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Subject: new IPCC-SRES Zero Order Draft
Date: Tue, 10 Mar 1998 13:20:19 +0100

Dear Colleagues:

I am sending you a copy of Ged Davis' IPCC-SRES Zero Order Draft on storylines and scenarios. The text is appended below, but I am also attaching versions in MS Word and in Rich Text formats so that you can better view the graphics.

Please send any comments directly to Ged Davis at

Ged.R.Davis@si.simis.co

Regards,

Anne Johnson

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Zero Order Draft

IS99
Storylines and Scenarios

February, 1998

Ged Davis et al

For Comment Only
Draft Paper for the IPCC Special Report on Emissions Scenarios

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Contents

1. Introduction

The IS99 scenarios have been constructed to explore future developments in the global environment with special reference to the production of GHGs. These scenarios are being developed in three phases:
- Phase 1: the Special Report on Emissions Scenarios (SRES) team is preparing a set of scenarios for wide public discussion, which is the subject of this note,
- Phase 2: the scenarios will be placed on the World Wide Web, subject to public scrutiny, and suggestions for relevant modification of the scenarios will be sought,
- Phase 3: the scenarios will be finalised for peer review, incorporating suggestions received during the public review, by April 1999.
Phase 1 centred on a facilitated open process for Lead Authors at workshops in Paris, Vienna and Utrecht. The scenarios developed allow for a broad range of GHG emissions and provide a basis for reflection on policy.

1.1 What are scenarios?
Scenarios are pertinent, plausible, alternative futures. Their pertinence, in this case, is derived from the need for climate change modelers to have a basis for assessing the implications of future possible paths for Greenhouse Gas Emissions (GHGs). Their plausibility is tested by peer review, in an open process, which includes their publication on the World Wide Web.

There are clearly an infinite number of possible alternative futures to explore. We have consciously applied the principle of Occam's Razor , seeking the minimum number of scenarios to provide an adequate basis for climate modelling and challenge to policy makers. The alternative futures constructed are not, and cannot be, value free since like any work they self-evidently reflect the team's view of the possible. The scenarios should not be construed as being desirable or undesirable in their own right and have been built as descriptions of possible, rather than preferred, developments. There can be no objective assessment of the probability of the scenarios, although in the prevailing zeitgeist some will appear to individuals to be more likely than others. Scenarios are built to clarify ignorance rather than present knowledge -- the one thing we can be sure of is that the future will be very different from any of those we describe!

2. Scenarios - overview

2.1 Scenarios: key questions and dimensions
Developing scenarios for a period of one hundred years is a relatively new field. Within that period we might expect two major technological discontinuities, a major shift in societal values and a change in the balance of geopolitical power. A particular difficulty is that people are not trained to think in these time-spans, are educated in narrow disciplines and our ability to model large-systems, at the global level, is still in its infancy. Additionally, most databases do not go back much further than 50 years and many less than that. How best to integrate demography, politico-economic, societal and technological knowledge with our understanding of ecological systems? Scenarios can be used as an integration tool, allowing an equal role for intuition, analysis and synthesis.

Terminology
Storylines, Scenarios and Scenario Families

Storyline: a narrative description of a scenario (or a family of

scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of the scenarios.

Scenario: projections of a potential future, based on a clear logic and a quantified storyline.

Scenario family: one or more scenarios which have the same demographic, politico-societal, economic and technological storyline.

Scenario Classification

Our approach has been to develop a set of four "scenario families". The storylines of each of these scenario families describes a demographic, politico-economic, societal and technological future. Within each family one or more scenarios explore global energy industry and other developments and their implications for Greenhouse Gas Emissions and other pollutants. These are a starting point for climate impact modelling.

The scenarios we have built explore two main questions for the 21st century, neither of which we know the answer to:
- Can adequate governance -- institutions and agreements -- be put in place to manage global problems?
- Will society's values focus more on enhancing material wealth or be more broadly balanced, incorporating environmental health and social well-being.
The way we answer these questions leads to four families of scenarios:
- Golden Economic Age (A1): a century of expanded economic prosperity with the emergence of global governance
- Sustainable Development (B1): in which global agreements and institutions, underpinned by a value shift, encourages the integration of ecological and economic goals
- Divided World (A2): difficulty in resolving global issues leads to a world of autarkic regions
- Regional Stewardship (B2): in the face of weak global governance there is a focus on managing regional/local ecological and equity

Within these scenario families we examine plausible energy industry and other developments which will contribute to GHG emissions. Although the storylines cannot have explicit climate change policy measures in them there are examples of indirect mitigation measures in some of the scenarios. The scenario quantifications of the main indicators related to growth of population and economy, the characteristics of the energy system and the associated greenhouse gas emissions all fall within the range of prior studies .

3. Golden Economic Age (A1)

This scenario family entitled "Golden Economic Age", describes rapid and successful economic development. The primary drivers for economic growth and development "catch up" are the strong human desire for prosperity, high human capital (education), innovation, technology diffusion, and free trade. The logic of successful development assumes smooth growth with no major political discontinuities or catastrophic events. The scenario family's development model is based on the most successful historical examples of economic growth, i.e., on the development path of the now affluent OECD economies. Historical analogies of successful economic "catching up" can be found in the Scandinavian countries, Austria, Japan, and South Korea. "Intangible" assets (human capital, stable political climate) take precedence over "tangible" assets (capital, resource, and technology availability) in providing the conditions for a take-off into accelerated rates of development. Once these conditions are met, free trade enables each region to access knowledge, technology, and capital to best deploy its respective comparative economic and human resource advantages. Institutional frameworks are able to successfully sustain economic growth and also to handle the inevitable volatility that rapid economic growth entails.

The "intangible" prerequisites for accelerated rates of economic growth also offer long-term development perspectives for regions that are poorly endowed with resources or where current economic prospects are not

auspicious, such as Sub-Saharan Africa. There, for instance, fostered regional trade and capital availability enhance the pull-effects of a strong South African economy. In other regions, growth may be fuelled by domestic know-how and high human capital valued at the international market. An example of this is the thriving software industry of the Indian subcontinent. In yet other regions, growth could be stimulated by the expansion of regional economic partnerships and free trade arrangements (e.g., extensions of NAFTA and the European Union).

The main difference with the historical OECD experience is a certain acceleration in time and space, (i.e., "leapfrogging") made possible by better access to knowledge and technology, a consequence of the high-tech and free trade characteristics of development. Successful catching up becomes pervasive; all parts of the "developing world" participate, though with differences in timing. The final outcome is that practically all parts of the world achieve high levels of affluence by the end of the 21st century, even if disparities will not have disappeared entirely. The current distinction between "developed" and "developing" countries will in any case no longer be appropriate.

As in the past, high growth (a "growing cake") eases distributional conflicts. Everyone reaps the benefits of rapid growth, rising incomes, improved access to services, and rising standards of living. The economic imperatives of markets, free trade, and technology diffusion (i.e., competition) that underlie the high growth rates provide for efficient allocation of resources. Efficiency and high productivity are the positive by-products of the highly competitive nature of the economy. They also provide the economic resources for distributive and social measures required for a stable social and political climate, vital for sustaining high growth rates in human capital, productivity, innovation, and hence economic growth.

The economic development focus explains its central metric: the degree of economic development as reflected in per capita income levels (GDP at market exchange rates as well as at purchasing power parity rates). The principal driver is the desire for prosperity, all major driving forces are closely linked to prosperity levels, with actual causality links going in both directions. For example, demographic variables co-evolve with prosperity: mortality declines (i.e. life expectancy increases) as a function of higher incomes (better diets and affordable medical treatment). In turn, changes in the social values underlying the fertility transition also pave the way for greater access to education, modernisation of economic structures, and market orientation. These are key for innovating and diffusing the best practice technologies underlying the high productivity, and hence economic growth, of the scenario.

3.1 Key Scenario Drivers and their Relationships

3.11 Population and Economic Development

High education, stable social relations, and incentives for innovation and experimentation are the preconditions for productivity increases underlying rapid economic development in this world-- as a result, social, economic, and demographic development are highly correlated .

The link between demographic and economic variables in the scenario corresponds to present empirical observations: the affluent live long and have few children. High per capita incomes are thus associated with both low mortality and low fertility. Together, this results in rather low population growth, characterised in addition by a considerable "greying" of the population.

This family of scenarios combines high life expectancy with low fertility, where OECD rates are assumed to stabilize at current (below replacement) levels, and developing countries follow a similar transition by the mid-21st century. Fertility rates range between 1.3 to 1.7 children per woman. Life expectancy can approach some 95 years, with a regional variation between 80 and 95 years. Global population grows to some 9 billion by 2050, and declines to 7 billion by 2100, the result of continued below replacement fertility in all regions.

Population ageing results in economic growth rates somewhat lower than historical experience, especially in the OECD countries. Economic growth rates slow over time in proportion to the reduction of the potentially

economic active population (age 15 to 65), which decline in some regions to 50 percent compared to the historical average of approximately 70 percent.

For "developing countries", economic growth is based on the most successful cases of economic "catch up" found in history. The economic growth profile of Japan after WW II served as a model to delineate the upper bounds of possible GDP growth for all regions. Consistent with growth theory, GDP expansion initially accelerates, passes through a peak, in which growth rates around 10 percent per year can be sustained for several decades, and then declines. Once the economic and industrial base is firmly established and the economy matures, growth rates decline with increasing income levels. This reflects saturation effects and a higher emphasis on quality rather than quantity at high income levels.

The global economy in the "Golden Economic Age" expands at an average annual rate of three percent per year to 2100. This is about the same rate as the global average since 1850 and in this respect may simply be considered "dynamics as usual". Non-Annex-I economies expand with an average annual growth rate of four percent per year, twice the rate of Annex-I economies. By approximately 2030 Non-Annex-I GDP surpasses that of the Annex-I economies. Per capita income disparities are reduced, but differences between regions are not entirely eliminated. Non-Annex-I per capita income reaches the 1990 Annex-I level (14,000 $/capita) by around 2040. By 2100 per capita income would approach 100,000 $/capita in Annex-I countries and 70,000 $/capita in Non-Annex-I countries.

3.12 Equity

Equity issues are not a major concern in the world, but is rather a by-product of the high rates of economic development. Existing per capita income gaps between regions close up in a similar way as between Western Europe and Japan compared to the US in the 20th century. Disparities continue to persist between regions, but more so within particular regions. Nevertheless, the high economic growth rates require a certain degree of income distribution. Extreme income disparities are found to be negative influencing factors for economic growth. Additionally, fair income distribution only assures the large consumer markets and the social cohesion and stability required for the realisation of high economic growth.

3.13 Settlement patterns/communication

Communication technologies and styles are highly homogeneous and extremely developed -- rather than a "global village" future, this is one of "global cities." Existing trends towards urbanisation continue, as cities provide the highest "network externalities" for the educational and R&D-intensive economic development pattern underlying the scenario. Regional differences in settlement patterns persist. They range from fragmented, compact, but large (i.e., 20+ million inhabitants) cities that depopulate their respective rural hinterlands in Latin America to urban "corridors" connected by high capacity communication and transport networks (in Asia). Regional transport networks include high speed trains and maglevs, which ultimately fuse short- and long-distance transport means into single interconnected infrastructures. In some parts of the world high-tech cars take the place that high-tech trains occupy in other parts.

The large urban agglomerates and the high transport demands of a high material growth economy generate vast congestion constraints. These are solved by applying market-based instruments (prices) rather than regulation. Economic instruments include access and parking fees, auctioning off the limited number of new car and truck licenses in megacities, much along the lines of the current stringent Singapore model. Therefore, even at very high income levels, car ownership rates could be comparatively low in parts of the world. In extremely densely populated areas, cars remain a luxury rather than a means of mass transport (viz. Hong Kong). In areas with lower population density, car densities are high (+1 car per inhabitant). Car fuels could be either oil, synfuels, electricity, or hydrogen. Intercontinental transport is provided by energy- and GHG-intensive hypersonic aircraft fuelled by methane or hydrogen. They are the physical transport equivalent of the high capacity virtual communication links of a truly global economy.

3.14 Environmental Concerns/Ecological resilience

Ecological resilience is assumed to be high. In and of themselves,

ecological concerns receive a low priority. Instead, the valuation of environmental amenities is strictly in economic terms, e.g., a function of affluence. Non-congestion, clean water and air, and recreational possibilities in nature all assume increasing importance with rising affluence, although preferences for environmental amenities may differ across regions and income levels. For instance, urban air quality and human health are valued highly even at income levels lower than those prevailing in England, where stringent air quality measures were introduced after the "killer smog" of 1952. Reduced particulate and sulphur air pollution become a matter of major consumer preference at levels of $2,000 - 3,000/capita income in Asia. Altogether, the concept of environmental quality changes from "conservation" of nature to active "management" --and marketing-- of natural and environmental amenities and services.

3.2 Scenarios

The core bifurcation (with respect to GHG emissions) of the scenario family unfolds around alternative paths of technology development in the agriculture and energy sectors. In the energy sector, the central question is how to manage the transition away from the current reliance on conventional oil and gas. In the agricultural sector, the key issue concerns land productivity.

Alternative technology bifurcations lead to a number of scenarios embedded and consistent within the overall theme of "prosperity via high techologies". All scenarios provide the high quantities of clean and convenient energy forms and diverse, high quality food demanded in an affluent world. Because technological change is cumulative, it can go in alternative, mutually exclusive directions, i.e., changes become "path dependent". Alternative directions unfold around the interrelated cluster of variables of resource availability and conversion technologies in both energy and agriculture. For instance, new technologies may enable humanity to tap either the vast quantities of fossil resources existing in the form of coal, unconventional oil, and gas with technologies that are both highly economic, efficient, and clean in terms of traditional pollutants, such as particulates or sulphur. Alternatively, technological change could unfold favouring non-fossil technologies and resources, such as nuclear and renewables.

A similar bifurcation unfolds in the agricultural sector. In one sub-scenario, only incremental improvements are achieved in farming practices and land productivity. This is combined with a gradual global diffusion of meat-based diets. Both of these trends are land- (and deforestation-) intensive. Alternatively, global agriculture could move in the direction of genetically engineered, high productivity crops and "sea-farming," combined with a quality- and health-oriented diet based on fish and vegetables, both of which are relatively less land intensive. As a result, GHG emissions range widely even for otherwise similar scenario characteristics.

3.21 Energy Resources/Technology

Resource availability and technology are tightly interrelated. The "Golden Economic Age" of high productivity growth results from substantial technological innovation. Both contribute to economic growth, expansion of accessible resources, and improved efficiency in resource use. Factor productivity improvements occur across the board for agricultural land, materials, and energy. Improvement rates largely follow long-term historical trends and are entirely technology- and income- driven. Energy intensity (total commercial and traditional primary energy use per unit of GDP) improves at an aggregate global rate of 1.5 percent per year. Improvement rates vary across regions as a function of distance from the productivity frontier and the turnover rates of capital stock. Ceteris paribus, improvement rates are higher in regions with currently lower efficiency and greater than average GDP growth. This assumes no particular policy intervention or additional price regulation apart from the ones consistent with a free market environment (i.e. price subsidies are removed, and full costing principles are established).

Per capita final energy use gradually converges as income gaps close. Final energy use per capita in non-Annex-I countries would reach approximately 85 GJ (2 tons of oil equivalent) by 2050 and approximately 125 GJ (3 toe) by 2100, i.e., about the current average of OECD countries

outside North America. Despite improvements in productivity and efficiency, the high income levels lead to resource use close to the upper bounds of the scenarios available in the literature. For instance, global final energy use would increase to approximately 1000 EJ by 2100.

The scenarios developed are a function of the different directions taken by technological change. The key question is which primary resources may become economically accessible in the future, and which technologies will become available to convert these primary resources into the final goods and services demanded by consumers. In the energy area, resources/technologies are key variables in determining the timing and nature of the transition away from currently dominant conventional oil and gas.
Four pathways are possible:
1. Progress across all resources and technologies.
2. "Clean coal" technologies: environmentally friendly except for GHG emissions and possible resource extraction impacts.
3. "Oil/Gas": smooth transition from conventional to unconventional oil and gas, tapping the vast occurrences of unconventional fossil fuels, including methane clathrates.
4. "Bio-Nuclear": rapid technological progress in non-fossil supply and end-use technologies, e.g. renewables, such as solar and biomass combustion, nuclear and hydrogen-fuelled end-use devices, such as fuel cells.

For the scenario quantification, a number of contrasting cases, characterised by the main energy form used in the second half of the 21st century, have been evaluated with the aid of formal energy models:
1. The dominance of Non-Fossil fuels -- the "Bio-Nuclear" scenario (A1R).
2. The dominance of unconventional gas, including hydrates, and oil (A1G)
3. The dominance of "Clean Coal" (A1C)

A brief scenario taxonomy is given below.

Scenario
Dominant
Oil/Gas Resource
Technology Improvements

	Fuel	Availability	Coal	Oil/Gas	Non-fossil
A1R	Non-fossil	Medium (<50 ZJ)	Low	Medium	High
A1G	Oil/Gas	High (>75 ZJ)	Low	High	Low
A1C	Coal	Low (<35 ZJ)	High	Low	Low

*
Depending on the assumed availability of oil and gas, (low/medium/high) and corresponding improvements in production and conversion technologies for coal, oil/gas, and non-fossil technologies, different energy systems structures unfold. For instance, in the dynamic technology cases, liquid fuels from coal or unconventional oil/gas resources would become available at less than $30 /barrel, with costs falling further by about one percent per year with exploitation of learning curve effects. Non-fossil electricity (photovoltaics, new nuclear) would become available at costs of less than 10 mills/kWh ($.01/kWh) and continue to improve further as a result of learning curve effects. The basic premise of the "dynamic technology" scenarios is that energy services could be delivered at long-run costs not higher than today, but with technologies having radically different characteristics, including environmental. In the event that such technology dynamics do not materialise, energy costs and prices would be significantly higher than suggested above -- illustrative model runs suggest energy demand would be up to 20 percent lower for a fossil scenario without significant cost improvements .

3.22 Agriculture
In the agricultural sector, two contrasting scenarios of land productivity could unfold, depending on the nature of advances in agricultural technologies. However, CO2 emissions from land use changes could range from 0.5 (low) to 1.5 (high) GtC by 2030 and from -1 to -2 (low) to zero (high) GtC emissions by 2100. In the latter case tropical forests essentially become depleted as a result of land-use conversions for agriculture and biomass fuel plantations. In the former case, land productivity gains are so substantial that ploughing of marginal

agricultural land is no longer economically feasible and is abandoned, following recent trends in the OECD. The resulting expansion of forest cover leads to a net sequestration of atmospheric CO2.

3.23 Scenario Quantification

An initial scenario quantification in terms of population, GDP, energy use, and CO2 emissions for the three energy resource/technology sub-scenarios is summarised in Appendix 1 . The global scenario for 2100 is also summarised in the form of a snowflake diagram. All scenario quantifications are tentative and subject to revisions.

[Figure: "Snowflake" for A1 scenarios]

3.24 CO2 Emissions

The diverging pathways of resource availability and technological change characteristic of the three scenarios examined result in a wide range of annual CO2 emissions: from 10 to 33 GtC by 2100. It is interesting to note that the emissions of the two "fossil fuel" sub-scenarios, "clean coal" and "oil and gas," are quite close to each other (33 CtC versus 29 GtC). Continued reliance on oil and gas, coupled with demand growth, explain the emission patterns for the oil/gas scenario. Coal is the only fossil resource available in the "clean coal" scenario. Therefore, over time coal is increasingly required for conversion into premium fuels such as synliquids and syngas. This conversion "deepening" leads to a feedstock premium for coal and increases the market potential of non-fossil fuels. CO2 emissions are therefore not as high as in traditional coal-intensive scenarios.

4. Sustainable Development (B1)

The central elements of this scenario family include high levels of environmental and social consciousness, successful governance including major social innovation, and reductions in income and social inequality. Successful forms of governance allow many problems which are currently hard or difficult to resolve to fall within the competency of government and other organisations. Solutions reflect a wide stakeholder dialogue leading to consent on international environmental and social agreements. This is coupled with bottom-up solutions to problems, which reflect wide success in getting broad-based support within communities.

The concerns over global sustainable development, expressed in a myriad of environmental and social issues, results in the eventual successful management of the interaction between human activities and the biosphere. While no explicit climate policy is undertaken, other kinds of initiatives lead to lower energy use, and clean energy systems, which significantly reduce greenhouse gas emissions. Besides cleaning up air quality, there is emphasis on improving the availability and quality of water.

4.1 Key Scenario Drivers and their Relationships

4.11 Technological Development

High levels of technological development focused on achieving sustainable development leads to high levels of material and energy saving, innovations in emissions control technology, as well as labour productivity. The latter is essential to support the rapid growth in personal income, given that a major increase in labour force participation is implicit in the equity assumptions. Technologies tend to be implemented in an industrial ecology mode, implying a much more highly integrated form of industrial production than at present. Information technology achieves a global spread, and is fully integrated into production technologies. Advances in international institutions permit the rapid diffusion of new technologies -- R&D approaches two percent of GDP.

4.12 Population and Economic Development

Population -- reaches only 9 billion by 2100 -- due to a faster than expected completion of the demographic transition arising from a large increase of women in the labour force, universal literacy, and concern for the environmental impacts of high population levels. The potential impacts of ageing populations which emerge from this low level of population growth are offset by relatively high levels of immigration, which reduce the negative impacts of ageing populations on savings and the ability of societies to adapt and implement new and cleaner technologies.

This world has a faster than expected transition from traditional to modern economic sectors throughout the developing world. In addition, widespread education leads to high labour productivity, and high labour force participation. Migration serves to sustain the size of the labour force in developed countries, which helps to maintain their growth in per capita income. Developing countries experience few institutional failures, enabling them to grow at or near the historical upper bounds of experience given their per capita incomes.

This yields a world of high levels of economic activity, with significant and deliberate progress being made with respect to international and national inequality of income. The current order of magnitude differences in income between developing and developed countries are reduced to a factor of two, with moderate growth continuing to occur in OECD countries. Gross World Product (GWP) reaches $350 trillion by 2100 and average global incomes $40,000 per capita. Economic development is balanced and, given the high environmental consciousness and institutional effectiveness, this leads to a better quality environment, with many of the aspects of rapid growth being anticipated and dealt with effectively. Active management of income distribution is undertaken through use of taxes and subsidies. The composition of final demand will evolve to a mix reflecting lower use of materials and energy, thus easing the impact of high income levels.

4.13 Equity

In this world there is a preparedness to address issues of social and political equity. The increases in equity, reflect a shift in values which, with widespread education, leads to greater opportunity for all. New social inventions, such as the Grameen Bank's micro-credit schemes, are a significant contributor to an increase in institutional effectiveness and equity improvement.

4.14 Communications, Settlement Patterns and Environment

The social innovations and effective governance rest on high levels of communication, both in a passive (i.e. TV) and active sense. Governance systems reflect high levels of consent from those affected by decisions, and this consent arises out of active participation in the governance process. Settlement patterns arise from design, and tend to reflect a distributed, compact, city design structure. This results in high amenity levels, and the careful design and location of these cities results in a lessening of the natural disasters which plague many cities today. Advanced hazard warning systems and careful design limit the impact of such disasters. Low emission technologies, and careful management of land use, preservation of large tracts of land, and active intervention to counteract the impacts of imprudent societal actions strengthen the resilience of the ecological system.

4.2 Scenarios

4.21 Energy Resources/Technology

Energy efficiency innovations, and successful institutional innovations disseminating their use, result in much lower levels of energy use relative to historic patterns. The forward-looking nature of societal planning results in relatively smooth transitions to alternative energy systems as conventional oil and gas resources dwindle in availability. There is major use of unconventional natural gas as fuel supply during the transition, but the major push is towards renewable resources such as solar and wind. The impact of environmental concerns is a significant factor in the planning for new energy systems.

Two alternative energy systems, leading to two sub-scenarios, are considered to provide this energy:

1. Widespread expansion of natural gas, with a growing role for renewable energy (scenario B1N). Oil and coal are of lesser importance, especially post-2050. This transition is faster in the developed than in the developing countries.
2. A more rapid development of renewables, replacing coal and oil; the bulk of the remaining energy coming from natural gas (scenario B1R).

4.22 Scenario Quantification

Per capita incomes in the developed world are close to ___ in 2100, while average per capita income in the developing world grows from ___ % of the

developed world in 1990 to ____ % in 2100. Energy per unit of output continues to fall at about historical rates in the developed countries, resulting in total energy use of ____ EJ in 2100. Rapid spread of technology from developed to developing countries enables an energy growth of ___ percent less than GDP, resulting in total energy use of ___ EJ in the developing part of the world

An initial quantification of the scenarios in terms of population, GDP, energy use, and CO2 emissions for the two energy resource/technology scenarios is summarised in Appendix 1. The global scenario for 2100 is also summarised in the form of a snowflake diagram. All scenario quantifications are tentative and subject to revisions.

[Figure: "Snowflake" for B1 scenarios]

4.23 CO2 Emissions

The range of carbon in CO2 emissions for the scenarios is 7.5 to 20 billion tons in 2100, reflecting 3 and 2 percent per year reductions in carbon per unit of GDP

5. Divided World (A2)

In a retreat from the globalising trends of the previous century, the world "consolidates" into a series of roughly continental economic regions. Regions pursue different economic strategies based on the resources and options available to them. Trade within economic regions increases, while trade between regions is controlled by tariff and non-tariff barriers to support the region's economic strategy. High income regions restrict immigration and impose selective controls on technology transfer to maintain high incomes for their residents.

High income regions encourage higher levels of education to increase the productivity of their labour force. They impose restrictions on immigrants, except skilled immigrants, to keep per capita incomes high. They also try to impose selective restrictions on technology transfer to maintain the productivity of their labour force.

Low income regions are only able to increase per capita incomes slowly. They do not have the resources to invest in educating the labour force or in research and development. Investment from other regions is constrained. Thus exports are primarily products manufactured with low cost labour and some natural resource-intensive products. Population growth is high relative to high income regions. Income inequality becomes more pronounced within low income regions and increases between regions.

Regions use non-tariff barriers, such as differences in standards and labelling requirements, to limit trade. Trade is also dampened by differences in tastes in products. These factors favour the use of resources found within each region. Regions that have abundant coal resources but very limited oil resources, for example, encourage use of "local" coal by heavy industries and electric utilities while allowing restricting free imports of crude oil and petroleum products .

5.1 Key Scenario Drivers and their Relationships

5.11 Population and Economic Development

Fertility rates vary among regions. North America, Northwest Europe and Asia experience falling fertility rates and populations. The Middle East, Africa, and to some extent, Southern Europe and South America see rising population although the rate of growth decreases. This leads to a shift in the world population balance from the Indian sub-continent and South East Asia to the Middle East and Africa by the end of the century. World population reaches 16 billion by 2100.

Regional economies emphasise self-sufficiency with wide variations in growth levels. Average global economic growth is relatively low at around 2.5%/year, leading to a GWP of $250 trillion by 2100. Trade across regions consists primarily of raw materials and semi-finished goods in a relatively low trust world where dependence on other regions is minimised.

5.12 Government and Geopolitics

National boundaries become less important within the regions as an increasing share of policy is agreed at the regional level. This allows considerable cultural diversity within regions. Governmental style is also

diverse across regions. In some, government and religion strengthen their links, in others, secular democracy is maintained or consolidated. Education is strengthened in most regions with a deepening understanding of cultural history and religion. The growing strength of the economic regions, and their competing economic interests, lead to reduced international co-operation. Global environmental, economic and social issues are subject to relatively weak governance. Conflicts between ethnic and religious groups within economic regions become less violent as a result of economic pressures on the parties. Where ethnic and religious violence persists, the groups are excluded from the economic region. Thus wars occur in the boundary zones between economic regions. Wars may also occur near regional boundaries for control of scarce natural resources.

5.13 Technology Developments

While underlying science is conducted in all regions an information about scientific developments are available world-wide, consumption and production patterns and hence, technology and practices, are determined by local circumstances.

Research activity increases in all regions; in high income regions due to the need to increase productivity with limited regional resources and in low income regions due to the growing size of the population. Restrictions on transfer of some technologies to other regions is widespread.

High income regions invest heavily in education to enhance labour productivity. Some high-income regions move towards broad-based education for a knowledge-based society. Others move towards practical education (lots of science and engineering) for an advanced industrial society. Low income regions are not able to invest as heavily in education, but the levels (and future rates of economic growth, vary significantly.

Technological change is rapid in some regions, slow in others, with industry adjusting to local resource endowments, cultural characteristics and education levels.

5.14 Communication and Settlement Patterns

Languages become more uniform within regions, but globally more diverse. Speakers of the main world languages are fairly evenly split. Computerised translation eliminates the language barrier to technology diffusion and economic development.

Urban concentration continues except in Europe and North America, which move towards larger numbers of smaller cities and towns. Urban shares of population in other countries rise to current OECD levels by 2020. While there is free movement within most regions, there is very little migration among regions. Refugee problems are confined to edge areas, for example, Baltics and Tibet.

5.15 Environmental Concerns

Environmental management follow pragmatic paths: with rising incomes, people become increasingly concerned first about urban pollution, then about regional pollution, finally about global problems. In this world, global environmental problems are discussed extensively but the will to tackle them is lacking. Propensity to worry about the environment is regionally variable. Sulphur emissions are rapidly reduced in South and South East Asia due to the impacts on agriculture but increase in Africa with exploitation of coal and minerals there.

5.2 Scenarios

Divided World is explored through a single scenario.

5.21 Resource Availability

Regions try to use their resource endowment for their economic advantage. Regions with abundant energy and mineral resources use those resources domestically and to produce exports (surplus to expected long-term needs). Regions poor in energy and mineral resources will minimise their dependence on these resources. High-income, resource-poor regions will develop as service-based, dematerialised economies, while low-income, resource-poor regions are forced to limit their consumption of resources.

High-income regions without indigenous oil and gas undergo a near-complete

conversion to an energy economy based on nuclear or renewable based electricity and synthetic gases and liquids by 2050. India and China adopt these technologies at the largely exhausting domestic coal reserves by 2050. Renewable input, zero waste industry is pioneered in South East Asia and adopted in Europe, minimising mineral and fossil fuel requirements by 2050. Oil and gas-rich regions (North Africa, the Middle East, Central Asia, Russia) continue to use fossil fuels but towards 2050 the falling cost of renewable technology (wind and biomass in Russia, photovoltaic in the other regions) begins to make them competitive even in these regions

5.22 Scenario Quantification

An initial quantification of the scenario in terms of population, GDP, energy use, and CO2 emissions is summarised in Appendix 1. The global scenario for 2100 is also summarised in the form of a snowflake diagram. All scenario quantifications are tentative and subject to revisions.
[Figure: "Snowflake" for A2 scenarios]

5.23 CO2 Emissions

The level of carbon in CO2 emissions for the scenario is 15 billion tons in 2100 as only oil and gas rich regions continue to use fossil fuels.

6. Regional Stewardship (B2)

"Regional Stewardship" is based on a natural evolution of the present institutional policies and structures. As such it does not incorporate major geopolitical power shifts or fundamental technological discontinuities. There is relatively low trust, global agreements are difficult to reach and the result is 'multiple islands' with inward looking policies.

This is a world of good intentions, which are not capable of being implemented. The late 20th century value shift towards environmental stewardship continues, for example as envisioned in the Cairo and Rio Programs of Action, with increasing recognition of the importance of human welfare and inequity. These concerns cannot be tackled at a global level and are resolved regionally or locally. Environmental solutions are tempered by the desire for balance with economic goals in many areas - but poor governance means that meeting the needs of the poor and future generations is hampered by limited prosperity.

Families think seriously about the fact that their offspring may be dealing with a more ecologically stressed world, moreover one with limited financial resources for dealing with such problems. Education levels are high so that the ability of families to internalise global concerns in their family planning decisions is also high. The relative stabilisation of world population growth after 2050 leads to general optimism about the ability of society to solve problems such as food and water supply.

6.1 Key Scenario Drivers and their Relationships

6.11 Population

Both local governance and environmental concerns limit population growth. The world largely supports efforts to reduce unwanted births both as a social service but also because there is an implicit belief that even increasing populations have severe environmental consequences. Education and welfare programs for the young and illiterate are widely pursued.

Population stabilises at 10.5 billion people by 2100. Since economic growth is relatively slow, fertility rates do not decline strongly. But, the effect of fertility rate declines on lowering population size outweigh those of mortality rate decreases increasing population size.

The stabilisation of global population (largely after 2050) leads to a new atmosphere for social planning. It becomes considerably easier than at present for education, health care and pension programs. Age cohort sizes are much more stable through time than at present, although of course, overall ageing continues.

6.12 Economic Development

GWP grows to around 240 trillion $ in 2100 with a North/South income ratio of approximately 7/1 (presently 13/1). Concerns about the ecological costs

of consumerist lifestyles receive wide attention and attempts are made, first in industrial countries, but later in developing countries, to seek satisfaction through community activities rather than high consumption. Overall people are eager to find alternatives to the high income world of materialism.

6.13 Governance

Governance is weak globally but strong nationally and regionally. Deliberate policies to limit trade for environmental and social reasons hinder the transfer of technologies. However pollution trading concepts catch on as a way of driving down the costs of pollution control. International alliances occur based on particular national circumstances, such as in the development of biomass technologies. This fragmentation gives rise to pockets of environmental and social justice activists. Environmental policies vary widely across regions, for example in acceptable sulphur emission levels. NGO and public interest groups are strong, influential and busy.

6.14 Equity

While strong redistribution policies are enacted within regions to reduce income disparity, income differences between regions persist globally throughout the century and even increases in absolute terms, although the relative inequity decreases. The mechanism by which global equity increases relates in part to population dynamics: as fertility rates decline in developing countries, the decrease in youth dependency ratios leads to an increase in savings rate and strengthened economic growth during the first half of the century. In the developed regions, by contrast, ageing becomes an increasing drag on economic growth in helping to converge global incomes, concerns about the persistence of income inequality world-wide are swamped by the local concerns and conscious policies to limit international trade.

6.15 Settlement Patterns

A strong deurbanization trend occurs in this world because of increasing concern about the marginalization of the very poor that accompanies massive urbanisation. There are also concerns about managing large transient populations that migrate seasonally to cities for short term employment, for example in the construction industry.

Immigration is controlled but accepted, partly to compensate for very low fertility rates in some regions and partly to help economic development worldwide without the problems of uncontrolled globalisation.

6.16 Environmental Policy

Environmental improvement is strongly pursued although regional policies vary widely such as with sulphur controls. Marked reductions in S, CH_4, deforestation, CFCs and N_2O occur and water quality is addressed. Ecological resilience is not seen as high. The environment is viewed as quite fragile and requiring careful policy stewardship. Resource extraction is viewed as intrinsically problematic and scepticism persists regarding the ability of society to prevent environmental disasters like the Valdez oil spill and Kuwaiti oil fires. Indeed the world is increasingly sensitive about and intolerant of such events and much tension exists concerning this aspect of development. Environment groups lobby hard on these themes and paint a picture of rapidly depleting natural resources.

6.2 Scenarios

6.21 Energy Resources/Technology

Because of the concern about ecological fragility, alternative and renewable energy systems are viewed with much hope and are socially and politically encouraged. Biomass technologies and policies are invigorated. The labour and land intensive developing countries pursue biomass production while the capital intensive developed regions develop the required technologies. A degree of co-operation coalesces about such mutually symbiotic activities.

Consumers accept a rather long return in evaluating energy-efficiency investments. Mass transit systems are very successful and profitable.

Advances in transportation technology are rapid.

Hydroelectric power is a constrained bag. Dams are viewed with disdain because there are soon no more wild rivers anywhere and the rights of indigenous people have been egregiously violated. Although they are relatively clean from the perspective of carbon emissions, their effects on indigenous people (mercury poisoning of fish, etc.) becomes unacceptable. Decommissioning dams is widespread to restore pristine ecological systems downstream.

Reduction in carbon intensity is not viewed as a policy goal but it declines for other reasons. It is a frugal world with limited resource availability and so the paradigm grows that it is less costly to save energy than it is to buy it and use it. This spurs the development of technologies that use carbon more efficiently. In addition the accompanying emissions of NOx and SOx and tropospheric ozone are increasingly viewed as unacceptable.

6.23 Scenario Quantification
An initial scenario quantification in terms of population, GDP, energy use, and CO2 emissions for the scenario is summarised in Appendix 1. Energy intensity declines at a rate of 1.3%/year to a value of 0.12 toe/$1000 in 2100. This represents a total global energy usage in 2100 of 1250 EJ, of which 300 EJ is oil and gas; 100 EJ coal and 900 EJ is non-carbon renewables, with nuclear's role limited.

The global scenario for 2100 is also summarised in the form of a snowflake diagram. All scenario quantifications are tentative and subject to revisions.
[Figure: "Snowflake" for B2 scenario]

6.24 CO2 Emissions
By 2100 CO2 emissions 11.5 GtC/year, of which 5 GtC/year is emitted by the North and 6.5 GtC/year by the South. Carbon intensity declines at a rate of 0.8%/year to 2100, to a value of 0.3 tC/toe, some 50% of today's value.

7. Scenario Comparisons
[To be written]

8. Conclusions
[To be written]

Appendix 1: Scenario Quantification
[To be written]

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