The New Global Growth Path: Implications for Climate Change Analysis and Policy

Peter Sheehan

CSES Climate Change Working Paper No. 14
Centre for Strategic Economic Studies
Victoria University
Melbourne
2007

Centre for Strategic Economic Studies
Victoria University
PO Box 14428
Melbourne VIC 8001 Australia
Telephone +613 9919 1340
Fax +613 9919 1350
Website: http://www.cfses.com
Email: csesinfo@vu.edu.au
Contact: peter.sheehan@vu.edu.au

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Abstract

In recent years the world has moved to a new path of rapid global growth, largely driven by the developing countries, which is energy intensive and heavily reliant on the use of coal – global coal use will rise by nearly 60% over the decade to 2010. On unchanged policies global CO_2 emissions from fuel combustion are likely to nearly double their 2000 level by 2020 and continue to rise beyond 2030. Neither the SRES marker scenarios nor the reference cases assembled in recent studies using integrated assessment models capture this abrupt shift to rapid growth based on fossil fuels and centered in key Asian countries. An international effort to develop new, realistic projections to 2030, with a range of scenarios beyond that time, is urgently required. Recognition of this path as a realistic possibility will have significant effects on the impact and damage estimates in an unchanged policy case, on the analysis of achievable stabilisation paths and on estimates of the costs of achieving stabilisation at a given GHG concentration level. Finally, such recognition means that, if widely desired stabilisation goals are to be achieved, policies with an immediate effect on emissions, perhaps such as price, tax and regulatory measures to reduce energy use and the rapid diffusion of existing non-fossil fuel technologies, will be required, together with greater knowledge about the effectiveness and the economic costs of such policies.

1. The new global growth path

For more than two decades the world economy has been changing rapidly, with that change driven by two different but related factors: successive waves of new computing and communications technologies and an expanding process of liberalisation of national and international markets, in areas such as trade, finance, technology and labour. This process has entered a new stage in recent years, especially since the entry of China into the World Trade Organisation in 2001 and the strong growth being achieved in India. Global economic growth has been higher than expected for some years and energy demand has been very strong, much greater than anticipated by markets, providers and analysts.

Table 1 provides summary information on trends in global GDP and energy use over 1972–2006. While there was considerable variation within them, in each of the three decades from 1972–2002 the average annual growth of world GDP (in constant purchasing power parity prices) was 3.5%, with per capita GDP growth at around 2%.

[1] The author gratefully acknowledges valuable advice and input from Roger Jones and Fiona Sun; high quality research support from Alison Welsh and Margarita Kumnick; comments from the editor and two referees that stimulated substantial improvements in the paper; and funding from the Australian Research Council under a Linkage Grant and the support of the Industry Partners to that Grant (the Department of Industry, Tourism and Resources, the Australian Greenhouse Office and the Australian Business Council).

By contrast, over the four years 2002–06 the global growth rate was 4.9%, with per capita GDP growth at 3.7%, a very high rate in historical terms. The growth in primary energy use over 2002–06 (3.3%) was more than twice that over 1992–2002 (1.5%), while the share of coal in primary energy use rose strongly, from 25.5% in 2002 to 28.4% in 2006. Indeed, while over the 1972–2002 period coal use grew less rapidly than all other energy sources, over the last four years this has been reversed, with coal use growing by 6.1% per annum, more than twice the rate of all other energy sources (2.3%). Thus coal consumption has provided nearly half of the increase in total primary energy consumption in the last four years, with the absolute increase in coal consumption over 2002–06 (653 mtoe) greater than the increase over the whole of the two decades 1982–2002 (583 mtoe).

Table 1. World GDP, energy use and coal consumption, 1972–2006

	1972	1982	1992	2002	2006
World GDP (index 1970=1000, PPPs)	100	140.5	197.4	278.8	337.6
Change[1] – % per annum		3.5	3.5	3.5	4.9
World GDP per capita (index 1970=1000, PPPs)	100	117.9	140.1	173.6	201
Change[1] – % per annum		1.7	1.7	2.2	3.7
Primary energy use (mtoe)	5429	6582	8211	9549	10878
Change[1] – absolute (mtoe)		1153	1629	1338	1329
– % per annum		1.9	2.2	1.5	3.3
Coal consumption (mtoe)	1529	1854	2202	2437	3090
Change[1] – absolute (mtoe)		325	348	235	653
– % per annum		1.9	1.7	1.0	6.1
Coal share of primary energy use (%)	28.2	28.2	26.8	25.5	28.4

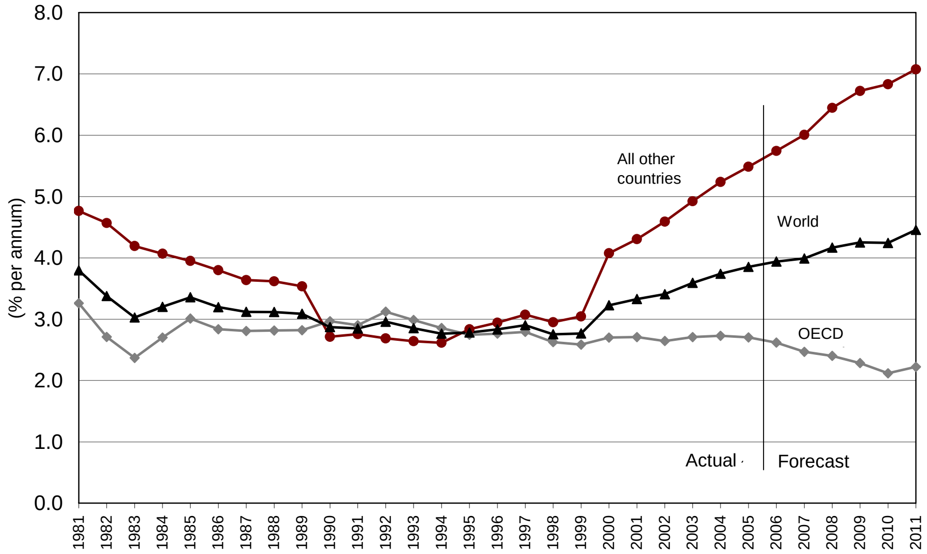
[1]Change since previous year shown in the table.
Sources: For GDP, IMF (2007); for energy use and coal consumption, BP (2007).

The quite different outcomes shown for 2002–06 relative to the previous three decades shown in Table 1 might well be dismissed as cyclical fluctuations. But it is now widely accepted that fundamental, long term factors are at work: the sustained emergence of China and India as economic powers, more rapid growth in other developing countries, the revival of Japan from its stagnation over a decade or more, better economic prospects in Russia and other CIS states, and more generally an open world economy with low inflation. Reflecting both current demand and revised expectations for the future, global market prices for oil, coal and resources have risen sharply and large scale investment plans for energy and resource development have been put in place, both in key markets such as China and India and in supplier countries such as Australia, Brazil and Russia. This new global economic path has led to a flurry of activity by governments and businesses around the world, as they seek to reassess their position in a world in which China and India are major economic powers.

As a result, longer-term growth forecasts from both private groups and public agencies are being revised upwards. For example, Figure 1 summarises the aggregate forecasts for GDP (in constant purchasing power parity prices) from the IMF World Economic Outlook published in April 2007, using a ten-year moving average annual growth rate. The IMF's projected global growth rate over 2002–2012 is 4.9%, the same as the actual growth rate for 2002–06. This is not driven by the advanced countries, whose overall growth is projected to slow gradually, but by accelerating growth in all other countries, expected to reach 7.1% per annum over 2002–2012.

Figure 1 also illustrates the changing dynamics of the world economy, as the growth rates of the two country groupings diverge and developing countries contribute a growing share of world output. The share of the advanced countries in world GDP (in PPPs) is now nearly down to 50%, and the increasing weight of more dynamic countries such as China and India in the global total will drive faster aggregate growth in the future.

Figure 1. Long-term growth in GDP in the OECD and non-OECD areas, 1982–2012 (ten-year moving average annual growth in GDP, at purchasing power parity prices)



Source: IMF (2007).

The climate implications arise not only from the likelihood of higher long term rates of world economic growth, but from two key facts about this growth path: that energy use and CO_2 emissions continue to increase in the developed countries and that many of the developing countries driving growth, such as China and India, rely heavily on coal for their energy needs. As an example within the developed countries, the 2007 projections from the US Department of Energy's Energy Information Agency for the USA, still the largest user of energy in the world, show energy use and CO_2 emissions from fuel combustion growing at 1.1% and 1.2% per cent per annum respectively from 2005–2030, with energy use and emissions from coal use both growing at 1.6% per cent per annum (DOE, 2007). In the second half of 2006, 140 new coal-fired power stations were in planning or construction in the US (Romero, 2006). In terms of the reliance on coal in key developing countries, in 2004 coal provided 71% of total primary energy supply (excluding biomass and waste) in China and 55% in India, by comparison with 17% for the rest of the world (IEA, 2006). As noted above, increased use of coal is already evident in the historical data – world coal consumption has risen by 30% between 2000 and 2006, about the same as the total percentage increase over the previous two decades, and growth of nearly 60% over the decade to 2010 seems inevitable.

This paper aims to document the reality of the new growth path and to explore its implications for climate analysis and policy, without embarking on the major task of providing a detailed projection and/or scenario consistent with it or exploring the climate implications of such a path through the use of climate models.[2] In pursuit of these aims, some further evidence of the reality of the new growth path is given by reviewing developments in China and India, and an indicative quantification out to 2030 is provided, based on the analysis of these two countries and recent IEA projections (Section 2). Then in Section 3 the implications of the new growth path for the viability of the SRES scenarios, and for the reference cases used by many climate modellers, are analysed and the appropriate role of scenarios and projections considered. In sections 4 and 5 some of the implications of such a growth path for the analysis of climate change and for climate policy are reviewed briefly, with conclusions presented in Section 6.

2. The impact of China and India on global trends

2.1 The shift to rapid growth in energy use in China

There has been widespread discussion in recent years about the rapid rate of economic growth taking place in China, and about the impact of that development on world markets for coal, oil and natural gas. Energy use has indeed grown very rapidly – over the five years 2001–06 total energy consumption grew by 71.5% (11.4% per annum), with GDP growth of 10.0% per annum.[3] This explosive growth in energy use was in sharp contrast with earlier trends. From the ‘opening to the market’ in 1979 to 2001 energy use grew at a much lower rate than GDP, with average rates of growth of 4.1% and 9.7% for energy use and GDP respectively, with the energy intensity of China’s GDP falling continuously through to 2001 and the elasticity of energy use with respect to GDP being only 0.42. This decline in energy intensity was especially marked in the second half of the 1990s, so that the shift to rates of growth in energy use in excess of GDP growth after 2001 had profound and unexpected implications in energy markets, and led to severe shortages in 2003 and subsequent years.

The decline in energy intensity in China over 1979–2001 was highly unusual for a developing country,[4] but most existing projections of China’s future energy use assume an early reversion to an energy elasticity of 0.5–0.7%, For example, the most well known projections internationally are those of the International Energy Agency (IEA), published biennially in its *World Energy Outlook*. In the 2006 edition, with an assumed average growth rate of GDP (in constant purchasing power parity prices) of 5.5% per annum over 2004–30, the IEA projected growth of only 3.2% per annum in

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[2] A companion paper, with colleagues from CSIRO Marine and Atmospheric Research and the Centre for Strategic Economic Studies, has developed an initial projection for global energy use and CO_2 emissions from fuel combustion to 2030 built on an interpretation of this new growth path, developed a lower bound extension from 2030 to 2100 based on a review of the technology literature and used the MAGICC model and a probabilistic meta-analysis of the scientific literature to explore the climate implications of the resulting emissions path (Sheehan, Jones et al., 2007).

[3] In the first half of 2007 China’s real GDP growth rate, relative to the same period of 2007, was 11.4% (NBSC, 2007b), while coal production was also up by 11.4% and electricity generation rose by 16.0% (NBSC, 2007c).

[4] There are many reasons why, in developing countries, the energy intensity of GDP is normally greater than one, as the development process shifts the pattern of production and of lifestyles towards more energy intensive activities and products. For example, for eight countries of South East Asia (excluding China) the unweighted mean elasticity of energy use with respect to GDP over 1971–2002 was 1.12, while for another 61 developing countries for which data are available the unweighted mean elasticity over this period was 1.45 (IEA, 2006, database).

total primary energy use in China over that period (IEA, 2006). This implies an elasticity of energy use with respect to GDP of 0.58, and that the rate of growth of China's energy use over 2004–2030 will be little more than half its rate over 1971–2002 (5.5%).

Of the existing published projections the most realistic, in terms of the trends that have emerged over 2001–06, is the unchanged policy case contained in China's National Comprehensive Energy Strategy and Policy (NDRC, 2004; see also Dai and Zhu, 2005). The unchanged policy scenario in this report projects annual average growth in energy use and CO_2 emissions over 2000–2020 of 4.7% and 4.6% respectively. These growth rates are reasonably close to the outcomes for 1971–2002 noted above, and well above the IEA 2006 growth rate estimates for 2002–2030. Nevertheless, Table 2 shows clearly that energy use in the Chinese economy is expanding much more rapidly than envisaged in scenario A. In terms of the main aggregate indicator, primary energy use, the actual figure for 2006 is about 15% greater than the projected figure for 2010, and electricity generating capacity in 2006 was 11% above the projected level for 2010. The demand for coal has been extremely strong, with the 2006 actual being 18.5% above the projected figure for 2010. The demand for oil was broadly in line with projections in 2006, as higher oil prices impacted on demand and led to fuel substitution, and usage of natural gas is also within the projection range. In terms of total energy use, and in particular coal use, the Chinese economy is on a path well above that in the 2004 official Chinese projections, which in turn are well above the IEA 2006 projections.

Table 2 also illustrates one of the main reasons for growth in energy demand ahead of the projection. It shows the actual output data for 2006 for four energy intensive industries for which output projections were provided in the NDRC report (2004). Output is running well ahead of expectations in these industries: for two industries (iron and steel and cement) output in 2006 was ahead of the 2020 projected level; paper production in 2006 was closer to the 2020 than to the 2010 projection, while ethylene output is also somewhat ahead of the projection. Consistent with these data, many observers (e.g., CASS, 2007) believe that a structural shift towards energy intensive industries is the main reason for rapid growth in energy use since 2001.

The Chinese Government has expressed concern about the economic, environmental and social impact of continuing high rates of growth of energy demand. In the 11th Five Year Plan (2006–10) the Government included as a priority target a reduction of 20% in energy use per unit of real GDP over the five-year period (Wen Jiabao, 2006). The precise implications of this target for the growth in energy use and the energy elasticity of GDP depend on the rate of growth of GDP achieved, but the implied elasticities range from 0.41 with 8% per annum GDP growth to 0.52 with 10% growth. Thus the current target also implies a return to the elasticity levels achieved over the 1979–2001 period.

Table 2. Projections for selected variables, China, Scenario A, National Comprehensive Energy Strategy and Policy to 2020, and actual values for 2005 and 2006

	Actual		Strategy Report – Scenario A		Actual
	2000	2005	2010	2020	2006
Primary energy demand (mtce)	1297	na	2137	3280	2460
Electricity generation capacity (GW)	319	402	559	947	622
Demand for fossil fuels					
Coal (100 m tons)	12.7	16.2	20.0	29.0	23.7
Oil (100 m tons)	2.3	2.9	3.8	6.1	3.2
Natural gas (100 m cubic metres)	272	399	840	1654	556
Output of main energy intensive products					
Iron and steel (m tons)	128.5	250	300	280	423
Cement (m tons)	597	680	790	1070	1235
Ethylene (10,000 tons)	450	790	1200	2000	941
Paper (10,000 tons)	2487	4000	5000	7500	6804

Note: Actual data for 2006 are from NBSC (2007a), except for electricity generation capacity; the figure for electricity generation capacity is an official one (People's Daily Online, 2007).
Source: For actual 2000 and strategy report values see NDRC (2004).

Issues concerning the shift from an energy elasticity of GDP of less than 0.5 over 1979–2001 to a value greater than one over 2001–06, together with the prospects of reverting to earlier levels in the near future, are thus critical to understanding the future path of China's energy use. The reasons for the low elasticity over 1979–2001 have been analysed in an extensive literature (e.g., Sinton and Levine, 1994; Lin and Polenske, 1995; Garbaccio et al., 1999; Sinton et al., 1998; Zhang, 2003; Andrews-Speed, 2004) but limited scholarly attention has as yet been given to the post-2001 trends. In terms of the declining aggregate energy intensity up to 2001, there is strong evidence that this reflected a widespread fall in sectoral energy intensities and took place in spite of an ongoing shift to a more energy intensive economic structure. The fall in sectoral intensities was in turn due to a combination of energy conservation programs and technological change being driven by a planned economy with energy rationing, with rising relative energy prices also playing a significant role in the 1990s. Sheehan and Sun (2007) conclude that, now that energy supplies are abundant, the enforcement mechanisms of the command economy no longer available and rapid growth in energy intensive industries is continuing, an elasticity of significantly less than one will be difficult to achieve, and will require sustained and integrated policy implementation.

Consistent with this analysis, Sheehan and Sun (2007) use a simple but disaggregated model to project China's energy use and emissions out to 2030. They conclude that, on the policies in force in 2005, China's energy use and CO_2 emissions from fuel combustion are likely to grow by more than 6% per annum over 2005–30. This would imply emissions from energy use (excluding cement production) of 6.2 GtC in 2030, by comparison with an overall global figure in 2004 of 7.2 GtC. Their simulations indicate that achieving major reductions will be difficult, but that a sustained new policy implementation process, involving use of the full range of instruments, could reduce China's energy use and CO_2 emissions by about 35% relative to this projected level by 2030, implying a growth rate over 2005–30 of 4% per annum.

2.2 The sustained rise of India

India's growth has been accelerating since the late 1970s, and reached 5.5% in the Ninth Plan period, 1997–2002. The preliminary GDP growth rate outcome for the Tenth Plan period, 2002–07,[5] is 7.6% per annum, by comparison with a target of 8.1%, and growth in the last two years of the plan period averaged 9.2% (http://www.mospi.nic.in). The Planning Commission (PC) has set a growth rate target of 9% for the Eleventh Plan period, 2007–12, with sectoral growth rates of 4.1% for agriculture, 10.5% for industry and 9.9% for the service sector (PC, 2007). India's growth has traditionally been driven by services rather than industry, but a notable feature of recent trends has been an increase in the growth of secondary industry (and especially manufacturing) relative to the overall growth of GDP. The target growth rate for real value added in manufacturing is 12% per annum.

The energy elasticity of GDP (excluding energy from biomass) for India was 1.15 over the period 1971–2005, although it was lower over 1990–2002 than in the earlier period. Energy use in India has been limited to date by a focus on service industries and by supply shortages, and half the country's population remains without electricity (PC, 2007). But industrial and household demand is increasing and sustained efforts are being made to increase electricity generation, primarily through coal-fired power stations. The Planning Commission projects that the demand for coal will rise by 7.6% per annum between 2005–06 and 2011–12 (PC, 2007). India has also been highly dependent on energy from biomass and waste. But with expansion possibilities limited in these traditional areas, growing demand for energy will need to be increasingly met from commercial sources.

The major forward-looking study of India's energy requirements is the Report of the Expert Committee on Integrated Energy Policy, prepared for the Planning Commission and published in August 2006 (Parikh, 2006). This report outlines both India's growing energy needs in the context of rapid growth and the programs that are being put in place to ensure that they are met. On the demand side, and on the basis of a range of assumptions about growth rates and the energy elasticity of GDP, it projects growth in commercial energy demand in India between 5.6% and 7.2% per annum over 2006–07 to 2031–32. On the supply side the authors run eleven alternative scenarios, starting from an existing policy case in which the least cost energy sources are developed (scenario 1) through a cascading series of policy scenarios in which the potential of non-fossil energy sources and of energy savings are maximised. In scenario 11 all such policies are implemented simultaneously. For their preferred case of 8% GDP growth, scenario 1 projects an increase in commercial energy use of 6.0% per annum over 2006–07 to 2031–32, while for scenario 11 the figure is 5.1% per annum. In scenario 1 CO_2 emissions from energy use are expected to rise about 7% per annum to 1.5 GtC by 2031–32, while projected emissions by that date are about one third lower in scenario 11 at 1.0 GtC, a growth rate of about 5.5%.

[5] The Indian year 2006–07, often referred to as the 2007 year, concludes in the January-March quarter 2007.

2.3 An indicative quantification of the implications of the new growth path

The purpose of the preceding discussion is to provide evidence, for two major countries, on emerging trends in GDP growth and energy use. The new growth path will, of course, impact on many other countries in different ways. But it is important to note the scale of developments in China and India: if, in the light of the trends reviewed above, CO_2 emissions from fuel combustion and cement production are assumed to grow by 6% per annum in both China and India over 2004–30, the *additional emissions* in 2030, over and above the IEA (2006) projection for that year, amounts to 52.5% of global energy demand in 2004. That is, these revised assumptions alone produce a further increase of over 50% in global emissions relative to the 2004 level, in addition to the increase of 59% already envisaged in the IEA 2006 projections, by 2030.

Short of an authoritative international projection of the implications of the new growth path being available, the strategy of Sheehan, Jones et al. (2007) is adopted here to provide an indicative quantification for working purposes. They start from the IEA (2006) projections, but adjust them to take account of the trends discussed above in China and India, and in a number of other rapidly developing countries in East Asia, but otherwise adopt the IEA (2006) assumptions and results. The methodology and detailed assumptions used are described in that paper while the results, for CO_2 emissions from fuel combustion and cement, are provided in Table 3. Emissions in 2030 are 120% above the 2004 level (and 150% above the 2000 level), and still growing at over 2% per annum at that time. This projection is an unchanged policy projection, based on policies that were enacted or adopted by mid 2006, but not taking account of any future policy initiatives. But it does allow for the improvements in energy supply and end use technologies, and in energy efficiencies, that can reasonably be anticipated under existing policies. For further details of the unchanged policy specification see IEA (2006, Chapter 1).

Table 3. CO_2 Emissions from fuel combustion and cement production, selected countries and world, actual 1971–2004, projected on unchanged policies to 2030

	CO_2 emissions (GtC)			Annual change (% per annum)				
				Actual	Projected			
					Current paper			IEA (2006)
	1971	2004	2030 (projected)	1971-2004	2004-15	2015-30	2004-30	2004-30
OECD	2.6	3.6	4.3	1.0	1.0	0.5	0.7	0.7
Transition	0.6	0.7	0.9	0.4	1.4	0.5	0.9	0.9
China	0.2	1.4	6.8	5.8	7.9	4.9	6.2	3.3
India	0.1	0.3	1.4	5.4	5.8	5.7	5.7	3.3
Other countries	0.4	1.5	3.3	3.9	3.8	2.6	3.1	2.5
World	3.9	7.5	16.6	2.0	3.5	2.8	3.1	1.8

Note: The table covers CO_2 emissions from fuel combustion, including bunkers, and cement production, measured in gigatonnes of carbon (GtC).
Source: Sheehan, Jones et al. (2007), using historical data to 2004 is from IEA website (http://data.iea.org/ieastore/statslisting.asp).

There are two main limitations of this preliminary approach, but they are likely to be offsetting rather than reinforcing. One is the growth effect of the new economy on other countries. Strong growth in China and India will pull through more rapid growth in other countries, especially those that can provide goods or services to those markets, even as exports from China and India accelerate structural change in many advanced countries. This stronger growth is evident, for example, in providers of capital goods and intermediate inputs such as Japan and Korea, in resource suppliers such as Australia, Russia and Brazil, and in some developing countries. The other effect is the impact on resource and energy prices. Continued strong global growth will lead to sustained growth in the demand for energy and resources, and to increases in prices for these commodities relative to what would otherwise have been the case. Other things being equal, such higher prices will slow global growth in energy use relative to the reference case. The full analysis of these partially offsetting issues for the new economy is an urgent but complex task. In the interim the present analysis is provided as a first approximation. In what follows this unchanged policy projection (termed the NGP projection) is used as a broad indication of what the new growth path might imply, on existing policies.

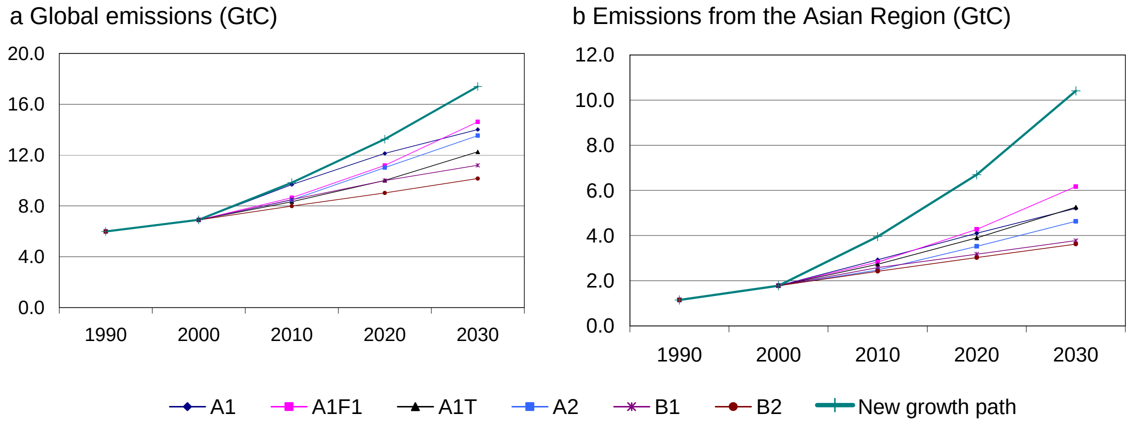
3. Implications for emissions projections and scenarios

3.1 Consistency with the SRES scenarios

Scenarios have long been an important part of the IPCC process, based on the view that uncertainty in socio-economic variables needs to be represented by a range of systemic, consistent scenarios covering both socio-economic variables and an explicit representation of how the variables interact. In 1996 the IPCC established a writing team to prepare a new set of emissions scenarios, to provide input to the Third Assessment Report. After a lengthy open process, which involved six integrated assessment models being used to assemble 40 specific scenarios for four ‘storylines’ that describe quite different social, economic and technological paths, the SRES scenarios were published in 2000 (Nakiçenovic and Swart, 2000). Much of the application of the SRES scenarios has made use of six ‘marker’ scenarios which summarise the variety evident in the full 40 scenarios, and that simplifying device is also employed here. These scenarios have provided the socio-economic foundation for a vast range of climate change analyses, including those underpining the IPCC’s Fourth Assessment Report. The SRES authors did not assign likelihoods to particular outcomes beyond their being plausible, arguing that this was not possible and that “the appropriate use of scenarios … focuses on how a range of scenarios describes the most important uncertainties at stake” (Nakiçenovic et al., 2003, p. 195). Nakecenovic et al. also acknowledge that “in time, there is no doubt that the SRES scenarios will need to be revised and updated or replaced by a new set” (p. 188). What is at issue here is whether the growing evidence for the new growth path means that the SRES scenarios still remain individually plausible and together describe ‘the most important uncertainties at stake’.

Table 4 and Figure 2 show the future paths of CO_2 emissions from fuel combustion and cement production to 2030 for the six SRES marker scenarios and for the new growth path projection (NGP), both for global emissions and for emissions from the Asian region. The new growth projection is here standarised to the common SRES values for 1990 and 2000, with the SRES definition of the Asian region matched as far as possible. For the world as a whole, new growth path emissions are well above the SRES marker range after 2010. By 2030 the range of emissions in the SRES marker scenarios is defined by A1FI (the highest) and B1 (the lowest); emissions in the new growth path projection in that year are 17% above the A1FI level and 53% above the B1 level. The rate of growth of emissions in the NGP (3.1% per annum over 2000–30) is double that of the lower SRES scenarios (B1 and B2) and about 25% above that of A1FI. The differences between A1FI and NGP emerge quickly, with NGP emissions 17% higher than those in A1FI by 2020, with similar growth rates in both cases in the 2020s. Beyond 2030 emissions in A1FI continue to grow strongly.

Figure 2. CO2 Emissions from fuel combustion and cement production, SRES scenarios and new growth path projection to 2030, world and Asia (GtC)



Sources: Nakiçenovic and Swart (2000), Sheehan, Jones et al. (2007) and estimates of the author.

Table 4 and Figure 2 also show that the divergence between NGP and all six SRES marker scenarios in projections of emissions from the Asian region is very large. By 2030 Asian emissions in NGP are 10.0 GtC, with about 80% of those emissions arising from China and India. By contrast the SRES range is from 3.6 GtC (B2) to 6.2 GtC in A1FI. Thus by 2030 NGP Asian emissions are nearly three time B2 emissions and 61% higher than A1FI emissions. The divergence between NGP and A1FI again starts early, with NGP Asian emissions being 36% higher than those in A1FI by 2010 and 54% higher by 2020. By contrast, the new growth path projection for all other countries taken as a whole is well within the SRES range, and indeed is lower than in four of the six SRES marker scenarios.

To the extent that NGP is a reasonable projection of global trends on current policies out to 2030, it follows that all of the SRES marker scenarios seriously understate unchanged policy emissions over that time, and do so because they do not capture the extent of the expansion in energy use and emissions that is currently taking place in Asia. Nor, as a consequence, do they capture the rapid growth in coal use that is also occurring. In all of the SRES marker scenarios other than A1FI, coal use is much lower as a share of primary energy use in 2030 than in 1990, with the falls ranging from 13% in A2 to 44% in B2. Only in A1FI does the coal share rise, and in both A1FI and in NGP the coal share is about 30% higher in 2030 than in 1990.

Table 4. CO_2 Emissions from fuel combustion and cement production, world and Asian region, SRES scenarios and new growth path projection, by major region to 2030 (GtC)

	1990	2000	2010	2020	2030	2000-10	2010-20	2020-30	2000-30
	World (GtC)					Per cent change (% pa)			
A1	6.0	6.9	9.7	12.1	14.0	3.4	2.3	1.5	2.4
A1FI	6.0	6.9	8.7	11.2	14.6	2.3	2.6	2.7	2.5
A1T	6.0	6.9	8.3	10.0	12.3	1.9	1.8	2.1	1.9
A2	6.0	6.9	8.5	11.0	13.5	2.1	2.7	2.1	2.3
B1	6.0	6.9	8.5	10.0	11.2	2.1	1.6	1.1	1.6
B2	6.0	6.9	8.0	9.0	10.1	1.5	1.2	1.2	1.3
New growth path	6.0	6.9	9.7	13.1	17.1	3.5	3.1	2.7	3.1
	Asia (GtC)					Per cent change (% pa)			
A1	1.2	1.8	2.9	4.1	5.2	5.1	3.5	2.4	3.6
A1FI	1.2	1.8	2.8	4.3	6.2	4.7	4.2	3.7	4.2
A1T	1.2	1.8	2.7	3.9	5.3	4.4	3.6	3.0	3.7
A2	1.2	1.8	2.5	3.5	4.6	3.4	3.6	2.8	3.2
B1	1.2	1.8	2.6	3.2	3.8	3.8	2.1	1.7	2.5
B2	1.2	1.8	2.4	3.0	3.6	3.1	2.2	1.8	2.4
New growth path	1.2	1.8	3.8	6.6	10.0	7.8	5.6	4.3	5.9
	All other countries (GtC)					Per cent change (% pa)			
A1	4.8	5.1	6.8	8.0	8.8	2.8	1.7	0.9	1.8
A1FI	4.8	5.1	5.8	6.9	8.4	1.3	1.7	2.0	1.7
A1T	4.8	5.1	5.6	6.1	7.0	0.9	0.9	1.4	1.0
A2	4.8	5.1	6.0	7.5	8.9	1.6	2.3	1.7	1.9
B1	4.8	5.1	5.9	6.8	7.4	1.5	1.4	0.8	1.2
B2	4.8	5.1	5.6	6.0	6.5	0.8	0.7	0.8	0.8
New growth path	4.8	5.1	5.9	6.6	7.1	1.4	1.1	0.7	1.1

Sources: Nakiçenovic and Swart (2000), Sheehan, Jones et al. (2007) and estimates of the author.

The SRES scenarios were a substantial intellectual achievement, and have stood the test of time for almost a decade. But the central feature of global economic trends in the early decades of the 21st Century – the new growth path shaped by the sustained emergence of China and India, in the context of an open, knowledge-based world economy – could not be foreseen in the 1990s, and is not covered by these scenarios. Many of the SRES scenarios are no longer individually plausible, and as a whole the marker scenarios can no longer be said to 'describe the most important uncertainties'. As a result, and especially given the emissions intensity of the new growth path, there is an urgent need for new approaches.

3.2 Consistency with the EMF-21 and CCSP baselines

Similar points can be made about the reference cases developed in a wide range of other modelling and scenario building exercises that have been undertaken in recent years. For example, Table 5 shows a summary comparison of NGP with the reference cases of some of the models used in the EMF-21 modelling comparison (Weyant et al., 2006) and of the three models used in the Synthesis and Assessment Product 2.1a of the US Climate Change Science Program (CCSP) (Clarke et al., 2007). Global data are available for eighteen models participating in the EMF – 21 project, although only ten provided details for both China and India. Table 5 shows emission levels in 2025 for both the highest and the lowest cases of the ten models (GTEM and GRAPE respectively[6]) as well as the arithmetic mean of all available scenarios (18 for the

[6] In terms of global CO2 emissions from fuel combustion and cement in 2025, GTEM is very close to the top of the 18 models (with a figure of 11.5 GtC by comparison with the highest, PACE and FUND,

world and 10 for the two countries). The table also shows the level of CO_2 emissions for selected years for the three models used in the Clarke et al. study, again by comparison with the NGP projection. There is some overlap between the models included in the two exercises, with MERGE and MiniCAM in both, although the model runs were done at different times and to somewhat different specifications.

In the EMF-21 exercise, each modelling team developed its own reference scenario, using its own exogenous or endogenous assumptions about key variables, but not including the Kyoto Protocol (Weyant et al., 2006). The results of the comparison of the EMF-21 reference cases to the NGP projection are similar to those for the SRES scenarios. By 2025 the NGP level of projected global emissions is 43% higher than the mean of the 18 EMF-21 models, and 27% above that in the highest, GTEM (Table 5). Although data for China and India are only available for 10 of the 18 models, for these 10 models the substantial difference is driven by a fundamentally different perspective on China and India, with the aggregate NGP figures for emissions from all other countries being within the EMF-21 range. The NGP projections for 2025 emissions from China and India are nearly treble the EMF-21 mean, and 123% higher than the GTEM estimate. Here again the key factors driving the new growth path do not seem to be captured in the EMF-21 reference cases.

Table 5. CO2 Emissions from fuel combustion and cement production, references cases for selected EMF-21 models, the CCSP analysis and the new growth path, by major region, (GtC)

Selected EMF-21 models					Models used in CCSP analysis					
	2000	2015	2025	Annual change (% pa)			2010	2020	2030	Annual change (% pa)
World		(GtC)		2000-25	**World**			(GtC)		2000-30
GTEM	6.3	na	11.5	2.4	MERGE	6.6	7.2	8.5	9.3	1.1
Mean	6.7	na	10.2	1.7	MiniCAM	6.7	8.2	9.5	10.9	1.6
GRAPE	6.5	na	9.9	1.7	IGSM	6.7	8.6	10.8	12.9	2.2
NGP	*6.6*	*11.0*	*14.6*	*3.2*	NGP	*6.6*	*9.3*	*12.7*	*16.6*	*3.1*
China and India					**Non Annex 1**					
GTEM	0.9	na	3.0	3.7	MERGE	2.6	3.2	4.0	4.8	2.1
Mean	1.3	na	2.6	2.9	MiniCAM	2.7	3.9	5	6.3	2.9
GRAPE	0.9	na	2.4	2.6	IGSM	2.7	4.0	5.4	6.7	3.1
NGP	*1.2*	*4.0*	*6.7*	*7.0*	NGP	*2.6*	*4.9*	*7.9*	*11.6*	*5.1*
Other countries					**Annex 1**					
GTEM	5.2	na	8.5	2.0	MERGE	4.1	4.0	4.5	4.5	0.3
Mean	5.5	na	7.7	1.4	MiniCAM	4.1	4.3	4.5	4.6	0.4
GRAPE	5.3	na	7.5	1.4	IGSM	4.0	4.6	5.4	6.2	1.5
NGP	*5.4*	*7.0*	*8.0*	*1.6*	NGP	*4.0*	*4.5*	*4.8*	*5.*	*0.7*

Sources: Weyant et al. (2006), Clarke et al. (2007), Sheehan, Jones et al. (2007) and estimates of the author.

For the Clarke et al. study, the modellers were asked to prepare their reference cases on the basis that no new climate policies were imposed beyond current commitments, which were to include the first period (2008–12) commitments of the Kyoto Protocol and the US goal of reducing emissions per unit of GDP by 18% by 2012 (Clarke et al., 2007). For these reference cases, the available data file allows a comparison to be made with the NGP projection for global emissions from fuel combustion and

both at 11.6 GtC), while GRAPE is well above the lowest figure (AMIGA at 8.4GtC, by comparison with 9.9 GtC for GRAPE).

industrial processes, disaggregated into Annex 1 and non-Annex 1 countries (Table 5). The NGP figure for global emissions in 2030 is 52% higher than the mean of the three model runs, being 29% higher than the IGSM figure and 79% higher than the MERGE figure. The NGP projection is in the centre of the three model range for Annex 1 countries but is nearly double the mean figure for non-Annex 1 countries, being 73% above the IGSM figure and 142% above that for MERGE. Again there is no apparent reflection in these models of the surging growth in GDP, energy use and emissions in key developing countries documented in earlier sections of this paper.

3.3 The SRES scenarios and the existing literature

An obvious question that arises is why, if this new growth trajectory is real and has generated considerable response on the part of governments and business, has it has little impact to date in the quantitative climate literature? The simple answer is, as Van Vuuren and O'Neill (2006) have shown, the SRES scenarios are largely consistent with existing projections of energy use and CO_2 emissions from fuel combustion. This transfers the question to why, if the new growth path is real, is it not embedded in existing projections of energy use and emissions, or at least those reviewed by Van Vuuren and O'Neill? Indeed, most of the criticism of the SRES scenarios in the literature has been that they are too high, either because they failed to adopt purchasing power parity measures for GDP (e.g., Castles and Henderson, 2003) or for other reasons (e.g., Hansen et al., 2000), rather than that they understate future growth.

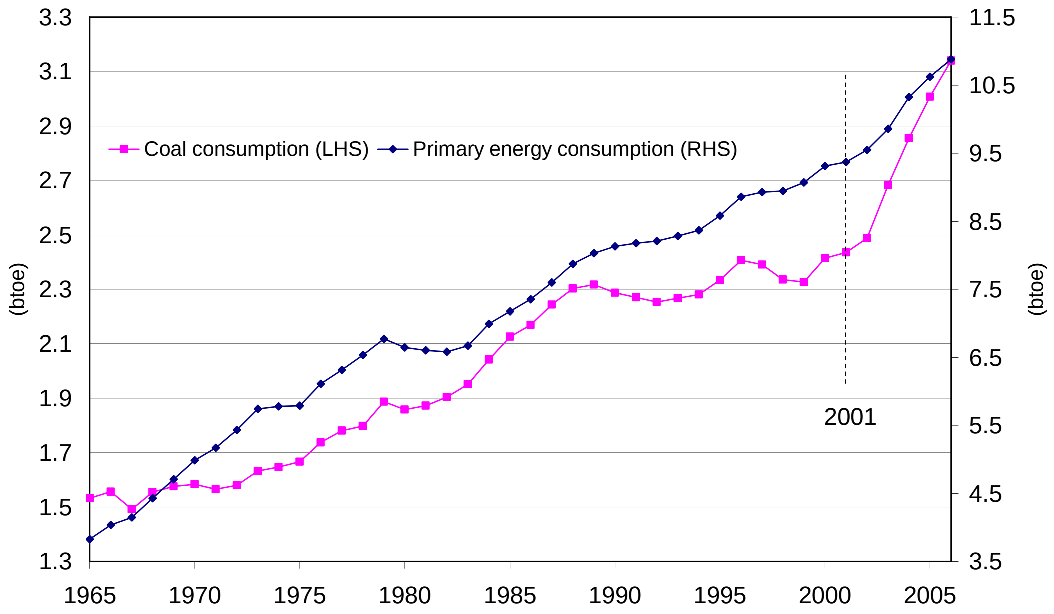
In respect of GDP, energy use and CO_2 emissions, Van Vuuren and O'Neill find that "the SRES scenarios…(are) largely consistent with historical data for the 1990–2000 period and with recent projections" (2006, p. 9). There is little doubt that this claim is correct for projections published up to 2004, and the main projections that Van Vuuren and O'Neill use as reference points are the IEA's *World Energy Outlook 2004* and the US Department of Energy's *International Energy Outlook 2004*. The 2006 editions of both these publications are now available, and again largely substantiate the conclusions reached by Van Vuuren and O'Neill.

To interpret the difficulties here it is necessary to place these projections in historical context. Figure 3 shows world total primary energy supply (TPES) and coal consumption, measured in billion tonnes of oil equivalent, from 1965 to 2006. One notable feature of the data is the slow growth in energy consumption, and the virtual stagnation in coal consumption, between 1989 and 2001. Over this period of twelve years TPES grew by only 1.3% per annum and global coal consumption by only 0.4% per annum (BP, 2007).[7] Thus in 2003 and indeed as late as the first half of 2004 (when only data up to 2002 were available) an energy analyst, using the historical data as a guide to the future, would see a picture of subdued growth, if any, in the key energy aggregates. These data undoubtedly contributed both to subdued projections and to an argument that the SRES scenarios overstated long run trends. As we have

[7] The reasons for this low growth in TPES and in coal consumption are now fairly clear. They include the decline in TPES, and especially in coal use, in the countries of the former USSR; the under-reporting of energy use, and again especially coal use, in China in the second half of the period, combined with the slowdown in industrial production in China at that time; and the substitution of either or both natural gas and nuclear energy for coal use in many countries in Europe. Revisions to data also blur the picture: using an earlier edition of the same source (BP, 2003), coal consumption fell by 2% between 1989 and 2001, and the rise in TPES was only 1.1% per annum.

seen, trends since 2001, and since 2002 in particular, have indeed been very different. Global TPES has grown at 3.3% per annum over 2002–06, and global coal consumption by 6.1% per annum. But models are estimated on or calibrated on historical data, and analysts are rightly reluctant to give undue weight to sharp changes evident in a few recent observations. Thus even a major change in the long term trend, if it indeed proves to be such, takes a considerable time to become fully incorporated in projections or model reference cases.

Figure 3. Global primary energy consumption and coal consumption, 1965–2006



Source: BP (2007).

If the new growth path is indeed a reality of the 21st Century world economy it will take considerable time for it to be reflected fully in large scale projections and in model-based analyses. In the case of the IEA projections, discussed and used above, the 2006 estimates differ little from those prepared in 2004, although the IEA did indicate when releasing the *World Energy Outlook 2006* that the 2007 edition will focus on the implications of developments in China and India for global energy markets. However, the IEA's full global forecasts are prepared only every two years, with the next set due for release in November 2008.

3.4 Projections and scenarios

It is often stressed that climate change is a long-term phenomenon, with the implications of increasing levels of CO_2 in the atmosphere being felt over a period of centuries and even millennia. But the time scale of the anthropogenic factors driving emissions are quite different from that of the physical processes driving climate change in response to those emissions. While the SRES scenarios emphasise the need for consistent frameworks for socio-economic analysis covering a century or more, the key socio-economic processes are operating on a much shorter timeframe than that. If it is likely, or even possible, that the unchanged policy emissions path to say 2030 would lock in serious climate consequences irrespective of which of a variety of possible paths beyond 2030 were followed, then a detailed analysis of the characteristics and implications of that path, whichever of many possible scenarios applied after than time, is an urgent task.

In terms of techniques to analyse the future, scenarios and projections are quite different, and emphasise different forms of knowledge. A scenario is an attempt to provide a consistent specification of one way in which the world might develop, based on relationships estimated from past experience and on the specification of a consistent set of assumptions for the future. An unchanged policy projection is an attempt to identify the most likely outcome under present policies, taking account of past relationships between key variables and information about future trends that can be gleaned from current practices, investments and intentions. There is a good deal of information, about future trends and the constraints on them, embedded in global economic and energy systems and in the development and diffusion of energy technologies. For example, asset lives of plant and equipment (e.g., of power stations) are very long, fuel types used and technologies in place change slowly, development trajectories in some countries seem well established and many complex social, economic and technological factors dampen rapid change at the system level. Thus trends in the global energy system over a 20–25 year period are much better understood than longer term ones. As a result it is possible to define a 'most likely' pathway describing those medium-term trends. Certainly the use of reference projections – the best available estimates of the implications of present policies for 20–25 years – is common practice in many areas in business and government analysis.

It is an empirical matter, relating to the shape of future developments, whether scenarios or projections are likely to be of most value for the analysis of future climate change. In the 1990s, when the IPCC decided to develop the SRES scenarios, it was reasonable to argue that the long-term nature of the uncertainties, in terms of both emissions and impacts, meant that scenarios would be most valuable. Now, with rapid growth in global energy use and emissions underway, there is an urgent need for the development of a detailed unchanged policy projection of global emissions over the next 20–25 years, as a basis for detailed modelling of the climate implications and as a basis for a variety of scenarios beyond the projection period.

4. Some implications for climate change analysis

In general the risks of climate damage will be greater and the cost of damage incurred higher for a high growth reference case than for a more subdued one, and these differences will impact on both cost-benefit assessments of policy initiatives and on stabilisation paths for given GHG concentration levels. This is clearly so for a reference scenario that is relatively high over the long term, say to 2100, but the discussion above relates only to the medium term, say out to 2030. Any full assessment requires an extension of the NGP projection out to 2100, but that issue can not be addressed here.[8] Nevertheless, the medium term emissions path remains of critical importance: the growth in emissions will constrain what longer term paths are available, may already be sufficient to trigger key environmental damages and will strongly influence the costs to be incurred in meeting any given stabilisation target.

[8] Sheehan, Jones et al. (2007) develop one method of addressing this issue, in terms of minimum emissions paths after 2030.

Here the potential implications of the NGP projection on climate change analysis are illustrated with the specific issue of stabilisation pathways.

There have been several recent analyses of pathways to stabilisation, and two such are discussed here. Meinshausen et al. (2006) developed a new method for estimating multi-gas emissions pathways, the equal quantile walk (EQW) approach, and used EQW inter alia to generate pathways consistent with stabilisation of atmospheric GHG concentrations at different levels. They estimate multi-gas emissions pathways by assuming that emissions of each gas in each region and year correspond to the same quantile of the respective distribution of emissions in a pool of 54 scenarios (40 non-intervention SRES scenarios and 14 post-SRES stabilisation scenarios (Swart et al., 2002)), with fossil fuel CO_2 emissions in the OECD region as the driver path. Emissions follow the median of the 54 scenario set until the departure year (2010 for Annex 1 countries and 2015 for other countries), after which year they are assumed to decline at a constant percentage rate, which is allowed to change at one point in the future. Simulations with the MAGICC model and an iterative optimisation procedure are used to identify the EQW paths consistent with various stabilisation levels.

In Meinhausen et al. (2006) this method was used to calculate EQW paths to achieve stablisation at various levels of CO_2 concentrations (from 350 ppm to 750 ppm), and in Meinshausen (2006) to estimate stabilisation paths for various CO_2 equivalent GHG gas concentrations. For stabilisation at 550 ppm CO_2e, for example, global fossil fuel emissions peak at approximately 8 GtC per annum around 2010–15, thereafter decreasing to 7.5GtC by 2035 and continuing to fall to about 4.5 GtC by 2100 (Meinshausen, 2006). The Stern Review used the underlying model (SiMCaP EQW), together with its own reference case (for fossil fuel emissions based on IEA, 2006) and some alternative assumptions, to examine alternative pathways consistent with stabilisation at 550 ppm CO_2e. They concluded that stabilisation at 550 ppm CO_2e requires global emissions of GHG to peak in the next 10–20 years, at about 46–56 $GtCO_2$e per annum, and then to decline by 1–3% per year, to be around 25% lower than current levels by 2050 (Stern et al., 2007). This implies peaking of fossil fuel CO_2 emissions in the next 10–20 years in the range of some 8–11 GtC, followed by steady decline.

The assumptions made about the reference path are critical to these calculations, and taking the new growth path projections seriously would have major implications for them. The use by Meinshausen and his colleagues of the median path of the 54 SRES and post-SRES scenarios means that they use a very low reference case, lower than most of the SRES marker scenarios discussed above. Given the current growth trajectory, there is no realistic prospect of CO_2 fossil fuel emissions peaking at as low a figure as 8 GtC during 2010–15; in the NGV projection these emissions are at 9.3 GtC by 2010, GtC by 2015 and 12.7 GtC by 2020, and still rising rapidly. Using such an unrealistic reference case means that the Meinshausen et al. analysis seriously understates the challenge involved in achieving stabilisation at 550 ppm CO_2e. The Stern Review uses a higher reference case (based on IEA, 2006) than Meinshausen et al., but one that has been shown above also to be unrealistic, and hence their conditions for achieving 550 ppm CO_2e stabilisation are also understated. On the NGV projection CO_2 emissions are at 14.5 GtC by 2020, and still growing rapidly. If stabilisation at 550 ppm CO_2e is to be achieved, given this underlying reference path, emissions would need to peak much earlier, and/or fall more rapidly, than suggested by either study.

The CCSP study reports on the use of three models (MERGE, MiniCAM and IGSM) to derive stabilisation paths to achieve various maximum long run levels of radiative forcing (3.4, 4.7, 5.8 and 6.7 W/m^2 from pre-industrial levels), broadly equivalent to the standard 450, 550, 650 and 750 ppm CO_2e levels. Emissions are constrained relative to the reference case in each model by the imposition after 2012 of a uniform global price for each unit of GHG emitted, which is designed to rise over time, at rates from 4% per annum in IGSM to about 6% per annum in MiniCAM.[9] As Clarke et al. (2007) note, the nature of the reference case is critical to the emissions reduction task implied by a given stabilisation target, and hence to the carbon price required to achieve it.

Table 6. Reduction in fossil fuel CO_2 emissions and the required carbon price, world, 2020–50, 550 ppm CO_2e stabilisation scenarios, three CCSP study models

	2020	2030	2040	2050
Reduction in global fossil fuel CO_2 emissions relative to reference case (%)				
MERGE	-0.8	-2.3	-7.8	-17.1
MiniCAM	-5.1	-9.0	-14.4	-21.0
IGSM	-24.2	-34.2	-32.7	-36.4
Level of carbon prices (2000US$ per tonne of carbon)				
MERGE	8	13	22	36
MiniCAM	15	26	44	69
IGSM	75	112	165	245

Sources: Clarke et al. (2007) and estimates of the author.

Table 6 shows, for the 550 ppm CO_2e stabilisation scenarios, the implied reduction in CO_2 emissions from fuel combusion and industrial processes relative to the reference case for the three models, from 2020–2050, together with the required carbon price, expressed in constant 2000 US dollars. As noted above, both MERGE and MiniCAM use very low reference cases, with global CO_2 emissions from fuel combustion at only 9.3 GtC and 10.9 GtC in 2030 respectively, 44% and 34% below the NGP projection by that time. As a result the required medium term reductions in CO_2 emissions to achieve this target are relatively modest – by 2030 only 2.3% for MERGE and 9% for MiniCAM – and the implied levels of the carbon price are also low – $13 and $26 by 2030 in the two models. This contrasts with the case of IGSM, which has a higher reference case (22% below the NGP projection by 2030) and which hence implies much higher carbon prices – $75 in 2020 and $112 in 2030. It is clear that the required carbon price using a reference case consistent with NGP projection would be much higher again, with the extent depending on the specification of the path after 2030, and that there is limited analytical or policy value in simulations, such as these runs with MERGE and MiniCAM, that use unrealistic reference cases.

[9] MERGE allows inter-temporal optimisation to find the cost-minimising allocation of emissions reductions across GHGs and over time, and the optimal the rate of change in the carbon price. This is influenced by the positive discount rate and other factors (such as the preservation of existing capital stock and the time required for the development of new technologies) that favour a gradual build-up of emissions reductions. In MiniCAM the rate of increase in the carbon price is set equal to the rate of interest plus the average rate of removal of carbon from the atmosphere by natural systems, while in IGSM it is set at 4% per annum (Clarke et al., 2007).

5. Some Implications for Policy Analysis

There are standard economic arguments for a gradual response to climate change, with the largest reductions in emissions delayed into the future – these include the costs of scrapping embedded capital, the time required to develop the most cost-effective new technologies and the lower net present value of future costs when positive discount rates are used (e.g., Wigley, 1996, Clarke et al., 2007). Such an approach is, for example, built into the CCSP scenarios discussed above. But the NGP path implies that much more urgent action is necessary if widely desired climate goals, such as stabilisation at 550 ppm CO_2e or limiting warming to 2^0C above industrial levels, are to be achieved, with major reductions in global emissions relative to the NGP path necessary within the next decade. If, on present policies, CO_2 emissions in 2020 are likely to be nearly double their 2000 level and still rising rapidly, there is an apparent conflict between the gains from gradualism and the need for immediate, large scale reductions relative to that reference path.

There has for some time been an extensive literature on the optimum choice of policy instruments for reducing emissions, and more recently studies have appeared that compare a wide range of different instruments to this end (e.g., Fischer and Newell, 2005; Gerlagh and van der Zwaan, 2006). Both of these studies find that the most efficient option is some direct pricing measure for carbon, with or without the investment of revenue received in renewables development, and that subsidies for technology development or for the increasing use of renewable energy sources are among the least efficient options. But little attention has been given to evaluating instruments in terms of timing: given implementation and other issues, which instruments are likely to achieve the maximum reduction in emissions in a given time span, and what would be the efficiency trade-offs involved? For example, the studies reported above have not been deployed to this end. Gerlag and van der Zwaan run their model with a baseline case in which CO_2 emissions increase very gradually, being less than 10 MtC in 2030 and less than 15 MtC in 2050, with the policy-driven deviation of emissions from the baseline mainly emerging after 2025. Thus these results also relate to gradual adjustment over an extended period of time.

There are many dimensions to the question posed above about the most effective instruments for achieving maximum emissions reduction in a given time, including the following.

- Should priority be given to measures to reduce the rate of growth of energy use, or that encourage investment in new ways of producing energy that create little or no carbon emissions?
- Should priority be given to increased utilisation of existing energy saving and renewable energy production technologies, or to the development of major new technologies with these characteristics?
- Should priority be given to the implementation of regulatory, tax and pricing measures, or to the development of unified market structures (such as a global cap and trade system) to ensure an efficient response?

There seems to be an a priori case that the implementation by the main emitting countries of regulatory, tax and pricing measures to reduce the rate of growth of energy use and to encourage the rapid utilisation of existing renewable energy technologies would produce a more rapid reduction in emissions than other approaches. Tax, pricing and regulatory measures can be implemented quickly, through existing structures; lower energy use directly reduces the demand for fossil fuels, and raises the possibility of phasing out the most polluting plants (e.g., old coal-fired generating stations); incentives for the increased use of existing renewables technologies might lead to a quick rise in investment, while also creating a larger market for renewables and hence incentives for further technology development; action by the key countries limits the need for lengthy international negotiations and for the creation of complex global structures. Such an approach would be in stark contrast to the current policy focus in many countries, which remains on long term technology development, both for fossil fuel and renewable energy sources, and on structural initiatives to create carbon markets in the context of global agreements.

This prima facie case cannot be confirmed, however, because little work has been done on the short-term effectiveness of various policies in reducing emissions, and on the extent of the notional efficiency losses involved in pursuing more immediately effective options. Given the new global growth path, serious attention needs to be given by policymakers to implementing measures to achieve a substantial reduction in emissions relative to that reference path within the decade. Achieving this will in turn require an improved knowledge base on the relative effectiveness of different policies in achieving immediate reductions and on the economic costs involved.

6. Conclusion

This paper provides evidence for five propositions. First, in recent years the world has moved to a new path of rapid global growth, largely driven by the developing countries, which now comprise 40% of world GDP. This growth path remains energy intensive and heavily reliant on the use of coal – global coal use will rise by nearly 60% over the decade to 2010. Second, if the key developing countries in Asia continue to drive growth after 2010, albeit at a more subdued pace, then on unchanged policies global CO_2 emissions from fuel combustion are likely to double their 2000 level by about 2020 and continue to rise beyond 2030. This must be considered a realistic, though of course not inevitable, unchanged policy outcome. Third, the SRES marker scenarios, finalised in 1998, do not capture this abrupt shift to rapid growth based on fossil fuels and centered in key Asian countries, and no longer provide a realistic guide for climate change analysis. The reference cases assembled in recent studies using integrated assessment models also fail to recognise this new reality. An international effort to develop new, realistic projections to 2030, with a range of scenarios beyond that time, is urgently required. Fourth, recognition of this new emissions path as a realistic possibility is likely to have a significant effect on the impact and damage estimates from an unchanged policy case, on the analysis of achievable stabilisation paths and on estimates of the costs of achieving stabilisation at a given GHG concentration level. Finally, recognition of this new growth path also means that policy must focus on the short-run dynamics of emissions, and on measures with immediate impact. For example, if stabilisation is to be achieved at 550 ppm CO_2e a significant reduction in global emissions relative to the reference path is needed in the next ten years. This in turn will require an emphasis on policies with an immediate effect on emissions, perhaps such as price, tax and regulatory measures to reduce energy use and the rapid diffusion of existing non-fossil fuel technologies, together with greater knowledge about the effectiveness and the economic costs of such policies.

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