

Climate Change Mitigation

WHAT DO WE DO?



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Preface

Climate change and its impact on our environment, our economies and our security, is the defining issue of our era. But every day of inaction makes its consequences more irreversible, so we need to act now.

The OECD has been at the forefront of climate change policy analysis for the past two decades. The economics of climate change lie at the epicentre of any viable solution. This publication summarises recent OECD analyses and it strengthens the main OECD message: that an ambitious and comprehensive strategy to curb greenhouse gas (GHG) emissions is economically rational. It provides arguments to help policy-makers explain why postponing decisions, using the current economic circumstances as an excuse, is a short-sighted policy.

To achieve the emission reductions necessary to forestall a continuing cycle of global warming, a broad range of policy instruments will need to be deployed; and action by all countries will be required. The pricing of GHG emissions, directly via carbon taxes or – more probably – through cap-and-trade systems, is an essential element of any comprehensive strategy. Such pricing leads to cost-effective emissions abatement and creates incentives to innovate and deploy new technologies. Cost-effectiveness is essential for creating the necessary consensus for effective climate change policies.

In this document, the OECD expands its analysis in two important domains: first, it focuses on the role of technological innovation in bringing down the costs of climate change mitigation over time. It argues that a concerted research and development effort can indeed be expected to yield important benefits, but not by itself. The pricing of GHG emissions is critical for ensuring that new technologies, once developed, are rapidly deployed where they are most needed.

The second new element is an analysis of carbon leakage: that is, the concern that GHG-intensive industries located in countries that take action will lose competitiveness vis-à-vis competitors in countries that do not. The OECD assessment is that while such effects are of concern, they diminish quite rapidly as the set of countries participating in climate change mitigation efforts grows. Excluding energy-intensive industries from GHG emission abatement rules is not economically efficient because it substantially increases abatement costs for the economy as a whole. In the absence of wide country participation in mitigation action, sector-specific arrangements for some of these industries may be an appropriate instrument for reducing carbon-leakage concerns. But it is clearly second best.

OECD will continue to advise countries to help them design effective climate change policies. A second phase of our work following this analysis will further investigate carbon leakage and competitiveness challenges and how to address them; international financial arrangements that would enhance incentives for action by all large emitters; comprehensive and cost-effective global action that can be progressively built-up by linking and expanding existing and prospective policies; identification of the conditions necessary for well-functioning local and global emissions permits markets; and policies to meet the challenges of deforestation and reforestation. We will be sharing the results of this new analysis in the course of the coming year.

In the meantime, while we work to restore confidence in the financial markets and to reactivate the world economy, we must integrate in such efforts the need to stop and reverse climate change and promote a “green recovery”. Indeed, the current economic crisis can be used to make progress in a new direction, to speed up our efforts to create a new “low-carbon growth” era. At OECD we believe it is possible to find opportunity in turbulence. I am confident that this analysis will help.



Angel Gurría
OECD Secretary-General

Introduction

Climate change is a fact of life. We need to act urgently if we are to avoid an irreversible build-up of greenhouse gases (GHGs) and global warming at a potentially huge cost to the economy and society worldwide. OECD analysis suggests that if we act now, we have 10 to 15 years' "breathing space" during which action is possible at a relatively modest cost. But every year of delay reduces this breathing space, while requiring ever more stringent measures to make a difference. Current financial turmoil is not a reason to delay. Indeed, its macroeconomic consequences will be resolved in a relatively short time, after which growth will resume, while the consequences of inaction on global warming will continue to grow more and more costly over time.

This booklet presents some of the major economic issues that will need to be considered in formulating a strategy to address climate change. It is grounded mainly in the wide-reaching OECD report on "The Economics of Climate Change Mitigation" (OECD, forthcoming 2008) and aims to present some of the key conclusions contained in that report and provide, in a relatively non-technical way, the necessary context. For much of the underlying evidence, and further clarification of important issues, the reader is referred back to the source report.

The focus of this booklet is on what is needed for a cost-effective approach to reducing GHG emissions. Some climate change is unavoidable, due to past and present emissions. Measures will be needed to adapt to this situation: such adaptation policies are explored in depth in other OECD work, but are not addressed here.

Is a cost-effective climate change strategy possible?

The build-up of greenhouse gases (GHGs) in the atmosphere, much of it driven by human activity, is already affecting the global climate. Under current projections, concentrations of GHGs will continue to increase into the indefinite future, entailing a process of continued global warming. Estimates of the costs of inaction on climate change vary widely, but there is no doubt that beyond a certain level of global warming these costs will be large, particularly in many developing countries as sea-levels and storm surges rise, heatwaves become more frequent and intense, and agricultural yields in rural areas decline. Even more disturbingly, each degree of global warming increases the risk of more destructive climate events, causing large and possibly irreversible damage worldwide.

If we look at the costs – and especially the risks – of inaction, ambitious action to reduce GHG emissions makes economic sense. It is vital that such action stabilises GHG concentrations, to slow down and limit global warming. The OECD analysis on which this booklet is based looks at a number of mitigation scenarios. They consider different target levels for long-term concentrations of GHGs, different time frames for achieving them and different ways of compiling the numbers. Any scenario designed to stabilise GHG concentrations at a level that keeps the risks of more destructive climate events moderate is an ambitious one. Most of the long-term targets being discussed would require, for example, eventually reducing GHG emissions to one-third or one-quarter of 2005 levels over the long term. Such radical change requires a

transformation of the economy that will not be either easy or cheap, and there is thus an enormous premium on developing a cost-effective set of policy instruments to achieve the required abatement.

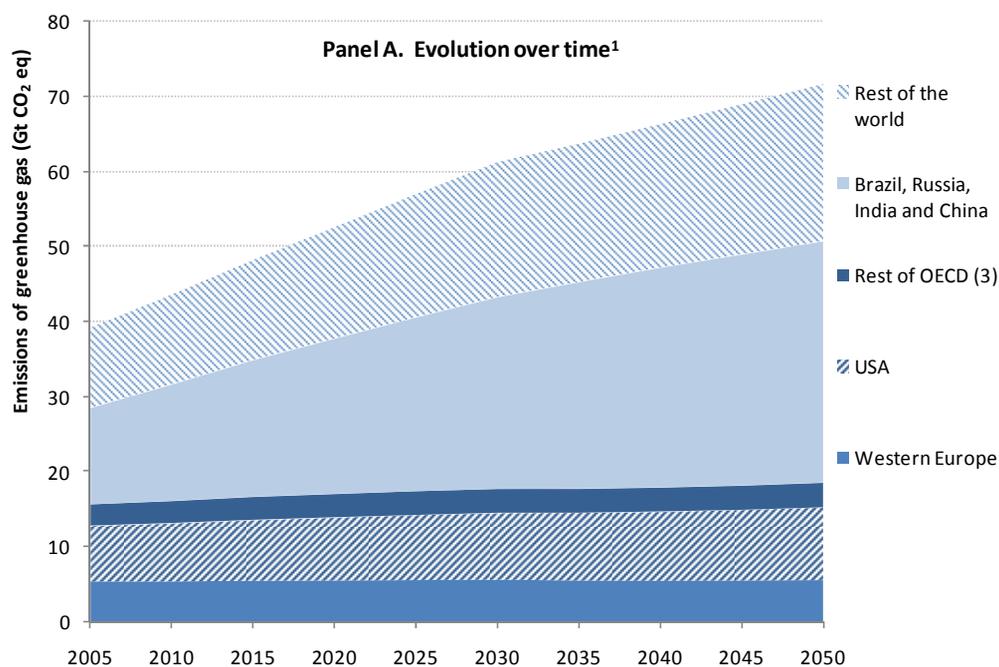
This booklet first offers an overview of where we are, where we are headed and where we need to go as regards climate change. It then focuses on three core issues for reducing global GHG emissions:

- To be cost-effective, cuts in emissions need to be made where they are cheapest. More specifically, the costs of any additional emission cut need to be equal for all sources of emissions, so that it would not be possible to lower overall costs by redistributing cuts. Putting a price on GHG emissions is the most obvious way to achieve this. Equally important, such pricing establishes incentives to undertake research and development (R&D) and innovate more generally in energy-saving and climate-friendly technologies. Such innovation is the best hope for containing the costs of curbing GHGs in the long run. However, in practice a broad mix of policy instruments will have to be deployed, because price measures cannot solve all problems effectively and the coverage of pricing schemes may be less than complete for some time.
- One concern that arises when some countries take ambitious action to abate GHG emissions but others do not is that energy-intensive sectors in abating countries will see the costs as too high for them, due to loss of competitiveness vis-à-vis countries that do not take action. The amount of “leakage” of emissions to countries which are not taking part in the effort appears to be relatively small if the pool of abating countries is reasonably large. However, short-term concerns in these countries about the impact of job-losses in energy-intensive sectors on overall employment could hamper progress in implementing climate policies. This booklet examines measures to address these concerns.
- The costs of both climate change and abatement action are unevenly distributed across regions and sectors. For this reason, incentives to participate in an abatement framework are also heterogeneous. A range of approaches and instruments may be helpful in providing support for action and generating buy-in, thereby achieving the wide country coverage required for cost-effectiveness.

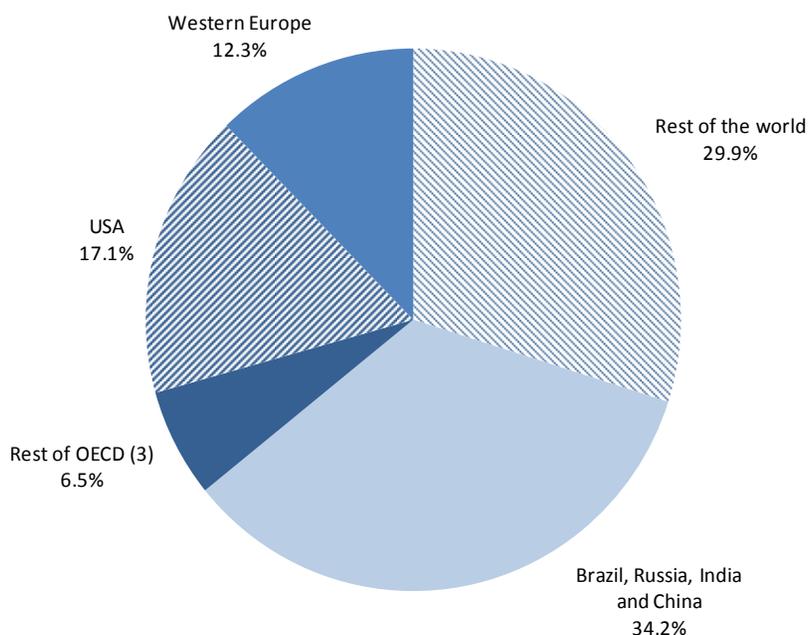
Where are we now, and where are we headed?

World GHG emissions have roughly doubled since the early 1970s, and on current policies could rise by over 70% during 2008-2050. Historically, energy-related GHG emissions were predominantly from the richer developed countries of the OECD, so that the rise in GHG concentration from the industrial revolution to today is largely accounted for by economic activity in these countries. Today, however, two-thirds of the flow of new emissions into the atmosphere is accounted for by developing countries outside the OECD, and without new policies this share is set to rise further to 2050.

Figure 1. **Developing countries would account for most of the projected increase in world greenhouse gas emissions over the coming decades**



Panel B. Breakdown in 2005²



1. Excluding emissions from Land Use, Land-Use Change and Forestry.
2. Including emissions from Land Use, Land-Use Change and Forestry.
3. Rest of OECD does not include Korea, Mexico and Turkey, which are aggregated in Rest of the World.

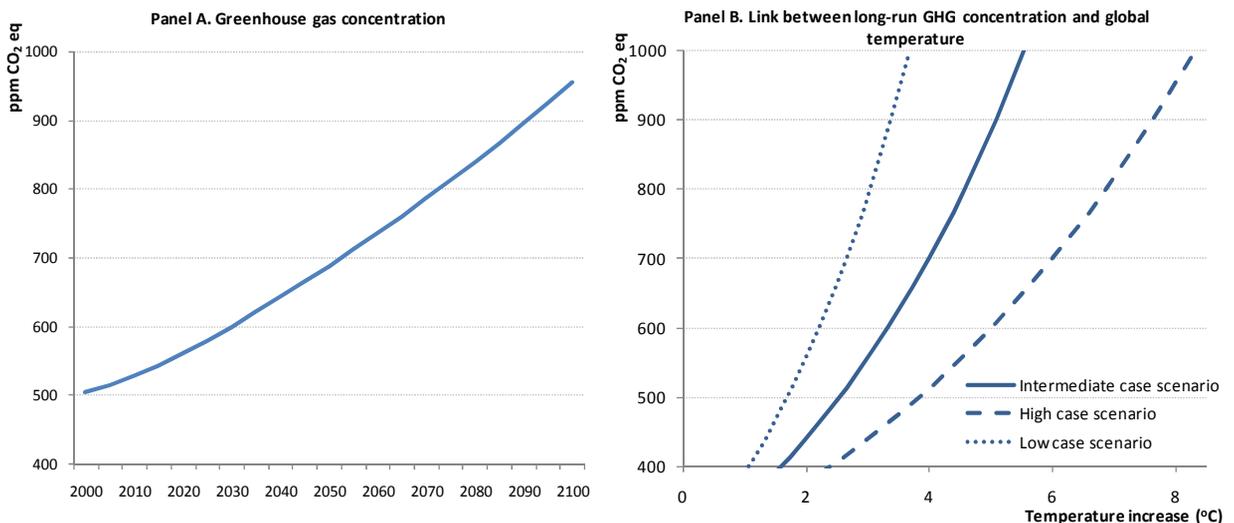
Source: OECD Environmental Outlook to 2030 (2008) and OECD ENV-Linkages model.

Greenhouse gases are emitted by many economic activities. Quantitatively, the largest share is accounted for by power generation (electricity production and transformation were responsible for 26% of global emissions in 2004), followed by industry generally (about 19%) and transportation (13%). It is important to note that deforestation and forest degradation (about 17%) are estimated to account for more emissions globally than the entire transport sector.

Figure 2 illustrates the likely build-up of GHG concentrations to 2100 based on a “business as usual” scenario and without any climate policies beyond those currently in place. It also shows the ultimate extent of global warming associated with these GHG concentrations. The OECD baseline scenario assumes world economic growth averaging just over 3.5% in purchasing-power-parity terms up to 2050, with a gradual catch-up in living standards of developing countries to those of the developed ones. In terms of emissions and resulting concentrations, the baseline is quite close to the average of other recent studies; some are more optimistic, but others less so.

Figure 2. Greenhouse gas concentration and world temperature would rise sharply without new policy action

(Projected trends in greenhouse gas concentration and associated temperature increases in the absence of new climate change policies)



Note: The scenarios embed different values for the climate sensitivity parameter. This parameter measures the impact on temperature of a doubling of concentration and determines the link between long-run GHG concentration and global temperature at the steady state. Because of the inertia of the system, steady-state temperatures may be reached several decades after concentration stabilisation. The climate sensitivity parameter equals 4.5 in the “high case” scenario, 3 in the “intermediate case” scenario, and 2 in the “low case” scenario.

Source: Magic 5.3, OECD ENV-Linkages model and IPCC (2007), AR4.

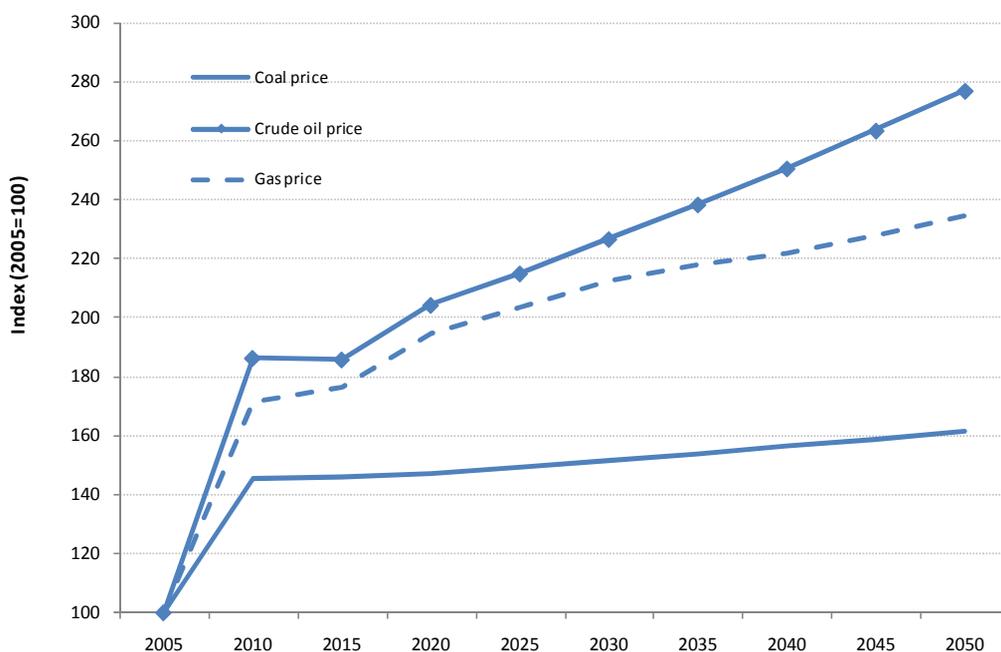
There are clearly grounds for concern. The mid-range estimate for global warming to the end of the century, close to 4° Celsius compared with pre-industrial levels, brings temperature to a level where destructive climate events are not improbable; and the temperature would keep rising into the next century even if concentration were to stabilise at that point. It has to be noted

that in many respects the OECD baseline scenario is not a particularly pessimistic one. Energy intensity – the amount of energy used to produce a given level of gross domestic product (GDP) – is assumed to fall continuously, partly because as living standards across the world converge, GDP shifts steadily towards less energy-intensive products. At the same time, ongoing efficiency gains are expected in the use of energy, partly as a result of high energy prices.

Some might argue that the problem just cannot be this bad, and at least two lines of argument deserve brief comment here. One is that the rise in oil and other energy prices in recent years should, if sustained, trigger major changes in behaviour that would in turn curb emissions. The second is that the baseline scenario underestimates the capacity for technological innovation to find solutions to problems.

There is of course an important element of truth in the energy price argument, although volatile oil prices do not provide clear signals to motivate long-term changes in behaviour. Figure 3 shows the energy price paths built into the OECD baseline. The price of oil is projected to keep rising as conventional oil becomes increasingly scarce relative to demand because of the depletion of oil reserves. But while oil is scarce, other hydrocarbons – notably non-conventional oils such as the Canadian tar sands and coal – are much less so. So the OECD baseline shows the price of coal, in particular, as levelling off even as more coal is being used. The problem is that non-conventional oil and coal are actually more carbon-intensive than petroleum, so that the estimated CO₂ intensity per unit of energy consumed rises by some 35% between now and 2050. In other words, any possible reduction in emissions due to less use of motor transport due to high oil prices is mostly offset by a shift to more CO₂-intensive coal in power generation.

Figure 3. **The conventional oil price is set to rise but coal would lag**



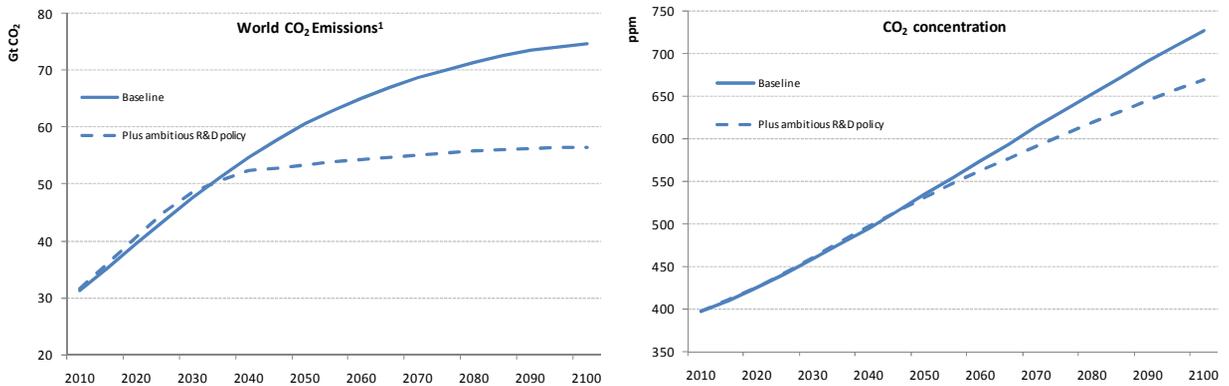
Source: OECD ENV-Linkages model.

When it comes to the argument that innovation will save the day, it is certainly true that innovation policies will play a central role in making a mitigation strategy affordable. But Research and Development (R&D) efforts, however intensive, cannot by themselves accomplish enough if the incentives to deploy new technologies are weak. Figure 4 seeks to illustrate this point by presenting an alternative scenario that includes an aggressive world-wide policy of investing in abatement-related R&D, raising such spending four-fold from current levels as a share of global GDP back to the peak levels observed in the early 1980s, but without applying any other policies to reduce emissions.

While such an R&D-led approach clearly yields some results, OECD estimates suggest that these are not nearly enough to stabilise GHG concentration levels by the end of the century. In fact, even a 30-fold increase in worldwide public R&D spending on low-carbon technologies, raising it to about 1% of global GDP annually, would not be enough to achieve this target. The essential problem is that, even if innovative and effective technologies emerge, they will not be intensively used until their costs come down close to those of existing competing technologies, unless incentives are put in place for people to use them. Such cost falls typically take a very long time. Carbon capture and storage (CCS) technology provides a telling and extreme example of this challenge. This technology is still new and expensive. Intensive R&D efforts would in all likelihood bring costs down steadily. But this technology would not be widely used in power generation unless there were significant incentives to cut carbon emissions, since otherwise it reduces generating efficiency and hence raises costs without providing any return.

Figure 4. R&D is needed but alone is not sufficient

(The impact of R&D policies acting alone on CO₂ emissions and concentrations)



1. CO₂ emissions excluding emissions from land use, land-use change and forestry. Emissions of non-CO₂ gases are not covered by the model used in this analysis and are therefore excluded from these simulations.

Source: WITCH model simulations.

What can be done?

Faced with the consequences and costs of inaction, governments have reached a consensus internationally that global emissions need to be cut significantly. Countries are working towards an international framework for action, with the aim of reaching agreement at the UN Climate Change Conference to be held in Copenhagen in late 2009.

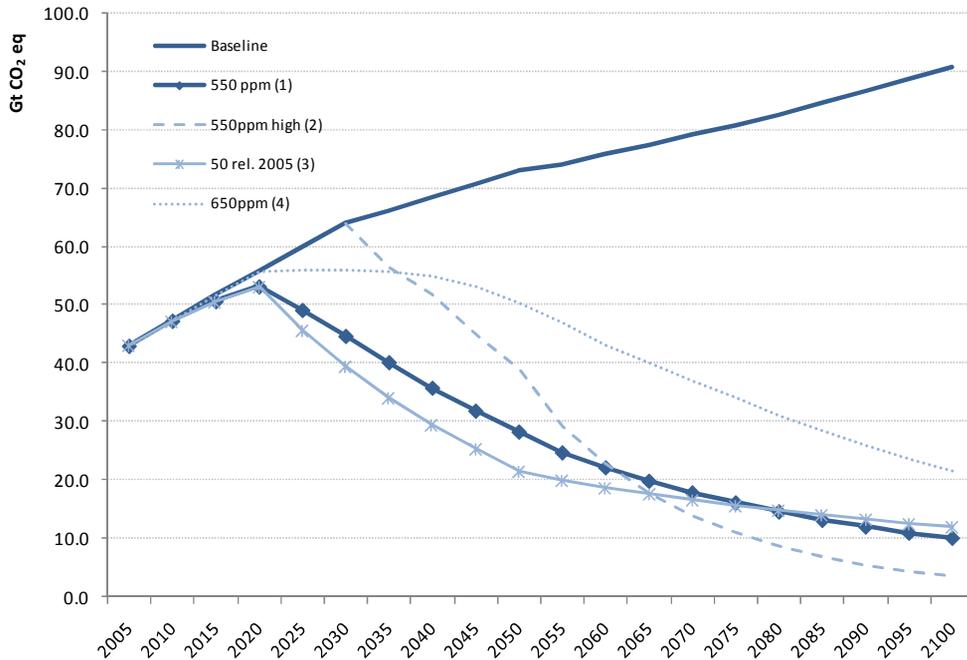
The OECD has simulated a number of possible scenarios for ambitious reductions in GHG emissions along with their economic and environmental impacts compared with those of the baseline scenario with no new policy action. Figure 5 presents the time path of GHG emissions associated with these scenarios.

For illustrative purposes the economic issues involved in designing a comprehensive approach to reducing emissions are explored here primarily by examining one mitigation reference scenario. This scenario eventually stabilises GHG concentrations at a level equal to 550 parts per million (ppm) of CO₂ (or about 450 ppm CO₂ only), while allowing a moderate overshooting of this level over an interim period. It has to be emphasised that this scenario has no specific normative significance. Indeed, many countries have taken the view that a more ambitious objective would be appropriate as would be required, for instance, to cap the extent of global warming at 2°Celsius. But for illustrative purposes, this booklet focuses on one scenario and uses this to examine quantitatively how different policy assumptions might affect overall results.

Major changes in behaviour and production methods will be needed to achieve GHG mitigation at the lowest possible cost. Mitigation is achieved by reducing both the energy intensity of GDP and the carbon intensity of energy used. As a side effect of these changes, GDP growth will also be affected, as shown in the top panel of Figure 6. Under the mitigation reference scenario examined here, it is estimated that the average growth of the world economy over the period 2008-2050 would be some 0.13 percentage points lower than in the absence of climate change policies. The impact on GDP growth is small in the early years, but increases significantly after 2025. By 2050, the level of world GDP is estimated to be some 4.8% below what it would be in the absence of climate change policies. The reason for this GDP loss is that substantial human and capital resources will have to be shifted to working on GHG mitigation, thus reducing the resources available for producing other goods and services. While abatement obviously generates other benefits in terms of avoided climate change damage, such benefits are not always directly captured in conventional GDP, and are not reflected here.

Figure 5. **Stabilising the climate will ultimately require large emission cuts**

(Greenhouse gas emissions in an illustrative 550 ppm stabilisation concentration scenario, 2005-2100)

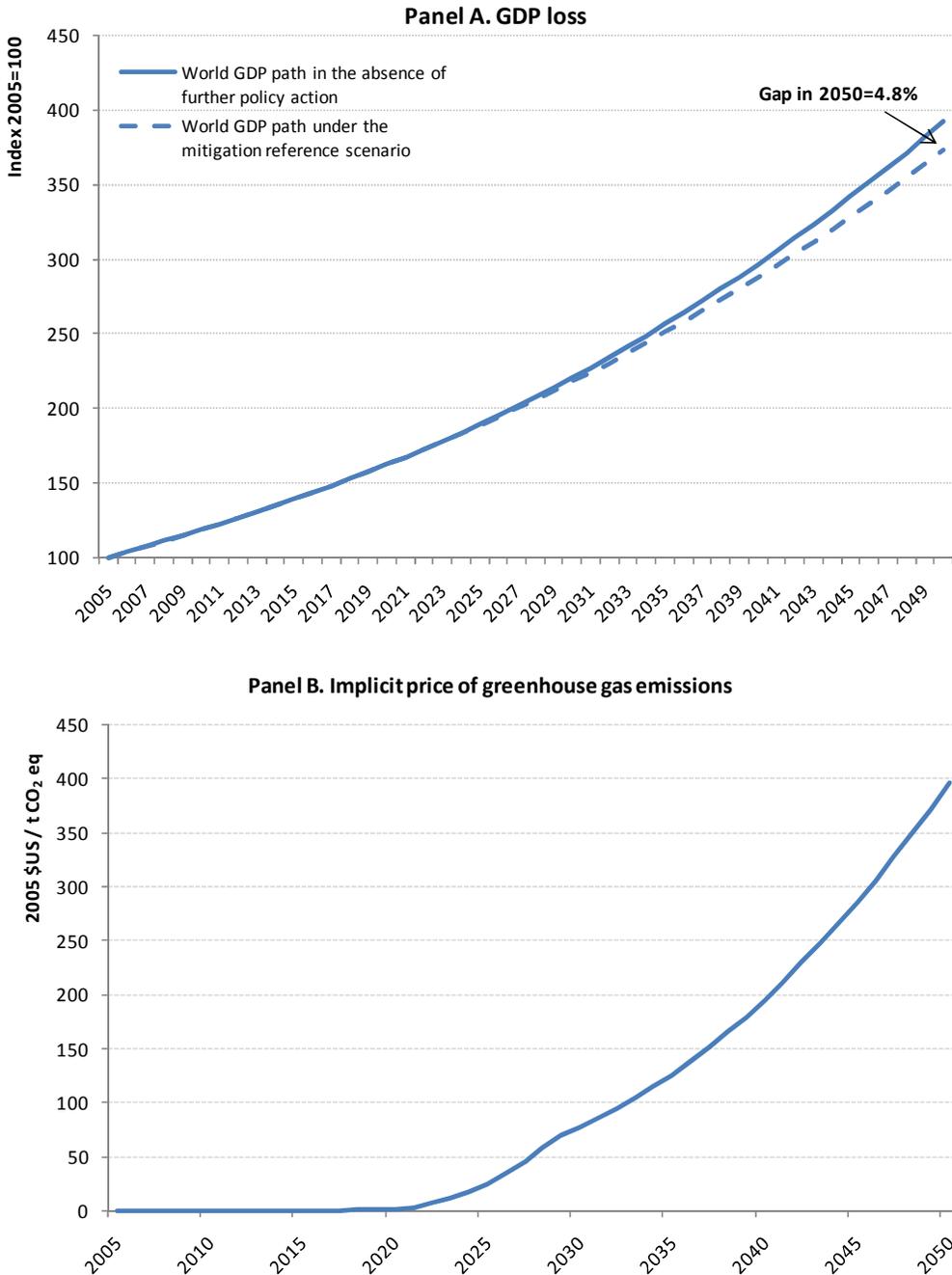


1. Stabilisation at 550ppm CO₂ eq all gases included (corresponding to about 450ppm CO₂ only) with modest overshooting.
2. Stabilisation at 550ppm CO₂ eq all gases included (corresponding to about 450ppm CO₂ only) with high overshooting.
3. 50% GHG emission cut in 2050 with respect to 2005 levels.
4. Stabilisation at 650ppm CO₂ eq all gases included (corresponding to about 550ppm CO₂ only) without overshooting.

Source: OECD ENV-Linkages model.

Ambitious GHG abatement is economically rational, but it will not be cheap. The costs would be lower if a less stringent emissions pathway were chosen, or if greater overshooting of the target were allowed. For instance, allowing more interim overshooting (to over 600 ppm instead of about 560 ppm) could lower the GDP loss in 2050 to around 2%. But such overshooting would come at the price of greater risks of irreversible damage from climate change and would merely postpone some of the costs farther in the future. It is also the case that the cost estimate presented could be lower if certain mitigation options not built into the reference scenario were taken into account. Three of these, related to energy subsidies, reforestation and the emergence of major new low-carbon technologies, are discussed below. On the other hand, the cost estimates may be optimistic in that they assume that all world emission sources are covered and that the large required shifts in resources all take place smoothly, without transitional costs.

Figure 6. **Cost-effective mitigation action would imply only limited costs in the first decades**
 (Time profiles of economic costs and the implicit price of greenhouse gas emissions under the mitigation reference scenario)



Source: OECD ENV-Linkages model.

The bottom panel of Figure 6 shows the development over time of the price that emitters would need to be charged for each ton of GHG emissions to induce them to reduce emissions enough to keep global emission trends on track with the scenario. This implicit price of GHG emissions plays a central role in the reference scenario and indeed in other cost-efficient alternatives. It is assumed

to apply to all greenhouse gases, across all sectors and all regions. This approach ensures that abatement costs are equal at the margin across all abatement options, so that abatement takes place where it can be done most cheaply. This is important. If for instance, pricing, covered only CO₂ rather than all greenhouse gases, the GDP cost of meeting the abatement target would almost double. Likewise, if pricing – and in fact any mitigation action – applied only to Kyoto Protocol “Annex I” countries (essentially most OECD countries plus Eastern European economies in transition, including Russia) and left out the rest of the world, the mitigation reference scenario would be unattainable since it would require emissions for the Annex I countries to fall below zero. Participation by the major emerging economies such as China, India and Brazil will therefore be essential to reach ambitious emission reduction targets.

The implicit price of GHG emissions in this scenario is relatively low in the early years. This is because a cost-efficient scenario begins by cutting emissions where this can be done most cheaply, and because there is still an abundance of such cheap options available to exploit. For example, technologies are available that can sharply reduce methane emissions from landfill at relatively low cost but such technologies are by no means generally implemented. The low initial price also reflects the fact that the pace of abatement is relatively slow at the beginning (see Figure 5). The reason for this is that trying to move too quickly can be very costly if it means scrapping existing carbon-intensive facilities before they need replacing. Some facilities, notably in power generation, often have an effective lifespan of more than 50 years; it takes 10 to 20 years to renew a fleet of automobiles. But by the same token, long-lived investment decisions being made today will need to be geared to the much higher emissions price that will prevail in the longer term.

The implicit price of emissions in the scenario rises sharply as cheap abatement options are exhausted and increasingly costly ones need to be implemented. Indeed, by 2050 the “market value” of total emissions reaches some 6% of world GDP. OECD analysis of the reference mitigation scenario using a model allowing for detailed technological analysis can give some flavour of the kinds of adjustments that take place as the price rises:

- Much of the economic response comes in the power sector, currently the largest source of emissions. As carbon emissions become more expensive, nuclear power generation, which does not emit carbon, becomes increasingly attractive. Indeed, it accounts for a growing share of total power generation capacity in the reference scenario. At the same time, coal-powered generation increasingly uses carbon capture and storage technology (CCS). In the mitigation reference scenario, power from renewable energy such as wind and solar will also increase strongly in percentage terms. However, their contribution to total energy production in global terms is assessed by OECD to remain relatively small.
- In industry, currently-available technological alternatives are less easily identifiable. Of course, higher carbon prices will induce changes in consumption patterns, leading to a shift in production towards less carbon-intensive sectors. At the same time, both market-driven and policy-induced technological progress can be expected to generate a range of improvements.

- The transport sector may be the most challenging in the sense that even very large changes in the cost of emissions appear to have only modest impact on their level. Price changes seem to produce only small behavioural changes in automobile use in the short run, and are slow to come even when public transport alternatives are well-developed, as in Europe.

As noted above, three important *caveats* need to be appended to the mitigation reference scenario presented here. The first is that it does not include some low-cost abatement options. For instance, current policies that actually subsidise carbon emission could be eliminated. Figure 7 shows estimated energy subsidies in selected developing and middle income countries in 2005. Current subsidies are unlikely to be any lower than this, given that energy prices have increased significantly since 2005 and policies in many countries have not yet fully caught up, as the IEA's 2008 World Energy Outlook points out. Of course, such subsidy programmes are intended to achieve other objectives, but they may not be effective even for these. Take India, for example. The 2007 OECD *Economic Survey of India* found that energy subsidies were not achieving the social objectives they were designed for but were constraining growth. Another option not included in the mitigation reference scenario is to reduce trade-barriers on environment-friendly and energy-efficient products; this would directly reduce abatement costs by making such goods cheaper in countries that reduce their trade protection.

The second *caveat* concerns deforestation/reforestation options. Currently, global deforestation and forest degradation (despite some reforestation in OECD countries) is releasing large volumes of CO₂ emissions into the atmosphere, strengthening the greenhouse effect. Compared with the tapering off of global deforestation built into the baseline, the mitigation reference scenario embodies no further action in this sector. But an aggressive policy to eliminate deforestation and boost reforestation could contribute significantly to achieving the required abatement. However, there is still much uncertainty about both the costs and the effects of such policies (or indeed, how to design them) and hence these were not explored quantitatively in the OECD analysis.

The final *caveat* relates to as-yet unidentified technologies that may be developed in the future and which could significantly alter the costs of mitigation. Three points in particular should be noted:

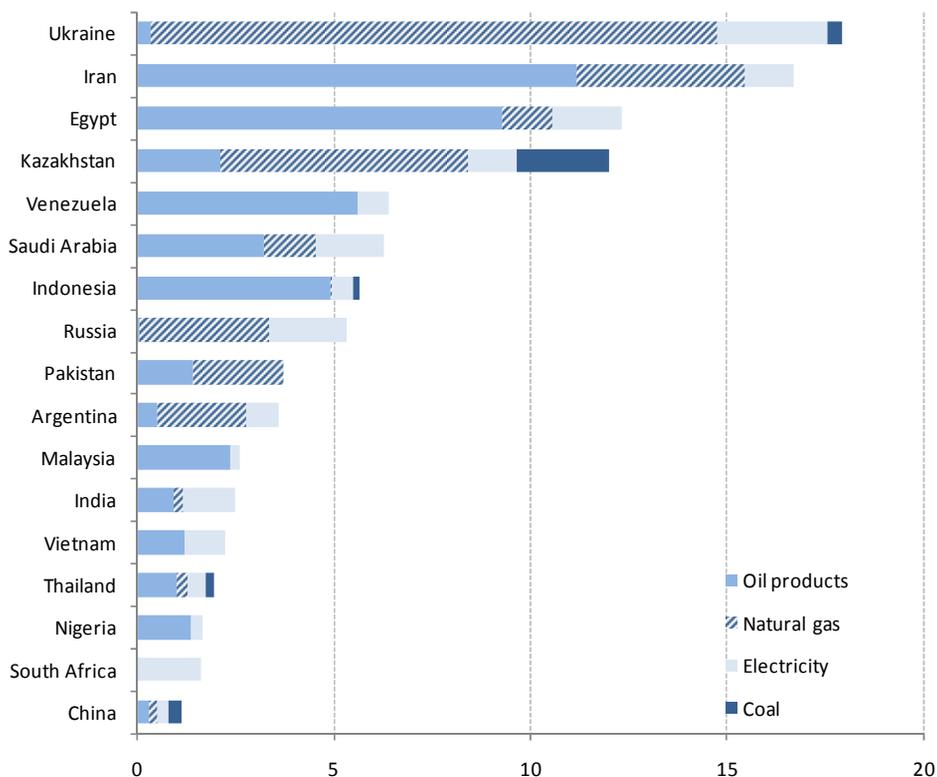
- Very significant reductions in the costs of meeting the mitigation scenario could be achieved if intensified R&D policies resulted in the early development of radical new technologies for energy generation and, above all, for the transport sector. Fuel-cell technology, for instance, might provide such a breakthrough for the transport sector; but at this stage a wide range of technological options need to be explored.
- Initially, such new technologies would likely be prohibitively expensive, but R&D and learning-by-doing might bring their costs down to economically relevant levels over time in the face of strongly rising costs of emitting GHGs. The relatively greater urgency for technological breakthrough in the transport sector reflects the fact that nuclear power and CCS provide substantial scope for reducing GHG emissions from power generation, even if no breakthrough technology emerges in that sector. If social or other concerns were to inhibit the full deployment of nuclear and CCS options, a new solution for the power sector would

become equally urgent. Figure 8 makes the point that, provided emission pricing creates incentives to deploy them, the availability of new technologies could reduce the overall global costs of meeting the mitigation reference scenario objectives by as much as one-half by mid-century. By contrast, in the absence of new technologies, constraints on the deployment of nuclear and CCS would raise the cost of achieving these objectives substantially, as shown in Figure 9.

- However, major breakthroughs do not come for free. Developing new technologies will require a massive up front R&D effort in the years to come, boosting such R&D several fold. This will raise the medium-term costs of meeting the ultimate objectives in the sense that these R&D efforts will drain resources from other sectors, thereby lowering their growth potential. But they will substantially lower the long-term costs of GHG abatement and bring down the implicit price of carbon relative to the mitigation reference scenario.

Figure 7. **Energy subsidies remain high in a number of developing and middle-income countries**

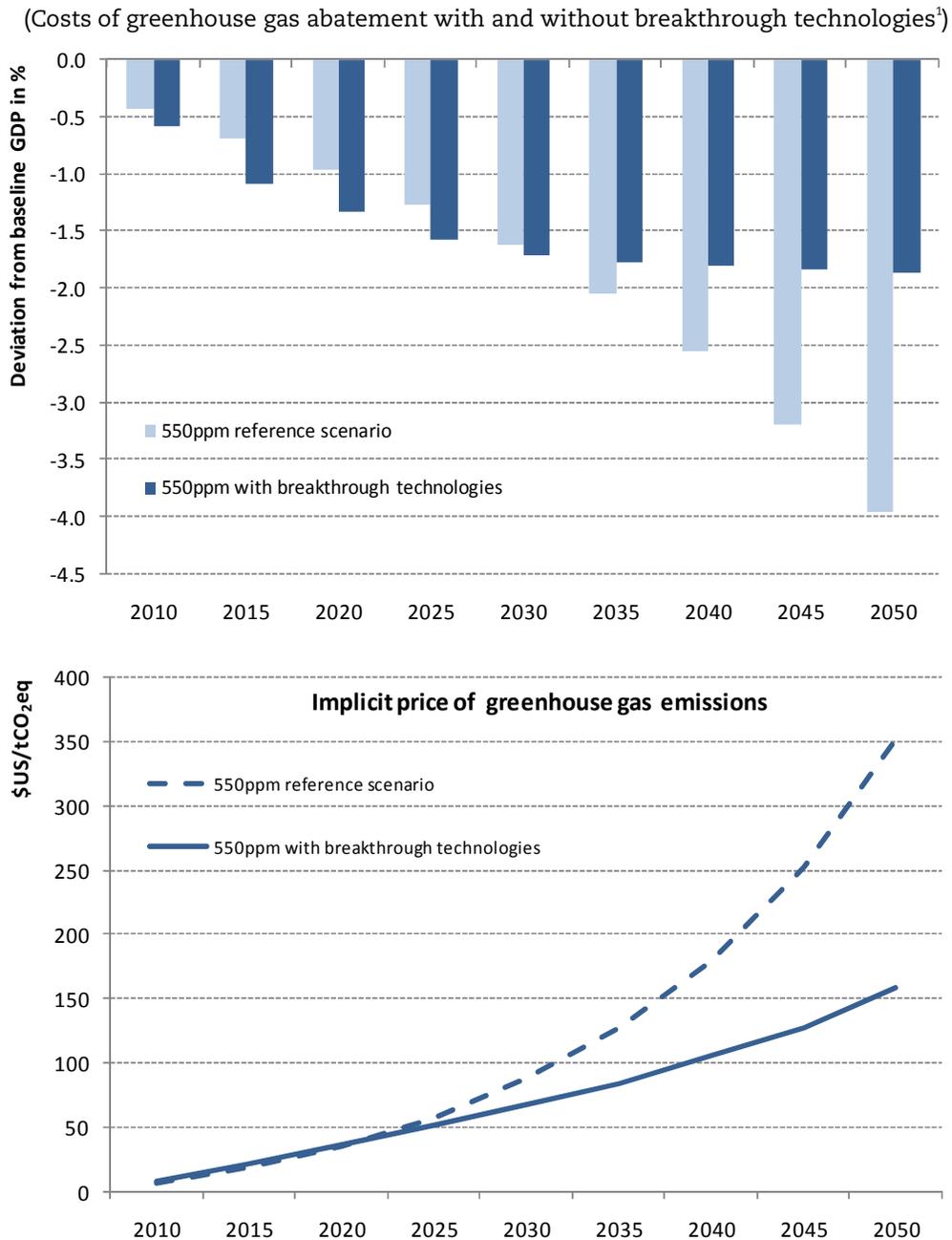
(Energy subsidies as a % of GDP, 2005)



1. Such subsidies can take the form of direct financial interventions by government, such as grants, tax rebates or deductions and soft loans, and indirect interventions, such as price ceilings and free provision of energy infrastructure and services.
2. Although no comprehensive up-to-date data on energy subsidies are available, existing evidence points to large increases in recent years. For instance, according to IEA, oil subsidies in China, India and the Middle East have increased from about \$US50 billion overall in 2005 to \$US85 billion in 2007. These figures do not account for the most recent reductions in subsidies, however.

Source: IEA (2006).

Figure 8. **Major technological breakthroughs could halve mitigation costs by mid-century**

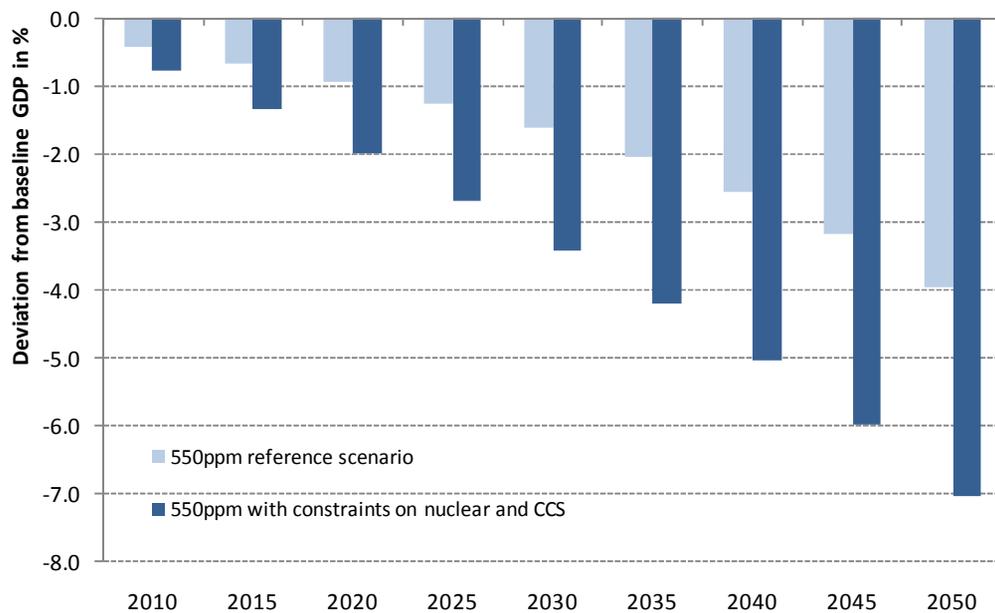


1. Emissions of non-CO₂ gases are not covered by the model used in this analysis and are therefore excluded from these simulations. The 550ppm greenhouse gas concentration stabilisation scenario run here is in fact a 450 ppm CO₂ only scenario and greenhouse gas prices are CO₂ prices. Stabilisation of CO₂ concentration at 450ppm corresponds to stabilisation of overall greenhouse gas concentration at about 550ppm.

Source: WITCH model simulations.

Figure 9. **A wide range of technological options are needed to keep mitigation costs low**

(Projected costs under the mitigation reference scenario, with and without constraints on nuclear energy and carbon capture and storage¹)



1. Emissions of non-CO₂ gases are not covered by the model used in this analysis and are therefore excluded from these simulations. The 550ppm greenhouse gas concentration stabilisation scenario run here is in fact a 450 ppm CO₂ only scenario. Stabilisation of CO₂ concentration at 450ppm corresponds to stabilisation of overall greenhouse gas concentration at about 550ppm.

Source: WITCH model simulations.

What mix of policy instruments is needed to implement a cost-effective strategy?

GHG abatement in the reference scenario described above is driven by an implicit price of GHG emissions that equalises abatement costs across all sources of emissions at each point in time. This implicit price rises over time to bring in increasingly costly abatement options as less-costly ones are exhausted. It is these features of the scenario that make it cost-efficient. However, actually establishing such a path in the real world is far from straightforward. We cannot expect markets by themselves to set an emissions price since the atmosphere is a free dumping-ground for any individual emitter. One straightforward way of setting a price is to put a tax on all carbon emissions. Another option is to require all emitters to acquire permits for their planned emissions. This option, which is increasingly the focus of action in individual countries or regions (see Box 1), may need a few words of explanation. First and foremost it requires setting an overall target for emissions. Permits are then issued up to this target. Permit holders can trade them among themselves, so that those who exceed their emissions target can buy extra emission rights from those who do not use all of theirs. The price of traded permits will reflect the overall tightness of the target relative to current emission levels; and the higher the price, the greater the incentive to cut emissions. How permits are allocated initially is an

important issue: they can be auctioned off by an issuing authority; or they can be distributed free to existing emitters in proportion to past emissions (“grandfathering”) or allocated by some other rule.

Such a scheme, called a cap-and-trade or emissions trading system, can be implemented at various levels – nationally or internationally, covering all sectors or only specific ones. The wider the coverage, however, the broader the trading options among emitters, and hence the greater the cost efficiency of the system. Such a “cap-and-trade” system is now in operation in the European Union, Norway, and some states in North America. A number of other countries are discussing or planning to introduce such a system. Cap and trade seems to be increasingly of more interest than GHG taxes. Box 1 summarises the relative costs and benefits of these two approaches.

Box 1. **Why cap-and-trade?**

Both GHG taxes and cap-and-trade systems generate prices for GHG emissions, but they do so in different ways. In an uncertain world these differences affect the relative attractiveness of these options, though currently cap-and-trade approaches are increasingly the focus of interest in most countries or regions considering market-based approaches to reducing GHG emissions. Five points are worth noting:

- A GHG tax in principle provides price certainty to markets. Polluters can calculate how much their emissions will cost them in taxes and take the appropriate abatement actions to reduce these costs. Cap-and-trade systems cannot provide such certainty since the permit price will be determined by supply and demand which can fluctuate over time, and may indeed be quite volatile. However, cap-and-trade provides greater certainty as to the resulting emissions, which are the target of the measures.
- Cap-and-trade schemes may be more robust, and hence credible. Credibility is extremely important because it is not so much today’s price that drives decisions about what abatement and R&D efforts are worthwhile, but rather the prices expected in the future. In the case of GHG taxes, the problem is that governments cannot commit to future tax changes, so that their announcements about future plans may not be believed. It is of course equally true that governments cannot pre-commit to cap levels that will be applied in the future. But once a cap-and-trade system is set in motion, a constituency progressively develops that has a clear interest in seeing the scheme continue – namely permit holders and other market actors (e.g. brokers). Having invested in permits, this constituency would lose money if the cap were subsequently eased because the price of permits would fall. This “locking-in” effect only works if permits can be “banked” – that is, if permits not used today can be used tomorrow. So companies who foresee strong growth in their production plans will buy extra permits today, bank them, and use them later rather than risk having to go into the market in the future when permit prices might be high. Long-dated permits that provide emission rights over a number of years would work in the same way.

Box 1. Why cap-and-trade? *(Continued)*

- Another important feature of a cap-and-trade approach is that it allows for a decoupling of who undertakes abatement and who pays for it. While the total amount of permits issued has to be equal to the agreed emissions cap, these permits can be allocated to individual emitters (or individual countries in a global scheme) in a variety of ways, so that some may get more permits than they need and sell the excess to earn income, while others are forced to buy permits on the market to meet their needs. It is important to emphasise that, at the margin, buyers and sellers face the same incentive to abate, so the allocation of permits has no implications for the efficiency of the scheme, but only for who bears what share of the cost.

Finally, a GHG tax generates government revenue and thus in principle provides scope to lower other taxes and offset some of the economic costs stemming from the higher GHG taxes. Under cap-and-trade, government revenues would also be increased if permits are auctioned off to emitters. Governments could of course choose to distribute permits for free, and initially this was largely the approach taken in the EU system, with permits allocated to emitters in proportion to their previous emission levels. However, if such an approach (grandfathering) is needed to achieve buy-in from energy-intensive firms, it should be phased out rapidly, as it is costly and risks entrenching competitive advantages for incumbents vis-à-vis potential new entrants (whether domestic or foreign). By contrast, auctioning off permits from the start or after a brief transition could provide revenues to replace existing taxes.

In practice, a broad mix of policy instruments in addition to GHG pricing will need to be deployed to achieve the desired abatement. Indeed, there are many other ways to create incentives to reduce emissions, apart from setting a price via a tax or emissions trading. While non-price instruments do not necessarily guarantee cost-efficiency by equalising marginal abatement costs across emission sources, there are a number of reasons why these instruments are nonetheless essential. Four examples are worth highlighting:

- Some markets are not as responsive to price signals as they should be. For example, in markets where a small number of large firms are dominant, responses may be delayed. This is even more likely to be the case if such firms are publicly owned and assigned objectives other than economic efficiency. In such cases performance standards in terms of emission reductions may yield better results. Also, some markets are characterised by problems of information asymmetry. Take housing – landlords are unlikely to invest optimally in environmental design because it is the tenant, who in many cases has less information than the landlord about the cost and availability of energy efficient alternatives, who pays the costs of inferior design. Performance standards built into building codes is one way of addressing this problem.
- While emissions monitoring is improving, there will always remain areas where such measurement is difficult, reducing the effectiveness of price-based instruments. For example, leakage from gas pipelines may generate large GHG emissions. But such leakages may go undetected for a long time. Strict technical requirements to limit the risks of leaks might be required in this case.

- Two very important sectors, international shipping and air transport, appear to be very difficult to integrate into any cap-and-trade scheme since it is inherently unclear which country is actually responsible for the emission. Specific global approaches to addressing these sectors would seem to be required.
- Perhaps most important, R&D investment and innovation more generally, are not adequately guided by price signals alone. The core of the problem is that the incentive to innovate requires not only that the innovation is valuable in the marketplace, but that the innovator can reap these rewards and not have them expropriated by imitators. Intellectual property rights regimes are designed to achieve this by assuring the innovator exclusive right to the innovation for some period. But such regimes also slow down the speed with which the innovation is diffused throughout the economy, which creates incentives to weaken them. This problem is likely to be particularly acute with respect to R&D related to climate change for two reasons. First, developing countries may consider access to the most efficient abatement technologies to be an important element in their agreeing to participate in overall abatement efforts. But from the perspective of innovators, this weakens the credibility of intellectual property rights and thus reduces their incentive to undertake innovation. Second, the value of R&D in climate change is essentially dependent on the credibility of the abatement policies that have been instituted. If innovators are not sure that governments will follow through on their intended policies, incentives for the private sector to invest in such R&D are likewise weakened. There is no simple answer to dealing with this issue, but it suggests that there will be an important role for government action to foster – and indeed initiate – R&D on climate-change technologies.

While a multiplicity of instruments and measures will need to be deployed, one important insight from the implicit global carbon price built into the mitigation reference scenario needs to be re-iterated. To keep the costs of action low, the cost of abating an additional ton of CO₂ equivalent must be equalised across countries and across the various instruments (see Box 2). It will thus be important that all measures are evaluated and perhaps modified over time to assure that the implicit carbon prices generated or implied by different measures do not diverge too much from that generated by a comprehensive price-based mechanism. At the same time, it needs to be recognised that if non-price and price-based instruments overlap, there may be significant distortions that need to be addressed. Efficiency concerns may be particularly important with respect to measures that target abatement through technology standards (i.e. standards that impose a particular technology on specific activities). Failure to update such measures as new technological opportunities open up could thus risk locking enterprises into sub-optimal technological choices. Performance standards, which require a specified outcome, but leave the decision about how to achieve it up to the individual enterprise, are less vulnerable in this respect.

Whatever global framework for GHG abatement emerges from international discussions, it is unclear whether a cost-effective approach can be implemented at one stroke. But a growing number of countries will likely implement abatement strategies using the various instruments available. Already, most industrialised countries are either implementing, planning, or considering cap-

and-trade schemes. As such, it is likely that price-based mechanisms will constitute an important part of national strategies to address climate change.

Instead of a grand global bargain, it is easier to envision an evolutionary approach to developing a comprehensive framework for reducing emissions worldwide. Given the urgency of the problem, however, it is essential that such an approach is accelerated, since time lost will steadily increase the ultimate cost of reaching a sustainable outcome. Even if cap-and-trade is implemented in a fragmented way initially – for example through agreements covering certain countries only, perhaps complemented by sector-based approaches for carbon-intensive sectors – linkages across such initiatives could be developed progressively. Countries initially unprepared to sign up for a binding emissions cap could be encouraged to do so once a certain development threshold is achieved. Countries initially reluctant to participate in concerted international action could nonetheless agree to undertake specific important abatement efforts. Indeed, actions or commitments that become increasingly ambitious with time would seem to be essential for some large players, notably India and China, if climate change abatement is to have any chance of durable success. Through avenues such as these, a global comprehensive approach for reducing emissions can be built up progressively. The absence of a comprehensive framework in the near term does, however, create additional problems, in particular that of “carbon leakage”, which is taken up in the next section. Considerations for how to maximise global buy-in are then addressed in the final section.

Box 2. The implicit carbon price of regulations and other policy instruments

While a carbon tax or the price of a permit under a cap-and-trade scheme provide explicit prices, non-price instruments also place an implicit price on GHG emissions. For instance, setting emission standards for automobiles requires manufacturers to invest heavily in the technology and vehicle redesign needed to meet such standards; and if the standards are tough, the cost could be very high.

Requiring that a certain share of power generation has to come from renewable sources creates higher demand for such renewables, driving up their price and eliciting more supply. The resulting gap between the price of renewable energy and conventional energy represents the “implicit price” of carbon emissions generated by this regulation.

One other important example concerns current biofuel subsidies. These are widely used in OECD countries, and a lot of taxpayers’ money is spent on them. This obviously encourages biofuel production. Measuring these subsidies in terms of how much is paid per ton of CO₂ emissions avoided gives estimated implicit prices in excess of \$1 000. Given that the price of CO₂ in the mitigation scenario described here does not rise above \$50 (2005 dollars) until sometime after 2025, these subsidies seem a rather costly way of achieving emissions reductions. Of course, they may also be contributing to other policy objectives. Energy independence is one; another is that these high subsidies now contribute to encourage learning-by-doing, which will eventually result in the development of much more cost-effective biofuel, for example using so-called “second generation” biofuel technologies. But it can be questioned to what extent deployment subsidies on this scale, as opposed to direct support for R&D in this area, are efficient.

How to deal with the economics and political economy of carbon leakage?

Some argue that a certain number of inherently energy-intensive sectors might be excluded from a climate change abatement strategy on the grounds that they could not survive a high and rising carbon price, with consequent massive job losses. The logic of this argument is hard to accept if the abatement strategy is truly global in its reach, since costs would then rise for all producers in these sectors, wherever they are located. Prices for these products would rise, demand for them would fall, the industries concerned would shrink somewhat and their emissions-intensity would diminish. Overall emissions would be reduced through both channels, which is precisely what is required. Human and capital resources released from the contracting sectors would move to other uses, not least to the new climate-friendly industries that would be growing rapidly in this environment. On the other hand, excluding energy-intensive sectors such as steel, aluminium and cement from a climate-change abatement effort could, by forcing more stringent abatement on other sectors, increase the costs of meeting the mitigation scenario examined here by over 50%, according to OECD analysis.

There is an argument, however, that if only some countries or regions participate in ambitious climate policies, then energy-intensive industries in participating countries would be at a disadvantage *vis-à-vis* competitors in non-participating countries. At the same time global emissions would not fall by as much as expected due to “carbon leakage”, where emission reduction in participating countries may be offset by higher emissions in others. This argument has been particularly active recently within the European Union, where a regional cap-and-trade scheme is operating, as well as in discussions about cap-and-trade schemes in other countries, such as Australia and the United States.

In fact, carbon leakage operates through two distinct channels: a competitiveness effect, and an energy-intensity effect that may also lead to increased emissions outside the participating countries. The energy-intensive effect would come because abatement in participating countries would reduce demand for fossil fuels worldwide, pushing their price down. This may lead non-participating countries to produce and consume more energy-intensive products than they otherwise would as these become cheaper.

Measuring the quantitative significance of these effects is not entirely straightforward. Plant location decisions are complex, for example, and it is difficult to assess how strongly avoiding a carbon price figures among all the incentives for shifting production. In particular, energy-intensive plants typically embody a lot of capital, and scrapping costs are often high particularly for newer, more energy-efficient plants. At the same time, the extent to which reduced global demand for fossil fuels will affect their price is difficult to assess, particularly for petroleum and natural gas, since the major world suppliers have substantial market power and could pursue a range of supply strategies.

With these caveats, two relatively robust findings emerge:

- First, carbon leakage effects can be important if the group of countries that constrain emissions is small; but these diminish rapidly as this group grows. As a concrete illustration, if the European Union were (counterfactually) to act alone to curb its GHG emissions by 50% between

now and 2050, while other countries took no action, about 20% of this emission reduction would be offset by increased emissions elsewhere. But if Annex I countries were to implement a 50% cut in their emissions, the increase in emissions outside this group would fall to just over 9%. It would obviously fall much further still if major developing countries were also to participate. This sharp reduction in leakage mainly reflects the fact that competitiveness effects are weakened when more potential competitors are covered by the abatement effort.

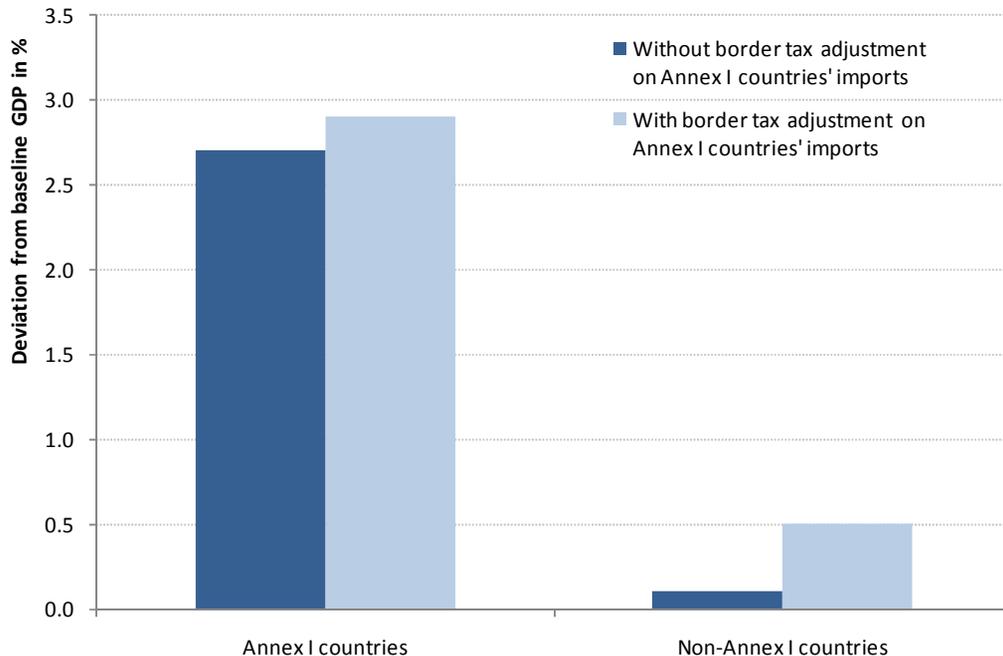
- In terms of the output of energy-intensive industries, what stands out is that if the European Union were to act alone, these energy-intensive industries might shrink by some 6% by 2050, while continuing to grow in the rest of the world so that world production in these sectors barely declines. In this case, the contribution of these sectors to emission abatement at a global level might even be negative, because the same sectors would tend to be more emission intensive outside the European Union. By contrast, in a global framework where all countries participate, world output of these sectors would decline by some 14%, but EU production by only some 7%. This again partly reflects the fact that in Europe these industries are relatively carbon-efficient compared to the average in the rest of the world. From the standpoint of producers and workers, energy-intensive industries in Europe will shrink in any event under local or global mitigation action. The big difference is whether this shrinkage yields no global benefits in terms of lower emissions – as would be the case if the European Union were acting alone – or substantial benefits, if there is wider participation.

Whatever the uncertainty around such numbers, it is clear that, from the perspective of cost-effective abatement, carbon leakage as such is a second-order concern relative to the much more powerful point that insufficient inclusiveness of an abatement strategy will make it impossible to achieve the required abatement. But from a political-economy perspective it is important. If certain industries, and their workers, feel threatened by abatement strategies that weaken their competitiveness, the leakage argument has considerable weight in sectoral terms. There is a very real risk that opposition by these industries could undermine the willingness of particular regions to continue to make progress in putting in place a comprehensive global mitigation approach.

One suggestion for addressing this problem is to allow countries applying ambitious climate-mitigation policies to impose border taxes on carbon-intensive imports from countries not applying such policies, in an amount that reflects the carbon-content of such imported goods. There are serious problems with such an approach. First, it would be extremely difficult to implement, as the embedded carbon-content of specific imports is very difficult to measure. What is more, a corresponding border tax might require re-negotiation of certain WTO rules, which is a risky prospect, especially given present tensions in the world economy. Second, OECD analysis suggests that the limited benefits to energy-intensive sectors of such border taxes would be more than matched by an increase in costs for domestic consumers (see Figure 10). Hence, the overall economic effects would be negative, both for the country imposing such taxes and for the world as a whole. Furthermore, they would only contribute marginally to carbon-emission reduction in countries that are subject to the border taxes. Finally, from a political-economy perspective, where the top priority should be to stimulate international action to combat climate change,

such taxes would be divisive and could well trigger a spiral of retaliatory measures that would leave everyone very much worse off.

Figure 10. **Border tax adjustments would increase the cost of mitigation action**
(Cost of a 50% reduction in greenhouse gas emissions from Annex I countries in 2050, % of GDP)



Source: OECD ENV-Linkages model.

A more promising way forward on this difficult issue may be to work towards specific co-operative approaches on sectoral action in the most carbon-intensive sectors. This could help to share technological know-how to increase the efficiency of production in these sectors, and ensure wider country coverage to bring in enough participants to marginalise competitiveness and carbon-leakage concerns. While some initiatives are already underway internationally to support the rapid uptake of climate-friendly technologies in specific sectors, common understanding of – let alone agreement on – what a broader sector-based approach might look like internationally is still developing.

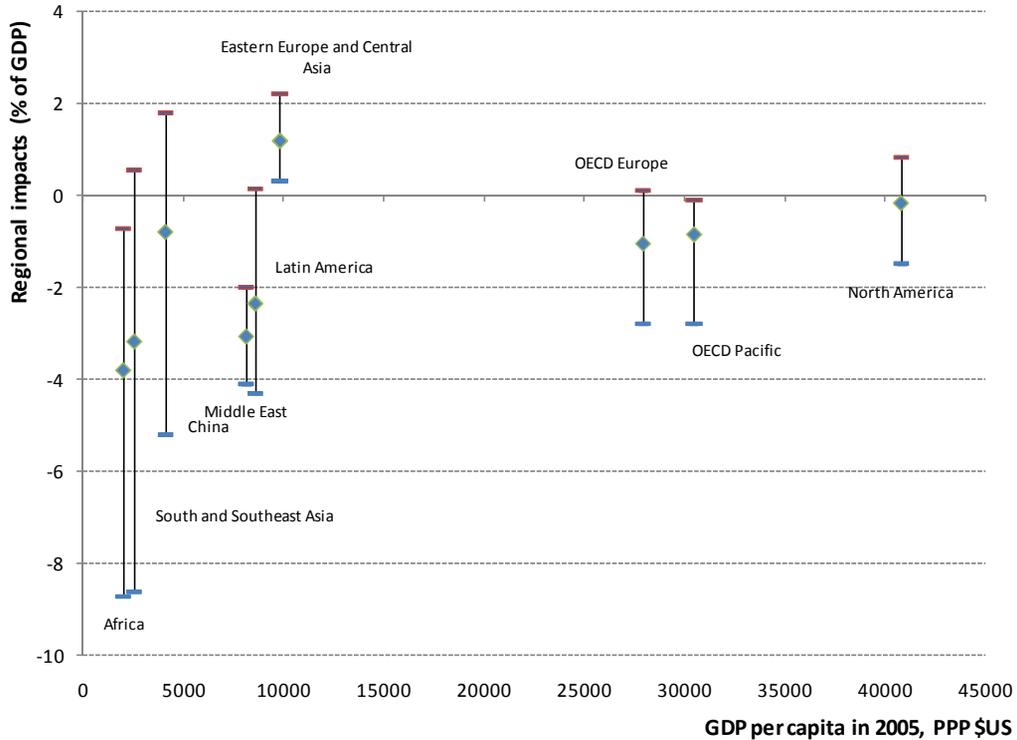
Achieving global buy-in: What are the incentives and instruments?

Long-term stabilisation of GHG concentrations will not be achieved, or will be achieved at an unacceptably high level of emissions or cost, unless there is widespread buy-in to an abatement strategy. At the same time, there is resistance to a comprehensive global approach. Strong industry interests in OECD countries are likely to be hostile to approaches that leave out their competitors; but many developing countries are equally likely to resist any binding commitments that may call into question their own capacities to grow rapidly and achieve income convergence to the OECD level. Who pays for global emission reduction is thus a central issue.

To get a first rough fix on incentives, Figure 11 attempts to provide an indication of how the measurable costs of a moderate (2 to 2.5°C) long-run increase in global temperature might be distributed across regions.

Figure 11. **Who is most hurt by global warming?**

(Dispersion of long-run impacts across countries of a 2.0-2.5°C increase in temperature above its pre-industrial level)



Note: Estimates come from different sources that are not entirely comparable. Those by Mendelsohn (2000) and Nordhaus and Boyer (2000) represent the annual GDP impact (relative to a no-climate-change scenario) observed at the time when a +2.5° increase in temperature is reached (i.e. in 2100 in both exercises). They are not entirely comparable to first-generation estimates surveyed by IPCC (1995), which are static estimates representing the annual GDP impact of a +2.5°C rise in temperature based on 1990 economic structures. The figure should be read as follows: For example, for Africa, the impacts of a warming of 2-2.5°C is expected to fall within the range of -1% to -9% of GDP according to existing estimates, with an average value of about -4% of GDP.

Source: Nordhaus and Boyer (2000), Mendelsohn et al. (2000) and IPCC (1995).

The margin of uncertainty is large, and we must bear in mind that available estimates do not account for the costs of catastrophic climate events, which are not calculable. The most robust conclusion that can be drawn from this figure is that many of the poorest countries in the world, in Africa and South Asia, are likely to be hardest hit by climate change. Countries of the Middle East are also likely to suffer significant impacts. OECD countries as a group face fewer direct costs; and some countries in the OECD, Russia, and some central Asian countries, might at least initially derive some economic benefits from very low levels of global warming.

Assessing the costs across countries of implementing a comprehensive mitigation strategy is obviously highly dependent on how emission reductions are assumed to be implemented, both initially and over time. Based on the

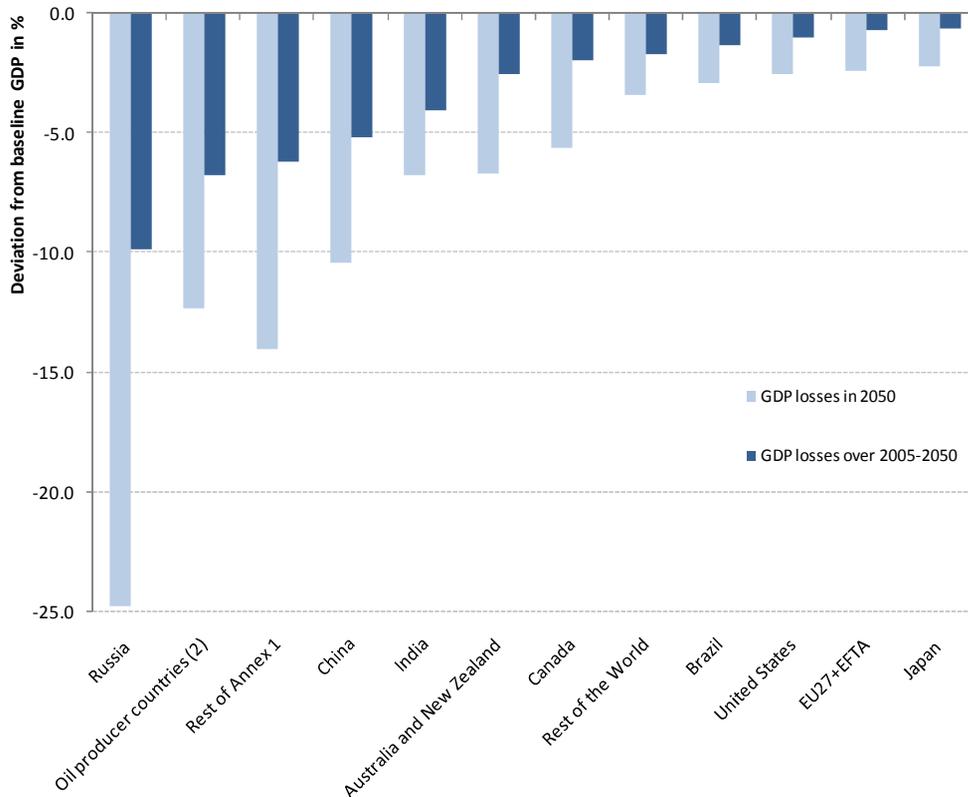
mitigation reference scenario examined here in which global costs are minimised and assuming as a benchmark that abatement in each country is fully paid for by the country concerned, OECD analysis suggests that OECD countries would bear relatively less in terms of reduced GDP growth than non-OECD countries. This is because of the higher emission intensity of non-OECD economies. For this reason, China, for instance, would bear a relatively large impact, while other main losers in such a scenario would include OPEC oil exporters, who would experience a significant terms-of-trade loss if global abatement efforts result in lower global demand for oil. Russia would face both lower terms-of-trade for its energy exports and the costs of bringing down the very high level of energy-dependence built into its present industrial structure. It should be noted that the indicated costs for Russia may be unrealistically high, since the Russian economy could already achieve a significant reduction in emissions at a gain to the economy by removing energy subsidies. The relative cost estimates associated with the mitigation reference scenario are shown in Figure 12.

With all their uncertainties, the above figures suggest that underlying incentives for taking part in a global emissions-reducing framework vary significantly among countries. Three points are worth noting:

- International support to help with adaptation to climate change will be essential for many of the poorest countries who are likely to bear the brunt of the cost of climate change, but who have limited resources and capacity available to adapt to the impacts of climate change.
- India and China are key global partners in an effective abatement strategy. Their own long-term advantage is not obviously best served by an opt-out strategy, but these economies face strong and at the same time uncertain growth prospects. Thus, they may see binding emission caps as potentially significant impediments to future growth. In this respect, emissions targets, defined in terms of absolute levels, might appear more risky to them than less stringent commitments such as carbon intensity targets.
- Finally, buy-in by energy-intensive sectors within the OECD will be essential for the credibility of any programme that has global engagement as its aim. Global sectoral agreements may encourage broad engagement and complement economy-wide instruments such as cap and trade.

Figure 12. **Costs of abatement without redistribution**

(Regional costs from stabilising long-run greenhouse gas concentration at 550 ppm, GDP losses relative to baseline¹)

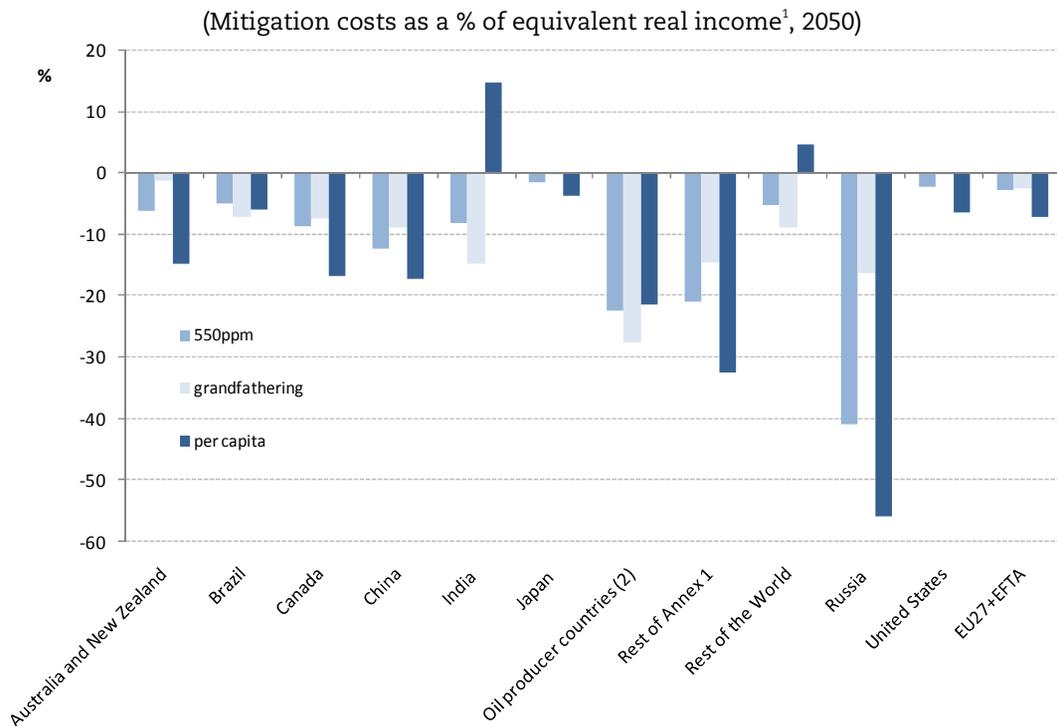


1. This scenario assumes the implementation of a world carbon tax, or equivalently of a world permit trading system with full auctioning. "GDP losses in 2050" denotes the cost as a per cent of GDP in 2050 relative to baseline. "GDP losses over 2005-2050" denotes the gap (in per cent) between the (undiscounted) sum of annual GDPs over 2005-2050 in the 550ppm scenario and the corresponding sum in the baseline scenario.
2. The region includes the Middle East, Algeria-Libya-Egypt, Indonesia, and Venezuela.

Source: OECD ENV-Linkages model.

In terms of potentially available instruments to achieve the widest possible buy-in, the most powerful and flexible one in a cap-and-trade scheme is how permits are allocated across countries or how emission reduction commitments are distributed. As noted earlier, any distribution pattern that is collectively agreed could in principle be implemented without affecting efficiency. But the costs for individual countries of participating in the mitigation scheme are compensated (or augmented) by the net income obtained from selling (or buying) permits. In Figure 13 two alternative benchmark allocation rules, respectively a "grandfathering" (permits allocated on the basis of baseline emissions) and a "per capita" rule (equal emissions *per capita* across countries) are shown alongside the reference rule of each country paying its own way as described above.

Figure 13. **Permit allocation rules are powerful policy tools to redistribute the costs of action**



Note: The 550ppm scenario is the mitigation reference scenario, where a carbon tax (or equivalently a world permit trading system with full auctioning) is imposed to achieve long-run stabilisation of greenhouse gas concentration at 550 ppm. Under "grandfathering", for the same emissions pathway, permits are allocated according to emissions in 2012. Under a "per capita" allocation rule, for the emissions pathway target, permits are allocated each year according to population.

1. Hicksian "equivalent real income variation" defined as the change in real income (in percentage) necessary to ensure the same level of utility to consumers as in the baseline projection. This contrasts with figure 12 where mitigation costs are presented in GDP (rather than income equivalent) terms.
2. The region includes the Middle East, Algeria-Libya-Egypt, Indonesia, and Venezuela.

Source: OECD ENV linkages model.

Clearly, a grandfathering rule would favour countries that are now relatively energy-intensive; while a *per capita* rule would be very attractive to those countries with low energy consumption *per capita*. Indeed, for most poorer developing countries, and also notably for India, a *per capita* rule is estimated to generate a rise, rather than a fall in real incomes. Interestingly, the two rules do not generate strikingly different results for China: this country is substantially more energy intensive on a *per capita* basis than India, and over the long horizon of the scenario, it would tend to be penalised by a *per capita* rule because its population is projected to decline.

The following considerations and instruments may help to effectively encourage wider country buy-in for mitigation action:

- *Considering co-benefits of climate policies.* One consideration that could considerably increase interest in participation by a number of countries is a greater understanding of the co-benefits of GHG abatement for achieving other environmental goals. A key example is reduced local air pollution because most instruments that might be deployed to achieve GHG abatement would also reduce local air pollution and detrimental effects on human health. The benefits of local air pollution abatement resulting from GHG emission reduction help to offset the cost of undertaking GHG abatement. OECD analysis suggests however that this effect, by itself, is not strong enough to make GHG abatement “pay for itself” because targeted policies to cut local air pollution by a given amount can generally do so more cheaply than the GHG abatement needed to achieve the same reduction. Still, for many countries, these co-benefits are found to offset GHG abatement costs significantly.
- A closely related issue is that there may be co-benefits in terms of increased *energy independence*, which is seen as an important priority by a number of countries. While the benefits of energy independence are hard to quantify, under any effective GHG abatement strategy energy intensity will decline substantially, and oil prices are also likely to be lower than in the absence of such a strategy. In addition, there will be some shift towards locally produced renewable energy. All these factors will serve to limit the macro-economic impact of global oil-price shocks on individual economies. On the other hand, it is unlikely that a GHG abatement effort along the lines of the mitigation reference scenario will radically alter the share of oil consumption in oil-importing countries that comes from existing suppliers, given the high concentration of world oil-reserves in a few regions and the fact that reduced demand for oil products will be largely matched by reduced supply from peripheral suppliers.
- *Facilitating technology transfers.* It is important to stress that putting a price on carbon emissions will by itself stimulate not only innovation but also its diffusion internationally, including to developing countries that participate in such a pricing scheme. More targeted policies may also be relevant. Indeed, technology transfer is likely to be an element of an international response to the climate change challenge and a number of initiatives to support the rapid diffusion of climate-friendly technologies have been launched. New and innovative approaches are being discussed: one approach might be, in the context of a strong regime to protect intellectual property rights, for technology funds to simply purchase patents generated by researchers and then make the patented technologies available globally.
- *Scaling up financing for mitigation action, including through the Clean Development Mechanism.* While many of the cheap options for reducing emissions can be found in developing countries, some of these countries lack the capacity or financing to implement these reductions without support. In addition to bilateral and multilateral funds for mitigation action, the Clean Development Mechanism (CDM) under the Kyoto Protocol is designed to help encourage private financing for mitigation action in developing countries. The number of projects initiated under the CDM has been rising strongly in recent years, with a large majority of

such projects located in China. But this mechanism is not without problems. For example, the cornerstone of this mechanism is additionality – the principle that the CDM can only be used for emission cuts that would not have taken place without it. But verifying this is difficult and has resulted in bottlenecks in the auditing process leading to delays in project implementation, high transaction costs and concerns about the environmental integrity of the projects. If CDM is to be expanded, it might be worthwhile to consider moving away from a project-based approach towards a more sectoral or programmatic one to improve its cost effectiveness. For example, CDM credits could be linked to specific policies adopted in developing countries – e.g. if countries impose effective CCS requirements on coal-fired power plants, CDM credits could facilitate the transfer of that technology.

Summing up

Whatever the precise instruments used – and this booklet suggests that a wide range of instruments will be needed – an effective global strategy should ideally meet a number of core requirements. These can be summarised as follows:

- Comprehensiveness both in terms of addressing all GHG gases and in engaging the largest possible number of countries and sectors, including especially the largest emitters.
- Some degree of de-coupling between where abatement takes place and who pays for it, to ensure emission reductions take place where they are cheapest, even if there are limited resources to pay for the reductions locally. No doubt this represents an important challenge for international diplomacy; but it is clear that, at least for the world's poorest countries, support through such a de-coupling will be required.
- The strategy has to be both credible and flexible. Credibility is essential because no strategy, no matter how well designed, will elicit the required behavioural responses if people lack confidence that it will be carried through. Flexibility is also needed, because uncertainty margins about both the economic and environmental results of any strategy remain large, so that mid-term corrections to any strategy will almost certainly be required. Building-in from the start such a capacity to make periodic corrections would reduce risks of deadlock that might arise if all changes had to be negotiated along the way. There is no doubt some element of trade-off between credibility – which requires clear targets – and flexibility, which requires the capacity to adjust them. Combining strongly-anchored long-term objectives with rolling shorter-term commitment periods may be one way of balancing this trade-off.
- Finally, the strategy needs to be put into place urgently. The illustrative mitigation reference scenario considered in this booklet suggests that even under an ambitious abatement strategy, the required implicit price of carbon emissions is relatively modest over the next 10 to 15 years. This creates a “breathing space”, but this breathing space will be used productively only if the strategy provides an immediate and clear signal for the longer term. Such a breathing space is extremely important for two reasons. First, it provides time for long-lived investment decisions to

be made now so that the abatement capacity is in place when it is needed. Second, it avoids a “price-shock” that would in fact be required if the strategy is delayed, and which could well make it much more difficult for governments vis-à-vis their electorates to buy into the strategy. Every year of delay reduces this breathing space, and at the same time raises the stringency of the measures required to meet the objective. In this double sense, delay is extremely costly.

This booklet provides a summary of the main analysis from the forthcoming report OECD (2008), “The Economics of Climate Change Mitigation”. The analysis was developed under the joint guidance of the OECD Economic and Environment Policy Committees.

The messages presented in this booklet are supported by two main modelling frameworks:

- **The OECD ENV-Linkages model:** a recursive dynamic multi-country and multi-sector general equilibrium model housed at the OECD, which incorporates a full representation of international trade flows and has been developed to examine global and regional macroeconomic impacts of climate change or other policies and related trade issues. For more information see *OECD Economics Department Working Paper n. 653 (2008)* available at www.oecd.org/eco/working_papers.
- **The WITCH (World Induced Technological Change Hybrid) model:** a forward-looking multi-country general equilibrium model with a detailed representation of the energy sector developed by the climate modelling group at the Fondazione Eni Enrico Mattei (FEEM), which is especially suited for the analysis of R&D and technology deployment policies and their interactions with price-based instruments. For more information see www.feem-web.it/witch/model.html.

Each of these models has its strengths and weaknesses, and the results of any such model-based work need to be seen in this light. In this booklet, the results presented are generally a compilation of elements from the two models.

The Organisation for Economic Co-operation and Development (OECD) is a multi-disciplinary inter-governmental organisation, providing a unique forum and the analytical capacity to assist governments of its 30 member countries and partners to compare and exchange policy experiences, and to identify and promote good practices through policy decisions and recommendations.

The OECD has been working on climate change economics and policy since the early 1990s, helping governments to identify and implement least-cost policies to reduce greenhouse gas (GHG) emissions, as well as more recently to integrate adaptation to climate change into all relevant policy areas.

For more information on OECD work on climate change: www.oecd.org/env/cc.

Climate Change Mitigation

WHAT DO WE DO?