I. SCENARIOS OF GLOBAL DEVELOPMENT

Summary

In this section we consider several scenarios of global development. Our purpose is to identify ways in which concerns regarding economic growth, ecological integrity and the distribution of income might support or conflict with one another.

Section I.A begins by comparing seven noted quantitative scenarios of long-range global development. Some address environmental values, and some address income inequality among countries. None address income inequality within countries.

Section I.A continues by presenting a model of global development that addresses income inequality within countries. The model is used to answer the question: what would it take to achieve a world in which annual energy use is limited to 30 terawatts, economic inequality among countries has been eliminated, and economic inequality within countries has been reduced to the level represented by a ratio of 2.5 between the upper and lower per capita income quintiles, within the next 150 years?

We develop a scenario that suggests that such a world could be achieved if global energy efficiency improves by about a factor of five, if low income countries grow at per capita rates of 4-5% for most of this century and then slow to zero over the following half century, if the high income countries reduce their rate of economic growth to zero by the middle of this century, and if households in the top income quintile of the high income countries are willing to undergo an absolute reduction of their incomes of 17% over the century beginning in 2050. We find that the top income quintiles of the high income countries can avoid having to undergo an absolute reduction of incomes if more affirmative steps are taken, earlier, to address income inequality.

Section I.B reviews thirty-three sets of mostly narrative scenarios of global development. We identify four advocated scenarios, distinguished largely by different political-economic

commitments: techno-global neoliberalism, social democratic internationalism, Green sustainability, and civilization-of-civilizations.

Section I.B continues by presenting a framework for integrating the various quantitative and narrative scenarios. We identify our ideal scenario, combining Green sustainability and quantitative Scenario 5. Section I.B concludes by noting the many questions that need to be addressed in order to evaluate the credibility of any of the scenarios, and in particular of the ideal scenario. These questions are to be addressed in Section II.

I. SCENARIOS OF GLOBAL DEVELOPMENT

I.A. QUANTITATIVE SCENARIOS OF GLOBAL DEVELOPMENT

I.A.1. REVIEW OF PAST SCENARIOS

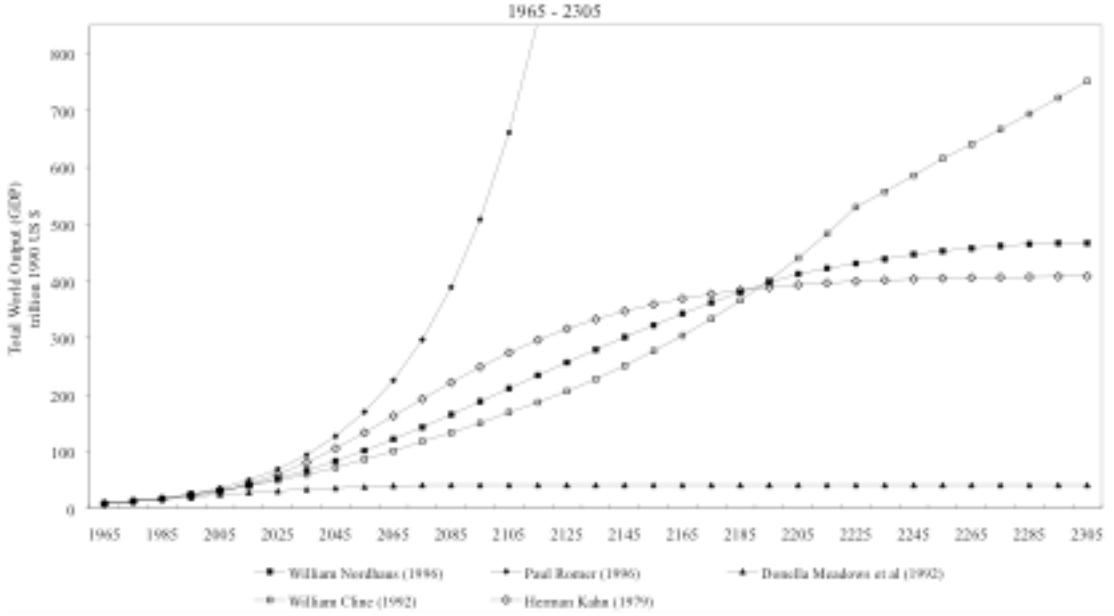
Box IA-1 shows projections of total world output associated with five noted models of world development. The scenarios are described in **IA-2**.

How do the authors of these models motivate these scenarios? Meadows, Nordhaus and Kahn all show economic growth coming to an end, but at different final levels and for different reasons. Meadows believes that biogeophysical limits to economic growth will compel us to live within them. Nordhaus believes that productivity-enhancing technological innovation will become increasingly subject to diminishing returns. Kahn believed that as wealth increases people will become satiated and jaded and lose their entrepreneurial and acquisitive desires. Romer's scenario does not show limits to growth. He believes that increasing returns to technology and knowledge should allow growth to continue indefinitely. Cline's growth projections are extensions of projections made by the Intergovernmental Panel on Climate Change and are not further motivated.

Different assumptions concerning population growth are not an important reason for the differences among the scenarios. Other than Meadows, all the authors use standard projections prepared by the United Nations. In these, population stabilizes at about 11 billion by the middle of the next century. Meadows uses a lower stabilization value of 7.7 billion.

These globally aggregated projections are a useful initial reference, but if we wish to consider questions regarding income inequality we need regionally disaggregated models. **IA-3** shows projections of economic growth for six scenarios ending in 2100, four of which—by

BOX IA-1. WORLD OUTPUT TRAJECTORIES



BOX IA-2. WORLD OUTPUT TRAJECTORIES – DESCRIPTIONS

1. World Output Trajectories, 1965-2305 (Box IA-1)

Box IA-1 shows projections of total world output made by noted economists and other analysts for the period 1965-2305. All figures are in 1990 U.S. dollars.

Nordhaus: This is the reference case output trajectory used by Nordhaus for his RICE model (Nordhaus and Yang, 1996). He uses United Nations mid-range population forecasts, which show stabilization at 10.6 billion. World per capita output reaches $20,500 by 2100 and stabilizes near $42,000 shortly after 2200.

Romer: At the July 1996 Western Economic Association annual convention in San Francisco Paul Romer estimated that the global economy should be able to sustain a per capita output growth rate of about 2 to 3 percent for the indefinite future. The trajectory shown in the chart uses a value of 2.5%, along with the United Nations population projections used by Nordhaus. Per capita output in 2100 is about $60,000.

Meadows: This is the path of global output that Meadows et al., in *Beyond the Limits to Growth* (1992), suggest should be followed in order to avoid the catastrophic reduction in output that would otherwise result as biogeophysical limits are exceeded. Population is limited to 7.7 billion and per capita output is estimated to stabilize at about $5,400.

Cline: This is the reference case output trajectory used by Cline in *The Economics of Global Warming* (1992). It is based on extrapolations of mid-range projections used by the World Bank and the United Nations for the coming century, tempered by Cline's judgment that these rates will slow in later decades. In 2100 population is stable at 10.5 billion and per capita output is about $15,200.

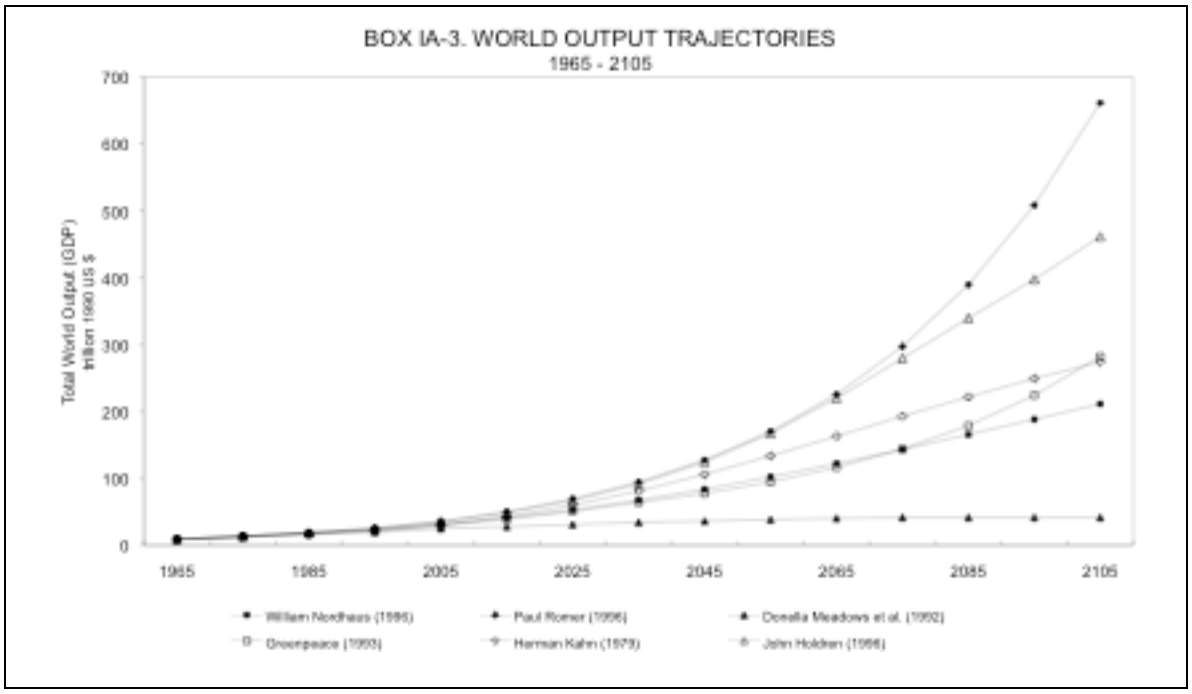
Kahn: This is the output trajectory offered by Kahn in *World Economic Development* (1979) as an alternative to that offered by the authors of *The Limits to Growth*. Population stabilizes at 10 billion. In 2100 per capita output is about $26,000 and it stabilizes a century later at about $40,000.

2. World Output Trajectories, 1965-2105 (Box IA-3)

Box IA-3 shows output trajectories for the period 1965-2105. Four of the trajectories (Nordhaus, Romer, Meadows and Kahn) are the same as those shown in Box IA-1 but here cover only the period through 2105. Cline's trajectory has been deleted and new ones by Holdren and Greenpeace have been added.

Holdren: John Holdren (1996) presented his "best plausible" scenario for reducing reliance on fossil fuels and achieving distributional equity among nations at an April U.C. Berkeley symposium. The trajectory shown in IA-3 is the output trajectory used in this best plausible scenario. In 2100 population has stabilized at 9 billion and per capita output is about $47,700.

Greenpeace: This is the growth path used in the study *Towards a Fossil Free Energy Future* (1993) prepared for Greenpeace by Lazarus et al. of the Stockholm Environmental Institute. It uses the same population and total world output assumptions adopted by the Intergovernmental Panel on Climate Change (IPCC), but modifies per capita output growth rates among regions to reduce inequities. In 2100 population has stabilized at 11.3 billion and per capita output is about $22,400.


BOX IA-3. WORLD OUTPUT TRAJECTORIES
1965 - 2105
Total World Output (GDP)
trillion 1990 US $
700
600
500
400
300
200
100
0
1965
1985
2005
2025
2045
2065
2085
2105
William Nordhaus (1995)
Paul Romer (1996)
Donella Meadows et al. (1992)
Greenpeace (1993)
Herman Kahn (1979)
John Holdren (1995)

Holdren, Nordhaus, Kahn, Greenpeace--are disaggregated on a regional basis.[1] These scenarios are described in IA-2.

Readers familiar with the global futures debate might suspect that I've mislabeled the projections in IA-3. Nordhaus and Kahn present "business-as-usual" scenarios in which world GDP reaches $211 and $274 trillion, respectively, by 2105. Greenpeace and Holdren present "preferred" scenarios in which world GDP reaches $282 and $460 trillion by that date. How can it be that the *preferred* scenarios recommended by two noted environmental advocates show *greater* economic growth than do the *business-as-usual* scenarios presented by two noted pro-growth, neo-classical economists?

The answer is that the Greenpeace and Holdren scenarios incorporate a normative desire that the economic disparities between the rich and the poor countries of the world be significantly reduced, while the scenarios of Nordhaus and Kahn do not. Because income inequality between the rich and the poor countries is in fact so large, Greenpeace and Holdren must show strong, continuous economic growth by poor countries if they are to offer any hope that economic disparities can be reduced by more than a trivial amount within any time less than several centuries.[2]

The Greenpeace and Holdren scenarios also incorporate a desire that total world output does not grow so large that important environmental values are threatened. Holdren sets a limit of 30 terawatts (TW) on the growth of world energy use, which he estimates is the maximum desirable level that can be provided with renewable sources alone. For Greenpeace the limit is set by the desire to eliminate the use of fossil fuels by 2100. In order to live within these limits, while

[1] Box IA-3 includes the scenarios shown in IA-1 except for Cline's, and adds new ones by Holdren and Greenpeace. Cline's scenario was not included to avoid crowding. Termination of the time horizon at 2105 allows the main points of this section to be illustrated more conveniently.

[2] Appendix 1 shows that under the conventional business-as-usual assumptions used by Cline, the gap between the developed and the developing countries would be eliminated sometime between 2600 and 2700, at which time mean GDP would be about $2,000,000 per household (1990 US$).

simultaneously reducing income inequality among countries, economic growth in the highest income nations must slow over the coming decades. This can be seen clearly in **IA-4** and **IA-5**.

In the Nordhaus and Kahn scenarios the growth rates of low income countries exceed those of the richer countries by little more than 1-1.5%. The result is that only minimal progress is made in reducing economic inequality among countries by 2100. The Nordhaus regional projections are shown in **IA-6**. Further inspection of the Nordhaus and Kahn scenarios shows that economic growth in all regions slows to zero while substantial economic inequalities still exist. This condition is problematic, to say the least.

The distribution of income between countries has rightly received great attention among global scenario modelers over the past thirty years, but the distribution of income *within* countries has received much less.[3] This is a remarkable omission. Income inequality is arguably the single greatest source of social conflict throughout history and at the present time. Scenarios of global development that are intended to help inform broad world-views of the human prospect cannot do this unless they include projections of income distribution within countries, and describe how these might be expected to change under different conditions and policies.

The topic of income inequality within countries is discussed at length in Section II.B. As we'll see, empirical studies and analytic models suggest that the distribution of income tends to change only slowly over time, and is resistant to policy.

This brief review suggests that there are important ways in which economic growth, environmental protection and distributional equity between and within countries either conflict with or help support one another. In the next section we present a simple regionalized world model that can help us study these relations in more detail.

[3] Authors who have sought to model within-country income distributions over time include Chenery, Ahluwalia, et al (1974), Adelman and Robinson (1978), Taylor and Lysy (1979), Chichilnisky and Cole (1978), Moreland (1984), and Bessant and Cole (1985). In general their projections do not show results for periods much longer than several decades.

BOX IA-4. HOLDREN'S SCENARIO

[Holdren 1996]

Figure 1. World Per Capita GDP under Business-As-Usual Scenario

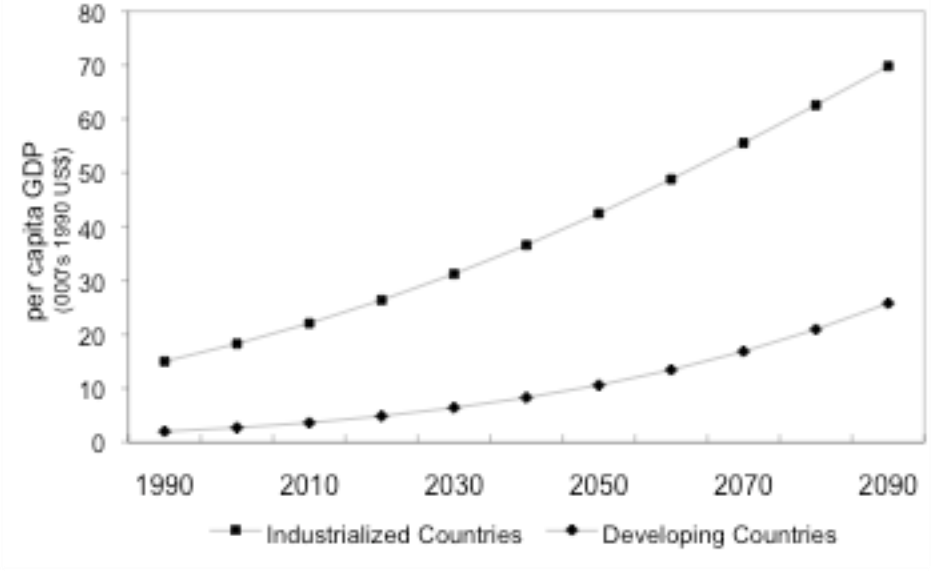
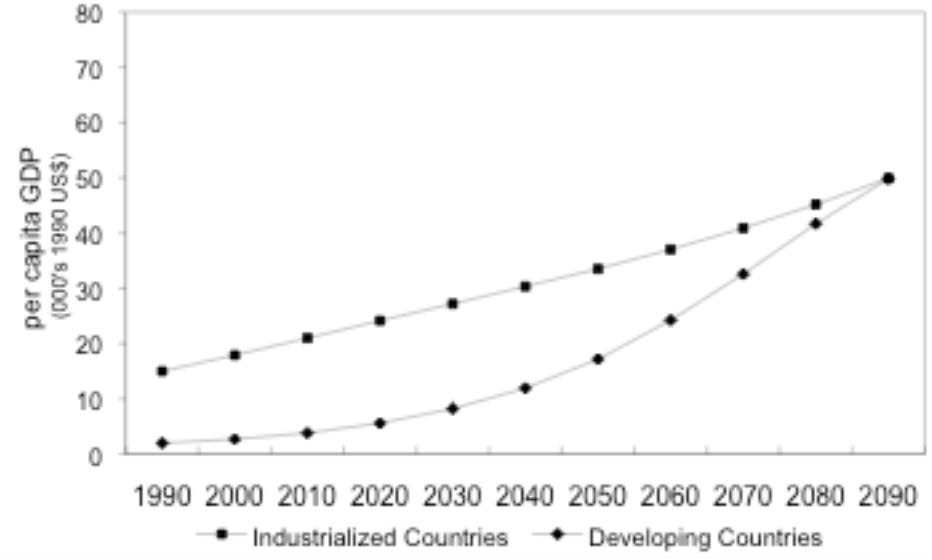


Figure 2. World Per Capita GDP under "Best Plausible" Scenario



BOX IA-5. GREENPEACE SCENARIOS OF PER CAPITA GDP GROWTH
[Lazarus et al., 1993]

Figure 1 shows reference scenario per capita GDP growth for six world regions from 1990 to 2100 adopted by the IPCC (1990). Greenpeace modified this trajectory to give the "Equity Scenario" shown in Figure 2. Under the Equity Scenario:

"[W]e propose an assumption for regional income equity wherein the ratio of highest to lowest average income drops to 2:1by 2100, compared with the current ratio of over 14:1. We maintain the IPCC90 projected regional growth rates over the next 20 years, and then gradually adjust them over the 2010-2100 period to achieve this increased equity objective." (p 23)

Figure 1. Per Capita GDP under the IPCC 1990 Reference Scenario (1985 US$)

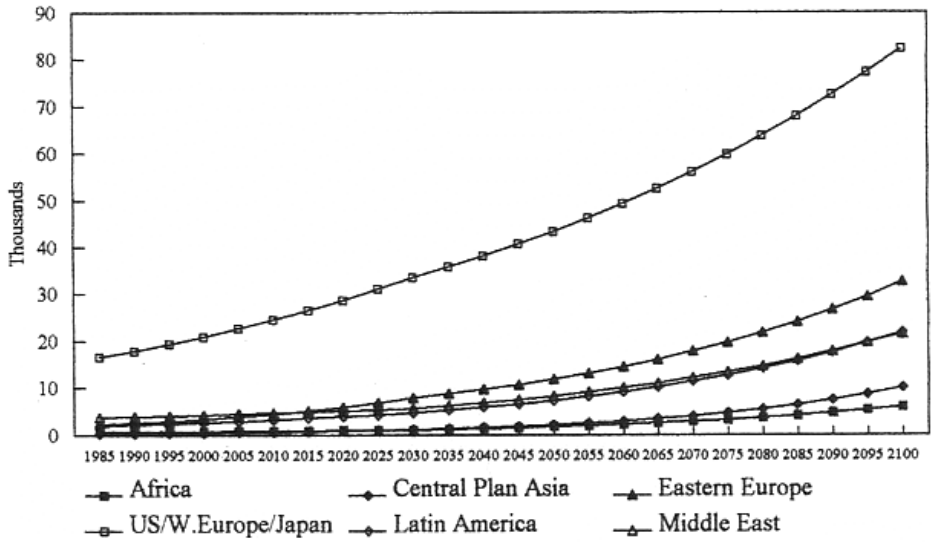
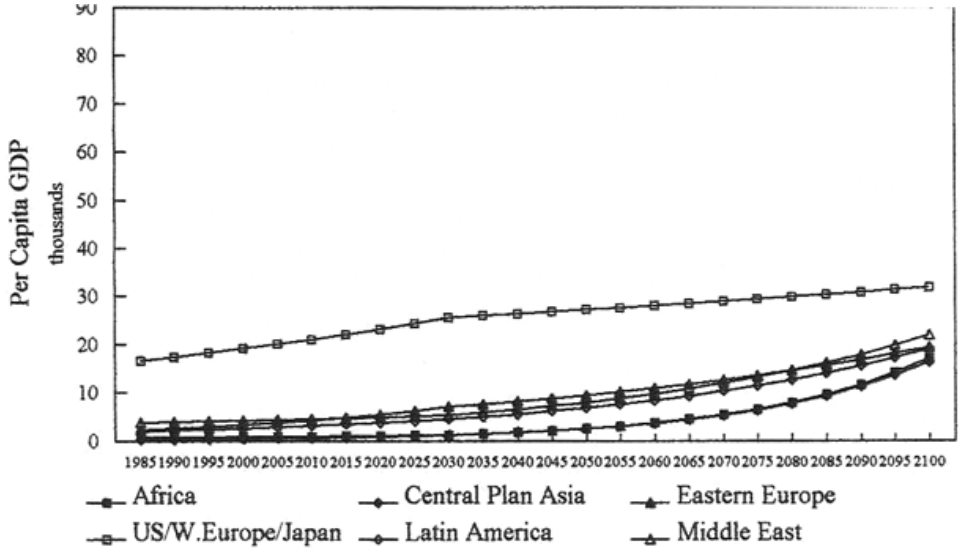
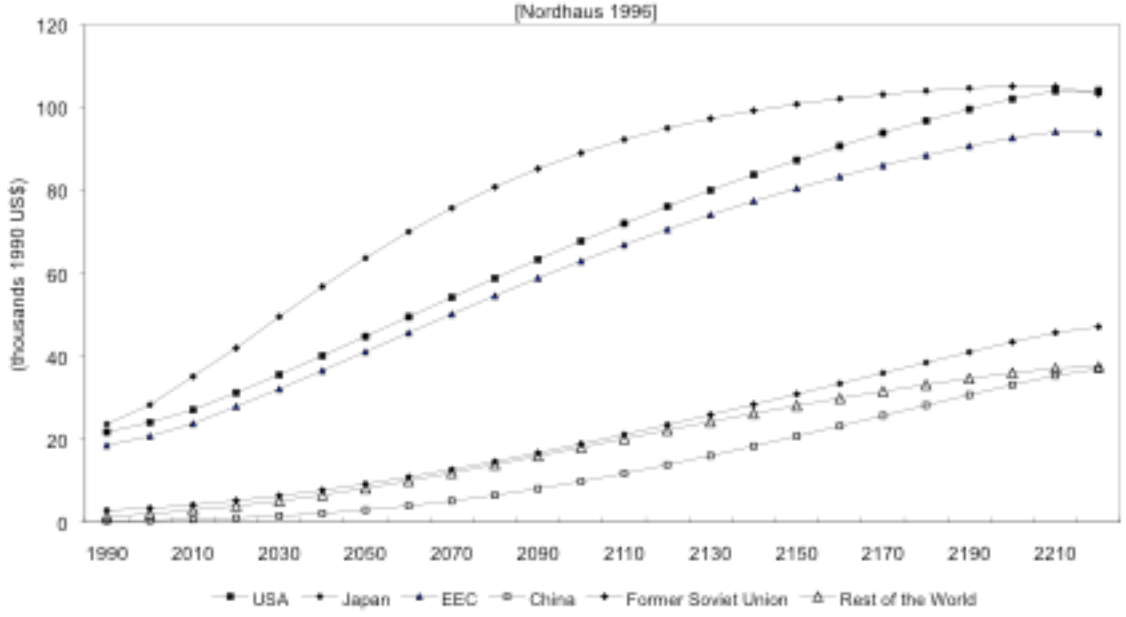


Figure 2. Per Capita GDP under the Greenpeace "Equity Scenario" (1985 US$)



BOX IA-6. RICE REFERENCE SCENARIO PROJECTIONS OF PER CAPIITA INCOME

[Nordhaus 1996]



2. MODEL A

This section describes a model of world development that will be used to study how economic growth, environmental values and social equity support or conflict with one another. This model is called "Model A."

Model A shows changes in population, economic output, energy use and income distribution within countries over the period 1994-2150. For most purposes we use 2000 as the initial year of reference. Model A aggregates the countries of the world into four sectors: low-income countries, China, middle-income countries, and high-income countries.[4] Decadal rates of change of population, per capita output, energy efficiency and income distribution are specified exogenously.

Below is a brief description of Scenario 1, the reference or business-as-usual scenario, that we use in the remainder of this section. **IA-7, IA-8** and **IA-9** show the values of important variables that make up Scenario 1. All money values are given relative to 1990 US dollars. The equations of the model are shown in **IA-10** and **IA-11**. Appendix 2 describes derivation of the initial values and growth rate projections. A complete print-out of Scenario 1 appears in **IA-26** at the end of this section.

* Population growth: Population growth decreases in all sectors and world population stabilizes at 11.3 billion by about 2090.

* Economic growth: Per capita GDP growth rates in the low income countries increase and are able to stay between 2.5% and 3% for most of the coming century, after which they decline. China's current high growth rates decline over the next several decades, reaching 3% in 2050, at which point the low income countries and China follow the same trajectory. The middle income countries grow at 2% for most of the next century. Growth rates for the high income

[4] These sectors follow the classification used by the World Bank in its World Development Report (1996), with the exception that we show China as a separate sector, while the World Bank groups it with the other low income countries. See Appendix 2, Box A2-4 for the list of countries included in each sector.

BOX IA-7. SCENARIO I - REFERENCE SCENARIO - SUMMARY TABLES

Population (10^9 persons)

	1990	2000	2020	2050	2100	2150
low income	1.8	2.3	3.2	4.4	5.2	5.2
China	1.1	1.3	1.6	1.8	1.9	1.9
mid income	1.5	1.7	2.2	2.9	3.3	3.3
high income	0.8	0.9	0.9	0.9	0.9	0.9
WORLD	5.3	6.2	7.9	10	11.3	11.3

Per Capita GDP (1990 US $)

	1990	2000	2020	2050	2100	2150
low income	346	366	557	1,279	4,883	11,539
China	275	628	1,342	3,541	13,524	31,959
mid income	2,731	2,752	4,065	7,709	18,037	31,577
high income	22,742	26,689	37,497	55,382	91,309	136,217
WORLD	4,514	4,877	6,038	8,624	17,311	31,120

Per Capita GDP Growth Rates (% per year)

	1990	2000	2020	2050	2100	2150
low income	-0.08	1.9	2.6	3	2.1	1.3
China	11.7	4	3.4	3	2.1	1.3
mid income	-1.3	1.9	2.1	2	1.3	1
high income	1	1.8	1.4	1.1	0.8	0.8
WORLD	0.11	1.1	1.1	1.4	1.3	1.1

Ratio of Per Capita Incomes of High Income Countries to Others

	1990	2000	2020	2050	2100	2150
low income	66	73	67	43	19	12
China	83	42	28	16	7	4
mid income	8	10	9	7	5	4
high income	1	1	1	1	1	1

Total Energy Use (TW)

	1990	2000	2020	2050	2100	2150
low income	0.64	0.78	1.7	4.7	16.8	35
China	1.1	1.6	3.4	8.7	26.7	55.7
mid income	3.5	4.1	7.4	16.7	34.6	53.5
high income	6.2	7.1	9.5	12.2	15.9	20.6
WORLD	11.5	13.6	22.1	42.3	93.8	164.8

DISTRIBUTION OF INCOME

(values shown are per capita incomes for each population quintile, in '90 US $)

Low Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	106	113	176	412	1617	3906
middle 20%	251	267	406	926	3500	8254
top 20%	827	876	1318	2964	10980	25525

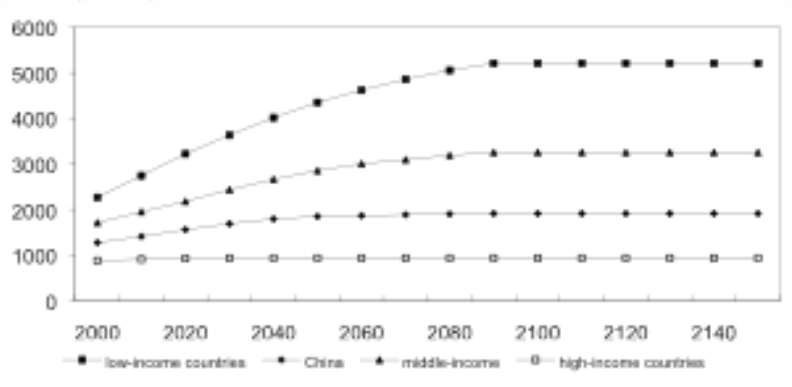
China	1994	2000	2020	2050	2100	2150
bottom 20%	136	194	415	1100	4223	9906
middle 20%	346	491	1037	2701	10164	23839
top 20%	962	1363	2861	7395	27589	64712

Middle Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	828	887	1349	2656	6245	10899
middle 20%	1911	2032	3006	5707	13286	23187
top 20%	6135	6495	9471	17613	40750	71117

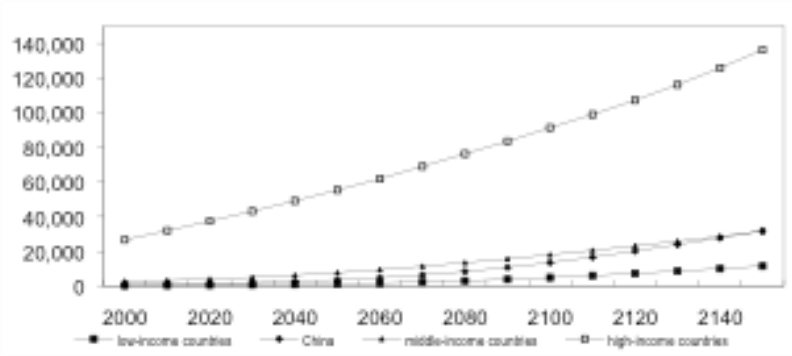
High Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	7373	8303	11632	17137	28184	41978
middle 20%	20475	23058	32303	47590	78267	116575
top 20%	48135	54208	75941	111881	183999	274058

BOX IA-8. SCENARIO I - REFERENCE SCENARIO - POPULATION AND ECONOMY TRAJECTORIES

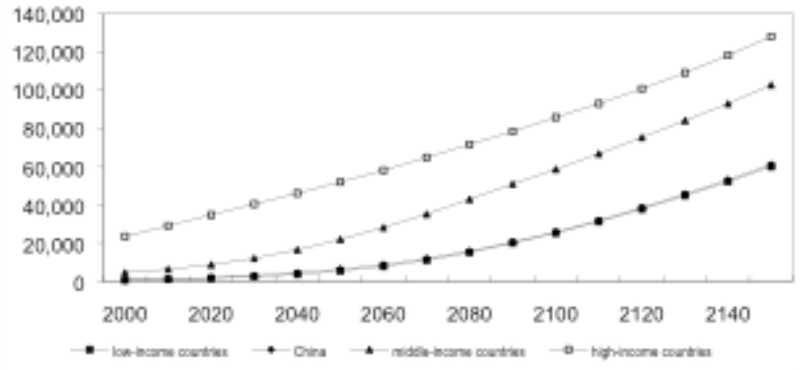
population (millions)



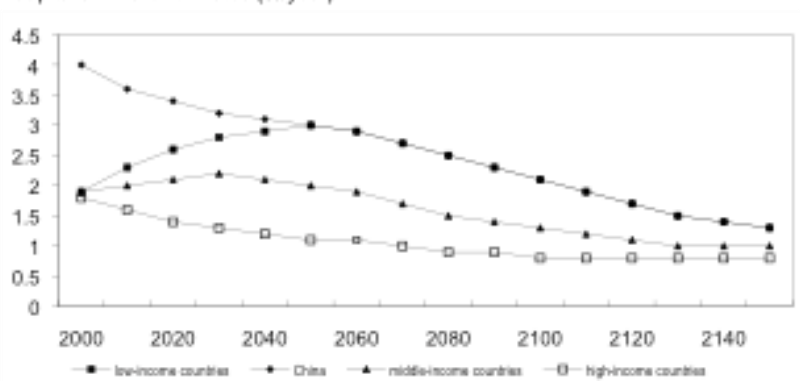
per capita GDP (1990 US $)



Total GDP (billion 1990 US $)



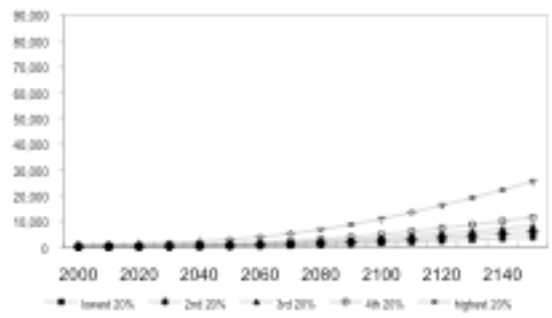
Per Capita GDP Growth Rates (%/year)



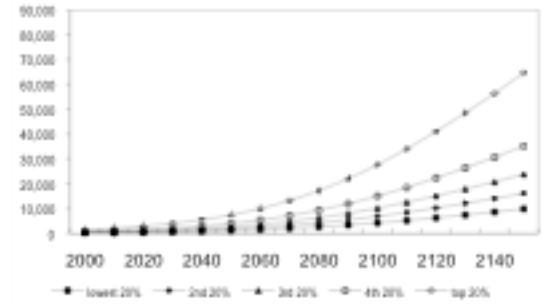
BOX IA-9. SCENARIO I - REFERENCE SCENARIO - INCOME DISTRIBUTION TRAJECTORIES

[All values 1990 US $; all vertical axes to the same scale]

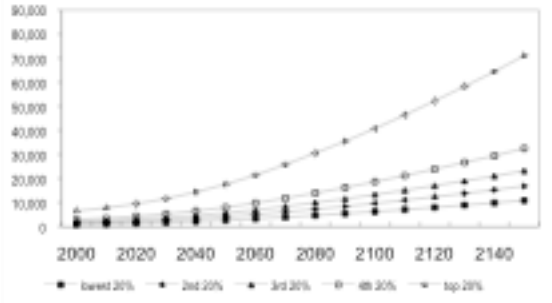
LOW-INCOME COUNTRIES
mean per capita income by quintile



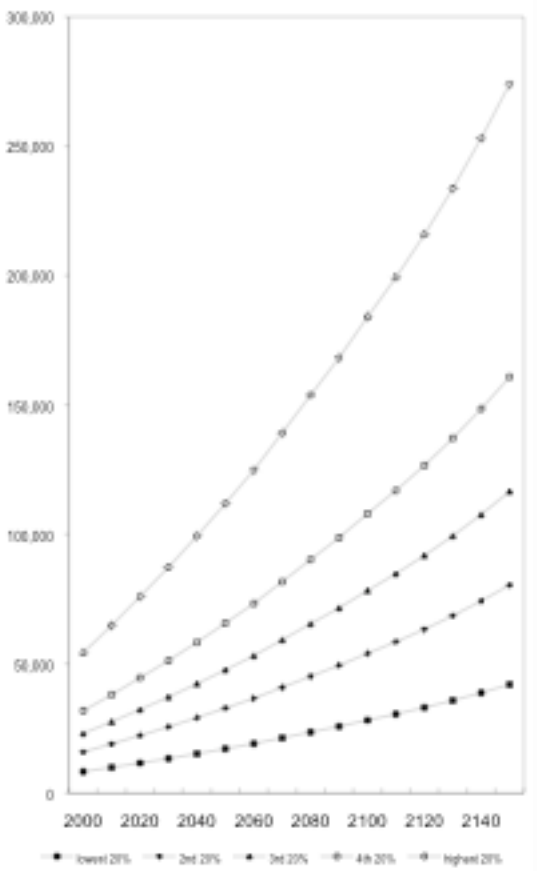
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



HIGH-INCOME COUNTRIES
mean per capita income by quintile



BOX IA-10. MODEL A

Equations of the Model

(1) $P_{i\,1} = P_{i\,0}(1 + n_{i\,0})^{10}$ population growth

(2) $y_{i\,1} = y_{i\,0}(1 + g_{i\,0})^{10}$ per capita income growth

(3) $e_{i\,1} = e_{i\,0}(1 + q_{i\,0})^{10}$ changes in energy intensity

(4) $y_{i\,j\,1} = y_{i\,j\,0}(1 + g_{i\,0})^{10} + s_{i\,j}\, r_{i\,0}(y_{i\,4\,0} + y_{i\,5\,0} - 2\, y_{i\,0})$; $j = 1, 2, 3$

$= y_{i\,j\,0}(1 + g_{i\,0})^{10} - r_{i\,0}(y_{i\,j\,0} - y_{i\,0})$; $j = 4, 5$

changes in income distribution
[see Box IA-11 and Appendix 3 for discussion]

(5) $G_{i\,0} = 1.2 - [\,[\,\Sigma^{5}_{j\,=\,1}(6 - j)\, y_{i\,j\,0}\,] / 12.5\,(y_{i\,0})^{2}]$

Gini coefficient
[see Appendix 4 for discussion]

Variables and Parameters of the Model

P = population (billions)
y = per capita income (1990 US $)
e = energy intensity (total terawatts/total GDP)
G = Gini coefficient

n = population growth rate (%/year)
g = per capita income growth rate (%/year)
q = energy intensity growth rate [<0] (%/year)

i = sectoral index: 1, 4 [low income, China, middle income, high income]
j = income quintile: 1, 5 [Q1, Q2, Q3, Q4, Q5]
time subscript = 0, 1, 2… = 2000, 2010, 2020…

$s_{i\,j}$ = redistributive proportionality factor = $(y_i - y_{i\,j}) / [3\, y_i - (y_{i\,1} + y_{i\,2} + y_{i\,3})]$
r = rate of redistribution (%)

Initial and Reference Scenario values are shown in Box IA-7. Selection of initial values is described in Appendix 2.

BOX IA-11. MODELING CHANGES IN THE DISTRIBUTION OF INCOME

The equations below model changes in the distribution of income within an income sector. The per capita income of sector i grows at annual rate g_i, compounded decadally. In the absence of redistributive pressure (r = 0) all quintiles share equally in this growth. At the end of each decade income can be redistributed from those quintiles in which income is above the sector mean to those quintiles in which income is below the mean. The proportion of the total income above the mean that is redistributed in any period is given by the redistributive variable r, with $0 < r \leq 1$. The value of r can be varied by time period. Meanwhile, the proportionality factor s ensures that the amount which a quintile whose income is below the mean receives from the total amount to be distributed is proportional to the amount by which that quintile is below the mean. If a constant r is maintained over decades the incomes of all quintiles converge. The larger the value of r, the faster the convergence. We can also show $r < 0$, in which case incomes will be redistributed from those quintiles below the mean to those above the mean. Appendix 3 illustrates the derivation and interpretation of the model in more detail. The model is a calculatory convenience that allows scenarios to be generated showing changes in the level and distribution of income. It does not embody a theory of income distribution. This would require that r be made a function of other variables in the model, such as the growth rate g or per capita income, rather than standing as an exogenous variable.

(4.1) $y_{i11} = y_{i10} (1 + g_{i0})^{10} + s_{i1} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.2) $y_{i21} = y_{i20} (1 + g_{i0})^{10} + s_{i2} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.3) $y_{i31} = y_{i30} (1 + g_{i0})^{10} + s_{i3} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.4) $y_{i41} = y_{i40} (1 + g_{i0})^{10} - r_{i0} (y_{i40} - y_{i0})$

(4.5) $y_{i51} = y_{i50} (1 + g_{i0})^{10} - r_{i0} (y_{i50} - y_{i0})$

where

(6) $s_{ij} = (y_i - y_{ij}) / [3y_i - (y_{i1} + y_{i2} + y_{i3})]$

(7) $y_i = 1/5 \Sigma y_{ij}$

definitions:
y_{ijt} = per capita income of quintile j of income sector i in year t
y_{it} = per capita income of the full income sector i in year t
g_{it} = growth rate of per capita income in income sector i in year t
s_{ij} = redistributive proportionality factor for each quintile j of income sector i
r_{it} = rate of redistribution for income sector i in year t

countries decline steadily over the next century until they reach 0.8%. They remain at this level through 2150. By 2100 world per capita income has reached $17,300, a level 3.7 times its level in 1994. By 2150 per capita income has reached $31,100, a level 6.9 times its l994 level. In 2150 per capita income is still growing, at a global rate of 1.1%. This represents a doubling time of 63 years. In 1994 the ratio of per capita income in the high-income sector to that of the low-income sector is 69 to 1. By 2100 this difference declines to 19 to 1, and by 2150 it is 12 to 1.

* Energy use: Energy use per dollar of GDP declines steadily in all regions, but most rapidly in China and least rapidly in the low and middle income countries. By 2050 the rate of decline of energy intensity in all sectors has converged on a value of 0.5% per year, remains at that rate until 2100, and continues after that at a rate of 0.25% per year. Total energy use reaches 94 TW by 2100 (8 times the level of world energy use in 1996) and 165 TW by 2150. The trends in energy intensity used in Scenario 1 are shown in **IA-12** and are discussed further in Appendix 2 and illustrated in Appendix Box A2-7. **IA-13** illustrates the relation between energy intensity, total energy use and per capita GDP.

* Income distribution within countries: For Scenario 1 I adopt a simple "no surprises" set of assumptions. In the high income countries the distribution of income does not change from its current values—a Gini coefficient of .32 and an 80/20 ratio of 6.5 to 1--over the 150-year time horizon of Model A.[5] In light of recent trends this might be considered optimistic but until quite recently it would have been considered pessimistic. In the other three sectors income is presently less equally distributed than it is in the high income sector. As these three sectors grow their distributions of income approach that of the high income sector, matches it when their per capita incomes reach $10,000, and remains unchanged after that.[6] In 2000 the mean incomes of the top and bottom quintiles in the high income countries are $54,000 and $8,300 respectively, which

[5] See Appendix 4 for definitions of the Gini coefficient and other inequality measures.

[6] Changes in income distribution in the high income countries during and following World War II had largely stabilized by 1960, at which time per capita income was about $10,000 (1990 US $).

BOX IA-12. ENERGY INTENSITY TRENDS

[See Appendix 2 and Box A2-7 for derivations and notes]

Figure 1. Scenario 1 (Reference Scenario) Energy Intensity Trends

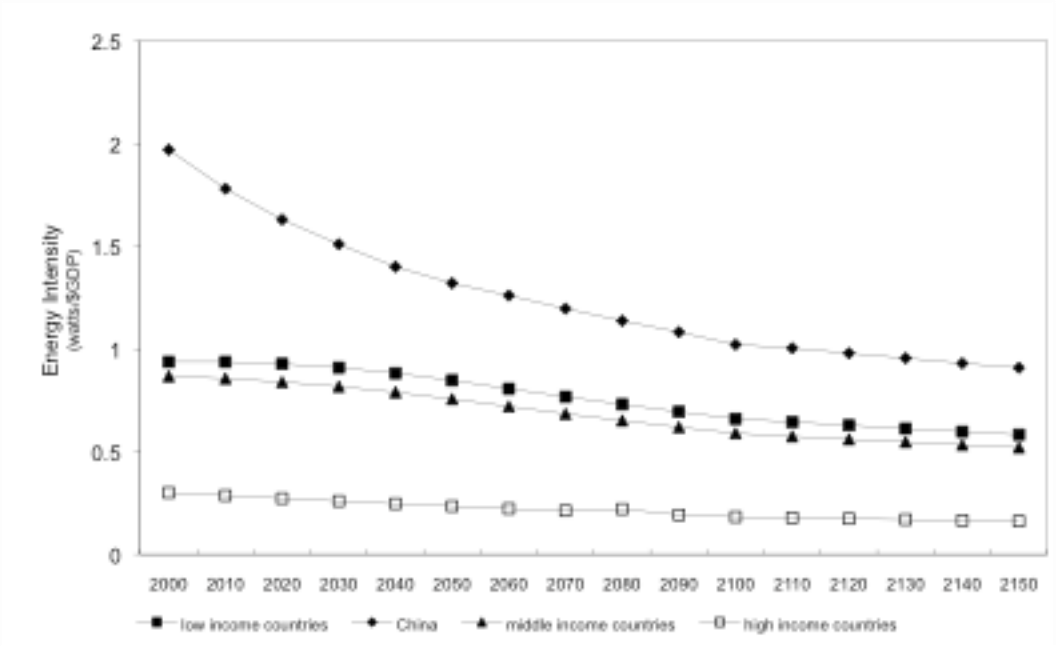
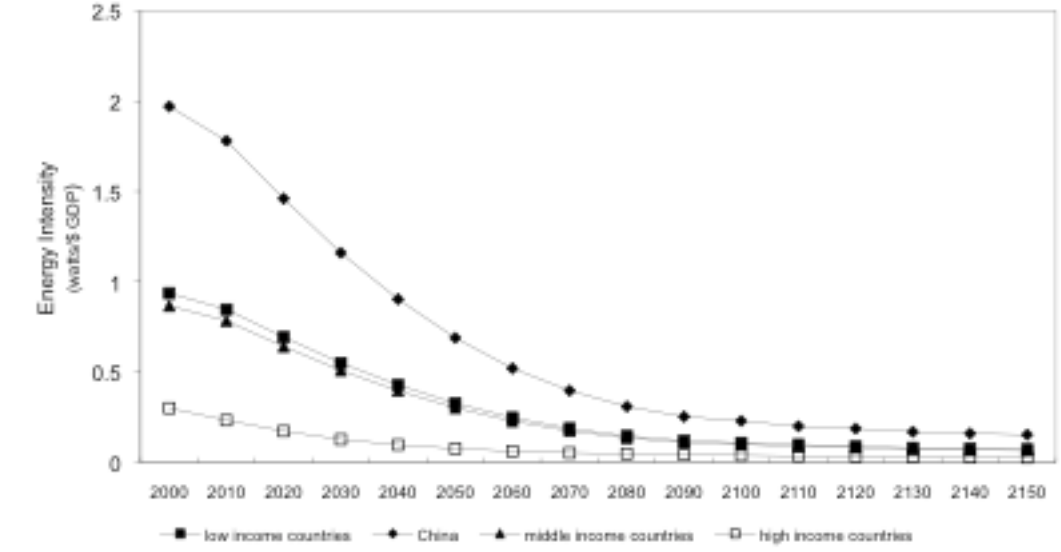


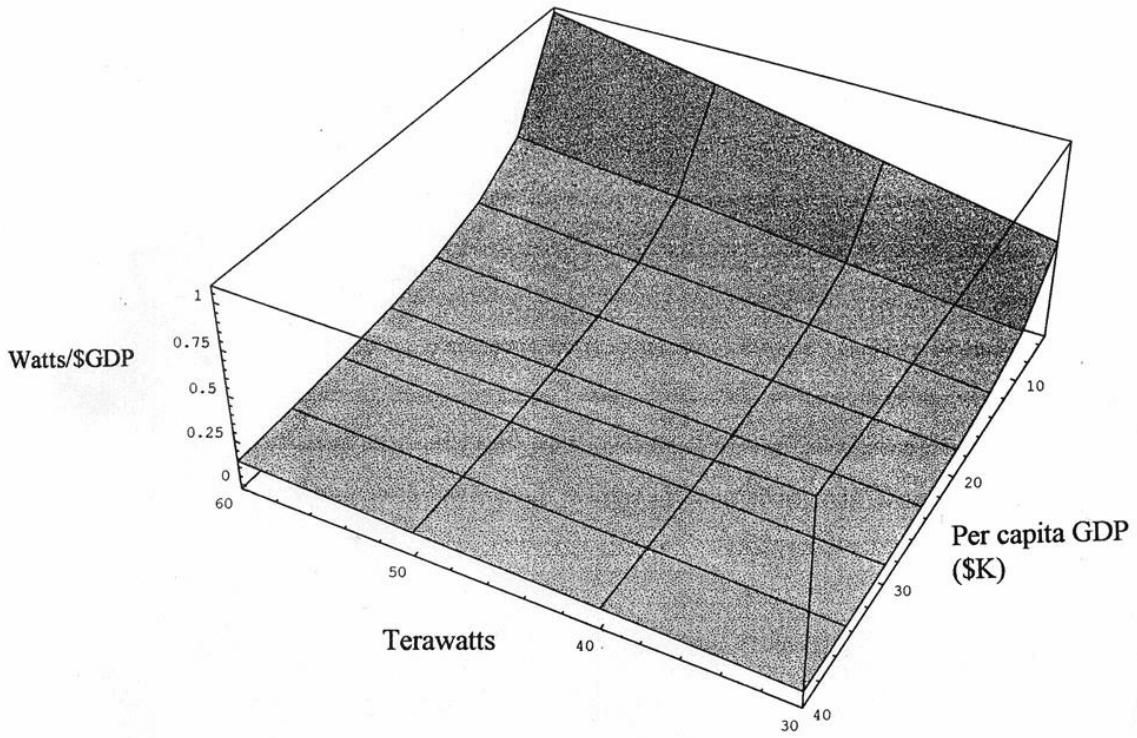
Figure 2. "Maximum Practicable" Improvements in Energy Intensity - Scenarios 3-6



BOX IA-13. TRADE-OFFS BETWEEN TOTAL ENERGY USE, ENERGY INTENSITY AND PER CAPITA GDP

The diagram shows levels of per capita GDP, energy intensity (in watts/$GDP) and total energy use (in terawatts) that can be realized at a point in time. The values shown assume a population of 11 billion, and are consistent with the Reference Scenario for the period around 2040.

Suppose that at a point in time we are using 30 terawatts of energy, at an intensity of .50 watts/$GDP. This supports a per capita GDP of about $5,500. Suppose too that we plan to double per capita GDP, to $11,000, by growing at an average of 1.5% per year over 46 years. We would need to either double total energy use, from 30 to 60 terawatts, or cut energy intensity in half, from .50 to .25 watts/$GDP, or achieve some other combination of higher total energy use and lesser energy intensity shown on the trade-off surface of the diagram.



The diagram was produced with Mathematica software using settings as follows:

In [63]: = enggdp: = {{.531, .708, l885, 1.062}, {.265, .353, .442, .531}, {.177, .236, .295, .354}, {.133, .177, .221, .265}, {.106, .142, .177, .212}, {.088, .118, .147, .177}, {.076, .101, .126, .152}, {.066, .088, .111, .133}}
ListPlot3D [enggdp] - Show [q, ViewPoint -> {-1.3, 2.4, 2}, Meshrange -> {{30, 60}, {5, 40}}, Axeslabel -> {“Terawatts”, “pc GDP”, “W/$GDP.”}]

gives an 80/20 ratio of 6.5. By 2150 these grow to $274,000 and $42,000; the 80/20 ratio is unchanged. The low income countries start out in 2000 with top and bottom mean incomes of $876 and $113, which represents an 80/20 ratio of 7.7. By 2150 these incomes have grown to $25,525 and $3,906. The 80/20 ratio now matches the 6.5 value of the high-income countries.

Evaluation and Discussion

Let's assume for the moment that most people would prefer to live in a world where economic growth continues at some steady pace, a healthy environment is maintained, and economic inequality, both between and within countries, does not exceed some acceptable level. Does Scenario 1 reflect these preferences? Put somewhat differently, are there reasons we would want to have the world develop in a manner other than as shown in Scenario 1?

Clearly, different people would answer this question in different ways.

Some people, perhaps especially those from high-income countries, might object that the annual rates of per capita income growth shown for that sector, which for most decades lie between 0.8% to 1.8%, are too low. They'd like to see growth rates of at least 2.2% (this is the non-inflationary growth rate target identified by the U.S. Council of Economic Advisors in 1995) and preferably closer to the 3.5-4% rates that the industrial nations maintained or exceeded for the two decades after WWII.

Other people, perhaps especially those from lower income countries, might object that the rate of per capita income convergence between the rich and poor nations is too slow. If the growth rates shown in 2150 were to continue unchanged, convergence would take place in about 2500. People who find this unsatisfactory might want to see steady per capita income growth rates in the lower income countries of at least 4 to 5 percent per year.

Still others – for example, environmentalists - might be concerned about the high level of energy use that Scenario 1 shows--14 times today's level in 2150--even given the steady improvement in energy efficiency that the scenario incorporates. They might propose that strong

efforts be made to increase energy efficiency even further, and if necessary, that we learn to live at levels of material consumption below those projected in Scenario 1.

Finally, others might object that the level of income inequality within the high income countries today is hardly acceptable as a final goal, whether to be maintained by the high income countries or aspired to by others. They might call for measures that, for example, would reduce the 80/20 ratio in the high income countries (and thereafter in the rest of the world) from its current value of 6.5 to 1 to something in the neighborhood of 3 to 1, which is the ratio achieved in several Scandinavian countries and in the Soviet Bloc before its dissolution.

It is clear that an attempt to realize all these preferences would be conflictual, but it is not clear how serious these conflicts are. In the next section we use Model A to explore how close we can come to realizing sets of these preferences.

I.A.3. ALTERNATIVE SCENARIOS

Suppose we wish to achieve a lower degree of environmental degradation and a higher degree of economic equality, both among and within countries, than is shown in Scenario 1. What scenarios might enable this to happen?

As our goal for limiting environmental degradation, let's use Holdren's goal in which world energy use does not exceed an upper limit of 30 TW. This represents nearly a 3-fold increase over today's 11 TW.

Let's set 2150 as the year by which we wish to have achieved equality of per capita incomes among countries.

Finally, let's say that by 2150 we want the distribution of income in all countries to be such that the ratio of mean per capita incomes received by the top and the bottom quintiles is no greater than 2.5 to 1.[7]

[7] This is about as close to complete distributional equality as might reasonably be believed to be practicable. A distribution in which all quintiles receive equal incomes would not allow for income

We'll approach our set of goals incrementally, changing only a few assumptions at a time over the course of four policy scenarios. This approach helps us understand the relative impact of each goal as part of the total package.

Scenario 2:

a) faster growth in developing countries
b) greater energy efficiency

In Scenario 2 we assume a) that the growth rate of per capita GDP in the low and middle income countries, and China, can increase to and be maintained at 4-5% per year for most of the coming century. We also assume b) that energy intensity declines along the high efficiency path described in Table 2 of Box A2-7 in Appendix 2.

The results of implementing Scenario 2 are shown in **IA-14, IA-15** and **IA-16**. World GDP in 2100 is $469 trillion, 2.4 times greater than the value shown in Scenario 1. The gap between the high income and the low income countries is reduced quite dramatically, from a ratio of 73 to 1 in 2000 to a ratio of 1.4 to 1 by 2150. If the rates of per capita GDP growth shown in 2150 were to continue unchanged the gap would be completely closed after another 50 years. At that time the per capita income of all countries would be $209,000, (43 times the per capita income in 2000) and would be growing at close to 1.5% per year.

Under Scenario 2 we find that global energy use in 2100 is 73 TW (down from 94 TW in Scenario 1) and in 2150 is 136 TW (down from 165 TW). These are improvements but are still quite far above our goal of 30 TW. Higher rates of energy efficiency improvement have been largely offset by higher rates of economic growth. At the end of 2150 we show world energy intensity decreasing by 0.5% per year in all sectors and world per capita GDP increasing at 1%. This means that at the end of our time horizon energy use is increasing at 0.5% per year, which, although slow, nonetheless represents a doubling time of 139 years.

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mobility over the course of a lifetime as experience and skills increase. In any event, a ratio of 2.5 to 1 is consistent with a case in which *life-time* incomes are identical among all persons.

BOX IA-14. SCENARIO 2 - SUMMARY TABLES

Population (10^9 persons)

	1990	2000	2020	2050	2100	2150
low income	1.8	2.3	3.2	4.4	5.2	5.2
China	1.1	1.3	1.6	1.8	1.9	1.9
mid income	1.5	1.7	2.2	2.9	3.3	3.3
high income	0.8	0.9	0.9	0.9	0.9	0.9
WORLD	5.3	6.2	7.9	10	11.3	11.3

Per Capita GDP (1990 US $)

	1990	2000	2020	2050	2100	2150
low income	346	366	776	3,306	29,838	94,235
China	275	628	1,707	6,920	37,882	######
mid income	2,731	2,752	5,827	17,504	47,581	######
high income	#####	#####	#####	55,382	91,309	######
WORLD	4,514	4,877	6,685	12,932	41,411	######

Per Capita GDP Growth Rates (% per year)

	1990	2000	2020	2050	2100	2150
low income	-0.08	3.5	4.5	5	3	1.5
China	11.7	5	5	4	3	1.5
mid income	-1.3	3.5	4	2	2	1.5
high income	1	1.8	1.4	1.1	0.8	0.8
WORLD	0.11	1.5	2	2.1	2.3	1.4

Ratio of Per Capita Incomes of High Income Countries to Others

	1990	2000	2020	2050	2100	2150
low income	66	73	48	17	3	1.4
China	83	42	22	8	2	1.3
mid income	8	10	6	3	2	1.2
high income	1	1	1	1	1	1

Total Energy Use (TW)

	1994	2000	2020	2050	2100	2150
low income	0.64	0.78	1.7	5.5	24.1	51
China	1.1	1.6	3.9	10.3	23.7	45.3
mid income	3.5	4.1	8.2	17.6	22.2	36.6
high income	6.2	7.1	6.1	4	3.5	3.5
WORLD	11.5	13.6	19.9	37.4	73.4	136.4

DISTRIBUTION OF INCOME

(values shown are per capita incomes for each population quintile, in '90 US $

Low Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	106	113	243	1031	9273	29742
middle 20%	251	267	559	2317	20097	62934
top 20%	827	876	1817	7425	63097	194789

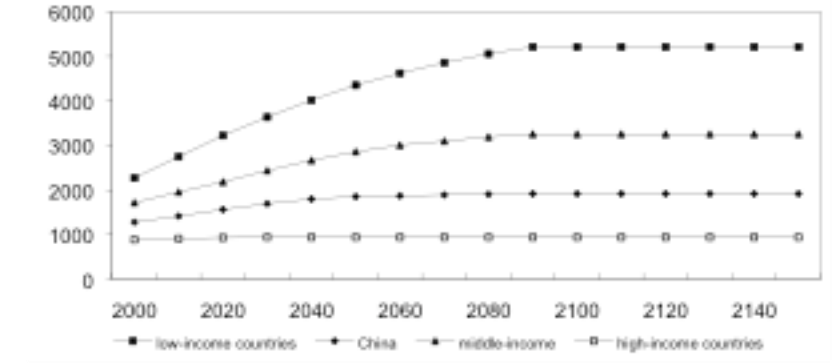
China	1994	2000	2020	2050	2100	2150
bottom 20%	136	194	523	2092	11385	32163
middle 20%	346	491	1306	5139	27413	77446
top 20%	962	1363	3601	14079	74430	210274

Middle Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	828	887	1913	5882	16035	39120
middle 20%	1911	2032	4266	12657	34147	83306
top 20%	6135	6495	13441	39083	104787	255643

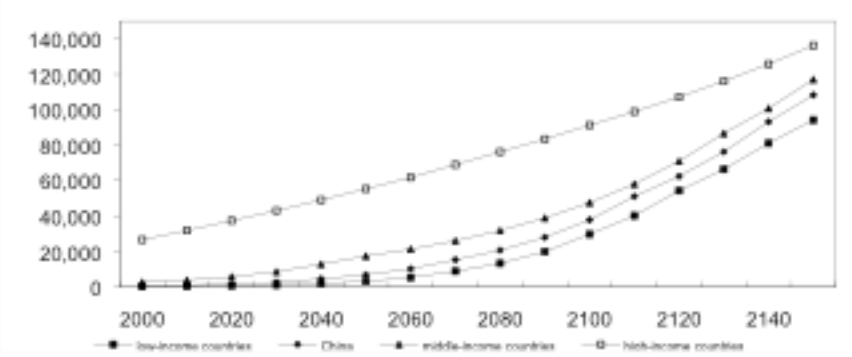
High Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	7373	8303	11632	17137	28184	41978
middle 20%	20475	23058	32303	47590	78267	116575
top 20%	48135	54208	75941	111881	183999	274058

BOX IA-15. SCENARIO 2 - POPULATION AND ECONOMY TRAJECTORIES

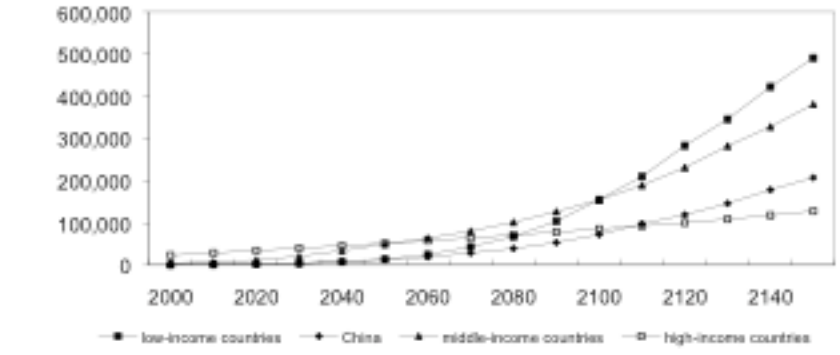
population (millions)



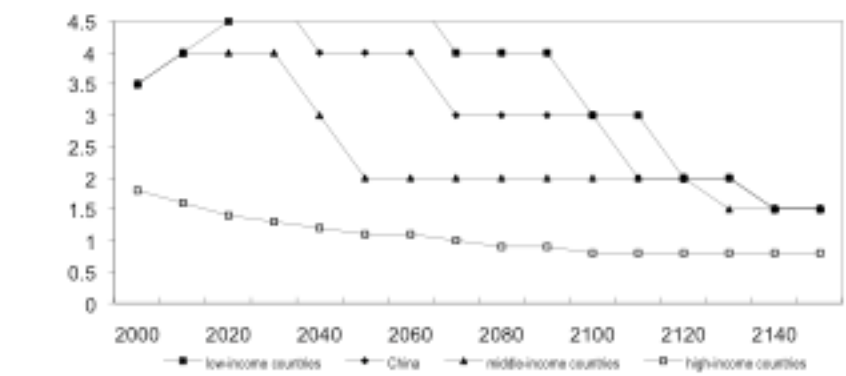
per capita GDP (1990 US $)



Total GDP (billion 1990 US $)

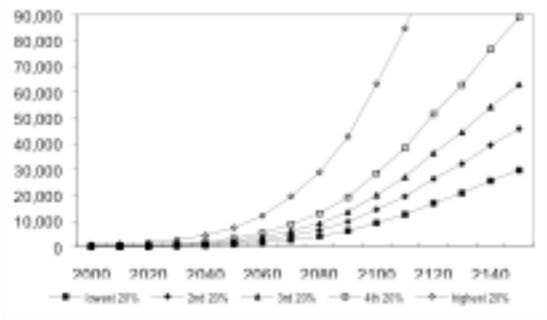


Per Capita GDP Growth Rates (%/yr)

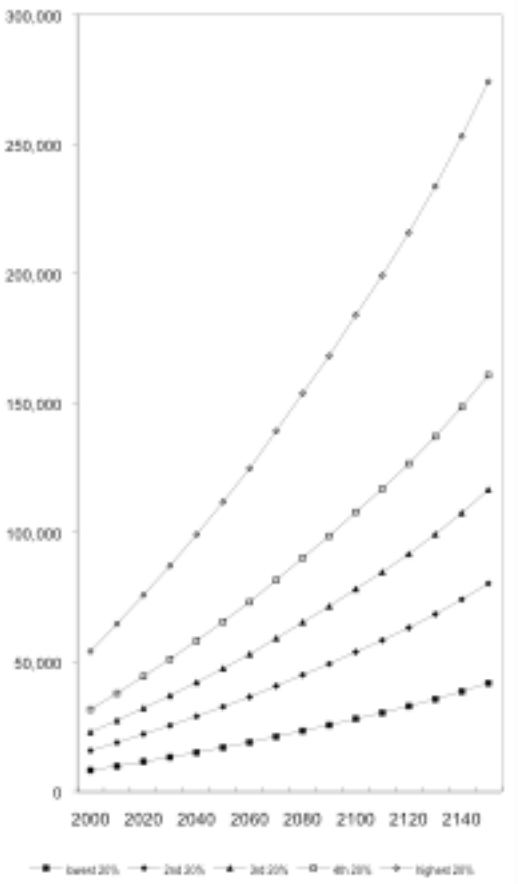


BOX IA-16. SCENARIO 2 - INCOME DISTRIBUTION TRAJECTORIES
[All values 1990 US $; all vertical axes to same scale]

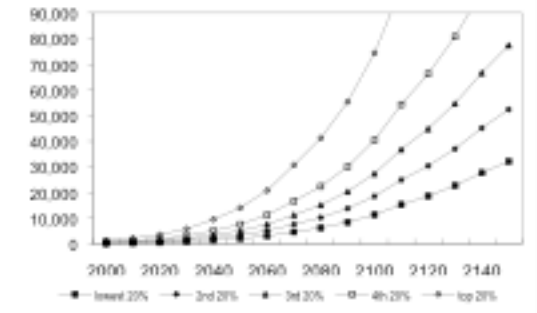
LOW-INCOME COUNTRIES
mean per capita income by quintile



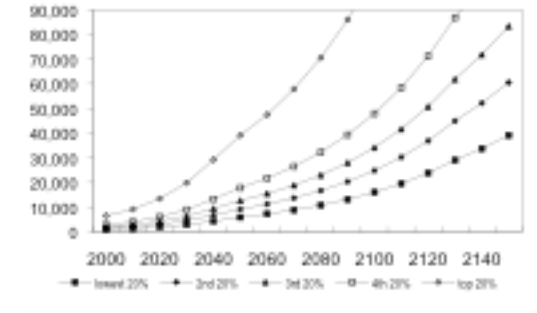
HIGH-INCOME COUNTRIES
mean per capita income by quintile



CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



Under Scenario 2 the quintile income shares in each sector are unchanged from their Scenario 1 values. However, the absolute difference between quintiles in the three developing country sectors increases markedly, as seen in **IA-16**. In the low income countries, for example, the absolute difference between the highest and lowest quintile in 2150 was $21,600 in Scenario 1 but $165,000 in Scenario 2.

Scenario 2 represents the conventional responses to the challenge of economic inequality among nations--"increase per capita incomes in the developing countries"--and of environmental sustainability--"increase the efficiency of resource use." The results are encouraging in some ways but disconcerting in others. We've come very close to our goal of eliminating economic inequality among the countries of the world. The distribution of income within the developing countries has improved, but is unchanged in the high-income countries and still far from our goal. Total energy use is still 4.5 times higher than our goal of 30 TW, despite considerable improvements in energy efficiency.

Scenario 3:

a) faster growth in developing countries
b) *maximum practicable* energy efficiency
c) slower population growth
d) slower growth in high income countries

Scenario 3 modifies Scenario 2 by assuming that population will stabilize in mid-century at 9 billion rather than at 11 billion.[8] Scenario 3 also assumes that per capita GDP growth in the high and middle income countries slows at rates sufficient to allow the low income countries to catch up by 2150. Energy intensity declines along the "maximum practicable" energy efficiency path, shown in Figure 2 of IA-12 and described further in Appendix Box A2-7.

[8] A stable world population of 9 billion in the second half of the next century is the low projection made by IIASA (1994).

Results for Scenario 3 are shown in **IA-17, IA-18** and **IA-19**. Per capita GDP in 2150 is $82,000, in all four sectors. For the high income countries this is 40% less than they would have been realized under Scenario 2, but it is still 3.4 times the income they received in 1994.

In Scenario 3 energy use in 2150 is 61 TW. This is a dramatic improvement over the 136 TW of Scenario 2 but still double our goal of 30 TW.

Scenario 4:

a) faster growth in developing countries
b) maximum practicable energy efficiency
c) slower population growth
d) slower growth in high income countries
e) greater income equality within countries

In Scenario 4 we keep the per capita GDP growth and energy-efficiency improvement rates used in Scenario 3, but also model a reduction of income inequality within each of our four country sectors, using the procedure explained in IA-11.[9] Our goal is to reduce the 80/20 ratio of the high income countries, currently 6.5, to 2.5 by 2150. As noted earlier, the developing countries will approach the 80/20 level of the high income countries at a rate proportionate to the convergence of their per capita incomes. We make the simplifying assumption that the rate of growth of per capita GDP is invariant to changes in the distribution of income within the ranges shown in this exercise.[10]

Boxes IA-20 and **IA-21** shows how Scenario 4 compresses the quintile distributions in all four country sectors. In Scenario 3 the mean incomes of the top and bottom quintiles of the high income countries in 2150 are $164,000 and $25,000 (a ratio of 6.5 to 1) but in Scenario 4 these are $126,000 and $50,000 (a ratio of 2.5 to 1). In Scenario 3 all quintiles in each sector grow at

[9] At this point the cause of this improvement in the distribution of income need not be specified. It could be the result of policies of direct redistribution of income from high to low quintiles, of greater support for education and training of low income workers, of market forces unaccounted for in Scenario 1, or of other causes.

[10] The important topic of the relation between levels and rates of economic growth and economic inequality is discussed at length in Section II.B.2. The discussion there supports the simplifying assumption used here.

BOX IA-17. SCENARIO 3 - SUMMARY TABLES

Population (10^9 persons)

	1990	2000	2020	2050	2100	2150
low income	1.8	2.3	3.2	3.9	3.9	3.9
China	1.1	1.3	1.5	1.8	1.8	1.8
mid income	1.5	1.7	2.2	2.5	2.5	2.5
high income	0.8	0.9	0.9	0.9	0.9	0.9
WORLD	5.3	6.2	7.8	9	9	9

Per Capita GDP (1990 US $)

	1990	2000	2020	2050	2100	2150
low income	346	366	776	3,306	32,976	82,747
China	275	628	1,707	6,920	39,035	80,196
mid income	2,731	2,752	5,827	17,504	52,585	82,470
high income	#####	#####	#####	49,119	63,070	80,984
WORLD	4,514	4,877	6,598	12,587	42,605	81,991

Per Capita GDP Growth Rates (% per year)

	1990	2000	2020	2050	2100	2150
low income	-0.08	3.5	4.5	5	3.3	0.5
China	11.7	5	5	4	3	0.5
mid income	-1.3	3.5	4	3	1.5	0.5
high income	1	1.7	1.2	0.5	0.5	0.5
WORLD	0.11	1.4	1.9	2.5	2.3	0.5

Ratio of Per Capita Incomes of High Income Countries to Others

	1990	2000	2020	2050	2100	2150
low income	66	73	47	15	2	1
China	83	42	22	7	1.6	1
mid income	8	10	6	3	1.2	1
high income	1	1	1	1	1	1

Total Energy Use (TW)

	1994	2000	2020	2050	2100	2150
low income	0.64	0.78	1.7	4.2	13.9	23.4
China	1.1	1.6	3.9	8.4	15.8	21.8
mid income	3.5	4.1	8.1	13.1	13.1	13.7
high income	6.2	7.1	5.9	3.5	2.3	2
WORLD	11.5	13.6	19.6	29.2	45.1	60.9

DISTRIBUTION OF INCOME

(values shown are per capita incomes for each population quintile, in '90 US $)

Low Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	106	113	243	1031	10203	26083
middle 20%	251	267	559	2317	22155	55191
top 20%	827	876	1817	7425	69435	170822

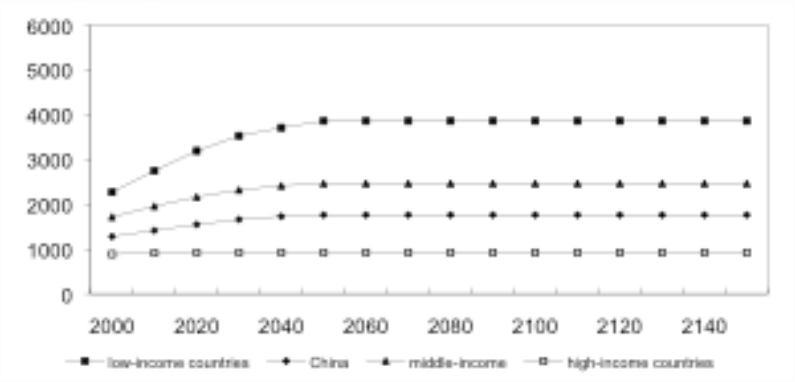
China	1994	2000	2020	2050	2100	2150
bottom 20%	136	194	523	2092	11720	23903
middle 20%	346	491	1306	5140	28222	57556
top 20%	962	1363	3601	14079	76627	156272

Middle Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	828	887	1913	5882	17676	27656
middle 20%	1911	2032	4266	12657	37645	58900
top 20%	6135	6495	13441	39083	115530	180761

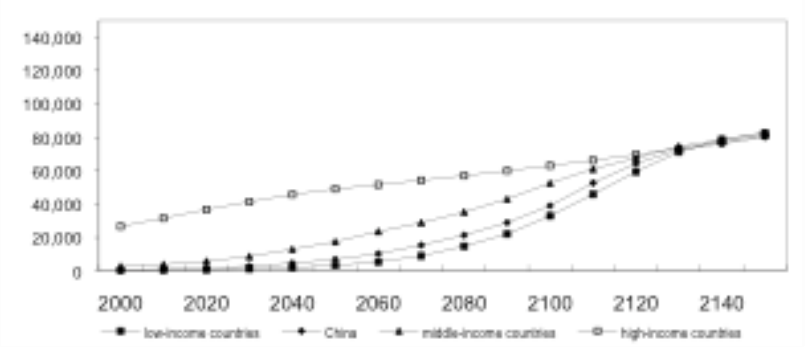
High Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	7373	8303	11405	15220	19531	25063
middle 20%	20475	23058	31673	42268	54239	69601
top 20%	48135	54208	74462	99368	127511	163626

BOX IA-18. SCENARIO 3 - POPULATION AND ECONOMY TRAJECTORIES

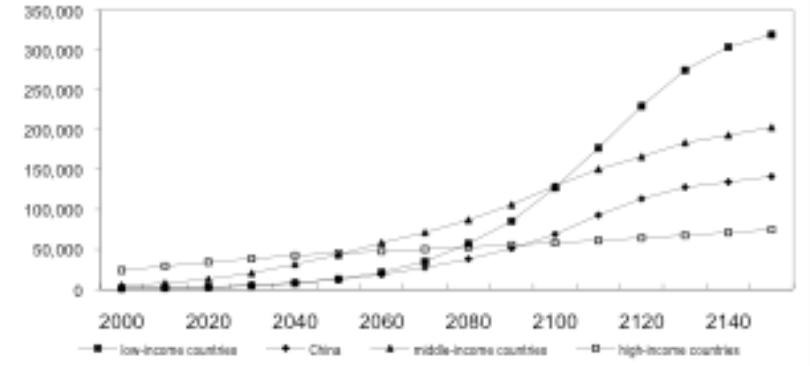
population (millions)



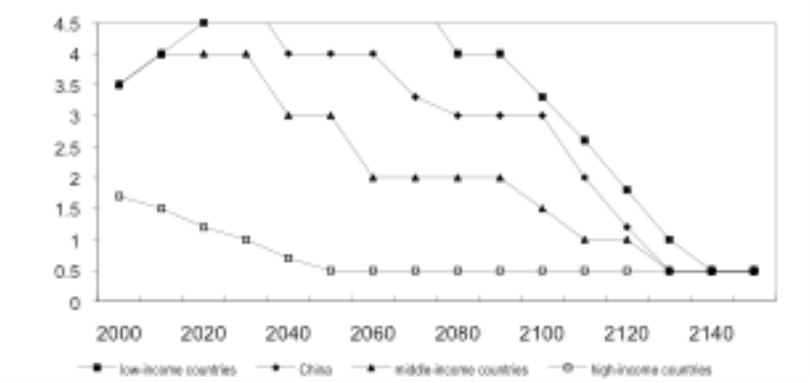
per capita GDP (1990 US $)



Total GDP (billion 1990 US $)



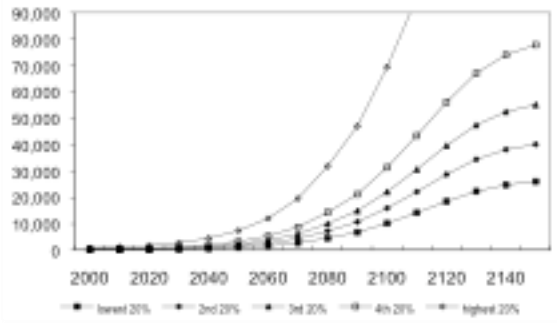
Per Capita GDP Growth Rates (%/yr)



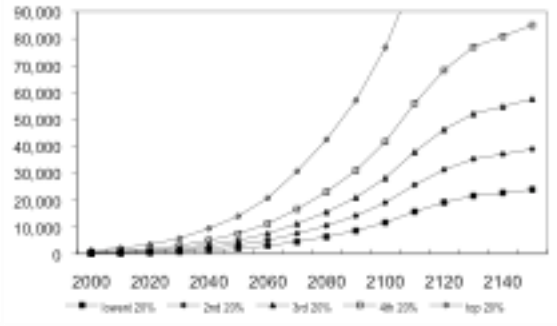
BOX IA-19. SCENARIO 3 - INCOME DISTRIBUTION TRAJECTORIES

[All values 1990 US $; all vertical axes to same scale]

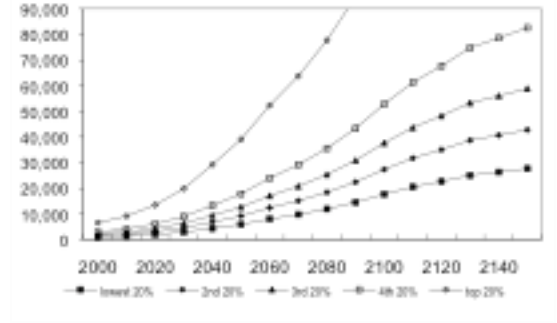
LOW-INCOME COUNTRIES
mean per capita income by quintile



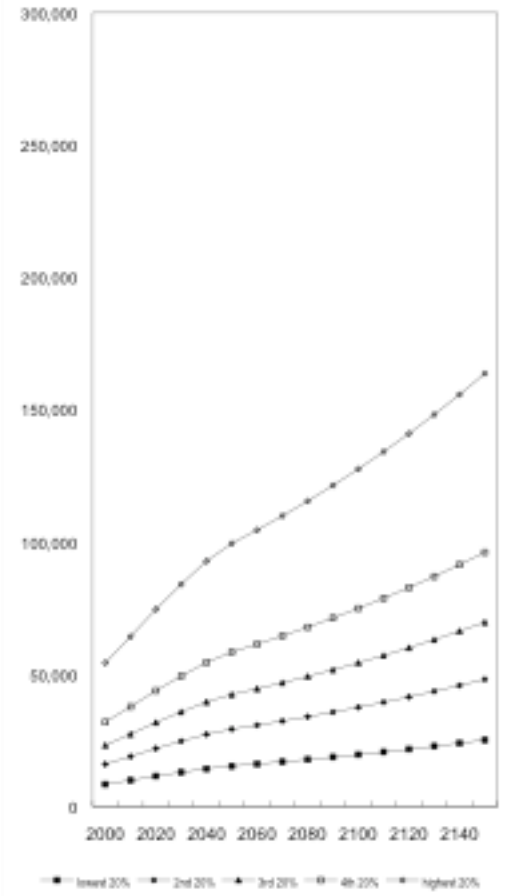
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



HIGH-INCOME COUNTRIES
mean per capita income by quintile



BOX IA-20. SCENARIO 4 - SUMMARY TABLES

[note: Scenario 4 differs from Scenario 3 only in the distribution of income]

Population (10^9 persons)

	1990	2000	2020	2050	2100	2150
low income	1.8	2.3	3.2	3.9	3.9	3.9
China	1.1	1.3	1.5	1.8	1.8	1.8
mid income	1.5	1.7	2.2	2.5	2.5	2.5
high income	0.8	0.9	0.9	0.9	0.9	0.9
WORLD	5.3	6.2	7.8	9	9	9

Per Capita GDP (1990 US $)

	1990	2000	2020	2050	2100	2150
low income	346	366	776	3,306	32,976	82,747
China	275	628	1,707	6,920	39,035	80,196
mid income	2,731	2,752	5,827	17,504	52,585	82,470
high income	22,742	26,689	36,754	49,119	63,070	80,984
WORLD	4,514	4,877	6,598	12,587	42,605	81,991

Per Capita GDP Growth Rates (% per year)

	1990	2000	2020	2050	2100	2150
low income	-0.08	3.5	4.5	5	3.3	0.5
China	11.7	5	5	4	3	0.5
mid income	-1.3	3.5	4	3	1.5	0.5
high income	1	1.7	1.2	0.5	0.5	0.5
WORLD	0.11	1.4	1.9	2.5	2.3	0.5

Ratio of Per Capita Incomes of High Income Countries to Others

	1990	2000	2020	2050	2100	2150
low income	66	73	47	15	2	1
China	83	42	22	7	1.6	1
mid income	8	10	6	3	1.2	1
high income	1	1	1	1	1	1

Total Energy Use (TW)

	1994	2000	2020	2050	2100	2150
low income	0.64	0.78	1.7	4.2	13.9	23.4
China	1.1	1.6	3.9	8.4	15.8	21.8
mid income	3.5	4.1	8.1	13.1	13.1	13.7
high income	6.2	7.1	5.9	3.5	2.3	2
WORLD	11.5	13.6	19.6	29.2	45.1	60.9

DISTRIBUTION OF INCOME

(values shown are per capita incomes for each population quintile, in '90 US $)

Low Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	106	113	265	1365	16843	49448
middle 20%	251	267	568	2448	24723	64369
top 20%	827	876	1773	6751	56028	123640

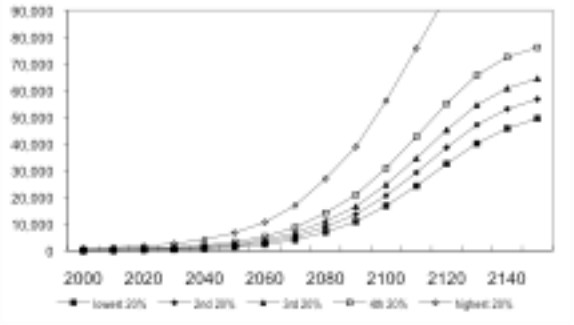
China	1994	2000	2020	2050	2100	2150
bottom 20%	136	194	566	2740	19327	46749
middle 20%	346	491	1319	5337	30543	64526
top 20%	962	1363	3526	12956	63444	116673

Middle Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	828	887	2065	7545	28439	52382
middle 20%	1911	2032	4325	13299	41804	68448
top 20%	6135	6495	13136	35743	93916	131108

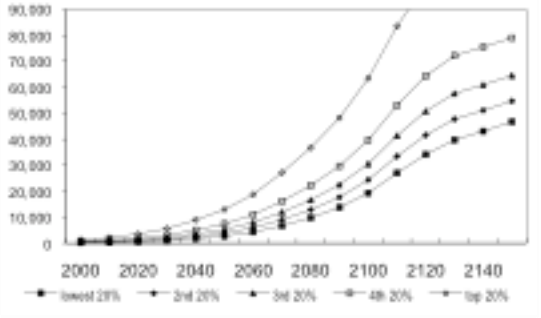
High Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	7373	8303	12382	20154	33266	50280
middle 20%	20475	23058	31865	43265	56931	74544
top 20%	48135	54208	72996	91961	106892	125769

BOX IA-21. SCENARIO 4 - INCOME DISTRIBUTION TRAJECTORIES
[All values 1990 US $; all vertical axes to same scale]

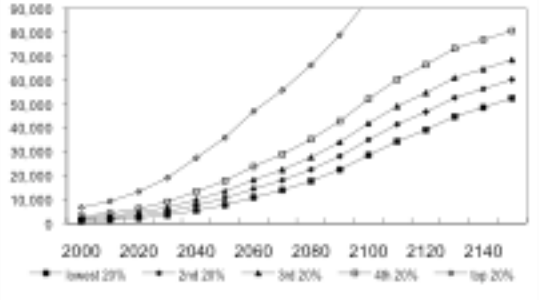
LOW-INCOME COUNTRIES
mean per capita income by quintile



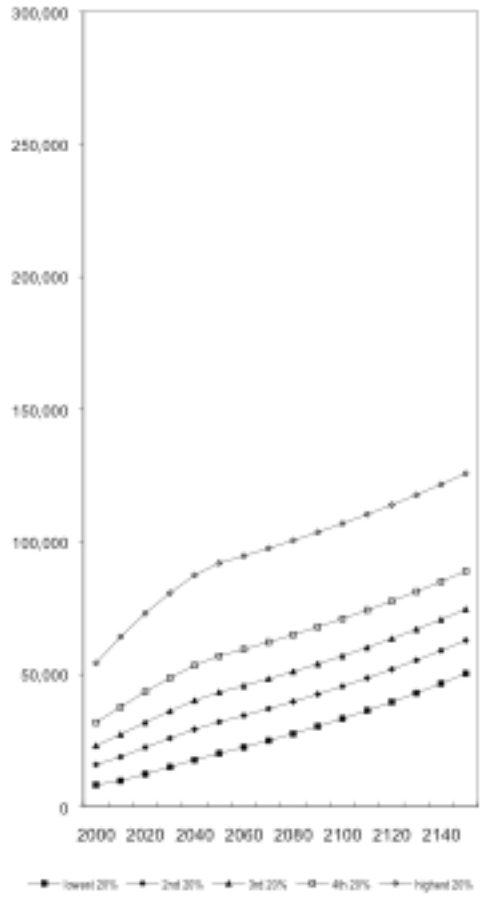
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



HIGH-INCOME COUNTRIES
mean per capita income by quintile



the same rate, but in Scenario 4 the higher income quintiles grow more slowly and the lower income quintiles grow more rapidly. For example, in Scenario 3 the growth rate of per capita income at the end of our study is 0.5% for all quintiles, but in Scenario 4 the rates are 0.76% for the lowest quintile and 0.63%, 0.54%, 0.46%, and 0.33% for the others, in ascending order.

Scenario 5:

a) faster growth in developing countries
b) maximum practicable energy efficiency
c) slower population growth
d) slower growth in high income countries
e) greater income equality within countries
f) zero output growth by 2150

In Scenario 4 we found that we are able to meet most of the conditions for a desirable world that we specified at the beginning of this exercise, at least through the year 2150.

However, we were not able to reach our goal of stabilizing energy use at 30 TW – the best we could do was 61 TW.

Scenario 5 models a world in which energy use can be sustained at about 30 TW after 2150. To achieve this we increase the rate of decline of the growth rate of income of the high income countries, such that by 2050 it reaches zero. The developing countries continue to grow for the rest of the century in order to achieve economic equality, but later in the century growth in these countries begins to slow as well, and zero economic growth is reached by 2150 or earlier. No other modifications of Scenario 4 are made.

Boxes IA-22, IA-23 and **IA-24** show the results. World energy use stabilizes at 33 TW, which is close enough, for the purposes of this exercise, to our goal of 30 TW. Per capita income stabilizes at $45,000. This is certainly less than the $106,000 we achieved in Scenario 2, but it is still 10 times the current world per capita income figure of $4,500, and indeed twice as much as the current per capita income of the top quintile in the high income countries ($23,671). Per capita income is the same in all four sectors. Within countries the 80/20 ratio is 2.5 to 1. Per

BOX IA-22. SCENARIO 5 - SUMMARY TABLES

Population (10^9 persons)

	1990	2000	2020	2050	2100	2150
low income	1.8	2.3	3.2	3.9	3.9	3.9
China	1.1	1.3	1.5	1.8	1.8	1.8
mid income	1.5	1.7	2.2	2.5	2.5	2.5
high income	0.8	0.9	0.9	0.9	0.9	0.9
WORLD	5.3	6.2	7.8	9	9	9

Per Capita GDP (1990 US $)

	1990	2000	2020	2050	2100	2150
low income	346	366	775	3,306	22,551	44,513
China	275	628	1,706	6,920	29,799	45,352
mid income	2,731	2,752	5,827	17,504	40,546	44,809
high income	#####	#####	#####	44,892	44,892	44,892
WORLD	4,514	4,877	6,345	12,154	31,177	44,797

Per Capita GDP Growth Rates (% per year)

	1990	2000	2020	2050	2100	2150
low income	-0.08	3.5	4.5	5	2.8	0
China	11.7	5	5	4	1.7	0
mid income	-1.3	3.5	4	3	0.5	0
high income	1	1.4	1.1	0	0	0
WORLD	0.11	1.2	1.9	2.4	1.4	0

Ratio of Per Capita Incomes of High Income Countries to Others

	1990	2000	2020	2050	2100	2150
low income	66	73	45	14	2	1
China	83	42	20	6	1.5	1
mid income	8	10	6	3	1	1
high income	1	1	1	1	1	1

Total Energy Use (TW)

	1990	2000	2020	2050	2100	2150
low income	0.64	0.78	1.7	4.2	9.5	12.6
China	1.1	1.6	3.9	8.4	12.1	12.3
mid income	3.5	4.1	8.1	13.1	10.1	7.5
high income	6.2	7.1	5.5	3.2	1.7	33.5
WORLD	11.5	13.6	19.2	28.9	33.3	35.2

DISTRIBUTION OF INCOME

(values shown are per capita incomes for each population quintile, in '90 US $)

Low Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	106	113	264	1365	11708	27147
middle 20%	251	267	568	2448	17168	35298
top 20%	827	876	1773	6751	38856	67681

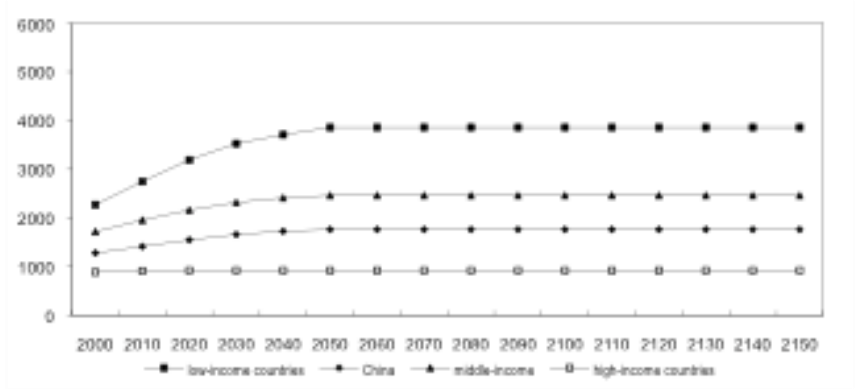
China	1994	2000	2020	2050	2100	2150
bottom 20%	136	194	566	2740	14881	26793
middle 20%	346	491	1319	5337	23497	36938
top 20%	962	1363	3526	12956	48770	66697

Middle Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	828	887	2065	7545	22034	28877
middle 20%	1911	2032	4325	13299	32364	37431
top 20%	6135	6495	13136	35743	72653	71577

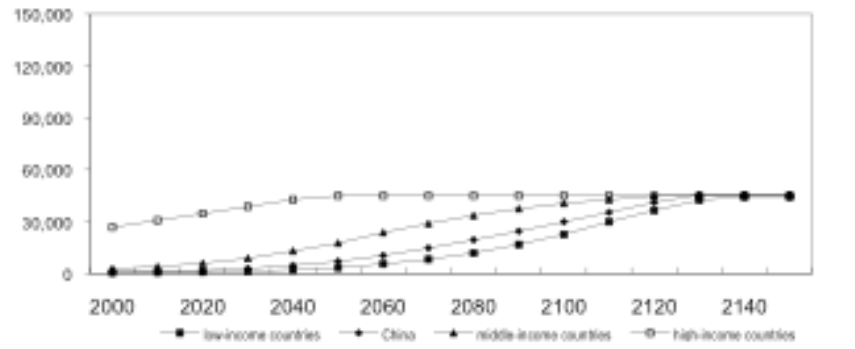
High Income Countries	1994	2000	2020	2050	2100	2150
bottom 20%	7373	8303	11673	18445	23747	27987
middle 20%	20475	23058	30035	39558	40597	41427
top 20%	48135	54208	68800	84129	76170	69818

BOX IA-23. SCENARIO 5 - POPULATION AND ECONOMY TRAJECTORIES

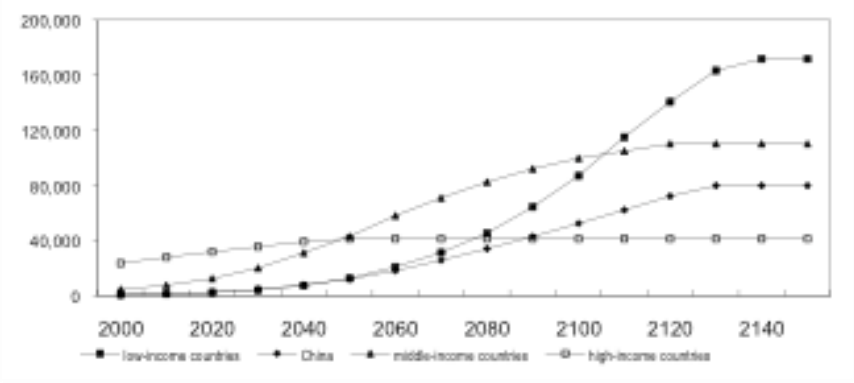
population (millions)



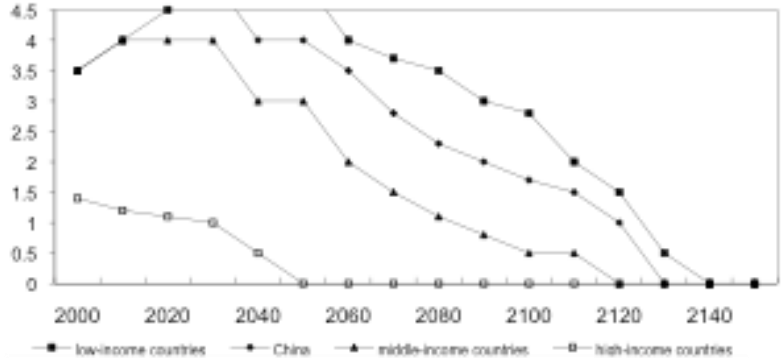
per capita GDP (1990 US $)



Total GDP (billion 1990 US $)



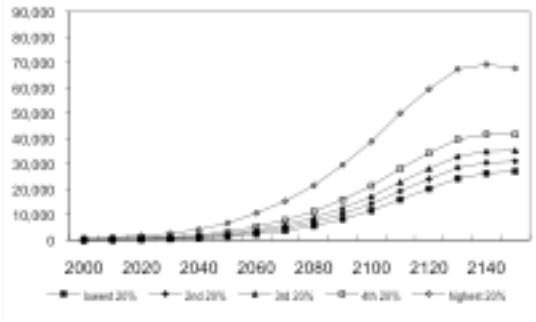
Per Capita GDP Growth Rates (%/yr)



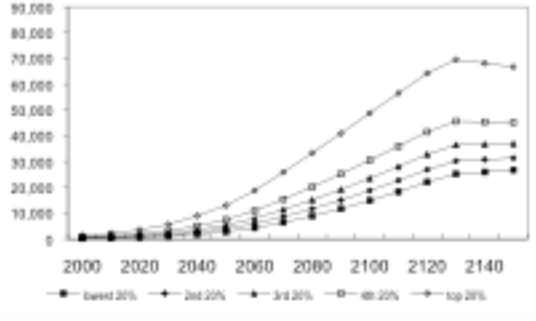
BOX IA-24. SCENARIO 5 - Income Distribution Trajectories

[All values 1990 US $; all vertical axes to same scale]

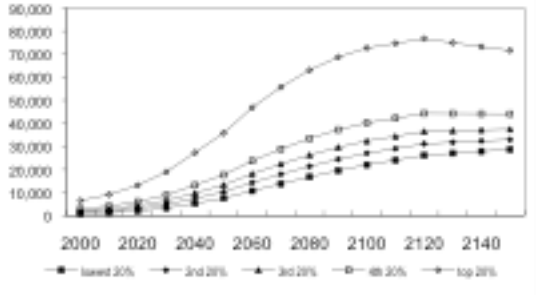
LOW-INCOME COUNTRIES
mean per capita income by quintile



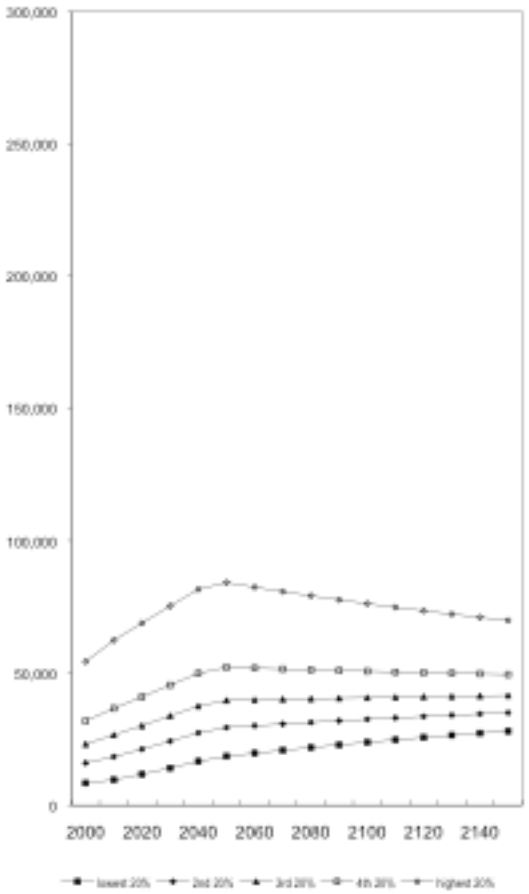
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



HIGH-INCOME COUNTRIES
mean per capita income by quintile



capita income for the top quintile in all sectors is about $70,000 and for the bottom quintile about $28,000.

It is important to note that in this scenario the top income quintile undergoes an absolute reduction of income, not just a relative one. In the high income countries this begins in 2050, when per capita incomes in the top quintile are $84,000, and declines to $70,000 by 2150, a decrease of 17%. In the developing countries this decline doesn't begin until the final decades before 2150, and is proportionately much smaller. This absolute reduction in top quintile incomes is an arithmetic necessity if we desire both a level of output consistent with a 30 TW world *and* distributional equity of the degree reflected in an 80/20 ratio of 2.5 to 1. Note that during the period that the incomes of the top quintile in the high income countries are declining, those of the lower quintiles are still increasing. This is precisely the relation that we would expect if distributional equity is increasing at the same time that per capita output growth has come to an end.

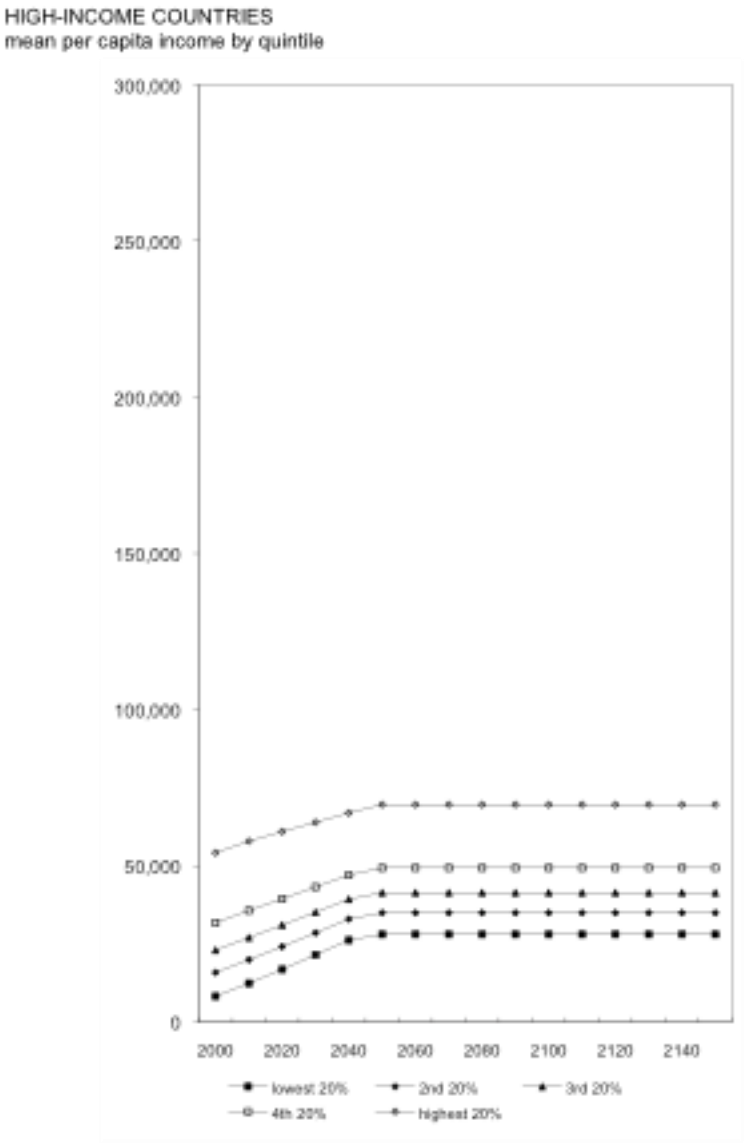
Is it realistic to expect that upper quintile households would agree to the protracted reduction in their absolute levels of income shown in Scenario 5? I don't know.[11] Is there any way that this feature of Scenario 5 could be avoided? Yes, but there is trade-off. **IA-25** displays the high-income country income growth trajectories for Scenario 6, which achieves all of the same final goals that Scenario 5 does but does so without requiring that the top income quintiles undergo any absolute reduction of income.[12] We see that in order for this to happen, the gap between the top and bottom quintiles must be reduced much more rapidly than in Scenario 5. Rather than wait until 2050 for significant redistributive policies to come into force, they would

[11] We discuss public opinion and values concerning economic inequality, well-being and growth at length in Sections II.B.4 and II.C.3.

[12] Under Scenario 6 the per capita GDP growth trajectories for the low income countries, China and the middle income countries are very similar to those shown in Box IA-24, except that the final per capita income level of the top quintile--$70,000—is approached and achieved monotonically, in the final two or three decades before 2150.

BOX IA-25. SCENARIO 6 - INCOME DISTRIBUTION TRAJECTORIES

[All values 1990 US $]



need to be in effect in the very first decades of the 21st century, and we would need to have achieved our stated distributive goals (for the high income countries) by 2050, not 2150.

Scenarios 5 and 6 end in 2150 with steady-state levels of both resource use and per capita GDP. It might be objected that continued efficiency gains, beyond the 500% improvement already assumed, could allow per capita GDP to continue to grow, even while resource throughput remains constant. This is true. But if we showed such growth, the objection could be raised that we were simply refusing to acknowledge that there must be *some* limit to the ability of a constant flow of resources to generate increasingly greater quantities of output, and that by doing so we were avoiding having to deal with the profound social and political implications of any scenarios that call for a steady-state level of resource use. This tension is a set-piece of the growth/environment discourse, and is irresolvable analytically. The critical questions involve our expectations and values concerning the nature of technological change. These topics are discussed at length in Section II.A.3, in Section II.E, and throughout the text. For the time being we leave Scenarios 5 and 6 with steady-state levels of both throughput and output, for the express purpose of forcing us to engage the social and political challenges that such scenarios present.

I.A.4. ASSESSMENT

The purpose of this exercise was to find out what it would take to achieve a 30 TW world in which inequality among countries has been eliminated and inequality within countries has been reduced to the level represented by an 80/20 ratio of 2.5, within the next 150 years.

We found that such a world could be achieved if energy efficiency improves along the maximum practicable path shown in Figure 2 of IA-12, if population stabilizes at 9 rather than 11 billion, if the low income countries grow at per capita rates of 4-5% for most of this century and then reduce their growth rates to zero over the following half century, if the high income countries are willing to reduce their rate of economic growth to zero by the middle of this century, and if households in the top income quintile of the high income countries are willing to

undergo an absolute reduction of their incomes of 17% over the century beginning in 2050. The more rapidly income inequality is reduced, the more easily the top income quintile in the high income countries will be able to avoid an absolute income decline.

Clearly, this exercise is the beginning of an inquiry, not the end. Are the assumptions concerning energy efficiency improvements and population growth too pessimistic, or maybe too optimistic? What would it take, practically, for the lower income countries to achieve the high growth rates shown in Scenario 5?

In our exercise, energy use served as a proxy for a wide range of threats to the environment. How might a fuller analysis of potential environmental dangers change our results? Are there biogeophysical limits that might enforce an end to economic growth, perhaps catastrophically? If so, are these limits close enough to motivate important changes in our lives, or are they so distant that we can afford some period, perhaps a very long period, of conventional output growth?

Are there limits to the ability of technology to generate, decade after decade, the product and efficiency innovations that enable output to grow? If there are, then economic growth would slow to a stop on its own accord. How close to or far from such limits might we be?

How credible is our assumption that there is little dynamic relation between economic growth and economic inequality? This assumption cries out for more study. If continued growth tends to generate greater inequality then our desires to protect the environment and to ensure economic justice could reinforce one another. If continued growth tends to generate greater equality then these desires may be in conflict. But the degree of economic inequality might itself have an impact—either positive or negative--on the rate of economic growth. In that event the question of how the several values we are juggling might reinforce one another, or work against one another, becomes very complicated.

Finally, what would it take for the high income countries to agree to bring their economic growth to an end within the next 50 years, and for the top 20% of income earners to agree to a

reduction of their incomes? What would it take for all of humankind to agree to stable incomes as of 2150?

These are just a few of the questions that we try to provide answers for in Section II of this exercise. But before we do that, we need to expand and enrich the quantitative scenarios developed in this section by considering a number of important political, social and cultural factors that bear on our concerns for economic well-being, ecological integrity and social equity.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	BOX IA-26. MODEL A SCENARIO 1 - REFERENCE SCENARIO - FULL PRINT-OUT (PART 1)																					
2																						
3																						
4					1990	1995	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
5																						
6	POPULATION GROWTH (%/yr)																					
7	low-income countries				2.17	2.2	1.9	1.6	1.2	1	0.8	0.6	0.5	0.4	0.3	0	0	0	0	0	0	0
8	China				1.2	1.2	1	1	0.8	0.6	0.3	0.1	0.1	0.08	0.06	0	0	0	0	0	0	0
9	middle-income countries				1.5	1.5	1.3	1.1	1.1	0.9	0.7	0.5	0.3	0.3	0.2	0	0	0	0	0	0	0
10	high-income countries				0.7	0.7	0.3	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
11																						
12	world				1.541568	1.5722	1.329689	1.169263	0.969477	0.799845	0.600003	0.424947	0.327233	0.261325	0.205123	0	0	0	0	0	0	
13																						
14	POPULATION (10^6)																					
15	low-income countries				1826	1991	2271.947	2747.351	3234.046	3635.151	4017.408	4352.007	4621.12	4858.55	5056.31	5210.298	5210.298	5210.298	5210.298	5210.298	5210.298	5210.298
16	China				1135	1191	1279.915	1414.524	1563.291	1693.493	1798.213	1852.977	1871.599	1880.409	1905.593	1917.061	1917.061	1917.061	1917.061	1917.061	1917.061	1917.061
17	middle-income countries				1479	1570	1717.854	1956.36	2183.82	2437.75	2687.324	2885.727	3007.399	3098.988	3193.366	3257.877	3257.877	3257.877	3257.877	3257.877	3257.877	3257.877
18	high-income countries				827	850	886.4603	913.457	931.9101	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276
19																						
20	world				5267	5602	6156.175	7031.672	7903.067	8707.621	9424.221	10006.99	10441.39	10788.72	11096.55	11326.51	11326.51	11326.51	11326.51	11326.51	11326.51	11326.51
21																						
22	PER CAPITA GDP																					
23	GROWTH RATE (%/yr)																					
24	low-income countries				-0.08	1	1.9	2.3	2.6	2.8	2.9	3	2.9	2.7	2.5	2.3	2.1	1.9	1.7	1.5	1.4	1.3
25	China				11.7	6	4	3.6	3.4	3.2	3.1	3	2.9	2.7	2.5	2.3	2.1	1.9	1.7	1.5	1.4	1.3
26	middle-income countries				-1.3	1	1.9	2	2.1	2.2	2.1	2	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1	1	1
27	high-income countries				1	2	1.8	1.6	1.4	1.3	1.2	1.1	1.1	1	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
28																						
29	world				0.106173	1.215774	1.089686	1.045744	1.092993	1.17929	1.248092	1.384691	1.448196	1.397857	1.339495	1.480748	1.38442	1.242182	1.169256	1.087324	1.061745	
30																						
31	PER CAPITA GDP ($/k)																					
32	low-income countries				346	345	366.3336	442.9888	557.5457	723.0978	956.7522	1278.63	1725.97	2306.634	3021.608	3879.821	4883.143	6034.227	7284.794	8634.701	10032.09	11539.65
33	China				275	436	627.7883	936.5665	1.342.406	1886.51	2597.277	3541.193	4780.11	6388.271	8368.408	10745.25	13523.97	16684.22	20175.39	23913.99	27784.09	31959.31
34	middle-income countries				2731	2592	2752.28	3328.194	4065.065	5014.982	6249.052	7709.318	9416.183	11386.52	13496.49	15680.69	18037.08	20541.14	23160.07	25853.08	28572.07	31577.02
35	high-income countries				22742	23671	26988.98	31952.51	37486.62	43131.37	49119.23	55381.78	61821.47	68509.95	76267.79	83450.25	91309.12	98913.99	107152.2	116076.6	125744.3	136217.2
36																						
37	world				4514.524	4533.738	4876.819	5438.274	6037.779	6735.052	7578.04	8624.989	9805.923	11449.57	13197.45	15048.74	17311.47	19723.51	22332.2	25102.19	27985.53	31120.35
38																						
39	GDP GROWTH RATE (%/yr)																					
40	low-income countries				2.09	3.2	3.8	3.9	3.8	3.8	3.7	3.6	3.4	3.1	2.8	2.3	2.1	1.9	1.7	1.5	0.5	1.3
41	China				12.9	7.2	5	4.6	4.2	3.8	3.4	3.1	3	2.78	2.56	2.3	2.1	1.9	1.7	1.5	1.4	1.3
42	middle-income countries				0.2	2.5	3.2	3.1	3.2	3.1	2.8	2.5	2.2	2	1.7	1.4	1.3	1.2	1.1	1	1	1
43	high-income countries				1.7	2.7	2.1	1.8	1.5	1.3	1.2	1.1	1.1	1	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
44																						
45	world				1.647741	2.787974	2.419375	2.214007	2.09237	1.978135	1.894095	1.809638	1.775429	1.679282	1.549587	1.480748	1.38442	1.242182	1.169256	1.087324	1.061745	
46																						
47	GDP (10^9 $)																					
48	low-income countries				631	686	832.2904	1217.045	1797.553	2628.534	3843.664	5564.606	7975.913	11205.74	15278.19	20215.03	25442.63	31388.02	37955.95	44889.37	53270.19	601 25.03
49	China				312	522	803.5281	1324.794	2098.572	3193.945	4670.457	6561.747	8949.451	12079.45	15946.78	20599.3	25926.27	31984.68	38977.46	47844.58	53263.8	61247.96
50	middle-income countries				4038	4070	4728.015	6511.08	8877.37	12225.27	16868.24	22054.25	28318.22	35286.67	43099.24	51085.74	58762.59	66920.5	75462.66	84226.15	93084.29	102874
51	high-income countries				18797	20120	23998.72	29187.24	34943.47	40998.53	46234.75	52129.54	58191.94	64957.4	71789.03	78549.72	85947.88	93105.36	100859.8	109090.2	118360.1	128218
52																						
53	world				23778	25396	30022.55	38248.16	47716.97	59946.28	71417.12	86310.14	103431.4	123526.3	146113.2	170449.8	199078.6	223398.6	252465.9	284320.2	316978.4	352485
54																						
55	RATIO OF HIGH-INCOME PER CAPITA																					
56	GDP TO THAT OF OTHER COUNTRIES																					
57	low-income countries				65.72832	68.61159	72.8543	72.12699	67.25099	59.64805	51.33956	43.31338	35.81839	29.91854	25.24079	21.50879	18.69884	16.41937	14.78903	13.44354	12.53421	11.80427
58	China				82.69818	54.04338	42.51283	36.1167	27.90239	23.86911	19.91182	15.6393	12.93306	10.8026	9.113775	7.766247	6.751651	5.926546	5.311037	4.853922	4.525767	4.262207
59	middle-income countries				8.327353	9.13233	9.697042	9.600555	9.224112	8.600505	7.890249	7.183745	6.565449	6.069473	5.690934	5.321849	5.0623	4.815409	4.628594	4.488857	4.400952	4.313907
60	high-income countries				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
61																						

THIS BOX AS SUPPLIED SEEMS WRONG