ISSN 1835-9728

Environmental Economics Research Hub
Research Reports

Climate Change Economics and Policy in the Asia Pacific

Frank Jotzo

Research Report No. 11

January 2009

About the authors

Frank Jotzo is a Research Fellow in the Resource Management in Asia-Pacific Program, Research School of Pacific and Asian Studies, The Australian National University. The author thanks colleagues at the Garnaut Climate Change Review, especially Stephen Howes, for many helpful discussions on the subject matter. Thanks to Jeff Bennett and Ron Duncan for helpful comments. Support from the Environmental Economics Research Hub is gratefully acknowledged.

Environmental Economics Research Hub Research Reports are published by the The Crawford School of Economics and Government, Australian National University, Canberra 0200 Australia.

These Reports present work in progress being undertaken by project teams within the Environmental Economics Research Hub (EERH). The EERH is funded by the Department of Environment and Water Heritage and the Arts under the Commonwealth Environment Research Facility.

The views and interpretations expressed in these Reports are those of the author(s) and should not be attributed to any organisation associated with the EERH.

Because these reports present the results of work in progress, they should not be reproduced in part or in whole without the authorisation of the EERH Director, Professor Jeff Bennett (jeff.bennett@anu.edu.au)

Crawford School of Economics and Government
THE AUSTRALIAN NATIONAL UNIVERSITY

http://www.crawford.anu.edu.au

Table of Contents

Climate Change Economics and Policy in the Asia Pacific

Frank Jotzo[*]

****Abstract****

This research report examines the implications of international efforts to mitigate the impacts of human activity on climate for countries in the Asia-Pacific region. The Asia-Pacific region is the major source of global growth in greenhouse gas emissions. To reduce global emissions requires strong action in Asian countries, particularly China and India. Domestic policies to limit the growth in greenhouse gas emissions are already in place in some Asian countries, in part driven by the desire to limit energy consumption. But much more ambitious policies are needed to turn emission trends around.

**An earlier version was published in *Asian-Pacific Economic Literature* 22(2), 2008,
available at www.blackwell-synergy.com**

[*] Frank Jotzo is a Research Fellow in the Resource Management in Asia-Pacific Program, Research School of Pacific and Asian Studies, The Australian National University. The author thanks colleagues at the Garnaut Climate Change Review, especially Stephen Howes, for many helpful discussions on the subject matter. Support from the Environmental Economics Research Hub is gratefully acknowledged.

Introduction

Climate change has risen high up the policy agenda internationally, including in many countries of the Asian Pacific region. There is a high probability that human-induced climate change is real and that the costs of future climate change could be high (IPCC 2007, Stern 2007, Garnaut 2008). Perhaps the most important factor for climate policy is that climate change is no longer seen by researchers, policymakers and much of the wider community as just an environmental problem, but as a challenge to economic development and prosperity.

Growth in global greenhouse gas emissions accelerated during the period 2000-07, driven by rapid growth in developing countries. The task in reducing emissions to levels considered ‘safe’ is considerable, as it involves fundamental changes in many parts of the world’s energy systems, selected industries, and consumption of some goods. Significant options to reduce emissions exist, but will need policy action to be realised. Some policies have been implemented in countries of the Asia Pacific and more are being planned or prepared.

Questions remain as to whether, when, and how the US and China will embark on comprehensive policies to curtail greenhouse gas emissions, and how such action by the largest emitters will fit into a future international climate agreement. These are the key issues in the international climate negotiations, which, following the Bali conference, have a broad roadmap but clear-cut destination. This research report surveys the issues and relevant recent literature.

The report was finalised in January 2009, on the basis of an earlier version written before the onset of the global financial crisis and subsequent slowdown in economic growth. The possible effect of a recession are addressed in selected parts of the report, but do not pervade the analysis.

The economics and science of climate change: Stern and the IPCC

Two studies marked the change in public perception and policymakers’ attitudes to climate change. The first was the Stern Review on the economics of climate change (Stern 2007). Sir Nicholas Stern, a former World Bank economist, was commissioned by the UK government to provide a report on the economics of moving to a low-carbon economy, and of adaptation to changes in the climate. He drew strong conclusions that shifted the parameters of the policy debate: climate change could have very serious impacts on growth and development; the costs of stabilising the climate are significant but manageable, if strong action is taken soon; and action across all countries is needed, using a comprehensive suite of policies to overcome ‘the greatest market failure the world has ever seen’ (Stern 2007:644).

The Stern Review used economic modelling from which it was concluded that if no action was taken on climate change, the costs and risks of future climate change would amount to losing 5 to 20 per cent of GDP; whereas the costs of reducing greenhouse gases to avoid the worst of the impacts could be limited to one per cent of GDP. Though often interpreted as a cost–benefit analysis, it was not: there was no assessment of climate damage under the scenario where emissions are reduced, and the time scales for assessment of climate change damage and mitigation costs differed.

The estimates provoked debate in the economics profession (Weitzman 2008b; Nordhaus 2008; Dasgupta 2007 and for a recent summary analysis Baker et al. 2008), with disagreement especially about the chosen discount rate (see Quiggin 2008 for an overview of the discounting issues). The discount rate is a crucial parameter because costs from reducing emissions (mitigation) would be incurred immediately, whereas the benefits of mitigation in the form of reduced climate change impacts would occur over time spans measured in centuries. Stern used a discount rate lower than in many previous analyses, comprising of a near-zero pure rate of time preference and a relatively low parameter for the intertemporal rate of substitution.

Debate also revolved around the valuation of future climate impacts in Stern’s modelling. Some disputed that future (richer) societies would be as vulnerable as assumed, for example, to the spread of malaria (Tol and Yohe 2006). Others argued that increases in relative prices of environmental goods needed to be taken into account—which would lead to higher damage estimates—and that non-market damage from climate change was underestimated (Sterner and Persson 2007); that the loss of non-substitutable natural capital and the risk of catastrophic changes was under-priced (Neumayer 2007; Baer 2007); and that conventional methods of economic analysis were applied to a problem for which they are unsuitable (Spash 2007). Stern was also criticised for presenting the analysis as overly definitive when there are so many uncertainties.

Notwithstanding the debate among economists about modelling reported in one of 27 chapters of what is generally seen as an authoritative report, the Stern Review had a powerful effect on governments. It forcefully made the argument that, globally, policies to reduce greenhouse gas emissions will be in the interest of economic growth rather than hampering it: though it remains tremendously difficult to achieve global cooperation, as discussed below. Other countries are preparing, or have prepared, assessments of the economics and policy of climate change. Australia's Garnaut Climate Change Review (Garnaut 2008a) is to date the most comprehensive exercise of its kind examining policy options for a particular country.

The second influential publication marking the greater urgency of the issue was the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007). The IPCC reports are a systematic assessment of the relevant literature, and the summaries are agreed between governments. Despite criticisms of the process, the IPCC reports are widely regarded as an accurate reflection of climate science, and carry weight with decision makers.

The IPCC reports unequivocal observations that global warming is taking place, with 11 of the past 12 years among the 12 warmest on record, declining snow and ice cover and accelerating sea-level rise, changes in precipitation, and the number of hot days and nights. These changes are generally attributed to human-induced rises in atmospheric greenhouse gas concentrations. With further increases in atmospheric concentrations of greenhouse gases, there is predicted to be further warming and sea-level rise, reduced snow and ice cover, increases in heat waves and heavy rainfall events, more intense tropical storms, and changed patterns of rainfall and winds. These changes are predicted to affect a large range of human and natural systems, from agriculture through settlements and health to biodiversity.

Most recent indications are that the summary of the science in IPCC (2007) may be underestimating the risk of future climate change, because many of the most recent findings were not included in the IPCC report (Pittock 2006). For example, the IPCC's range of potential sea-level rise does not take account of the risk of disintegration of the ice sheets of Greenland and Antarctica. Understanding of the dynamics of ice sheets is still limited, but it appears that feedback mechanisms could lead to these sheets entering the sea, which would raise sea levels by many meters (Hansen 2007).

The possibility of climate system ‘tipping points’ (Lenton et al. 2007), with risks (even if small) of very large-scale or catastrophic climate change impacts raises complex questions for economic policymaking. It takes economics out of the realm of expected utility maximisation and into the field of decision making under uncertainty and the need for precaution (Weitzman 2008a).

Greenhouse gas emissions

The task of reducing global greenhouse gas emissions is immense. This section reviews drivers of emissions growth, the reductions thought to be necessary to limit climate change, and options to achieve them.

Emissions trends

Emissions of carbon dioxide, the main greenhouse gas, have grown steadily since industrialisation began. The average rate of growth was about 2.5 per cent throughout the 20th century (Marland et al. 2007). Carbon dioxide from burning coal, oil, and gas accounts for about 60 per cent of combined annual greenhouse gas emissions in terms of global warming potential. Annual growth in global fossil fuel emissions accelerated from about one per cent during the 1990s to about three per cent for the first half of the current decade, compared to about two per cent over the 1970s and 1980s. The dip in emissions growth in the 1990s was, in large measure, due to economic collapse and economic industrial restructuring in Russia and Eastern Europe, and also industrial modernisation in China. But, as discussed below, this largely was a one-off gain in improving the efficiency of energy use in industry, and was soon overtaken by resumed emissions growth. As pointed out by Raupach et al. (2007), recent growth rates in carbon dioxide emissions exceed that in almost all of the scenarios of future global emissions developed by the IPCC in the late 1990s (Nakicenovic et al. 2000), including for a scenario of high economic growth and fossil fuel dependence.

Another important contributor to global emissions is land-use change, principally deforestation in the tropics, which accounts for 15 to 20 per cent of global emissions (IPCC 2007). Deforestation is thought to have peaked in the early 1990s and to have been on a slight decline since then (Houghton 2003), but large potential for future emissions remains. Methane and nitrous oxide are the most important human-made greenhouse gases apart from carbon dioxide, accounting for about 14 and 8 per cent of global emissions, respectively, in terms of global warming potential. They arise from agriculture, mining, landfills, transport, and some industrial processes. In recent history, emissions of these gases have grown at an annual average global rate of about 1.4 per cent (EPA 2006).

Growth in global emissions is driven by the fast-growing developing and industrialising countries, especially China and other Asian countries. Non-OECD countries accounted for just under half of total energy-related carbon dioxide emissions in 2005, but for 85 per cent of the total increase in emissions from 2000 to 2005. China alone accounted for 55 per cent of the global rise. China is believed to have overtaken the US as the largest carbon dioxide emitter in 2007, and India is expected to become the third largest emitter by 2015 (IEA 2007b).

Analysis of likely trends shows that global emissions could remain on a high growth trajectory for some time in the absence of widespread policies to address climate change, and that many mainstream projections and scenarios tend to underestimate the potential for high emissions growth (Garnaut et al. 2008; Sheehan forthcoming; and see also the emissions baseline scenario in IMF 2008).

Why emissions growth accelerated in the early 2000s

The world economy in recent years expanded significantly faster than in earlier decades. Measured in purchasing power parity terms, global GDP grew at about five per cent annually in the past few years, compared to 3.0 to 3.5 per cent in the preceding decades. China's GDP growth of 10 per cent or more per year is the largest contributor, and has helped sustain high growth rates elsewhere, particularly in the developing countries (Garnaut 2008).

Increased economic activity goes hand in hand with increased energy use. In the early 2000s, global energy consumption grew at almost three per cent per year, implying a growth elasticity of energy use to GDP around 0.7 (IEA 2007a). Energy intensity (energy per dollar of GDP) fell by almost two per cent per year during the 1990s, with strong improvements in China and Eastern Europe, but the annual decline has slowed to around one per cent since 2000, in line with the average since the 1970s. In China, energy demand has been growing almost as fast as GDP in recent years, according to official data (Table 1).

The final factor in the decomposition is the amount of emissions for each unit of final energy demand, also referred to as the carbon intensity of energy. Historically, this ratio slowly declined, but over recent years the trend has been reversed. Fast rising oil prices have also pushed up the price of gas, driving the expansion of coal, the most carbon-intensive fuel, and the expansion of high-carbon 'synthetic fuels' such as oil from tar sands (Kolbert 2007).

The outlook for the 2009 recession and beyond

At the time of writing in January 2009, indications are that the global financial crisis is resulting in a global recession, with aggregate economic growth well below rates of previous years, and likely to turn negative for some amount of time in most developed countries. This will result in lower energy use, as evidenced already in sharply falling prices for fossil fuels, and lower or even negative global emissions growth during the recession. There is little however to suggest that the longer-term outlook is changed significantly. When world economic growth resumes, it will translate into growing greenhouse gas emissions, unless policies change relative prices of fuels and energy sources, and/or large investments are directed into low-emissions energy sources and energy conservation.

Table 1: Statistics for selected countries

	Average annual growth rates, 2000-2005 (%)			Share in global carbon dioxide emissions (%)	
	GDP (PPP adjusted)	Energy use	Carbon dioxide emissions from fuel combustion	At 2005	Cumulative 1950-2004
China	9.4	9.1	10.8	19.0	9.9
India	7.0	3.2	3.5	4.2	2.6
United States	2.4	0.3	0.4	21.6	26.7
EU-27	1.9	1.1	0.7	14.7	20.0
Japan	1.4	0.1	0.7	4.5	4.8
Australia	3.3	2.0	2.1	1.4	1.2
World	*3.8*	*2.7*	*2.9*	*100*	*100*
Average annual growth rates, 1990-2000 (%)					
World	*3.2*	*1.4*	*1.1*		

Data sources: IEA 2007a, and WRI 2007 for cumulative emissions.

Stabilising greenhouse gas concentrations

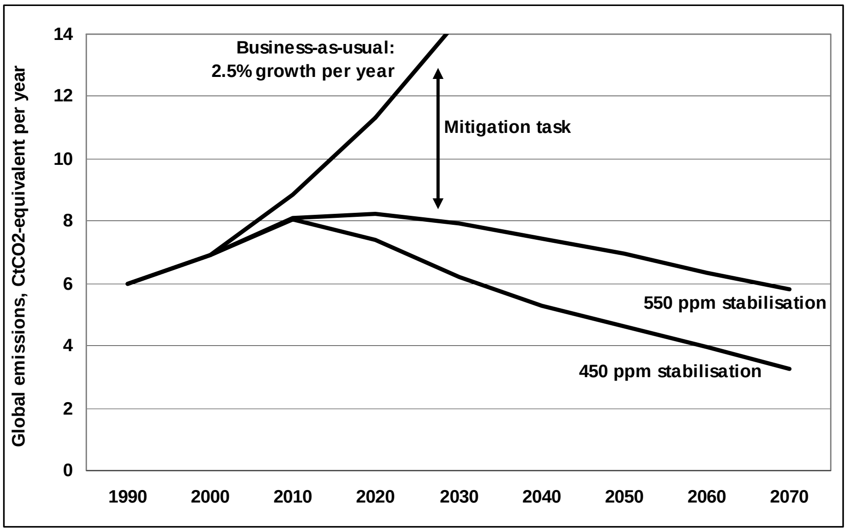
Containing the increase in the global mean temperature to two degrees above pre-industrial levels is now widely seen as necessary to keep the risk of dangerous climate change at an acceptable level, and to limit climate impacts (Schellnhuber et al. 2006). Recent scientific findings, not included in the IPCC (2007) report, point to greater than

There are great uncertainties about the temperature increases that result from particular levels of atmospheric concentration. The mean results from various assumptions and models indicate that, in order to have a good chance of limiting global average temperature increases in the long run to 2 degrees, atmospheric concentration of all greenhouse gases need to be stabilised at about 450 ppm of carbon dioxide equivalent (Meinshausen et al. 2006).

IPCC summaries of studies indicate that keeping concentrations in the range of 445–490 ppm requires global emissions to peak by 2015, and to fall by between 50 to 85 per cent by 2050 (as compared to 2000). Stabilisation at the next highest class of scenarios (535–590 ppm, which, under the mean model result, would result in an eventual temperature increase of 3 degrees), would require emissions peaking before 2030, and a change of –30 to +5 per cent by 2050. Continuing on present trends would result in much higher concentrations and greatly elevated risks of abrupt or catastrophic climate change.

Thus, to limit climate change, the annual global emissions growth of two to three per cent needs to be turned around to reductions of perhaps the same magnitude, as illustrated in Figure 1. Given that the bulk of annual increases in emissions is from developing countries, it is inescapable that emissions growth needs to be curbed and later reversed in developing countries, even if rich countries make very deep cuts in their emissions.

Figure 1: Emissions trajectories for stabilisation



Note: Illustrative stabilisation trajectories from the SimCap model (Meinshausen et al. 2006).

Options for mitigation

Slowing economic growth to achieve climate change mitigation is not a realistic policy option. Therefore, addressing climate change will require a change in the nature of economic growth: 'de-carbonisation' of global energy and industrial systems is needed, so that increasing economic activity is compatible with lower emissions. This will require pervasive changes in energy supply structures and technologies, as well as changes in consumption patterns.

Much of the 'low-hanging fruit' in reducing emissions is in improving energy efficiency, both in industry and for consumers. Many options carry negative costs; that is, the energy cost savings outweigh the investment costs (see for example Farrell et al. 2008). Standards, better information, and emissions pricing could all help overcome barriers to adopting more energy-efficient equipment and practices.

However, there are limits to energy efficiency improvements. To make large cuts in emissions from energy supplies also requires a shift to low-carbon energy sources, principally renewable energy sources (such as wind, hydro, solar, geothermal, bio-fuels, and others), nuclear power, or the capture and sequestration of carbon dioxide from fossil fuels.

It has been shown that it would be technically feasible to supply a large share of total energy needs from the renewable sources available today (for the case of Australia, see Diesendorf 2007), but in most cases these technologies carry higher energy supply costs than the fossil fuel alternatives, and some promising renewable technologies need further development.

Nuclear power is set to experience a renaissance in many countries, in large part because it is a low-emissions substitute for coal-fired power in electricity grids. However, as the recent Australian discussion has shown, the cost of nuclear power remains well above that for coal-fired electricity (Commonwealth of Australia 2006), and adoption in countries that do not already have nuclear power faces multiple hurdles (Owen 2006).

With ‘carbon capture and storage’ (CCS) technology, carbon dioxide from large point sources such as power stations would be pumped into underground geological formations, such as depleted oil or gas fields (Metz et al. 2005). High hopes are placed on the technology in countries that are large users and producers of coal (such as Australia), as it could secure the continuation of coal use and coal-based energy infrastructure in a carbon-constrained world. But CCS is a long way from being commercially available; it depends on suitable reservoirs being located within reasonable distance of power plants, and retrofitting of existing plants is likely to present difficulties. It will add significant costs, because new installations are needed and because separating and pumping the carbon dioxide uses up a portion of the energy released in combustion. Still, it is expected that CCS could play a major part in global greenhouse gas mitigation, especially if there is large investment in relevant research and development (Anderson and Newell 2004).

Deforestation and agriculture are the other main greenhouse gas sources. The net loss in global forest area is estimated at about 13 million hectares per year (FAO 2007), mainly in tropical developing countries and mainly for conversion to agricultural land. The largest land-use, climate change-related emitter in the Asia Pacific, and possibly globally, is Indonesia. With respect to land use, the mitigation options are to slow deforestation, regenerate damaged forests, and plant trees where there are none now. The potential for such action differs greatly between regions and within countries, often faces institutional hurdles, and usually carries an opportunity cost of foregone alternative uses of the land (Nabuurs et al. 2007). In agriculture, greenhouse gas emissions arise mostly from nitrous oxide emissions from soils and methane from ruminant animals (constituting significant shares of total emissions in New Zealand and Australia), as well as biomass burning, rice production (an important source in many Southeast Asian countries) and manure management (EPA 2005). Mitigation options vary greatly.

Emissions pricing of greenhouse gas emissions, by way of a tax or tradable emissions permits, is generally seen as the lynchpin of mitigation policy, as it can provide a pervasive price signal and drive shifts throughout the economy. Government support for development and deployment of low-emissions technologies will be needed to correct externalities in R&D where private actors cannot capture the full benefit from innovation. Removing barriers could involve providing better information to consumers, setting minimum technology standards, and revamping existing rules and regulations to facilitate the uptake of low-emissions practices and technologies.

Greenhouse policies in the Asia-Pacific

A workable international framework is likely to be essential for achieving the cooperation and coordination necessary for strong, yet cost-effective, global action on climate change. Nevertheless, the choice, design and implementation of policies will, to a large measure, be up to national or even sub-national governments. For example, domestic policies could take the form of emissions taxes, emissions trading, and regulatory measures, or indeed a mix of these policies, and still be compatible with an international system of emissions targets. Policies being implemented or under discussion in countries of the Asian Pacific region show diversity of approaches and level of ambition. The discussion here focuses on China and the US, the two largest global emitters by far. Their stance will be decisive for the progress of international climate policy.

China

Developments in China will be the most important variable in global greenhouse gas trajectories over coming decades. As discussed above, China has probably overtaken the US as the largest emitter and its emissions are growing faster than in any other major economy, driven by rapid economic growth fuelled by carbon-intensive energy consumption.

During the 1990s and earlier, major improvements were achieved in the energy intensity of the economy, which can be traced to strong improvements in industrial energy efficiency driven by government regulation, including shutdown of small, inefficient power plants (in part motivated by concerns about local air pollution), changes in ownership of state-owned enterprises, rising energy prices, and structural change (Fisher-Vanden et al. 2004; Wu et al. 2005; Sinton and Fridley 2000). These actions kept the growth in energy use and emissions at bay (Table 2).

However, many of the efficiency gains in the 1990s were one-off, and the move toward greater private sector control of the economy weakened emphasis on energy-saving measures. Quadrelli and Peterson (2007) report that investment in energy conservation as a share of total energy investment in China declined from 13 per cent in 1983 to 7 per cent in 1995 and to 4 per cent in 2003. Together with the boom in China's export industries, this decline resulted in a jump in the energy intensity of economic growth.

Meanwhile, the average carbon intensity of China's energy use has kept increasing, so that carbon dioxide emissions have grown faster than energy use and GDP—in recent years at over 10 per cent per year.[1] This fast growth is largely due to the changing energy mix, with growth concentrated in fossil fuels. From 1990 to 2005, coal energy demand doubled and the share of coal in total energy demand increased from 61 to 63 per cent (data from IEA 2007b). Increased coal use is predominantly for use in power generation, which is almost 80 per cent coal-based and booming; in 2006, nearly 90 per cent of new electric generation capacity was coal-fired. Lower or zero-emission sources (renewables, including hydroelectricity, nuclear power and gas) have been growing fast but from low bases; or in the case of biomass, stagnated in absolute terms. From 1990 to 2005, oil use, especially from transport, almost trebled, increasing its share in total energy use from 13 to 19 per cent.

[1] Growth in other greenhouse gas emissions is thought to be much slower. Emissions of methane and nitrous oxide, which account for about one-sixth of China's emissions in carbon dioxide equivalent terms, are reported to have grown by only 0.6 per cent per year from 1994 to 2004 (Government of China 2007).

Table 2: Growth in China's GDP, energy use and carbon dioxide emissions, historical and projections

		Average annual growth rates, 2000-2005 (%)		
		GDP (PPP adjusted)	Energy use	Carbon dioxide emissions from fuel combustion
Historical data (from IEA 2007a)				
1990-2000		10.4	2.5	3.2
2000-2005		9.4	9.1	10.8
IEA (2007b) WEO reference scenario projection				
2005-2015		7.7	5.1	5.4
2015-2030		4.9	2.0	1.9
Sheehan and Sun (2007) projection, base case				
2005-2015		9.6	7.9	7.8
2015-2030		6.3	5.4	4.9

Projections show continued strong increases in GDP, energy use, and emissions, but with growth rates diminishing as China's per capita income grows, a greater share of the economy is in the tertiary sector, and energy efficiency improves. Analysts disagree mostly over the extent and timing of the future slowdown in growth.

The International Energy Agency's projections (IEA 2007b) have China's average annual growth in energy and emissions at a little over five per cent to 2015, and just two per cent from 2015 to 2030. These numbers are predicated on the assumption that China's economic growth will slow considerably in the period after 2015 to just one-half the current rates, and that the energy intensity of growth will decline dramatically (Figure 1).

There are clearly substantial opportunities for improving energy efficiency further, especially with additional policy action (Farrell et al. 2008). However, other analysts do not expect that such a slowdown in energy use and emissions will occur under current policy settings. For example, Sheehan and Sun (2007) argue that China has now reverted to the typical developing country pattern of an elasticity of energy use to GDP of about one, and that a reversal to the pre-2000 relationship could only be achieved through strong policy action. If China's elasticity of energy use remains near one and the very high GDP growth rates continue, average annual emissions growth from 2005 to 2030 would be 6.1 per cent per year, as compared to 3.3 per cent per year under the IEA projections. The difference in emission levels by 2030 is striking: China’s emissions would double under IEA assumptions but increase four-fold under the assumptions made by Sheehan and Sun.

The Chinese government has recognised the challenges of climate change in official documents, and has put forth a set of objectives and principles for domestic policies to slow the growth in energy use and greenhouse gas emissions (Government of China 2007). The most far-reaching target, contained in China’s 11th Five-Year Plan, is to reduce energy intensity of GDP by 20 per cent from 2005 to 2010. Note that by framing the target in terms of intensity, the slower GDP growth expected for 2008 and 2009 (and possibly beyond) translates into a lower absolute target for energy consumption. Consequently, the economic slowdown does not necessarily make it easier to achieve the target, unless the cut in growth is concentrated in energy-intensive activities.

The 2005-10 energy target is part of a broader strategy of quadrupling GDP over the period 2000 to 2020, while doubling energy consumption (Government of China 2005). A reduction of roughly four per cent per year would be a sharp turnaround from the almost unchanged intensity over the previous five-year period. Energy statistics for 2006 show only a one per cent reduction in intensity (Energy Foundation 2007). Analysis of energy savings options (Lin 2007) concludes that with vigorous policy action, it is not impossible to meet the 20 per cent target through efficiency improvements in the industrial and buildings sectors, coupled with significant structural changes; but time is running out for the 2010 deadline.

Various policies and programs to reduce energy consumption have been launched or announced (Government of China 2007; and see Pew Center 2007 for an overview). They include closing inefficient power plants to the extent of about eight per cent of current generating capacity, closing small or outdated industrial plants, agreements linked to incentives with the largest 1,000 enterprises, promotion of end-use efficiency through standards and labelling, and mandatory fuel-economy standards for cars that are more stringent than those in the US.

Policies and plans to address the carbon intensity of energy supply include increasing the share of renewable sources, predominantly through a doubling of hydropower capacity. Nuclear power capacity is to be quadrupled. Within the thermal power generation sector, the development of high-efficiency coal power plants is to be accelerated, and methane arising from coal mining is to be utilised for power generation to a greater extent. China is also involved in initiatives with the US and Europe on carbon capture and storage. Programs to reduce emissions are also planned or underway outside of the energy sector, such as accelerated reforestation and the development of rice varieties that have lower methane emissions (Government of China 2007).

Limiting energy use and phasing out old plants is not primarily motivated by climate change objectives, but more so by China's concerns about energy security (Downs 2004), and local environmental impacts such as air pollution. It is unclear to what extent comprehensive policies to limit greenhouse gas emissions will be implemented. Even if fully implemented, they would fall short of stopping the growth in China's emissions. The Chinese Government (2007) cautions that 'with current level of technology development, to reach the development level of the industrialized countries, it is inevitable that per capita energy consumption and CO_2 emissions will reach a fairly high level' (p.19).

It is inescapable that 1.3 billion people seeking a western-level material lifestyle, in a country rich in coal and an economy expanding its infrastructure and manufacturing base, will increase their greenhouse gas emissions unless comprehensive mitigation policies are implemented. However, strong domestic policy action in China is likely to eventuate only if there is commensurate action in other major countries, especially the US, and ideally under an international agreement.

United States

Developments in the US could be the pivotal factor in determining global climate policy. Though emissions growth rates are low, the US is historically the largest global emitter by far and has among the highest per capita emissions and per capita income (Table 1). Together with its geopolitical status, this creates strong expectations for the US to lead international climate policy and to curb emissions at home. Inaction by the US has long served as a rallying point for developing countries opposed to taking on greenhouse gas commitments

The Bush administration rejected the Kyoto Protocol in 2001, and took an uncompromising line against policies to mitigate greenhouse gas emissions in its first term in office, refusing any policies that might reduce energy consumption, and casting doubt on climate change science (Depledge 2004). That position began to soften over the course of its second term, in the context of a growing sense in society that the threat of climate change is real, with President Bush calling climate change a ‘serious challenge’ in the 2007 State of the Union address. Bush called for a halt in America’s greenhouse gas emissions growth by 2025 (White House 2008b). A plethora of US initiatives and bills introduced into Congress (see below) show much greater ambition.

Pressure is growing from business and civil society groups for effective climate policy. For example, in January 2007, a group of major energy and manufacturing companies and environmental organisations called for ‘the prompt enactment of national legislation in the United States to slow, stop and reverse the growth of greenhouse gas emissions over the shortest period of time reasonably achievable’ (USCAP 2007:2).

Internationally, for most of its two terms the Bush administration opposed international climate policy under a UN framework, and partly withdrew from the climate negotiations. Over the course of 2007, the US began re-engaging with the UN process. In parallel, the US continues to pursue an approach focused on technology policy and voluntary approaches among a smaller group of countries, through its ‘major economies meetings’ begun in 2007.[2]

Domestically, policy at the federal level remains limited, encompassing selective measures such as fuel standards and ethanol subsidies (in part to reduce oil dependence, and tied up with farm policy), and funding for some technology initiatives. American greenhouse gas policy in recent years has been driven by the states. An agreement covering emissions targets and trading for the power sector is due to start in ten Northeastern and Mid-Atlantic states in 2009, dubbed the ‘Regional Greenhouse Gas Initiative’ (RGGI 2007). The scheme caps emissions at 2009 levels; then reduces total permits by 10 per cent by 2019. California has legislated for strong reductions in statewide emissions (Schwarzenegger 2006), with emissions reduced to 1990 levels by 2020, and 80 percent below 1990 levels by 2050. Subsequently, the

[2] At the first meeting in Washington in September 2007, representatives attended from Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Korea, South Africa, United Kingdom, the European Union, the European Commission, and the United Nations (White House 2008a). Subsequent meetings were held in 2008.

‘Western Climate Initiative’ was established, under which California, Arizona, New Mexico, Utah, and the Canadian provinces of British Columbia and Manitoba agreed on a regional, economy-wide greenhouse gas emissions target of 15 percent below 2005 levels by 2020 (WCI 2007).

A host of bills have been introduced in the US Congress, mostly cap-and-trade schemes for US greenhouse gas emissions (Pew Center 2008). None have passed but many are enjoying increasing support. The bill widely regarded as most likely to be passed is the Lieberman-Warner Climate Security Act (s2191 of October 2007). It proposes an economy-wide, cap-and-trade system for all greenhouse gases, with an aggregate cap four per cent below 2005 levels by 2012, 19 per cent below by 2020, and 71 per cent below by 2050. Other legislative proposals have broadly similar features, with 2050 targets between 60 and 80 per cent below 1990 levels. Despite all these initiatives, a fundamental reluctance to embark on significant policy action remains unless key developing countries do likewise: which was the ultimate reason for the resounding rejection by Congress of the Kyoto Protocol.

It is a widely shared expectation that both the US position internationally and domestic climate policies will change sharply under President Obama who has proposed a reduction to 1990 levels by 2020, and an 80 per cent reduction by 2050. . At the time of writing in January 2009, the newly elected Obama administration appears intent on introducing a variety of measures to curb greenhouse gas emissions, including in the context of reducing dependence on imported oil and providing fiscal stimulus to the economy, but details are not yet clear. Questions remain as to what extent and under what terms the US will be part of a post-2012 international climate agreement to succeed the Kyoto Protocol’s first phase.

Japan and Korea

Japan has strong political and symbolic incentives to comply with the Kyoto Protocol and ensure its continuation—given that it was conceived in Japan’s imperial city—but finds reducing emissions difficult. Japan is already the most energy efficient of the major developed countries, and thus finds it harder to reduce emissions by increasing efficiency.

In 2008, Japan announced a long-term target of a 60 to 80 per cent cut in emissions by 2050 from current levels. This is to be achieved through emissions trading, renewable energy targets, and low-emissions automobile targets. A limited, voluntary emissions trading scheme has been in place since 2005, which was succeeded in 2008 by a (still voluntary) prototype emissions trading scheme, which may be turned into a mandatory scheme in coming years (Hitomi and Tuerk 2008).

Korea is notable for essentially being a developed country, with a per capita income above that of the EU average, and a member of OECD, but with no commitments to limit or reduce emissions under the Kyoto Protocol.[3] In August 2008, Korea announced plans for an emissions target that would slow emissions growth until 2020 (Carbonpositive 2008).

Indonesia

Indonesia would generally not be thought of as a candidate for comprehensive climate policies, given its state of development and the fact that, despite its large population, it is not one of the large players in global politics. However, deforestation and land management put Indonesia in a special category with regard to climate change policy.

Indonesia is thought to have been the world's third largest emitter in the late 1990s, if emissions from deforestation are comprehensively counted (PEACE 2007). Indonesia has the greatest rate of land clearing, ahead of Brazil, and in addition to carbon lost from trees removed and soils exposed, vast amounts of carbon are released through fires, especially in peat soils (Page et al. 2002; Tacconi 2003; Hooijer et al. 2006). Despite high and rising opportunity costs for land conversion, especially to oil palm plantations, slowing deforestation in Indonesia offers large opportunities to reduce emissions, often at very low cost compared to options in other countries' energy sectors (Chomitz 2006). Indonesia's strategy for long-term reductions in emissions, released at the Bali UN climate change conference in December 2007, has as its central plank the reduction of deforestation, coupled with reforestation.

However, the institutional challenges inherent in controlling land-use change and improving land and fire management are enormous. Availability of large-scale international financing could help in creating incentives to reduce emissions; but the issue remains how the financial incentives can be applied effectively at the local level where decisions about land use are taken.

[3] A number of other countries classified as high-income by the World Bank also have no quantitative commitments under the Kyoto Protocol.

Indonesia's emissions from fossil fuel are still small on a per person basis but are growing fast. Energy use is increasing almost as fast as GDP, and emissions are growing significantly faster than GDP, principally because of a shift from oil into coal. Plans for expansion of the power system using low-grade coal are reinforcing this trend (Narjoko and Jotzo 2007).

Australia and New Zealand

Australia's climate policy under the Howard government, especially between 2001 and 2006, was characterised by a defensive approach, epitomised by the refusal to ratify the Kyoto Protocol and to implement any market-based mechanisms to control greenhouse gas emissions at the federal level (Christoff 2005). Climate policy relied almost exclusively on voluntary initiatives and government support for technological solutions, especially for removing carbon dioxide emissions from the combustion of coal, Australia's largest energy source and energy export. Only in late 2006 did the government's position on climate change begin to shift (Jotzo 2007).

Internationally, Australia promoted voluntary, technology-based cooperation with selected countries under the Asia-Pacific Partnership on Clean Development and Climate, which involved Australia, China, India, Japan, South Korea, and the US (APP 2006). APP created various government–industry task groups and action plans for development and deployment of cleaner technology, but funding commitments were small relative to the magnitude of the task.[4] It has been criticised for distracting attention from emissions pricing (Pezzey et al. 2008), and as an attempt to obstruct progress under the UN framework (McGee and Taplin 2006). Others lauded it as an opportunity to develop better policy by virtue of involving a smaller number of important countries (Kellow 2006). Despite the apparent demise of APP, it is clear that technology policy has a role in climate change mitigation, and may well be one of the key pillars of international cooperation, including between the US and China (Zhang 2007).

Australia's government under Prime Minister Rudd has ratified the Kyoto Protocol and announced that emissions trading will begin in 2010. Australia's longer-

[4] Government funding commitments were A$100 million over five years by Australia (subsequently withdrawn by the Rudd Government), and US$52 million by the US (blocked by Congress). This funding, compared to projected energy sector investment, needs over US$100 billion annually in North America alone, and over US$500 billion per year globally, averaged until 2030 (IEA 2003).

term national emissions target commitment as announced by the government is a 60 per cent reduction by 2050 relative to the year 2000. For 2020, the government's announced targets are a five per cent reduction compared to 2000 levels irrespective of the outcome from the international climate negotiations, and a reduction by up to 15 per cent depending on commitments by other countries. A white paper on an emissions trading scheme for Australia was released in December 2008 (Government of Australia 2008; for some preliminary analysis see Jotzo and Betz 2009).

New Zealand plans to introduce emissions trading from 2008, starting with forestry and subsequently expanding to other sectors (Government of New Zealand 2007). At the time of writing in January 2009, legislation had been passed, but it was unclear whether the new government would change it. New Zealand is planning an open trading regime, wherein emitters would be free to buy permits in the international carbon markets to make up any shortfall. The aggregate target for the economy is the Kyoto target of 2008-12 emissions, limited to 1990 levels. The estimated shortfall for New Zealand as a whole over the Kyoto period is estimated at about 20 million tons of carbon dioxide equivalent, valued at about NZ$500 million (New Zealand Treasury 2008).

The Clean Development Mechanism

As a means to make compliance with target commitments easier, the Kyoto Protocol allows using offset credits from emissions reduction projects in developing countries, under the Clean Development Mechanism (CDM). Under the CDM, firms or governments can propose and implement emissions reductions on a project-by-project basis. The resulting credits are bought by firms or governments that are under emissions reduction obligations. Large project categories are renewable energy (mainly using hydropower instead of fossil fuels), reduction of methane emissions from landfills, coal mines, and cement production, and destruction of potent industrial gases.

As of December 2008, there were over four thousand CDM projects underway or in preparation, which, if implemented and approved, would yield expected emissions reductions of almost three billion tons of carbon dioxide equivalent by 2012 (UNEP Risoe Centre 2008). The Asian Pacific region accounts for 80 per cent of the CDM credits that are currently expected to be generated, with China accounting for over one-half, followed by India as the next largest supplier at 15 per cent. The World Bank (2008) cites supply estimates of 1.4 to 2.2 billion credits by 2012. This is sizeable relative to the reduction commitments in countries that implemented the Kyoto Protocol, but small relative to global emissions and the growth of emissions. Europe accounts for 90 per cent of CDM purchases, mainly by private companies. CDM credits are traded at around 15 euros per tonne (PointCarbon 2008), implying a total value of the CDM market in the tens of billions of dollars.

However, there are fundamental questions over the soundness of some of the emissions reductions credited under the CDM. Whether claimed emissions reductions are 'real' and would not have happened anyway cannot be proved, as actual emissions under a project can only ever be compared to a counterfactual baseline (Sugiyama and Michaelowa 2001). The rules for proving 'additionality' have been tightened, but the in-principle paradox cannot be overcome in an offset mechanism. Wara and Victor (2008) argue that the CDM suffers from non-additionality, that it has wasted large financial flows by paying high prices for credits from very low-cost abatement options, and that it creates perverse incentives because it 'encourages countries to avoid binding limits on emissions and to concentrate emission-reduction activities on marginal investments for which it is easiest to assert that the investment is "additional"' (Wara and Victor 2008:24).

Fundamentally, the CDM cannot by itself drive global emissions reductions, because a tonne of emissions reduced under the CDM is offset by an additional tonne released in a country with an emissions target. Offset mechanisms are a way to spread the abatement effort, begin engaging developing countries, and save costs, but not drive mitigation *per se*. How to get developing countries to accept and implement comprehensive emissions limits is the core problem in international climate policy.

Toward an effective global climate agreement?

The overriding problem in limiting climate change is lack of international cooperation. This arises because greenhouse gas emissions are an almost pure public ‘bad’. Emissions mix perfectly in the atmosphere, so the benefit from any person’s or country’s action to reduce their emissions will be spread over the whole world, as well as over future generations. The atmosphere is thus a global commons, and subjected to overuse unless and until mechanisms can be put in place to facilitate cooperation between nations and groups of nations. The nature of the problem is such that it requires a ‘combined effort of all states’ (Barrett 2007): to be effective, a large proportion of countries must contribute.

The challenge for international climate negotiations is to design and agree on a policy framework that leads to broad-based mitigation action in the majority of countries, including developing countries. In a follow-up to his review, Stern (2008) called for binding emissions targets for developing countries from 2020. To achieve this, not only must the free-rider problem be solved but also the vexed question of international equity. Developing countries account for the bulk of current and future increases in emissions and so need to be part of the solution, but have contributed a relatively minor share of man-made greenhouse gases currently in the atmosphere, and have lower emissions per capita and less economic capacity to mitigate.

The UN Framework Convention and the Kyoto Protocol

The UN Framework Convention on Climate Change (UNFCCC 1992; and see Yamin and Depledge 2004) has been ratified by nearly all countries. Its ultimate objective is to stabilise greenhouse gas concentrations ‘at a level that would prevent dangerous anthropogenic interference with the climate system’ (UNFCCC 1992:4). It has spelled out the principle of ‘common but differentiated responsibilities’, putting the onus on developed countries to take action as a first step toward comprehensive global action.

The Kyoto Protocol (UNFCCC 1997; and see Grubb et al. 1999 for a history and interpretation) committed developed countries and the transitional economies of Eastern Europe (including Russia) to quantitative emissions targets over the period 2008-12. The European Union is the key supporter of the Kyoto Protocol, while the US has rejected the Kyoto Protocol, referring to the lack of commitment by developing countries. Because of the limited participation and relatively unambitious targets, the Kyoto Protocol would reduce global emissions only marginally below what they would be without the treaty.

Setting targets *ad hoc* on the basis of current or past emissions levels, as under the Kyoto Protocol, will be unacceptable to developing countries, which are on a rising trajectory but at much lower levels of emissions per person.

The Bali Roadmap

Talks and negotiations about international climate policy are taking place in various forums (Höhne et al. 2008), but the UNFCCC is the main arena. During 2007, political expectations for UN climate negotiations were raised, including through the G8 summit declaration (G8 2007).

The 2007 UN climate conference in Bali marked the start of formal negotiations toward a post-2012 international climate agreement. The Bali Roadmap sets out an agenda and the cornerstones for negotiations aimed to culminate in an agreement at a conference in Copenhagen at the end of 2009 (Clémençon 2008; Eckersley 2008). This is an ambitious timeline, especially since the next US administration will not be in place until early 2009 and so will have little time to help shape the agreement. Many observers see progress in global climate policy pivoting around the US and China (Chandler 2008). To date each has cited the other’s inaction as a justification for their own lack of commitment; but if a deal could be reached between the two largest emitters it would change the global dynamics.

The Bali plan (UNFCCC 2007) has four pillars, namely mitigation, international cooperation on adaptation to climate change impacts, technology development and transfer, and financing for climate change-related investment. Of these, mitigation is the make-or-break issue. The plan calls for a long-term goal for reducing emissions, with ‘quantified emission limitation and reduction objectives by all developed country Parties’, and ‘nationally appropriate mitigation actions by developing country Parties’ (UNFCCC 2007:2). This is a clear advance over the Kyoto Protocol, but nevertheless perpetuates the dichotomy of developed and developing countries, with a presumption against quantitative commitments by the latter. The post-Bali talks over the course of 2008 have brought only slow progress, and the December 2008 climate conference in Poznan did not bring agreement on any major issues, rather it was an exercise of taking stock and preparing the 2009 negotiations. Most countries have been waiting for the new US administration to enter the international arena.

Conclusions

Global concern over climate change impacts and risks has increased greatly in recent times, and mitigating climate change has been recognised as an economic challenge and not just an environmental challenge.

The Asian Pacific region is home to the fastest-growing, large economies in the world, and has been the dominant source of the global growth in greenhouse gas emissions. To limit and reduce global emissions requires action in developing countries, in particular in Asia. Large opportunities to reduce emissions exist, but most carry economic costs and so will not be implemented unless policy settings change. Some domestic policies, in part driven by the desire to limit energy consumption, are already in place in China, the world's largest and fastest growing emitter, and in other developing countries. But much more ambitious policies will be needed to turn emission trends around in developing and developed countries alike.

The international dynamics are of the mutually reinforcing type: one country's action depends on other countries doing their bit. The more countries that commit to significant policies, the easier it will become to draw others in. Conversely, if some countries refuse to take part in collective action, others will find it tempting to exclude themselves.

An effective global response to climate change will need to involve both China and the US, be it in parallel domestic regimes, in a bilateral deal, or as part of a multilateral agreement. Most other large and medium-sized economies will need to be part of mitigation action. Following the Bali UN climate conference, and the election of US President Obama, there is an opening for more comprehensive international climate policy. For a post-2012 agreement to succeed in getting the world on to a lower-emissions pathway, the door must be kept wide open for developing countries to engage fully in mitigation policies, with the support of high-income countries.

References

Anderson, S. and Newell, R., 2004. 'Prospects for carbon capture and storage technologies', *Annual Review of Environment and Resources,* 29:109–142.

APP, 2006. *Charter for the Asia-Pacific Partnership on clean development and climate,* Inaugural Ministerial Meeting, Sydney, 11-12 January 2006, Asia-Pacific Partnership on Clean Development and Climate.

Baer, P., 2007. The worth of an ice-sheet: a critique of the treatment of catastrophic impacts in the Stern Review, Ecoequity. Available at <www.ecoequity.org>, accessed 10 July 2007.

Baker, R.; Barker, A.; Johnston, A. and Kohlhaas, M., 2008. *The Stern Review: an assessment of its methodology*, staff working paper, Productivity Commission, Melbourne.

Barrett, S., 2007. *Why Cooperate? The Incentive to Supply Global Public Goods,* Oxford University Press, Oxford/New York.

Carbonpositive, 2008. Sth Korea to set loose emissions target, Carbon Positive Trading Ltd., 26 August 2008. Available at <http://www.carbonpositive.net/viewarticle.aspx?articleID=1212>, accessed 2 Sep 2008.

Chandler, W., 2008. *Breaking the suicide pact: US–China cooperation on climate change*, Policy Brief 57, Carnegie Endowment for International Peace, Washington DC**.**

Chomitz, K.M., 2006. *At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests*, World Bank, Washington, DC.

Christoff, P., 2005. 'Policy autism or double-edged dismissiveness? Australia's climate policy under the Howard Government', *Global Change, Peace and Security*, 17(1):77–86.

Clémençon, R., 2008. 'The Bali Road Map: a first step on the difficult journey to a post-Kyoto Protocol agreement', *The Journal of Environment & Development* 17(1):70–94.

Commonwealth of Australia, 2006. *Uranium mining, processing and nuclear energy – opportunities for Australia?*, Report to the Prime Minister, the Uranium Mining, Processing and Nuclear Energy Review Taskforce, Department of Prime Minister and Cabinet, Canberra**.**

Dasgupta, P., 2007. 'Commentary: the Stern Review's economics of climate change', *National Institute Economic Review*, 199:4–7.

Depledge, J., 2004. 'Against the grain: the United States and the global climate change regime', *Global Change, Peace and Security*, 17(1):11–27.

Diesendorf, M., 2007. *Greenhouse Solutions with Sustainable Energy*, UNSW Press, Sydney.

Downs, E.S., 2004. 'The Chinese energy security debate', *The China Quarterly*, 177:21–41.

Eckersley, R., 2008. *The Bali Roadmap and beyond: Opportunities for Australia,* Policy Commentary, Australian Institute of International Affairs, Canberra. Available at <www.aiia.asn.au>, accessed 10 July 2008.

Energy Foundation, 2007. Year two: national 20-percent energy efficiency target for 2020, China Sustainable Energy Program, Beijing and San Francisco. Available at **<**www.efchina.org>, accessed 10 July 2008.

EPA, 2006. *Global mitigation of non-CO2 greenhouse gases*, EPA Report 430-R-06-005, US Environmental Protection Agency, Washington DC. Available at <http://www.epa.gov/climatechange/economics/international.html>, accessed 9 July 2008.

——2005. *Global anthropogenic non-CO2 greenhouse gas emissions: 1990-2020*, EPA Report 430-R-06-005, US Environmental Protection Agency, Washington DC. Also available at < http://www.epa.gov/climatechange/economics/international.html>, accessed 9 July 2008.

FAO, 2007. *State of the World's Forests 2007*, Food and Agriculture Organisation, Rome.

Farrell, D.; Nyquist, S.S. and Rogers, M.C., 2008. 'Curbing the growth of global energy demand', *McKinsey Quarterly*, 12 May 2008.

Fisher-Vanden, K.; Jefferson, G.H.; Liu, H. and Tao, Q., 2004. 'What is driving China's decline in energy intensity?', *Resource and Energy Economics*, 26(1):77–97.

G8, 2007. *Growth and responsibility in the world economy*, summit declaration, G8 Summit, Heiligendamm.

Garnaut, R., 2008. 'Will climate change bring an end to the platinum age?', *Asian-Pacific Economic Literature,* 22(1):1–14.

Garnaut, R., 2008a. The Garnaut Climate Change Review. Cambridge University Press. (also available at <www.garnautreview.org.au>).

Garnaut, R.; Howes, S.; Jotzo, F. and Sheehan, P., 2008. 'Emissions in the Platinum Age: the implications of rapid development for climate change mitigation', *Oxford Review of Economic Policy,* forthcoming.

Government of Australia, 2008. *Carbon Pollution Reduction Scheme Green Paper*. Department of Climate Change, Canberra.

Government of China, 2007. China's national climate change programme, National Development and Reform Commission, Beijing. Available at <www.cchina.gov.cn>, accessed 10 July 2008.

——, 2005. China's national comprehensive energy strategy and policy, Development Research Centre of the State Council, Beijing. Available at <www.efchina.org>, accessed 10 July 2008.

Government of New Zealand, 2007. A guide to the Climate Change (Emissions Trading and Renewable Preference) Bill, Ministry of Environment, Wellington. Available at <www.mfe.govt.nz>, accessed 10 July 2008.

Grubb, M.; Vrolijk, C. and Brack, D., 1999. *The Kyoto Protocol: a guide and assessment*, Royal Institute of International Affairs Energy and Environmental Programme, London/Washington, DC.

Hansen, J.E., 2007. 'Scientific reticence and sea level rise', *Environmental Research Letters,* 2(2):024002.

Hitomi, K. and Tuerk, A., 2008. 'Emerging Japanese Emissions Trading Schemes and prospects for linking', Climate Strategies, Cambridge, UK.

Höhne, N.; Yamin, F. and Haites, E., 2008. 'The history and status of the international negotiations on a future climate agreement', in C. Egenhofer (eds.), *Beyond Bali: strategic issues for the post-2012 climate change regime*, Centre for European Policy Studies, Brussels**:**13-35.

Hooijer, A.; Silvius, M.; Wösten, H. and Page, S., 2006. *PEAT-CO2: assessment of CO_2 emissions from drained peatlands in SE Asia*, Delft Hydraulics report Q3943, Delft, the Netherlands**.**

Houghton, R.A., 2003. 'Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management', *Tellus*, 55:378–90.

IEA, 2007a. *CO_2 Emissions from Fuel Combustion: 1971/2005*, OECD Publishing, Paris**.**

——, 2007b. *World Energy Outlook 2007: China and India insights*, International Energy Agency, Paris**.**

——, 2003. *World Energy Investment Outlook 2003*, International Energy Agency, Paris.

IMF, 2008. *World Economic Outlook*, International Monetary Fund, Washington DC**.**

IPCC, 2007. *Fourth Assessment Report, Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Jotzo, F., 2007. 'Climate policy: where to and how?', *Agenda*, 14(1):17–34.

Jotzo, F. and Betz, R., 2008. 'Linking the Australian emissions trading scheme', Research Report 11, Environmental Economics Research Hub, Canberra.

Kellow, A., 2006. 'A new process for negotiating multilateral environmental agreements? The Asia-Pacific climate partnership beyond Kyoto', *Australian Journal of International Affairs*, 60:287–303**.**

Kolbert, E., 2007. 'Unconventional crude', *The New Yorker*, 12 November: 46–51.

Lenton, T.; Held, H.; Kriegler, E.; Hall, J.; Lucht, W.; Rahmstorf, S. and Schellnhuber, H.J., 2007. 'Tipping elements in the Earth’s climate system', *Proceedings of the National Academy of Sciences*, 105(1786-193).

Lin, J.; Zhou, Nan; Levine, Mark D. and Fridley, David, 2007. *Achieving China's target for energy intensity reduction in 2010: an exploration of recent trends and possible future scenarios*, report, China Energy Group, Lawrence Berkeley National Laboratory, Berkeley.

Marland, G.; Andres, B. and Boden, T., 2007. *Global CO_2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2004*, Carbon Dioxide Information Analysis Center, Oak Ridge, Tennessee. Available at <www.cdiac.ornl.gov>, accessed 10 July 2008.

McGee, J. and Taplin, R., 2006. 'The Asia–Pacific partnership on clean development and climate: a complement or competitor to the Kyoto Protocol?', *Global Change, Peace and Security*, 18(3):173–92.

Meinshausen, M.; Hare, B.; Wigley, T.M.M.; Vuuren, D.V.; Elzen, M.G.J.D. and Swart, R., 2006. 'Multi-gas emissions pathways to meet climate targets', *Climatic Change*, 75(1-2):151–94.

Metz, B.; Davidson, O.; Connick, H.D.; Loos, M. and Meyer, L. (Eds.), 2005. *Special Report on Carbon Dioxide Capture and Storage, Special Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Nabuurs, G.J.; Masera, O.; Andrasko, K.; Benitez-Ponce, P.; Boer, R.; Dutschke, M.; Elsiddig, E.; Ford-Robertson, J.; Frumhof, P.; Karjalainen, T.; Krankina, O.; Kurz, W.A.; Matsumoto, M.; Oyhantcabal, W.; Ravindranath, N.H.; Sanchez, M.J.S. and Zhang, X., 2007. 'Forestry', in B. Metz; O.R. Davidson; P.R. Bosch; R. Dave and L.A. Meyer (eds.), *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Nakicenovic, N.; Swart, R. et al., 2000. *Emissions Scenarios: Special Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Narjoko, D.A. and Jotzo, F., 2007. 'Survey of recent developments', *Bulletin of Indonesian Economic Studies*, 43(2):143–70.

Neumayer, E., 2007. 'A missed opportunity: the Stern Review on climate change fails to tackle the issue of non-substitutable loss of natural capital', *Global Environmental Change,* 17(3-4):297–301.

New Zealand Treasury, 2008. New Zealand's liability under the Kyoto Protocol, the New Zealand Treasury, Wellington**.** Available at <http://www.treasury.govt.nz/government/liabilities/kyoto>, accessed 10 July 2008.

Nordhaus, W.D., 2008. 'A review of the Stern Review on the economics of climate change', *Journal of Economic Literature,* 45(3):686–702.

Owen, A., 2006. 'Nuclear power for Australia?', *Agenda,* 13(3):195–210.

Page, S.E.; Siegert, F.; Rieley, J.O.; Boehm, H.-D.V.; Jaya, A. and Limin, S., 2002. 'The amount of carbon released from peat and forest fires in Indonesia during 1997', *Nature*, 420:61–5.

PEACE, 2007. *Indonesia and climate change: current status and policies*, prepared by A.P. Sari, R.E. Sari, R.N. Butarbutar, M. Maulidya, W. Rusmantoro, PT Pelangi Energi Abadi Citra Enviro (PEACE) for World Bank and DFID, Jakarta.

Pew Center, 2008. *Economy-Wide Cap & Trade Proposals in the 110th Congress*, Pew Center on Global Climate Change, Arlington, VA.

——, 2007. *Climate change mitigation measures in the People's Republic of China,* International Brief, April 2007, Pew Center on Global Climate Change, Arlington, VA.

Pezzey, J.C.V.; Jotzo, F. and Quiggin, J., 2008. 'Fiddling while carbon burns: why climate policy needs pervasive emission pricing as well as technology promotion', *Australian Journal of Agricultural and Resource Economics,* 52(1):97–110.

Pittock, A.B., 2006. 'Are Scientists Underestimating Climate Change?' *EOS Transactions American Geophysical Union,* 87(34):340

Point Carbon, 2008. Point Carbon Secondary CER OTC assessment, Point Carbon, Oslo. Available at <www.pointcarbon.com>, accessed 10 July 2008.

Quadrelli, R. and Peterson, S., 2007. 'The energy-climate challenge: recent trends in CO2 emissions from fuel combustion', *Energy Policy,* 35(11):5938–52.

Quiggin, J., 2008. 'Stern and his critics on discounting and climate change: an editorial essay', *Climatic Change*, 89(3/4):195–205.

Raupach, M.R.; Marland, G.; Ciais, P.; Quere, C.L.; Canadell, J.G.; Klepper, G. and Field, C.B., 2007. 'Global and regional drivers of accelerating CO_2 emissions', *Proceedings of the National Academy of Sciences*, 104(24):10288–10293.

RGGI, 2007. Overview of RGGI CO_2 Budget Trading Program, Regional Greenhouse Gas Initiative. Available at <www.rggi.org>, accessed 10 July 2008.

Schellnhuber, H.J.; Cramer, W.; Nakicenovic, N.; Wigley, T. and Yohe, G. (Eds), 2006. *Avoiding Dangerous Climate Change*, Cambridge University Press, Cambridge.

Schwarzenegger, A., 2006. 'Gov. Schwarzenegger signs landmark legislation to reduce greenhouse gas emissions', Press release**,** 27 September 2006, Office of the Governor, California.

Sheehan, P., (forthcoming). 'The new global growth path: implications for climate change analysis and policy', *Climatic Change.*

Sheehan, P. and Sun, F., 2007. *Energy use in China: interpreting changing trends and future directions*, CSES working paper no.13, Victoria University, Melbourne.

Sinton, J.E. and Fridley, D.G., 2000. 'What goes up: recent trends in China's energy consumption', *Energy Policy*, 28(10):671–87.

Spash, C., 2007. 'The economics of climate change impacts à la Stern: Novel and nuanced or rhetorically restricted?', *Ecological Economics*, 63(4):706–13.

Stern, N, 2007. *The Economics of Climate Change: the Stern Review,* Cambridge University Press, Cambridge.

——, 2008. Key elements of a global deal on climate change, London School of Economics and Political Science, London. Available at <www.lse.ac.uk>, accessed 10 July 2008.

Sterner, T. and Persson, U.M., 2007. *An even Sterner Review: introducing relative prices into the discounting debate*, discussion paper 07-37, Resources for the Future, Washington DC.

Sugiyama, T. and Michaelowa, A., 2001. 'Reconciling the design of CDM with inborn paradox of additionality concept', *Climate Policy*, 1:75–83.

Tacconi, L., 2003. *Fires in Indonesia: causes, costs and policy implications*, CIFOR occasional paper no. 38, CIFOR, Bogor.

Tol, R.S. and Yohe, G.W., 2006. 'A review of the Stern Review', *World Economics*, 7(4):233–50.

UNEP Risoe Centre, 2008. CDM/JI pipeline analysis and database, UNEP, Nairobi. Available at <www.cd4cdm.org>, accessed 27 January 2009.

UNFCCC, 2007. *Ad Hoc working group on long-term cooperative action under the convention: proposal by the President*, FCCC/CP/2007/L.7/Rev.1, Climate Change Secretariat, Bali.

——1997. *The Kyoto Protocol to the Convention on Climate Change*, Climate Change Secretariat, Bonn.

——1992. *United Nations Framework Convention on Climate Change*, **,** Climate Change Secretariat, Bonn**.**

USCAP, 2007. A call for action: consensus principles and recommendations from the U.S. Climate Action Partnership: a business and NGO partnership, United States Climate Action Partnership, Washington, DC. Available at <www.us-cap.org>, accessed 10 July 2008.

Wara, M.W. and Victor, D.G., 2008. *A realistic policy on international carbon offsets*, PESD working paper #74, Stanford University, Stanford.

WCI, 2007. 'Five Western Governors announce regional greenhouse gas reduction agreement', press release, February 26, Western Climate Initiative. Available at <www.westernclimateinitiative.org>, accessed 10 July 2008.

Weitzman, M.L., 2008a. *On modeling and interpreting the economics of catastrophic climate change*, paper, Harvard University Department of Economics, Cambridge, MA.

——, 2008b. 'A review of the Stern Review on the economics of climate change', *Journal of Economic Literature*, 45(3):703–24.

White House, 2008a. *Major economies meeting on energy security and climate change*, fact sheet, White House, Washington, DC. Available at<http://www.whitehouse.gov/news/releases/2007/09/20070927.html>**,** accessed 10 July 2008**,** Washington DC.

——2008b., 'President Bush Discusses Climate Change', Press release**,** 16 April 2008, White House, Washington, DC.

World Bank, 2008. *State and Trends of the Carbon Market 2008*, the World Bank, Washington DC.

WRI, 2007. Climate analysis indicator tool, version 5.0, World Resources Institute, Washington DC. Available at <cait.wri.org>, accessed 18 December 2007.

Wu, L.; Kaneko, S. and Matsuoka, S., 2005. 'Driving forces behind the stagnancy of China's energy-related CO_2 emissions from 1996 to 1999: the relative importance of structural change, intensity change and scale change', *Energy Policy*, 33:319–35.

Yamin, F. and Depledge, J., 2004,. *The International Climate Change Regime: a guide to rules, institutions and procedures*, Cambridge University Press, Cambridge.

Zhang, Z.X., 2007. 'China, the United States and technology cooperation on climate control', *Environmental Science & Policy*, 10(7-8):622–8.