available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

The evolution of the IPCC's emissions scenarios

Bastien Girod [a,*], Arnim Wiek [a,b], Harald Mieg [c], Mike Hulme [d,e]

[a] Institute for Environmental Decisions, Natural and Social Science Interface, ETH Zurich, Universitaetstrasse 22, 8092 Zurich, Switzerland
[b] Institute for Resources, Environment, and Sustainability, University of British Columbia, 2202 Main Mall, Vancouver V6T 1Z4, Canada
[c] Institute of Geography, Humboldt University Berlin, Unter den Linden 6, 10099 Berlin, Germany
[d] School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom
[e] Tyndall Centre for Climate Change Research, UK

ARTICLE INFO

Published on line 24 January 2009

Keywords:
Climate change
IPCC
Emissions scenarios
SRES
Evaluation
Science-policy interface

ABSTRACT

The IPCC's emissions scenarios form the basis for the majority of long-term climate change projections, including those of the current Fourth Assessment Report. The main characteristics of the IPCC's three scenario series – published in 1990, 1992 and 2000 – have changed significantly over time: titles, classification, assumptions and methods have all changed. This article analyses the evolution of the structure, description, process development and context of the IPCC's emissions scenarios, identifying the most important changes and their scientific and political causes. These changes are evaluated against the criteria of saliency, credibility and legitimacy. Our analysis indicates, first, enhanced credibility through an improved scenario construction methodology (multiple baseline scenarios; storylines), even though these achievements are diluted by particularities of the scenario approach used. Second, a reduced saliency through absence of titles, an inappropriate classification and the relatively high number of baseline scenarios, limits and weakens their wider applicability. These latter trends were due in part to concessions made to the intergovernmental nature of the construction process (trade-offs). The article concludes by proposing for the future the employment of a more formal qualitative construction approach as well as revisions to scenario labelling and classification practices.

1. Introduction

The emissions scenarios of the Intergovernmental Panel on Climate Change (IPCC) quantifying global greenhouse gas emissions up to the year 2100 have significantly changed during their evolution from the First (1990, SA90), through the Second (1995, IS92), to the Third Assessment Report on Climate Change (2000, SRES) (IPCC, 1990b, 1995, 2001a). The latest series from 2000, published in the Special Report on Emissions scenarios (SRES) (IPCC, 2000a), has not yet been updated—it was used as the basis for the Fourth Assessment Report (IPCC, 2007b). Diverging from the general IPCC mandate, the emissions scenarios represent original work rather than an assessment of existing research (Alcamo et al., 1995; IPCC, 1990b, 1992b, 2000a).

The IPCC's emissions scenarios are intended to guide scientific investigations, as well as political endeavours, as pointed out in the SRES: "We recommend that the new scenarios be used not only in the IPCC's future assessments of climate change, its impacts, and adaptation and mitigation options, but also as the basis for analyses by the wider research and policy community of climate change and other environmental problems" (IPCC, 2000a, p. vii). In accordance with these intentions, the emissions scenarios have been widely used as the basis for scientific studies (e.g., Arnell et al., 2004; Knutti et al., 2002; Nicholls and Tol, 2006) and as reference point for the

* *Corresponding author*. Tel.: +41 44 632 63 13; fax: +41 44 632 10 29.
E-mail address: bastien.girod@env.ethz.ch (B. Girod).
1462-9011/$ – see front matter
doi:10.1016/j.envsci.2008.12.006

political and societal discourse on climate change (e.g., Rosenthal and Revkin, 2007; UK Government, 2007).

Much of the criticism on the IPCC's emissions scenarios is directed at specific components of the scenarios (e.g., van Vuuren and Alfsen, 2006) and at the underlying assumptions (e.g., Webster et al., 2003; Pielke et al., 2008). Some of the literature deals with an individual IPCC scenario series – IS92 or SRES – from a broader evaluative perspective (e.g., van Vuuren and O'Neill, 2006). The IPCC has reacted to the critical discussions by acknowledging the need for new emissions scenarios that ought to be available before completion of the Fifth Assessment Report which is scheduled to be finalized in 2014 (IPCC, 2008). The development of new scenarios is coordinated by the IPCC and the scenarios are planned to being published in 2010 (IPCC, 2008).

Despite the broad discussion, there has been no systematic study on the evolution of the three sets of IPCC's emissions scenarios and their main components. Relevant questions therefore remain unanswered—for example about the absence of intervention scenarios in the IS92 and SRES scenario series, about the reason for the similar projected emissions range for 2100 between IS92 and SRES, and about the interactions between scientific and governmental agents in the review procedure for the IS92 and SRES scenario series.

The study presented in this article deals with the main changes from the SA90 to the SRES series, the reasons for these changes, and the question whether these changes were beneficial or detrimental to the purposes of the scenarios as set out by the IPCC. We put special emphasis on the more or less obvious interplay between scientific and non-scientific (broader societal) interests in the evolution of knowledge on climate change. We contend that the IPCC's emissions scenarios are hybrid constructs and boundary objects that result from extensive construction and negotiation processes among numerous scientists and governmental agents (cf. Hulme and Dessai, 2008). As such, they represent very interesting cases for analyzing and critically reflecting on the science-policy interface in climate change politics.

2. Conceptual approach and methods applied

We applied a simple conceptual approach to analyze and evaluate the main characteristics of the scenario series, their changes over time and possible reasons for these changes. Regarding each of the three IPCC's emissions scenarios series, we distinguished between the verbal *description* (words) of the scenarios and their underlying numerical *structure* (numbers) in the report. With respect to the *development process*, we analyzed the changes in the primary process (leading to preliminary documents) and the changes in the subsequent process (from preliminary documents to the final documents). Regarding the *context*, we analyzed changes in the *scientific setting* (e.g., methodology and participating scientists) and in the *triggers* (e.g., Terms of References which guide the work of the IPCC teams), as well as the changing *applicability* for scenario users (e.g., decision- and policy-makers, climate change scientists).

2.1. Analysis of changes

To capture the relevant changes during the evolution of the IPCC scenarios, we applied document analysis in studying the relevant IPCC's documents (Alcamo et al., 1995; de Vries et al., 2000; IPCC, 1990a,b, 1992a,b,c, 2000a,b,c,d,e; Jiang et al., 2000; Kram et al., 2000; Mori, 2000; Riahi and Roehrl, 2000; Roehrl and Riahi, 2000; Sankovski et al., 2000).

For the description of the IPCC's emissions scenarios, we refer to the official IPCC documents (IPCC, 1990a, 1992a, 2000a). We did not consider the post SRES scenarios of the Mitigation Report (IPCC, 2001b) as the SRES scenarios are the "official" IPCC's emissions scenarios, standing in line with the SA90 and the IS92 scenarios and being used centrally in the Fourth IPCC Assessment Report (IPCC, 2007b).

We used the Kaya identity on the global level for the comparison and evaluation of the structure of the three series. The Kaya identity was proposed by Japanese energy economist Yoichi Kaya to analyze the key components of the emissions scenarios and was used in the IPCC's evaluation of the IS92 scenario series (Alcamo et al., 1995) as well as in the SRES report (IPCC, 2000a):

$$\mathrm{CO_2\ emissions} = \mathrm{population}\ \underbrace{\left(\frac{\mathrm{GDP}}{\mathrm{population}}\right)}_{\text{income}}\ \underbrace{\left(\frac{\text{energy use}}{\mathrm{GDP}}\right)}_{\substack{\text{energy}\\ \text{intensity}}}\ \underbrace{\left(\frac{\mathrm{CO_2\ emissions}}{\text{energyuse}}\right)}_{\substack{\text{carbon}\\ \text{intensity}}}$$

As done in the SRES, GDP was measured in prices and exchange rates from 1990 in US-Dollars (US$ 1990). For the energy use the total primary energy consumption was considered (J), and for the CO_2 emissions the carbon emissions from energy use were considered (gC). A harmonization of these variables for scenarios drawn from the published literature is provided by the Emission Scenario Database (ESD), which was set up to compare the SRES with scenarios from literature (Morita, 1999).

In addition, we conducted 11 expert interviews with academic scholars from various institutions in Europe involved in the construction of the emissions scenarios, namely: Arnulf Grubler, Bert de Vries, Bert Metz, Keywan Riahi, and Nebojsa Nakicenovic (SRES lead authors); Mike Chadwick (SRES review editor); Rob Swart, William Pepper and Jane Leggett (authors of the IS92 and SA90 scenarios); Detlef van Vuuren (Netherlands Environmental Assessment Agency) and Leonardo Barreto (Paul Scherrer Institute). All statements used from the interviews were authorized by the interviewees and are published in Girod (2006).

2.2. Evaluation of changes

We assessed how the analyzed changes score against the criteria of saliency, credibility and legitimacy (Cash et al., 2003; Hulme and Dessai, 2008; Siebenhüner, 2003). Saliency refers to the relevance and comprehensibility of the scenarios for political decision-makers and other scenario users (including scientists). Credibility is concerned with the scientific adequacy of the technical component of the scenarios spelt out in