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Emissions in the Platinum Age: the implications of rapid development for climate-change mitigation

Ross Garnaut,* Stephen Howes,** Frank Jotzo,*** and Peter Sheehan****

Abstract Rapid global economic growth, centred in Asia but now spread across the world, is driving rapid greenhouse-gas emissions growth, making earlier projections unrealistic. This paper develops new, illustrative business-as-usual projections for carbon dioxide (CO_2) from fossil fuels and other sources and for non-CO_2 greenhouse gases. Making adjustments to *2007 World Energy Outlook* projections to reflect more fully recent trends, we project annual emissions by 2030 to be almost double current volumes, 11 per cent higher than in the most pessimistic scenario developed by the Intergovernmental Panel on Climate Change (IPCC), and at a level reached only in 2050 in the business-as-usual scenario used by the Stern Review. This has major implications for the global approach to climate-change mitigation. The required effort is much larger than implicit in the IPCC data informing the current international climate negotiations. Large cuts in developed country emissions will be required, and significant deviations from baselines will be required in developing countries by 2020. It is hard to see how the required cuts could be achieved without all major developing as well as developed countries adopting economy-wide policies.

Key words: greenhouse gas emissions projections, climate change mitigation, developing countries, economic growth, energy intensity

JEL classification: Q43, Q54, O53

I. Introduction

The world has entered a period of exceptionally fast economic growth, with rapid economic development especially in China, followed by India and many other low-income countries.

*Australian National University, e-mail: ross.garnaut@anu.edu.au
**Australian National University, e-mail: stephen.howes@anu.edu.au
***Australian National University, e-mail: frank.jotzo@anu.edu.au
****Victoria University, Melbourne, e-mail: peter.sheehan@vu.edu.au

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This is the 'Platinum Age', to use the terminology of Garnaut (2008*a*), who notes that recent rates of economic growth have been even higher than the average in the 'Golden Age' of the 1950s and 1960s. The downturn in United States economic growth in 2007 and 2008 is having some dampening effect on global growth but is not expected to alter fundamentally the strong developing and global growth outlook of the early twenty-first century. This growth for the most part is heavily dependent on energy use. The rising global oil prices since 2003, and the exceptionally high prices of 2008, can be expected to reduce substantially the growth in petroleum consumption, but not necessarily the rate of expansion in total fossil-fuel emissions, given the widespread availability of coal.

These developments have not yet been fully incorporated into the projections and scenarios of future greenhouse-gas emissions. The most influential projections used in climate-change analysis are still the *Special Report on Emissions Scenarios* (SRES; Nakiçenovic and Swart, 2000) of the Intergovernmental Panel on Climate Change (IPCC), which provide a wide range of future emissions paths out to 2100 under four different 'storylines' about growth and technology.

The SRES authors did not assign likelihoods to particular scenarios, but rather argued that they were all equally plausible. In practice, most attention has been given to low- and mid-range emission-growth scenarios. For example, the video presentation by the Chairman of the IPCC, Rajendra Pachauri, at the Conference of the Parties in Bali, referred to a range of possible temperature increases, but placed more emphasis on the lowest end of the range represented by scenario B1 (Pachauri, 2007). Other analyses give all SRES scenarios equal weight, rather than asking which ones are more soundly based. Reliance on only the more pessimistic IPCC scenarios is seen as 'unbalanced'. One of the criticisms of the Stern Review has been that the SRES scenario the Review relied on showed 'high range greenhouse gas emissions' (Baker *et al*., 2008, p. xi). Stern himself, however, in his recent Ely lecture (2008) has noted that his Review underestimated the likely growth of emissions.

The SRES scenarios have been criticized for not applying an economic framework that adequately reflects sources of economic growth and endogenous structural change (McKibbin *et al*., 2004). Specific criticism of the SRES scenarios in the literature has been that they overstated emissions growth, either because they failed to adopt purchasing power parity (PPP) measures for GDP (Castles and Henderson, 2003) or because the more rapid emission growth SRES scenarios are inconsistent with long-term (Hansen *et al*., 2000) or recent (van Vuuren and O'Neill, 2006) trends in emissions. Post-SRES scenarios reflect these criticisms of the SRES scenarios. Thus GDP growth, total energy use, and carbon-dioxide (CO_2) emissions are all lower in the median post-SRES non-intervention scenario than in the median pre-SRES/SRES scenario (Fisher *et al*., 2007).

This paper builds on earlier work by Garnaut (2008*b*) and Sheehan *et al*. (2008) to make the case that, in the absence of a serious policy response to climate change, even the most pessimistic SRES and post-SRES scenarios may underestimate future emissions growth and levels.

The paper examines the evolution of greenhouse-gas emissions in recent decades and then projects their 'business as usual' path out to 2030, i.e the path they would take in the absence of any further response to climate change. The focus on the period to 2030 is for three reasons. First, it is the period that matters for the policy issue at hand. As we show in the concluding section, if concentrations of greenhouse gases are to be kept to acceptable levels, action will need to be taken well before 2030. Second, it is the period for which we can have greater confidence in our projections. Third, it is the period covered by the International Energy Agency *2007 World Energy Outlook*, and (roughly) the period used by a number of projection exercises.

Most of the analysis of the paper is in terms of CO_2 emissions from fossil fuels. We discuss recent trends in those emissions and their drivers (section II), before presenting our alternative projections (section III). Section IV analyses non-CO_2 emissions (contributing a quarter of global anthropogenic greenhouse-gas emissions) and CO_2 emissions from land-use change and forestry (another sixth). Section V summarizes our results, and compares them to existing projections. Section VI examines the implications of ongoing rapid growth in emissions for the global approach to climate-change mitigation, and section VII concludes.

II. Recent trends in the growth of CO_2 emissions from fossil fuels

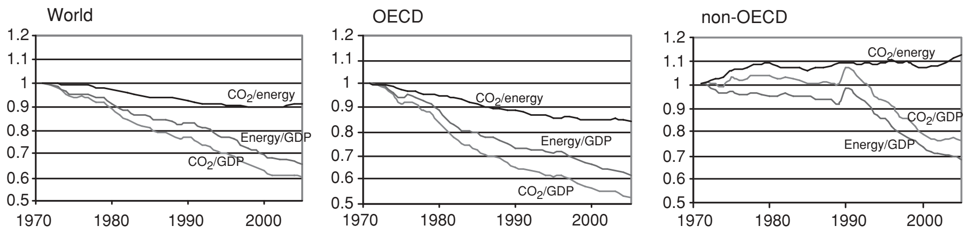
CO_2 emissions from fossil-fuel burning increased by only 1 per cent a year on average in the 1990s, but grew by 3 per cent a year from 2000 to 2005 (Table 1). Through the

Table 1: A comparison of GDP, energy, and CO_2 emissions growth rates and elasticities for the world, OECD, and non-OECD countries

Average annual growth rates and elasticities	**1971–90**	**1990–2000**	**2000–5**
World			
Emissions growth (%)	2.1	1.1	2.9
GDP growth (%)	3.4	3.2	3.8
Energy growth (%)	2.4	1.4	2.7
Emissions/GDP elasticity	0.62	0.35	0.76
Energy/GDP elasticity	0.71	0.43	0.69
Emissions/energy elasticity	0.87	0.82	1.10
OECD			
Emissions growth (%)	0.9	1.2	0.7
GDP growth (%)	3.2	2.7	2.1
Energy growth (%)	1.5	1.6	0.8
Emissions/GDP elasticity	0.28	0.45	0.31
Energy/GDP elasticity	0.48	0.61	0.38
Emissions/energy elasticity	0.59	0.73	0.80
Non-OECD			
Emissions growth (%)	4.2	0.9	5.5
GDP growth (%)	3.8	4.0	6.2
Energy growth (%)	3.8	1.0	4.6
Emissions/GDP elasticity	1.10	0.23	0.88
Energy/GDP elasticity	0.98	0.25	0.74
Emissions/energy elasticity	1.12	0.90	1.18

Notes: Emissions growth is CO_2 from fossil fuels (excluding industrial processes). Energy growth is total primary energy supply measured in million tonnes of oil equivalent (mtoe). GDP growth is measured using 2000 US$ PPP.
Source: IEA (2007*b*).

Figure 1: Emissions/GDP, energy/GDP, and emissions/energy for the world, OECD, and non-OECD countries, 1971–2005 (1971 = 1)



Notes and Source: As per Table 1.

Kaya identity,[1] this acceleration in emissions growth can be decomposed to changes in economic growth, higher energy intensity (of GDP), and higher carbon intensity (of energy):

$$\Delta CO_2 = \Delta GDP^{*}\Delta(Energy/GDP)^{*}\Delta(CO_2/Energy). \qquad (1)$$

Summary data for these variables are presented in Table 1. It can be seen that there has been a worldwide acceleration this decade in the growth of all three of these variables (see also Raupach *et al*., 2007).[2]

Disaggregating between OECD (developed) and non-OECD (developing including transition) countries shows that it is the latter group that is driving global trends. In the early 1970s, non-OECD countries were responsible for roughly one-third of global emissions, energy, and output. In 2005 they were responsible for just over half of global energy use and emissions, and 45 per cent of global output. Since 2000, non-OECD emissions have been growing almost six times as fast as OECD emissions, accounting for 85 per cent of the growth in emissions.

The OECD countries show a slowdown in growth in emissions, GDP, and energy in this decade (2000–5) compared to the last. In the non-OECD countries, the rate of growth in all three has increased significantly this decade.

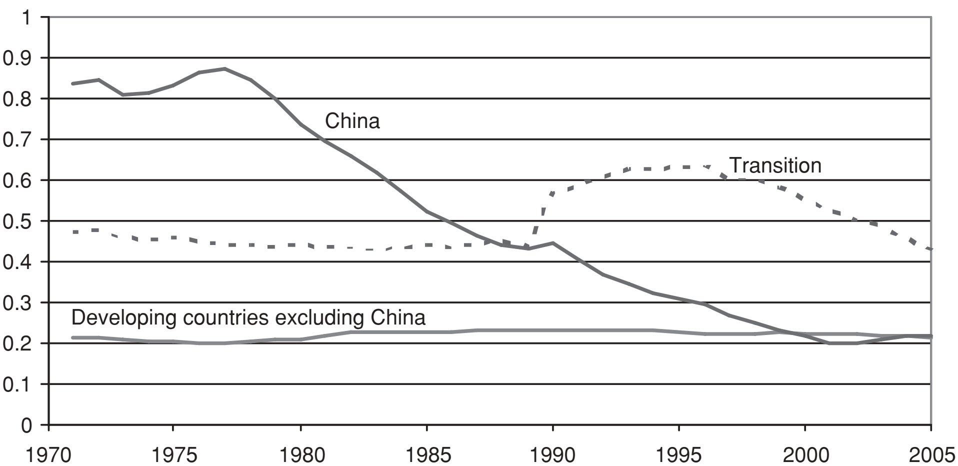
There has also been a significant reduction among the non-OECD countries in the rate of decline of the energy intensity of economic activity and the carbon intensity of energy use. The 1990s saw a rapid decline in energy intensity in the non-OECD group. Energy grew at only a quarter of the rate of GDP, and emissions grew slightly more slowly than energy. This decade has seen the resumption of energy-intensive and carbon-intensive growth in the developing and transition world: energy use has grown at three-quarters the rate of GDP, and carbon emissions at a rate a fifth faster than energy use.

Figure 1 shows just how differently energy intensity (the energy/GDP ratio) has behaved in OECD and non-OECD countries. Though it has fallen in both, in the developed world one sees a smoothly and continuously declining energy/GDP curve. In the developing world, energy intensity fell only slowly over the 1970s and 1980s, plunged in the 1990s, and has now flattened out, at around 70 per cent of its 1971 level. The elasticity of energy use to GDP in non-OECD countries was nearly one in the 1970s and 1980s, only 0.25 in the 1990s, and is at 0.74 for 2000–5.

[1] Kaya and Yokobori (1997). The Kaya identity further decomposes economic growth into population growth and growth in income *per capita*.

[2] Since energy intensity and carbon intensity are declining, an acceleration for them means that they are declining less rapidly.

Figure 2: Energy intensities of GDP for China, other developing countries, and transition countries, 1971–2005



Notes and sources: As for Table 1. Prior to 1990, transition economies are defined residually as non-OECD non-developing countries. The ratio is of energy (total primary energy supply measured in Mtoe) over GDP (in 2000 US$ in PPP).

The carbon intensity (emissions/energy) curve shows greater consistency across the two sets of countries. In the developed world, the emissions/energy curve declined to the mid-1990s but has now flattened out at around 85 per cent of its 1971 level. In the developing world, the emissions/energy curve has been flat throughout most of the period and is now actually rising.

These results appear paradoxical in two regards. First, the reduction in energy intensity appears to contradict the finding that the energy elasticity for most developing countries is one or more (Sheehan, 2008). Second, the flattening and increase in the carbon intensity of energy seems odd in light of the recent large price increases in oil and other fossil fuels. The resolution to these paradoxes lies, respectively, in China and coal.

Figure 2 shows energy intensity separately for China, other developing countries, and the transition countries. It shows that energy intensities are remarkably constant for developing countries once China is excluded. China started out with an enormously high energy intensity which declined through the 1980s and 1990s, due to a shift away from subsidized prices and central planning, flattening only at the turn of the century (Sheehan and Sun, 2007).

The transition countries show constant energy intensity up to the 1990s, then a rising energy intensity (as GDP collapsed faster than energy use), and in recent years a fall in energy intensity, which is continuing.

On the second paradox, the increasing reliance on coal, which is more carbon-intensive than oil and gas, has kept the carbon intensity of energy roughly constant in recent years.[3] While increasing demand and limitations on expansion of production have in recent years

[3] The EIA (1998) reports that, on average, oil emits 40 per cent more CO_2 than gas, and coal 27 per cent more than oil, per unit of energy input.

Table 2: Coal, oil, and gas growth in the world, OECD, and non-OECD countries, 1980–2005 (%)

	World		OECD		Non-OECD	
	1980–2000	2000–5	1980–2000	2000–5	1980–2000	2000–5
Coal	1.3	4.8	0.6	0.7	1.5	9.5
Oil	0.8	1.9	0.5	0.6	1.5	3.8
Gas	2.7	2.4	1.9	0.8	3.6	4.2
Total fossil fuel	1.4	2.9				
Total energy demand	1.3	2.7				

Source: IEA (2007*a*).

lifted oil prices to exceptional levels, there is no similar scarcity constraint on coal. Coal prices have risen, but only reflecting short-term capacity constraints, rather than long-term resource limits. In the 1980s and 1990s, a reduction in the share of oil in total energy demand was made up for by a corresponding increase in gas. But since 2000, the share of gas has remained constant, and the share of coal has increased.

As Table 2 shows, the same trends in relation to coal are evident in both developed and developing regions, though in much more dramatic terms in the latter. Between 2000 and 2005, coal use increased in developing countries on average by 9.5 per cent per year, and by 11.7 per cent in China.[4] In 2005, 61 per cent of the world's coal was consumed in developing countries, up from 51 per cent just 5 years earlier. In 2005, coal provided 63 per cent of China's energy, 39 per cent of India's energy, and only 17 per cent of the rest of the world's energy (IEA, 2007*a*).

In summary, the acceleration of emissions this decade has been caused by three factors: the rapid acceleration of growth in the developing world; the ending of the period of rapid decline in energy intensity in China, which lasted from the 1970s to the 1990s; and the end to the decarbonization of energy supply in both the developed and (especially) the developing world.

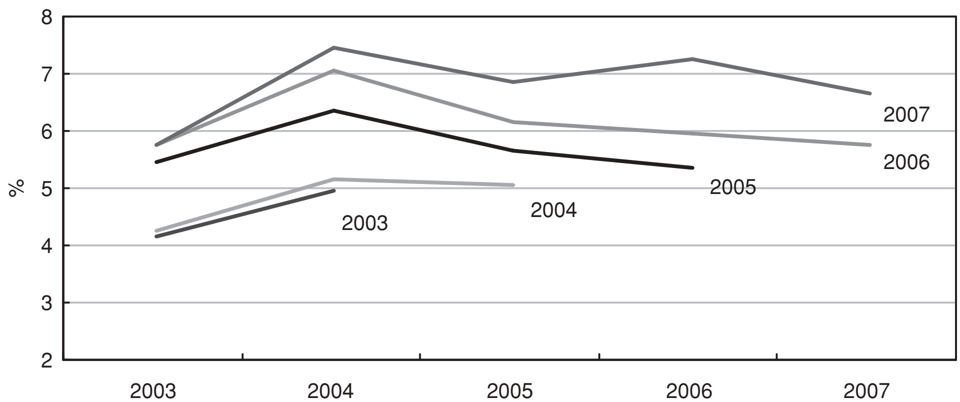
These rapid changes in the developing world have caught observers by surprise. Figure 3 illustrates using successive World Bank *Global Economic Prospects* GDP forecasts. Developing-country economic growth forecasts and estimates have been repeatedly revised upwards, by 2 percentage points or more over a period of 4–5 years each for the years 2004, 2005, and 2006.

By contrast, long-term emission forecasts produced by the International Energy Agency have been relatively stable in recent years. The IEA projected an average annual growth of 1.8 per cent in CO_2 emissions from fossil fuels out to 2030 in 2002, and did so again in 2007. Over the same period, average annual GDP growth was revised from 3 to 3.6 per cent.[5] The implied downward revision of the emissions intensity of GDP is not consistent with recent experience. A re-examination of emissions projections is warranted.

[4] In 2006, China's coal consumption grew by 11.9 per cent and in 2007, according to preliminary estimates, by 7.8 per cent (see National Bureau of Statistics of China, 2007*a*,*b*).

[5] The projection period in the 2002 WEO was 2000–30, and in the 2007 WEO 2005–30. The 2007 WEO does include a rapid growth scenario with higher emissions growth (2.1 per cent per annum over 2005–30), but this is not the reference case.

Figure 3: World Bank GDP growth estimates and forecasts for developing countries: a series of upward adjustments



Source and notes: Successive World Bank *Global Economic Prospects* (GEPs). The GEP is brought out at the start of each year. Each edition includes forecasts for the current and following year, and preliminary estimates or actuals for earlier years. The graph shows that next-year forecasts in the GEP for developing-country economic growth in any given recent year have been replaced in the following year's GEP by a higher this-year forecast, which has in turn been replaced in the subsequent GEP by a higher last-year estimate, and so on.

III. Carbon-dioxide emissions from fossil fuels out to 2030

This section projects fossil-fuel-related CO_2, CO_2(FF) for short, emissions out to 2030, under a 'business-as-usual', constant-policy approach. Policies already in place to reduce emissions are assumed to continue, but no new ones are assumed to be put in place, even if a government has committed to do so. We start from the most recent International Energy Agency (IEA) *2007 World Energy Outlook* (WEO) projections, which make use of extensive information on energy systems in a partial equilibrium framework. Using an emissions growth decomposition framework, we then make adjustments, based on the analysis presented in the paper, to selected macroeconomic assumptions, namely GDP growth in non-OECD countries and the intensity of energy use with regard to GDP in China. The strength of this approach is that it builds on the specialist knowledge of the IEA, and makes clear what assumptions might need rethinking. Its limitation is that it does not capture the general equilibrium effects that would derive from the changes in assumptions.

(i) Economic growth

We review WEO growth rates for the three most populous developing countries, China, India, and Indonesia, and then for other developing and transition regions.

China deserves special attention. In 2005, China was responsible for 19 per cent of global CO_2(FF) emissions. China has averaged about 10 per cent GDP growth per annum since 1990. The latest figures, for 2006 and 2007, are 11.6 and 11.9 per cent growth respectively.[6]

[6] See China's National Bureau of Statistics, 'Announcement on Verified GDP Data in 2006 and 2007', available at http://www.stats.gov.cn/english/newsandcomingevents/t20080410_402473201.htm, 10 April 2008.

Table 3: Growth accounting projections for China, 2005–25

Annual average growth (%)	**2005–2015**		**2015–2025**	
	Perkins-Rawski	**Platinum Age**	**Perkins-Rawski**	**Platinum Age**
Labour growth (%)	2.0	2.0	1.0	1.0
Capital growth (%)	9.8	11.0	5.6	7.3
Capital share	0.43	0.43	0.43	0.43
TFP growth (%)	3.6	3.1	3.0	3.1
GDP growth (%)	**9.0**	**9.0**	**6.0**	**6.8**

Notes: All 'Platinum Age' (current paper) assumptions from Perkins and Rawski (2008) unless otherwise stated. Note that the Perkins and Rawski's 3.6 per cent TFP growth figure for 2005–15 is not presented as a realistic estimate, but derived by the authors to show what, given their projected capital and labour growth, it would take to achieve 9 per cent GDP growth.

Our growth forecasts for China draw on the growth accounting framework of Perkins and Rawski (2008). We accept the Perkins–Rawski projections for education-enhanced labour, and assume a figure of 3.1 per cent total factor productivity (TFP) growth for the entire period, which is the rate of TFP growth in the last decade. Perkins and Rawski assume a slowdown in the rate of capital formation. But investment rates are rising, and Garnaut and Huang (2005) argue that investment rates are, in fact, likely to rise even higher than current levels. We assume investment stays at 45 per cent of GDP to 2015 and then falls to 40 per cent by 2025. Embedding these assumptions into the Perkins–Rawski framework results in growth of 9 per cent from 2005 to 2015 and 6.8 per cent for 2015–25 (Table 3).[7] Considered against China's recent performance, and its good prospects for continued double-digit growth (Garnaut and Huang, 2005, 2007), we consider this projection to be relatively conservative.

Growth first lifted in India in the 1980s. It averaged about 6 per cent from 1980 to 2000. It accelerated again starting around 2004, and has averaged 8.9 per cent between 2004 and 2007. This new higher-growth trajectory is soundly based, supported by strong trade performance and a growing savings rate. Our growth projection for India is based on Oura (2007), which surveys a range of growth-accounting exercises and possible assumptions and finds potential growth for India for the medium term in the range of 7.3–9.5 per cent. Oura defines the medium term only out to 2012, but there is plenty of evidence that these rates of growth can be sustained for much longer (see Rodrik and Subramanian, 2004, for example). We use 7.5 per cent for 2005–30 as a conservative projection.

Indonesia, an example of a mid-sized developing country outside the fastest growing parts of the developing world, also has reasonable prospects for growth, albeit not at the same speed as China or India (see Hofman *et al*., 2007). Indonesia has a strong resource base and potential for expansion in both manufacturing and service sectors, but has been hampered in recent years by low investment. After prolonged adjustment to the 1997 Asian financial crisis and political and institutional change, including far-reaching decentralization, Indonesia's recent growth rate has increased to 6 per cent, after averaging 4.7 per cent from 2000 to 2005. This is well below growth rates in previous decades, and future growth may be somewhat higher. Van der Eng (2006) shows a mid-point estimate of the potential growth rate until 2030 of 6.5 per cent. This is the GDP growth rate we assume in our projection.

[7] We extend the latter projection out to 2030.

Table 4: Historical and projected GDP *per capita* for the United States, China, India, and Indonesia

	in 2005 PPP USD			**USA = 100**		
Per capita GDP	2005	2015	2030	2005	2015	2030
United States	42,096	54,414	75,418	100.0	100.0	100.0
China	4,067	9,068	23,194	9.7	16.7	30.8
India	2,139	3,836	9,776	5.1	7.0	13.0
Indonesia	3,132	5,282	12,219	7.4	9.7	16.2

Notes: US$ in PPP, 2005 prices. GDP assumptions as per Table 5. Population from the IEA 2007 WEO. These figures use baseline PPP GDP data from ICP (2008), that is, they use the new PPP data; the rest of the paper uses older PPP numbers to be consistent with the IEA 2007 WEO.

Note that we assume constant aggregate and/or TFP growth in these three countries up to 2030. Rapid GDP growth over several decades of 7 per cent or more, consistent with sustained high TFP growth, has not been achieved by many countries, but was achieved in Asia in the past by Indonesia, Japan, Korea, and Taiwan. As Perkins and Rawski (2008) note, growth slowed in the last three of these countries when their income *per capita* reached about \$13,000 in PPP (2005 prices). According to our projections, China will reach that level in about 2020 (Table 4). If Perkins and Rawski are correct, a slow-down in growth could occur at \$13,000. However, with the frontier income level also increasing, it is possible that today faster growth can be sustained at higher levels of income. Under our projections, by 2030 the ratio of China's, India's, and Indonesia's income *per capita* to that of the United States will be below the ratios for Japan, Taiwan, and Korea at the points of deceleration of growth in those countries.

The recent acceleration of growth in the developing world has extended well beyond China, India, and Indonesia. The growth acceleration is most evident from the period 2004–7, during which time all developing and transition regions grew at 5 per cent per annum or more (Table 5). We see this acceleration of growth in developing countries as owing much both to better policy settings, and to the spillover effect of rapid Chinese growth, and therefore as sustainable. WEO projections again seem on the low side. For example, the 'rest of developing Asia' region (excluding China and India) is projected to grow at 4.6 per cent for 2005–15, which is lower than the average for 1990–2005, and much lower than the 7.1 per cent achieved in 2004–7. Our alternative projections for developing countries other than China, India, and Indonesia, are a weighted average of WEO projections (two-thirds) and performance of the last 4 years (one-third). This is admittedly *ad hoc* but captures conservatively the idea that official projections are not adequately reflecting recent experience.

Recent growth data, WEO projections, and our 'Platinum Age' or rapid growth projections are shown in Table 5 below. Growth rates are in terms of purchasing power parities. OECD growth rates are taken from the reference scenario of the WEO 2007. We do not make downward adjustments in light of the recent slowdown of the US and other advanced economies. Equally we do not represent possibly growth-enhancing flow-on effects from higher growth in China and elsewhere to OECD countries.[8] Growth rates outside the OECD are adjusted upwards as per the above discussion.

[8] We do not take the assumptions of the WEO 2007 'high growth' scenario as the default because they are not provided in detail.

Table 5: GDP growth by region: historical data and alternative projections

	Actual				2007 WEO		Platinum Age	
GDP (USD PPP 2000), annual average growth (%)	**1971 to 1990**	**1990 to 2000**	**2000 to 2005**	**2004 to 2007**	**2005 to 2015**	**2015 to 2030**	**2005 to 2015**	**2015 to 2030**
OECD	3.2	2.7	2.1	2.8	2.5	1.9	as per WEO	
OECD North America	3.3	3.3	2.4	2.9	2.6	2.2		
OECD Europe	2.7	2.3	1.9	2.7	2.4	1.8		
OECD Pacific	4.3	2.2	2.2	2.8	2.2	1.6		
Transition	2.6	–2.5	5.4	7.0	4.7	2.9	5.5	4.3
Developing Countries	4.3	5.5	6.3	7.8	6.2	4.4	7.1	6.1
Developing Asia	5.7	7.3	7.8	9.4	7.0	4.8	8.0	6.7
China	7.8	10.2	9.4	10.8	7.7	4.9	9.0	6.8
India	4.5	5.5	7.0	8.9	7.2	5.8	7.5	7.5
Indonesia	7.1	4.2	4.7	5.6	4.6	3.1	6.5	6.5
Other	4.3	4.7	5.5	6.7	4.6	3.1	5.3	4.3
Latin America	3.2	3.1	2.6	5.4	3.8	2.8	4.3	3.7
Middle East	2.9	3.7	4.3	5.8	4.9	3.4	5.2	4.2
Africa	2.8	2.5	4.3	5.9	4.5	3.6	5.0	4.4
Dev'ing countries excl China	3.6	3.9	4.7	6.1	5.2	4.0	5.7	5.4
World	3.4	3.2	3.8	5.2	4.2	3.3	4.6	4.4

Note: IEA projections are not provided separately for Indonesia, but are included in other developing Asia.
Source: IEA (2007*b*) for actuals; 2004–7 data from IMF (2007, 2008).

The growth rates of all countries and regions in Table 5 appear reasonable in the light of recent experience. Note, in particular, the projection that growth outside the OECD in the period 2015 to 2030 will not revert to rates seen in the 1970s and 1980s. All developing and transition countries are projected to be growing faster than they were in the latter decades of the last century, but slower than at rates observed over the last 4 years, with the exception of Indonesia. The growth rates for China, India, and Indonesia are supported by our growth-accounting analysis, and the assessment of the authors, whose expertise in development covers these three countries.

(ii) Energy intensity

The 2007 IEA WEO projects significant falls in the energy intensities—the ratio of total primary energy supply to GDP, measured using PPP—of developing countries from current levels (Table 6). Consider the developing world excluding China. Until 1990, energy intensities increased for the developing world, and since then they have stayed roughly constant (Figure 2). Yet, as Table 6 shows, the IEA projects an annual average decline of just under 2 per cent for energy intensity in the developing world (excluding China) over the next 25 years. Some of the contrasts between the historical record and projections for particular regions are stark. For example, energy intensity in the Middle East is expected to shift from a 1–4 per cent annual growth to a 1 per cent annual reduction, or in Africa from unchanged levels to a 2 per cent annual reduction (over the entire projection period). Energy intensities in China and India also fall sharply in the IEA projections: these countries are projected to lead the world in both economic growth and energy de-intensification.

Table 6: Energy intensity levels and growth by region: historical data and WEO projections

	Levels			Annual average growth rates (%)			
	Actuals	IEA 2007 WEO		Actuals		IEA 2007 WEO	
Primary energy supply (Mtoe)/ GDP (billion USD PPP 2000)	2005	2015	2030	1971 to 2000	2000 to 2005	2005 to 2015	2015 to 2030
OECD	0.18	0.16	0.13	−1.4	−1.3	−1.3	−1.3
OECD North America	0.21	0.19	0.15	−1.8	−1.7	−1.3	−1.4
OECD Europe	0.15	0.13	0.11	−1.4	−0.7	−1.7	−1.4
OECD Pacific	0.17	0.16	0.14	−0.4	−1.4	−0.8	−1.1
Transition	0.36	0.26	0.19	−0.3	−4.2	−2.9	−2.0
Developing Countries	0.22	0.17	0.13	−0.8	−0.7	−2.3	−2.2
Developing Asia	0.21	0.16	0.11	−2.2	−0.9	−2.5	−2.4
China	0.22	0.17	0.11	−4.5	−0.1	−2.5	−2.8
India	0.16	0.11	0.08	−1.0	−3.5	−3.3	−2.1
Indonesia	0.24	0.20	0.18	−1.0	−0.3	−1.6	−1.4
Other	0.23	0.20	0.16	−0.1	−0.3	−1.6	−1.4
Latin America	0.16	0.14	0.12	−0.3	−0.7	−1.2	−0.8
Middle East	0.37	0.33	0.28	3.8	1.0	−1.0	−1.1
Africa	0.29	0.23	0.17	0.6	−0.7	−2.6	−1.8
Dev'ing countries excl China	0.22	0.18	0.14	0.2	−0.9	−2.1	−1.6
World	0.21	0.17	0.13	−1.2	−1.1	−1.8	−1.8

Source and notes: IEA (2007*b*) for actuals. Prior to 1990, transition economies are defined as non-OECD non-developing countries.

What lies behind the assumptions of declining energy intensity in the 2007 WEO? It is mentioned that energy intensity 'resumes its steady downward path in China' (p. 120). But we saw in section II that the sharp reduction in China in energy intensity in the 1980s and 1990s was more in the nature of a one-off adjustment than a 'steady downward path' (see also Garnaut and Song, 2006). The 2007 WEO also argues that energy intensity will fall as the structure of the Chinese economy shifts from heavy to light industry. However, normally the opposite would be expected as an economy develops with a high level of investment (extraordinarily high in China's case) underpinning a shift in comparative advantage towards more capital-intensive manufacturing.

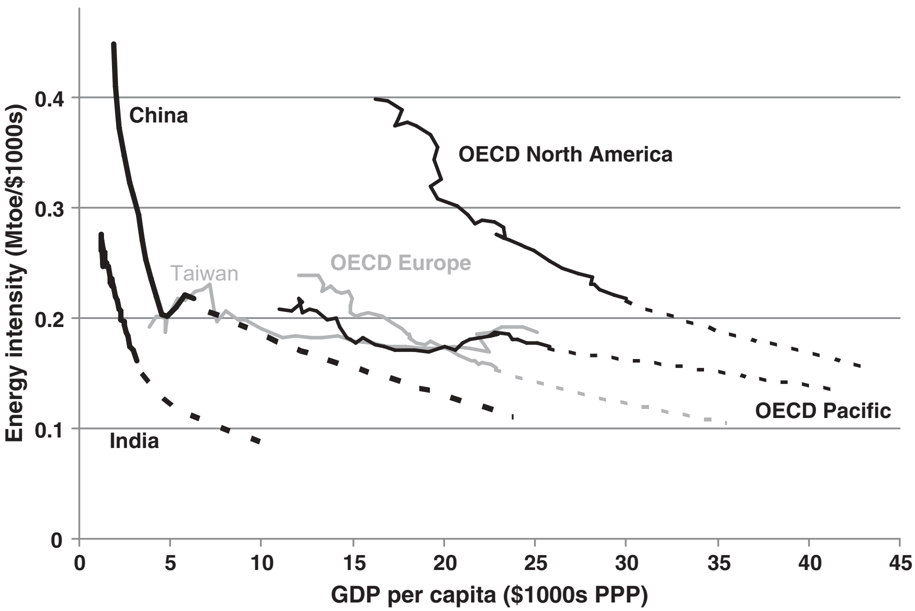
It is true that China is already explicitly targeting a reduction in energy intensity, and has put in place a number of policies to achieve this (e.g. taxes on energy-intensive exports). But it has been missing its targets, and will continue to do so without an intensification of policy effort (Sheehan, 2008). Energy intensity remained unchanged between 2000 and 2005. Energy intensity fell in 2006 by 2 per cent.[9] First half figures for 2007 indicated a fall in energy intensity of 2.8 per cent.[10]

In India, energy intensity has fallen slowly since 1970, and rapidly this decade as growth accelerated in the service sector. However, with the more recent pick-up of industrial growth, it is far from clear that energy intensities will fall from their current extremely low levels.

[9] In 2006, energy consumption grew by 9.6 per cent, and GDP by 11.6 per cent. Energy figures from National Bureau of Statistics of China (2007*a*) (consumption of energy). For GDP figures, see footnote 7.

[10] See National Bureau of Statistics of China (2007*b*). Provisional figures for 2007 indicate energy consumption growth of 7.8 per cent (National Bureau of Statistics of China, 2008). This would imply a faster reduction in energy intensity (−3.7 per cent), but GDP has been revised upwards since the energy figures were released.

Figure 4: Energy intensity and GDP *per capita* for various countries and regions: historical (solid lines) and projected by the 2007 WEO (dashed lines)



Sources and notes: IEA (2007*b*). GDP measured in US$ PPP in 2000 prices. Years for actuals (solid lines) are from 1971 to 2005 except for China (from 1990). IEA 2007 WEO projections (dashed lines) run from 2005 to 2030 (see Table 6).

Rectifying the currently low level of rural electrification will lead to a surge in energy demand. India's current energy intensity is lower than that of other major countries and regions, and comparable to that in Japan and the more low-energy European countries. The expert committee headed by Kirit Parikh (2006) projects growth in commercial energy demand in India between 5.6 and 7.2 per cent per annum over 2006/7 to 2031/2. Even with our higher estimates of economic growth, applying the IEA energy-intensity assumptions gives energy growth of only 4.7 per cent over this period.

Analysis of the historical experience of Japan, Taiwan, and Korea shows only small decreases in energy intensity as *per capita* income increases, with energy intensity roughly flattening out at or above 0.15 toe/$1,000. Even at GDP *per capita* levels in excess of $15,000 (USD 2000 PPP), energy intensity remained flat rather than declining to around or under 0.10 toe/$1,000 as projected by the WEO for China and India. Figure 4 illustrates. The different OECD regions show continued downward trends in energy intensity, but levels are still above 0.15, even at the prevailing very high *per capita* incomes in these countries.

One reason why energy intensities might fall in the future in developing countries (unlike in the past) is that, although the world has abundant coal supplies to support rapid, energy-intensive expansion, high energy prices and constraints around the supply of oil might force greater energy efficiency. For example, the IEA projects that, for its reference case, oil exports from the Middle East will have to increase from 20m barrels a day in 2006 to almost 40 m by 2030 (see Figure 1.7 in IEA, 2007*a*). There must be a question whether such expansion will materialize. Substitution from oil to shale oil and coal will be possible (and, with an abundant supply, coal prices are not expected to rise in the long term) but permanently higher

Table 7: China energy intensity, historical data and alternative projections

	Base			WEO		Platinum Age	
	1990	**2000**	**2005**	**2015**	**2030**	**2015**	**2030**
Energy intensity	44.7	21.8	21.6	16.9	11.0	18.3	13.8
		1990 to 2000	**2000 to 2005**	**2005 to 2015**	**2015 to 2030**	**2000 to 2015**	**2015 to 2030**
Annual average growth in energy intensity		−6.9%	−0.1%	−2.5%	−2.8%	−1.6%	−1.9%
Energy/GDP elasticity		0.25	0.98	0.66	0.40	0.80	0.71

Note: Energy intensity levels are in Mtoe/billion USD (2000 prices, PPP).

prices for oil and its close substitutes may drive improvements in energy efficiency and so dampen growth in energy use. However, a decline in energy intensity for this reason is not inevitable. It is possible that current high prices will induce such high levels of investment in coal production that coal prices fall relative to oil, encouraging use of coal.

Given the uncertainties, we do not make across-the-board adjustments to the WEO's projected energy intensities. However, the WEO's energy intensities for China appear particularly implausible, especially given recent experience. The WEO projects energy intensity in China to fall faster than in any other developing country/region, at −2.7 per cent a year over the projection period. Even with our more rapid growth, this implies annual average growth of 4.8 per cent in energy supply between 2005 and 2030, significantly below the 6.4 per cent annual growth estimated by Sheehan and Sun (2007).[11] The WEO emission-intensity projections for China are also low relative to what is projected for developed countries. Energy intensity in China, which today is almost 40 per cent above that of OECD Europe, is projected to have almost converged with OECD Europe by 2030 (Figure 4). Given China's specialization in manufacturing, and continued high investment levels, it is hard to see how the energy intensity of the Chinese economy could fall relative to Europe's.

For China, we instead assume that energy intensities decline at two-thirds the rate assumed by the IEA (Table 7). This gives China a rate of energy intensity reduction still equal or below the developing country average. It gives energy elasticities for China of 0.8 for 2005–15 and 0.7 for 2015–30, consistent with or below the work of Sheehan and Sun (2007). Auffhammer and Carson (2008), in dynamic statistical models for China's emissions based on regional data, forecast a CO_2 emissions elasticity with regard to income of around unity until 2010, which implies no reduction at all in energy intensity.

(iii) Carbon intensities of energy and other assumptions

For the carbon intensity of energy use (CO_2/total primary energy supply), we adopt WEO projections, which assume that carbon intensities stay broadly constant (Table 8). This is a conservative approach on two accounts. First, in recent years, emission intensities have in fact been increasing in the developing world, owing to the shift to coal (Figure 1). The tighter

[11] Without changing the growth assumption, the WEO forecast for China is only 3.2 per cent for annual average energy growth between 2005 and 2030.

Table 8: Carbon intensity of energy levels by region: historical data and IEA projections

Emissions ($GtCO_2$)/Primary energy supply (Mtoe)	Actual			2007 WEO	
	1971	2000	2005	2015	2030
OECD	2.8	2.3	2.3	2.3	2.2
OECD North America	2.7	2.4	2.4	2.4	2.3
OECD Europe	2.9	2.2	2.2	2.1	2.1
OECD Pacific	2.7	2.3	2.4	2.3	2.1
Transition	2.6	2.5	2.4	2.4	2.2
Developing Countries	1.7	2.2	2.3	2.4	2.4
Developing Asia	1.7	2.3	2.5	2.6	2.6
China	2.0	2.7	2.9	3.0	3.0
India	1.3	2.1	2.1	2.3	2.5
Indonesia	0.7	1.8	1.9	1.9	2.1
Other	1.6	1.7	1.8	2.0	2.0
Latin America	1.8	1.9	1.9	1.9	1.8
Middle East	2.4	2.5	2.5	2.5	2.4
Africa	1.3	1.4	1.4	1.4	1.5
Dev'ing countries excluding China	1.5	1.9	1.9	1.9	2.0
World	2.5	2.3	2.3	2.4	2.4

Notes and source: As for Table 6.

supply constraints on oil, and the associated tendency for the relative price of coal to decline, suggest that this may continue. Second, if energy use does turn out to be higher than projected by the IEA (as we argue it will), then a disproportionate amount of the extra demand will be met by (emissions-intensive) coal. For example, our projections have emissions growing at the same rate as energy in the non-OECD world (about 5 per cent), whereas we know coal has been growing at 9 per cent p.a. from 2000 to 2005, compared to energy growth for the same region and period of 4.6 per cent.

Indonesia's experience of fuel switching towards coal is instructive. In 1990, oil constituted 59 per cent of total energy use (excluding energy from biomass and waste), falling to 51 per cent in 2005, while the share of gas fell from 32 to 24 per cent. The share of coal over the same period increased from 7 to 20 per cent, a more than sixfold increase in level terms (IEA, 2007*c*). The shift to carbon-intensive coal is expected to continue apace, with industrial plants substituting coal for gas (which fetches high prices in export markets) and planned expansions in electricity generation predominantly using low-grade coal (Narjoko and Jotzo, 2007).

There are two final inputs needed to complete these projections. Energy from fuel used to power ships (marine bunkers) is included in the IEA projections (though not aviation fuel). We use the 2007 WEO projections unchanged. Second, unlike the IEA projections, SRES projections for CO_2 emissions from fossil fuels also include CO_2 emissions from industrial processes. These in theory cover non-fossil-fuel CO_2 emissions from iron and steel, lime, and cement production, but in practice only emissions from cement tend to be covered. To make our projections comparable with SRES projections, we also provide projections for cement. Cement emissions are equivalent to about 4 per cent of fossil-fuel emissions. Emissions in cement have tracked world growth fairly closely over the last three decades, and were ahead in the first half of this decade. We assume that cement growth is proportional to global economic growth (for actual figures see Table 9).

Table 9: Emissions of CO_2 (FF) in 2005 and projected: growth, shares in global total and *per capita* emissions

	Annual average growth (%)			Share of total excluding cement (%)		*Per capita* emissions (t)	
	2005–15	2015–30	2005–30	2005	2030	2005	2030
OECD	0.8	0.5	0.6	48.3	26.8	11.0	11.6
OECD North America	1.1	0.7	0.8	25.3	14.7	15.6	15.6
OECD Europe	0.3	0.5	0.4	15.3	8.0	7.6	7.9
OECD Pacific	1.0	0.0	0.4	7.8	4.1	10.3	11.7
Transition	2.1	1.8	1.9	9.8	7.4	7.7	13.2
Developing countries	5.8	4.4	5.0	39.8	63.3	2.2	5.4
Developing Asia	6.7	4.8	5.5	28.6	51.9	2.3	6.9
China	7.5	4.7	5.8	19.1	37.4	3.9	14.5
India	4.9	5.8	5.4	4.3	7.6	1.0	3.0
Indonesia	4.6	6.4	5.7	1.3	2.4	1.5	4.9
Other	4.7	2.9	3.6	3.9	4.5	1.4	2.4
Latin America	3.0	2.8	2.9	3.5	3.4	2.1	3.3
Middle East	4.1	3.0	3.4	4.6	5.1	6.6	10.1
Africa	2.3	3.0	2.7	3.1	2.9	0.9	1.1
Developing countries excluding China	4.0	3.9	4.0	20.8	25.9	1.5	2.8
Marine bunkers	7.8	1.3	3.9	2.0	2.5		
				Gt CO_2			
World total excluding cement	3.3	2.8	3.0	26.7	56.4	4.2	6.9
Cement	4.8	4.4	4.5	1.0	3.1	0.2	0.4
World total including cement	3.4	2.9	3.1	27.8	59.6	4.3	7.2

Source: Population data from IEA (2007*a*,*b*). Cement from CDIAC (2007): 2005 is an estimate for cement based on 2004 actuals.

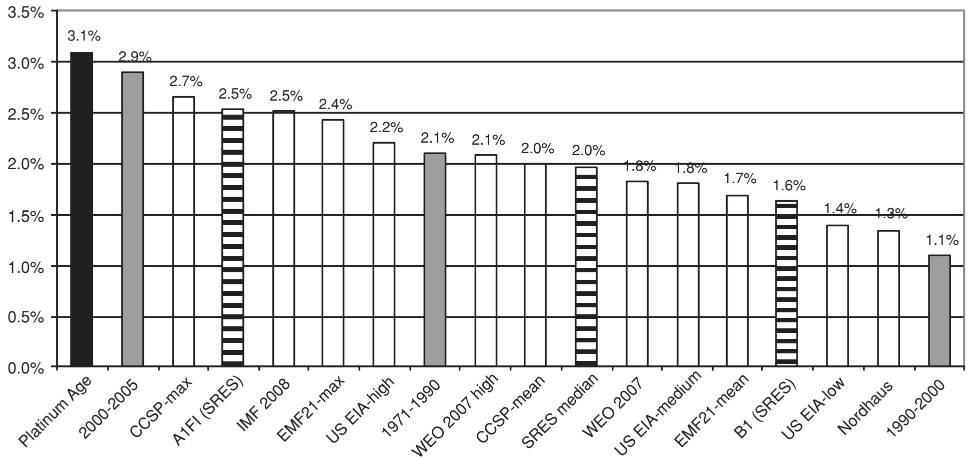
(iv) Platinum Age projections for CO_2 emissions from fossil fuels

Incorporating our revised growth assumptions for the developing world, and energy intensities for China, as well as our projections for cement emissions gives a projection of annual average emissions growth of 3.1 per cent from 2005 to 2030. Table 9 shows the contribution of different countries and regions to this result.

Note the emerging dominance of China in the global emissions profile. Under these projections, by 2030, China will be responsible for 37 per cent of global emissions, up from 19 per cent currently. This is a product of China's exceptionally high growth, population, and carbon intensity (Table 8). In terms of *per capita* emissions, China will catch up with Europe by 2015, and almost reach North American emissions levels by 2030. The developing world excluding China increases its weight in global emissions much more slowly, from 21 per cent in 2005 to 26 per cent in 2030.

Total business-as-usual CO_2 emissions from fossil fuels (excluding cement) are 8 per cent higher under Platinum Age assumptions than under 2007 WEO ones by 2015, and 34 per cent higher by 2030. China is responsible for almost two-thirds of this difference.

Figure 5: A comparison of annual projected growth rates in SRES and post-SRES scenarios (c. 2005–30) with historical data for global CO_2 emissions from fossil fuels and the Platinum Age projections (2005–30)



Note: The grey bars show average annual emissions growth for various historical periods. The striped bars show various SRES scenarios, and the transparent bars post-SRES scenarios. The black bar gives the projections of the authors. Historical data are from Table 1. The SRES scenarios (Nakiçenovic and Swart, 2000) used are: A1FI (AIG MINICAM), which shows the most rapid emissions growth, both to 2030 and to 2100; B1 (BI IMAGE), which is at the lower end of the range; and the median SRES scenario (which is defined as the median for each variable and each decade of the four SRES marker (or main) scenarios). The SRES scenarios give projections for every 10 years from 1990 to 2100; we report here projections for 2000–30. Post-SRES scenarios included are: the mean and maximum emission baselines from the EMF-21 (Energy Modelling Forum) project (Weyant *et al*., 2006), which included 18 different emission projection models for 2000–25; the mean and maximum projections from the US Climate Change Science Program (CCSP) (Clarke *et al*., 2007), which used three models; the base case from the well-known Nordhaus (2007) model for 2005–35; projections for 2005–30 from the IEA 2007 *World Energy Outlook* (both the base case and a rapid-growth scenario with higher growth projected for China and India); the high, medium, and low projections from the US EIA (2007) for 2004–30; and the IMF *World Economic Outlook* baseline for 2002–30 (IMF, 2008).

By 2030, emissions are 85 per cent higher in China under Platinum Age than under 2007 WEO assumptions.

Figure 5 puts this result into perspective, by showing average growth rates for CO_2 emissions from fossil fuels for a number of SRES and post-SRES scenarios for the period c. 2005–30, as well as average emission growth in the 1970s and 1980s, the previous decade, and so far in this decade (2000–5).

Most emissions projections for growth out to 2030 forecast annual average growth of about 2 per cent. Our Platinum Age projections predict that, without a shift in policies, global emissions growth in the coming decades will be basically a continuation of what has been seen since 2000—growth of around 3 per cent. Although economic growth and energy intensity are both projected to fall from current levels, the rising weight of the rapidly growing developing economies in the global economy combined with their higher emissions intensity of output will cause the rate of growth of emissions to stay high.

If China's energy intensity is not adjusted from WEO projections, and only non-OECD economic growth rates are adjusted as per Table 5, the growth rate of global emissions falls to 2.7 per cent. This is still in excess of the A1FI SRES scenario (2.5 per cent growth for 2000–30), which depicts a high-growth, fossil-fuel-intensive scenario for the world and has to date been generally considered ‘extreme.’[12]

This is a broad-brush, illustrative projection. We do not regard it as an unreasonable one, and point out that our adjustments to IEA projections are both conservative and restricted to selected countries and regions. Growth rates and energy and emission intensities could all be higher than we have projected. While we have not attempted to quantify the substitution away from energy in an era of high and increasing energy prices, the energy intensities projected embody a powerful effect of rising energy prices on energy use.

IV. Other emissions

Non-fossil-fuel-related CO_2 emissions contribute significantly to global warming. According to the IPCC Fourth Assessment Report (Rogner *et al*., 2007), in 2004, CO_2 from fossil-fuel use and industrial processes contributed 59 per cent of greenhouse-gas emissions. CO_2 from land-use change and forestry contributed 17 per cent, and non-CO_2 emissions contributed the remaining 23 per cent. This section considers these latter two sources of greenhouse gas emissions.

(i) Non-CO_2 greenhouse gases

Methane (CH_4) and nitrous oxide (N_2O) are the two most important non-CO_2 greenhouse gases. They constitute, respectively, 14 and 8 per cent of total emissions in CO_2-e terms (Rogner *et al*., 2007). [13]

Firm historical data for non-CO_2 gases are only available till 2000.[14] Projections for non-CO_2 gases from 2000 onwards are shown in Table 10. The very detailed, recent US Environmental Protection Agency (EPA) projections show annual growth in non-CO_2 gases of 1.5 per cent, slightly higher than the rate of growth seen in the SRES A1FI scenario.

EPA projections for Annex I countries are largely based on official national projections. For non-Annex I countries, a ‘Tier 1’ method is used, generally by applying IPCC emissions coefficients to projections of economic drivers based on EIA (2002) or from other official sources. The EIA (2002) projections for GDP growth and for energy use are definitely by now outdated. We adjust the EPA projections for CH_4 emission from energy (about a third of the total) by the ratio of our growth rates for a given country or region (in section II(i)) to the corresponding EIA (2002) estimates. For other non-CO_2 emissions, we assume that growth rates will be partly but not entirely responsive to higher GDP growth. Hence we

[12] See for example Agerup (2004): ‘The A1FI scenario depicts an extremely unlikely future.’

[13] Fluorinated compounds (F gases) are not included in these projections owing to their small size (about 1 per cent of greenhouse-gas emissions) and the difficulties of making comparisons with the SRES scenarios using these gases.

[14] IEA (2007*b*) does publish data for non-CO_2 gases for 2005. However, some of these data appear identical to 2000 data (including for major countries such as China and India). There are varying estimates of non-CO_2 emission levels. For example, EPA (2006) has combined CH_4 and N_2O emissions in 2000 of 9.1 Gt CO_2-e; IEA (2007*b*) of 10.5 Gt CO2-e.

Table 10: Projections of methane and nitrous-oxide emissions growth

Measured in CO_2-e, % growth	CH_4	H_2O	CH_4+H_2O
SRES projections (2000–2030)			
AIFI	1.4%	1.5%	1.4%
SRES median	1.1%	0.3%	0.9%
B1	0.6%	0.5%	0.6%
EMF projections (2000–2025)			
EMF-21 mean	1.3%	1.0%	1.2%
EMF-21 max	2.0%	2.2%	2.0%
EMF-21 min	0.7%	−0.1%	0.5%
EPA projections (2000–2020)	1.5%	1.3%	1.5%
Platinum Age (2005–30)	1.8%	1.9%	1.8%
2005 level (Gt CO_2-e)	6.6	3.3	9.9
2030 level (Gt CO_2-e)	10.3	5.3	15.6

Notes and sources: For SRES and EMF projections, see Figure 5. EPA projections are from EPA (2006). Platinum Age projections adjust EPA forecasts using the methodology set out in the text. They extrapolate EPA projections to 2020 out to 2030, and use a 2005 starting point.

adjust the EPA projections by half of the differential between our growth projections and the corresponding EIA (2002) figures. These broad adjustments lead to a projected annual average growth rate of CH_4 and N_2O combined of 1.8 per cent a year.

(ii) CO_2 emissions from land-use change and forestry

Emissions of CO_2 from land-use change and forestry (LUCF) are large, poorly measured, difficult to project, and highly variable (Nabuurs *et al.*, 2007). CO_2 (LUCF) emissions, as defined here, are made up of three types: emissions from biomass burning (reported by IEA, 2007*b*); emissions from peat fires and decay of drained peat soils (from Hooijer *et al.*, 2006); and emissions from decay of above ground biomass that remains after logging and deforestation (which is derived residually from Rogner *et al.*, 2007, Figure 1.1).

CO_2 (LUCF) emissions are more extensive than thought earlier. In particular, only recently have peat-related emissions, mainly originating from Indonesia (Hooijer *et al.*, 2006; Page *et al.*, 2002) been taken into account. Table 11 demonstrates this by comparing CO_2 (LUCF) emissions assumed in the SRES and EMF-21 base years (1990 and 2000, respectively) with latest estimates for those years (see Figure 5 for more details on these two well-known sets of projections). The latter are 40–100 per cent higher. Earlier, LUCF emissions were thought to contribute about 10 per cent of greenhouse-gas emissions. They are now thought to contribute 15–20 per cent.

It is very difficult to project CO_2 emissions from land-use change and forestry. Historical growth is significant: 2.3 per cent in the 1990s and 1.3 per cent in the first half of this decade, though there are large margins of error around these numbers. SRES and EMF-21 projections forecast both positive and negative growth. Houghton (2003), who is widely cited, has slightly higher emissions in 2000 (7.6 Gt CO2) but declining to about 6.2 Gt in 2030.[15]

[15] Canadell *et al*. (2007) who update Houghton's work have a lower CO_2 (LUCF) value for 2000 (5.05 Gt CO_2).

Table 11: CO_2 emissions from land-use change and forestry: latest estimates, earlier estimates, and projections

Gt CO_2	Estimates			Projections
	1990	**2000**	**2005**	**2030**
A. Latest estimates				
Biomass burning	2.4	3.3	3.5	3.5
Biomass decay	1.5	1.8	2.0	2.0
Peat decay and burning	1.7	1.9	2.0	2.1
Total	**5.6**	**7.0**	**7.5**	**7.6**
Period ave. growth rate (%)		2.3	1.3	0.05
B. Earlier estimates				
Total	4.1	3.4		

Notes and sources: Biomass burning from IEA (2007*b*). Peat decay and burning from Hooijer *et al*. (2006). Biomass decay is estimated from Rogner *et al*. (2007, Figure 1.1), and is actually for 2004. 2030 projections for biomass burning from Hooijer *et al*. (2006). Zero growth assumed for other sources. Earlier estimates are the SRES baseline (1990) and the mean EMF baseline (2000) for CO_2 (LUCF). For sources for these projections, see Figure 5.

Sathaye *et al.* (2006) have a reference case where annual deforestation emissions slowly increase until 2030, then slowly decline. Projections for peat decay and fire are available from Hooijer *et al.* (2006), who projects growth of about 1 per cent per year out to 2020, and then a period of slow negative growth. For want of better information, no growth is assumed in the other two categories from the 2005 base, consistent with the approach taken in Jotzo and Pezzey (2007). The results are shown in Table 11.

V. Summary of results

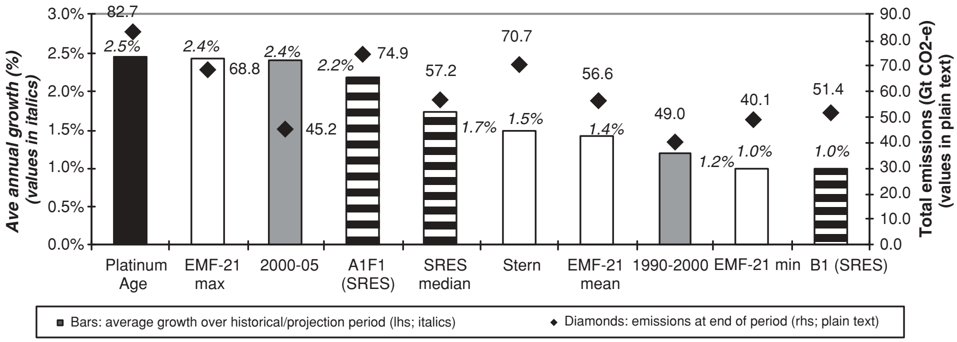
Platinum Age projections give annual average growth in greenhouse-gas emissions of 2.5 per cent over the period 2005–30—lower than the 3 per cent for CO_2 emissions from fossil fuels largely because of the assumed low growth in CO_2 emissions from land-use change and forestry. This overall growth rate is slightly above the upper-end of existing scenario growth rates (Figure 6).

End-period emissions are significantly higher than in existing rapid-growth scenarios because of the higher forestry emissions built into the base. We project annual emissions of 83 Gt CO_2-equivalent by 2030, almost double their current level, 11 per cent higher than the 'extreme' A1FI scenario, and a level of emissions reached only in 2050 in the business-as-usual scenario used by the Stern Review (Stern, 2007, p. 202).

VI. Implications for post-Kyoto negotiations

The importance of an urgent response to the threat of climate change is noted in the Bali Action Plan agreed in December 2007 to guide climate negotiations on the UN Framework

Figure 6: Comparison of Platinum Age projections with other projections and historical data in terms of average growth rates (bars; italics; left axis) and total emissions (diamonds; plain text; right axis)



Notes: The striped bars are the SRES scenarios; grey are actuals; transparent are post-SRES projections; black is the Platinum Age projection. Growth rates are for the projection or historical period; values are end-of-period. The mean, maximum, and minimum EMF-21 projections are composites of different projections: they use the projections with the mean/maximum/minimum projected growth rates for CO_2 (FF), CO_2 (LUCF), NO_2, and CH_4, respectively, and combine them. The Stern projection is the business-as-usual projection from ch. 7 of the Stern Review: this is a composite projection based on various published projections for different sources of global warming (it is different from the A2 SRES scenario which Stern uses elsewhere in his report). To obtain a 2030 total emissions figure for EMF-21, we extrapolate to 2030 using the average growth rate for 2000–25. For more details on the SRES scenarios, and for all sources, see notes to Figure 5. There are not as many projections in this figure as in Figure 5 because only a subset of projections go beyond CO_2 (FF) to project other sources of global warming.

Convention on Climate Change. What these new projections make clear is that an effective urgent response has to be an ambitious one. To illustrate this point, consider Box 13.7 from the IPCC Fourth Assessment Report (Gupta *et al.*, 2007) made famous by the prominence given it in the Bali negotiations. At one point, a summary of this box was to appear in the agreed text arising from these international negotiations; it ended up being referred to in a footnote (UN FCCC, 2007). This box (which we will call the 'Bali Box') gives the extent of cuts in emissions required by both Annex and non-Annex I countries by both 2020 and 2050 if various stabilization targets are to be achieved. It quantifies cuts required for Annex I countries (developed and transition countries), and gives qualitative assessments of what is required for the other countries. Cuts for Annex I countries are given relative to 1990. Cuts for other countries are given relative to the baseline.

Sheehan (2008) examines the 16 studies which are surveyed to produce the famous box. He notes that 15 of these undertake empirical analysis, and that all of these 15 are 'within the SRES marker scenario range'—that is, predicting significantly lower emissions growth and levels up to 2030 than now appears reasonable (i.e. significantly lower than the Platinum Age projections).

With higher business-as-usual or baseline emissions, to achieve a given emissions target, one of two adjustments must be made. Either higher deviations from the baseline will be required (for non-Annex-I countries) or higher cuts from 1990 levels (for Annex I countries.) Given our new projections, by how much will Annex I and non-Annex I countries have to cut emissions by 2020 to achieve the stabilization targets set out in the Bali box?

Table 12: Extent of deviations required from business-as-usual baseline by non-Annex-I countries assuming given reductions from 1990 levels by Annex I countries

Scenarios		**Stabilization pathways**			
		450 ppm CO_2-e		**550 ppm CO_2-e**	
		Annex I deviation by 2020 from 1990		**Annex I deviation by 2020 from 1990**	
		−25%	−40%	−10%	−30%
		Implications for non-Annex-I countries			
IPCC synthesis ('Bali Box')	Deviation from baseline (for range of Annex I cuts above)	Substantial deviation from baseline [in most regions]		Deviation from baseline [in some regions]	
SRES median marker	Deviation from baseline (2020)	−15%	−4.7%	−8%	5.6%
	Annual average growth (2005–20)	2.1%	2.9%	2.6%	3.6%
Platinum Age	Deviation from baseline (2020)	−40%	−33%	−35%	−26%
	Annual average growth (2005–20)	0.0%	0.7%	0.5%	1.4%

Sources and notes: Gt CO_2-e targets from Stern (2006, Figure 8.4): 40 Gt CO_2-e for the 450 CO_2-e ppm target; and 45 Gt CO_2-e for the 550 CO_2-e ppm. IPCC Synthesis from the 'Bali Box' (Box 13.7 in Gupta *et al.*, 2007). For SRES median marker, see Figure 5; Annex I median calculated separately from the four marker scenarios. For Platinum Age projections, CO_2 (FF) emissions from Table 9 (bunker and cement emissions allocated as per national fossil-fuel emissions); CO_2 (LUCF) emissions from Table 11 (all emissions in this category allocated to non-Annex-I countries); non-CO_2 emissions from Table 10 (emissions allocated to Annex I (actually, OECD and transition countries) and non-Annex I (all other) countries as per baseline data from EPA and growth rules described in text).

To answer this question, we need a pathway of global emissions towards atmospheric stabilization. Of course, there can be many, and so this answer is only illustrative. We use the stabilization paths given by the Stern Review (2007, Figure 8.4) associated with the 450 and 550 ppm CO_2-e concentration targets.[16] Baseline emissions are allocated between the two groups of countries (Annex I and non-Annex I) based on the data and projection methods described in the previous two sections. Note that the analysis only goes out to 2020, and so conclusions can be reached with greater confidence than they can for 2030.

We compare for given Annex-I reduction targets (at the bottom and the top of the Bali Box range), the implied cuts for non-Annex-I countries for two projections: one, the SRES median marker scenario; and, two, the Platinum Age projections.

If the SRES median scenario is used, the Bali Box write-up for the implications for non-Annex-I countries seems reasonable (Table 12). Even for Annex-I country cuts at the bottom of the respective ranges, modest reductions from the baseline are required for other countries.

[16] As per the Bali Box, and the Stern Review, since it is impossible to stabilize at 450 ppm CO_2-e without overshooting, we consider a 450 target with temporary overshooting of that target to 500 ppm CO_2-e.

For example, a 10 per cent cut by Annex I countries relative to 1990 requires a cut of 8 per cent from the non-Annex-I baseline if the 2020 target arising from the 550 ppm CO_2-e stabilization path is to be adhered to. This would still allow annual average emissions growth of 2.6 per cent per annum in developing countries.

However, if the Platinum Age projections are used, the picture changes completely. Consider the results based on the top-of-the-range level of cuts for Annex I countries: 30 per cent for the 550 stabilization path, and 40 per cent for the 450 one. Even then the 450 path will require a 33 per cent cut from the non-Annex-I baseline by 2020, which allows for annual growth of only 0.7 per cent between 2005 and 2020. The 550 path, and its 2020 target, will require a 26 per cent cut from baseline for non-Annex-I countries, which limits annual average emissions growth in these countries to 1.4 per cent. This would imply no growth in *per capita* emissions in the developing world.

VII. Conclusion

Projecting business-as-usual greenhouse-gas emissions decades out from now requires difficult judgements. No doubt the projections we have presented could be improved in various ways. While we have tried to make allowance for it, there remains uncertainty about the impact of high energy prices. Nevertheless, there is clearly a compelling case that existing emissions projections are unduly conservative, and that, in the absence of effective mitigation over the coming decades, emissions will be significantly higher in terms of both growth and level than previously thought. If this conclusion is accepted, then two implications for climate-change mitigation follow. First, it will be extremely difficult to adhere to pathways consistent with stringent stabilization targets (such as stabilization at 450 ppm CO_2-e), even with some overshooting. Second, even given moderate stabilization targets, and greater back-end loading of the stabilization task than used in the example of the previous section, large cuts for developed countries will be required, and developing countries will need to bring down emissions substantially below business as usual.

Cuts below baseline growth of such dimensions will not be made in a framework of voluntary commitments and selective policies. They will only be made if major developing countries also become subject to quantified national targets. The terms of the climate-change discussion need to be shifted. There is no room any longer for defending the view that the 'differentiation' of effort called for in the United Nations Framework on Climate Change Convention between developing and developed countries should be based on the application of emissions targets and comprehensive policies to the latter, and not the former. Differentiation is critical, but should enter the frame through developed countries taking on more stringent targets, and through their provision of finance to back mitigation efforts in developing countries. Differentiation within the group of non-Annex I countries is also critical, with middle-income countries shouldering greater effort and high-income countries currently part of the non-Annex I group graduating to taking on full binding commitments. Without all major emitters accepting economy-wide targets and implementing comprehensive policies, given rapid emissions growth, the prospects for the global climate-change mitigation effort are bleak.

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