CLIMATE CHANGE DRIVING FORCES

NUCLEAR ENERGY & THE LATEST IPCC EMISSION SCENARIOS

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How the world will develop over the next 100 years is riddled with uncertainties. Yet analysts can assess alternative developmental paths and diverse sets of driving forces to gain an image of the future -- in fact a number of images, depending on assumptions they use.

Over the past decades, the scientific and research community has devoted considerable attention to studying issues of climate change, and to modeling its possible future development, impact and ways to mitigate potential effects. The studies are complex, involving assessments of social, economic, and technological developments in diverse fields.

In early 2000, the Intergovernmental Panel on Climate Change (IPCC) approved a *Special Report on Emission Scenarios (SRES)* for the period through 2100. It contains 40 scenarios, prepared with six computer models, for the world and its main regions, and focuses largely on the main greenhouse gases (GHGs) and sulphur dioxide. The scenarios are designed to provide a basis for assessments of climate change and its impact. *(See boxes, pages 32 and 33.)*

The new scenarios are "non-intervention" ones with regard to climate change -- that is, they exclude measures to reduce greenhouse gas emissions. However, policies with respect to other environmental factors are included; this includes, for example, progress in sulphur abatement technologies in developing countries, which results in lower global sulphur dioxide emissions than in previous IPCC assessments.

This article briefly reviews the latest IPCC emission scenarios and looks closely at the projected role of nuclear energy, which can provide a valuable long-term perspective for nuclear development. This perspective is especially useful since the possible "nuclear futures" were modelled in the scenarios without taking into account considerations specifically related to climate change. Rather, the scenarios focused on technical and economic competition among energy supply options as the key driving force for determining the fuel mix in the energy system.

BASIC FEATURES OF THE SCENARIOS

The 40 SRES scenarios are structured into four groups (called "scenario families"): A1 (17 scenarios); A2 (6 scenarios); B1(9 scenarios); and B2 (8 scenarios). Each scenario family was built on a set of qualitative guidelines (called "storylines"). One representative scenario (called the "marker scenario" or the "marker") was selected as illustrative for every storyline. This does not imply, however, that it has a higher probability than the other scenarios. (*See box, page 32.)*

NUCLEAR SHARES & THE ENERGY MIX

The SRES uses a dynamic approach to energy resources and technologies -- in other words, advances in technologies provide more opportunities for the expansion of the resource base.

The primary energy mix for the four marker scenarios shows the following:

- There is a substantial increase in primary energy by 2100 -- from 40% in B1 up to a six-fold increase in A1;
- All scenarios show a significant decrease in the share of fossil fuels;
- The combined share of renewables and nuclear energy increases two- to- threefold by 2100;

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THE IPCC EMISSION SCENARIOS

A decade ago, the Intergovernmental Panel on Climate Change (IPCC) -- established by the World Meteorological Organization and the United Nations Environment Programme -- developed its first long-term emission scenarios for use in analyzing the complex issue of climate change. In early 2000, the IPCC issued a new set of scenarios that reflect the latest scientific understanding and knowledge. As described in a *Summary for Policymakers*, the scenarios are open to various interpretations and are based on extensive assessments of published studies and developments.

Future greenhouse gas emissions are the product of very complex dynamic systems, determined by driving forces such as demographic development, socio-economic development, and technological change. Their future evolution is highly uncertain, and the scenarios present alternative images of how the future might unfold. As such, they are an appropriate tool with which to analyze how driving forces may influence future emission outcomes and to assess the associated uncertainties. They assist in climate change analysis, including climate modeling and the assessment of impacts, adaptation, and mitigation.

The latest IPCC scenarios cover a wide range of the main driving forces of greenhouse gas and sulphur emissions. Each scenario represents a specific quantitative interpretation of one of four storylines. Each storyline assumes a distinctly different direction for future demographic, social, economic, technological, and environmental developments. All the scenarios based on the same storyline constitute a scenario "family".

Altogether 40 scenarios were developed using a multi-model approach. Thirteen of these explore variations in energy technology assumptions. None of the 40 scenarios explicitly assume implementation of the United Nations Framework Convention on Climate Change, or the emissions targets of the Kyoto Protocol. However, the influence on greenhouse gas emissions of non-climate change policies is broadly reflected in the storylines and scenarios.

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three groups are distinguished by their technological emphasis: fossil intensive, non-fossil energy sources, or a balance across all sources.

Credit: C.Sherburne/PhotoLink

- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.
- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than in the A2 storyline, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

More information about the IPCC and the emission scenarios is accessible over the Internet on the IPCC Web pages at http://www.ipcc.ch.

MAIN CHARACTERISTICS OF THE IPCC "MARKER" STORYLINES & SCENARIO FAMILIES

Scenario family	Family storyline	World population (billions)			GDP per capita (thousands of US $ 1990)			Primary Energy (Gigajoules per capita)			CO_2 (Gigatonnes carbon) (annual/cumulative)			Primary Energy Source	Shares of Primary Energy		
		1990	*2050*	*2100*	*1990*	*2050*	*2100*	*1990*	*2050*	*2100*	*1990*	*2050*	*2100*		*1996*	*2050*	*2100*
A1	High economic growth, low population growth, rapid introduction of new technologies; convergence to a "homogeneous world" with a closure of regional differences	5.3	8.7	7.1	4.0	20.8	74.9	66	138	295	7.1 -- -	16.4 -- 738	13.5 -- 1499	Fossil fuels	83.4%	59.9%	30.7%
														Renewables*	14.3%	29.9%	65.5%
														Nuclear (1)**	2.3%	10.2%	3.7%
														Nuclear (2)	*6.5%*	*25.6%*	*10.5%*
														Nuclear, GWe***	351	~5600	~3500
A2	Development into a "heterogeneous world": fertility patters are not converging, population growth is high, economic development remains regionally fragmented	5.3	11.3	15.1	3.8	7.2	16.1	59	86	114	7.1 -- -	17.4 -- 736	29.1 -- 1862	Fossil fuels	83.4%	82.0%	71.9%
														Renewables	14.3%	11.6%	14.4%
														Nuclear (1)	2.3%	6.4%	13.6%
														Nuclear (2)	*6.5%*	*17.1%*	*32.4%*
														Nuclear, GWe	351	~2800	~10600
B1	A "homogeneous world" as in A1, but with economy "dematerialization" (dominance of services and information); emphasis on global sustainability is modelled	5.3	8.7	7.0	4.0	15.6	46.6	70	93	73	7.1 -- -	11.3 -- 606	4.2 -- 983	Fossil fuels	83.4%	69.8%	47.7%
														Nuclear+ Renewables	16.6%	30.2%	52.3%
														Nuclear, GWe	351	not estimated	
B2	A "heterogeneous world" as in A2, but with more attention to sustainability; relevant solutions are sought but, in contrast with B1, regionally	5.3	9.4	10.4	4.0	11.7	22.6	67	93	130	7.1 -- -	11.0 -- 562	13.3 -- 1164	Fossil fuels	83.4%	70.2%	50.7%
														Renewables	14.3%	24.4%	38.8%
														Nuclear (1)	2.3%	5.5%	10.5%
														Nuclear (2)	*6.5%*	*14.9%*	*26.1%*
														Nuclear, GWe	351	~2200	~6400

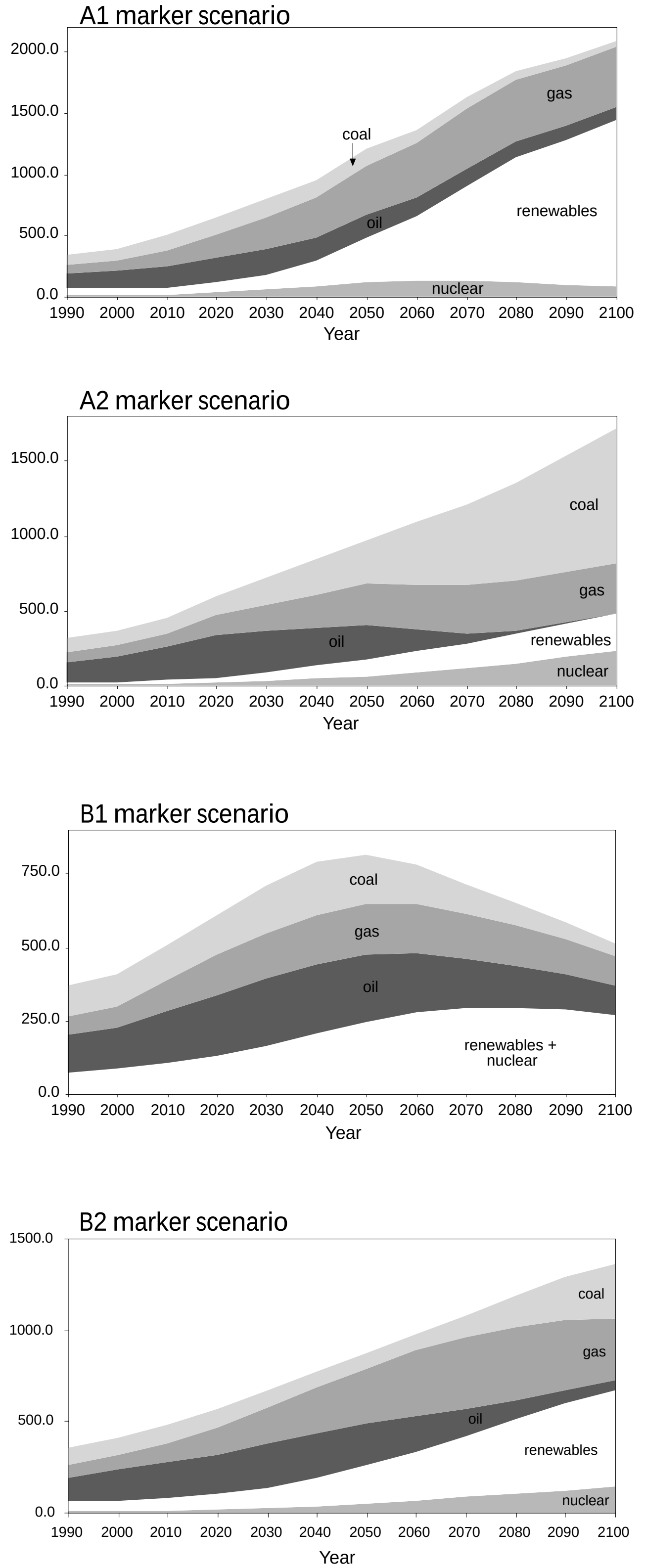
*Renewables include hydro, solar, wind, geothermal, and biomass energy.

**Two data sets -- shown as nuclear (1) and nuclear (2) -- reflect differences in the approach to calculations. Nuclear (1) reflects the SRES recalculation of nuclear's share of primary energy suppy. SRES recalculated nuclear electricity into primary energy by unit conversion from terawatt-hours to exa-joules. This leads to nuclear shares of about 2% in 1996, which differs from the more usual number of 7% obtained by accounting for the thermal efficiency of nuclear plants. Nuclear (2) follows the approach used by the International Energy Agency of the Organization for Economic Cooperation and Development and is shown in italics to reflect the differences.

***Capacity is estimated from the SRES results in primary energy as E (energy in EJ) 31.71 (unit conversion to GW per annum) /0.7 (assumed average capacity factor).

STRUCTURE OF ENERGY SUPPLY IN THE IPCC MARKER SCENARIOS

(EXA-JOULES)



■ Within the growing group of non-fossil energy, there is a varying nuclear share. Nuclear's present 6% to 7% of primary energy could reach to between 10% to 30% by 2100. This would be equivalent to a total nuclear capacity of 3500 to 10,600 Gigawatts-electric (GWe).

In assessing this projected picture, it is important to recall that the scenarios were built on different assumptions for technical and economic developments. This has led to the following consequences:

■ In the A1 marker scenario, renewables outpace both fossil fuels and nuclear energy in economic performance. Although the nuclear share significantly grows until 2050, this factor leads to its subsequent decline from the maximum of about 5500 GWe in 2050 to 3500 GWe in 2100.

■ The A2 marker scenario assumes the fastest progress in coal technologies, with the penetration of renewables seen as more gradual. Nuclear energy remains competitive and its capacity increases up to 10,600 GWe.

■ In the B1 marker scenario, the share of non-fossil energy reaches about 50% in 2100. Separate shares of nuclear energy and renewables were not calculated for this marker. The range of possibilities is illustrated through two extreme "non-marker" cases from the B1 family. In these scenarios, the nuclear shares in 2100 are 340 GWe and 4200 GWe, respectively, which proves that the nuclear future can widely differ depending on factors of competitiveness against renewables.

■ In the B2 marker scenario, nuclear capacities increase to 6400 GWe in 2100. This reflects projected slower progress in renewables and a regional pattern of development that sustains nuclear energy where it has proved to be viable.

REGIONAL DIMENSIONS OF THE SCENARIOS

The SRES presents a regional breakdown for four world regions. They are designated as OECD90 (all members of the Organization for Economic Cooperation and Development in 1990), REF (countries of Central and Eastern European plus the Newly Independent States of the former Soviet Union), ASIA (all developing countries in Asia), and ALM (the rest of the world).

The scenarios illustrate that nuclear development can vary regionally as well as globally. For example, the projected nuclear capacity in 2100 for OECD90 in the A1 and A2 scenarios is 680 GWe and 3300 GWe, respectively; in ASIA, the corresponding projections are 1400 GWe and 4100 GWe.

This indicates a significant shift of nuclear development from OECD90 to ASIA and, to a lesser extent, ALM. For example, already by 2050, both the A1 and A2 scenarios project higher nuclear capacities in ASIA than in OECD90.

SUMMING UP THE PICTURES

In summary, the new IPCC emission scenarios show the following ranges of development for nuclear energy:

■ Most scenarios assume that nuclear energy would retain its important role in the world energy supply. In 2100, the projected global nuclear capacity for three of the four representative scenarios varies between 3500 GWe and 10, 600 GWe, depending on how successfully nuclear energy competes with fossil fuels and renewables. This can be compared with some 350 GWe of nuclear capacity today.

■ At the same time, some scenarios show that rapid improvements in renewable energy options (relative to nuclear technologies) may lead to nuclear stagnation or decline.

Under one such scenario, the total nuclear capacity increases to a peak of 5500 GWe at mid-century but then declines to 3500 GWe by 2100. Some other scenarios indicate the stagnation of nuclear capacities at the present level. Thus, the SRES confirms that the long-term role of nuclear energy is highly uncertain, in particular because of the uncertainty in the expected competitiveness of different energy technologies.

■ Regionally, countries in Asia are expected to increase significantly their use of nuclear energy; the nuclear growth rates in the other regions are lower. In contrast with the present situation, by 2050 there may be more nuclear capacity in Asia than in the OECD countries.

■ Reaching higher nuclear shares of electricity generation would necessitate significant technological development for nuclear plants to remain competitive with the best alternative technologies. Extensive growth would impose more stringent requirements on the efficiency of uranium utilization in reactors as well as on the methods of waste management.

In most of the scenarios, the SRES assumes significant (and varying by scenario) improvements in nuclear technologies as compared with existing designs. However, as similar to the non-nuclear technologies in the SRES, these changes were introduced generically as assumed cost reductions while specific design solutions were not considered. The availability of such solutions would be highly important, as would a positive social attitude to nuclear energy (which was not explicitly analyzed in the SRES).

■ The terms of reference for the SRES mandated the exclusion of greenhouse gas mitigation policies in SRES scenarios. Such policies, if implemented, may have an additional positive impact on non-fossil energy options, including nuclear energy.

Overall, the IPCC study shows that the future development of nuclear energy does not necessarily depend upon considerations of climate change, and that the nuclear option is seen to remain a notable part of the energy mix irrespective of greenhouse gas mitigation policies. These are important messages of a thorough long-term study covering the period through the end of the 21st century. ❐