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Sustainable Development Scenarios for Rio+20

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Feedback: Your feedback is most welcome: roehrl@un.org.

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1. Introduction

This report is the result of a collaborative effort of 49 global modellers and scenario analysts. It draws lessons from 40 years of global sustainable development scenarios based on 98 models, with a particular focus on the most recent scenarios, many of which have been created specifically for the UN Conference for Sustainable Development, informally referred to as "Rio+20". Scenarios are documented in terms of ultimate goals, visions, strategy (including goals and targets), pathway characteristics, and policies and actions, as well as investment needs. Past trends towards sustainable development are compared with baseline scenarios for the future and contrasted against sustainable development scenarios. Synergies and trade-offs are discussed for a range of clusters of sustainable development goals. A case is made for renewed efforts to create global sustainable development scenarios that can build on synergies and resolve the most important trade-offs, in support of the development of the Sustainable Development Goals, envisaged at Rio+20. Reflections are offered on how to improve the science-policy interface, by creating a better "team" of scenario analysts, scientists and policy makers. The report concludes with issues for consideration.

1.1. From Rio to Rio+20

UNCSD ("Rio+20") in 2012

The United Nations Conference on Sustainable Development (UNCSD), popularly referred to as "Rio+20", was held in Rio de Janeiro, Brazil, from 20-22 June 2012. Its purpose was to review progress since the United Nations Conference on Environment and Development (UNCED), popularly referred to as the "Earth Summit", which was held in Rio in 1992, twenty years after the first UNCED in Stockholm in 1972.

Earth Summit ("Rio") in 1992

Key outputs of the Earth Summit of 1992 comprised of two documents: the Rio Declaration which contained the "Rio principles" and a global action plan ("Agenda 21"). These two documents were endorsed at the highest political level, the United Nations General Assembly. At the Earth Summit in 1992, the international community adopted the concept of "sustainable development" which brought together development and environment concerns, and suggested to address them in an integrated way, in view of strong inter-linkages, trade-offs and synergies between objectives and actions in the development and environment realms.

Brundtland report (1987)

The intellectual basis for sustainable development was popularized in broad terms by the "Brundtland report"[1] in preparation of the Earth Summit. Even though sustainable development had been an area of academic research and scenario analysts since at least the 1960s, the Brundtland report popularized the concept in a way that was amenable to decision-makers.

The "Rio deal" in 1992

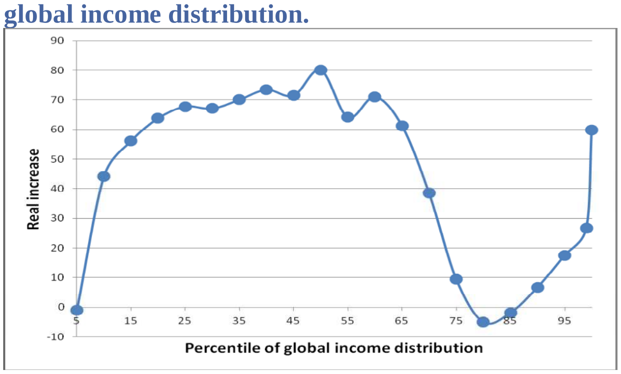
The report paved the way for a grand deal between developing and developed countries to come together and work towards a "common future" which also became the title of the report. The deal broke an impassé at the international level which had become all too apparent since the 1970s,[2] following the independence of a large number of former colonies. The grand deal meant that developed countries would take the lead in addressing environmental issues. Developing countries would take early commitments and action on environmental issues despite their more pressing poverty and development challenges. In turn, developed countries would support developing countries with "means of implementation", especially with finance, capacity building and technology. The deal of 1992 led to a series of international conventions, including on climate change (UNFCCC), biodiversity (CBD) and successive global and regional plans and programmes. Since 1992, various world

[1] The name derives from the fact that it was chaired by then Prime Minister of Norway, Gro-Harlem Brundtland.
[2] This was as evidenced, for example, by the Vienna Conference on Science and Technology for Development in 1979, and to a lesser extent already at the original UNCED in Stockholm in 1972.

events and the rise of emerging economies have eroded the basis for the original Rio deal. In fact, the majority of developed countries do no longer accept the deal, as evidenced, for example, by their rejection of reaffirmations of major elements of the Rio principles and elements of Agenda 21.

Figure 1 shows the global winners and losers in real income from 1988 to 2008. All income gains have been reaped by the rising middle-class in developing and newly industrialized countries, as well as the super-rich in all countries. In contrast, incomes of the poorest in developing countries and of low and middle-income groups in developed countries have stagnated or decreased. The overall result has increased inequality within countries and catch-up growth of an increasing number of developing countries.

Figure 1. Changes in real income vs. percentile of the global income distribution.



Note: real income calculated in 2005 international dollars.
Source: Milanovic (2012).

1.2. Objectives, scope, and target group of the study

UN Study on "Sustainable Development in the 21st Century" (2011-2012)

There had been suggestions for a new report to support the preparatory process for Rio+20.[3] However, views within and outside the UN differed greatly as to whether such report would be desirable and what it might want to achieve. In 2011, the United Nations Department for Economic and Social Affairs, which also served as the Secretariat for Rio+20, received funding from the European Commission for a series of studies and a UN report for Rio+20. The output of the project entitled "*Sustainable Development in the 21st Century*" became known as the "*SD21 study*".[4] In view of great differences in worldviews and expressed opinions among governments, international organizations and major groups, the SD21 study focused on describing these differing views and on pointing out possible ways forward in finding common ground, rather than being normative. The stated overall objective of the SD21 study was "*to construct a coherent vision of sustainable development in the 21st century.*"

Objective of the present report

The present report is one of the background reports under the SD21 project. Its objective is to review and draw lessons from forty years of global sustainable development scenarios, with a particular focus on the most recent scenarios, many of which have been created specifically for Rio+20.

It is a technical, analytical, and descriptive contribution to the global debate on sustainable development that draws upon and critically assesses facts and figures, in order to shed light on how the communities of scenario analysts, scientist, and policy makers interact.

Target group

The target group of the report comprises of scenario analysts, modellers, scientists, policy makers and decision-makers in private and public sectors.

Global scope

We consider primarily *global* sustainable development scenarios, in terms of issues, impacts, institutions and technology. Aspects at the regional, national and local levels are covered to the extent necessary.[5]

[3] E.g., http://www.endseurope.com/13338/brende-urges-new-brundtland-report, posted 17 April 2007; or http://www.un.org/wcm/content/site/climatechange/pages/gsp/termsofreference

[4] The SD21 study was the only publication of the UN system being part of the official UN budget of Rio+20.

[5] For example, aspects of the climate-land-energy-water nexus are also discussed at the national and local levels.

Definition of sustainable development

We follow the definition suggested in the Brundtland report which refers to "*development which meets the needs of current generations without compromising the ability of future generations to meet their own needs.*" While this general definition has been widely accepted, more specific definitions derived from an operational translation of the principle of inter-generational equity differ greatly, especially in terms of their vastly different scopes. These definitions are grounded in different worldviews that ultimately arise from different sets of values. The different choices of values lead to different emphases on what is to be sustained and what is to be developed, as well as on different relevant time scales. Table 1 illustrates the results of a comprehensive literature review of sustainable development definitions. Different sets of values lead to definitions that typically cover a subset of issues under any of the six areas, and different time perspectives. In fact, using a different time perspective alone leads to different scopes. For example, issues of importance on the order of 100 years, such as climate change, are pretty much irrelevant in a perspective of 5 to 10 years.

Scope of sustainable development scenarios

Sustainable development scenarios typically follow sustainable development definitions that are based on elements of nature, life support, people, and economy. Not much work includes the community and society dimensions. Of course, modellers are further constrained by the limitations of their models and choose practical subsets of goals and targets.

Table 1. Literature review of sustainable development definitions

Values	What is to be sustained?	For how long?	What is to be developed?
Freedom Equality Solidarity Tolerance Respect for nature Shared responsibility ….	**(S1) Nature** Earth Biodiversity Ecosystems	5, 10, 20, 50, 100 years, forever, etc.	**(D1) People** Child survival Life expectancy Education Equity, Equal opportunity Human security
	(S2) Life support Ecosystem services Resources Environment		**(D2) Economy** Wealth Productive sectors Consumption
	(S3) Community Peace Cultures Groups Places		**(D3) Society** Institutions Social capital States Regions

Note: Adapted from NRC (1999) and Kates et al. (2005).

1.3. Outline

Chapter 2 presents the methodology and terminology used and outlines milestones in the SD21 scenario process that has led to this report. Chapter 3 sketches the experience with global models and scenarios since 1970. It focuses on those models, scenarios and approaches that have eventually led to the recent sustainable development scenarios developed for Rio+20 which are described in more detail in Chapter 4. Common strengths and weaknesses of these scenarios are discussed in Chapter 5. Chapter 6 translates the key messages of all Rio+20 scenarios into simple, alternative narratives (or "stories") of the future which are compared past progress towards frin 1950 to 2010. The story of continuing like in the past (*dynamics-as-usual scenario*) is presented, as is that of a better world that we could feasibly achieve (*sustainable development scenario*), and that of an alternative "prediction" of the future (*Randers' scenario*). Chapter 7 provides survey results and findings on the effectiveness of the current practise of using scenarios at the global science-policy interface. Finally, chapter 8 concludes with issues for consideration.

The report's chapters are mostly self-contained. Hence, a non-technical reader interested mainly in policy questions could focus on chapters 1, 6, 7 and 8, whereas scenario analysts might be especially interested in chapters 2, 4, and 7.

2. Methodology, terminology and process

This section introduces the methodology and terminology used, and summarizes milestones in the SD21 scenario process that has led to this report.

2.1. What are scenarios?

Definition

There are many types of scenarios being used in policy business and academia. But all scenarios have in common that they are understood as *internally consistent, plausible paths describing developments into the future*. One prominent example is the definition of scenarios suggested by the Intergovernmental Panel on Climate Change (IPCC) which undeniably has been the centre of global scenario work in recent years (Box 1). Policy makers often refer to scenarios as *pathways*, which is used synonymously in this report.

Box 1. Definition of "scenario"

"Scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might unfold. A set of scenarios assists in the understanding of possible future developments of complex systems. Some systems, those that are well understood and for which complete information is available, can be modelled with some certainty, as is frequently the case in the physical sciences, and their future states predicted. However, many physical and social systems are poorly understood, and information on the relevant variables is so incomplete that they can be appreciated only through intuition and are best communicated by images and stories. Prediction is not possible in such cases."

IPCC-SRES (2000)

The IPCC scenario definition makes it clear that scenarios typically do not aim to make forecasts or predictions of the future. Good scenario analysis has nothing at all to do with prophecy or apocalyptic thinking, which are instead common in religious contexts. Similarly, scenario development is very different from utopian thinking (such as Thomas Moore's Utopia of 1516), even though utopian thinking has - at times - influenced the conception of normative goals as inputs to scenario development. Scenario analysts do not intend to say anything definite about how the future will unfold. Instead, they use various techniques to deal with complex systems when asking *"if, then…"-questions*. In other words, scenario analysts make assumptions about the future and the underlying system dynamics, in order to say something consistent about plausible future developments.

Visions

Visions underlying scenarios show some similarity to enlightened futures (such as those of H.G. Wells and Jules Verne), but the idea of scenarios is to be a tool for ensuring internal consistency.

Box 2. IPCC view on descriptive vs. normative scenarios.

"Although no scenarios are value free, it is often useful to distinguish between normative and descriptive scenarios. Normative (or prescriptive) scenarios are explicitly values-based and teleologic, exploring the routes to desired or undesired endpoints (utopias or dystopias). Descriptive scenarios are evolutionary and open-ended, exploring paths into the future. The SRES scenarios are descriptive and should not be construed as desirable or undesirable in their own right. They are built as descriptions of possible, rather than preferred, developments. They represent pertinent, plausible, alternative futures."

IPCC-SRES (2000).

Sustainable development scenarios

Sustainable development (SD) scenarios explore futures that develop and/or sustain various elements that are considered essential or desirable, based on the values of their authors. Hence, sustainable development scenarios are inherently normative in nature. The dominant current approach is to agree on normative goals, targets or end-points and to design feasible pathways to achieve these normative goals. It is important to note that the IPCC in its influential *Special Report on Emissions Scenarios* (SRES) report, published in 2000, emphasized its intention to create descriptive, rather than normative scenarios (Box 2). This is important to note, in view of the fact that one of the IPCC-SRES scenario groups, the B1 scenario group, has been influential in the development of global sustainable development scenarios ever since, including those for Rio+20 described here.

Why scenarios?

Why do we make use of scenarios? Scenarios provide a minimum level of coherence and consistency, providing a feasibility check. They have helped envisioning futures and have inspired action. Some argue that good governance calls for participative scenario analysis for sustainable development goals, action plans, and policies (e.g., World Bank, 2010).

At the same time, it needs to be recognized that scenario analysis is an art, not a science. It has its fair share of pitfalls, especially when it operates at the science-policy and science-business interface. But its purpose is not primarily progress in science, but rather to find ways to make the scientific body of knowledge amenable to decision-making. It draws on science, but uses it to provide actionable insights for decision-making. In this sense, scenario analysis is "art" rather than science. It should be noted, however, that there is no general agreement on this conclusion, as evidenced by the IPCC definition of scenario (Box 1).

Scenarios can be a powerful interface between the body of knowledge and actual decision-making, as they provide a minimum level of coherence, consistency and feasibility checks. Scenarios have helped envisioning futures, have inspired action, and participative scenario processes have contributed to better governance. Today more than ever, there is a need for scenarios that follow a plausible, robust strategy to achieve comprehensive lists of sustainable development goals.

2.2. What are global scenario models?

Global models (or world models) aim to contribute to finding solutions to *global problems*. A global problem is one that is "*long-term, persistent, pervasive, affecting many people, the 'ownership' of the problem being difficult to establish, the characteristics of the 'solution' being unknown, and proposed solutions requiring new styles of cooperation for implementation.*" (Asboth, 1984, p.4f).

UNESCO offered a widely accepted definition of global models (Box 3). Hence, as far back as in 1985, it was clear that global models would aim to capture all three pillars of sustainable development and explicitly acknowledge political issues, as the default option. Despite much greater computing powers and knowledge of salient dynamics and interrelationships, quantifications with such wide scope have been exceptions rather than the rule in the past twenty years. The global models and scenario for Rio+20 have been the latest attempt to re-capture all three pillars of sustainable development.

Box 3. Definition of "global models"

> *"… global or world modelling… is the attempt to rigorously represent economic, political, social, demographic, and/or ecological issues and their interdependencies on a global scale. The models map these relationships as explicit equations, 'run' them forward in time and study their dynamic behaviour. This simulation of future developments is done with computers able to handle such a set of complex simultaneous direct and indirect effects of the factors represented in the model."*
>
> UNESCO (1985, p.11)

2.3. Overall nature of the report

The present report is not an academic, scientific report, nor is it a political, negotiated one. Instead, it aims to link the rigorous, academic literature with the needs of decision makers. For example, it reports on findings and conclusions of scientific scenario studies, but reports them with policy makers in mind who only need to grasp the key messages, in order to make informed decisions. And it reports on findings and decisions of policy makers, such as international commitments, in a way in which it should be readily usable by scenario analysts. Hence, the present report operates directly at the global science-policy interface.

2.4. Methodology

Action research

The present report is based on outputs and insights from a "scenario process" organized by the UN from January 2011 and June 2012. To-date, almost all scenario studies commissioned or undertaken by the UN system are carried out by paid experts, in order to provide a particular product, such as a chapter in a report on a specific topic (e.g., climate change). As a result, in these studies the overall content, messages/agenda and approach are typically donor-driven, whereas the results, assumptions and model designs are typically controlled by scientists and scenario analysts. And partnerships are often influenced by the contractual relationships related to these studies. Some have criticised these studies to be geared to confirm pre-determined solutions of policy makers, whereas others have deplored what they consider undue influence of experts on policy making without sufficient stakeholder participation (Girod, 2006). Whatever it may be, it is clear that in institutional setups in which Governments or UN organizations provide funds or commission scenario studies to individual groups, the science policy interface does not operate as a "one way street". Instead, such scenario reports will tend to be the result of strategic games between scientists, scenario analysts, policy makers and facilitators (e.g., UN staff). Hence, the fact that scenario analysts have become increasingly dependent on extra-budgetary funding and consultancy contracts, has important implications for the content and independence of their work.

Against this background, UN staff who organized the SD21 scenario study made it explicitly clear that they would be actors in this game and could not pretend to be neutral bystanders, no matter how hard they would try. Indeed, the present report is the result of action research.

To minimize undue influence, UN organizers decided not to provide funding to scenario analysts for scenario work. The only funding provided was for participation in a face-to-face expert group meeting in Vienna in June 2011. Despite this decision, scenario work undertaken by participating experts for Rio+20 was significant, with resources of several million US dollars committed, which was much more than could have been raised through the project.

The expected approach, possible outputs and timeline were specified by UN staff at the beginning of 2011, but it was made clear that the activities and timeline would essentially be up to the collaborative decision of participating experts.

Data collection

Data contained in this study were collected from official statistics, analysis of documents, model in- and outputs, and through surveys of and feedback from scenario experts.

Scenario models

Participating scenario experts used a range of integrated assessment models and modelling approaches which are outlined in chapter 4 together with a summary of highlights of the Rio+20 scenarios.

Scenario comparison

The scenarios presented in this report differ greatly in terms of scope and underlying modelling approaches. To maximize comparability, scenarios are documented along a simple hierarchy of five levels (Table 2).

Table 2 Five-level hierarchy for scenario comparison.

Typical scenario model implementation	***Levels***	**What they represent**
Normative model input	*Level 1*	Ultimate goal
	Level 2	Vision
	Level 3: Strategy	Themes
		Goals
		Targets
Model output	*Level 4: Blueprint*	Pathway characteristics
Ex-post policy interpretation of model results	*Level 5: Implementation*	Policies and actions
		Investments

Source: David le Blanc and R. Alexander Roehrl

Level 1 refers to the ultimate goal being explored by the scenario, level 2 refers to the underlying vision, and level 3 describes the scenario strategy, including themes, goals and targets. In most cases, these elements are normative model inputs. Level 4 describes the scenario's blueprint to achieve the goals and targets by particular dates, i.e., the pathway characteristics, which are typically a model output. Level 5 outlines the implementation of the blueprint, in terms of policies, actions and investments, which are typically model outputs or ex-post policy interpretations of model results (Table 2).

Rationale for the five-level hierarchy – the cupboard story

Despite its simplicity, the five-level hierarchy of Table 2 provides a powerful means of summarizing scenarios. In fact, it resembles the systematic approach typically used by programme and project managers. It is a useful way of organizing material and analysing different perspectives, and appears to be a natural way of organizing policy makers' choices.

There must be agreement between policy makers and scenario analysts on most if not all five levels, in order for an effective science-policy interface supported by scenarios. The following analogy to organizing a messy room with an cupboard was used by the project team as a unifying concept for the SD21 studies.

Imagine your room is a real mess. Maybe your landlord has confronted you over it and you might even face eventual eviction. You consult with your family and decide to clean up your mess. Among the various options you have you decide to buy a cupboard that satisfies a list of criteria. You look through the catalogue and select a cupboard that seems fit and buy it. In the box that comes with it there is a note with assembling instructions. You have a look, get your tools and assemble the cupboard and the fill it (
Table 3). However, later you find that your room is still a mess. You sit together with your family and discuss what went wrong. Maybe your wife thinks you did not do a good job in assembling the cupboard and hence she could not put enough stuff in it (Level 5). But maybe you perfectly followed the assembling instructions, but the instructions were wrong (Level 4). Or maybe you did not buy a cupboard model that satisfies your actual needs (Level 3). Or maybe your overall approach was wrong, i.e., maybe buying a cupboard wasn't the right thing to do (Level 2), and it would have been better to have a garage sale to get rid of household goods and to acquire fewer household goods in the future. Or maybe your family members did not really agree on the ultimate goal to clean up the room in the first place (Level 1), which led to only half-hearted support.

In a perfect world, you would have agreed among family members on the decisions at all five levels. But in a less than perfect world, *making the right decisions is essential on levels 5 and 3*. If you did not assemble the cupboard (Level 5) or did not select a suitable cupboard (Level 3), there is no way to clean up the room. On the other hand, even though the assembling instructions might have been wrong (Level 4), you might have still assembled a great cupboard due to your great practical skills. Similarly, you might just have accidentally chosen a suitable cupboard, even without a systematic plan for what you are looking for in the first place (Level 2). Finally, even though some family members might not have agreed with the idea of cleaning up the room in the first place (Level 1), this would only become a serious problem, if they were sufficiently influential (e.g., the housewife).

There is a surprisingly good analogy between this cupboard story and our collective efforts toward sustainable development (
Table 3). Twenty years after the Rio Earth Summit and forty years after Stockholm, global progress has been mixed at best and humanity is left with a "mess".[6] While the international community officially agreed on sustainable development as the ultimate goal in 1992, we are far from a real global consensus on the ultimate goal (Level 1). In fact, most powerful players follow the ultimate goal of economic growth instead. There is no global consensus on what to sustain and develop and for how long (Level 2). The international community has agreed on a series of strategies, including goals and targets (e.g., MDGs). Yet, there is no agreement on a systematic set of goals on sustainable development (Level 3), and discussions on the logical consistency between existing goals

[6] Just to name one example, global CO_2 emissions have increased at an accelerated rate in the first decade of the new century, faster than in preceding decades. Thus, we have not even managed to slow the increase let alone to reduce them.

hardly takes place. UN member States agreed on various blueprints upon which action might be based, in particular Agenda 21 and JPOI (Level 4). Yet, these plans have not been taken seriously everywhere, as evidenced by the ignorance of the existence of these plans even in parts of governments that are responsible for their implementation. It should be noted that these plans also include a long list of specific goals (Section 7.4). In particular, Agenda 21 already included most of what became the Millennium Development Goals a decade later. Finally, there is almost universal agreement that there is a significant "implementation gap" (Level 1), an issue emphasized especially by the group of G77 and China in UN debates. In view of this gap on Level 1 alone, it is impossible to identify with certainty the ultimate reason for our collective failure to move onto a global sustainable development path.

Yet, the scientific evidence on global sustainability has been relatively clear for several decades. Scenarios have been instrumental in making this body of knowledge available to and actionable for policy makers. Scenarios have facilitated a conversation between science and policy on sustainable development. Hence, we can also look at scenarios at the science-policy interface following the cupboard analogy, in order to shed light on where things went well and where they might have gone wrong.

Table 3. The IKEA cupboard story

Level	What it represents	Cleaning your room ("cupboard story")	Sustainable development progress	Scenarios at the science-policy interface for sustainable development
1	**Ultimate goal**	You want to clean the room	SD as the ultimate goal, including the scientific basis	Sustainable development as the common ultimate goal for policy makers, scientists and scenario analysts.
2	**Overall approach – visions (ends)**	Decide to buy a cupboard that satisfies a list of criteria	What to sustain and develop: e.g., people, economy, society, life support, nature, and community.	Common vision followed by policy makers, scientists and scenario analysts on what to sustain and develop and for how long
3	**Goals and strategies (means)**	Select a cupboard that seems fit and buy it	Strategy, including goals and targets: e.g., MDGs, SDGs	Common goals adopted by policy makers, scientists and scenario analysts, and analyzed in scenarios.
4	**Policies, programmes and action plan**	IKEA assembling instructions	Blueprints upon which action is based: e.g., Agenda 21 and JPOI	Scenarios supporting policies, programmes and action programmes.
5	**Implementation**	You and your tools	Implementation of specific actions included in plans	Joint action supported by scenarios.

Source: David le Blanc and R. Alexander Roehrl

2.5. SD21 scenario process and outputs

This section provides more details on the SD21 scenario process and describes its most important outputs.

The present report would not have been possible without the scenario development, inputs and suggestions by 49 scenario analysts and modellers who participated in the SD21 scenario process organized by DESA from 2011 to 2012. Contributors represent different worldviews and modelling approaches.[7]

Original plan

Following several months of internal consultations at the United Nations Secretariat, in January 2011, the SD21 team launched the SD21 scenario process, in order to engage a wider spectrum of scenario modellers.

[7] The list of experts is provided in the acknowledgements with their affiliations.

The original plan - outlined in DESA's "*Note on SD21 scenarios*"[8] – was to form an expert team of scenario analysts and modellers who had published global sustainable development scenarios and/or planned scenario contributions for Rio+20 in 2012. The team was to comprise of both integrated assessment modellers and sectoral modellers. It would work together to carry out a meta-analysis of most recent Rio+20 scenarios and to jointly develop SD21 sustainable development scenarios that would capture all of the dominant perspectives in the Rio+20 debates.

The team was to present results in the form of semi-quantitative stories that would be fully comprehensive in the sense of capturing elements from all six areas included in Table 1. Such a story could have provided the "vision", "pathways", and "roadmaps" that governments repeatedly called for in the Rio+20 preparatory process. In addition, it would have provided a first systematic and relatively comprehensive assessment of the trade-offs and synergies in attaining sets of sustainable development goals within and across sectors. Indeed, relative to assumptions on what actions might be feasible, it would have a provided a first glimpse as to which sets of sustainable development goals might be feasibly attained simultaneously and which not. Such information could have been used to inform delegates to support realistic decision-making on the Rio+20 outcome document. The scenario meta-analysis was to draw upon existing model comparison projects and follow a simple ImPACT classification, in order to allow broad-brush comparison across sectors and modeling communities.

In order to support discussions across worldviews dominant in Rio+20 negotiations, it was suggested to jointly developing stylized scenarios for each of the dominant perspectives which would be associated with sustainable development goals to be explored by modelers. Hence, the intention was to be as comprehensive as possible, covering all relevant sectors, modeling approaches, and worldviews. It was also envisaged to include at least an overview of extreme events and their implications for lessons-learned from mainstream scenarios that do not typically include the possibility of these low probability, high impact events. In contrast to earlier scenario efforts under UN auspices, the team planned to be as participative as possible, including through an open-source, open-data process.

Challenges encountered

The challenges encountered required changes in the original plan. Some of these challenges are sketched out here, because they shed light on the constraints and challenges that scenario developers face these days.

Above all, internal and external politics were *the* most important challenge. In particular, it highlighted very different perspectives on what the role of science should be in policy making, and hence what the role of scenarios should be (if any). Another political factor was the ongoing competition between established scenario processes and existing groups providing advice to decision-makers, including between UN entities.

Over-commitment of major players was a very important constraint. In this context, some have said that a "scenario industry" has developed, especially in the climate change context, with a lot of assessments almost exclusively financed on an ad hoc project basis by public and private donors. As a result, most of the resources are dedicated for modelling single issues, which today overwhelmingly means climate change. It leaves limited time and resources for new, innovative work and even less for new model development. Another consequence is strategic gaming and complex contractual relationships in the "industry". Administrative and political constraints in the UN, including in terms of collaboration between UN organizations, were also significant.

Scenario experts expressed no interest in collaborating on scenario meta-analysis, in part because it was considered a highly resource-intensive task. Most interestingly, there was no interest in the joint development of SD21 sustainable development

[8] For more details, please refer to the original "Note on SD21 scenarios" by David le Blanc and R. Alexander Roehrl of DESA, Jan. 2011, http://www.un.org/esa/dsd/dsd_sd21st/21_pdf/conceptnote4.pdf

scenarios across sectors and modeling communities. Experts on development, water, food, and energy did not see clear advantages to working together, nor was there an interest to work together among experts from a mainstream technology perspective, from a green growth perspective, or from a limits-on-consumption perspective.

Only a minority was interested in the debate on extreme events. Similarly, some participants clearly disliked the idea of the envisaged review of models, scenarios and science-policy interaction since 1992.

Milestones achieved, 2011-2012

The SD21 scenario process started in January 2011, and it was organized as an open, non-discriminatory, and non-judgemental process. In an initial phase of consultation and stock-taking, a concept note on the scenario process with initial scenario storylines was produced (Table 4).

Table 4. Suggested SD21 scenario families, as of January 2011.

Scenario families	*Endpoints / SD21 scenarios*	"Partial" environ-mental	GHG concentrations	Other long-term environ-mental	Economic	Social
Brown	**Business-as-usual scenario** ("Growth first")					
	Dynamics-as-usual scenario ("Growth first with continued incremental improvements")					
	Catch-up scenario ("Growth first with focus on catch-up development")				Yes	
Green	**Green economy scenario** ("Growth with partial environmental objectives")	Yes				
	Climate scenario ("UNFCCC world")		Yes			
	Planetary boundaries scenario ("One planet world")		Yes	Yes		
Yellow	**Development scenario** ("MDG+ economy")					Yes
Rainbow	**Sustainable development scenario** ("SD21 scenario")		Yes	Yes	Yes	Yes

Source: David le Blanc and R. Alexander Roehrl

UN-DESA, which also served as the Secretariat for Rio+20, assembled a team of 49 scenario experts and convened the "*Expert Group Meeting on Sustainable Development Scenarios for Rio+20*", hosted by the International Institute for Applied Systems Analysis (IIASA) in Vienna/Laxenburg from 27 to 29 June 2011[9], in order to discuss the overall approach, assemble scenario inputs, and to agree on a work plan.

The scenario experts recommended more than 1,000 papers and contributions that were considered. These cover several sectors and approaches. Two surveys were conducted among modelers on worldviews and on sustainable development goals and targets, results of which are documented in this report. In addition to global scenario work, inputs were also received from the OSEMOSYS and CLEWS communities with work at the national level.

A number of scenario teams developed new scenario variants for Rio+20 as inputs to the SD21 study (see chapter 4), and also documented them separately (Table 5) in what amounts to multi-million dollar scenario studies. Some of the studies were published in a Special Issue of the Natural Resources Forum on Scenarios for Rio+20. Based on the Rio+20 scenario

[9] www.un.org/esa/dsd/dsd_sd21st/21_pdf/report.pdf

model contributions, a simple, open-source meta-model of sustainable development is being developed by DESA which will be maintained in an open-data, open assumptions process in the years to come.

The Rio+20 scenario work continues to contribute to shaping the level of scientific insights considered by decision-makers and, above all, the extent to which humanity will make progress toward sustainable development.

Most importantly, we believe the project consultations across communities and worldviews has started a process of future collaborative work of greater relevance to sustainable development policy. In particular, the scenarios provide essential input to the formulation of consistent sustainable development goals and outline alternative pathways toward them.

Table 5. Rio+20 scenarios, lead modellers, institutional affiliations, and key publications.

Rio+20 scenario set	Lead modellers or authors	Affiliation	References
IIASA-GEA scenarios	Keywan Riahi and Detlef van Vuuren	International Institute for Applied Systems Analysis (IIASA), Austria	Riahi, K., et al. (2012). *Energy Pathways for Sustainable Development* (Chapter 17). *In:* Global energy assessment. Cambridge University Press. McCollum, D., and Riahi, K., (2012). *To Rio and Beyond: Sustainable Energy Scenarios for the 21st Century*. IIASA, April 2012. (based on GEA scenario chapter)
PBL-Rio20 scenarios	Detlef van Vuuren, Marcel Kok	PBL, Netherlands	PBL (2012). Van Vuuren, D., Kok, M. (eds.) (2012). *Roads from Rio+20: Pathways to achieve global sustainability goals by 2050*. PBL Netherlands Environmental Assessment Agency, with contributions by the Overseas Development Institute, UK, and the Agricultural Economics Research Institute, Netherlands, ISBN 978-94-91506-00-0, June 2012.
RITE-ALPS scenarios	Keigo Akimoto	RITE, Japan	Akimoto, K., et al. (2012). *Consistent assessments of pathways toward sustainable development and climate stabilization*. RITE, Japan.
SEI-SDA scenarios	Charlie Heaps	Stockholm Environment Institute (SEI), Sweden	Nilsson et al. (2012). *Energy for all in the Anthropocene: towards a shared development agenda*. SEI, April 2012. Nilsson et al. (2012b). *Energy for a Shared Development Agenda: Global Scenarios and Governance Implications*. SEI, June 2012.
OECD green growth scenarios	Rob De Link, Tom Kram and Detlef van Vuuren	OECD, France	OECD (2012). *Environment Outlook for 2050: the consequences of inaction*, OECD, June 2012, ISBN 978-92-64-12224-6; and Chateau, J., Rebolledo, C., Dellink, R., (2011). *An Economic Projection to 2050: The OECD 'ENV-LINKAGES' Model Baseline'*, OECD Environment Working Papers, No. 41, OECD Publishing.
Exploratory WITCH scenarios	Massimo Tavoni and Enrica de Cian	FEEM, Italy	Carraro, C., De Cian, E., Tavoni, M., (2012). "*Human Capital, Innovation, and Climate Policy: An Integrated Assessment*", Working Papers 2012.18, Fondazione Eni Enrico Mattei. De Cian, E., Bosetti, V., Sgobbi, A., Tavoni, M., (2009). "*The 2008 WITCH Model: New Model Features and Baseline*", Working Papers 2009.85, Fondazione Eni Enrico Mattei.
CLEWS scenarios	Mark Howells, Charlie Heaps, Guenther Fischer, et al.	Royal Institute of Technology (KTH), Sweden	IAEA, KTH and SEI (2012). *Finding CLEWS in Burkina Faso - An Analysis of the Climate, Land Use, Energy and Water Interrelation in Burkina Faso*. March 2012. Howells, M., et al. (2012). *Integrated analysis for climate change, land-use, energy and water strategies*. KTH et al. (draft)
Great transition scenario	Paul Raskin	Tellus, USA	Raskin, P., et al. (2010). *The Century Ahead: Searching for Sustainability*. Sustainability 2010, Vol. 2, pp. 2626-2651. *Note:* This is an update of Global Scenario Group's work.
Randers forecast for 2052	Jorgen Randers	BI Norwegian School of Management, Norway	Randers, J., (2012). *2052 - A Global Forecast for the Next Forty Years*. A Report to the Club of Rome Commemorating the 40th Anniversary of The Limits to Growth. Chelsea Green Publishing, White River Junction, Vermont, USA, ISBN 978-1-60358-467-8.
Global Simulation	Michael Zgurovsky and	National Academy of Sciences of Ukraine;	Zgurovsky, M., Gvishiani, A., (2008). *Sustainable Development Global Simulation: Quality of Life and Security of the World Population*.

scenarios	Alexei Gvishiani	Geophysical Center of Russian Academy of Science; Ukrainian Branch of World Data Center.	Publishing House "Polytekhnika, 2008, ISBN 978-966-299-5. Zgurovsky, M. (2007). *Sustainable Development Global Simulation: Opportunities and treats to the planet*. Russian Journal of Earth Sciences, Vol.9, ISSN: 1681-1208.
Other reviews of scenarios			
Living Planet	?	World Wildlife Fund (WWF)	WWF (2012). *Living Planet Report 2012: Biodiversity, biocapacity and better choices*. World Wildlife Fund, ISBN 978-2-940443-37-6.
GEO-5 scenario review	Detlef van Vuuren	UN Environment Programme (UNEP)	UNEP (2012). Scenario chapter of GEO-5. UN Environment Programme.
WBCSD sustainable vision 2050	Per Sandberg, Nijma Khan, Li Li Leong	World Business Council for Sustainable Development (WBCSD)	WBCSD (2010). *Vision 2050: The new agenda for business*. World Business Council for Sustainable Development (WBCSD), Feb. 2010. ISBN: 978-3-940388-56-8.
WEF global risk	?	World Economic Forum	WEF (2012). *Global risk report*.

Source: authors' compilation. *Note*: These studies have also been made available on the SD21 Website, http://sustainabledevelopment.un.org/sd21.html

3. Forty years of sustainable development scenarios and integrated assessment models

Sustainable development scenarios developed for Rio+20 in 2012 are grounded in the historical evolution of scenario models since 1970. Global scenario modelling is highly resource intensive, and hence it has overwhelmingly progressed in an incremental way.

3.1. Landscape of global scenario models, 1970 to 2012

Scenario analysis has been used for a long time, especially for military planning. However, only the advent of ever more powerful computers enabled the development of complex, quantified global scenarios since the end of the 1960s. Then since the 1980s, personal computers made access to computers far easier and cheaper.

In the 1960s and 1970s, a number of global models were created for the purpose of quantifying scenarios, hence their name *scenario models*. These early models have shaped the course of scenario model development ever since.

In 1985, UNESCO reviewed the state of global scenario models and their evolution in the preceding decades (UNESCO, 1985). It identified *three distinct schools* of *world modelling* (Box 4). They are grounded in either:

(a) Political science;

(b) Econometrics; or

(c) Systems dynamics.

Box 4. State of global scenario models in 1985

"Our study sketches the confluence of three distinct modelling streams from political science, systems dynamics, and econometrics into what today comprises global modelling. In recent years, modelling efforts have increasingly sought to explicitly incorporate global modelling, the lack of which had been a major criticism regarding earlier models. At the same time, global models have been developed, somewhat broadened in scope <u>and</u> put to use by policy-making institutions, in order to aid short-to-medium term projections… The modelling time horizon has in general become shorter and the issues addressed more specific… More so than in the past does global modelling lack a centre of gravity. While the major modelling efforts have their home base, many modellers regret the absence of a consolidating infrastructure, since the Global Modelling Conferences sponsored by the International Institute for Applied Systems Analysis… were terminated in 1981."

UNESCO (1985).

The political science tradition of global models was pioneered by Harald Guetzkow and colleagues at Northwestern University in the 1960s (Guetzkow and Valadez, 1981). It focused on heuristic simulation exercises. The Simulated International Processor Model (Bremer, 1977), GLOBUS and SIMPEST were computerized versions of this approach in the late 1970s and early 1980s.

While there were strong reservations from some economists against global models, a sizable number of economic models for long-term analysis of global issues were developed since the 1970s (Richardson, 1984). These consisted mainly of linked national econometric models for short-to-medium term economic forecasting, scenario construction and policy analysis. They typically quantified especially trade flows, exchange rates, interest rates, prices and regional macro-variables (UNESCO, 1985).

The systems dynamics tradition for global modelling was by pioneered by Jay Forrester at MIT and popularized by the Club of Rome in the early 1970s (UNESCO, 1985). This tradition pioneered the application of advanced mathematical and programming tools in models that aimed to tackle sustainable development in all its dimensions. Within this tradition, interdisciplinary teams working at (or in partnership with) IIASA developed a variation of these models with a strong focus on the role of technology change. These models emphasized North-South and environmental issues. Not surprisingly, the Brundtland report of 1987 which popularized sustainable development at the global political level drew almost exclusively on scenario modelling results of this community.

The political science tradition of global models all but disappeared from the global modelling context by the 1990s. The econometric tradition continued and lived on in the Project LINK hosted by UN-DESA. By the 2000s, this community moved to modelling MDGs, but most recently re-discovered its roots in tackling global sustainable development problems.

Today, the systems dynamics tradition of IIASA, with ever increasing technology resolution is clearly the dominant type of global modelling framework which typically incorporates macro-economic models and scientific models, too.

Regular Global Modelling Conferences, hosted at IIASA, an international institution of Academies of Sciences or their equivalents, brought the various modelling traditions together until 1981. However, since then there has been no institutional home for global scenario modelling. This may change in the near future, with the process to strengthen the science-policy interface through a recurring Global Sustainable Development Report to inform the deliberations of the High-level Political Forum on Sustainable Development, created by Rio+20. These efforts are spear-headed by UN DESA.

Figure 2 reproduces a diagram contained in the UNESCO review of 1985 which showed the dominant global models, their supporting institutions, and interdependencies in terms of personnel. The leading institutions running global models then, such as the OECD, UN-DESA, IIASA, the Club of Rome, and Academies of Sciences are still key players today.

In the context of the SD21 project, more than one hundred global scenario models used today were reviewed. A family tree of these models shows which models were derived from which or used in a framework with which other model (Figure 3). Hundreds of global models fall into only six model families, five of which were derived from (or use the same overall approach as) global models originally developed in the 1970s.

In other words, while models have become more sophisticated, especially in terms of data and software implementation, the main institutional actors and dominant modelling approaches have not changed significantly in the past 30 years. This is an illustration of the incremental progress in the evolution of global scenario models and their communities. As investments in model development and data are large, models have typically looked for problems to solve, rather than vice versa.

The design of "good" scenario models is tailored to answering a specific question. Table 6 lists typical questions asked by pioneering models of the 1970s. Today, there are scenario models that follow the very same traditions. It should be noted, however, that all Rio+20 scenarios fall into the first two categories (World3, Bariloche), as do almost all of today's dominant scenarios.

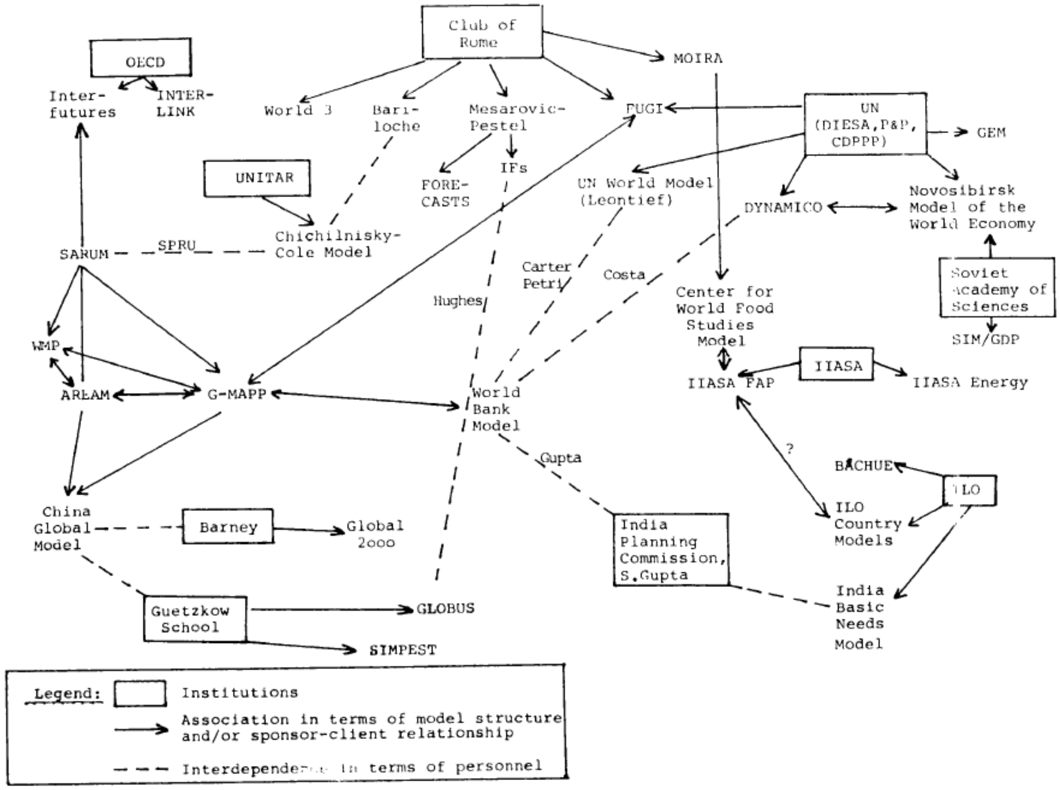
Table 6. Typical questions asked by scenario models of the 1970s.

Model	Question
World3	What will happen unless something is done soon?
Bariloche	What could be realized, if something were done?
SARUM	What is likely to happen, if the global system continues to work as it does?
OIRA	What policies are likely to lead to a better-fed world?
WIM	What social adjustments and political decisions need to be made, in order to achieve global equilibrium?
FUGI	What economic developments are consistent with other economic developments?

Source: UNESCO (1985).

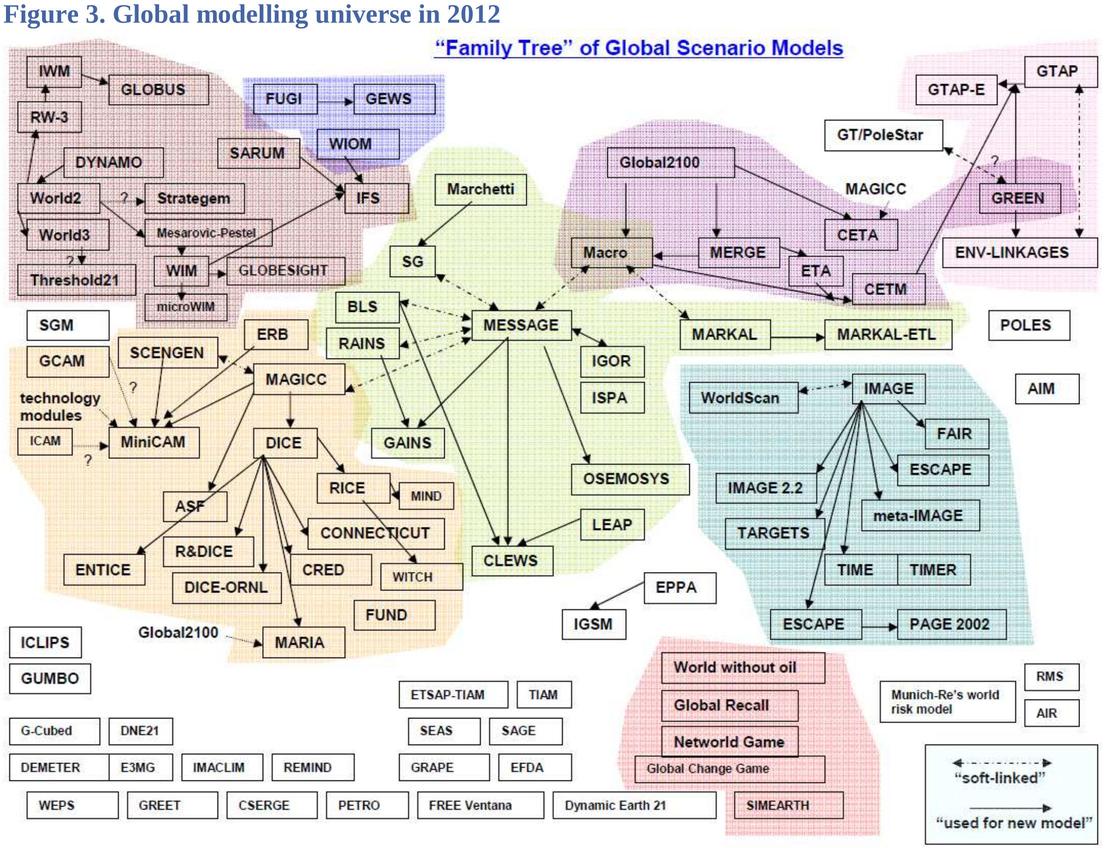
Global scenario studies have been influential. As UNESCO pointed out in the mid-1980s, "*Politically, it [global modelling] forced a new perspective on leaders and the public on the nature of, and solutions to, long-term global problems*". This statement is equally true today. It highlights the two-way feedback between scientists and policy makers facilitated by scenario analysts.

Figure 2. Global modelling universe in 1985.



Source: UNESCO (1985)

Figure 3. Global modelling universe in 2012



Source: SD21 project. *Note*: Shading denotes scenario model families, i.e., models that either derive from one parent model or that follow a similar overall approach.

3.2. Global scenarios and projections

This section sketches key scenario studies since the 1970s. In particular, it tracks the evolution of business-as-usual scenarios, dynamics-as-usual scenarios, sustainable development scenario, as well as forecasts and projections.

3.2.1. "Limits to Growth" and "Energy in a Finite World"

In 1972, the Club of Rome published a study, entitled "*Limits to Growth*" (LTG) (Meadows et al., 1973). There is probably no other scenario study that has as much inspired the thinking and imagination of the general public. The study was the result of project work by Dennis Meadows and his team at MIT from 1970 to 1972. The project aimed to address the following questions: "*Are current policies leading to a sustainable future or to collapse? What can be done to create a human economy that provides sufficiently for all?"* (Meadows et al., 2004).

The World3 model was used to develop 12 scenarios which explored consistent and plausible pathways for global population, industrialization, food production, resource use, and pollution up to 2100, under a range of assumptions. For example, scenario variants quantified the implications of the following: "*What would happen if more money was put into population control? What would happen if agricultural techniques were changed in order to reduce land erosion? What would happen if there actually were less non-renewable resources in the world than believed at the time? What would happen if people ended their romance with economic growth*?" (Randers, 2012, p.302).

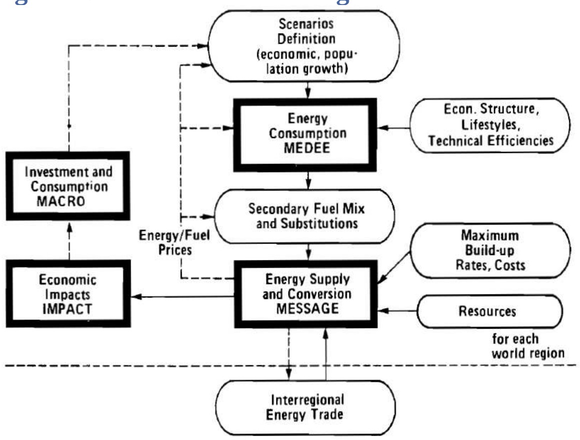
Some of the LTG scenarios showed humanity growing beyond the sustainable carrying capacity of the globe leading to low quality of life after the overshoot, whereas others followed smoother trajectories. But a key message of the report was that global economic and population growth might crash into the physical constraints of the planet in the first half of the 21st century, leading to overshoot from which there were only two ways forward "*managed decline or collapse induced by nature"* (Randers (2012). These implied the need for stabilizing policies, such as upper limits on per capita consumption, a conclusion that was clearly unacceptable to many at the time. In the words one of its authors "*The medicine was seen as worse than the disease"* (Randers, 2012, p.303).

LTG was a scenario analysis, even though much of the public perceived it as a forecast. Such misperception has continued until today, as evidenced by the discussions of the study's twenty and thirty year updates in 1992 and 2002, respectively. These discussions almost entirely revolved around whether the original LTG quantifications turned out to be "right".

It is important to note that most of today's Rio+20 scenarios are based on model frameworks in the tradition of another strand of systems dynamics modelling that emerged at IIASA since the early 1970s. This work, pioneered by Haefele and colleagues, was also seen as a response to the LTG work. The IIASA community and its collaborators around the world emphasized the role of technology progress as the most important lever of choice for achieving a sustainable future. They embarked on the development of a scenario model that aimed to represent great technological detail, technology performance characteristics and interrelationships, all of which was based on strictly empirical analysis. In a sense, this work was an engineers' response to the LTG work.

The work in the 1970s resulted in the publication of the report "*Energy in a Finite World*" in 1981 which provided a scientific-technocratic picture of how a sustainable world energy system could be achieved from 1980 to 2030 (Haefele, 1981). The study looked at the whole range of sustainable development issues (much wider than most of today's energy studies) and included technologies that are only now, thirty years later, being discussed as *new* technologies, including carbon capture, geo-engineering, modern renewables, highly-efficient and clean fossil-fuelled technology, and a hydrogen infrastructure system. Scenario quantification was carried out with the MESSAGE modelling framework, with a bottom-up technology-systems model integrated with various economic and environmental modules. It is the prototype for most of Rio+20 scenario models in 2012.

Figure 4. MESSAGE modelling framework in 1981



Source: Haefele (1981).

Newer versions of the MESSAGE modelling framework have remained the mainstay of scenario work ever since. For example, it has been the leading model for the Brundtland report, IPCC reports, the World Energy Council, the UN's World Energy Assessment, and most recently the Global Energy Assessment and Rio+20. What is more, due to its success and pragmatic technology-focused approach, it has influenced the development and application of many similar frameworks over the years.

3.2.2. Business as usual (BAU) and dynamics as usual scenarios (DAU)

A plethora of "business-as-usual" (BAU) scenarios has explored the potential consequences of the world continuing its dominant development model.

Most recent scenarios of this type were designed as "dynamics-as-usual" (DAU) scenarios that assume across the board incremental improvements following past dynamics. In principle, these scenarios are the closest to future projections, assuming there will not be any major breaks in the overall dynamics.

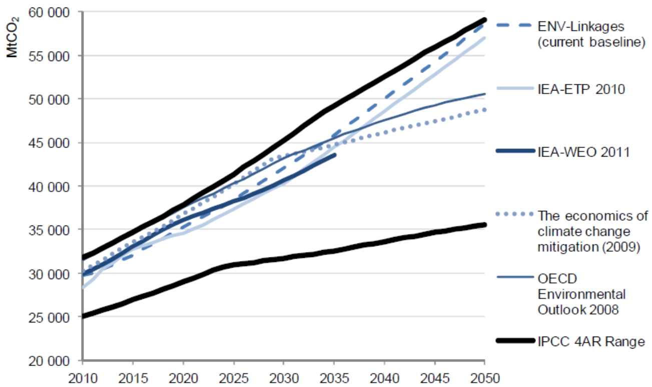
Most scenarios - but especially BAU scenarios - have been shaped by the prevailing short-term trends. Therefore, it is not surprising that BAU scenarios created by global modellers in the 1970s and 1980s typically overestimated both future material demand and the speed of technological progress. The net results were scenarios of environmental pressures that have proven to be more or less in line with real outcomes. For example, actual global energy demand in 2010 was in line with the low demand scenario of "*Energy in a Finite World*" (Haefele et al., 1981) used in the Brundtland report. Yet, actual GHG emissions were much in line with the report's BAU scenario, and actual shares of low emissions energy technologies were much lower than in the BAU scenario.

Mainstream DAU scenarios developed in the 1990s greatly underestimated actual global economic growth and energy demand in the 2000s, and continued to overestimate the rate of technology change, resulting in projections of lower environmental pressures than actually occurred. For example, actual GHG emissions in the 2000s followed the highest scenario (A1C) contained in the set of IPCC-SRES scenarios (created in 1997 and published in 2001), much higher than the DAU scenario (B2) of IPCC-SRES. Global economic growth had been greatly underestimated and technology change overestimated (when judged ex-post in 2012).

There remains no doubt that dominant short-term trends at the time of scenario creation have greatly influenced modellers assumptions about the longer-term future. Hence, it is not too surprising that the latest BAU and DAU scenarios created in recent years for Rio+20 project very high economic growth, energy demand and environmental pressures, which reflects the dominant global experience of the past fifteen years.

In addition to such "*short-termism*", work by the Energy Modelling Forum (hosted by Stanford University) and work by OECD show that baseline scenarios have become increasingly "conservative" in the past decade. For example, Figure 5 shows that the BAU scenario underlying OECD's green growth scenarios for Rio+20 is at the highest end of the full range of scenarios reviewed in the fourth Assessment report of IPCC published in 2007. If there had been no change, one would expect the newest BAU scenario to be somewhere in the middle. It should also be noted that OECD's BAU scenario for Rio+20 is in line with most of the other BAU scenarios for Rio+20 in 2012.

Figure 5. Comparison of global CO_2 emissions from fossil fuel combustion in the OECD economic projection with other studies

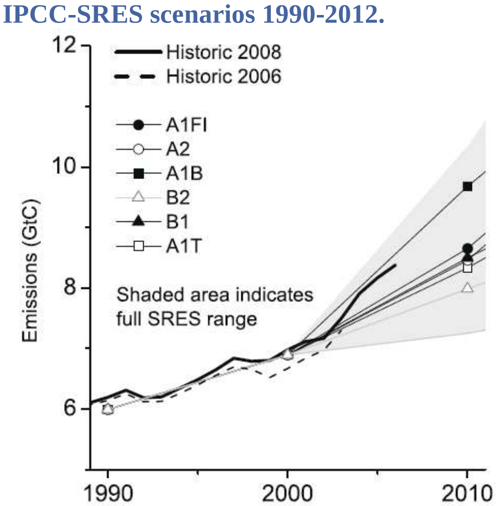


Source: Chateau et al. (2011).

The academic debate about the IPCC-SRES scenarios is another case in point. Initial versions of these scenarios which continue to inform climate change negotiations under the UNFCCC were developed between 1997 and 1998. Four scenario families (A1, B1, A2, and B2) with altogether 40 scenarios were developed, including dynamics-as-usual scenarios (B2), high-demand globalization scenarios (A1), sustainable development scenarios (B1), and scenarios of stagnating regional blocks (A2). In line with the mandate of the IPCC, the construction of the B2 scenario relied on an extensive review of past scenarios. A number of scholars criticised the A1 scenario family as exhibiting implausibly high demand and economic growth. (Some even saw a deliberate political effort to over-exaggerate demand and hence GHG emissions, in order to spur needed mitigation actions.) Yet, from 2000 onwards the world economy and global primary energy demand grew at rates not seen since the 1970s, and GHG emissions increased at higher rates than ever before in modern history, which was also due to the "coal revival" in view of high oil and gas prices (Figure 6, Figure 7).

In other words, by no means were high growth assumptions in the IPCC-SRES A1 scenarios implausible. Assessment of scenarios was influenced by the most recent experience and did not adequately differentiate between short- and long-term scenarios. In fact, as the purpose of long-term scenarios is to show the "if then" link between assumptions and consequences in the long-run, it does not really make sense to assess the plausibility of long-term scenarios through their performance against actual short-term trends. And, most importantly, even DAU scenarios are *not* forecasts. They are assuming continuation of past trends. Yet, trends and underlying dynamics do change, as illustrated in the example.

Figure 6. Actual GHG emissions 1988-2008 vs. IPCC-SRES scenarios 1990-2012.

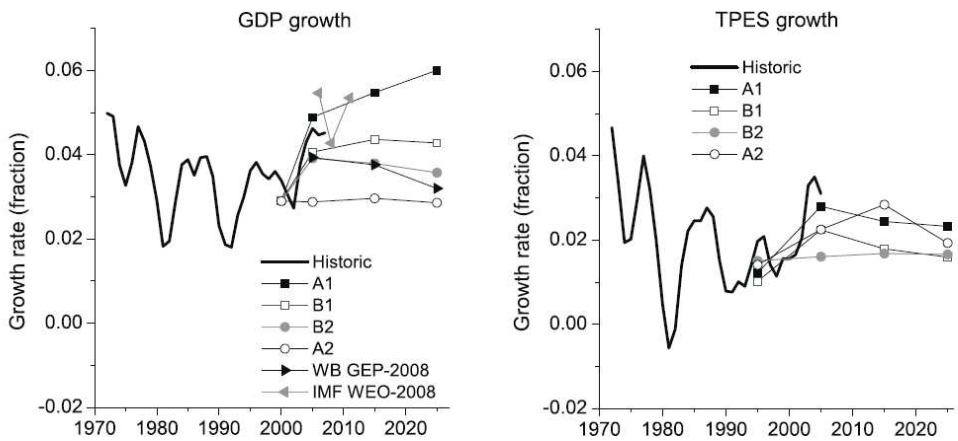


Source: Van Vuuren and Riahi (2008)

The most recent debate about the IPCC-SRES scenarios led some to question whether recent emission trends might imply higher emissions forever (Van Vuuren and Riahi, 2008). Those who answer this question with yes, again assume that the latest change in dynamics to higher growth rates would continue unchanged into the future.

These lessons from the past can help us making sense of the latest Rio+20 scenarios. In fact, their baseline scenarios are closer to the high-growth scenarios (A1) than the DAU scenarios (B2) of IPCC-SRES. The underlying assumption is that the higher growth rates of the past 15 years will continue more or less unabated. But, of course, no-one knows what will really happen.

Figure 7. Actual global economic and primary energy growth vs. IPCC-SRES scenarios.



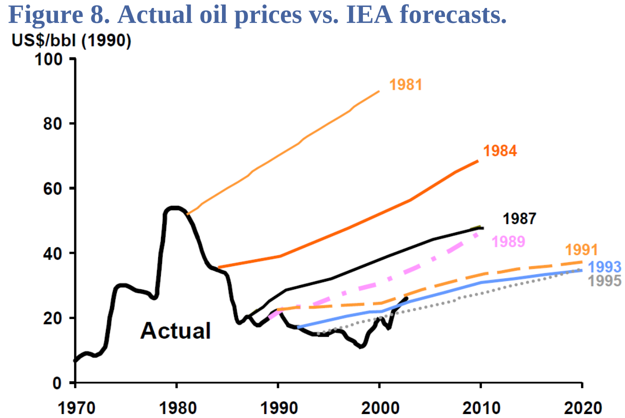
Source: Van Vuuren and Riahi (2008)

3.2.3. Forecasts and projections

Since the early 1970s, most global scenario modellers shied away from forecasts and projections. Instead, they developed scenarios to assess the consequences of certain assumptions for the future ("if, then" iteration). Already thirty years ago, it was noted that "*Although modellers themselves cautioned about the predictive capabilities of these models, the general public took a growing interest in world modelling because of the predictive power it associated with these models*" (UNESCO, 1985).

In response to requests by political decision-makers and the general public, global forecasts continue being made. The predictive power of these forecasts has remained dismal, as reported by Smil (2003), himself a pioneer of global modelling. Yet, this has not deterred government agencies, international organizations, banks and various corporations to continue publishing projections and forecasts to guide decision-making. Cases in point are the oil price forecasts of the International Energy Agency (Figure 8) which are also a good illustration of "short-termism". Long-term oil prices clearly have not followed short-term expectations.

Figure 8. Actual oil prices vs. IEA forecasts.



Source: IEA

The real value of forecasts and projections is that they provide a good account of decision-makers' expectations which guide investment decisions. Hence, forecasts might be considered to be just as valuable as scenarios, but they serve a very different purpose.

These are important lessons for understanding the one global forecast developed for Rio+20, the so-called "Rander's forecast for 2052", which is described in chapter 4 (see also Box 8). Interestingly, its author, Jorgen Randers, was one of the co-authors of the original LTG study, and his newest forecast was published for the Club of Rome in lieu of a forty year update of the LTG.

Box 5. Are long-run forecasts are possible?

"Is it possible to make a forecast of global developments over a forty-year period? Clearly it is possible to make a guess—just like it is possible to guess who will win the soccer championship in 2016. And guessing is simple; it can be done without any knowledge whatsoever about the topic.

There is a chance that your guess is right. And a much larger chance that it is wrong, as in all gambling. In the normal use of the term, "forecasting" is a more ambitious exercise. A forecast is expected to have a higher chance of being right than wrong—ideally much higher. People understand that it is an advantage to know a lot about the system before one tries to forecast its future path. If rational players plan to rely on a prediction, they usually prefer an educated forecast over uninformed guesswork. Guessing is for the less informed.

My learned—and other—friends never stop pointing out that predicting the world future to 2052 is impossible. Not only in practice, but also in theory. Of course they are right. I am the first to accept this, having spent a lifetime making nonlinear dynamic simulation models of socioeconomic systems. But my critics need to be more precise. They are right in the sense that it is impossible to predict individual events in the future, even with deep knowledge about the system. The weakness of weather forecasts beyond five days proves this to most outdoorsmen. But they are not right when it comes to forecasting broad developments. Technically speaking, it is possible to say something about trends and tendencies that are rooted in stable causal feedback structures in the world system."

Randers (2012), p.4-5

3.2.4. Sustainable development scenarios

The purpose of sustainable development (SD) scenarios is to illustrate in a coherent way what feasibly could be achieved, if we did all "the right things"[10] to move onto a sustainable development trajectory. The majority of these scenarios have been normative. Science and politics have suggested normative SD goals, and scenarios have tried to explore feasible pathways towards them. They are typically contrasted against DAU or BAU scenarios. This kind of approach was also followed by most of the Rio+20 scenarios.

It is important to appreciate the historical background, as it has strongly shaped mainstream global scenarios since, including those of the Intergovernmental Panel on Climate Change, the World Energy Council, the World Business Council, the Global Energy Assessment, and, most recently, the global scenario studies for Rio+20.

The origins, 1973- 1986

Many of the global scenarios developed between 1972 and 1986 were broad sustainable development scenarios that were contrasted with BAU scenarios.

The "Limits to Growth" (LTG) study of 1972 was only one of the early examples. The World2/3 model used for the LTG report focused on overall feedback mechanism between economic development, resource use and pollution, rather than sectoral goals.

The techno-economic systems analysis tradition was a response to these efforts by those systems analysts who preferred more technical detail, taking into account key constraints to changes in techno-economic systems. The latter tradition culminated in the "Energy in a Finite World" report (Haefele, 1981) and related reports by the techno-economic systems analysis community from the early 1970s (Haefele et al., 1974). It already addressed most of the sustainable development issues currently high on the agenda, such as development, climate change, local air pollution, resource use, global population and health, energy access, security, and sustainable consumption and production. The suggested policy solutions, most of which were technology-centric,

[10] This refers to the mainstream suggestions. Beyond the mainstream, there are a wide range of views of what would be the "right" actions to pursue.

are reminiscent of today's mainstream sustainable development scenarios and debate. For example, this included carbon capture and storage as well as rapid deployment of low-carbon energy technologies already in the 1970s.

The climate change era, 1990-2005

From the 1990s onwards, governments especially in the developed world shifted their attention to climate change as an important issue. Consequently, global modelling work on finding optimal solutions for GHG emissions mitigation received by far the largest support from donors. As a result, most global scenarios were GHG emissions scenarios. Achieving a broader range of sustainable development goals seized to be the primary objective. Nevertheless, the following global sustainable development scenarios are noteworthy exceptions:

- The C1 scenario of the World Energy Council (WEC, 1998). The extent of sustainability achieved by this scenario was illustrated in the World Energy Assessment (WEA, 2000) (see Table 7).
- The B1, B1T and A1T scenarios of Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC, 2001).
- The Japanese Government's Millennium Project systematically analyzed the sustainability of these scenarios and the above mentioned WEC scenarios and suggested a set of global sustainable development goals (Schrattenholzer et al., 2005).
- The great transitions scenarios of the Global Scenario Group (Raskin et al., 2002).
- The global challenge scenario of PBL developed for the Club of Rome (Van Vuuren et al., 2009)

One important trend to note is that sustainable development scenarios have become ever more ambitious in terms of their SD goals. CO_2 mitigation goals are a good example. Despite or precisely because of accelerating levels of global CO_2 emissions, declared CO_2 mitigation goals have become ever more ambitious. Whereas twenty years ago, a 550ppmv target was considered a very ambitious one and a 450pmv target an extreme outlier, today's international community has agreed on the 450ppmv target as the default option and considers a 350ppmv target ambitious. These levels should be compared with current CO_2 concentrations which were measured at Mauna Loa Observatory at 391ppmv in September 2012.

Table 7. SD characteristics/goals in the WEC C1, B and A3 scenarios

Indicator of sustainability	1990	WEC scenarios		
		C1	B	A3
Eradicating poverty	low	very high	medium	very high
Reducing relative income gaps	low	very high	medium	very high
Providing universal access to energy	low	very high	high	very high
Increasing affordability of energy	low	very high	medium	very high
Reducing adverse health impacts	medium	very high	high	very high
Reducing air pollution	medium	very high	high	very high
Limiting long-lived radionuclides	medium	high	very low	high
Limiting toxic materials	medium	high	low	high
Limiting GHG emissions	low	very high	low	very high
Raising indigenous energy use	medium	very high	low	very high
Improving supply efficiency	medium	very high	high	very high
Improving end-use efficiency	Low	very high	medium	very high
Accelerating technology diffusion	low	medium	medium	medium

Note: The C1 scenario was characterized as sustainable development scenario; scenario B as dynamics-as-usual; and scenario A3 as a high growth scenario with rapid technology progress.
Source: WEA (2000).

3.3. Note on progress in global scenario modelling

We conclude this chapter with a note on overall progress in global models and scenarios since 1970.

More details, but more limited scope

Today's global models are generally much more user-friendly, can tap into better data, and be run on higher performing computers than in the past. In particular, models have become geographically more disaggregated and draw on extensive technology and environmental data, including in spatial form. However, these additional details have come at a price in terms of models focusing increasingly on single or few issues and objectives. Similarly, scenario time-horizons have become shorter.

The primary concerns that global models address have moved from fundamental questions to specific, single issues. Most recently, global econometric models have re-emerged to quantify economic policies in the sustainable development context, especially for energy and climate change.

Better modelling of technology change, but less focus on other levers of change

By some accounts, the single most important progress in global modelling has been in modelling of technology change. However, this focus has had the impact of conveying the message that technology is the single most important or even the only lever of change for achieving sustainable development. Some models have also explicitly included political variables.

Large-scale collaborations, but limited consensus across communities

Very large-scale collaborations have emerged with tens or even hundreds of collaborators in some global modelling projects. At the same time, the limited consensus among modellers is apparent. There is limited agreement on SD scenarios development and especially on the nature and level of scientific-technical, political, social, economic and financial "limits" (see chapter 7).

The predictive performance of baseline scenarios has remained low. They have tended to be more pessimistic than actual trends that unfolded in reality. In particular, the performance of most global scenarios that were explicitly designed as "predictions" or "most likely cases" has been low.

Rise of a donor-driven scenario "industry" but under-investment in basic research

In the past 20 years, a donor-driven global scenario model "industry" has arisen with many players and disjoint communities. Extra-budgetary donors have had a strong influence on the topics addressed and the overall policy messages.

Expenditures have focused on model applications and adaptations for government and business clients. A decreasing share has been invested in "basic research", model methodologies and the development of completely new models.

In short, progress has been made in key areas, but weaknesses and limitations have become apparent in some areas as well. This is also illustrated in comments from an academic, Bob van der Zwaan, on the potential and limitations of scenario models (Box 6).

Box 6. An academic's view on the potential and limitations of scenario models

The predictive value of long-term scenario models is limited. Why then do we use these models, notably for ongoing sustainability studies of the IPCC and UNFCCC?

Two recent examples demonstrate that particularly integrated assessment models that simulate or optimize energy-economy-climate interactions possess little practical use when it comes to forecasting: nuclear energy and hydrogen technology. Long-term energy scenario modelling may nevertheless provide useful insight, such as for answering 'What if' questions. Also, one cannot adequately investigate long-term environmental challenges with short-sighted models. Long-term energy scenario models are often essential to set the backdrop for the operation of short-term ones. Insights can be obtained with long-term models unachievable with short-term frameworks of analysis.

A few examples indicate what long-term energy scenario models can be useful for. Suppose one would want to phase out nuclear energy as climate management option in favour of coal-based plants complemented with CCS technology, how much will the improvements in CCS need to be in order to render it economically the most cost-efficient option and let *'clean coal' appear as dominant alternative in the modelling solution? Suppose CCS is accompanied by physical leakage of CO_2 from the geological formation in which it was stored, what then are the climate mitigation costs incurred, and how much leakage would be allowed from a climate control perspective? Suppose an 'air capture' technology is developed that allows 'washing CO_2' from the atmosphere for subsequent use or storage, can it be effectively used to reach a stringent climate control target? Long-term integrated assessment models allow answering such questions and formulating internally consistent sustainability scenarios plus, more broadly, permit investigating the feasibility and global price tag of reaching a maximum of 2˚C for the global average atmospheric temperature increase.*

(Bob van der Zwaan, University of Amsterdam, Columbia University, and John Hopkins University) *Source*: Private communication, 2011.

3.4. Potential ways forward

Global scenario models remain essential for exploring policy options and for ensuring coherence and feasibility of SD goals, visions, strategies, action plans and their implementation. Hence the need for more focused support for scenario model development and application that is independent from the constraints of day-to-day politics.

The need for the resurrection of an open, global forum for sustainable development scenarios, following the tradition of IIASA forums on world models in the 1970s, has become apparent. And the UN Secretariat is well-placed to re-initiate such a forum with its partners for the benefit of a more effective science-policy interface in the future.

More investment in basic research and model development is needed, and support for global modelling should be less donor-driven.

There is a clear need for the global scenario modelling community to take up the task of assessing comprehensive lists of Sustainable Development Goals, in support of the ongoing UN process, in the follow-up to Rio+20.

4. Sustainable development scenarios for Rio+20 – some highlights

This chapter provides summaries of the sustainable development scenarios for Rio+20, in terms of approach and rationale; modelling framework; model inputs, outputs and policy interpretation; synergies and trade-offs; and lessons-learned.

4.1. IIASA's global energy assessment (GEA) scenarios for Rio+20

The International Institute for Applied Systems Analysis (IIASA) has been one of the pioneers of global modelling and of sustainable development scenarios (see Chapter 3). Their modelling approach, developed in the 1970s, has become the most widely used approach for the development of sustainable development models. Most recently, IIASA led a multi-year modelling effort, in partnership with PBL and others, to develop sustainable energy scenarios as part of the Global Energy Assessment (GEA) published in 2012 and presented at Rio+20 in June 2012. Details are provided in:

- Riahi, K., et al. (2012). *Energy Pathways for Sustainable Development (Chapter 17)*. In: Global energy assessment. Cambridge University Press.
- McCollum, D., and Riahi, K., (2012). *To Rio and Beyond: Sustainable Energy Scenarios for the 21st Century*. IIASA, April 2012. (based on GEA scenario chapter)
- GEA scenario database with full data access, www.iiasa.ac.at/web-apps/ene/geadb

The GEA is by far the most in-depth expert assessment of global energy issues to-date.

4.1.1. Approach and rationale

The GEA scenarios explored the sustainable energy futures that could be realized and what it would take to achieve them. The scenarios were developed in an interdisciplinary, expert-led scientific-technocratic process. They are energy scenarios which take into account important inter-linkages with other sectors and issues. Inter-linkages were modelled either directly or through soft-linking with other models, and as ex-post feasibility and scenario validation tests.

In the GEA scenarios, a great amount of technological detail was captured, which allows for the discussion of detailed technology strategies and future technology markets.

Four global goals and associated targets for 2030 and 2050 were set at the beginning of the modelling process (Table 8). Then scenario pathways were sought to achieve these goals and targets.

Table 8. Goals and targets in IIASA's GEA scenarios

Goals	Targets
Improve energy access	Universal access to electricity and modern cooking fuels by 2030
Reduce air pollution and improve human health	Achieve compliance with WHO air quality standards (PM2.5 concentration < 35mug/m3) by 2030
Avoid dangerous climate change	Limit global average temperature change to 2°C above pre-industrial levels with a likelihood of >50%.
Improve energy security	Limit energy trade, increase diversity and resilience of energy supply (by 2050).

Source: McCollum et al. (2012), Riahi et al. (2012).

Table 9. Scenario branching points

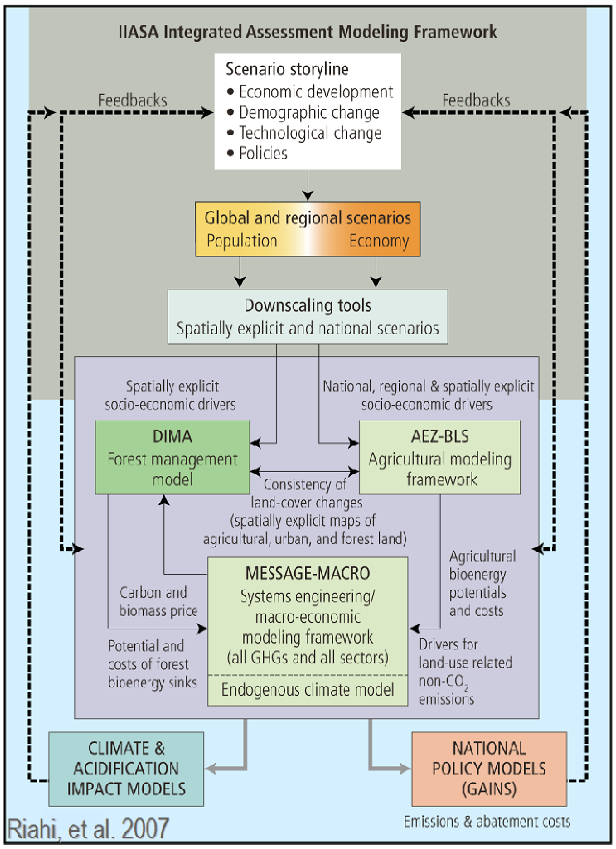
Branching points		
What is the level of energy demand?	**What are the dominant transportation fuels and technologies?**	**How diverse is the portfolio of supply-side options?**
GEA-Efficiency (low demand) GEA-Supply (high demand) GEA-Mix (intermediate demand)	Conventional (liquid fuels) Advanced (electricity, hydrogen)	Full portfolio (all options) Restricted portfolio (excludes or limits particular options): • No CCS • No Biomass w/ CCS • No enhanced carbon sinks • No nuclear • No nuclear and no CCS • Limited renewables • Limited biomass • Limited biomass and renewables • Limited biomass, no BioCCS, no sinks

A total of sixty scenarios were developed, forty-one of which achieved the targets listed in Table 8. Scenarios were categorized in terms of answers to the three branching questions listed in Table 9. Hence, the forty-one sustainable development GEA scenarios describe worlds with a wide range of future energy demands, technologies and transportation systems. The GEA refers to these sustainable energy pathways as "*interpretations of a single overarching storyline, in which the normative sustainability targets for the four energy objectives are simultaneously achieved.*" (McCollum et al., 2012).

4.1.2. Modelling framework

Figure 9 illustrates the modelling framework which is essentially a collection of soft-linked models.

Figure 9. IIASA integrated assessment modelling framework



At the heart of the framework is the MESSAGE model. The soft-linked MAGICC model calculates internally consistent (probabilistic) scenarios for climate change. The soft-linked MACRO model assesses economic feedbacks on energy demand. The soft-linked GLOBIOM agricultural model assesses land, forest, and water implications of the scenarios' energy systems. The soft-linked GAINS air pollution framework assesses the health impacts of the scenarios' energy systems.

MESSAGE-MACRO results from the linking of a detailed energy supply model (MESSAGE) with a macroeconomic model (MACRO).

The MESSAGE model describes the supply side of the energy system in great detail. However, the demand side in MESSAGE is exogenous (i.e., it does not respond to dynamics in the model). The MACRO model receives prices related to the total and marginal costs of energy supply from the MESSAGE model. From these it supplies the quadratic demand functions for MACRO so that the overall energy demand can be adjusted. MESSAGE is then rerun with these adjusted demands to give adjusted prices. This cycle is repeated until prices and energy demands stabilize.

MACRO defines and maximizes an inter-temporal utility function for a single representative producer-consumer in each of the model's world regions. The main variables are production factors, such as capital stock, available labour, and energy inputs, which together determine the total output of an economy. The optimal quantities of the production factors are determined by their relative prices. Energy demand curves are given in two categories, electric and non-electric energy, for all time periods. Actual demands are determined by MACRO in a way that is consistent with projected GDP. MACRO also disaggregates total production into macroeconomic investment, overall consumption, and energy costs.

4.1.3. Model inputs, outputs and policy interpretation

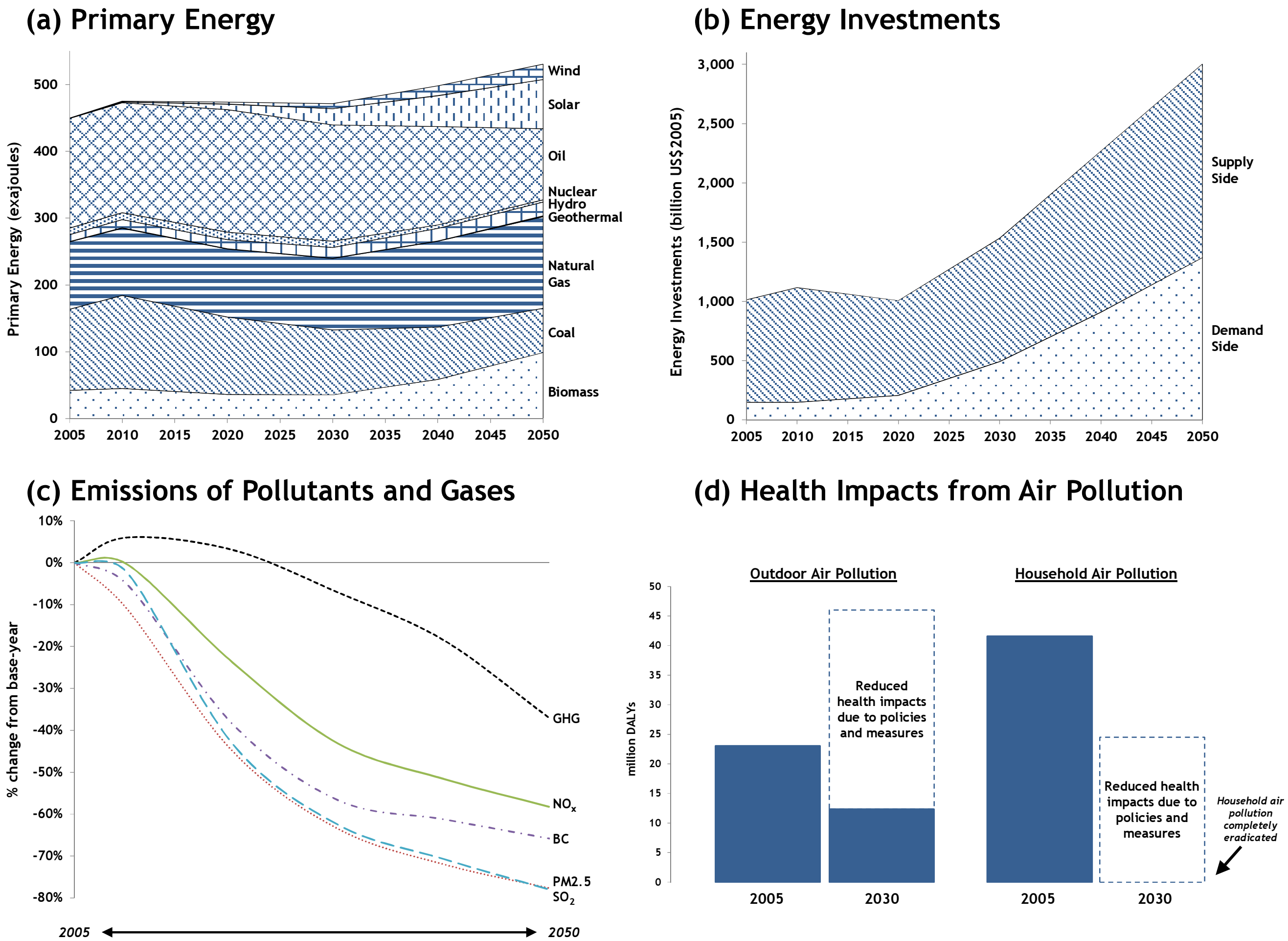
Table 10 provides a summary of model inputs, outputs, and ex-post policy interpretations in the GEA scenarios. Key model inputs include the four normative targets. Key outputs are the various pathway characteristics and detailed investment requirements. Policy instruments and actions are captured in various direct and indirect ways, which necessarily need to stay at the aggregate level in global models. Hence, specific policy instruments and actions were not direct model outputs, but were suggested ex-post by the GEA modellers, in line with their modelling results.

Table 10. Summary of model inputs, outputs and ex-post interpretations of IIASA's GEA scenarios

Normative model input							*Model output*	*Ex-post interpretation of results*	*Model outputs*
Level 1	*Level 2*		*Level 3: Strategy*				*Level 4: Blueprint*	*Level 5: Implementation*	
Ultimate goal	**Vision**		**Themes**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Investments**
Sustainable development	To develop	(D1) People	Access	Improve energy access	Universal access to electricity and modern cooking fuels	2030	Diffusion of clean and efficient cooking appliances. Extension of high voltage electricity grids and decentralized micro-grids. Increased financial assistance from industrialzied countries to support clean energy infrastructure.	Micro-creditors/grants for low emission biomass and LPG stoves in combination with LPG/kerosene subsidies for low income populations Grants for high voltage grid extemsions and decentralized micro-grids	Estimated investment to connect 1.6 billion people with lowest income: US$55-130 billion per year to 2030. Estimated investment to provide rural grid connections: >US$11 billion per year to 2030.
		(D2) Economy	Security	Improve energy security	Limit energy trade, increase diversity and resilience of energy supply	2050	Increase in local energy supply options (e.g., renewables to provide 40-70% of primary energy by 2050). Increase in diversity of imported fuels and reduce dependency (e.g., reduce share of oil in imports in primary energy by 30-80% by 2050 compared to 2000). Infrastructure expansion and upgrades to support interconnections and back-up, including increased capacity reserves and stockpiles.	Public procurement strategies and regulations to support local supplies (e.g., renewable obligations). Interconnection and back-up agreements between energy network operators. Stockpiling of critical energy resources for coordinated release during acute market shortages.	Estimated investment in infrastructure upgrades for the electricity grid: >300 billion per year by 2050. Co-benefits of stringent climate mitigation policies reduce overall security costs (import dependency & diversity) by about 75%.
	To sustain	(S2) Life support	Clean air	Reduce air pollution and improve human health	Reduce premature deaths due to air pollution by 50%	2030	Tightening of technology standards across transportation and industrial sectors (e.g., vehicles, shipping, power generation, industrial processes). Combined emissions pricing and quantity caps (with trading). Fuel switching from traditional biomass to modern energy forms for cooking in developing countries.	Vehicles: Euro 5-6 standards for vehicles in decveloping countries by 2030 (e.g., -70% NO_x, PM by 2030) Shipping: Revised MARPOL Annex VI and NO_x Technical Code 2008 (-80% SO_x, NO_x by 2030) Industry/Power: Rapid desulfurization, De NO_x and PM control across the world by 2030.	Estimated investment to meet air pollution targets: US$200 billion per year to 2030 (~12% of energy costs). Co-benefits of stringent climate mitigation policies reduce overall pollution control costs by about 75%.
		(S1) Nature	Climate	Avoid dangerous climate change	Limit global average temperature change to 2C above pre-industrial levels with a likelihood of >50%.	2050, 2100	Widespread diffusion of zero and low-carbon energy supply technologies, with substantial reductions in energy intensity. Global CO_2 emissions peak by 2020 and are reduced to 35-75% by 2050 on 2000 levels. Globally comprehensive mitigation efforts covering all major emitters. Financial transfers from industrial countries to support decarbonisation.	Combination of cap-and-trade and carbon taxes (with initial carbon price of >30 $/t$CO_2$, increasing over time). Technology standards	Upscaling of investments into low-carbon technologies and efficiency measures > US$465 billion per year to 2050. Additional financial transfers to developing countries of about 2-5% of total energy system costs to 2050, depending on the domestic commitment of industrialized countries.

Source: Adapted from: Riahi et al. (2012).

Figure 10. GEA mix scenario – selected results: primary energy, energy investments, emissions of pollutants and gases, and health impacts from air pollution.



Source: McCollum et al. (2012)

The ultimate goal explored in the GEA scenarios is sustainable development, in the sense of four of the six sustainable development dimensions. The normative goals achieved were to: (a) improve energy access; (b) improve energy security; (c) reduce air pollution and improve human health; and (d) avoid dangerous climate change.

Despite the differences among the GEA sustainable development scenarios, they all shared similar pathway elements (Table 10):

In order to improve energy access, the model suggested the diffusion of clean and efficient cooking appliances; the extension of high voltage electricity grids and decentralized micro-grids; and increased financial assistance from industrialized countries to support clean energy infrastructure.

In order to improve energy security, the model suggested an increase in local energy supply options (e.g., renewables to provide 40 to 70% of primary energy by 2050); an increase in the diversity of imported fuels and reduce dependency (e.g., reduce share of oil in imports in primary energy by 30 to 80% by 2050 compared to 2000); and infrastructure expansion and upgrades to support interconnections and back-up, including increased capacity reserves and stockpiles.

In order to reduce air pollution and improve human health, the model suggested tightening of technology standards across transportation and industrial sectors; combined emissions pricing and quantity caps (with trading); and fuel switching from traditional biomass to modern energy forms for cooking in developing countries.

In order to avoid dangerous climate change, the model suggested widespread diffusion of zero and low-carbon energy supply technologies, with substantial reductions in energy intensity; global CO_2 emissions to peak by 2020 and to be reduced to 35 to 75% by 2050 on 2000 levels; globally comprehensive mitigation efforts covering all major emitters; and financial transfers from industrial countries to support decarbonisation.

Figure 10 provides selected scenario results. The GEA mix scenarios depict a future world powered increasingly by natural gas, biomass and modern renewables (especially solar). Annual energy investments would need to triple over the next forty years, with most increases needed on the demand side.

Explicit policies and actions required can be inferred from their indirect modelling and the model results, a selection of which is highlighted in Table 10. For example, they suggest a combination of cap-and-trade and carbon taxes with an initial carbon price of >30 US$ per tonne CO_2 which would increase over time.

Model outputs also include long-term investment needs for various technologies. While they are scenario specific, the following broad picture emerges. Estimated investment needs to connect 1.6 billion poor people until 2030 are roughly US$55 to 130 billion per year to 2030, with investment needs to provide rural grid connections at >US$11 billion per year. While these are large amounts, they are significantly lower than the costs of achieving any of the other three goals. Estimated investment needs in infrastructure upgrades for the electricity grid to improve energy security are more than 300 billion per year by 2050. Estimated investment needs to meet the air pollution targets are about US$200 billion per year to 2030 (or 12% of energy costs). Reaching GHG mitigation goals through up-scaling of low-carbon technologies and efficiency measures would require at least US$465 billion per year to 2050. Reaching GHG mitigation goals would also require additional financial transfers to developing countries of about 2 to 5% of total energy system costs to 2050, depending on the domestic commitment of industrialized countries.

4.1.4. Synergies and trade-offs

The GEA scenario study was one of the first that systematically quantified synergies and trade-offs of key policies and those arising from the simultaneous pursuit of multiple SD goals compared to single objectives.

The quantitative results show that synergies can be large, indeed. For example, stringent climate mitigation policies can reduce overall security costs (import dependency & diversity) by about 75% (or US$130 billion by 2030) and can reduce overall pollution control costs by about 75% (or about US$500 billion per year). It also finds that there are no/negligible trade-offs between providing energy access and the other objectives, including GHG mitigation.

The GEA scenarios also highlight major trade-offs that limit the options for simultaneously addressing a comprehensive list of sustainable development goals (Table 11). For example, increased bio-energy production is expected to drive land-use change with the potential to compete with food crops and to be detrimental to biodiversity. Additional bio-energy production in the scenario would also grow to consume 3 to 6% of global freshwater resources, corresponding to about three-quarters of current global water use. And while the increased innovative potential of a wealthier, higher-tech world is good news, such world will consume much larger amounts of nutrient fertilizers, minerals, and rare earth metals than today.

The GEA scenario study concludes: "*Far too often policy makers approach energy issues with a single-minded viewpoint; this often leads to costlier solutions than necessary. More advantageous would be an integrated, holistic perspective that recognizes the important synergies between objectives. Such synergies tend to be overlooked at present, or they are simply not understood and subsequently ignored*" (McCollum et al., 2012).

Table 11. Synergies and trade-offs highlighted in the GEA scenarios

GEA mix scenarios. ***Models: MESSAGE-MACRO and IMAGE.***	
Issue clusters	**Synergies (SY) and trade-offs (TO)**
Energy-Climate-Air-Security	**SY:** Synergies are large for addressing simultaneously climate change mitigation, energy security, and air pollution. Stringent climate policy is most beneficial, reducing global pollution control costs by US$500 billion per year and energy security costs by US$130 billion per year by 2030.
Energy-Access-Poverty	**SY:** The objective of universal energy access is much cheaper to attain and pretty much independent from the others.
Energy-Land-Food-Biodiversity	**TO:** Increase in land use (<10% in 2050) as a result of bio-energy production, even if every effort is made to use agricultural residues as a feedstock and to source purpose-grown biomass from degraded or marginal lands so that it does not compete with food crops. This implies further biodiversity loss and increased land scarcity.
Energy-Water	**TO:** Additional bio-energy production in SD scenarios grows to consume 3 to 6% of global freshwater resources, corresponding to about three-quarters of current global water use.
Energy-Nutrients-Minerals-Rare-Earths	**TO:** More populated, wealthier, higher-tech world will consume much larger amounts of nutrient fertilizers, minerals, and rare earth metals than today

4.1.5. Lessons-learned

The GEA scenarios illustrate numerous, alternative, technically feasible pathways toward achieving multiple sustainable development goals. To achieve them, a number of "*must-haves*" become apparent. They include promoting end-use efficiency, the rapid deployment of low-carbon energy sources, and a push to eradicating energy poverty. In particular, the authors note that "*[the] transition pathways make clear that reducing wasteful energy use in buildings, transport and industry is the single most important strategy for achieving energy sustainability*" (McCollum et al., 2012)

The GEA study also highlights the importance of going beyond the energy sector explicitly taking into account synergies and trade-offs. Most noteworthy, GHG mitigation was identified as a unique entry point for simultaneously achieving multiple goals.

No single technology, policy or action will be sufficient. Instead, SD progress requires a broad suite of policies which, however, are ready for implementation. "*The path toward sustainable development, especially for the energy system, will require a broad suite of clear policies and measures. A number of options are available and ready for implementation, but enacting them is contingent upon sufficient political will and the priorities of decision makers.*" (McCollum et al., 2012).

4.2. PBL's sustainable development scenarios for Rio+20

In addition to its collaboration with IIASA on the GEA scenarios, PBL Netherlands Environmental Assessment Agency also prepared its own set of sustainable development scenarios for Rio+20 which are described next. Details are provided in:

- PBL (2012). Van Vuuren, D., Kok, M. (eds.). *Roads from Rio+20: Pathways to achieve global sustainability goals by 2050*. PBL Netherlands Environmental Assessment Agency, with contributions by the Overseas Development Institute, UK, and the Agricultural Economics Research Institute, Netherlands, ISBN 978-94-91506-00-0, June 2012.

4.2.1. Approach and rationale

The new PBL scenarios build on the "*Challenge Scenario*" that had been prepared by PBL for the Club of Rome in 2009. In both cases, the objective was to identify possible pathways for simultaneously meeting a number of sustainable development goals. The backcasting analysis focused on the following issue clusters: food, land and biodiversity; and energy, air pollution and climate.

The PBL approach is broader in scope than IIIASA's. PBL's integrated assessment modelling framework captures a wider range of sectors and issues, but the technology resolution is much lower..

In a first step, a set of sustainable development goals and targets for 2030 and 2050 were identified by PBL, based on internationally agreed goals, the results of UN advisory groups and insights from the scientific literature (Table 12). An important selection criterium was to focus on the minimum conditions for development and to include only human development goals that have a direct link to the environment, such as access to food, water and energy. In addition to goals that were used as model inputs, three "*monitoring goals*" were used, including water scarcity, interference with the phosphorous and nitrogen cycle, and human health. It should be noted that the identified goals and targets are not independent from each other.

Table 12. Sustainable development goals and targets used in PBL's scenarios for Rio+20

Themes	Goals	Targets	Reference
Human development	Eradicate hunger	Halve, by 2015, the proportion of people who suffer from hunger *and eradicate hunger by 2050*	UN (2001) MDG1, Target 1c
	Ensure universal access to safe drinking water and improved sanitation	Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation *and ensure full access by 2030*	JPOI-25; JPOI-7a; UN (2001) MDG7, Target 7c; *Stockholm statement 2011*
	Ensure universal access to modern energy	*Achieve universal access to electricity and modern cooking fuels by 2030*	JPOI-Para 9(a); *UNSG (2011); AGECC (2011)*
	Reduce Outdoor Air Pollution	*Keep PM2.5 concentration below 35 $\mu g\ m^{-3}$ by 2030*	*WHO (2010)*
Climate change	Prevent dangerous anthropogenic interference with the climate system	Avoid temperature increase above $2^{o}C$ in 2100 with a likelihood of >50%. *Keep atmospheric GHG concentration below 450 ppm CO2 equivalent*	UNFCCC (1992) – Art. 2; UNFCCC (2010); *Meinshausen (2006)*
Terrestrial biodiversity loss	Conservation of biological diversity, sustainable use of its components and fair and equitable benefit sharing	By 2020, prevent extinction of threatened species and improve situation of those in most decline. *Stabilize biodiversity at the 2020/2030 level in 2050 (depending on region)*	Convention on Biological Diversity (2010)
Water scarcity	Ensure sustainable use of water resources. Introduce measures to improve the efficiency of water use, to reduce losses and to increase water recycling	Reduce the number of people living in water scarce areas compared to baseline. Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation *and ensure full access by 2050*	JPOI-Para 26 UN Millennium Declaration (2000), MDG7, Target 7.C
Interference with P and N cycles	Avoid acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems. Avoid major (incl. regional) oceanic anoxic event.	Reduce N/P use where possible (but without harming the ability of the agricultural system to meet the hunger target)	
Human health	Reduce environmental health threats	Decrease impact of environmental factors on DALY	JPOI-Para 7.

Italics indicate extensions by PBL team based advisory reports or scientific literature, in order to achieve quantifiable objectives. Targets are formulated for 2050, unless specified otherwise.

Three sustainable development scenarios were developed, all of which would meet the same sustainable development endpoints (Table 13): Global technology (GlobT scenario), Decentralised technology solutions (LocT scenario), and consumption change, lifestyle and technology (L&T scenario).

Table 13. Key assumptions in PBL's sustainable development scenarios for Rio+20.

Scenario	Assumptions
Global Technology (GlobT)	Achieve the 2050 targets with a focus on large-scale technologically optimal solutions, such as intensive agriculture and a high level of international coordination, for instance, through trade liberalization.
Decentralised technology solutions (LocT)	Achieve the 2050 targets, with a focus on decentralised solutions, such as local energy production, agriculture that is interwoven with natural corridors and national policies that regulate equitable access to food.
Consumption change, lifestyle and technology (L&T).	Achieves the 2050 targets, with a focus on changes in human consumption patterns most notably by limiting meat intake per capita, by ambitious efforts to reduce waste in the agricultural production chain and through the choice of a less energy-intensive lifestyle.

Source: PBL (2012).

4.2.2. Modelling framework

The scenarios were quantified with PBL's modelling framework. At its core is the Integrated Model to Assess the Global Environment (IMAGE). IMAGE had initially been developed as an integrated assessment model to study anthropocentric climate change (Rotmans, 1990). Later it was extended to include a wider range of global change issues in an environmental perspective (e.g., Alcamo, 1994; IMAGE, 2001). IMAGE is used to contribute to scientific understanding and support decision-making with respect to the society-biosphere-climate system (Bouwman et al., 2006). It consists of a set of models addressing global environmental change, energy dynamics and climate policy and is linked to models addressing quality of life and biodiversity loss. Figure 11 provides a simplified view of the model coverage and inter-linkages between the socio-economic systems, the Earth system, and environmental impacts of human activities. The model coverage is impressively broad, indeed. Hence, the model framework can produce scenarios that are consistent in terms of global demography; world economy; agricultural economy and trade; energy supply and demand; land allocation; emissions; carbon, nitrogen and water cycles; climate impacts, land degradation, water stress, biodiversity, water and air pollution.

Figure 11. Flow diagram of the IMAGE framework

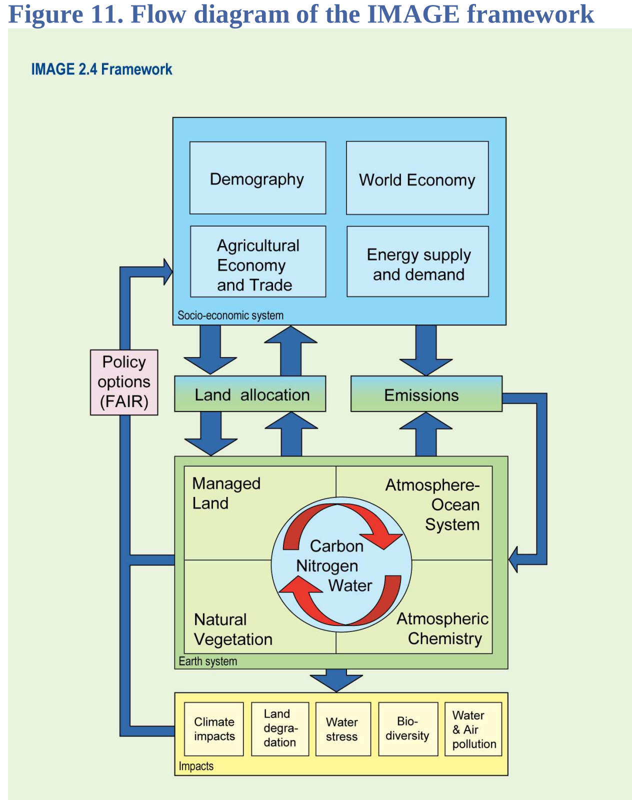
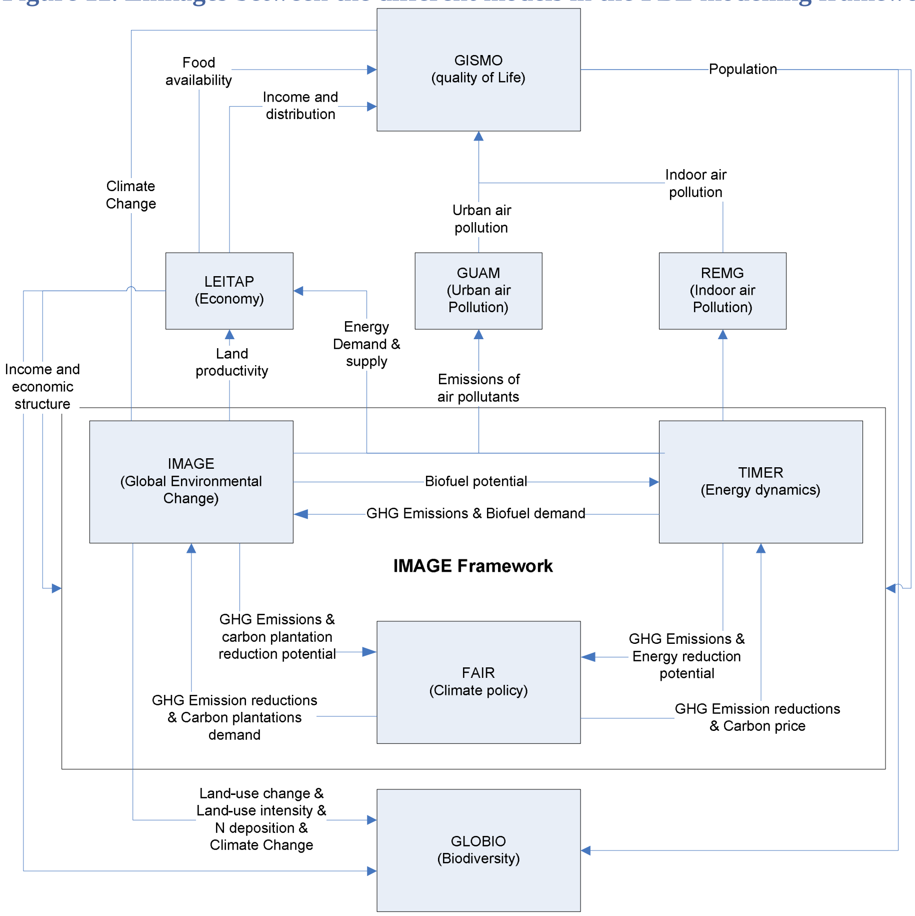


Figure 12 shows the most important linkages between the models in PBL's framework which includes the IMAGE model (global environmental change), TIMER (energy dynamics), FAIR (climate policy), GLOBIO (biodiversity), GISMO (quality of life), LEITAP (economy), GUAM (urban air pollution) and REMG (indoor air pollution).

Figure 12. Linkages between the different models in the PBL modelling framework



Source: PBL (2012)

4.2.3. Model inputs, outputs and policy interpretation

Table 14 provides a summary of model inputs, model outputs and policy interpretations in the three sustainable development scenarios prepared by PBL for Rio+20. Similar to the IIASA scenarios, key model inputs included the normative goals and targets, whereas key outputs were the various pathway characteristics and detailed investment requirements. Policy instruments and actions are captured in various direct and indirect ways, resulting in specific instruments and actions suggested ex-post by modellers. Due to the wider coverage and accounting modules, investment requirements were also subject to a certain level of ex-post interpretation, in contrast to the IIASA scenarios which have a more detailed technology representation.

Food, land use and biodiversity

The following main challenges were identified for achieving food security and halting biodiversity loss: (a) eradicating inequality in access to food; (b) increasing food production to meet demand of a growing and more affluent population; (c) limiting biodiversity loss to land conversion and other pressures; and (d) managing the benefits of ecosystems goods and services. The scenario analysis illustrated that these challenges can be simultaneously met in three fundamentally different pathways. However, rapid productivity increases would be needed in all three cases. The need for productivity increases would be less, if dietary changes could be achieved and overall agricultural systems improved. In any case, the proliferation of competing claims on land would increase the importance of land use planning and management in many regions. Large-scale bio-energy would be part of all sustainable development scenarios.

Identified priority areas for short-term action included sustainable intensification of agriculture; a more robust food system; mainstreaming biodiversity and ecosystems in land use planning and management; and appreciation of the potential of adjustments in lifestyles and consumer habits.

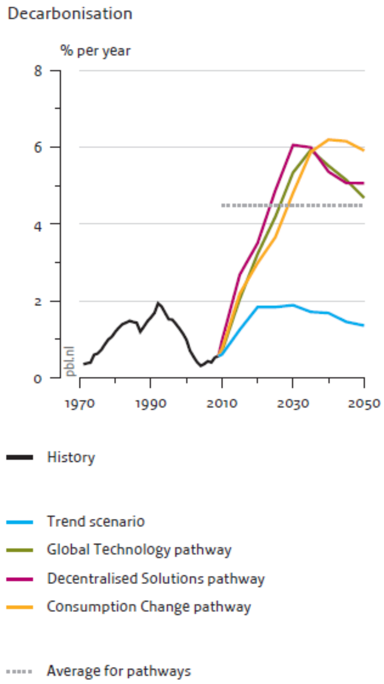
Energy and climate

The following main challenges were identified in the energy sector: (a) providing sufficient energy for the rapidly increasing global demand for energy services; (b) ensuring access to modern energy for all; (c) reducing the environmental impacts of the energy system; and (d) improving energy security. The scenario analysis showed three fundamentally different pathways towards the same sustainable development goals. Achieving PBL's sustainability targets would require fundamental changes in the energy sector compared to current trends. A broad portfolio of measures would be required, especially in response to the climate change challenge.

The costs of meeting a 2°C climate target were estimated at around 2% of GDP. Figure 13 illustrates the magnitude of the challenge in having to reverse the historical trend to reach decarbonisation rates three times as high as the maximum rate achieved two decades ago during the "dash for gas". Three very different approaches can lead to the same result in terms of decarbonization. Yet, the underlying future worlds differ greatly.

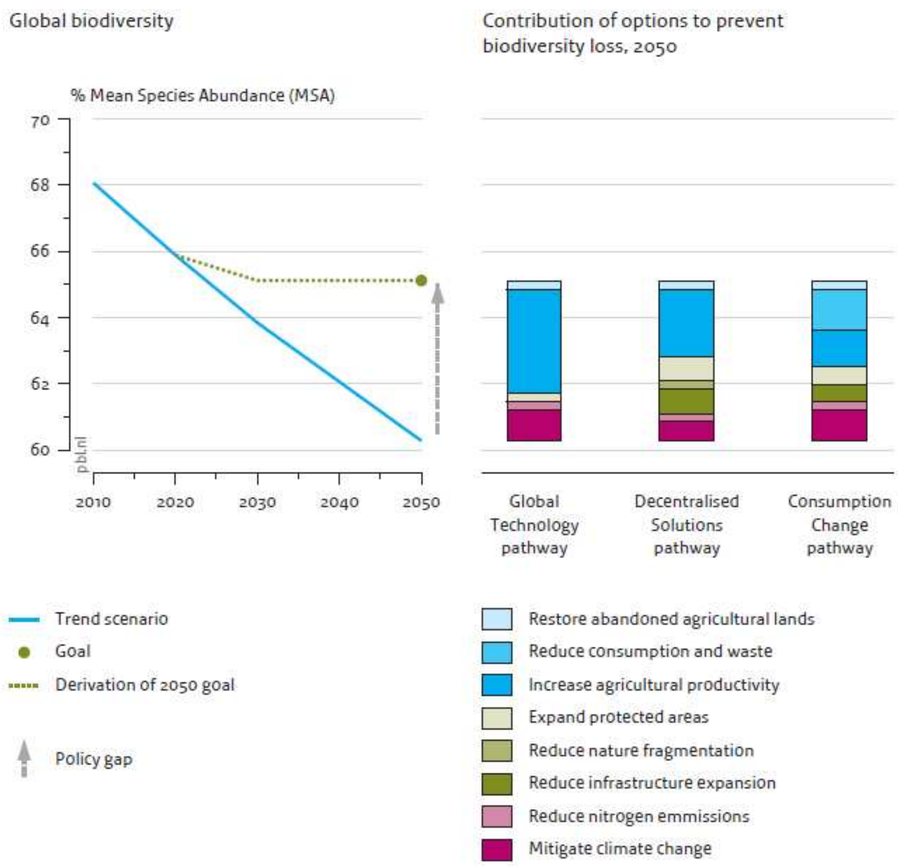
shows the different approaches pursued in the three sustainable development scenarios to reach the same biodiversity target. It illustrates the magnitude of the challenge in having to reverse the historical trend to reach stabilization of biodiversity at a lower level after 2020.

Figure 13. Global decarbonisation rate in the PBL scenarios



Identified priority areas for short-term action included seeking progress based on “radical incrementalism”; phasing out the building of coal power plants without carbon capture and storage; modern fuels to be made accessible and affordable; removing current national energy policy inconsistencies; addressing energy-intensive lifestyles; and arranging public and private finance for energy transition infrastructures.

Figure 14. Global biodiversity in the PBL scenarios



Source: PBL (2012).

Table 14. Sustainable development goals and targets used in PBL's scenarios for Rio+20 (GlobT: Technology-Global orientation; LocT: Technology-Decentralized solutions; L&T: Lifestyle and Technology)

Normative model input							*Model output*	*Ex-post policy interpretation of model results*	
Level 1	*Level 2*		*Level 3: Strategy*				*Level 4: Blueprint*	*Level 5: Implementation*	
Ultimate goal	**Vision**		**Theme**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Investments**
Sustainable development	To develop	(D1) People	Poverty	Eradicate hunger	Halve the proportion of people who suffer from hunger by 2015, further halve it by 2030	2015, 2030	*GlobT:* follows trend. *LocT and L&T:* inequality in access to food due to income convergence by 2050. Meat consumption per capita levels off at twice the consumption level suggested by a supposed healthy diet (*L&T*). Waste is reduced by 50% (15% of production) (*L&T*). In all regions, 15% (*L&T*), 20% (*LocT*) or 30% (*GlobT*) increase in crop yields by 2050 compared to trend. 15% increase in livestock yield (*GlobT and LocT*).	Accelerate the sustainable intensification of agriculture through: infrastructure; access to credit; transparent and fair price formation; secure land tenure; fair balance of power between governments, producers and their buyers/ suppliers; removal of other forms of urban bias. Create a more robust food system; Initiate a shift towards alternative consumption patterns;	n.a.
					Eradicate hunger	2050			
			Access	Ensure universal access to safe drinking water and improved sanitation	Halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015, further halve it by 2030.	2015, 2030	Achieves targets. Another 230 million (250 million) people have access to an improved water source, and 1 billion (1.4 billion) more to basic sanitation facilities by 2030 (by 2050).	Introduce measures to improve the efficiency of water use, to reduce losses and to increase recycling of water. Remove certain subsidies for energy and water.	Additional annual investments of $6.8 billion from 2010-2030, and US$ 9.9 billion from 2030-2050, with almost 50% in sub-Saharan Africa.
					Ensure full access.	2050			
				Ensure universal access to modern energy	Universal access to electricity and modern cooking fuels	2030	Grid investments; subsidies for modern fuels and micro-credit for stoves; improved biomass stoves for poorest households	Building technical, financial and administrative capacities in developing countries	US$30-70 billion per year from 2010 to 2030.
	To sustain	(S2) Life support	Clean air	Reduce air pollution	Keep PM2.5 concentration below 35 $\mu g\ m^3$	2030	End-of-pipe measures	n.a.	n.a.
		(S1)	Climate change	Prevent dangerous anthropogenic	Avoid temperature increase above 2°C with a likelihood of >50%.	2100	Bio-energy constrained by sustainability criteria. Emphasis on CCS, H_2 and nuclear	Remove policy inconsistencies through integrated policy-making. Efficiency targets; For the 2 °C	Increase in energy investments by 50% compared to trend.

					Keep atmospheric GHG concentration below 450 ppm CO_2-eq.	2000-2100			
			Terrestrial biodiversity loss	Conservation of biological diversity, sustainable use of its components and fair and equitable benefit sharing	Prevent extinction of known threatened species and improve situation of those in most decline.	2020	17% protected. Expansion allocated close to existing agriculture. Forest plantations supply 50% of timber demand. almost all selective logging based on reduced impact logging. *LocT and L&T:* Slower expansion of infrastructure (by 2050 at the level of the Trend scenario for 2030)	Integrate land-use planning with biodiversity and ecosystem services: e.g., decision-support instruments; spatial planning; taxes, fees and charges; payments for ecosystem services (incl. REDD); premiums for sustainable land-use certification; access restrictions; public disclosure; liability for environmental damages.	n.a.
					Halve the rate of loss of natural habitats and reduce degradation and fragmentation. Conserve at least 17% of terrestrial and inland water.	2020			
					Halve the rate of biodiversity loss	2020			
					Stabilize biodiversity at the 2020/2030 level (depending on region).	2050			

Source: Based on: PBL (2012).Note: Names of scenarios: GlobT (Technology-Global orientation); LocT (Technology-Decentralized solutions); L&T (Lifestyle and Technology).

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Other monitoring goals which are not necessarily achieved in the PBL scenarios								
Level 2		***Level 3: Strategy***				***Level 4: Blueprint***	***Level 5: Implementation***	
Vision		**Themes**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Investments**
To develop	(D1) People	Health	Reduce environmental health threats	Decrease impact of environmental factors on DALY	2050	n.a.	n.a.	n.a.
To sustain	(S2) Life support	Water scarcity	Ensure sustainable use of water resources.	Reduce the number of people living in water scarce areas compared to trend scenario.	2050	Climate mitigation and water-use efficiency will significantly reduce the demand for water (by 25% compared to trend), but the total number of people living in severely water-stressed river basins will only marginally decrease (from 3.7 to 3.4 billion people). Reduced demand for thermal cooling in power generation as fossil-fuel replaced by renewables. Keeping agricultural land area as compact as possible to reduce pressure on nature areas and biodiversity, the irrigated area is not changed from the trend and hence the water deficit at the field level remains the same.	Climate mitigation policies. Policies to keep agricultural land area as compact as possible. Stringent efficiency measures in industry and domestic water use, implying behavioural changes besides the widespread deployment of water-saving equipment	n.a.

	(S1) Nature	Interference with P and N cycles	Avoid acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems. Avoid a major oceanic anoxic event (including regional), with impacts on marine ecosystems	Reduce N/P use where possible (but without harming the ability of the agricultural system to meet the hunger target)	2050	Fertiliser-use efficiency improved by 50% for extra yield increase compared to trend. 15% (*GlobT*) or 5% (*LocT*) lower excretion rates due to higher feed-use efficiency. *LocT only:* Manure is recycled and better integrated in the agricultural system. And recycling of human N and P from households with access to improved sanitation.	Better integration of animal manure. Recycling of human excreta.	n.a.

4.2.4. Synergies and trade-offs

The PBL scenarios explicitly identified the most important trade-offs and synergies associated with actions to achieve multiple sustainable development goals, including eradication of hunger; universal access to safe drinking water; universal access to modern energy; ensuring clean air; climate change mitigation; and halting biodiversity loss (Table 15).

Table 15. Synergies and trade-offs between SDGs identified in the PBL scenarios for Rio+20

Action to / Effects on	Eradication of hunger	Universal access to safe drinking water	Universal access to modern energy	Ensuring clean air	Climate change mitigation	Halting biodiversity loss
Eradicate hunger		ns	ns	ns	More GHG emissions from increased production (fertilisers; land expansion, tractors)1)	More impact of agriculture on ecosystems
Universal access to safe drinking water	Access to safe drinking water helps to prepare safe food Competition as well as synergy between water for residential use and in agriculture		ns	ns	ns	ns
Universal access to modern energy	Allows making use of income opportunities when less time is spent on collecting fuels, and health improved through less indoor air pollution	Water required for power generation Modern energy helps to improve access to safe water (e.g. pumps)		Less pollution from traditional energy sources (charcoal, firewood)	Less deforestation vs more fossil-fuel use, but modern energy more efficient than traditional energy systems	Less disturbance of natural ecosystems from wood collection for fuel or charcoal
Ensuring clean air	Less impact of air pollution on crop yields and quality	Less contamination from the deposition of airborne pollutants	ns		Depends on the choice of air pollutants to be targeted (BC/CH_4)	Lower deposition of atmospheric pollutants on ecosystems
Mitigate climate change	Less risk of disruption of vital ecosystem services Bio-energy competes with food and feed and may spur scrambles for land; but also opportunities for poor in rural areas	Effects of climate change on precipitation patterns and potential evapo-transpiration	Higher energy price	Less pollution thanks to a reduced use of fossil fuels, particularly oil and coal		Less impact of climate change on biodiversity Effects of GHGs and climate change on crop yields Additional land required for bio-energy crops
Halt biodiversity loss	Less land used for food production Preservation of ecosystem services helps safeguard long-term sustainable food supply	A more gradual / uniform flow and cleaner water to rivers and aquifers Increased water use by permanent vegetation	ns	More intact ecosystems contribute to air quality	Fewer CO2 emissions from land conversion and agriculture Restoration of degraded land creates new CO2 sinks	

Type of interaction: ■ *positive;* ■ *negative;* ■ *mix of positive and negative;* ■ *ns: no significant interactions expected (until 2050).*

Source: PBL (2012).

PBL's scenario analysis showed that an integrated approach to sustainable development goals, rather than to single sectors or issues, can help realizing significant synergies between simultaneously addressing air pollution and climate change; between addressing food security and restoring agricultural ecosystems; between conserving ecosystems, security of supply, productive capacities, and regulating functions (water, timber, fisheries but also soils, temperature); and between addressing competitiveness and sustainability. In particular, providing full access to food, water and energy alone (as assumed in the report) would prevent more than 800,000 child deaths by 2050.

Important trade-offs were identified, too. In particular, the attainment of the stated goals for hunger, energy, climate, biodiversity, and air pollution might make it very difficult to attain other sustainable development goals, including those on water stress, safe drinking water and basic sanitation, and anthropogenic changes to N/P flows (without harming the ability of the agricultural system to meet the hunger target). Other identified dilemmas include: conflicts between national and global goals; present demand growth rates requiring growth in the use of renewables as well as fossils; intensification of agriculture vs. less productive but more sustainable per ha; bio-energy; rebound effects, for instance from reduced energy use and meat consumption; protection of highly bio-diverse areas versus local/national development; trade-offs between long-term and short-term options, including lock in threat of focusing on quick wins.

4.2.5. Lessons-learned

The problem

Despite the efforts made in the follow-up to the Earth Summit of 1992 and despite global progress in improved welfare, reduced poverty and improved local environment, key unsustainable trends have not been reversed, including in the areas of food, land and biodiversity, as well as in the areas of energy and climate. Without renewed efforts, sustainable development goals will not be achieved in the coming decades.

A comprehensive set of SDGs could be achieved

There are alternative pathways along which sustainable development goals (derived from existing international agreements) could be achieved. However, in any case, substantial efforts will be needed. Pathways in which overall demands and lifestyles are not addressed require significantly larger efforts and technological progress.

Eradicating hunger and maintaining a stable and sufficient food supply while conserving biodiversity

Food production will need to be increased by 60% from 2010 to 2050, despite a slowdown of the increase in agricultural productivity. The impacts of climate change and increasing demands for bio-energy and wood products will spur competition over land, leading to higher and more volatile food prices and increasing pressures on biodiversity and ecosystem services.

Identified short-term policy priorities include the need to create conditions to accelerate sustainable agricultural intensification; to ensure a more robust food system to reduce hunger; to mainstream biodiversity considerations in land-use planning and management; and to promote changes in consumption patterns.

Ensuring access to modern energy sources for all, while limiting global climate change and air pollution

While global energy use will increase by around 60% over the next four decades, greenhouse gas emissions would need to be halved in order to achieve the 2°C climate change target.

The analysis showed that access to modern energy could be improved by financial instruments to lower the cost of modern fuels and stoves, distribution programmes for improved stoves, and ambitious electrification programmes, all targeted at the poorest households. The development and health benefits of such a transition would be large.

In order to reduce greenhouse gas emissions, improved energy efficiency would be a "must". Further electrification in the transport and household sectors could ensure more flexibility in reducing emissions. On the supply side, by 2050 around 60% of all energy would need to come from non-CO_2-emitting energy sources, such as renewables, bio-energy, nuclear power, and fossil fuel combined with CO_2 capture, while these sources account for only 20% today. Reducing non-CO_2 greenhouse gas emissions would also be needed.

Identified short-term policy priorities include the need to increase efforts to ensure modern energy for all; to peak global greenhouse gas emissions around 2020; to introduce appropriate pricing instruments; and to ensure sufficient financing and reform of international climate policy, including R&D efforts.

Transformative change needed

Marginal improvements would not be enough. Instead, large-scale, transformative changes would be needed. However, the good news is that there is no fundamental trade-off between eradicating hunger as well as providing full access to modern energy, on the one hand, and achieving environmental sustainability, on the other.

Ways to implement the transformation

The PBL study called for more effective approaches to sustainable development, including through: (a) development of a shared vision with long-term goals and consistent short-term targets, integrating various areas of sustainable development, as well as public and private actions; (b) governance based on a shared vision; (c) adapting day-to-day rules of decision-making to provide the "right" incentives; (d) increasing coherence between decision-making processes; and (e) reform of policy-making at the international level (PBL, 2012).

4.3. RITE's ALPS scenarios for Rio+20

Since RITE has undertaken a multi-year project to create a set of "*ALternative Pathways toward Sustainable development and climate stabilization*" (ALPS), interim results of which were also provided for Rio+20 as input to the SD21 project. They are summarized here, whereas details can be found in:

- Akimoto, K., et al. (2012). *Consistent assessments of pathways toward sustainable development and climate stabilization*. RITE-ALPS, Japan.

4.3.1. Approach and rationale

RITE's modelling framework is the most complex one of all the frameworks presented in this report. It includes all kinds of technologies, inter-linkages between sectors and issues, and explicitly models 54 world regions, many of which are individual countries. Generally speaking, RITE's approach follows in the same tradition as those of IIASA and PBL.

Four scenario families were explored: base scenario (A), high economic growth scenario (B), climate policy prioritized scenario (C), and energy security prioritized scenario (D) (Table 16).

Table 16. ALPS scenario families

ALPS Scenario families	Scenario characteristics
A: Base scenario	Moderate per-capita GDP growth and moderate population growth; current trends of balanced world in terms of economics, climate change, and energy security
B: High economic growth scenario	High per-capita GDP and low population growth
C: Climate policy prioritized scenario	High priority on climate change
D: Energy security prioritized scenario	High priority on energy security

Source: Akimoto et al. (2012).

While these scenarios illustrate the consequences of different policy focuses, all ALPS scenarios were analysed against all the goals, targets and indicators listed in Table 17.

Table 17. Sustainable development assessment indicators used in the ALPS scenarios

Category	Indicator
Economics and poverty	Income (GDP per capita)
	People living in poverty (including impacts of climate change and mitigation measures)
	Food access (amount of food consumption per GDP) (including impacts of climate change and mitigation measures)
Agriculture, land-use, and biodiversity	Agriculture land area (including impacts of climate change)
	Food security (amount of food imports per GDP) (including impacts of climate change and mitigation measures)
Water	People living under water stress (including impacts of climate change)
Energy	Sustainable energy use (cumulative fossil fuel consumption)
	Energy use efficiency (primary energy consumption per capita and per GDP)
	Energy security (share of total primary energy consumption accounted for by oil and gas imports with country risks)
Climate change	Economic impact of mitigation measures (marginal abatement cost (carbon price) and GDP loss)
	Global mean temperature change
	Aggregated economic impact of climate change
	Ocean acidification (pH and impacts on Aragonite (CaCO3))

Source: Akimoto et al. (2012).

4.3.2. Modelling framework

RITE's scenario modelling framework has been used to develop the ALPS scenarios. It consists of a number of soft-linked models, including energy systems models, a climate change model, a land-use and water-use model, and a biodiversity (and ocean acidification) model (Figure 15).[11] The purpose of the soft-linking is to ensure consistency.

The soft-linked RITE models show different geographic resolutions.

[11] The following description is based on Akimoto et al. (2012). Please refer to the original paper for more details.

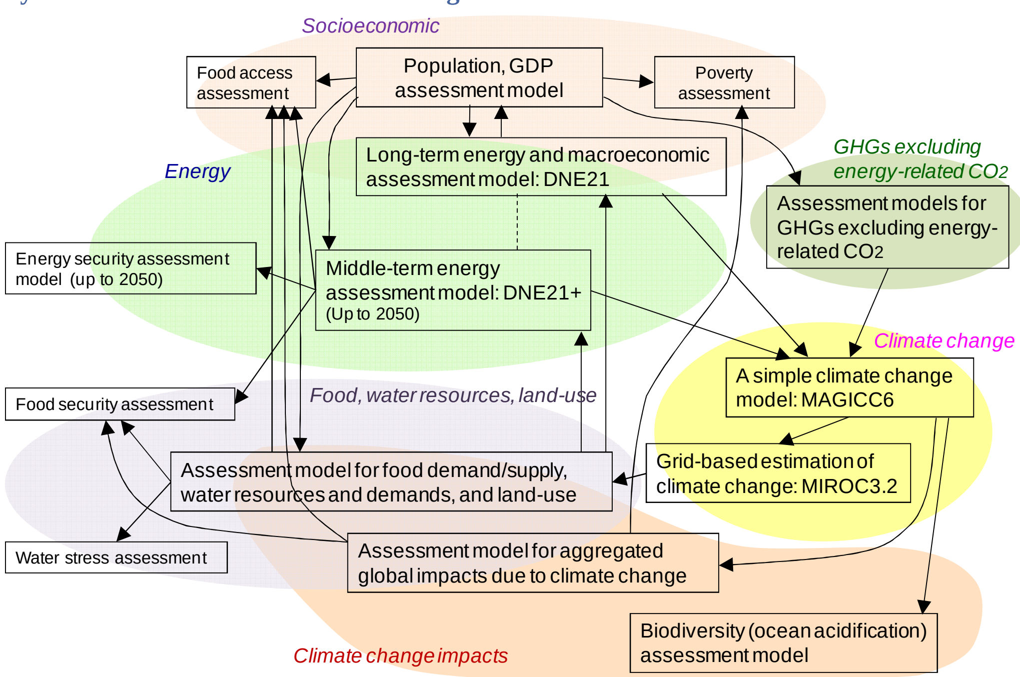
The DNE21+ model has 54 world regions (Akimoto et al. 2010; 2008) and captures most large economies at the national level, especially in Asia. DNE21+ captures the medium-term period up to 2050 and is limited to model energy-related sectors and technologies. It was used to assess energy and CO_2 emission technologies at both supply and demand levels.

The DNE21 model has 10 world regions and a modelling time frame up to 2150. It captures the entire macro-economy, with a detailed representation of the energy sector (Akimoto et al. 2004; Fujii and Yamaji, 1998).

The land-use and water-use model is a 15-minute-grid model, whereas the integrated food supply and demand sub-module has 32 regions. Crop productivity, including effects of climate change, is estimated with a sub-module based on the Global Agro-Ecological Zones (GAEZ) framework (Fischer et al., 2002). The water assessment module estimates annual withdrawals-to-availability ratios using the definition of river basin provided by Oki (2001).

The simple climate change model MAGICC6 (Meinshausen et al., 2011) was used to quantify climate change variables, including atmospheric CO_2 and GHG concentrations, radiative forcing, and global mean temperature change. The grid-based projections for monthly temperature, precipitation, and the like provided by MIROC3.2-Medres (K-1 model developers, 2004) were adopted for estimations of climate change patterns (refer to Hayashi et al. (2010) for the method). The RITE modelling framework includes also other models, such as a human health assessment model, which generally show large uncertainties.

Figure 15. Stylized overview of the ALPS modelling framework



Source: Akimoto et al. (2012).

4.3.3. Model inputs, outputs and policy interpretation

Table 18 provides a summary of model inputs, model outputs and policy interpretations in RITE's ALPS sustainable development scenarios. Similar to the IIASA and PBL scenarios, key model inputs included the normative goals and targets, whereas key outputs were the various pathway characteristics and detailed investment requirements. Policy instruments and actions were captured in various direct and indirect ways, resulting in specific instruments and actions suggested ex-post by modellers.

The ALPS sustainable scenario pathways show the following characteristics.

The number of people living in poverty as well as income are rather similar to the ALPS baseline scenario. Figure 16 shows the success of poverty eradication: the number of people in poverty declines from 1.6 billion in 2000 to less than 200 million by 2050. Total income increases similar to the baseline.

Primary energy uses per capita increase by 13% in 2050 and 48% in 2100 relative to 2010, despite improved energy efficiency. Primary energy uses per GDP improves by 46% in 2050 and 64% in 2100 relative to 2010. The use of renewables, including hydro, more than triples from 2010 to 2050. During the same period, coal use decreases by 0.7 times and gas trade increases by more than six times. The vulnerability in terms of energy security increases in most regions (Figure 17).

The number of people under water stress will increase from 1.7 billion in 2000 to 3.1 billion in 2050 (Figure 18), after which it will decrease to 2.9 billion in 2100.

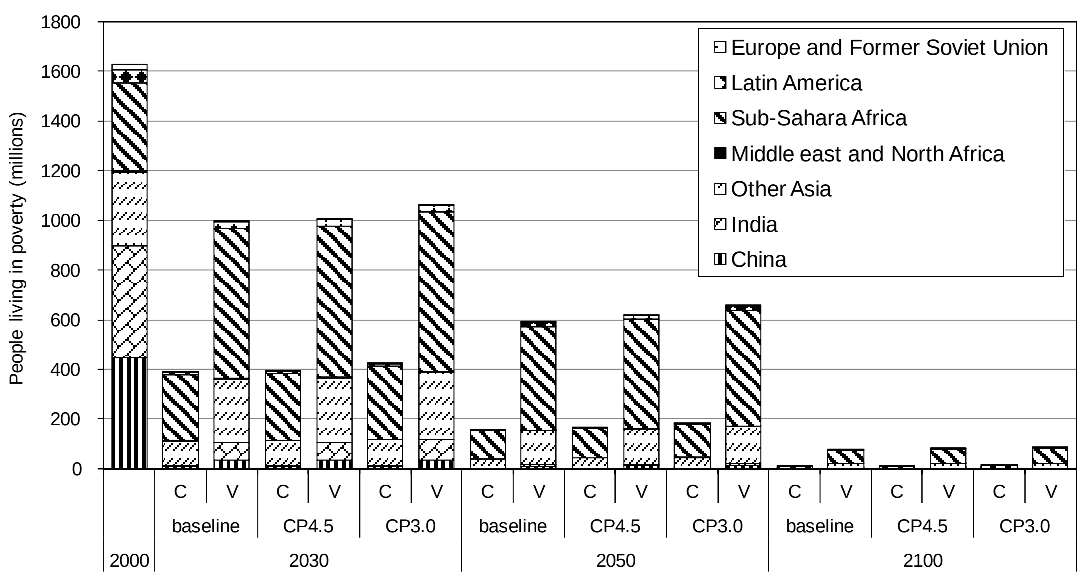
Air pollution is rapidly reduced relative to the 2010 level. SO2 emissions decrease by 42% in 2050 and 72% in 2100. Black carbon emissions decrease by 21% in 2050 and 70% in 2100.

Food security worsens, but not more than in the baseline scenario. The global cropland area for food production will increase by 15% until 2050 and decline thereafter. The cropland area for energy-crop productions would decrease to nearly zero in 2020, but make a comeback after the middle of this century. The world total of irrigated area under food production would decrease by 5 % in 2050, and by 15% in 2100 (compared to 2000).

Economic impact of GHG mitigation is estimated to be as large as 3.6% and 4.1% of GDP loss in 2050 and 2100, respectively (relative to the baseline scenario). The global average aggregated economic impact of climate change is 0.77%, 1.14% and 1.29% in 2050, 2100 and 2150, respectively, relative to baseline scenario.

Atmospheric GHG concentrations reach 530 ppmv $CO_{2\text{-eq.}}$ in 2050 and 550 ppm $CO_{2\text{-eq.}}$ in 2100. As a result, the global mean temperature rises by 2.1˚C in 2050 and 2.8˚ C in 2100 above preindustrial levels.

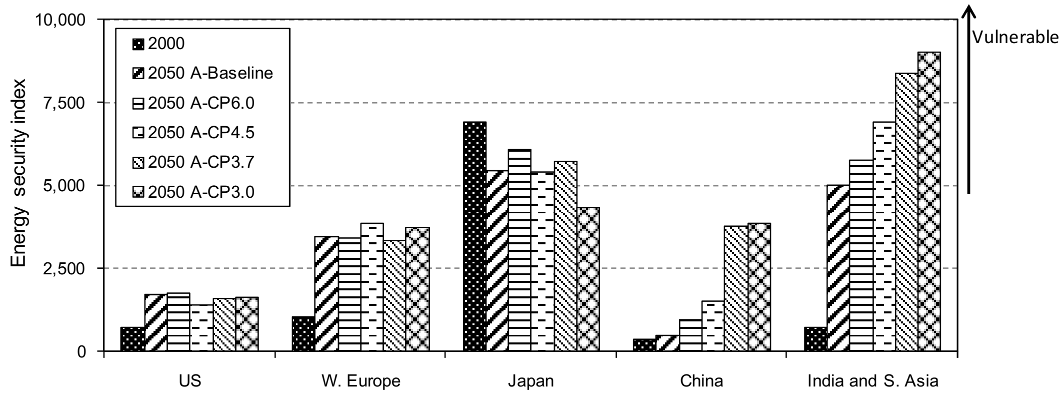
Figure 16. People living in poverty under Scenario A



Note: “C” and “V” denote a constant poverty line of 1.25$/day and a variant poverty line determined using future oil price, respectively. The estimates are made assuming a constant Gini coefficient for all countries in the future. If distributions in income change in the future, the estimates will also change.

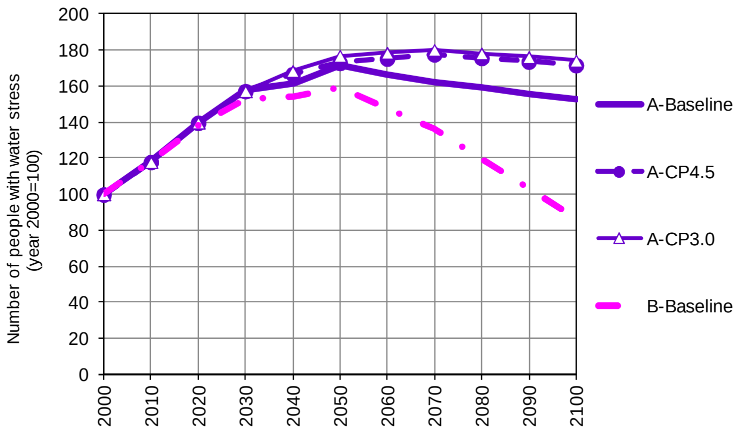
Source: Akimoto et al. (2012).

Figure 17. Energy security index in the ALPS scenarios



Source: Akimoto et al. (2012).

Figure 18. People under water stress worldwide in the ALPS scenarios



Source: Akimoto et al. (2012).

Table 18. RITE's ALPS scenarios

Normative model input							*Model output*	*Ex-post policy interpretation of model results*	
Level 1	*Level 2*		*Level 3: Strategy*				*Level 4: Blueprint*	*Level 5: Implementation*	
Ultimate goal	**Vision**		**Themes**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Invest-ment**
Sustainable development	To develop	(D1) People	Poverty	Reduce poverty	People living in poverty	2100	Number of people living in poverty is almost the same as in the baseline scenario.	Balanced measures for policies and measures on sustainable development and climate change.	n.a.
			Food access		Food access (food consumed per GDP)	2100	Food access is only slightly worse than in baseline.	Balanced measures for policies and measures on sustainable development and climate change.	n.a.
		(D2) Economy	Income	Increase incomes	Income (GDP per capita)	2100	Income is almost the same as in the baseline.	n.a.	n.a.
			Energy efficiency	Increase efficiency	Energy use efficiency (primary energy use per capita and per GDP)	2100	Energy use efficiency improves relative to the baseline through technology improvements. Energy intensity (primary energy use per GDP) improves by 46% from 2010 to 2050 and by 64% from 2010 to 2100. Primary energy use per capita increases by 13% from 2010 to 2050 and by 48% from 2010 to 2100, but is lower than in the baseline scenario.	Tailored energy efficiency standards.	n.a.
			Food security	Improve security	Food security (amount of food imports per GDP)	2050	Food security is slightly worse than in the baseline scenario.	Balanced policy measures for bioenergy, climate change, and sustainable development.	n.a.
			Energy security		Energy security (share of total primary energy consumption accounted for by oil and gas imports with country risks)	2050	Renewable energy (including hydro) use increases by 3.1 times from 2010 to 2050. Coal use decreases by 0.73 times and gas trade increases by 6.2 times. Global increase in vulnerability to energy shocks. The Population-weighted-average of the energy security index increases by 2.3 times. In 2050, this vulnerability is 1.7 larger than in the baseline scenario.	Balanced policy measures for climate change and sustainable development.	n.a.
	To sustain	(S2) Life support	Water stress	Reduce water stress	People living under water stress	2100	The number of people under water stress increases from 1.7 billion in 2000 to 3.1 billion in 2050 and declines thereafter to 2.9 billion in 2100.	n.a.	n.a.
			Clean air	Reduce air pollution	SO_x and black carbon emissions	2100	Air pollution decreases from 2010 levels. SO_2 emissions are reduced by 42% from 2010 to 2050 and by 72% from 2010 to 2100. Black carbon emissions are reduced by 21% from 2010 to 2050 and by 70% from 2010 to 2100.	In addition to a basket approach, bottom-up approaches are important.	n.a.
			Land use	Reduce degradation of forest, land etc.	Agricultural land area	2100	The cropland area required for food production increases by 15% until 2050 and declines thereafter. The land area for energy-crop production decreases to nearly zero in 2020, but makes a come-back after the middle of this century. The irrigated land area for food production decreases by 5% from 2000 to 2050 and by 15 % from 2000 to 2100.	n.a.	n.a.

			Fossil fuel use	Reduce fossil fuel use	Sustainable energy use (cumulative fossil fuel consumption)	2100	Cumulative fossil fuel use is lower than in the baseline scenario, due to energy efficiency improvements and the diffusion of nuclear power and renewable energy. Cumulative fossil fuel use amounts to 520 Gtoe from 2010 to 2050, and to 1,000 Gtoe from 2010 to 2100..	Reduce fossil fuel subsidies	n.a.
			Climate change economics	Limit economic impact of climate change	Economic impact of mitigation measures (marginal abatement cost and GDP loss)	2100	The global GDP loss due to GHG mitigation amount to 3.6% and 4.1% (relative to GDP in baseline scenario) in 2050 and 2100, respectively..	n.a.	n.a.
					Aggregated economic impact of climate change	2150	The global average aggregated economic impact of climate change are 0.77%, 1.14% and 1.29% (relative to GDP in baseline scenario) in 2050, 2100 and 2150, respectively.	n.a.	n.a.
		(S1) Nature	Climate change	Avoid dangerous climate change	Atmospheric GHG concentration and global mean temperature change	2100	Atmospheric GHG concentrations reach 530 ppm $CO_{2\text{-eq.}}$ in 2050 and 550 ppm $CO_{2\text{-eq.}}$ in 2100. The global mean temperature rise relative to the pre-industrial level is 2.1˚C and 2.8 ˚C in 2050 and in 2100, respectively.	While it is clear that significant emissions reductions are necessary, the most appropriate target level “to avoid dangerous climate change” remains uncertain.	n.a.
					Ocean acidification (pH and impacts on Aragonite ($CaCO_3$))	2150	pH=8.0 in 2150, which is slightly less than current levels, so that the aragonite is stable.	Large emission reductions are necessarily.	n.a.

Source: Based on Akimoto et al. (2012).

4.3.4. Synergies and trade-offs

The synergies and trade-offs highlighted in RITE's ALPS scenarios are summarized in Table 19. It is found that efforts to deeply reduce GHG emissions can result in serious vulnerabilities in the areas of food access, food and energy security. There are complex trade-offs among several climate change and food objectives, the precise nature of which depend on mitigation levels and strategies. Similarly complex are inter-linkages between energy security and climate change, where GHG emissions reduction can lead to either an increase or decrease in energy security. This finding is different from the other SD scenarios for Rio+20 and due to the higher geographic resolution of the ALPS scenarios. In fact, with increasing geographic resolution, it becomes increasingly difficult to resolve the various trade-offs. In other words, it appears that the more stylized models greatly underestimate the actual challenges in resolving trade-offs and achieving multiple sustainable development goals.

Table 19. Synergies and trade-offs highlighted in RITE's ALPS scenarios for Rio+20

RITE's ALPS scenarios: B (high economic growth), C (climate policy prioritized), D (energy security prioritized). *Models: DNE21+, GAEZ, MAGICC etc.*	
Issue clusters	**Synergies (SY) and trade-offs (TO)**
Climate – Food and energy security	**TO:** Issues related to food access, food security, and energy security can result in vulnerabilities with deep emissions reductions.
Climate change – Food	**TO:** Complex trade-offs among several objectives, depending on mitigation levels and strategies.
Energy security – Climate Change	**TO and SY:** Some of the complex indicators include those relating to energy security, which increase in some countries and decrease in others with CO_2 emission reduction measures.

4.3.5. Lessons-learned

RITE's ALPS scenario study concludes that complex trade-offs among multiple objectives need to be addressed at the global level. In particular, the patterns of climate change impacts on a variety of countries can be very complex. Hence, balanced and flexible policy measures are found to be indispensable.

Global GHG emission reductions are necessary, but deep GHG emission reductions alone do not lead to sustainable development, nor do high levels of economic growth and development alone. However, most of the indicators relating to sustainable development will improve with economic growth in the future. GHG emission reductions to achieve temperature increases below 2˚C can reduce climate change damage such as ocean acidification.

There is no single "best" solution or policy for sustainable development. Bottom-up measures and policies need to be tailored to each issue, country, and sector.

4.4. OECD's green growth scenarios - Environmental Outlook for 2050

4.4.1. Approach and rationale

OECD prepared an in-depth scenario study for Rio+20. The purpose of this "*Environmental outlook for 2050*" was to design and quantify a "*green growth*" scenario compared with a conventional baseline scenario.

The key model inputs were green growth policies, not normative goals or targets. In this approach it is simply assumed that effective green growth policies would lead to a sustainable future. It should also be noted that green growth policies are not modelled directly, but captured indirectly as ex-post interpretations of model runs.

Details are provided in:

- OECD (2012). *Environment Outlook for 2050: the consequences of inaction*, OECD, June 2012, ISBN 978-92-64-12224-6; and
- Chateau, J., Rebolledo, C., Dellink, R., (2011). *An Economic Projection to 2050: The OECD 'ENV-LINKAGES' Model Baseline'*, OECD Environment Working Papers, No. 41, OECD Publishing.

4.4.2. Modelling framework

Two distinct modelling frameworks were used for the *OECD Environment Outlook for 2050*: (a) PBL's modelling framework with the IMAGE model at its core; and (b) OECD's ENV-Linkages model. Reference is made to the description of PBL's modelling framework contained in Section 4.2 above.

OECD's ENV-Linkages is a general economic equilibrium model. The ENV-Linkages model is the successor to the OECD GREEN model (Burniaux, et al., 1992). It describes how economic activities are linked to each other across sectors and regions, and to environmental pressures (e.g., GHG emissions). The model projects these links between economic activities and emissions several decades into the future to shed light on the medium- and long-term impacts of environmental policies. ENV-Linkages does not represent physical processes.

ENV-Linkages has 15 world regions, each with 26 economic sectors, including 5 electricity sectors. Economic input-output tables identify all the inputs into an industry (rather than individual firms) and identify all the industries that buy specific products in a region. Industries use land or other resources (e.g., fish, minerals or trees).

Production in the model is represented using a nested sequence of constant elasticity of substitution functions. Input factors include labour, capital, energy and a sector-specific natural resource (e.g. land). Production is assumed to operate under cost minimisation, perfect markets and constant returns to scale technology. The substitutability between inputs means that the intensity of using capital, energy, labour and land changes when their relative price changes.

It is important to note that the same PBL modelling framework that is used for PBL's normative Rio+20 scenarios is used for the OECD's green growth scenarios that do not start with normative thematic targets, but stop at the overall goals level.

4.4.3. Model inputs, outputs and policy interpretation

Table 21 provides a summary of model inputs, model outputs and policy interpretations in OECD's green growth scenarios. Key model inputs included broad normative goals and green growth policies. Yet, green growth policies and actions were subject to a certain ex-post interpretation, since they were primarily captured indirectly. In contrast to the IIASA, PBL and RITE scenarios described above, quantifiable targets were not direct inputs, but instead model outputs, indicators of interest that are monitored. Other key model outputs include the scenario pathway characteristics and certain investment requirements.

Despite the similarities in modelling approaches, OECD's scenario model outputs were presented in a rather different fashion. The un-sustainability of the baseline was described in great detail, in particular for four priority challenges that were identified. Then the level of policy ambition needed is outline and selective solutions that are part of the counterfactual green growth scenarios are presented in the form of a number of "what if"-statements.

Priority challenges identified

Climate change, biodiversity, water and the health were identified as the highest priority challenges, requiring action now action now to avoid significant costs and impacts. In fact, issues were identified in terms of three categories in order of urgency for policy action (Table 20).

In particular, it was shown that without more ambitious policies, by 2050, more disruptive climate change would likely to be locked-in (global GHG emissions increase by 50%); biodiversity loss would be projected to continue, especially in Asia, Europe and Southern Africa; freshwater availability would be further strained with 2.3 billion more people than today projected to be living in river basins experiencing severe water stress; health impacts of urban air pollution would continue to worsen; and the burden of disease related to exposure to hazardous chemicals would be significant worldwide.

Level of policy ambition needed

The OECD study concluded that "*progress on an incremental, piecemeal, business-as-usual basis in the coming decades [would]…not be enough. Without new policies, progress in reducing environmental pressures [would]…continue to be overwhelmed by the sheer scale of growth.*" (OECD, 2012)

But the study also showed that acting now is not only environmentally rational, but also economically rational. "*Well-designed*" green growth policies could reverse the adverse baseline trends, sustaining "*long-term economic growth and the well-being of future generations*" (OECD, 2012).

What ifs…

The potential beneficial impacts of green growth policies actions (compared to a baseline) were presented in the form of answers to "what-if" questions (OECD, 2012).

What if NO_x, SO_2 and black carbon emissions were cut by 25% by 2050? This would "*not make much difference in preventing the expected doubling of premature deaths*", requiring even more ambitious targets, but it could lead to a reduction in global CO_2 emissions by 5%.

What if we start today to limit GHG concentrations to 450 ppm using carbon pricing to meet the 2°C goal? The costs were estimated to slow economic growth by 0.2 percentage points per year on average, amounting to 5% of global GDP in 2050 (compared to baseline). This is less than the 14% of average world consumption expected to be lost due to climate change impacts over the same time frame.

What if the emission reduction pledges that industrialised countries indicated in the Cancún Agreements were to be implemented through carbon taxes or cap-and-trade schemes with fully auctioned permits? Tax revenues were estimated at about 0.6% of their GDP in 2020 which is about US$250 billion.

What if the social impacts of climate mitigation policy were not properly addressed? Increased energy costs could lead to an additional 300 million poor people lacking access to clean but more expensive energy sources in 2050, causing an additional 300,000 premature deaths from indoor air pollution (compared to baseline). Hence, targeted policies would be needed to support poor households.

What if the global community decided to promote universal access to an improved water source and basic sanitation in two phases by 2050? It would requite an additional, annual investment of US$1.9 billion from 2010 increasing to US$7.6 billion by 2050 (compared to the baseline).

In the above list the overwhelming climate change issues related is apparent.

Table 20. Key global environmental challenges assuming no new policies, identified by OECD Environment Outlook 2012.

Issue	Well-managed issues (“green light”)	Issues that remain a challenge but management improving (“yellow light”)	Not well-managed issues or worsening (“red light”)
Climate change	• Growing GHG emissions (especially energy-related CO2); growing atmospheric concentrations. • Increasing evidence of a changing climate and its effects. • Copenhagen/Cancún pledges falling short of a cost-efficient 2°C pathway.	• Declining GHG emissions per unit of GDP (relative decoupling) in OECD and BRIICS. • Declining CO2 emissions from land use change (mainly deforestation) in OECD and BRIICS. • Adaptation strategies being developed in many countries but not yet widely implemented.	
Biodiversity	• Continued loss of biodiversity from growing pressures (e.g. land use change and climate change). • Steady decrease in primary (virgin) forest area. • Over-exploitation or depletion of fish stocks. • Invasion by alien species.	• Protected area expansion, but underrepresentation of certain biomes and marine protected areas. • Forest area expanding mainly due to afforestation (e.g. plantations); deforestation rates slowing but still high.	• Progress by the Convention on Biological Diversity in 2010 on the Strategic Plan for Biodiversity 2011-2020 and the Nagoya Protocol.
Water	• Increase in the number of people living in river basins under severe water stress. • Increase in groundwater pollution and depletion. • Deterioration of surface water quality in non-OECD countries; increase in nutrient loading globally and risk of eutrophication. • Urban dwellers increasing faster than people with connection to water services; large remaining number of people without access to safe water in both rural and urban areas; MDG on sanitation not achieved. • Increase in volume of wastewater returned to the environment untreated.	• Increase in water demand and competition among users, and need to reallocate water among users. • Increase in number of people at risk from floods.	• Decrease in point-source water pollution in OECD countries (from industry, municipalities). • MDG on access to an improved water source likely to be met in BRIICS.
Health and environment	• Substantial increase in SO_2 and NO_x emissions in key emerging economies. • Increase in premature deaths linked to urban air pollution (particulates and ground-level ozone). • High burden of disease from exposure to hazardous chemicals, particularly in non-OECD countries.	• Decrease in child mortality from lack of access to safe water and improved sanitation. • Better, but still inadequate, information on exposure to and health impacts of hazardous chemicals in the environment, in products and from combined exposures. • Many OECD governments have changed, or are in the process of changing, legislation to expand regulatory coverage of chemicals, but enforcement still incomplete. • Decrease in premature deaths due to indoor air pollution from traditional solid fuels, but potential trade-offs if climate mitigation policies increase energy prices. • Decrease in premature mortality from malaria, despite climate change.	• Decrease in emissions of SO_2, NO_x and black carbon in OECD countries.

Notes: Green light = environmental issues which are being well managed, or for which there have been significant improvements in management in recent years but for which countries should remain vigilant. Yellow light = environmental issues which remain a challenge but for which management is improving, or for which current state is uncertain, or which have been well managed in the past but are less so now. Red light = environmental issues which are not well managed, are in a bad or worsening state, and which require urgent attention.
Source: OECD (2012).

Table 21. Green growth scenario variants for the OECD Environment Outlook for 2050.

Normative model input					*Model output*		*Model output*	*Indirect input and ex-post policy interpretation of model results*	
Level 1	*Level 2*		*Level 3: Strategy*				*Level 4: Blueprint*	*Level 5: Implementation*	
Ultimate goal	**Vision**		**Themes**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Investments**
Sustainable development	To develop	(D1) People	Water access	Towards universal access	Universal access to improved water source and basic sanitation.	2050	+242 million people with improved water supply and +1.4 billion with basic sanitation (vs, baseline). Universal access to public sewerage (2030). 50% of the urine from connected households collected/recycled (2050).	Accelerate the deployment of water supply and sanitation infrastructure in developing countries. Explore innovative options which consume less water, energy or capital. This can be funded partially by OECD member states, e.g. by increasing the portion of official aid to these areas, and the private sector can also play an essential role. Scale up investment in water supply and sanitation. The benefit-to-cost ratios can be as high as 7 to 1 in developing countries.	n.a.
		(D2) Economy	Water demand	Increase water efficiency	Water demand increases (3,560 km^3 to 4,140 km^3; -25% baseline).	2000-2050	Largest water demand reductions compared to baseline in electricity sector (-37%) and manufacturing (-30%).	Improve water pricing to signal scarcity and to create incentives for efficient water use in all sectors. Implement flexible water allocation mechanisms (e.g. by combining water rights reform and pricing policies). Improve water governance to ensure coherence with other policy areas such as energy, agriculture and urban planning. Engage all relevant stakeholders. Assess and reform subsidies that encourage unsustainable water use. Invest in better water-related information.	n.a.
	To sustain	(S2) Life support	Water resources	Reduce water stress	+2 bln people under severe water stress (reaching 3.7 bln)	2000-2050	Number of people living under *severe* water stress increases from 1.6 to 3.7 billion (-220 million vs. baseline). Number of people under no water stress increases from 2.3 to 3.2 billion (-400 million vs. baseline). Number of people under water stress from 3.9 to 6 billion (vs. 6.4 billion in baseline).	Invest in innovative water storage capacities which do not conflict with other environmental policy objectives (e.g. preservation of ecosystem services, forests or biodiversity).	n.a.
				Improve water quality			n.a.	Better co-ordinate the expansion of wastewater collection (sewerage systems) with wastewater treatment to avoid wastewater being discharged untreated. Innovative techniques and business models will be needed; the private sector is an important player. Improve and increase the use of appropriate wastewater treatment equipment and techniques, and the efficient management of nutrients and agricultural run-off. Encourage further R&D to speed up and disseminate innovation. Build capacity through training and education.	n.a.
				Mitigate water-related disasters			n.a.	Reduce the impact and occurrence of water–related disasters by restoring the ecosystem functions of floodplains and wetlands, paying attention to hydromorphology and removing incentives which encourage people to settle or invest in risk-prone areas	n.a.

			Air pollution	Reduce air pollution	-25% in NO_x, SO_2 and black carbon emission vs. baseline	2050	Maximise synergies between local air pollution abatement and climate change mitigation policies. Avoid 90,000 premature deaths in 2030 and 180,000 in 2050 (vs. baseline).	Curb the growing health impacts of air pollution through more ambitious and targeted regulatory standards and economic instruments, such as taxes on polluting activities. Reduce motor vehicle emissions through policy mixes which include taxes and regulations, and promoting cleaner public transport. Encourage behavioural changes in business models and lifestyle.	n.a.
			Chemicals	-	None	-	n.a.	Intensify international co-operation in the management of chemicals.	n.a.
		(S1) Nature	Climate change	Reduce anthropogenic interference	2 °C target	2010-2100	n.a.	Adapt to inevitable climate change. Integrate adaptation into development co-operation. Set clear, credible, more stringent and economy-wide GHG-mitigation targets. Put a price on carbon (revenues: ~ 0.6% of GWP or US$250 billion by 2020). Global phase-out of fossil fuels subsidies. Foster innovation and support new clean technologies (with government funded R&D, carbon price, and financial policies). Additional targeted regulatory instruments (such as fuel, vehicle and building-efficiency standards).	Cost of reaching the 2°C goal: slows GWP growth from 3.5 to 3.3% p.a. (costing ~5.5% of GWP in 2050).
			Biodiversity	Protect critical amount of ecosystems	CBD Aichi protected area targets of 17% of terrestrial and inland water areas and 10% of coastal and marine areas	2020	9.8 million km^2 of land to be protected.	Adopt more ambitious policy measures to achieve internationally agreed plans, targets and strategies (Aichi targets). Mainstream and integrate biodiversity conservation and sustainable use into other policy areas to enhance synergies and prevent trade-offs. Remove and reform environmentally harmful subsidies, including those that promote, without any environmental considerations, the intensification or geographic expansion of agriculture, bioenergy, fishing, forestry and transport. Scale up private-sector engagement in biodiversity conservation and sustainable use, including through innovative financing mechanisms at the local, national and international level. Clear price signals for natural resource use and pollution. Improve the quantity and quality of data available to inform biodiversity policy	n.a.
			P and N cycle	Reduce anthropogenic interference	P removal in wastewater treatment Increases from 0.7 Mt in 2000, 1.7 Mt in 2030, to 3.3 Mt in 2050	2030, 2050	25% of P-based detergents replaced by P-free detergents (2030), 50% in 2050. Removal of N and P through wastewater treatment plants will increase. Removed P provides 15% of the need for fertiliser production in 2050 (22 Mt).	In each 20-year period: 50% of “no treatment” is replaced by mechanical; 50% of mechanical treatment is replaced by biological; 50% of biological is replaced by advanced treatment.	n.a.

Source: Based on: OECD (2012).

4.4.4. Synergies and trade-offs

Trade-offs exist but they are considered not that important in the face of good green growth policies. In this approach no normative, quantified sustainable development targets are chosen. Instead policy coherence is considered important. However, the OECD report sketches the most important inter-linkages that are underlying synergies and trade-offs. It also offers a wide range of technology solutions to resolving trade-offs.

Green growth policies will be most cost-effective and hence the assumption is that they will be the right way to address trade-offs where they exist after all: *"Not all of the solutions will be cheap, which is why seeking out the most cost-effective among them is so important. A key task is to improve understanding of the challenges and trade-offs that need to be made."* (OECD, 2012).

Yet, the study also acknowledged the "*complexity of the environmental challenges and the inter-linkages among them*" which would call for a "*wide array of policy instruments…often in combination*" (OECD, 2012).

4.4.5. Lessons-learned

An important conclusion of the OECD scenario study was that the green growth policies suggested in the OECD green growth strategy are needed. Full internalization of external costs and marketization of ecosystem services and mitigation choices was found to be the most efficient way to address a multitude of sustainable development challenges.

Since the green growth policy solutions are known, the real challenge is considered to be political leadership and widespread public acceptance: "*The implementation of effective green growth policy mixes will depend on political leadership and on widespread public acceptance that changes are both necessary and affordable.*" (OECD, 2012).

4.5. SEI scenarios for Rio+20

In preparation for Rio+20, Stockholm Environment Institute (SEI) organized an international collaboration to create a set of sustainable energy scenarios. Details are provided in:

- Nilsson et al. (2012). *Energy for all in the Anthropocene: towards a shared development agenda*. SEI, April 2012.
- Nilsson et al. (2012b). *Energy for a Shared Development Agenda: Global Scenarios and Governance Implications*. SEI, June 2012.

4.5.1. Approach and rationale

The SEI scenarios take the GEA efficiency scenario of IIASA and PBL as a starting point (see section 4.1 above) and explore the potential of global cooperation furthering greater between country and within country equity. A baseline (BAS) is compared with a basic energy access scenario (BEA) and a shared development scenario (SDA). Table 22 provides an overview of the key assumptions of these scenarios.

Table 22. Key assumptions of SEI scenarios for Rio+20

Scenario	Key assumptions			
	Demographics	**Economics**	**Climate policy**	**Energy**
Baseline (BAS)	Business as usual	Business as usual	No major new policies	No major new policies.
Basic energy access (BEA)	Business as usual	Business as usual	Major effort to mitigate climate policy	Provision of basic energy services
Shared develop-ment agenda (SDA)	Business as usual	Same global GDP. More growth in poorest regions, less in richest. Average incomes grow in all. Improved income distribution within regions.	Major effort to mitigate climate policy	Energy in all regions at least consistent with middle income development (beyond basic access to reflect more productive uses of energy)

Source: Nilsson et al. (2012).

The baseline scenario is a typical business as usual scenario that does not foresee major new climate or energy policies. In contrast, the basic energy access scenario (BEA) assumes special efforts to achieve universal access to clean energy services and major efforts to mitigate climate policy, in essence assuming ambitious policy objectives as stated in the UN debate will be achieved in the coming decades.

The shared development agenda scenario (SDA) also assumes major efforts to mitigate climate policy and universal clean energy access, yet it goes much further in targeting energy services in all regions to be at least consistent with middle-income development, reflecting more productive uses of energy well beyond basic access. Most importantly, the SDA scenario assumes a more equal distribution of incomes across regions and within countries, with the same total global GDP, though. In the SDA scenario, poor countries reach at least US$10,000 per capita by 2050[12], which corresponds to a doubling of the poorest countries' GDP over the baseline by 2050.

In other words, the SDA scenarios explore the global energy transformation needed to meet sustainable development

[12] in 2005 PPP

goals, such as development for all, while mitigating climate change, limiting bioenergy and hydropower use, and ensuring food safety. The scenarios "*are created as a backcast that explores what needs to be done, sector by sector and region by region, to meet these goals*" (Nilsson et al., 2012b).

4.5.2. Modelling framework

The SEI scenarios were implemented with its Long-range Energy Alternatives Modelling System (LEAP). LEAP is an accounting model with 20 world regions plus two non-geographic regions ("bunkers").

The SEI scenario was designed to build on the baseline and efficiency scenarios of the Global Energy Assessment described in section 4.1 above (Riahi et al. 2012) which were created with the MESSAGE model and the IMAGE/TIMER model.

4.5.3. Model inputs, outputs and policy interpretation

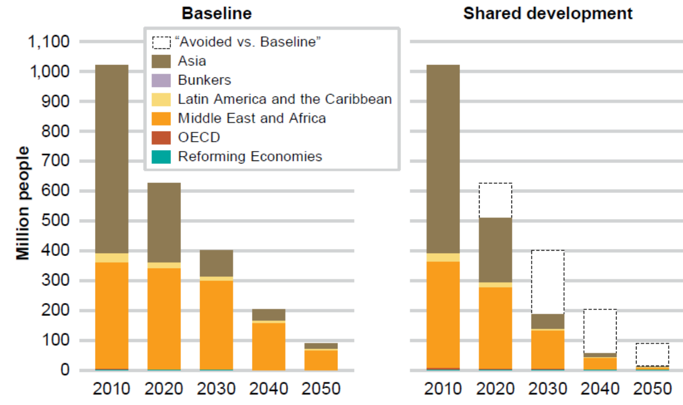
Table 23 provides a summary of model inputs, model outputs and policy interpretations in SEI's SDA sustainable development scenarios. Similar to the IIASA and PBL scenarios, which were used as input here, key model inputs included the normative goals and targets, whereas key outputs were the various pathway characteristics and detailed investment requirements. Policy instruments and actions were captured in various direct and indirect ways, resulting in specific instruments and actions suggested by modellers ex-post only.

The findings for the SDA scenarios are striking, illustrating the potential of global collaboration that would b e primarily focused on equity across and between countries. In the words of the authors "*we find that the [SDA] scenario has minimal additional impacts on overall energy consumption and* CO_2 *emissions compared to the basic energy access (BEA) scenario*" (Nilsson et al., 2012b).

Hence, in a more equitable world there does not need to be any trade-off between the development aspirations of the poorest countries and global environmental objectives. The SDA scenario achieves a virtual global eradication of absolute poverty by 2050 (Figure 19). However, it requires major efforts in increased efficiency, electrification, and low-carbon energy supply.

This is in stark contrast to conventional future worlds without a special focus on increased equity but an emphasis on technology solutions, worlds in which the above trade-off is strong and binding, as highlighted in many scenario studies.

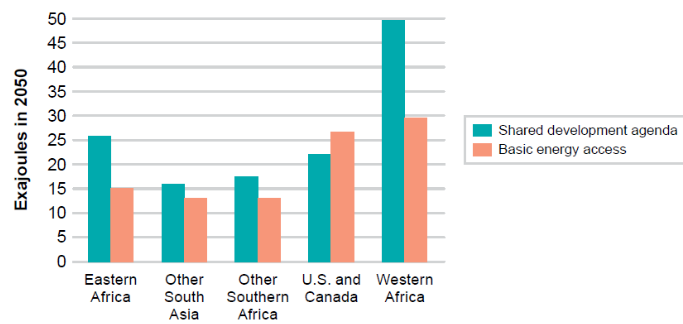
Figure 19. Poverty levels in BAS/BEA scenario compared to SDA scenario



Source: Nilsson et al. (2012).

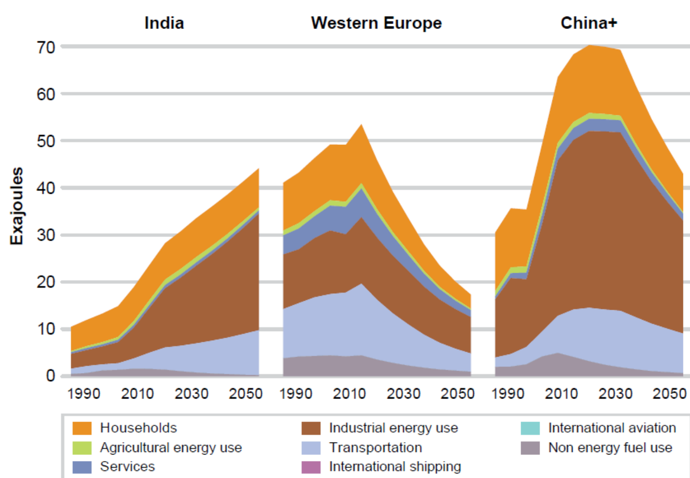
Figure 20 illustrates the magnitude of the higher levels of energy use in the poorest regions in the SDA scenario, even compared to the BEA scenario.

Figure 20. Total energy demand in BEA vs. SDA scenarios in 2050



Source: Nilsson et al. (2012).

Figure 21. Energy use in India, Western Europe and China+ in SDA scenario.

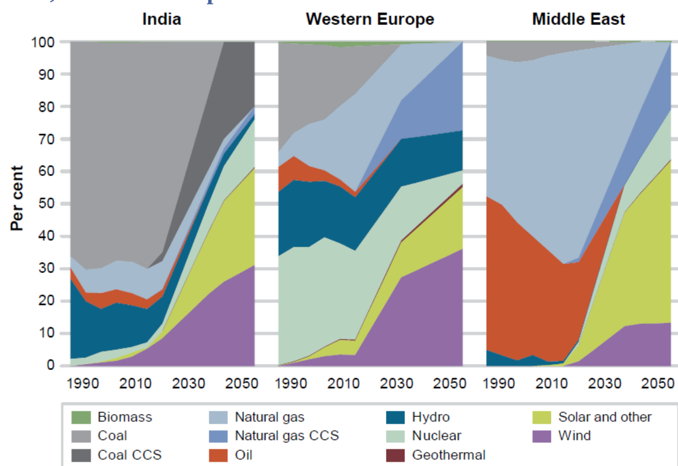


Source: Nilsson et al. (2012).

Figure 21 shows the energy use in selected regions in the SDA scenario from 1990 to 2050. Whereas overall demand is significantly curbed in Western Europe, it continues to increase in India through out the time horizon. In China, energy use increases rapidly until about 2030 after which it decreases back to the level it showed in 2000.

In the SDA and BEA scenarios, global energy use eventually decreases, while electricity use increases rapidly, with conventional fossil-fired electricity generation technologies being phased out well before 2050. Wind, solar, geothermal and, in some regions, hydro and nuclear expands rapidly in the SDA scenario.

Figure 22. Share of various sources in electricity generation in India, Western Europe and the Middle East in the SDA scenario.

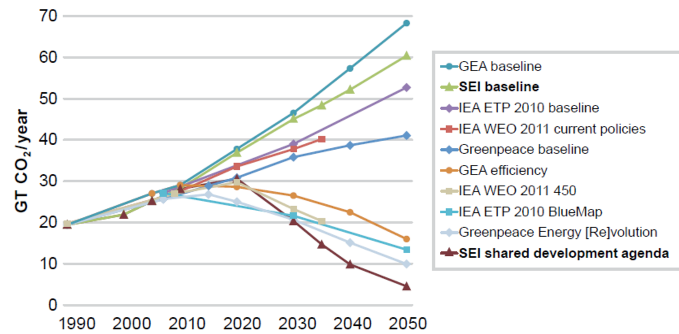


Source: Nilsson et al. (2012).

Energy intensities in the SDA scenario decrease much more rapidly than in the past, at rates of 2.8% per year. By 2050, energy intensities will be less than one third of their 2010 level.

It is important to note that the SDA scenario achieves a very, very low GHG emissions path after 2020. In fact, it is even lower than the Greenpeace Energy Revolution scenario (Figure 23). Even so the authors conclude that it will be "*extremely difficult*" to achieve "*keeping global emissions within a 2°C pathway…, particularly since roughly 30% of the aggregate of the allowable CO2 budget for 2000–2050 has already been emitted up to 2012.*" (Nilsson et al., 2012)

Figure 23. Global energy-related CO2 emissions in SDA scenario compared to the literature



Source: Nilsson et al. (2012).

Table 23. SEI's sustainable development scenario for Rio+20: Shared development agenda (SDA) scenario

Normative model input							*Model output*	*Ex-post policy interpretation of model results*	
Level 1	***Level 2***		***Level 3: Strategy***				***Level 4: Blueprint***	***Level 5: Implementation***	
Ultimate goal	**Vision**		**Themes**	**Goals**	**Targets**	**By**	**Pathway characteristics**	**Policies and actions**	**Investment**
Sustainable development	To develop	(D1) People	Poverty	Eliminate poverty	Eliminate poverty worldwide	2050	Global solidarity. Gini coefficients improve in each region with improvements in governance and democratic participation.	Global large-scale transfers.	n.a.
			Access	Improve energy access	Modern energy access for all.	2050	Specific efforts are made by the international community to provide basic energy access to the world's poor, through addressing poverty itself	Poverty reduction policies. Reduction of primary energy use in all regions which reach critical income levels, e.g., absolute energy demand reduced in Western Europe by 2050 to one third of present level, in China reduced after a peak in 2025, and continues to rise in India to more than 4-times current levels.	n.a.
		(D2) Economy	Income convergence	Global "middle-class"	GDP per capita > US$10,000 PPP in all regions	2050	Gross world product grows at 2.8% per year to 2050. GDP per capita grows in all world regions. Faster economic growth in the poorest regions (Southern, Western and Eastern Africa, and South and South-East Asia) so that average GDP per capita reaches at least US$10,000 PPP in all regions by mid-century.	Global large-scale transfers.	n.a.
	To sustain	(S1) Nature	Climate change	Avoid dangerous climate change	Keep global average temperature rise <2°C with 60% probability.	2012-2100	No significant mitigation efforts until 2015. In lower income regions, efforts are assumed to start even later, with the poorest regions beginning significant efforts in 2020. *Energy intensities* decline by 2.8% per year, decreasing to 32% of the 2010 value by 2050. *Fossil fuel use* is reduced by 75% by 2050 from its peak of 481.4 EJ in 2015. *Switching to lower carbon fuels*, especially from coal and oil to biomass and natural gas.	*Energy Efficiency* is pursued aggressively in all sectors and all regions, including insulation of buildings and efficiency improvements of lighting, heating, cooling, industrial processes, road vehicles, shipping and airplanes. *Electrification and renewable power*, including increases in the share of electricity in final energy use. *Conventional fossil fuel-based technologies* virtually phased out well before 2050, with the exception of natural gas CCS systems and some coal-based CCS in developing regions. Unprecedented scale-up of renewable energy, e.g., 8900 GW of wind power by 2050 (~ building 248 GW per year, or 25-times the current rate). *Sufficiency measures* needed to address overall levels of consumption, including urban planning, reduced growth in transportation, healthier diets, smaller/efficient housing.	n.a.

Source: Based on: Nilsson et al. (2012).

4.5.4. Synergies and trade-offs

The SDA scenario highlights the fact that there is little trade-off between faster income growth in the poorest countries on the one hand and energy and climate goals on the other hand. In fact, the SDA scenario has only 11% higher global energy use and 4% higher CO_2 emissions than the BEA scenario by 2050 (Table 23). It should also be noted that this trade-off is essentially zero in the BEA scenario compared to a dynamics as usual baseline.

Table 24. Synergies and trade-offs highlighted in SEI's shared development agenda scenario

SEI's sustainable development scenarios: Shared development agenda scenario (SDA) *Models: LEAP-OSEMOSYS*	
Issue Clusters	**Synergies and Trade-offs**
Income – Energy access - Climate	SDA scenario has only 11% higher energy use and 4% higher CO_2 emissions by 2050, compared to BEA scenario. Little trade-off between faster income growth in the poorest countries and energy or climate goals.

4.5.5. Lessons-learned

The SEI-SDA study concludes that "…*achieving the emissions reductions implied by the 67% probability is now almost impossible even with extremely ambitious assumptions about mitigation*", since action has been delayed for too long.

Most importantly, the study illustrates how much could be achieved with a shared development agenda which could potentially lead to a better life everywhere. Income and quality of life improvements of the poorest billions on the planet are not only compatible with addressing the most pressing global environmental issues, but may very well be the only sustainable route to addressing them. Instead, global environmental problems arise primarily from overconsumption among the richest segments of populations in developed and developing countries alike. Hence, the shared development agenda explored in the SDA scenario offers a veritable, new way forward for a collaborative problem to our global challenges.

4.6. FEEM's goals and targets assessed with the WITCH model

4.6.1. Approach and rationale

FEEM's contribution was in the form of exploratory, global scenarios with the stylized WITCH model. Hence, the objective was to estimate the order of magnitude of a wider range of trade-offs and synergies between environmental, development, economic, energy, education and innovation policy objectives.

Sustainable development scenarios were contrasted against a dynamic baseline scenario. Key assumptions for the baseline scenario included slow economic convergence in GDP per capita (affluence); slow convergence in energy per capita (intensity of use); fast convergence in emission intensity of output (eco-efficiency); slow convergence in carbon intensity of energy (techno-efficiency); medium emissions (similar to the IPICC SRES B2 scenario) (impact); and slow convergence in R&D and education expenditure.

In the framework, adaptive and mitigative capacities are functions of potential climate change damage, expenditures on education and R&D, population characteristics, fossil fuel intensity, institutions, and average incomes. Respective assumptions differ greatly for rich countries, emerging economies, and poor countries.

Table 25. Factors determining mitigative and adaptive capacities in the FEEM scenarios

Factors	**Country groups**		
	Rich countries	***Emerging economies***	***Poor countries***
Climate change damage	High/low	High/low	High
R&D expenditure	High	Medium	Low
Educational expenditure	High	Medium	Low
Population	Low	High	High
Fossil fuel intensity	Medium	High/low	Low
Institutions	Good	Weak	Weak
GDP per capita	high	low	Low

Source: Tavoni and de Cian (2011).

Details are provided in:

- Carraro, C., De Cian, E., Tavoni, M., (2012). "*Human Capital, Innovation, and Climate Policy: An Integrated Assessment*" Working Papers 2012.18, Fondazione Eni Enrico Mattei.
- De Cian, E., Bosetti, V., Sgobbi, A., Tavoni, M., (2009). "*The 2008 WITCH Model: New Model Features and Baseline*" Working Papers 2009.85, Fondazione Eni Enrico Mattei.

4.6.2. Modelling framework

The WITCH model incorporates a representation of the energy sector into an inter-temporal growth model of the economy, thereby allowing energy saving technology-related issues to be studied within a general equilibrium framework. De Cian et al. (2009) extended the formulation of endogenous technical change to generic innovation and human capital, which drive capital and labour productivities, respectively. The integration of human capital dynamics into an integrated assessment model allows evaluating sustainable development scenarios in a consistent way.

4.6.3. Goals and targets

The sustainable development targets that were evaluated in the FEEM scenarios for 2030, 2050, and 2100, include:

- Universal primary education from 2015 onward
- Reduce GHG concentrations
- GDP convergence across countries
- Increase R&D expenditure,
- Energy use: less than 70GJ/pc by 2050.
- Increase energy efficiency of production, reduce carbon intensity of energy
- SD targets can be imposed in the "sustainability transition scenarios":
- Climate policy (GHG stabilization target, 550ppmv and 650ppmv or threshold 3t$CO_{2\text{-}eq}$ per capita by 2050)
- Education policy (education expenditure to achieve MDG in all regions by 2015)
- Innovation policy (minimum total R&D expenditure. All regions spend 1% of GDP in innovation)
- Clean energy/ Green economy: technology policy (minimum R&D expenditure. Regions invest in energy R&D as much as they would in the presence of a carbon price (550ppme), but without any climate policy signal. Or OECD regions spend in R&D the same amount as in the 80's.)
- Energy use: less than 70GJ/pc by 2050
- Convergence: catch-up of Africa
- Clean energy, all regions spend at least 0.09% of GDP in energy R&D
- Innovation policy (minimum total R&D expenditure. All regions spend 1% of GDP in innovation)

4.6.4. Synergies and tradeoffs

Although the FEEM scenarios mostly highlight the existence of synergies, trade-offs can also be identified, especially in the short-term. The main lessons-learned are the following:

Synergies between education, economic growth, technology, and the environment

More investments in human capital stimulate medium- and long-run economic growth. The positive scale effect on economic growth lead to more CO_2 emissions in the medium term, because economic growth puts an upward pressure on energy demand. However, the expansion of economic activity increases the amount of resources available for innovation. Because human capital and technological progress are complements, investments in R&D are also stimulated. As a consequence, spending more resources on education eventually induces a technique effect, or a technological transformation, that improves econ- and techno-efficiency. Additional education expenditure comes at the costs of lower consumption, but only in the short-term. After 2035, the growth effect increases consumption possibilities as well, as indicated by the positive value of the elasticity.

Synergies between climate policy and development of low-carbon technologies

Climate policy stimulates clean R&D investments that improve the energy performance of existing technologies. If the climate goal is ambitious enough, R&D might also foster major technological breakthroughs that would add to the portfolio of existing clean substitutes to high-carbon options.

Synergies between climate policy, the development of carbon-free and general purpose technologies

Because of the complementarities that exist between different forms of knowledge and the spillovers across different R&D sectors, climate policy can stimulate not only green R&D, but it can also foster general purpose technologies R&D.

Trade-off between climate policy, economic growth, and education expenditure

Climate policies that aim at low GHG concentration (550ppme) reshapes the optimal mix of investments to meet the policy goal at the minimum cost. Investments that have a higher emission reduction potential are favoured, at the cost of other forms of expenditure with a lower potential, such as education. This investment reallocation reduces global GDP and GDP per capita, two indicators of the macroeconomic costs of climate policies.

Trade-offs and synergies between climate, education, and technology policies

Sustainable development can be achieved by combining multiple policy goals. Inspection of a policy mix that combines climate and education targets shows that increased human capital stimulates long-run economic growth, which ultimately reduces the GDP loss induced by the climate policy.

Including technology and R&D goals in the policy mix can augment the potential for positive synergies because market imperfections in the accumulation of knowledge leads to under-investments in R&D. Climate policy, by stimulating clean R&D, partly addresses the R&D market failure, but still the R&D level remain suboptimal. Adding a specific clean R&D goal on top of the climate and education targets can increase GDP, reducing further the GDP loss of the climate policy (Table 26). This result has important policy implications considering the growing concern that effective climate policy is conditional on solid economic development and therefore it needs to be supplemented with other policy targets.

Table 26. Macroeconomic costs (net present value, 5% discount rate) of combinations of policies in the FEEM scenarios.

Policies/Scenarios	***Climate policy***	***Climate and education policy***
Education expenditure	-5.3%	1.1%
Generic R&D	4.2%	4.6%
Energy R&D	318.0%	316.1%
Output	-1.4%	-1.0%
Consumption	-1.1%	-1.1%

Source: Tavoni and de Cian (2011).

4.7. IASA Ukraine's Global Sustainable Development Simulation

An interesting set of global simulation scenarios have been prepared by scientists at the National Academy of Sciences of Ukraine; the Geophysical Center of Russian Academy of Science; and the Ukrainian Branch of World Data Center. In contrast to the "mainstream" approaches presented above, these scenarios are derived from a systematic effort aimed to captured the long-term dynamics and based on wider empirical work in the tradition of Kondratiev. In this approach, a wide range of indicators is aggregated in the form of an overall measure of progress, the so-called sustainable development gauging matrix applied to countries, country groups and the world.

More details are provided in:

- Zgurovsky, M., Gvishiani, A., (2008). Sustainable Development Global Simulation: Quality of Life and Security of the World Population. Publishing House "Polytekhnika, 2008, ISBN 978-966-299-5.

- Zgurovsky, M. (2007). Sustainable Development Global Simulation: Opportunities and treats to the planet. Russian Journal of Earth Sciences, Vol.9, ISSN: 1681-1208.

4.8. Tellus' great transitions scenario for Rio+20 (Global Scenario Group update 2010)

In the 1990s, the Global Scenario Group (GSG) provided an influential set of scenarios depicting a great transition to sustainable development: the great transitions scenarios. One of its authors, Paul Raskin, provided an update of this work which was also used in the preparations for Rio+20, most notably as input to the *UN Secretary General's High-level Panel on Global Sustainability* which convened from 2010 to 2012. The strength of the GSG work is in its very broad coverage of sustainable development issues which, however, comes at the expense of capturing the complex underlying dynamics.

Details are provided in:

- Raskin, P., et al. (2010). *The Century Ahead: Searching for Sustainability*. Sustainability 2010, Vol. 2, pp. 2626-2651.
- For data and regional results see: www.tellus.org/result_tables/results.cgi

4.8.1. Approach and rationale

The overall idea of the GSG scenarios an their update by Tellus is to contrast conventional worlds with alternative visions, in order to inspire new solutions that go beyond an engineering fix to global sustainable development challenges (Table 27).

Two conventional future worlds were explored that capture key trends and approaches. The Market Forces (MF) scenario explores the implications of a continued market-oriented, growth-focused globalization, while the Policy Reform (PR) scenario explores the potentials of a Government-led redirection of growth toward sustainability goals.

Two alternative visions are suggested that include a significant break with recent trends and approaches. The Fortress World (FW) scenario explores the implications of an authoritative path chosen in response to mounting crises. The Great Transition (GT) scenario explores the potential of a fundamental societal and economic transformation towards sustainable development. It should be noted that, while the term "great transition" is increasingly being used in UN debates, such use is most often rhetoric to support incremental policy change in line with Policy Reform Scenario. In contrast, the Great Transitions Scenario illustrates a significant break.

It should be noted that the conceptualization of the GSG scenarios has been highly influential in global scenario modelling. In the following, the Great Transitions Scenario is described as a sustainable development scenario contribution of Tellus to Rio+20.

Table 27. Stylized characteristics of the Tellus' update of the Global Scenario Group scenario

Type	Name	Description
Conventional worlds	Market Forces (MF)	Market-oriented growth-oriented globalization
	Policy Reform (PR)	Government-led redirection of growth toward sustainability goals
Alternative visions	Fortress World (FW)	An authoritative path in response to mounting crises
	Great Transition (GT)	A fundamental transformation

Source: Raskin et al. (2010).

4.8.2. Modelling framework

The great transitions scenarios were created with an accounting model. It is essentially a database system linked to a computational framework, the PoleStar System . PoleStar was originally developed by the Tellus Institute and the Stockholm Environment Institute. The global scenarios are disaggregated by region, major sectors and subsectors of the economy, and social variables. The coverage of environmental and natural resource issues is rather comprehensive (Table 28).

Table 28. Issues modelled by Tellus

	Issue
Social	• Population • Gross Domestic Product (GDP) and value-added by sector • Income (GDP per capita) • Income distribution within and between regions • Poverty • Hunger line (income for adequate diet) • Employment (productivity and length of work week)
House-hold	• Energy use by fuel • Water use • Air pollution • Water pollution
Service	• Energy use by fuel • Water use • Air pollution • Water pollution
Trans-por-tation	• Passenger by mode: public road (buses, etc.), private road, rail, air • Freight transportation in following modes: road, rail, water, air • Energy use by mode and fuel • Air pollution
Agricul-ture	• Diet by crop and animal product categories • Livestock: animal type, seafood (wild, farmed), other products (milk, etc) • Crops: coarse grains, rice, other (fruits, vegetables, etc.), sugarcane, biofuels • Energy use by fuel • Irrigation • Fertilizer use • Air pollution • Water pollution
Industry	• Energy use by fuel and subsector: iron and steel, non-ferrous metals, stone, glass, and clay, paper and pulp, chemical, other • Energy feedstock by subsector. • Water use by subsector • Air pollution from both fuel combustion and process • Water and toxic pollution
Forestry	• Primary wood requirements • Secondary wood for final demand, and input to paper and pulp, lumber, biofuel
Land use	• Conversions between built environment, cropland, pasture, forest types (unexploitable, exploitable, plantation, and protected), other protected (marshes, bays, etc.), other • Each category broken down by arable and non-arable areas • Cropland disaggregated by crop type, and irrigated/non-irrigated
Energy conver-sion	• Conversion from primary to secondary fuels (i.e., electricity production and oil refining) • Requirements for coal, biomass, natural gas, renewable (wind, solar, geothermal, etc), crude oil, nuclear, hydropower • Air pollution
Water	• Freshwater resources • Desalinization and waste-water recycling for water resources • Use-to-resource ratios • Water stress
Solid waste	• Generation from household and service sectors • Landfill, incineration, recycling and other disposal technologies • Energy generation from incineration

Source: Raskin et al. (2010).

4.8.3. Goals and targets

While the model monitors indicators for all the areas covered in Table 28, the Great Transitions scenario was designed to achieve a limited set of sustainable development goals relating poverty, climate, freshwater and ecosystem pressure (Table 29). Compared to the SEI's SDA scenario, the GT scenario is less ambitious in terms of poverty eradication, but highly ambitious in terms of GHG emissions mitigation, freshwater, land use and fisheries.

Table 29. Sustainable development goals achieved by Tellus' great transitions scenario

Dimen-sion	Indicator	2005	2025	2050	2100
Poverty	Chronic hunger (millions of people)	893	446	223	56
	% of 2005 value	100%	50%	25%	6%
Climate	CO_2 concentration	380 ppmv	Stabilize at <350ppmv		
	Warming	-	<2°C		
	Cumulative CO_2 emissions since 2005	-	<265 GtC		
Fresh-water	Use-to-resource ratio	Varies by basin	Decrease in areas of water stress		
	People in water stress [billions]	1.73	<2		
Eco-system pressure	Deforestation	Varies by region	Slow and reverse		
	Land degradation	Varies by region	Slow and reverse		
	Marine overfishing	Perva sive	Slow and restore stocks		

Source: Raskin et al. (2010).

4.8.4. Lessons learned

The study concludes that a muddling-through approach, as explored by their *Market Forces Scenario* shows a high risks of increasing "*deterioration of life-support ecosystems and civilized norms*" (Raskin et al, 2010).

Such deterioration could - in principle - be prevented through a *"long and tenacious process of proactive adjustments in policy and technology"* (Raskin et al, 2010), explored in the *Policy Reform Scenario*.

However, it would require unprecedented, globally coordinated, rapid, large-scale action which might not be feasible for socio-political reasons after all.

In case such approach of radical incremental change fails, triggering crises, the response of mankind might be the authoritarian path of the *Fortress World Scenario* with likely disastrous outcomes for global sustainable development.

The Great Transition Scenario – while highly ambitious in terms of its expectations for transformative changes to technologies, human values, economic systems and institutions – appears to be a low-risk path toward sustainable development: "*a planetary civilization that pursues peace and justice, delivers material sufficiency and rich lives, and understands humanity as a respectful member of a wider community of life*" (Raskin et al, 2010).

4.9. Rander's forecast for 2052

Twenty and thirty years after the original *Limits to Growth* (LTG) Study of 1972, their authors provided updates which generally showed that many of the actual trends were still consistent with some of the LTG scenarios leading to global collapse sometime in the 21st century. As discussed in chapter 3 above, the LTG scenarios were typically misread by politicians and the general public alike as forecasts for the future, despite the assertion of the LTG authors that they had created a set of scenarios.

Against this background, it is interesting that one of the original LTG authors, Jorgen Randers of the Norwegian School of Management, published a global *forecast* for 2052, forty years after the LTG. In fact, among all contributions for Rio+20, his is the only forecast.

More details are provided in:

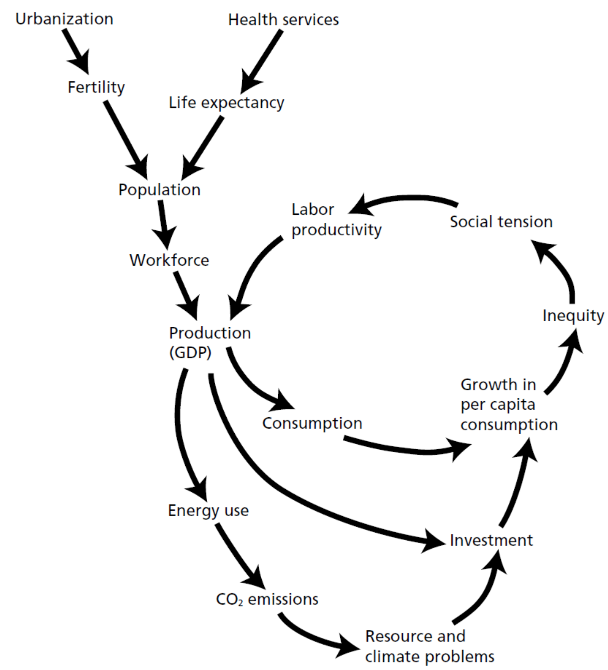
- Randers, J., (2012). *2052 - A Global Forecast for the Next Forty Years*. A Report to the Club of Rome Commemorating the 40th Anniversary of The Limits to Growth. Chelsea Green Publishing, White River Junction, Vermont, USA, ISBN 978-1-60358-467-8.

4.9.1. Approach and Modelling framework

The "*Rander's forecast*" is an outlier, in view of its explicit objective to be a forecast for 2052 (Randers, 2012). The "deterministic backbone" of Rander's forecast is a number of "slow variables" that change only gradually over time. These include population, GDP, energy use, climate gas emissions, temperature, industrial infrastructure, and certain fundamental values[13].

The model comprises of a number of cause-and-effect relationships which drive global trends (Figure 24). There are no a priori goals set for any of the indicators shown in Figure 24. However, the feedbacks in the system and the existence of obvious critical thresholds (such as for inequity triggering social strife) keep the system within certain planetary boundaries. Hence, like in the original LTG study, "*overshoot*" can lead to "*managed decline*", in order to readjust to hard boundaries set by natural and human systems.

Figure 24. Main cause-and-effect relationships behind the 2052 forecast.



Source: Randers (2102), p. 57

[13] Examples include the belief in democracy, scientific research, free markets, small government, free trade, and the belief that nature is there for humans to use.

Five world regions are modelled with an Excel model: USA, OECD-less-USA, China, BRISE (large emerging economies: Brazil, Russian Federation, India, South Africa and ten other populous economies like Indonesia, Mexico, and Vietnam), and Rest of World.

4.9.2. Results of the forecast

Similar to the most of scenarios described in this chapter, key modelling outputs were the pathway characteristics, including investment requirements, and policy instruments and actions were captured in various direct and indirect ways, resulting in specific instruments and actions suggested by modellers ex-post only. Since the Randers forecast is a forecast, indeed, there are no normative goals or targets used as inputs like in most of the other scenarios in this chapter.

However, important assumptions were made by the modeller on which human responses to expect beyond certain threshold levels of impacts of various negative trends, such as those relating to worsening climate change or increased inequalities. In the end, these act just like targets which are, however, higher/worse than the thresholds, implying overshoot and managed decline.

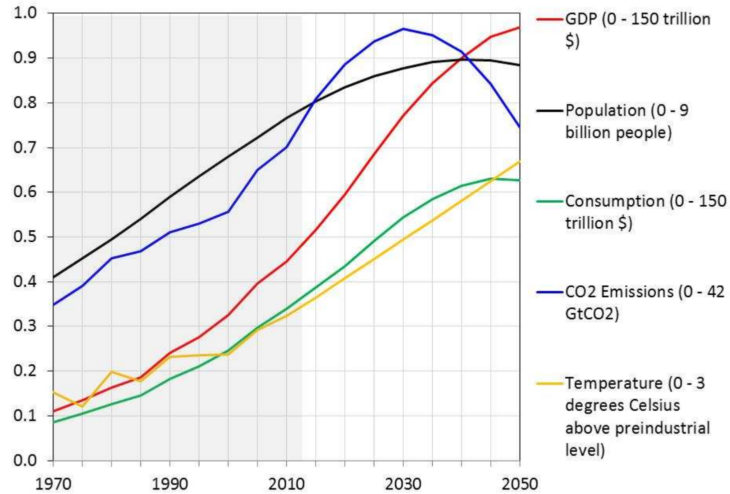
Selected slow variables

The findings on the pathways are striking, including in terms of the slow variables (Figure 25).

Population is projected to peak at almost 8.1 billion in 2040 and decrease thereafter. Birth rates are lower and death rates higher than even in the "UN low" population projection. This is due to smaller family size in an increasingly urban world.

GDP will continue to increase from US$ 67 trillion in 2010 to US$145 trillion in 2050, but growth rates will slow especially after 2020. This is the result of slowing in labour productivity "*because of problems with resource depletion, pollution, climate change, and rising inequity*" (Randers, 2012). Overall increase in consumption will slow even more than GDP, due to ever greater investments required to deal with global environmental challenges, but it will still almost double in the next forty years.

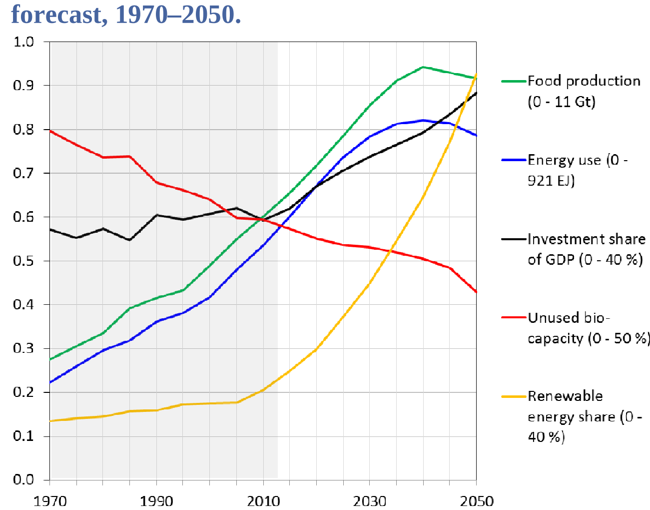
Figure 25. Selected slow variables in the Randers forecast, 1970–2050.



Relative scale: GDP and consumption (0 - US$150 trillion); population (0-9 billion people); CO_2 emissions (0-42 $GtCO_2$); temperature increase (0-3˚C).
Source: Randers (2012, p. 232).

Global energy use will continue to increase by about 50% in the next thirty years to 755 EJ, but decrease after 2040 in absolute terms (Figure 26). This is the result of the dynamics of consumption and sustained increases in energy efficiency.

Figure 26. World production in the Randers forecast, 1970–2050.



Relative scale: Food production (0–11 billion tonnes); energy use (0–921EJ); investment share of GDP (0%–40%); unused bio-capacity (0%–50%); renewable energy share (0%–40%).
Source: Randers (2012, p. 232).

CO_2 emissions will increasingly decouple from energy use, in line with ever increased renewable energy deployment across the world. As a result CO_2 emissions increase by another third to 41 $GtCO_2$ in 2030 and thereafter decrease to 31GtCO2 in 2050 which is slightly lower than emissions in 2011 (Figure 25). The result is a continuous increase in the atmospheric concentrations of greenhouse gases, e.g., to 491ppmv CO_2 in 2050 (with no stabilization) compared to 391ppmv in 2010. The result is increased climate change damage.

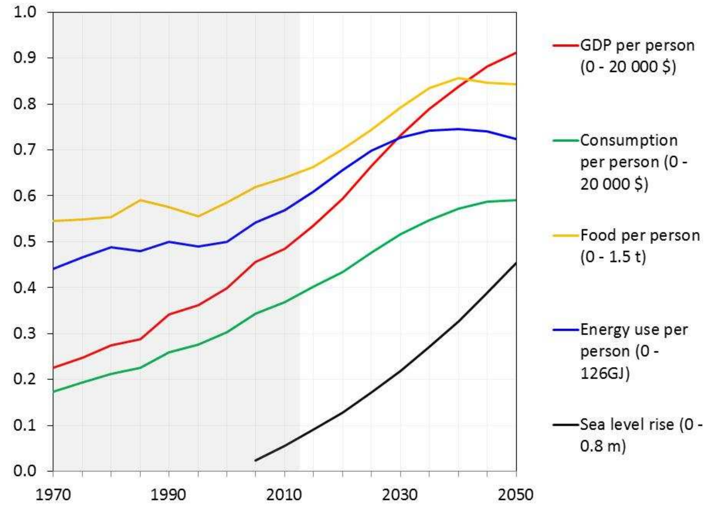
Societal response

In view of resource depletion, pollution, and inequity, global investments will more than triple over the next forty years which might solve some of the problems, but also depress consumption, which will cause *"growing inequity, tension, and social strife, which in turn will accelerate the decline in labor productivity…a negative spiral can occur" (Randers, 2012).*

The World in 2050

In 2050, global GDP per capita will reach more than US$18,000 which is almost twice the current level. Yet, consumption per capita will only by 60% higher than today. There will be 30% more food and energy on average for each person (Figure 27). As much as 37% of energy will be from renewable sources, compared to 8% today. Yet, this will come at the expense of using up land and water resources, leading to distributional conflicts. Unused bio-capacity would be dwindling to as low as 18% compared to 28% today.

Figure 27. World standard of living, in the Randers forecast, 1970–2050.



Relative scale: GDP per person and consumption per person ($0–$20,000); food per person (0–1.5 tonnes); energy use per person (0–126GJ); sea-level rise (0–0.8 meters).
Source: Randers (2012, p. 233).

Table 20 quantifies key trends.

Table 30. Selected global indicators of Randers Forecast

	Historical data				Forecast				
Selected slow variables	**1970**	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
GDP [trillion US$]	17	24	36	49	67	89	116	135	145
Population [billion people]	3.70	4.45	5.31	6.12	6.90	7.51	7.90	8.07	7.97
Consumption [trillion US$]	12.8	18.8	27.5	37.0	50.9	65.3	81.6	92.3	94.0
CO_2 emissions [$GtCO_2$]	14.7	19.0	21.4	23.3	29.4	37.3	40.5	38.4	31.3
Temperature above pre-ind. level [˚C]	0.46	0.59	0.70	0.71	0.97	1.22	1.48	1.74	2.01
Production	**1970**	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Food production [Gt]	3.0	3.7	4.6	5.4	6.6	7.9	9.4	10.4	10.1
Energy use [EJ]	205	273	333	384	493	619	722	755	724
Investment share of GDP [%]	22.9	23.0	24.2	24.3	23.7	26.8	29.5	31.7	35.3
Unused biocapacity [%]	36.9	34.3	32.3	30.6	28.3	26.4	25.5	23.6	18.5
Renewable energy share [%]	5.4	5.8	6.4	7.0	8.2	12.0	18.0	25.8	37.1
Standard of living	**1970**	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
GDP per person [1,000 US$]	4.5	5.5	6.8	8.0	9.7	11.9	14.7	16.8	18.2
Consumption per person [1,000 US$]	3.5	4.2	5.2	6.1	7.4	8.7	10.3	11.4	11.8
Food per person [t]	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.3
Energy use per person [GJ]	55	61	63	63	72	82	91	94	91
Sealevel rise [mm]					45	103	175	262	363

Data source: Randers (2012).

In 2050, resource conflicts and inequity will have contributed to "*huge regional and class differences… social friction, even armed conflict" (Randers, 2012).* The world will be urban, aged and "*some deeply held values about what is worth fighting for will have begun to give way to new ways of thinking*" (Randers, 2012).

4.9.3. Lessons learned

Many lessons can be learnt from the Rander's forecast. Above all, it highlights the importance of capturing human behaviour and responses to social, environmental and economic challenges. The resulting differences between the Rander's forecast and mainstream baseline scenarios, such as those of OECD or PBL, are striking. Consumption levels in the latter are so much higher that it may appear implausible that these scenarios do not include a strong human response. Hence, mainstream scenario modellers might revise their conceptualization of baseline scenarios.

At the same time, it should be noted that Rander's forecast is far from a sustainable development scenario, even though some overall indicators (e.g., consumption and CO_2 emissions) reach levels not unlike those in some scenarios that are considered to depict sustainable development. In fact, the underlying world in 2052 in the Rander's forecast is one that is not ready to efficiently take on its global challenges in the 2nd half of the 21st century. Yet, *"the stage will be set for major transformations in the way we organize our politics, our financial systems, and even our lives." (Randers, 2012).*

4.10. Reviews of sustainable development scenarios for Rio+20" WBCSD, WWF, WEF, and UNEP

It is important to note that a number of scenario reviews were prepared for (or presented at) Rio+20. These include, for example WBCSD's sustainable development vision 2050; WWF's Living planet; WEF's global risk report; and UNEP's GEO-5 report. These review reports draw on a wide range of previous scenarios, but do not include the latest findings of sustainable development scenarios prepared for Rio+20. They include very important quantitative scenario information and provide a good overview of the past literature. We felt no need to reproduce or yet again summarize their work here. For more details, please refer to:

- WWF (2012). Living Planet Report 2012: Biodiversity, biocapacity and better choices. ISBN 978-2-940443-37-6.
- UNEP (2012). Scenario chapter of GEO-5.
- WBCSD (2010). Vision 2050: The new agenda for business. World Business Council for Sustainable Development (WBCSD), Feb. 2010. ISBN: 978-3-940388-56-8.
- WEF (2012). Global risk report.

5. Reflections on the strengths and weaknesses of the Rio+20 sustainable development scenarios

The sustainable development scenarios for Rio+20 presented in this report illustrate what would be needed to achieve a better future for everyone. They were designed to inspire decision-making. Hence, they are extremely important for a functioning science-policy interface. Yet, a realistic look at the scenarios highlights some important strengths and weaknesses of the current state of the art, including in terms of ambition; trade-offs and synergies; and agreement on policy recommendations.

5.1. Level of ambition: no paradise vision and limited scope of goals

The sustainable development scenarios for Rio+20 illustrate futures that most people would consider more desirable than the trend scenarios. Yet, the level of ambition of the sustainable development goals is limited both in terms of their scope and their target levels.

Table 31 lists all the explicit sustainable development goals and targets used in the sustainable development scenarios prepared for Rio+20 by PBL, IIASA-GEA, SEI, OECD, FEEM, GSG, and others. While these scenarios differ in various aspects, they are nevertheless fairly similar in spirit and content, not least because they all bear close "family resemblance" with the IPCC-SRES scenario B1. The sustainable development scenarios for Rio+20 describe a much "better world" than BAU/DAU, a world that is more sustainable in important environmental and social dimensions and that promises a decent quality of life for everyone (Table 31).

Yet, these sustainable development worlds appear far from a paradise visions for 2050. In fact, they are not free from contradictions, and confront decision-makers with a number of unresolved trade-offs. They highlight the enormity of the global sustainable development challenge, and indicate that - no matter what - at some point in the future we will be forced to make more drastic behavioural changes. It is the strength of these mainstream scenarios to highlight this important fact, based firmly on assumptions about the future that are considered plausible and reasonable today. Essentially, they show what could be achieved would we overcome - at a global level - all the socio-economic and political constraints, exploring the utmost at pushing back technological limits.

The sustainable development goals and targets compiled in Table 31 from the sustainable development scenarios for Rio+20 are similar to major international development and sustainability goals that are either agreed or are under consideration. They are also grounded in (subsets of) existing mainstream scientific sets. However, for a number of reasons they leave out elements of wider sustainable development perspectives that typically include community or societal aspects, such as peace or social capital. Even leaving aside goals in the areas of community and society, there is no single sustainable development scenario that captures the complete range of sustainable development goals commonly used (Table 31).

5.2. Trade-offs and synergies

All the sustainable development scenarios for Rio+20 include unresolved trade-offs and untapped synergies. Many sustainable development scenarios are *unsustainable* in at least one or more respects. Furthermore, none of the mainstream scenarios for Rio+20 explores a path towards sustainable development path in 2050 that achieves the full set of sustainable development goals suggested by science.[14]

[14] It might be noted that more generic scenario studies like those of Global Scenario Group (Raskin et al., 2010) tend to achieve a wider range of sustainable development goals. However, others argue that these generic studies do not take scientific account of certain scientific-technological constraints and might thus be extremely hard to achieve under real world conditions.

Table 31.Goals and targets in sustainable development scenarios for Rio+20

Vision		Theme	Types of goals, targets, and outcomes	IIASA-GEA	PBL	SEI	OECD	RITE-ALPS	FEEM	GSG
To develop	People	Poverty	Eradicate hunger by 2050		X					X
			Eliminate poverty by 2050			X				
		Access	Universal access to improved water source and basic sanitation by 2050		X		X			
			Universal access to electricity and modern cooking fuels by 2030 {or 2050}	X	X	{X}				
		Health & education	Decreased impact of environmental factors on DALY		X					
			Universal primary education by 2015						X	
	Economy	Income	GDP per capita > US$10,000 PPP in all regions by 2050			X				
			Income convergence; catch-up of Africa by 2050						X	
		Resources	Primary energy use less than 70GJ per capita by 2050						X	
			Primary energy use per capita is only 13% higher in 2050 than in 2010, and 48% higher in 2100.					X		
			Use of renewables increase by 3.1 times from 2010 to 2050.					X		
			Water demand increases from 3,560 km^3 in 2000 to only 4,140 km^3 in 2050				X			
		Security	Limit energy trade, increase diversity and resilience of energy supply by 2050	X						
			Population weighted average of energy security index increases only by 2.3.					X		
To sustain	Life support	Resources	Limit the increase in the number of people under severe water stress to an additional +2 bln {or +1.4 bln) from 2000, reaching 3.7 bln {or 3.1bln} in 2050.				X	{X}		
			People under severe water stress <2 bln until 2050 {or 2.9 billion in 2100}					{X}		X
			Reduce number of people living in water scarce areas vs. trend scenario		X					
			Reduce the area for energy crop production to almost zero by 2020. From 2010 to 2050, limit increase in cropland area for food production to +15%, and reduce the irrigated area for food production by 5%.					X		
			Cumulative fossil fuel use limited to <520 Gtoe from 2010 to 2050					X		
			Slow and later reverse deforestation and land degradation							X
			Slow overfishing and later restore fish stocks							X
		Air pollution	Keep PM2.5 concentration below 35 µg m^3 by 2030		X					
			Reduce NO_x, SO_2 and black carbon emission by 25% vs. baseline by 2050				X			
			Reduce SO_2 by 42% and black carbon by 21% by 2050 vs. 2010					X		
			Reduce premature deaths due to air pollution by 50% by 2030	X						
	Nature	Climate change	Limit global average temperature change to 2°C [or 2.8°C] above pre-industrial levels with a likelihood of >50% {or 60%} by 2100.	X	X	{X}	X	[X]		X
			Atmospheric GHG concentration stabilization below 450 ppm [or 350ppmv] {or 550ppmv} CO_2-eq. by 2100.		X				{X}	[X]
			Limit ocean acidification to keep aragonite stable, with pH=8.0 in 2150					X		
		Biodiversity	By 2020: Prevent extinction of known threatened species and improve situation of those in most decline; halve the rate of biodiversity loss; halve the rate of loss of natural habitats and reduce degradation and fragmentation by 2020; conserve at least 17% of terrestrial and inland water. By 2050: stabilize biodiversity at the 2020/2030 level.		X					
			CBD Aichi protected area targets of 17% of terrestrial and inland water areas and 10% of coastal and marine areas by 2020.		X		X			
		Phosphorus and nitrogen cycles	Phosphorus removal in wastewater treatment increases from 0.7 Mt in 2000, 1.7 Mt in 2030, to 3.3 Mt in 2050				X			
			Reduce N/P use where possible, but without harming the ability of the agricultural system to meet the hunger target		X					

Sources: IIASA-GEA (Riahi et al., 2012); PBL (van Vuuren et al., 2012) ; SEI (Nilsson et al., 2012), OECD (2012) ; RITE-ALPS (Akimoto et al., 2012) ; FEEM (2011) ; GSG (Raskin et al., 2010).

One key problem is the existence of important trade-offs across time, sectors, and issues. For example, proposed solutions suggested by energy policy makers may be inconsistent or even contradictory with trade policy, monetary goals, or ecological objectives. Even sustainable development goals agreed at the global level may be inconsistent when defined by sectoral experts and policy makers.

Table 32 summarizes the most important trade-offs and synergies highlighted in the sustainable development scenarios for Rio+20.

Table 32. Summary of trade-offs and synergies highlighted in the sustainable development scenarios for Rio+20

Scenario set	Cluster	Synergies (SY) and Trade-offs (TO)
IIASA-GEA	Energy-Climate-Air-Security	**SY:** Synergies are large for addressing simultaneously climate change mitigation, energy security, and air pollution. Stringent climate policy is most beneficial, reducing global pollution control costs by US$500 billion per year and energy security costs by US$130 billion per year by 2030.
	Energy-Access-Poverty	**SY:** The objective of universal energy access is much cheaper to attain and pretty much independent from the others.
	Energy-Land-Food-Biodiversity	**TO:** Marginal increase in land use (<10% in 2050) as a result of bio-energy production, even if every effort is made to use agricultural residues as a feedstock and to source purpose-grown biomass from degraded or marginal lands so that it does not compete with food crops. This implies further biodiversity loss and increased land scarcity.
	Energy-Water	**TO:** Additional bio-energy production in SD scenarios grow to consume 3 to 6% of global freshwater resources, corresponding to about three-quarters of current global water use.
	Energy-Nutrients-Minerals-Rare-Earths	**TO:** More populated, wealthier, higher-tech world will consume much larger amounts of nutrient fertilizers, minerals, and rare earth metals than today
RITE-ALPS	Climate – Food and energy security	**TO:** Issues related to food access, food security, and energy security can result in vulnerabilities with the deep emission reductions.
	Climate change – Food	**TO:** Complex trade-offs among several objectives, depending on mitigation levels and strategies.
	Energy security – Climate Change	**TO and SY:** Some of the complex indicators include those relating to energy security, which increase in some countries and decrease in others with CO_2 emission reduction measures.
PBL for Rio+20	Hunger-Climate-Energy-Biodiversity-Air pollution vs. Environment-Land-Energy-Water-Nutrients-Health	**TO:** Attainment of stated goals for hunger, energy, climate, biodiversity, and air pollution might make it very difficult in these scenarios to attain other SD goals on water and N/P flows. **SY:** Air pollution and climate change; food security and restoration of agricultural ecosystems; conservation of ecosystems and their services and stability, security of supply, productive capacities, regulating functions (water, timber, fisheries but also soils, temperature, etc.); competitiveness and sustainability. **TO:** Dilemmas include: conflicts between national and global goals; Present demand growth rates require growth of renewables as well as fossils; Intensification of agriculture vs less productive but more sustainable per ha; Bio-energy; Rebound effects, for instance from reduced energy use and meat consumption; Protection of highly bio-diverse areas vs. local/national development; Between long-term and short-term options, lock in threat of focusing on quick wins or long term uncertain big shifts.
SEI for Rio+20	Income – Energy access - Climate	SDA scenario has only 11% higher energy use and 4% higher CO_2 emissions by 2050, compared to BEA scenario. Little trade-off between faster growth in poorest countries and energy or climate goals.
OECD outlook 2050	None	Trade-offs exist, but are irrelevant in the face of good green growth policies. No goals anyway. What is important is coherence in policies.
FEEM	Climate – Education - Technology policy	**TO and SY:** Sustainable development can be achieved by combining multiple policy goals. Inspection of a policy mix that combines climate and education targets shows that increased human capital stimulates long-run economic growth, which ultimately reduces the GDP loss induced by the climate policy.
	Education - Economic growth – Technology-Environment	**SY:** More investments in human capital stimulate medium- and long-run economic growth. The positive scale effect on economic growth lead to more CO_2 emissions in the medium term because economic growth puts an upward pressure on energy demand. However, the expansion of economic activity increases the amount of resources available for innovation. Because human capital and technological progress are complements, investments in R&D are also stimulated. As a

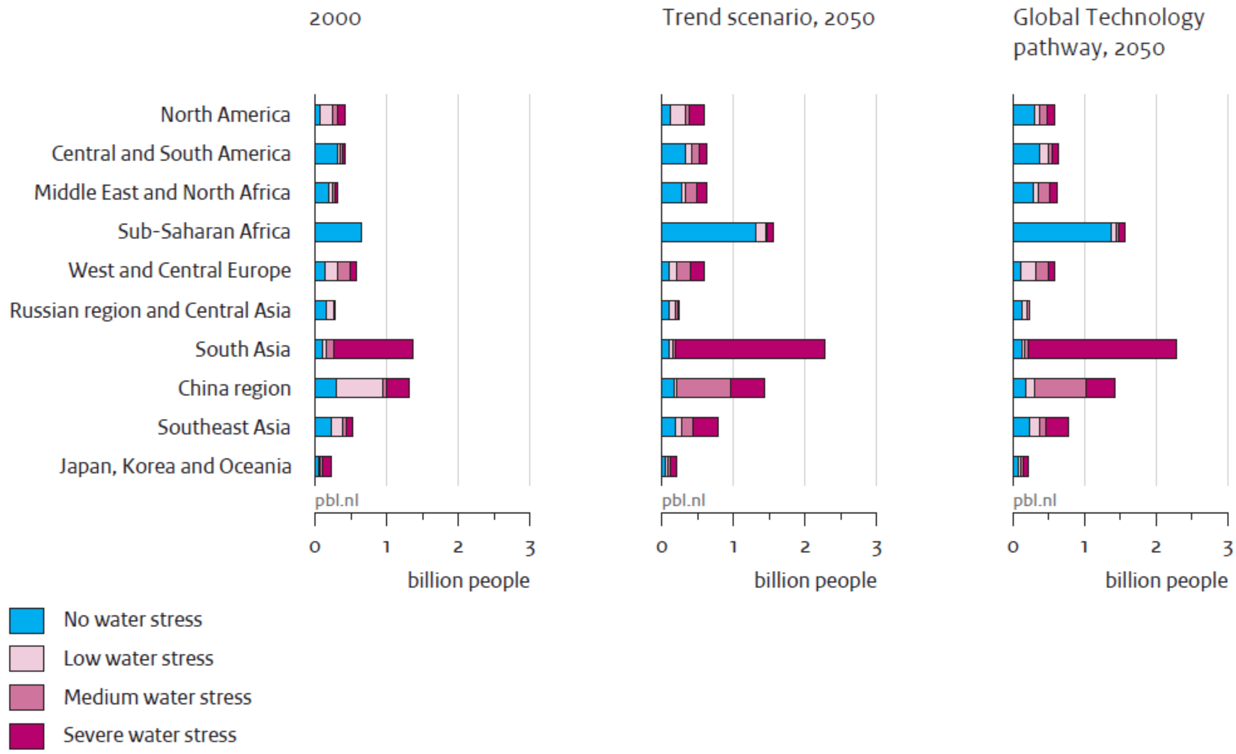
		consequence, spending more resources on education eventually induces a technique effect, or a technological transformation, that improves economic and techno-efficiency. Additional education expenditure comes at the costs of lower consumption, but only in the short-term. After 2035, the growth effect increases consumption possibilities as well, as indicated by the positive value of the elasticity
	Climate policy and development of low-carbon technologies	**SY:** Climate policy stimulates clean R&D investments that improve the energy performance of existing technologies. If the climate goal is ambitious enough, R&D might also foster major technological breakthroughs that would add to the portfolio of existing clean substitutes to high-carbon options.
	Climate policy - carbon-free and general purpose technologies	**SY:** Because of the complementarities that exist between different forms of knowledge and the spill-overs across different R&D sectors, climate policy can stimulate not only green R&D, but it can also foster general purpose technologies R&D.
	Climate policy - economic growth - education expenditure	**TO:** Climate policies that aim at low GHG concentration (550ppme) reshape the optimal mix of investments to meet the policy goal at the minimum cost. Investments that have a higher emission reduction potential are favoured, at the cost of other forms of expenditure with a lower potential, such as education. This investment reallocation reduces global GDP and GDP per capita, two indicators of the macroeconomic costs of climate policies.

The scenario studies for Rio+20 illustrate synergies and opportunities that could be reaped with integrated policy strategies geared to the simultaneous achievement of multiple sustainable development goals (Table 32). Synergies are especially large for simultaneously addressing climate change mitigation, energy security, and air pollution. However, in some countries CO_2 emission reduction measures can also lead to reduced energy security. Furthermore, the objective of universal energy access is much cheaper to attain and pretty much independent from the others. Synergies are also large between ensuring food security and restoring agricultural ecosystems; between conservation of ecosystem services and security of supply; between climate policy and R&D; and between education, R&D, environmental improvements and economic growth.

The scenario studies for Rio+20 also illustrate trade-offs between pursing objectives that need to resolved (Table 32). For example, all the mainstream SD scenarios for Rio+20 see increases in biofuel production and deployment of modern renewables, and consequently lead to significantly increased water and land use, increased water stress for the majority of the world population, as well as unsustainable anthropogenic interference with P and N flows. These trade-offs are unresolved. Yet, these scenarios were designed to be sustainable development scenarios. They satisfy the sustainable development goals chosen by modellers, yet would fail a wider range of scientifically accepted goals.

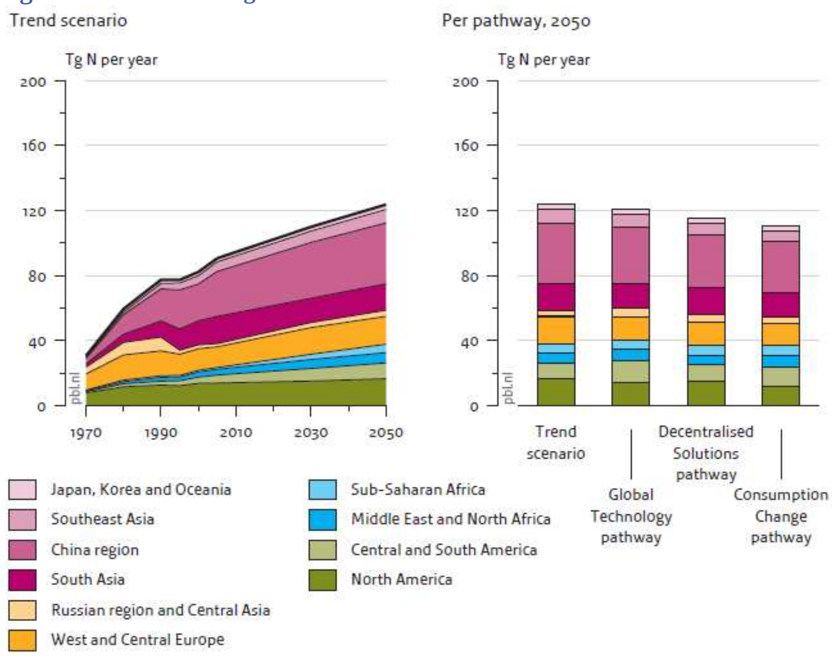
Among the sustainable development scenarios for Rio+20 considered here, the PBL scenarios go the furthest in trying to resolve the broadest range of sustainable development goals. However, even in that case, some trade-offs remain unresolved. For example, in these scenarios climate mitigation and water-use efficiency will significantly reduce the demand for water, but the total number of people living in severely water-stressed river basins will only marginally decrease (Figure 28). Similarly, in all their Rio+20 scenarios, global nitrogen fertilizer use continues to increase by at least another 50% until 2050 (Figure 29). The same applies to phosphorus fertilizer use. "*Nitrogen and phosphorus fertilizer use will inevitably have to increase to sustain the increasing food production. The increase is particularly strong in developing countries.*" (PBL, 2012). It should be noted that the planetary boundaries for nitrogen (Rockstroem et al., 2009) and phosphorus (Carpenter and Bennet, 2012) were already being exceeded in 2010. And there would still be more than 400,000 children dying from hunger, unsafe water, and traditional energy use in the PBL's GlobT scenario by 2050.

Figure 28. People in water-stressed areas in 2000 and in 2050 in PBL's GlobT and the trend scenarios



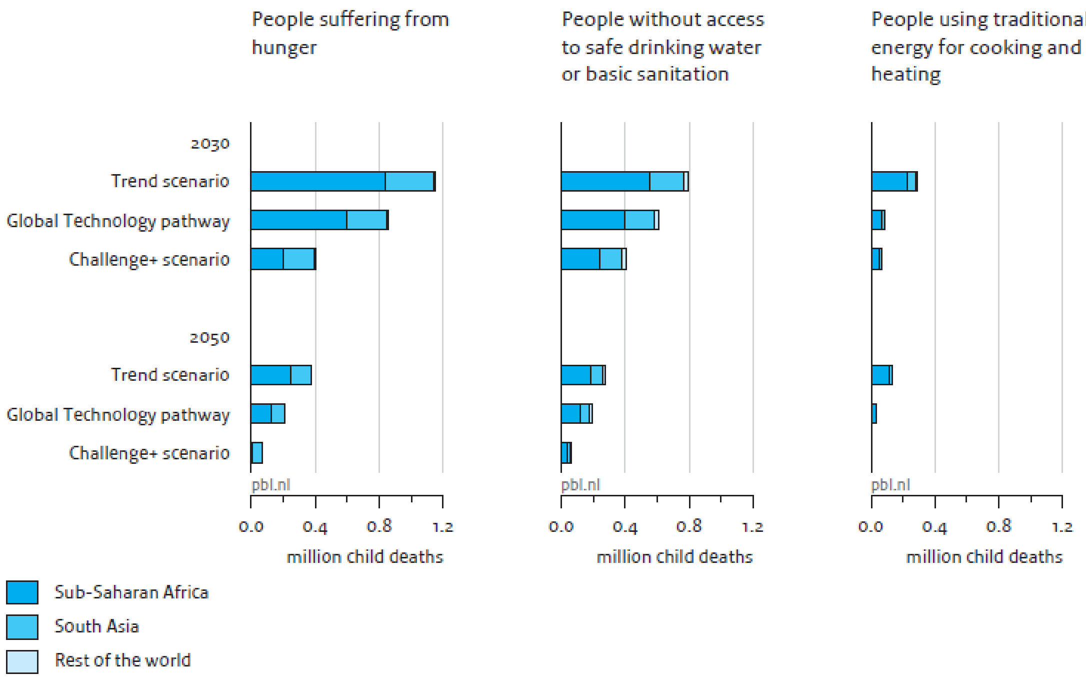
Source: PBL (2012).

Figure 29. Global nitrogen fertilizer use: trend vs. PBL's scenarios for Rio+20



Source: PBL (2012)

Figure 30. Global child deaths by cause



Source: PBL (2012)

The SD21 project component on sustainable development scenarios confirmed that most of sectoral scenario studies (e.g., those on food, water, forests, or development), as well as national integrated studies, are carried out in isolation from integrated, cross-sectoral global scenario studies. Hence, while these national and sectoral studies show ways of overcoming some of the local and sectoral trade-offs, they all but disregard feedbacks and constraints across sectors or world regions. At the same time, it should be noted that the global integrated studies also underestimate binding constraints to overcoming trade-offs, since they aggregate over local constraints, basically assuming free availability of resources over large geographic areas. In other words, it is highly likely that sustainable development scenarios in general tend to underestimate the challenge of what would need to be done to move humanity onto a truly sustainable development path. The lesson is an expressed need for greater caution and humility at what can be done.

In summary, all sustainable development scenarios for Rio+20 illustrate important trade-offs and synergies, the magnitude of which varies greatly depending on assumptions. No sustainable development strategy was proposed and quantified in any of these scenarios that does not show unresolved trade-offs leading to un-sustainability in several areas. There is a need for scenarios that follow a plausible, robust sustainable development strategy to achieve a really comprehensive list of sustainable development goals.

5.3. Level of agreement on policy solutions

Among the scenarios reviewed here, there is a high level of agreement on overall scenario conclusions, but little agreement on specific policy suggestions (Table 33).

Table 33. Selected conclusions of sustainable development scenarios for Rio+20

Scenario set	Scenario(s)	Models	Selected conclusions
IIASA-GEA (Riahi et al., 2012)	GEA mix	MESSAGE-MACRO, IMAGE	Numerous, technically feasible pathways. Must-haves: end-use efficiency, rapid deployment of low-carbon energy sources, energy poverty eradication push. GHG mitigation a unique entry point for simultaneously achievement of multiple goals. Making progress in one dimension can lead to both synergies and trade-offs in others. Requires broad suite of policies which are ready for implementation, but needs sufficient political will.
PBL for Rio+20 (Van Vuuren et al., 2012)	Global Technology; Decentralized solutions; Consumption change;	IMAGE, TIMER, FAIR, LEITAP, BLOBIO, GISMO, etc.	Areas that are most likely unsustainable in these scenarios: water scarcity; and interference with P and N cycles; There are multiple pathways to SD. Needed this decade for food access, agriculture and biodiversity: sustainable intensification of agriculture; a more robust food system; mainstreaming biodiversity and ecosystems in land use planning and management; appreciation of the potential of adjustments in lifestyles and consumer habits. Needed this decade for energy and climate: seek progress based on radical incrementalism rather than on grand policy designs; phase out the building of coal power plants without CCS; modern fuels need to be made accessible and affordable; remove current national energy policy inconsistencies; address energy-intensive lifestyles; identify and stimulate change of behavioural drivers for the energy-intensive lifestyles in industrialised and emerging economies; arrange public and private finance for energy transition infrastructures.
SEI for Rio+20 (Nilsson et al., 2012)	Shared development agenda scenario (SDA).	LEAP, OSEMOSYS	"…achieving the emissions reductions implied by the 67% probability is now almost impossible even with extremely ambitious assumptions about mitigation". Action delayed for too long.
OECD env outlook 2050	Green growth scenario	IMAGE, ENV-Linkages	Green growth policies needed (as listed in OECD strategy). Internalization and marketization.
RITE-ALPS (Akimoto et al., 2012)	A: Base scenario, B: High economic growth scenario, C: Climate policy prioritized scenario, D: Energy security prioritized scenario.	DNE21+, GAEZ, MAGICC etc.	Complex trade-offs among multiple objectives to be tackled globally. Climate change impacts on a variety of countries are very complex. Balanced measures will be indispensable. Deep GHG emission reductions alone cannot save the world or achieve sustainable development, nor can high levels of economic development alone. Most of the indicators relating to sustainable development will improve with economic growth in the future. Global GHG emission reductions are necessary. GHG emission reductions to achieve temperature increases below 2C can reduce climate change damage such as ocean acidification. There is no single solution or policy for sustainable development. Bottom-up measures and policies need to be tailored to each issue, country, sector, etc.
FEEM (Tavoni and de Cian, 2011)	Stylized scenarios	WITCH	Including technology and R&D goals in the policy mix can augment the potential for positive synergies because market imperfections in the accumulation of knowledge leads to under-investments in R&D. Climate policy, by stimulating clean R&D, partly addresses the R&D market failure, but still the R&D level remain suboptimal. Adding a specific clean R&D goal on top of the climate and education targets can increase GDP, reducing further the GDP loss of the climate policy. This result has important policy implications considering the growing concern that effective climate policy is conditional on solid economic development and therefore it needs to be supplemented with other policy targets.
SD scenario review study (Schrattenholzer et al.,	IPCC-SRES: A1T, B1, B1T, B1G. WEC: C1, C2, A3.	MESSAGE-MACRO	Broad pursuit of SD is far superior in performance to pursuit of single-issue objectives, and later introduction of policy constraints for issues of concern (e.g., promote economic growth and introduce cap-and-trade-later). Except for A1T-550, all other stabilization/mitigation scenarios are *un*sustainable in one of the 4 dimensions. Policies needed to shape transitions between technology clusters, infrastructure clusters,

2005)			and public acceptance clusters, to stimulate transitions between market success clusters.

5.3.1. High level of agreement on overall scenario conclusions

Despite a variety of modelling approaches and sustainable development goals, the SD scenarios for Rio+20 agree to a high extent in terms of their overall conclusions:

- There are numerous, feasible pathways to SD.
- There is no agreement on "must have" lists, but scenarios show the benefit of reigning in overall material and energy use, increased end-use efficiency, and reduced poverty.
- Making progress in one dimension can lead to both synergies and trade-offs.
- Complex trade-offs related to the global commons need to be tackled globally.
- There is no single solution or policy for sustainable development. Bottom-up measures and policies need to be tailored to each issue, country, and sector.
- Politicians' SD goals have become increasingly ambitious, while their attainment has become increasingly difficult.
- Education, RD&D and population goals are essential with very large synergies to the development and environmental dimensions.
- A broad pursuit of SD is far superior in performance over pursuing single-issue objectives in isolation[15] (e.g., promote economic growth first and introduce cap-and-trade later).

5.3.2. But little agreement on specific policy suggestions

Great differences remain in terms of specific policy recommendations that are drawn ex-post from the scenario results, reflecting the range of analysts' worldviews and organizations' interests. This is despite the fact that these scenario development teams showed large overlaps in terms of participation of few prominent modellers and models.

There is also a close family resemblance between the sustainable development scenarios for Rio+20. Indeed, authors explicitly refer back along the scenario family lines. Scenarios of the IPCC-SRES B1 family (2000) closely resemble WEC-C (1997). The GEA mix scenario (IIASA and PBL) resembles IPCC-SRES B1, as does PBL's earlier SD scenario for the Club of Rome (2009). SEI scenarios for Rio+20 were explicitly designed to follow the GEA scenario. The OECD green growth scenarios were to a significant extent developed by PBL colleagues, resembling PBL's parallel work for Rio+20. WBCSD vision draws on the WEC scenarios. RITE-ALPS scenarios are based on IPCC-SRES and TAR work. FEEM scenarios are somewhat more stylized, but were also influenced by the SRES work.

Table 34 summarizes findings regarding the SD scenarios for Rio+20 using the IKEA cupboard hierarchy introduced in section 2.4.

[15] Schrattenholzer et al. (2005) illustrate this for the IPCC and WEC scenarios. They show that - except for the A1T-550 scenario of IPCC-TAR (a highly techno-optimistic scenario the feasibility of which is far from ensured) - all other stabilization/mitigation scenarios are unsustainable in at least one of four dimensions.

Table 34. Summary of findings on sustainable development scenarios for Rio+20 along the IKEA cupboard hierarchy

Levels		Sustainable development (SD) scenarios for Rio+20	
		Questions	***Findings***
1	**Ultimate goal**	Are the ultimate goals explicitly stated or implied in these futures? Is sustainable development the goal?	In the majority of the scenarios, SD is the ultimate goal, but it is explicitly stated in the minority of cases. Some have different ultimate objectives
2	**Overall approach – visions (ends)**	Are SD visions articulated and what do they cover?	SD visions are not comprehensively articulated in any of the SD scenario studies. Their coverage varies, and none of them covers all six dimensions identified by Kates (2003).
3	**Goals and strategies (means)**	What are the SD goals and targets that are achieved?	A mix of SD goals that are int'lly agreed, suggested by governments or scientists is implemented (Table 31). High level of agreement on overall scenario conclusions.
4	**Policies, programmes and action plan**	What kind of pathways are suggested?	Pathways of radical incrementalism. Little agreement on specific policy suggestions
5	**Implementation**	What are the implementation recommendations including in terms of investment?	Wide range of recommendations with no clear agreement (Table 33).

Source: Authors' elaboration; Notes: SD:= sustainable development.

6. Narratives of the future – pathways to a better world in 2050

Here we describe a series of semi-quantitative future pathways from 2010 to 2050. They are written as simple "stories", in order to be accessible for non-experts. Yet, it should be noted that these "stories" are coherent and feasible, as they are based on the in-depth modelling work carried out to develop the sustainable development scenarios for Rio+20 presented in chapter 4 above.

6.1. Where we come from – sustainable development progress from 1950 to 2010

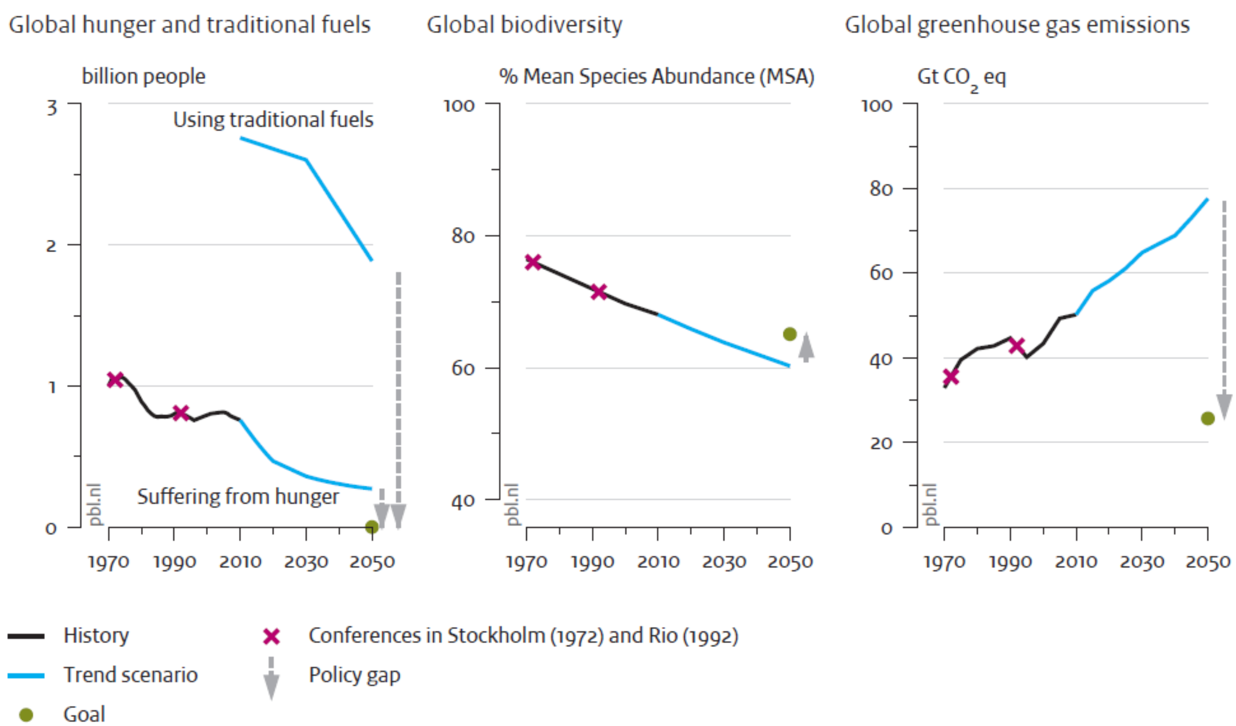
This section summarizes long-term historical trends in the form of Table 35, using the same template as for the documentation of the future scenarios to allow for easy comparison.

Historical progress towards sustainable development has been mixed since 1950. There has been progress in some areas, but worsening trends in others. Kates and Parris (2003), which was based on NRC (1999), provided an excellent, concise overview of global progress towards sustainable development from 1950-2000. Their material is used extensively in this subsection, with permission from the author. Where available, we provide an updated for 2010 (Table 35). We just highlight a few examples.

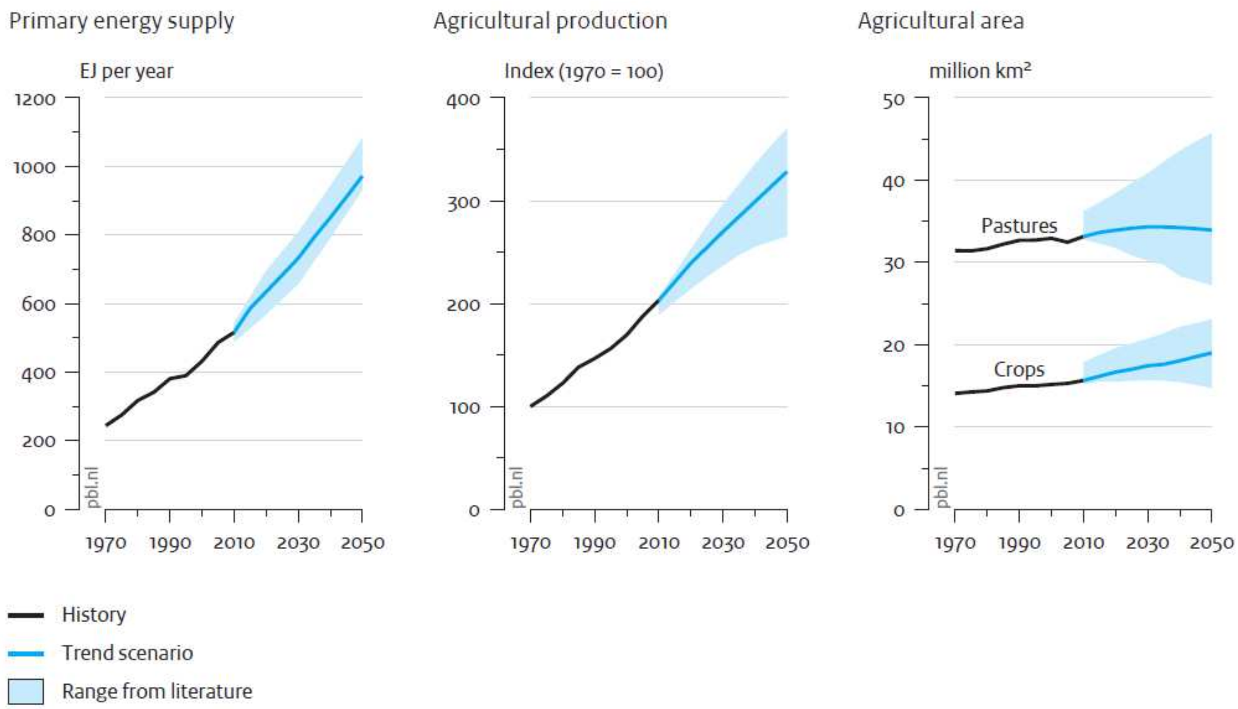
Since 1970, global primary use and agricultural production more than doubled (Figure 31b), and trends foresee another increase by 100% and 50% in the coming forty years, respectively.

While the absolute number people suffering from hunger decreased by more than 200 million from 1970 to 1990, no more absolute reductions were achieved in the past 20 years. Global biodiversity has continued to decrease and global GHG emissions have continued to increase and are expected to continue so in the future (Figure 31a).

Figure 31. Sustainability progress since 1970 and trend expectations for 2050.



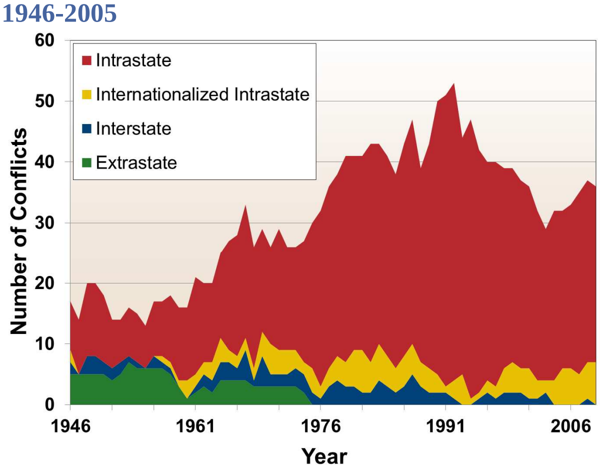
Source: PBL (2012).



Source: PBL (2012).

Since the 1950s, the number of State-based armed conflicts increased until 1991, but decreased until 2005 to levels not seen since the 1970s (Figure 32). Thereafter, this number increased again. There is also evidence for a very long-term trend toward more frequent and ever more intense conflicts (Zgurovsky and Gvishiani, 2008).

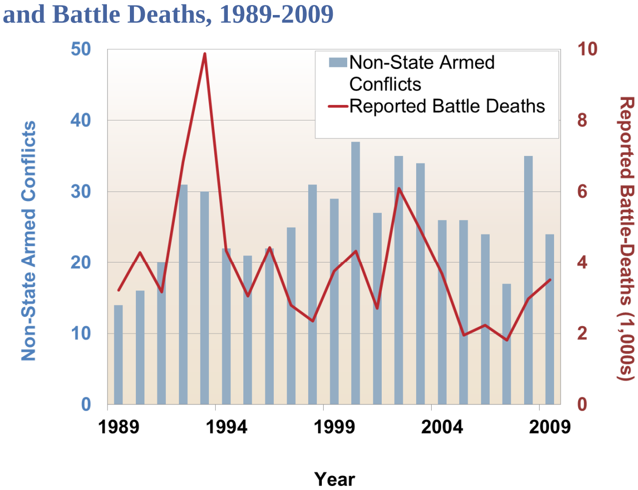
Figure 32. Number of State-based armed conflicts, 1946-2005



Data Source: UCDP/PRIO (2006). Published in the Human Security Report 2012.

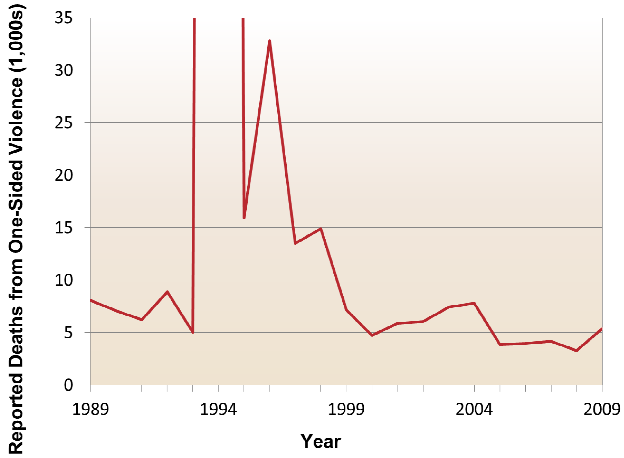
In contrast to the perception created by international media, the number of reported battle-deaths from non-State armed conflicts (such as international terrorism) has decreased since 1992 and today is less than half of that level. Even more striking, today's number of deaths from *one-sided violence* (such as "terrorism") is one hundredth of its peak in 1994 (Figure 34).

Figure 33. Global Trends in Non-State Conflicts and Battle Deaths, 1989-2009



Data Source: UCDP/HSRP Dataset. Published in the Human Security Report 2012.

Figure 34. Global Trends in Deaths from One-Sided Violence, 1989-2009



Data Source: UCDP/HSRP Dataset. Published in the Human Security Report 2012

History highlights the complexity of global interlinked systems and the limits to what governments can do to change long-run trends ("slow variables"). There are instances of well-intended government policies that had unintended consequences in the aggregate.

It should be noted that the scientific community engaged in assessment of these trends has become increasingly separate from global modellers who increasingly focus on the short- to medium-term market-focused fixes.

Table 35.Past sustainable development progress, 1950-2000 and 2000-2011

Vision		Themes	***Historical trends***	
			1950- 2000	**2000-2011**
To develop	(D1) People	Hunger	The absolute number people suffering from hunger decreased from about 1 billion by more than 200 million from 1970 to 1990, but no more absolute reductions were achieved in the past 20 years. World food production per capita rose by 22% from 1950 to 2000.	More or less constant global number of people suffering from hunger: 800 million. Beginning in 2006, food prices surged and the numbers of hungry rose, as food production declined from adverse weather or shifts in production to biofuels and costs rose especially for fuel.
		Well-being	*Improved well-being and greater human equality?* Since WWII, the overall well-being of people has substantially improved, as measured by the HDI. Greater equality is evident in improvements in such indicators as the male–female ratio in primary education, the numbers of people living in countries with democratic or partly democratic regimes, and the growing willingness of the international community to protect civilians from internal conflict, to protect national minorities, and to bring to justice perpetrators of war crimes, genocide, and extreme forms of repression.	Long-run trend to greater well-being continued on average, but was punctuated by a significant set-back caused by the global economic crisis and high commodity prices, especially from 2008. Long-run trend to democratization continued. However, certain human rights have been increasingly under attack, including in countries with historically good track records in their protection. Increasingly severe immigration restrictions in many countries.
		Poverty	*Persistent poverty*: The proportion of impoverished people has declined, but with population growth, the absolute number remained more or less constant. Poverty was extensive with ~1.2 billion (23%) people living on <$1 per day and 2.8 billion (56%) on <$2 per day in 1998.	The global numbers for poverty and hunger are declining. In 2004, almost 1 billion people (18%) were living on less than $1.08/day in 2004 and 2.5 billion people (48%) on less than $2.15/day.
		Water and sanitation access	Unmet need for household water use, with 1.2 billion people in developing countries lacking access to a safe and reliable supply and 2 billion lacking access to sanitation.	Water pollution remained a major problem in rapidly growing urban areas in Africa, Asia, and Latin America, and infectious water-borne disease claims lives of millions, especially children.
		Energy Access	The number of people without access to electricity increased from 1.8 billion in 1970 to 2 billion in 1990.	In 2010, 1.27 billion people (24% of developing world) were without access to electricity and 2.59 billion people (49% of developing world) relied on the traditional use of biomass for cooking, which causes harmful indoor air pollution. These people lived in primarily in developing Asia, Sub-Saharan Africa, and in rural areas.
		Life expectancy	Life expectancy has been extended >20 years from 1950 to 2000.	Average life expectancy for a newborn child further increased to 69 years (due to reductions in infant/child mortality).
		Health	*Better health and shifting disease:* Reductions in infant and child mortality and morbidity for which immunization, improved water, sanitation, and nutrition have played major roles. But with increased life expectancy, disease shifted from infectious diseases characteristic of developing countries to chronic diseases of industrialized countries. "Third epidemiological transition": Recent re-emergence of infectious diseases, such as HIV, tuberculosis, yellow fever, lyme disease, and dengue fever, due to increased global trade and mobility and antimicrobial resistance.	Global trends to better health continued, but major health problems persist. A child born in Africa still has 25 years less life expectancy than one in Europe, a difference that has not changed in more than a century.
		Education	Adult literacy has risen >20% since 1970	Continued improvements in literacy.
		Population growth	*Slowing and differential population growth:* World population growth declined from a peak of ~2.2% per year in the early 1960s to ~1.22% in 2000, reaching 6.3 billion in 2000 (from 3.7 billion in 1970).Although all regions of the world showed declining fertility without migration, almost all of the projected growth took place in developing countries.	World population was 6.9 billion in 2010 and grew at 1.1% per year, adding about 77 million.
		Aging	*Increased aging of the population,* reached ~10% of the world's population (>60 years) in 2000.	Continued aging, including in many developing countries.
		Urbanization	The global urbanization ratio increased from 30% in 1950 to 47% in 2000.	By 2007, for the first time in human history, more people lived and worked in the urban centers of the world than in rural areas

		Migration	*Pulsating international migration:* International migration grew slowly at a rate slightly higher than population growth, and ~150 million people worldwide in 2000 were living in a country other than that of their birth. International migration was punctuated by cyclical periods of either economic growth and immigration liberalization, or by periods of forced emigration from war, conflict, and political change.	In 2010, there are 214 million migrants worldwide, 37% more than twenty years ago, and more mobility than at any time in world history.
	(D2) Economy	Economic growth	*Affluence has increased amidst persistent poverty:* Per capita gross domestic product has grown >8-fold since 1820. Per capita gross domestic product (purchasing power parity) has more than tripled since 1960. All regions of the world except Africa, where growth has stopped in the 1990s, showed such growth. However, differences between regions persist. GDP increased from US$17 trillion in 1970 to US$36 trillion in 1990 to US$49 trillion in 2000.	GDP increased from 49 to 67 trillion US$. Average GDP per capita increased from 8000 to 9700 US$ per capita.
		Income convergence	*Growing income inequality and shrinking entitlements:* There has been a narrowing of disparities in wealth among rich countries, but inequality has increased between rich and poor countries, with the notable exceptions of those in East and Southeast Asia. At the same time, within-country inequality has grown in many rich and poor countries. Since WWII, entitlements grew in centrally planned countries and all industrialized market-oriented countries. But since the 1980s, many of these entitlements shrunk or disappeared. In developing countries, entitlements also shrunk, partly because of IMF's structural adjustment programmes.	Income inequality increased significantly in most countries.
		Trade	Since 1950, trade has grown at more than twice the rate of economic growth, and current trade in money and capital is 100 times greater than trade in goods and services.	?
		Energy use	Energy use quadrupled from 1950-2000. Primary energy use doubled from 1970 to 2010. The renewable energy share increased from 5.4% in 1970 to 7.0% in 2000.	Energy use increased from 384eJ in 2000 to 493EJ in 2010. The renewable energy share increased from 7.0 to 8.2%.
		Water use	Human modification, management, or appropriation of nature reached about one-quarter of the freshwater supply.	?
			Growing but slowing water withdrawals. Global withdrawals of water to satisfy demands grew rapidly in the 20th century. Between 1900 and 1995, water withdrawals increased by over six times, more than double the rate of population growth. However, per capita withdrawals peaked in the mid-1980s. Since then, per capita water withdrawals have declined and absolute water withdrawals have slowed worldwide. In industrialized countries, greater efficiency of use has led to reduced per capita consumption (e.g., -22% in the US from 1980 to 1995).Agriculture, primarily irrigation, accounts for 70% of current freshwater withdrawals.	Per capita water withdrawals declined in some industrialized countries.
		Material consumption	For the poorest people and least developed countries, consumption is grossly inadequate, with unmet needs for energy and materials for food production, housing, consumer goods, transportation, and health.	Global consumption increased from US$37 trillion in 2000 to US$51 trillion in 2010.
		Energy security	?	?
	(S3) Community	Peace and Conflict	*Increasing conflict amid cold war:* Steady increase in the incidence of armed conflict worldwide during "cold war": ~300 armed conflicts (>500 fatalities) of international, civil, ethnic, and genocidal violence and warfare (~25 million deaths). Peak in 1992: one-third of the countries of the world contained such conflicts, 40 million refugees and displaced persons. There is also evidence for a very long-term trend toward more frequent and ever more intense conflicts. *Marked downturn in all forms of conflict in the 1990s*. Share of states experiencing warfare declined from one-third to less than one-fifth (1992-1999)	Organized conflict has further declined, including terrorism, state, and non-state conflict. Violent crime is the leading fear for personal security in many countries. The number of State-based armed conflicts further decreased until 2005 to levels not seen since the 1970s, but increased thereafter. The number of reported battle-deaths from non-State armed conflicts has decreased since 1992 was less than half of that level in 2009. In 2009, the number of deaths from one-sided violence was one hundredth of its peak in 1994.

To sustain	(S2) Life support	Resources	Water	*Growing regional and local water scarcity.* Many places in the world suffered local freshwater shortages, and in water stress was widespread in one-third of the world, where withdrawals exceeded 20% of available supply in 2000. In many places, the quality of available water continues to decline because of pollution and salinization.	?
			Material consump	*Greater consumption and less per unit of value*: The growth in material consumption exceeded the growth in population, but was less than the growth in income or value of product. Over the second half of the 20th century, while world population more than doubled, food production almost tripled, energy use more than quadrupled, and the overall level of economic activity quintupled.	?
			Crop lands	*Sustained expansion of croplands* in developing economies, especially the tropics, arid and semiarid lands, and high mountains. Arable land per person has been cut from 0.42 ha to 0.23 ha while food production rose 160% from 1950 to 2000.	Land covers of the ice free earth is divided into dense settlements (1%), villages (6%), croplands (21%), rangelands (30%), forests (19%), and wildlands (23%).
		Ecosystems	Forests	*Decreasing tropical forests and increasing temperate and boreal forests.* Despite the loss of ~47% of the world's forests historically to domestication, they occupied about one-fourth of the world's ice-free land area in 2000, with over one-half located in the tropics. Tropical forests declined at an estimated rate of 12.3–14.2 million ha per year from 1990 to 2000. Temperate and boreal forests were reforesting in the 1990s, with the exception of Siberia where deforestation was significant and occurring at high rates	The area of tropical forests continues to decline, but temperate forest areas have been increasing.
			Grasslands	*Modification of grasslands and pasturelands.* Trends for grasslands and pasturelands are poorly understood and, but agreement exists that grasslands have been extensively modified worldwide, perhaps increasingly degraded in terms of standing biomass. Small areas of abandoned cultivation reverted to grasslands in the USA.	?
		Environment	Air pollution	*Decreasing and increasing air pollutants.* By 1990, global SO_x emissions increased a factor of >5.5 from their levels in 1900. They peaked in 1989 and declined by 2.6% by 2000. In industrialized countries, tropospheric air pollution was significantly reduced, as in the U.S., where nationally averaged concentrations of nitrogen dioxide, ozone, sulfur dioxide, carbon monoxide, and lead have respectively declined. Although rapidly industrializing countries such as China and South Korea have been recently successful in reducing emissions of some pollutants (e.g., SO_x), emissions of others (e.g., NO_x, non-methane volatile organic compounds) continue to grow rapidly.	?
			Chemi cals	n.a.	?
			Tropospheric Ozone	*Declining but stabilizing stratospheric ozone.* Increasing release of chlorofluorocarbon gases since 1930 with a peak in the late 1980s. The ozone layer on a path to stabilization by 2020/2030.	?
			Agriculture	*Intensification and expansion in cultivated lands.* Intensified production on prime croplands in most countries predicated on high inputs of water, fertilizer, pesticides, and improved seeds, although limits to yield increases became apparent.	?

		Ocean Fisheries		*Decreasing ocean fisheries.* Despite strong international consensus to preserve maximum sustainable yields, commercial fisheries were significantly more stressed in 2000 than in 1970. The percentage of stocks being fished beyond maximum sustainable yield nearly tripled from 10% in 1970 to 28% in 1999, and 75% of all stocks were either overfished or at capacity. For those fish that require freshwater in their life cycle, habitat degradation added further stress, as did widespread coral bleaching and direct destruction of coral reefs for reef-based fish.	?
		Coastal zones		*Degrading coastal zones:* In 1994, ~44% of Earth's population lived within 200 km of a coastline, a number that has grown over time. Much of their waste, garbage, and waterborne pollutants, as well as ship-borne waste, oil spills, and distant agricultural runoff, ended up offshore.	?
	(S1) Nature	Earth	Climate change	*Increasing concentrations of "greenhouse" gases and global warming.* The CO_2 content of the atmosphere has increased ~85 parts per million from 1750 to 2000, and the Earth warmed 0.6 ± 0.2°C from 1861 to 2000. The 1990s was the warmest decade on record since measurements began in 1861. In the Northern Hemisphere, the last century was the warmest in the last 1,300 years.	The 2000s have been the warmest since records began in 1861.
				Increasing emissions of greenhouse gases: Global carbon emissions from the consumption and flaring of fossil fuels were 8.3% greater in 2000 than in 1990.	CO_2 emissions increased from 23.3 $GtCO_2$ in 2000 to 29.4 $GtCO_2$ in 2010. Despite the global economic crisis, this was the fastest rate of global emissions increase (+2.4% per year) in any decade since the 1970s.
			Interference with P and N	?	?
		Biodiversity	Human interference	Human modification, management, or appropriation of nature reached about one-half of the terrestrial ecosystems and one-quarter of the freshwater supply.	Continued trend.
			Biological diversity	*Decreasing biological diversity.* Decreasing diversity through either species extinction and species reduction in managed agroforestry systems. In 2000, extinction rates were 100–1,000x their pre-human levels. 11% of bird species, close to 18% of mammals, ~8% of plant species, and 5% of fish species were threatened. In areas where studies have been carried out, ~20% of freshwater species were threatened, endangered, or extinct	Recorded extinctions reveal rates of extinction much larger than those found in the fluctuation of the fossil record.
			Biological invasions	*Increasing biological invasions.* Exotic species have increased diversity in some places and decreased it elsewhere as immigrant species replace local ones.	Continued trend
		Ecosyste ms	Oceans	*Warming oceans:* Because of their enormous size, the chemical composition of the open oceans, with the exception of lead, had not been greatly affected by human activities. But the oceans have warmed leading to sea level rise of 10–20 cm over the last century. There was no clear evidence yet that continued warming had significantly altered the system of ocean currents.	Some 41% of the oceans show high human-induced impacts on marine ecosystems, with the highest impacts in coastal regions.

	(S3) Society	Institutions	*Widening governance and globalization:* At a global level, new institutions of governance have emerged, transnational corporate and financial institutions grow and consolidate, and networks of nongovernmental institutions collaborate and expand. At the subnational level, government has devolved, privatization is common, and civic society in many places has been strengthened. Power has shifted from the national state upward to the global level and downward to the local level, and at all levels from the public to the private	Crisis of multilateralism.
		Social capital	*Changing values:* Extraordinary changes in values, attitudes, and actual behaviour, in particular the attitudinal and behavioral shifts in sex and reproduction, the role of women, the environment, and human rights.	Continued trend.
		States	n.a.	?
		Regions	n.a.	?

Source: Based on Kates (2003, 2010). PBL (2012), and Smil (2010).

6.2. If we continue like in the past: a "dynamics-as-usual scenario", 2010-2050

No one knows which path the world will take in the next 40 years. But there should remain no doubt that, while the precise magnitude and dynamics of the future sustainability challenge and eco-efficiency, there has been an impressively strong consensus among experts since 1970s about the major sustainability issues and the broad direction of trends. In contrast, big differences exist on the suggested policy solutions arising from different world views, grounded in different values.

The following is a sketch of what the world could look like in 2050, if we continued the historical path of incremental improvements in reaction to perceived crises, instead of a shift toward a long-term perspective that aims to anticipate the troubles ahead (Table 36).[16]

This DAU world in 2050 is one of excessive material consumption by 6 billion people in both "North" and "South" which will be at the expense of another 3 billion people living in abject poverty, suffering much of the negative consequences of the others' overconsumption which by its sheer scale will have transgressed the majority of planetary boundaries, eventually leading to global collapse. Such potential collapse is not included in any of the mainstream trend scenarios. Hence, the following is a highly optimistic view of the consequences of continuing as in the past.

6.2.1. Overall storyline

The dynamics-as-usual scenario ("Growth first!") describes a future world that results from a continuation of incremental progress, in line with historical patterns and trends. It is the closest to a future "projection". It provides a less conservative and more dynamic benchmark than BAU for comparison with the other scenario families. In line with current trends, economic growth remains the top policy priority in most countries, but an increasing number of social and environmental issues are increasingly taken seriously and are being addressed within the given growth-focussed paradigm. This will also be reflected in an increasingly complex and wide ranging system of regional and global institutions.

Incremental technology progress proceeds in line with historical patterns, including in terms of eco-efficiency. This is achieved with ever increasing public commitments and investments, as gaps become increasingly evident. As a result, "green" sectors are supported by governments and develop faster than other sectors, but do not receive support commensurate with the social and environmental efforts. Many of the planetary boundaries, including in terms of climate change, are expected to be breached. Irreversible environmental events and social strife are of increasing concern. Governments focus on crisis response rather than structural change. More extreme scenario variants might also be explored where governments react massively in the face of environmental disaster or social conflicts. For example, a collapse of the global thermohaline circulation might trigger large-scale geo-engineering, migration flows, and military conflicts.

There are only isolated national examples of systematic, direct efforts to change consumption patterns by mid-century. Instead, policy makers rely primarily on price signals to impact consumer behaviour, but prices remain too low to achieve eco-efficiency changes commensurate with the challenges, in view of the successful lobbying efforts of special interest groups and strategic gaming behaviour of market actors.

Pollution loads by industry continue past trends, including for pollution from toxic chemicals. Transfer of chemical and electronic waste to developing countries is progressively restricted to reflect stricter regulations or enforcement in some regions.

Protected land areas continue to increase slowly, as well as marine protected areas. No global management of fisheries is reached. Limited effort is made on climate (continuing the increase in

[16] If not explicitly otherwise stated, tis description of the world in 2050 follows OECD (2012) and PBL (2012).

voluntary emissions reductions), reflecting lack of a binding multilateral agreement post Kyoto.

Renewable energy diffuses slowly into the global primary energy mix, with large differences among countries. Until at least the mid-21st century, fossil fuels remain the dominant energy source. Governments fully implement the present biofuels mandates for 2020-2025, but thereafter there is potentially a significant backlash, in view of ensuing land conflicts and rising food prices. Progress toward universal access to electricity and modern cooking fuels continues, but its pace differs greatly among countries. Global universal access is not achieved before the end of the 21st century. Energy efficiency, water efficiency, and crop yields continue to improve as per past trends.

Population follows the UN median projection.

Public investments in education, health, water and sanitation tend to increase in today's developing countries, and especially emerging economies, but are gradually reduced in today's developed countries. Social safety nets in developing countries evolve slowly towards increased coverage, but remain limited to the formal economy, whereas the coverage is gradually reduced in today's developed countries. There are no special efforts to reduce income disparities between countries or within countries. The trade, IPR, and investment and financial systems, including ODA flows follow the assumptions in the business-as-usual scenario.

6.2.2. People in 2050

A more crowded, urban world

World population will be 9.2 billion in 2050, which is 2.2 billion higher than today, with most of the increase in South Asia, the Middle East and Africa. Urbanization will reach 70%, implying an increase of 2.8 billion people in urban areas, compared to a decrease of 0.6 billion in rural areas.

Persistent poverty and hunger amid riches

Great progress is expected for another 2 billion people being lifted from poverty and hunger. As in recent decades, such progress will be fast enough to compensate for the growing world population, but leave roughly as many people extremely poor (almost 3 billion people living on <US$2 per day) as there are today. The number of people going hungry will likely be reduced by 500 million people, still leaving 250 million with insufficient food intake.

One billion people without access to basic services

More than 240 million people, mostly in rural areas, will remain without access to improved water sources, and 1.4 billion people without access to basic sanitation. Child mortality from diarrhoea, caused by unsafe water supply and poor sanitation, will decrease, but Sub-Saharan Africa will lag behind. In 2050, there will still be some 1.8 billion people without access to modern energy services for cooking and heating, down from 2.75 billion in 2010.

Billions excluded from otherwise improved global health

For example, global premature mortality from malaria is expected to be halved to 0.4 million from 2010 to 2050.

Universal primary and secondary education for all

Great progress is expected on making not only primary, but also secondary education universal, with women most likely accounting for most of the higher-level degrees worldwide in 2050.[17]

6.2.3. Economy in 2050

A global middle class in a US$300 trillion world economy amid abject poverty

Gross world product quadruples to US$300 trillion, with BRICS alone accounting for 40% of the world economy in 2050. Income convergence across countries continues rapidly, reaching ranges between emerging and developed countries similar ranges between developed countries today. Average GDP per capita is expected to triple to US$33,000 in 2050, a level similar to OECD countries today where GDP per capita is expected to double to US$69,000. GDP per capita in BRICS would quintuple to

[17] Source: DESA (2012).

US$37,000 in 2050. However, some of the most vulnerable and poorest economies remain marginalized and in abject poverty.

An energy-hungry, fossil-fuelled world

Global primary energy use increases by 80%, with a fairly stable mix of fossil fuels (85%), modern renewable sources (10%), and nuclear energy (5%). Rapid energy efficiency and intensity improvements will continue to be outstripped by energy demand. Absolute demand for biofuels will increase by at least on third by 2035, requiring additional land, including from clearing forests and pastureland conversions, which will put additional pressure on food prices leaving millions of urban dwellers hungry.

A thirsty world

Water demand increases by 55%, mainly due to manufacturing (+400%), electricity (+140%) and domestic use (+130%). In the face of competing demands, there will be little scope for increasing irrigation.

A world repeatedly rippled by price shocks and supply disruptions

National energy security is expected to decrease for most countries, especially the large, Asian economies. Pressure on exploration and opening of lower quality, unconventional fossil fuel sources will contribute to repeated major energy crises that will adversely affect the poor and food security.[17]

6.2.4. Life support in 2050

Two thirds of world population under water stress

In 2050, a whopping 3.9 billion people (>40% of world population) will live in river basins under severe water stress, and 6.9 billion people will experience some water stress. Groundwater continues to be exploited faster than it can be replenished (>280 km^3 per year) and is also becoming increasingly polluted. Surface water and groundwater quality is stabilized and restored in most OECD countries, whereas it deteriorates in developing countries. The number of people at risk from floods might increase by 400 million to 1.6 billion, with the value of assets at risk almost quadrupling to US$45 trillion.

Global deterioration of urban air pollution, but fewer deaths from indoor air pollution

Urban air quality will continue to deteriorate globally, with concentrations in many cities far exceeding acceptable health standards. Premature deaths from exposure to particulate matter might double to 3.6 million per year, SO_2 emissions increase by 90% and NO_x emissions by 50%. This is despite continued declines in SO_2, NO_x and black carbon emissions in developed countries. Yet, there will be fewer premature deaths from indoor air pollution after 2020.

Fewer forests, more land for agriculture until 2030, then reversed trends

Agricultural land area is expected to increase until 2030, intensifying competition for land, and might decline thereafter, in line with declining population growth and agricultural yield improvements. Deforestation rates most likely continue to decline, especially after 2030, but most primary forests might be destroyed by 2050.

Unabated increase in hazardous chemicals exposure

World chemicals industry sales are expected to grow by about 3% per year to 2050, leading to an unabated increase in the global burden of disease attributable to exposure to hazardous chemicals.

Global collapse of ocean fisheries

Continued overfishing beyond maximum sustainable yield, together with ocean warming and acidification, eutrophication, habitat degradation, and destruction of coral reefs, might lead to a global collapse of ocean fisheries based on “wild catch”, with efforts to replace by aquaculture-based fisheries.[17]

6.2.5. Nature in 2050

Accelerated increase in GHG emissions and global warming

GHG emissions are expected to increase at an accelerated rate at least until 2030, leading to an increase 48 to 83 $GtCO_{2\text{-equiv}}$ from 2010 to 2050. Most of the GHG emissions increase will be due to large emerging economies. This is despite expected decreases in LULUCF emissions from 2040 onwards. Atmospheric GHG concentrations might reach about 685 ppmv ($CO_{2\text{-equ.}}$), eventually leading to a 3-6˚C warming.

Unabated, continued loss of biodiversity

Biodiversity[18] is expected to decline by at least 10%, with the highest losses in Asia, Europe, and Southern Africa[19], and pressure from invasive alien species will increase. Primary forests will steadily decrease until few will be left, even if zero net forest less were to be achieved after 2020.

Massive human interference with P and N cycles well beyond safe thresholds

Eutrophication of surface water and coastal zones is expected to increase almost everywhere until 2030. Thereafter, it might stabilize in developed countries, but continue to worsen in developing countries. Globally, the number of lakes with harmful algal blooms will increase by at least 20% until 2050. Phosphorus discharges will increase more rapidly than those of nitrogen and silicon (exacerbated by the rapid growth in the number of dams).

6.2.6. Society in 2050

Mainstream BAU/DAU scenarios say nothing about future trends in neither community nor society. This is in contrast to some sustainable development assessments of the past. In terms of society, continuing past trends would suggest *widening governance*, *continuing globalization* (with possible regional ups and downs), *changing values*, and a greatly *enhanced role of women*.

6.2.7. Community in 2050

In terms of community, continuing past trends suggest a *continued resurgence of intra- and inter-country conflict* at least for the medium-term, fueling multiple, protracted crises.

6.3. A better world we can achieve: a sustainable development scenario, 2010 to 2050

The following description of a sustainable development future in 2050 is based on results from recent sustainable development scenarios by PBL, IIASA-GEA, SEI, OECD, FEEM, GSG, and others for Rio+20.While they do not refer to one single scenario, these mainstream scenarios are fairly similar in spirit and content, not least because they all bear close "family resemblance" with the IPCC SRES scenario B1.

It describes a world that is clearly much more in line with the world that we all want. It is more sustainable in important environmental and social dimensions and promises a decent quality of life for all people. Yet, this world in 2050 is far from a paradise vision.

Box 7. The human being at the centre of the universe

> *"Two different worlds are owned by man: one that created us, the other which in every age we make as best as we can."*
>
> Zobolotsky (1958), from Na zakate, p. 299.

6.3.1. Overall storyline

The sustainable development scenario describes a future world in which policy follows an integrated approach to economic, social and environmental goals, and major institutional change, with the overall goal of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

The scenario family reflects an integrated focus on the three pillars of sustainable development, as well as an explicit integration of planetary limits to ecosystems capacity. Conscious efforts are made by the international community to achieve and sustain MDGs-related goals relating to basic access to services, education, and health, and to reduce aggregate income disparities across regions in the

[18] measured as terrestrial mean species abundance
[19] While the area of natural land converted to agriculture might decrease after 2030, biodiversity impacts will continue for decades thereafter.+

long term. Coordinated efforts are made to curb greenhouse gas emissions in order to achieve scientifically recommended targets (e.g. 350 ppm), through the whole range of possible policies, technologies and regulations. In the long term (2100), sustainable development is achieved in the sense that all regions are developed, poverty is eradicated, and the demand on natural sources and sinks does not exceed their regeneration capacity.

This scenario implies new economic structures, different allocation of capital and investment among public and private sectors, cooperative management of the commons at the global and national levels. By the end of the 21st century, differences in GDP per capita between countries worldwide will be similar to the prevailing such differences between OECD countries today. This leads to much lower differences in incomes across countries, as well as conscious efforts to limit intra-country income differences, and thus significantly lower conflict potential. Possibly, in this scenario the 500 million richest people, regardless in which developing or developed country they live, take a leading role in changing their consumption pattern and contribute resources to eradicate poverty. The high willingness to pay for technology performance by these "rich" leads to accelerated technology change toward cleaner clusters that are thereafter gradually adopted by lower income groups.

6.3.2. People in 2050

Hunger and poverty "eliminated" by 2050

In the sustainable development world, the proportion of people who suffer from hunger would be halved by 2015. It would further halved by 2030, and eradicated by 2050 (PBL, 2012). In another account of such world, chronic hunger would be reduced by 50%, 75% and 94%, by 2025, 2050, and 2100, respectively (GSG, 2012). Poverty as a whole could be virtually eliminated worldwide by 2050 (SEI, 2012).

Great progress would be made in terms of improving access to water and sanitation. In particular, the proportion of the population without sustainable access to safe drinking water and basic sanitation by could be halved by 2015, followed by another halving 2030. Eventually, universal access to improved water source and basic sanitation would be achieved by 2050 (PBL, 2012).

Universal access to electricity and modern cooking fuels could be achieved by 2030 (IIASA-GEA, 2012; PBL, 2012). Others believe it might take until 2050 (SEI, 2012). This achievement, together with other pollution measures, would significantly decrease the impact of environmental factors on human health, as measured by DALY (PBL, 2012)

Universal primary education is achievable by 2015. (FEEM, 2011). Global population growth would slow, with an expected peak population to be reached in 2050. Global population could be reduced by about one billion, simply by making contraception available to all who want it and by increasing opportunities for girls and women to have education and jobs (Kates, 2003).

This world would continue to become more urban like in the dynamics-as-usual world. Yet, special efforts will be made to ensure the provision of reliable and high quality public services not only in smaller urban centres but also in remote areas, which, however, is not expected to significantly alter the global trend toward urbanization and a global network of mega-cities.

6.3.3. The economy in 2050

In the sustainable world, economic growth would no-longer be the primary goal, nor one of the most important goals. Yet, as a result of pursuing other SDGs, global income convergence is expected, including through catch-up development of African countries by mid-century (FEEM, 2011). As a result, GDP per capita might be more than US$10,000 (in PPP terms) in all regions by 2050 (SEI, 2012).

Despite this much higher incomes in all world regions, the world would manage to optimize energy efficiencies and conservation, so that it could do with primary energy use of less than 70GJ per capita by 2050 (FEEM, 2011).

Absolute water use will increase from 3,560 km^3 in 2000 to 4,140 km^3 in 2050. This is at least 25% lower than in the trend scenario due to accelerated increases in water efficiency and conservation (OECD, 2012).

The sustainable development world would also benefit from higher energy security, due to limited energy trade, increased diversity and resilience of energy supply by 2050, much of which as a co-benefit of environmental policies (IIASA-GEA, 2012).

6.3.4. Life support in 2050

Despite all the water measures taken in the sustainable development world, it is expected that there might be an additional 2 billion people living under severe water stress compared to the year 2000, reaching 3.7 billion people living under water stress in 2050 (OECD, 2012). More optimistic scenarios outline pathways toward a future in which the number of people living under severe water stress could be limited to less than 2 billion until 2050 (GSG, 2012). In all these cases, it would mean a significant reduction of the number of people living in water scarce areas compared to the trend scenario (PBL, 2012). However, overall flooding risks, as well as surface or groundwater quality are expected to continue to worsen, even in this "better world we can achieve".

Great improvements could be achieved in terms of reducing air pollution. In particular, it should be possible to keep PM2.5 concentrations below 35 µg m^3 by 2030 (PBL, 2012), and to reduce NO_x, SO_2 and black carbon emissions by 25% compared to the baseline by 2050 (GSG, 2012). Reduced air pollution could reduce the number of premature deaths globally by 50% by 2030 (IIASA-GEA, 2012).

Similarly, in this world deforestation and land degradation will be slowed and later even reversed deforestation (GSG, 2012).

In this world, increased efforts will be made to minimize chemicals pollution to the environment and related health hazards. However, even with such efforts, chemicals will most likely continue to pose serious and even increasing threats to human health and the environment in the future. This is in part due to chemicals and materials needed for the production of "green technologies" needed to address the series of global commons issues.

Overfishing will be slowed and fish stocks later restored towards mid-century (GSG, 2012).

6.3.5. Nature in 2050

Global average temperature change could be limited to 2°C above pre-industrial levels with a likelihood of at least 50% (or 60%) from 2050 to 2100 (PBL, 2012; GSG, 2012; IIASA-GEA, 2012; OECD, 2012). This could be achieved by stabilizing atmospheric GHG concentrations below 450 ppmv $CO2_{-eq}$. from 2010 to 2100 (PBL, 2012), even though lower targets of 350ppmv appear possible as well by 2100 (GSG, 2012), all of which would however, require unprecedented measures and global collaboration.

In this "better future we can achieve", the extinction of known threatened species will be prevented and the situation improved of those in most decline by 2020. In quantitative terms, the world will achieve halving the rate of biodiversity loss by 2020 and stabilizing biodiversity at that level (depending on region) by 2050. The rate of loss of natural habitats would be halved and degradation and fragmentation reduced by 2020. Ultimately, at least 17% of terrestrial and inland water areas and 10% of coastal and marine areas would be conserved by 2020, in line with the CBD Aichi protected area targets (PBL, 2012; OECD, 2012)

Great efforts will be made to limit the continued rise of human interference with the global phosphorus and nitrogen cycles, however, only with limited success, through removal in wastewater treatment and reduction in its use, but without harming the ability of the agricultural system to meet the hunger target (OECD, 2012; PBL, 2012).

6.3.6. Community and society

Developments in community and society will be essential to achieve such comprehensive transformation to a sustainable development world. However, as scenario analysts do not offer a clear vision of what changes this would precisely entail, we do not offer any further details in this area either.

Table 36.Contrasting baseline/trend scenarios (mainly OECD, PBL) with goals contained in SD scenarios for Rio+20

Vision		Themes	***OECD baseline/trend scenario***	***SD scenarios (and scenariettes) for Rio+20***	
			Pathway characteristics, 2010-2050	**Goal/target**	**Scen. set**
To develop	(D1) People	Hunger	[PBL]: The number of people going hungry is reduced by 500 million people, still leaving 250 million with insufficient food intake (down from 750 million in 2010).	Halve the proportion of people who suffer from hunger by 2015, further halve it by 2030, and eradicate hunger by 2050	PBL
				Reduce chronic hunger by 50%, 75% and 94%, by 2025, 2050, and 2100, respectively.	GSG
		Poverty	[DESA]: Progress in poverty reduction is fast enough to compensate for the growing world population, but leave the same absolute number of people poor as in 2010 (almost 3 billion people living on <US$2 per day).	Eliminate poverty worldwide by 2050	SEI
		Water and sanitation access	> 240 million people (most of them in rural areas) will be without access to improved water source, and 1.4 billion people without access to basic sanitation. Child mortality from diarrhoea (caused by unsafe water supply and poor sanitation) will decrease, but Sub-Saharan Africa will lag behind.	Halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015, further halve it by 2030.	PBL
				Universal access to improved water source and basic sanitation by 2050	PBL, OECD
		Energy Access	[PBL]: Decrease in the number of people without access to modern energy services for cooking and heating, from 2.75 billion in 2010 to 1.8 billion in 2050.	Universal access to electricity and modern cooking fuels by 2030	GEA, PBL
				Modern energy access for all by 2050.	SEI
		Health	Global premature mortality from malaria halved to 0.4 million from 2010 to 2050.	Decrease impact of environmental factors on DALY [monitoring target only]	PBL
		Education	[DESA] Universal primary education by 2020, universal secondary education by 2050. Women will account for the majority of higher-level degrees worldwide.	Universal primary education by 2015	FEEM
		Population growth	World population grows by 2.2 billion to 9.2 billion (mostly South Asia, Middle East and Africa).	(Projected peak population in 2050 can be reduced by ~1 billion by making contraception available to all who want it and by increasing opportunities for girls and women to have education and jobs.)	(Kates)
		Urbanization	Urbanization reaches 70% (+2.8 billion people in urban areas, -0.6 billion in rural areas).	n.a.	
	(D2) Economy	Economic growth	Gross world product quadruples to US$300 trillion, with BRICS accounting for 40%.	n.a.	
		Income convergence	GDP per capita increases from US$33,000 to 69,000 in OECD, from US$7500 to 37,000 in BRICS, US$11,100 to 33,000 globally.	GDP per capita > US$10,000 PPP in all regions by 2050	SEI
				Income convergence; catch-up of Africa by 2050	FEEM
		Energy use	Primary energy use increases by 80%. Mix remains fairly stable: fossil fuels (85%), modern renewable sources (10%), nuclear (5%). Energy intensity improvements outstripped by energy demand.	Primary energy use less than 70GJ per capita by 2050	FEEM
		Water use	Water demand increases 55% (mainly from manufacturing (+400%), electricity (+140%) and domestic use (+130%)).In the face of competing demands, there is little scope for increasing irrigation.	Water demand increases from 3,560 km^3 in 2000 to 4,140 km^3 in 2050 (i.e., -25% baseline).	OECD
		Energy security	[DESA] National energy security to decrease for most countries (especially the large Asian economies), leading to repeated global energy crises, adversely affecting the poor and food security.	Limit energy trade, increase diversity and resilience of energy supply by 2050	GEA
sus tai	En e	Water resources	3.9 billion people (>40% of world population)will live in river basins under severe water stress. 6.9 billion under water stress, compared to 2.8 billion under no water	+2 bln people under severe water stress from 2000, reaching 3.7 bln in 2050	OECD

				People under severe water stress <2 bln until 2050	GSG
			Groundwater is being exploited faster than it can be replenished ($>280\ km^3$ p.a.) and is also becoming increasingly polluted.	Reduce the number of people living in water scarce areas compared to trend scenario [monitoring target only]	PBL
			Surface water and groundwater quality is stabilise and restored inmost OECD countries, whereas it deteriorates in developing countries due to nutrient flows from agriculture and poor wastewater treatment. Micro-pollutants (medicines, cosmetics, cleaning agents, biocide residues) a concern.	n.a.	
			The number of people at risk from floods will be 1.6 billion (up from 1.2 billion). Value of assets at risk will almost quadruple to US$45 trillion.	n.a.	
		Air pollution	Urban air quality will continue to deteriorate globally, with concentrations in many cities far exceeding acceptable health standards. Premature deaths from exposure to particulate matter will double to 3.6 million p.a. SO_2 emissions increase 90% and NO_x emissions 50%. OECD emissions of SO_2, NO_x and black carbon (precursors to PM and ozone pollution) will continue to decline.	Keep PM2.5 concentration below 35 µg m^3 by 2030	PBL
				-25% in NO_x, SO_2 and black carbon emission vs. baseline by 2050	OECD
			There will be fewer premature deaths from indoor air pollution after 2020.	Reduce premature deaths due to air pollution by 50% by 2030	GEA
		Land use and agriculture	Agricultural land area increases until 2030 (intensifying competition for land) and declines thereafter (in line with declining population growth and yield improvements). Deforestation rates continue to decline, especially after 2030.	Slow and later reverse deforestation	GSG
				Slow and later reverse land degradation	
		Chemicals	World chemicals industry sales grow ~3%/year to 2050. Global burden of disease attributable to exposure to hazardous chemicals will increase unabated.	n.a.	
		Fisheries	[DESA]: Global collapse of ocean fisheries before 2050.	Slow overfishing and later restore fish stocks	GSG
	(S1) Nature	Climate change	GHG emissions will increase by 70%, from 48 to 83 $GtCO_{2\text{-equiv}}$. Most of the GHG emissions increase will be in BRICS. LULUCF are projected to decrease by 2040.	Limit global average temperature change to 2°C above pre-industrial levels with a likelihood of >50% from 2050 to 2100.	GEA, PBL, OECD, GSG
				Keep global average temperature rise <2°C with 60% probability from 2012 to 2100.	SEI
			Atmospheric GHG concentrations reach 685 ppmv ($CO_{2\text{-equ.}}$), (eventually leading to 3-6C warming).	Keep atmospheric GHG concentration below 450 ppm $CO_{2\text{-eq}}$. from 2010 to 2100.	PBL
				GHG stabilization target, 550 and 650 GHGs, or threshold 3tCO2eq/pc by 2050	FEEM
				CO_2 stabilization <350ppmv by 2100.	GSG
		Biodiversity	Biodiversity (measured as terrestrial mean species abundance) declines by 10% (with highest losses in Asia, Europe, and Southern Africa). Pressure from invasive alien species increases. Area of natural land converted to agriculture decreases after 2030, but biodiversity impacts continue for decades thereafter. Primary forests steadily decrease. Rate of global deforestation decreases leading to no net forest loss after 2020. Continued lack of understanding of the complex non-linear dynamics of ecosystems.	Prevent extinction of known threatened species and improve situation of those in most decline by 2020.	PBL
				Halve the rate of biodiversity loss by 2020.	
				Stabilize biodiversity at the 2020/2030 level (depending on region) by 2050.	
				Halve the rate of loss of natural habitats and reduce degradation and fragmentation by 2020. Conserve at least 17% of terrestrial and inland water by 2020.	
				CBD Aichi protected area targets of 17% of terrestrial and inland water areas and 10% of coastal and marine areas by 2020.	OECD

		Interference with P and N cycles	Eutrophication of surface water and coastal zones increases everywhere until 2030, then stabilises in some regions (e.g., in OECD and the Russian Federation), but continues to worsen in developing countries. The number of lakes with harmful algal blooms increases globally by 20% until 2050. Phosphorus discharges increase more rapidly than those of nitrogen and silicon (exacerbated by the rapid growth in the number of dams).	P removal in wastewater treatment Increases from 0.7 Mt in 2000,1.7 Mt in 2030, to 3.3 Mt in 2050	OECD
				Reduce N/P use where possible (but without harming the ability of the agricultural system to meet the hunger target) [monitoring target only]	PBL

Source: Based on: OECD (2012), etc.

6.4. The most likely world in 2050? A prediction for the world in 2052

Jorgen Randers, one of the authors of the "Limits to Growth" report in 1972, presented a new report to the Club of Rome in May 2012. In the book, entitled "2052" he reflects on his forty years of "*worrying about the future*", based on which he prepared a "forecast" for 2052 (see section 4.9). Indeed, it is a forecast and not as a scenario, as he believes that humanity will continue not take the necessary actions to get on a desirable SD path that could have prevented overshoot. It is against this background that he predicts a future world in "*managed decline*" (Randers, 2012).

While Jorgen considers a wide range of constraints, such as finite reserves of fossil fuels, finite availability of arable land, finite amounts of wild fish, and finite space for biodiversity reserves, he foresees the emerging climate crises as the most pressing global constraint over the next forty years. GHG emissions are already two times higher than what is absorbed by oceans and forests. Jorgen notes that the world is already in "overshoot", heading towards the climate crises. Increasing atmospheric GHG concentrations and rising temperatures will worsen humanity's living conditions increasingly. Actions are not expected to be sufficient to limit global warming to below plus 2°C. However, there are signs that humanity will avoid "collapse induced by nature" and has rather embarked on a path of "managed decline". For example, *the UNFCCC and IPCC and climate change negotiations have been conducted for decades already, in order to get in place a well-organized, effective, and fair reduction of climate gas emissions.*" (Randers, 2012, p. 303).

What can be expected from "managed decline"? Most variables are still expected to follow historical trends until around 2030, after which a number of "*variables start to stagnate and decline*". Temperatures and sea-levels will continue rising as will the share of renewable energy use.

While global CO_2 emissions might peak around 2030, they will fall back to 2010 levels by 2050, due to economic decline and continued incremental progress in emissions mitigation. While global CO_2 emissions will fall linearly from 2050 to zero in 2100, global temperature will continue increasing through the second half of the 21st century.

Global population might peak by 2040 and slowly decline thereafter.

Global primary energy use is forecast to peak in the year 2042, staying almost flat between 2030 and 2050. Per capita energy use will decline gradually after 2035, due to energy efficiency investments.

Global consumption (i.e., the annual expenditure, private and public, on goods and services) will peak around 2050. Gross world product keeps growing until the second half of the 21st century, but at an ever decreasing rate. GDP per person continues increasing, as does annual production of goods and services. Investment shares in GDP start rising, in view of needed investments to tackle depletion, pollution, climate change, and biodiversity loss. Production of consumer goods and services per person peaks around 2050 and declines thereafter.

Food production peaks around 2040 at a level 60% above today's current levels, in terms of tonnes of food per year. Climate change starts to reduce the amount of land suitable for agriculture and to slow the rise in land yields, overwhelming the fertilizing effect of more CO2 in the atmosphere. Per capita food availability stagnates at 30% above today's level, which means that many people will still go hungry.

The ecological cost of growth will be seen in the continuing fall in the amount of unused biological capacity. By 2050 half of all land that had been unused by humans in 2010 will have been grabbed for human use, e.g., for buildings, infrastructure, forestry, and agriculture.

Most insightful is Jorgen Rander's characterization of the future depicted in his forecast as a future world where no-one would want to go (Box 8). Yet, the author, a pioneer of sustainability and systems analysis, sees collective failure as the most likely future outcome.

Box 8. Reflections on the desirability of the world in 2052.

"I would not say the future I've just described is anyone's goal. It is not where I, nor the contributors to the book, or likely you as a reader, would want to go. Therefore it is important to repeat that we won't go there as a result of consciously bad intent. Rather, we will go there in a forty-year-long marathon during which global society will try to create a better life for everyone—mainly through continued economic growth. The effort will succeed in some places, but not everywhere. Billions will be better off in 2052 than in 2012, and some will reach Western lifestyles. The poorest two billion will be stuck near where they are today.

That effort to raise material standards will involve increasing energy use, and we'll rely on fossil energy longer than is good for the climate. So, in 2052 the world will be looking back at forty years of accelerating climate damage, caused by continuous global warming, and bracing itself for the possibility of self-reinforcing, and therefore runaway, climate change. At the middle of the twenty-first century a huge effort will finally be in swing to reduce the human ecological footprint, based on collectively agreed upon and state-financed proactive investment seeking to reduce the chance of climate disaster. Democracies, formerly dominated by short-termism and delay, will have begun to copy the faster and more centralized decision-making style of more authoritarian regime.

The road to 2052 will not be smooth. There will be increasing inequity, tension, and social strife. Some nations will collapse. Many will fray at the bottom. But in 2052 a new urban and virtual civilization will be discernable, far distanced, however, from our natural human roots. A paradigm shift toward more holistic and sustainable values will be well under way. But temperatures will be rising, ecosystems will be in retreat, and the world of 2052 will not be an optimal starting point for the ensuing forty years."

Randers (2012), p.229

7. Scenario analysts, scientists and policy makers – making a good team?

This chapter provides an overview of the role of scenario analysis as a tool to support a "conversation" between scientists, stakeholders, and decision-makers. The main message is that scenarios at the science-policy interface can be a powerful tool and might be considered essential, but nevertheless remain imperfect, with a long list of improvements that might be considered, especially in terms of institutions. The present chapter is organized along the hierarchical framework of the "IKEA cupboard story" introduced in the beginning of this report and followed throughout (Table 37).

Table 37 Five-level hierarchy.

<table>
<tr><th>Typical scenario model implementation</th><th>Levels</th><th>What they represent</th></tr>
<tr><td rowspan="6">Normative model input</td><td>Level 1</td><td>Ultimate goal</td></tr>
<tr><td>Level 2</td><td>Vision</td></tr>
<tr><td rowspan="4">Level 3: Strategy</td><td>Themes</td></tr>
<tr><td>Goals</td></tr>
<tr><td>Targets</td></tr>
<tr><td>By</td></tr>
<tr><td>Model output</td><td>Level 4: Blueprint</td><td>Pathway characteristics</td></tr>
<tr><td rowspan="2">Ex-post policy interpretation of model results</td><td rowspan="2">Level 5: Implementation</td><td>Policies and actions</td></tr>
<tr><td>Investments</td></tr>
</table>

7.1. The science-policy interface and its historical context

The very term "science-policy interface" evokes a perspective in which two completely separate communities require an "interface" that helps them talk to each other. As a result of the great success of the scientific and technological revolution, a dominant public view in many countries is that science and technology should provide the "*objective*" inputs to policy makers, in order to depoliticize and improve decision-making. It is the basic rationale behind today's expert groups, and scientific or technical advisory panels (e.g., the IPCC or national sustainable development advisory groups). Yet, there are very different views on the science in decision-making. Some believe there is no role at all. Others believe that politics should guide and direct science rather than vice versa.

Computers enabled the modern science-policy interface

Systematic, science-based decision-support at various levels of government, in State-owned enterprises, and international organizations became only really influential since the 1950s. With the wider availability of computers, computer-based, data-intensive scenario models were increasingly used to assess projects, programmes, policies and, since the early 1970s even strategies. In fact, it developed so quickly that today's global scenario models are still almost exclusively derived from only six ancestor models created in the 1970s (see Section 3.1).

In other words, computer-based scenario models led to new forms of the science-policy interface. In this scientific-technocratic approach, scenario analysis and related processes became much more than just one of many decision-support tools. It became the interface itself. Hence, scenario analysis was dubbed an art, not a science. While good analysts were fully aware of that this "art" had its fair share of pitfalls, especially when it operated at the science-policy or science-business interface, its influence on public perception of policy options has been immense since the 1970s. Simple cases in point are the World model runs for the "Limits to Growth" which have shaped the worldview of a generation. Most recently, the highly featured IPCC scenarios have evoked the imaginations and triggered actions of millions.

The Science-Lobbyists-Policy interface

Critics of past efforts to "*strengthen the international science-policy interface*" argue that what is really suggested is a think tank/lobbyist-policy interface. Indeed, think-tanks whose economic well-being depends on those commissioning studies are typically most influential in this context, and they are expected to operate differently from scientists without a need for raising extra-budgetary resources. Others claim that this type of criticism is mostly self-interested and a covert effort to discredit and disregard scientific evidence in decision-making with generally disastrous impacts for our well-being.

7.2. The ultimate objective - sustainable development? (Level 1)

In the following sections we delve deeper into the commonalities and differences in perspectives among and between policy makers, scientists and scenario analysts. Ideally, there would be a working consensus among these three groups at all five levels (Table 37) in order to move forward in the same direction.

Worldviews

Arising from our values, we follow one or a combination of worldviews which provide a simplified view of "*how the world works*". According to some, this is "*important to live a happy life*" (Box 10), especially in today's complex world. But it is important to be aware of assumptions and simplifications made, when trying to find understanding between people with different worldviews. In fact, our worldviews are so intrinsic that we are often are not aware of their existence (Box 9, Box 10).

Box 9. Donella Meadows on paradigms/worldviews

> *"Your paradigm is so intrinsic to your mental process that you are hardly aware of its existence, until you try to communicate with someone with a different paradigm."*
>
> Donella Meadows

Box 10. Jorgen Randers on paradigms/worldviews

> *"A paradigm is a worldview. There are many different worldviews. Marxism is one, religious conservatism another. None is right. Different paradigms simply highlight different aspects of reality. A paradigm is also a simplification that helps you distinguish the noise from significant trends (as defined by your own paradigm, that is). But it is most important to understand that your chosen paradigm—which is normally tacit, rarely described—has surprisingly strong impact on what you see….*
>
> *The current Western world has a dominant paradigm. It includes basic beliefs like "the efficiency of market-based economies," "the self-correcting ability of democratic government,"… and "increased welfare through free trade and globalization." When trying to clarify the next forty years, it is important to include the possibility of a change in the dominant paradigm…*
>
> *Yes, simplification is important to live a happy life in the current world. But when looking forty years ahead, it becomes important to choose the right simplification. And it may be safer to try many, in the hope of losing fewer babies with the bathwater."*
>
> Randers (2012), p.9

Worldviews are characterized strongly by their ultimate objective that is being pursued. The most dominant ultimate objective of governments remains "economic growth". Others examples are "poverty eradication", "industrial development", "sustainable development", "climate change", or "green growth", etc. A very important question is to which extent policy makers, scientists, scenario analysts, and other stakeholders agree (among each other and in their respective groups) on "sustainable development" as the ultimate objective. As we explained in the IKEA cupboard example, for sustainable development progress, agreement at least among the most powerful groups is essential.

No consensus on the role of science in policy

There is no agreement on sustainable development as the "ultimate objective" and hence no agreement on the role of science in policy at the global level. Despite the Stockholm and Rio Summits in 1972 and 1992, there are still only a handful of global SD scenarios that aim to address even a rudimentary list of multiple SD goals. In fact, recently popular green growth and green economy scenarios focus on the "how" and typically exclude the consideration of sustainable development goals.

No consensus on limits

Strikingly, there is no consensus on the scientific-technical, political, social, economic and financial "limits" or constraint. There is a temptation for both policy makers and scenario analysts to choose selective limits in line with desired conclusions.

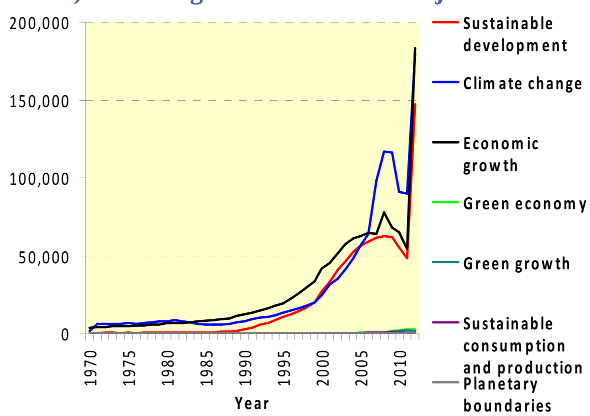
7.2.1. Perspectives of scientists, scenario analysts, policy makers and the general public

Scientists on the ultimate objective

According to conventional wisdom, it is scientists that have promoted the paradigm of sustainable development over more narrow objectives. Indeed, whenever political statements refer to sustainable development they most often than not refer to scientific evidence or to a call from a group of concerned scientists. It is hard to prove or disprove such a sweeping view, as comprehensive, hard data does not exist on this.

However, there is some empirical evidence that provides a glimpse of the general direction toward and answer. For one thing, Sustainability Science has emerged as a veritable scientific discipline in the past 20 years. Publication records provide additional evidence of the increasing number of scientists working on sustainable development issues.

Figure 35. Number of articles (contained in Google Scholar) indicating selected ultimate objectives.



Note: 2012 data is based on data from January to May and was adjusted proportionally for the remaining 7 future months of the year.

Figure 35 shows the number of academic articles (contained in Google Scholar) that use the terms "sustainable development", "climate change", "economic growth", "green economy", "green growth", "sustainable consumption and production", or "planetary boundaries", for each year in which they were published since 1970.

The number of articles on sustainable development increased rapidly from 1,210 in the year 1988 to 62,100 in 2009. Following a general decline in 2010 and 2011, 61,400 articles were published on sustainable development in the first five months of 2012 alone (if this trend continued we might expect as many as 147,000 such articles published in 2012). In part, this increase is the result of better coverage of electronic archives for recent years and a general increase in global academic output volume. Hence, it is most important to compare with the increasing volume of articles focused on alternative worldviews. Except for the years 2000 to 2004, in every single year since 1970, more articles were published on climate change than on sustainable development. Especially since 2006, there were about twice as many articles on climate change published than on sustainable development. It should be noted that climate change was important in the academic literature already forty years ago, with more than 6,100 articles published on the subject in 1972 alone. This is about four times as many than on "green growth" in 2011. Indeed, sizeable numbers of publications on "green economy" or "green growth" only appear since the mid-1990s and especially since 2009, but their current levels remain very low compared to dominant paradigms. This probably explains in part the lukewarm reception by scientists of the green economy concept that has been pushed by UNEP for a number of years and has become one of the main themes of Rio+20. Similarly, "sustainable consumption and production" and "planetary boundaries" denote worldviews of great political importance at the global level, but for which only a rather small academic literature exists. Most interestingly, while there has long been a sizable academic literature on "economic growth" it has been smaller in volume than that on "climate change" from 1970 to 1983, after which it quickly became the area with the largest publication output and remained so until 2006. Only from 2007 did the climate change literature overtake that of economic growth, but not for a long time. In the first five months of 2012, about 76,300 articles were published on "economic growth", more than for any of the other paradigms contained in Figure 35.

In summary, sustainable development has been an increasingly important paradigm explored by scientists since the Brundtland report of the late 1980s. However, the majority of academics have found a focus on climate change and economic growth more fruitful. With only a short break from 2007 to 2011, economic growth has been the most important paradigm among academics. But there has been no single paradigm that reigned supreme at any time during the last forty years. Another way to look at this is also to conclude is that there is no general consensus among scientists as to the "ultimate objective".

The general public on the ultimate objective

Do these trends in academic focus follow similar trends in interest in the general public? Google trends provides a unique source of information on the frequency of various Google search terms since the beginning of 2004. Figure 36 provides global trends. Similarly to the academic literature there is a spike of interest in climate change from 2006 to 2010, but the search volume for "climate change" returns almost to its 2004 value by May 2012. In contrast to the academic literature volumes though, Google search volume for "sustainable development" as well as for "economic growth" has decreased since 2004. However, in the run-up to Rio+20m, there has been an increased number of searches for "green economy".

Most interestingly, the top source countries and languages used in Google searches differ greatly for these search terms.

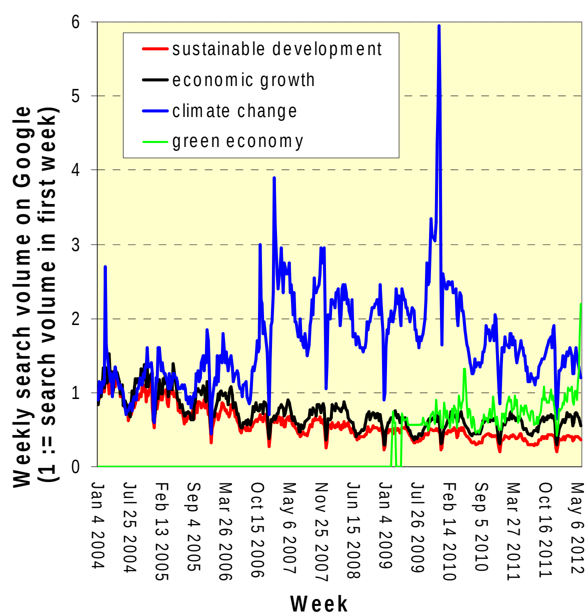
Most of the searches for "sustainable development" originate from Africa and Asia-Pacific, with Tagalog and English being the most important languages used. There have been more searches in Swedish language than Chinese, more Thai language searches than in Spanish, despite greatly differences in Internet populations using these languages (Figure 37).

Most of the searches for "economic growth" originate from Africa (with Ethiopia topping the list!) and emerging economies of Asia. There were Google searches for "economic growth" in Korean language than in English, and more in Chinese language than in Russian, German and French language combined.

Most of the searches for "climate change" originate from developed countries (with Australia topping the list) and large emerging economies. The English and Chinese languages dominate the searches for this term.

Most of the searches for "green economy" originate from Europe and selected African and Asian countries. The Italian, Indonesian and Korean language dominate searches for this term, far more than in English.

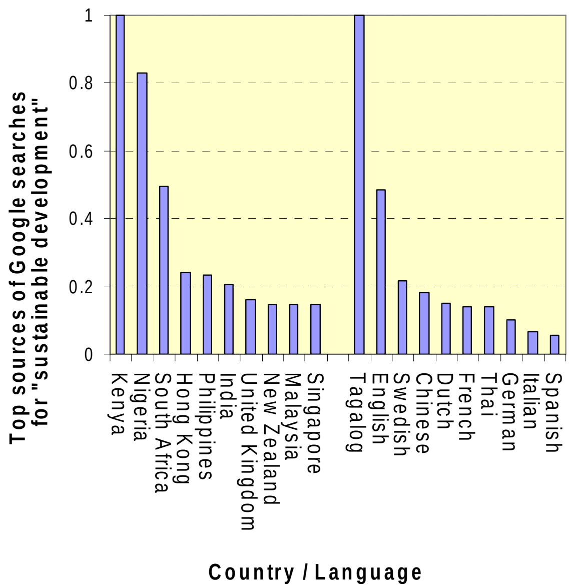
Figure 36. Weekly search volume on Google for various terms, relative to their search volume in the week of 4 January 2004.



Data source: Google trends, www.google.com/trends

In short, there are significant differences in the worldviews and ultimate objectives that prevail in different parts of the world. In particular, sustainable development and economic growth is perceived as of far greater significance for poorer countries than climate change or the green economy.

Figure 37. Top source countries and languages of Google searches for "sustainable development", Jan. 2004- May 2012



Data source: Google trends, www.google.com/trends

Policy makers on the ultimate objective

The general Google search trends just reported are more or less in line with common stereotypes on the worldviews of policy makers in various regions and countries of the world. This is not surprising, as general awareness and media attention is expected to follow the political agenda and vice versa. However, it should also be noted that other concepts of great relevance in negotiations at the UN level, such as "sustainable consumption and production" and "planetary boundaries" have such low Google search volumes that Google trends does not even report their data.

In addition, it is obvious from decisions and actions taken at global, regional and national levels that the overwhelming majority of policy makers have followed a single ultimate objective, namely "economic growth". There has been agreement on sustainable development objectives, but these have always been of lower priority. More recently, European countries and the Republic of Korea have promoted green economy and green growth. European countries and small islands have pushed for a climate change perspective. Only a small group of countries has followed an objective that was not primarily economic growth focused. These countries have suggested agendas associated with "harmony with nature", "happiness" and "self-sufficiency".

Scenario analysts on the ultimate objective

Where do scenario analysts fit in here? If they primarily serve as the interface between science and policies with an objective to make the body of scientific knowledge available amenable for political decision-making, then we should expect that they follow the worldviews and ultimate objectives found in the scientific literature. On other hand, if modellers are closer to (or even driven by) the political agenda, their worldview should be closer to policy makers'.

It turns out that scenario analysts follow a mix of worldviews and ultimate objectives, which apparently arises from their conversation with both policy makers and scientists.

Indeed, a survey among scenario analysts and modellers in the context of the present SD21 project clearly indicates that there is no general agreement of modellers on SD as the ultimate objective. Table 38 shows the results of a feedback survey among some of the world's leading scenario modellers. At the beginning of the project and over a glass of wine, they were asked with which of a set of 40 statements they would agree or disagree (Table 38). Without exception, these statements were drawn from actual statements and conversations that the author followed in the UN context since the year 2000. Hence, the statements provide a stylized overview of key "beliefs", points of agreement and disagreement held by decision-makers engaged at the UN.

The results are interesting, indeed. The statements in Table 38 are organized in order of the level of agreement among scenario experts. Hence, at least 70% of scenario experts agreed on 10 statements and jointly disagreed on 14 statements. Opinions were sharply divided on the remaining 16 statements. Interestingly the one and only statement on which all respondents agreed was on the critical role of technology for achieving sustainability. Equally, no-one agreed with the assertion that corporations should be equal partners with government and civil society in a sustainable world. There was strong agreement on the important role of governments in promoting sustainable development, market instruments, conservation and the special responsibility of developed countries. Views on a number of other issues were sharply divided, including on the monetary valuation of the environment, the role of nuclear power, the efficiency of markets, population control, the need for behavioural changes, the role of Governments in managing the commons, and the impacts of free movement capital and of migration.

Table 38. Results of a survey on worldviews of ten of the world's leading scenario experts, in the context of the SD21 project.

No	Do you agree with the following statements?	Yes	No
1	Technology will be critical to achieving sustainability	10	0
2	There is a need for conserving and protecting much larger areas of the globe	9	1
3	The State should be strongly involved in health provision	9	1
4	Market-based instruments are essential to solve environmental problems.	8	2
5	Governments have a critical role to play to redistribute wealth	8	2
6	Developed countries have to assume their historical responsibility and support development in the rest of the world	8	2
7	Corporations can be mobilized as a force for positive change to achieve sustainability	7	3
8	In a globalized world, local identities and societal values are at risk of being lost.	7	3
9	Free mobility of labour needs to accompany the free mobility of other factors worldwide.	7	3
10	A fair society includes a decent minimum income for everyone	7	3
11	Development is the national responsibility of each country	6	4
12	Compared to common ownership, the private property regime creates better incentives.	6	4
13	GMOs are part of the solution to the world's hunger problems.	6	4
14	Education is the single most important ingredient of development	6	4
15	There can be no lasting development without democracy	6	4
16	Uncontrolled migration may lead to social problems and negatively impact standards of living and economic growth.	6	4
17	Free movement of capital across borders is necessary for economic efficiency	5	5
18	If the environment were to be properly valued in monetary terms, a green economy would develop quite naturally.	5	5
19	The State cannot manage the commons effectively	5	5
20	A global nuclear phase-out is highly desirable	5	5
21	The world population is too large	5	5
22	We can change consumption behaviours by putting in place clever incentives	5	5
23	Markets deliver more choice for everybody.	5	5
24	Development aid entertains an assistance mentality that prevents developing countries from building critical own capacities to develop	4	6
25	The main role of government is to provide an enabling environment where private activities can flourish	4	6
26	Within-country distributional issues are separate from trade issues.	4	6
27	The sovereign right of States to exploit their own resources pursuant to their own environmental and	3	7

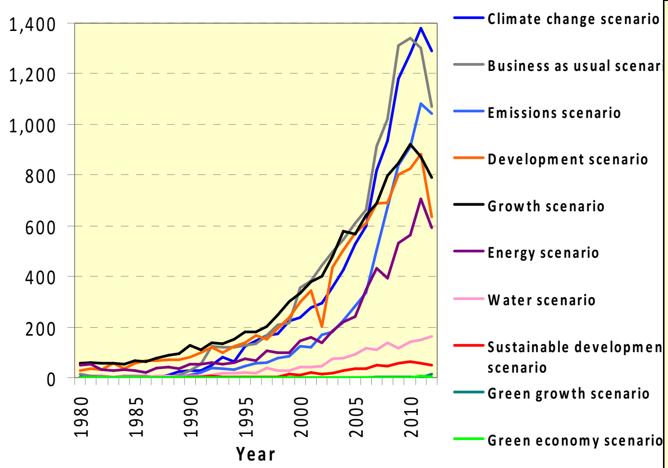
	developmental policies is now an obsolete notion because of global environmental problems such as climate change.		
28	The key to sustainable development is a combination of political will, finance and technology transfer to developing countries	3	7
29	A global shift to green technologies is going to create more jobs than a business-as-usual course of action	3	7
30	The best way of solving global environmental problems is through binding multilateral agreements	2	8
31	Developing countries like Brazil, India and China do not have an adequate voice in international institutions	2	8
32	Denmark is on the leading front of sustainability	2	8
33	Environmental integrity should supersede economic growth if sustainability is to be achieved.	2	8
34	The future of energy systems is in smart, small decentralised units running on renewables	2	8
35	Insufficient global commitment is the main reason for environmental degradation and unsustainable patterns of production and consumption.	1	9
36	Industry interests are the single most important obstacle to sustainable transformations.	1	9
37	Free trade is a win-win proposition; it should be the baseline of any discussion on trade and development	1	9
38	Climate change is the most pressing issue facing humanity today.	1	9
39	The international community should be pursuing global convergence of average income levels across all countries	1	9
40	In a sustainable world, corporations should be equal partners to governments and civil society.	0	10

Notes: Survey carried out in Vienna, Austria, on June 2011.

As illustrated earlier in this report, there are only a handful of global SD scenarios that at least aim to address a somewhat comprehensive list of SD objectives, despite the high-level of political attention to SD. Green growth and green economy scenarios focus on the how and explicitly exclude SD as objective. There is also no consensus on which limits we can overcome and on new possibilities in the future.

Figure 38 shows the number of academic articles -contained in Google Scholar- which refer to various types of scenarios. It shows the rapid increase in the overall number of scenario articles in the past 15 years. Until about seven years ago, most published scenarios were growth scenarios, Today, most published scenarios are climate change scenarios, emissions scenarios, or business as usual scenarios that are typically used as counterfactuals. There are also many growth scenarios, development scenarios and energy scenarios. Only a small fraction of scenarios deal with water or sustainable development. And there are almost no green economy or green growth scenarios, which is also evidence for the fact that these were more popular among policy makers than scientists or scenario analysts. At the same time, there were already a sizable academic literature on energy and sustainable development scenarios some 30 to 40 years ago.

Figure 38. Number of articles (contained in Google Scholar) on various types of scenarios.



Note: 2012 data is based on data from January to May and was adjusted proportionally for the remaining 7 future months of the year.

In line with the survey results presented above, technology is clearly considered the primary lever of choice among scenario drivers. This also appears evident from the fact that - in line with the IPAT identity (Ehrlich and Holdren, 1972; Waggoner and Ausubel, 2002) – impacts (I) can be addressed through focusing on any combination of driving forces population (P), affluence (A), consumption patterns (C) and technology (T). Since there is a wide range of resistance to limiting population, affluence or consumption, the only lever of choice remaining is technology (Box 11).

Box 11. The primacy of technology as lever of choice among scenario drivers

"Technological innovation, especially in the energy sector, is fundamental for establishing sustainable development given its concomitant economic, developmental, and environmental benefits. Economies-of-scale, R&D and learning-by-doing are the main mechanisms behind technological change, which are complementary yet inter-linked phenomena… Targeted efforts to promote deployment of new energy technologies play a major role… Even for maturing technologies that have displayed learning effects, market or resource constraints can eventually reduce the scope for further improvements in their fabrication or use. It appears likely that some technologies, such as wind turbines and photovoltaic cells, are significantly more amenable than others to industry-wide learning."

Bob van der Zwaan, private communication (2011).

7.3. Visions - what to sustain and develop? (Level 2)

No general, scientific consensus on "what to develop" and "what to sustain"

Sustainable development visions are rarely articulated. Some analysts are aware of their own vision, but shy away from being explicit about it in academic publications. While most analysts emphasize the importance of increasing political vision and will, they do not necessarily agree on its feasibility.

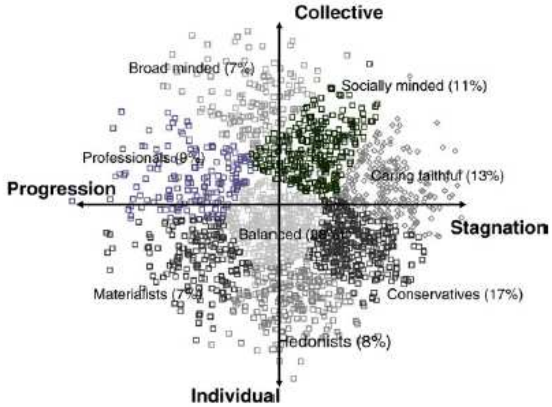
History highlights the complexity of global interlinked systems and the limits to what governments can do to change long-run trends ("slow variables"). There are instances of well-intended government policies that had unintended consequences in the aggregate. This may also be responsible for the mixed long-term progress on SD, with progress in some areas and worsening trends in others. In this context, it has not helped that the scientific SD assessment community has become increasingly separate from that of global scenario analysts who have increasingly focused on the short- to medium-term market-focused fixes (e.g., the "green economy").

There is no general scientific consensus on “what is sustainable development”, and consequently no consensus on global goals and targets, nor on what should be done and how. SD definitions are based on different sets of values that make up a worldview. Different values lead to different emphasis of what is to be sustained and what is to be developed, and for how long. However, a number of scientific sets of SD goals and targets have been suggested. Yet, strong a scientific consensus exists on certain issues (e.g., climate change) and communities.

7.3.1. Perspectives of scientists, scenario analysts, policy makers and the general public

De Vries and Petersen (2009) categorized the perspectives of individuals along four axes of a “value space”. Using these categories the value orientations of Dutch population were empirically measured. The results presented in Figure 39 show the very wide range of different values and resulting worldviews in the Dutch population. If such survey existed for the world, the resulting range would most certainly be even wider. In any case, it illustrates vividly why there cannot be full agreement on whether sustainable development should be the ultimate objective, nor on what sustainable development should entail.

Figure 39. Value orientations of Dutch population



Source: Aalber (2006, p. 18)

Worldviews of policy makers and scenario analysts are often grounded in scientific theory. With or without their knowledge, scientific theories provide a basis for worldviews that provide simple models of the world. Table 39 lists examples of important schools of economic thought, their basic tenets, objectives, associated sustainability concepts and their typically recommended types of strategies and policy instruments.

The majority of academia, civil society and policy makers in governments have worldviews that are more or less grounded in conventional (neoclassical) economics. In this view, the primary objective is economic growth maximization, with strategies focused on economic efficiency and progress measured by GDP. The current debate on the green economy is grounded in environmental economics where growth is still the objective, but adjusted for environmental and social costs, with strategies focus on eco-efficiency and internalization of environmental costs. Yet, the scientific community that has essentially created the paradigm of sustainable development has already moved on for decades and now follows a thinking grounded in ecological economics or even deep (human) ecology, which leads very different policy recommendations.

Since 1992, the international community has developed different visions of the world corresponding to different world views and approaches to addressing sustainable development. Prominent recent examples include the scenarios developed under IPCC; those currently developed under the Global Energy Assessment, and the push for a green economy promoted by UNEP. Yet, there is no one vision that would be acceptable to the great majority of governments of the world. Box 12 presents one of the latest efforts by the High-level Panel on Global Sustainability (convened by the UN Secretary General) to create a joint sustainable development vision in preparation for Rio+20. Yet, there was no global consensus possible even on such general vision.

Table 39. Schools of economic thought.

Objectives	Conventional	Environmental economics	Ecological economics	Deep (human) ecology

	(neoclassical) economic			
Basic tenets	Consumer sovereignty; frontier economics; utilitarian.	Consumer sovereignty, limited by government intervention and environmental costing; utilitarian.	Collective responsibility for protection of nature's assets; reformed utilitarian.	Equality of species; symbiotic relationship with nature; non-utalitarian.
Objectives	Profit, utility, welfare and economic growth maximization.	Profit, utility, welfare and growth maximization, taking environmental and social costs into account.	Reduced or zero growth rates; qualitative development.	Negative growth of economy and population.
Sustainability concepts	Produced capital maintenance (very weak sustainability)	Produced and natural capital maintenance (weak sustainability).	Dematerialization of the economy (relative strong sustainability)	Restoration and preservation of nature (strong sustainability).
Strategies and policy instruments	Economic efficiency; unfettered markets set environmental priorities.	Eco-efficiency; environmental cost internalization by market instruments.	Eco-efficiency and sufficiency; delinkage of growth and environmental impacts according to environmental norms and standards.	Sufficiency and consistency; command and control; moral suasion.
Assessment and monitoring	National accounts (GDP, capital formation, etc.)	Integrated environmental and economic accounts (environmentally adjusted economic indicators)	Material flow accounts (material input and output); indicators of sustainable welfare and development; indicators of human quality of life.	Assessment of carrying capacity and resilience of ecosystems; ecological footprint.

Source: Bartelmus, P. (2008, p.24).

Box 12. Vision of the UN Secretary General's High-level Panel on Global Sustainability

"The vision: a future worth choosing

A quarter of a century ago, the Brundtland report introduced the concept of sustainable development to the international community as a new paradigm for economic growth, social equality and environmental sustainability. It argued that sustainable development could be achieved by an integrated policy framework embracing all three of those pillars. Since then, the world has gained a deeper understanding of the inter-connected challenges we face, and the realization that sustainable development provides the best opportunity for people to choose their future. The High-level Panel on Global Sustainability argues that by making transparent both the cost of action and the cost of inaction, political processes can summon both the arguments and the political will necessary to act for a sustainable future. The long-term vision of the panel is to eradicate poverty, reduce inequality and make growth inclusive, and production and consumption more sustainable, while combating climate change and respecting a range of other planetary boundaries. in light of this, the report makes a range of recommendations to take forward the panel's vision for a sustainable planet, a just society and a growing economy."

UN Secretary General's High-level Panel on Global Sustainability (GSP, 2012, p.6)

Stereo-typical worldviews of scenario analysts and policy makers are also encapsulated in the SD21 "storylines" prepared by the project team (see Annex to this report). They include:

- *Business-as-usual world* that results from a continuation of current policies and practises primarily geared toward achieving a sufficiently high level of economic growth.
- *Dynamics-as-usual world* that results from a continuation of incremental progress, in line with historical trends and patterns.
- *Catch-up growth world* that continues to focus on growth, but with special efforts to achieve catch-up growth of the economies of LDCs and Africa.
- *Green economy/ green growth world* which focuses on growth and selective environmental objectives. Economic instruments are the preferred means to improve eco-efficiencies, in particular through "getting-prices-right" and additional public investments for clean technologies.
- *Climate change world* that sees climate change as the most important threat and takes decisive action in terms of mitigation and adaptation. Other objectives, such as development, are

increasingly formulated in terms of the climate policy goals.

- *Planetary boundaries world* that emphasizes action to ensure that humanity develops within a range of planetary boundaries (with climate change constituting one of them) to avoid global environmental collapse.

- *Development/MDG+ world* that emphasizes poverty reduction initiatives that primarily address social, education and health goals, but also take into account selected economic and environmental issues.

- *Sustainable development world* in which policy follows an integrated approach to economic, social and environmental goals, and major institutional change, with the overall goal of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

7.4. Goals and strategies – sustainable development goals? (Level 3)

Sub-optimal science-policy interaction in the selection of feasible, multiple goals and targets

Only in the past ten years have scenarios started explicitly detailing their implicit SD strategy, including in terms of goals and targets. Earlier strategies, goals and targets were known to good analysts but not necessarily reported explicitly. Yet, scenario analysis by the mid-1990s highlighted the higher performance of broad SD scenarios even for single issue objectives.[20]

A survey among modellers conducted in the context of the SD21 project showed only limited agreement on a comprehensive "shopping list" of goals, targets and policy means. Modellers are further constrained by the limitations of their models and typically choose practical subsets of goals/targets.

[20] For example, the IPCC-SRES B1 scenario is superior to most IPCC-TAR GHG mitigation scenarios, even in terms of lower GHG emissions and achieved at much lower costs.

SD scenarios typically follow SD definitions that are based on elements of nature, life support, people, and economy. Polarized views (two groups) dominate the debate on the binding nature of social limits and on whether it is desirable or feasible to change them, especially with respect to population issues. Only few proponents remain of changes in lifestyles, behavioural change, population control, and no-grow-strategies.

Contrasting views on synergies and trade-offs

A wide range of scenario pathways and action plans exist that exhibit contrasting views on synergies and trade-offs. There appears to be a continuum of views on new economic and financial possibilities and limits. Paradoxically, limits of affordability have been considered as more and more stringent, despite vastly increased global wealth compared to the past. Confusion over what are costs and benefits has increased. For example, in its latest report on a vision for 2050, WBCSD welcomed "costs" as tremendous "new market opportunities".

7.4.1. Perspectives of scientists, scenario analysts, policy makers and the general public

Scientists and stakeholders on SD goals

Definitions of sustainable development are essentially based on different sets of values that make up a worldview. The different choices of values lead to different emphasis of what is to be sustained and what is to be developed, as well as different relevant time scales. The table below is based on a literature review of sustainable development definitions (Table 40). Modellers are further constrained by the limitations of their models and choose practical subsets of goals/targets. SD scenarios typically follow SD definitions that are based on elements of nature, life support, people, and economy. Not much work includes the community and society dimensions.

Various communities of scientists and policy analysts have suggested sets of scientifically sound sustainable development goals and indicators. Some of them have been inspired by politics or linked to intergovernmental processes, whereas others followed a purely scientific, “tabula rasa” approach. The sets differ greatly, mainly due to different definitions of sustainable development and boundaries of academic disciplines.

There is no scientific consensus on “what is sustainable development, and consequently no consensus on global goals, targets, nor on what should be done and how. SD definitions are based on different sets of values that make up a worldview. Different values lead to different emphasis of what is to be sustained and what is to be developed, and for how long.

However, a number of scientific sets of SD goals and targets have been suggested. Some of them have been inspired by politics or linked to intergovernmental processes, whereas others followed avowedly a purely scientific, “tabula rasa” approach. The sets differ greatly, due to different SD definitions and boundaries of academic disciplines. The set by Parris and Kates appears to be the only truly comprehensive set in the literature (Table 41). It covers at least two of the six areas typically covered by sustainable development definitions: human needs and life support systems. In contrast, ecologists of the Russian Academy of Sciences have suggested one based on their insights on biotic regulation.

But there is a strong scientific consensus on certain issues (e.g., climate change) and communities. As a consequence, most scientific sets focus only on one or two themes (e.g., climate change) or one area (e.g., the global environment, as in the “planetary boundaries” suggestion).

Table 40. Literature review of sustainable development definitions

Values	What is to be sustained?	For how long?	What is to be developed?
Freedom Equality Solidarity Tolerance Respect for nature Shared responsibility ….	**(S1) Nature** Earth Biodiversity Ecosystems	5, 10, 20, 50, 100 years, forever, etc.	**(D1) People** Child survival Life expectancy Education Equity, Equal opportunity Human security
	(S2) Life support Ecosystem services Resources Environment		**(D2) Economy** Wealth Productive sectors Consumption
	(S3) Community Peace Cultures Groups Places		**(D3) Society** Institutions Social capital States Regions

Note: Adapted from NRC (1999) and Kates et al. (2005).

Sustainability Science

By the late 1990s, “sustainability science” emerged as a discipline with the objective to tear down the disciplinary boundaries to build a comprehensive, rigorous and authoritative body of knowledge on the science of sustainable development. Based on an in-depth review of global progress toward sustainable development conducted by the US National Academy of Sciences in preparation for the Johannesburg Summit in 2002, Parris and Kates (2003) identified a minimum set of goals, quantitative targets and associated indicators that are scientifically sound and based on or inspired by “*consensus embodied in internationally negotiated agreements and plans of action*” (p.1) (Parris and Kates, 2003) (Table 41). Such approach would, of course, be the most preferred to prepare a draft of sustainable development goals for negotiations. Yet, to the best of our knowledge, the set by Parris and Kates is the only comprehensive set in the literature. It covers at least two of the six areas typically covered by sustainable development definitions: human needs (D1) and life support systems (S2).

"Planetary boundaries" suggested by Earth System Science

Most scientific sets focus only on one subsets of one of the six SD areas listed in Table 40. A set of "planetary boundaries" has recently attracted much attention by Governments. This set aims to be comprehensive with respect to the global environment, i.e., covers much of S1. It illustrates the idea that human activities have reached a scale where planetary boundaries are being breached. The boundaries were defined based on estimated critical system levels. The first three planetary boundaries highlighted in pink in Table 41 have already been breached.

Table 41. Minimum set of scientifically sound goals, targets and indicators based to the extent possible on internationally agreed commitments.

	Goal	Target	Indicator	Ref.
Human needs (D1)	Improve health	Reduce to 1/3 of 1990 rate by 2015	Childhood mortality	IMF, OECD, WB (2010)
	Provide education	Reduce illiteracy to ½ of 2000 rate by 2015	Literacy	
		Eliminate gender disparities in primary and secondary education by 2005	Male-female secondary enrolment rates	
	Reduce hunger	Reduce prevalence to ½ of 2000 levels by 2015	Prevalence of undernourishment	MDG (2000)
		Virtual elimination of vitamin A deficiency and its consequences, including blindness, by 2000	Prevalence of vitamin A deficiency	WSfC (1990)
	Reduce poverty	Reduce the proportion of the world's people whose income is <$1/day to ½ of 2000 rate by 2015.	Poverty rate	MDG (2000)
	Provide housing	Ensure that 75% of the urban population are provided with on-site or community facilities for sanitation by 2000	Access to improved sanitation services	Rio (1992)
Life support (S2)	Reduce emissions of atmospheric pollutants	Reduce overall emissions of greenhouse gases by at least 5% below 1990 levels by 2008-2012	Greenhouse gas emissions	Kyoto (1997)
		Reduce SO_x emissions (target varies by agreement)	SO_x emissions	ECE (1985, 1994, 1999), IJC (1991).
	Stabilize ocean productivity	Not stated	Biological community condition	
	Maintain fresh water availability	Not stated	Consumptive fresh water withdrawal	
	Reduce land use/cover change	Not stated	Land use/cover change	
	Maintain biodiversity	Not stated	Land use/cover change in biodiversity hotspots	
	Reduce emissions of toxic substances	Reduce or eliminate releases from unintentional production as measured by toxic equivalency units	Dioxin and furan emissions	

Note: Adapted Parris and Kates (2003b).

Table 42. Planetary boundaries (S1)

	Goal	Earth system process	Indicator	Target boundary	Current status	Pre-industrial
Nature (S1)	Stay within planetary boundary	Climate change	Atmospheric CO_2 concentration (ppmv)	350	387	280
			Change in radiative forcing (W/m^2)	1	1.5	0
		Rate of biodiversity loss	Extinction rate (number of species per million species p.a.)	10	>100	0.1-1

		Nitrogen cycle	Amount of N_2 removed from the atmosphere for human use (mill. t/a)	35	121	0
		Phosphorus cycle	Quantity of P flowing into the oceans (mill. t/a)	11	8.5-9.5	-1
		Stratospheric ozone	Concentration of ozone (Dobson unit)	276	283	290
		Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
		Global freshwater use	Consumption of freshwater by humans (km^3/a)	4000	2600	415
		Change in land use	Share of global land cover converted to cropland	15%	11.7%	Low
		Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	To be determined		
		Chemical pollution	e.g., amount emitted to, or concentration of POPs, plastics, endocrine disrupters, heavy metals and radioactive waste	To be determined		

Note: The nitrogen and phosphorus cycles are part of the same planetary boundary.
Source: Rockstroem et al. (2009).

Economists and national planners have suggested many national goals and targets with respect to the economy (D2), but not a single global goal or target could be identified. Furthermore, not a single set developed by scientists or policy analysts could be identified that would have aimed to capture community (S3) and society (D3) themes.

"Biotic regulation": ecologists in the Russian Academy of Sciences

Ecologists at the Russian Academy of Sciences have followed a rather different approach. They have shown the overarching importance of conserving the biotic regulatory function which is primarily based on the health of a complex system of micro-organisms. As humanity destroys this system through conversion of land, the biotic regulatory function cannot be restored at sufficiently rapid speed. This community suggests as high priority sustainable development goals to: (a) reduce population; and (b) to drastically increase areas under conservation and rapidly to reforest.

An important conclusion from this perspective is that most of the currently preferred, technology-focused policies and solutions are unsustainable. Conservation and restoration of damaged ecosystems must be the primary focus. In this view, GHG mitigation through modern renewables is a stark example of misguided policies where low power density options are promoted which will further destroy the biotic regulatory functions and hence greatly accelerate rather than slow anthropogenic climate change in the long-term.

Physics and complexity science

Murray Gellman and colleagues working on complexity science and physics are in the process of developing a theory of sustainable development. Initial results indicate the special role of cities, networks and innovation. Hence, in this perspective humanity should dedicate its resources on accelerating innovation and spatial planning of a global network of mega-cities.

Policy makers on SD goals

How do these SD goals suggested by scientific communities compare with those of policy makers? Next, we illustrate the latter through a brief review of goals and targets that are either internationally agreed at present, or were suggested in preparatory process for Rio+20.

There are hundreds of time-bound, measurable goals and targets that have been agreed internationally in various fora. Table 43 lists selected internationally agreed goals and targets in the areas of health and education. Hundreds of these goals and targets have been identified in a range of sectors and themes in the issue notes for Rio+20.[21]

Table 44 lists the priority themes, clusters and related goals identified in selected documents from Member States, the UN, and civil society, in the

[21] see http://www.uncsd2012.org/rio20issuesbriefs.html

context of the preparatory process for Rio+20 from 2011 to 2012. It provides a glimpse of priority issues for Governments.

Table 45 provides a list of SDGs that were suggested for adoption in the preparatory process for Rio+20.[21] Table 46 shows the priority areas for SDGs officially suggested by Governments Dec. 2012.

Table 43. Selected, internationally agreed goals and targets, in the areas of health and education.

Issue	Goal/target	Target date	Source
Health	…eliminate guinea worm disease (dracunculiasis); …eradicate polio; …effectively control onchocerciasis (river blindness) and leprosy; …provide health and hygiene education and to ensure universal access to safe drinking water and universal access to sanitary measures of excreta disposal, thereby markedly reducing waterborne diseases such as cholera and schistosomiasis and reducing: ….the number of deaths from childhood diarrhoea in developing countries by 50 to 70 per cent; and …the incidence of childhood diarrhoea in developing countries by at least 25 to 50 per cent; …to initiate comprehensive programmes to reduce mortality from acute respiratory infections in children under five years by at least one third, particularly in countries with high infant mortality; …to provide 95 per cent of the world's child population with access to appropriate care for acute respiratory infections within the community and at first referral level; …to institute anti-malaria programmes in all countries where malaria presents a significant health problem and maintain the transmission-free status of areas freed from endemic malaria; …to implement control programmes in countries where major human parasitic infections are endemic and achieve an overall reduction in the prevalence of schistosomiasis and of other trematode infections by 40 per cent and 25 per cent, respectively, from a 1984 baseline, as well as a marked reduction in incidence, prevalence and intensity of filarial infections;	2000	A21 (6.12)
	…reduce measles deaths by 95 per cent and reduce measles cases by 90 per cent compared with pre-immunization levels;	1995	
Health	…to incorporate appropriate environmental and health safeguards as part of national development programmes in all countries; …to establish, as appropriate, adequate national infrastructure and programmes for providing environmental injury, hazard surveillance and the basis for abatement in all countries; …to establish, as appropriate, integrated programmes for tackling pollution at the source and at the disposal site, with a focus on abatement actions in all countries;	2000	A21 (6.40)
Health	54. (e) Promote and develop partnerships to enhance health education with the objective of achieving improved health literacy on a global basis by 2010, with the involvement of United Nations agencies, as appropriate;	2010	JPOI ch. IV
	54. (f) Develop programmes and initiatives to reduce, by the year 2015, mortality rates for infants and children under 5 by two thirds, and maternal mortality rates by three quarters, of the prevailing rate in 2000, and reduce disparities between and within developed and developing countries as quickly as possible, with particular attention to eliminating the pattern of disproportionate and preventable mortality among girl infants and children;	2015	
	55. Implement, within the agreed time frames, all commitments agreed in the Declaration of Commitment on HIV/AIDS adopted by the General Assembly at its twenty-sixth special session, emphasizing in particular the reduction of HIV prevalence among young men and women aged 15 to 24 by 25 per cent in the most affected countries by 2005, and globally by 2010, as well as combat malaria, tuberculosis and other diseases….	2010	
Health	1C. Halve, between 1990 and 2015, the proportion of people who suffer from hunger 4.A. Reduce by two thirds, between 1990 and 2015, the under-five mortality rate 5.A. Reduce by three quarters the maternal mortality ratio 5.B. Achieve universal access to reproductive health 6.B. Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it 6.C. Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases 6.A. Have halted by 2015 and begun to reverse the spread of HIV/AIDS 8.E. In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries	2015	MDG
Health	Achieve a 10 to 40 per cent improvement in [urban] health indicators by the year 2000. [para. 6.33 mentions the need to develop specific targets for indicators such as infant mortality, maternal mortality, percentage of low-birth-weight newborns, diarrhoeal diseases, tuberculosis, industrial and transportation accidents, drug abuse, violence and crime.]	2000	A21 ch.6
Life in slums	10. To achieve a significant improvement in the lives of at least 100 million slum dwellers, as proposed in the 'Cities without slums' initiative.	2020	JPOI ch. II

Education	25.5 Each country…should ensure that more than 50 per cent of its youth, gender balanced, are enrolled in or have access to appropriate secondary education or equivalent educational or vocational training programmes by increasing participation and access rates on an annual basis.	2000	A21 (25.5)
Education	116 (a) Meet the Millennium development goal of achieving universal primary education, ensuring that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling; 120. Eliminate gender disparity in primary and secondary education by 2005, as provided in the Dakar Framework for Action on Education for All, and at all levels of education no later than 2015, to meet the development goals contained in the Millennium Declaration, with action to ensure, inter alia, equal access to all levels and forms of education, training and capacity-building by gender mainstreaming, and by creating a gender-sensitive educational system.	2015	JPOI ch.X
Education	(e) Support the development of national programmes and strategies to promote education within the context of nationally owned and led strategies for poverty reduction and strengthen research institutions in education in order to increase the capacity to fully support the achievement of internationally agreed development goals related to education, including those contained in the Millennium Declaration on ensuring that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling and that girls and boys will have equal access to all levels of education relevant to national needs;	2015	JPOI ch.VIII
Education	2.A. Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling 3.A. Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	2015	MDG

Source: Rio2012 issues notes; Stakeholder Forum (2012).

Table 44. Priority themes/clusters and related goals identified in selected documents from Member States, the UN, and civil society.

Themes identified	**Colombia and Guatemala**[a]	**Brazil**[b]	**EU**[c]	**DESA official speeches**[d]	**Stakeholder Forum**	**High-level Panel on Global Sustainability**
Sustainable consumption and production patterns	X	X			X	
Combating poverty	X	X				
Promoting sustainable human settlement development	X	X		X		
Biodiversity and forests	X		X		X	
Oceans and marine resources	X	X	X	X	X	X
Clean water	X	X	X	X	X	X
Advancing food security and sustainable agriculture	X		X	X	X	X
Energy, including from renewable sources	X	X	X	X	X	X
Economy for sustainable development		X				
Innovation		X				
Green jobs and social inclusion				X		
Improved resilience and disaster preparedness				X		
Waste management			X			
Sustainable livelihoods, youth and education					X	
Decent jobs						X
Climate sustainability					X	
Green cities					X	
Subsidies and investment					X	
New indicators of progress					X	
Access to information					X	
Access to redress and remedy					X	
Environmental justice for the poor					X	
Basic health					X	

Notes: a: Source: Colombia, Ministerio de Relaciones Exteriores, Rio+20: sustainable development goals, a proposal from the Governments of Colombia and Guatemala.
b: Source: personal notes of James Tee from the meeting in Brazil
c: Source: European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions, Rio+20:towards the green economy and better governance, Brussels, 20 June 2011, COPM(2011) 363 final
d: Source: Sha Zukang, speech to the National Press Club Event, 18 june 2011, as delivered

Table 45. List of all suggested SDGs in the preparatory process for Rio+20, 2011-2012.

		Issue	Goal/target	Target date	Elements suggested by
What is to be developed?	People (D1)	Poverty reduction	• Eradication of extreme poverty [Brazil] (see by MDG1) • Include other dimensions of poverty [El Salvador]	?	UNISDR, Blueprint for Oceans and Coastal Sustainability, UNDP
		Food and nutrition security	• By 2020, 20% increase in total food supply-chain efficiency – reducing losses and waste from field to fork [Stakeholder Forum for a Sustainable Future]	2020	Brazil, Japan, Liechtenstein, Rep Korea, ECLAC, UNISDR, Specialist Group on Soils and Desertification of the IUCN Commission on Environment
		Social protection and employment	• Access to decent work, socially fair and environmentally correct [Brazil]; • All governments have, as a minimum a Social Protection Floor in place by 2020 [International Trade Union Confederation].	2020	Brazil, International Trade Union Confederation, Rio+20 Earth Summit Sustainable Cities Working Group
		Equity	• ?	?	ECLAC, UNDP, ITU, Oxfam
		Energy access	• By 2030, universal access to modern, clean and affordable energy services		UNIDO, World Bank, Oxfam, APRODEV and Act Alliance, Stakeholder Forum for a Sustainable Future, Liechtenstein, ECLAC, UN-DPI, UNDP, UNIDO, Brazil, Indonesia – Solo, Kenya, IAEA
		Access to sustainable transport	• Ensure universal access to sustainable transport through support for safe, affordable public transport and safe, attractive facilities for walking and bicycling [Rio+20 Earth Summit Sustainable Cities Working Group]. • Cut traffic-related deaths in half by 2025.	2025	
		Access to safe water	• by 2030, universal access to safe drinking water [Brazil, Kenya, Liechtenstein, UNICEF, ECLAC, World Bank, UN-Habitat, UNSGAB, UN-Water] and adequate sanitation [UNICEF, ECLAC, World Bank, UN-Habitat, UN-Water]; • drinking water networks to supply water continuously (24/7) in order to ensure safety and availability of water [UNSGAB];	2030	
		ICT access	• Access to ICT and broadband [ITU] – related to MDG 8, target 8.F • increase of ICT in public schools [El Salvador] • By 2020, every major city should become a “smart” city that enables all of its residents to have electronic access to sustainability data and governmental decision-making [Rio+20 Earth Summit Sustainable Cities Working Group]		ICAO
		Access for women	• Promote women’s access to services and technologies needed for water, energy, agricultural production,		

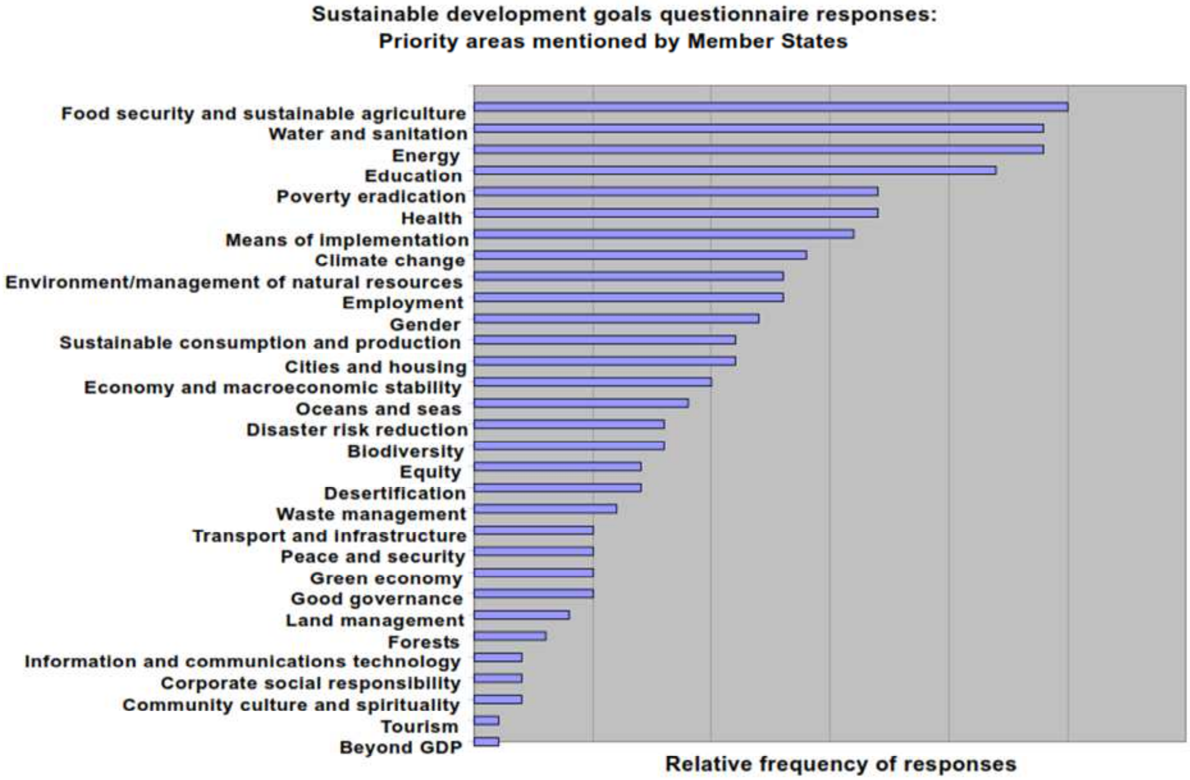
			family care, household management and business enterprises [Women];		
		Life in slums	• By 2030, halve the proportion of people living in slums [UN-Habitat]; • Prevent the formation of new slums [UN-Habitat]; • By 2030, Improve the lives of urban dwellers by significantly increasing their life expectancy and access to decent work by 20% [UN-Habitat]	2030	
		Health	• Replace "combat" by "prevention" in MDG 6 [El Salvador]; • Combat communicable diseases [Liechtenstein] – covered by MDG 6 • Universal access [Liechtenstein] • Combat non-communicable diseases [Liechtenstein], • Link environment and human health [Liechtenstein]; impact of pollution on human health [Russian Fed, Canada]		
		Child health	• Sufficient resources devoted to child malnutrition [El Salvador] • Reduce child mortality [Liechtenstein]		
		Maternal health	• Provide safe health care facilities, including for sexual and reproductive health [Women]; • More adequate hospital network coverage [El Salvador]		Liechtenstein, UNFPA
		Women	• women's quality of life and women-biased informal employment [El Salvador]; • Secure women's greater access and control over assets, land tenure, inputs and natural resources including traditional common lands [Women]; • Provide comprehensive social protection measures, especially for women [Women]; • Enable women and men to combine their jobs with childcare [Women]; • Support investments in women's economic, social and political empowerment, including through new financing and credit facilities accessible to women [Women]; • Support for traditional knowledge systems and management practices [Women];		
		Education	• Integrated education for sustainable development [Liechtenstein] • green skills training [Liechtenstein] • Include delinquencies and social insecurity situations [El Salvador]; • Universal education [Liechtenstein] – Universal primary education is covered by MDG2		Liechtenstein, UN-DPI, Interagency Committee on DESD, Stakeholder Forum for a Sustainable Future, UNFPA
		Youth	?		UN-DPI, Stakeholder Forum for a Sustainable Future
	Economy (D2)	Sustainable agriculture	?	?	Liechtenstein, Rep Korea, UN-DPI, Stakeholder Forum for a Sustainable Future
		Green growth	?	?	Liechtenstein, Rep Korea
		Green jobs	• To ensure that at least half of the workers of the world have decent jobs by 2020 [International Trade Union Confederation];	2020	International Trade Union Confederation, Rio+20 Earth Summit Sustainable

			• A country by country self-identified target on decent and green jobs to be reached in the next 5-10 years, accompanied by a package of decent work policies to secure jobs quality - this target should help at least doubling the number of 'green and decent jobs' [International Trade Union Confederation];		Cities Working Group
		Green cities	• Green cities [UN-DPI, Business and Industry, Stakeholder Forum for a Sustainable Future] that are environmentally sustainable, socially responsible and economically productive [UN-Habitat] and sustainable human settlements [Brazil, UK, UNISDR]; • In urban locations, increase public space up to 30% through adequate planning, land use and building regulations by 2030 [UN-Habitat]; • Reduce cities' ecological footprints by reducing greenhouse gas (GHG) emissions by 30%, increasing the share of renewal energy sources by 30%, improving energy efficiency in all public buildings by 20% and doubling access to public transport and non-motorized transport infrastructures by 2030 [UN-Habitat]; • Reduce urban poverty [World Bank]		
		Efficient energy system	• Improve energy intensity or efficiency [ECLAC, ITU, Russian Fed, Canada], increase energy efficiency in buildings and appliances [World Bank] by doubling the rate of improvement in energy efficiency [UNIDO, World Bank] – increasing the current pace of improvement to 2.5 percent per year, achieving a 30 or 40 percent reduction in global energy intensity by 2030 [UNIDO (40), Oxfam (30)]; • By 2020 energy demand is reduced through efficiency and conservation by at least 20% [Stakeholder Forum for a Sustainable Future] • Reduce energy losses in generation and distribution [World Bank];	2030	
		Eliminate environmentally harmful subsidies	• Eliminate direct and indirect subsidies to fossil fuels [ECLAC, UN-DPI]; • By 2020, eliminate subsidies to activities associated to environmental destruction and harmful to biodiversity [ECLAC, IUCN]	2020	
	Society (D3)	Institutions / Justice	• Access to redress and remedy [UN-DPI, Stakeholder Forum for a Sustainable Future] • Environmental justice for the poor and marginalized [UN-DPI, Stakeholder Forum for a Sustainable Future]	?	UN-DPI, Stakeholder Forum for a Sustainable Future
		Equality	• Equality – intra-generational, inter-generational, among countries and within them [Brazil]		
		Women	• Determine specific targets for women with regard to technology training, business management skills and extension services [Women]; • Promote women's participation in government and business leadership, with targets of at least 40% women [Women]; • Strengthen women's organizations/self help groups, entrepreneurs and networks to enable them to negotiate the terms of their engagement with sustainable development projects [Women]; • Develop in-house capacities for gender mainstreaming within implementing agencies and local partners [Women].		Brazil, UN-Women, UNFPA, Women

			• Access to information [Liechtenstein, UN-DPI, UNGIS, Stakeholder Forum for a Sustainable Future]: • Public participation [Liechtenstein, UN-DPI, UNGIS, UNV, Stakeholder Forum for a Sustainable Future] • Empowering People for Sustainable Development Governance [Rio+20 Earth Summit Sustainable Cities Working Group] • Inclusion [UNDP, ITU, Oxfam]		
What is to be sustained?	**Nature (S1)**	Planetary boundaries	• Adjustment of the ecological footprint to the planet's capacity of regeneration [Brazil] • Sustainable consumption and production [Liechtenstein, UK, UN-DPI, UNISDR, Stakeholder Forum for a Sustainable Future] • Sustainable livelihoods [UN-DPI]	?	Brazil, Liechtenstein, UK, UN-DPI, UNISDR, Stakeholder Forum for a Sustainable Future
		Renewable energy	• By 2030, at least 50% of the world's energy supply comes from renewable sources [Stakeholder Forum for a Sustainable Future] or, by 2030, double the share of renewable energy in the global energy mix by 2030 [IRENA, UNIDO, World Bank] • Carbon free power sector [IRENA]; • Ensure global transport greenhouse gas emissions and transport sector fossil fuel consumption peak by 2020 and are cut by at least 40 percent by 2050 compared to 2005 levels, while ensuring transport contributes to timely attainment of healthful air quality	2020, 2030, 2050	
		Biodiversity	• Establishment of marine protected areas [Liechtenstein, Blueprint for Oceans and Coastal Sustainability]; • Ensure that biodiversity targets are relevant for business [Business and Industry] • Reduce biodiversity loss [Liechtenstein]; - covered by MDG 7, target 7B		
		Climate change	• Reduction of GHG emissions; - related to MDG 7 indicator 7.2 (CO2 emissions) • Share of trips taken by low carbon modes of transportation [World Bank]		CARICOM, Japan, Liechtenstein, Rep Korea, UK, UN-DPI, UNISDR, UNOPS, Blueprint for Oceans and Coastal Sustainability, Stakeholder Forum for a Sustainable Future
	Life support (S2)	Desertification and land degradation	• To achieve a zero net land degradation [Collaborative Partnership on Forests, UNCCD]; • To restore 150 million hectares of degraded lands by 2020 [Collaborative Partnership on Forests]	2020	Rep Korea, Russian Fed, Canada, Collaborative Partnership on Forests, World Bank, Specialist Group on Soils and Desertification of the IUCN Commission on Environment
		Forests	• Sustainable management and good governance of forests [Liechtenstein]; • Restoration of over 150 million hectares of cleared or degraded forest landscapes is achieved by 2020 [Stakeholder Forum for a Sustainable Future]; • A policy of no net loss of forestland, globally and nationally, is achieved by 2020 [Stakeholder Forum for a Sustainable Future] • halt and reverse forest loss [Liechtenstein]; (see MDG 7)	2020	Liechtenstein, UN-DPI, UNISDR, Stakeholder Forum for a Sustainable Future
		Air pollution	• Reduce atmospheric pollution in urban centers		

			[ECLAC]; • Improved air quality [World Bank]		
		Natural resources	• Resource productivity and resource efficiency in key economic sectors and industries, such as energy, industry, transport [UNIDO]		Russian Fed, Canada, UK, UNIDO, Business and Industry
		Fisheries	• Fisheries [Rep Korea]		
		Water	• sustainable water management [Liechtenstein, ECLAC, UNIDO], • reduced water pollution [Liechtenstein], • By 2020, 20% increase in water use efficiency in energy production – more kWh per drop [Stakeholder Forum for a Sustainable Future]; • By 2020, 20% increase in the quantity of water reused [Stakeholder Forum for a Sustainable Future]; By 2020, 20% decrease in water pollution [Stakeholder Forum for a Sustainable Future]; • reduce the amount of water pollution arising from agriculture [UNSGAB]; • reduce the amount of water pollution released by industry • Improved water quality [World Bank]		
		Water in agriculture	• Increase water productivity in agriculture [Liechtenstein]; By 2020, 20% increase in water efficiency in agriculture – more nutrition and crop per drop [Stakeholder Forum for a Sustainable Future]; • Irrigated agriculture to grow more food with the same amount of freshwater and without overabstracting water tables [UNSGAB]; • 70% of irrigated land using technology that increases crop per drop by 20xx [UNSGAB]; • Organizing urban use of water to allow its reuse in agriculture in all water scarce areas [UNSGAB];		
		Waste water	• double the availability and use of waste water treatment and solid waste management services by 2030 [UN-Habitat]; • reduce the percentage of wastewater that is not collected safely from households [UNSGAB]; • reduce the percentage of wastewater that is discharged into the natural environment without treatment [UNSGAB]; • increase the percentage of urban wastewater that is treated for safe reuse in agriculture and industrial processes [UNSGAB];	2030	

Table 46. Priority areas for SDGs officially suggested by Governments Dec. 2012.



Source: SG report A/67/634, Dec. 2012.

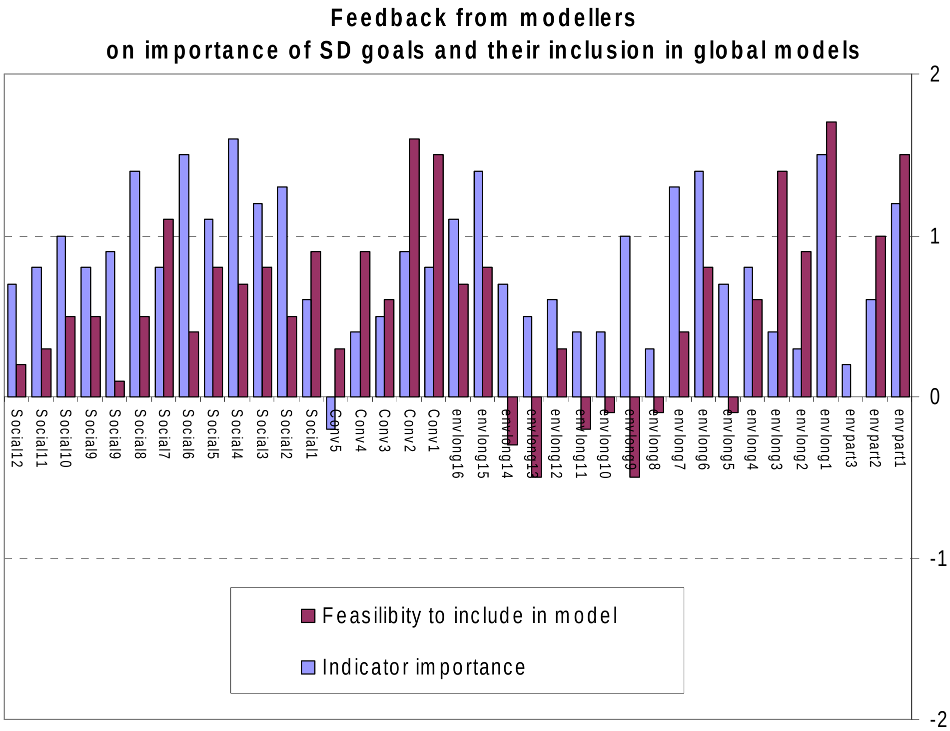
7.4.2. Scenario analysts

Earlier in this section, a survey conducted among scenario analysts and modellers in the context of the SD21 project was mentioned. The comprehensive "shopping list" of goals, targets and policy means contained in Table 47 was distributed among the scenario analysts and modellers contributing to the SD21 project in 2011. The list contains environmental, economic and social goals that are typically referred to in the global debate on sustainable development. Some of them have been internationally agreed, others have been suggested by scientists or analysts. Environmental goals that followed a typical green economy perspective were indicated as a separate group, in view of the high profile of the green economy concept as one of the two main topics of Rio+20.

The results of the survey are detailed in Figure 40. It should also be noted that the overall result showed only limited agreement on both the importance and feasibility to include these goals into the scenario modelling exercise. Also, it appears that there remain only few proponents of changes in lifestyles, behavioural change, population control, and no-grow-strategies.

Scenario modellers generally rated social goals important, but indicated that they are difficult to implement in the model. Similarly, a few long-term environmental goals relating to, e.g., pollution from minerals extraction, water use, and deforestation were considered very important, but difficult to implement in the model. On the other hand, a number of the economic and green economy-related goals and targets are considered relatively easy to include in the models, yet are considered less important. Modellers are further constrained by the limitations of their models and typically choose practical subsets of goals/targets. The consequences of modellers' preferences and model constraints are illustrated by the list of goals and targets actually implemented in the global scenarios for Rio+20, as evidenced by the review Table 31 .

Figure 40. Result of SD21 survey among scenario modellers



Note: Abbreviations of goals are detailed in Table 47.

Table 47. "Shopping list" of goals, targets and policy means used in the SD21 survey among modellers.

Theme	Sub-theme	Possible target for endpoint	Comment	Code
Green economy	Relative decoupling	Resource efficiency and energy efficiency of production doubled (or quadrupled) compared to historical trends (sector by sector)		envpart1
	Price system	Elimination of subsidies for fossil fuels, agriculture, and fisheries	Ex-post taken into account in many energy-economy-environment models	envpart2
	Investment in natural assets	One percent of GDP invested in restoration and maintenance of natural assets	Various ways of indirect or direct modelling of such elimination used.	envpart3

Long-term environmental	GHG concentration in atmosphere (in CO_2-eq.) and emissions	GHG concentration stabilization at: (a) 350 ppmv; (b) 450 ppmv; (c) 650 ppmv	(a) Rockstroem et al. (2009); (b) UNFCCC Cancun 2011: Limit global average temperature change to 2°C above pre-industrial levels by 2100 with a probability of greater 50%. Also GEA 2011.Target in terms of temperature perhaps more conflictual due to uncertainty on climate sensitivity parameter.	envlong1
		Energy imbalance:+1 W/m^2	Rockstroem et al. (2009)	envlong2
		GHG emissions <3 tCO_{2-eq}. for all people on the planet by 2050	WESS 2011	envlong3
	Land use	<15% of global ice-free land surface converted to cropland.	Rockstroem et al. (2009). Millennium Ecosystem Assessment (2005) ("Prevent another 10-20% conversion of grassland and forests from 2000 to 2050")	envlong4
	Water use	Global freshwater use: <4000 km^3 per year.	Rockstroem et al. (2009)	envlong5
	Deforestation	Net deforestation (in flow) <=0 in 2050 and beyond; or:	CBD (2010). Both flows and stocks are important.	envlong6
		Total net forest cover lost by 2050 <= XX percent or hectares		envlong7
	Ocean acidification	Sustain 80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability.	Rockstroem et al. (2009)	envlong8
	Biodiversity	<10 extinctions per million species per year (E/MSY); or number of identified biodiversity hotspots unaffected by land use change.	Rockstroem et al.(2009). CBD (2010). Hard to include directly in most models - land use and LUC may be the best proxies. Necessary to track at least at the regional level. (ideal = agro-ecological zone).	envlong9
	Anthropogenic interference with the P and N cycles	P: < 10× natural weathering inflow to oceans.	Rockstroem et al. (2009)	envlong10
		N: Limit industrial and agricultural fixation of N_2 to 35 Mt N per year, which is ~ 25% of the total amount of N^2 fixed per annum naturally by terrestrial ecosystems.	Rockstroem et al. (2009)	envlong11
	Stratospheric ozone depletion	<5% reduction from pre-industrial level of 290 DU.		envlong12
	Pollution from minerals extraction	????	Not sure how this is tracked, if at all. and what are the assumptions on changes over time.	envlong13
	Chemical pollution	Decrease the concentration of POPs, plastics, endocrine disruptors, heavy metals, and toxic waste.	JPOI, Stockholm, Rotterdam, Basel. Probably included in very few IAMs if any . Need to identify if included in at least one model.	envlong14
	Regional air pollution	Critical loads of SO_x and black carbon.	Take from RAINS model and European air pollution conventions.	envlong15
		No country-sized “brown clouds"	Take from RAINS model and European air pollution conventions.	envlong16

Economic	GDP convergence across regions	Inter-country differences in GDP per capita between all countries by 2100 not different from those which prevailed between OECD countries in 1990.	IPCC SRES.	Conv1
	Specific focus on Africa and LDCs	Africa catches up with the other developing regions (in terms of GDP per capita); or absolute goal (GDP/capita in 2050 > XX).	To mimic the "special attention" given to Africa in JPOI, various initiatives, and the fact that most LDCs are in Africa.	Conv2
		All LDCs graduate by 2020.		Conv3
	Energy use	Primary energy use: < 70GJ/cap for all people on the planet by 2050.	Energy chapter of WESS 2011	Conv4
	Trade	No customs tariffs by ??. NTBs reduced to xx by xx?	See WTO agenda.	Conv5
Social	Global income inequality	I90/I10 from world income distribution does not rise	Problem: more an issue of allocation/ distribution than production. how is that covered in IAMs ?	Social1
	Poverty	People suffering from hunger <= XX in 2050		Social2
		Absolute poverty <=XX people	Issues with definitions, PPPs, measurement, etc.	Social3
	Primary education	Universal access by 2050	One of the MDGs	Social4
	Access to modern energy	Universal access to electricity and modern cooking fuels by 2030	JPOI; GEA 2011; and Recommendation of SG's advisory group on energy can climate change	Social5
	Access to drinking water and sanitation	Universal access by 2050	MDG, JPOI	Social6
	Population	Global population growth rate negative by 2050		Social7
	Education	Sustain universal primary education by 2050	MDG	Social8
	Gender	Global gender equality by xx?	MDG	Social9
	Health impacts of pollution	Reduce premature deaths due to air pollution by 50 per cent by 2030.	GEA 2011.	Social9
		Reduce child mortality	MDG	Social10
		Improve maternal health		Social11
		Combat HIV/AIDS, malaria and other diseases		Social12

7.5. Policies and action plans – for sustainable development? (Level 4)

A wide range of scenario pathways and action plans are suggested, with contrasting views on synergies and trade-offs. There is a continuum of views on new economic and financial possibilities and limits. Paradoxically, limits of affordability are seen as more and more stringent, despite vastly increased global wealth compared to a few decades ago. Confusion over what are costs and benefits has increased (e.g., WBCSD welcomed "costs" as tremendous "new market opportunities").

7.6. Implementation – project assessment and investment for sustainable development? (Level 5)

While views used to be polarized on what would be technologically feasible, the importance of technology as the single most important policy lever of choice for SD has become the most visible agreement among modellers today, which was also confirmed by the SD21 survey.

Mainstream views have become more technologically optimistic, but are sharply divided over the potentials of various groups of technologies (e.g., nuclear vs. modern renewables). Some techno-optimistic views of specific preferred technologies have at times even disregarded scientific-physical limits set by the laws of nature.

While modellers' messages have tended to move to echoing policy makers' conservative views, in particular on political will, technology, finance, capacity building, and green economy, parts of the business community today have progressed to more nuanced messages going far beyond the earlier technology and eco-efficiency-focused messages echoing the dominant position among modellers 20 years ago, as evidenced by WBCSD.

Similarly, there is also a very wide range of estimates of "investment needs".

Rise of a scenario model industry

A rise of a donor-driven global scenario model "industry" has been witnessed in the past 20 years. This "industry" has arisen with many players and separate communities tailoring for their donor communities. Increasingly, extra-budgetary donors have dictated the topics and focused resources on model applications designed to confirm the donor's preferred policy messages.

Continuing under-investment in "basic" research, model methodologies and model development has been observed for decades. Expenditures have increasingly focused on applications rather than basic research, methodologies or model development. Yet, global scenario models remain essential for exploring options, ensuring the coherence and feasibility of SD goals, visions, strategies, action plans and their implementation. Hence the need for more focused support separated from politics.

7.7. Summary of agreement on the five levels

Table 48 summarizes the findings of this section on the level of agreement among and between scenario analysts, scientists and policy makers. The sobering result is that there is no agreement on any of the five levels, not between the groups, nor generally within them. Like in the IKEA cupboard story, we still have a mess (i.e., insufficient progress towards sustainable development), but we have no way to know what the precise cause for the break-down of the science-policy interface is. As in the IKEA cupboard story, it would be essential to find agreement at least on the goals and strategies (level 3) and the implementation details (level 5).

Table 48. Agreement between scenario analysts, scientists and policy makers on various levels.

Levels		Scenario analysts, scientists and policy makers – making a good team?	
		Questions	**Findings**
1	**Ultimate goal**	Is there agreement on the ultimate goal of sustainable development? Is there a role for science in policy?	No agreement on SD as the ultimate goal, nor on the role of science in policy.
2	**Overall approach – visions (ends)**	Is there agreement on what to develop and what to sustain? Is there scientific consensus?	No general agreement. No general scientific consensus.
3	**Goals and strategies (means)**	Is there agreement on goals and strategies? What is the science-policy interaction like in the selection of goals/targets? Is it feasible to attain multiple goals?	No general agreement. Complex, two-way interaction. Multiple goals are feasible, but unresolved trade-offs remain.
4	**Policies, programmes and action plan**	Is there agreement on policies, programmes and action plans? Are scientific scenarios supporting the development of action plans?	No agreement. Action plans are typically developed without scientific guidance.
5	**Implementation**	Is there agreement on implementation, including project-level assessment, resource requirements and investments?	Low level of agreement.

Source: Authors' elaboration
Notes: SD:= sustainable development.

8. Issues for consideration

In this concluding chapter, a number of issues are suggested for consideration by scenario analysts, scientists and policy makers.

8.1. Which world do we really want for ourselves and our children?

The mainstream sustainable development scenarios for Rio+20 have sketched alternative paths toward "a better world that we can achieve". It is undeniable that these proposed futures are much better than the outcomes of a trends scenario which assumes we simply continue improving and adapting at historical rates of change.

Table 49 recaps the list of goals and targets achieved in the sustainable development scenarios for Rio+20.

To achieve these “better futures”, “radical incrementalism” (PBL, 2012) is suggested. This means we continue greatly up-scaling and accelerating those actions that appear to work. The recipe appears a pragmatic and doable one. Yet, we have also seen that the “better worlds we can achieve” are really not perfect futures, but worlds which are still riddled with unresolved SD issues. There is still not a single mainstream SD scenario that would convincingly show how *all* the complex trade-offs and resulting unsustainabilities could be overcome by following the kind of “radical incrementalism” that they explore.

As we are talking about a future in forty years, it begs the question whether the mainstream SD world is really the one that we want for our children and ourselves?

When one of the authors of this study asked children (9-13 years of age) from different countries what kind of future they would like to see for the world in 2050, their response was typically a wish-list broader (but less quantitative) than what all prominent SD scenarios combined have explored since the 1970s. In particular, they often included wishes for a harmonious and peaceful world and sustainable, pleasant, and healthy local communities. Of course, the long-term future that we are exploring here is primarily for our children, which should be an additional reason to carefully listen to them.

Maybe the most important lesson is that at some point we will need to be well beyond radical incrementalism and embrace systemic change along the full range of SD dimensions, including those that appear politically intractable at present, such as issues of conflict, community and social equity. Scenario analysts of various trades need to work together and explore truly sustainable development scenarios across all these dimensions. And decision-makers will need to be far more courageous in making systemic institutional changes, opening up new options for going forward. It is time to listen to our children.

Table 49.Goals and targets in sustainable development scenarios for Rio+20

Vision		Theme	Types of goals, targets, and outcomes	IIASA-GEA	PBL	SEI	OECD	RITE-ALPS	FEEM	GSG
To develop	People	Poverty	Eradicate hunger by 2050		X					X
			Eliminate poverty by 2050			X				
		Access	Universal access to improved water source and basic sanitation by 2050		X		X			
			Universal access to electricity and modern cooking fuels by 2030 {or 2050}	X	X	{X}				
		Health & education	Decreased impact of environmental factors on DALY		X					
			Universal primary education by 2015						X	
	Economy	Income	GDP per capita > US$10,000 PPP in all regions by 2050			X				
			Income convergence; catch-up of Africa by 2050						X	
		Resources	Primary energy use less than 70GJ per capita by 2050						X	
			Primary energy use per capita is only 13% higher in 2050 than in 2010, and 48% higher in 2100.					X		
			Use of renewables increase by 3.1 times from 2010 to 2050.					X		
			Water demand increases from 3,560 km^3 in 2000 to only 4,140 km^3 in 2050				X			
		Security	Limit energy trade, increase diversity and resilience of energy supply by 2050	X						
			Population weighted average of energy security index increases only by 2.3.					X		
To sustain	Life support	Resources	Limit the increase in the number of people under severe water stress to an additional +2 bln {or +1.4 bln) from 2000, reaching 3.7 bln {or 3.1bln} in 2050.				X	{X}		
			People under severe water stress <2 bln until 2050 {or 2.9 billion in 2100}					{X}		X
			Reduce number of people living in water scarce areas vs. trend scenario		X					
			Reduce the area for energy crop production to almost zero by 2020. From 2010 to 2050, limit increase in cropland area for food production to +15%, and reduce the irrigated area for food production by 5%.					X		
			Cumulative fossil fuel use limited to <520 Gtoe from 2010 to 2050					X		
			Slow and later reverse deforestation and land degradation							X
			Slow overfishing and later restore fish stocks							X
		Air pollution	Keep PM2.5 concentration below 35 µg m^3 by 2030		X					
			Reduce NO_x, SO_2 and black carbon emission by 25% vs. baseline by 2050				X			
			Reduce SO_2 by 42% and black carbon by 21% by 2050 vs. 2010					X		
			Reduce premature deaths due to air pollution by 50% by 2030	X						
	Nature	Climate change	Limit global average temperature change to 2°C [or 2.8°C] above pre-industrial levels with a likelihood of >50% {or 60%} by 2100.	X	X	{X}	X	[X]		X
			Atmospheric GHG concentration stabilization below 450 ppm [or 350ppmv] {or 550ppmv} CO_2-eq. by 2100.		X				{X}	[X]
			Limit ocean acidification to keep aragonite stable, with pH=8.0 in 2150					X		
		Biodiversity	By 2020: Prevent extinction of known threatened species and improve situation of those in most decline; halve the rate of biodiversity loss; halve the rate of loss of natural habitats and reduce degradation and fragmentation by 2020; conserve at least 17% of terrestrial and inland water. By 2050: stabilize biodiversity at the 2020/2030 level.		X					
			CBD Aichi protected area targets of 17% of terrestrial and inland water areas and 10% of coastal and marine areas by 2020.		X		X			
		Phosphorus and nitrogen cycles	Phosphorus removal in wastewater treatment increases from 0.7 Mt in 2000, 1.7 Mt in 2030, to 3.3 Mt in 2050				X			
			Reduce N/P use where possible, but without harming the ability of the agricultural system to meet the hunger target		X					

Sources: IIASA-GEA (Riahi et al., 2012); PBL (van Vuuren et al., 2012) ; SEI (Nilsson et al., 2012), OECD (2012) ; RITE-ALPS (Akimoto et al., 2012) ; FEEM (2011) ; GSG (Raskin et al., 2010).

8.2. Filling the cupboard with lessons learned

Table 50 summarizes the report's findings regarding the issues for consideration, separately for each of the five levels of the IKEA cupboard framework. Again, for the science-policy interface to function at all, we need to fix levels 3 and 5. Agreement on the other levels is not absolutely essential, but would increase the efficiency of the system.

Table 50. Filling the cupboard with issues for consideration

Levels		Issues for consideration	
		Questions	***Findings***
1	**Ultimate goal**	To which extent do we need to agree on SD as the ultimate goal? How?	Agreement on SD would help greatly, but progress could be made without such agreement.
2	**Overall approach – visions (ends)**	To which extent do we need to agree on a common vision? How? Which one?	Agreement on a common vision is somewhat more important, but not absolutely essential.
3	**Goals and strategies (means)**	To which extent do we need to agree on a strategy, including goals and targets? How? Which ones?	Agreement is essential. Goals should be scientifically determined, yet, no such agreement exists as of today.
4	**Policies, programmes and action plan**	To which extent do we need to agree on policies, programmes and action plans? Which ones?	Again, agreement would increase efficiency, but is not essential.
5	**Implementation**	To which extent do we need to agree on implementation, including investments?	Agreement is essential, but non-existent at the moment.

Source: Authors' elaboration; Notes: SD:= sustainable development.

Box 13 summarizes a number of basic lesson-learned for scenario modellers and analysts.

Scenario modellers should be more aware of the fact that their models reflect specific worldviews and that they have greatly shaped the worldviews of decision-makers.

Scenario modellers also need to understand that there is no agreement on the role of science in policy making. Hence, not everyone thinks scenario analysis is a useful activity. Hence, scenario modellers might want to be especially cautious with policy recommendations that they make underlying assumptions clear to decision-makers.

Scenarios have served as a powerful science-policy interface. But most often than not, model results are "cherry-picked" by decision-makers. Scenario analysts need to anticipate such cherry-picking and offer their recommendations with this fact in mind.

It is easier to agree on goals/targets than on policies, actions or indicators. Importantly, there is no consensus on limits, but almost everyone agrees that technology is important.

To-date, no scenario exists that would consider the full range of SD goals suggested by science or by politics. And the broader the set, the more unresolved trade-offs and synergies remain. This is a serious challenge for the scenario community and will require significant resources to resolve.

For the past forty years, global models have been looking for applications, rather than vice versa. The results are fragmented modellers communities focusing on applications. More model development tailored to specific new problems is needed.

There are obvious problems with an increasingly complex hierarchy of assessments, which is perceived as burdensome by some parts of government. In order to make scenario modelling relevant and sustainable at the same time, this problem must be acknowledged and the many lower level assessments be replaced by fewer higher-level, strategic assessments.

Results require a long time. This is especially true in the case of policy impacts of scenario work. Hence, scenario analysts should be patient and focus on the long-term, rather than quick-wins through government contracts guiding their work.

Box 13. Basic lessons-learned from global scenario modelling

- World models have greatly shaped the world-views of decision-makers since the 1970s.
- Many disagree with the idea that science should provide "objective" inputs to policy makers.
- Scenarios can be a powerful interface between the scientific knowledge and decision-making.
- Complex hierarchy of assessments in need of improvement.
- Global IA results are considered useful even for decisions on regional and local programmes.
- Back-of the envelope calculations are essential.
- It is easier to agree on goals and targets than on policies, actions or indicators.
- There is no consensus on limits. Almost everyone agrees that technology is important.
- Models reflect worldviews and results are "cherry-picked" by decision-makers.
- Scenario modellers need to reclaim their independence from donors and political influence.
- Strategic gaming typically trumps everything else.
- It's a "conversation" between many stakeholders.
- Results require a long time.

8.3. Potential way forward

There is a need to agree at least on "ground-rules" for the roles for science and business in policy. As always, the devil is in the institutional details. Better institutional solutions are needed for the science-policy-business interface. In this context, lessons might be learned from the role of Central Banks in today's modern economies. Central banks were created and later made independent to provide the necessary level of analysis and to make corrective decisions to the monetary system without undue political influence. Similar institutional solutions might be explored for SD policy. For example, independent assessment centres could have the power to adjust market rules, permit prices, technology regulations, and so on.

Institutional arrangements are needed to allow for reaching a minimum level of scientific consensus on what to develop and what to sustain. This needs to draw on all relevant disciplines and academic communities, not just those dominant in few a Western countries or economic disciplines, as has been the case with various high-level panels hijacked by lobbying efforts.

There is enormous room for improvement of the science-policy interaction for the purpose of selecting goals, targets and indicators. The policy community must consider scientists' participation, and the scientists and analysts need to seriously take up independent cross-checking of the feasibility of simultaneous attainment of multiple SD goals and targets.

Many of the suggested, well-intended SD policies are unsustainable in several dimensions. This calls for a serious rethinking of current priorities in the hierarchy of formal and informal assessment tools and processes from projects to programmes, policies and strategies, across sectors and geographical units. Scientific scenarios are also needed to inform the development of action plans and projects, and more truly integrated assessment studies are needed at the national levels.

It remains to be seen whether the world is ready to make the next step towards a more effective and trustworthy science-policy interface. As was the case in the remaking of this interface through computers some 40 years ago, maybe it is time to make the next step based on modern technologies.

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9. Annex: SD21 "storylines"

In order to put the following futures into context, we start with simple narratives describing possible futures according to stylized worldviews or paradigms that are influential in the negotiations on sustainability and development issues are global level, including the ongoing preparative process for Rio+20. Since SD21 team members have decided not to develop full-scale scenario quantifications of these futures, they are primarily qualitative, in contrast to the other subsections of this chapter which present fully-quantified scenarios. Nevertheless, we believe the SD21 "storylines" provide important context to understand the way in which the other scenarios will be received and compared by various governments and stakeholders. Each of the following scenario "storylines" reflects a representative view of the range of positions taken in the global sustainable development debate.

Policy focus	***SD21 scenario characterization***
Economic pillar	**Business-as-usual world** that results from a continuation of current policies and practises primarily geared toward achieving a sufficiently high level of economic growth.
	Dynamics-as-usual world that results from a continuation of incremental progress, in line with historical trends and patterns.
	Catch-up growth world that continues to focus on growth, but with special efforts to achieve catch-up growth of the economies of LDCs and Africa.
Major issues in the economic and environment pillars	**Green economy/green growth world** which focuses on growth and selective environmental objectives. Economic instruments are the preferred means to improve eco-efficiencies, in particular through "getting-prices-right" and additional public investments for clean technologies.
	Climate change world that sees climate change as the most important threat and takes decisive action in terms of mitigation and adaptation. Other objectives, such as development, are increasingly formulated in terms of the climate policy goals.
	Planetary boundaries world that emphasizes action to ensure that humanity develops within a range of planetary boundaries (with climate change constituting one of them) to avoid global environmental collapse.
Social pillar, but also takes into account selected economic and environmental issues	**Development/MDG+ world** that emphasizes poverty reduction initiatives that primarily address social, education and health goals, but also take into account selected economic and environmental issues.
Integrate all sustainable development pillars	**Sustainable development world** in which policy follows an integrated approach to economic, social and environmental goals, and major institutional change, with the overall goal of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

Next we present these eight storylines.

9.1. Business-as-usual world ("Growth first")

The business-as-usual scenario ("Growth first") describes a future world that would result from a continuation of current policies and practices which are primarily geared toward achieving a sufficiently high levels of economic growth. It provides a conservative benchmark for comparison with the other scenario families.

It is essentially a world dominated by the "Washington consensus" characterized by privatization, limited regulation, liberalization and ever increasing globalization and regionalization. Institutional changes are driven primarily by the private sector rather than governments. No commensurate government-driven globalism or regionalism emerges. Multilateral solutions continue to be sought on selected economic and environmental issues, but in general voluntary commitments by the private sector are the main avenue taken.

The one success criteria against which economies and governments measure themselves continues to be GDP growth. The belief is that economic growth is the most efficient way of reducing poverty and addressing social objectives through the "trickle down" effect. Similarly, the belief is that economic growth itself will take care of environmental pollution and inequity (through the "Kuznets curve"), and that price signals will efficiently take care of resource scarcities.

Population follows the UN median projection.

Technology transfers result in overall improvement of technology performance, in line with user demand and preferences. Research, development and demonstration are considered as a private sector issue, and public investments are seen as unwelcome distortions of the market. Without additional government support for R&DD, overall technology change is driven strongly by technology transfer, rather than technology performance improvements. Essentially, the performance of individual technologies is "frozen" for decades, while that of the global mix continues to improve, albeit at a slowing rate. "Green" sectors develop as they become competitive but receive no extra "push" from governments.

Renewable energy develops at the rates of the past, and fossil fuels remain the dominant. Current biofuel mandates are implemented, potentially leading to conflicts in land use. Water efficiency slowly or hardly improves, but better use is achieved through reallocation. In agriculture, global crop yields only slowly improve, mainly through re-allocation of crops across arable land.

No significant efforts are made to directly change consumption towards more sustainable patterns. Instead, governments refer to price signals to generate the most efficient consumption behaviour. The same applies to production patterns, associated pollution loads, chemical pollution and waste. In terms of nature conservation, protected land and marine areas continue to increase slowly, and there are no government-driven solutions to global fisheries management.

Global warming and resulting water scarcity, land degradation, desertification, soil erosion, and extreme weather events become increasing challenges, especially for the poor. Economic growth is seen as the optimal solution, as higher incomes are expected to make communities more resilient to these challenges.

Limited GHG mitigation efforts are being made, but no binding global post-Kyoto agreement is achieved. Efforts are mainly based on implementation of the present voluntary pledges by developed countries.

Investments in education, health, water and sanitation do not change much. Social safety nets evolve only slowly in developing countries and are limited to the formal economy. No efforts are made to mitigate income disparities between countries and regions. The resulting conflict potential is apparent, but governments justify their inaction in this respect by invoking the general need for rapid economic growth which comes at a "cost".

There is no significant reform of the global trade system, neither in terms of social, development or environmental objectives. Some progress might be achieved in terms of tighter global investment guarantees and development of strong IPR systems in the emerging economies. There is no change in the mandates, procedures, and operations of the IMF and the multilateral development banks. ODA flows are gradually reduced in line with higher incomes in developing countries.

9.2. Dynamics-as-usual scenario ("Keep it up!")

The dynamics-as-usual scenario ("Growth first!") describes a future world that results from a continuation of incremental progress, in line with historical patterns and trends. It is the closest to a future "projection". It provides a less conservative and more dynamic benchmark than BAU for comparison with the other scenario families. In line with current trends, economic growth remains the top policy priority in most countries, but an increasing number of social and environmental issues are increasingly taken seriously and are being addressed within the given growth-focussed paradigm. This will also be reflected in an increasingly complex and wide ranging system of regional and global institutions.

Incremental technology progress proceeds in line with historical patterns, including in terms of eco-efficiency. This is achieved with ever increasing public commitments and investments, as gaps become increasingly evident. As a result, "green" sectors are supported by governments and develop faster than other sectors, but do not receive support commensurate with the social and environmental efforts. Many of the planetary boundaries, including in terms of climate change, are expected to be breached. Irreversible environmental events and social strife are of increasing concern. Governments focus on crisis response rather than structural change. More extreme scenario variants might also be explored where governments react massively in the face of environmental disaster or social conflicts. For example, a collapse of the global thermohaline circulation might trigger large-scale geo-engineering, migration flows, and military conflicts.

There are only isolated national examples of systematic, direct efforts to change consumption patterns by mid-century. Instead, policy makers rely primarily on price signals to impact consumer behaviour, but prices remain too low to achieve eco-efficiency changes commensurate with the challenges, in view of the successful lobbying efforts of special interest groups and strategic gaming behaviour of market actors.

Pollution loads by industry continue past trends, including for pollution from toxic chemicals. Transfer of chemical and electronic waste to developing countries is progressively restricted to reflect stricter regulations or enforcement in some regions.

Protected land areas continue to increase slowly, as well as marine protected areas. No global management of fisheries is reached. Limited effort is made on climate (continuing the increase in voluntary emissions reductions), reflecting lack of a binding multilateral agreement post Kyoto.

Renewable energy diffuses slowly into the global primary energy mix, with large differences among countries. Until at least the mid 21st century, fossil fuels remain the dominant energy source. Governments fully implement the present biofuels mandates for 2020-2025, but thereafter there is potentially a significant backlash, in view of ensuing land conflicts and rising food prices. Progress toward universal access to electricity and modern cooking fuels continues, but its pace differs greatly among countries. Global universal access is not achieved before the end of the 21st century. Energy efficiency, water efficiency, and crop yields continue to improve as per past trends.

Population follows the UN median projection.

Public investments in education, health, water and sanitation tend to increase in today's developing countries, and especially emerging economies, but are gradually reduced in today's developed countries. Social safety nets in developing countries evolve slowly towards increased coverage, but remain limited to the formal economy, whereas the coverage is gradually reduced in today's developed countries. There are no special efforts to reduce income disparities between countries or within countries. The trade, IPR, and investment and financial systems, including ODA flows follow the assumptions in the business-as-usual scenario.

9.3. Catch-up scenario ("Growth first with catch-up")

The catch-up scenario ("Growth first with catch-up") describes a future world which continues to focus on economic growth as the primary objective, but makes special efforts to achieve catch-up economic growth in the Least Developed Countries, especially in Africa. The world witnesses a formidable catch-up growth, essentially assuming a replication of the East Asian experience and development model since 1980 across the world. By the end of the 21st century, differences in GDP per capita between countries worldwide will be similar to the prevailing such differences between OECD countries today. This leads to much lower differences in incomes across countries, but large intra-country differences with significant conflict potential. In the short term (e.g. to 2030), income disparities across world regions do not increase, and that the least developed countries reach a threshold level for GDP per capita. In the longer run (2100), there is a slow convergence of aggregate incomes across the globe.

Over the course of the 21st century, these developments puts even more pressure on the global resource base, surpassing local and regional critical loads and breaching the planetary boundaries. This exacerbates intra-country differences even further, but does not lead to a significant change of course. The solution is economic growth and (where necessary) migration. While the marker scenario assumes a “muddling-through” the social and environmental challenges, a more extreme scenario variant will be explored in which irreversible and dramatic changes are triggered in the biophysical system that lead to social and political strife in many parts of the world.

The catch-up scenario family will provide a perspective on proposals for a significant an conscious effort to put macroeconomic policies in place that would lead to long-term convergence in per capita incomes between developed and developing countries. Macro-economic tools explored include increased ODA, preferential trade treatment for developing countries, and incentives for private investment in developing regions. The particular combination of such instruments might be idiosyncratic to scenario variants in this family.

In contrast to the “development scenario”-family, the catch-up scenario family assumes no additional efforts to achieve and sustain MGD-style goals and or to implement them on the micro-level, nor are social issues at the forefront of government policy. There are no additional efforts to mitigate GHG emissions beyond the current trends. The limited efforts are based on voluntary commitments and market-based carbon finance, which reflect a stalemate in international climate change negotiations. Other planetary boundaries are not addressed at all, as they are seen as “unfair green protectionism” and ideological constraints on economic growth aspirations of poor countries. In particular, renewable energy diffuses into the global market at the current slow rate, driven mainly technology cost and performance factors.

9.4. Green economy scenario (“Green growth”)

The green economy scenario (“Green growth”) describes a future world which focuses on growth and (partial) environmental objectives. Economic instruments are the preferred means to achieve policy objectives which are increasingly framed in terms of eco-efficiency, in particular through “getting-prices-right” and additional public investments for clean technologies.

One variant of this scenario family might explore the normative path suggested by the UNEP’s Green Economy Report, published in 2011. The scenario follows dynamics-as-usual in a wide range of variables, but goes further in terms of a number of selected environmental targets. The primary means to achieve the envisaged environmental goals are economic and market instruments, in order to “get prices right”, i.e., to fully account for environmental externalities.

The green economy scenario emphasizes the potential for additional public investment devoted to speeding-up deployment of renewables, improvements in energy efficiency, resource efficiency, and pollution abatement in all sectors and all countries. Additional public investments in natural assets lead to more rapid increases in agricultural yields, and a significant increase in the surface covered by protected terrestrial and marine areas. Changes in greenhouse gas emissions and other pollutants are assumed to be achieved through market-based incentives, including a moderate price of carbon, reflecting regional GHG markets rather than a science-based global agreement on climate. One scenario variant might also explore the impacts of a global carbon tax regime. Similarly, changes in forest cover result from market arbitrage reflecting changed prices that incorporate a price for carbon.

Coordination is achieved with respect to the management of fish stocks, but a number of planetary boundaries are expected to be breached.

There are no significant efforts made to limit the world population increase, nor to directly interfere with consumption patterns. Governments rely mostly on price signals to direct consumption behaviours, pricing out lower income groups but hardly impacting consumption patterns of the rich. There are also no significant, direct efforts made to reduce income disparities between countries and regions. There are no significant, direct efforts made to achieve major social objectives other than those related to energy and water, reflecting the assumption that improved resource efficiency and investment in natural assets will automatically generate welfare gains for the poor. In particular, international institutions governing financial and capital markets as well as trade are not significantly reformed.

The main emphasis of governments is on technology and market-based incentives. Due to increased investments, improvements in energy and resource efficiency are faster than the most recent trends since 1990. Most of the new financial incentives benefit modern renewable energy. In particular, current mandates for biofuels are fully implemented and new mandates are taken in emerging regions. There is a push for faster universal modern cooking fuels in developing regions through ODA and contributions of private and NGO sectors.

9.5. Climate change scenario ("IPCC world")

The climate scenario ("IPCC world") describes a future world that considers climate change as the most important threat to humanity and takes decisive action in terms of mitigation and adaptation. Other objectives, such as development, are replaced or increasingly formulated in terms of the climate policy goals.

The scenario family reflects a focus on climate change and other planetary limits as the main threats to the pursuit of current dynamics. While economic growth is still given priority, serious coordinated efforts are made to curb greenhouse gas emissions to achieve scientifically recommended targets (e.g. 350 ppmv, 450 ppmv, and 550 ppmv), through the whole range of possible policies, technologies, and regulations. The mix of instruments to achieve environmental objectives and their timings in this century are determined on a least-cost basis, in contrast to the Green Economy scenario. Only few environmental limits are exceeded in the long term by 2100.

The efforts to mitigate climate change and limit pollution take precedence over social goals. There are no specific efforts made to reduce disparities in per capita income across countries and regions. There are no additional efforts made to achieve MDGs or to sustain them is the future. One variant will explore a climate constrained world in which full catch-up growth of developing countries is achieved by the end of the 21st century.

9.6. Planetary boundaries scenario ("One planet world")

The Planetary boundaries scenario ("One planet world") describes a future world that emphasizes action to ensure that humanity develops within a range of planetary boundaries (with climate change constituting one of them) to avoid global environmental collapse. It is essentially a variation of the IPCC world which, however, aims to address all the "planetary boundaries" described in Rockstroem et al. (2009).

9.7. Development scenario ("MDG+ world")

The development scenario ("MDG+ world") describes a future world that emphasizes poverty reduction initiatives that primarily address social, education and health goals, but also take into account selected economic and environmental issues.

The scenario family reflects a strong commitment by the international community to achieve MDG-related goals relating to basic access to energy, water and sanitation, services, education, and health and sustain them over the long term. Such social goals are given top priority together with economic growth. However, no specific efforts are made to reduce disparities in per capita income across countries and regions. Environmental goals are not explicitly pursued further than the current trends suggest, reflecting a failure to achieve coordinated agreements on greenhouse gases and management of other global commons. In the long term (2100), poverty is "eradicated", social outcomes at the micro level are considerably improved, potentially at the price of largely exceeding human demand on natural sources and sinks. Possibly, the least developed countries reach a threshold level for GDP per capita. In the longer run (2100), there is a slow convergence of aggregate incomes across the globe.

9.8. Sustainable development scenario ("SD21 world")

The sustainable development scenario describes a future world in which policy follows an integrated approach to economic, social and environmental goals, and major institutional change, with the overall goal of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

The scenario family reflects an integrated focus on the three pillars of sustainable development, as well as an explicit integration of planetary limits to ecosystems capacity. Conscious efforts are made by the international community to achieve and sustain MDGs-related goals relating to basic access to services, education, and health, and to reduce aggregate income disparities across regions in the long term. Coordinated efforts are made to curb greenhouse gas emissions in order to achieve scientifically recommended targets (e.g. 350 ppmv), through the whole range of possible policies, technologies and regulations. In the long term (2100), sustainable development is achieved in the sense that all regions are developed, poverty is eradicated, and the demand on natural sources and sinks does not exceed their regeneration capacity.

This scenario implies new economic structures, different allocation of capital and investment among public and private sectors, cooperative management of the commons at the global and national levels. By the end of the 21st century, differences in GDP per capita between countries worldwide will be similar to the prevailing such differences between OECD countries today. This leads to much lower differences in incomes across countries, as well as conscious efforts to limit intra-country income differences, and thus significantly lower conflict potential. Possibly, in this scenario the 500 million richest people, regardless in which developing or developed country they live, take a leading role in changing their consumption pattern and contribute resources to eradicate poverty. The high willingness to pay for technology performance by these "rich" leads to accelerated technology change toward cleaner clusters that are thereafter gradually adopted by lower income groups.