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Future IPCC scenarios – lessons learned and challenges to scenario building in climate change policy

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Abstract

Based on a broad analysis and appraisal of the development of the IPCC scenarios, the authors propose various methodological improvements regarding future IPCC scenario building, considering not only scientific credibility but also the relevance, comprehensibility and legitimacy of the scenarios for scenario users by introducing 1. formal methods to qualitative scenario analysis and construction, 2. an explicit consideration of stakeholders participating in the review and publication phase of the reports as well as actors relevant to future green-house gas (GHG) emissions, 3. the integration of functional physical units to describe the evolution of consumption patterns, and 4. the use of the Business-as-Past instead of the so-called Business-as-Usual concept. Applying these methods would allow meeting the challenges recognized in our evaluation of the past IPCC scenarios.

Keywords: IPCC; emissions scenarios; storylines; consistency analysis; actor analysis; climate change policy.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) is the major international scientific body to assess the scientific literature on climate change and its scientific basis, vulnerability and mitigation options (IPCC, 2004). Thus, the Panel is situated at the science-policy interface. This becomes manifest in the process of publication. The Panel, which is formed by scientists and governmental agents, signs off the IPCC reports. The reports are written by scientists from all over the world and have to pass an extensive expert review. At the end the so-called “Summary for Policymakers”, which summarizes the voluminous reports, undergoes a line-by-line governmental review and finally needs approval by the governmental plenary for publication (IPCC, 2003). While the main work of the IPCC is to review scientific literature, in case of the scenarios the IPCC has always taken an active role, by proposing scenarios which have been, later on, used in the entire scientific literature (IPCC, 2000b, IPCC, 1990b, IPCC, 1992b). This active role will be maintained. The IPCC plans to develop a fourth series of scenarios for its upcoming fifth assessment report (IPCC, 2006, IPCC, 2005b, IPCC, 2005a). However, scenarios are also different from the rest of climate science reviewed by the IPCC – because they are not “pure” science. Emissions scenarios bridge climate *science* and *policy*. Scenarios

reflect the consequences of political actions – or inaction. Hence, the emissions scenarios have a crucial role in the challenge we face with climate change. Since scenarios can have different functions (Wiek et al., 2006), the question arises what kind of scenarios are most suitable to cope with climate change According to Cash et al. (2003) scenarios have to perform well against the criteria of saliency, credibility and legitimacy in order to contribute to sustainable development. However, the scenario group of the IPCC proposes an array of methodological improvements which mainly focus on the criteria of (scientific) credibility (IPCC, 2008). In addition little emphasis is put on the particularity of the scenario construction at the science-policy interface and past IPCC scenarios are, understandably, not evaluated too critically for possible shortcomings. This contribution, first, aims at analyzing possible deficiencies of past IPCC scenarios and deriving challenges in scenario construction – considering the peculiarity of IPCC's science-policy setting. Second, different scenarios approaches are proposed which might effectively meet the recognized challenges. Thereby we not only focus on the narrow criteria of scientific credibility but also include the saliency and legitimacy in our consideration.

The contribution sets out with an evaluation of the past IPCC scenarios and shortcomings of the "Special Report on Emissions Scenarios (SRES)". Section 3 thereof derives major challenges for upcoming IPCC scenarios. To meet these challenges the introduction and application of new scenario methods for the IPCC scenarios is proposed in section 4. Finally, we draw conclusions by showing how these proposed methods would allow improving the IPCC scenarios regarding the recognized challenges (section 5). While this article focuses on the IPCC scenarios, the insights can also be applied to scenarios in other fields with a science-policy interface.

2. Analysis and appraisal of past IPCC scenarios

We analyze the changes in the evolution of the IPCC scenarios against the criteria of credibility, saliency and legitimacy (Siebenhüner, 2003, Hulme and Dessai, 2008, Cash et al., 2003): *Credibility* deals with the scientific adequacy of the technical components of the scenarios spelt out in literature. *Saliency* refers to the relevance of the scenarios to, and their comprehensibility for, political decision makers and other users (including scenario modelers). *Legitimacy* refers to transparency, participation and fairness of the scenario construction process. These criteria were operationalized for evaluating the evolution of the IPCC scenarios (Girod et al., 2009) (see Table 1).

Table 1. Definition and operationalization of criteria to evaluate the quality of scenarios

Criteria	Definition	Operationalization for appraisal of scenarios
Saliency	Relevance of the scenarios to, and their comprehensibility for, political decision makers and other users	Comprehensibility of description to scenario users (including transparency and traceability of scenarios construction); Capability for evaluation climatic consequences of non-intervention futures and intervention futures
Credibility	Scientific adequacy	Accordance of methods, description and estimates with literature; accuracy of verbalization
Legitimacy	Transparency, participation and fairness of the scenario construction process	Transparency of review; breadth (representativeness) and balance (fairness) of participation by scientists and governmental agents

Sources: Criteria and description (Siebenhüner, 2003, Hulme and Dessai, 2008, Cash et al., 2003); Operationalization (Girod et al., 2009)

The major improvements achieved during the development of the IPCC scenarios are seen to be (i) an increased legitimacy through an intensified review procedure and a broader participation in scenario construction; (ii) a higher credibility through more sophisticated models and the use of storylines; (iii) the renunciation of the use of a single Business-as-Usual (BaU) scenario, and projecting instead of "predicting" future emissions scores high against the criteria of saliency (Girod et al., 2009). Nevertheless also shortcomings were detected.

2.1 Intervention characteristic not declared

The IPCC scenarios according to the SRES are described as "non-intervention" scenarios and "baselines". This gives the impression that these scenarios are "free" of policy or value with direct effects on carbon emissions (solely representing trends); the IPCC, however, only excludes declared climate policy, whereas, for instance, major efforts as to R&D of renewable and efficiency or even energy taxes are included in the low-emissions SRES scenarios (IPCC, 2000b). Moreover, similar scenarios like the A1T and B1 scenarios from literature are clearly categorized as intervention scenarios. This ambiguity was recognized by the IPCC, admitting that ''in practice, many policies can both reduce greenhouse gas emissions and achieve other goals'' and that a clear distinction between intervention and non-intervention might be difficult if such policies were assumed (IPCC, 2001a, p. 122).

Table 2. Comparison of the SRES storylines with storyline scenarios from literature

GSG (Raskin et al., 2002)	**SRES** (IPCC, 2000b)	**WBCSD** (WBCSD, 1997)	**GEO-3** (UNEP, 2002)	**WWV** (Gallopin and Rijsberman, 1999)	**OECD** (OECD, 2001)	**MA** (Raskin et al., 2005)
Conventional	*Worlds*					
Market Forces	A1	FROG!	Market first	BaU	Reference	(Global Orchestration)
Policy Reform	B1	GEO policy	Policy first	Technology & economics	Policy variants	
Barbarization:						
Breakdown	A2					
Fortress World			Security first			(Order from Strength)
Great Transitions:						
Eco-Communalism	B2					(Adapting Mosaic)
New Sustainability Paradigm		Jazz	Sustainability first	Lifestyle and values		(Techno Garden)

GSG: Global Scenario Group, SRES: Special Report on Emissions scenarios, WBCSD: World Business Council on Sustainable Development, GEO-3: Third Global Environment Outlook, WWV: World Water Vision, OECD: Organization for Economic Co-operation and Development, MA: Millennium Ecosystem Assessment
Note: The classification follows Raskin et al. (2005) except for scenarios in brackets which are grouped by the present authors.

2.2 No scenario titles chosen

Regarding *saliency* the description suffers a lack of meaningful scenario titles. The authors themselves as well as the reviewers of the SRES scenarios proposed similar scenario titles (Table 3), and comparable scenarios in the literature use distinct scenario titles (Table 2). The absence of scenario titles compounds misunderstanding the term “non-intervention”. One could argue that the storylines of the scenarios are described in the SRES and, therefore, that their basic assumption with implications for policies is unambiguous. In the ‘‘Summary for Policymakers’, however, the Fourth Assessment Report presents the SRES climate projections as ‘‘Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies)’’ (IPCC, 2007b, Table SPM.5) while the storylines are not described in the summary. The referenced main report only provides a brief description of the scenarios which does not allow scenario users recognizing the assumed interventions relevant for carbon emissions in the B1 and A1T scenarios (IPCC, 2007c, p. 44). This shows that scenarios are even separated from the description of their content in the IPCC report. Using scenario titles in this case would avoid a relevant loss of information for scenario users.

Table 3. Scenario titles for IPCC SRES marker (baseline) scenarios as proposed by modeling teams and reviewers

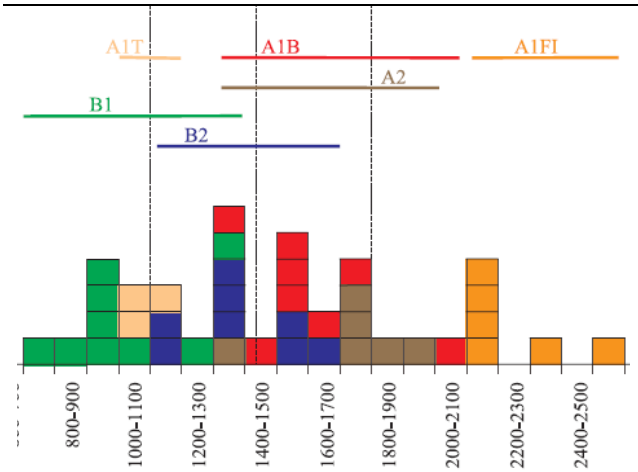
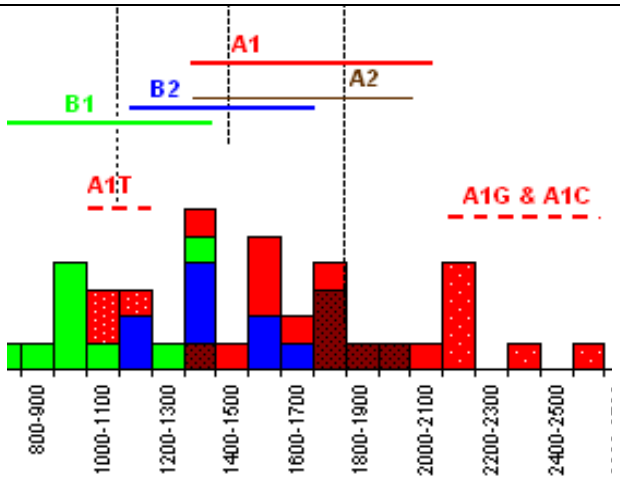
SRES	**AIM modeling team** (Jiang et al., 2000)	**ASF modeling team** (Sankovski et al., 2000)	**Jim Shrouds** (USDT/USA) (IPCC, 2000b)	**Switzerland** (IPCC, 2000c)
A1	Catch up (Scenarios C)	High Growth	Global Affluence	Convergence
A2	Domestic Supply (Scenario D)	Regionalization	Regional Identities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

USDT: US Dept. of Transportation; AIM: Asian Pacific Integrated Model, ASF: Atmospheric Stabilization Framework.
[1]"Shortcut" denotes an improvement of the quality of the environment in the developing Asia-Pacific countries before reaching a level as bad as that in the OECD countries during their own development period.

2.3 High number of scenarios

For the *saliency* of the scenarios a large number of scenarios is problematic because (i) climate models have to be run several times using a higher calculation capacity and (ii) illustrating and applying the resulting climate change becomes increasingly difficult for cognitive reasons (Alcamo, 2001). This is even more relevant to baseline scenarios which should be used to develop additional mitigation scenarios. Consequently most emissions-scenarios series in literature just provide a few baseline scenarios. Evaluating the Emission Scenario Database (Morita, 1999) 44 scenario series only provide one baseline scenario, eleven series provide two and one series three baseline scenarios (Girod and Mieg, 2008). However, the SRES explicitly recommends to use all six baseline scenarios (IPCC, 2000b, p. 46, Box TS-4). Girod et al. (2009) showed that the increase in the number of scenarios was caused by request during the governmental review.

Table 4. Increasing number of SRES baselines by upgrading A1 groups after final draft

SRES final *report* (IPCC, 2000a)	**SRES final *draft*** (IPCC, 2000a)
	

2.4 Storyline construction intransparent

The storyline construction for the IPCC SRES scenarios can be described as follows:

> *The idea to develop storylines came [up] in the beginning of the scenario construction and was decided at the first meeting of the SRES authors. The Shell strategic planning group supported the construction of storylines (Gerald Davis (lead author) and Douglas McKay (contributing author) from Shell International Petroleum were members of the SRES writing team). 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. (Girod, 2006, p. 61).*

However, in the IPCC SRES Report this "elaborate and extensive process" for developing the storylines is not described, neither the criteria by which they were chosen. The description of the storyline construction and the selection process is mainly summarized by the following paragraph of the IPCC scenario report:

> *The writing team consciously applied the principle of Occam's Razor (i.e., the economy of thought, Eatwell et al., 1998). They sought the minimum number of scenarios that could still serve as an adequate basis to assess climate change and that would still challenge policy makers to test possible response strategies against a significant range of plausible futures. The team decided on four storylines, as an even number helps to avoid the impression that there is a "central" or "most likely" case .(IPCC, 2000b, p. 70)*

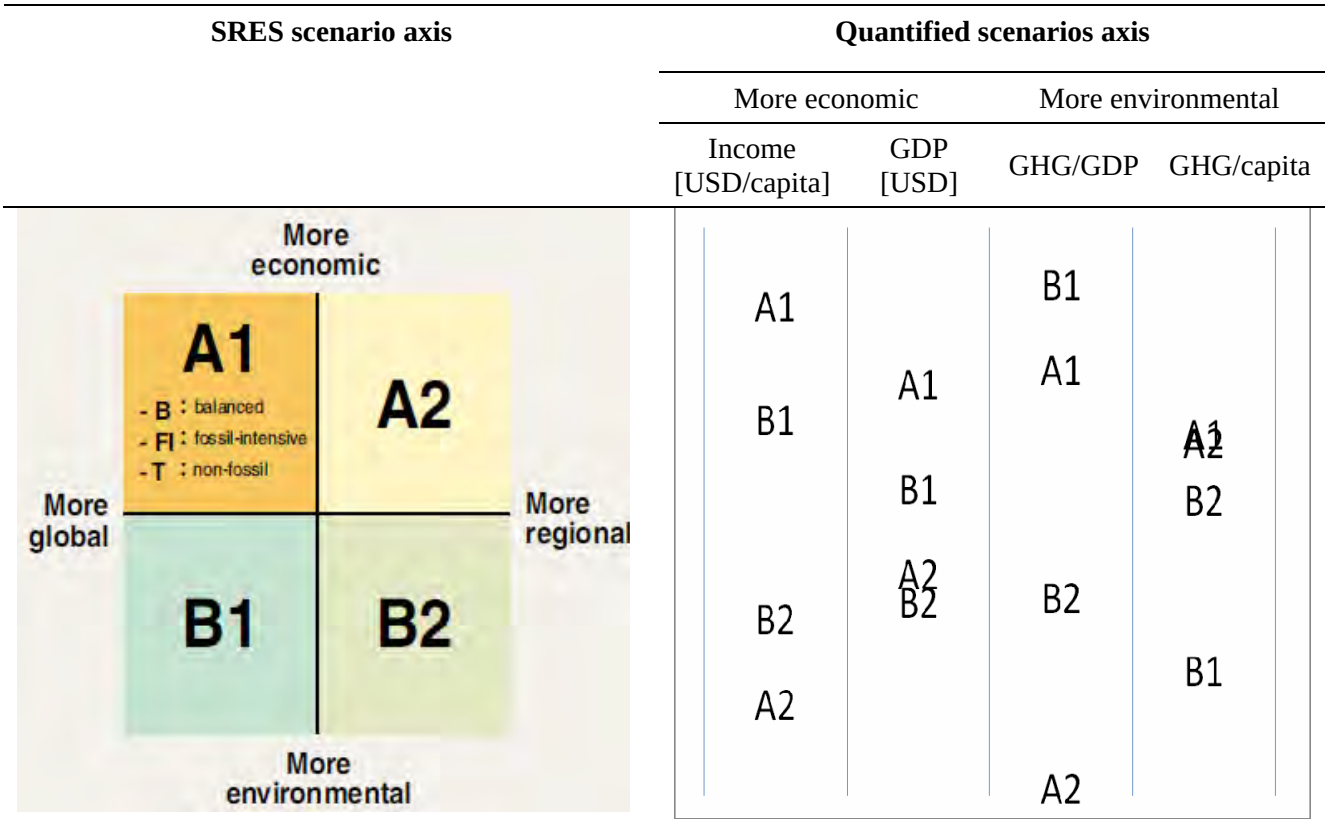
This obvious defect in the description of the storyline construction process and the methods applied scores poorly against the criteria of credibility.

2.5 Use of scenario axis inconsistent

The use of the scenario axis is an improvement, since it makes the main uncertainties explicit. But: Because the axe titles 'globalization' and 'sustainability' "are not necessarily viewed by everyone as being value-free", the two dimensions were alternatively rephrased as "more global or more regional" and "more economic or more environmental" (IPCC, 2000b, p. 173). Labeling "more economic vs. more environmental" (IPCC, 2001b) contrasts with the definition of sustainability as a guiding concept that intergenerational balances economic, ecological, and social needs (WCED, 1987). This labeling is misleading for the SRES B scenario families positioned at the environmental pole of the "economic vs. environmental" axis. The B scenario families explicitly rely on "economic, social and environmental sustainability", emphasizing not only the relevance of environmental issues but also oriented toward social equity and economic growth (de Vries et al., 2000, Riahi and Roehrl, 2000). A further weakness is the asymmetric representation of the scenario axes in the SRES scenarios. For instance, sustainability is included very differently in the B families although these are both positioned at the environmental/high sustainability pole. Whereas in the B1 family the transition towards sustainability is assumed to be nearly completed by the end of the 21st century (de Vries et al., 2000), the B2 scenario assumes comparatively little emphasis on sustainability (Riahi and Roehrl, 2000). Table 4 illustrates

the insufficiency of (i) the labeling of “more economic” versus “more environmental” axis and (ii) the unequal consideration of these scenario characteristics in the SRES: If the increase in income (1990 up to 2000) is used for “more economic”, the B1 and B2 scenarios perform better than the A2 scenario, despite their position at the IPCC scenario axis. Choosing GDP, the B1 scenario is still “more economic” than the A2 scenario. Using GHG emissions per GDP for the “more environmental” leads to better a performance of A1 compared to B2. Only the change in GHG emissions per capita puts the SRES scenarios into the right order. However, here still an asymmetric interpretation of “more environmental” can be observed.

Figure 1. Representation of IPCC storylines by scenarios axis



Note: The distribution of the storylines (A1, A2, B1, B2) on the quantified scenarios axis (columns: income, GDP, GHG per GDP and GHG per capita) refers to the growth rate of these variables on the global level from 1990 up to 2100 (IPCC, 2000b).

2.6 Undue influence of governmental review

The *legitimacy* of the scenarios suffers from an unbalanced process during the review phase (Girod et al., 2009): On the one hand, the countries threatening not to approve the final report (China, USA and Saudi Arabia) were successful in their major demands to merge the gas and oil scenarios of the A1 family with one fossil-intensive scenario (A1FI), thus upgrading the sub-families of the A1 scenarios (A1B, A1T, A1FI) to the same level of the other scenario families (B1, B2, A2) and deleting the section on the climate consequences of the SRES scenarios. On the other hand, countries requesting the inclusion of the impact of the SRES scenarios were not successful (Girod et al., 2009). Apart of the direct requests the governmental review probably also

has an indirect influence because the scientists anticipate possible difficulties in the final plenary and governmental review. For instance two interviewed authors justify the absence of scenario titles in the final report with the following reasons: (i) different words mean different things to different people, (ii) titles are likely to be insufficient to capture the complex characteristics of the storylines and (iii) it would be very difficult to agree on titles in an intergovernmental approval process on the "Summary for Policymakers" (Girod et al., 2009). However, Tables 2 and 3 show that the titles proposed in previous publications, as well as the titles proposed by reviewers, are very similar even though they come from different sources. In addition scenarios from literature (Table 2) have a similar complexity and still use scenario titles. The third reason seems to be the most adequate explanation for the absence of scenario names which, nevertheless, is detrimental to balanced participation.

Another major influence of the governments is manifested by the request to exclude policy scenarios in the *Terms of Reference* of SRES. According to one of the authors involved in all three of IPCC's emissions scenario series, the First IPCC Assessment Report eventually led to the United Nations Framework Convention on Climate Change in 1992. "Only [by] 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 [Second and the Third Assessment Reports] excluded specific climate policies" (Girod, 2006, p. 69). The evaluation of the IS92 scenarios suggested to include intervention scenarios "because the IS92 scenarios were not designed and are not suitable [to evaluating the environmental/climatic consequences of intervention to reduce greenhouse gas emissions], new scenarios may be needed to fulfill these purposes" (Alcamo et al., 1995). Hence, the request to exclude intervention scenarios undermines a balanced participation because it was requested by the minority of governments and had a negative influence on the saliency of the final report as it led to reduced applicability.

3. Challenges of scenario construction – lessons from the past

While contributions to improve emissions scenarios through the IPCC are fully acknowledged, the failures highlighted in the former section show that further improvements are needed. The recognized deficiencies indicate challenges which have to be met for upcoming scenarios. We will structure these challenges according to the criteria for science-policy boundary objects defined by Cash et al. (2003): saliency, credibility, legitimacy.

Salient description of the IPCC scenarios: The description of the IPCC scenarios is a particular challenge which has to be acknowledged. This is so because the Panel has to agree on the description of the IPCC scenarios. The "Summary for Policymakers" passes a line-by-line approval by the final Panel, which includes the members of many countries (IPCC, 2003). At the same time consistency of the whole report with the summary should be guaranteed. Hence, the whole description of the scenarios must virtually pass the agreement of the plenary.

Credible storyline construction and representation: The storylines of the SRES are certainly an improvement compared to the former IS92 scenarios. However, the description of the storylines construction, their selection as well as the representation of the storylines on the storyline axis need serious improvements. The challenges will be that the participants of the governmental review have different worldviews and each would like to see the storyline describing his or her worldview supposedly leading to low GHG emissions. This is also an explanation why the scenario group of the A1 storyline leading to very low emissions (A1T) was upgraded mainly due to the request of the US. This results in the following message: We can resolve the climate problem in a US world (A1 storyline) through technological improvements. The pressure will certainly remain that storylines describe wishful thinking – where climate problems are almost automatically solved – instead of consistent future development paths. By the unequal pressure from the countries (see above) on the scenarios this could lead to an underestimation and bias of the scenarios projections.

Balanced participation: The difficulty of reaching a balanced participation for IPCC scenarios is twofold: First, the governments have different interests and values considering climate policy; some fear legally binding agreements whereas others would like international pressure on climate policy actions. Second, since there are values underlying the scenarios and the future development is inherently uncertain it is more difficult to agree on the scenarios and scenario assumptions. The latter is unlikely for other fields: If all climate models result in a certain range for global warming for a specific atmospheric GHG concentration, the influence of the governments to "negotiate" this result is very limited. These challenges are amplified by the need that all IPCC member countries agree on the "Summary for Policymakers" in order to reach approval by the plenary for the publication of the entire report. Since countries opposing legally binding agreements are less interested in the publication of the reports (and therewith raising pressure for action) they can exert more pressure so that their comments are considered in the report.

4. New approaches to meet the scenario challenges

After highlighting different shortcomings and resulting challenges of the IPCC emission scenario construction, we propose four methodical improvements which could contribute to tackle the challenges.

4.1 Formative scenario construction

The formative scenario analysis was developed for transdisciplinary projects (Scholz and Tietje, 2002, p. 79-116). It consists of a system description of the future GHG-relevant development allowing to increase the system understanding and recognized active and passive variables (Wiek et al., 2008). The variables derived in the system analysis are the basis for the formal scenario construction. For each variable different future states are defined. Subsequently the consistency of these different states are assessed by rating how different future states can evolve together (Wiek et al., 2009, Tietje, 2005). This method also facilitates the selection of final scenarios since the criteria of consistency (credibility of the scenarios) and coverage of different future

states can be formally applied (Tietje, 2005). A similar approach to formally derive consistent scenarios is the so-called cross-impact analysis (Hayashi et al., 2005, Schweizer, 2007).

Appling this method to the IPCC SRES scenarios would have allowed to (i) make transparent, how the scenario experts judge the consistency of different future states occurring at the same time, (ii) all combinations of future states would have been subject to expert judgment, and (iii) since the "no climate policy" assumption would also be rated with the different future states, the higher similarity of the SRES A1B, B2 and especially A1T and B1 scenario with policy scenarios would could have been easily shown.

An example of a major inconsistency in the SRES, which would not be possible with a formative scenario construction, is the virtual elimination of coal use in the A1T and B1 and, to some extend, also in the A1B scenario. This is not consistent since, on the one hand, these are all non-climate-policy scenarios and, on the other hand, there is plenty of coal available and using "clean coal" technology would allow exploring these resources without local pollution. This inconsistency was also criticized by different experts in the review of the SRES scenarios (Girod, 2006, p. 77). Interestingly, Schweizer concluded from applying the cross-impact analysis that the A1T scenario is not consistent, but "global environmental policy targeted to strongly promote low carbon energy structures, and somewhat promote low energy intensity, introduces the A1T1 as consistent scenario" (Schweizer, 2007).

4.2 Actor analysis

The first IPCC scenarios were backward scenarios starting with future atmospheric concentration. The subsequent second and third IPCC scenarios were projections of future emission. For the next generation of IPCC scenarios, the IPCC decided to begin with possible evolution patterns for the atmospheric concentration of greenhouse gases (so-called "representative concentration pathways, RCPs") which will simultaneously serve for the development of new climate-model simulations and new socio-economic and emissions scenarios (IPCC, 2008). Hereby the role of the scenario modeler also changes. The question is no longer "what could future emissions amount to?" The question instead is "which development leads us to which RCP?" and "what is the contribution of different measures and actions to reach the low RCPs?" Finally addressing action, this, at the same time, takes us to the important actors – and, thus, the purpose of the scenarios: to reach decisions. Hence, the focus should be more on which change can contribute how much to reach a certain RCP and what is the potential of the different possible decision of the relevant actors, including governments, companies, households, and science. One might even consider to go to a meta-level and analyze the IPCC process itself, with the major actors and their interests, agendas, strengths and eventual biases, since the process, in some sense, simulates a – limited – societal discourse and deserves to be scrutinized (Flüeler et al., 2007a, Flüeler et al., 2007b). Recognizing complexity in research, paradigmatically climate change research, leads to the insight that broader approaches are required (Flüeler, 2007). For durable solutions to complex and controversial problems have to be socially robust, that is if and when most arguments, evidence, social alignments, interests, and cultural values lead to a consistent option (Rip, 1987). Actor analysis allows recognizing non-fulfillment of required functions, non-availability of required knowledge, and deviations

between self- and cross-perception (Wiek et al., 2007). In addition the conflicts between relevant actors can be made transparent and the scenarios can be rated and improved regarding the resulting conflicts between the different actors (Bots, 2007). An actor analysis might also help in setting up effective and efficient adaptation measures (Prins and Rayner, 2007) which will be needed in the case mitigation does not reach the results required by the recommended 2-degree Celsius threshold (IPCC, 2007a).

4.3 Integration of household consumption in functional units

Current scenarios are mainly based on the different GDP projections, using cost optimization models to derive different energy intensities (J/USD) and carbon intensities (CO_2e/J). However, herewith the role of the household – the "bottom-up" perspective – is not considered. How many kilometers will households in the different world regions travel in 2050? How much meat will they eat? Will they go for quality or for quantity? All these questions considering the household consumption have a major influence on total GHG emissions. Using a household consumption approach to total GHG emissions would therefore increase consistency as well as comprehensibility of the scenarios. The latter because it is easier to imagine changes in consumption in physical units than by income growth. We therefore propose the following formulation:

$$GHG_{i,t} = P_{i,t} \cdot \left(\frac{fu}{cap.} \right)_{i,n,t} \cdot \left(\frac{material}{fu} \right)_{i,n,t} \cdot \left(\frac{ghg}{material} \right)_{i,n,t},$$

where GHG describes the total GHG emissions in the world region i, at the time t; P describes the population; $\left(fu / cap. \right)_{i,n,t}$ stands for the functional units per capita for each consumption category n. $\left(material / fu \right)_{i,n,t}$ describes the material intensity per functional unit which is determined by the industry, and $\left(ghg / material \right)_{i,n,t}$ describes the carbon intensity of the industry which is determined by the energy mix .

The following improvements could be reached by considering household consumption in functional units:

Description of scenarios: By describing which change in household consumption the different scenarios assume there is an increase in the comprehensibility of the scenarios and the possibility for scenario users to judge the scenarios themselves. For instance the authors of the B1 scenarios assumed strong changes in mobility (de Vries et al., 2000); however, to which extent mobility changes in the different scenarios is not transparent in the SRES.

Evaluation of consistency of household consumption and storylines: In a world richer and more globalized than today (A1 and B1 scenarios), expenditure for mobility, especially air travel, must be expected to increase considerably more steeply than in a world with low globalization (A2, B2). This should lead – considering household consumption only – to higher GHG emissions per capita and lower GHG efficiency for scenarios assuming faster globalization. However, the SRES predicts the contrary. It argues that in a globalized world technology diffusion will be better, and hence higher efficiency and faster emergence of zero-emissions technology will lead to lower GHG emissions (IPCC, 2007a). Whether this effect on the industry can outweigh the shift towards worst-practice consumption on the household part still remains to be seen. This

would be possible if the emissions scenarios made the underlying assumption for household consumption transparent, also indicating functional units of consumption such as person kilometers, square meters of living space or mass of goods consumed.

Other aspects which could be analyzed are: to which extent the increasing quality level of consumption found for marginal consumption towards higher income for today's households (Girod and de Haan, 2009 (submitted)) is assumed; or whether constant travel time and money budgets (Schafer and Victor, 1999) are considered.

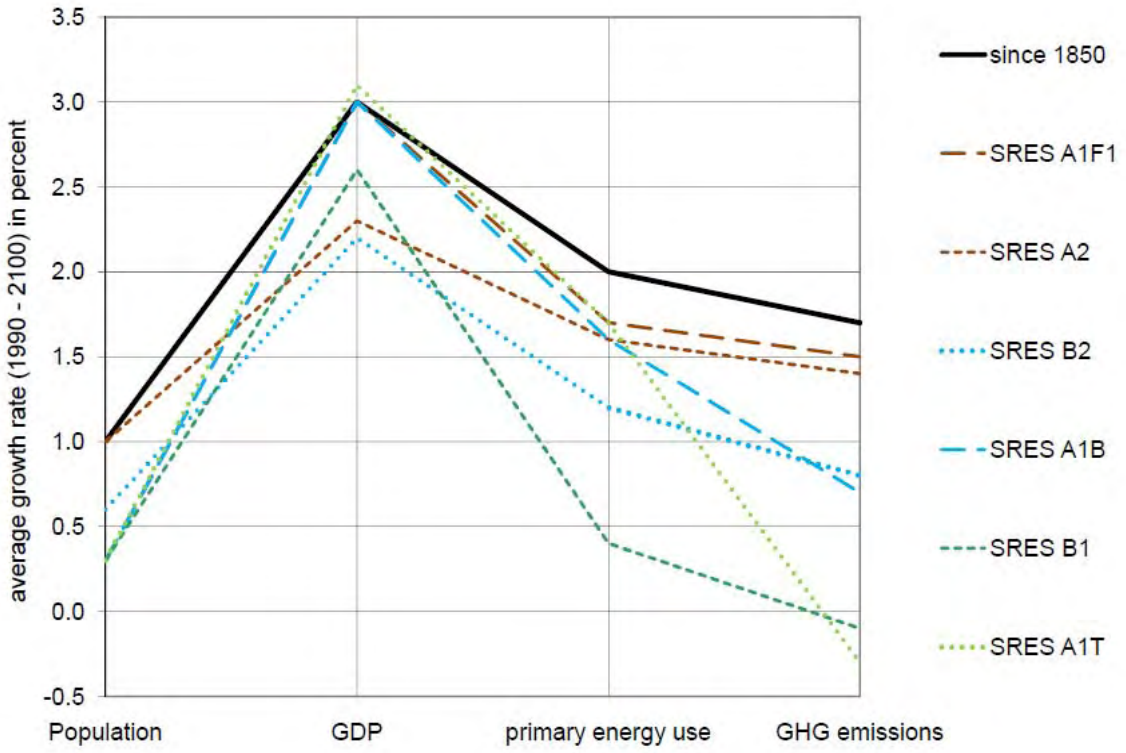
4.4 From BaU to BaP: from "Business as Usual" to "Business as Past"

While the first IPCC scenarios (SA90) had a Business-as-Usual scenario (IPCC, 1990a), the second series of IPCC scenarios only has a "central case" (IS92a) (IPCC, 1992a), and the SRES finally states (IPCC, 2000b, p. 46):

> *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.*

The IPCC authors are certainly right in so far as Business-as-Usual (BaU) scenarios neglect the uncertainty of future development. However, BaU is a strong concept to illustrate what might happen in the absence of (climate) policy, which explains that the concept is still in use by prominent IPCC climate scientists (Schneider, 2009). We therefore propose to use the Business-as-Past criteria, which is more objectively measurable, by comparing the change of key variables with the past development. Figure 2 shows growth rates projected by the SRES scenarios for key variables of GHG emissions scenarios (population, GDP, primary energy use and GHG emissions). It reveals that the A1FI and A2 scenario are closest to the Business-as-Past, while the A1T and B1 scenario clearly break away from the past trends. Interestingly Pielke et al. (2008) showed that no SRES scenario assumes the sharp increase in carbon emissions as observed in the real world. This demonstrates that the scenarios failed to span the correct range of possible development. All are more optimistic than Business-as-Past which proved to be a better approximation for the last ten years considering the resulting GHG emissions.

Figure 2. SRES key variables to global development since 1850



5. Conclusions

The shortcoming in past scenario construction (section 2) highlights the challenges for saliency, credibility and legitimacy of future IPCC scenarios (section 3). The proposed methodological improvements (section 4) allow meeting these challenges effectively:

Saliency: The *formative scenario construction* allows using the active variables in their different states for scenario description. This also facilitates the selection of scenario titles. The *integration of household consumption in functional units* would allow a major improvement in the description of the scenarios, by indicating how consumption patterns are assumed to change in the future. By also applying the *Business-as-Past* concept, a comparison of the changes in consumption pattern with past changes is possible. The latter concept would emphasize the assumed "change" in the different scenarios leaving it up to the scenario users to subjectively rate how likely such changes are.

Credibility: The storylines and their translation into quantitative inputs for the GHG emission models would benefit in traceability, integrity and consistency from a *formative scenario analysis*. The *actor analysis* would allow new consistency measures, since it is more consistent that future developments follow paths that have lower conflict levels. Also the *integration of household consumption in functional units* would allow new consistency checks for the changes on the macro level.

Legitimacy: All proposed *formative scenario analysis, integration of household consumption and Business-as-Past concept* reduce the danger of a "negation" on description and selection on the scenarios (and therewith unbalanced influence) by providing formal background to the selection and description of the scenarios. Up-grading scenarios as done in the final review of the IPCC SRES scenarios would be no more possible without reducing the measurable criteria of consistency and variability of the scenarios. In addition the actor analysis makes a major contribution to the legitimacy by increasing transparency on different kinds of conflicts of the actors relevant to GHG emissions as well as the stakeholders to the IPCC reports (e.g. participants of governmental review) – some actors being both (relevant to GHG emissions and stakeholders).

Finally, ***the different methods combined*** allow an improvement even larger than the sum of their individual contributions, due to their interplay. Considering both *actor analysis and formative scenario analysis*, these are tools developed for transdisciplinary case studies (Scholz and Tietje, 2002). Their suitability for use in climate scenarios underlines that the challenge of mitigating the climate change is a transdisciplinary project on the global level where not only society should learn from science but also science from the society, by working together with the public and stakeholders (e. g., from science-policy panels like IPCC to science-policy forums, developing Kinzig et al.'s recommendations, Kinzig et al. 2003). The *introduction of household consumption in functional units* is mainly an increase in resolution of the GHG models by explicitly introducing the micro-level allowing a multitude of improvements in different regards. Finally, using the *Business-as-Past concept* can also be seen as the recognition that, despite all new insights into the complexity of our society and influences on future development, the past is still a very good yardstick for the future development as factual indicators, such as efficiency (MJ/GDP) und decarbonization (CO2/MJ), are measurable reference entities and, as such, not subject to normative influences and beliefs about how the society works.

The impacts of climate change on energy systems and the increasing global energy demand, with associated ecological, economic, and political side effects, pose great challenges to the process of peaceful adaptation and transformation (IPCC, 2007a, IPCC, 2007d). Our suggestions are meant to improve the quality and validity of the IPCC work, which, in turn, is finally meant to help policy makers sustainably govern global, regional and local change.

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