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Use of scenarios in PREPARED

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This report is: **PU** = Public

Executive summary

The PREPARED project aims to help utilities to adapt water and sanitation systems to cope with a changing climate. This aim raises several questions: What is adapting? What water and sanitation systems are we dealing with? What do we mean by 'cope'? How do we get systems to adapt? How is climate changing? What aspects of these changes should we be concerned with? How long for and how certain are we? Much of the challenge relates to the latter as we are very uncertain about the future, the drivers and how they will change and also our capability to adapt and cope with them. This uncertainty is unlikely to reduce for the foreseeable future and it is therefore necessary that the PREPARED project take note of this uncertainty: '*For scientists, the lesson here is clear. Caution is warranted when promising decision-makers a clarified view of the future. Guaranteeing precision and accuracy over and above what science can credibly deliver risks contributing to flawed decisions.' ..Building a climate-resilient future is about much more than straining to know the unknowable*' (Hulme et al 2009).

This report aims to help the partners in PREPARED to deal with uncertainty about the future. The report is not about predicting the future using descriptive futures research, but envisaging plausible and logically consistent versions of futures in a Foresighting process. Visions of the future may be termed 'scenarios' and can be used to represent how things might look at some time in the future and are frequently used in the water sector (e.g. SCENES project). There are many versions of scenarios in use and often these are available in each country; in different forms for various utility sectors, services and infrastructure. Hence there is no single scenario or even set of scenarios that can be used exclusively for scenario planning even within a particular sector or country. These and the background to scenario planning, foresighting, roadmapping and other approaches are set out in a more detailed report provided by WA6: 'WA6 discussion document - Use of scenarios in PREPARED' (January 2011).

A practical approach is given here to ensure that there is consistency across PREPARED in how futures are considered based on a widely applicable model using a matrix of 4 scenarios on two axes representing: state of economic development/vitality and ranges of climate change. Individual Work Areas in PREPARED and cities can then position their specific conditions and innovations within this 2x2 matrix of scenarios to consider their robustness to future changing drivers. The overall process of analysis requires consideration of what the drivers, threats and challenges might be to water supply and sanitation systems under each of the particular scenarios and matching the possible adaptation response measures identified in PREPARED to these. Where a response is seen to be robust across all scenarios and future time epochs, it may be considered as a very valuable measure in adapting to climate change. Many possible adaptation response measures would only be effective under a limited number of scenarios and at certain times in the future and would therefore be considered less robust and as measures with less value in providing robustness to future change.

Glossary

Adapt: the process of changing to fit some purpose or situation

Adaptation capacity: the ability to undertake adaptations is constrained by socio-economic, political and physical factors and is context specific and changing dynamically (adapted from Smit & Wandel, 2006)

Adaptation potential: a quantifiable expression of the ability of the system to adapt its structure and processes based on possible (re)developments within the assessment period so that it will become more resilient to climate (and other) change (adapted from Lim et al. 2005).

Driver: (Force) Exerts pressure on a system

Epoch: a particular period of time or a point in time

Foresight(ing): process of planning for the future

Impact: effect of a driver on the system, passed on via a pressure

Pressure: the way in which a driver exerts influence on a system

Response: reacting in a planned or unplanned way to drivers, pressures or impacts

Roadmap: a plan that integrates market and customer needs, product evolution, and introduction of new technologies

Robustness: being strong enough to withstand challenge from drivers

Scenario: Internally consistent verbal picture of a phenomenon, sequence of events, or situation (e.g. the future), based on certain assumptions and factors (variables)

Scenario Planning: the use of internally consistent, plausible, but not necessarily expected visions of the future

State: of the system defined by variables and attributes

WSSTP: (EU) Water Supply and Sanitation Technology Platform [http://www.wsstp.eu/site/online/home]

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1 Introduction

1.1 Background

The concept of the PREPARED project was developed from a roadmapping approach used in the WSSTP. Roadmapping envisages a pathway to a desired future state, together with ideas as to which technologies are needed to change the water and sanitation systems to achieve this desired future. Much of the work in PREPARED relates to inventing, developing and utilising improved and innovatory technologies and other measures. Unfortunately the uncertainties about the future: the drivers and also the socio-economic conditions can challenge the potential effectiveness and value of such innovative technologies depending upon what the future actually will become. Although PREPARED has been derived from the WSSTP that uses the roadmapping approach the project needs to take a more strategic and cautious view of the future, due to the level of uncertainty in predictions about the challenges, responses to these and the opportunities. Roadmapping differs from other approaches to futures studies as it is used to promote the take-up of particular technologies using 'technology-push' and 'market-pull' for forecasting and planning take-up and for identifying market needs that inform technological development. Elsewhere, a variety of futures approaches are being taken, here a combination of Foresighting and scenarios is proposed.

Coping with future uncertainty in the delivery of infrastructure, goods and services requires judgements about investments and asset management that should be as robust as possible. Visions of the future can enlighten or confuse decision makers especially where these are claimed to be 'predictions'. Foresighting, the use of scenario planning and roadmapping are each useful approaches to studies that include the future and that explore possible, probable and/or preferable futures that can help inform policy and decision making (Saritas & Aylen, 2010). Foresighting is simply the process of exploring the future, whereas 'scenario planning' has many meanings in literature. Here it relates to the use of internally consistent, plausible, but not necessarily expected visions of the future.

1.2 Why use Foresighting and scenarios in PREPARED?

Futures planning is important in PREPARED for two reasons. The **first** reason is the need to define the boundaries within which changes due to external (to system) drivers may be expected to occur, and the pressures and impacts these exert on the state of water supply and sanitation systems and, from this, the robustness of possible responses to these. The **second** reason is to highlight and examine the veracity in the tacit or implicit presumption in the project that *a preferred or preferable model* will be developed for the future characteristics of an adaptable (or adapted) water and sanitation system. These two reasons are introduced further below.

1.2.1 Defining the boundaries of change

These boundaries include those set by climate change scenarios, such as the SRES used in the IPCC estimates of possible changes in climate. Looking to the future – not *predicting* the future using descriptive futures research, but *envisaging plausible and logically consistent versions of futures* is a Foresighting process. Visions of the future may be termed 'scenarios' and can be used to represent how things *might* look at some time in the future, not *how we expect them to look.*

There are many versions of scenarios in use to envisage how the future might look. These are not meant to be predictions of the future but simply logically, consistent and plausible visions to test innovations (responses). Various scenarios are available in each country, in different forms for various sectors of services and infrastructure. Hence there is no single scenario or even set of scenarios that can be used exclusively for scenario planning even within a particular sector, country or region. This is therefore a major challenge for PREPARED as many countries and scales of case studies are being looked at. Any futures planning in the project needs to be based on an approach that is equally applicable at all of these scales and for all types of adaptation measure (hard or soft, Wolff & Gleick, 2003; Gleick, 2003) across the various water supply and sanitation sectors.

PREPARED mentions scenarios or aspects of futures in several places in the original application (WA2, WA4, WA5 and WA6) but fails to define a consistent approach or a responsible WA for defining futures and how these need to be considered within the project as a whole. Much of PREPARED is predicated on a 'positivist' view of the future, with normative visions of the 'best' technologies in the water and wastewater sector. This approach is contestable (e.g. Ehrlich et al, 1999) as the future is uncertain and we cannot know what technologies will necessarily be ideally applicable in the future or even if today's clever technologies will actually be appropriate in a future world. The presumption of 'invent it and they will use it'[1] is naïve. The water sector is but one of many sectors essential for human life and is usually a 'follower' in technology advance, not a leader. Therefore many of the advances in this sector are reactive to other sectoral innovations. It is then apparent that an exploratory approach needs to be taken in PREPARED alongside the standard normative vision implicitly embedded in the WSSTP research agenda. It is also necessary to ensure that if the envisaged roadmap pathway does not ensue, i.e. the future will not be what we think it will, PREPARED will still deliver valuable outputs to water utilities and others.

As part of the boundary setting for considering innovations, their benefits and limitations, consideration of the socio-economic aspects of future scenarios is required to determine the drivers, impacts and consequential economic, social and environmental effects of climate and other changes. The socio-economic factors within the scenarios define much of the need, capacity and willingness of the actors in the future to respond to the climate change stresses as technological capacity, innovation and cultures are embedded in any assumed scenarios. PREPARED needs to define a logical and consistent approach to scenarios in order to better plan and evaluate the effectiveness of the responses needed to adapt to climate change and to see if these are credible and robust across the range of scenarios used. An ideal response measure is one that appears robust under any assumed future scenario (Evans et al, 2004a). However, experience suggests that there are rarely any single measures that exhibit such robustness across the range of all potential futures.

1.2.2 Examining the 'preferable' future

The **second** reason why PREPARED needs to consider scenarios at the heart of any work is because of the tacit or implicit presumption in the project that *a preferred or preferable model* will be developed for the future characteristics of an adaptable (or adapted) water and sanitation system; a concept termed 'descriptive futures' (Mannermaa, 1991). Such a 'preferable' system (and there may be more than one model for this) is unlikely to be robust across a range of

[1] Unlike in the film 'Field of Dreams' where *they do* come once he has built it

scenarios and hence this tacit assumption needs to be exposed and the limitations widely acknowledged amongst the PREPARED team.

For example, would a real-time operated wastewater system occur in a future where low or decentralised technologies are the norm (the UK's local stewardship scenario, akin to Swedish Eco villages, Evans et al, 2004b)? Maybe or maybe not?

A WA6 discussion report reviews in some detail the recent use of and types of Foresighting, scenario planning, roadmapping and other futures research, especially in the water sector and sets out ideas for a framework for how scenario planning might be done in the context of PREPARED to help define the boundaries and test the robustness of ideas and innovations. It does not define which or how many scenarios should be used[2].

The report presented here builds on that review and sets out a step-by-step process as to how scenarios may be used within the PREPARED project.

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[2] Ashley R M. (2011). WA6 discussion document - Use of scenarios in PREPARED. January 2011.

2. Scenarios in PREPARED

Examples of the types and potential uses of scenarios are shown in Figure 2-1. Predictions of the future follow the left hand route in the figure 2-1, the Roadmapping process follows the right hand route, whereas the scenario planning outlined here follows the central route.

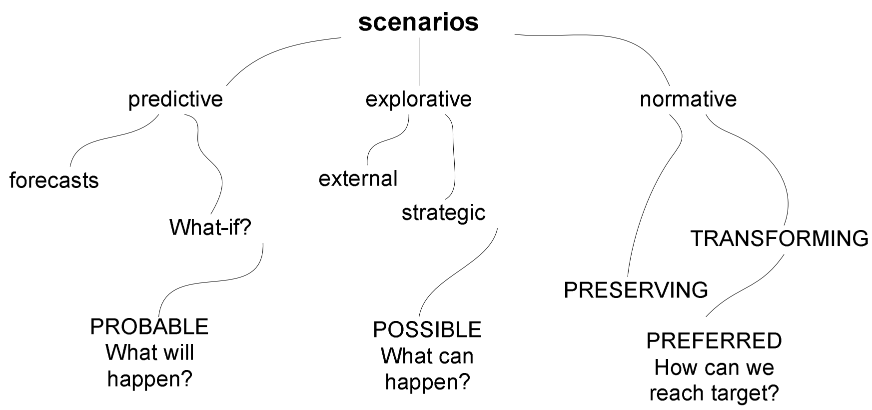


Figure 2-1 Scenario typology with 3 categories and 6 types (Börjeson et al, 2006)

2.1 Defining scenarios in PREPARED

There are a number of earlier and on-going EU and other projects of relevance to scenario building and application. Of most recent relevance is the SCENES[3] project (EU 6th framework completing 2011) investigating concepts and methods to improve policy making under conditions of high uncertainty. SCENES is developing a set of comprehensive scenarios of Europe's freshwater futures up to 2025. The project links qualitative (storyline development) and quantitative (formal modelling and statistical analysis) methods. As yet there are no accessible publications from the project dealing with scenarios but these are expected in the near future.

In the guide presented here there are two types of scenarios relevant to PREPARED: driver scenarios and socio-economic scenarios as outlined below.

2.1.1 The driver scenarios

The ***driver*** scenarios are those that are potentially impacting on the state of water supply and sanitation systems. Their effects can be envisaged using a Driver-Pressure-State-Impact-Response framework, Figure 2-2. The most useful of these are the IPCC SRES (environmental) scenarios[4] that are generally used to estimate the various possible climate change trajectories (illustrated in Appendix A) and hence changes to key meteorological and hydrological parameters. However, there are many other drivers that continue to exert pressure on the state

[3] http://www.iiasa.ac.at/Research/RAV/Projects/scenes.html [accessed 25-08-11]
[4] Special Report on Emissions Scenarios (SRES) by the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic, N and Swart, R. (eds): 2000, Emissions Scenarios: Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK, 570 pp.) (Appendix A)

of water supply and sanitation systems, some of which are more or less amenable to human control. In Europe, environmental regulations are a major group of drivers that continue to alter the state of these systems and may be to some extent, controlled. Drivers are considered further in section 2.2.

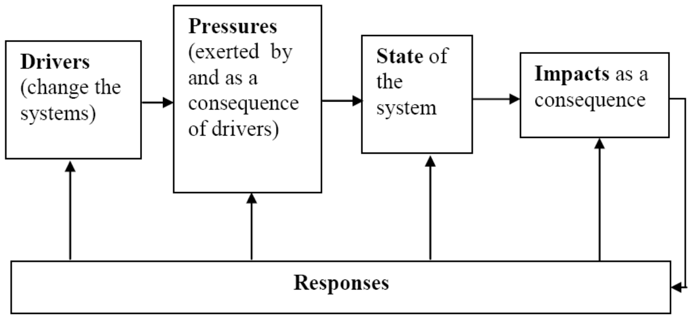


Figure 2-2 DPSIR framework (e.g. Kwadijk et al., 2010)

2.1.2 The socio-economic scenarios

The ***socio-economic*** (S-E) scenarios influence the driver scenarios above in that societal behaviour also affects how the climate changes (e.g. due to more or less greenhouse gas emissions) (e.g. van Vuuren et al, 2011). These also control how water and wastewater systems are regulated. S-E scenarios also define the context, capacity, capability and attitudes as to how climate change and other driver pressures and impacts are, or can be, responded to. For example, the scale: regional or local controls; the state of functionality of an organisation; the resources available – mainly economic; the willingness to try new and innovative ideas and methods.

The economic strength of a society is possibly the most significant here and will be different depending on the future scenario. For example, major infrastructural projects require considerable capital investment and hence available wealth, whereas a low technology or soft solution may require incremental implementation and longer-term maintenance, being more appropriate where large up-front financial investment is not viable. As adaptive capacity is strongly related to wealth this will also affect the ability of the local service provider or community to adapt.

The S-E scenario set include the willingness, capability and approach within that scenario's societal system to develop, access and utilise innovative technologies, practices or behaviours. Societal futures are strongly influenced by value systems that change as society 'progresses' into the future, although these are a part of the many feedback loops between social-economic-environmental and technological change processes. Such value systems influence strongly how decision makers and others handle the uncertainties in the drivers and also the effectiveness of the responses as behaviour is generally within a 'bounded rationality' that constrains willingness to change. For example, the use of scenario analysis in considering the future of natural systems within England, by Natural England used a progressively more detailed set of questions and workshops with key stakeholders (Figure 2-3) and the Ethnographic Futures Framework (EFF) to ensure that all aspects of human society, cultural and societal change are included (Kass et al, 2011).

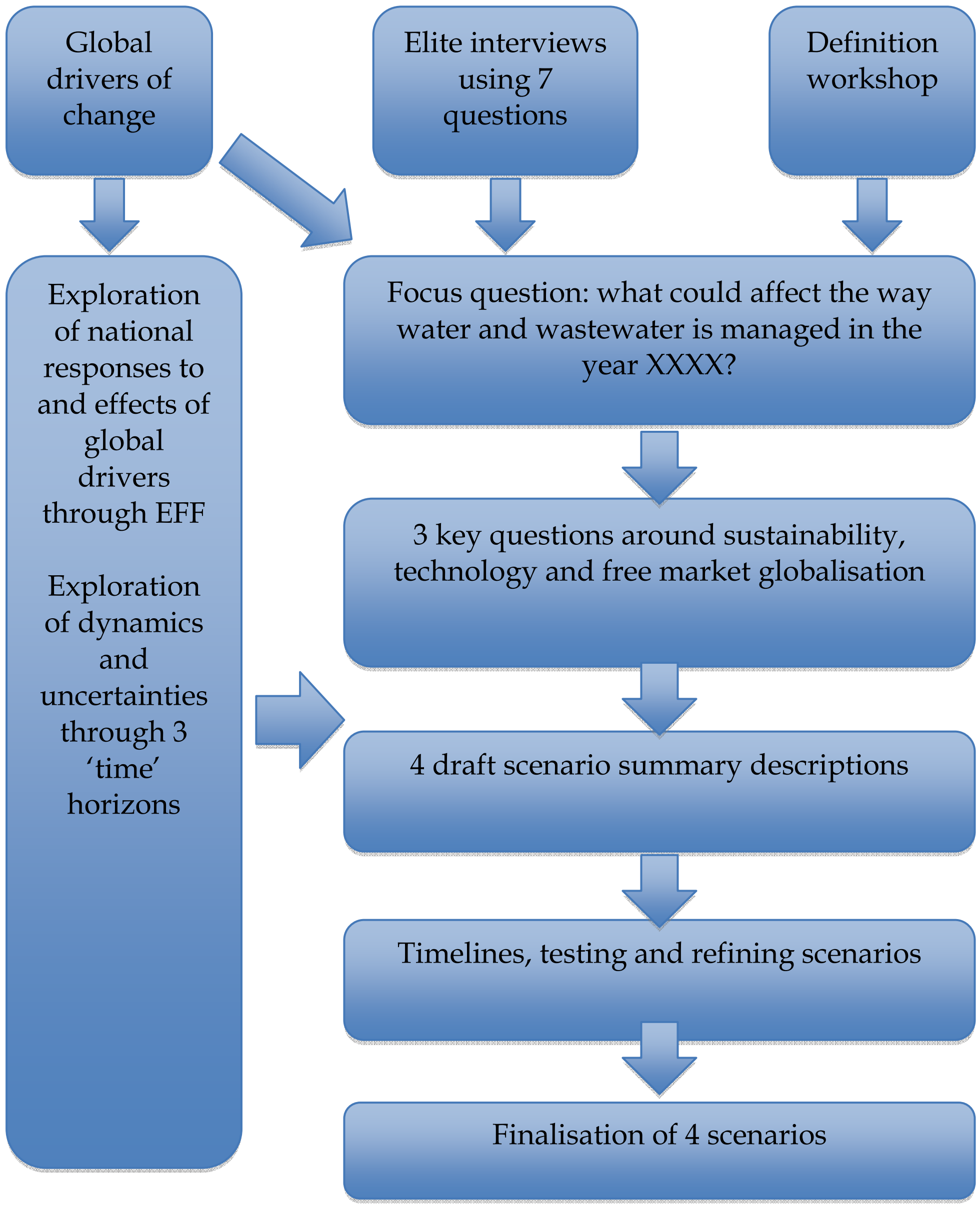


Figure 2-3 Illustration of the scenario development process (adapted from Kass et al, 2011)

In Figure 2-3 the 7 questions asked of the Elite interviewees have been adapted here in the context of PREPARED:

i) If someone could tell you what would you want to know about how future society and environment will change?
ii) If things went well, how would you expect water and wastewater systems to perform in the future and what would be the key signs that this was coming about?

iii) How could circumstances change to make things very difficult and how could the way in which water and wastewater systems are managed go most wrong?
iv) From your knowledge of how water and wastewater systems are managed now, what would need to be changed to stop things going wrong into the future?
v) How did water and wastewater systems get to where they are today?
vi) What decisions need to be made now to ensure that the desired long-term outcome happens?
vii) If you had complete freedom what more would you do?

The drivers were identified separately by review and interviews. The EFF categories were used to explore the drivers and anticipate what the societal impact in the future might be if a driver progressed along alternative trajectories. The EFF categories are shown in Table 2-1.

Table 2-1 Ethnographic Futures Framework (EFF) (Schulz, 2009)

Framework categories	Definition	Examples
Define	Changes in concepts, ideas and paradigms we use to define ourselves and the world, including changes	Social value and attitudes Scientific models and paradigms Economic models Public policy paradigms
Relate	Change in social structures and the relationships that link people, organisations and changes in how people relate to natural and built environment	Demographics Lifestyles Work and economy Business models and practices Technology
Connect	Changes in technologies used to connect people, places and things	IT Language Infrastructure
Create	Changes in processes and technologies through which goods and services are produced	Engineering Manufacturing and economic infrastructure Innovation processes Life sciences
Consume	Changes in goods and services created by society and the way in which they are acquired, used, abandoned, discarded and destroyed	Consumer goods Energy Food Natural resources Public services

The 3 'time' horizons were not related to specific epochs, rather to: a 1st Horizon that relates to the current dominant system as it continues into the future; losing conformity over time as external drivers change; a 3rd horizon comprising ideas about the future that appear to be unrealistic today but may provide better fit to the changing drivers over time; a 2nd horizon which is at the intersection of the 1st and 3rd horizons in an unstable transition space which contains ideas from the existing and new that are being contested by the main players.

The 3 questions that emerged in the process were: will the world have found a way to live sustainably? Will technology have solved all the problems or will lifestyles need to change? Will the world be dominated by free-market economics?

2.1.3 Using these scenarios

In this 'how-to-do' report for PREPARED it is mainly the socio-economic (S-E) scenarios that are considered to be of interest as these affect not only greenhouse gas emissions, but the other challenges and opportunities that may affect how water utilities and others deal with climate change. These also influence many of the drivers. The definition or storyline describing the attributes of these S-E scenarios should ideally be plausible, credible and internally consistent. They are not visions of *expected* futures, but visions of plausible and within themselves, consistent futures.

Scenarios need to be used in PREPARED to help identify the range of future risks, essentially from the IPCC predictions of climate change together with the impacts on society (defined in terms of a set of S-E scenarios and the impacts) – these same scenarios may then be used to consider the capacity to respond to the risks.

2.1.4 Sudden changes

In addition to the longer term (largely chronic) drivers and impacts considered in scenario analysis, there is also a need to consider the potential for acute shocks – sudden tipping points or discontinuities that may be caused e.g. by tsunamis or volcanic eruptions. In addition, economic discontinuities, such as the banking collapse affecting (mainly) Western Europe in 2007-8 are also important for the S-E scenarios. Such events should also be considered in the analysis.

2.2 Defining the drivers

As PREPARED is interested in adaptation to climate change, it is the climate change scenarios that are of greatest interest and the SRES scenarios can be used based on the latest IPCC publications for any geographical location. From these, a suite of climate change drivers can be defined within 4 climate scenarios as shown in Table 2-2. Note that the S-E scenarios used to define these are global and hence not readily applicable nationally or locally.

Table 2-2 greenhouse gas emissions associated with the IPCC scenarios

IPCC (2000)[5] scenario	*Greenhouse gas emissions*
B1	Low
B2	Medium-low
A2	Medium-high
A1F1	High

[5] Special report on Emissions Scenarios (SRES): A special report of Working Group III of the intergovernmental panel on climate change. Cambridge University Press.

Guidance on selecting specific values for climatic change drivers for any of the PREPARED case studies is provided by a WA2 report[6].

There are a number of other drivers that may be of significance when considering water supply and sanitation systems in PREPARED. In the flooding domain, Hall et al (2007) list examples in terms of their potential controllability, shown in the first row of Table 2-2. When considering how sewerage systems may alter during the current century, Ashley et al (2006) defined the main drivers as given in the second row of Table 2-2. In each case the relative importance of specific drivers may become more or less significant with time. For example, the drivers defined by Ashley et al (2006) were considered in ranked order of relative importance at the time in 2005 as numbered in Table 2-3. Note that the Hall et al (2007) drivers were not ranked in the same way so are not numbered. As regards the 2nd row drivers, with current knowledge it is now arguable that energy should rank comparably with climate change as a main driver influencing the state of sewerage systems now and into the foreseeable future. However, in a more recent UK study, it is demographics and lifestyles that were seen as having the greatest potential impacts on the performance of sewer systems (Mott MacDonald, 2011). It is not intended here to debate which drivers may be of the greatest significance, rather to illustrate the difficulties and uncertainties surrounding the definitions of which are the key drivers when looking into the future.

Table 2-3 Examples of drivers and potential for their control

Study	No control potential	←	DRIVERS	→	High control
Hall et al (2008) Flood risk and management (to 2080s)	Earth's orbit	Global values Global prosperity Global greenhouse gas emissions	EU policy and regulation National prosperity Public perceptions Insurance industry	Urban and rural land use Building practices	Flood defences Flood forecasting and warning
Ashley et al (2006) 21st Century sewerage (to 2080s)		1. Climate change	2. Environmental and other legislation 4. Energy and other resource use	3. Land use and urbanisation Demographics	5. Asset condition, performance and serviceability 6. Science, engineering and technology

These types of driver need to be developed and considered in relation to the defined S-E scenarios (section 2.3). It is necessary to iterate the definitions in order to define both the key drivers and the S-E scenarios together for a particular application (location, scale and sector) in PREPARED. Note that the drivers in Table 2-3 were all developed for UK applications and therefore may or may not be applicable elsewhere. Although a similar approach has been taken in an OECD project investigating the global need for future investment in water supply and sanitation systems (Ashley & Cashman, 2006; Cashman & Ashley, 2009). In each of these cases,

[6] PREPARED WA2 Report Overview of climate change effects which may impact the urban water cycle.

definition of the drivers and likely importance over timescales and epochs has been developed through panels, workshops and discourse with experts. This is a process recommended for PREPARED.

2.3 Defining S-E scenarios in PREPARED

Many countries in the EU and elsewhere have sets of S-E scenarios. Most of these comprise combinations of possible governance and enterprise or social systems on a 2 dimensional grid, providing 4 possible scenario combinations A - D as illustrated in Figure 2-4.

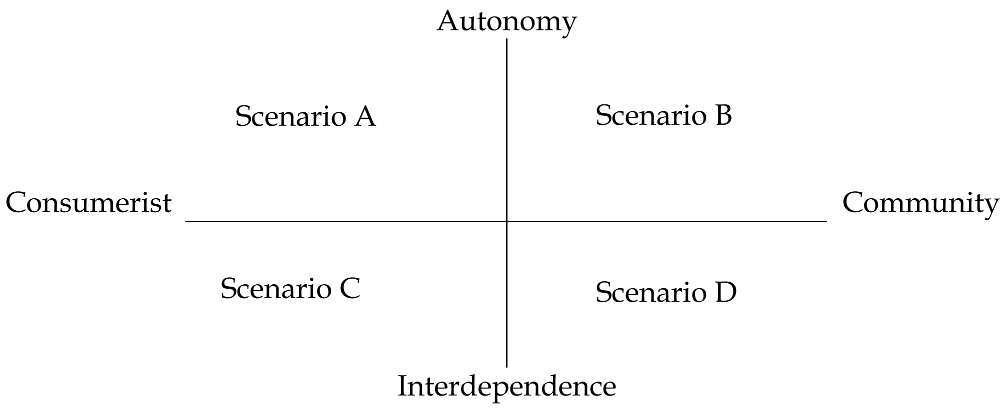


Figure 2-4 Example of a two dimensional S-E scenarios grid (adapted from Hall et al, 2007 and SPRU, undated)

Thus Scenario A is a society which is highly consumer focused and with considerable individual autonomy and limited regulation. Under Scenario C, markets are subject to social regulation to ensure more equally distributed opportunities and the aspiration is for a high quality local environment. Small-scale and regional economic activities are promoted. In Scenario B people aspire to material wealth, but within a structure commited to building national capabilities.

The Scenario D society has a strong community ethos and a highly interdependent governance structure at all levels. Although these types of S-E scenarios have no direct correspondence with the SRES climate scenarios as they are national or sectoral based, they can be matched to the 4 types of emission cases described in Table 2-1. This provides 4 combined scenarios as has been used in the UK Foresight Future Flooding study (Evans et al, 2004a, 2004b). In each type of scenario, the trajectory or development of society can be envisaged over periods of time in time-slices or epochs and in the latter, two epochs were selected, the 2050s and the 2080s.

Timescales are essential when considering scenarios and in PREPARED three epochs E1-E3 should be considered:

E1	Year 2025-2030s	Climate changes are already in process (2011) and cannot be altered 2011-2025 Represents the typical lifetime of mechanical and electrical assets in water and wastewater systems.
E2	2050s	Climate by then may change in ways not reliably predicted at the present time (2011). 2011-2050 Is the lifetime of many water and

		wastewater assets; thus 2050 would correspond with the end of the 'design life' of many of the current infrastructure assets in European urban water systems. Major refurbishment or replacement would be considered.
E3	2080-2100s	Predicting climate change for this period is highly uncertain This period is probably the future limit of what can be reasonably imagined from a position in 2011. Current major infrastructure assets would be failing; replacement would be essential.

In order to simplify the scenario analysis process in the PREPARED project it is proposed to combine the climate and S-E scenarios into a single 2 dimensional grid as shown in Figure 2-5 with grid axes defined by the degree of climate change and the relative socio-economic capacity/vitality of the country.

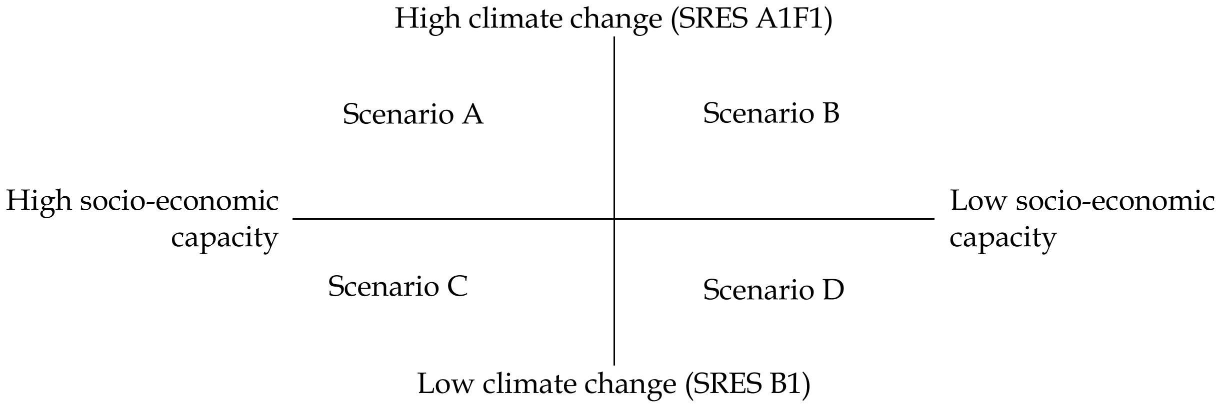


Figure 2-5 PREPARED combined climate and socio-economic scenarios

Socio-economic capacity (or capacity and vitality) has been selected in place of the usual governance or social structure axis as a primary indicator of adaptation potential, as this is strongly related to actually adapting (Kelly & Adger, 2000). What this means is that in a societal system with significant financial reserves (disposable income or savings) or high economic turnover, there are possibilities to spend some of these on adapting. However, even where wealth is or seems high (adaptation potential is high), alternative prioritisation of investments may mean that using it to adapt water supply and sanitation systems to climate change may not actually be an option or a priority (low adaptive capacity). In earlier versions (6 and before) of this report, 'socio' capacity was not included. On-going discussions regarding application, has however, elicited the need to add this in as a key capacity regarding adaptation potential. Earlier versions of the report were based on the view that defining the characteristics/attributes of socio-economic capacity may be too difficult for PREPARED partners. This view has been revised due to the clear importance of social capacity[7] and people's views and attitudes in the scenario process (Kass et al, 2011). The EFF approach (section 2.1, Figure 2-3 and Table 2-1) can be used to ensure that due consideration is given to social and cultural aspects.

There are important differences between adaptation potential and adaptive capacity when thinking about these scenarios. The former is considered as the opportunity or capability to

[7] Defined loosely here as the ability or capacity of society, or parts of society to adapt – this may be interpreted locally slightly differently by the PREPARED partners

adapt the structure and processes of the (water and sanitation) system so that it will become more resilient to climate (and other) change within the assessment period and specific measures can be identified and costed (Lim et al. 2005). Whereas the latter is the actual ability to change the system in order to make it more resilient or robust to unwanted change. In scenario planning the distinction between these two concepts is important as the former is a measure of how flexible the existing systems are, whereas the latter defines how capable the S-E system under consideration is in effecting changes. Therefore adaptive potential (enabling) is especially relevant to technological innovation, whereas adaptive capacity is constrained, enabled or enhanced by S-E factors.

There are clear limitations with using economic capacity or vitality, not least the problem of it being presumed to correlate mostly with GDP. While GDP is an indicator that is used globally and much liked by international organisations such as OECD, it is not necessarily the best measure for how wealth is distributed, how it may be used politically nor of social welfare as illustrated by the economic decline in western countries after 2008 following many years of chasing the GDP (van den Bergh, 2011). In PREPARED it is incumbent on the participants to interpret how best to apply the concept of economic capacity/vitality within their particular case studies. However, the combination of social and economic capacities requires judgements to be made about the ability or otherwise of society to adapt, e.g. take-up innovations; change behaviours etc., which depend as much upon social mores, cultures, norms, practices and attitudes as on wealth.

In each application in PREPARED it will be necessary to define the attributes (characteristics that make up the details and context) of the 4 scenarios under each of the 3 epochs depending upon local circumstances as illustrated in the example given in Table 2-4.

In each of the boxes in Table 2-4 the key elements required to envisage the future under that scenario need to be defined through expert dialogue.

Following on from the definition of the key elements of these scenarios in climate and S-E terms, a further analysis needs to be carried out to define the important drivers (and hence challenge) under each scenario and epoch.

2.4 Considering responses in PREPARED scenarios

Much of PREPARED concerns the development of measures that may be used to help adapt water, sanitation and drainage systems to climate change. WA1 will continue to collate a catalogue of possible adaptive measures (both hard and soft) throughout the project. The next stage of the scenario analysis here considers the suitability of adaptive measures when used to address the key drivers and challenges identified from the scenario analysis described above.

Where an adaptation measure is being considered for application, it should be assessed in terms of its' likely performance under each of the four scenarios and each of the three epochs. It is probable that any given measure will satisfy the needs of certain challenges in particular epochs, but will not be sufficiently robust to provide continual and across-scenario sufficiency over the whole of the next century. Most studies indicate that combinations of mitigation and adaptation strategies are needed in the water sector to address the challenges and that the balance between mitigation and adaptation will change over time (e.g. Arnell et al, 2011; van Vuuren et al, 2011).

The scenario-based approach outlined here can help identify when and where such combinations may be needed.

As a final stage in the PREPARED scenario analysis, a further Table should be produced by a collective of stakeholders and innovators that lists potential adaptation responses and their likely level of robustness in terms of the drivers and challenges given in the combinations of scenarios and epochs illustrated in Table 2-3.

Table 2-4 Table illustrating definitions of characteristics and attributes relevant to water supply and sanitation systems under each scenario and epoch – example applied to UK (adapted from Hall et al, 2007)

Scenario	Characteristics of Scenario	Examples of Attributes/Epoch (changes from today)				
		Criteria*	Today	E1 2025-2030	E2 2050s	E3 2080- 2100
A	High Socio-economic capacity High climate change	%GDP growth per year	2.5	3.5	3.5	5
		Investment in water and sanitation (%GDP)	8	8	10	6
		Primary energy consumption change per year from today (%)	-	+1.7	+2.0	+1.5M
		Population change from today	-	+2M	+5M	+6M
		Social Values, attitudes and capacity	Nationalist, individualistic, high capacity	Nationalist/Internationalist /entrepeneurial, high capacity	Internationalist, libertarian, high capacity	Internationalist, libertarian, high capacity
		Governance Structures	Declining Regulations	Deregulating and consultative	Weak, Dispersed and consultative	Weak, Dispersed and consultative
		Equity	Apparently promoted	Strongly declining	Strongly declining	Not considered relevant
B	Low Socio-economic capacity High climate change	%GDP growth per year	0.5	2	1.5	1.0
		Investment in water and sanitation (%GDP)	8	4	3	2.5
		Primary energy consumption per year change from today (%)	-	+1.0	+1.0	+0.5
		Population change from today	-	+1M	+0.5M	+0.25M
		Social Values, attitudes and capacity	Nationalist/strongly regulated, low capacity	Nationalist/commutarian, growing capacity	Nationalist/ commutarian, growing capacity	Nationalist/ commutarian, growing capacity
		Governance structures	Declining Regulations	weak, national, closed	weak, national, closed	weak, national, closed
		Equity	Apparently promoted	Declining	Declining	Declining

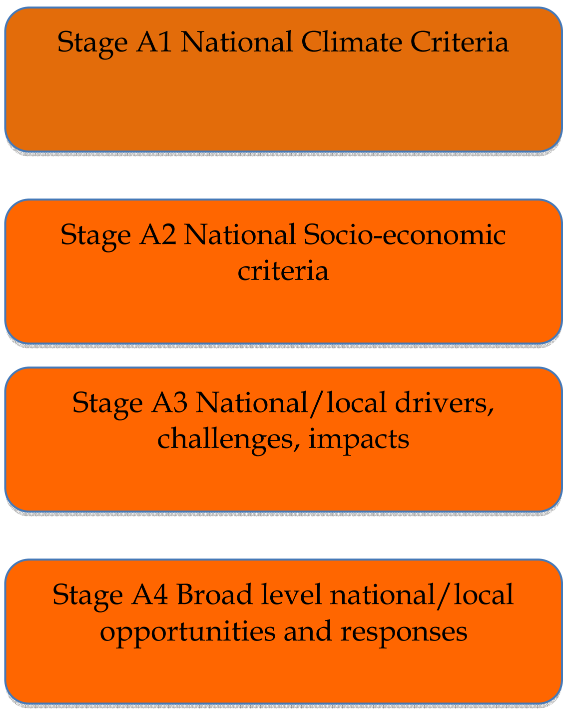
Scenario	Characteristics of Scenario	Examples of Attributes/Epoch (changes from today)				
		Criteria*	Today	E1 2025-2030	E2 2050s	E3 2080- 2100
C	High Socio-economic capacity Low climate change	%GDP growth per year	2.5	2.8	3.5	4
		Investment in water and sanitation (%GDP)	8	8	8	8
		Primary energy consumption per year change from today (%)	-	+0.1	+0.1	0
		Population change from today	-	+1.5M	+1M	+0.5M
		Social Values, attitudes and capacity	Nationalist and individualist, strong capacity	Internationalist/ entrepreneurial, strong capacity	Internationalist/ entrepreneurial, strong capacity	Internationalist/ entrepreneurial, strong capacity
		Governance Structures	Declining regulations	strong, coordinated, consultative	strong, coordinated, consultative	strong, coordinated, consultative
		Equity	Apparently promoted	Improving	Improving	Improving
D	Low Socio-economic capacity Low climate change	%GDP growth per year	0.5	1.25	0.5	0.2
		Investment in water and sanitation (%GDP)	8	4	2	1
		Primary energy consumption per year change from today (%)	-	-1.0	-2.0	-5.0
		Population change from today	-	0	-0.5M	-1M
		Social Values, attitudes and capacity	Nationalist/individualist, low capacity	Localist, cooperative, growing capacity	Localist, cooperative, growing capacity	Localist, cooperative, growing capacity
		Governance Structures	Declining regulations	Strong, local participative	Strong, local participative	Strong, local participative
		Equity	Apparently promoted	Strongly Improving	Strongly Improving	Strongly Improving

*Criteria are examples only; there may be others to be decided in context

3. Step-by-step process for the use of scenarios in PREPARED

Details of the components of the scenario analysis have been described in Section 2 above. Here the process is itemised in individual steps that may be used for a particular case study area or when considering a particular technological innovation or implementing an innovatory plan. The initial stages A, are required irrespective as to the type of adaptation response measure being considered. Depending upon the application, subsequent analysis should follow either/or Stages B1, B2 and/or B3. Stage B1 deals with the use of the scenario approach for the consideration of the robustness of a particular technology or innovation. Stage B2 with a particular case study area and the assessment of a wide range of optional responses. Stage B3 applies to the implementation of innovatory plans, rather than specific technologies. The final step, C considers major shocks, i.e. those that potentially create a step change, rather than the gradual changes envisaged by the scenarios. Figure 3.1 illustrates the process.

Stage A – setting the Regional and National context



Step A1 define national climate criteria

For the country within which the study is set: determine the climate changes expected for each of the 3 epochs, detailing the maximum and minimum values for meteorological and hydrological parameters, also sea level, winds and storminess where the study area is on or near the coast. These will be obtained from SRES predictions and national interpretations of what these mean along the Y axis as shown in Figure 2-5. These values define the limits to the High and Low climate ranges, which also provide some idea of the relative uncertainty in the climate change estimates.

Step A2 define national S-E criteria and attributes

For the country within which the study is set: determine the likely economic capacity for each epoch, assigning the lowest capacity estimates to the Low economic scenario and the highest to the High capacity economic scenario. In most countries there are standard estimates made by central Government for e.g. GDP, however, these need to be considered carefully as regards economic capacity especially where there are serious inequalities in wealth distribution. Where these are not available reference may be made to OECD estimates of GDP or wealth.

Using expert judgements, derive associated parameters describing e.g. degree of innovation and uptake of technology; societal attitudes and responsiveness to change; type of institutional structures related to the water sector and effectiveness to adapt to change (e.g. public or private); propensity for centralised or decentralised systems. The particular parameters of relevance may change between scenarios and epochs and may vary between different case studies.

Step A3 define national/local drivers, challenges and impacts

Using expert judgement, together with the information in Steps A1 and A2 above, list and define the key drivers and challenges within each scenario and for each of the three epochs. Assign an uncertainty rating to each of these, which may be on a simple scale of e.g. 1-5. Where there is a key driver/challenge that is highly certain then this should be prioritised. Assess the impact that these drivers may have on the state of the water supply and sanitation system under each scenario and for each epoch, working from national (drivers) to local impacts. Where impacts are likely to be significant and there is a high degree of certainty about these, then they should be prioritised for responding to. Workshops should be held with all key stakeholders in participative activities (SPRU, undated).

Step A4 identify broad level national/local responses

In the first stage of Step A4, a list of all possible adaptation responses should be drawn up to match all of the key drivers, challenges and impacts and allocated within each of the 4 scenarios as potentially available/useful/ practicable and within the time epochs. This can be done by an expert group. In the second stage, each of these responses should be considered in detail. These will be a portfolio of policy, economic, soft and hard infrastructure responses. As above, workshops should be held with all key stakeholders in participative activities (SPRU, undated).

Stage B Effectiveness of Responses

Stage B1 – to consider a specific technological or other innovation as a single response to drivers

Stage B1 Assess specific individual response to drivers/impacts

Stage B1.1 Review drivers and impacts from A3 in relation to specific technology/innovation

Stage B1.2 Assess how the specific response technology or innovation can deal with these drivers

Step B1.1 review the drivers and impacts identified in A3 above in relation to the specific technology

Stage B1 entails taking a more in-depth look at the key drivers and impacts identified above for a particular national area, locale or need. It is likely that the drivers of most interest will be those directly impacting on water and wastewater processes, e.g. temperature change impacts on treatment process effectiveness and efficiency. List the important ones in order of greatest to least likely significance under each scenario and epoch.

Step B1.2 assess how the specific technology or innovation may be used to address the drivers and impacts

Consider the technology or innovation in relation to each of the 4 scenarios and time epochs. Would the innovation be available under the scenario condition and at that time? Would it be accessible and acceptable to users? Would it address all of the drivers? Fully or partially? A table/matrix can be drawn up covering each scenario and epoch with a scored rating as to the likely effectiveness of the innovation using e.g. +++, ++, +, 0, -, --, --- ratings. Where an innovation seems applicable under each scenario in a given epoch in time, then it is likely to be robust and therefore a key potential innovation to help adapt water supply and sanitation systems to cope with future change. The wider 'sustainability' of the innovation should also be assessed under the scenario and epoch; e.g. the technology may be robust, but its' energy needs may mean it is impacting on the environment and/or it may be very expensive. Expert judgement and workshops should be held to make these assessments.

Stage B2 – considering responses to a particular problem or in a specific case study locale or application

Stage B2.1 Review drivers and impacts from A3 in relation to specific case study or location

Stage B2.1 Review drivers and impacts from A3 in relation to specific case study or location

Stage B2.2 Assess likely effectiveness of a range of individual responses and of a group of responses

Step B2.1 Is similar to step B1.1 in that the important drivers are reviewed and redefined in depth

The stage entails taking a more in-depth look at the key drivers and impacts identified above for a particular national area, locale or need. It is likely that in B2.1, the drivers of most interest will be those directly impacting on an area, such as a catchment or a town, e.g. flood risk impacts due to changes in climate. List the important drivers in order of greatest to least likely significance under each scenario and epoch.

Step B2.2 assess the likely effectiveness of a number of responses and a portfolio of responses

Assessing the potential effectiveness of individual responses or innovations can be made similarly to B1.2 above. However, aggregating the effectiveness of a portfolio of these for each scenario and epoch is complex. This entails asking questions such as, 'if this innovation is used, will this one also be used as well, and how much of one innovation will be used compared with another innovation?' Where there are a wide range of potential innovations, these may also be coupled with traditional approaches, providing a wide landscape of possibilities. Assessing the applicability and effectiveness of such portfolios of measures can only be done subjectively using expert judgement and in workshops with stakeholders. In practice of course, it is most likely that portfolios of measures will be used rather than single innovations, so this step is the one that is most likely to reflect future conditions and robustness of responses. As for B1.2, the relative sustainability of the potential portfolio of measures also needs to be assessed under each scenario/epoch.

Stage B3 – Implementation of innovatory plans/frameworks /strategies

Step B3.1 Review drivers and impacts from A3 in relation to specific framework and area of interest

Step B3.2 consider how the drivers impact and how the system/process or cycle may change in response to the drivers

Step B3.3 consider how the plan/framework/strategy may inhibit/encourage or have no influence on system change

Step B3.4 consider how the plan/framework/strategy might be adapted to obtain a moe desirable outcome

Step B3.1 Is similar to step B1.1 in that the important drivers are reviewed and redefined in depth

The stage entails taking a more in-depth look at the key drivers and impacts identified above in relation to the plan or framework and area of interest. It is likely that in B2.1, the drivers of most interest will be those directly impacting on an area, such as on the water cycle or wastewater cycle as a whole. List the important drivers in order of greatest to least likely significance under each scenario and epoch.

Step B3.2 consider how the drivers impact and how the system/process or cycle may change in response to the drivers

The drivers will exert pressures on the system and these need to be defined for each scenario and epoch. It is highly probable that as a consequence the system will alter. For each scenario and epoch the potential system changes need to be defined by consensus.

Step B3.3 consider how the plan/framework/strategy may inhibit/encourage or have no influence on system change

Consider how the plan/framework/strategy being applied may inhibit/enhance or not affect the system change processes resulting from the drivers and whether or not change is good or undesirable. Each scenario and epoch need to be considered individually.

Step B3.4 consider how the plan/framework/strategy might be adapted

Under each scenario/epoch consider if the plan/strategy/framework needs to be modified/adapted to ensure that any system changes that occur are beneficial and/or the desired outcome will come about in every scenario and in the appropriate epoch.

Step C - Accounting for major shocks

It is wise to consider sudden change by considering how innovations can handle natural shock events (e.g. tsunamis, hurricanes) and man-made events (e.g. economic collapse, ecosystem collapse). As shocks could occur under any of the 4 scenarios, the success or otherwise of an innovation or a portfolio of innovations under a shock occurring in each scenario should be considered again by workshops with stakeholders. A list of possible shocks needs to be drawn up – these may be unique to a given scenario or common across more than one of the 4. Then each of these needs to be considered individually in the context of the particular scenario. Step B2 deals with looking at the effectiveness of responses in terms of a particular challenge and the approach given there may be followed for considering shocks.

4 Summary and conclusion

The approach laid out in Section 3 of this report will provide the means for PREPARED partners to ensure that appropriate consideration is given to the future in their parts of the project. Without this there is a risk that, partners will take a disparate, fragmented and non-commensurate approach to including the future in there development of innovative ideas, tools and techniques in PREPARED. The scenarios approach tests the potential robustness into the future of these innovations in coping better with climate and other changes. It also tests the potential take-up of technology and other measures to address the challenges and maximise the opportunities. The approach presented is by no means the only one possible, but has been developed to be as simple and straightforward as possible in application as well as generic enough to apply to all of the scales, temporal and physical, contexts and jurisdictions being considered in PREPARED. Application will require considerable workshop activity both to further refine the approach (PREPARED partners) and to implement it (PREPARED stakeholders and partners). It will also be reviewed and further amended (PREPARED partners).

This is intended to be a living document that will be revised from time to time as evidence for its application becomes available in the PREPARED project.

Appendix A SRES scenarios

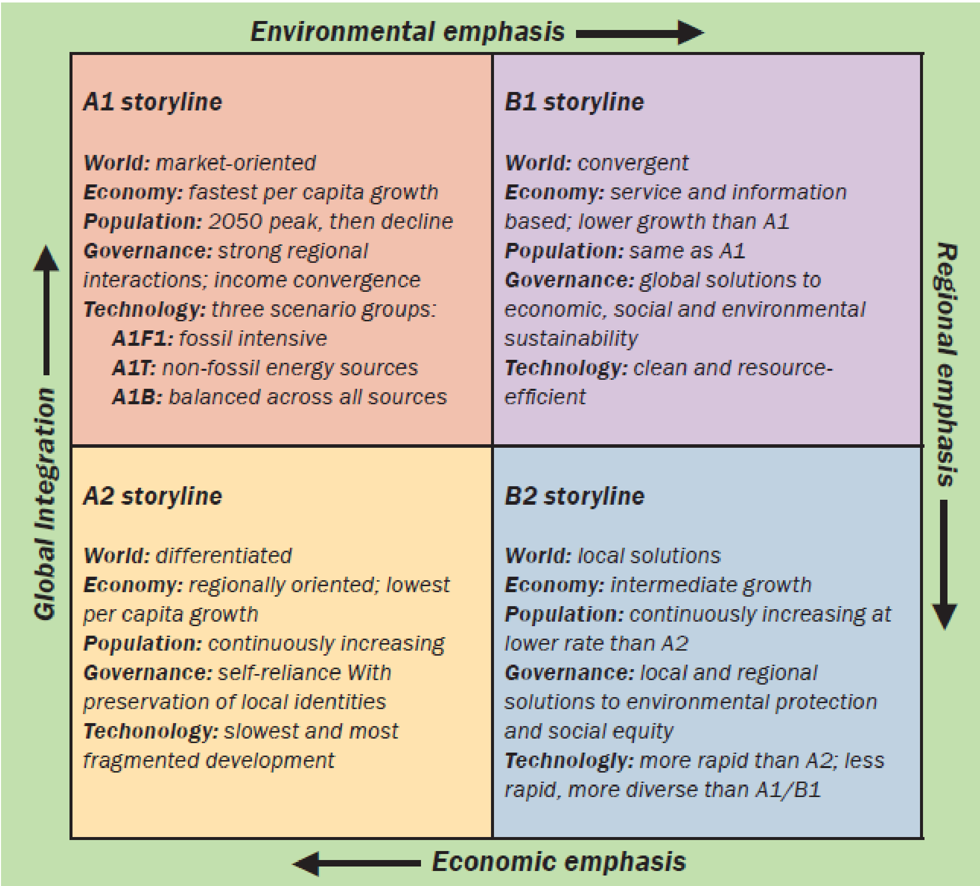


Figure A-1 Summary characteristics of the four SRES storylines

The A1, A2, B1, B2 scenarios illustrate the consistent narratives that have been used in developing the IPCC reports.

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