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Avoiding dangerous climate change: strategies for mitigation

“We shall require a substantially new manner of thinking if mankind is to survive.”

Albert Einstein

“Speed is irrelevant if you are going in the wrong direction.”

Mahatma Gandhi

“Alone we can do so little; together we can do so much.”

Helen Keller

CHAPTER 3

Avoiding dangerous climate change: strategies for mitigation

Living within a sustainable 21st Century carbon budget requires that rich countries cut emissions of greenhouse gases by at least 80 percent by 2050, with 30 percent cuts by 2020

Climate change is an immense, long-term and global challenge that raises difficult questions about justice and human rights, both within and across generations. Humanity's ability to address these questions is a test of our capacity to manage the consequences of our own actions. Dangerous climate change is a threat, not a pre-ordained fact of life. We can choose to confront and eliminate that threat, or we can choose to let it evolve into a fully fledged crisis for poverty reduction and for future generations.

Approaches to mitigation will determine the outcome. The more we delay action, the more atmospheric concentrations of greenhouse gases will rise, the more difficult it will be to stabilize below the 450 ppm CO_2e target—and the more likely the 21st Century will experience dangerous climate change.

On our sustainable emissions pathway set out in chapter 1, mitigation would start to make a difference after 2030 and world temperatures would peak around 2050. These outcomes highlight the lag between action and results in tackling climate change. They also draw attention to the importance of thinking beyond the time-horizon defined by political cycles. Dangerous climate change is not a short term emergency amenable to a quick fix. The current generation of political leaders cannot solve the problem. What they can do is to keep open and then widen the window of opportunity for future generations to take up the battle. The 21st Century carbon budget set out in chapter 1 provides a roadmap for achieving this objective.

Keeping the window open will require early and radical shifts in energy policy. Since the industrial revolution, economic growth and human prosperity have been fuelled by carbon-based energy systems. Over the next few decades, the world needs an energy revolution that enables all countries to become low-carbon economies. That revolution has to start in the developed world. Living within a sustainable 21st Century carbon budget requires that rich countries cut emissions of greenhouse gases by at least 80 percent by 2050, with 30 percent cuts by 2020. If the targets are to be achieved, the collective emissions curve will have to peak and start bending in a downwards direction between 2012 and 2015. Developing countries will also have to chart a low-carbon transition pathway, albeit at a pace that reflects their more limited resources and the imperative of sustaining economic growth and cutting poverty.

This chapter looks at the strategies needed to achieve a rapid transition to a low-carbon future. The 21st Century carbon budget provides a roadmap for reaching the agreed destination—a world free of dangerous climate change. But targets and roadmaps are not a substitute for policies. They will only contribute to the battle against climate change if they are backed by effective mitigation strategies.

There are three foundations for success. The first is putting a price on carbon emissions. Market-based instruments have a critical role to play in creating incentives that signal to business and consumers that there is a value in reducing emissions—and that the Earth's capacity for

Successful mitigation ultimately requires that consumers and investors shift demand to low-carbon energy sources

absorbing CO_2 is marked by scarcity. The two broad options for pricing emissions are taxation and cap-and-trade.

The second foundation for mitigation is behavioural change in the broadest sense. Successful mitigation ultimately requires that consumers and investors shift demand to low-carbon energy sources. Price incentives can encourage behavioural change—but prices alone will not deliver reductions on the scale or at the pace required. Governments have a critical role to play in encouraging behavioural change to support the transition to a low-carbon economy. Setting standards, providing information, encouraging research and development, and—where necessary—restricting choices that compromise efforts to tackle climate change are all key parts of the regulatory toolkit.

International cooperation represents the third leg of the mitigation tripod. Rich countries have to take the lead in tackling dangerous climate change: they have to make the deepest and earliest cuts. However, any international framework that does not establish targets for all major greenhouse gas emitting countries will fail. Avoiding dangerous climate change requires a low-carbon transition in developing countries too. International cooperation can help to facilitate that transition, ensuring that reduced emission pathways do not compromise human development and economic growth.

This chapter provides an overview of the mitigation challenge. It starts out by looking from global to national carbon budgeting. Converting the global 21st Century carbon budget into national budgets is the first step towards mitigation of dangerous climate change. It is also a precondition for the successful implementation of any multilateral agreement. With governments negotiating the post-2012 framework for the Kyoto Protocol, it is important that national targets are aligned with credible global targets. Currently, many target-setting exercises suffer from a lack of clarity and consistency, compounded in some cases by a divergence between stated goals and energy policy frameworks.

In section 3.2 we then turn to the role of market-based instruments in the transition to sustainable carbon budgeting. We set out the case for carbon taxation and cap-and-trade schemes, while highlighting the problems that have reduced the effectiveness of the world's largest such scheme—the European Union Emissions Trading Scheme (EU ETS). Section 3.3 looks beyond taxation and cap-and-trade to the critical role of wider regulation and standards and public–private partnerships in research and development.

The chapter concludes by highlighting the underexploited potential of international cooperation. In section 3.4 we show how financial support and technology transfer could raise the energy efficiency of developing countries, providing a win–win scenario for human development and climate change: extending access to affordable energy while cutting emissions. Deforestation and land-use change, currently the source of about 20 percent of world greenhouse gas emissions, is another area of unexploited opportunity in international cooperation.

3.1 Setting mitigation targets

Expiry of the current commitment period of the Kyoto Protocol in 2012 creates an opportunity for early progress in climate change mitigation. In chapter 1, we argued for a multilateral framework geared towards well-defined global carbon budget goals. Such a framework has to combine long-term goals (a 50 percent reduction on 1990 levels in emissions of greenhouse gases by 2050), with medium-term benchmarks set out in rolling commitment periods. The multilateral framework also has to provide a practical guide for implementing the principle of "common but differentiated responsibility", identifying broad pathways for developed and developing countries.

Without a credible multilateral framework the world will not avoid dangerous climate change. However, no multilateral framework will deliver results unless it is underpinned by national targets, and by policies that are aligned with those targets. The corollary of a meaningful global carbon budget for the 21st Century is the development of national carbon budgets that operate within the global resource envelope.

Carbon budgeting—living within our ecological means

National carbon budgeting is a necessary foundation for the post-2012 multilateral framework. At their most basic level, carbon budgets set a limit on the total quantity of CO_2e emissions over a specified period of time. By setting a rolling budget period of, say, 3–7 years, governments can strike a balance between the certainty needed to meet national and global emission reduction targets, and the annual variation that will accompany fluctuations in economic growth, fuel prices or the weather. From a carbon mitigation perspective, what matters is the trend in emissions over time rather than annual variations.

There are parallels between global and national carbon budgeting. Just as the global carbon budget discussed in chapter 1 establishes a bridge between current and future generations, national carbon budgets provide for continuity across political cycles. In money markets, uncertainties over the future direction of policies on interest rates, money supply or price level can all fuel instability. That is why many governments use independent central banks to address the problem. In the case of climate change, uncertainty is an obstacle to successful mitigation. In any democracy, it is difficult for a government to irrevocably commit its successors to specific mitigation policies. However, fixing multilateral commitments into national legislation aimed at achieving long-run mitigation goals is vital for policy continuity.

National carbon budgeting is also a foundation for international agreements. Effective multilateral agreements have to be based on shared commitments and transparency. For countries participating in international agreements aimed at rationing global greenhouse gas emissions, it is important that partners are seen to stick to their side of the bargain. Perceived free-riding is guaranteed to weaken agreements by eroding confidence. Ensuring that multilateral commitments are enshrined in transparent national carbon budgets can counteract this problem.

At a national level, carbon budgets can reduce the threat of economic disruption by sending clear signals to investors and consumers on the future direction of policy. Beyond the market, carbon budgets can also play an important role in increasing public awareness and holding governments to account, with citizens using carbon budget outcomes to assess the contribution of their governments to multilateral mitigation efforts.

Emission reduction targets are proliferating

Recent years have witnessed an increase in target-setting exercises on climate change. National governments have adopted a wide range of goals. Within countries, state and regional governments have also been active in setting emission reduction targets (table 3.1).

The growth of target setting has produced some impressive results. The Kyoto Protocol itself was an exercise in setting national limits linked to global mitigation goals. Most OECD countries—Australia and the United States are the major exceptions—are committed to achieving reductions by 2008–2012 against a 1990 base year. Many have even embraced additional targets. The European Union is an example. Under the Kyoto Protocol, the European Union is required to achieve an 8 percent reduction in emissions. However, in 2007 it committed itself to cutting greenhouse gas emissions by "at least" 20 percent by 2020 and by 30 percent if an international agreement is reached, with a reduction of 60–80 percent by 2050. Several member states have adopted national targets for reductions against 1990 levels, among them:

- The United Kingdom has set itself a 'Kyoto–plus' target in the form of a 20 percent cut on 1990 levels by 2010. Legislation

No multilateral framework will deliver results unless it is underpinned by national targets, and by policies that are aligned with those targets

Table 3.1 **Emission reduction targets vary in ambition**

Greenhouse gas reduction targets and proposals	Near term (2012–2015)	Medium term (2020)	Long term (2050)
HDR sustainable emissions pathway (for developed countries)	**Emissions peaking**	**30%**	**at least 80%**
Selected countries			
	Kyoto targets [a] (2008–2012)	**Post-Kyoto**	
European Union [b]	8%	20% (individually) or 30% (with international agreement)	60–80% (with international agreements)
France	0%	–	75%
Germany	21%	40%	–
Italy	6.5%	–	–
Sweden	4% increase (4% reduction national target) (by 2010)	25%	–
United Kingdom	12.5% (20% national target)	26–32%	60%
Australia [c]	8% increase	–	–
Canada	6%	20% relative to 2006	60–70% relative to 2006
Japan	6%	–	50%
Norway	1% increase (10% reduction national target)	30% (by 2030)	100%
United States [c]	7%	–	–
Selected United States state-level proposals			
Arizona	–	2000 levels	50% below 2000 (by 2040)
California	2000 levels (by 2010)	1990 levels	80% below 1990 levels
New Mexico	2000 levels (by 2012)	10% below 2000 levels	75% below 2000 levels
New York	5% below 1990 (by 2010)	10% below 1990 levels	–
Regional Greenhouse Gas Initiative (RGGI) [d]	Stabilization at 2002–2004 levels (by 2015)	10% below 2002–2004 levels (by 2019)	–
Selected United States Congress proposals			
Climate Stewardship and Innovation Act	2004 levels (by 2012)	1990 levels	60% below 1990 levels
Global Warming Pollution Reduction Act	–	2% per year reduction from 2010–2020	80% below 1990 levels
Climate Stewardship Act	2006 level (by 2012)	1990 levels	70% below 1990 levels
Safe Climate Act of 2007	2009 level (by 2010)	2% per year reduction from 2011–2020	80% below 1990 levels
United States non-governmental proposals			
United States Climate Action Partnership	0–5% increase of current level (by 2012)	0–10% below "current level" (by 2017)	60–80% below "current level"

a. Kyoto reduction targets are generally against 1990 emission levels for each country, by 2008–2012, except that for some greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) some countries chose 1995 as their base year.
b. Kyoto targets only refer to 15 countries which were members of the European Union in 1997 at the time of signing.
c. Signed but did not ratify the Kyoto Protocol, therefore commitment is not binding.
d. Participating states include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont.

Source: Council of the European Union 2007; Government of Australia 2007; Government of Canada 2007; Government of France 2007; Government of Germany 2007; Government of Norway 2007; Government of Sweden 2006; Pew Center on Climate Change 2007c; RGGI 2005; State of California 2005; The Japan Times 2007; UNFCCC 1998; USCAP 2007.

under preparation would establish a statutory obligation on Government to achieve reductions of 26–32 percent by 2020, and 60 percent by 2050.[1]

- France has a national target of a 75 percent cut in emissions by 2050.[2]
- In 2005, Germany updated its National Climate Change Programme to include the target of a 40 percent reduction by 2020 (subject to the European Union subscribing to a 30 percent reduction).[3] In August 2007, the German Federal Government

reaffirmed this commitment by adopting a policy package to achieve the target.[4]

Target setting has also emerged as an issue on the agenda of the G8. At their 2007 summit, the G8 leaders accepted in principle the need for urgent and concerted action to avoid dangerous climate change. No formal targets were adopted. However, the summit agreed to "consider seriously" decisions made by Canada, the European Union and Japan to set a level of ambition aimed at halving global emissions by 2050.[5]

Target setting from below in the United States

The United States currently lacks a national target for overall emission reductions. Under the 2002 Global Climate Change Initiative (GCCI), the Federal Government set a national goal for reducing greenhouse gas emissions intensity, as measured by the ratio of greenhouse gas emissions to GDP. However, the absence of a national emission reduction goal has not prevented the emergence of a range of target-setting initiatives, with states and cities setting out quantitative goals of their own. Prominent examples include:

- *State initiatives.* With the passage of the 2006 Global Warming Solutions Act, California has set an enforceable target of achieving 1990 levels of greenhouse gas emissions by 2020, with an 80 percent reduction on 1990 levels by 2050 (box 3.1). Concerns that these targets will necessarily compromise competitiveness and employment are not well supported by the evidence. Modelling work has found that new incentives created by the state's cap on emissions could create an additional US$59 billion in income and 20,000 new jobs by 2020.[6] In total, there are now 17 states across the United States with emissions targets.[7]
- *Regional initiatives.* The Regional Greenhouse Gas Initiative (RGGI) established in 2005 is the first mandatory cap-and-trade programme in the United States, setting limits on emissions from power plants. It now extends to 10 states.[8] The target is to cap emissions at current levels from 2009 to 2015 and then to reduce them by 10 percent by 2019. In 2007, the creation of the Western Regional Climate Action Initiative—involving Arizona, California, New Mexico, Oregon, Utah and Washington—expanded the reach of regional initiatives. The Canadian provinces of British Columbia and Manitoba joined in 2007, turning it into an international partnership. By 2009, these states will set a regional emissions target and devise market-based programmes to achieve them.[9]
- *City initiatives.* Cities are also setting emission reduction targets. In total, around 522 mayors, representing 65 million Americans, are aiming to reach what would have been the United States Kyoto target of a 7 percent reduction below 1990 levels by 2012.[10] New York has introduced caps on emissions from the city's power stations. The New York City Government has also passed legislation that requires a city-wide inventory of greenhouse gas emissions and a city-wide goal of 7 percent reductions below 1990 levels by 2020. While the reductions are voluntary for the private sector, the City Government is committed to 30 percent emissions cuts.[11]

These initiatives have to be placed in context. If California were a country, it would be the world's fourteenth largest source of CO_2 emissions—that is why its leadership is of global importance. However, the bulk of emissions still originate in states with no planned caps on emissions: California and the RGGI states together account for around 20 percent of United States' greenhouse gas emissions. Just as greenhouse gases from India and the United States mix in the Earth's atmosphere, so a tonne of CO_2 from San Francisco has the same impact as a tonne from Houston. In the absence of binding Federal targets, emission reductions in some states can be swamped by increases in others. Even so, state-level and regional government initiatives have created a political impetus towards the establishment of emission ceilings at the Federal level.

That impetus is reflected in the United States Congress. Recent years have witnessed a steady proliferation in proposed legislation aimed at setting targets for future emissions of

At their 2007 summit, the G8 leaders accepted in principle the need for urgent and concerted action to avoid dangerous climate change

Box 3.1 Leadership by example in carbon budgeting—California

The world's sixth largest economy, California has long been a national and international leader on energy conservation and environmental stewardship. Today, it is setting the standard for global action on climate change mitigation.

The 2006 Global Warming Solutions Act requires California to cap greenhouse gas emissions by 2020 at 1990 levels, with a long-term reduction goal of 80 percent by 2050. This legislation represents the first enforceable state-wide programme to cap emissions from all major industries, with in-built penalties for non-compliance.

Legislation is rooted in strong institutional provisions. The state plan grants the State Air Resources Board (SARB) authority to establish how much industry groups contribute to emission reductions, assigning emission targets and setting non-compliance penalties. It sets a 2010 deadline for establishing how the system will work, allowing industries three years to prepare for implementation. The SARB is also required to develop a strategy "for achieving the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions by 2020". That strategy, to be enforceable by 2010, includes a cap-and-trade programme based on quantitative targets.

California's targets are backed by substantive policies. Among the most important:

- *Vehicle emission standards.* Over the past four years California has pioneered higher emission standards. Current vehicle standards legislation will require a 30 percent reduction in greenhouse gas emissions from new vehicles by 2016. The state is also developing a low Carbon Fuel Standard aimed at reducing fuel emissions intensity by 10 percent to 2020. This is expected to create incentives for emissions cuts in petroleum processing, biofuels and electricity-driven vehicles.
- *Performance standards for electricity.* Public policy action in this area has received less public attention than the Global Warming Solutions Act, but it has important implications. Under the relevant legislation, the California Energy Commission is required to set stringent emission standards for electricity procured under long-term contracts, whether the power is produced within the state or imported from plants in other states. The standards will drive low-carbon electricity generation, including research and development of power plants that capture and store CO_2.
- *Renewable energy.* California is one of twenty-one states with a 'renewable portfolio standard' setting a target for renewable energy. By 2020 California aims to generate 20 percent of its power from renewable sources. The state will pay an estimated US$2.9 billion in rebates over 10 years to households and businesses that install solar panels, with further tax credits to cover 30 percent of the cost of installation. These subsidies are part of the 'One Million Solar Roofs' initiative.
- *Setting conservation standards.* During 2004 California announced a stringent energy conservation target aimed at saving the equivalent of 30,000 GWh by 2013. In order to achieve this goal, new appliance and building standards have been introduced.

Three important features of the California case have wider lessons for carbon budgeting. First, the legislation establishes a credible target. Applied by all developed countries, the 80 percent reduction by 2050 would put the world on to a potentially sustainable emissions trajectory. Second, compliance and monitoring are overseen through strong institutional mechanisms that provide a basis for transparency and accountability. Third, the legislation establishes a balance between mandated targets, incentives and regulatory measures aimed at cutting emissions and spurring innovation.

Source: Arroyo and Linguiti 2007.

greenhouse gases. In the first half of 2007, seven separate bills aimed at setting economy-wide quantitative ceilings were under consideration in Congress.[12] One of these—the Climate Stewardship and Innovation Act—envisages an emissions pathway with 20 percent cuts below 1990 levels by 2030, deepening to 60 percent by 2050, for the electricity generation, transportation, industrial and commercial sectors.

Beyond Congress, there has been a surge of multi-constituency initiatives bringing together industry, environmentalists and others. The United States Climate Action Partnership (USCAP) is an example. An alliance of 28 major companies—including BP America, Caterpillar, Duke Energy, DuPont and General Electric—and six leading NGOs (with a membership of over one million), USCAP has called for a combination of mandatory approaches, technological incentives and other actions to achieve a peak of emissions by 2012, with reductions up to 10 percent by 2017, and 80 percent by 2050 with respect to 'current' levels.[13] Many of the companies involved have set voluntary targets for reducing emissions, anticipating the future development of mandatory targets.

USCAP's proposals are instructive. Beyond the targets themselves, they reflect important changes in approaches to climate change mitigation. Five years ago, many of America's largest companies were hostile in principle to the

Special contribution

New York City takes the lead on climate change

In the battle against climate change, it's easy to talk about lofty, far-away goals, but the question is: What are you doing today to achieve them? In New York City, we recently unveiled an ambitious yet achievable plan to combat global warming and create the first truly sustainable 21st Century city. The plan, which we call *PlaNYC,* includes 127 specific initiatives designed to reduce air and water pollution, clean-up polluted land, modernize our infrastructure and energy network, and significantly reduce the city's carbon footprint. In short, it's about leaving our children a greener, greater city.

Gone are the days when public and private sector leaders could act as though environmental sustainability and economic competitiveness work against one another. In fact, the very opposite has proven true. Fighting global warming begins, in many ways, with learning how to become more efficient. Investing in energy-saving technology allows governments, businesses and families to save significant amounts of money over the long term. As part of *PlaNYC,* for instance, New York City has committed to reducing its energy use by 30 percent over the next 10 years. We're also incentivizing private sector 'green' construction. And we're in the process of upgrading all 13,000 of our famous yellow taxi cabs, doubling their fuel efficiency to match or beat today's hybrid cars. This will not only mean less CO_2 and air pollution, but also lower gas bills for drivers—and that means more money in their pockets.

PlaNYC will help us to maintain our economic growth and protect our environment. But it will also allow us to fulfill our broader responsibilities as global citizens. The *Human Development Report 2007/2008* states plainly that climate change is one of the greatest challenges facing humanity, and it is the world's most vulnerable populations who are most immediately at risk. The actions of the wealthiest nations—those generating the vast majority of greenhouse gases—have tangible consequences for people in the rest of the world, especially in the poorest nations.

We can't sit back and wait for others to act—and that's why cities around the world are leading the charge. Leaders of cities focus on results, not politics—on taking action, not toeing the party line. Although international climate accords have been difficult to reach and harder to enforce, city leaders have been driving new innovations and sharing best practices. In February 2007, the United States Conference of Mayors launched the Climate Protection Center to provide mayors with the guidance and assistance they need to lead their cities' efforts to reduce greenhouse gas emissions. And in May of this year, New York City hosted the C40 Large Cities Climate Summit, which brought together more than 30 mayors from the world's largest cities to exchange ideas and best practices for combating climate change.

The leading role that cities have played against climate change is evidenced by the fact that many of the initiatives in *PlaNYC* were inspired by other cities. We drew on the experiences of London, Stockholm and Singapore in formulating our traffic-reducing congestion pricing plan; on Berlin for our renewable energy and green roof policies; on Delhi, Hong Kong and Shanghai for our innovative transit improvements; on Copenhagen for our pedestrian and cycling upgrades; on Chicago and Los Angeles for our plan to plant one million more trees; on Amsterdam and Tokyo for our transit-oriented development policies; and on Bogota for our plans for Bus Rapid Transit. By taking a global approach to a global problem, we were able to formulate a distinctly local plan that will allow us to do our part in the fight against climate change—and, we hope, to be a model for others to follow.

As the *Human Development Report 2007/2008* makes clear, it is no longer acceptable for the world's governments to ignore the threat of climate change, or for elected officials to announce distant goals without putting forth substantive plans to achieve them, including interim targets that allow the public to hold those officials and their successors accountable for making steady progress. As public leaders, we have a responsibility to take bold action that will lead to real change—starting today.

Michael R. Bloomberg
Mayor of the City of New York

idea of mandatory quantitative restrictions on greenhouse gas emissions. That is now changing. Increasingly, companies see quantitative targets not as a threat but as an opportunity that will create incentives and prospects for low-carbon investments.

Ironically, the absence of a national framework setting mandatory ceilings on greenhouse gas emissions is now regarded by many major companies as a problem, partly because it creates market uncertainty, and partly because the surge of state-level and regional-level initiatives is creating a complex patchwork of regulatory systems. The Alliance of Automobile Manufacturers, which includes General Motors and Ford Motor Company, has called for "a national, federal, economy-wide approach to addressing greenhouse gases".[14]

Many of the targets set are, at best, only weakly related to sustainable carbon budget requirements

The Electric Power Supply Association also announced its support for "comprehensive, mandatory federal legislation to minimize the impact of greenhouse gases".[15]

Four targeting problems in carbon budgeting

Is the new trend towards target setting in developed countries providing a foundation for carbon budgets that will enable the world to avoid dangerous climate change?

The answer to that question is a qualified 'no'. While the adoption of targets is an encouraging indication that public concern is registering on the political radar screen, many of the targets set are, at best, only weakly related to sustainable carbon budget requirements. Insufficient ambition is a common problem. Another is the confusion associated with a proliferation of targets, especially when those targets are inadequately reflected in energy policies. There are four broad potential sources of error in carbon budget targeting that need to be addressed:

- *Insufficient ambition.* Our sustainable emissions pathway establishes two plausible benchmarks for assessing where emissions ceilings need to be set by developed countries. The broad trajectory: peaking in the period 2012 to 2015, cuts of 30 percent by 2020 and cuts of at least 80 percent by 2050, against a 1990 baseline. There are two problems. First, some targets—the United Kingdom's and several proposals in the United States are examples—fall short of these benchmarks (table 3.1). Second, the selection of reference years can obscure under-ambition in target setting. For example, some governments interpret the commitment made at the G8 to "seriously consider" halving emissions by 2050 as an implied reduction from 'current' levels. Simple carbon arithmetic demonstrates why changes in reference years matters. Shifting the United States reference year from 1990 to 2004, for example, would increase the permitted emissions base by over 900 Mt CO_2e—roughly equivalent to total German emissions in 2004.[16] For Canada, the same shift in reference years would raise the baseline for emissions by 27 percent over 1990 levels. From a carbon budgeting perspective, any change in base year should include adjustments in reduction targets to compensate for any increase in emissions from 1990.
- *Inaccurate indicators.* Some governments present targets for reduced carbon intensity as equivalent to climate change mitigation goals. This confuses means and ends. Reducing the amount of CO_2 emitted for every dollar in wealth created (the carbon intensity of growth), or for every unit of power generated (the carbon intensity of energy), is an important goal. No mitigation strategy is likely to succeed without progress in these areas. However, what ultimately matters is the 'overall reduction' in emissions. From a sustainable carbon budget perspective, carbon intensity targets in isolation are a mitigation red-herring. Many countries have an impressive record in cutting carbon intensity but still have an overall increase in emissions (figure 3.1). The United States has reduced greenhouse gas intensity by around 25 percent since 1990 but its overall emissions have gone up by an equivalent amount. The GCCI targets a further reduction in greenhouse gas intensity of 18 percent between 2002 and 2012—broadly consistent with the trend since 1980. However, the Energy Information Administration projects an increase in CO_2 emissions over the same period of around 25 percent.[17]
- *Inadequate sectoral coverage.* Effective carbon accounting requires that all emissions are reflected in the budget. Unfortunately, current reporting systems keep some sectors 'off-budget'. For example, aviation is excluded from international inventories of greenhouse gases for the Kyoto Protocol. The Earth's atmosphere is less discriminating. Since 1990, emissions of CO_2 from aviation fuel have increased from 331 Mt CO_2 annually to 480 Mt CO_2. The

latter figure represents around 2 percent of global emissions. However, because the emissions are released directly into the high atmosphere, the radiative forcing effects are far stronger, accounting for 3 percent (2–8 percent range) of global warming.[18] For several OECD countries, aviation represents a significant and growing share of the national contribution to global warming. In the United Kingdom, annual emissions from aviation are projected to grow by between 62 and 161 Mt CO_2 by 2050. In order to offset emissions from the aviation sector and achieve the national target of a 60 percent reduction in overall emissions by 2050, other sectors would have to reduce their emissions by 71–87 percent.[19] This is not a plausible option, suggesting that aviation will have to be subject to cuts in emissions.

- *Insufficient urgency.* Sometimes decisions in public policy can be postponed without great cost. That is not the case with climate change. Because emissions are long-lived, delaying the decision to reduce them adds to the stock of greenhouse gases and cuts the time frame for reducing it. Several legislative proposals for the United States envisage limited cuts to 2020 against 1990 levels, followed by steeper declines thereafter. That approach may be ill-advised. One study for the United States shows that a pathway for contributing to a global stabilization level at 450 ppm CO_2e can be achieved with annualized reductions of 3 percent a year by 2050. However, delaying action until 2020 would require reductions of 8.2 percent a year—which would require stringent adjustments and an implausible rate of technological innovation.[20]

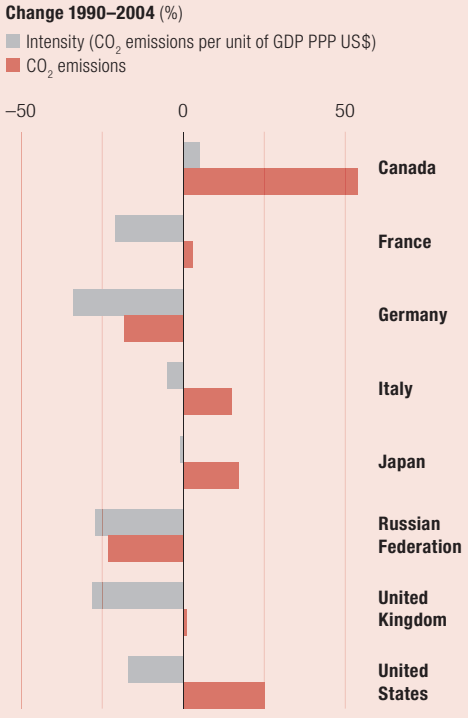
Targets matter, but so do outcomes

Setting targets is not the same as delivering results. Experience under the Kyoto Protocol provides a constant reminder of the limited progress made in aligning climate security goals with energy policies.

The experience of two countries at different ends of the Kyoto Protocol performance league is instructive. In Canada, energy-intensive economic growth has comprehensively undermined the prospects for delivery against the country's Kyoto commitments (box 3.2). Unlike Canada, the United Kingdom is on-track to meet its Kyoto targets, though not primarily as a result of energy policy reform: a shift in energy mix from coal to natural gas has been more important. The country has now defined an ambitious carbon budget that sets a pathway for reduced emissions through to 2050. However, CO_2 emissions from the United Kingdom have not fallen over the past decade—and there are serious questions over whether or not the country will achieve national targets for reduced emissions (box 3.3).

Institutional arrangements play an important role in determining the credibility of emissions reduction targets. In carbon budgeting, as in financial budgeting, governance matters a great deal, not least in ensuring that targets are translated into outcomes. This is another area in which California has provided leader-

Figure 3.1 Falling carbon intensity does not always lower emissions



Source: Indicator Table 24.

Experience under the Kyoto Protocol provides a constant reminder of the limited progress made in aligning climate security goals with energy policies

Box 3.2 Targets and outcomes diverge in Canada

Carbon-intensive economic growth has pushed Canada well off track from its Kyoto commitments. The country's experience powerfully demonstrates the difficulties in aligning domestic economic policies with international commitments.

In 2004, Canadians contributed around 639 million tonnes of CO_2 to the Earth's atmosphere. While this is only 2 percent of the world total, Canada has one of the highest levels of per capita emissions in the world—and the carbon footprint is deepening. Since 1990, CO_2 emissions from fossil fuel have increased by 54 percent, or 5 tonnes per capita. That increase is greater than the total per capita CO_2 emissions from China.

Canada is far from meeting its Kyoto Protocol commitments. Emissions have increased by 159 million tonnes of CO_2e since 1990—a 27 percent overall increase and 33 percent above Kyoto target levels.

Why has Canada missed its Kyoto targets by such a wide margin? Rapid economic growth has been one factor. Another has been the carbon intensity of growth, driven by a surge in investments in natural gas and oil production. Greenhouse gas emissions associated with exports from this sector have increased from 21 million to 48 million tonnes per annum since 1990.

Developments in oil and natural gas markets have contributed to Canada's Kyoto deficit. With rising oil prices, it has become commercially viable to exploit tar sands in Alberta. Unlike conventional oil extracted through wells, oil is extracted from tar sands by stripping away upper layers of soils, or by using high-pressure steam to heat the underlying sands and make the bitumen less viscous. The energy requirements and the greenhouse gas intensity per barrel of oil extracted from tar sands are almost double that for conventional oil.

Oil sands exploration has important implications for Canada's greenhouse gas emissions trajectory. The Canadian Association of Petroleum Producers and the Canadian National Energy Board estimate that C$95 billion (US$108 billion) will be spent on oil sands operations from 2006 to 2016. Output is expected to triple, to over three million barrels a day. Translated into carbon footprint terms, greenhouse gas emissions from oil sands could increase by a factor of five to 2020, rising to over 40 percent of national emissions by 2010.

Changing this trajectory will be difficult given the high levels of investment already in place. In 2006, new targets were set under a Clean Air Act that specifies reductions of 45–65 percent below 2003 levels by 2050. However, the targets are not binding—and they are not linked to specific policies. Initiatives at a provincial and municipal level have established more concrete provisions, producing some impressive results. For example, Toronto has achieved deep cuts in emissions (40 percent below 1990 levels in 2005) through energy efficiency initiatives, retro-fitting of old buildings and land fill policy.

Canada has a long history of global leadership on global atmospheric environmental issues, from acid rain to ozone depletion and climate change. Maintaining this tradition will require tough decisions. The David Suzuki Foundation has called for a 25 percent cut in emissions by 2020, with an 80 percent cut by 2050. Those targets are attainable, but not with current policies. Among the options:

- Accelerated deployment of low-carbon technologies and increased investment in carbon sequestration to reduce long-term emissions;
- A requirement on exporters that the purchase of Canadian oil and natural gas is linked to the purchase of verifiable emissions reductions through carbon market trading;
- The introduction of a carbon tax on investors in oil sands production to finance technological innovation and the purchase of emissions credits;
- Strict regulation of production standards and price incentives for low-emission production of oil sands and natural gas.

Source: Bramley 2005; Government of Canada 2005; Henderson 2007; Pembina Institute 2007a, 2007b.

ship. In order to implement the state's cap on emissions, a strong agency—the California Air Resources Board—has been directed to develop regulations, establish a mandatory reporting system and monitor emission levels. While the targets are set by elected political leaders, implementation and administration are conducted through public agencies with a strong technical capacity. At the same time, the targets have been backed by far-reaching reforms in energy policy (see box 3.1). By contrast, the European Union has set ambitious targets for cutting emissions, without having either an institutional framework for implementation or a coherent agenda for energy reform: energy policy is overwhelmingly a national responsibility (box 3.4). Transition economies have also adopted targets under the Kyoto Protocol. While most are on track for achieving the targets, this owes more to the economic recession of the 1990s than to energy reform—an area in which progress has been mixed (box 3.5).

The limits to voluntarism

Some countries have relied primarily on voluntary programmes to achieve climate change mitigation goals. Results have been mixed. In some cases, voluntary action has made a difference.

Box 3.3 The United Kingdom's climate change bill—setting a carbon budget

The United Kingdom's Climate Change Bill is a bold and innovative proposal to create a national carbon budget that supports global mitigation efforts. Legislation would commit Government to mandatory cuts in emissions over time. Applied more widely across the developed world, the broad approach could underpin a strengthened post-2012 Kyoto system. However, there are serious questions about the level of ambition—and about the United Kingdom's capacity to meet its own carbon reduction targets.

The Climate Change Bill charts a pathway for emissions reductions to 2050. An expressed aim is to contribute to international efforts to avoid dangerous climate change, which the United Kingdom Government identifies as a global mean temperature increase in excess of 2°C. The roadmap sets the 2050 target for greenhouse gas emissions reductions at 60 percent, with an interim target of 26–32 percent reductions by 2020 against levels in 1990.

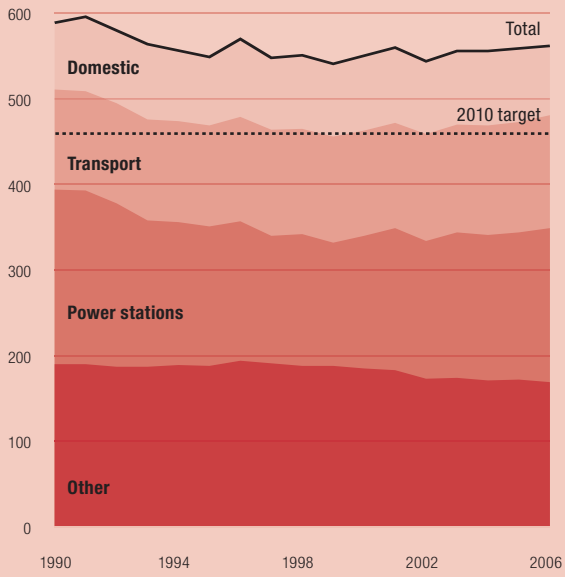
These targets would be fixed in a system of 'carbon budgets'—rolling 5-year limits on CO_2 emissions. Three budgets would be set in advance, helping to create a long-term horizon for business and investment decisions. Legislation would create enabling powers that make future policies for controlling emissions quicker and easier to introduce. However, two issues will have to be addressed if the Climate Bill is to provide the framework for a sustainable carbon budget.

The first problem is one of overall ambition. Emission targets in the Climate Bill are not consistent with the objective of avoiding dangerous climate change. Our sustainable emissions pathway suggests that developed countries need to cut emissions of greenhouse gases by at least 80 percent by 2050 against 1990 levels, not 60 percent. Moreover, the current framework excludes aviation and shipping. Factoring them in would raise the cumulative United Kingdom carbon budget to 2050 by around 5.5 Gt CO_2, or 27 percent.

If the rest of the developed world followed the pathway envisaged in the United Kingdom's Climate Change Bill, dangerous climate change would be inevitable. It would lead to approximate atmospheric concentrations of greenhouse gases in excess of 660 ppm CO_2e, and possibly 750 ppm CO_2e. These are outcomes that would correspond to a rise in average global temperatures of 4–5°C, well beyond the dangerous climate change threshold. The overarching requirement for keeping within the 2°C threshold is a stabilization of greenhouse gas stocks at 450 ppm CO_2e.

The second problem to be addressed is the direction of current greenhouse gas emissions (see figure). On a positive note, the United Kingdom is one of a small group of European Union countries that is on-track for achieving its Kyoto Protocol target. While the economy has expanded by 47 percent since the 1990 base year for Kyoto, emissions of CO_2 are 5 percent lower. The less positive news is that all the reduction took place prior to 1995. Since 2000, emission levels have increased by 9 Mt CO_2 (to 567 Mt CO_2 in 2006). The upshot is that the national target of reducing CO_2 emissions to 20 percent below 1990 levels by 2010 is now unattainable: the likely outcome is a reduction less than one-half this target.

CO_2 trends are off track for national target



Source: Government of United Kingdom 2007c.

Breaking down emission sources for CO_2 by sector helps to identify some of the challenges facing the United Kingdom. Emissions from power stations, which represent around one-third of the total, have increased in five of the last seven years. The transport sector, now the second largest source of emissions, is on a sharply rising trajectory, while emissions from industry and the residential sector have not moved significantly. Changing these CO_2 emission trajectories to make possible a reduction of 26–32 percent by 2020 will require radical new policies that align energy policy with climate change mitigation goals. Among the options:

- *Carbon taxation and strengthened cap-and-trade.* Carbon pricing is critical to sustainable carbon budgeting. Signalling a commitment to carbon taxation in the range outlined in this chapter offers one route for aligning energy markets with sustainable carbon budget goals. Working through the European Union's cap-and-trade scheme is another option (section 3.2), provided that the ceiling on emissions is set at a level consistent with 26–32 percent cut in emissions by 2020.
- *Power generation.* The future energy mix in power generation will shape the United Kingdom's emissions trajectory. Since early 2000, increased use of coal, the most polluting fossil fuel, has been instrumental in driving up emissions. Regulatory mechanisms could be deployed to initiate the rapid retirement of highly polluting plants, with a commitment to the accelerated introduction of zero-emission coal plants. Britain also lags far behind best European Union practice on renewable energy: it currently produces only 2 percent of its overall energy from renewables.

Box 3.3 **The United Kingdom's climate change bill—setting a carbon budget** (continued)

The Renewables Obligation, a regulatory instrument, stipulates the amount of electricity that power suppliers have to access from renewable sources. It has achieved mixed results. The current target is for the share of renewables to reach 10 percent by 2010, rising to 15 percent by 2015. However, current trends fall far short of these targets, and shorter still of the European Union's 20 percent target by 2020. If Britain is to achieve its own stated goals, it will need to accelerate the development of wind and tidal power. One option would be a system of renewables support modelled on the German feed-in tariff system, with stronger price incentives backed by public investment.

- *Cutting emissions from transport.* Taxation and regulation are mutually reinforcing instruments for cutting transport emissions. Increased taxation on petrol is one demand management mechanism. More broadly, vehicle excise duties could be adjusted, with a steeper graduation to reflect the higher CO_2 emissions associated with low fuel-efficiency vehicles, especially sports utility vehicles. The national carbon budget could establish 'carbon pricing' in vehicle taxation as a source of revenue for investment in renewable energy, with vehicle tax registration for all new cars after 2010 graduated to reflect more stringent pricing on CO_2 emissions. Rising emissions from transport also reflect weaknesses in the public transport infrastructure and a decline in the cost of private transport relative to public transport.
- *The residential sector.* Energy use in the residential sector remains highly inefficient. An average existing home requires four times as much energy to heat as a new home. Around one-third of the homes that will be occupied in 2050 are yet to be built. With adoption and implementation of the best European Union standards, this represents an opportunity for deep cuts in emissions.

Setting the right targets is the starting point for sustainable carbon budgeting. Ultimately though, governments have to be judged on policies and outcomes. Impressive inflation targets count for little in the face of uncontrolled money supply. The same applies to climate change targets. The challenge for the United Kingdom is to align a more stringent target with wide-ranging energy policy reform.

Source: Anderson and Bowes 2007; Government of the United Kingdom 2006b, 2006c, 2007b, 2007c, 2007e; Seager and Milner 2007.

However, faced with a threat on the scale posed by climate change, voluntarism cannot substitute for effective state action.

Developed countries that have not ratified the Kyoto Protocol have relied on voluntary targets. The only Federal target in the United States is the (non-binding) emissions intensity target. Other flagship programmes—such as the Combined Heat and Power Partnership and the Clean Energy–Environment State Partnership—attempt to encourage voluntary reductions by the corporate sector. In Australia, the national climate change strategy does have a non-binding target: emission cuts of 87 Mt CO_2 by 2010.[21] Voluntary measures, such as consumer education and engagement with the private sector, are the primary mechanism for achieving the objective.

Outcomes have not been encouraging. The centrepiece of the voluntary programme in Australia is the Greenhouse Challenge Plus (GCP) initiative. Participating companies are required to develop and publish company-level greenhouse gas inventories and strategies for cutting emissions. The GCP has played an important role in informing public debate and many participating companies have adopted innovative strategies for cutting emissions. However, Australia's overall greenhouse gas emissions in 2004, not including land-use change, were 25 percent above 1990 levels.[22] Emissions of CO_2 from energy were up by one-third and by 16 percent for industrial processes.[23] Voluntarism is clearly not delivering the required outcome.

Recognition of this fact has prompted several state and territory governments to argue for a national programme for mandatory emissions cuts to supplement voluntary efforts. One prominent example is New South Wales, which has set a target of reducing greenhouse gas emissions by 60 percent by 2050.[24] More immediately, state legislation passed in 2002 aims to cut emissions per capita from the production and use of electricity from 8.6 tonnes to 7.3 tonnes between 2003 and 2007—a reduction of 5 percent against the Kyoto Protocol threshold.[25] The Greenhouse Gas Abatement Scheme sets annual statewide greenhouse gas reduction targets, and then requires individual electricity retailers to meet mandatory benchmarks based on the size of their share of the electricity market.[26] As in the United States, this is an example of political leadership on climate change from below.

Box 3.4 The European Union—2020 targets and strategies for energy and climate change

"The aim is that the European Union leads the world in accelerating the shift to a low-carbon economy."

José Manuel Barroso, President of the European Commission, January 2007

What the European Union does in energy policy matters for the world. Its 27 countries account for around 15 percent of CO_2 emissions worldwide and Europe has a strong voice in international negotiations. Making that voice count depends critically on the demonstration of leadership by practical example.

Ambitious targets have been set. In 2006, European governments agreed to aim at cuts of 20 percent in greenhouse gas emissions against 1990 levels by 2020, rising to 30 percent in the event of an international agreement. At the heart of the strategy for achieving the target is a commitment to a 20 percent increase in energy efficiency.

Translating targets into concrete policies is proving more difficult. Proposals from the European Union to achieve greater efficiency through market liberalization, including the 'unbundling' of energy production, are contested by several member states. More broadly, there is no European Union-wide strategy for translating the 20 percent reduction commitment into national carbon budgets through taxation, strengthened efficiency standards or a more stringent cap-and-trade system. The European Union Emission Trading Scheme (EU ETS) is the world's largest cap-and-trade programme but it is not geared towards attainment of the 20–30 percent cuts in emissions (section 3.2).

Prospects for the European Union meeting its Kyoto Protocol reduction commitments remain uncertain. For the pre-2004 member states, it is estimated that current policies will achieve a reduction of 0.6 percent from the 1990 baseline. This means that the member states are less than one-tenth of the way to achieving the target of an 8 percent reduction. More stringent enforcement of existing energy efficiency regulations would go a long way towards closing the gap.

The European Union has taken one step towards leadership in global carbon mitigation: it has set ambitious targets. Translating these targets into a coherent set of policies will require greater coherence and bold reforms of the EU ETS, including far more stringent cuts in quota.

Source: CEC 2006b, 2007a; EC 2006c, 2007b; High-Level Task Force on UK Energy Security, Climate Change and Development Assistance 2007.

Governments in countries that ratified the Kyoto Protocol have also engaged with the private sector in voluntary initiatives. In Japan, the Voluntary Action Plan (VAP) was drawn up by Government in consultation with the Japanese Business Federation. It covers seven major industrial sectors. The problem is that companies are free to set their own targets. In 2005, the Japanese Government set out a new plan aimed at getting the country back on-track to meet its Kyoto commitments by achieving a 9 percent cut in emissions of the industrial sector by 2010. The target under the VAP is for the industrial and energy converting sectors is to achieve emissions levels in 2010 that are below those in 1990.[27]

None of this is to downplay the importance of corporate sector voluntary action. In the United States, many companies are not waiting for mandatory government targets to change business practices. They are acting now.[28] In 2003, 35 investors with US$4.5 trillion in assets signed up to the Carbon Disclosure Project—a voluntary arrangement for reporting corporate emissions. There are now 155 institutional investors with combined assets of US$21 trillion represented.[29] Many are participating in a voluntary programme—'Energy Star'—that sets standards for energy efficiency. Companies in the power sector are investing in the development of renewable energy capacity. Meanwhile, one of the world's largest energy supply companies—American Electric Power—has set itself the ambitious target of building one or more Integrated Gas Combine Cycle power-plants by 2010. Pollution-intensive industries—such as steel and cement—have also developed technologies to cut emissions.

Box 3.5 Reducing carbon intensity in transition economies

The experience of countries in Central and Eastern Europe (CEE) and the Commonwealth of Independent States (CIS) serves to highlight the important role of markets—and the consequences of sending the wrong price signals.

When these countries moved from communist rule some 18 years ago, they exhibited some of the highest levels of energy intensity in the world. Heavy subsidies for coal-based energy generation and low prices for energy users created strong disincentives for efficiency, and high levels of CO_2 pollution.

The transition from centrally planned economies has taken the region through a painful restructuring process. During the first half of the 1990s, energy demand and CO_2 emissions tracked the economy in a dramatic decline—a fact that explains why transition economies 'over-achieved' against their Kyoto targets. Since then, energy policy reforms have produced a mixed picture.

Energy intensity (energy consumption per unit of GDP) and the carbon intensity of GDP have fallen in all countries, albeit at very different rates—and for different reasons (see table). In the Czech Republic, Hungary and Poland advances have been driven by economic reforms and privatization. Poland has almost halved energy intensity against 1990 levels. Deep reforms in the energy sector, including sharp increases in real prices, and the transition from an economy based on large state enterprises to private sector firms, have spurred rapid technological change. Ten years ago, Poland used 2.5 times more energy per unit of cement production than the European Union average. That differential has now been eliminated. The energy intensity of GDP has fallen by half since 1990.

Ukraine has achieved far lower reductions in energy and carbon intensity. Moreover, the reductions owe less to reform than to a change in energy mix: imports of natural gas from the Russian Federation have halved the share of coal. The energy reform process has yet to take off. Energy prices remain heavily subsidized, creating disincentives for efficiency gains in industry. An influential commission created by the Government—the Blue Ribbon Commission—has called for far-reaching reforms. The proposals range from cost-recovery pricing to the creation of an independent energy regulator and the withdrawal of subsidies. Progress towards implementation has been slow, but has gathered pace following an interruption of gas supplies from the Russian Federation in 2006.

Developments in the Russian Federation's energy sector are a matter of global concern for climate change. The country is the world's third largest emitter of CO_2, with a per capita carbon footprint close to the OECD average.

The Russian Federation ratified the Kyoto Protocol in 2004. When it did so, greenhouse gas emissions were 32 percent below 1990 levels—a fact that bears testimony to the depth of the recession that accompanied transition. Compared with 1990 levels, there has been considerable progress. However, the Russian Federation remains an energy intensive economy—twice as intensive as Poland. One reason for this can be traced to the partial nature of economic reforms. While many of the most inefficient state enterprises have been dismantled, economic recovery has been driven by energy-intensive sectors, such as minerals and natural gas.

Energy reform has also been partial. The natural gas sector illustrates the problem. In 2004, it is estimated that Gazprom, the state energy company, lost nearly 10 percent of its total production through leaks and inefficient compressors. Inefficient flaring of gas is another problem. Independent estimates suggest that around 60 billion cubic metres of natural gas—another 8 percent of production—is lost through flaring, suggesting that the Russian Federation may be responsible for around one-third of global emissions from this source.

Countries such as the Russian Federation demonstrate the immense potential for achieving win–win outcomes for national energy efficiency and climate change mitigation. Emissions trading through carbon markets such as the EU ETS could play a role in supporting low-carbon investment. However, unlocking the win–win potential will require the creation of new incentive structures through energy reform. Higher energy prices, the scaling down of subsidies, the introduction of a more competitive energy sector with strengthened independent regulation, and wider governance reforms are among the priorities.

Carbon and energy intensity is reducing in transition economies

	Total CO_2 emissions (Mt CO_2)			CO_2 emissions per capita (t CO_2)		Energy intensity (Energy use per unit of GDP PPP US$)		Carbon intensity (CO_2 per unit of GDP PPP US$)	
	1990	2000	2004	1990	2004	1990	2004	1990	2004
Russian Federation [a]	1,984	1,470	1,524	13.4	10.6	0.63	0.49	1.61	1.17
Poland	348	301	307	9.1	8.0	0.36	0.20	1.24	0.68
Ukraine [a]	600	307	330	11.5	7.0	0.56	0.50	1.59	1.18
Hungary	60	55	57	5.8	5.6	0.24	0.17	0.50	0.37
Czech Republic [a]	138	119	117	13.4	11.4	0.32	0.26	1.03	0.66
Slovakia [a]	44	35	36	8.4	6.7	0.37	0.26	0.96	0.51
CEE and the CIS	4,182	2,981	3,168	10.3	7.9	0.61	0.47	1.49	0.97
OECD	11,205	12,886	13,319	10.8	11.5	0.23	0.20	0.53	0.45

a. 1990 data refer to 1992.

Source: HDRO calculations based on Indicator Tables 22 and 24.

Source: GUS 2006; High-Level Task Force on UK Energy Security, Climate Change and Development Assistance 2007; Olshanskaya 2007; Perelet, Pegov and Yulkin 2007; Stern 2006; UNDP, Ukraine 2005; Ürge-Vorsatz, Miladinova and Paizs 2006.

As these positive examples suggest, voluntary initiatives for climate change mitigation have an important role to play. They can inform consumer choice, create incentives for companies and establish best practice models. But voluntary action is not enough. It has not been enough to push emission trends in a downward direction in Australia or in the United States. In other areas of public policy—national security, nuclear safety or the regulation of environmental pollution, for example—governments would not consider reliance on voluntary action alone. Yet when it comes to climate change, there is a damaging tendency to overstate the role of 'choice' and understate the importance of government action. Ultimately, failure to recognize the limits to voluntarism will compromise climate change mitigation.

The monetary and wider social costs of carbon emissions are large but uncertain—and they are spread across countries and generations

3.2 Putting a price on carbon—the role of markets and governments

The debate on climate change has shifted in recent years. The argument is no longer about whether or not the world is warming, or whether or not human-induced climate change is responsible. Today, the debate is about how to tackle the problem.

In an ideal world, the marginal cost of carbon would be aligned with the damage—or externalities—caused by additional emissions, leaving the actors responsible for those emissions to pay the full social cost of their actions. In the real world, putting the full-cost price on carbon is a tricky business. The monetary and wider social costs of carbon emissions are large but uncertain—and they are spread across countries and generations. One important outcome is that emitters do not face the consequences of their own pollution.

None of this represents an insurmountable obstacle to the development of carbon pricing. We may not be able to calculate the precise social costs of emissions. However, we know the order of magnitude for emission reductions required to avoid dangerous climate change. Our sustainable emissions pathway provides a first approximation. The immediate challenge is to push the price of carbon to a level consistent with this pathway, either through taxation or quota, or both.

Taxation versus 'cap-and-trade'

The case for putting a price on carbon as part of a climate change mitigation strategy is increasingly widely accepted. But where should the price be set? And how should it be generated? These questions are at the heart of a somewhat polarized debate over the relative merits of carbon taxation and 'cap-and-trade' programmes. The polarization is unhelpful—and unnecessary.

Both carbon taxation and cap-and-trade systems would create economic incentives to drive emission reductions. Under a carbon tax, emitters are required to pay a price for every tonne of emissions they generate. Using a tax to achieve a specified reduction in emissions requires decisions on the level of tax, who should pay and what to do with the revenue. Under a cap-and-trade programme, the government sets an overall emissions cap. It then issues tradable allowances—in effect, 'permits to pollute'—that allow business the right to emit a set amount. Those who can reduce their emissions more cheaply are able to sell their allowances to others who would otherwise be unable to comply. Using a cap-and-trade programme means taking decisions on where to set the pollution ceiling, who should be issued with allowances and how many of the allowances should be sold rather than given away free.

The case for carbon taxation

Proponents of carbon taxation claim a broad range of advantages over cap-and-trade systems.[30] These can be clustered into four categories:

There are strong grounds for introducing cap-and-trade, especially to meet the short term and medium-term goals upon which success in avoiding dangerous climate change ultimately depends

- *Administration.* Advocates of tax-based approaches maintain that they offer wider administrative advantages. In principle, duties on CO_2 emissions can be introduced through the standard tax system, with opportunities for evasion limited by enforcement at key points in the economy. One estimate for the United States suggests that a carbon tax applied to 2000 entities could cover virtually all fossil fuel consumption, limiting opportunities for evasion.[31]
- *Limiting distortions caused by vested interests.* As in any system of quota allocation, cap-and-trade schemes are open to manipulation by vested interests. As one commentator has written, issuing allowances is "in essence printing money for those in control of the permits".[32] Who gets how many permits and at what price are issues that have to be determined through political processes. Inevitably those processes are open to influence by powerful actors—power companies, oil companies, industry and retailing, to name a few. Pandemic cheating has been highlighted as the Achilles' heel of cap-and-trade approaches.
- *Price predictability.* While both taxation and cap-and-trade raise the cost of CO_2 emissions, they do so in very different ways. Carbon taxes directly influence price in a predictable fashion. By contrast, cap-and-trade schemes control quantity. By fixing the quantity of emissions, such schemes will drive prices through whatever adjustment corresponds to the quota ceiling. Critics of cap-and-trade argue that quotas will accentuate energy price fluctuations, affecting business investment and household consumption decisions.
- *Revenue mobilization.* Carbon taxation has the potential to generate large streams of revenue. Because the tax base for carbon levies is so large, even a modest tax could deliver considerable amounts. For the OECD, a tax on energy-related CO_2 emissions set at US$20/t CO_2 would release up to US$265 billion annually.[33] Revenues derived from carbon taxation can provide a source of finance for the reform of taxation systems, while maintaining fiscal neutrality (leaving the tax-to-GDP ratio unchanged). Carbon tax revenue can be used to reduce taxation on employment and investment, or to create new incentives for the development of low-carbon technologies. For example, in the early 1990s Norway introduced a carbon tax on energy which now generates almost 2 percent of GDP in revenue. The revenue flows from carbon taxation have supported technological innovation and financed reductions in labour taxes.[34] In Denmark, carbon taxation has played an important role in reducing carbon intensity and promoting the development of renewable energy. Since 1990, the share of coal in primary energy use has fallen from 34 to 19 percent, while the share of renewables has more than doubled to 16 percent.

Taxes and quotas: the difference can be exaggerated

Carbon taxation does offer an effective route for cutting emissions. Many of the claimed advantages are real—as are many of the problems highlighted with cap-and-trade systems. Yet there are strong grounds for introducing cap-and-trade, especially to meet the short term and medium-term goals upon which success in avoiding dangerous climate change ultimately depends. Moreover, differences between cap-and-trade and taxation can be overstated. In practice, neither approach is inherently more complex than the other. Both require monitoring, enforcement and effective governance systems—and both have to address the question of how to distribute costs and benefits across society.

Administrative complexity is one area in which the differences have been overstated. Quota-based systems in any economic sector can create formidably difficult administrative problems.[35] However, the concentration of CO_2 emissions in large-scale power plants and carbon-intensive industries makes it possible to operate cap-and-trade schemes through a relatively small number of enterprises. The EU ETS, considered in more detail below, operates through less than 11,000 enterprises.

Administration of carbon levies through the tax system may have some operational

advantages. Even so, tax systems can also be highly complex, especially when, as would be the case with carbon taxation, they incorporate exemptions and special provisions. Moreover, the design and implementation of taxation systems is no less open to lobbying by vested interests than permit allocations under cap-and-trade programmes.

Price volatility is a challenge in cap-and-trade systems. Here too, however, it is important not to over emphasize the differences. If the policy aim is to achieve quantitative goals in the form of reduced emissions, carbon taxation will have to be constantly amended in the light of quantitative outcomes. Marginal tax rates would have to be adjusted to reflect undershooting or overshooting, and uncertainties over marginal tax rates could become a source of instability in energy prices.

What about the argument that carbon taxation offers a predictable revenue stream to finance wider tax reform? This is an important potential benefit. However, cap-and-trade programmes can also generate revenues, provided that they auction permits. Transparent auctioning offers several advantages apart from revenue mobilization. It enhances efficiency and reduces the potential for lobbying by vested interest groups, addressing two of the major drawbacks with quota systems. Signalling the gradual introduction and scaling up of auctioning to cover 100 percent of permit allocation should be an integral part of cap-and-trade design. Unfortunately, this is not happening under the EU ETS, though several states of the United States have proposed the development of auction-based cap-and-trade systems.

From a climate change mitigation perspective, cap-and-trade offers several advantages. In effect, taxes offer greater price certainty, while cap-and-trade offers greater environmental certainty. Strict enforcement of the quota guarantees a quantitative limit on emissions, leaving markets to adjust to the consequences. The United States acid-rain programme provides an example of a cap-and-trade scheme that has delivered tangible environmental benefits. Introduced in 1995, the programme targeted a 50 percent reduction in emissions of sulphur dioxide (SO_2). Tradable permits were distributed in two phases to power plants and other SO_2-intensive units, creating incentives for rapid technological change. Today, the targets are close to attainment—and sensitive ecosystems are already recovering.[36]

In the context of climate change, quotas may be the most effective option for achieving the stringent near-term goals for emission reductions. Put simply, cap-and-trade offers a quantitative mechanism for achieving quantitative targets. Getting the price right on marginal tax would produce an equivalent effect over time. But getting the price wrong in the early stages would compromise mitigation efforts because it would lead to higher emissions requiring more stringent future adjustments.

What is important in the context of any debate over the relative merits of carbon taxation and cap-and-trade is clarity of purpose. The ambition has to be aligned with the carbon emissions trajectory for avoiding dangerous climate change. For developed countries, that trajectory requires 30 percent cuts by 2020 and at least 80 percent cuts by 2050 against 1990 levels. The credibility of any cap-and-trade scheme as a mechanism for avoiding dangerous climate change rests on its alignment with these targets—a test that the EU ETS currently fails (see below).

Estimating carbon taxation levels consistent with our sustainable emissions pathway is difficult. There is no blueprint for estimating the marginal taxation rate consistent with that pathway. One reason for this is uncertainty about the relationship between changed market incentives and technological innovation. Economic modelling exercises suggest that a carbon price in the range of US$60–100/t CO_2 would be broadly consistent with the mitigation efforts required. The introduction of the tax would have to be carefully sequenced to achieve the twin goal of signalling the long-term direction of policy, without disrupting markets. One possible option is a graduated approach along the following lines:

- A tax of US$10–20/t CO_2 introduced in 2010;

Economic modelling exercises suggest that a carbon price in the range of US$60–100/t CO_2 would be broadly consistent with the mitigation efforts required

The climate change benefits of carbon taxation or cap-and-trade systems will be limited if governments do not complement reforms in these areas with a curtailment of fossil-fuel subsidies

- An annualized increase in taxation of US$5–10/t CO_2 adjusted on a rolling basis to take into account the national emissions trajectory.[37]

It should be emphasized that the aim of introducing carbon taxation is climate change mitigation—not revenue raising. Taxes on CO_2 can be increased without raising the overall tax burden. Indeed, fiscally neutral carbon tax reform offers a potential to finance wider reforms of the taxation system. As seen before, lowering taxes on employment or investment can create incentives for the development of low-carbon technologies. Because carbon taxation has the potential to feed through into higher prices for energy, overcoming the regressive effects by using revenues to support low income groups is also important.

Where should carbon taxes or cap-and-trade programmes be applied? The optimal approach would be to create a single global price for carbon, with the distributional consequences addressed through international transfers (just as national transfers are used to compensate for the effects of taxation). In theory, it is possible to design a transitional route to this goal, with taxes or cap-and-trade quotas graduated to reflect the circumstances of rich and poor countries. In practice, the world lacks the political, administrative and financial governance structures to oversee taxation or cap-and-trade systems covering both developed and developing countries.

That does not mean that the world cannot move towards a global carbon price regime. The issue is one of sequencing. For developed countries, the priority is to build upon current cap-and-trade schemes or to introduce carbon taxation consistent with the emission reduction targets set out in our sustainable emissions pathway. Integrating emerging carbon markets in Australia, Europe, Japan and the United States provides a skeletal structure for global carbon trading. Developing countries could gradually integrate into international systems by establishing their own cap-and-trade schemes, or by introducing carbon taxation as they seek to reduce their emissions over a longer-term time horizon.

Eliminating perverse subsidies

Whatever their respective merits, the climate change benefits of carbon taxation or cap-and-trade systems will be limited if governments do not complement reforms in these areas with a curtailment of fossil-fuel subsidies. While OECD countries as a group have been reducing these subsidies over time, they continue to distort markets and create incentives for carbon-intensive investments. Overall, OECD subsidies for fossil-fuel energy are estimated at US$20–22 billion annually. From a climate change mitigation perspective, these subsidies are sending precisely the wrong market signals by encouraging investments in carbon-intensive infrastructure. Among the examples:

- In the United States, the congressional Joint Committee on Taxation estimates tax concessions for exploration and development of fossil fuels at US$2 billion annually for 2006–2010.[38] Old coal power plants in the United States are also subject to weaker pollution controls under the Clean Air Act than newer plants—in effect providing them with an indirect subsidy for pollution.[39]
- In 2004, the European Environment Agency estimated on-budget state subsidies for coal production to total €6.5 billion (US$8.1 billion), dominated by Germany (€3.5 billion, some US$4.4 billion) and Spain (€1 billion, some US$1.2 billion), with off-budget support generating a similar amount.[40] In 2005, the European Commission approved a €12 billion (US$15 billion) grant for 10 coal mines in Germany.[41]
- Aviation fuel used in domestic and international flights is exempt from fuel duty in many countries. This is an obvious contrast to the position for petrol used in cars, where fuel duties figure prominently in final prices paid by consumers. The tax advantage enjoyed by aviation fuel represents an implicit subsidy on air transport, though the level of subsidy varies across countries.[42]

Subsidy elimination and taxation on flights and fuel, or the application of cap-and-trade to the aviation industry are priorities.

Cap-and-trade—lessons from the EU Emission Trading Scheme

Climate change *realpolitik* presents a powerful case for cap-and-trade. Whatever the theoretical and practical merits of carbon taxation, the political momentum behind cap-and-trade is gathering pace. The next few years are likely to witness the emergence of mandatory emissions controls in the United States with an expansion of institutionalized carbon trading. More broadly, there is a prospect that the post-2012 Kyoto framework will witness a process of integration between carbon markets in the developed world, with strengthened carbon financing links to developing countries. None of this precludes an expanded role for carbon taxation. However, cap-and-trade programmes are emerging as the primary vehicle for market-based mitigation—and it is vital that they are implemented to achieve the central objective of avoiding dangerous climate change. These are important lessons to be learnt from the European Union.

The EU Emission Trading Scheme—a big scheme with a short history

The EU ETS is by far the world's largest cap-and-trade scheme. For the European Union it represents a landmark contribution to climate change mitigation. To its critics, the EU ETS is a design-flawed confirmation of all that is wrong with cap-and-trade schemes. Reality is more prosaic.

The first phase of the EU ETS ran from 2005 to 2007. Phase II will run for a 5-year period to the end of 2012.[43] Writing off an experiment on the scale of the EU ETS before the end of its pilot phase might be considered a case-study in premature judgement. However, the scheme has undoubtedly suffered from a number of flaws in design and implementation.

The origins of the EU ETS can be traced to the 'flexibility mechanisms' introduced under the Kyoto Protocol.[44] Through these mechanisms, the Protocol aimed to create a mechanism for achieving emission reductions at lower cost. The EU ETS operates through the allocation and trading of greenhouse gas emission permits. The permits are allocated to member states and distributed to identified emitters, which in turn have the flexibility to buy additional allowances or to sell surplus allowances. In the first phase of the EU ETS, 95 percent of allowances had to be distributed free of charge, severely restricting the scope for auctioning.

Other Kyoto flexibility mechanisms have been linked to the EU ETS. The Clean Development Mechanism (CDM) is an example. This allows countries with a Kyoto target to invest in projects that abate emissions in developing countries. The rules governing the generation of mitigation credits through the CDM are based on the twin principles of 'supplementarity' and 'additionality'. The former requires that domestic action on mitigation should be the primary source of emission reductions (though there are no quantitative guidelines); the latter requires evidence that the abatement would not have occurred in the absence of the CDM investment. Between the end of 2004 and 2007, there were 771 registered projects with a declared reduction commitment of 162.5 Mt CO_2e. Just four countries—Brazil, China, India and Mexico—accounted for three-quarters of all projects, with sub-Saharan Africa representing less than 2 percent.[45]

Rapid institutional development is one of the positive lessons to emerge from the EU ETS. During the first phase, the scheme covered around one-half of the European Union's total greenhouse gas emissions, spanning 25 countries and over 10,000 installations in a wide range of sectors (including power, metals, minerals and paper). It has spawned a large market. In 2006, transactions involving 1.1 billion tonnes of CO_2e worth €18.7 billion (US$24.4 billion) took place in a global carbon market worth €23 billion (US$30 billion).[46]

Rapid institutional development is one of the positive lessons to emerge from the EU ETS

Three systematic problems

The EU ETS provides an institutional structure that has the potential to play a key role in an ambitious European Union climate change mitigation strategy. That potential has yet to be realized, however. During the first phase, three systemic problems emerged:

- *Overallocation of permits, creating the wrong price signals.* In the initial stages of

allowance trading, prices climbed to €30/t CO_2 (US$38/t CO_2) in April 2006, before collapsing and stabilizing at prices below €1/t CO_2 (US$1.3/t CO_2) in 2007.[47] The reason for the collapse: publication of data showing that the cap had been set *above* emission levels.[48] Overallocation, the short time-horizon for the first phase, and uncertainty about allocations in the second phase have fuelled price volatility and kept prices depressed though there are signs of recovery (figure 3.2).

- *Windfall profits for the few.* Carbon trading during the first 3 years of the EU ETS did little to reduce overall emissions, but it did generate very large profits for some. In the power sector in particular, companies were able to cover their emissions through free quotas, pass on costs to consumers and benefit from market opportunities to trade excess quotas.[49] The United Kingdom Government estimates that large electricity generators gained £1.2 billion (US$2.2 billion) in 2005.[50] Estimates for the power sectors in France, Germany and the Netherlands put the windfall profit generated through emissions trading at around €6 billion (US$7.5 billion) for 2005.[51]
- *Lost opportunities for revenue mobilization.* CO_2 emissions permits have a real market value. For their holders they are the same as cash-in-hand. Selling quotas through auction can enable governments to mobilize resources, avoid political manipulation and achieve efficiency goals. This has not happened under the EU ETS. In the first phase, a ceiling of 5 percent was set on the share of allowances that could be auctioned. In the event, just one country—Denmark—took advantage of this limited opportunity. Allowances have been distributed on the basis of historic emissions, rather than efficiency—an arrangement known as 'grandfathering'. The result is that governments have foregone opportunities for revenue mobilization and/or tax reductions, with the 'rents' from emissions trading privatized.

Figure 3.2 Carbon prices in the European Union have been volatile

Source: Point Carbon 2007.

Prospects for the second phase

Will these problems in the EU ETS be corrected in the second phase, which runs from 2008 to 2012? While the scheme has been strengthened in some areas, serious problems remain. Governments have not seized the opportunity to use the EU ETS to institutionalize deep cuts in emissions. Most seriously, the scheme remains de-linked from the European Union's own emissions reduction targets for 2020.

Allowances have so far been approved for 22 member states.[52] The cap for these countries has been lowered: it is around 10 percent below the level set for the first phase and marginally below verified 2005 emissions. There is already evidence that markets are responding to stronger political signals. Prices for Phase II allowances on futures markets have recovered. Market forecasts by Point Carbon anticipate a price range of €15–30/t CO_2 (US$19–37/t CO_2), depending on the costs of abatement.

These are positive developments. Even so, when measured against the yardstick of sustainable carbon budget management the design of the second phase of the EU ETS has to be judged quite harshly. The cap set for 2008 to 2012 is just 2 percent below verified emissions for 2005. This is not compatible with a sustainable emissions pathway that would lead to a 30 percent cut in emissions by 2020 based on 1990 levels. For most countries, the EU ETS second phase will not require major adjustments (table 3.2). An underlying problem is that the EU ETS has been interpreted by European Union governments as a vehicle for delivering on the very limited Kyoto commitments, rather than as an opportunity to act on the 2020 commitments. This is despite of the fact that the mandate for the EU ETS extends to "emissions development and reduction potential".[53] Another element of continuity with the first phase is auctioning. While the bar has been raised, there is still a limit of 10 percent on the share of permits that can be distributed through auctioning, perpetuating losses for public finance and efficiency.[54]

Negotiations on the second phase of the EU ETS have highlighted a number of wider challenges for the European Union. As long as cap-setting remains the remit of individual member states, the battle to set more robust targets will continue. Most governments sought Phase II allowances above 2005 emission levels. The underlying problem is that cap setting at a national level is a highly political exercise that opens the door to intensive, and highly effective, lobbying by national industries and 'energy champions.' So far, European governments have shown a tendency to succumb to pressure from highly polluting industries, with the result that very weak limits have been placed on overall emissions.[55] Bluntly stated, European Union governments have been bolder in setting aspirational targets for 2020 than they have been in setting concrete emission caps under the actually functioning EU ETS.

Against this backdrop, there is a strong case for empowering the European Commission to set—and enforce—more robust targets aligned with the European Union's 2020 emission reduction goals. Another priority is to rapidly increase the share of quotas that are auctioned in order to generate the incentives for efficiency gains and finance wider environmental tax reforms. Aiming at 100 percent auctioning by

Table 3.2 Proposals for the European Union Emissions Trading Scheme

		Emissions cap for 2008–2012 period		
	2005 verified emissions under Phase II of ETS (Mt CO_2)	Proposed by government (Mt CO_2)	Allowed by European Commission (Mt CO_2)	Allowed by European Commission as % of 2005 emissions
Austria	33	33	31	94
Belgium	56	63	59	105
Czech Republic	83	102	87	105
Finland	33	40	38	115
France	131	133	133	102
Hungary	26	31	27	104
Germany	474	482	453	96
Greece	71	76	69	97
Ireland	22	23	21	95
Italy	226	209	196	87
Netherlands	80	90	86	108
Spain	183	153	152	83
Sweden	19	25	23	121
United Kingdom	242 [a]	246	246	101
Total	1,943 [a]	2,095	1,897	98

a. Does not include the United Kingdom's installations which were temporarily excluded from the scheme in 2005 but will be covered in 2008 to 2012, estimated to amount to 30 Mt CO_2.

Source: European Union 2007c.

Effective public policies can help create win–win outcomes for global climate security, national energy security and living standards

2015 is a realistic goal. For sectors—such as power generation— facing limited competition, rules could be revised to allow for one-half of permits to be auctioned by 2012.

There are two CDM-related dangers that the European Union also has to address. The first is the danger of overuse. Opportunities for generating emission trading credits overseas should not totally displace mitigation in the European Union. If companies are able to meet their EU ETS obligations primarily by 'buying in' mitigation in developing countries while putting in place carbon-intensive investments at home, that is evidence for insufficiently ambitious targets. One detailed study of national allocation plans for nine countries estimates that between 88 and 100 percent of emissions reductions under the second phase of the EU ETS could take place outside of the European Union.[56] Against this backdrop, it is important that emission credits play a supplementary role, as envisaged under the Kyoto Protocol.

The second danger concerns the authenticity of CDM emission reductions. Rules governing the arrangement require that emission reductions are 'additional'—that is, they would not have happened in the absence of CDM investments. In practice, this is difficult to verify. There is evidence that some CDM credits have been acquired for investments that would have taken place anyway.[57] Far more stringent independent monitoring is required to ensure that carbon trading does not act to dilute real mitigation. The need for such stringent monitoring raises questions about the further expansion of the CDM based on the current model.

3.3 The critical role of regulation and government action

Putting a price on carbon either through taxation or cap-and-trade schemes is a necessary condition for avoiding dangerous climate change. But carbon pricing alone will not be sufficient to drive investments and change behaviour at the scale or speed required. There are other barriers to a breakthrough in climate change mitigation—barriers that can only be removed through government action. Public policies on regulation, energy subsidies and information have a central role to play.

There are no blueprints for identifying in advance the appropriate policies to create an enabling environment for low-carbon transition. However, the problems to be addressed are well-known. Changing the energy mix in favour of low-carbon energy requires large up-front investments and a long-term planning horizon. Markets alone will not deliver. Government regulatory mechanisms backed by subsidies and incentives have a key role in guiding investment decisions. Energy efficiency standards for buildings, electrical appliances and vehicles can dramatically curtail emissions at low cost. Meanwhile, policy support for research and development can create conditions for a technological breakthrough.

Effective public policies can help create win–win outcomes for global climate security, national energy security and living standards. Improvements in end-use efficiency illustrate the potential. Scenarios developed by the International Energy Agency (IEA) point to the potential for efficiency savings to cut emissions by 16 percent in OECD countries by 2030. Every US$1 invested in securing these reductions through more efficient electrical appliances could save US$2.2 in investment in power plants. Similarly, every US$1 invested in more efficient fuel standards for vehicles could save US$2.4 in oil imports.[58]

While estimates of the cost–benefit ratios for efficiency gains vary, as these figures demonstrate, there are large gains on offer. Those gains can be measured in terms of consumer savings, reduced dependence on oil imports and reduced costs for industry. They can also be measured in terms of cut-price climate change

mitigation. Viewed differently, the failure to unlock efficiency gains is a route to 'lose–lose' outcomes for global climate security, national energy security and consumers. In this section we look at the place of regulatory provision and public policy in four key areas:

- Power generation;
- Residential sector;
- Vehicle emission standards;
- Research, development and deployment of low-carbon technologies.

Power generation—changing the emissions trajectory

Power generation is the main source of CO_2 emissions. It accounts for four in every ten tonnes of CO_2 dispatched to the Earth's atmosphere. How countries generate electricity, how much they generate and how much CO_2 gets emitted with each unit of energy produced are critical in shaping the prospects for stringent climate change mitigation.

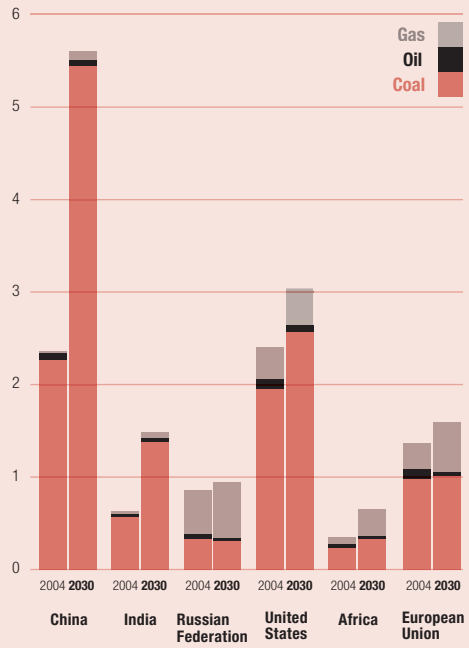
Current scenarios point in some worrying directions. World electricity demand is projected to double by 2030. Cumulative investments for meeting this demand are projected by the IEA at US$11 trillion from 2005 to 2030.[59] Over half of this investment will happen in developing countries characterized by low levels of energy efficiency. China alone will account for around one-quarter of projected global investments. Projected investments for the United States are estimated at US$1.6 trillion, reflecting a large-scale replacement of existing power generation stock.

Emerging power generation investment patterns point in a worrying direction. They suggest that the world is being too locked into the growth of highly carbon-intensive infrastructures. Coal figures with growing prominence in planned power supply. The largest increases in investment are planned in China, India and the United States—three of the four largest current sources of CO_2 emissions. In each of these countries, rapid expansion in coal-fired power generation capacity is already under way or in the pipeline. In 2006, China was building an estimated two new coal-fired power stations every week. Authorities in the United States are considering proposals for building over 150 coal-fired power plants, with planned investment of US$145 billion to 2030.[60] Over the next 10 years, India is planning to increase its coal-fired electricity generation capacity by over 75 percent.[61] In each case, the expansion in capacity is one of the major drivers of a large projected increase in national CO_2 emissions (figure 3.3).

What are the prospects for achieving deep cuts in CO_2 emissions linked to power generation? The answer to that question will depend partly on the rate at which new low-carbon technologies are developed and deployed, partly on the rate at which major developing countries adopt these technologies, and partly on demand-side factors such as savings through efficiency gains—issues that we consider in later sections of this chapter. Public policies that shape the energy mix will be important in each of these areas.

Power generation is the main source of CO_2 emissions. It accounts for four in every ten tonnes of CO_2 dispatched to the Earth's atmosphere

Figure 3.3 Coal set to raise CO_2 emissions in power sector



Note: 2030 emissions refer to the IEA Reference scenario as defined in IEA 2006c.

Source: IEA 2006c.

The energy mix

Current energy mix in the OECD countries is heavily dominated by fossil fuels. Changing this mix in favour of low-carbon or zero-carbon energy could lead to cuts in emissions. However, energy systems cannot be transformed overnight.

Nuclear power is one low-carbon option. However, it is an option that raises some difficult questions for policymakers. On the one hand, nuclear power offers a source of electricity with a near-zero carbon footprint. It has the additional advantages of reducing dependence on imported fossil fuels and providing a source of energy that is less subject to price volatility than fossil fuel. On the other hand, nuclear energy raises concerns about safety, the environmental repercussions and the proliferation of nuclear weapons—concerns that are reflected in widespread public opposition to expansion. On balance, nuclear energy is likely to remain an important part of overall supply. However, in terms of long-run climate mitigation potential, it is unlikely to play a prominent role and its market share could shrink (box 3.6).[62]

Renewable energy from the sun, wind and sea tides remains substantially underexploited. Discounting hydroelectricity, the renewables sector currently accounts for only around 3 percent of power generation in OECD countries. Achieving a target of 20 percent by 2020, as envisaged by the European Union, is a practical goal. With current technologies, renewable energy is not competitive with coal-fired power. However, scaling up a tax on carbon emissions to US$60–100/t CO_2 would radically change incentive structures for investment, eroding the advantage currently enjoyed by carbon-intensive power suppliers. At the same time, a range of supportive policies are required to stimulate

Box 3.6 Nuclear power—some thorny questions

Does nuclear power provide a cost-effective route for aligning energy security and climate security? Proponents point to potential benefits for carbon mitigation, price stability and reduced dependence on oil and gas imports. Critics of nuclear energy contest the economic arguments and claim that the environmental and military risks outweigh the benefits. The real answer probably lies somewhere in between these positions.

Nuclear energy reduces the global carbon footprint. It currently accounts for around 17 percent of the world's electricity generation. Some four-fifths of this capacity is located in 346 reactors in OECD countries. The share of nuclear in the national energy mix for electricity production ranges from over 20 percent for the United Kingdom and the United States to 80 percent in France. Phasing out nuclear energy without phasing in an equivalent supply of non-nuclear, zero-carbon energy from an alternative source is a prescription for increased emissions of CO_2.

That does not make nuclear power a panacea for climate change. In 2006, one reactor was started up—in Japan—while six were shut down in other OECD countries. Just to keep pace with retirements, eight new plants a year will be needed to 2017. While some countries (such as Canada and France) have announced plans for expanding nuclear energy, in others (including Germany and Sweden) a phase-out is under active consideration. In the United States, no nuclear plants have been ordered for over three decades. Medium-term projections point to a static or shrinking nuclear share in global energy supply.

These projections could change—but there are big economic questions to be addressed. Nuclear plants are highly capital-intensive. Capital costs range from US$2–3.5 billion per reactor, even before decommissioning and the disposal of nuclear waste are factored in. In the absence of government action to provide guaranteed markets, reduce risks and dispose of nuclear waste, there would be little private sector interest in nuclear power. The question for governments is whether nuclear is more cost-effective over the long term than low-carbon alternatives, such as wind power and solar power.

Non-economic questions relating to governance and regulation also loom large in nuclear energy debates. In many countries, public concerns over safety remain deeply entrenched. At an international level, there is a danger that nuclear technologies can be used to generate weapons-grade fissile material, irrespective of whether the material is designated for military purposes. Without an international agreement to strengthen the Non-Proliferation of Nuclear Weapons Treaty, the rapid expansion of nuclear energy would pose grave risks to all countries. Institutional mechanisms to restrict the crossover between civilian and military applications of nuclear energy have to include enhanced verification and inspection. Greater transparency, allied to clearly defined, monitorable and enforceable rules on the use and disposal of weapons-usable material (highly enriched uranium and plutonium) in civilian nuclear programmes, is also required. Developed countries could do far more to meet the governance challenge, notably by reducing their own nuclear arsenals and promoting more active diplomacy to advance non-proliferation.

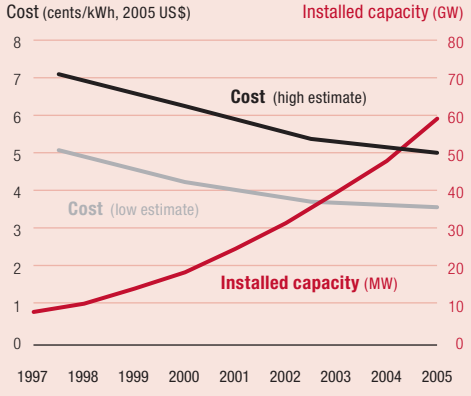
Source: Burke 2007; IEA 2006c; NEA 2006.

investment through the creation of predictable and stable markets for renewable energy.

Current trends underline the potential for rapid growth in renewable energy provision. Both wind power and solar power are expanding sources of energy. Global investment in renewable energy has increased rapidly, from US$27 billion in 2004 to US$71 billion in 2006 alone.[63] Remarkable efficiency gains have been registered. Modern wind turbines produce 180 times more energy at less than half the cost per unit than turbines 20 years ago.[64] Investments in the United States have increased wind capacity by a factor of six in the intervening period (figure 3.4).[65] Much the same has happened in solar power. The efficiency with which photovoltaic cells convert sunlight into electricity has climbed from 6 percent in the early 1990s to 15 percent now, while their cost has fallen by 80 percent.[66]

Public policies have the potential to support a rapid expansion in renewable energy. Regulatory intervention is one instrument for the creation of incentives. In the United States, around 21 states have renewable portfolio standards requiring a certain proportion of power sold to come from renewable energy suppliers: in California, the proportion is 20 percent by 2017.[67] By providing guaranteed markets and setting favourable tariffs over several years, governments can provide renewable suppliers with a secure market in which to plan investments.

Figure 3.4 Wind power in the US—capacity is increasing and costs are falling



Source: NREL Energy Analysis Office 2005a; World Wind Energy Association 2007.

Germany's Renewable Sources Act is an example. This has been used to fix the price of renewable power for 20 years on a sliding scale. The aim has been to create a long-term market while at the same time creating competitive pressures that create incentives for efficiency gains (box 3.7). In Spain, the Government has used a national premium tariff to increase the contribution of wind power. This now meets around 8 percent of the country's electricity demand, rising to more than 20 percent in the densely populated provinces of Castilla-La Mancha and Galicia. In 2005 alone, the increase in wind turbine capacity in Spain saved around 19 million tonnes of CO_2 emissions.[68]

Fiscal policy also has an important role to play in supporting renewable energy development. The United States has emerged as one of the world's most dynamic markets for renewable energy, with states such as California and Texas now established as global leaders in wind power generation. Market support has been provided through a three-year Production Tax Credit programme. However, uncertainty over the renewal of tax credits has given rise in the past to large fluctuations in investment and demand.[69] Many countries have combined a wide range of instruments to promote renewable energy. In Denmark, the wind power sector has been encouraged through tax breaks on capital investment, preferential pricing and a mandated target. The result: in the space of two decades, wind power has increased its share of electricity generation from less than 3 percent to 20 percent.[70]

The development of renewable energy is not a panacea for climate change. Because supplies are contingent on natural forces, there are problems with intermittent output. The initial capital costs of connecting to national grids can also be high, which is why the rapid expansion of the industry in recent years has been linked to the provision of subsidies. However, fossil fuel based energy has also been heavily subsidized over many decades—and in contrast to fossil fuels, renewable energy provides important returns for climate change mitigation.

Many countries have combined a wide range of instruments to promote renewable energy

Box 3.7 Renewable energy in Germany—success of the 'feed-in tariff'

Experience in Germany confounds the argument that energy economics militates against the rapid scaling up of renewable energy provision in national grids. Public policy has combined market regulation with structured incentives aimed at combining climate change goals with the generation of dynamic efficiency gains over time.

Under legislation introduced in the early 1990s—the Electricity Feed Act (EEG)—successive German Governments have used their regulatory authority to achieve public policy goals on carbon mitigation. The EEG, which was replaced in 2000 with an expanded Renewable Energy Sources Act, established the principle that utilities were required to accept electricity from wind power and other renewable sources. Policy intervention is geared towards the target of renewable energy supply for 12.5 percent of Germany's energy needs by 2010.

Regulatory intervention has been backed by direct intervention in energy markets. Prices for renewable energy have been fixed for 20 years on a sliding scale that declines over time. The objective has been to create a predictable market for renewable investors, thereby stimulating innovation, while at the same time ensuring that competitive pressures are maintained and efficiency gains are passed on to the public. Solar power providers receive €0.45 per KWh (US$0.6 per KWh), which is around eight times the rate for coal power, though subsidies have been coming down over time.

How successful has the German programme been? In 2005, not including hydropower, over 7 percent of electricity came from renewable energy, almost 50 percent higher than the European Union average, with the sector generating € 21.6 billion (US$27 billion) in total turnover and €8.7 billion (US$11 billion) worth of investment. Spin-off benefits include the employment of an estimated 170,000 people and German domination of the growing global market for photovoltaic cells. The reduction of CO_2 emissions is estimated at 52 Mt in 2010. While other factors have also been important, the rapid development of the renewable sector has played an important part in enabling Germany to meet its Kyoto Protocol commitment.

Source: Butler and Neuhoff 2005; Henderson 2007; Mendonca 2007.

The residential sector—low-cost mitigation

Some ways of cutting CO_2 emissions are cheaper than others. And some ways cost nothing at all over the long run. The residential and services sector provides a particularly striking example. Current practices across the world forcefully demonstrate the scope for measures that will save electricity, reduce emissions and cut costs for households and national economies.

Energy use patterns in the residential sector have an important bearing on the global carbon footprint. In the OECD countries, around one-third of the electricity produced ends up in heating and cooling systems, domestic refrigerators, ovens, lamps and other household devices. The residential sector accounts for around 35–40 percent of national CO_2 emissions from all fossil fuels, with appliances alone producing roughly 12 percent.[71]

There is an enormous untapped potential for energy savings in the residential sector. Realizing that potential would generate a double benefit: international climate change mitigation efforts would gain with a fall in CO_2 emissions, and the public would save money. Recent studies have highlighted the scale of this potential. One detailed exercise for OECD countries examines a wide range of policies on building standards, procurement regulations, appliance standards and energy-efficiency obligations to assess the potential costs and benefits of achieving emission reductions.[72] The results point to a 29 percent saving in emissions by 2020, representing a reduction of 3.2 Gt CO_2—a figure equivalent to around three-times current emissions from India. The resulting energy savings would counterbalance the costs. Another study estimates that the average European Union household could save €200–1000 (US$250–1243) annually through improved energy efficiency (2004 prices).[73]

Electrical appliances are another major potential source of efficiency gains. Some appliances use energy more efficiently, and produce a lower carbon footprint, than others. If all electrical appliances operating in OECD countries from 2005 onwards met the best efficiency standards, it would save some 322 million tonnes of CO_2 emissions by 2010.[74] This would be equivalent to taking 100 million cars off the road—a figure that represents all vehicles in Canada, France and Germany combined.[75] By 2030, these higher standards would avoid emissions of 572 Mt CO_2 a year, which would be equivalent to removing 200 million cars from the road or closing 400 gas-fired power stations.

Would these efficiency gains deal a devastating blow to household budgets? On the contrary, they would reduce residential electricity consumption by around one-quarter by 2010. For North America, where households consume 2.4 times more electricity per household than in Europe, that reduction would save consumers an estimated US$33 billion for the period. By 2020, for every tonne of CO_2 emissions avoided, each household in the United States would save around US$65. "In Europe, each tonne of CO_2 avoided would save consumers some €169"[76] (reflecting Europe's higher electricity cost and lower efficiency standards).

Lighting provides another example. World lighting represents around 10 percent of global electricity demand and generates 1.9 Gt CO_2 per year—7 percent of total CO_2 emissions. As a glance around any developed country city day or night will confirm, much of this electricity is wasted. Light is routinely cast on spaces where nobody is present and delivered through inefficient sources. Simple installation of low-cost sources—such as compact fluorescent lamps—could reduce total lighting energy use by 38 percent.[77] The payback period for investment in more efficient lighting? Around 2 years on average for OECD countries.

Regulation and information are two of the keys for unlocking energy efficiency gains in the building and residential sector. Public policy has a key role to play not just in enhancing consumer awareness but in prohibiting or creating strong disincentives for practices that drive down efficiency and drive up carbon emissions. While there are costs associated with regulation and information provision, there are substantial climate change mitigation benefits. There are also large consumer costs associated with regulatory standards that allow inefficient energy use. Enhanced energy efficiency in this area can achieve emission savings with a net benefit. Among the public policy instruments:

- *Appliance standards.* These are among the most cost-effective mitigation measures. One example comes from Japan's 'Top Runner' scheme. Introduced in 1998 to support national efforts to comply with Kyoto reduction commitments, this scheme requires that all new products meet specified efficiency standards. Energy efficiency gains of over 50 percent have been recorded for some products, including cars, fridges, freezers and televisions. Research in a wide group of countries points to large benefits from reducing CO_2 through improved energy standards. This is an area in which effective demand management can cut carbon and energy costs, creating win–win benefits for the economy and the environment. Research in the European Union and the United States points to estimated benefits in a range from US$65/t CO_2 to 190/t CO_2.[78]
- *Information.* This is one of the keys to unlocking efficiency gains. In the United States, the Energy Star programme, a voluntary endorsement labelling scheme, provides consumers with extensive information on the energy efficiency of over 30 products. It is estimated to have delivered annual savings of US$5 billion in 2002.[79] In Australia, mandatory labelling of certain appliances—including freezers and dishwashers—has contributed in savings of CO_2 with benefits estimated at around US$30/t CO_2.[80]
- *Building codes.* Building standard regulations can generate very large savings in CO_2 emissions linked to energy use. Enforcement matters as much as the rules. In Japan, where the implementation of energy efficiency standards in buildings is voluntary, energy savings have been moderate. Far greater savings have been registered in countries such as in Germany and the United States, where compliance is enforced more stringently. The European Union estimates that efficiency gains in energy consumption could be increased by one-fifth, with potential savings of €60 billion (US$75 billion).[81] One-half of the gains would result from simple implementation of existing regulatory standards, most of them in the building sector.

Regulation and information are two of the keys for unlocking energy efficiency gains in the building and residential sector

Vehicle emission standards

Personal transportation is the world's largest consumer of oil—and its fastest growing source

The regulatory environment for transport is a critical part of the international carbon mitigation effort

of CO_2 emissions. In 2004, the transport sector produced 6.3 Gt CO_2. While the share of developing countries is rising, OECD countries account for two-thirds of the total.[82] The automobile sector in these countries accounts for about 30 percent of total greenhouse gas emissions, and the share is rising over time.[83]

The regulatory environment for transport is a critical part of the international carbon mitigation effort. Aggregate greenhouse gas emissions from any vehicle is a function of three factors: miles travelled, amount of fuel used for each mile travelled, and the carbon content of the fuel. Emissions are rising in many countries because the distances travelled are growing faster than fuel-use efficiency, and because fuel economy gains have been reduced by a trend towards bigger and more powerful vehicles.

Setting the standard

Countries vary widely in their fuel efficiency standards. The European Union and Japan have the highest standards, while the United States has the lowest in the developed world—lower, in fact, than in China (figure 3.5).[84]

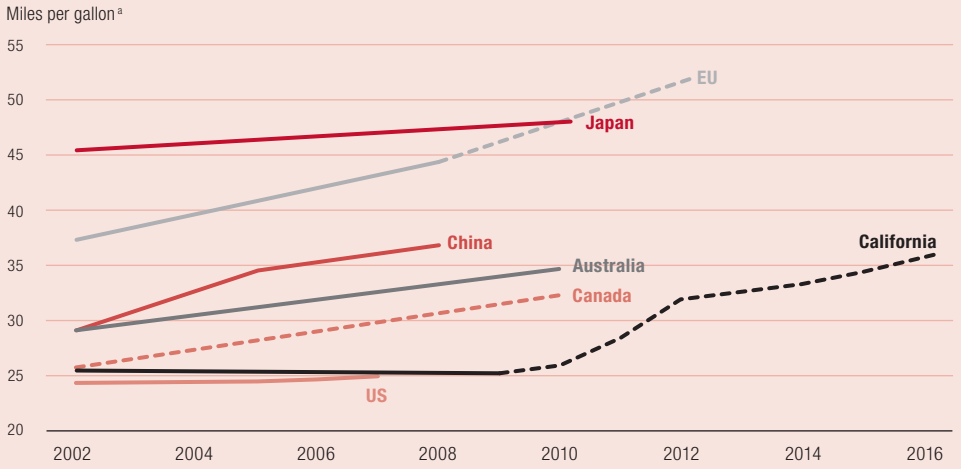
Efficiency standards in the United States relative to the rest of the world have slipped over time. One reason for this is that they have changed only marginally over the past two decades, whereas other countries have been setting higher standards. Another is the prevalence of regulatory gaps favouring low-efficiency sports utility vehicles.

These gaps have reduced fleet efficiency and driven up emissions. Since 1990, emissions from transport have increased at an annual average rate of 1.8 percent, almost double the rate for all other sources. The primary driver of the emissions upsurge is vehicle miles travelled (which has climbed by 34 percent) and an increase in the use of light-duty trucks (box 3.8).[85]

Improvements in United States regulatory standards could make a global difference in climate change mitigation, with large associated benefits for national energy security. According to the National Commission for Energy, increasing the fuel efficiency requirement for cars in the United States by 20 miles per gallon (equivalent to 8.5 kilometres per litre) would reduce projected oil consumption by 3.5 million barrels a day, diminishing CO_2 emissions by 400 million tonnes per year in the process.[86] The savings from that regulatory shift would be equivalent to France's total CO_2 emissions. Apart from the benefits for climate change mitigation, the associated reduction in oil imports would achieve one of the central goals of United States energy security policy.

While the European Union has attained relatively higher fuel efficiency than the United States, it faces problems in aligning standards with its stated climate change goals. Since 1990,

Figure 3.5 Rich country fuel efficiency standards vary widely



a. Recalculated to comply with Corporate Average Fuel Economy (CAFE) test cycle as used in the United States.

Source: NREL Energy Analysis Office 2005b.

Box 3.8 Vehicle emissions standards in the United States

Established in 1975, the United States' Corporate Average Fuel Economy (CAFE) programme is one of the world's oldest regulatory regimes on fuel efficiency. It is also one of the most important: the United States accounts for around 40 percent of oil-based CO_2 emissions from transport.

Where the United States sets its vehicle fuel efficiency standards registers in the world's carbon footprint. In the 1970s, CAFE rules were instrumental in doubling vehicle fuel economy, spurring investment in new technologies. However, fuel economy standards have not been increased for passenger cars over the past 20 years, and they have increased only slightly for light trucks.

As a result, the fuel efficiency standard divide between the United States and the rest of the world has widened. Today, the United States' standard is just over one half of the level in Japan. The 136 million passenger cars on United States' roads contribute 35 percent of national transport-based greenhouse gas emissions, and the 87 million light trucks another 27 percent.

The design of CAFE standards has had an important bearing on transport-related emissions. Average fuel standards for cars (27.5 miles per gallon or 11.7 kilometres per litre) are higher than for light trucks (20.7 mpg or 8.8 km/L). Rising demand for light trucks has led to an overall decrease in the fuel economy of new light-duty vehicles. In 2002, the number of light trucks sold exceeded new passenger cars sold for the first time. The upshot: fuel efficiency today is lower than in 1987.

CAFE standards are at the centre of an active national debate. The 2007 State of the Union Address proposed CAFE standard reforms to achieve a 5 percent reduction in gasoline consumption, based on projected future demand (rather than current levels). No numerical target for fuel efficiency was identified.

Would more stringent targets undermine employment and competitiveness? That question is at the centre of debates over CAFE standards. Research indicates that light-duty fuel efficiency could be increased by one-quarter to one-third at less than the cost of the fuel saved—and without compromising vehicle safety. Over the medium term, more stringent standards would create incentives for investment in advanced diesel engines, hybrid vehicles and hydrogen-powered fuel-cell vehicles.

With oil prices and concerns over CO_2 emissions rising, weak efficiency standards could send the wrong signals to the automobile industry. While recent years have seen significant improvements in engine technologies and vehicle design, such improvements have been used to increase power, performance and safety rather than to enhance fuel economy. One result is that firms in the United States have lost out to Japanese competitors in markets for more fuel-efficient models.

More stringent CAFE standards in the United States could create a triple benefit. They would demonstrate United States leadership in international climate change mitigation efforts, advance national energy security goals by reducing dependence on imported oil and open up new opportunities for investment in the automobile industry.

Source: Arroyo and Linguiti 2007; Merrill Lynch and WRI 2005; NCEP 2004b; Sperling and Cannon 2007.

the European Union has reduced overall emissions of greenhouse gases by around 1 percent. However, emissions from road transport have increased by 26 percent. As a result, the share of transport in overall emissions has climbed from around one-sixth to over one-fifth in little more than a decade.[87] Road transport is the biggest source of rising emissions, with passenger vehicles accounting for around one-half of the total. If domestic transport greenhouse gas emissions continue to rise with economic growth, they could be 30 percent above 1990 levels by 2010 and 50 percent by 2020.[88] Thus current trends in the transport sector are not consistent with the European Union's commitment to achieving 20–30 percent reductions in overall greenhouse gas emissions by 2020.

Aligning regulatory policies with more stringent climate change mitigation goals has been difficult. Current approaches are based on three pillars: voluntary commitments by the automobile industry, fuel-economy labelling and promotion of efficiency through fiscal measures. The long-standing aim has been to achieve a fuel-efficiency goal of 120g CO_2/km. However, the target date for achieving this goal has repeatedly been pushed back, initially from 2005 to 2010 and now to 2012, in the face of lobbying by the automobile industry and opposition in some member states. The interim target is now 140g CO_2/km by 2008–09.

As for the United States, where the European Union sets the fuel-efficiency bar matters for international climate change mitigation. It matters in a very immediate sense because more stringent standards will cut emissions of CO_2. Over the 10-year period to 2020, a 120g CO_2/km target would reduce emissions by about 400 Mt CO_2—more than the total emissions from France or Spain in 2004. That figure represents around 45 percent of total current European Union

Many governments now see biofuels as a technology that kills two birds with one stone, helping to fight global warming while reducing dependence on oil imports

emissions from transport. More broadly, because the European Union is the world's largest automobile market, tighter emission standards would signal an important change in direction to the global automobile industry, creating incentives for components suppliers to develop low carbon technologies. However, the European Union is not on track for achieving its long-standing target. As an assessment by the European Commission puts it: "In the absence of additional measures, the European Union objective of 120g CO_2/km will not be met at a 2012 time horizon."[89]

Efforts to change this picture have produced a political deadlock. The European Commission has proposed regulatory measures to raise fleet average efficiency standards to achieve the long-standing 120g CO_2/km goal by 2020. As in the past, the proposal has attracted opposition from the European Automobile Manufacturers Association—a coalition of 12 global automobile companies. Some European governments have supported that opposition, arguing that more stringent regulation could undermine the competitiveness of the industry.

This is a position that is difficult to square with a commitment to the European Union's 2020 targets. Arguments on economic competitiveness are also not well supported by the evidence. Several companies in the global automobile industry have lost out in fast-expanding markets for low-emission vehicles precisely because they have failed to raise efficiency standards. With supporting policies, it would be possible for the European Union to sustain progressive improvements in efficiency standards consistent with its climate goals, with fleet average standards improving to 80g CO_2/km by 2020.[90]

Regulatory standards cannot be viewed in isolation. Car taxation is a powerful instrument through which governments can influence the behaviour of consumers. Graduated taxation that rises with the level of CO_2 emissions could help to align energy policies in transport with climate change mitigation goals. Annual vehicle excise taxes and registration taxes on new vehicles would be means to this end. Such measures would support the efforts of car manufacturers to meet improved efficiency standards, along with the efforts of governments to achieve their stated climate change goals.

The role of alternative fuels

Changing the fuel mix within the transport sector can play an important role in aligning energy policies with carbon budgets. The CO_2 emissions profile of an average car journey can be transformed by using less petroleum and more ethanol produced from plants. Many governments now see biofuels as a technology that kills two birds with one stone, helping to fight global warming while reducing dependence on oil imports.

Developing countries have demonstrated what can be achieved through a judicious mix of incentives and regulation in the transport sector. One of the most impressive examples comes from Brazil. Over the past three decades, the country has used a mix of regulation and direct government investment to develop a highly efficient industry. Subsidies for alcohol-based fuel, regulatory standards requiring automobile manufacturers to produce hybrid vehicles, preferential duties and government support for a biofuel delivery infrastructure have all played a role. Today, biofuels account for around one-third of Brazil's total transport fuel, creating wide-ranging environmental benefits and reducing dependence on imported oil.[91]

Several countries have successfully changed the national transport sector fuel-mix by using a mixture of regulation and market incentives to promote compressed natural gas (CNG). Prompted partly by concerns over air quality in major urban centres, and partly by a concern to reduce dependence on imported oil, both India and Pakistan have seen a major expansion of CNG use. In India, several cities have used regulatory mechanisms to prohibit a range of vehicles from using non-CNG fuel. For example, Delhi requires all public transport vehicles to use CNG. In Pakistan, price incentives have supplemented regulatory measures. Prices for CNG have been held at around 50–60 percent of the price of petroleum, with Government supporting the development of an infrastructure for

Special contribution

National action to meet a global challenge

Climate change is the defining challenge facing political leaders across the world today. Future generations will judge us on how we respond to that challenge. There are no easy solutions—and no blueprints. But I believe that we can win the battle against climate change by acting nationally and working together globally.

If we are to succeed in tackling climate change we have to start by setting out the ground rules. Any international strategy has to be built on the foundations of fairness, social justice and equity. These are not abstract ideas. They are guides to action.

The *Human Development Report 2007/2008* should be mandatory reading for all governments, especially those in the world's richest nations. It reminds us that historic responsibility for the rapid build-up of greenhouse gases in the Earth's atmosphere rests not with the world's poor, but with the developed world. It is people in the richest countries that leave the deepest footprint. The average Brazilian has a CO_2 footprint of 1.8 tonnes a year compared with an average for developed countries of 13.2 tonnes a year. As the Report reminds us, if every person in the developing world left the same carbon footprint as the average North American we would need the atmospheres of nine planets to deal with the consequences.

We only have one planet—and we need a one-planet solution for climate change. That solution cannot come at the expense of the world's poorest countries and poorest people, many of whom do not have so much as a light in their home. Developed countries have to demonstrate that they are serious by cutting their emissions. After all, they have the financial and the technological resources needed to act.

Every country faces different challenges, but I believe the experience of Brazil is instructive. One of the reasons that Brazil has such a low per capita footprint is that we have developed our renewable energy resources and now have one of the world's cleanest energy systems. Hydro-power accounts for 92 percent of our electricity generation, for example. The upshot is that Brazil not only has a lighter carbon footprint than rich nations, but that we generate less than half as much CO_2 for every dollar in wealth that we generate. Put differently, we have lowered our emissions by reducing the carbon intensity and the energy intensity of our economy.

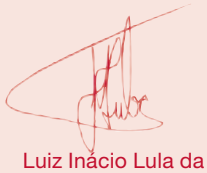
The transport sector provides a striking example of how clean energy policies can generate national and global benefits. Brazil's experience with the development of ethanol from sugar cane as a motor fuel goes back to the 1970s. Today, ethanol-based fuels reduce our overall emissions by about 25.8 million tonnes of CO_2e every year. Contrary to the claims made by some commentators lacking familiarity with Brazilian geography, the sugar production that sustains our ethanol industry is concentrated in São Paulo, far from the Amazon region.

Today, we are expanding our ethanol programme. In 2004, we launched the National Program of Biodiesel Production and Use (PNPB). The aim is to raise the share of biodiesel in every litre of diesel sold in Brazil to 5 percent by 2013. At the same time, PNPB has introduced fiscal incentives and subsidies aimed at expanding market opportunities for biofuel production for small family farms in the North and the North-East region.

Brazil's experience with biofuels can help to support the development of win–win scenarios for energy security and climate change mitigation. Oil dominates the transport fuels sector. However, concerns over high prices, reserve levels, and security of supply are prompting many countries—rich and poor—to develop policies for reducing oil-dependency. Those policies are good for energy efficiency and good for climate change.

As a developing country Brazil can play an important role in supporting the transition to low-carbon energy. South–South cooperation has a vital role to play—and Brazil is already supporting the efforts of developing countries to identify viable alternative energy sources. However, we should not downplay the potential for international trade. North America and the European Union are both scaling-up heavily subsidized biofuel programmes. Measured against Brazil's ethanol programme these score badly both in terms of costs and in terms of efficiency in cutting CO_2 emissions. Lowering import barriers against Brazilian ethanol would reduce the costs of carbon abatement and enhance economic efficiency in the development of alternative fuels. After all, there is no inherent virtue in self-reliance.

Finally, a brief comment on rainforests. The Amazon region is a treasured national ecological resource. We recognize that this resource has to be managed sustainably. That is why we introduced in 2004 an Action Plan for Preventing and Controlling Deforestation in the Amazon. Encompassing 14 ministries, the plan provides a legal framework for land use management, establishes monitoring arrangements, and creates incentives for sustainable practices. The decline since 2004 in the rate of deforestation recorded in states such as Mato Grosso demonstrates that it is possible to reconcile economic growth with sustainable environmental management.



Luiz Inácio Lula da Silva
President of the Federative Republic of Brazil

production and distribution. Some 0.8 million vehicles now use CNG and the market share is rising fast (figure 3.6). Apart from cutting emissions of CO_2 by around 20 percent, using natural gas creates wide-ranging benefits for air quality and public health.

In the developed world biofuel development is one of the energy-based growth industries

of the past 5 years. The United States has set particularly far-reaching goals. In his 2007 State of the Union Address, President Bush set a target of increasing the use of biofuels to 35 billion gallons in 2017—five times current levels. The ambition is to replace around 15 percent of imported oil with domestically produced ethanol.[92] The European Union is also actively promoting biofuels. Targets include raising to 10 percent the share of biofuels in all road-transport fuel consumption by 2020. That figure is double the target for 2010—and around 10 times the current share.[93]

Impressive targets have been backed with impressive subsidies for the development of the biofuels sector. In the United States, tax credits for maize-based ethanol production were estimated at US$2.5 billion in 2006.[94] Overall subsidies to ethanol and biodiesel, currently estimated at US$5.5–7.5 billion discounting direct payments to maize farmers, are expected to rise with production.[95] With the share of maize production directed towards ethanol mills growing, prices are rising sharply. In 2007 they reached a 10-year high, even though the crop of the previous year was the third highest on record.[96] Because the United States is the world's largest exporter of maize, the diversion of supply to the bioethanol industry has been instrumental in pushing up world prices. In Mexico and other countries in Central America, rising prices for imported maize could create food security problems for poor households.[97]

'Biofuel mania' has not so far left such a deep mark on the European Union. However, this is likely to change. Projections by the European Commission point to increasing prices for oilseeds and cereals. The arable area for producing biofuels will rise from an estimated 3 million hectares in 2006 to 17 million hectares in 2020.[98] Most of the increase in supply of biofuel in the European Union will come from domestic production of cereals and oilseeds, though imports are projected to account for 15–20 percent of total demand by 2020. For European agriculture, the prospective biodiesel boom offers lucrative new markets. As the Commission puts it: "The targets for renewable energy can be seen as good news for European agriculture: they [...] promise new outlets and a positive development of demand and prices at a time when farmers are increasingly faced with international competition."[99] Under the reformed Common Agricultural Policy, a special premium is payable to farmers for the production of energy crops.[100]

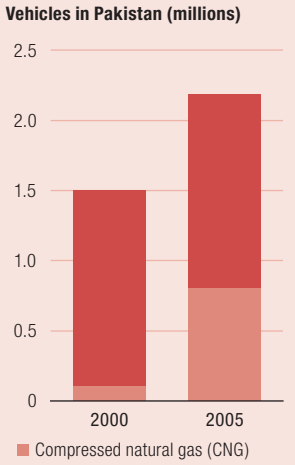
Unfortunately, what is good for subsidized agriculture and the biofuels industry in the European Union and the United States is not inherently good for climate change mitigation. Biofuels do represent a serious alternative to oil for use in transport. However, the cost of production of those fuels relative to the real amount of CO_2 abatement is also important. This is an area in which the United States and the European Union do not score very well. For example, sugarcane-based ethanol can be produced in Brazil at half the unit price of maize-based ethanol in the United States and whereas sugar-based ethanol in Brazil cuts emissions by some 70 percent, the comparable figure for the maize-based ethanol used in the United States is 13 percent.[101] The European Union is at an even greater cost disadvantage (figure 3.7).

Comparative advantage explains an important part of the price differentials. Production costs in Brazil are far lower because of climatic factors, land availability and the greater efficiency of sugar in converting the sun's energy into cellulosic ethanol. These differences point to a case for less reliance on domestic production and an expanded role for international trade in the European Union and the United States.

There is no inherent virtue in self-reliance. From a climate change mitigation perspective, the priority is to achieve carbon abatement at the lowest marginal cost. The problem is that trade barriers and subsidies are driving up the cost of carbon mitigation, while simultaneously adding to the cost of reducing oil dependency.

Most developed countries apply import restrictions on alternative fuels such as bioethanol. The structure of protection varies widely—but the net effect is to substantially lower consumer demand. The European Union allows duty free market access for ethanol for around 100 developing countries, most of which do not export ethanol. In the case of

Figure 3.6 Rapid transition of the car fleet is possible—Pakistan



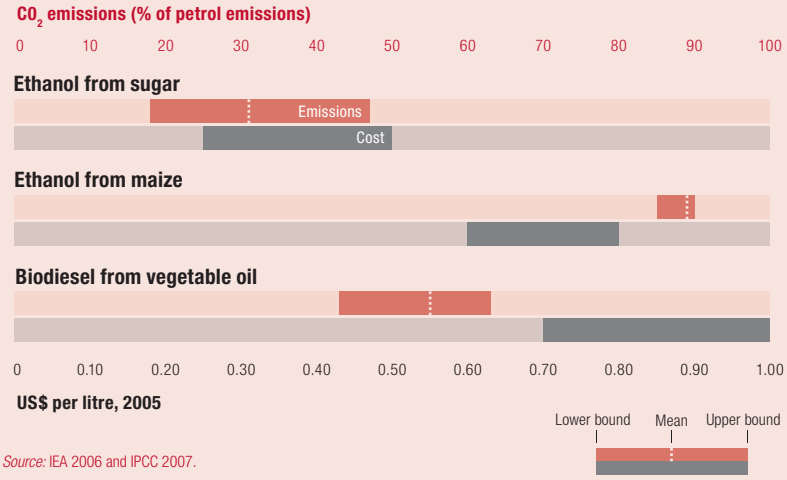
Source: Government of Pakistan 2005.

Brazil, an import duty of €0.73 (US$1) per gallon is applied by the European Union—a tariff equivalent in excess of 60 percent.[102] In the United States, Brazilian ethanol faces an import duty of US$0.54 a gallon.[103] While lower than in the European Union, this still represents a tariff of around 25 percent at 2007 domestic market prices for ethanol.

Trade policies applied to ethanol conflict with a wide range of climate change goals. Ethanol from Brazil is disadvantaged even though it is cheaper to produce, generates lower CO_2 emissions in production, and is more efficient in reducing the carbon-intensity of vehicle transport. More broadly, the high levels of tariff applied to Brazilian ethanol raise serious questions for economic efficiency in the energy sector. The bottom-line is that abolishing ethanol tariffs would benefit the environment, climate change mitigation, and developing countries which—like Brazil—enjoy favourable production conditions. In the European Union, Sweden has argued strongly for a reduced emphasis on protectionism and stronger policies for the development of 'second-generation' biofuels in areas such as forest biomass.[104]

Not all international trade opportunities linked to biofuels offer benign outcomes. As in other areas, the social and environmental impacts of trade are conditioned by wider factors—and benefits are not automatic. In Brazil, the sugar production that sustains the ethanol industry is concentrated in the southern State of São Paulo. Less than 1 percent originates from the Amazonia. As a result, the development of biofuels has had a limited environmental impact, and has not contributed to rainforest destruction. The picture in other countries and for other crops is mixed. One potential source of agricultural inputs for biodiesel is oil palm. Expansion of cultivation of that crop in East Asia has been associated with widespread deforestation and violation of human rights of indigenous people. There is now a danger that the European Union's ambitious biofuel targets will encourage the rapid expansion of oil palm estates in countries that have failed to address these problems (box 3.9). Since 1999, European Union imports of palm oil (primarily from Malaysia and Indonesia) have more than doubled to 4.5 million tonnes, or almost one-fifth of world imports.[105] Rapid expansion of the market has gone hand-in-hand with an erosion of the rights of small farmers and indigenous people.

Figure 3.7 Some biofuels cost less and cut CO_2 emissions more



Source: IEA 2006 and IPCC 2007.

R&D and deployment of low-carbon technologies

Joseph Schumpeter coined the phrase 'creative destruction' to describe a "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one". He identified three phases in the process of innovation: invention, application and diffusion.

Successful climate change mitigation will require a process of accelerated 'creative destruction', with the gap between these phases shrinking as rapidly as possible. Carbon pricing will help to create incentives for the emergence of these technologies—but it will not be enough. Faced with very large capital costs, uncertain market conditions and high risks, the private sector alone will not develop and deploy technologies at the required pace, even with appropriate carbon price signals. Governments will have to play a central role in removing obstacles to the emergence of breakthrough technologies.

The case for public policy action is rooted in the immediacy and the scale of the

Box 3.9 Palm oil and biofuel development—a cautionary tale

The European Union's ambitious targets for expanding the market share of biofuels have created strong incentives for the production of cereals and oils, including palm oil. Opportunities for supplying an expanding European Union market have been reflected in a surge of investment in palm oil production in East Asia. Is this good news for human development?

Not under current conditions. Oil palm can be grown and harvested in environmentally sustainable and socially responsible ways, especially through small-scale agroforestry. Much of the production in West Africa fits into this category. However, large-scale mono-cropping plantations in many countries do not have a good record. And much of the recent surge in palm oil production has taken place on such plantations.

Even before the European Union's renewable energy targets generated a new set of market incentives, oil palm cultivation was expanding at a prolific rate. By 2005, global cultivation had reached 12 million hectares—almost double the area in 1997. Production is dominated by Indonesia and Malaysia, with the former registering the fastest rate of increase in terms of forests converted into oil palm plantations. The estimated annual net release emissions of CO_2 from forest biomass in Indonesia since 1990 is 2.3 Gt. European Union markets for biofuel materials can be expected to create a further impetus for oil palm plantations. Projections by the European Commission suggest that imports will account for around one-quarter of the supply of biodiesel fuels in 2020, with palm oil representing 3.6 million out of a total of 11 million tonnes of imports.

Palm oil exports represent an important source of foreign exchange. However, the expansion of plantation production has come at a high social and environmental price. Large areas of forest land traditionally used by indigenous people have been expropriated and logging companies have often used oil palm plantations as a justification for harvesting timber.

With palm oil prices surging, ambitious plans have been developed to expand cultivation. One example is the Kalimantan Border Oil Palm Project in Indonesia, which aims at converting 3 million hectares of forest in Borneo. Concessions have already been given to companies. While national legislation and voluntary guidelines for industry stipulate protection for indigenous people, enforcement has been erratic at best and—in some cases—ignored. Areas deemed suitable for oil palm concessions include forest areas used by indigenous people—and there are extensively documented reports of people losing land and access to forests.

In Indonesia, as in many other countries, the judicial process is slow, the legal costs are beyond the capacities of indigenous people, and links between powerful investors and political elites make it difficult to enforce the rights of forest dwellers. Against this backdrop, the European Union has to carefully consider the implications of internal directives on energy policy for external human development prospects.

Source: Colchester et al. 2006a, 2006b; Tauli-Corpuz and Tamang 2007.

threat posed by climate change. As shown in previous chapters of this Report, dangerous climate change will lead to rising poverty in poor countries, followed by catastrophic risks for humanity as a whole. Avoiding these outcomes is a human development challenge. More than that, it is a global and national security imperative.

In earlier periods of history, governments have responded to perceived security threats by launching bold and innovative programmes. Waiting for markets to generate and deploy the technologies to reduce vulnerability was not considered an option. In 1932, Albert Einstein famously concluded: "There is not the slightest indication that nuclear energy will ever be obtainable." Just over a decade later, the Allied powers had created the Manhattan Project. Driven by perceived national security imperatives, this was a research effort that brought together the world's top scientists in a US$20 billion (in 2004 terms) programme that pushed back technological frontiers. The same thing happened under President Eisenhower and President Kennedy, when Cold War rivalries and national security concerns led to government leadership of ambitious research and development drives, culminating in the creation of the Apollo space programme.[106]

Contrasts with the R&D effort to achieve a low-carbon transition are strikingly evident. R&D spending in the energy sectors of OECD countries today is around one-half of the level in the early 1980s in real terms (2004 prices).[107] Measured as a share of turnover in the respective sectors, the R&D expenditure of the power industry is less than one-sixth of that for the automobile industry and one-thirtieth of that for the electronics industry. The distribution of research spending is equally problematic. Public spending on R&D has been dominated by nuclear energy, which still accounts for just under half of the total.

These R&D patterns can be traced to a variety of factors. The power sector, in particular, is characterized by large central power plants dominated by a small number of suppliers, with restricted competition for market share. Heavy subsidies to fossil fuel-based power and nuclear energy have created powerful disincentives for investment in other areas such as renewable energy. The end result is that the energy sector has been characterized by a slow pace of innovation, with many of the core technologies for coal and gas power generation now over three decades old.

'Picking winners' in coal

Developments in the coal sector demonstrate both the potential for technological breakthroughs in climate change mitigation and the slow pace of progress. There is currently around 1200 GigaWatts (GW) of coal-fired power capacity worldwide accounting for 40 percent of the world's electricity generation and CO_2 emissions. With natural gas prices rising and coal reserves widely disbursed across the world, the share of coal in world energy generation is likely to rise over time. Coal-fired power generation could be the driver that takes the world beyond the threshold of dangerous climate change. However, it also provides an opportunity.

Coal-fired power plants vary widely in their thermal efficiency.[108] Increased efficiency, which is largely a function of technology, means that plants generate more power with less coal—and with fewer emissions. The most efficient plants today use super-critical technologies that have attained efficiency levels of around 45 percent. During the 1990s, new Integrated Gasification Combined Cycle (IGCC) technologies emerged. These are able to burn synthetic gas produced from coal or another fuel and to clean gas emissions. Supported by public funding in the European Union and the United States, five demonstration plants were constructed in the 1990s. These plants have attained levels of thermal efficiency comparable to the best conventional plants, with high levels of environmental performance.[109]

What is the link between IGCC plants and climate change mitigation? The real potential breakthrough technology for coal is a process known as Carbon Capture and Storage (CCS). Using CCS technology, it is possible to separate the gas emitted when fossil fuels are burned, process it into liquefied or solid form, and transport it by ship or pipeline to a location—below the sea-bed, into disused coal mines, depleted oil wells, or other locations—where it can be stored. Applied to coal plants, CCS technology offers the potential for near-zero CO_2 emissions. In theory, any conventional coal plant can be retrofitted with CCS technology. In practice, IGCC plants are technologically the most adaptable to CCS, and by far the lowest cost option.[110]

No single technology offers a magic bullet for climate change mitigation, and 'picking winners' is a hazardous affair. Even so, CCS is widely acknowledged to be the best-bet for stringent mitigation in coal-fired power generation. Large-scale development and deployment of CCS could reconcile the expanding use of coal with a sustainable carbon budget. If successful, it could take the carbon out of electricity generation, not just in power stations but also from other carbon-intensive sites of production such as cement factories and petrochemical facilities.

Demonstration plants operated through private–public partnerships in the European Union and the United States have shown the feasibility of CCS technology, though some challenges and uncertainties remain.[111] For example, the storage of CO_2 beneath sea-beds is the subject of international conventions and there are safety concerns about the potential for leaks. Encouraging as the demonstration project results have been, the current effort falls far short of what is needed. CCS technology is projected to come on-stream very slowly in the years ahead. With planned rates of deployment, there will be just 11 CCS plants in operation by 2015. The upshot of this late arrival is that the plants will collectively save only around 15 Mt CO_2 in emissions, or 0.2 percent of total coal-fired power emissions.[112] At this rate, one of the key technologies in the battle against global warming will arrive on the battlefield far too late to help the world avoid dangerous climate change.

The real potential breakthrough technology for coal is a process known as Carbon Capture and Storage

At present, conventional coal-fired power plants enjoy a commercial advantage for one simple reason: their prices do not reflect the costs of their contribution to climate change

Barriers to accelerated development and disbursement of CCS technologies are rooted in markets. Power generation technologies that can facilitate rapid deployment of CCS are still not widely available. In particular, IGCC plants are not fully commercialized, partly because there has been insufficient R&D. Even if full-scale CCS systems were available today, cost would be a major obstacle to deployment. For new plants, capital costs are estimated to be up to US$1 billion higher than conventional plants, though there are large variations: retrofitting old plants is far more costly than applying CCS technology to new IGCC plants. Carbon capture is also estimated to increase the operational costs of electricity generation in coal plants by 35–60 percent.[113] Without government action, these cost barriers will continue to hold back deployment.

Coal partnerships—too few and too limited

Some of the obstacles to the technological transformation of coal-fired power generation could be removed through carbon pricing. At present, conventional coal-fired power plants enjoy a commercial advantage for one simple reason: their prices do not reflect the costs of their contribution to climate change. Imposing a tax of US$60–100/t CO_2 or introducing a stringent cap-and-trade scheme, would transform incentive structures in the coal industry, putting more highly polluting power generators at a disadvantage. Creating the market conditions for increased capital investment through tax incentives is one of the conditions for a low-carbon transition in energy policy.

Policies in the United States are starting to push in this direction.The 2005 Energy Act has already boosted planning applications for IGCC plants by putting in place a US$2 billion Clean Coal Power Initiative (CCPI) that includes subsidies for coal gasification.[114] Tax credits have been provided for private investment in nine advanced clean coal facilities. Public–private partnerships have also emerged. One example is the seven Carbon Sequestration Regional Partnerships that bring together the Department of Environment, state governments and private companies. The total value of the projects is around US$145 million over the next four years. Another example is FutureGen, a public–private partnership that is scheduled to produce the United States' first near-zero power plant in 2012.[115]

The European Union has also moved to create an enabling environment for the development of CCS. The formation of the European Technology Platform for Zero Emissions Fossil Fuel has provided a framework that brings together governments, industry, research institutes and the European Commission. The aim: to stimulate the construction and operation by 2015 of up to 12 demonstration plants, with all coal-fired power plants built after 2020 fitted with CCS.[116] Total estimated funding for CO_2 capture and storage technologies for 2002 to 2006 was around €70 million (US$88 million).[117] However, under the current European Union research framework, up to €400 million (US$500 million) will be provided towards clean fossil-fuel technologies between 2007 and 2012, with CCS a priority.[118] As in the United States, a range of demonstration projects are under way, including collaboration between Norway and the United Kingdom on the storage of carbon in North Sea oil fields.[119]

Emerging private–public partnerships have achieved important results. However, far more ambitious approaches are needed to accelerate technological change in the coal industry. The Pew Center on Global Climate Change has argued for the development of a 30-plant programme over 10 years in the United States to demonstrate technical feasibility and create the conditions for rapid commercialization. Incremental costs are estimated at around US$23–30 billion.[120] The Pew Center has proposed the establishment of a trust fund created by a modest fee on electricity generation to cover these costs. While there are a range of financing and incentive structures that could be considered, the target of a 30-plant programme by 2015 is attainable for the United States. With political leadership, the European Union could aim for a comparable level of ambition.

The danger is that public policy failures will create another obstacle to CCS development

and deployment. Higher costs associated with CCS-equipped plants could give rise to a 'non-CCS lock-in' as a result of investment decisions on the replacement of current coal-fired capacity. In the absence of long-term carbon price signals and incentive structures to reward low-carbon electricity, power generators might take decisions that would make it more difficult to make the transition to CCS.

This would signal another lost opportunity. Around one-third of existing coal-fired capacity in the European Union is expected to reach the end of its technical lifetime in the next 10–15 years.[122] In the United States, where coal is resurgent, applications or proposals have been made for the development of over 150 new coal-fired power plants to 2030, with a projected investment of around US$145 billion.[123]

Both the European Union and the United States have an opportunity to use the retirement of old coal-fired power stock to create an enabling environment for an early transition to CCS. Seizing that opportunity will require bold steps in energy policy. Increasing investment in demonstration projects, signalling a clear intent to tax carbon emissions and/or introducing more stringent cap-and-trade provisions, and using regulatory authority to limit the construction of non-IGCC plants are among the policy requirements.

Increased financial and technological support for low-carbon power generation in developing countries is one priority area

3.4 The key role of international cooperation

International cooperation could open the door to wide-ranging win–win scenarios for human development and climate change mitigation. Increased financial and technological support for low-carbon power generation in developing countries is one priority area. Cooperation here could expand access to energy and improve efficiency, lowering carbon emissions and supporting poverty reduction efforts in the process. Deforestation is another problem that offers an opportunity. International action to slow the pace of rainforest destruction would reduce the global carbon footprint while generating a range of social, economic and environmental benefits.

Current approaches are failing to unlock the potential in international cooperation. Under the terms of the UNFCCC, international cooperation was identified as a key element in climate change mitigation. Developed countries pledged to "take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies".[124] In 2001, an agreement was drawn up—the Marrakesh Accords—aimed at giving greater substance to the commitment on technology transfer. Yet delivery has fallen far short of the pledges made, and even further short of the level of ambition required. Progress in tackling deforestation is similarly discouraging.

Negotiations on the next commitment period for the Kyoto Protocol provide an opportunity to change this picture. There are two urgent priorities. First, the world needs a strategy to support low-carbon energy transitions in developing countries. Developed countries should see this not as an act of charity but as a form of insurance against global warming and as an investment in human development.

In the absence of a coherent international strategy for finance and technology transfer to facilitate the spread of low-carbon energy, developing countries will have little incentive to join a multilateral agreement that sets emission ceilings. There are 1.6 billion people in the world lacking access to electricity—often women who walk many miles to fetch wood and/or collect cow dung to use as fuel. Expecting governments that represent them to accept medium-term ceilings on emissions that compromise progress in access to energy is unrealistic and unethical. It is also inconsistent with international commitments on poverty reduction.

The second priority is the development of a strategy on deforestation. Carbon markets

One unit of electricity produced in a developing country emits 20 percent more CO_2 than an average unit in developed countries

and financial transfers alone do not provide an answer to the problem. However, they can help to reduce the perverse incentives that currently act to promote deforestation, with negative consequences for people and the planet.

An expanded role for technology transfer and finance

Low levels of energy efficiency hold back human development and economic growth in many countries. Enhanced efficiency is a means to generate more power with less fuel—and fewer emissions. Rapidly narrowing the efficiency gap between rich and poor countries would act as a powerful force for climate change mitigation, and it could act as a force for human development.

Coal provides a powerful demonstration of the point. The average thermal efficiency for coal plants in developing countries is around 30 percent, compared with 36 percent in OECD countries.[124] This means that one unit of electricity produced in a developing country emits 20 percent more CO_2 than an average unit in developed countries. The most efficient supercritical plants in OECD countries, so called because they burn coal at higher temperatures with less waste, have achieved efficiency levels of 45 percent.[125] Projections for future emissions from coal-fired power generation are highly sensitive to the tech-nological choices that will influence overall efficiency. Closing the efficiency gap between these plants and the average in developing countries, would halve CO_2 emissions from coal-fired power generation in developing countries.[126]

The potential mitigation impact of efficiency gains can be illustrated by reference to China and India. Both countries are diversifying energy sources and expanding renewable energy provision. However, coal is set to remain the main source of power generation: the two countries will account for around 80 percent of the increase in global demand for coal to 2030. Average thermal efficiency in coal-fired power plants is increasing for both countries, but is still only around 29–30 percent.[127] Rapid expansion of coal-fired power generation built on this level of efficiency would represent a climate change disaster. With large investments going into new plants, there is an opportunity to avert that disaster by raising efficiency levels (table 3.3). Getting more energy from less coal would unlock wide ranging benefits for national economies, the environment and climate change mitigation.

China and India highlight the tension between national energy security and global climate security goals. Coal is at the heart of these tensions. Over the next decade, China will become the world's largest source of CO_2 emissions.[128] By 2015, power generation capacity will increase by around 518 GW, double current levels. It will increase again by around 60 percent, according to IEA projections, by 2030. To put the figures in context, the increase in power generation to 2015 is equivalent to current capacity in Germany, Japan and the United Kingdom combined. Coal will account for roughly three-quarters of the total increase by 2030.

Coal-fired power capacity is also expanding rapidly in India. In the decade to 2015, India will add almost 100 GW in power generation capacity—roughly double current power generation in California. The bulk of the increase will come from coal. Between 2015 and 2030, coal-fired power capacity is projected to double again, according to the IEA. While both China and India will continue to have far smaller per capita footprints than OECD countries, the current pattern of carbon-intensive energy growth clearly has worrying implications for climate change mitigation efforts.

Enhanced energy efficiency has the potential to convert a considerable climate change threat into a mitigation opportunity. We demonstrate this potential by comparing IEA scenarios for China and India covering the period 2004 to 2030, with more ambitious scenarios based on strengthened international cooperation. While any scenario is sensitive to assumptions, the results graphically illustrate both the benefits of multilateral action in supporting national energy policy reform and the implied costs of inaction.

Even modest reforms to enhance energy efficiency can deliver significant mitigation. The IEA compares a business-as-usual 'reference scenario' for future emissions with an 'alternative

scenario' in which governments deepen energy sector reforms. Under these reforms, it is assumed that overall coal-fired efficiency in China and India increases from current levels of around 30 percent to 38 percent by 2030. Most of the reforms would build incrementally on existing measures aimed at reducing demand.

It is possible to imagine a more ambitious scenario. Energy efficiency standards could be strengthened. Inefficient old plants could be retired more rapidly and be replaced by new supercritical plants and IGCC technologies, paving the way for an early transition to carbon capture and storage. Of course, these options would require additional financing and the development of technological capabilities. But, they would also deliver results.

Looking beyond the IEA scenario, we consider a more rapid transition to low-carbon, high-efficiency coal-fired power generation. That transition would see average efficiency levels raised to 45 percent by 2030—the level of the best-performing OECD plants today. We also factor in an additional element: early introduction of CCS technology. We assume that 20 percent of the additional capacity introduced between 2015 and 2030 takes the form of CCS.

These assumptions may be bold—but they are hardly beyond the realm of technological feasibility. Measured in terms of climate change mitigation, the emission reductions that would result are considerable:

- *China*. By 2030, emissions in China would be 1.8 Gt CO_2 below the IEA reference scenario level. That figure represents about one-half of current energy-related CO_2 emissions from the European Union. Put differently, it would reduce overall projected CO_2 emissions from all developing countries by 10 percent against the IEA reference scenario.
- *India*. Efficiency gains would also generate large mitigation effects in India. These amount to 530 Mt CO_2 in 2030 against the IEA reference level—a figure that exceeds current emissions from Italy.

Both of these illustrations underline the potential for rapid mitigation through efficiency gains in the power sector (figure 3.8). In important respects, the headline figures understate the potential gains for climate change mitigation through enhanced energy efficiency. One reason for this is that our alternative scenario focuses just on coal. It does not consider the potential for very large energy efficiency gains and CO_2 reductions through wider technological innovations in natural gas and renewable energy, for example. Nor do we factor in the large potential for achieving efficiency gains through technological breakthroughs in carbon-intensive industrial sectors, such as cement and heavy industry (table 3.4). Moreover, we present the gains in terms of a static one-year snapshot for 2030,

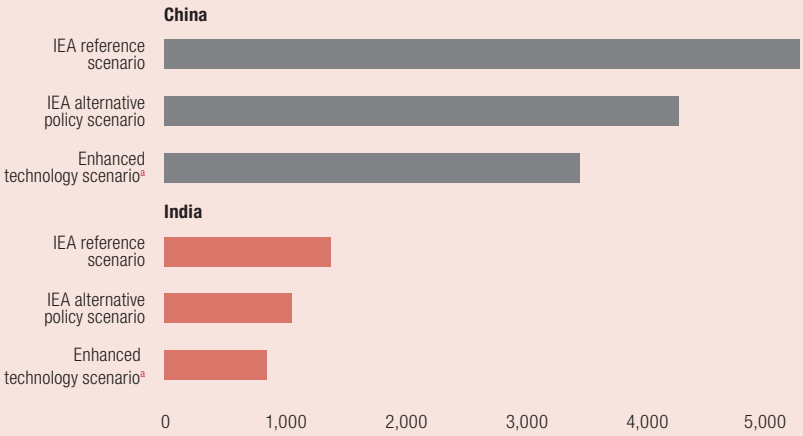
Table 3.3 Carbon emissions are linked to coal plant technology

	Approx. CO_2 emissions (g/kWh)	Reduction from Chinese average (%)	Lifetime CO_2 saving (Mt CO_2)[a]
Coal-fired plants:			
Chinese coal-fired fleet average, 2006	1140	–	–
Global standard	892	22	73.3
Advanced cleaner coal	733	36	120.5
Supercritical coal with carbon capture	94	92	310.8

a. Lifetime savings assume a 1GW plant running for 40 years at an average capacity factor of 85 percent in comparison with a similar plant with Chinese average efficiency (currently 29 percent).

Source: Watson et al. 2007.

Figure 3.8 Increased coal efficiency could cut CO_2 emissions



a. Based on IEA alternative policy scenario but assumes 45% average efficiency levels in coal power plants and 20% carbon capture and storage (CCS) for new plants (2015–2030)

Source: Watson 2007.

Table 3.4 Industrial energy efficiency varies widely

Energy consumption per unit produced (100=most efficient country)	Steel	Cement	Ammonia
Japan	100	100	–
Europe	110	120	100
United States	120	145	105
China	150	160	133
India	150	135	120
Best available technology	75	90	60

Source: Watson et al. 2007.

whereas the benefits of emission reductions, like the costs of rising emissions, are cumulative. Accelerated introduction of CCS technologies in particular could produce very large cumulative gains in the post-2030 era.

Our focus on China and India also understates the wider potential benefits. We apply our alternative energy scenario to these countries because of their weight in global emissions. However, the exercise has broader relevance.

Consider the case of South Africa. With an energy-sector dominated by low-efficiency coal-fired power generation (which accounts for over 90 percent of electricity generation) and an economy in which mining and minerals production figure prominently, South Africa is the only country in sub-Saharan Africa with a carbon footprint to rival that of some OECD countries. The country has a deeper footprint than countries such as France and Spain—and it accounts for two-thirds of all CO_2 emissions from sub-Saharan Africa.[129] Raising average efficiency levels for coal-fired power generation in South Africa to 45 percent would reduce emissions by 130 Mt CO_2 by 2030. That figure is small by comparison with China and India. But it still represents over one-half of all energy-related CO_2 emissions from sub-Saharan Africa (excluding South Africa).[130] In South Africa itself enhanced efficiency in the coal sector would help address one of the country's most pressing environmental concerns: the serious problems caused by emissions of nitrous dioxide and sulphur dioxide from coal combustion.[131]

For the world as a whole, enhanced energy efficiency in developing countries offers some obvious advantages. If climate security is a global public good, then enhanced efficiency is an investment in that good. There are also potentially large national benefits. For example, China is attempting to reduce emissions from coal plants to address pressing public health concerns (box 3.10). About 600 million people are exposed to sulphur dioxide levels above WHO guidelines and respiratory illness is the fourth most common cause of death in urban areas. In India, inefficiencies in the power sector have been identified by the Planning Commission as a constraint on employment creation and poverty reduction (box 3.11).[132] As these examples demonstrate, both countries stand to gain from enhanced energy efficiency and reduced pollution—and the entire world stands to gain from the CO_2 mitigation that would come with improved efficiency. Conversely, all parties stand to lose if the gaps in coal-fired energy efficiency are not closed.

If the potential for win–win outcomes is so strong why are the investments in unlocking those outcomes failing to materialize? For two fundamental reasons. First, developing countries themselves face constraints in financing and capacity. In the energy sector, setting a course for low-carbon transition requires large front-loaded investments in new technologies, some of which are still in the early stages of commercial application. The combination of large capital cost, higher risk and increased demands on technological capabilities represents an obstacle to early deployment. Achieving a breakthrough towards a low-carbon transition will impose substantial incremental costs on developing countries, many of which are struggling to finance current energy reforms.

Failures in international cooperation represent the second barrier. While the international climate security benefits of a low-carbon transition in the developing world may be substantial, the international financing and capacity-building mechanisms needed to unlock those benefits remain underdeveloped. In energy, as in other areas, the international community has not succeeded in developing a strategy for investing in global public goods.

This is not to understate the importance of a range of programmes that are now underway.

Box 3.10 Coal and energy policy reform in China

With the world's fastest growing economy, one-fifth of its population, and a highly coal-intensive energy system, China occupies a critical place in efforts to tackle climate change. It is the world's second largest source of CO_2 emissions after the United States and is on the verge of becoming the largest emitter. At the same time, China has a small per capita carbon footprint by international standards, just one-fifth of that in the United States and a third of the average for developed countries.

Climate change confronts China with two distinctive but related challenges. The first challenge is one of adaptation. China is already registering highly damaging climate change impacts. Extreme weather events have become more common. Droughts in north-eastern China, flooding in the middle and lower reaches of the Yangtze River and coastal flooding in major urban centres such as Shanghai are all examples. Looking to the future, it would be no exaggeration to say that China faces the prospect of a climate change emergency. Yields of the three major grains—wheat, rice and maize—are projected to decline with rising temperatures and changed rainfall patterns. Glaciers in western China are projected to thin by 27 percent to 2050. Large reductions in water availability are projected across several river systems, including those in northern China—already one of the world's most ecologically stressed regions.

As these scenarios suggest, China has a strong national interest in supporting global mitigation efforts. The challenge is to change the emissions trajectory in a high-growth economy without compromising human development. Currently, emissions are on a sharply rising trend. They are projected by the IEA to double to 10.4 Gt CO_2 by 2030. Under its 11th Five-Year Plan, the Chinese Government has set a wide range of goals for lowering future emissions:

- *Energy intensity.* The current targets include a goal of reducing energy intensity by 20 percent below 2005 levels by 2010. Achieving that goal would reduce business-as-usual CO_2 emissions by 1.5 Gt by 2020. Progress to date has been slower than anticipated, at around one-quarter of the required level.
- *Large enterprises.* In 2006 the National Development and Reform Commission (NDRC) launched a major programme—the Top 1000 Enterprises Programme—to improve energy efficiency in the country's largest enterprises through monitored energy efficiency improvement plans.
- *Advanced technology initiatives.* China is now becoming active in the development of IGCC technologies that could enhance energy efficiency and set the scene for an early transition to CCS. However, while a demonstration project has been authorized, implementation has been delayed by financing constraints and uncertainties over commercial risks.
- *Retiring inefficient power plants and industrial enterprises.* In 2005, only 333 of China's 6,911 coal-fired power units had capacities in excess of 300 MW. Many of the remainder have a capacity of less than 100 MW. These smaller units tend to use outmoded turbine designs that combine low efficiency with high levels of emissions. An NDRC plan envisages the accelerated closure of small, inefficient plants with a capacity of less than 50 MW by 2010. Targets have also been set for closing inefficient plants in areas such as steel and cement production, with stipulated reduction quotas for regional and provincial governments. In 2004, large and medium-sized steel mills consumed 705 kg of coal per tonne of steel, while smaller mills consumed 1045 kg/tonne.
- *Renewable energy.* Under a 2005 renewable energy law, China has set a national target of producing 17 percent of primary energy from renewable sources by 2020—more than twice the level today. While hydropower is envisaged as the main source, ambitious goals have been set for wind power and biomass, backed by financial incentives and subsidies.

These are ambitious targets. Translating them into measures that shape energy market outcomes will be difficult. For example, very small and highly inefficient units (less than 200 MW) accounted for over one-third of the new capacity installed from 2002 to 2004. That outcome points to a governance challenge in energy policy. In effect, a significant proportion of Chinese coal-fired power plant development is out of central government control, with local government not enforcing national standards. Similarly, there are very large gaps in efficiency between small enterprises and the larger enterprises subject to government regulatory authority.

Enhancing energy efficiency and reducing carbon intensity will require sustained reforms in China. At the same time, the current direction of energy reform, with a growing emphasis on efficiency, renewables and carbon mitigation, opens up opportunities for international cooperation and dialogue on climate change. The entire world has an interest in China deploying coal technologies that will facilitate the earliest and most rapid cuts in CO_2 emissions—and the earliest transition to CCS. Multilateral financing and technology transfer could play a critical role by meeting the incremental costs of a low-carbon transition, creating incentives and supporting the development of capacity.

Sources: CASS 2006; Li 2007; Watson et al. 2007; World Bank 2006d.

Yet the experience of coal again provides a powerful demonstration of current failures in international cooperation. While there has been a proliferation of exercises in cooperation, delivery has been largely limited to dialogue. One example is the Asia-Pacific Partnership on Clean Development. This brings together a large group of countries—including China, India, Japan and the United States—committed to expanding the development and deployment of low-carbon technology. However, the partnership is not based on binding commitments and has so far

Box 3.11 Decarbonizing growth in India

Rapid economic growth over the past two decades has created unprecedented opportunities for poverty reduction in India. Sustained growth, allied to policies that tackle deep social disparities, is a basic requirement for overcoming the country's large human development deficit. But is there a tension between the national energy security policies needed to support economic growth and global climate security?

From a global climate change mitigation perspective, rapid economic growth fuelled by coal in the world's second most populous country poses an obvious challenge. Yet it also provides an opportunity for international cooperation.

India is now the world's fourth largest emitter of CO_2. Between 1990 and 2004, emissions increased by 97 percent—one of the highest rates of increase in the world. However, per capita energy use is rising from a low base. The average Indian uses 439 kg of oil-equivalent energy (kgoe), less than one-half of the average for China. The comparable figure for the United States is 7,835 kgoe. India's per capita carbon footprint places the country 128th in the world league table.

The energy shortfalls behind these figures have implications for human development. Around half of India's population—some 500 million people—do not have access to electricity. At a household level, low levels of energy use are reflected in high levels of dependence on biofuels (see figure). Meanwhile, persistent power shortages and unreliable supply act as a constraint on economic growth, productivity and employment. The all-India average for peak power shortages is 12 percent.

Energy occupies a critical place in India's development planning. The ambition set out in its Eleventh Five-Year Plan is to sustain economic growth rates in excess of 8–9 percent a year. At this level, energy generation will also have to double. Over the longer term, sustaining growth at current levels through to 2030 will require a fivefold increase in energy generation.

Coal is likely to provide most of the increase. With abundant domestic supplies—India accounts for around 10 percent of the world's known reserves—and concerns over the security of imported energy supplies, coal will remain the preferred fuel. Business-as-usual scenarios point to an increase in the share of coal in power supply and CO_2 emissions. Coal–based emissions are projected to rise from 734 Mt CO_2 in 2004, to 1,078 Mt CO_2 in 2015 and 1,741 Mt CO_2 by 2030.

Radical changes to this emissions trajectory are possible. Low levels of energy efficiency are holding back India's efforts to increase energy supply and expand access to electricity, while driving up emissions. Research carried out by the Planning Commission estimates that India could generate the same amount of power with one-third less fuel. As shown in this chapter, efficiency gains have the potential to generate deep cuts in emissions.

Technology provides part of the explanation for the low levels of efficiency in the coal sector. Over 90 percent of India's coal generation capacity is subcritical, much of it concentrated in small-scale plants. Improving the efficiency of these plants would generate large energy sector benefits for India, along with global climate change mitigation benefits.

Domestic policy reform is one requirement for unlocking efficiency gains. The power sector in India is dominated by large monopolies that control both power supply and distribution. Most state power utilities are in a financially weak condition, with average annual losses running at 40 percent. Uncollected bills, the provision of heavily subsidized electricity to agriculture (where most benefits are captured by high income farmers) and wider inefficiencies all contribute to these losses. The upshot is that utilities lack the financial resources needed to upgrade technology.

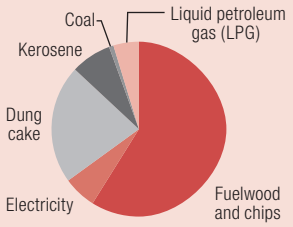
Current reforms are addressing these problems. The 2003 Electricity Act provides a framework for more efficient and equitable tariffs. New regulatory structures have been created, and some states—such as Andhra Pradesh and Tamil Nadu—have started to break electricity boards up into more competitive units for generation, transmission and distribution.

Energy reform in India provides the international community with an opportunity to support national policies that will also advance global climate change mitigation goals. Early adoption of clean coal technologies and best-practice international standards would enable India to change its emissions trajectory while meeting rising energy demand.

Research carried out for this Report by the Tata Energy Research Institute estimates that an annualized increase in investment of around US$5 billion is needed for the period 2012–2017 to support a rapid transition to low-carbon energy generation, over and above current investment plans. Mobilizing these resources through the type of multilateral mechanisms proposed in this chapter could create a win–win outcome for energy efficiency in India and global climate change mitigation.

Traditional energy sources still dominate

Energy consumption (July 1999–June 2000, % of total)



Source: Government of India 2006a.

Source: Government of India 2006a, 2006b; Mathur and Bhandari 2007; MIT 2007; Watson et al. 2007.

produced little more than information exchange. Much the same is true of the G8's Plan of Action for Climate Change, Clean Energy and Sustainable Development.

The failure to develop substantive cooperation on CCS is particularly worrisome. From a global public goods perspective, there is an overwhelming interest in developed

countries speeding-up the deployment of CCS technologies at home, and then ensuring that they are available to developing countries as soon as possible and at the lowest price. Perhaps the most concrete example of cooperation in this area to date is the Near-Zero Emissions Coal Project, which is part of the European Union–China Partnership on Climate Change. The project is planned in three phases, starting with a three-year feasibility study (2005–2008) to explore technological options. The ultimate target is a single demonstration plant in 2020. However, progress in implementation has been slow—and details for implementing later phases have yet to be revealed.[133] Collaboration between the United States' FutureGen 'clean coal' project and Huaneng, China's third largest coal-power generation company, has been beset by similar uncertainties.

The missing link—a framework for finance and technology transfer

What is missing from the current patchwork of fragmented initiatives is an integrated international framework for finance and technology transfer. Developing that framework is a matter of urgency.

There are several areas in which international cooperation could help strengthen climate change mitigation efforts through support for national energy policy reforms. Under the UNFCCC, developed countries undertook to "meet the agreed full incremental costs" of a range of measures undertaken by developing countries in the three core areas of finance, technology and capacity building.[134] National resource mobilization will remain the primary financing vehicle for energy policy reform. Meanwhile, the focal point for international cooperation is the incremental financial cost and the enhanced technological capabilities required to achieve a low-carbon transition. For example, international cooperation would mobilize the resources to cover the 'price gap' between low-carbon options such as renewable energy and enhanced coal-efficiency options on the one side, and existing fossil-fuel based options on the other side.

The underlying problem is that developing countries already face deep financing constraints in energy policy. Estimates by the IEA suggest that an annual investment for electricity supply alone of US$165 billion annually is needed through to 2010, rising at 3 percent a year to 2030. Less than half of this financing is available under current policies.[135] Financing deficits have very real implications for human development. On current trends there will still be 1.4 billion people lacking access to electricity in 2030, and one-third of the world's population—2.7 billion people—will still be using biomass.[136]

Developing countries themselves have to address a wide range of energy sector reform problems. In many countries, heavily-subsidized energy prices and low levels of revenue collection represent a barrier to sustainable financing. Electricity subsidies are often directed overwhelmingly towards higher-income groups partly because they are distributed through large centralized grids to which the poor have limited access. Greater equity in energy financing and the development of decentralized grid systems that meet the needs of the poor are two of the foundations for meaningful reform. However, it is neither realistic nor equitable to expect the world's poorest countries to finance both the energy investments vital for poverty reduction at home and the incremental costs of a low-carbon transition to support international climate change mitigation.

These costs are linked to the capital requirements for new technologies, the increase in recurrent costs in power generation and the risks associated with the deployment of new technologies. As with any new technology, the risks and uncertainties associated with low-carbon technologies that have yet to be widely deployed even in the developed world represent a large barrier to deployment in developing countries.[137]

The multilateral framework for the post-2012 era will have to include mechanisms that finance these incremental costs, while at the same time facilitating technology transfer. Putting a figure on costs is difficult. One ballpark estimate for the investment costs to facilitate access to low-carbon technology broadly consistent with

On current trends there will still be 1.4 billion people lacking access to electricity in 2030

The Kyoto Protocol and the framework provided by the UNFCCC provide the primary platform for addressing global cooperation on climate change under United Nations leadership

our sustainable emissions pathway suggests that an additional US$25–50 billion per annum would be required for developing countries.[138] However, this is at best an approximation. One of the most urgent requirements for international cooperation is the development of detailed national financing estimates based on national energy policy plans.

Whatever the precise figure, financial transfers in the absence of cooperation on technology and capacity-building will be insufficient. The massive new investments required in developing countries' energy sectors over the next 30 years provide a window of opportunity for technological transformation. However, technological upgrading cannot be achieved through a simple process of technological transfer. New technologies have to be accompanied by the development of knowledge, capabilities in areas such as maintenance, and the development of national capacities to climb the technology-ladder. This is an area in which international cooperation—including South–South cooperation— has an important role to play.

Strengthened cooperation on financing, technology and capacity-building is vital for the credibility of the post-2012 Kyoto Protocol framework. Without that cooperation, the world will not get on to an emissions trajectory that avoids dangerous climate change. Moreover, developing countries will have little incentive to join a multilateral agreement that requires significant energy policy reforms on their part, without providing financial support.

History offers some important lessons. Perhaps the most successful of all international environmental treaties is the 1987 Montreal Protocol—the agreement forged to cut back emissions of ozone-depleting substances. Prompted by alarm over the expansion of the ozone hole above Antarctica, the treaty set stringent time-bound targets for phasing out these substances. Developing countries' participation was secured through a multilateral fund under which the incremental costs of achieving the targets were met by developed countries. Today, no countries are significantly off track for achieving the Montreal Protocol targets—and technology transfer is one of the primary reasons for this outcome.[139] The benefits of international cooperation are reflected in the fact that the ozone hole is shrinking.

Experience under the Montreal Protocol has informed the multilateral response to climate change. Under the UNFCCC, the Global Environment Facility (GEF) became a financial instrument to mobilize resources for climate change activities in mitigation and adaptation. While overall financing has been limited, especially in the case of adaptation (see chapter 4), funds controlled under the GEF have demonstrated a capacity to leverage larger investments. Since its inception in 1991, the GEF has allocated US$3 billion, with co-financing of US$14 billion. Current resource mobilization is insufficient to finance low-carbon transition at the pace required. Moreover, the GEF continues to rely principally on voluntary contributions—an arrangement that reduces the predictability of finance. If the GEF is to play a more central role in mitigation in support of nationally-owned energy sector reforms, financing provisions may have to be placed on a non-voluntary basis.[140]

Building international cooperation on climate change is a formidable task. The good news is that the international community does not have to start by reinventing the wheel. Many of the individual elements for successful cooperation are already in place. The Kyoto Protocol and the framework provided by the UNFCCC provide the primary platform for addressing global cooperation on climate change under United Nations leadership. The CDM has provided a mechanism linking the mitigation agenda to financing for sustainable development in developing countries. This is done through greenhouse gas reducing projects that generate emission credits in developing countries which can be used by developed countries to offset their own domestic emissions. In 2006, CDM financing amounted to US$5.2 billion.[141] At one level, the CDM is potentially an important source of carbon financing for mitigation in developing countries. At another level, the CDM suffers from a number of shortcomings. Because it is project-based, transaction costs are high. Establishing that CDM emission reductions

are 'additional', and monitoring outcomes, is also problematic. There are legitimate concerns that many of the emissions reductions under the CDM have been illusory. Moreover, carbon abatement has often been purchased at prices far higher than costs (box 3.12). Even without these problems, scaling-up the CDM in its current form to achieve emission reductions and financing transfers on the scale required would be enormously complex. It would require the establishment of thousands of projects, all of which would have to be validated and registered, with subsequent emission outcomes subject to verification and certification.

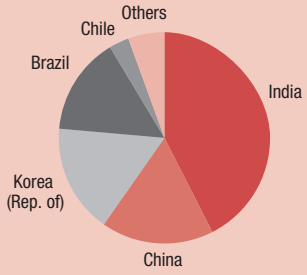
Box 3.12 Linking carbon markets to the MDGs and sustainable development

With cap-and-trade programmes set to play an increasingly prominent role in the mitigation efforts of rich countries, carbon markets are set to take-off on a global scale. Firms and governments will continue to seek low cost abatement opportunities in developing countries. Could flows of carbon finance help to expand opportunities for sustainable development and a low-carbon transition in the poorest countries?

Flexible mechanisms that have emerged from the Kyoto Protocol have created opportunities for developing countries to participate in carbon markets. The CDM market is set to grow from its current level of around US$5 billion. However, CDM projects are heavily concentrated in a small number of large developing countries. These countries have developed a strong capacity to market mitigation in large industrial enterprises. So far, the poorest developing countries have been bypassed—and there have been limited benefits for broad-based sustainable development (see figure).

Most CDM projects go to a handful of countries

Certified emission reductions (% of total), 2004–2007



Source: UNFCCC 2007b.

Perhaps unsurprisingly, carbon markets have concentrated finance in countries offering to reduce carbon emissions at the lowest abatement price. Sub-Saharan Africa represents less than 2 percent of credits, with only one country figuring in the 2007 project pipeline. Moreover, carbon finance flows have been heavily skewed towards greenhouse gases (other than CO_2) known as HFCs, especially in countries such as China and India. Because the cost of destroying these gases, which account for over one-third of all emission credits, is much lower than the price that credits can make on the open market, carbon trading has generated large profits for chemical companies and carbon brokers. Benefits for the world's poor have been less evident.

Market barriers provide one explanation for the limited participation of developing countries. Current rules for the flexibility mechanisms in the Kyoto Protocol restrict the scope of carbon financing linked to land use (section 3.4). The more serious structural problem is that groups such as small-scale farmers and forest dwellers do not have opportunities to engage in carbon markets, partly because the markets themselves are remote; and partly because they lack marketable rights in land and environmental resources. Marginal women farmers in Burkina Faso or Ethiopia are not well placed to negotiate with carbon brokers in the City of London—and carbon brokers seeking to minimize transaction costs have an inbuilt preference for large suppliers of mitigation credits.

Social organization is one of the keys to tapping the potential of carbon markets for sustainable development. In 2006, Kenya's Greenbelt Movement successfully marketed a programme to reforest two mountain areas in Kenya as part of an emissions reduction agreement. Women's groups will plant thousands of trees, with revenues coming from a carbon trade for the reduction of 350,000 tonnes of CO_2. The aim is to generate wide-ranging social and environmental benefits, including the restoration of eroded soils.

Innovative new approaches are being developed to address barriers to market entry. One example is the MDG Carbon Facility launched by the UNDP. In an effort to link carbon financing to sustainable development goals, UNDP 'bundled' a portfolio of projects sourced over 2 years, generating up to 15 Mt CO_2e within the first Kyoto commitment period (2008–2012). The credits will be marketed by Fortis Bank. One cluster of projects aims at renewable energy programmes to bring electricity to remote areas. Another will support the use of animal dung to generate biogas, freeing up women and children from fuelwood collection. Stringent processes have been established to ensure that the projects deliver mitigation and benefits for the poor.

The MDG Carbon Facility is an attempt to achieve a wider distribution of benefits from carbon markets. It involves the development of new operational and financing mechanisms. If successful, it will give some of the world's poorest countries the opportunity to participate in these markets. And it will link climate change mitigation to pro-poor sustainable development.

Source: UNDP 2007; UNFCCC 2007d; Zeitlin 2007.

Under a programme-based approach, developing countries could pledge to achieve a specified level of emission reduction, either in a specific sector (such as electricity generation) or for the country as a whole

Shifting the focus towards programme-based approaches could yield far more positive outcomes. Under a programme-based approach, developing countries could pledge to achieve a specified level of emission reduction, either in a specific sector (such as electricity generation) or for the country as a whole. The target could be set against a specific benchmark either in terms of reductions from a business-as-usual reference scenario or in terms of absolute cuts. Developed countries could support achievement of the targets by agreeing to meet the incremental costs of new technologies and capacity building. For example, current energy plans in China and India could be revisited to explore the potential and the costs for reductions in CO_2 emissions through the introduction of expanded programmes for renewable energy and accelerated introduction of clean coal technologies.

Negotiations on the post-2012 Kyoto Protocol framework provide an opportunity to put in place an architecture for international cooperation that links climate change mitigation to sustainable energy financing. One option would be the creation of an integrated Climate Change Mitigation Facility (CCMF). The CCMF would play a wide-ranging role. Its overarching objective would be to facilitate the development of low-carbon energy systems in developing countries. To that end, the aim would be to provide through multilateral channels support in key areas, including financing, technology transfer and capacity-building. Operations would be geared towards the attainment of emission reduction targets agreed under the post-2012 framework, with dialogue based on nationally-owned energy strategies. Rules and governance mechanisms would have to be developed to ensure that all parties deliver on commitments, with CCMF support geared towards well-defined quantitative goals and delivered in a predictable fashion. The following would be among the core priorities:

- *The mobilization of finance.* The CCMF would mobilize the US$25–50 billion needed annually to cover the estimated incremental costs of facilitating access to low-carbon technologies. Financing provisions would be linked to the circumstances of countries. In middle-income countries—such as China and South Africa—concessionary finance might be sufficient, whereas low-income countries might require grants. The development of a programme-based CDM approach linking carbon markets in rich countries to mitigation in developing countries would be another instrument in the CCMF toolkit. One of the broad objectives of the CCMF would be to leverage private investment, domestic and foreign. Public finance could be partly or wholly generated through carbon taxation or levies on cap-and-trade permits.
- *Mitigating risks.* Commercial risks associated with the introduction of new, low-carbon technologies can act as a significant barrier to market entry. CCMF financing could be used to reduce risks through concessional loans, along with partial or full risk guarantees on loans for new technology—extending an approach developed under the World Bank's International Finance Corporation (IFC).
- *Building technological capabilities.* The CCMF could act as a focal point for wide-ranging cooperation on technology transfer. The agenda would extend from support for developing countries seeking financing for technology development, to the strengthening of capacity in state and non-state enterprises, strategies for sharing new technologies, and support for the development of specialized training agencies and centres of excellence in low-carbon technology development.
- *Buying out intellectual property.* It is not clear that intellectual property rights are a major barrier to low-carbon technology transfer. In the event that transfers of breakthrough technology were constrained by intellectual property provisions, the CCMF could be used to finance a structured buy-out of intellectual property rights, making climate-friendly technologies more widely accessible.
- *Expanding access to energy.* Meeting the needs of populations lacking access to modern energy services without fuelling dangerous climate change is one of the greatest challenges in international cooperation. There

are strong efficiency and equity grounds for developing decentralized, renewable energy systems. Here too, however, there are large financing gaps. Under an Action Plan for Energy Access in Africa drawn up by the World Bank and others, strategies have been identified aimed at increasing access to modern energy from 23 percent today to 47 percent by 2030.[142] Implementation of these strategies will require an additional US$2 billion in concessional financing each year—roughly double current levels. The CCMF could provide a focal point for international efforts to mobilize these resources.

Creating a CCMF would not entail the development of vast new institutional structures. Large international bureaucracies that duplicate existing mechanisms will not help advance climate change mitigation. Neither will a 'more-of-the-same' model. If the world is to unite around a common mitigation agenda, it cannot afford to continue the current patchwork of fragmented initiatives. What is needed is a multilateral framework that links ambitious targets with ambitious and practical strategies for transferring low-carbon technologies. That framework should be developed under the auspices of the UNFCCC as part of the post-2012 Kyoto Protocol. And it should be designed and implemented through a process that gives developing countries, including the poorest countries, a real voice.

The starting point is political leadership. Stringent climate change mitigation will not happen through discrete technological fixes and bilateral dialogue. Government leaders need to send a clear signal that the battle against climate change has been joined—and that the future will look different to the past. That signal has to include a commitment on the part of developed countries to technology transfer and financing for a low-carbon transition. More broadly, what is needed is a partnership on mitigation. That partnership would be a two-way contract. Developing countries would draw on international support to strengthen current efforts to reduce emissions, setting quantitative targets that go beyond current plans. Developed countries would underwrite attainment of incremental elements in these targets, supporting nationally-owned energy strategies that deliver tangible outcomes.

Developed through a CCMF framework, this approach could provide a focal point for a broad-based effort. Because a low-carbon transition is about far more than technology and finance, specialized agencies of the United Nations—such as UNDP and UNEP—could focus on an enhanced capacity-building effort, building the human resource base for deep energy reforms. The World Bank would be well-placed to oversee the financing provisions of the proposed CCMF. Its role could entail management of the subsidy element in the CCMF, the blending of concessional and non-concessional finance, oversight of subsidized credits to reduce risk, and the leveraging of private sector support. At a time when the future role of the World Bank in much of the developing world is uncertain, the CCMF could provide the institution with a clear mission that links improved access to energy and energy efficiency to climate change mitigation. Substantive engagement with the private sector would be imperative given its critical role in finance and technological innovation.

If the world is to unite around a common mitigation agenda, it cannot afford to continue the current patchwork of fragmented initiatives

Reducing deforestation

The world's forests are vast repositories for carbon. The erosion of those repositories through deforestation accounts for about one-fifth of the global carbon footprint. It follows that preventing deforestation can mitigate climate change. But forests are more than a carbon bank. They play a crucial role in the lives of millions of poor people who rely on them for food, fuel and income. And tropical forests are sites of rich biodiversity. The challenge for international cooperation is to find ways of unlocking the triple benefits for climate mitigation, people and biodiversity that could be generated through the conservation of forests.

Governments are not currently meeting the challenge. The facts on deforestation tell their own story (figure 3.9). Between 2000 and 2005, net forest loss worldwide averaged 73 thousand

Across the developing world, rainforests are being felled for gains which, in a functioning carbon market, would be dwarfed by the benefits of conservation

square kilometres a year—an area the size of a country like Chile.[143] Rainforests are currently shrinking at about 5 percent a year. Every hectare lost adds to greenhouse gas emissions. While forests vary in the amount of carbon that they store, pristine rainforest can store around 500 tonnes of CO_2 per hectare.

Between 1990 and 2005, shrinkage of the global forest estate is estimated to have added around 4 Gt CO_2 to the Earth's atmosphere each year.[144] If the world's forests were a country, that country would be one of the top emitters. On one estimate, deforestation, peat land degradation and forest fires have made Indonesia the third largest source of greenhouse gas emissions in the world.[145] Deforestation in the Amazon region is another of the great sources of global emissions. Data from the Instituto de Pesquisa Ambiental da Amazônia, a research institute in northern Brazil, suggest that deforestation is responsible for emissions of an estimated 730 Mt CO_2 each year.[146]

The many drivers of deforestation

Deforestation is driven by many forces. In some cases, poverty is the driver, with agricultural populations collecting fuelwood or expanding the frontier for subsistence agriculture. In others, opportunities for wealth generation are the main engine of destruction.

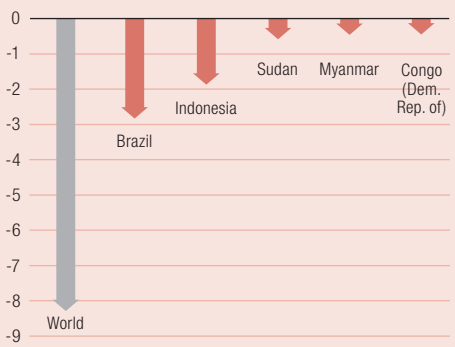
The expansion of national and international markets for products such as beef, soybeans, palm oil and cocoa can create strong incentives for deforestation. In Brazil, devaluation and a 30 percent increase in prices for soy exports from 1999 to 2004 gave a boost to forest clearance. In the 5 years to 2005, the states of Goias, Mato Grosso and Mato Grosso do Sul planted an additional 54,000 square kilometres of soy—an area slightly larger than Costa Rica. At the same time, forests are under pressure from commercial logging, much of it illegal. In Cambodia, to take one example, illegal logging of hardwood timbers for export was responsible for much of the 30 percent reduction in primary rainforest cover since 2000—one of the most rapid losses recorded by the FAO.[147]

Commercial pressures on rainforests are unlikely to dissipate in the near future. Croplands, pastures, plantations and logging are expanding into natural forests across the world. Population growth, rising incomes and opportunities for trade create incentives for deforestation—as does market failure on a global scale.

The scale of market failure is revealed in the basic economics of rainforest conversion. Across the developing world, rainforests are being felled for gains which, in a functioning carbon market, would be dwarfed by the benefits of conservation. Consider the following example. In Indonesia, oil palm cultivation generates an estimated value of US$114 per hectare. As the trees that stood on that hectare burn and rot, they release CO_2 into the atmosphere—perhaps 500 tonnes a hectare in dense rainforests. At a carbon price of US$20–30 a tonne, a plausible future range on the EU ETS, the carbon market value of that release would amount to US$10,000–15,000 a hectare. Put differently, farmers in Indonesia are trading a carbon bank asset worth at least US$10,000 in terms of climate change mitigation, for one worth US$114, or around 2% of its value.[148] Even commercial logging, which generates a higher market return, represents less than one-tenth of the value of the carbon bank. And these figures do not include the market and non-market values of environmental services and biodiversity.

Perverse incentives are at the heart of a 'lose–lose' scenario. The world is losing

Figure 3.9 Forests are in retreat



Source: FAO 2007.

immense opportunities for carbon mitigation through forest conversion. Countries are losing assets that could have a real value in terms of carbon finance. And people depending on forests for their livelihoods are losing out to economic activities operating on the basis of a false economy. Viewed in narrow commercial terms, deforestation makes sense only because markets attach no value to carbon repositories. In effect, standing trees are obstacles to the collection of money lying on the ground. While national circumstances vary, in many countries most of that money is appropriated by large-scale farmers, ranchers and illegal loggers. The upshot is that market failures are creating incentives that are bad for climate change, bad for national environmental sustainability and bad for equity.

What would it take to change the current incentive structure? Economic analysis can provide a very partial insight. The World Bank estimates that a price of US$27/t CO_2 would induce conservation of 5 million km^2 of rainforest by 2050, preventing the release of 172Gt CO_2.[149] However, markets cannot be considered independently of institutions and power relationships. Translating market incentives into rainforest conservation will require wide-ranging measures to distribute the benefits to poor farmers, thereby reducing poverty-related deforestation pressures, and to regulate the activities of large commercial farmers and illegal actors.

Carbon markets alone will not provide an automatic corrective for the wider forces driving deforestation. This is because forests are far more than carbon banks. Many of their ecological functions are unmarketed. Markets do not attach a price to the 400 plant species in Indonesia's Kerinci-Sebat National Park in Sumatra, nor to the immense biodiversity in Brazil's *cerrado* or savannah woodland. This generates an illusion that a zero price is associated with a zero economic value. As one commentator has written: "When conservation competes with conversion, conversion wins because its values have markets, whereas conservation values appear to be low. Prices and values should not be confused."[150]

Inequalities in political power are another source of deforestation not easily amenable to correction through the market. In Brazil, the incursion of commercial agriculture into rainforest areas has been associated with violations of the human rights of indigenous people and recourse to violence.[151] In Papua New Guinea, forest rights reside with indigenous communities in legislative theory. However, formal legal tenure has not prevented logging companies from operating without the consent of indigenous people.[152] In Indonesia, laws have been passed which recognize the rights of indigenous forest dwellers.[153] However, the eviction of indigenous people with the expansion of illegal logging and commercial plantations continues unabated. Living in remote areas, lacking economic power and with a weak voice in policy design and enforcement, forest dwellers carry less weight than powerful vested interests in forest management.

Governance of forests has to reflect their diverse functions. Forests are ecological resources that generate wide-ranging public and private benefits. They are the home and basis of livelihoods for many poor people and a source of potential profit for large commercial interests. They are a productive asset, but also a source of biodiversity. One of the challenges in forest governance is to balance the demands of competing interests with very different levels of power.

Some countries are developing institutional structures to address that challenge. In 2004, Brazil started implementing an Action Plan for Preventing and Controlling Deforestation. That plan integrates the work of 14 separate ministries. It establishes a legal framework for land-use decisions, strengthens monitoring and creates a legal framework for sustainable forest management. Outcomes will depend upon implementation and enforcement through state governments—an area where the record to date has been mixed. However, preliminary data for 2005 and 2006 suggests that the rate of deforestation has slowed by around 40 percent in the state of Mato Grosso.[154] Government commitment and the active engagement of civil society have been critical to this step in a positive direction.

Translating market incentives into rainforest conservation will require wide-ranging measures to distribute the benefits to poor farmers

The rehabilitation of severely degraded grasslands, and the conversion of degraded croplands to forests and agroforestry systems, can also build carbon storage capacity

International cooperation on climate change alone cannot resolve the wider problems driving deforestation. Respect for the human rights of indigenous people, the protection of biodiversity and conservation are issues for national political debate. However, the world is losing an opportunity to join up the climate change mitigation agenda with a range of wider human development benefits. International cooperation in the context of the post-2012 Kyoto commitment period could help to create incentives to unlock these benefits.

Filling the gaps

The current Kyoto Protocol suffers from a number of shortcomings as a framework for addressing the greenhouse gas emissions associated with land-use changes. There is significant potential for creating triple benefits from climate change mitigation, to adaptation and sustainable development. However, existing mechanisms limit the possibility of harnessing carbon finance as a mechanism for sustainable development.

Deforestation does not figure in the current Kyoto Protocol beyond a very limited provision to support 'afforestation' through the CDM. The rules of the CDM place a 1 percent cap on the share of carbon credits that can be generated through land use, land-use change and forestry, effectively de-linking activities in this sector from the climate change mitigation agenda. The Protocol does not allow developing countries to create emission reductions from avoided deforestation, limiting opportunities for transfers of carbon finance. Nor does it establish any financing mechanisms through which developed countries might provide incentives against deforestation.

Forests are the most visible ecological resource written out of the script for international cooperation on mitigation. But, they are not the only such resource. Carbon is also stored in soil and biomass. The rehabilitation of severely degraded grasslands, and the conversion of degraded croplands to forests and agroforestry systems, can also build carbon storage capacity. Because the environmental degradation of soils is both a cause and an effect of poverty, tapping into carbon finance for these purposes could unlock multiple benefits. These include an increased flow of finance into environmental sustainability, support for more resilient livelihood systems in the face of climate change, and benefits for climate change mitigation.

Several innovative proposals have been developed to address the gaps in the current Kyoto approach. The Coalition of Rainforest Nations, led by Costa Rica and Papua New Guinea, has argued for 'avoided deforestation' to be brought into the Kyoto framework, opening the door to the use of CDM credits. Broadly, the idea is that every hectare of forest that would have been cut down but is left standing is a contribution to climate change mitigation. If incorporated into a CDM-type arrangement, this would open the door to potentially large flows of finance to countries with standing forests. A proposal tabled by Brazil sets out an alternative approach. This calls for the provision of new and additional resources for developing countries that voluntarily reduce their greenhouse gas emissions through reduced deforestation. However, under the Brazilian proposal the reductions would not register as developed country mitigation credits. Others have called for a revision of CDM rules to allow for an increased flow of carbon finance into soil regeneration and grassland restoration (box 3.12).

Proposals such as these merit serious consideration. The limitations of carbon markets as a vehicle for avoiding deforestation have to be recognized. Serious governance issues are at stake. 'Avoided deforestation' is clearly a source of mitigation. However, any standing rainforest is a potential candidate for classification as 'avoided deforestation'. Using trend rates for deforestation activity does not help resolve the problem of quantifying commitments, partly because information on trends is imperfect; and partly because changes in reference years can produce very big shifts in results. Other concerns, widely voiced during the last round of Kyoto negotiations, also have to be addressed. If avoided deforestation were integrated into the CDM without clear quantified limits, the sheer volume of CO_2 credits could swamp carbon markets, leading to a collapse in prices. Moreover,

the permanence of mitigation through 'avoided deforestation' is difficult to establish.

Serious as the governance challenges are, none of these problems represents a case against the use of well-designed market instruments to create incentives for conservation, reforestation or the restoration of carbon-absorbing grasslands. There may be limits to what carbon markets can achieve. However, there are also vast and currently untapped opportunities for mitigation through reduced deforestation and wider land-use changes. Any action that keeps a tonne of carbon out of the atmosphere has the same climate impact, no matter where it occurs. Linking that action to the protection of ecosystems could create wide-ranging human development benefits.

Cooperation beyond carbon markets will be needed to tackle the wider forces driving deforestation. The world's forests provide a wide range of global public goods, of which climate change mitigation is one. By paying for the protection and upkeep of these goods through financial transfers, developed countries could create strong incentives for conservation.

International financial transfers, as advocated by Brazil, could play a key role in sustainable forest management. Multilateral mechanisms for such transfers should be developed as part of a broad-based strategy for human development. Without such arrangements international cooperation is unlikely to slow deforestation. However, successful outcomes will not be achieved just through unconditional financial transfers. Institutional mechanisms and governance structures for overseeing shared goals have to extend beyond conservation and emission targets to a far wider set of environmental and human development concerns, including respect for the human rights of indigenous people.

There are vast and currently untapped opportunities for mitigation through reduced deforestation and wider land-use changes

Conclusion

Stringent climate change mitigation will require fundamental changes in energy policy—and in international cooperation. In the case of energy policy, there is no alternative to putting a price on carbon through taxation and/or cap-and-trade. Sustainable carbon budgeting requires the management of scarcity—in this case the scarcity of the Earth's capacity to absorb greenhouse gases. In the absence of markets that reflect the scarcity implied by the stabilization target of 450 ppm CO_2e energy systems will continue to be governed by the perverse incentive to overuse carbon-intensive energy.

Without fundamental market-based reform the world will not avoid dangerous climate change. But pricing alone will not be enough. Supportive regulation and international cooperation represent the other two legs of the policy tripod for climate change mitigation. As we have shown in this chapter, there has been progress on all three fronts. However, that progress falls far short of what is required. Negotiations on the post-2012 framework for the Kyoto Protocol provide an opportunity to correct this picture. Incorporating an ambitious agenda for finance and technology transfer to developing countries is one urgent requirement. Another is international cooperation to slow the pace of deforestation.