USING WATER WISELY

# Stylized Scenarios

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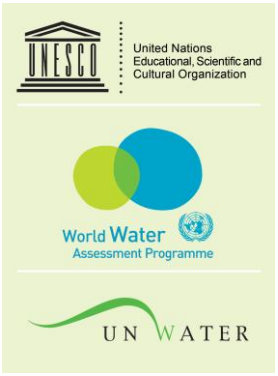

*This report provides an initial exploration of long-range global water scenarios as a contribution to the fourth* World Water Development Report (WWDR4). *Justification for the need to develop a new generation of World Water Scenarios is provided in Alcamo and Gallopín (2009). Rather than detailed descriptions, it offers qualitative summaries of possible futures as input to the deliberations of the Scenario Focus Group (SFG), the WWDR4's collective of decision-makers, modellers and scenario and sectoral experts. Since the present exercise is intended only as a first approximation, we refer to the alternative futures discussed as 'stylized scenarios'. The purpose is to open the discussion on the universe of possible trajectories of the world water system, with the likelihood that the scenarios generated ultimately by the SFG will be different from the ones sketched here.*

## The scenario approach

Special challenges arise when attempting to explore the future of water as a global issue. First, a long-term perspective is needed in order to account for the slow unfolding of hydrologic and some critical social processes and the impacts of new water infrastructure. Second, there are methodological problems in how to gain this long-term perspective. It would seem logical to use forecasting techniques to estimate future water use and water resources. But although they may be reliable over the short term, predictive forecasts become untrustworthy as the time horizon expands from months and years to decades and generations due to error accumulation, our limited understanding of human and ecological processes and the intrinsic indeterminism of complex dynamic systems (Gallopín, 2004). The third challenge arises from the dependence of future water conditions on human decisions that are yet to be made.

The term scenario has been introduced into the planning literature to mean 'a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points' (Kahn and Wiener, 1967). It is important to emphasize that scenarios are not projections, forecasts or predictions. Rather, they are stories about the future with a logical plot and narrative governing the manner in which events unfold (Schwartz, 1991). Scenarios usually include images of the future – snapshots of the major features of interest at various points in time – and an account of the causal flow of events leading from the present (or the base situation) to such future conditions.

Scenario development typically involves the following elements:

- Characterization of the *current situation*, with a diagnosis of the starting state of the scenarios, focused on the focal issue or problem under consideration (water in this case).
- Identification of major *driving forces* that represent the key factors, trends or processes that influence the situation, focal issue or decisions and that propel the system forward and condition the story's outcome.

Some of these forces are *invariant* (e.g. they apply to all scenarios) and to a large extent predetermined. Some of the driving forces may represent *critical uncertainties*, the resolution of which can fundamentally alter the course of events. These driving forces (or drivers, for short) influence but do not completely determine the future. Thus, while the initial state of the drivers is the same in all scenarios, the trajectory of the system follows a different course in each one.

- Formulation of the *plot* – the current state, driving forces, strategic invariants and critical uncertainties form the backbone of the scenarios. In addition, all scenarios unfold according to an internal logic (the plot) that links the various elements.
- Construction of an *image of the future* – the endpoint is a snapshot of the future resulting from the unfolding of the scenario.[1]
- The scenarios and their images are assessed according to previously selected *critical dimensions (*Gallopín and Rijsberman, 2000), which jointly define the most important attributes of the alternative futures.

In the present first exploration, only the driving forces and the critical dimensions are discussed further; the plots are barely sketched under each of the scenarios, and the final image of the future is simply represented by the relative values of the critical dimensions.

## Time horizon

The time horizon of the scenarios is between 20 and 40 years (i.e. somewhere between 2030 and 2050), although a longer horizon (e.g. up to 2100) should also be considered in order to take into account the impacts of long-term changes in climate, land use and socio-economic driving forces. The longer the time horizon, the more difficult it becomes to have a reasonable assessment of what could happen; on the other hand, there are some slow but crucial processes that may not manifest themselves in the shorter time scales. The final choice should be made by the SFG, after assessing the trade-off between scales.

## Driving forces

A number of major clusters of potential driving forces for consideration of the scenario panel are identified here. Some were included in the third edition of the *World Water Development Report* (WWAP, 2009), some were identified by the scenario panel that defined the scenarios of the World Water Vision (Cosgrove and Rijsberman, 2000), some were identified by the author of this report and some were suggested by William Cosgrove and Jerome

[1] This is the case for *exploratory scenarios*, which probe the future starting from the present; *normative* (also called *backcasting) scenarios* begin with a description of the desired image and work backwards to the present.

Glenn. In identifying the major drivers, a literature review was conducted and experts consulted (WWAP, 2011). These clusters are believed to cover the key trends, processes or 'developments' that influence the futures of the world water system. (Other important forces that do not impinge strongly upon the water systems are not included here.) A development as used here is simply one of the specific driving forces, trends or processes included within one cluster. The SFG might select a subset of the forces identified below, cluster together some of them (some are correlated, such as economic growth and pace of technological innovation) or select other forces not identified here. Hopefully, the driving forces listed below represent a fair coverage of the important factors.

### Demographic

- Demographic evolution (birth and death rates, fertility rate, etc.)
- Changed life expectancy and morbidity as result of changes in water-related diseases and other medical/health conditions
- Migration trends (mainly from poor to rich countries, but also between developing countries, especially in relation to environmental refugees (including those affected by climate change) and to people displaced by national armed conflicts (including conflicts over water) and resource degradation (including pressures on land use, e.g. deforestation and urban spread)
- Water-related diseases affecting humans
- Urbanization trends (rapid increase in developing countries, far above population growth)
- Populations living in fragile nations and regions
- Changes in demographic structure (especially increasing senescence of the population in industrial countries and the growing fraction of working-age population, with concomitant demands for job creation, in developing regions); the impacts on water will be mainly indirect, through economic and social factors

### Economic

- Economic growth and type: high or low throughput of energy and matter, particularly water); water infrastructure development; increasing prosperity in many developing countries
- Demand for food, energy and other natural resources
- Global trade (including virtual water trade)
- Economic globalization (increasing interdependency among nations; possibility of new global economic crisis – and synergies)
- Cost of food, water and energy (implications for hunger and poverty, and competitiveness of alternative water-related technologies, e.g., desalination, solar, irrigation, etc.)
- Evolution of capitalism through qualitative change

### Technological [2]

- Technological innovation and dissemination (new and improved sources of energy[3], communication and information technologies, biotechnology, automation, new materials, nanotechnology); increases in water use efficiency; cost-effective desalination technologies; technologies to reduce water pollution; water decontamination techniques; development of new crops (i.e. salt-tolerant varieties); desalination plants; traditional and science-based eco-technologies, new water storage and transportation technologies
- Changes in water productivity, water use and use efficiency
- Weather manipulation and control
- Improvements in sensors and remote-sensing systems to assess water quantity and quality
- Rate and significance of technological development and diffusion (such as low cost desalination and eco-technologies, saltwater agriculture and growing meat without animals)
- Access to modern information technology and sources of information
- Fundamental scientific discoveries (such as new catalysts that make low cost extraction of hydrogen from sea water practical)

### Water resources

- Water stocks, including geographic and temporal distribution, renewability, quality and availability (as affected by climate change, by ecosystem processes, by agricultural, industrial and drinking consumption and by technology employed)

### Water infrastructure

- Proportion of infrastructure designed to meet multiple needs
- Changes in water infrastructure design (i.e. from massive to small-scale and flexible; integration of ecosystems into infrastructure)
- Ratio of water stored to potential for storage
- Transbasin and transboundary water transfers
- Obsolescence of existing waterworks (e.g. due to climate change as well as ageing)

[2] Care should be taken in distinguishing innovations that might be operative within the time horizon of the scenarios (i.e., cheap desalination and water decontamination methods, synthetic photosynthesis and even nanotechnological developments related to water extraction, efficiency and storage) and those that might be available beyond that horizon or not at all (i.e. space-based solar energy stations, exploitation of ice-asteroids, weather management, etc). Nuclear fusion might lie within or outside the time horizon of the scenarios, depending on the expert consulted.

[3] Classifying energy within the technological cluster is somewhat arbitrary; it could as well be included in the environmental cluster, being one of the natural resources available from the biosphere-geosphere.

- Changes in groundwater reserves and withdrawals
- Level of overpumping of groundwater and mining of fossil aquifers

### Global climate change

- Climate change and variability and their impacts on precipitation, runoff and water storage, quality and distribution across space and time
- Increasing frequency of extreme climatic events (i.e. droughts and floods)
- Changes in agro-climatic zones
- Changes in the hydrological systems and likely obsolescence of existing waterworks (bridges, dams, irrigation systems) as the historical hydrological parameters no longer hold
- Spread of alien species (including pests and pathogens) as habitats change
- Rising sea levels (flooding of deltas and coastlines and aquifer intrusion)
- Shrinking lakes and reduced streamflow due to changed precipitation patterns, mountain glacier melting and increased evapotranspiration in many regions

### Environmental (including agriculture)

- Environmental impacts of mitigation and adaptation measures adopted in response to global climate change
- Possible trespassing of global tipping points (Lenton *et al.*, 2008) and new and emerging environmental surprises
- Water-related diseases
- Agricultural soil erosion and degradation (salinization, fertility loss, etc.)
- Changes in the extent and volume of irrigation
- Changes in agricultural water productivity
- Impacts of agrochemical on water quality
- Groundwater depletion
- Deforestation
- Deterioration of ecosystem health
- Loss of biodiversity from habitats to genes (processes that strongly interact with global climate change) and implications for food production, global human health and migration pressure
- Changes in value of ecosystem services related to water
- Changes in land use patterns

**Social, cultural and ethical**

- Poverty[4] and inequality (affecting conflict potential, migration pressure, local and global environmental degradation, local and global human health and population growth)
- Culture and values (including global cultural homogenization and shifts in ethical, religious and spiritual values) as they affect lifestyles and consumption patterns
- Education and capacity-building in relation to awareness as regards overconsumption, waste and unsustainability of current consumption patterns, and specifically on water use, management and conservation
- Global networking of people across different areas of concern
- Evolution of lifestyles and consumption patterns (from heightened consumerism to greater preference for non-material dimensions of quality of life and commitment to sustainability); changes in food preferences
- Public acceptance of genetically modified crops in the South and the North
- National food self-sufficiency versus global food security
- Number of people without reasonable access to reliable safe water supplies and sanitation services
- Equity in access to water, sanitation, education, food and employment

**Institutional/governance** [5]

- Proactive decision-making (anticipating policy consequences and negative impacts)
- Global, national and local water policies, regulations and laws
- Functioning water resource and use of monitoring and reporting systems in place
- Integration of water resource management with national development planning
- Effective and efficient water management at national and river basin levels involving government and nongovernmental organizations
- Transboundary basins with information sharing and cooperative integration of water management into national socio-economic development plans
- Farm subsidies
- Access to effective water information systems
- Changes in corporate behaviour (i.e. corporate social responsibility)
- Degree and pervasiveness of corruption



[4] Poverty represents a deprivation of basic human needs and its eradication is central to the MDGs; here, only the most direct links between poverty and the water system are highlighted.

[5] Some belong to the water sector, but most are broader of necessity.

- Global security trends: national and regional water conflicts; international conflict arising from global inequalities; expansion or mitigation of global terrorism, international crime, arms traffic, drugs traffic; new mechanisms for conflict resolution[6]
- Potential for use of water or water infrastructure as a medium for biological terrorism

**Political [7]**

- Global power structure (e.g. from a unipolar to a multipolar world); weakening or strengthening of multilateral and intergovernmental decision-bodies (e.g. the United Nations); implications for global equity, enforcement of international agreements and law and global sustainability
- Possible trends towards isolationism versus increased interdependence
- Steering of the globalization process in its multiple dimensions to minimize negative impacts and conflict in a setting of increasing interconnectedness
- Trends in global cooperation through policy initiatives, such as the Millennium Development Goals (MDGs), and their prospects for implementation
- Development policies and aid to economically weak and water-stressed countries
- Evolution of democratic forms of government and public participation

The distinction between *driving* and *driven* forces is not always clear-cut. Many drivers are in turn driven by other forces; for instance, environmental changes impinge upon the world water system but are also the consequences of other drivers or of changes in the water system itself (e.g. climate change is a clear driver of the world water system but is also driven by population and economic changes; soil erosion affects the water cycle and land use, impinging back upon the water system). The causal diagram introduced next illustrates such circular causality clearly.

## The causal links between drivers

Each of the reviewers of the cluster of driving forces (WWAP, 2011) was asked to describe and rank the causal links between each development or specific driving force in the reviewed cluster with the other driving forces as 'strongly important', 'somewhat important' or 'not relevant'. The reviews included in most cases a description of the linkages, but they usually did not distinguish the direction of the link (to or from the other drivers). In any event, an overview of

[6] Obviously important per se, security factors are included here because they directly affect the potential for sustainable and equitable management of water resources and their watersheds, as well as the prospects for international cooperation on water issues. (There are worrisome signs that concerns for security have recently displaced development issues in the international agenda.)

[7] Here referring mostly to global and geopolitical aspects.

the importance of the linkages between the drivers as perceived by the reviewers may be gleaned from Figure 1. The figure shows an incidence matrix[8] in which the number in each cell represents the average (over all developments or specific driving forces) strength of the causal links between clusters of driving forces.[9] The ways drivers affect each other are discussed in the Drivers Report (WWAP, 2011).

| | No. Developments | Water resources & ecosystems | Climate change | Governance (Institutions) | Technology | Economy and Security | Agriculture | Infrastructure | Demography | Ethics, society & culture | Politics |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water resources and ecosystems | 10 | | 3.0 | 2.7 | 2.8 | 2.8 | 3.0 | 2.8 | 2.5 | 2.0 | 2.0 |
| Climate change | 1 | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Governance (Institutions) | 12 | 2.8 | 1.7 | | 2.9 | 3.0 | 2.9 | 2.8 | 3.0 | 3.0 | 2.8 |
| Technology | 7 | 2.7 | 2.7 | 3.0 | | 2.9 | 2.7 | 2.1 | 2.9 | 2.4 | 2.0 |
| Economy | 7 | 3.0 | 3.0 | 3.0 | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Security | 6 | 2.5 | 2.2 | 2.7 | 2.2 | 2.5 | 1.3 | 1.3 | 1.7 | 3.0 | 3.0 |
| Agriculture | 7 | 2.4 | 2.6 | 1.4 | 2.7 | 2.4 | | 1.9 | 1.9 | 2.4 | 1.9 |
| Infrastructure | 5 | 3.0 | 2.2 | 2.2 | 2.2 | 2.8 | 3.0 | | 3.0 | 2.0 | 2.2 |
| Demography | 3 | 3.0 | 3.0 | 3.0 | 2.0 | 2.7 | 3.0 | 2.7 | | 3.0 | 2.3 |
| Ethics, society and culture | 7 | 2.9 | 5.4 | 2.4 | 2.7 | 2.6 | 2.9 | 2.4 | 2.7 | | 2.3 |
| Politics | 14 | 2.3 | 2.3 | 2.2 | 2.5 | 2.0 | 2.3 | 2.4 | 2.4 | 2.0 | |

**Figure 1.** The number of developments of the driver distinguished by the author of the review of the driver appears in the first column after the name of the driver. The value in the rest of the cells is calculated by averaging the values (3=strongly important; 2=somewhat important; 1=not relevant) assigned to the link between each development or component of a given driver in the row and the other driver in the corresponding column. The values range from a minimum of 1.3 to a maximum of 3.0. This range is divided into three equal intervals: values less than or equal to 1.9 are considered to have lower importance (yellow), values between 1.9 and 2.4 have medium importance (orange), and values above 2.4 have higher importance (red).



[8] Because the Security driver was separated from Economy after the exercises started, unbeknownst to the other authors, no one but the author dealing with Economy and Security allocated a link to it; thus the matrix does not have the same number of rows and columns.

[9] Of course, as the ranks are not real numerical variables, this is just a rough indication, not a proper mean; besides, the 'average' is calculated as if all developments had the same weight.

From even this crude matrix we can draw some tentative conclusions: 1) The links supposedly represent causal relationships (rather than final impacts); this is useful information for both scenario builders and modellers. 2) All reviewers see their drivers causally linked to all the others, with most of the links viewed as 'strongly relevant'.[10] 3) Some authors lumped 'influences from the considered driver' with 'influences from other drivers upon the considered driver'. The second conclusion is the most useful, as presumably the author of the report on a driver cluster is the best judge of which other drivers have a causal influence on it.

## The overriding drivers and major causal links

For the purposes of initiating discussion on potential scenarios, the driving forces considered to be the most dominant in determining the sustainability of the world water system within the time horizon of the exercise were grouped into a more inclusive set of clusters. Considering that the major focus of the World Water Scenarios is the future of water availability in terms of its impacts on human well-being (including the health of the ecosystems on which it also depends), some of the principal causal links to be considered in building the logic (or plot) of the scenarios have been tentatively identified.

Figure 2 represents a systemic arrangement of drivers and their relations for conceptual purposes (in which the arrows are not directly derived from Figure 1). It shows that water stress and sustainability (top oval) are a direct function of the water resources available and of water withdrawal and consumption. In turn, both resources and consumption variables depend on many factors[11] (only the major factors and links relevant for water scenarios are shown here). Human well-being (middle oval) and water are two central criteria to assess the desirability of the scenarios. The main drivers are arranged in the figure in a sequence from top to bottom showing the *direct drivers* (top row of boxes) that directly impinge upon water stress and sustainability and the *indirect drivers* (bottom row of boxes) that exert their effect mostly through their impacts upon the proximate drivers. The arrows indicate causal influences between factors. Note that in some cases there is reciprocal (feedback) causality between them, indicated by an arrow with two blue heads. Figure 2 represents a systemic arrangement of drivers and their relations for conceptual purposes (in which the arrows are not directly derived from Figure 1).



[10] It is to be expected that the criteria to allocate categories of importance vary across the different authors, so a strict comparison would require a discussion (directly or by using a Delphi technique) involving the authors in order to converge on common criteria.

[11] As discussed in the previous section, all drivers are to some extent interlinked; thus, Figure 2 is clearly a prioritized simplification made for the purpose of clarity.

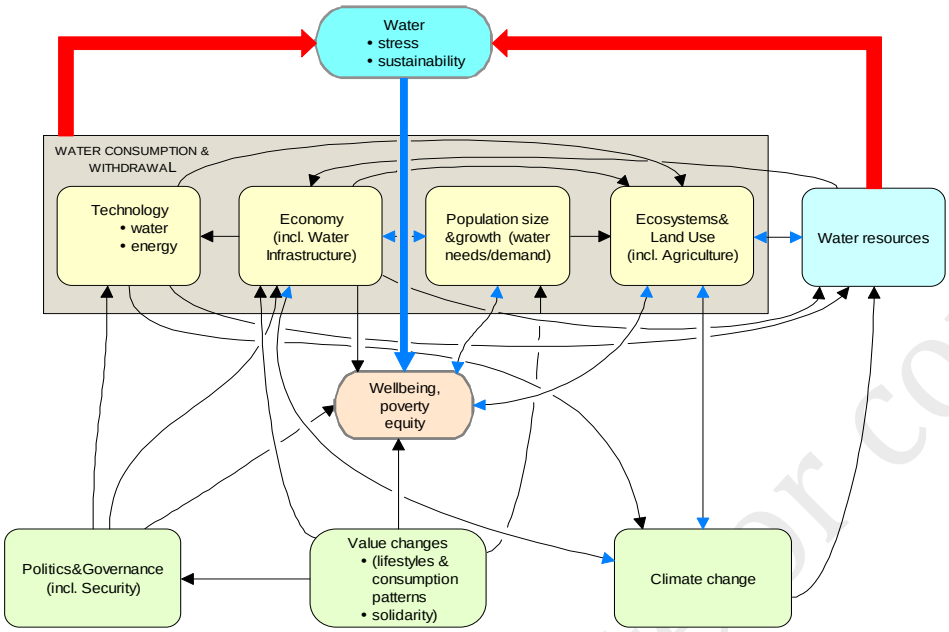


**Figure 2.** Key drivers and causal links affecting water stress and sustainability and human well-being. See the text for further explanation.

## Critical dimensions

The critical dimensions of the scenarios define, collectively, the multidimensional space within which scenarios are mapped or constructed. Dimensions do not necessarily imply causal assumptions; rather, they are defined in terms of their salience as descriptors of the most important attributes of the images of the future. They are the fundamental indicators used to evaluate the desirability and sustainability of the alternative futures.

Selected from elements of the driving force clusters, nine dimensions are suggested as crucial (see Figure 3) in the sense that, taken together, they give a sense of the quality and sustainability of the scenario endpoint:

1. Water stress
2. Well-being (quality of life, poverty, equity)
3. Population growth
4. Values and lifestyles
5. Economic growth
6. Technological development
7. Climate change
8. Ecosystem health
9. Global cooperation

Note: desirable and undesirable values of each of the nine dimensions are denoted in the figure by text in green and red, respectively.

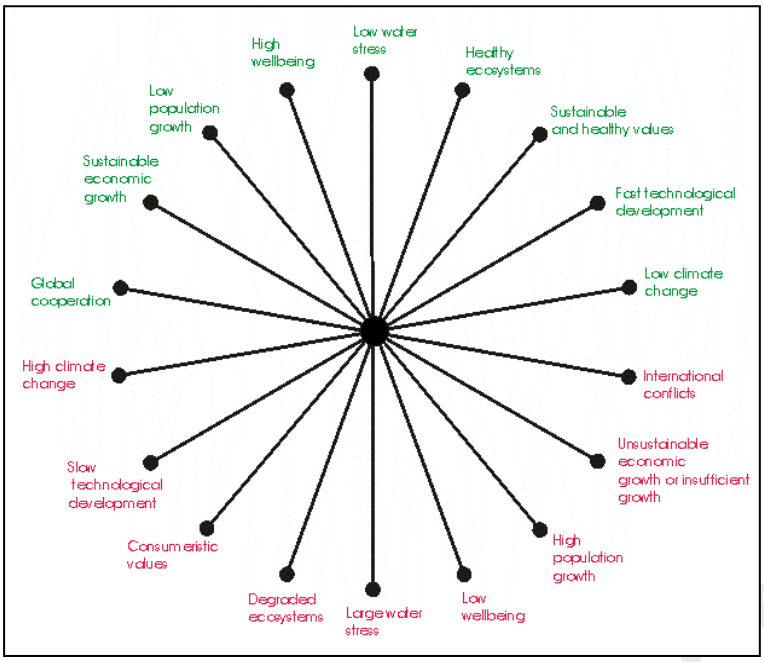


**Figure 3.** Critical dimensions.

## The stylized Scenarios

Five contrasting possible scenarios are sketched here, intended as input to the in-depth scenario development effort of the SFG. We present summary descriptions of the unfolding processes propelling the scenarios or, in other words, the plots and the logics of the scenarios. The plot narratives are outlined below with reference to the nine critical dimensions discussed above. Figure 4 presents a broad summary of the final image of the scenarios in 'radar diagrams', with values of the dimensions ranging from zero to three. With this semi-quantitative subjective illustration of the images it is possible to easily compare the outcomes of the different scenarios.

A sixth vision scenario should probably be added, reflecting the shared aspirations of the decision-makers and experts representing stakeholders from different parts of the world that collectively constitute the SFG. Obviously, this yet-to-be developed vision cannot be defined here, although it is hoped that aspects of the five stylized scenarios could be used as a departing point.

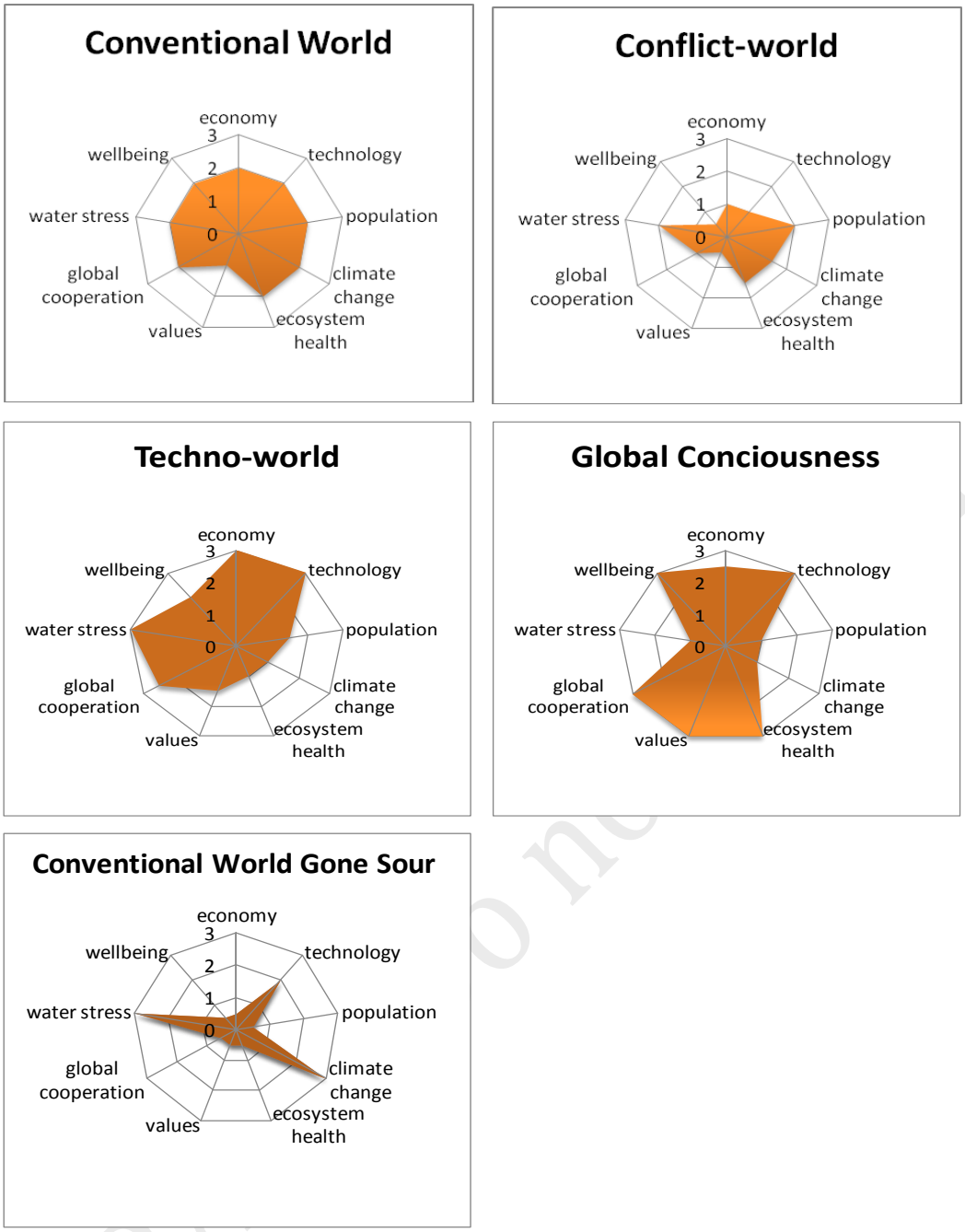


**Figure 4.** Ranking of fundamental traits of the final state of each scenarios. Depending on the indicator, higher values may be better or worse with respect to sustainability goals.

### Scenario 1: Conventional World

This is the reference, or 'business-as-usual', scenario. It is emphatically not a projection (linear or otherwise) of current trends but a scenario based on what could be expected according to widespread conventional expectations about the future, including an exacerbation of current trends and the assumption that the behaviour of decision-makers in governments and societies in the next few decades will not be substantively different from that exhibited in

the last 40 years (i.e. finding solutions to short-term problems without considering the long view), all operating within the constraints of the currently known laws of the physical world.

*Global economy:* Resumes growth after the financial crisis of the end of the last decade, with more efficient control systems in place but without major changes. Growth is propelled increasingly by the emerging countries. However, a significant number of countries do not share in the benefits.

*Population*: Continues increasing but not as fast as in the past.

*Technology*: Vigorous technological innovation and dissemination continues, leading to increasing water use efficiency and sanitation deployment but at a pace insufficient to cope with the growing requirements.

*Climate change*: Intensifies due to insufficient political will and growing consumption pressures; towards the end of the period, more substantive measures are taken, but their mitigating impact will only be felt with a lag of decades.

*Ecosystem health*: Agricultural lands (both rainfed and irrigated) expand, driven by increasing food demand and diet preferences shifting towards animal products. Terrestrial and aquatic ecosystems continue the trend of gradual degradation, aggravated by deforestation for agricultural lands and urban expansion, widespread pollution (despite increased controls in many countries) and the shifting of ecoclimatic zones associated to climate change. While agro-ecosystems adaptation is promoted through the use of new varieties and crop systems, many natural ecosystems dominated by slow-growing organisms (forest, tundra, etc.) disappear or are drastically reduced.

*Global cooperation*: The international political order increasingly concentrates on security issues, with development concerns lagging. Many of the MDGs are not reached by the 2015 deadline, and progress is uneven across goals and regions. Cross-boundary water-related conflicts escalate in dry regions. The world becomes more multipolar, but power is still concentrated in a minority of countries.

*Values*: Consumerist values predominate, with some (very minor) subcultures adopting alternative lifestyles. Individual self-interest and myopic visions are the norm.

*Water stress*: Underground water resources are depleted in most nonhumid regions of the world due to excessive withdrawal. Surface runoff is also widely affected by increasing withdrawals as well as by increased evaporation and evapotranspiration and shifting precipitation patterns across space that are associated with global warming. The frequency and severity of extreme weather events escalates. Water stress becomes critical in arid regions, especially in the developing world, and the rising uncertainty and vulnerability of the water system affects societies, economies and ecosystems.

*Well-being*: Global absolute poverty persists, although there are modest decreases in relative poverty (the fraction of total population in poverty). Inequality keeps increasing within and between countries, feeding conflicts and the exclusion of billions of the global poor.

**Scenario 2: Conflict-world**

*Global economy*: The global economy resumes sporadic growth after the global financial crisis but enters into a long instability phase with many ups and downs.

*Population*: Continues increasing but not as fast as in the past.

*Technology*: Technological innovation stagnates, affected by the turbulent economic situation, with the exception of military and security technology. Technological dissemination becomes erratic, affected by a general climate of isolationism and mistrust.

*Climate change*: Climate change is subject to competing pressures: on the one hand, lack of international agreement and cooperation on required actions exacerbates problems, but on the other hand economic downturns moderate global emissions. On balance, emissions tend to grow slower than in the Conventional World scenario, but they still increase.

*Ecosystem health*: Agriculture expands and/or intensifies in all countries in an attempt to reach the maximum possible food self-sufficiency. The strong push to intensify/expand agriculture (including use of marginal and fragile lands) results in deforestation and encroachment of natural ecosystems and increases agrochemical pollution, affecting the quality of watercourses and contaminating aquifers. On the other hand, the growth rate of industrial pollution is contained because of the volatile trends in the general economy.

*Global cooperation*: Economic instability leads to increasing conflicts associated with inequality within and between countries and the exclusion of the poor masses. Global terrorism thrives. In this general climate of discord, water-related conflicts flare up and expand beyond the countries directly involved. International migration barriers are increased in rich countries. An incipient trend towards militarization of international relations keeps gathering momentum. Trends towards economic and political isolationism are visible, despite some circumstantial alliances based on short-term interests. International governance weakens, and military governments take power in many countries.

*Values*: Consumerism remains a personal goal for most people, but individual self-interest and paranoid mistrust dominate.

*Water stress*: Security and military concerns siphon resources away from the building and maintenance of water infrastructure (dams, pipelines, distribution networks), resulting in their gradual degradation. Water stress increases, due mostly to the unrestricted expansion of irrigated agriculture and the deterioration of the water infrastructure. The shifting of climate zones and increased frequency of extreme weather events due to climate change, combined with the deterioration and obsolescence of waterworks, generate new zones of high water stress (but also mitigates aridity in some areas due to increased precipitation).

*Well-being*: Absolute and relative poverty increase in many regions of the world. Fear and anxiety, along with mistrust of the 'other', characterize the mood of the times; the general quality of life in both its objective and subjective dimensions diminishes.

**Scenario 3: Techno-world**

*Global economy*: After the dip in the late 2000s, the global economy resumes vigorous growth. The lessons of the global financial crisis are learned, and a radical redesign of national and international economies is implemented. Global markets expand continuously, but wealth continues to be highly concentrated in the major corporations. Some very poor countries remain excluded from the global economy. Due to water scarcity, global economic expansion slows by the end of the period, threatening to stagnate in the longer time horizon.

*Population*: The rate of growth gradually declines in association with increased prosperity in a rising number of countries. At the same time, average per capita consumption increases; this factor dominates and results in unprecedented global demand for goods and services.

*Technology*: The pace of technological innovation accelerates. The new capitalism pushes against its material and energetic limits by investing in new technological solutions. Recognizing the economic risk of climate change, increased efforts towards harnessing nuclear fusion succeed near the end of the period. Gigantic spatial mirrors are used to channel concentrated solar energy towards Earth, providing large sources of non-carbon energy. Ocean fertilization to increase uptake of carbon dioxide by microalgae is attempted massively. Energy and material efficiency is increased in all phases of production and consumption, mitigating but not eliminating the impact of the increased throughput. Point-source chemical pollution is effectively controlled in most countries, but the cumulative effect of diffuse pollution persists. Natural forests are increasingly replaced by engineered agroforestry systems, with artificial plantations combined with agricultural land for optimizing production while sequestering carbon. Technological solutions, including 'social engineering', are sought for all major problems.

*Climate change*: As the result of the phasing out of carbon-based sources of energy and the increased absorption of carbon, the greenhouse effect is effectively mitigated, although due to lags in the global climate system the impacts of past emissions continue unfolding during the whole period.

*Ecosystem health*: Despite the mitigation of climate change, the pervasive interventions such as climate manipulation, ocean fertilization, tampering with the food chains and the integrity of ecosystems, biodiversity loss, etc., trigger new global ecospheric disturbances, resulting in the proliferation of new pests and epidemic diseases, shifted ecological balances and the setting off of previously unknown 'biospheric tipping points'.

*Global cooperation*: Together with governments, large corporations dominate the international scene. Corporations strongly influence the governments and divide the world in great zones of influence. Military power becomes increasingly a support for economic policies defined jointly by the national governments and the transnational corporations. Conventional wars are very rare and international cooperation is directed towards business goals and the control of the negative collateral effects of economic growth and the patterns of consumption, and particularly of the conflicts arising from the increasing inequalities between countries.

*Values*: Consumerism reigns supreme; corporate long-term self-interest leads to measures that mitigate some of the most destabilizing situations in order to control conflict and preserve business benefits.

*Water stress*: Water resources become increasingly the most insurmountable limiting factor for future economic growth. Withdrawals reach peak value; all practicably accessible water courses are managed, and groundwater is pumped out to the limit of sustainability. The realization that the level of generalized water stress is reaching unsustainability thresholds leads to placing high priority on water use efficiency; however, the accomplishments are not sufficient to sustain global economic growth. After trying very costly solutions, such as large desalinization plants and transporting icebergs from the polar zones, water quotas are established.

*Well-being*: The material conditions are improved for a large fraction of the global population with the exception of the excluded zones ('failed economies'). In the latter, poverty is widespread. Inequity is high between and within countries.

### Scenario 4: Global Consciousness

*Global economy*: The global financial crisis lasts years longer than initially expected, with ups and downs, exposing deep flaws in the international economic system. Finally the governments decide to pull together to fundamentally redesign the mechanisms of checks and balances, giving high priority to the long-term sustainability of the system. To this end, and accompanying the gradual shift in preferences of growing sectors of the population, economic policies are put in place to reduce material economic growth while vigorously developing the non-material economy (i.e. social services, information services, cultural goods and services, etc.). The material and energy throughput of the global economy stops growing and thereafter steadily decreases.

*Population*: As a consequence of the eradication of poverty and the changes in values, population growth declines much faster than in the Conventional World scenario and some societies opt temporarily for birth rates below replacement levels; total world population stabilizes within the century at the low end of the United Nations long-range projections.

*Technology*: Technological innovation and dissemination increasingly focus on sustainable solutions; technology hybridization (constructive combination of hi-tech with traditional and eco-friendly technologies) spreads, and new eco-technologies that operate with the ecological processes and cycles are developed. Increased knowledge about the functioning of the Earth System and biogeochemical cycles allow fine-tuning of agricultural and industrial processes, increased material and energy efficiencies, reduced wastes and further de-materialization of the economy.

*Climate change*: Greenhouse emissions slow down during the extended economic crisis, resume for the period of economic recovery and gradually diminish thereafter, due to the changes in technology and consumption patterns. Nevertheless, global warming keeps increasing due to the lags in the climatic systems, but the global climate gradually stabilizes in a safe regime before the end of the century.

*Ecosystem health*: Aquatic and terrestrial ecosystems are subject to diminished exploitation pressures during the economic crisis, and later on the spread of eco-technologies and the restoration of ecological processes and

cycles result in a generalized recovery of the health of the ecosystems (including the neoecosystems nurtured by the new forms of gentle ecosystem management). Biodiversity loss is arrested.

*Global cooperation*: In tune with the reformulation of economic systems, new channels for international cooperation develop; realizing the universal threats posed by extreme inequality, unprecedented levels of international cooperation result in drastic reductions in poverty and a gradual process of convergence between countries. By the end of the period, a Global Federation begins to take shape as a new system of international governance. A multicultural global society slowly but surely unfolds.

*Values*: Awareness of the unfeasibility (and undesirability) of the conventional historical trajectory spreads among people and governments, accelerated by the prolonged economic crisis and the increasing catastrophic events associated with climate change. Consumerism quickly loses its glamour and is gradually replaced by a growing interest in social interaction, cultural activities and the search for individual and collective meaning as participants in the evolution of life in the universe. Solidarity, reaching from individuals to the level of the human species, becomes a shared value, albeit with different shades and colours in accordance with the diversity of cultures.

*Water stress*: The diminished pressure on water associated with eco-technological developments, the reduction of the water throughput of the economy and the stabilization of populations allow the recharge of aquifers and gradual restoration of surface sources. Eco-management of water cycles plays an important role, in combination with existing water infrastructure. Water stress, already critical in some arid areas of the world at the beginning of the period, diminishes gradually with the implementation of the economic, technological and lifestyles changes.

*Well-being*: With the dramatic increase in equity, the eradication of poverty and the changes in values, the quality of life of people across the world reaches a historically high level.

### Scenario 5: Conventional World Gone Sour

*Global economy*: Resumes growth after the financial crisis of the end of the 2000s, with more efficient control systems in place but without major changes. Growth is propelled increasingly by the emerging countries, although a significant number of countries do not share in the benefits. By mid-period, dramatic changes in climate carry large financial costs and produce economic setbacks in many countries; the global economy is disrupted, leading to the longest recession in modern history.

*Population*: Continues increasing as in the Conventional World scenario, until mid-period. Later, massive famines and catastrophic floods and droughts result in large waves of environmental refugees trying to migrate in an attempt to survive. Global population begins to diminish, mostly due to increased death rates.

*Technology*: Initially, vigorous technological innovation and dissemination continues, but it later stagnates along with the economy and proves inadequate for providing sustainable solutions to the mounting problems.

*Climate change*: Initially, climate change intensifies due to insufficient political will and higher consumption pressures. It soon becomes evident that impacts are advancing faster than was earlier projected by most scientists. A

combination of positive feedbacks triggers some of the global 'tipping elements' of the Earth System that then interact among themselves, resulting in the irreversible shifting of the global climate into a new regime. This includes the chilling of north-western Europe due to the halting of the 'Atlantic conveyor belt' that maintained benign temperatures in the region and the dying of most of the Amazonian forest, among other changes, resulting in generalized climatic instability and serious deterioration of the economies and well-being of people across the world.

*Ecosystem health*: Agricultural lands expand, driven by increasing food demand and shifting diet preferences. Terrestrial and aquatic ecosystems continue the trend of gradual degradation, as in the Conventional World scenario. But the violent changes in the global climate system produce strong ecological transformations, the extinction of some ecosystems and the genesis of neoecosystems, many of them unsuitable for human use or habitation. These phenomena override the reduction in anthropogenic pressures due to the economic disruption and population loss.

*Global cooperation*: With an initial evolution similar to the Conventional World scenario concentration on security, actions to mitigate global climatic change are insufficient and tardy. As the impacts of climate transformations spread and grow, crisis management increasingly dominates global concerns. International cooperation collapses as each country fights for its own survival amid unprecedented uncertainties. Countries close their doors to immigration. International conflicts over shared sources of water escalate.

*Values*: The pursuit of consumption predominates among social values, until the deteriorating situation shifts the dominant values to the fight for survival and competition for resources; social order increasingly disappears and small bands proliferate.

*Water stress:* Initially evolving as in the Conventional World scenario, by mid-term the volume and location of surface water resources change significantly and unpredictably in response to the drastic alteration of the levels and spatial patterns of precipitation and evaporation. From the beginning of the period, water stress becomes critical in arid regions, a condition that spreads to other regions as weather patterns grow more erratic, with increasing frequency of unprecedented floods and droughts. As these shifts alter the geography of food production and human habitability, water sufficiency becomes only one among other major survival concerns.

*Well-being:* Relative poverty initially diminishes, but both relative and absolute poverty sharply increase later due to economic crises and famines. Masses of environmental refugees wander around looking for better survival chances. International migration is strongly restricted, limited to illegal migrants who manage to evade the harsh controls imposed by the destination countries. International and national crime levels become the highest in history.

## Concluding remarks

While starting from the same initial conditions, the five scenarios result in rather diverging futures, some of them clearly undesirable and others desirable (as evaluated against the critical dimensions). The worst scenario is Conventional World Gone Sour, with the lowest well-being, high water stress and high climate change, followed by

Conflict-world. Conventional World (if feasible) would lie in a middle ground, although it is probably unsustainable in the long run. Both Techno-world and Global Consciousness are better that Conventional World, but the latter exhibits the highest level of well-being and is probably the most sustainable.

Although the scenarios, as emphasized at the beginning, should not be taken as predictions of the future, they all seem plausible evolutions from the current situation, depending on how the major driving forces develop and interact. In this sense, they illustrate the diversity of alternative futures for the global water situation. With feasibility and plausibility in mind, these stylized scenarios scope a broad range of possibilities. Many other intermediate scenarios could materialize, particularly in light of the possibility of 'wild card' developments, including surprising developments in the physical and social realms that cannot now be imagined. Only a few wild cards were considered here, and these are all being discussed, or even proposed, today. The scenarios are, in this sense, conservative.

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