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Depletion of fossil fuels and anthropogenic climate change—A review

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HIGHLIGHTS

- Review of the development of emission scenarios.
- Survey of future fossil fuel trajectories used by the IPCC emission scenarios.
- Discussions on energy transitions in the light of oil depletion.
- Review of earlier studies of future climate change and fossil fuel limitations.

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ABSTRACT

Future scenarios with significant anthropogenic climate change also display large increases in world production of fossil fuels, the principal CO_2 emission source. Meanwhile, fossil fuel depletion has also been identified as a future challenge. This chapter reviews the connection between these two issues and concludes that limits to availability of fossil fuels will set a limit for mankind's ability to affect the climate. However, this limit is unclear as various studies have reached quite different conclusions regarding future atmospheric CO_2 concentrations caused by fossil fuel limitations.

It is concluded that the current set of emission scenarios used by the IPCC and others is perforated by optimistic expectations on future fossil fuel production that are improbable or even unrealistic. The current situation, where climate models largely rely on emission scenarios detached from the reality of supply and its inherent problems are problematic. In fact, it may even mislead planners and politicians into making decisions that mitigate one problem but make the other one worse. It is important to understand that the fossil energy problem and the anthropogenic climate change problem are tightly connected and need to be treated as two interwoven challenges necessitating a holistic solution.

1. Introduction

Mankind's energy production is the principal contributor to mankind's release of greenhouse gases (GHG), in particular CO_2, to the atmosphere with fossil fuel combustion as the key factor. As a result, anthropogenic GHG emissions and human-induced global warming are fundamentally linked to future energy production. Projections of how the global energy system will develop over the next century are cornerstones in the assessment of future climate change caused by mankind.

The Intergovernmental Panel on Climate Change (IPCC) and many others use climate models that rely on various emission scenarios to depict possible trajectories for future fossil fuel production and their correlating release of CO_2. The Special Report on Emission Scenarios (SRES) (the current set of emission scenarios) was published by the IPCC in 2000 and remains an integral part of climate change modeling, as it has been used by the last IPCC reports (IPCC, 2001, 2007).

As of 2010, world oil production remains around 85 million barrels per day (Mb/d) or 3900 million tons of oil equivalents (Mtoe) annually, with coal and natural gas at 3700 corresponding to 2900 Mtoe per year (BP, 2012). Some scenarios foresee a tenfold increase in world gas production, while others depict future oil production to reach 300 Mb/d by 2100. For example, 16 of the 40 coal scenarios contained in SRES simply grow exponentially until the year 2100 (Patzek and Croft, 2010). Emission scenarios also contain assumptions about future prices, technological developments and many other details related to fossil energy exploitation.

This article reviews the emission scenarios witnessed throughout history, their underlying assumptions on resource availability and future production expectations. Future scenarios with high emissions of CO_2 also display significant increases in world production of oil, natural gas and coal. Can such assumptions

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Table 1
Model names in SRES and developing team behind them.

Abbreviation	Full name	Origin
AIM	Asian Pacific Integrated Model	National Institute of Environmental Studies (NIES), Japan
ASF	Atmospheric Stabilization Framework Model	ICF Consulting, USA
IMAGE	Integrated Model to Assess the Greenhouse Effect	National Institute for Public Health and Hygiene (RIVM), Netherlands
MARIA	Multiregional Approach for Resource and Industry Allocation	Science University of Tokyo, Japan
MESSAGE	Model of Energy Supply Strategy Alternatives and their General Environmental Impact	International Institute of Applied Systems Analysis (IIASA), Austria
MINICAM	The Mini Climate Assessment Model	Pacific Northwest National Laboratory (PNNL), USA

remain justified in the light of the growing body of evidence suggesting that depletion of the world fossil energy resources, primarily oil, is a growing problem? In addition, published critique raised against the fossil fuel projections used by the IPCC is reviewed. Finally, this study compiles recent studies on how fossil fuel constraints may impact anthropogenic climate changes.

1.1. Historical background to anthropogenic climate change

The Swedish Nobel prize laureate Arrhenius (1896) was among the first to theorize about the impact of CO_2 on the earth's climate. However, these ideas were initially met with criticism and fell into obscurity until around the 1950s. Growing concern about mankind's increasing impact on the environment and refined analytical methods revitalized the issue of greenhouse gases after the 1950s. Separate threads of research were pursued by isolated groups of scientists, although an increasing number of studies pointed towards a connection between global warming and anthropogenic emissions of greenhouse gases (Peterson et al., 2008). Mainstream media and politicians largely ignored these results and only expressed concern over these findings much later.

In the 1980s, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) began to investigate the role of carbon dioxide and other emissions. Their interest leads to the establishment of the IPCC in 1988. This new organization became responsible for assessing scientific, technical and socio-economic information relevant for understanding mankind's role in climate change. Their synthesized results have been published in several assessments and special reports over the years (IPCC, 1990, 1995, 2001, 2007). However, these findings are also largely dependent upon a set of assumed trajectories for future fossil fuel production and related emissions.

Various future pathways for society, its energy system and the associated release of greenhouse gases are a cornerstone in the estimation of future climate change. Such outlooks are commonly referred to as emission scenarios and are being used as input into climate models that transform the projected emissions into climatic changes. The IPCC has used a number of emission scenarios throughout its work. The first set was published in 1990, followed by subsequent publications in 1992 and the latest version from 2000. Titles, methods, classifications, assumptions have all changed over time and Girod et al. (2009) reviewed this in more detail.

The 1995 IPCC review of the old emission scenarios recommended that the full range of scenarios should be used as an input rather than just a single scenario. The conclusion was that there was no objective basis on which to assign likelihood to any of the scenarios (SRES, 2000). Meanwhile, a number of other weaknesses were also identified, such as the limited range of carbon intensities, the absence of a scenario with economic closure in the income gap between industrial and developing countries (SRES, 2000), or how the rapid growth in sulfur emissions did not reflect regional and local air quality concerns that might prompt limits on the future release of sulfur into the atmosphere (Grübler, 1998).

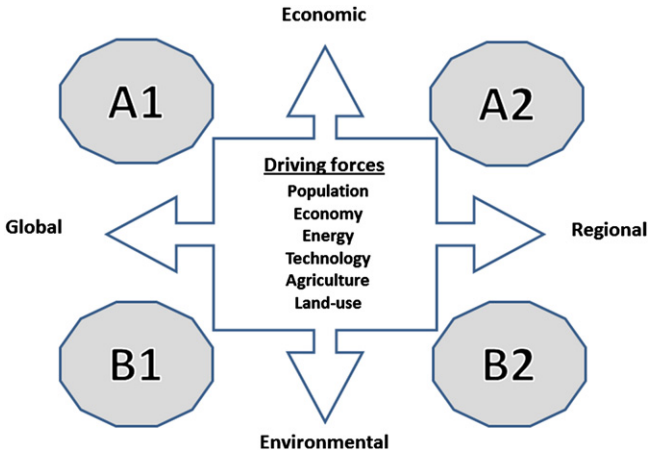

Fig. 1. Schematic illustration of the SRES scenarios with their driving forces and main orientations.

In addition, it was found that all scenarios from 1992 exaggerated recent trends for climate and economic development, leading to correspondingly exaggerated atmospheric GHG concentrations (Gray, 1998). In 1996, the IPCC chose to develop new scenarios and initiated the painstaking process of developing a new set for utilization in future climate change assessments (Nakićenović et al., 1998). This resulted in the current emission scenario set – often known as the Special Report on Emission Scenarios (SRES) – being published in 2000. This report forms the foundation of most recent long-term climate change projections, including those of the Fourth Assessment Report (IPCC, 2007).

1.2. The special report on emission scenarios

The SRES writing teams outlined four different narratives to be used as storylines for the future. Six modeling teams (Table 1) generated quantifications of the narratives that laid the foundation of the 40 different scenarios contained in SRES. The scenarios can be divided into four families, each exploring different variants of global and regional development and their implications for global greenhouse gas emission. SRES storyline titles are simply named A1, A2, B1, and B2. They are characterized by global-regional focus and economic–environmental orientation and can be placed in a two-dimensional figure (Fig. 1). No scenario should be considered as a "*business-as-usual*", even though the A1 family is often used as an example of how continued global focus on economic growth might evolve. It is also imperative to emphasize that none of the scenarios contain additional climate initiatives such as GHG reduction schemes or adaptations to the expected climate change. No disaster scenarios were considered and possible surprises, such as new world wars or economic downturns, were also disregarded.