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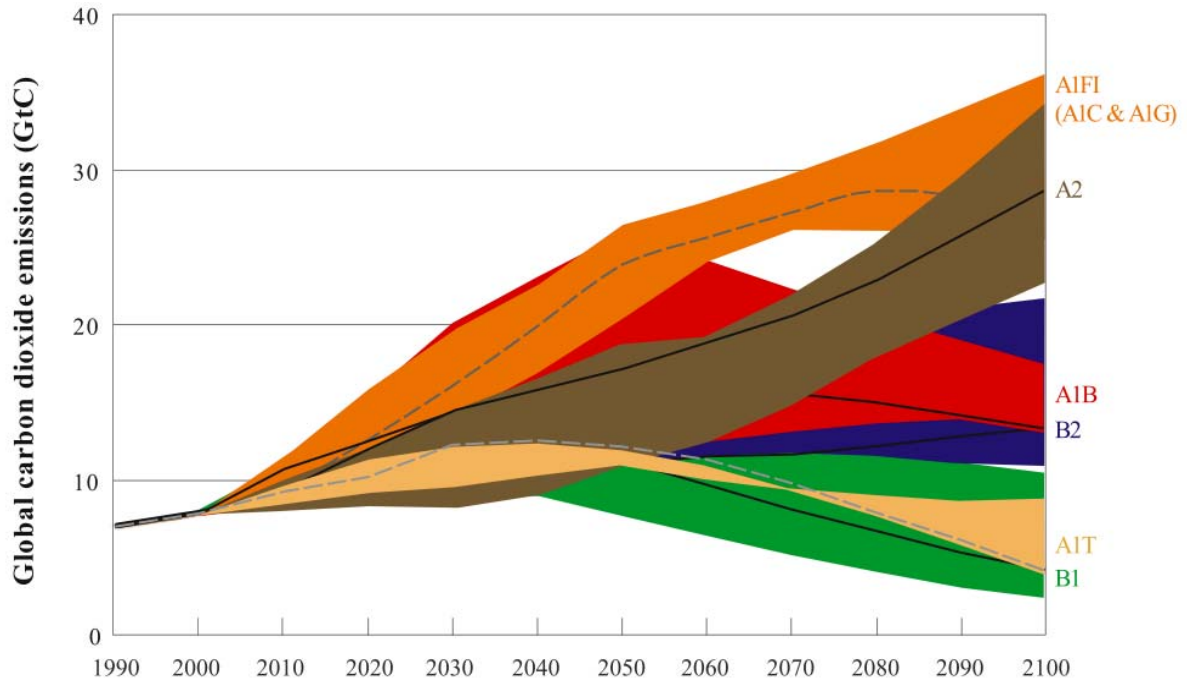

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A research on the reasons for the growing baseline uncertainty of the IPCC scenarios

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Source of cover figure: IPCC (2000d)

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Why six baseline scenarios?

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Abstract

While in 1990 the IPCC scenarios had only one baseline scenario, in 2000 the IPCC published six different baselines scenarios in the Special Report on Emission Scenarios (SRES). The reason for this growing baseline uncertainty is analyzed in this diploma thesis. The research includes interviews with SRES authors, an evaluation of the open archive with the requests on the SRES Drafts from government and experts review, finally a comparison with 75 baseline emission scenarios as well as 8 global scenarios. The results are: The use of six baseline scenarios of the SRES can be explained by external influences and conceptual reasons. The external influences come from the government requests and the IPCC approval procedure. The conceptual problem is a consequence of the ambiguous classification of intervention and non-intervention. Concluding, the low emission SRES scenarios should no more be described as non-intervention and external influence as well as conceptual problems should be addressed in the upcoming construction of new IPCC scenarios. Implications of this work for new scenarios are discussed.

Keywords: IPCC; Emission Scenarios; Business-as-Usual; Baseline; Non-Intervention; SRES

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Summary

Why six baseline scenarios? This question arose, because there was a single baseline scenario in the first IPCC scenarios of 1990, while two series of six non-intervention baseline scenarios were published in 1992 and 2000 (chapter 1).

To analyze this question the research focuses on the CO_2-emissions from energy consumption, since the variation in the projections of this greenhouse gas and source is the main cause for the different baselines. In a preliminary research, the main drivers for CO_2-emissions of the three IPCC scenario series are compared and reasons for their variation evaluated (chapter 2). The main research focused on the SRES scenarios. External influences, conceptual problems and scientific findings were assumed as possible explanations for the changing structure of the IPCC scenarios (chapter 3). Different methodological approaches were chosen to evaluate these hypotheses (chapter 4). Interviews with scenario experts and SRES authors allowed a fast competence building and insight in the dynamic of the SRES scenario construction procedure as well as the SRES scenario thinking. The findings from the expert interviews were the basis for additional literature research, including the open archive of the SRES, which provide all the requests made by experts and governments on drafts of the SRES during the IPCC review. In addition, the SRES were compared with 75 baseline emission scenarios as well as 8 global storyline scenarios. The results are the following (chapter 5):

The external influence on the SRES is obvious. Without the final plenary, instead of six illustrative scenarios only the four marker scenarios would have been recommended as smallest set of emission scenarios. The high emission scenarios of the A1 storyline would be represented by two scenarios with different fossil directions – A1C (coal) and A1G (gas and oil) – instead of only one fossil intensive scenario (A1FI). In addition, there were indirect influences on the SRES. First, no scenario names were proposed, mainly because of the feared difficulties of an agreement on such names in the final plenary. If the B1 scenario had been named “sustainability”, it would have been clear for all users that this in fact is more an interventionist than a baseline scenario. Hence the non-use of scenario names led to an increase of the baseline uncertainty for the scenario users, who did not carefully read the underlying assumptions of the scenarios and did not recognized the amount of policies used in the low emission scenarios. A second indirect influence on the SRES scenarios is the direct influence on the IS92. For the IS92 scenarios, a central scenario was proposed in the first draft. Only in response to governmental requests were additional baselines included and a larger uncer-

tainty range explored. Since one of the motivations for the SRES was to update the IS92 scenarios, the influence on these former scenarios is partially adapted in the SRES.

Beside the external influences the high baseline uncertainty is also caused by the used categorization of baseline and non-intervention scenarios. This categorization allows assuming climate polity with co-benefits, as for instance additional R&D for non-fossil energy supply or policies for sustainability in non-intervention scenarios. With a stricter categorization of non-intervention, which excludes all interventions that could be motivated also by climate change concerns, the range of the SRES scenarios would become smaller, since the A1B and B2 and especially A1T and B1 scenarios wouldn't be non-intervention.

Scientific findings reasons for the increase of the baseline to six scenarios could not be found. It is undisputable that the future development is inherently uncertain and the SRES span a plausibly wide range of uncertainty. But this inherent uncertainty is not new and findings since 1990 about coherences of the key drivers for future CO_2-emissions even reduced this uncertainty. In addition, scenarios from literature use fewer baselines and assume a smaller range for future decarbonization, even though they deal with the same inherent uncertainty.

The final discussion (chapter 6) shows that recent scenarios comparisons of the SRES with other non-intervention scenarios are consistent with the conclusion that the A1T and B1 scenario have emissions that are to low for non-intervention scenarios. The ambiguity of the categorization used by the IPCC can be explained by the increased importance of climate change for policymaker and the competence building of the SRES exercise. The external influence can be explained by the high importance of the IPCC emission scenarios for science and politics and by the fact that baseline are kind of a best guess, which can hardly be verified in present. Precondition for the external influence are the approval and request by a governmental plenary as well as the consensus decision in such this plenary.

The main conclusions (chapter 7) are that a new categorization for scenarios is needed and that more competence to the writing team should be given for the selection and description of the scenarios. A clear categorization and intermediate storyline could reduce the number and range of baselines.

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Finally Pascal and Marcel Girod for counterchecking the draft respectively the final version of this thesis.

[1] A more detailed description of the interviewed experts and their expertise is given in chapter 4.

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Shortcuts

IPCC	Intergovernmental Panel on Climate Change
BaU	Business-as-Usual
SRES	Special Report on Emissions Scenarios (IPCC 2000d:27)
IS92	Updated IPCC Scenarios (IPCC 1992)
SA90	First Scientific Assessment Report (IPCC 1990b)
WGI	IPCC Working Group I – Responsible for the assessment of scientific information on climate change
WGII	IPCC Working Group II – Responsible for the assessment of environmental and socio-economic impacts of climate change
WGIII	IPCC Working Group III – Responsible for the assessment of the response strategies
ToR	Terms of Reference
ESD	Emission Scenarios Database
MA	Millennium Ecosystem Assessment Report
GDP	Gross Domestic Product

1 From Business-as-Usual to six Baselines

1.1 Introduction

The first IPCC report had one baseline scenario, which was called BaU, and three intervention scenarios (IPCC 1990b). The revision of these scenarios in 1992 led to six baseline scenarios (IPCC 1992). In 2000 the IPCC published the Special Report on Emission Scenarios and recommended again the use of six baseline scenarios (IPCC 2000d). The uncertainty of the future emission level increased to the largest uncertainties in long term climate change projections (IPCC 2001b:31). This diploma thesis further investigates the question why the baseline uncertainty increased by investigating: "Why six baseline scenarios?"

1.2 Definitions

In this section a rough overview of definition and the typology of scenarios are given:

Scenario: Description of a possible future development. Is usually constructed to explore how a certain problem will evolve in the future.

Emission Scenario: In the case of climate change the scenarios describe possible future greenhouse gas emission paths. The climate modeler uses them to project the future impact of the climate change.

Scenario Type: *Non-Intervention Scenarios* describe a possible future development in absence of actions addressing the problem, which is the issue of the scenarios. In the case of the emission scenarios this means that no actions to reduce greenhouse gas emissions in order to reduce the climate change are assumed in the scenario. *Intervention Scenarios* describe a possible future development with a certain action addressing the issue of the scenarios. In the case of the emission scenarios this means actions to reduce greenhouse gas emissions. Surprise, Disaster, Extreme or Peripheral Scenario describe possible, but very unlikely future developments. Best Guess Scenario try to describe the most likely future development. *Baseline or Business as Usual Scenarios* describe the most likely future development in absence of ac-

tions addressing the investigated problem. In other words: Baseline or BaU Scenarios are the Best Guess of the non-intervention scenarios.

1.3 Actual Discussion

The SRES emphasizes that there is no objective way to assign likelihood on scenarios, hence there would be no BaU or Best Guess scenario. Therefore the SRES presents several baseline scenarios. Nevertheless, there is an ongoing debate about the reason why the SRES presents six baseline scenarios and not just one as in the first IPCC scenario series. Furthermore, this debate is caused by a contradiction in the needs of different users groups. According to the lead author of the SRES, Nebojsa Nakicenovic, the scientific assessments require complexity on one hand leading to a large ensemble of scenarios, on the other hand policy makers' prefer simplicity and a focus on single projections (IPCC 2005).

The discussion about number of baselines is closely linked to the discussion on attaching probabilities on the scenarios, since in this case simply the most likely (best guess) scenarios would be chosen for climate projection, thereby reducing the number and range of baselines. One of the most famous scientists questioning the fact that the multi-baseline of the SRES were not assigned probabilities is the climate scientist Stephen Schneider (van Vuuren 2006). He argues that even if there is no objective way to assign likelihood, subjective likelihood should be assigned by the scientists, since "science for policy" involves being responsive to policymakers' need for expert judgment at a particular time, given the information currently available (Moss and Schneider 2000).

Even though this debate goes on since the publication of the SRES, there is no research on the question why the SRES proposes six baseline scenario. However, Harald Mieg (2004) raised the question about the reasons for the changing logic of the IPCC scenarios at the Berlin Conference on the Human Dimension of Global Environmental Change "Knowledge for Sustainability Transition. The Challenge for Social Science". According to Mieg the IPCC scenarios were gaining in scientific evidence but loosing in terms of direct political relevance. As a possible explanation for this transformation of the IPCC scenarios, Mieg proposes on one hand the "re-arrangement of the two professional spheres of science and international politics" as a result of the difficulties of communication between science and politics, on the other hand the difficulty to find a validated scientific basis for intervention scenarios.

1.4 Hypothesis

This diploma thesis will analyze the question about the reasons for the increasing number and range of baseline scenarios. The explanations proposed from Mieg (2004) are used for the formulation of the main hypothesis of this research by differentiating between scientific and external reasons. Scientific reasons could be new scientific findings or changing use of scenarios in the scientific community. External reasons could be influence by policy or institutional restrictions. The two main hypotheses are therefore:

1. Scientific reasons explain the increase of the number of baseline to six scenarios.

2. External influences explain the increase of the number of baseline to six scenarios.

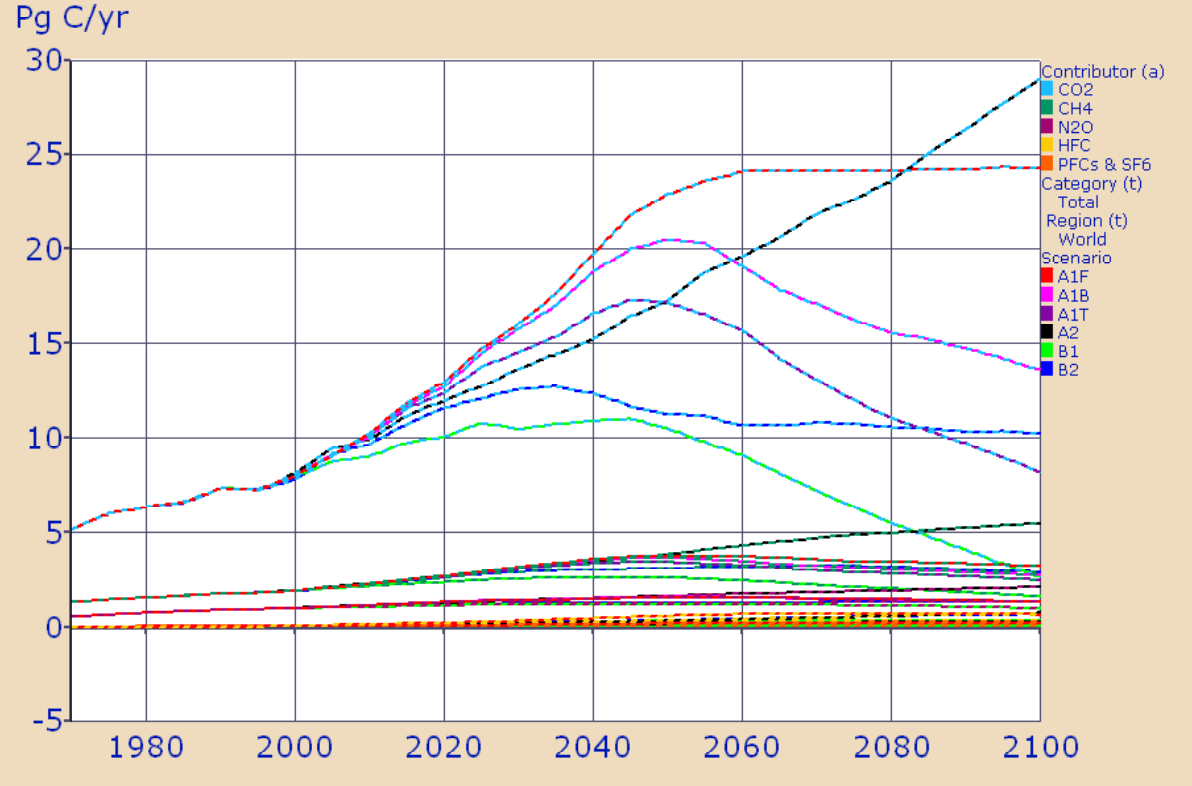
1.5 Approach

The structure of this work is given by the chronology of the research. In chapter 2 the three IPCC scenarios series published in 1990, 1992 and 2000 will be analyzed and compared on the basis of the underling IPCC reports. With the obtained information, chapter 3 concretizes the main hypothesis of section 1.4 into sub-hypothesis. In chapter 4 the methodology of the main research will be described. The results of the research for the different sub-hypothesis are specified in chapter 5. Finally, chapter 6 provides the discussion and chapter 7 the conclusion of the results.

Figure 1 illustrates the fact that for the SRES scenarios the CO_2-equivalent of CO_2 varies the most. For the CO_2-emission the main source is the combustion of fossil fuels. Presently, the CO_2-emissions from the use of energy amount about 82 percent of the all emitted CO_2-emissions[2] and it is projected in all SRES scenarios that this share of CO_2-emissions from energy use will increase to the end of the 21st century (IPCC 2000d). Consequently, the primary reason for the broad uncertainty of the future emission projection and hence the selection of several baselines is the uncertainty in the projection of the future CO_2-emissions from energy use. In order to reduce the complexity and amount of the task, the research will therefore focus on the CO_2-emission from energy use.

[2] 6 GtC/yr from fossil fuels, 1.1 GtC/yr from Deforestation and 0.2 GtC/yr from non-fuel sources of the industry.

Figure 1 Projections for future greenhouse gases



(IMAGE-team 2001)

2 Changing IPCC Scenarios

The goal of this chapter is to characterize and compare the IPCC scenarios to address more precisely the questions about their changing structure. By describing the procedure of the scenarios construction and by giving a short summary of the Evaluation of the IS92 conducted by the IPCC, the first section gives a brief overview of the context in which the IPCC scenarios were developed. In the second section the assumption for population, economic growth, efficiency and decarbonization IPCC scenarios are compared. The scientific background responsible for the changing assumptions and the plausibility of the storyline used in the SRES will be considered in section three. Section four describes the models used to make the greenhouse gas projections. Section five provides a characterization of the IPCC scenarios on the basis of the typology proposed by van Notten et al. (2003). The last section finally makes a rough comparison of the communication of the IPCC scenarios.

Although this chapter is the first part of the research on the IPCC scenarios and was conducted at the beginning of this work, some parts were slightly revised after the main research part. Some sections therefore already include findings from the expert interviews, even though the methodology of the expert interview is described in section 4.4 only.

2.1 From the SA90 to the SRES

2.1.1 SA90 Scenarios

The request for the SA90 scenarios came from the WGIII. The scenarios were constructed by a small number of authors (den Elzen 1994). One model, the atmospheres stabilization framework (ASF), was used for the development of the four SA90 scenarios. The scenarios were constructed in a backward procedure by envisaging a doubling of the CO_2-equivalent concentration by 2030, 2060 and 2090. Additionally, a fourth scenario was developed that would lead to stabilization of the CO_2-equivalent concentration at a level well below a doubling of pre-industrial atmospheric CO_2 (den Elzen 1994; IPCC 1990a). The economic growth and population assumptions were taken as equal for all scenarios, while the levels of technological development and environmental controls were varied (IPCC 1990b). The SA90 scenarios only passed through one informal review (Chadwick 2006; Swart 2006b). It only took about one year from the request to the publication of the SA90 (IPCC 1990a, 1992).

2.1.2 IS92 Scenarios

The WGIII was again responsible for the IS92 scenarios, but the request to update the SA90 Scenarios came from the Panel of the IPCC. The request explicitly excluded climate policy scenarios (IPCC 1992). The IS92 scenarios were again constructed by a small group of authors and used the same model like the SA90 scenarios (den Elzen 1994). The IS92 Scenarios took into account new available information to update the SA90 no-climate-policy-scenario. Sets of alternative, independent input assumptions for key variables were used to take into account the substantial uncertainty on how the future will evolve. In contrast to the SA90 scenarios, a forward procedure is applied by calculating future emissions on the basis of the key input assumptions (Pepper et al. 1992). The IS92 scenario passed through an expert and government review (Swart 2006b). Again, it only took about one year from the request to the publication of the SA90 and IS92 scenarios (IPCC 1990a, 1992).

2.1.3 Evaluation of IS92 Scenarios

In 1995 the IPCC published an Evaluation of the IS92 Scenarios (IPCC 1995b). A summary of some important results:

> The *important input assumptions* for energy related CO_2-emission are found to be population, economic growth, labor productivity, growth of energy demand in developing countries with rising income and the rate of technological improvements of energy efficiency. The report also states that current commitments to limitation of greenhouse gases have a relatively small impact on the IS92 emission scenarios.
>
> The *likelihood* that scenarios are close to real future developments depends mainly on the actual evolution of key input variables. The IS92a scenarios for instance provide a reasonable central case projection of global emissions, because medium or average assumptions are chosen. However, it should be clear that an intermediate is not the most likely scenario. The CO_2-emission on the global level of the 92a Scenario is near the centre of the range of published scenarios designed for similar purpose. Considering the degree of uncertainty, the wide range of views about future emissions and the absence of a most likely scenario, it is unwise to use only one scenario for climate analysis. Rather it is recommended to use the full range of IS92 Scenarios for this purpose. Users of the lowest (IS92) Scenario are cautioned, however, that the lowest (IS92c) has emission levels and some input assumptions that are more characteristic of a policy, rather than a reference scenario.

New scenarios may need to fulfill not only the purpose of offering input to evaluating the climatic consequence of "non-intervention", but also of intervention, to examine feasibility and costs of mitigating greenhouse gases. Furthermore, they should offer input for negotiating possible emission reductions for different countries and geographic regions. New scenarios, if developed, should especially include improvements in the estimation of baseline. The following should be included: Economic restructuring in different parts of the world, consequences of agreement on tariffs and trade, exploration of a variety of economic development pathways (e.g., a closing of the income gap between industrialized and developing regions), examination of different trends in technological change and latest information about emission commitments.

The *Process of Developing Scenarios* should open to a wide participation by the research community, particularly from the developing countries. A diversity of groups, approaches and methodologies should be encouraged. Reporting convention for input an output should be standardized and the input assumptions and methodologies for the scenarios should be harmonized to provide a common benchmark for scenario from different groups.

After the analysis of the SRES scenarios in section 2.2 and 2.3, it will be analyzed in subsection 2.3.4 which of these recommendations for *New Scenarios* and the *Process of Developing Scenarios* were considered.

2.1.4 SRES Scenarios

The SRES report was also requested by the IPCC Plenary and excluded "additional *climate* policy initiatives" (IPCC 2000d). The SRES writing team included more than 50 scientists from a broader range of disciplines and countries. After the formulation of "narrative" storylines, the writing team published a first set of four marker scenarios on the internet. During a so-called "open process", users and scientists could participate on the modeling of the scenarios. The final scenarios were modeled with six different models and this led to 40 different scenarios. The global input assumptions of 26 scenarios were harmonized. In the final report six illustrative scenarios, including the four marker scenarios, were chosen and recommended for the users (IPCC 2000d). The final report went through an extensive peer-review procedure, which included a first review for experts, a second review for experts and governments and a final line per line approval of the summary for policymaker by the governments. The SRES required four years from the request to the publication: In 1996 the Plenary of the IPCC requested a Special Report on Emissions Scenarios. In January 1997 the IPCC WGIII ap-

pointed the SRES writing team. Finally, the SRES Report was "accepted" by the WGIII plenary session in March 2000 (IPCC 2000d).

2.2 Structure

The main driving forces for CO_2-emissions from energy can be illustrated by the following equation, introduced by Kaya in 1990 (IPCC 2000d):

$$CO_2 Emissions = Population \cdot \underbrace{\left(\frac{GDP}{Population}\right)}_{Income} \cdot \underbrace{\left(\frac{Energy}{GDP}\right)}_{\substack{Energy \\ Intensity}} \cdot \underbrace{\left(\frac{CO_2}{Energy}\right)}_{\substack{Carbon \\ Intensity}}$$

Hence CO_2-emissions depend on population, income, energy intensity and carbon intensity. A property of the multiplicative identity is that component growth rates are additive. In Table 1 the growth rates calculated out of the IPCC reports (IPCC 1990a, 1992, 2000d) are listed. The main information indicated by this table is:

Compared with the historical trend since the middle of the 19th century all scenarios project a lower growth rate for CO_2-emissions for the next hundred years than the historical trend. Except of IS92f and the SRES A2 all scenarios assume a slowing down of population growth rate. Income, energy and carbon intensity of the scenarios vary around the historical growth rates. Carbon and Energy intensity decline is much faster in some SRES Scenarios.

The *SA90 scenarios* have the same assumptions about population and take an intermediate assumption for income, but the assumptions of energy intensity and especially carbon intensity span a wide range.

The *IS92 scenarios* assume a wide range of growth rates for population and income but a smaller range for energy and especially carbon intensity than the SA90 scenarios. The resulting emission levels are higher in the IS92 but the range is the same like in the SA90 scenarios.

The *SRES Scenarios* have a smaller range for the future population growth but the highest range of all IPCC scenarios for income, energy and carbon intensity. Particularly the latter two growth rates span a wide range.

Table 1 Growth rates SA90, IS92 and SRES [Percent/yr]

Scenario	Population	Income [GDP/cap.]	Energy intensity [J/ GDP]	Carbon intensity [C/ J]	CO_2-Emissions from fossil fuels [C]
since 1850	1.0	2.0	-1.0	-0.3	1.7
SA90, high	0.6	2.4			
SA90A, low	0.6	1.1			
SA90A[1]	0.6	1.7	-1.2	0.1	1.2
SA90B[2]	0.6	1.7	-1.7	0.0	0.6
SA90C[3]	0.6	1.7	-1.8	-0.9	-0.3
SA90D[4]	0.6	1.7	-1.7	-1.2	-0.6
IS92a	0.7	1.6	-1.0	-0.2	1.1
IS92b	0.7	1.6	-1.0	-0.3	1.0
IS92c	0.2	0.9	-0.7	-0.7	-0.2
IS92d	0.2	1.9	-0.8	-0.7	0.5
IS92e	0.7	2.3	-1.2	-0.2	1.6
IS92f	1.1	1.4	-1.0	-0.1	1.3
SRES A1F1	0.3	2.7	-1.3	-0.2	1.5
SRES A1B	0.3	2.7	-1.4	-0.9	0.7
SRES A1T	0.3	2.8	-1.4	-1.9	-0.3
SRES A2	1.0	1.3	-0.7	-0.1	1.4
SRES B1	0.3	2.3	-2.2	-0.4	-0.1
SRES B2	0.6	1.6	-1.0	-0.5	0.8

(IPCC 1990a, 1992a, 2001)

Note: The formula used for the calculation of the annual growth rates is described in section 4.2.3.

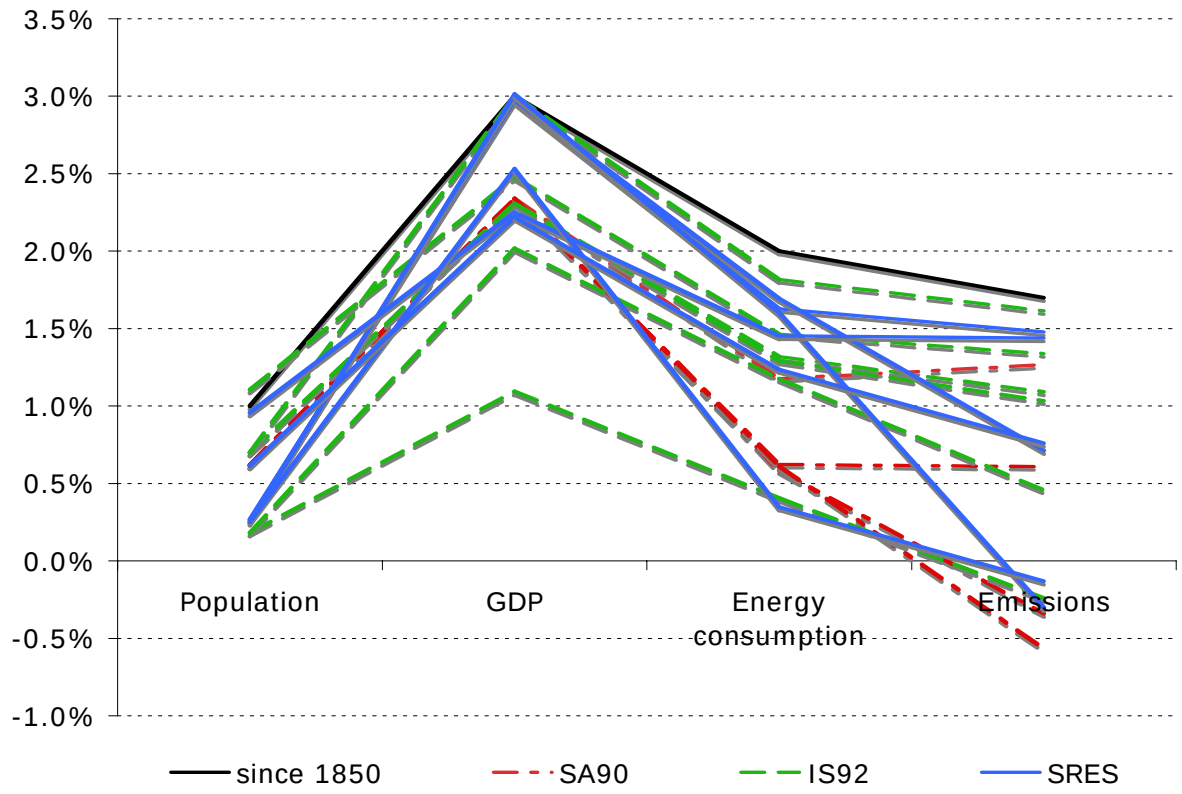
[1] Mean 2030 High Emission [2] Mean 2060 Low Emission [3] Mean Control Policies [4] Mean Accelerated Policies

Figure 2 illustrates the combination of the different key drivers in the scenarios, every line representing a single scenario. The following observation can be made:

The *IS92 scenarios* combine low population growth with low income growth, which leads to a very wide range of economic growth. Energy intensity slightly decreases and carbon intensity slightly increases this range.

The *SRES scenarios* contrarily combine high population growth with low income growth and vice versa. This leads to a much smaller range of GDP growth than for the IS92 Scenarios, although the range of the different kaya driver of the SRES is larger that in the IS92 Scenarios. The broad range of emission levels in the SRES is clearly caused by the difference in energy and carbon intensity of the Scenarios.

Figure 2 Changing range of SA90, IS92 and SRES growth rates



(IPCC 1990a, 1992a, 2000)

Note: The formula used for the calculation of the annual growth rates is described in section 4.2.3.

2.3 Assumptions

This section will describe the scientific assumptions, which led to the different structure of the scenarios received in the previous section.

2.3.1 SA90 Scenarios

The SA90 scenarios use the population estimate from the World Bank, assuming global population to reach 10.5 billion by the end of the 21st century. This signifies a lower population growth for the future than in the past, which is consistent with the observed decline of fertility in industrialized countries and the assumed global income growth (IPCC 1990a:10).

For each SA90 scenario, a higher and lower economic growth rate was specified, thus respecting uncertainty in the rate of economic development worldwide. The economic growth rate was calculated for different world regions. A greater uncertainty in the developing and centrally planned economies was considered in the growth rate range. A reduction of the economy growth rate with the decline in population growth rates was assumed. For the final scenarios the medium of the high and low economic growth was chosen (IPCC 1990a:10).

For all intervention scenarios a large increase in efficiency is expected, which explains the lower energy intensity. The different levels of carbon intensity is mainly due to the different assumptions about the energy mix. In the SA90 BaU scenario the energy supply is coal intensive. In SA90B Scenario the energy supply mix shifts towards lower carbon fuels, notably natural gas. In Scenario C a shift towards renewable and nuclear energy takes place in the second half of the next century. Finally, in Scenario D the shift towards renewable and nuclear energy already takes place in the first half of this century (IPCC 1990b:xxxiv).

2.3.2 IS92 Scenarios

Taking into account different estimates causes a widening of the range of the population growth in the IS92 scenarios compared to the SA90 scenarios. The IS92a and b update the World Bank estimate used in the SA90 scenario, which leads to a slightly higher estimate for population growth (11.3 instead of 10.5 billion people). As alternative population growth assumptions for some IS92 Scenarios (IS92c, IS92d) the UN medium-low forecast of 6.4 billion people is taken and for the IS92f scenario the UN medium-high case is considered, which leads to a global population of 17.6 billion by 2100. (Pepper et al. 1992:3)

The IS92 scenarios span a range for global average economic growth from 1.6 to 2.5 Percent - the SA90 high and low growth scenario assumed 1.1 and 3 Percent (Pepper et al. 1992:13). In addition, the IS92 does not use the mean of the high and low growth projections. This widening of the economic growth rate projections is the main cause for the increased range of the emissions level of the IS92 scenarios. Like in the SA90 scenarios, the GNP growth is as-

sumed to slow down towards the end of the 21st century because of the expected slowing of population growth. (Pepper et al. 1992:11)

Because there are no carbon fees or other climate policy assumed, the reduction of the energy intensity and carbon content is lower in the IS92 scenarios and has a smaller range than the SA90 scenarios series. Even though, the "share of different primary energy supplies change dramatically in all of the scenarios due to assumed limitation in fossil resources, expected advances in energy technologies, as well as calculated increase in energy prices" (IPCC 1992:84). The two central IS92 scenarios (IS92a, IS92b) assume conventional oil and gas production to be gradually replaced by unconventional fossil resources, by synthetic fuels from coal, and non-fossil energy supplies, leading to a to a non-fossil primary energy supply of 43% by 2100 (IPCC 1992:84). In the IS92 scenarios a tendency towards more optimistic and more pessimistic[3] scenarios can be observed, since high economic growth is coupled with high availability of conventional oil and gas resources as well as phase out of nuclear, slower decrease or even increase of the costs of renewable or nuclear energy (IS92e, IS92f). On the other side the scenario with low economic growth assume low conventional oil and gas resources, as well as higher decline in the costs for renewable and nuclear energy (IPCC 1992:84).

[3] Optimistic designates in this context assumptions that promote low greenhouse gas emissions and vice versa for pessimistic.

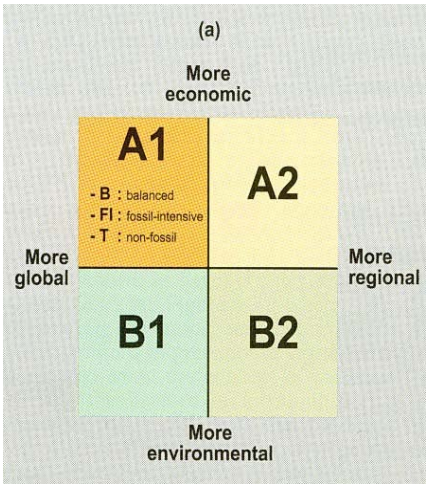
2.3.3 SRES Scenarios

Since the SRES scenarios are the most complex scenarios, they will be analyzed in more detail.

Storylines

The SRES scenarios are based on four different storylines for the future development. Figure 3 shows that the four storylines can be described by the two axis globalization and sustainability[4]. The A1 and B1 future assume a fast globalization, but while in the A1 world sustainability is not important, the B1 world assumes growing emphasis on sustainability. The A2 and B2 assume a heterogenic world, with slow globalization. Again the B2 version, contrary to the A2, assumes high emphasis on sustainability.

Figure 3 SRES storyline axis



(IPCC 2000)

Population

In the SRES scenarios the range of the projected population growth is slightly smaller than in the IS92 scenarios. Again, three different population levels are projected for 2100. The assumed global population depends on the speed and extends of demographic transition. For the medium estimate of the B2 scenario family, the fertility rates are assumed to converge to replacement levels, consistent with the UN medium scenario at 10.4 billion people. The A1 and B1 scenario families adopt a variant of the low population scenario, in which fertility falls below replacement level, peaks in the mid 21st century and declines to 7 billion people. A high population level of 15.1 billion people at the end of the next century is assumed in the A2 scenario families (IPCC 2000d:192).

[4] As the IPCC tried to have a "value-free" scenarios description, a more neutral description of the axes was chosen for the IPCC Reports: Instead of globalization "more global or more regional orientation" and instead of sustainability "more economic or more environmental orientation" (IPCC 2000d). Since the comprehensibility of the characteristics is very important to this thesis the more coherent terms "sustainability" and "globalization" are used to describe the axis.

Table 2 Growth rates and SRES storylines [%]

			less sustainability						
	Population	Income	Energy intensity	Carbon intensity	Population	Income	Energy intensity	Carbon intensity	
fast globalization	A1 Scenarios				A2 Scenario				**slow globalization**
	0.3	2.7	-1.4	-0.2[1]	1.0	1.3	-0.8	0.0	
	0.3	2.3	-2.2	-0.5	0.6	1.6	-1.0	-0.5	
	B1 Scenario				B2 Scenario				
			more sustainability						

[1] A1F1 Scenario, -1.0 for the A1B and -1.9 for the A1T Scenario.

Note: The formula used for the calculation of the annual growth rates is described in section 4.2.3.

In table 2 the kaya terms are listed according to the axis of the storylines. The population projections are consistent with the storylines. Fast globalization leads to a faster convergence of fertility pattern, consequently the B1 and A1 scenario assume the lowest population growth. Contrarily the high population in the A2 and B2 scenario is coupled with the assumed heterogeneous world, in which fertility patterns converge slowly. The lower population growth of the B2 scenarios compared to the A2 can be explained by the emphasize on sustainable development, which includes more equity, less income difference, education and welfare programs (IPCC 2000d:182).

Income

In the SRES scenarios the income range is smaller but higher than in the IS92 scenario. Furthermore as shown in figure 1 and indicated in table 2, low population growth and high income growth are coupled and vice versa. This leads to a decrease of the range of economic growth to 2.2 to 3 percent – smaller but above the low and high growth projections of the SA90 scenarios. The assumed and in empiric data evident relationship between low population growth and higher income growth (IPCC 2000d:194) is also plausible with the assumed storylines. The globalization on one side leads to lower growth rates caused by the convergence of the fertility patterns favored by the intensive exchange of the cultures, on the other side the globalizations also implies free trade, which favors higher economic growth.

Energy Intensity

In the SRES scenarios the range of energy and carbon intensity enlarges towards higher decrease. Interestingly the SA90 and the SRES scenarios have a similar kaya structure on the global level: Both have a relatively narrow GDP estimate and the assumptions about energy intensity and carbon intensity is the main cause for the widening of the emissions levels of the different scenarios. In Scenario B1 for energy intensity and in Scenario A1T1 for carbon content, an even higher decrease is assumed than in the SA90 scenarios, with the strongest emission controls. However, the energy intensity assumptions are linked plausibly to the storylines. As seen in table 2 energy intensity assumptions decreases faster with fast globalization and with more sustainability. The stronger decrease with globalization is caused by the assumptions that the energy intensities decline invariably with increasing income levels. The higher decrease with more sustainability is a consequence of a more economical use of natural resources, which is a plausible consequence of the environmental policies assumed for the B1 and B2 world (IPCC 2000d:82).

Carbon Intensity

Considering the A1FI scenario out of the A1 scenarios, the different rates of decrease in carbon intensity are plausible with the storyline axis. The high income and economic growth is correlated with faster technology improvements, which favors also the development of renewable energy. This increases the share of non-fossil fuel technologies in the fast globalization scenarios. In contrast, new technologies diffuse only slowly in a heterogenic world. The faster decrease of carbon intensity in the scenarios with more sustainability is due to the assumed policies for cleaner energy supply (IPCC 2000d:214). The reason that A1B and A1T have stronger decarbonization than the B1 Scenario is not directly plausible from the storylines axis.

Technology

The reason for the different decarbonization rates within the A1 scenario is the assumption of a different direction of technology development. Table 3 summarizes the assumptions for the technology improvements for extraction, distribution and conversion technologies as well as the share of zero carbon energy supply by 2100 for the different SRES scenarios.

Table 3 Technology improvements in illustrative SRES scenarios[1]

Scenario	Coal	Oil	Gas	Non-fossil	Zero carbon by 2100 [%][2]
A1FI[3]	Low	Very high	Very high	Medium	31
A1B	High	High	High	High	65
A1T	Low	High	High	Very High	85
A2	Medium	Low	Low	Low	28
B1	Medium	Medium	Medium	Moderate-high	52
B2	Low	Low-medium	Moderate-high	Medium	49

[1](IPCC 2000d:212) [2] Share of zero carbon in primary energy by 2100 (IPCC 2000d:16) [3]As in the final report the A1C and A1G scenario are summarized in A1F1 by taking a A1G Scenario, the assumptions for the A1G scenarios are given.

As shown table 3, A1B and A1T assume high improvements for non-fossil technologies, leading to a share of zero carbon in primary energy by 2100, which is higher than in the scenarios with assumed emphasis on sustainability (B1).

2.4 Models

2.4.1 IS92 and SA90: Atmospheric Stabilization Framework (ASF)

For the SA90 and the IS92 the Atmospheric Stabilization Framework (ASF) model was used. The ASF is an integrated set of computer models that utilize common assumptions of population growth, economic growth, and structural change to develop scenarios of emissions of greenhouse gases. The ASF energy module is a partial equilibrium model that uses energy prices to balance the supply and demand. The energy demand is calculated by a top down model, in which energy demand is estimated for four sectors and is a function of population, GDP, energy prices, and assumptions concerning autonomous efficiency improvements. The energy supply is modeled in several ways depending on the energy type. Fossil fuels are represented as finite resources, and marginal cost extraction curves define the price at which the resources can be developed. Nuclear and solar energy are represented with exogenous supply prices over time. Hydro energy is exogenously specified, and bio fuels are represented as finite resources estimates combined with production and conversion costs.

The development of energy CO_2 scenarios required four steps: First, assumptions concerning changes in energy intensity and energy supply mix were extracted from the Energy and Industry Subgroup scenario, extended past 2025 and reformatted for use in the ASF. Second, assumptions were made concerning energy resources and supply costs. Third, the Assumptions were incorporated into the ASF along with emission coefficients for CO_2 and other greenhouse gases. Fourth, the future emissions were calculated (Pepper et al. 1992).

2.4.2 SRES: Six Modeling approaches

In the SRES six models were used, among them again the ASF models. In addition, to the previous description of the ASF model, the Model for Energy Supply Strategy Alternatives and its General Environmental Impact (MESSAGE) from the IIASA will be described. This model was used for all marker scenarios and out of the final six illustrative scenarios, two were modeled with the MESSAGE (B2, A1T):

> Input assumptions for this model are population and per capita economic growth by region. Energy demand is derived using the Scenario Generator (SG) model, a dynamic model of future economic and energy development. The SG uses a set of regression equations estimated using economic and energy data sets. Important variables can be adjusted according to the storyline. The resulting final energy demands are disaggregated into six demand sectors: Industrial specific and non-specific, residential/commercial specific and non-specific, transportation and non-commercial (e.g. fuel wood). "Specific" means that energy with high exergy is required (like electricity or hydrogen).
>
> The MESSAGE model calculates cost-minimal supply structures under the constraints of resource availability, the menu of given technologies, and the demand of energy.
>
> The MESSAGE is linked to the MACRO model and used in tandem test scenario consistency, because the MESSAGE is a bottom-up model, while the MACRO is a top-down model. The MACRO maximizes the inter-temporal utility function of a single representative producer-consumer in each world region and estimates the relationships between macro-economic development and energy use (IPCC 2000d; Riahi and Roehrl 2000).

Even though the models have different regional aggregation, all have incommon four "macro-regions": The OECD countries, countries undergoing an economic reform (East Europe and

countries from the former Soviet Union), all developing countries in Asia and the rest of the world (Africa, Latin America and Middle East). These macro-regions are consistent with the Framework Convention on Climate Change: The first two groups of countries represent the Annex I and the second group the non-Annex I countries.

2.5 New Findings

In this sub-section the main changes are summarized and listed with the findings that led to these changes:

2.5.1 For the IS92 Scenarios

Concerning CO_2-emission from energy consumption, the new findings were the revision of the population forecast of the World Bank and economic growth due to political reforms in the former USSR, Eastern Europe and other countries. Furthermore, the war in the Persian Gulf was considered to possibly have an influence on log-term structural changes. Finally, there were new findings for a more optimistic assessment of the economical availability of renewable energy resources. This led to an update of the SA90 A Scenario. Additional scenarios were not the result of new findings, but form the intent to explore the sensitivity of the results to several sets of alternative, interdependent input assumptions for key variables. In the SA90 this was only made for GDP Growth, but didn't lead to different baseline scenarios, because a medium scenario was chosen (Pepper et al. 1992).

2.5.2 For the SRES Scenarios

Some findings leading to the need of new IPCC scenarios are described in the Evaluation of the IS92 through the IPCC (see sub-section 2.1.4). Beside the update of input assumptions, the exploration of a variety of economic development pathways (e.g., a closing of the income gap between industrialized and developing regions) and different trends in technological change was also recommended. These recommendations are considered by the SRES: In the B1 and A1 the income gap gets smaller in relative terms. The A1 family develops into three groups describing alternative directions of technological change in the energy system.

The recommendations about the process of developing scenarios were considered by choosing a broad writing team and having an "open process" where different modelers could partici-

pate. Additionally, an effort for the recommended harmonization of the input assumptions of the different models is done.

On the other hand the IPCC Evaluation of the IS92 scenarios led to the recommendation, that new scenarios fulfill not only the purpose of input to the evaluation of the climatic consequence of "non-intervention", but also of interventions. In addition new scenarios should examine the feasibility and costs of mitigating greenhouse gases and offer input for negotiating possible emission reductions for different countries and geographic regions. Only the first purpose is fulfilled by the SRES. Especially for the last purpose, a single or few baselines would be necessary. For the second purpose intervention scenarios would be needed.

In addition, to the consideration of recommendation of the IS92 Evaluation, the SRES also took into account new findings for the scenario construction. The most important for the SRES structure are the following:

1. Population projection: A scientific improvement for a narrower population projection is the incorporation of a correlation between mortality rates and fertility (Lutz 1996 in (IPCC 2000d)). Therefore the SRES range for the population projection by 2100 with 7 to 15.1 billion people is somewhat narrower than in the IS92 (6.4 billion to 17.6 billion). However this still spans a very large range of uncertainty, since a survey of demographic experts on probabilities of to the population projections showed that the 5^{th} and 95^{th} percentile intervals are between 6.7 and 15.6 billion people by 2100 (Lutz et al. 1997 in (IPCC 2000d)).

2. Barro (1997 in (IPCC 2000d)) reports a statistically significant correlation between per capita GDP growth and the variables life expectancy and fertility. This finding is considered in the SRES by combining high population growth with lower income growth and vice versa. These leads to a much smaller range of GDP, compared to the IS92 scenarios, even if the same range of uncertainties for income growth is assumed (see also figure 2 section 2.2)

3. Energy Resources and Reserves[5]: Since the specific demand for these fuels "converts" resources into reserves (Odell 1999 in (IPCC 2000d)), the remaining energy supply is seen as dynamic process, where the uncertainties is more about the future technologies

[5] Resources are defined by the SRES as occurrence of material in recognizable form. Reserves are resources which are recoverable under existing economic and operating conditions (IPCC 2000d).

than the estimates about resources and reserves. Table 4 shows the additional resources, which could get available with technological progress.

Table 4 Global energy reserves, resources, and occurrences [ZJ (10^{21}J)]

	Consumption			Conventional Resources		Recoverable with Technological Progress	Additional Occurence
	1860 - 1990	1990	Reserves Identified	Remaining to be Discovered			
Oil							
Conventional	3.35	0.13	6.3	1.6	5.9		
Unconventional	—	—	7.1			9	>15
Gas							
Conventional	1.7	0.07	5.4	9.4	22.6		>10
Unconventional	—	—	6.9			20	>22
Hydrates	—	—					>800
Coal	5.2	0.09	22.9			80	>150
Total	10.25	0.29	48.6	>11.0	>28.5	>109	>987
Nuclear	0.21	0.02	2			>11	>1,000

(IPCC 2000d)

2.6 Type of Scenarios

In this section a characterization of the scenarios according to the typology of van Notten et al. (2003) is conducted. Van Notten uses three overarching themes for the scenario classification: The project goal, the process design and the scenario content. Table 4 summarizes the main changing characteristics from type of the IPCC scenarios.

Table 5 Changing type of the IPCC scenarios[1]

Criterions[2]	SA90	IS92	SRES
Project goal	decision support	exploratory	exploratory approach /decision supporting results
Vantage point	back casting	forecasting	Forecasting
Process design	formal	formal	storylines and formal
Resources (Time / Authors)	≈ 1 year / 2 expert groups	≈ 1 year / 6 leading authors	≈ 3 years / 28 lead authors
Institutional conditions	-	no additional climate policy	no additional climate policy
Scenario content	complex	complex	very complex
Dynamics	Trend	with worst case and best case	with radical change
Level of deviation[3]	≈ 12.8 – 32 GtC[4]	≈ 4.6 – 34.9 GtC	≈ 4.3 – 30.3 GtC

[1] Only important changing characteristics are listed and only changing aspects are mentioned [2] Overarching themes in bold letters [3] For the SA90 Scenario the high and low economic growth scenario of the Non-Intervention (SA90 A) Scenarios is chosen. For the SRES the range of the illustrative scenarios is chosen.

2.6.1 Goal

The first overarching theme of scenario is the project goal. On one end of the scenario spectrum are the exploratory scenarios, on the other end the decision supporting scenarios. While exploratory scenarios – as indicated by their name – investigate different possible futures, the decision support scenarios in contrast examine path to the future that vary according to their desirability and may even propose concrete strategic options.

The SA90 scenario described a BaU and alternative scenarios. Latter scenarios describe the energy mix that need to be reached through climate policy by a certain time to reduce the climate change. Therefore the SA90 scenarios clearly are decision supporting scenarios. The IS92 scenarios explore alternative futures by choosing different input assumptions like population growth, income growth and availability of energy resources. The SRES scenarios also explore uncertainties, which can be described as speed of globalization, level of transition towards more sustainability and direction of technological change. As the latter two uncertain-

ties are in the area of climate policies, the SRES are also decisions supporting scenarios: The B1 and B2 scenarios show that an emphasis on sustainable development leads to lower emissions levels and the A1B and A1T scenarios show that even in absence of a sustainable development a shift in technology can lead to low emission futures. Therefore the SRES can be described as an explorative approach with a decision-supporting outcome.

The further characteristics of the project goal according to van Notten et al. (2003) are the inclusion of norms, the vantage point, the subject, the time scale and the special scale of the scenarios. Since it can be justifiably argued that all scenarios are normative as they consist of the interpretations, values, and interests of the scenario developers, van Notten et al. (2003) distinguish between descriptive scenarios that explore possible futures, and normative scenarios that describe probable or preferable futures. But as a possible future can also be a preferable future, a clear distinction within the IPCC scenarios is hardly feasible. Even though the SRES scenarios can be seen as more normative than the previous scenarios because they include values like sustainability, which is a normative concept. While the SA90 scenarios were constructed back casting, by assuming different duration for doubling atmospheric CO_2-equivalent concentration, the IS92 and SRES Scenario are clearly forecasting scenarios which calculate the future greenhouse gas emissions on the basis of different assumptions. The subject, time scale and special scale of the different IPCC scenarios are very similar or identical.

2.6.2 Design

The second overarching theme is process design. Here a distinction between formal scenarios on one side and intuitive scenarios on the other side is made. The SA90 and IS92 scenario were constructed in a very formal way. In the SA90 the necessary energy and carbon intensity was calculated in a backward procedure. In the IS92 Scenario a forward procedure calculated the future emissions on the basis of a wide range of assumptions. By developing storylines on which the qualitative assumptions are based to calculate the future greenhouse gas emissions, the SRES scenario combine intuitive and formal process design.

The further characteristic of the process design according to van Notten et al. (2003) are the type of date, the method of data collection, the resources and the institutional conditions. All IPCC scenarios are mainly quantitative scenarios and use computer models. The data-selection got more participatory with the SRES scenarios. Resources measured by the time and participants were massively higher for the SRES scenarios, compared to the primary IPCC scenarios. The most obvious changing institutional condition of the IPCC scenario is the request to exclude additional climate policy in the IS92 and SRES scenarios.

2.6.3 Content

The third and final overarching theme, the scenario content, looks at the composition of the developed scenarios. Certainly all IPCC scenarios are complex due to the complex issue they deal with. But the complexity of the scenarios increased with the SRES scenarios, as they take into account further interaction of the scenario drivers and new findings about technology dynamics.

According to van Notten et al. (2003), the further characteristic of the scenario content are the temporal nature, the nature of the variables, the nature of the dynamics, the level of deviation, and the level of integration. While the temporal nature and the nature of the variables are very similar in all the IPCC scenarios, the other characteristics are changing within the IPCC scenario series. For the dynamic scenarios van Notten et al. (2003) distinguish between peripheral and trend or surprise-free scenarios. If we compare only the non-intervention scenario (SA90 A, IS90, SRES) a clear change from trend to peripheral scenarios is obvious: From a single intermediate scenario (SA90 A) to a series with optimistic and pessimistic scenarios (IS92) and to a series of scenarios with radical changes (SRES).

2.7 Communication

2.7.1 From prediction to projection

A very obvious change in the communication of the scenarios is indicated by Mieg (2004). While the SA90 A scenario was used in the First IPCC Assessment Report to "predict" the future emissions and climate change (IPCC 1990b), the IS92 are used in the second report to "project" the future climate change (IPCC 1995a).

2.7.2 No more Impacts

Contrary to 1990 and 1992, the IPCC 2000 scenarios are not explicitly regarding global change. The SRES gives no information about the climatic impact of the different scenarios. However, the SRES are interpreted in the Climate-Change 2001 Synthesis Report (IPCC 2001b):

> "Question 3: What is known about the regional and global climatic, environmental, and socio-economic consequences in the next 25, 50, and 100 years associated with a range

of greenhouse gas emissions arising from scenarios used in the TAR (projections which involve no climate policy intervention)?

For the six illustrative SRES emissions scenarios, the projected concentration of CO_2 in the year 2100 ranges from 540 to 970 ppm, compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000. The different socio-economic assumptions (demographic, social, economic, and technological) result in the different levels of future greenhouse gases and aerosols. …" (IPCC 2001b)

2.7.3 No more Recommendations

The SA90 were called scenario A, B, C and D. The SA90 scenario was also called BaU scenario. This reflected the fact that the scenario A assumed a growth in CO_2-emisson similar to the historical trend, while the other scenarios make energy efficiency and carbon content assumptions which led to lower CO_2-emissions. The description of the different scenarios focuses on the assumed energy mix: SA90 A assumes coal intensive and only modest efficiency increase; SA90 B assumes that energy supply mix shifts towards lower carbon fuel; Scenario C shifts towards renewable and nuclear energy in the second half of the century and Scenario D assumes that this shift takes already place in the first half of the century (IPCC 1990b:xxxiv).

The IS92 are described as "how future emissions might evolve in the absence of climate policies beyond those already adopted" (IPCC 1992:10-11). The Special Report on Emission Scenarios (SRES) also emphasizes that there is no judgment offered in the report as to "… the preference for any of the scenarios, probabilities of occurrence, neither must they be interpreted as policy recommendations." (IPCC 2000d:3).

3 Possible reason for six SRES Baselines

In the first section the main hypothesis will be answered on the basis of the analysis of the previous chapter. A third main hypothesis is formulated. According to the remaining open questions each of the main hypotheses is divided into more specific sup-hypothesis.

3.1 Open Questions and Third Hypothesis

After the first analysis of the IPCC scenarios the question about reason for the large number of SRES baselines proposed by the two main hypotheses – external respectively scientific reason – will be answered as far as possible. Open question will be addressed in the following section by proposing sub-hypothesis.

3.1.1 From the SA90 to the IS92

The most obvious change in the structure of the IPCC scenario from the SA90 to the IS92 scenarios is the splitting up of the SA90 BaU scenario into six baseline scenarios and the loss of intervention scenarios. The loss of the intervention scenarios is clearly due to the ToR. Whether this request is an external influence is an open question. The use of six baseline scenarios can partially be explained by the intention to explore uncertainties. However, the SA90 also had an uncertainty range (high and low economic growth scenario), but an intermediate scenario was chosen. Therefore the reason for the selection of six baseline scenarios is an other open question.

Other changes like the update of the input assumptions and the forward calculating can be explained with scientific findings respectively more scientific methodology.

3.1.2 From the IS92 to the SRES

In the SRES again no intervention scenarios are considered due to the ToR and six-baseline scenarios are recommended as input for climate modeling. Therefore the questions persist concerning the reasons for the exclusion of interventions in the ToR and the recommendation of six baseline scenarios formulated for the IS92 scenarios. In addition, even if both, IS92 and

SRES, use six baseline scenarios, the uncertainty behind the scenarios is very different as observed by studying the kaya terms (see section 2.2). The smaller range of the GDP projection, despite the higher uncertainties assumed in income and population growth can be explained by the new finding about the linkage of small population growth and high economic growth. The closure of income gap in some scenarios is also a recommendation of the Evaluation of the IS92 scenario by the IPCC. The huge uncertainty concerning the decrease of energy and carbon intensity can also partially be explained by the recommendation of the IS92 Evaluation to examine different changes in technological directions. But it remains an open question why this recommendation is considered in a series of non-intervention scenarios, since an energy path in direction of renewable and nuclear energy is considered as intervention scenario in the SA90 scenarios. The reasons why two worlds with growing emphasis on sustainability (B1 and B1) are considered in the six non-intervention scenarios remain unclear. For scenario users who didn't recognize that some baselines explore a non-fossil technology or sustainability path the perceived baseline uncertainty is even higher, since they could get the false impression that all the baselines assume future energy shares or policies similar than today (see 2.7.2). Hence also the reason for the neutral communication of the scenario is an open question, which is important perceived baseline uncertainty.

3.1.3 Summary

In sum, the open questions to answer the two main hypotheses about the reason for the use of six baseline scenarios, and the absence of intervention scenarios are:

1. Is the request to exclude intervention scenarios in the IS92 and SRES scenarios influenced by external reasons?

2. Why are six non-intervention baseline scenarios chosen in the IS92 and SRES scenarios?

3. Why are the SRES non-intervention baseline scenarios extended with scenarios that explore the consequence of sustainability and/or technological change towards non-fossil energies?

4. Why were SRES labeled very neutrally, even if they assumed sustainability and/or technological change towards non-fossil energies?

The last question (4) doesn't directly address the reason for the use of six non-intervention baselines, but for scenario users the baseline uncertainty is perceived as higher if they are not fully aware of the underlying assumption. Therefore this question will be pursued.

For the second and third question not only external influence or scientific findings must be considered as an explanation, but also the categorization of the scenarios. Since the future policy has an influence on the range of future emission scenarios, it is important which policy is excluded from the non-intervention scenarios by the chosen categorization. Therefore the following third main hypothesis needs to be analyzed:

3. The used categorization explains the increase of the number of baseline to six scenarios.

Now there are three proposed reasons for the increase to six baseline scenarios: Scientific, external and conceptual reasons.

3.2 Scientific Reasons

The first hypothesis is that the use of six baseline scenarios can be explained by scientific reasons. Scientific findings lead to a reduction of the uncertainties about the GDP projection and availability of fossil resources (see section 2.5). Therefore new findings cannot explain the increase of the baseline range and number in the SRES. However, the uncertainty of the future development remains very high and it is therefore difficult to judge whether the smaller uncertainty range for SRES would be scientific. Hence this hypothesis is analyzed indirectly by analyzing if scenarios from literature translated the uncertainty in the same way like the SRES. For this reason a comparison of the SRES with scenarios from literature is needed. If scenarios from literature have the same structure and similar content than the SRES scenarios, the main hypothesis (1) must be adopted.

In order to judge if the "neutral" labeling of the scenarios is scientific, the communication of the SRES will In addition, be compared with storyline scenarios from literature:

i. The structure of the SRES scenarios is reflected by the structure of the scenarios from literature.

ii. The communication and/or contents of storylines in the SRES are reflected in literature.

3.3 External Influence

The second main hypothesis assumes external influence as explanation for the increase of the baseline to six scenarios. This hypothesis is also analyzed by the sub-hypothesis of the previous section, since an external influence on the SRES is more plausible, if the SRES are not reflected by the literature. A direct external influence on the SRES could be expressed via request, open process or review procedure. Moreover there could be an indirect influence on the SRES. The reason for the "neutral" communication will again be considered, since this increases the uncertainty for user not fully aware about the underlying assumptions. The following sub-hypothesis does not only attempt to analyze the presence but also the kind of influence:

iii. The SRES experienced an external influence on their structure and/or communication via:

   a. The Terms of Reference

   b. Storylines

   c. Open process

   d. Review procedure

iv. Governments had an indirect influence on the communication and/or structure of the SRES.

Although the main research will focus on the SRES, the hypothesis iii.a and iii.d will also be analyzed for the IS92 Scenarios.

3.4 Conceptual Reasons

Finally the third main hypothesis postulates that six baseline scenarios are used because of the unclear categorization. To prove the influence of the categorization, it must be analyzed which policy is allowed in the scenarios by the used categorization and which policies are actually assumed in the scenarios. Therefore the following hypotheses are made:

v. The share of zero emission primary energy of more than 63 percent by 2100 reached in the A1B and A1T scenarios can only be achieved by surprise or with additional policy.

vi. The B1 and B2 scenarios assume additional policy for sustainability, which leads to lower emissions.

vii. A stricter categorization of the non-intervention scenarios is possible and would lead to a smaller range of baseline scenarios.

3.5 Is a Bau possible?

If the hypothesis about the external influence would be approved, the hypothesis about the scientific reason rejected and the sub hypothesis about the smaller BaU range in case of a stricter categorization verified, then the question arise whether a business-as-usual scenario is feasible. Therefore the question, why there is no single baseline scenario (so-called BaU scenario) will also be analyzed during the research.

4 Methodology

This chapter describes the multitude of the methodologies used to analyze why the number of baseline increased to six scenarios and to answers the hypothesis specified in the previous chapter.

4.1 Overview

The following Table gives an overview of the hypothesis and how they will be analyzed:

Table 5 Overview of the methods and sub-hypothesis

	Hypothesis (for exact description see section indicated)	Database	Literature	Open Archive	Experts Interview
i	Scenarios structure is reflected by literature (3.2)	X			
ii	Storylines are reflected by literature (3.2)		X		
iii.a	ToR led to influence on SRES (3.3)			X	X
iii.b	Storyline led to influence on SRES (3.3)				X
iii.c	Open process led to influence on SRES (3.3)				X
iii.d	Review procedure led to influence on SRES (3.3)			X	X
iv	Indirect influence on SRES (3.3)			X	X
v	A1B and the A1T scenario assume policy (3.4)		X		X
vi	B1 and B2 Scenarios assume policy (3.4)		X		X
vii	Smaller baseline range with clear categorization (3.4)		X		X
viii	A BaU is feasible (3.5)		X	X	X

4.2 Emission Scenario Database

4.2.1 Description of the Database

The SRES Emission Scenario Database (ESD) was developed to manage and access a large number of data sets and emissions scenarios documented in the literature and is described in the Appendix of the SRES (IPCC 2000d). The database was developed for SRES by the National Institute for Environmental Studies (NIES) of Japan and can be accessed via Internet.

The main sources of data used in ESD were International Energy Workshop, Energy Modeling Forum (EMF-14 comparison studies) data, the previous database compiled for the IPCC Supplement Report, "Climate Change 1994", which examined emission scenarios produced prior to 1994, and individual emission scenarios collected by the SRES writing team. The database used for the SRES included the results of a total of 416 scenarios from 171 sources. Most of these scenarios date after 1994.

Most of total 416 scenarios focus on energy-related CO2-emissions (256). Only three models estimated land-use related emissions – the ASF model, the IMAGE 2 model, and the AIM model. Very few scenarios considered global SO2 emissions.

4.2.2 Transformation of Database

For the present research the database Ipccdbv1-20050512.mdm was used and downloaded the 9.July 2006. In the first step the database was converted into a SPSS File. Then all scenarios with a time frame until 2100 and values for CO_2-emissions, energy consumption, GDP and Population on the global level were chosen. Because some scenarios had different names for the same variable some of these had to be changed (see Protocol Annex 1.1). Table 5 describes the remained number of scenario, their type and the time of their publication. The forty scenarios published in 2000 are the SRES scenarios. The scenarios published after the SRES are not considered, since they are mostly based on the SRES baselines and therefore assume the same structure. In the further research the 224 scenarios from literature published before 2000 are compared with the forty SRES scenarios.

Table 5 Global emission scenarios for 21st century from the ESD

Scenario Type	Time of publication				
	to 1990	to 1995	to 1999	2000	Total
Uncertain			18		18
non-intervention	2	8	18		28
Baseline	3	32	40	40[1]	115
Intervention		2	101		103
Total	5	42	177	40	264

(ESD 2006) [1]SRES Scenarios

4.2.3 Method for quantitative Comparison

To compare the SRES with the scenarios from literature, again the kaya hypothesis will be applied and the values on the global level considered. For the description of the kaya identity see section 2.2. The annual growth rates (r) are calculated on the basis of the values (X) for 1990 and 2100, with the following formula:

$$r = \left(\frac{X_{2100}}{X_{1990}} \right)^{\frac{1}{110}} - 1$$

This leads to an underestimation of cumulative emission in case of a high emission growth in the middle of the century and a low growth in the end of the century. Nevertheless, it is a good indication for the change of the main drivers during the whole century, since the difference of the emission scenario gets more obvious in the end of the 21st century.

The scenarios classification from the ESD will be used. The variable "scenario type" categorizes the scenarios from the ESD into Non-Intervention: Baseline, Non-Intervention: Other, Intervention and Uncertainty (see table 7). For this study, these categories will be named baseline, non-intervention, intervention and uncertainty. "Baselines" are the non-intervention scenarios used as reference for intervention scenarios. "Non-intervention" scenarios were not used as baseline and for example assume accelerated technology development or disasters. The scenarios categorized with uncertainty could not be clearly classified. In addition, the SRES are grouped into all forty SRES Scenarios (described with "SRES") and the six illustra-

tive Scenarios recommended by the SRES as smallest set of Scenarios (described with "SRES Report"). To illustrate the difference between these six groups of scenarios, box plots are used. A more detailed statistical analysis is not conducted, because the scenarios are not independent. For example scenario series with numerous scenarios would have stronger influence on mean and median although they represent only one publication. The box plot allows comparing the distribution, to recognize trends and to make robust findings.

4.3 Expert Interviews

Even if only relatively few statements from experts were used and the main findings of this research were based on literature, scenario comparison or conceptual reflections, the experts interview are very important to build the explicatory framework to the question about the reason for the increase of IPCC baselines to six scenarios with the SRES.

4.3.1 Goal

There are two reasons why expert interviews are very important for this research question:

1. **Procedure:** Even if the main procedure of the SRES construction is well described, there is more information necessary to answer hypothesis (iii) and assess whether external influences were possible and to which extend they took place.

2. **Input Assumptions:** Even though models calculate the future emissions, they are strongly determined by the input assumptions. The model can't say if such an input assumption is likely without policy. Therefore the scenarios are a product of the knowledge of the experts, and experts judge best the questions about scenarios and their input assumptions, which is needed for hypothesis (v) and (vi).

The expert interviews were also used in an explorative way for different open question. Therefore the interviews are a kind of cement for the whole diploma thesis. However, as mentioned not all the received information is evaluated directly, some of the information are hidden by literature reference indicated by the experts.

4.3.2 Methodology

The experts interview are conducted on the advices given by Mieg and Näf (2005). The most important point to be considered is that the interviewed person is an expert on the issue of the question. Therefore only IPCC scenario authors or persons who are very familiar with the IPCC scenarios were interviewed. Each expert was asked about his involvement with the IPCC scenario, to guarantee that the questions refer on the expertise. In addition, the questions focused on the specific experience of the SRES. Also the evaluation of the answers considers the experience of the experts. Table 6 shows all the interviewed experts. Seven of the interviews were made live and recorded on tape, the other interviews were made by mail. The live interviews lasted about 45 Minutes in order to keep the expenditure of time of the experts small. The advantage of the live interview is the possibility to insist in some question until every needed detail is known. This is especially important for the reconstruction of the SRES scenario construction procedure. Furthermore, in some live interview, important additional information about the SRES scenarios were given.

The experts approved only the statements cited in this report. The remaining information from the interview will not be published, although it was an important contribution to the competence building for this work.

Table 6 Interviewed expert and their expertise

Expert	Place of Interview	Date of Interview	Expertise
Nebojsa Nakicenovic	IIASA	14.7.06 15:00-16:00	SRES coordinating lead author
Rob Swart	Mail	7.2006	SRES coordinating lead author, lead author of the IS92 Scenarios
Bert Metz	RIVM	25.7.06 11:15-12:00	SRES lead author, responsible for the review of the SRES and Co-Chair of WGIII
Bert de Vries	Utrecht[1]	24.7.06 11:15-12:15	SRES Lead author, member of the modeling team for the B1 illustrative Scenario
Arnulf Grubler	IIASA	14.7.06 16:10-17:10	Lead author of SRES and IS92 Evaluation
Detlef van Vuuren	RIVM	25.7.06 9:45-10:30	Scenario Expert, published papers on the SRES
Keywan Riahi	IIASA	14.7.06 17:20-17:55	SRES lead author, member of the modeling team for the A1T illustrative Scenario
Mike Chadwick	Mail		SRES review editor
Leonardo Barreto	PSI	02.8.06 13:00-13:45	Energy scenario expert, used SRES as baseline scenarios and worked at the IIASA
Jane Leggett	Mail	8.2006	Lead author of the IS92 Scenarios
William Pepper	Mail	8.2006	Lead author of the IS92 Scenarios

Key: Rijksinstituut voor volksgezondheid en milieu (RIVM) in Bilthoven, Netherlands; International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Vienna, Austria. Paul Scherrer Institute (PSI), Villigen, Switzerland.

[1] Home of Bert de Vires, Utrecht, Netherlands.

4.4 Literature Review

4.4.1 Other Storylines

Since the use of storylines has an important influence on the SRES, their use and content in literature will be analyzed and compared with the SRES storylines (hypothesis ii).

Due to timely limitation, only the following scenarios and their storyline will be analyzed: Scenarios from the Global Scenario Group (Raskin et al. 2002), Global Environment Outlook Scenarios (UNEP 2002), World Business Council on Sustainable Development Scenarios (WBCSD 1997), World Water Vision Scenarios (Gallopin and Rijsberman 1999), OECD Scenarios (OECD 2001)and Millennium Ecosystem Assessment Scenarios (Morita et al. 2005).

Contrarily to the quantitative comparison of the SRES with the literature, scenarios published after the SRES are considered, because there are only few global scenarios with storylines published before the SRES.

4.4.2 Assumptions for SRES Scenarios

The SRES not only was a literature assessment but also a generation of new scenarios and new findings. However, as given by the rules of IPCC, the SRES writing team had to publish their results first in peer-review papers. Most of these papers were published in the 63rd Journal of Technological Forecasting and Social Change. These publications may provide interesting details on the assumed policy and the intention of the authors of the scenarios and therefore are suitable to answer hypothesis (v) and (vi) about the policy assumed in the A1B, A1T, B1 and B2 scenarios. In addition, the communication of the scenarios is focused, since unlike in the SRES report, the peer-review publications are entirely within the scientific community and therefore not subject to direct external influence. Differences in the communication of the scenarios in these papers compared to the SRES are an evidence for external influence on the communication of the SRES, which is the subject of hypothesis (iii) and (iv).

4.4.3 Categorization of IPCC Scenarios

Since the categorization of the scenario is the subject of hypothesis (vii), the categorization in the different IPCC reports on scenarios will be analyzed. For that purpose, the IPCC Assessment Report (IPCC 1990b) with the SA90 Scenarios, the Supplementary Report (IPCC 1992) with the IS92 Scenarios, the Evaluation of the IS92 Emission Scenarios (IPCC 1995b) and the SRES (IPCC 2000d) will be reanalyzed, focusing on the used categorization. In addition, the Mitigation Report (IPCC 2001a), which provides Mitigation Scenarios will also be considered.

4.5 Open Archive on SRES Review

According to the principles of governing of the IPCC, all requests from expert and governments of the final review procedure should be retained for a period of at least five years in an open archive in a location determined by the IPCC Secretariat and made available on request (IPCC 2003). Even though these five years have passed, the RIVM still had a CD with all experts and policy comments on the SRES and the final Draft of the SRES, which could be used to analyze the view of the experts on the SRES and the influence of the governments on the final report (hypothesis (iii.d).

The review comments are collected from the IPCC Technical Support Unit of the Working Group III. For the analysis not all the requests were considered. For the first re- view the general comments or synthesis comments are evaluated. For the second review, which consisted of an expert and government review, the general comments or synthesis comments and the comments on the SPM are analyzed. In the review of the final Draft all comments on the SPM are considered for the evaluation, including line per line comments.

Since the first and second order drafts are not available, they will not be cited and evaluated. This leads to some difficulties, since the documents, to which the comments refer, are not available.

5 Results of Research

After the introduction of the different methodologies the chapter will analyze and answer the sub-hypothesis made in chapter 3. Each section first describes the results of the research relevant to answer the according hypothesis. After this description a short summary is made in each section and the results are interpreted in order to answer the sub-hypothesis. Finally, on the basis of the results of the sub hypothesis, the three main hypotheses will be answered.

5.1 Quantitative Comparison of SRES and Literature

For the comparison of the structure of the SRES and the literature, only the ESD was used. To answer the sub-hypothesis (i), the number of baselines and the structure of the kaya terms are compared.

5.1.1 Number of Baseline Scenarios

There are 68 Scenario Series published before the SRES and collected in the ESD. The categorization into Baseline, other Non-Intervention, Uncertainty and Intervention was already done in the ESD (see section 4.2). Table 8 shows that only two scenario series included more than two baseline scenarios. The scenario series with six baseline Scenarios are the IS92 scenarios, which were also published by the IPCC. This is to say that more than two baseline scenarios is unusual in literature and that the scenario published in literature and colleted in the ESD doesn't reflect the use of six baseline scenario.

Table 7 Number of baselines in scenario series from ESD

Number of Scenario in Series	Uncertainty	Non-Intervention	Baseline	Intervention
1	2	4	44	5
2	1	6	11	5
3	1	4	1	3
4	1	0	0	6
5	0	0	0	1
6	0	0	1	2
more than 6	1	0	0	5
Total Series	6	14	57	27
Total Scenarios	18	28	75	103

(ESD 2006)

5.1.2 Projections for 2100

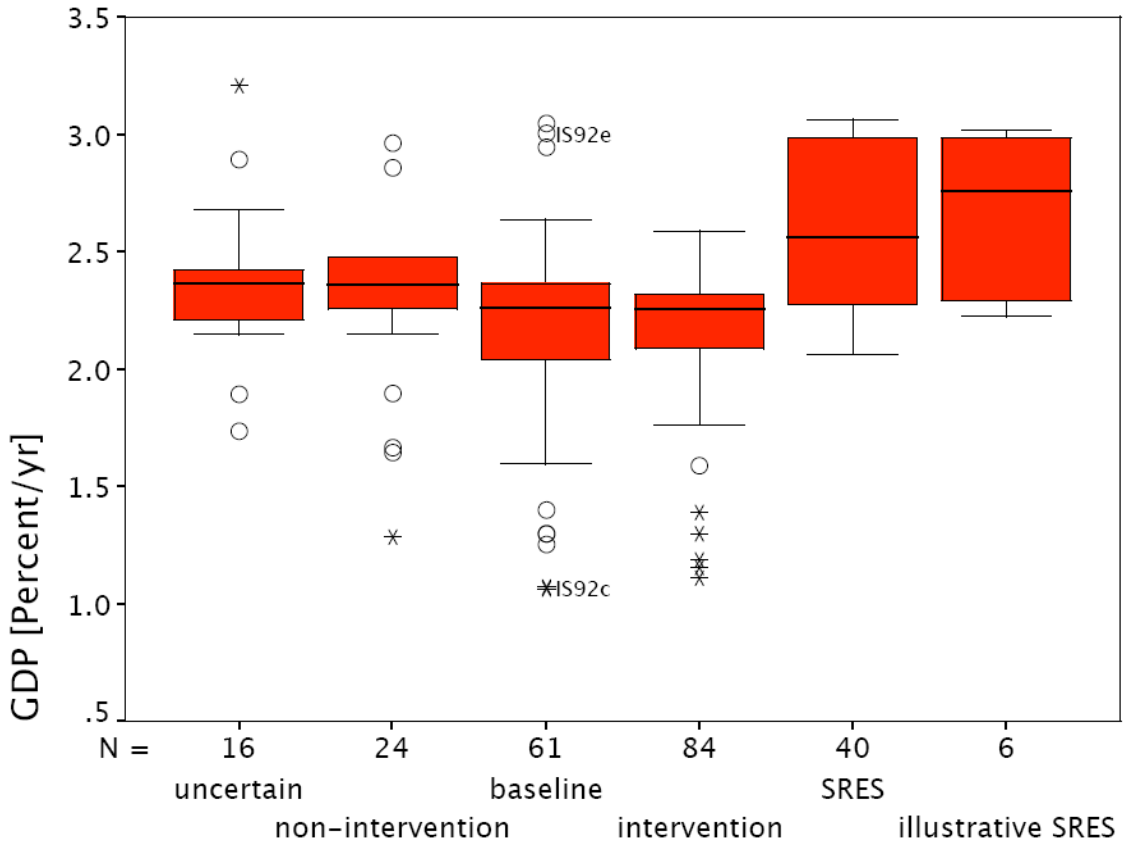
Population

Of the 248 scenarios published before the SRES and collected in the ESD, 55 Scenarios had a population projection. Only few different population estimates are used in literature for the emission scenarios. Most of the scenarios take a medium estimate of about 11.5 billion people in 2100. Only a couple of scenarios also use high and low estimates, with about 18 respectively 6 billion people in 2100. The SRES scenarios span also quite a large range from 7 to 15 billion people (Annex A 1.2).

GDP

Beside the SRES, 185 scenarios of the ESD provide GDP projections for 2100. Figure 4 shows that only few scenarios from literature assume GDP growth rates as high as the SRES, and that the low GDP projections from literature are not represented by the SRES. The selected illustrative SRES scenarios amplify this difference. No difference is visible between the three categorizes of scenarios from literature.

Figure 4 Comparison of GDP projection



(ESD 2006)

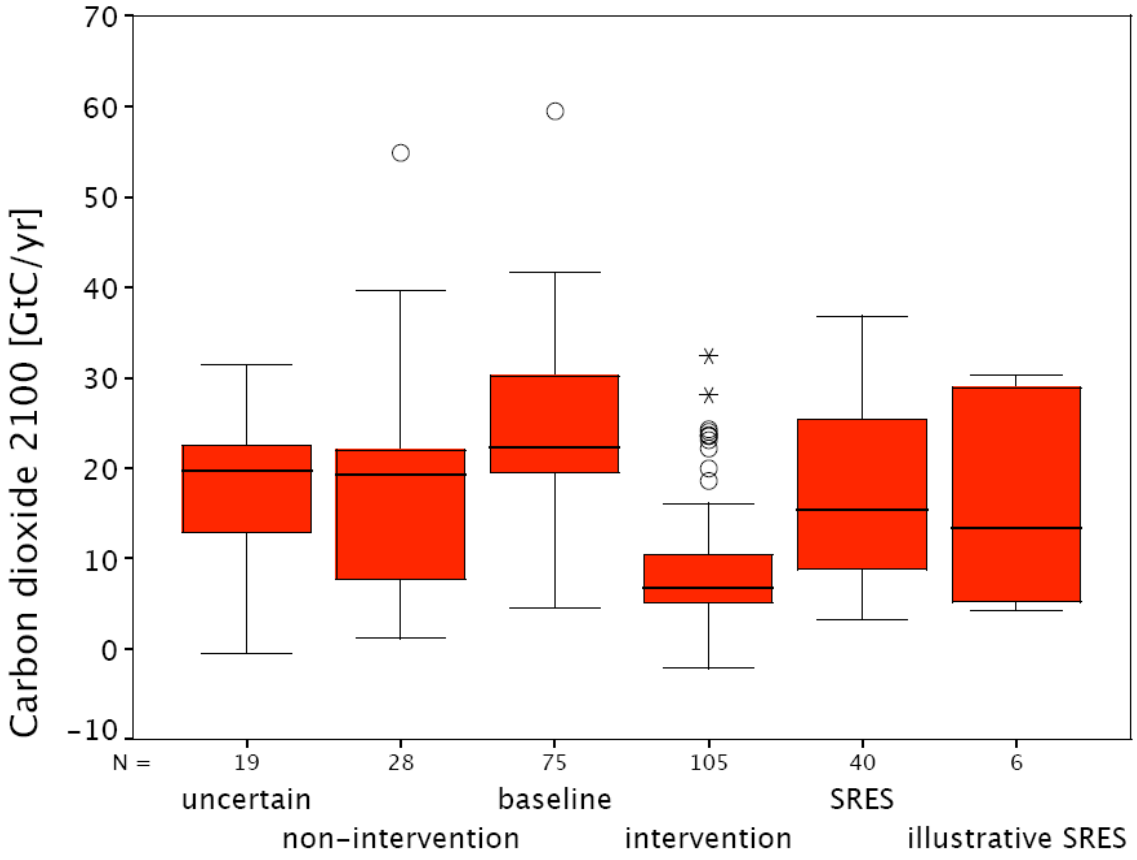
Energy Consumption

125 scenarios of the ESD provide projections for the energy consumption in 2100. The range of the energy consumptions in the SRES is reflected by the Literature (Annex A 1.3).

CO_2-Emissions

From the ESD scenarios beside the SRES, 227 scenarios provide projections for CO_2-emission for 2100. The Intervention Scenarios have clearly lower emission projections than the baseline scenarios. The SRES have deeper median emissions than the baseline scenarios, but reflects the range of the emission from the baseline scenarios from literature.

Figure 5 Comparison of CO_2-emission projection



(ESD 2006)

Income

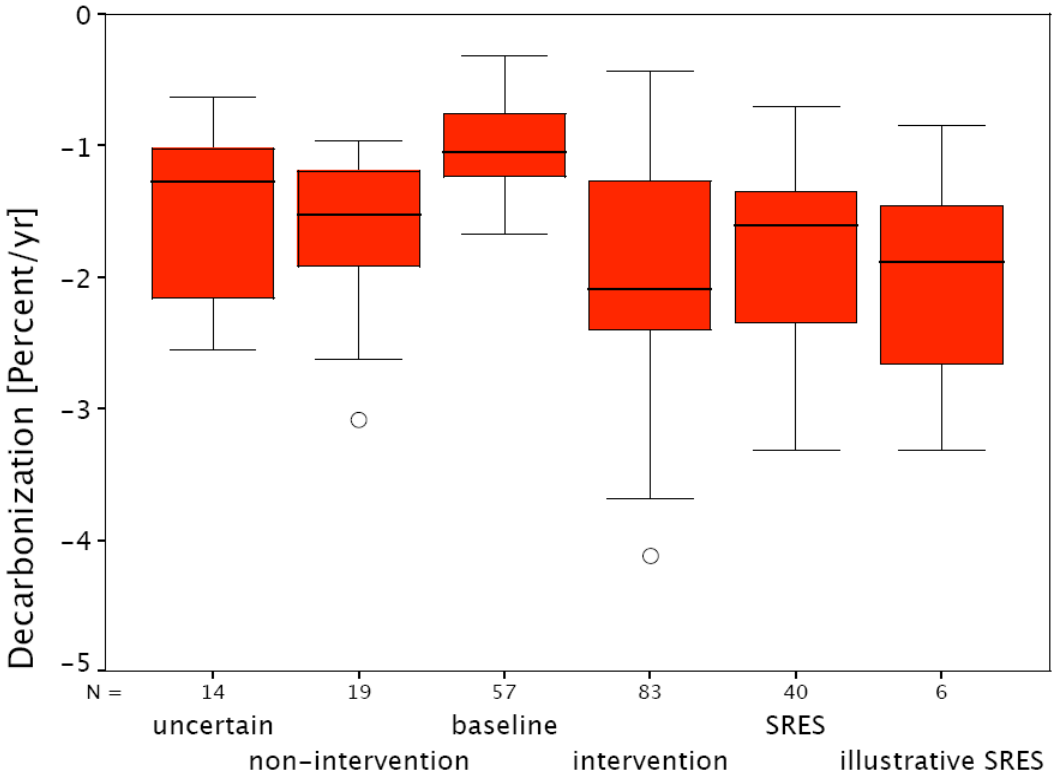
After the analysis of the aggregated kaya terms, the single terms will be analyzed, starting with the income growth. Similar to the GDP growth the income growth is clearly higher than in literature (Annex 1.4)

Decarbonization

The decrease of energy intensity of the SRES is more comparable with the intervention scenarios from literature than with the baseline scenarios (Annex A 1.5). This explains why the SRES have about the same energy projections than literature but much higher GDP growth. Also the decrease of carbon intensity is higher than in literature (Annex 1.6), therefore decrease of energy and carbon intensity is analyzed together. 173 of the 234 scenarios of the ESD provide projections for CO_2 and GDP. Figure 6 shows that the difference between inter-

vention and baseline scenarios is very clear for the decarbonization of CO_2 per GDP: The lower quartile of the baseline scenarios and the upper quartile of the intervention scenarios do not overlap. Also the upper quartile of the SRES scenarios doesn't overlap with the lower quartile of the baseline scenarios from literature. Moreover the distribution and range of the SRES scenarios fits much better with the intervention than with the baseline scenarios from literature. The six selected illustrative SRES scenarios even have a deeper medium decrease of CO_2 per GDP than the already deep medium of the forty SRES scenarios.

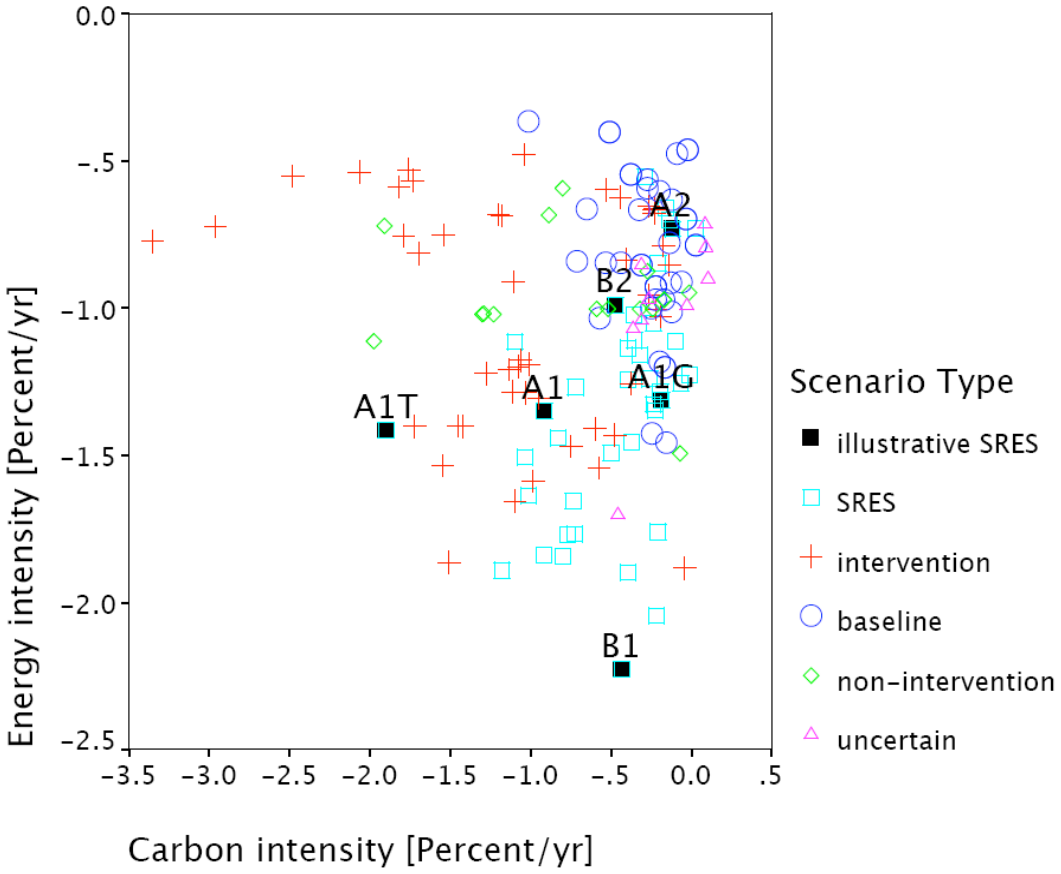
Figure 6 Comparison of decarbonization projections (in C per 1990US$)



(ESD 2006)

A more detailed analysis is made by plotting the values of the decrease in energy intensity against the decrease of carbon intensity. Beside the SRES, 96 scenarios provide values for these two axes. Figure 7 show that the baseline scenarios from literature don't pass the dashed line towards faster decarbonization. Therefore the decarbonization in the SRES is not reflected by the literature and the decrease of CO_2 per GDP of the illustrative A1T, B1 and A1B are in the range of intervention scenario from literature.

Figure 7 Decrease in energy and carbon intensity (C/J respectively J /1990US$)



(ESD 2006)

5.1.3 Summary

The comparison of the SRES scenario with the emission scenarios from literature collected in the ESD shows that except for the IPCC IS92 scenarios, not more that 3 baselines are used in literature. Most of the scenarios series use only one baseline scenario. The comparison of the kaya terms In addition, shows that the CO_2-emission from the SRES scenarios has a similar distribution as the non-intervention scenarios from literature. But the A1B, A1T and B1 Scenarios assume a decrease in CO_2 per GDP, which in literature was only assumed by intervention scenarios. This is not obvious when comparing only the CO2-emission, because the GDP projections of the SRES are much higher than in literature. Since neither the structure of the kaya terms nor the number of baseline scenarios is reflected by the literature collected in the ESD, hypothesis (i) can clearly be rejected.

5.2 Qualitative Comparison of SRES and Literature

For the assessment of sub-hypothesis (ii) a qualitative comparison of the scenario storyline of the SRES with the storylines used in literature is made.

5.2.1 Global Scenarios

Table 8 shows global scenario studies since 1995 that have a scientific and public policy orientation and are a subset of global exercises similar to the SRES scenarios. The table stems from the Millennium Assessment Report (Morita et al. 2005), but is updated with the Scenarios from the Millennium Assessment Report (MA) itself. The SRES are not described in detail, since they have already been introduced in chapter 2. The chronological order makes clear that most of these scenarios were published after the SRES. It is also an interesting finding that in most of the scenarios, member of the SRES writing team participated. Gerald Davis was in the project core team for the WBCSD scenarios (WBCSD 1997), Nebojsa Nakicenovic was in the Advisory Panel on the Environmental Outlook of the OECD (OECD 2001), Rob Swart was one of the authors of scenarios from the Global Scenarios Group (Raskin et al. 2002), Alcamo was one of the authors for the UNEP scenarios (UNEP 2002) and finally Morita and de Vries contributed to the MA scenarios (Morita et al. 2005).

Table 8 Global scenario using storylines

Study/ Horizon/ Focus	Scenario Structure
Study: WBCSD (1997) Horizon: 2050 Focus: Business and sustainability	1. FROG! („First Raise Our Growth!"): market-driven growth, economic globalization 2. GEOpolity (Global Ecosystem Organization): top-down approach to sustainability 3. Jazz: bottom-up approach to sustainability, ad hoc alliances, innovation
Study: WWV (Gallopin and Rijsberman 1999) Horizon: 2025 Focus: Freshwater crisis	1. Business-as-usual: current water policies continue, high inequity 2. Technology, Economics, and Private Sector: market-based mechanisms, better technology 3. Values and Lifestyles: less water-intensive activities, ecological preservation
SRES (IPCC 2000d)	A1; A2; B1; B2
Study: OECD (2001) Horizon: 2020 Focus: Environment in OECD countries	1. Reference Scenario 2. Subsidies removal 3. Subsidies removal + taxes
Global Scenarios Group (Raskin et al. 2002) Horizon: 2050 Focus: Environment; poverty reduction; human values	1. Conventional Worlds: gradual convergence in incomes and culture toward dominant market model a. Market Forces: market-driven globalization, trade liberalization, institutional modernization b. Policy Reform: strong policy focus on meeting social and environmental sustainability goals 2. Barbarization: social and environmental problems overwhelm market and policy response a. Breakdown: unbridled conflict, institutional disintegration, and economic collapse b. Fortress World: authoritarian rule with elites in "fortresses", poverty and repression outside 3. Great Transitions: fundamental changes in values, lifestyle, and institutions a. Eco-Communalism: local focus and bio-regional perspective b. New Sustainability Paradigm: new form of globalization that changes the character of industrial society
Study: GEO-3 (UNEP 2002) Horizon: 2032 Focus: Environment	1. Markets First (correspond 1a of GSG Scenarios) 2. Policy First (1b) 3. Security First (2b) 4. Sustainability First according to MA (3b)
Study: MA Horizon: 2100 Focus: Environment	1. Global Orchestration: socially conscious globalization, with emphasis on equity, economic growth, and public goods) 2. Order from Strength: regionalized, with emphasis on security and economic growth and with a reactive approach to ecosystems 3. Adapting Mosaic: regionalized, with an emphasis on proactive management of ecosystems, local adaptation, and flexible governance 4. TechnoGarden: globalize, with an emphasis on using technology to achieve environmental outcomes and with a pro active approach to ecosystems

5.2.2 Storyline Content

The narratives from the Global Scenario Group (GSG), which is an independent, international, interdisciplinary body that has been developing global and regional scenarios, spread the broadest range of the scenarios. Therefore the other scenarios can be allocated to the storylines of the GSG Scenarios. Table 11 shows such an allocation proposed by the MA.

Table 9 Comparison of storyline content

GSG	SRES	WBCSD	GEO-3	WWV	OECD	MA
Conventional Worlds						
Market Forces	A1	FROG!	Market first	BaU	Reference	(Global Orchestration)
Policy Reform	B1	GEO policy	Policy first	Technology and economics	Policy variants	
Barbarization						
Breakdown	A2					
Fortress World	(A2)		Security first			(Order from Strength)
Great Transitions						
Eco-Communalism	B2					(Adapting Mosaic)
New Sustainability Paradigm	(B1)	Jazz	Sustainability first	Lifestyle and values		(Techno Garden)

Key: GSG GEO-Global Environment Outlook, SRES Special Report on Emission Scenarios, WBCSD World Business Council on Sustainable Development, WWV World Water Vision, OECD Organization for Economic Co-operation and Development

Note: In brackets: Own allocation, other allocations from the MA (Morita et al. 2005).

The scenarios in bracket propose the allocation of the MA Scenarios. For the B1 Scenario the allocation made by the MA is not reflecting all the assumptions of the B1 world. In addition, the B1 world only assumes a A1 world with additional Policy Reforms, but also different lifestyle and values, which makes the B1 storyline more comparable with the Sustainable Sce-

nario form the GSG (de Vries et al. 2000). Table 9 also shows that the MA categorizes the storyline of the A1 scenario in the same way as the reference scenarios. Even though the storylines are qualitative, a distinction between intervention and non- intervention is obvious in literature. The names of the scenarios already indicate whether the scenario is interventionist or baseline. In literature, storylines like the B1 and B2 clearly are not baseline storylines.

Among the storylines scenarios from literature the content of the MA scenarios is closest to the SRES scenarios, although scenarios have been much more elaborated in the MA (Van Vuuren 2006). The Axis of the MA scenarios are governance and economic development (regional vs. global) and ecosystem service management (reactive vs. proactive). The SRES have similar axis: more regional vs. more global and more environmental oriented vs. more economic oriented. An interesting difference in the storylines is that the TechnoGarden scenario, which is similar to the B1, assumes climate policy.

5.2.3 Communication

Table 8 shows that except for the Jazz Scenario of the World Business Council for Sustainable Development (WBCSD) all scenarios are labeled with names more or less illustrating the main underlying assumptions. In addition, a closer look on the scenarios shows that all were used to strategic planning and to inform about the consequences of the scenarios. The WBCSD presented for each narrative a set of challenges to business and lessons to be drawn (WBCSD 1997). The World Water Vision (WWV) was conducted by the World Water Council to increase awareness of rising global water crisis and show which action can reduce or avoid this crisis (Gallopin and Rijsberman 1999). The OECD Scenarios already give the main policy recommendation with their names. Environmental consequences of the different scenarios are also illustrated (OECD 2001). The Global Scenario Group (GSG) provides the reader of “Great Transition - The Promise and Lure of the Times Ahead” not only with scenarios but also strategies of how to get there and what the scenarios mean for climate, peace, ecosystem, water stress and so on (Raskin et al. 2002). The UNEP scenarios of the third Global Environment Outlook (GEO-3) illustrated the environmental implications of the scenarios and give possible policy options (UNEP 2002). The Millennium Assessment (MA) gives clear information about the impact of the scenarios on the biodiversity and human well-being and provides recommendation for action needed.

5.2.4 Summary

In sum, it can be said that the SRES scenarios cover nearly the whole spectrum of storylines from literature. While the content of the SRES is reflected by the literature, the communication of the scenarios is not. Table 10 lists some communications characteristics. Contrary to the SRES, the literature clearly shows that some of the alternative scenarios are not baseline scenarios. In general, the A1 world is seen as BaU or reference scenarios, the A2 storyline as a worst case BaU. The B1 and B2 are clearly not seen as BaU scenarios, but as intervention scenarios, which assume specific actions, changing policy or values. In addition, all the scenarios from literature provide names, indicate the impact of the scenarios for the issue of the study and give clear recommendation for mitigation actions. Therefore hypothesis (ii) must be approved for the content, but rejected for the communication of the storylines. If the storylines from literature, which are clearly interventionist, are excluded, not even the content is reflected since no qualitative non-intervention scenario from literature assumes storylines as in B1 or B2.

Table 10 Comparison of the communication of the SRES storylines

Criteria	SRES	GSG	WBCSD	GEO-3	WWV	OECD	MA
Names	No	Yes	Yes	Yes	2 of 3	Yes	Yes
Impacts	No	Yes	Yes	Yes	Yes	Yes	Yes
Recommendation	No	Yes	Yes	Yes	Yes	Yes	Yes
Baseline and Intervention	No	Yes	Yes	Yes	Yes	Yes	Yes

Key: GSG GEO-Global Environment Outlook, SRES Special Report on Emission Scenarios, WBCSD World Business Council on Sustainable Development, WWV World Water Vision, OECD Organization for Economic Co-operation and Development

5.3 Direct Influence

This section is built mainly on the expert interviews, and in case of the IPCC review on the open archive. Each step of the SRES construction will be described. Thereafter it is evaluated if any external influence existed and if this influence led to a different structure of the SRES.

5.3.1 Terms of Reference

The request to exclude additional climate initiatives of the ToR was given because some countries insisted that there was a no agreement reached on emission reduction target and therefore to include specific climate policy interventions would be unwarranted (Swart 2006; Chadwick 2006). According to Swart, this is the same reason why intervention scenarios were excluded in the IS92 scenarios (Swart 2006).

Most of the interview authors didn't know exactly the reason for this request, because they were not involved with the SRES when the plenary decided.

5.3.2 Storylines

The idea to develop storylines came in the beginning of the scenario construction and was decided at the first meeting of the SRES authors (Swart 2006; De Vries 2006). The Shell strategic planning group supported the construction of storylines (De Vries 2006) and two "colleagues" from Shell International Petroleum - Gerald Davis (lead author) and Douglas McKay (contributing author) were members of the SRES writing team and facilitated the formulation of the storylines (Nakicenovic 2006). The storylines are based on qualitative scenario literature as well as on the quantitative emissions scenarios. This was a very elaborate and extensive process until the writing team agreed on four basic storylines that could cover most of the ranges of scenario driving forces from the literature, from population to energy and land use, to multigas emissions outcomes (Nakicenovic 2006). Some authors suggested to give the storylines simple attractive names (De Vries 2006), but relatively early in the process it was decided not to give names to the scenarios, because different words mean different things to different people and names are likely to be insufficient to capture the complex characteristics of the storylines. Also because of the former it was expected to be very difficult to agree on such words in an intergovernmental approval process for the eventual Summary for Policymakers (Swart 2006; Chadwick 2006)

The B1 storyline was contested those, who favored free market like some US participants and some economists. But also some environmentally oriented people (such as NGOs and environmental policy officials) felt the B1 baseline was too optimistic, lowering the urgency of policy intervention. (De Vries 2006; Metz 2006).

Having the storylines, it was a great challenge to derive from them the numbers needed for the model implementations of the scenarios (De Vries 2006). Also, not all the scenarios could follow the ideas of the storylines (De Vries 2006).

5.3.3 Open process

During the open process, the four provisional so-called marker scenarios were posted on the SRES website and everyone was invited to comment and/or make suggestions. This resulted in a lot of feedback and revision of the scenarios (Nakicenovic 2006; Swart 2006). The open process provided the first informal feedback and review by potential users of scenarios and enhanced the transparency of the scenarios and their development process (Nakicenovic 2006). That governments tried to use the open process to influence the scenarios to any significant extent for political purposes is not remembered; the input came predominantly from experts (Swart 2006).

During this open process a kind of third axis, technology, was introduced - mainly by members of the IIASA (De Vries 2006). The IIASA since the beginning intended to explore also the emissions-implications of technological change (Riahi 2006b).

5.3.4 Review

Rationale and Procedure of Review

The unique idea of IPCC is to co-produce knowledge. By participating in the process (defining terms of reference, outlines, reviewing the 2nd drafts, drafting summaries for policymakers) the policymakers acquire some ownership on the material, hopefully learn what is known and what not and take the assessments more seriously (Swart 2006). After having approved the reports, the government are a sort of bound and cannot simply walk away (Metz 2006).

The disadvantage of the government review is the political influence. Measures against political influence were therefore undertaken: First of all the responsible lead authors of the report are present in the room and have to agree that the changes are correct and not in conflict with the report. Even though the authors have to agree, they cannot insist on certain wordings. They only have to guarantee that the summary is factually consistent with what is in the report itself (Metz 2006).

Government agents who want changes in the SPM go back to the main report and argue why this or that should be different (Metz 2006).

Changes from Review

For the analysis of the changes and comments made on the SRES the general comments on the first order Draft (IPCC 2000b), the general comments and comments on the Summaries of the second order Draft (IPCC 2000c), all comments on the Summary for Policymaker of the final Draft (IPCC 2000a) and the final Draft itself (IPCC 2000e) were considered.

Overview

The main changes conducted during the IPCC review were made from the final draft to the final report at the approval meeting in Katmandu. These changes are:

- **Merge of A1C and A1G:** The A1 Family consists of four scenarios, with different direction technological improvements: A1C (Coal), A1G (Gas), A1B (Balanced) and A1T (Non-Fossil). In the final plenary A1C and A1G were merged to A1F1.

- **Upgrading of the A1 Family:** In the final Draft there were four marker scenarios (A1B, A2, B1, and B2). In the final plenary the A1T and A1FI (A1C and A1G) were upgraded to the same level than the marker scenarios, to the so-called six illustrative scenarios.

- **Deletion of section on radioactive forcing:** The final draft had also a short illustration of the radiative forcing of the different scenarios. This section was deleted in the final plenary.

In addition, during the review of the SRES, names were proposed for the scenarios. Contrary to the agreed deletion, the indication of the radiative forcing was welcomed by different countries and some even claimed the inclusion of temperature projection. In addition, some countries asked for better explanation of the assumed policies, stronger emphasis that some policies are directed towards the reduction of GHG emissions as well as the introduction of intervention scenarios. Other complained about the policies assumed in the SRES and that emissions in the SRES are to low compared to the median of the non-intervention scenarios from literature.

Upgrade of the A1 family

There were a lot of discussions in the plenary whether the four marker scenarios are sufficient to describe the full set of the SRES scenarios. The SRES authors originally selected four Scenarios as the minimal set to illustrate most of the ranges of the full 40 scenarios reported in SRES. This was largely the case because climate modelers prefer a small number of scenarios (Nakicenovic 2006). The main reason for the upgrading of two of the A1 scenario family members to be part of the final 6 "illustrative" set of scenarios was the request from the USA, who wanted to stress the importance of technology, notably the possibility that in an A1 type of world low emissions would not only be possible through changes in type of socio-economic development (B1) but also purely through technical change (A1T). (Swart 2006b).

The consideration of the open archive shows that in the second review (first government review) the US already asked for a splitting of the A1 family of scenarios into two families, based on continued trends in energy supply (e.g. A1C and A1G) and a family that would assume significant shifts in energy supply toward renewable and nuclear (e.g. A1B and A1T) (IPCC 2000c). Since the final report did not include these requested changes, the US wrote in the final review that they can only "accept" the report if it identifies a specific representative scenario for each of the seven scenarios groups and gives equal treatment to each of the seven representative scenarios. The US also explicitly recommended that analysts use the full set of seven representative scenarios or a comparable set of scenarios in subsequent climate change assessments (IPCC 2000a).

To defend the US against the suspicion of pushing scenarios that describe a reduction of greenhouse gas without any additional policy, it is to mention that they requested in the final report on the line per line review a better declaration of the influence of policy on the driving forces and the difficulty to distinguish between non-intervention and intervention scenarios. They even requested to state in the SRES that although no additional climate policies was adopted, the assumed policy interventions leading to significant penetration of non-fossil energy technologies reflect an interest in greenhouse gas reduction. These include for example policies to achieve sustainable or rapid economic development using fuels that do not result in greenhouse gas emissions. They argue for example that many of the scenarios assume the virtual elimination of coal despite the fact that non-greenhouse emissions related to coal could be easily addressed through technological controls and advanced combustion cycles (IPCC 2000a).

Merge of A1C and A1G

To collapse of the A1C and A1G to a fossil intensive case (A1FI) was also motivated by political reasons because the oil countries did not like the high emission scenarios. Saudi Arabia initiated to merge these scenarios (Metz 2006).

The consideration of the open archive gives clear information about the position of Saudi Arabia and the influence. In it's first comments on the SRES they criticize that the A2 scenario combines extreme assumptions leading to implausible high emission and propose more moderate assumptions. In addition, they judge the inclusion of calculations or other information or conclusions concerning atmospheric concentrations of carbon dioxide or radiative forcing resulting from the SRES scenarios in the SRES as a sufficient reason for the SRES "not to be accepted" by Working Group III or by the Panel. Interestingly, Saudi Arabia also criticizes the projected sulfur dioxide emissions to be too low (IPCC 2000c). In the final review Saudi Arabia states that it is "unacceptable" that the current SPM, the Technical Summary, and the Main text seek to give a status to the three subgroups in the A1 family (A1C, A1G, and A1T) equal to the status of the four marker scenarios (A1, A2, B1, and B2) and to have two scenarios (A1C and A1G) reflecting technological emphasis on fossil fuels, while only one scenario (A1T) reflects emphasis on non-fossil energy sources (IPCC 2000a).

Cancellation of radiative forcing

The climate implication was taken out of the report and summary, because some countries said this was not in the Terms of Reference (Metz 2006).

As mentioned according to the open review the Saudi Arabia were the first, which declared the inclusion of impacts into the SRES as "unacceptable". In the final review China also asked to remove the impact, since it is not in the ToR (IPCC 2000a). Austria on the other hand explicitly appreciates the section and the radiative forcing and in the second review they even ask to mention the temperature change (IPCC 2000a, 2000c).

Policy Recommendation and Names

During the expert interviews and government review names for the scenarios were asked. In the government review especially the better communication of the policies assumed explicitly or implicitly in the scenarios and clear policy recommendations. Some governments reviewer including the US asked for a central scenario (IPCC 2000a, 2000b, 2000c).

5.3.5 Summary

The *request to exclude additional climate policy* is clearly an external influence, since it is due to some countries, which do not push climate policy. It got also obvious from the comments during the government review that other countries would have preferred to include scenarios with clear additional climate policy. Therefore it is a combination of two external influences: The institutional restriction that IPCC need consensus decisions and some countries that didn't want to push climate polity. The influence of the ToR on the structure is clear, since the scenario series would certainly include intervention scenarios if the latter would not be excluded. Since the number of illustrative scenarios is limited for comprehensibility reasons, the inclusion of intervention scenario would have led to the need of reducing the number of baseline scenarios. Therefore hypothesis (iii.a) can clearly be verified for the SRES and the IS92 scenarios.

The *storylines* were certainly influenced by the participation of members from the Shell strategic planning team. The storyline approach led to four different marker scenarios and therefore had a clear influence on the structure of the SRES. Since the use and content of the storylines is reflected by literature (see section 5.2), this influence is scientifically founded. The hypothesis (iii.b) therefore can't be approved.

The *open process* was the second "official" possibility for external influence on the SRES. Although the open process led to transparency in the scenario construction by giving different users the possibility to comment the marker scenarios and to join the scenario modeling, it has a low transparency for the reconstruction of the scenario revision made during this phase, since there is no open archive as for the official review of the SRES, which contains the comments on the scenarios from the different users. However, since the main change of the open process, namely the introduction of the technology dynamics, is mainly due to the IIASA, which is very well represented in the writing team (three lead authors and one coordinating lead author), no external influence is recognizable. Therefore hypothesis (iii.c) cannot be approved.

The *governments review* lead to the increase in the number of baseline scenario and range of non-intervention baseline for the IS92 scenarios. Also for the SRES review compared to other reports the changes made in the SPM and Technical Summary were "fairly dramatic changes" (Metz 2006). Some of these changes, like the merge of the A1C and A1G scenario to the A1FI scenario, could only be made in the Summary for Policymakers and the Technical Summary (IPCC 2000d). Table 11 illustrates the changes made on the structure of the SRES

by comparing the same passage in the final Draft and final Report of the SRES. Therefore hypothesis (iii.d) can be approved for the SRES and IS92 scenarios.

It must however be mentioned that these changes can be explained together with the position of the SRES writing team to have an even number of illustrative scenarios, to avoid that users take a central case. Without this restriction, the first request of the US would perhaps have been fulfilled, which asked to split the A1 family into two groups and to consider them as illustrative scenarios (fossil trend and trend towards non-fossil). It is also likely that the merge of the two fossil cases only was accepted in order to avoid having an odd number of seven illustrative scenarios. In addition, the external influence needs to be seen in combination with the consensual decision and the motivation of the different governments. The US and the Saudi Arabia were the only governments that threatened to reject the report. Therefore their requests were certainly weighted stronger.

Table 11 Comparison of final report and final draft

Final Draft	Report
There is no single central or "best guess" scenario, and probabilities or likelihood are not assigned to individual scenarios. Instead, the writing team recommends that the smallest set of scenarios used should include…	
…the four designated marker scenarios.	…the four designated marker scenarios and the two additional illustrative scenarios selected from the scenario groups in the A1 family.
Tables SPM-1a and SPM-1b indicate that there are scenarios with high per capita incomes in all regions that lead to high CO2-emissions…	
… (e.g., in the high-growth, fossil fuel intensive scenario groups A1C and A1G).	… (e.g., in the high-growth, fossil fuel intensive scenario group A1FI).

5.4 Indirect Influence

Since it is difficult to detect an indirect influence, the following examples of possible or effective indirect influences on the SRES are not based on a specific hypothesis, like for the direct influences, but are the result of an explorative approach during the expert's interviews. This leads also to the fact that some of the mentioned examples for indirect influences are only described by few or one expert.

5.4.1 Upgrade of A1

According to De Vries (2006), most policymakers and economists thought at the time that the A1 world was describing the more probable future. Therefore this scenario family was chosen to show the importance of technology

In this context the criticism of Dale Rothman/Columbia (University/USA) in the first review is of interest. He states that to much attention is laid on the A1 Scenario, because it is called A1 and is the family with the most scenarios. He argues that this is likely to work against the writing team's goal of making sure that users do not anchor on any single particular scenario or scenario family (IPCC 2000b).

5.4.2 Storyline and different Views

According to Swart (2006) there is a political difference between the USA and the EU. While the USA focus primarily on technology, the EU also want to stress sustainable production and consumption patterns including lifestyles, which also permeates the scientific communities. Hence the IPCC Assessments do more neutrally stress the important potential of technology (A1T), but also address the many barriers to it implementation – as well as the possibility that technology develops fast, but in a fossil-intensive direction – and the importance of structural and behavioral change (B1).

The B2 and A2 can be grouped into different actors: According to Detlef van Vuuren and Bert de Vries (2006) the B2 is a "altermondialist"[6] scenario. And Nakicenovic (2006) states that each of the scenarios could be attractive to some people. However, since all these interests groups, have an influence on the development of the world; it is in the nature of scenario construction to consider such directions.

[6] Also named more normative as antiglobalist, but since this word is a strong simplification of the motivation of this movement, "altermondialist" (~alterglobalist) is used. This name was also used by the interviewed experts.

5.4.3 IS92 Scenarios

Request

The 1st IPCC assessment, which was presented at the Geneva world climate conference in 1990 led to the establishment of the International Negotiations Committee and in record time a UNFCCC in 1992. Only then the political relevance increased, and several countries (USA, OPEC) resisted any discussion on legally binding emissions reductions as pushed by the EU. Hence, the SAR and the TAR excluded specific climate policies (Swart 2006).

Government Review

There was also some sort of review, but much less formal than the IPCC reviews are today. Therefore comments of governments aren't available.

Serious changes had to be made on the IS92 scenarios after requests, the most important ones coming from the US (Swart 2006a). The IS92 scenarios were initially intended to reflect "business as usual" policies with no limits on CO_2-emissions and only a central scenario was developed in the first draft (Leggett 2006; Pepper 2006). There was strenuous demand that the IS92 scenarios reflect uncertainty in the key drivers of emissions and the scenarios were expanded to include five scenarios with varying buy internally consistent assumptions about how the future may unfold without explicit climate change policy. A sixth scenario was included which was a variation of the IS92a scenario that did include existing commitments to CO2-emission reductions at the time of the report (Leggett 2006; Pepper 2006).

5.4.4 Scenario Names

One indirect influence can be detected by the use or rather the non-use of scenario names. Table 12 summarizes the names given to the SRES by two of the modeling teams in peer-review papers and the proposed names during the IPCC review. Following reasons not to use scenario names were given: Different words mean different things to different people, names are likely to be insufficient to capture the complex characteristics of the storylines and because of the former it would be very difficult to agree on such words in an intergovernmental approval process for the eventual Summary for Policymakers (Chadwick 2006; Swart 2006b). Especially the last reason seems to be important, because scenarios with the same complexity in literature do have a name (see section 5.2.4), and it is certainly less sufficient to capture the complex characteristics of the storylines with one letter and one number. Table 12 also shows

that the different proposed names are not so different that a harmonization of the scenario names is not feasible. Therefore in the case of the names an indirect influence on the work of the SRES authors via the governmental review can be assumed.

Table 12 Names for Marker Scenarios

SRES	AIM modeling team (Jiang et al. 2000)	ASF modeling team (Sankovski, Barbour and Pepper 2000)	Jim Shrouds (USDT/USA) (IPCC 2000b)	Switzerland (IPCC 2000c)
A1	Catch up Scenarios (Scenarios C)	High Growth	Global Affluence	Convergence
A2	Domestic Supply Scenarios (Scenario D)	Regionalization	Regional Identities	Fragmentation,
B1	Shortcut[1] Scenarios (Scenario S)	Sustainability	Global Solutions	Dematerialization,
B2	Regional Equity Scenario (Scenarios E)	Regional Stewardship	Local Initiatives	Local Solutions

[1] Shortcut because the quality of the environment is improved in the Developing Asia-Pacific countries before reaching as bad as those in the OECD countries during their development period.

5.4.5 Summary

The higher attention paid to the A1 scenario family is not in contradiction with the qualitative literature, were the A1 kind of storylines is used as reference scenarios. But Dale Rothman's criticism is legitimate: Making a kind of technology sensitivity analysis within one scenario is a kind of mixing two scenario approaches. However this seems more to be a conceptual problem than an indirect external influence. The fact that the storyline reflects the different interests of players on global level makes it certainly easier for the different governments to agree on the scenario set in the final plenary. But since the global players will determine the global development it is also sound to consider their view in the different scenarios. It is however not sound to give every view the status of a non-intervention baseline scenario, since the "altermondialists" and NGOs prefer a world with changes and additional policies. Therefore these are intervention scenarios.

A clear indirect influence on the SRES is the direct influence on the IS92 scenario. The IS92 scenarios have several baselines and a higher uncertainty because of governmental requests. Since the SRES had to improve the baseline uncertainty of the IS92, the SRES number and range of baselines would probably be smaller if the IS92 didn't explore such a wide range.

A quite obvious indirect influence on the scenarios is given by the fact that the scientists can appreciate in advance what will be approved by the governments. Since it is normal that a scientist wants his work to be published in the end, there is a certain motivation to consider the government review already in his work. While this seems quite comprehensible, it is difficult to prove this phenomenon. Such a dynamic can however be observed when no names are used for the SRES. Some experts mention the government review as a reason for not labeling the scenario. That such names would be possible and appreciated by users is given by the fact that names are proposed by modeler of the scenarios as well as by reviewers. Furthermore, similar scenario exercises from literature use names for their scenarios too.

5.5 Sustainability for B1 and B2

In this section the hypothesis about the climate policy assumed in the B1 and B2 will be analyzed. First the B-storyline will be analyzed in general. Then the policy assumed in the two scenarios will be analyzed independently.

5.5.1 B-Storyline is not a BaU

The second section on the first page of the Mitigation Report already makes clear that the B-Storyline must also be considered as intervention storyline:

> "*Climate Change 2001: Mitigation* is the most comprehensive and up-to-date scientific, technical and economic assessment of options to mitigate climate change and their costs. The report makes clear that there are strong interlinkage between climate change policy and policies towards sustainable development" (IPCC 2001a)

The other storylines from literature also use stories similar to B1 and B2 as non-intervention cases of stories similar to A1 and A2. Adding policies and other action for sustainability to the A1 and A2 lead to B1 and B2. Figure 8 lists all scenarios from literature on the two SRES axis according to the Millennium Ecosystem Assessment Report section 5.2.3. It gets obvious that the vertical B-axis is an intervention axis.

Figure 8 Scenarios and SRES storylines

Detlef van Vuuren (2006) agrees that "the B-Line is moving out of the BaU". Rob Swart (2006) points out the idea that climate and sustainable development are closely interlinked, hence the introduction of the term co-benefits rather than ancillary benefits only started to be discussed during the TAR process (e.g. Chapter 1 of the WG3 TAR), and that there was basically very little literature about this at the moment of the SRES construction.

5.5.2 B1: An utopian World

The B1 World is full of policy and changing values, which are well described by the authors of this scenario (de Vries et al. 2000), a short overview of the assumed changes:

> "A rising growing interest in the non-material aspects of life is assumed, which leads to declining working hours, improving community services, a revived interest in spiritual values, and the like. Technology development and life-style trends increasingly incorporate the principles of sustainable resource use, partly in response to a growing concern

> by governments, business and the general public about the threat of social unrest and conflict and about worsening environmental problems. In other instances, it happens in response to people's search for more rewarding and meaningful lives, with more emphasis on leisure time, arts and crafts, childcare, interpersonal relationships, and the like. The trends of globalization and liberalization continue, but there is a strong commitment among national and international governments towards sustainable development initiatives. Support for "green parties" in the industrialized regions, and later in the less industrialized regions, increase. A large part of the world's productivity gains are invested in equity, social institutions, and environment protection. Also the "greening" of business gets an unexpected boom. This widespread search for more sustainable development paths results in the gradual introduction of subsidy and regulatory reforms, eco-taxes, regulations and standards, and new arrangements for rights and liabilities. Also in the area of Mobility a trend towards bicycle and electric buses etc. is assumed. And so on."

A interesting finding is that the "Ecologically Driven" scenario by the WEC and IIASA-WEC, which "shares several of the characteristics of the B1 type of futures" (IPCC 2000d) is categorized as an Intervention Scenario in the Emission Database (ESD 2006).

5.5.3 B2 an Intermediate

In the B2 fewer policies are assumed than in the B1 scenarios. According to the modeler of the B2 illustrative scenarios (Riahi and Roehrl 2000), the government policies and business strategies of the B2 storyline is characterized by two features:

> First there is a trend toward local self-reliance and stronger communities. The shift toward local decision-making structures and institutions comes at the expense of international institutions, which decline in importance. In addition, to technical solutions, priority issues are addressed through community-based, social solutions. The second key characteristic is the continuing high priority given to environmental issues, at least at national and regional levels. The increasing attention for to national and regional green issues (and politicians) in the OECD over the last three decades keeps growing, and both transitioning and developing countries follow suit.

The modeler of the B2 agree that the quantification of the B2 storyline is difficult, because the "storyline determines the energy system only loosely" and that their quantification does not assume a dramatic departure in environmental policies.

According to De Vries (2006) the B2 can be considered, in its intention as a "altermondialist" scenario. Bert de Vries and Detlef van Vuuren (2006) point out that the B2 scenario has rather higher emission than could be expected on the basis of the „altermonialist" interpretation of it's storyline. This is because it was modeled as an intermediate scenario and because local and regional policies, which are the substance of the B2 scenario, are very difficult to be captured by the simulation models.

Consequently the RIVM model, where Bert de Vries worked with, got emissions of 9.55 GtC/y, while the MESSAGE model used intermediate input assumptions resulting in 13.8 GtC/y by 2100. However this is still much lower than the A2 Scenario, which also assumes a heterogenic world with slow globalization, but without emphasis on sustainability. In addition, the classification of the B2 scenario with the "Eco-Communalism" from the GSG scenarios by the MA (Morita et al. 2005) shows the misleading contradiction between perceived storyline of the B2 and the translation of the B2 into an intermediate scenario.

5.5.4 Summary

According to the Mitigation Report (IPCC 2001a) the B-axis can clearly be considered as intervention axis, since climate policy and policy for sustainable development are closely interlinked.

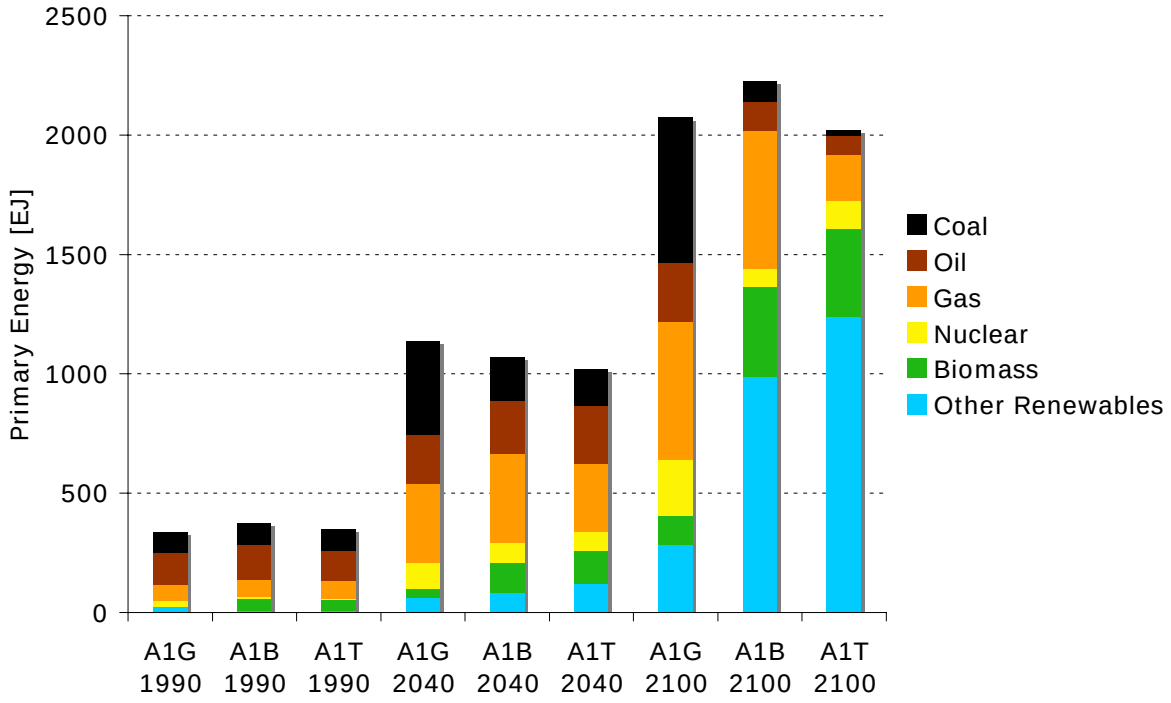
For the translation of the B1 and B2 scenario into quantitative input assumptions the emphasis on globalization was interpreted very differently. In the B1 world a strong transition towards sustainability is assumed, which includes changing lifestyle and policies. The B2 in contrary was modeled more as an intermediate scenario; this becomes obvious from the input assumption. A different interpretation of these storylines could lead to deeper emissions. However, both scenarios have clearly deeper emissions than the marker scenarios with the same speed of globalization, but no emphasis on sustainability (A1 and A2).

The hypothesis (vi) can therefore be validated. However, it is important to mention that the same hypothesis could not been verified on basis of literature before SRES, since the interlinkage of sustainability and climate change only arose after 2000.

5.6 Climate policy in A1B and A1T

Figure 9 shows that for the A1B and A1T a drastic increase of the share of zero carbon supply is assumed, while the share of gas, oil and specially coal decreas in these scenarios. Is this assumed radical change in the energy mix due to policy? This question, which will answer hypothesis (v), is difficult, because the policy is implicitly represented by the models through to the input assumptions. Learning rates of non-fossil technologies are assumptions from the modelers. Therefore the question is whether such learning rates are possible without additional policy. The assumptions of the authors of these scenarios must for this purpose be analyzed in detail as well as the literature on the decarbonization of the economy. In addition, the expert interview gave some answers to this question.

Figure 9 Projected primary energy consumption of the A1 scenarios



(ESD 2006)

5.6.1 R&D for non-fossil Technology

A common feature of the A1 world is the assumed "high rates of investment and innovation in education, technology and institutions at the national and international level" (Roehrl and Riahi 2000).

For the different A1 families various directions of the R&D are assumed. In the A1T scenario "large-scale and targeted RD&D investments are a prerequisite" (Roehrl and Riahi 2000). A large scale installation of new, inherently safe and cheap nuclear technologies and new renewable technologies is implied. The shift towards carbon-free and also decentralized technologies is assumed to be nearly complete in all world regions by 2100. All in all, A1T illustrates the evolution toward a hydrogen economy.

In the A1B a sort of coordination mechanism in technology RD&D is presumed, allowing regions/countries to specialize in the development of alternative technology clusters (e.g. "clean coal", nuclear, or renewable) and their subsequent effective diffusion and transfer at the international level (Roehrl and Riahi 2000).

5.6.2 No autonomous Development

The interviewed experts judged the question about the policy needed for zero emission carbon share of the A1T and A1B differently:

> According to Rob Swart (2006a) the necessary technology is largely known but has to be developed further and introduced at a widening scale. But he sees other reasons for this development, like security, safety, health, etc.
>
> Keywan Riahi (2006a) states that if the investment in technology doesn't change in the future, the chances that A1T or any other renewable-based energy system will emerge are low. He agrees that there are incentives, but in general expenditures in R&D of energy technologies are decreasing, and without targeted technology-related expenditures there will be no technology improvements.
>
> Arnulf Grubler (2006) explains that A1B and A1T don't emerge autonomous, but from the climate policy perspective these developments can be called autonomous, as such developments could also emerge in absence of climate policies.
>
> According to van Vuuren (2006) A1T (and B1) are full of policies that are more or less similar to those assumed in climate policy scenarios. Other scenarios such as A1B include policies but do not need to include specific policies to reduce fossil fuels use. In A1B non-fossils are simply assumed to get so cheap that market forces choose them when fossils become more expensive.

> Leonardo Barreto (2006) doesn't think that it is possible to get a share of 60 percent of non-carbon fuels until the end of the 21st century without intensive policy. Policy in this case means: R&D, Deployment of Technologies, Public-Private Partnership (because neither the companies nor the governments want to take the risk alone), but also targeted instruments like subsidies and inclusion of externalities (even if these are not climate externalities). In addition, because of the huge inertia of the energy system, R&D, Demonstration are needed right now in order for the renewable to emerge at the end of the 21st century. Barreto doesn't see the possibility that the market will go for renewable technologies autonomously. Particularly in liberalized energy markets like those already in place or being developed today, companies look at cash flows in maximum five year in advance and under those conditions, cleaner technologies which are expensive but hold a promising long-term potential may be disregarded. Barreto also doesn't see a reason beside the climate change to shift away from coal after the first step to "clean coal" is reached in countries with abundant coal resources, particularly since considerations related to security of energy supply are expected to remain high in the policy agenda of a number of countries. When markets are globalized and liberalized like in the A storyline there is no force there that will force the world to move away from a clean coal economy.

In the IPCC review as well there are comments that there is no reason beside climate change to go away from the “clear coal” and about the assumed decarbonization:

> Howard Gruenspecht (IPCC 2000b) states that the CO2-emissions are not necessarily reduced substantially as a result of aggressive strategies to address other pollutants – considering, for example, clean coal technologies that can cut nitrogen oxides, sulfur dioxides and particulates to near-zero levels while providing only modest cuts in carbon dioxide due to heat rate improvements.
>
> The US (IPCC 2000c) states that the rates of decarbonization and penetration of renewable energy supplies in the marker scenario appear to be unrealistically high. As a result in the A1T scenario, coal comprises only 1.4% of total energy supply in 2100 – well outside the range of likely outcomes for this storyline. They propose to split the A1 family into a family based on continued trends in energy supply (A1C and A1G) and a second family that assume significant shifts in energy supply toward renewable and nuclear (A1B and A1T).

5.6.3 Policy or Surprise Scenario

In literature there are two different main findings. On one side the future energy development can be very dynamic and emergence of renewable energy can occur within this century (Grubler, Nakicenovic and Victor 1999). On the other side the "increasing returns" can cause technologies that are ahead to get further ahead. This positive feedbacks would lead to a "lock in" of the heading fossil technologies (Arthur 1996).

Even tough new findings and modeling of technology dynamics illustrate the possibility of radical technology to emerge, they also state that such a process is not likely to develop autonomously and needs additional RD&D as well as a framework allowing an efficient diffusion of successful technologies. In "Dynamics of energy technologies and global change" (1999) Grubler et al. conclude that

1. Not only commercial investments – "learning by doing", which begins in niche markets – but also RD&D, crucial during the earlier innovation stage, should be considered for the technology improvement rates.

2. In general, diffusion and substitution of compatible technologies within an existing technological system or infrastructure occurs more rapidly (time constant of one to two decades) than diffusion of infrastructure and the technologies that are clustered together with numerous other technologies and infrastructures (5 to 10 decades).

3. The policy task may less be to promote zero carbon technologies from the laboratory bench to the market than to explore ways to ensure that network effects enhance rather than bar those low-carbon technologies, which will become innovations and commercialized in niche markets on their own. The results from the micro level and global optimization models suggest that when confronted with uncertainties – such as whether stringent action to slow global warming or other environmental externalities will be needed – it is socially rational to diversify technologies. There is some chance that, by surprise zero emission technologies will emerge autonomously.

5.6.4 Summary

The A1B and A1T scenarios assume additional R&D for non-fossil technologies, which in case of the A1T are more directed. In the A1B only some countries go for non-fossil technologies, but because of the assumed coordination mechanism the diffusion of this technology

is guaranteed. In both scenarios optimistic learning rates for renewable are assumed. Most of the authors judge that a share of non-fossil fuel like it is assumed in the A1B scenario is not feasible without additional R&D. Some authors even think that other policies are needed as well. Some experts criticizes that beside the reduction from the CO_2 there is no reason to shift away from "clean coal". Literature offers several papers, which conclude that A1B and A1T emerge by surprise or need intensive policy, because there is a observed inertia of the energy system of 50 to hundred years and a "lock in" which favors the fossil energy supply path. Riahi and Roherl (2000), the authors of the A1T illustrative scenario, conclude that: "Climate policies perhaps need to be extended to include technology policy"; their calculation illustrate the need to avoid a premature "lock-in" in a coal-based synthetic fuel economy; they shows that scenarios of accelerated technological change might require long-term RD&D commitment in new energy technologies, upfront investments and accumulation of expertise in niche markets.

Therefore hypothesis (v) can be approved, even though with less confidence for the A1B than for the A1T.

5.7 Ambiguous Categorization

First an overview and critic on the IPCC scenarios categorization is given. Then a sounder categorization is proposed to answer hypothesis (vii).

5.7.1 No Distinction possible

In 1992 IPCC declared their scenario to have a no-climate policy. The only policy increasing the price of fossil fuel combustion are emission control policies assumed in the high emission scenarios to reduce air pollution.

In 1995 Non-Intervention or reference scenarios are defined as "An emission scenario that does not make any assumptions about *climate* policies to reduce greenhouse gases." The report already mentions that "It is sometimes difficult to distinguish non-intervention and intervention scenarios. For example, assumed high prices for fossil fuel could stem from either resource scarcity or carbon taxes aimed to reduce greenhouse gas emissions."

In the SRES a scenario is identified as an intervention scenario if it meets one of the following two conditions:

- it incorporates specific climate change targets, which may include absolute or relative GHG limits, GHG concentration levels (e.g., CO_2 stabilization scenarios), or maximum allowable changes in temperature or sea level

- it includes explicit or implicit policies and/or measures of which the primary goal is to reduce GHG emissions (e.g., a carbon tax or a policy encouraging the use of renewable energy).

The SRES mention that this classification system is only a first step, and further work is needed to refine this taxonomy. The critical part of this categorization is that the climate policy is defined by the goal (see underlined part). This is highly ambiguous because non-intervention and intervention can assume exactly the same policy simply with a different goal.

In the Mitigation Report the problem of the differentiation between intervention and non-intervention scenario is addressed in Box 2.1 (IPCC 2001a). But again the scenarios are defined by the goal:

Climate Policy (also known as climate intervention or climate mitigation scenarios) is defined in this report as those that:

1. include explicit policies and/or measures, the primary goal or which is to reduce GHG emissions (e.g., carbon tax) and/or

2. mention no climate policies and/or measures, but assume temporal changes in GHG emission sources or drivers required to achieve particular climate targets (e.g. GHG emission levels, GHG concentration levels, temperature increase or sea level rise limits) (IPCC 2001a:122)

In the Mitigation Report the problem of the ambiguity of defining a scenario by the goal of the assumed policy is recognized:

> "The root cause of this potential confusion is that, in practice, many policies can both reduce GHG emissions and achieve other goals. Whether such policies are assumed to be adopted for climate of non-climate policy related reasons in any given scenario is determined by the scenario developer based on the underling scenario narrative." (IPCC 2001a)

Rob Swart, Bert de Vries and Bert Metz emphasize that the difficulty of the distinction between intervention and non-intervention be has to do with the changing relevance of the climate change and need to be seen in a timeframe. According to Bert Metz (2006):

> "Between 95 and 98 and 2004 Co-Benefits got important. During this period it is hard to say what is intervention and what is non-intervention. Pushing nuclear now is partly because of carbon emissions, it wasn't five years ago. "

5.7.2 Smaller Range with clear Categorization

The IPCC definition of Non-Intervention analyzed in the previous sub-section can be summarized as follows: Only climate policy without co-benefits cannot be assumed in non-intervention scenarios. Climate policy with co-benefits is assumed in the IPCC non-intervention scenarios.

Table 13 Mitigation actions within the SRES scenarios

	A1C	A1G	A1B	A1T	A2	B1	B2
Substitution among fossil fuels		Yes	Yes				
Switch to nuclear			Yes	Yes		Yes	Yes
Switch to biomass			Yes	Yes		Yes	Yes
Switch to other renewable			Yes	Yes		Yes	Yes
CO_2 scrubbing and removal							
Demand reduction						Yes	

Table 13 shows the source of the CO_2 reduction in the different scenarios. These criterions were also used in the Mitigation Report to illustrate the source of emissions reduction for stabilization scenarios. While the switch in energy mix is caused by the assumed additional R&D in case of the A1B and A1T, it is caused by the assumed emphasis on sustainability in the B1 and B2 scenarios (see also approved hypothesis in section 5.5 and 5.6). If non-intervention is not defined through the goal, but through the policies itself and hence climate policy with co-benefits like policies for sustainability and R&D for non-fossil fuels is excluded from the non-intervention, then not only the distinction between non-intervention and intervention gets clearer but also the range of the non-intervention scenarios gets smaller.

5.8 BaU possible?

According to the SRES there is no BaU Scenario and also the interviewed experts didn't accept the BaU concept. However the validation of the storylines shows that a BaU storyline would be feasible.

5.8.1 Arguments against the BaU

There are different reasons why the BaU concept is rejected. In the SRES (2000) the following reason is given:

> "Describing potential future developments involves inherent ambiguities and uncertainties. One and only one possible development path (as alluded to, for instance, in concepts such as "business-as-usual scenario") simply does not exist alone. And even for each alternative development path described by any given scenario, there are numerous combinations of driving forces and numeric values that can be consistent with a particular scenario description. The numeric precision of any model result should not distract from the basic fact that uncertainty abounds. However, the multi-model approach increases the value of the SRES scenario set, since uncertainties in the choice of model input assumptions can be separated more explicitly from the specific model behavior and related modeling uncertainties. "

The interviewed SRES authors see further reasons for rejecting the BaU concept, beside the high uncertainty about the future development:

1. The key point is that one BaU hides uncertainties in mitigation cost analysis, since costs depend as much on baselines assumptions as on assumed policy targets. (Swart 2006a)

2. The BaU is misleading because it indicates that we know the future (Nakicenovic 2006; Swart 2006a)

3. Having a BaU case does not allow to stress the important point that choices other than climate policy influence emissions at least as much (Swart 2006a).

4. The BaU depends on the different views: Americans and Europeans think that market world of A1 is the BaU case; in developing countries many people feel often that unequal A2 is the BaU world. (Swart 2006a)

5. The BaU concept generally ignores the unfolding dynamics of systems, extrapolating the current status quo far into the future, therefore a "Dynamics as Usual" Concept is more appropriate (Grubler 2006)

6. A BaU scenario is only possible for systems of limited complexity, such as a rather strictly separable techno-economic system (De Vries 2006).

7. There is no BaU scenario, because there is no BaU policy. There is a EU policy, there is a US Policy, there is a Japanese Policy, they all have influence on future emissions and policies change all the time (Nakicenovic 2006).

8. When BaU means frozen policy, frozen technology or frozen energy mix as some interpret it, it is stupid by design and ignore historical trends (Van Vuuren 2006).

However, the some authors didn't reject the idea to attach subjective probabilities to the scenarios. Van Vuuren (2006) states, that beside the storylines concept, he accepts scenarios that try to make a best guess. He thinks the probability approach is much stronger in the communication and much easier to understand. But he also states, that at the same time you are doing injustice to fundamental uncertainties.

5.8.2 Main SRES Uncertainties

Since baseline uncertainty is seen as the primary reason for rejecting the BaU concept, the uncertainty within the SRES is analyzed. To evaluate the uncertainty, the range of CO_2-emissions is analyzed for four cases:

1. Model; fully harmonized: Uncertainty range for different models with same input assumptions for final energy consumption, GDP and population on global and SRES region level.

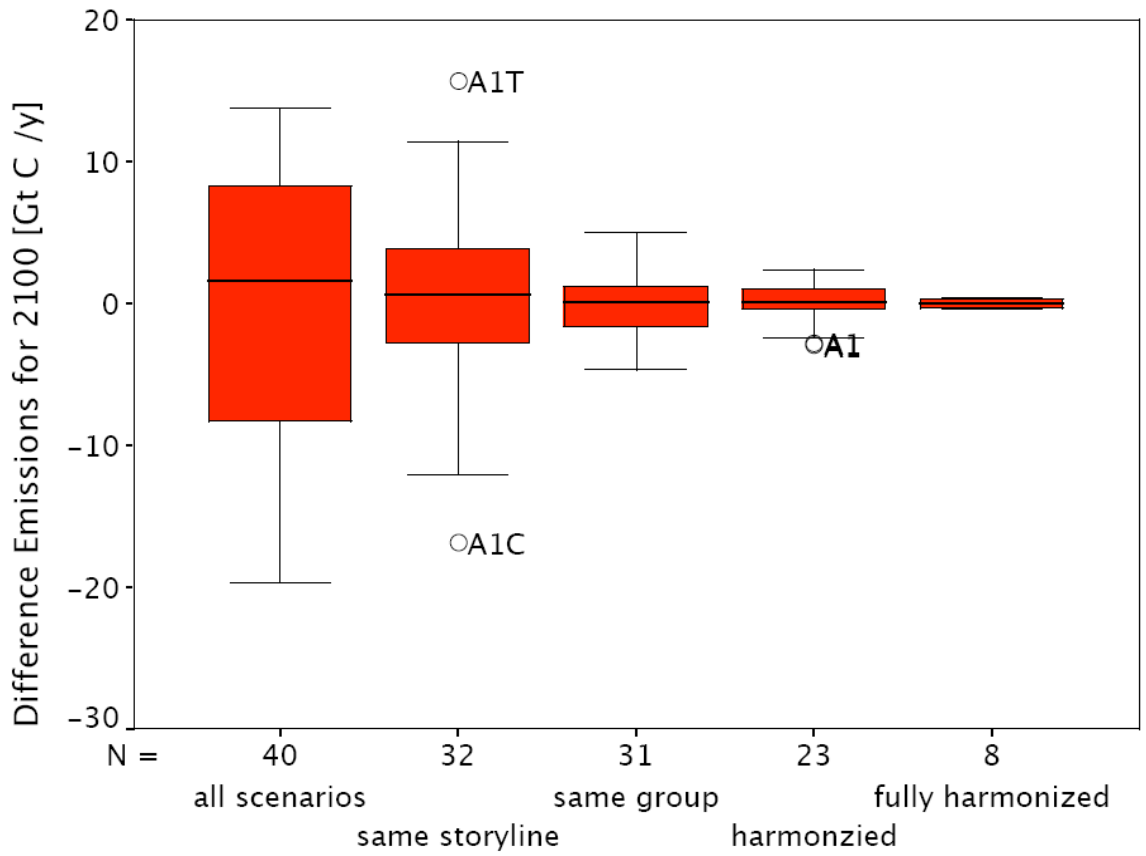
2. Model; harmonized: Uncertainty range for different models with same input assumptions for final energy consumption, GDP and population only on global level.

3. Translation; same storyline and direction of technology dynamic: Uncertainty range for different translation of the storylines and technological direction: coal, gas, balanced, non-fossil (with different harmonization efforts)

4. Translation; same storyline: Uncertainty range for different translation of the storylines (with different harmonization efforts)

For the uncertainty range the difference of the outcome of the individual scenarios and the mean of the group with same characteristics according to the above mention cases is calculated then the different groups within the cases are summarized. In the first case for example there were always only two models with fully harmonized inputs per storyline group. The difference of their outcome and their mean is summarized for the groups. Figure 10 shows the resulting deviation of the CO_2-emission in 2100 for the different cases:

Figure 10 Uncertainty within the 40 SRES Scenarios



(ESD 2006)

Since the uncertainty from the models and also the uncertainty of the translation of the assumption within a scenario group is small, the main uncertainty is captured in the different scenario groups. The scenario groups differ by the following assumptions:

1. Speed of globalization (or grade of future convergence)

2. Emphasis on sustainable development

3. Direction of Technological Development

All these assumptions depend on future decisions. Therefore the uncertainty of the future CO_2-emissions, captured in the SRES non-intervention baseline scenarios, is due to the uncertainty of the future decisions. This finding is consistent with the answers of the interview experts, who emphasize that the future development depends on the future decisions (see previous sub-section).

5.8.3 BaU in Literature

Millennium Ecosystem Assessment Report

Section 5.2.2 grouped the different storylines of different scenarios on the basis of the GSG Scenario storylines. The A1 Scenario is grouped by the MA with the BaU from the World Water Vision Scenario, with the Reference Scenario from the OECD and with the FROG! (First raise our growth), which was used as reference scenario in the WBCSD Scenarios (WBCSD 1997). Therefore it can be said that the A1 corresponds to the BaU Storylines from Literature.

IPCC Mitigation Report

The categorization made by the Mitigation Report for scenarios from Literature is also interesting (Table 2.3. on page 159). See Table 14. The Mitigation Report states that these groups correspond quite closely to the GSG Scenarios.

Table 14 Scenarios groups according to the Mitigation Report

Scenario group	Scenarios subgroups	Numbers of scenarios in literature
1. Pessimistic Scenarios	Breakdown: collapse of human society	5
	Fractured World: deterioration into antagonistic regional blocks	9
	Chaos: instability and disorder	4
	Conservative: world economic crash is succeeded by conservative and risk-adverse regime	2
2. Current Trends Scenarios:	Conventional: no significant changes from current and/or continuation of present-day trends	12
	High Growth: government facilitates business, leading to prosperity	14
	Asia Shift: Economic power shifts from the West to Asia	5
	Economy Paramount: emphasis on economic values lead to deterioration in social and environmental conditions	9
3. High-Tech Optimist Scenarios	Cypertopia: information & communication technologies facilitate individualistic, diverse and innovative world	16
	Technotopia: technology solves all or most humanity's problems	5
4. Sustainable Development Scenarios	Our Common Future: increase economic activity is made to be constant with improved equity and environmental quality	21
	Low Consumption: conscious shift from consumerism	16

The SRES can also be grouped according to the four Mitigation Report Groups:

A2 is a pessimistic scenario in the sense of population size and income (De Vries 2006) and refers to the subgroup “Fractured World”; the A1F1 is a current trend scenario of the sub-group “High Growth”; the A1B and A1T Scenarios are high tech Optimist scenarios since they assume “optimistic” learning rates for renewable (Riahi and Roehrl 2000) and the B1 and

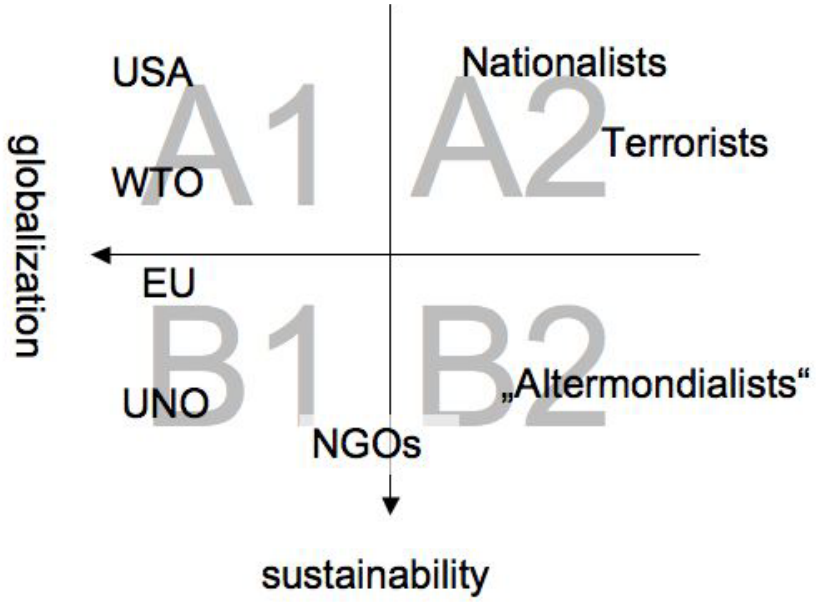
B2 are clearly Sustainable Development Scenarios, their storyline representing the "Our Common Future" respectively "Low Consumption"[7].

When a baseline scenario, is seen as a scenario that examines the consequences of continuing current trends in population, economy, technology and human behavior the current trends scenarios represent the BaU scenarios, this would lead to A1FI as BaU scenario.

5.8.4 Intermediate Storyline

While literature favors the A1 world as BaU scenario, there are different reasons why it is better to choose an intermediate of A1 and A2.

Figure 11 Global actors and storylines



Counterforce

According to De Vries (2006) the SRES storylines are rather caricatural extremes, which will never develop in this form, because whenever one of these becomes reality, the forces supporting the other three may start to counteract it. In this way, the future will unfold in ways

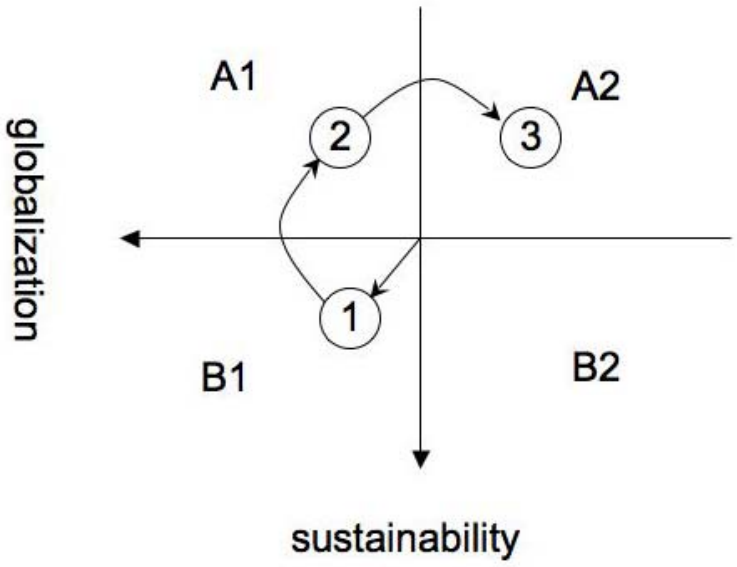
[7] This is what the position on the storyline axis would imply for B2, however it was translated by the modelling teams as intermediate scenarios, with moderate emphasis on sustainability.

which are difficult to predict and as a reflection of relative power relations in the physical, the economic and the cultural and informational realm. Also other SRES authors mentioned during the interviews that different interests groups prefer different storylines. Figure 11 suggests different interests groups and "their" scenario.

Past Development

Looking at the last twenty years, according to De Vries (2006), the world went in the direction of different storylines (see Figure 12): With the Brundtland Conference the World went a step towards B1 (1), in the 90ties with the fall of the former Soviet Union and the iron curtain and the subsequent rapid globalization, the world went more in direction of A1 (2). Its side effects such as marginalizing large groups of peoples at the same time as the mergence of the network/information society, lead to events such as Seattle 1999 and the terrorist attack of 9/11/2001. In the wake of this, the world now experiences the forces into the direction of an A2 world future (3).

Figure 12 SRES storyline and past development



(de Vries 2006)

5.8.5 Summary

The expert reject the BaU concept for following reasons: BaU hides uncertainties in mitigation cost analysis, BaU is misleading, BaU does not allow to stress the important point that

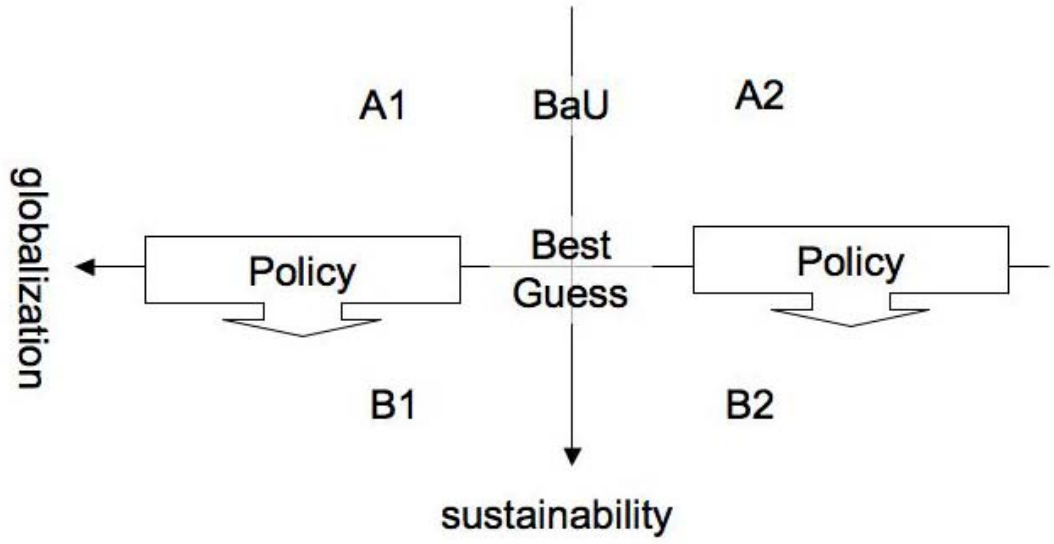
choices other than climate policy influence emissions at least as much, the BaU depends on the different views and others. The following findings detected during this study argue for the feasibility of a single or few BaU scenario:

- The main SRES uncertainties are due to the different scenario groups. If the decision for a technological change towards non-fossil fuels or more sustainability is considered as an intervention, the remaining scenario groups of the illustrative scenarios are the A1FI and A2 scenario, which differ in the assumed speed of globalization.

- According to the MA (Morita et al. 2005) storylines like the A1 scenario are chosen for BaU or baseline scenario in literature.

- The Mitigation Report proposed four groups for the classification of the scenarios from literature. The only SRES scenario that can be grouped as current trend scenario is the A1FI scenario.

Figure 13 Best guess, BaU and SRES storylines



- The analysis of the storyline shows that it is more likely that future will not evolve in only one of the storylines. This can also be explained from a theoretical point of view. Since the storylines represent "dynamics-as-usual", which are a disaggregation from the past development, it is unlikely that only one of these dynamics will unfold in the future. Rather there will be a mix of different dynamics. Therefore the Best Guess

storyline for the next hundred years will lie somewhere between the SRES dynamics described by A1, A2, B1 and B2 (see Figure 13). Since the BaU is only the Best Guess of the non-intervention futures, the intervention dynamics should not be considered for the BaU. Hence the BaU story most likely is between the A1 and A2 future (see Figure 13). The existence of counterforce for each storyline and the development of the world in the past twenty years back this interpretation of Best Guess and storylines.

- It can be deviated partially from their population assumptions that an intermediate of A1 and A2 is more likely for the non-intervention case. The A1 assume 7 billion the A2 15.1 billion persons. According to an extensive expert survey the 5^{th} and 95^{th} percentile intervals are between 6.7 and 15.6 billion people by 2100 (see section 2.3.3). Therefore the A1 and A2 span a very broad range of population growth and represent the two extremes. A population growth between these two projections is more likely according to most experts.

If one or few BaU scenario should be feasible the question remains, whether it is reasonable to construct such a scenario. This depends on users needs. For users who want to know how future develops, when current trends continue, few or even one baseline scenario would be useful. To explore uncertainty and alternative development path several scenarios are useful. However, it is misleading to call those alternative scenarios also baselines.

5.9 Main results

Finally the results of the sub-hypothesis are used to answer the three main hypotheses.

5.9.1 Scientific reasons

Even if the uncertainty of important input assumptions like population projections, GDP projection or availability of fossil resources decreased because of new findings (see section 2.3.4) the SRES still span a very wide range of uncertainty. Section 5.1 showed scenarios from literature translate the uncertainty for the decrease of CO_2 per GDP into a smaller range than the SRES scenarios. The A1B, A1T and B1 scenarios assume clearly higher decarbonization than the baseline scenarios of the ESD. There is no scenario series in the literature published before 2000 and collected in the ESD that uses more than three baseline scenarios except the two IPCC scenario series (IS92 and SRES). The storylines in literature have the same content for their scenarios like the SRES, but they are not called non-intervention or baseline scenar-

ios. According to the literature the storyline of A1 and A2 are non-intervention. Storylines similar to A1 are used as baseline scenarios. Therefore the main hypothesis that the SRES structure is explained by scientific reason cannot be approved.

5.9.2 External influence

Section 5.3 and 5.4 showed that governments had direct and indirect influence on the structure and communication of the SRES scenarios.

The request to exclude climate policy scenarios was motivated by countries which didn't want to push the discussions about climate policy. This exclusion of intervention scenarios was an important precondition to increase the number of baselines to six scenarios without losing comprehensibility of the scenario series. The government review led to the recommendation of six illustrative scenarios (A1FI, A1B, A1T, A2, B1, B2) to be used as smallest subset of scenarios instead of the four marker scenarios only (A1B, A2, B1, B2) suggested by the SRES writing team in the final report. In addition, the representation of the fossil cases within the A1 family was reduced from governments by merging the A1C (coal) and A1G (gas) scenario to the fossil intensive scenario (A1F1). The indirect influence is more difficult to detect, however one indirect influence on the broad range of uncertainty and high number of baseline scenario of the SRES is caused by the direct influence on the IS92 scenarios. Since the ToR referred on the IS92 scenarios, the SRES had also to be an update of the former IPCC scenarios. Not only the exclusion of the intervention scenarios, but also the broad uncertainty range and high number of baseline scenarios in the IS92 is caused mainly by governments and was not part of the first Draft of the IS92 scenario, where the IS92 proposed only one central scenario.

Beside the SRES structure the different communication of the SRES compared to storyline scenarios from literature (see section 5.2.3) can be mainly explained by external influence. The absence of policy recommendation is mainly the consequence of the request to exclud additional policy scenarios. The absence of the impacts of the scenarios is the result of the government review were the section on the radiative forcing got deleted on request of Saudi Arabia and China (see section 5.3.5). Finally, the non-use of scenario names can be explained by an indirect influence. Although similar storylines in literature with contributions by SRES authors provide scenario names (see section 5.2.3) and modeling teams as well as reviewers proposed names (see section 5.4.4), already the draft made no such suggestion. Some experts explain that an agreement on such names in the plenary would be very difficult. This absence of scenario names has no influence on the real SRES uncertainty and number of baselines.

However, for users who didn't read the underlying assumptions in detail and assumed baseline without interventionist elements, scenario names like "sustainability" for B1 or "local solutions" for B2 would have led to a smaller perceived baseline range.

Therefore the hypothesis (2) that the structure of the SRES can be explained by external influence is to adopt.

5.9.3 Conceptual problems

Finally the hypothesis on the influence of the categorization has to be answered. The detailed evaluation of the scenario assumption showed:

> The B-Storyline can be considered as intervention storyline (see section 5.6). However the intervention characteristics (assumed policy, life style change) are much more obvious in the B1 scenarios, since the B2 scenario was translated by the modeling teams more as an intermediate scenario without strong emphasize on sustainability.
>
> The A1T and A1B assume additional policy, which allows the efficient development and diffusion of non-fossil fuels. Such scenarios must be considered less likely than A1C or A1G scenarios in absence of changing policies. Since the non-fossil fuels need more R&D expenditures, new coal and gas technologies can diffuse faster as they need no new cluster and as increasing returns favor the technologies that are already ahead (see section 5.6.3).

However, the A1T, A1B, B1 and B2 scenarios can be categorized as non-intervention scenario, since the categorization used by the IPCC defines climate policy by the primary goal to reduce greenhouse gas emissions. Because it can be assumed that R&D for non-fossil fuels as well as policies for sustainability is implemented for other reasons than climate change, they don't need to be excluded from the IPCC non-intervention scenarios. However, this categorization is misleading, since in case all policy recommended by the IPCC Mitigation Report to reduce future greenhouse gases emissions is considered as climate policy, only the A1FI (A1C and A1G) and the A2 remain as non-intervention scenarios (see section 5.7.3). A stricter and clearer categorization of baselines would at least exclude the B1 and A1T scenario. In summary, the used categorization explains the changing structure of the SRES and therefore the hypothesis (3) can be approved.

5.9.4 BaU possible?

Since the conceptual problem as well as the external influence led to an increase of the range and number of baseline scenarios, the findings from this research are used to answer the question about the feasibility of a single BaU or the smallest number of baselines needed. The main uncertainties captured in the SRES scenarios are the speed of globalization, the direction of technological change and the future emphasis on sustainable development (see section 5.8.2). When non-intervention also excludes additional efforts for non-fossil fuels and additional emphasis on sustainable development – since these are also climate policies – the non-intervention uncertainty remains the speed of globalization, which is captured by the A1FI and A2 scenarios. Since the A1FI and A2 are based on very high and very low assumptions about population growth, an intermediate of these scenarios seems to be a better guess. In literature only the A1 kind of storyline is considered as Reference or BaU Scenario. If the categorization used by the Mitigation Report is applied to the SRES and BaU is defined as "Current Trend Scenario", the A1F1 is the remaining BaU scenario from the SRES (see section 5.8.3). When existing counter forces are considered and with regard to the direction of the development of the world in the past twenty years in reference to the different storylines, an intermediate between the A1 and A2 world seems to be the Best Guess for the non-intervention case (see section 5.8.4).

6 Discussion

The results will finally be compared with recent publications on the range of the SRES scenarios. Reasons for the conceptual problems and external influences will be discussed. Finally, possible implications for probabilistic scenarios are highlighted.

6.1 Recent publications and SRES

The literature comparison with qualitative and quantitative scenarios was part of the research and is consistent with the results (see section 5.1 and 5.2). Admittedly, only emission scenarios published before 2000 are considered, because the scenarios published after 2000 and collected in the ESD are based on the SRES Scenarios. However, the comparison with two independent (not based on SRES) scenarios published after 2000 is consistent with the result that low emission scenarios of the SRES move away from the non-intervention baseline projection:

Van Vuuren and O'Neil (2006) compare the SRES with the recent projection from the Energy Modeling Forum 21 (EMF 21). Their comparison shows that B1 clearly falls out of the range of the EMF 21 non-intervention projection, while the A1B and B2 are yet inside the low range of these scenarios (Van Vuuren and O'Neill 2006:Figure 8). The A2 Scenario is in the medium-upper region of the EMF 21 scenarios. Since only the marker scenarios are plotted, the A1T and A1F1 illustrative SRES scenarios are not included. In any case the A1T, like the B1, would clearly be lower than the EMF 21 scenarios.

Webster et al. (2002) used a probabilistic approach for the emission projection and they conclude that the SRES CO_2-emissions projections cover much of their 95 % confidence range, but "are biased toward lower CO_2-emissions by the end of the century" compared to their distribution. They explain this difference partly by the "inclusion of policy effects in some of the SRES scenarios", whereas they tried to develop probability distribution of emissions under "no climate policy" (Webster et al. 2002).

6.2 Reason for conceptual Problems

6.2.1 Importance of Climate Change for Politics

One question of the obtained results remains open: Why did the IPCC use an ambiguous categorization of non-intervention and intervention scenarios? The best explanation to this question is the growing importance of the climate change for politics. When the SRES authors started their work in 1997, it was much more plausible that sustainability or R&D for non-fossil fuels are pushed for other reasons than climate change. According to Rob Swart (2006), at that time there was nearly now publication about the interlinkage of climate policy and sustainability (see section 5.5.1). With the introduction of co-benefits by Mitigation Report (IPCC 2001a) the distinction between climate policy and other environmental policies became more difficult. The Mitigation Report emphasizes the importance of investments for R&D for non-fossil fuels and sustainability to reduce greenhouse gases. Nowadays a broad range of policies is also considered as climate policy. The definition of intervention scenario through the assumption of policy with the "primary goal to reduce greenhouse gas emission" is very ambiguous, because in case of the so-called policies with co-benefits, it is also theoretically possible that these policies are implemented for the co-benefits rather than the climate protection. This allows the author of the non-intervention to include policy, which other people would associate with climate policy. A similar explanation is proposed by Bert Metz (see section 5.7.1)

6.2.2 Competence Building of Scenario Construction

Scenario lead also to competence building about which decision matters for the future development (Wiek, Binder and Scholz 2006). From this perspective it can be said that the competence building outcome of the SRES exercise is the finding about the relevance of technology development and sustainability for future greenhouse gases. Therefore as an example the authors of the A1T illustrative scenarios conclude "climate policies perhaps need to be extended to include technology policy" (Riahi and Roehrl 2000). The interlinkage of sustainability and climate policy is one of the main messages of the Mitigation Report (IPCC 2001a), to which several SRES authors contributed. This competence building property of an scenario exercise is in contrast to the request from the ToR to exclude intervention scenarios. Without this request the A1T and B1 scenario, would perhaps be communicated as intervention scenario – similar to scenarios from literature, with comparable assumptions.

6.3 External Influence

An other open question is why such considerably changes were possible. Deleting a whole section or changes in the summaries, which can't be incorporated completely in the underling report, indicate the intensity of the external influence. Such changes in the last step of the approval procedure seems to be quite unusual, since some changes could only be incorporated with a footnote into the main report. In this section the basis for the external influence as well as the motivation of the governments and the difficulties of the communication between science and politics will be discussed.

6.3.1 Basis for external influence

There are two important preconditions for the external influence, which will be discussed below: First, the involvement of the governments in the approval of the IPCC report; second, the characteristics of non-probabilistic scenarios.

IPCC decision procedure

The basis for the external influence is the review procedure of the IPCC as well as the formulation of the Terms of Reference in combination with the consensual decision. The Terms of Reference were used to exclude climate policy scenarios in order to avoid pushing discussions about legally binding climate change policy (Swart in section 5.4.3). The review was used especially in 1992 to increase the range of the baseline scenarios. In addition, the consensual decision leads to an advantage for the countries which are not interested in pushing the climate change debate by new reports or findings, because an IPCC report will not be published or even ordered, if one single government does not accept it. Requests to improve the expressiveness of a report are less successful, since governments interested in such an improvement are also interested in the publication of the reports, and therefore will not reject a report, if for example important findings are not clearly mentioned in the summary. This dynamic is confirmed by the review of the SRES: Some governments requested to merge scenarios or to delete the section with the radiative forcing by threatening to reject the report, whereas none of the governments asking for better illustration of the implication or better description did so (IPCC 2000b, 2000c).

Plausible Scenarios

Beside the importance of the scenarios for climate science and policy, the second reason allowing strong influence is due to the fact that long-term scenarios cannot be verified. Since in the final approval the writing authors can only guarantee that the summary is factually consistent with the main report, they can hardly object to different selection and recommendation of scenarios or the exclusion of scenarios from the summary[8]. This is particularly true with regard to the main report including forty scenarios, described as equally plausible and without attached judgment on their probability.

A third constraint which is worth mentioning is the clear intention of the SRES authors to select a even number of scenarios (IPCC 2000d), as in case of an odd number users will tend to use the central scenario. This constraint certainly favored the external influence in case of the mergence of the A1C and A1G scenario: Because of the request from the US to upgrade all the A1 groups, there was the risk that seven scenarios would remain. By agreeing to merge the A1C and A1G, as requested by Saudi Arabia, the writing team could again obtain an even number of illustrative scenarios. However, it is disputable why a central scenario has to be avoided: In the IS92 scenarios the central scenario was the single scenario which the writing team proposed in the first draft.

6.3.2 Motivation of Governments

The motivation for the governments to influence the SRES is indicated by their comments on the SRES Drafts and by the experts (IPCC 2000b, 2000c): The request to exclude intervention scenario was motivated by those countries which refused discussions on legally binding greenhouse gas reduction targets (see section 5.4.3). While the US seems to have been motivated to stress particularly the possibility of technological solutions (see section 5.3.4), the Saudi Arabia seem to have intended to play down the climate change problematic: In their first comments the Saudi Arabia criticized the A2 scenario not being plausible. They stated that conclusions concerning atmospheric concentrations of carbon dioxide or radiative forcing resulting from the SRES scenarios are a sufficient reason for “the SRES not to be accepted”. Finally they criticized that the sulfur emissions (the most relevant cooling gas) are to low in all scenarios (IPCC 2000c). In the final review they successfully requested to merge the two high emission scenarios A1C and A1G (IPCC 2000a).

Beside the specific motivation, the general motivation to pay attention on the IPCC scenarios, can be explained by the importance of these scenarios for climate politics and climate science. On one side they are the basis for long term climate change projection, on the other side they show the consequences of different development path, which can refer to different political preferences.

6.3.3 Communication of Science and Politics

Since the first order Draft already recommended four marker scenarios, a further open question is, why the SRES authors didn't chose a smaller number and range of baseline scenario. Moss and Schneider recommend the lead authors of the TAR to attach subjective probabilities to their results. In case of the emission scenarios this would mean to attach probabilities, make a best guess or a better guess scenarios. Moss and Schneider see the IPCC as "science for policy", which includes being responsive to policymakers' need for experts judgment in a particular time, given the information currently available, even if those judgments involve a considerable degree of subjectivity (Moss and Schneider 2000). This "science for policy" is certainly desirable for IPCC reports, but in the case of the IPCC scenarios it is obvious that politics did not want "science for policy". And due to of the strong involvement of governments in the approval procedure for IPCC reports, "science for policy" is only feasible in the IPCC reports if politics agrees. More precisely: Only if all governments agree. Since the uncertainty must be described in the main report, a government can demand to take into account further uncertainty in the summary and authors can hardly argue against. This is what happened with the IPCC scenarios: In 1992 the authors first proposed a central scenario, but the governments refused and asked to explore the full uncertainty (see 5.4.3). The SRES authors already considered more uncertainty in their proposed four marker scenarios. But the plenary again refused this selection and upgraded also two groups of the A1 family (see section 5.3.4).

This confirms the observation that science has some how gone back to his own business because the political system showed reactance (Mieg 2004). Two problems arise when science is going back to his own business in the area of the IPCC scenarios. First, scenarios are a tool for transition management (Wiek et al. 2006) and this means "science for policy". This helps also to explain why scenario in literature did not recommend more than 3 baselines (see section 5.1.1), even though these scenarios are faced with the same uncertainty as the SRES. In

[8] The merge of the A1C and A1G Scenarios was in fact the selection of a high emission A1G scenario, and therefore a exclusion of the A1C from the Summary.

combination with the mission of the IPCC to assess the literature, this creates a contradiction, since IPCC should assess "science for policy scenarios", while the final plenary accepts no "science for policy". Second, if the scenarios are not for politics, then they are for the scientific community. In this case there seems no justification for an approval by the governments of these scenarios.

At least there is some hope that the reactance of policy decreases, since even the US asks for baseline and stabilization scenarios in their submission for new IPCC scenarios (IPCC 2005). The absence of a request to exclude intervention scenarios would already be an important step towards the direction of IPCC scenarios with similar structure than scenarios from literature.

Interesting in this context is the statement mentioned in the introduction of the research from the SRES lead author, Nebojsa Nakicenovic, who said that politics prefer a single baseline for simplicity reasons, while scientific assessment require a large ensemble of scenarios (IPCC 2005). This shows that in 1992 the scientists proposed "science for policy" and consequently one baseline scenario, while the politic asked for more uncertainty and several scenarios. Today it is the other way round: Policy ask for a single scenario, while science claims multiple scenarios. However, it seems important that with the actual approval design and the absence of subjective probabilities for the scenarios, "science for policy" is only possible if all governments agree.

6.4 Probabilistic scenarios

The feasibility of probabilistic scenario was not the primary issue of this research, but by analyzing the reason for the high baseline range and number of the SRES, the following indications relevant for the probabilistic scenarios approach are found:

1. No fixed probability for SRES storyline: The problem of attaching probabilities is that the probability change during the present development (IPCC 1995b) and therefore need to be updated. If the SRES attached probabilities in 2000 they certainly did not foresee the events and consequences of the 2001/9/11, which made A2 more likely.

2. Intermediate storyline for "better guess": If a better guess scenario has to be chosen an intermediate storyline should be developed since counter forces exist, which make the development of only one storyline unlikely (see section 5.8.5). Such intermediate scenarios would also be more robust against events mentioned in the previous point.

3. Probabilities within a scenario group: Within the scenario groups assumptions about future decisions are made. The remaining uncertainty stems from translation of the decisions into quantitative assumptions (see section 5.8.2). This uncertainty seems to be less difficult for making a best guess, since this was also made in the SRES procedure during the so called "harmonization", where common input assumptions were chosen by the scenario authors.

4. With a stricter definition of non-intervention, more assumptions about the future are made, which reduces the uncertainty. If for example non-intervention excludes also growing sustainability, only two SRES storylines remain, which differ in the speed of globalization. By taking an intermediate of these scenarios, only the direction of technology would remain uncertain. If also growing R&D for non-fossil energy supply is excluded, market force and future energy prices remain as uncertainty. This would lead to a moderate A1 storyline, which is consistent with the BaU storylines from literature (see section 5.2.2). There are several findings in the area of technology development, like the "lock-in" (Arthur 1989, 1996) and the time needed for a radical technology emergence (Grubler et al. 1999), which could be the basis for probabilistic on this remaining uncertainty about the technology development.

However, it is important to stress that probabilistic for the non-intervention case as proposed in point (4) are not good forecasts for the real development of the world. This is because the non-intervention case by it-self is not likely, since there are important forces pushing for interventions. Even though, such probabilistic non-intervention scenarios would be important for the cost assessment. The advantage of a strict definition of non-intervention is that in contrast to the SRES cost and efforts needed to R&D for non-fossil energy or sustainability are not underestimated. Indeed, when cost assessment is made on the basis of A1T or B1 the costs for these interventions are not included, which is misleading.

For a real forecasting non-intervention and intervention storylines must be considered. Such a forecasting must be updated regularly on the basis of the actual developments in the areas important to the key drivers of the future emissions, like population, economy, globalization, policy and consumer behavior. There are already approaches in literature, which use indicators for the storyline to show in which direction the world is actually moving (van Heiligenberg 2005). Such assessments of the actual development with regard to future emissions would be a strong improvement for climate policy.

7 Conclusions

The main results of this research are the following (chapter 5): The evaluation of the open archive showed that external influence via the final plenary led to the recommendation of six baseline scenarios instead of four and to the mergence of the two coal (A1C) and gas (A1G) scenario to the fossil intensive scenarios (A1FI). The expert interviews showed that already the high baseline uncertainty and the recommendation of six baselines in the former IPCC scenarios (IS92) were strongly influenced by government requests. The absence of comprehensive scenario name, which increases the perceived uncertainty for users who didn't read the underlying assumption carefully, can be seen as an indirect influence of the approval of the SRES by the final plenary. A second reason for the broad baseline uncertainty is the ambiguous definition of the IPCC for non-intervention baseline scenarios, which allows assuming strong efforts for sustainability and additional R&D for non-fossil energy supply in the baseline scenarios. Scenarios from literature consistently use a smaller number of baseline scenarios and a smaller range of decarbonization for baselines. In addition, similar storylines from literature provide scenario names and refer the content of the A1 storyline to reference or BaU scenarios.

Since the actual categorization is ambiguous, not objective and therefore misleading, it is recommended that:

1. A *new categorization* for baseline and specially non-intervention and intervention scenarios is developed. This categorization should no more classify policies by their "primary goal", since a lot of policies can have different goals and because it depends on subjective values and interests, which will be the primary goal of a policy. A clearer classification would also reduce some of the uncertainties within the baselines (see section 5.7) and would allow for a calculation of the complete intervention costs.

2. The *low emission SRES scenarios* (A1T and B1) should no more be described as non-intervention scenarios. They assume intensive policies or measures for non-fossil energy supply or sustainability (see section 5.5 and 5.6) and users could consider these policies also as climate policies, since they are also recommended by the IPCC Mitigation Report (IPCC 2001a).

For future scenario construction more attention has to be given on possible external influences. Following measures could avoid external influences by the plenary as happened in the SRES:

1. *Attach subjective probabilities:* Attaching subjective probabilities would reduce the possibility of external influence via final plenary,because a different selection of illustrative scenarios would not change the perceived probability. The conducted merge of the A1C and A1G scenario by the plenary (see section 5.3), for example, would have led to one scenarios with higher probability, instead of one scenario with equal plausibility.

2. *More competence on the wording:* Since it is crucial for scenarios that the users are fully aware of the underling assumptions, the authors of the report need more competence in the wording and description of their scenarios in the summaries. Guaranteeing that the summaries are factually consistent with the main report is not sufficient to avoid strong external influence and make sure that the summary reflects the main report in case of the scenarios. In the SRES the absence of scenario names for example is probably caused by the missing wording competence of the SRES authors (see section 5.4.4).

Beside a clearer categorization of the scenarios and the avoidance of external influence, also scientific progress is necessary to reduce the baseline uncertainty:

1. *Storyline uncertainty:* The storyline approach is certainly very useful, however when considering the existing counterforce for each storyline and the past development, it is very unlikely that only one storyline comes true (see section 5.8). Therefore intermediate storyline would be a good basis for best guess scenario and lead to more likely emission projection.

2. *Translation uncertainty:* A critical point of the storyline approach is the translation in the few numbers needed for population growth, economic growth, energy and technology development. In the SRES this uncertainty was artificially reduced by the so-called “harmonization” of the scenarios (IPCC 2000d). In addition, the emphasis on sustainability was differently translated in the B1 compared to the B2 scenario, even though they have the same position on the sustainability axis (see section 5.5.3). A robust translation is especially crucial if the storylines are used as

an input clearly for strategic planning, like for example in the UNEP scenarios (UNEP 2002).

3. *Market uncertainty:* By assuming additional policies in the SRES scenarios it was less necessary to research, which scenarios are possible without additional efforts for R&D sustainability or for non-fossil energy. Were would we go if only market decides? Is A1B possible without the assumed additional R&D for non-fossil fuels? The interviewed experts differed in their answers about this question, some said that A1B need a lot of policies, others that it could be reached only by marked forces and increasing prices fossil fuels (see section 5.6.2). More research in this area is especially needed when a stricter definition of non-intervention excludes additional policy or R&D for sustainability respectively non-fossil fuels.

4. *Assessment of the SRES:* The SRES are only the beginning of the storyline approach. Similar scenario like the MA or UNEP scenarios (Morita et al. 2005; UNEP 2002) developed this approach to a much more comprehensible tool for global transition management. The improvement of the evaluation of present and past development, in order to assess the SRES and their probability would increase the usefulness of the SRES scenario approach for an adequate response to the climate change challenge.

8 Literature

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A 1 Comparison of SRES and ESD Scenarios

A 1.1. Protocol

For the conducted quantitative scenarios comparison the Emission Scenarios Database (Filename: Ipccdbv1-20050512.mdm) was downloaded the 9.Juli 2006 from www-cger.nies.go.jp/scenario/index.html and transformed in the following way:

- Scenario selection: Only the scenarios with data for Population, Economic Growth, Energy consumption or CO_2-emissions for 2100 on the global level were selected.
- Selected variables and values:
    - CO_2-Emissoins: If only one variable was available for CO_2-emission this variable was taken, else the variable, which described the CO_2-emission from energy (see table 15). It was not possible to calculate growth rates for CO_2-emissions of the following Scenarios, because their value for 2100 was negative or zero: IMAGE2.1 (Intervention), WorldScan/EMF14 (Uncertainly), IIASA/EMF14 (Intervention).
    - GDP: In general scenario had a GDP variable. However, for some scenario series only GNP or GDP ratio was available to calculate the economic growth rates (see table 15).
    - Population and Energy consumption: All selected scenarios, which indicated the energy consumption had a variable labeled "Total primary energy consumption". Also for the population no different variable names were used within the scenario series.
    - Values for 1990: Some Scenarios had population, GDP and CO_2-emissons values for 2050 and 2100 but not for 1990. For these scenarios the median value of the other scenarios was taken (see table 15).

- Error Data: Since the ref (baseline) and a (intervention) scenario from the MARIA95 scenario series have the same values. And the values seems clearly be the one of the intervention scenarios, since the projected CO_2-emissions for 2100 are 1.7 Gt C/yr, these scenarios are excluded.

Table 15 Transformation of ESD for comparison with SRES

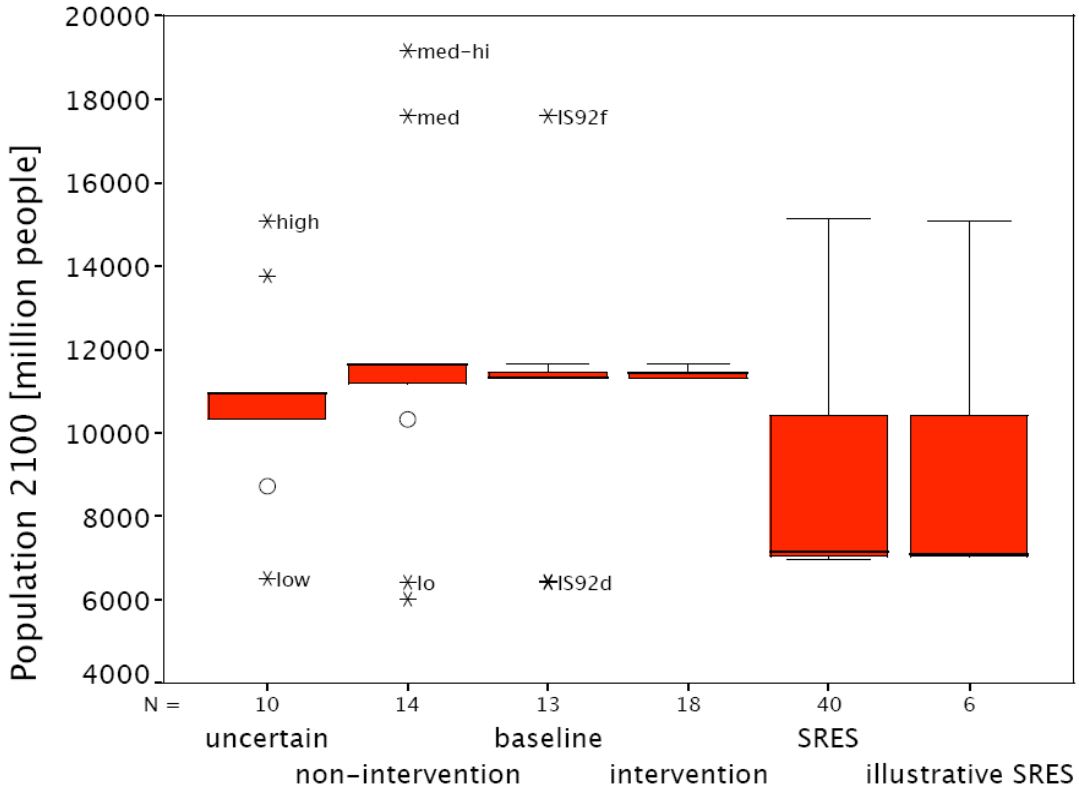
Scenario Series (Source)	Selected variable and conducted changes
Manne&Richels/IPCC94	GDP ratio
AIM94	GNP (or GDP), Real
CETA95/EMF	GNP (or GDP), Real
CRPS	GNP (or GDP), Real
DICE	GNP (or GDP), Real
FUND	GNP (or GDP), Real
HCRA	GNP (or GDP), Real
ICAM2	GNP (or GDP), Real
IMAGE2.0	GNP (or GDP), Real
MERGE/IEW97	GNP (or GDP), Real
MERGE3.0	GNP (or GDP), Real
MINICAM94	GNP (or GDP), Real
MIT	GNP (or GDP), Real
PEFM	GNP (or GDP), Real
RICE	GNP (or GDP), Real
TARGET	GNP (or GDP), Real
YOHE/IEW97	GNP (or GDP), Real
AIM96	GNP or GDP
MARIA95	GNP or GDP
IS92	CO_2-emission from "Combustion" GNP or GDP
AIM/SRES	CO_2-emission from "Energy"
ASF/SRES	CO_2-emission from "Energy"
IMAGE/SRES	CO_2-emission from "Energy"
MARIA/SRES	CO_2-emission from "Energy"
MESSAGE/SRES	CO_2-emission from "Energy"
MiniCAM/SRES	CO_2-emission from "Energy"
SGM97	CO_2-emission from "Fossil Fuels"
IIASA/WEC98	CO_2 from "emission Gross fossil"
IMAGE2.1	CO_2 from "energy production" GNP or GDP

EPA98	CO_2 from "Energy production" GNP or GDP
AIM95	CO_2 from "Industrial Sector"
IPCC90/IPCC94	GDP ratio and 100 for GDP ratio in 1990
N-Y/IPCC94	GDP ratio and 100 for GDP ratio in 1990
Nordhaus/IPCC94	GDP ratio and 100 for GDP ratio in 1990
AIM/IPCC94	GDP ratio, 100 for GDP ratio 1990 and median (5.93) for CO_2 1990
Bach/IPCC94	median (5.93) taken for CO_2 1990
IPCC90/IPCC94	median (5.93) taken for CO_2 1990
Ogawa/IPCC94	median (5.93) taken for CO_2 1990
Rogner/IPCC94	median (5.93) taken for CO_2 1990
TEC/IPCC94	median (5.93) taken for CO_2 1990
RICE99	median (5.93) taken for CO_2 1990 and median of 21062 for GDP 1990
RICE99	median (5.93) taken for CO_2 1990 and median of 21062 for GDP 1990
IIASA96	median of 5275.83 assumed for Population 1990
UN 92 LR	median of 5275.83 assumed for Population 1990
US Cens.Bur.	median of 5275.83 assumed for Population 1990
World Bank	median of 5275.83 assumed for Population 1990
EPA/IPCC94	1994 for Update, since source IPCC94 and Median for CO_2 1990

Note: If not mentioned scenario series for the CO2-emission the variable „ CO_2-emission“ and for GDP the variable „GDP“ was taken.

A 1.2. Population

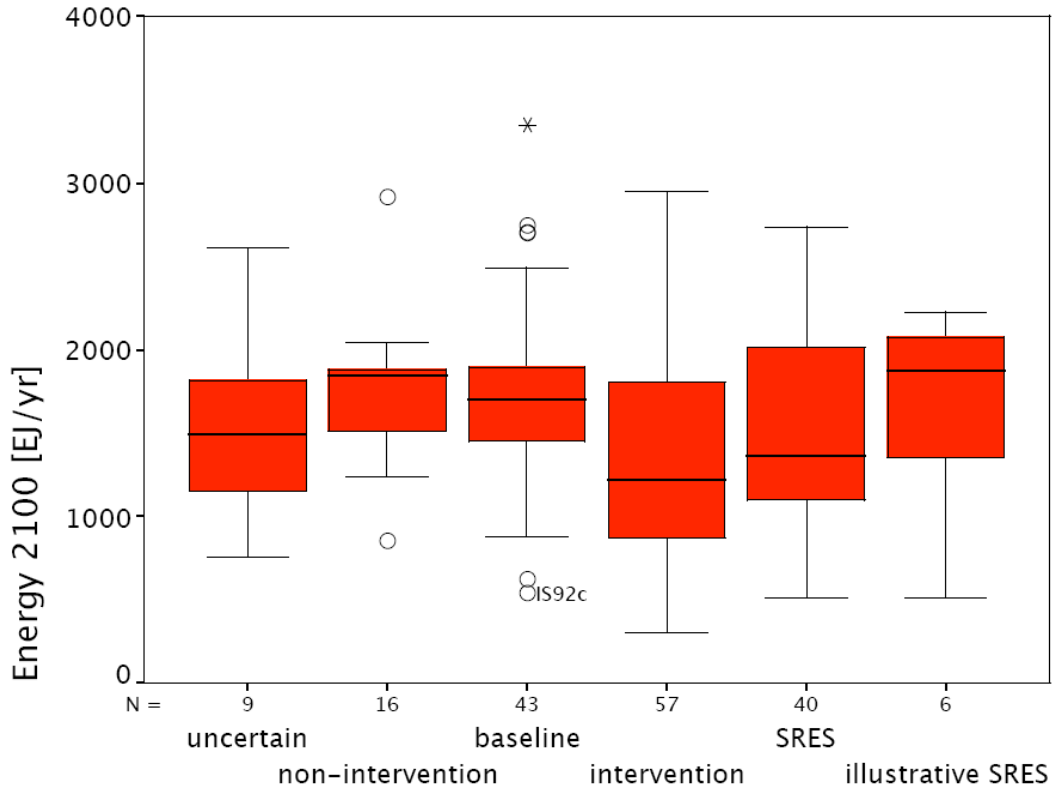
Figure 14 Comparison of population projections



(ESD 2006)

A 1.3. Energy Consumption

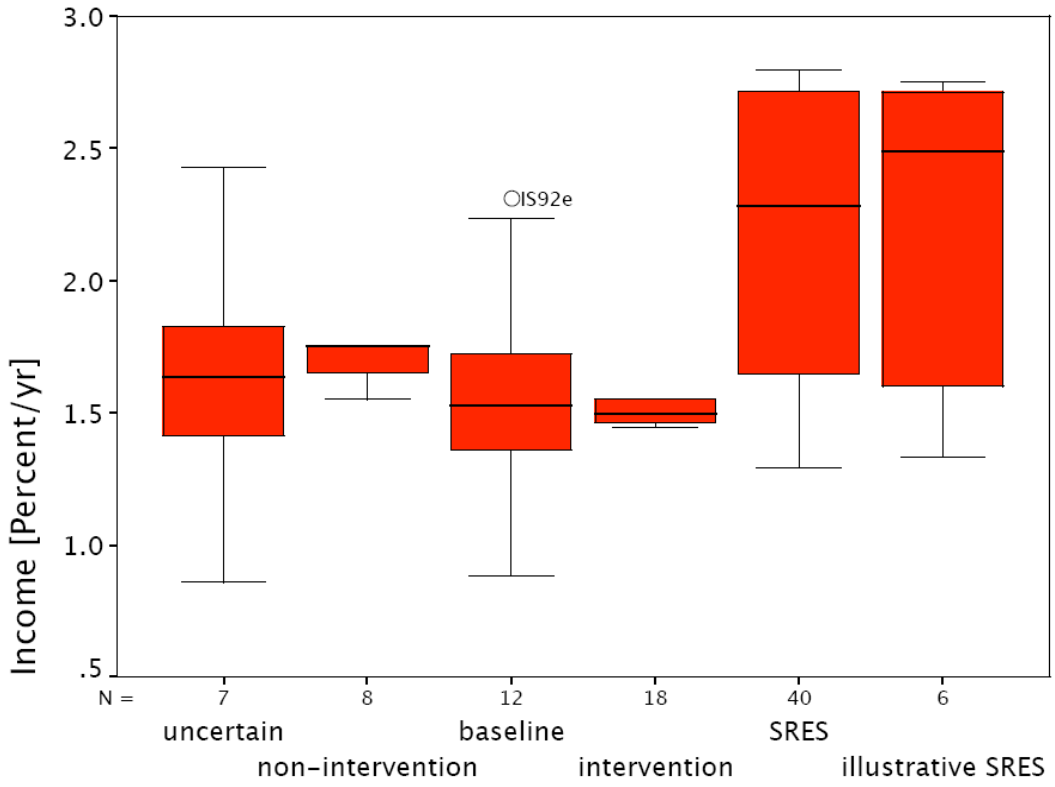
Figure 15 Comparison of energy consumption projections



(ESD 2006)

A 1.4. Income growth projection

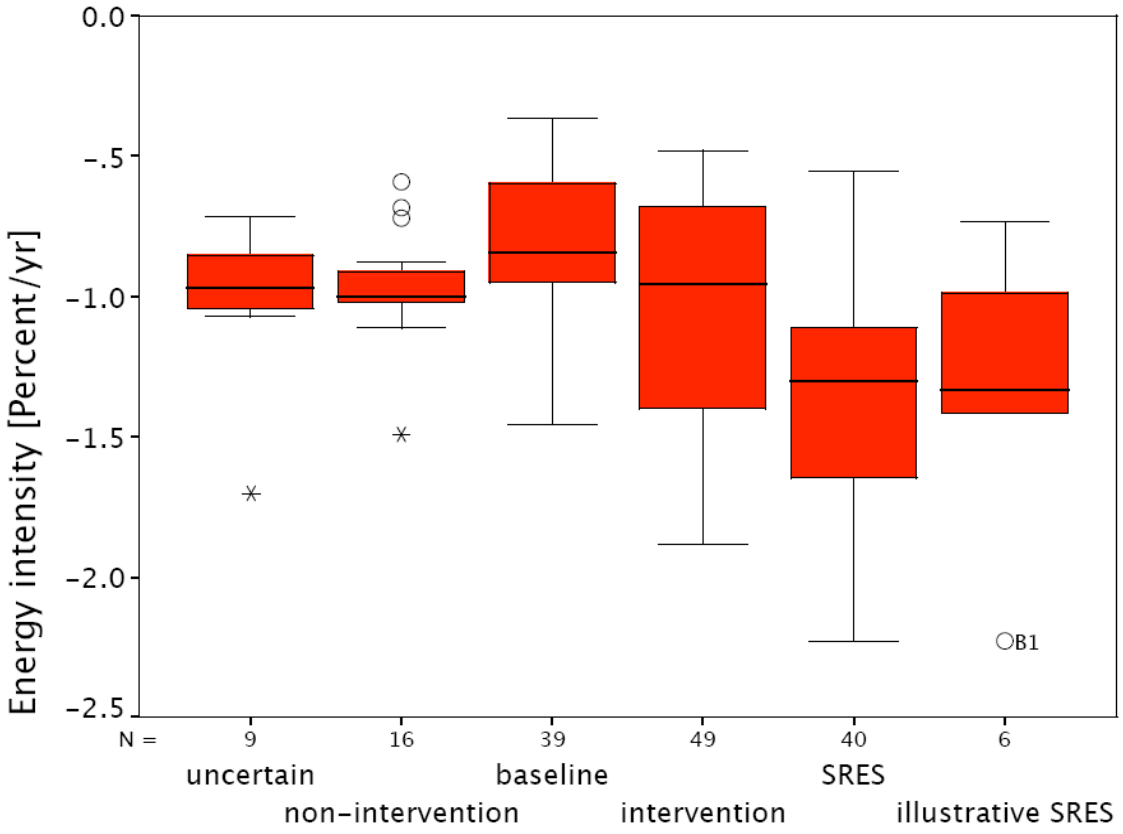
Figure 16 Comparison of income projections



(ESD 2006)

A 1.5. Decrease of Energy Intensity

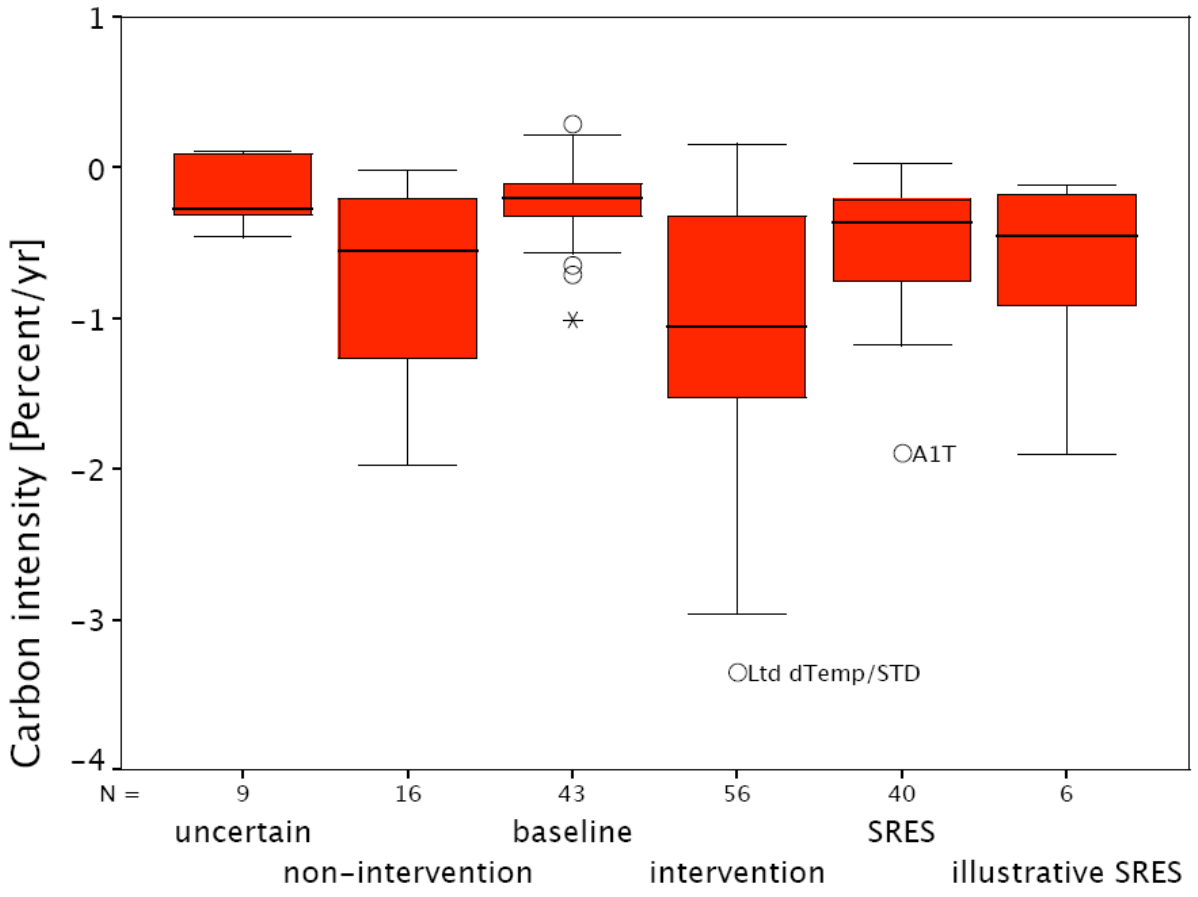
Figure 17 Comparison of energy intensity projection



(ESD 2006)

A 1.6. Decrease of Carbon Intensity

Figure 18 Comparison carbon intensity projections



(ESD 2006)