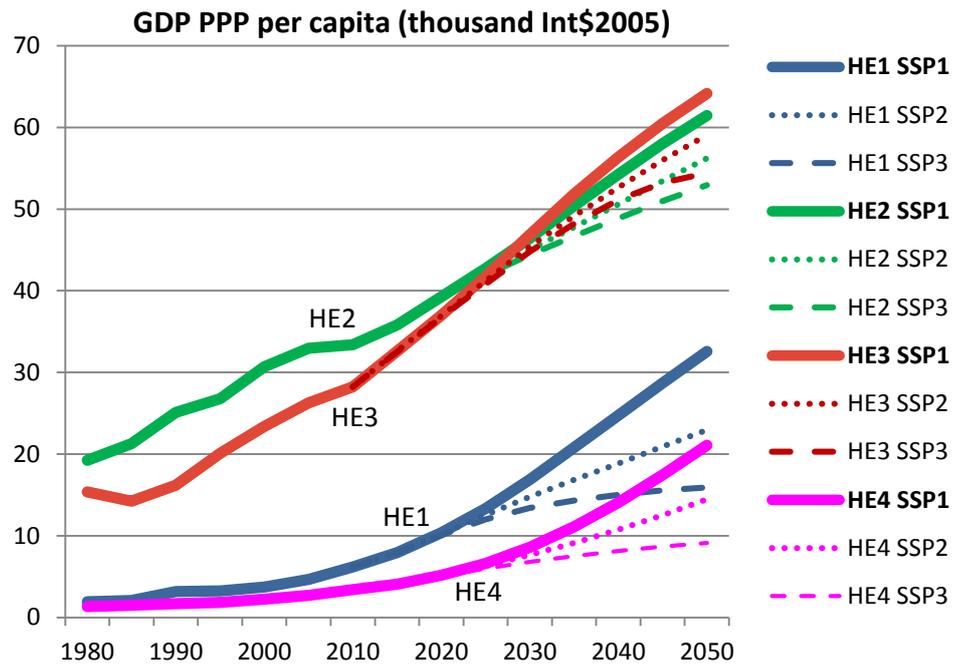
Nature

Climate Change	Low challenges to both mitigation and adaption
Land Use and Agriculture	Strong land use change regulation. Low environmental impacts. Tropical deforestation rates are strongly reduced. Emphasis on regional production. Risk management and related measures implemented to reduce and spread yield risks.
<i>Land Productivity</i>	Improvements in agricultural productivity through rapid diffusion of best practices and development of new cultivars and other technologies decrease challenges to food security. Crop yields are rapidly increasing in low- and medium-income regions, leading to a faster catching-up with high income countries.
<i>Agricultural Technology</i>	Quite rapid reduction of prevailing yield gaps toward environmentally sustainable and advanced technology yield levels.

Economy

Economic Development	Globally the service sector grows relatively quickly. In developing countries there is a continued focus on economic growth. Relatively high transportation costs. The importance of the manufacturing sector in the overall economy decreases further due to the increasing importance of the non-resource using service sector.
<i>Trade</i>	Markets are globally connected, but an emphasis on regional production reduces the incentives for specialization and limits the increase in trade volumes.

GDP



Inequalities

Prioritize progress towards achieving global and national development and sustainability goals, while reducing inequality (globally and within economies).

Technology

Technology Development

Strong, increased investment in research, implementation and adoption of new technologies.

Technology Transfer

Technology transfer is facilitated by international agreements on intellectual property rights and other issues

Sustainable Technologies

Relatively rapid technological change is directed toward environmentally friendly processes, including energy efficiency, clean energy technologies (renewables), and yield-enhancing technologies for land

Energy

Higher levels of resource efficiency.

Reducing overall energy and resource use over the longer term with a parallel shift in preferences on use of fossil fuels.

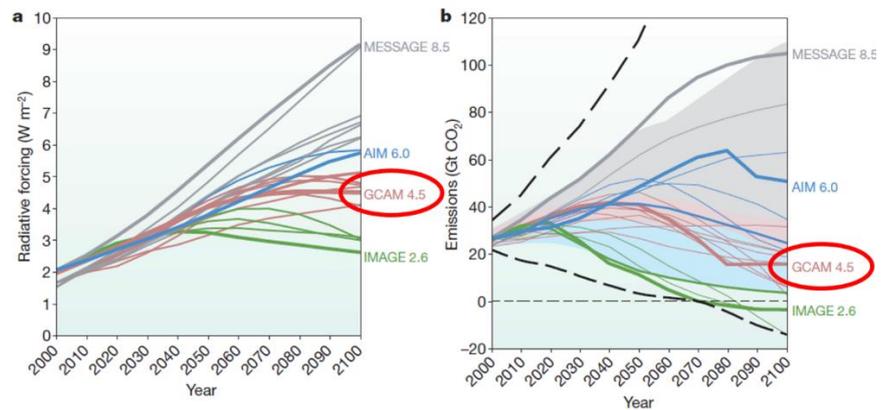
Traditional fuel use in developing countries is phased out rapidly as a consequence of high economic development, fast urbanization and a focus on sustainable development.

Energy Demand

Environmental consciousness and sustainable development objectives lead to acceptance of strong regulatory approaches (e.g., high energy taxes), resulting in only modest energy service demand levels (less material intensive).

Energy Intensity

Low energy intensity of services in industry, buildings and transportation.

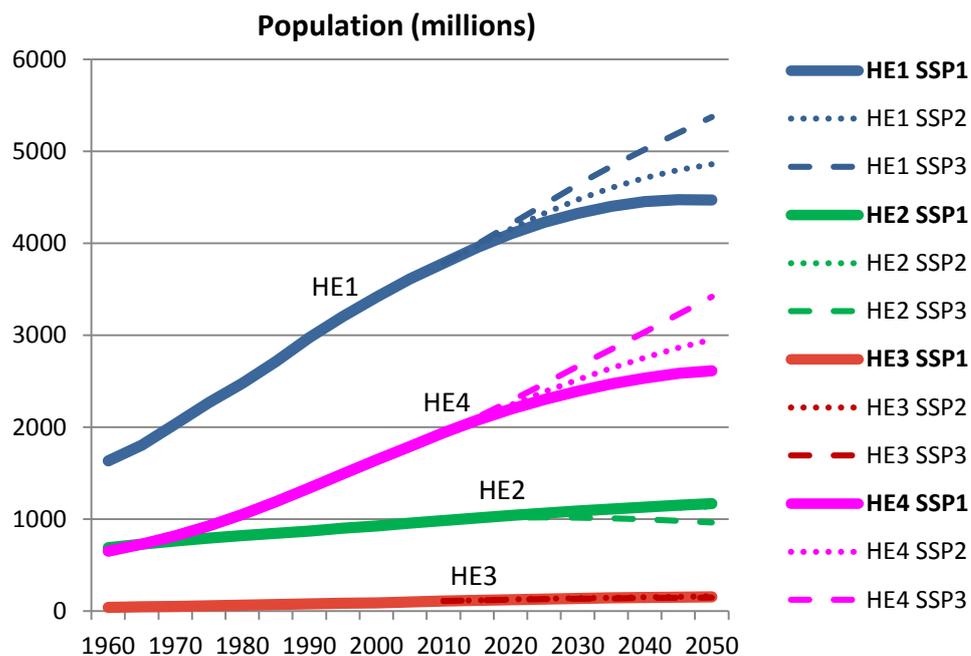


- a.** Changes in radiative forcing relative to pre-industrial conditions. Bold coloured lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing from ref. 47 and the larger set analysed by IPCC Working Group III during development of the Fourth Assessment Report.
- b.** Energy and industry CO₂ emissions for the RCP candidates. The range of emissions in the post-SRES literature is presented for the maximum and minimum (thick dashed curve) and 10th to 90th percentile (shaded area). Blue shaded area corresponds to mitigation scenarios; grey shaded area corresponds to reference scenarios; pink area represents the overlap between reference and mitigation scenarios.

Society

Demography

Population The demographic transition leads to a relatively low population with migration at intermediate levels (as an effect of improved regional livelihoods and the renewed emphasis on regional production)



Education Improved access to education and gender equality.

Urbanization Urbanization proceeds rapidly in all parts of the world.

Values, Lifestyles

Pro-environmental Values

High environmental awareness.

Formal and informal actions over time, help to fundamentally restructure the relationships between humans and the environment.

Consumption, Diets

There are shifts in public and private behavior reflected in changing consumption and investment patterns. Consumption is oriented towards low material growth and lower resource and energy intensity.

Healthy diets with low animal-calorie shares and low waste prevail.

Governance

Policy Orientation

Policies shift to align incentives with development and sustainability goals, including measures such as the adoption and use of standardized measures of well-being to complement GDP.

Increased attention to ensuring the growth is broad-based and does not come at the expense of long-term degradation of local environments. There are also changes in policies enhancing universal access to education, promoting higher education levels and gender equality. Policies shift to align incentives with development and sustainability goals, including measures such as improving the access of developing countries to international markets, including the opening of agricultural markets.

The governance and institutions are re-oriented toward sustainability principles and support cooperation on sustainable development.

Quality of Governance

Reductions in corruption levels, policies calling for greater transparency in all sectors of society, and strengthening of the rule of law gradually lead to

greater effectiveness of development policies. Effective institutions and governance support an open, globalized economy.

Environmental Policy

Stronger recognition of environmental considerations (including phase out of subsidies on fossil fuels -particularly coal and oil) and tightening of environmental regulation on the national and regional level.

There is a stricter environmental regulation successfully implemented on such issues as air pollution oil spill safety levels which improve health in developing countries.

If and when severe climate impacts do occur, coordination structures (e.g. integrated early warning systems, security alliances, and disaster relief services) are in place to assist those most at risk.

The transition from increased environmental degradation in the short-term to improved management of the local environment and the global commons over the longer term.

Global Cooperation

Relatively effective and persistent cooperation and collaboration of national and international organizations and institutions, the private sector, and civil society linked with an increasing integration of labor markets. Willingness to cooperate support an open, globalized economy. New global institutions and governance evolve to support cooperation on sustainable development.

Water

Water Governance

Enforced limits to groundwater over-exploitation.

Enhanced treatment and reuse of water.

Concern for pollution reduction and water quality, implying widespread application of precision farming and nutrient management.

Water Infrastructure

Reliable water infrastructure and water sources

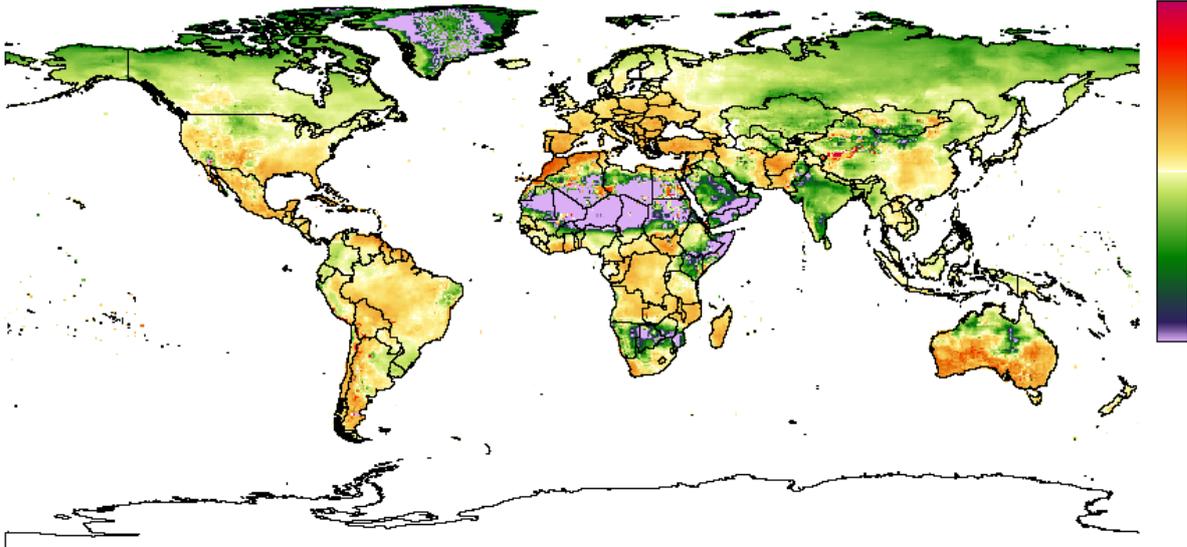
Water Pollution

Improved water quality

Available Water Resources

The map below shows calculated ratios of mean annual runoff around 2050 relative to the base period 1971-2000.

In these ratio maps values above 1 indicate an increase of mean annual runoff, values below 1 a decrease of future runoff.



Water Demand

Agriculture

Area equipped for irrigation stagnates or slightly declines while irrigation efficiency is improving fast. Economic and water scarcity will somewhat limit further increases of cropping intensity.

Energy

Reduction in energy demand will decrease the demand for water from the energy sector substantially even if world population, primary energy production, and electricity generation were to increase.

A shift away from traditional biomass toward less consumptive energy carriers, as well as the changing energy mix in electricity generation leads to water savings.

A favorable outlook for renewables will cause big structural and efficiency shifts in the choice of technology with variable consequences for water use intensity and efficiency, depending on the renewable type. For example, an expanding output of biofuels leads to a rise in water consumption, whereas a shift towards photovoltaic solar power or wind energy leads to a decrease in water use intensity.

Higher energy efficiency translates into a relatively lower water demand, improvements in water quality, following high standards that commit industry to continually improving environmental performance.

Overall, structural & technological changes results in decreasing water use intensities in the energy sector. For example the widespread application of water-saving technologies in the energy sector significantly reduces the amount of water used not only for fuel extraction and processing but also for electricity generation as well.

<i>Manufacturing</i>	<p>Manufacturing industries with efficient water use and low environmental impacts are favored and increase their competitive position against water intensive industries.</p> <p>Enhanced reuse of water and treatment.</p> <p>Widespread application of water-saving technologies in industry.</p> <p>Overall, both structural & technological changes result in decreasing industrial water use intensities.</p>
<i>Domestic</i>	<p>Significant structural and technological improvements in domestic water use intensity.</p>

Freshwater Ecosystems Health *work in progress ...*

Well-Being

Overview Relatively high economic growth in low-income countries reduces poverty, and a global focus on increasing equity also increases social cohesion, while maintaining high levels of social and cultural diversity within and across countries. There is a shift in emphasis from growth per se to well-being, equity, and sustainability. The overall standards of living are high.

Improved regional livelihoods.

Water Security Improved access to safe water

Health Improved health in developing countries.

Improved sanitation, and medical care.

Energy Access Improved energy access

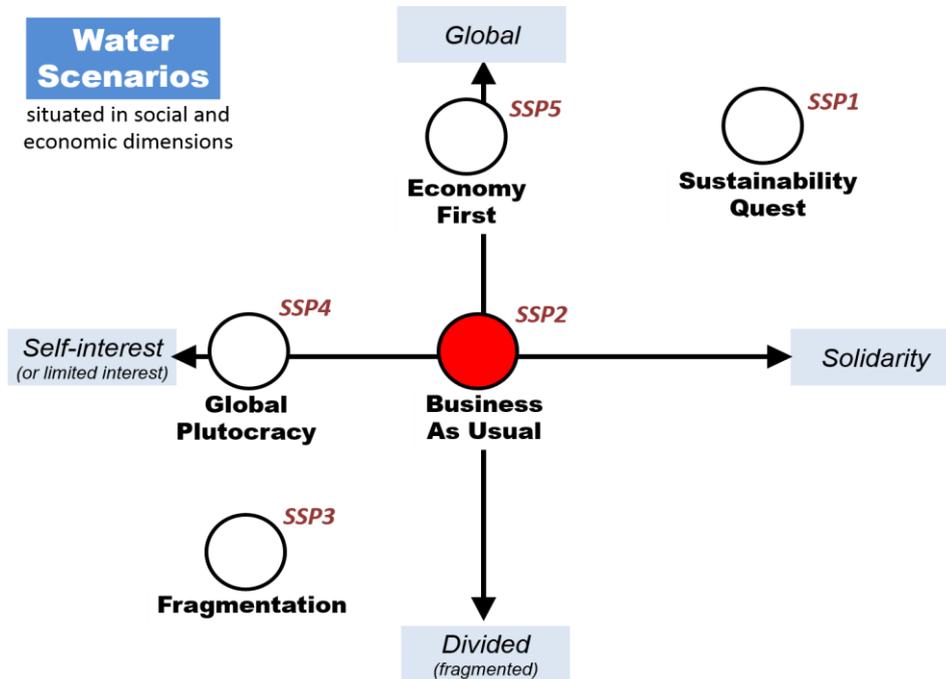
Food Security Improved food security.

Improved nutrition.

Equity Improved equity

2.2. SCENARIO 2: Business as Usual

Analysis based on SSP 2



2.1.3 Summary of Scenario 2

This world experiences only moderate progress towards a multitude of goals and interests. Development and income growth proceeds unevenly, with only some countries making relatively good progress. Most economies are politically stable. Globally connected markets continue to function imperfectly. Sustainable development goals are set for access to education, food, energy, safe drinking water, health care and a sustainable environment. Unfortunately, the dependence on water of achieving most of them and competition among them makes progress slow. Technological developments proceed apace, but without fundamental breakthroughs. Overall the intensity of energy use declines, with slowly decreasing water-dependent fossil fuel use. While improved weather forecasting is developed, it remains unavailable to those in less developed countries who need it to improve food production and reduce flood risks. Environmental systems experience more degradation, although economic benefits drive some improvements. 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 investments in low-income countries are not high enough to accelerate the transition to low fertility rates and slow population growth. This growth, along with persistent income inequality (globally and



within economies), stagnant institutions, societal stratification, and limited social cohesion, maintain challenges to societal and environmental change and constrain significant advances in human well-being.

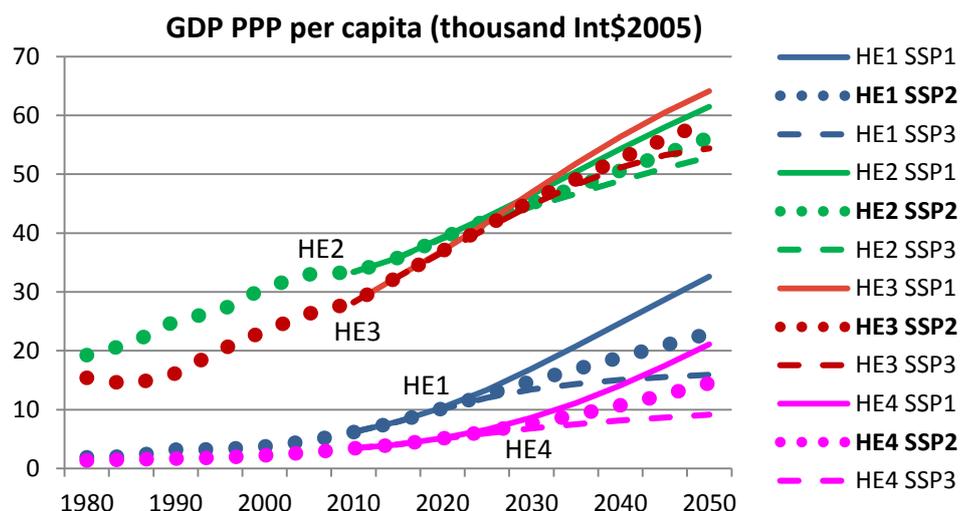
2.1.4 Analysis under Scenario 2

Nature

Climate Change	<p>Medium challenges to both mitigation and adaption.</p> <p>Only moderate success in reducing climate risks and vulnerability.</p>
Land Use and Agriculture	<p>Medium land use change regulation.</p> <p>Land use change is incompletely regulated, i.e. tropical deforestation continues, although at slowly declining rates over time.</p> <p>No effective measures to prevent pollution and degradation by agricultural practices; environmental risks caused by intensive application of fertilizers and agro-chemicals, and intensive and concentrated livestock production systems.</p> <p>Environmental systems experience degradation.</p>
<i>Land Productivity</i>	<p>Rates of crop yield increase decline slowly over time, but low-income regions catch up to a certain extent. Declining growth rate for high-income countries, converging rates for low-income countries.</p>
<i>Agricultural Technology</i>	<p>Moderate pace of technological change in the agricultural sectors.</p>

Economy

Economic Development	<p>High growth for some low-income countries. Emerging economies continue their rapid development for an initial period, but experience a slowdown as their economies mature. High-income countries continue to grow at moderate rates.</p> <p>Manufacturing GVA further declines in relative terms (as % of GDP).</p>
<i>Trade</i>	<p>Markets are globally connected but function imperfectly. Some trade barriers continue to exist. International trade remains to large extent regionalized.</p> <p>Access to global oil and gas markets continues to play a large role in international relations.</p>
<i>GDP</i>	<p>Development occurs at moderate rates on average.</p>



Inequalities Development with substantial differences on a regional level. Tensions within countries periodically threaten to boil over, but do so only rarely, and never catastrophically.

Tensions between countries periodically threaten to boil over, but do so only rarely, and never catastrophically.

Technology

Technology Development Technological progress but no major breakthrough.

Some international cooperation and investment in research and technology on providing access to modern energy and promoting sustainable development.

Technology Transfer New energy technologies developed in industrialized countries are only slowly shared with middle- and low-income countries, in part because of challenges to resolving intellectual property rights and other issues with technology transfer.

Sustainable Technologies Only moderate transformation toward environmentally friendly processes.

Energy

Continued reliance on fossil fuels, including unconventional oil and gas resources. Moderate pace of technological change in the energy sectors.

Regional diversity in energy demand and intensity.

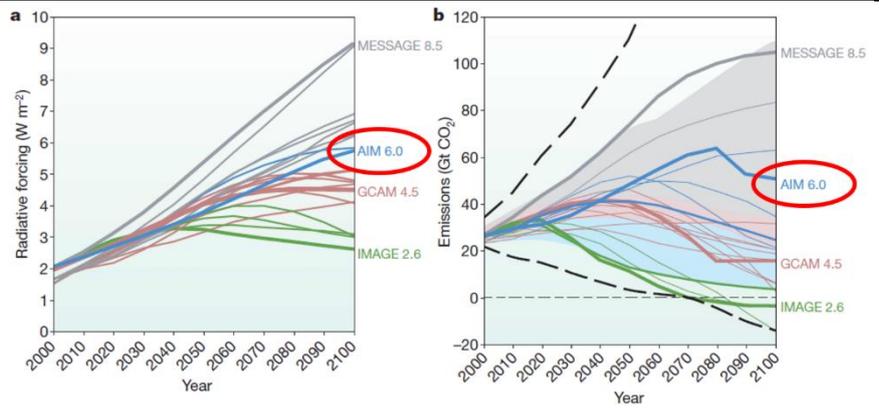
Energy Demand Intermediate phase-out of traditional fuel use, regionally diverse speed.

Medium service demands (generally material intensive).

Energy Intensity Medium energy intensity of services in industry, buildings and transportation.

Some progress towards reductions in energy and resource use intensity.

GHG Emissions (RCP) Representative concentration pathways



- c.** Changes in radiative forcing relative to pre-industrial conditions. Bold coloured lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing from ref. 47 and the larger set analysed by IPCC Working Group III during development of the Fourth Assessment Report.
- d.** Energy and industry CO₂ emissions for the RCP candidates. The range of emissions in the post-SRES literature is presented for the maximum and minimum (thick dashed curve) and 10th to 90th percentile (shaded area). Blue shaded area corresponds to mitigation scenarios; grey shaded area corresponds to reference scenarios; pink area represents the overlap between reference and mitigation scenarios.

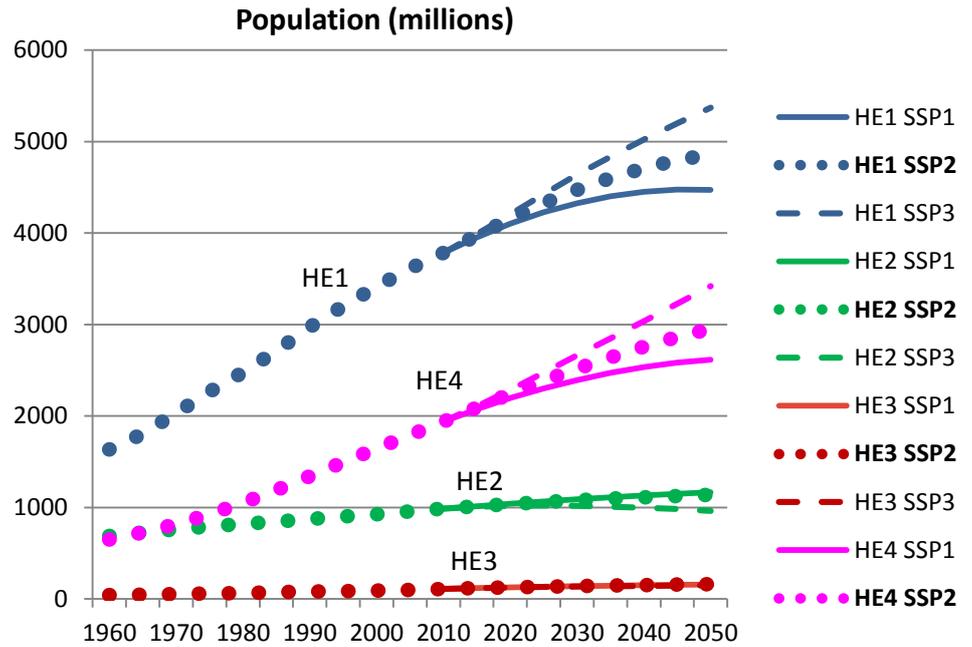
Society

Demography

Population

Population growth is moderate, with higher growth in low-income countries, slowing population growth in middle-income countries, and limited to negative population growth in most industrialized countries.

Migration between countries continues at intermediate levels owing to the restriction of labor markets.



Education Some progress towards universal education.

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

Urbanization Urbanization proceeds at rates and in patterns consistent with historical experience in different world regions.

Values, Lifestyles

Pro-environmental Values Moderate awareness of the environmental consequences of choices when using natural resources.

Consumption, Diets Consumption is oriented towards material growth.

Caloric consumption and animal calorie shares converge towards medium levels. Increasing per capita consumption of livestock products with growing incomes.

Governance

Policy Orientation

Quality of Governance Most economies are politically stable.

Moderate corruption levels and limited access to the rule of law slows effectiveness of development policies.

Environmental Policy

Global Cooperation Globally connected markets function imperfectly.

Relatively weak coordination and cooperation among national and international institutions, the private sector, and civil society for addressing environmental concerns.

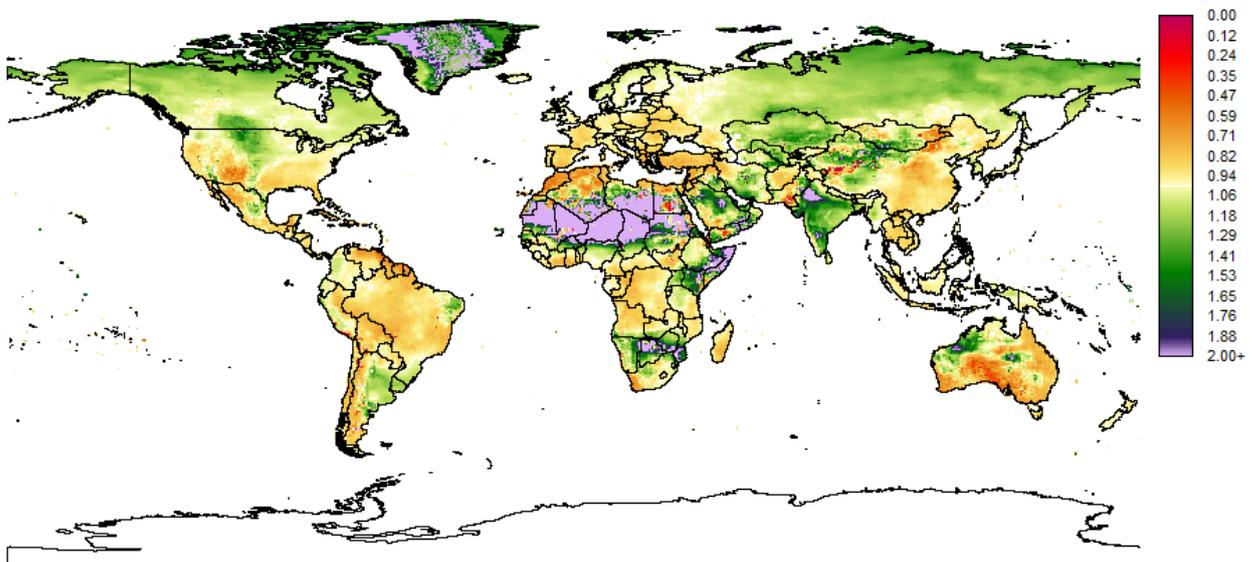
Water

Water Governance No effective halt to groundwater over-exploitation.

Water Infrastructure

Water Pollution Water pollution remains a significant problem in many (especially less developed parts of the world).

Available Water Resources The map below shows calculated ratios of mean annual runoff around 2050 relative to the base period 1971-2000. In these ratio maps values above 1 indicate an increase of mean annual runoff, values below 1 a decrease of future runoff.



Water Demand Weak environmental regulation and enforcement trigger only slow technological progress in water use efficiencies.

Some improvements of water use efficiency, but only limited advances in low-income countries.

In general, water use intensities will continue to decrease in the most developed regions. However, there will be slow progress in Africa, Latin America and other emerging economies.

Agriculture Further increase of irrigation cropping intensity with warming in most regions.

Medium growth of area equipped for irrigation.

Medium increase in irrigation efficiency.

Energy Reliance on fossil fuels may lead to only minor structural and efficiency shifts in technology.

Stabilization of overall energy demand over the long run will lead to little or no change in water demand for fuel extraction, processing and electricity generation.

A moderate pace in technological change will cause minor structural and efficiency shifts in technology and ultimately water use intensity will change only slightly.

Regional stress points will increase globally. Power generation in regional stress points will likely have to deploy more and more technologies fit for water-constrained conditions to manage water-related risks, though this can involve trade-offs in cost, energy output and project siting.

Manufacturing Moderate & regionally different decreases of manufacturing water use intensities.

Domestic Medium structural and technological improvements in domestic water use intensity.

Freshwater Ecosystems Health *work in progress ...*

Well-Being

Overview Slow progress in achieving development goals of education, safe water, health care.

Water Security Water and food insecurity remain as problems in some areas of low-income countries.

Health There is some progress towards access to health care.

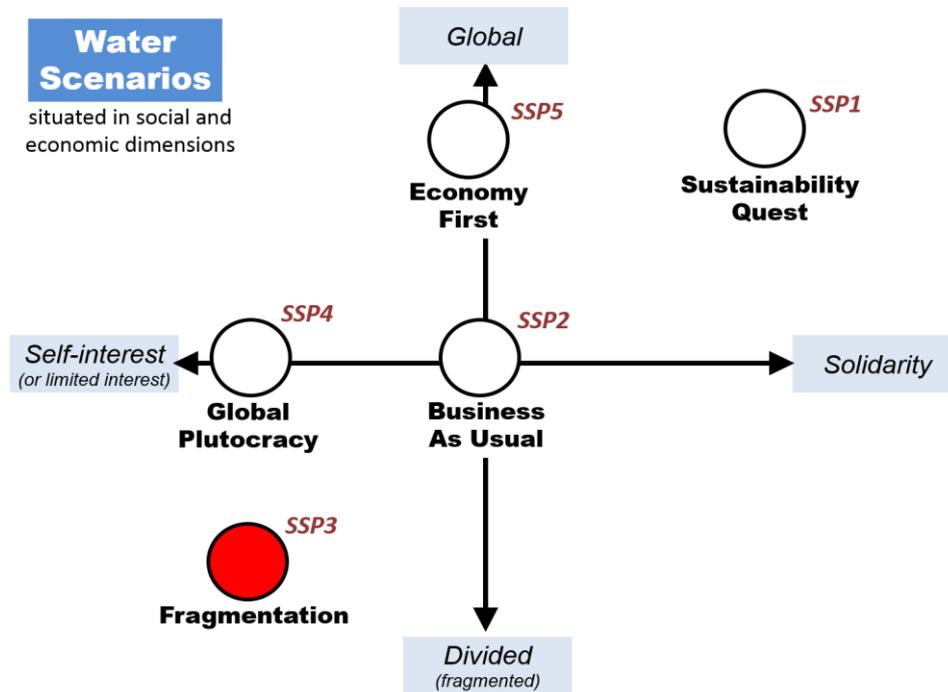
Energy Access Intermediate success in improving energy access for the poor.

Food Security Moderate progress in reducing food insecurity. Some reduction of food insecurity due to trickle down of economic development.
Food insecurity continue to be problems in disadvantaged areas of low-income countries.

Equity Societal stratification, and limited social cohesion.

2.3. SCENARIO 3: Fragmentation

Analysis based on SSP 3



2.1.5 Summary of Scenario 3

Strengthening regional identities, competitiveness between them and concerns for national security push countries to increasingly focus on domestic or, at most, regional issues. This trend is reinforced by the weakness of a number of global institutions, with uneven coordination and cooperation for addressing human well-being and environmental sustainability. Policies are oriented towards security, including barriers to trade, particularly in the energy resource and agricultural markets. Countries focus on achieving energy and food security goals within their own region, at the expense of broader-based development. A low international priority for addressing environmental concerns leads to environmental degradation in some regions. Water resources are considered to be the property of upstream countries which enjoy the precipitation without consideration of the needs of their neighbors. Population growth is low in industrialized and high in developing countries. There are pockets of extreme poverty alongside pockets of moderate wealth. Some countries



are struggling to maintain living standards and to provide access to safe water, improved sanitation, and health care for disadvantaged populations. In others, the wealthier have access to food, energy and safe drinking water and live in a clean environment without concern for their fellow citizens or those in neighboring countries. Global economic production increases through their contribution while they pay lip service to internationally agreed sustainable development goals and targets.

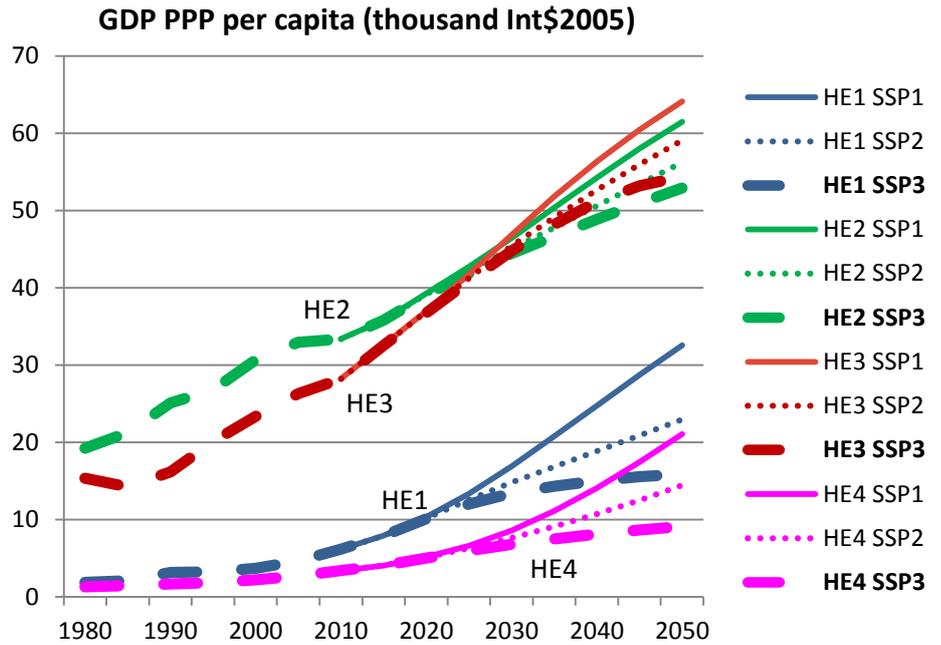
2.1.6 Analysis under Scenario 3

Nature

Climate Change	High challenges to both mitigation and adaptation.
Land Use and Agriculture	Land use change is hardly regulated, i.e. tropical deforestation continues at current rates. Growing protection of national agricultural sectors and increasing agricultural trade barriers. Low priority to halt environmental degradation caused by agriculture (erosion, deforestation, poor nutrient management, water pollution and exploitation).
<i>Land Productivity</i>	Lower rates of land productivity growth everywhere. Rates of crop yield increase decline strongly over time, due to little investment. • Widespread lack of sufficient investment and capacity for yield gap reduction in developing countries.
<i>Agricultural Technology</i>	
	Serious degradation of the environment in some regions.

Economy

Economic Development	Growing concerns about globalization and focus on national/regional issues and interests. Manufacturing GVA in relative terms (% of GDP) declines slower than historic trends.
<i>Trade</i>	The world has de-globalized, and international trade, including energy resource and agricultural markets, is restricted because of security concerns.
<i>GDP</i>	Slow economic growth in all regions.



Inequalities Persistent inequality within countries with pockets of extreme poverty alongside pockets of moderate wealth, with many countries struggling to maintain living standards.

World with high inequalities across countries separated into regional blocks with little interaction between them, resembling the Cold War period.

Technology Low technological capacity, and little investment in research and development

Technology Development

Technology Transfer

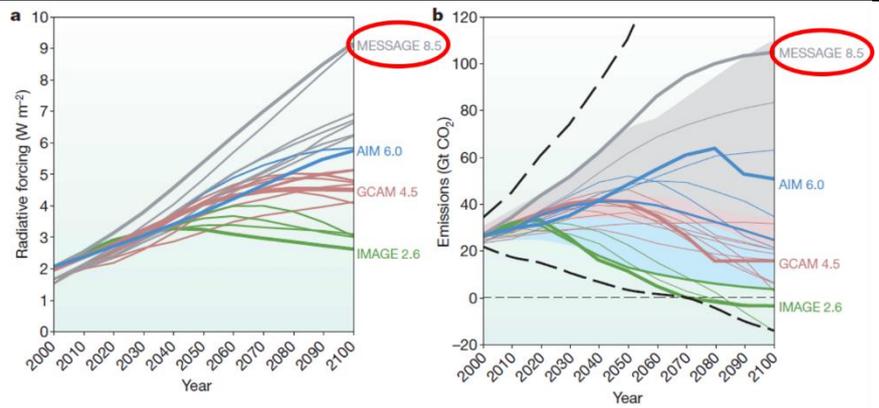
Sustainable Technologies

Energy Little progress in reducing fossil fuel dependency. Continued reliance on traditional fuels. Increase in resource use intensity. Reliance on fossil fuels leads to only minor structural and efficiency shifts in technology.

Energy Demand Increased energy demand driven by high population growth and little progress in efficiency.

Energy Intensity Medium energy intensity of services in industry, buildings and transportation.

GHG Emissions (RCP) Representative concentration pathways



e. Changes in radiative forcing relative to pre-industrial conditions. Bold coloured lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing from ref. 47 and the larger set analysed by IPCC Working Group III during development of the Fourth Assessment Report.

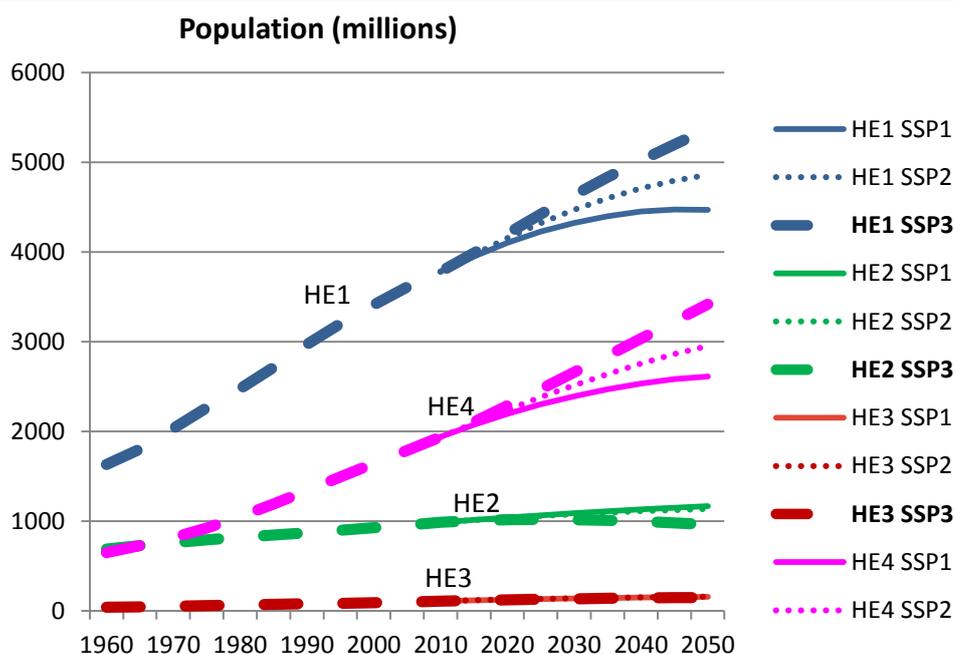
f. Energy and industry CO₂ emissions for the RCP candidates. The range of emissions in the post-SRES literature is presented for the maximum and minimum (thick dashed curve) and 10th to 90th percentile (shaded area). Blue shaded area corresponds to mitigation scenarios; grey shaded area corresponds to reference scenarios; pink area represents the overlap between reference and mitigation scenarios.

Society

Demography

Population

Global population growth is high. High mortality rates in developing countries, with many children dying from preventable diseases (malnutrition, diarrheal disease, malaria).



Education Low investments in human capital and education with poorly educated populations in some regions.

Urbanization Urbanization is slow in all regions. Disadvantaged populations continue to move to unplanned settlements around large urban areas, particularly in low-income countries.

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

Values, Lifestyles

Pro-environmental Values Low environmental awareness.

Consumption, Diets Unhealthy diets with high animal shares and high waste prevail.

Governance

Policy Orientation Countries focus on achieving energy and food security goals within their own region. Policies are oriented towards security, including barriers to trade.

Quality of Governance Government institutions dominate societal decision-making. Authoritarian regimes emerge or are strengthened in many parts of the world. The remaining participatory societies are increasingly bound by a strong ethic of supporting national priorities.

There is a considerable level of corruption from the entanglement of the private and public sectors.

Global governance and institutions are weak.

Environmental Policy Low priority for addressing environmental concerns.

Global Cooperation Growing concerns with respect to international competitiveness and national security, aided by renewed interest in regional identity and culture,

push societies to become more skeptical about globalization and increasingly focus on domestic or, at most, regional issues and interests. Global governance, institutions, and leadership are weak, also in addressing the multiple dimensions of vulnerability. There is a lack of or little cooperation and consensus because of the absence of institutions to facilitate global cooperative action.

Water

Water Governance

Water Infrastructure

Water Pollution

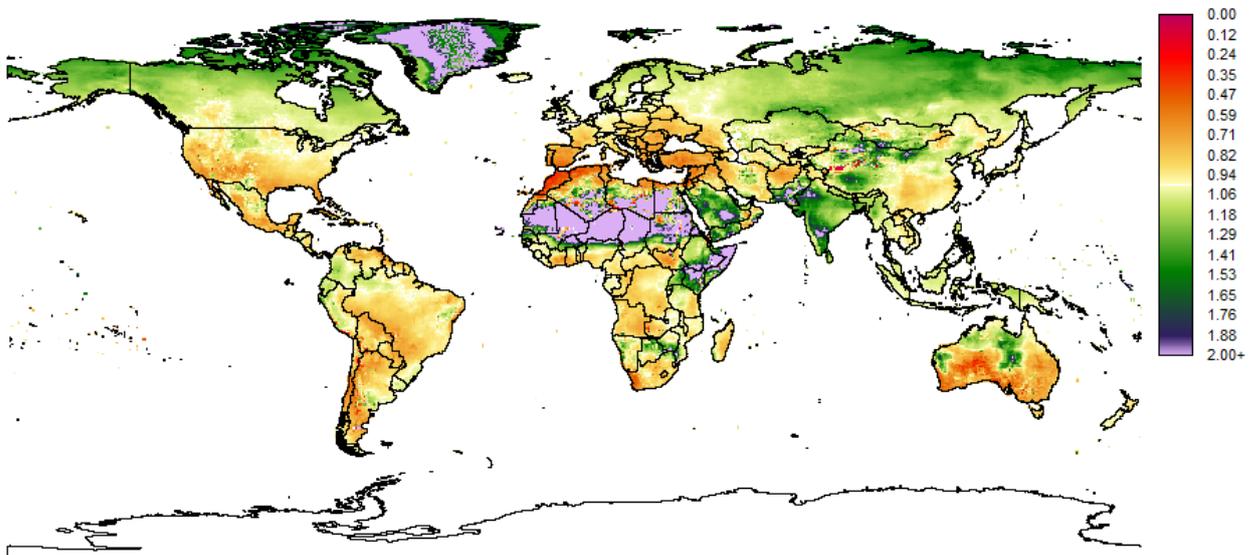
Available Water Resources

Persistent over-exploitation of groundwater aquifers.

Unreliable water and energy supply for agricultural producers.

The map below shows calculated ratios of mean annual runoff around 2050 relative to the base period 1971-2000.

In these ratio maps values above 1 indicate an increase of mean annual runoff, values below 1 a decrease of future runoff.



Water Demand

Barriers in trade may trigger slow technological progress in water use efficiencies. A moderate pace in technological change will cause minor structural and efficiency shifts in technology and ultimately water use intensity will change only slightly.

Weak environmental regulation and enforcement hamper technological progress in water use efficiencies, hence very low progress in water-saving technologies.

<i>Agriculture</i>	Further increase of irrigation cropping intensity with warming. Only modest improvements of irrigation water use efficiency. Area equipped for irrigation is expected to increase.
<i>Energy</i>	An increase in energy intensity will increase water demand where as little progress in efficiency would trigger increased water demand as energy use intensifies.
<i>Manufacturing</i>	Water use intensities increase only marginally, primarily in the most developed regions.
<i>Domestic</i>	Only small structural and technological improvements in domestic water use intensity.
Freshwater Ecosystems Health	<i>work in progress ...</i>

Well-Being

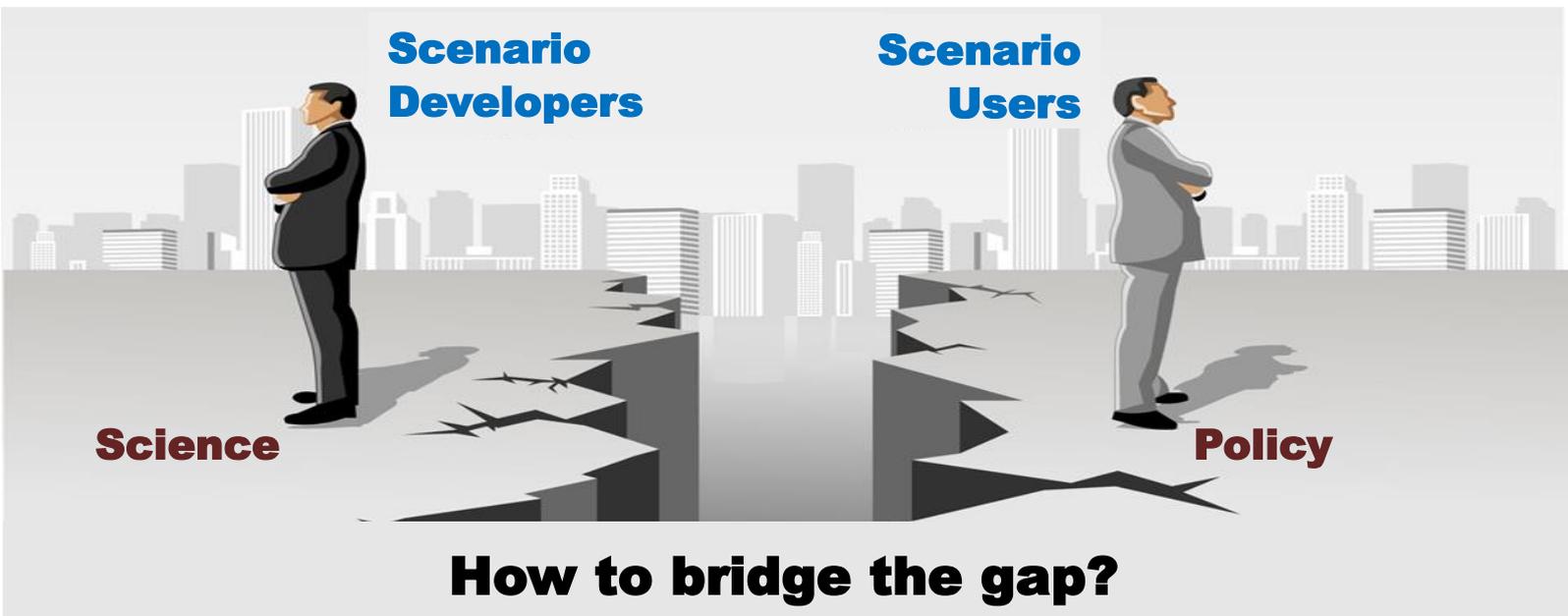
Overview	Failed attempts to achieve global development goals. Large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity. High population growth and insufficient development leave behind highly vulnerable human and environmental systems.
Water Security	Widespread lack of access to safe water and sanitation. Water insecurity persist as major problems in low-income countries.
Health	Many disadvantaged populations without access to improved sanitation and health care.
Energy Access	Widespread problems with energy access.
Food Security	Food insecurity persist as major problems in low-income countries.
Equity	Trends work against the reduction of social stratification, with little improvement for disadvantaged population groups.

3. Conclusions – challenges of the global water scenarios development

Global scenarios are significantly different than scenarios established in other decision domains. Although high stakes and deep uncertainties about the future make the case for using the scenario method to prepare ourselves for a wide range of future possibilities, a big challenge remains concerning how to address the specific needs of diverse user groups (see Parsons 2008). Users' engagement is considered critical to the effectiveness of scenarios (van der Heijden 1996). Scenario users jointly delineate their sphere of influence (where they can effectively make decisions and develop strategies) and a sphere of uncertainty (where they need to agree on most important but uncertain drivers and their possible trends).

When integrating scenarios across sectors and scales globally, the problem becomes for more complex due to overlapping spheres of influence and uncertainty. One single, small stakeholder group cannot be completely representative of all geographical, demographic, economic, institutional experience through all sectors, disciplines and scales. Drivers and decision variables also cannot then be fixed, since the drivers in one sector are the decision variables in another. Finally, scenario producers are not fully aware of the needs of all relevant decision and policy makers.

Another well known problem in developing global scenarios is that such scenarios tend to concentrate on variables that have available global data and can be easily aggregated (Parsons 2008). Variables that depend on local contexts are often discarded.



Despite the challenges, scenarios are useful to support policy-making process at different stages. Many reviews and evaluations of scenarios processes reveal that they have been quite successful in the business context, supporting strategic decisions at all stages of policy cycle. Their impact in the public sector has so far been mostly limited to the first stage of the policy cycle (Volkery and Ribeiro 2009), which can be called an indirect support. The beneficial uses of scenarios in this context are summarized in the table below.

Policy stage	Form of scenario-based decision support
Policy issue identification and framing	Stimulating wider debate about possible futures Getting stakeholders engagement and buy-in Clarifying issues importance with respect to stakeholders' needs and expectations Agreeing objectives
Policy measure development	Generating options for future actions Appraising robustness of options for future actions
Policy measure implementation	Using scenario framework and indicators for monitoring of results
Policy evaluation	Using shared understanding about stakeholders' needs, expectations and objectives as well as monitoring results to assess policy effectiveness and efficiency.

The distance from the more direct scenario-based decision support has been even greater for global scenarios. Many scenarios studies were described as “hollow diamonds, that sparkle alluringly but fail to contain real value to the decision-making process.” These findings stand in sharp contrast with the clear need for public policy at the global level to address future challenges and uncertainties. Can the success of the private sector in successful application of scenarios to tackle critical strategic problems be replicated?

Although this short analysis may sound pessimistic, many steps can be taken, and potential benefits are substantial even if moderate progress will be done. To this end it is recommended to establish a typology of scenario users and their needs to better tailor scenarios for those needs. Produced scenarios should be more transparent– especially with respect to judgments on uncertain factors. Finally there is need to institutionalize use of scenarios for policy development. Scenarios development and use is not a one-shot effort – its biggest worth lies in continued long term application, helping to achieve long-term goals in spite of complexity and uncertainty.

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