2 Carbon after the Great Crash

ON THE MORNING of 30 September 2008, I handed *The Garnaut Climate Change Review* to the then Prime Minister of Australia, Kevin Rudd.

First, however, the Prime Minister wanted to talk about an urgent calamity. Overnight—that morning Australian time—the New York Stock Exchange had suffered its largest-ever points fall. All of the media talk was of the collapse of the international financial system and of imminent global recession. The collapse did indeed turn out to be great, with most of the main Wall Street financial institutions disappearing, or being taken over by others, and in any case being rescued by government. This massive restructuring of the centre of global finance was accompanied by a freeze in global markets the like of which had not been seen in 80 years. The crash was followed by an equally dizzying plunge in world trade as a series of global economic imbalances were corrected with ruthless speed.

In developed economies the Great Crash was followed by a Great Recession, the largest blow to growth since the Great Depression of the 1930s. Overall, the growth in economic output in developed countries contracted by 2.7 percentage points from 2007 to 2009, with the biggest falls in Japan and Europe. Australia was one of the few developed countries to avoid recession, with GDP growing by 3.6 per cent from 2007 to 2009.

However, as precipitous as it was, the Great Crash proved to be only a temporary deceleration of growth in developing countries. Led by China and India, but extending to and beyond Indonesia and Brazil, they returned quickly to the strong economic growth that had characterised the early 21st century.

The Great Crash accelerated an emerging shift in the global economy. The developed countries of the northern hemisphere now face lower long-term growth paths. That, in turn, has shifted their projected carbon emissions onto a lower trajectory.

On the other hand, developing countries are now the growth engines of the world economy and the trajectory of their carbon emissions in the absence of mitigation policies has shifted moderately upwards.

The Great Crash has had other legacies. Government spending in developed countries increased dramatically in response to falling growth and the massive support provided to ailing financial institutions. In many countries—including China, the United States, the United Kingdom, Germany, the Republic of Korea and Japan—stimulus spending increased support for energy-saving and low-emissions technologies.

Higher levels of public debt from recession and its aftermath will cost governments more to service and over time will require some combination of lower government spending and higher taxes. A wave of fiscal austerity has already begun to sweep across Europe and is being extended to the United States and other developed countries. This affects short- to medium-term growth prospects as well as the ability of governments to fund investments in infrastructure, health, education and technology.

The Great Crash of 2008 and its aftermath have revealed vulnerabilities in the American and European economies that had previously not been apparent to most observers. Many of the fundamental weaknesses—for example in banking and economic policy frameworks—remain.

The outlook is more positive for developing countries. Prospects are good for continued rapid growth in China and India, and there is strong growth momentum in many other developing countries. Current growth rates are higher even than the estimates embodied in the 2008 Review's projections, which were themselves much higher than those incorporated in forecasts and projections of international organisations.

This broadening of global economic growth into the large developing countries is the essence of what I call the Platinum Age. It arises from the adoption of the techniques and ideas of modern economic growth by the populous economies of Asia. The resulting period of higher growth has been characterised by openness to trade and investment, generally cautious fiscal and monetary policies, and high and rising rates of savings and investment.

Chinese growth since the reform era began in 1978 has consistently outperformed expectations, the more so in the early 21st century. Driven by increasing wages and more productive use of capital, growth will remain strong into the 2020s. Productivity growth through improved labour skills and technological improvement can support China's rapid growth until the late 2020s. By 2030, its average incomes will be more than half of those in the advanced industrial countries. By then the Chinese economy will be similar in size to those of the United States and the European Union combined.

In the longer term, India has even stronger growth prospects from a much lower current base. Three factors have been fundamental to the acceleration of its economic growth over the past two decades. Most basic of all, as in China, there has been steady opening of the economy to international trade and investment. Second, India continues to undergo a demographic transition that is favourable to growth, with the proportion of the population of working age set to gradually increase over the next two decades. If this increasing 'demographic dividend' is accompanied by continued improvements in the skills of the Indian workforce and by continuing economic reform, then rapid economic growth can be sustained for decades to come. India can power ahead long after Chinese growth has eased to the more gradual rates of a high-income country starting in the late 2020s. The third factor has been the large increase in national savings rates as incomes have increased. This has allowed investment rates to rise without increased risks of economic instability.

Indonesia, the world's third most populous developing country, also has strong and sustainable growth momentum. Indonesia managed to maintain solid growth near 5 per cent through the years of the Great Crash, and is now returning to stronger growth rates. Since the traumatic democratic transition of the final years of the 20th century, it has been building the institutions that are necessary for sustained strong growth within a democracy.

These three large developing economies (China, India and Indonesia) are all at stages in which growth is highly energy-intensive. All three happen to have considerable domestic endowments of coal. Emissions of greenhouse gases will grow rapidly in the absence of strong and effective mitigation policies. Their own business-as-usual growth in emissions will quickly absorb the atmosphere's limited remaining capacity to absorb greenhouse gases without high risks of dangerous climate change. In the remainder of this chapter we examine the likely growth in greenhouse gas emissions over the next couple of decades under business as usual, and then look at the remaining capacity of the atmosphere to absorb greenhouse gases without our running high risks of dangerous climate change. The two sets of data indicate the size and the urgency of the global mitigation task that we face.

More energy

So, what kind of energy use and emissions growth would emerge from a Platinum Age if there were no climate change or mitigation? Answering this question is an artificial exercise but provides essential perspective on the global mitigation challenge.

The task is artificial because established mitigation policies have already bent the trajectory of future emissions significantly downwards. Business-as-usual emissions in many developed countries and in the major developing countries, most notably China, are now a thing of the past. Regrettably, as we will see, they are not so obviously a thing of the past in Australia.

The task is also artificial in not taking into account the possibility of damage to growth as a result of climate change over the next two decades. As discussed in Chapter 1, the science tells us that the effects of higher atmospheric concentrations of greenhouse gases are experienced with a lag of several decades. The increase in global average temperatures that has already occurred is the result of changes in atmospheric concentrations that were in place several decades ago. The greenhouse gas concentrations that have accumulated so far in the Platinum Age are on top of earlier accumulations. They will be the main determinants of warming to the end of the 2030s. Substantial climate change over the next three decades is now 'built in' to the global climate system and is likely to be constraining economic growth by the 2030s.

Some of the effects of climate change that will probably be evident before 2030 include the increase in intensity of extreme weather events that, among other things, affect global food production and prices. In some countries, food price volatility and other manifestations of extreme events may affect the stability of political systems in ways that feed back negatively into economic growth.

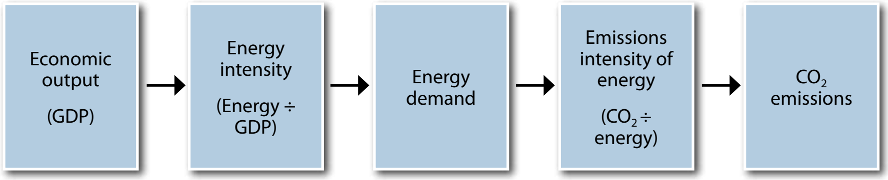
Unfortunately, lower rates of growth associated with political disorder in individual states, or in the international system, are unlikely to help reductions in emissions. The effects of lower growth on emissions are likely to be greatly outweighed by lower priority and effectiveness of mitigation policies.

To project business-as-usual emissions we must start with analysis of economic output. The projections ignore the effects of climate change on economic activity. The projections of output take into account trends in population growth, investment and the productivity with which labour and capital are used. Then judgments are made as to the likely energy intensity of this projected growth in output from which overall demand for energy can be derived. Finally, judgments are applied to the emissions intensity of energy demand which allow us to derive projections of carbon dioxide emissions. Changes in the emissions intensity of energy demand will reflect different sources of energy supply, developments in energy efficiency and related technological developments.

The chain linking economic output to energy demand and energy demand to carbon emissions is shown in Figure 2.1.

Energy intensity is a measure of how much energy is used per unit of economic output. It has declined over time in most countries as more energy-efficient equipment is used and as a greater share of economic activity comes from services and other less energy-intensive activities. There are, however, great differences in the underlying rate of change in different countries, depending on their stage of development, resource endowment, economic structure and other factors.

Figure 2.1: The decomposition of emissions growth



The outlook for future improvements in energy intensity is also affected by government policy, as well as by changes in the expected future costs of energy.

Looking forward to 2030, energy intensity of output in the absence of mitigation policies is projected to fall in all regions, with the ratio of energy consumption to GDP declining at average rates of between 0.9 and 2.7 per cent per year. The global average is projected to decline by 1.9 per cent annually between 2005 and 2030. Expectations of substantially higher fossil fuel prices have an important effect.

Applying these projections of energy intensity to the projections of economic growth yields projections of total energy use. These indicate that growth is tailing off across developed countries to a 0.2 per cent annual increase over the period 2005 to 2030.

Developing countries, by contrast, are projected to experience continued strong growth in energy use, at 4.7 per cent per year. Underlying energy demand growth is fastest in the rapidly growing economies of Asia, but strong across most developing countries.

More emissions

The extent to which increases in energy demand translate into increased emissions depends on the amount of emissions per unit of energy consumed (or the carbon intensity of energy). Carbon intensity is largely determined by the fuel mix in the energy system. Among the fossil fuels in common use, coal is the most carbon-intensive energy source, followed by oil, then gas. The energy mix changes over time, including varying proportions of nuclear and renewable energy that produce close to zero carbon emissions.

The projections under business as usual are for a 0.3 per cent per year increase in the global carbon intensity of energy supply between 2005 and 2030. There are variations between countries in a relatively narrow band. Carbon intensity is projected to fall slightly in developed countries, and to increase on average in the developing world. This is in line with recent trends, but will moderate over time. India is projected to experience the fastest rate of increase in carbon intensity, because so much of its energy supply is derived from coal. China's carbon intensity rose significantly from 2005 to 2009 as the importance of coal in the mix increased, but under these projections remains constant over the next two decades.

The prevailing fuel mix differs greatly between countries, depending on the availability and cost of different energy sources. The nature of the electricity supply system, the structure and size of energy-intensive industries, as well as of the transport and housing stock, also play a role.

Changes in the fuel mix tend to be relatively slow, as they mainly come about through gradual replacement of a large stock of long-lived energy infrastructure. A country's long-term fuel mix, in practice, is strongly influenced by climate change policies as well as energy policies—for example, energy policies directed at reduced reliance on overseas purchases.

Relative prices of different energy sources are the other principal determinant of the fuel mix. If oil prices increase relative to prices of other energy sources, as is widely considered to be likely, this will trigger a substitution away from oil and towards other energy sources. The effect on carbon emissions is unpredictable. Replacement energy sources may be lower in carbon intensity, as in the case of electricity from gas, nuclear or renewable sources. Alternatively, they may have greater carbon intensity, as in the case of coal, and coal-based liquid fuels, tar sands and conversion of gas to liquids.

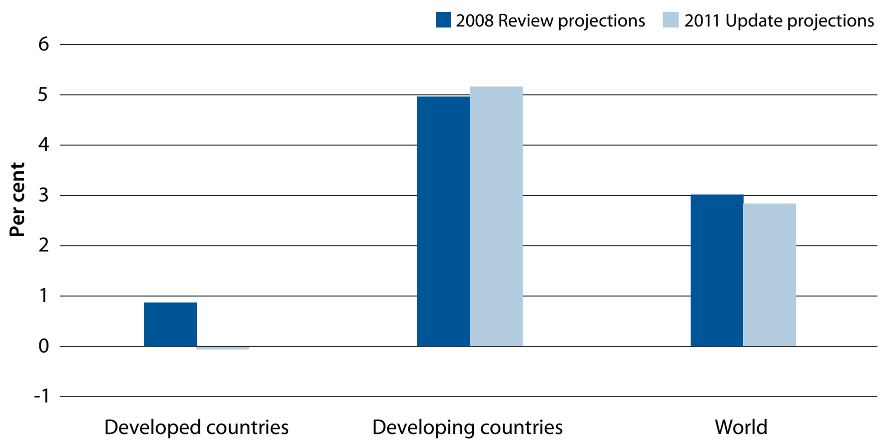
For the time being, the price of gas relative to oil will tend to fall in the United States and elsewhere as new supplies emerge in high volumes. However, the International Energy Agency argues that the decoupling of contract gas prices from oil prices does not necessarily mean weaker gas prices in the longer term. The price incentives to replace coal and oil by gas are likely to be positive and influential for a considerable while, but at some time will come under pressure from perceptions of scarcity.

A comparison of the global energy mix at 2030 under old and new International Energy Agency projections illustrates the point. The agency's most recent projections have the share of oil in global energy supply at 2030 at 28.5 per cent, down from 31.5 per cent in previous projections. This reduction is made up in roughly equal measure by increased use of coal, nuclear power and electricity from renewables, including biomass. The substitution effects differ greatly between countries, but the net effect of moving from the old to the new projections is to slightly reduce the expected carbon intensity of the global energy supply.

Amalgamating the above projections of the individual drivers of business-as-usual emissions, we find that global emissions to 2030 rise at an average of 2.8 per cent per year. Developed countries contribute 30 per cent of global emissions in 2030 under a business-as-usual scenario. Developing countries contribute 70 per cent of global business-as-usual emissions at 2030, up from 50 per cent today. China's and India's share in global emissions would be 41 and 11 per cent respectively. The share of other developing countries would remain at 19 per cent of the global total.

Total global emissions from fossil fuels are projected to double between 2005 and 2030 under business as usual. This is a similar perspective to that presented in the 2008 Review. The division of growth in emissions between developed and developing countries, however, changes dramatically. Developed country emissions are now expected to fall slightly between 2005 and 2030 under business as usual. Developing country emissions are expected to rise a bit more rapidly than anticipated in 2008. Total world emissions growth is expected to be slightly lower than was expected by the 2008 Review. The total burden is similar to that of three years ago, but more of it relates to emissions in developing countries (see Figure 2.2).

Figure 2.2: Projections of average annual growth in emissions in the absence of mitigation policies, 2008 Review and 2011 Update, 2005 to 2030



Sources: BP 2010, *Statistical review of world energy*; International Energy Agency 2010, *CO_2 emissions from fossil fuel combustion 2010* and *World energy outlook 2010*; 2008 Review.

Australia's emissions under existing policies

Australia weathered the Great Crash of 2008 better than any of the major advanced countries.

The factors that have driven the strong growth in Australia's economy and energy demand can be expected to continue for at least several years. Even with the mitigation policies that were in place by late 2010, emissions would grow strongly in the period immediately ahead as a once-in-history resources boom reaches its greatest height. In this, Australia is different from other developed countries. Australia's natural resources are likely to continue to provide fuel for the growth in China and India in the years ahead. The relative importance of gas, coal and uranium is likely to change over time in ways that depend on technological and price developments as well as climate change mitigation policies.

The strength of the resources sector will encourage Australian emissions growth through two channels. The first is through the effect of increased economic activity on energy demand. The second is through the emissions that are a by-product of the extraction of natural gas and coal.

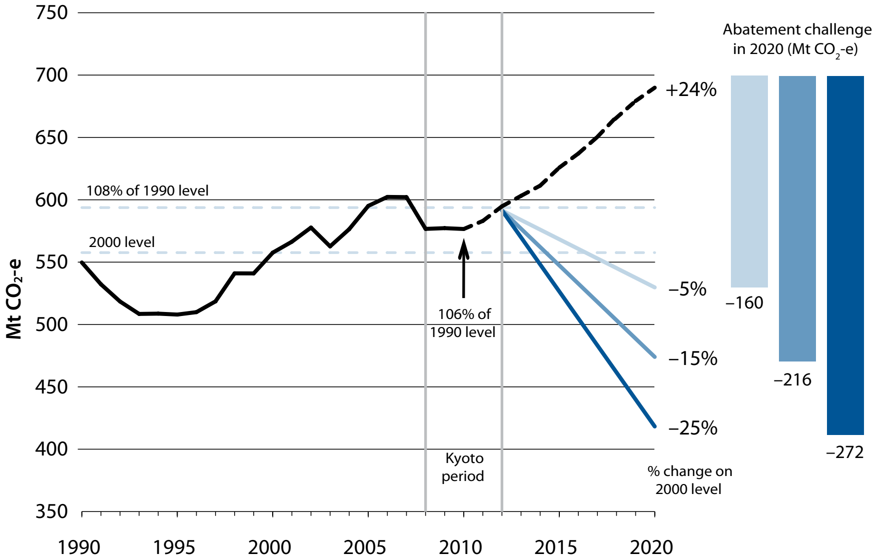
In the year to August 2010, gas generation supplied more than 11 per cent of eastern states' electricity demand, while black coal supplied 56 per cent and brown coal 24 per cent. Renewables, including hydroelectric and wind, supplied the remaining 9 per cent.

Australia releases annual projections of our emissions on the basis of current policies. The 2010 report shows that Australia is on track to meet its Kyoto Protocol target of limiting emissions to an average of 108 per cent of 1990 levels between 2008 and 2012, with emissions projected to reach 106 per cent of 1990 levels (see Figure 2.3).

However, the report forecasts strong growth in emissions in the absence of further policy action. Emissions are projected to increase by 24 per cent from 2000 levels by 2020. This represents a 4 per cent upward revision of the previous year's projections, and is 4 per cent above expectations in 2007.

Australia's 2020 emissions target, as reported to the United Nations Framework Convention on Climate Change, is an unconditional 5 per cent reduction relative to 2000, with conditional targets extending to a reduction of 25 per cent depending on the actions of others. The projected growth in emissions thus presents a substantial mitigation task in the decade ahead, and obviously higher still with higher levels of ambition.

Figure 2.3: Australia's emissions trends, 1990 to 2020



Note: Mt CO_2-e is megatonnes of carbon dioxide equivalent; 'abatement challenge' means the reduction in greenhouse gas emissions required to reach specific targets; and the bars represent the levels of abatement (in Mt CO_2-e) that would be required to reach the three targets for 2020: minus 5 per cent, minus 15 per cent and minus 25 per cent of 2000 levels.

Source: Australian Government 2010, *Australia's emissions projections 2010*, Department of Climate Change and Energy Efficiency, p. 8.

The strong growth in emissions over the coming decade is expected to be dominated by the extraction and preparation of energy resources for export. Over a third of the increase in emissions growth to 2020 derives from increased fugitive emissions from growing coal and gas exports. The total of fugitive emissions from coal mining and oil and gas extraction plus the direct fuel combustion emissions from gas liquefaction projects accounts for almost half the growth in Australia's emissions to 2020. Electricity generation is expected to play a much smaller role in emissions growth in the coming decade than in the past.

Budgeting carbon

If we juxtapose this assessment of business-as-usual emissions with the requirements of avoiding dangerous climate change, we get a good sense of the challenge.

The 2008 Review recommended, and the Australian Government and Opposition accepted, that it was in Australia's national interest to seek a global emissions concentrations objective of 450 parts per million (ppm) of carbon dioxide equivalent. This is broadly equivalent to the objective of holding temperature increases to 2°C above pre-industrial levels, which was agreed by the international community at the Cancun meeting.

To hold concentrations at a level that would mean warming of no more than 2°C would require a major elevation of the importance of climate change in national priorities.

From the perspective of 2011, for the world to hold emissions concentrations to 550 ppm carbon dioxide equivalent would be an achievement of international cooperation and innovation in national economic policy of large dimensions. To achieve 450 ppm carbon dioxide equivalent with only the degree of overshooting envisaged in the 2008 Review would be an achievement in international relations and national public policy of historic dimensions. The path to anything lower than 450 ppm carbon dioxide equivalent now has to involve overshooting.

In this light, the most important development in scientific discussion of mitigation goals since 2008 is an increasing focus on a cumulative emissions budget. Such a budget approach was favoured conceptually in the 2008 Review. The Review formulated the global mitigation problem as one of optimal depletion of a finite resource. The resource in this case is the earth's capacity to absorb greenhouse gases without dangerous climate change.

Cumulative carbon dioxide emissions can be determined so that a 'budget' can be defined that is essentially independent of timescale and trajectory.

However, it is not possible to achieve this for the full set of greenhouse gases over long time periods. For gases with a lifetime shorter than a few decades, the rate of emissions at a particular time has a strong influence on concentrations, and hence impacts, at that time. Similarly, longer-lived gases such as carbon dioxide and nitrous oxide can be expected to have a larger influence in the longer term; with carbon dioxide having by far the largest influence.

The main value of the cumulative, or budget, approach is to focus attention on the limited volume of greenhouse gases that can be released into the atmosphere over specified periods without creating large risks of dangerous climate change. The basic arithmetic within this approach is sobering. One recent study analysed the allowable global cumulative carbon dioxide emissions between 2000 and 2050 in terms of a number of different probabilities of exceeding 2°C of warming. The study found that a budget of 1,440 gigatonnes would have a 50 per cent chance of holding temperature increases to 2°C. An estimated 350 gigatonnes of carbon dioxide were emitted globally between 2000 and 2009, which represents about one-quarter of the total budget for 2000–50.

So at the rate of emissions of the first nine years of the century, the remainder of the budget would be exhausted by 2045. The world's emissions are already well above the average for 2000–09, and rising strongly. A major change of trajectory is needed quickly if 2°C is to remain a realistic possibility.

Overshooting

Overshooting scenarios were first considered around 2004, when it was recognised that such an approach would be necessary if a decision were made to aim for stabilisation of greenhouse gas concentrations at, or close to, those that would constrain temperature increases to 2ºC.

Overshooting scenarios allow a slower initial reduction in emissions. Some models have shown that the slow response of the climate system can allow a small, short overshoot in concentration without a corresponding overshoot in temperature. However, for a given concentration stabilisation target, any amount of overshoot increases the risk of reaching a level of climate change that could be considered dangerous.

To achieve reductions in atmospheric concentration and eventual stabilisation, emissions must fall below the natural level of removal from the atmosphere by the oceans and biosphere. As we have seen, the rate of removal can be affected by climate change itself, an outcome referred to as a 'carbon–climate feedback'. Research suggests that the rate of uptake by ocean and land sinks decreases as higher temperatures and greenhouse gas concentrations are reached.

The major risk and uncertainty associated with overshooting is the level of climate change reversibility. Some models suggest that it may be possible to reduce atmospheric concentrations of greenhouse gases significantly over one or two centuries. Other models indicate that the rate of reduction in concentrations may be considerably slower, and there is also the chance that the climate may be pushed past a point of no return.

While the timing of the climate response is still uncertain, an overshooting scenario is more likely to lead to containment of temperature increases than a scenario where concentrations are stabilised and held at the 'peak' level.

It is becoming more difficult for a concentration overshoot to be 'small and short' with an objective of 450 ppm carbon dioxide equivalent or 2ºC. While ambitious greenhouse gas concentration objectives are becoming increasingly reliant on an overshooting or peaking scenario, new science suggests that, when compared to stabilising concentrations without overshooting, such a scenario may be less successful in avoiding long-term temperature increases than previously expected.

If we are to avert serious overshooting to achieve the 2°C target, dramatic changes in emissions trajectories are required in the next decade.

It may be that much deeper emissions cuts in many countries will become possible following a large global political response to the reality of worsening impacts of climate change. That is, a catastrophe may result in a strong political response. However, at that point, the lags between emissions and warming would have locked in a good deal of additional warming.

The difficulty of attaining the 2°C goal increases as the momentum of emissions gathers with the expansion of modern economic growth in developing countries and with the slow start to large emissions reductions in developed countries.

Recognition of this reality has increased the attraction of approaches to mitigation that may delay for a while the full impact of warming from greenhouse gases, and of technologies that have the capacity to remove emissions from the atmosphere.

Solar radiation management—the placement in the high atmosphere of particles that deflect solar radiation away from the earth—has come into closer focus as a temporary buffer to the immediate consequences of global warming, while major emissions reductions are implemented. Recently this and other geoengineering techniques have moved from science fiction into the realm of responses that are being subject to analysis. And while geoengineering has the potential to help mitigate greenhouse gas emissions, in the absence of regulatory mechanisms, there are concerns about possible negative consequences.

A recent report looking at black carbon and tropospheric ozone noted that reducing these pollutants and their precursors, which have a relatively short lifetime in the atmosphere, would slow the rate of climate change within the first half of this century.

The reductions in near-term warming could be achieved through the recovery of methane from fossil fuel extraction and transport, methane capture in waste management, use of clean-burning stoves for residential cooking, use of diesel particulate filters for vehicles and the banning of field burning of agricultural waste.

Actions to reduce black carbon and solar radiation management would complement but not replace reductions in long-lived greenhouse gas emissions. Reductions would still be required to protect the climate in the long term, and resolve issues such as increased ocean acidification.

The urgency also increases the importance of sequestration—the capturing of carbon in geological or biological sinks—to keep alive the possibility of limiting global average temperature increases to 2°C above pre-industrial levels.

Chemical processes, biological processes and carbon capture and storage have all been suggested as possible methods for the sequestration of carbon. Carbon dioxide removal through biological processes, particularly reforestation and algal sequestration, are generally more mature technologies than solar radiation management, with fewer uncertainties. They have a good track record over many hundreds of millions of years. Their role in sequestration could be extended if accompanied by the harvesting and storage of hydrocarbons.

Conclusion

The shift in the centre of gravity of global growth towards the developing countries makes the mitigation effort more difficult. Even by 2030, the average income per person in developing countries would be only a little over a quarter of that in the United States. Today's differential is well over twice that large, so the next two decades would see a substantial narrowing of the gap in economic activity and living standards, but nowhere near its closure. China would see its per person income at above half that of the United States in purchasing power parity terms. In India, purchasing power per person would remain below a quarter of that in the United States.

The same continued potential for catch-up exists for greenhouse gas emissions. Seventy per cent of global emissions by 2030 would come from developing economies that are home to 80 per cent of the global population. Under business as usual, China's annual emissions per person would reach those in the United States by 2030 (at around 15 tonnes of carbon dioxide per person from fossil fuel combustion only). Across the developing countries, however, emissions per person would still only amount to 38 per cent of those in the United States (or China), with obvious strong potential for further growth.

However, there is also considerable hope. The picture changes dramatically under effective mitigation. As we will see in the next chapter, the developing world and China in particular have already moved a long way from business as usual. Developing countries have many exceptional opportunities to de-carbonise their energy supply, to increase energy efficiency, and to cut emissions through practices such as better forestry management, agriculture and industrial activities. It is often less costly not to enter a path of carbon-intensive development than to disentangle an economy from an established carbon-intensive structure. These circumstances of developing countries will need to be brought fully to account if the reasonable ambitions for improved living conditions of the majority of humanity are to be reconciled with the avoidance of dangerous climate change.

One important driver of emissions—global population growth—has been gradually easing over the past several decades in response to rising living standards in the developing world—reinforced or compounded in China by strong anti-natal policies. The acceleration of economic growth in developing countries in the early 21st century holds the prospect for further reductions in fertility and population growth.

Second, a surprising expansion of global gas reserves, in the United States and in many other countries, creates an opportunity for greater reductions in emissions intensity of energy use than anticipated in the business-as-usual projections, through gas replacing more emissions-intensive coal.

For the developed countries, the decline in expected emissions growth following the Great Crash makes it easier to realise announced mitigation targets. But this easing of demands on emissions in developed countries is matched by increased demands from developing countries. The arithmetic of greater concentration of anticipated global emissions growth in the developing countries points to the need for earlier and stronger constraints on emissions in developed and developing countries alike.

The emissions growth outlook is especially challenging for Australia. We stand out as the developed country whose anticipated business-as-usual emissions growth bucks the general trend of developed countries, largely as a result of the expansion of the relative role of resources in the economy.

Existing policies leave exceptionally high anticipated growth in emissions to 2020. This will not be easily understood by other countries, and is likely to bring Australian mitigation policy under close scrutiny. Any failure by Australia to do what others see as our fair share will invite critical and perhaps damaging international responses, as well as damaging some other countries' commitments to mitigation.