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OECD Environmental Outlook to 2030

Chapter 7

Climate Change

This chapter examines the projected emissions of greenhouse gases to 2030, by country and sector, and the expected impacts in terms of temperature change and other effects. Without new policies, it is projected that greenhouse gas emissions will increase by about 37% in 2030 compared to 2005 levels, with a wide range of impacts on natural and human systems. The chapter examines the key drivers of increases in greenhouse gas emissions, and explores a range of policy scenarios for reducing these emissions. It finds that early action by all emitters, covering all sectors and all greenhouse gases, can achieve an ambitious emission reduction target at low cost. It highlights the need to share the burden of the cost of mitigation action amongst countries.

KEY MESSAGES

Scientific evidence shows that past emissions of greenhouse gases are already affecting the Earth's climate, with resulting impacts on physical, ecological and social systems (IPCC, 2007a). Global temperatures are about 0.76°C higher than pre-industrial levels. Impacts will become more significant as temperatures and sea levels continue to increase and precipitation patterns shift during the latter part of the century and beyond.

The *Outlook* Baseline projects that current policies and emission trends will lead to a rapidly warming world (see graph and "Consequences of inaction" below). Protecting the climate requires reversing emission trends to reduce global GHG emissions significantly below today's levels by 2050.

Key drivers of emission growth are fossil fuel use (*e.g.* for power and transport) and unsustainable land use policies, including deforestation. Agriculture and waste also contribute to emission growth to 2050.

Recent progress has been made in establishing an international framework for action on climate change. There is also greater policy-making capacity today in many OECD countries to deal with climate change. In non-OECD countries there is also progress, for example to comprehensively monitor and report on emissions, to implement climate change and other relevant policies to reduce greenhouse gas emissions and adapt, and to host Clean Development Mechanism (CDM) projects. This experience will be of value for future climate policies.

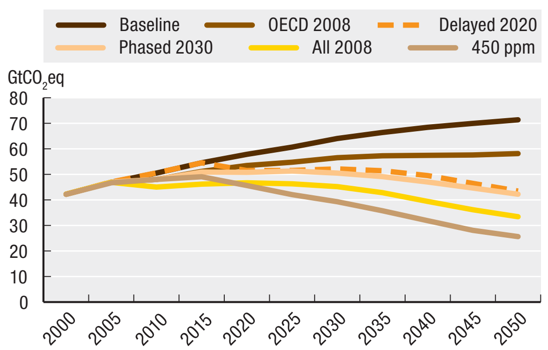
Policy options

- Start today to reduce global CO_2 and other emissions in order to stabilise atmospheric concentrations at acceptable levels, and to significantly limit global mean temperature increases, *i.e.* to 2-3°C, rather than the 4 to 6°C projected in the Baseline. This would significantly limit the risk of the worst climate change impacts in the long-term.
- Create conditions for broad participation by all the big emitting countries in mitigation action under a post-2012 framework. This will be essential to achieve these outcomes in a cost-effective manner.
- Develop and strengthen climate-specific policies and measures to put a global price on carbon to stimulate development and deployment of climate-friendly technologies, clean energy systems and provide incentives to change consumer behaviour and business practices.
- Strengthen national frameworks and strategies to better co-ordinate climate change mitigation and adaptation through existing sector policies *(e.g.,* energy, transport, waste, land use and agriculture).
- Expand capacity in national governments to work more effectively with non-governmental actors and organisations, sub-national and city level governments on both mitigation and adaptation.

Cost of mitigation

Emission reductions are not only possible, they are also feasible at limited cost. Simulations in this chapter compare Baseline (no new policy) projections for GHG emissions, global mean temperature and GDP increase with different policy cases of a phased-in carbon tax of USD 25 per tonne of CO_2eq (see graph). Costs of a globally applied tax policy starting in 2008 would decrease GDP by only 1% below its "business as usual" level by 2050. Another more radical scenario involves phasing in a global tax to stabilise atmospheric GHG concentrations at 450 ppm CO_2eq. This policy reduces climate impact substantially (see graph), but has more significant, though manageable, global costs. It is projected to reduce Baseline estimates of GDP by about 0.5% and 2.5% by 2030 and 2050 respectively, amounting to a loss of about 0.1 percentage point a year on average. Aggregate costs of global mitigation (% GDP), with all countries participating, would be lower in the OECD than in the BRIC and ROW countries, underscoring the need for burden-sharing in future agreements.

Impacts of policy scenarios on greenhouse gas emissions



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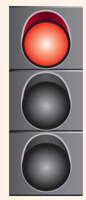
Consequences of inaction

The risks of inaction are high, with unabated emissions in the Baseline leading to about a 37% and 52% increase in global emissions in the 2030 and 2050 timeframe respectively compared to 2005, with a wide range of impacts on natural and human systems. This unabated emission pathway could lead to high levels of global warming, with long-term average temperatures likely to be at least 4 to 6°C higher than pre-industrial temperatures. The costs of even the most stringent mitigation cases are in the range of only a few percent of global GDP in 2050. Thus they are manageable, especially if policies are designed to start early, to be cost-effective and to share the burden of costs across all regions.

Introduction

This chapter presents the *Outlook* results for climate change. It begins with a brief review of the science of climate change to explain the nature of problem. This is followed by a review of historical greenhouse gas (GHG) emission trends and a description of Baseline projections. Next the chapter reviews the nature of the international and national policy challenge to respond to climate change. The chapter closes with a presentation of key results from the *Outlook* policy simulations, comparing the cost and effectiveness of alternative mitigation strategies to limit climate change between now and 2050 (and beyond). Climate change is a "stock pollutant problem" and is thus slow to develop; reductions of greenhouse gas emissions achieved today, and in the decades to come, will affect the climate of future generations. The chapter therefore places the policy challenge of today in the context of long-term climate change outcomes.



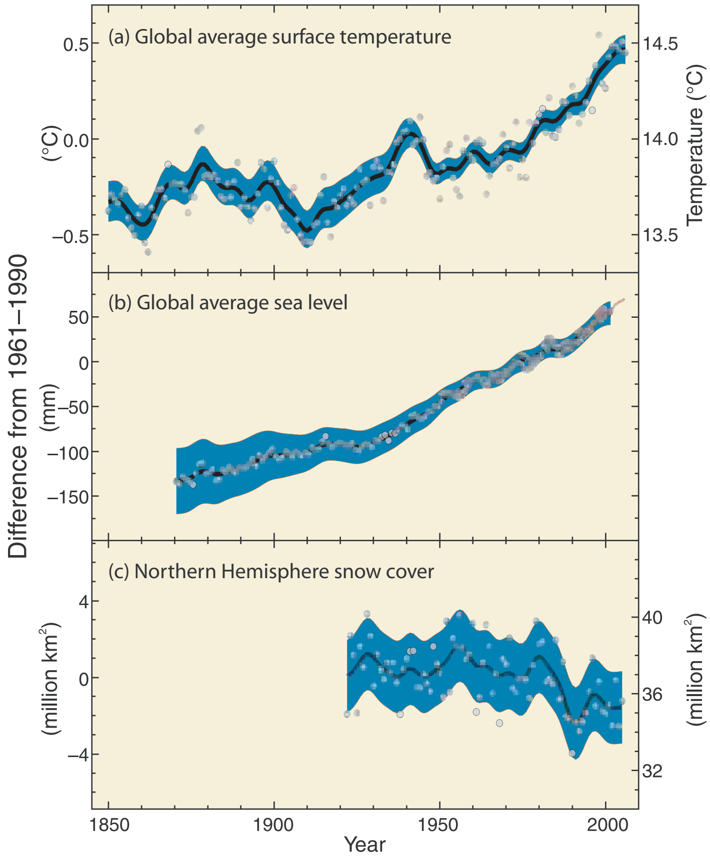
Scientific evidence shows unequivocal warming of the climate system.

Scientific evidence shows unequivocal warming of the climate system (IPCC, 2007a). The global surface temperature increased by 0.76 degrees Celsius from 1850-1899 to 2001-2005. Eleven of the 12 years between 1995 and 2006 rank among the 12 warmest years in the instrumental record since 1850 (IPCC, 2007a; and Figure 7.1). The rate of temperature change has also accelerated, rising to about 0.13°C per decade in the last 50 years, which is about twice the recorded rate of change for the previous 100-year period (IPCC, 2007a); this rate has increased in the last two decades.

The distribution of climate change varies widely by region, with more pronounced warming observed over the interiors of large land masses. Generally regional temperature increases are smaller towards the equator and larger towards the poles. Over the last century, average Arctic temperatures have increased at almost twice the rate of the rest of the world (IPCC, 2007a). Natural factors such as volcanoes and changes in solar radiation cannot explain these phenomena (IPCC, 2007a).

Numerous long-term changes in climate and in natural systems have been observed, many of which are attributable to human activities (IPCC, 2007a). Observed changes include large-scale declines in snow pack and ice cap coverage and glacier retreat in many regions (IPCC, 2007a). Changes have also been observed in many weather extremes since the 1970s, including more intense and longer droughts, particularly in the tropics and subtropics; an increase in the intensity of tropical cyclones (Emanuel, 2005; Webster *et al.*, 2005; IPCC, 2007a); as well as an increase in the frequency of heavy precipitation over most land areas (IPCC, 2007a). The duration and size of wildfires in the western United States are now partially attributed to changes in summer temperatures, precipitation patterns and earlier spring snowmelt (Westerling *et al.*, 2006; IPCC, 2007b). Some evidence of non-linear change is also evident in observed climate change; for example, studies suggest the Atlantic overturning circulation may be 30% slower than between 1957 and 2004 (IPCC, 2007b and c;

Figure 7.1. **Global temperature, sea level and Northern hemisphere snow cover trends, 1850-2000**



Note: Observed changes in *a)* global average surface temperature; *b)* global average sea level from tide gauge (blue) and satellite (red) data; and *c)* Northern hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).

Source: Reproduced from IPCC, 2007a, Figure SPM.3.

Bryden *et al.*, 2005). Changes in ocean acidity due to increases in carbon dioxide emissions, reported for the first time in 2004, are altering ocean chemistry and may threaten marine organisms (Feeley *et al.*, 2004; see also Chapter 15 on fisheries and aquaculture). Ecological systems of all types are shifting in elevation and geographical location (IPCC, 2007b; see also Chapter 9 on biodiversity). These observed changes suggest that ecosystems are among the most sensitive of natural and human systems to the pace and the magnitude of climate change, while also the least amenable to managed adaptation.

Most of the observed warming since the mid-20th century is due to changes in greenhouse gas concentrations and can be attributed to human activities (IPCC, 2007a). Climate change is driven by increases in the global population and economic growth, particularly the production and consumption of fossil fuels, the expansion of agriculture and deforestation, all of which have increased GHG emissions (IPCC, 2007a and c).

Atmospheric carbon dioxide and methane (CH_4) concentrations are higher than at any time in the last 650 000 years (Spahni *et al.*, 2005; Siegenthaler *et al.*, 2005; IPCC, 2007a).[1] Increased emissions of CO_2 over the last 100 years increased atmospheric CO_2

concentrations from approximately 280 to 379 parts per million (ppm) in 2005,[2] while methane concentrations increased from 715 to 1 774 parts per billion (ppb) (IPCC, 2007a). Higher concentrations of greenhouse gases in the atmosphere lead to warming, which is offset somewhat by cooling from sulphur aerosols.

As a result of lags in the Earth's systems, particularly the oceans, it is estimated that even if the composition of the atmosphere stabilised today, an additional increase in warming of 0.3-0.9 °C (with a best estimate of 0.6 °C) would still occur over this century (Hansen *et al.*, 2005; IPCC 2007a).[3] Without significant efforts in this century to reduce emissions below current levels, future predictions of climate change suggest it is likely or, in some cases certain, that we will see an acceleration of warming trends, associated climate changes and impacts.

Key trends and projections

Current sources, sinks and historical trends

The principal gases associated with climate change are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which together accounted for over 99% of anthropogenic GHG emissions in 2005. CO_2 is the dominant greenhouse gas, accounting for 64% of global emissions and about 83% of emissions from OECD countries in 2005, excluding land use and forestry emissions and removals. Including land use change and forestry increases the share of CO_2 in 2005 to 76% globally and does not significantly change the share for the OECD. Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) account for less than 1% of total global anthropogenic GHG emissions, but they are growing quickly. All these greenhouse gases are subject to international obligations under the United Nations Framework Convention on Climate Change (UNFCCC), including national monitoring and reporting of emissions and removals of greenhouse gases.

Fossil fuel combustion is by far the largest global source of CO_2 emissions, accounting for 66% of global GHG emissions in 2005. Of this, fossil fuel combustion in power generation is the most important source, and accounted for about one-quarter of all global GHG emissions in 2005. Electricity-related CO_2 emissions are also a rapidly-growing source of GHGs, particularly in Asia, reflecting both increased electrification rates and the continued predominance of fossil-fired electricity. Global CO_2 emissions from road transport are a significant contributor to global GHG emissions, at 11% of the total in 2005.

Trends in GHG emissions vary widely according to world region. Global anthropogenic GHG emissions (excluding CO_2 emissions or uptake from land use change and forestry and from international bunkers) increased by 28% between 1990 and 2005.[4] This increase was lower in OECD countries (+14%) than in BIC countries (Brazil, India, China), where emissions grew by about 70%. However, emissions in some countries – particularly those in Central and Eastern Europe – fell during the same period. Trends for OECD countries are broadly similar even if emissions or uptake from land use change and forestry are included, in which case OECD countries' emissions increased 10% over the period 1990-2005.[5] BIC countries' emissions also increase even more (nearly 110%) if CO_2 emissions from land use change and forestry are included.[6]

However, between 1990 and 2005 there were also large variations in these trends within different OECD countries. Emissions in nine OECD countries increased by more than 20% in this period,[7] and eight further OECD countries reported smaller increases.[8] However, emissions in several other OECD countries have decreased since 1990, including

Germany, Hungary, Finland, Norway, the Czech Republic and Slovakia, where 2005 emissions were between 67-80% of their 1990 value.

Future projections

There is a large body of literature that assesses future emissions of greenhouse gases (IPCC, 2007c). In almost all such studies, human activities are projected to cause emissions of greenhouse gases to increase for decades or more, unless policies are introduced to alter these trends by providing incentives to limit demand for energy or other emission intensive products, or to change behaviour and technologies in climate-friendly ways.

For the purposes of assessing climate change, the OECD *Outlook* is extended to 2050. Projected GHG emissions trends (including land use change and forestry) by region are shown in Table 7.1 and Figure 7.2. These trends show absolute growth in emissions through 2050 across all regions, with global emissions of all GHGs increasing by about 37% and 52% to 2030 and 2050 respectively. Growth is significantly higher in BRIC and ROW regions compared to the OECD. Accordingly, the share of BRIC and ROW within world emissions increases in this timeframe, growing from 60% in 2005 to 67% in 2050, while the OECD share declines slightly from 40% to 33% in the same period.

Table 7.1 also shows indicators of emission intensity, both per capita and per USD of gross domestic product (GDP). Intensity indicators show that emissions per capita increase in all regions, while emissions per USD of gross domestic product (in 2001 USD) decline across regions. Per capita GHG emissions in BRIC countries were only about one-third of those in OECD countries in 2005 (the equivalent of 5.1 tonnes (T) of CO_2eq per person in BRIC countries compared with 15 T CO_2eq per person for OECD countries)[9] and this pattern continues. The OECD remains the most emission intensive of the regions on a per capita basis, while it is the least emission intensive when measured on a GDP basis.

In the *Outlook* Baseline, CO_2 emissions from energy, industry and land use are also projected to increase from 35.9 GtCO_2 in 2005, to 49.8 GtCO_2 in 2030 and to 55.7 GtCO_2 in 2050, or an increase of 39% and 55% respectively (Figure 7.3).[10] The rapid increase of global energy-related CO_2 emissions is largely as a result of a projected continued expansion in the use of fossil fuel to support growing demand for electricity (Figure 7.3; and see Chapter 17, Energy). Demand for electricity is projected to double between 2000 and 2030, increasing emissions from power generation by 65% to 2030 and by 100% (to 22.2 GtCO_2 compared to nearly 11 GtCO_2 in 2005) to 2050. Global emissions of CO_2 from the transport sector are expected to expand from 6.1 GtCO_2 in 2005, to 9.6 GtCO_2 in 2030 and 12.2 GtCO_2 in 2050, thus roughly doubling by 2050 as the demand for cars increases, particularly in developing countries. Aviation is projected to be the most rapidly growing sub-sector (see also Chapter 16, Transport, and note 6 at the end of this chapter).

The IPCC recently summarised available literature on reference or baseline emission scenarios and established a range of outcomes across these scenarios to 2100. Looking at CO_2 from energy, the IPCC shows an increase ranging from 30-55% between 2005 and 2030, and 50-100% between 2005 and 2050.[11] By comparison, the *OECD Environmental Outlook* projects an increase of about 51% from 2005 to 2030 and 78% to 2050, while the IEA *WEO 2006* shows an increase of about 42% in CO_2 emissions from energy to 2030 from 2005. Both the OECD and the IEA baseline scenarios thus lie in the middle of the full range of emission scenarios available in the literature (Fisher *et al.*, 2007) (see also Chapter 17, Energy).

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Table 7.1. *Outlook* Baseline global emissions by region and GHG intensity indicators: 2005, 2030 and 2050

	2005	2030	2050
		All GHG – Gt CO_2eq	
OECD	18.7	23.0	23.5
BRIC	16.1	23.5	26.2
ROW	12.1	17.6	21.7
World	**46.9**	**64.1**	**71.4**
		Change in GHG, 2030 and 2050	
		% increase	% increase
OECD	Base year	23%	26%
BRIC	–	46%	63%
ROW	–	45%	79%
World	–	37%	52%
		Shares of total GHG by region	
	% share	% share	% share
OECD	40%	36%	33%
BRIC	34%	37%	37%
ROW	26%	27%	30%
		CO_2eq per capita (T/person)	
OECD	15.0	16.8	17.0
BRIC	5.1	6.1	6.4
ROW	5.8	5.9	6.0
World	**7.2**	**7.8**	**7.8**
		CO_2eq per GDP (kg/USD real)	
OECD	0.7	0.5	0.3
BRIC	4.6	2.2	1.3
ROW	2.9	1.6	1.0
World	**1.3**	**0.9**	**0.6**

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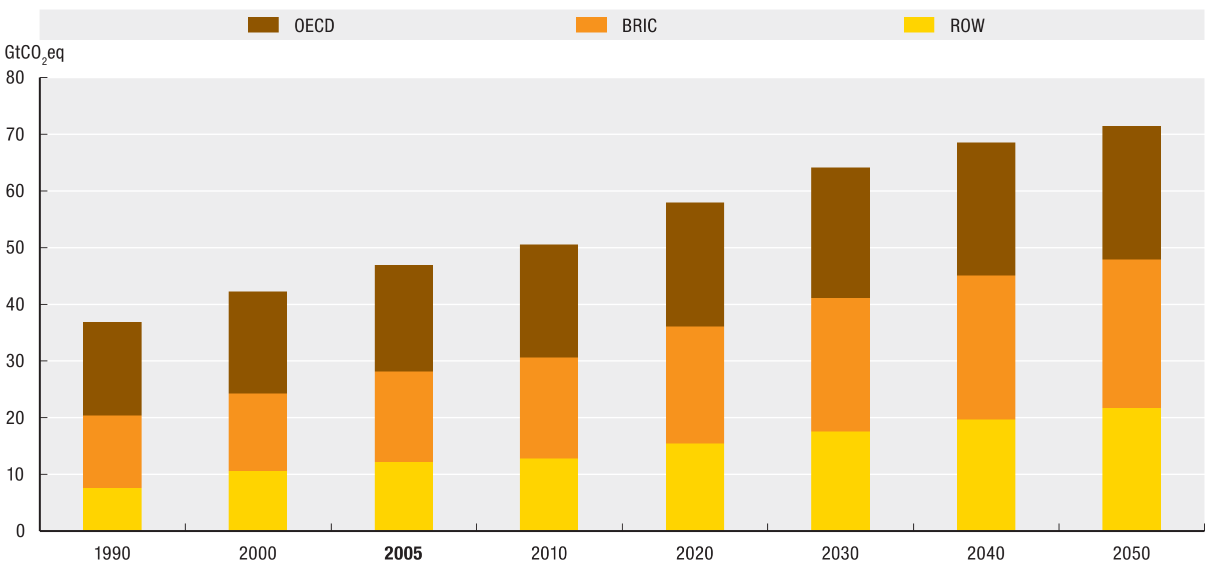
Note: Figures include land use change and forestry.
Source: OECD *Environmental Outlook* Baseline.

Figure 7.2. Baseline GHG emissions by regions, 1990 to 2050



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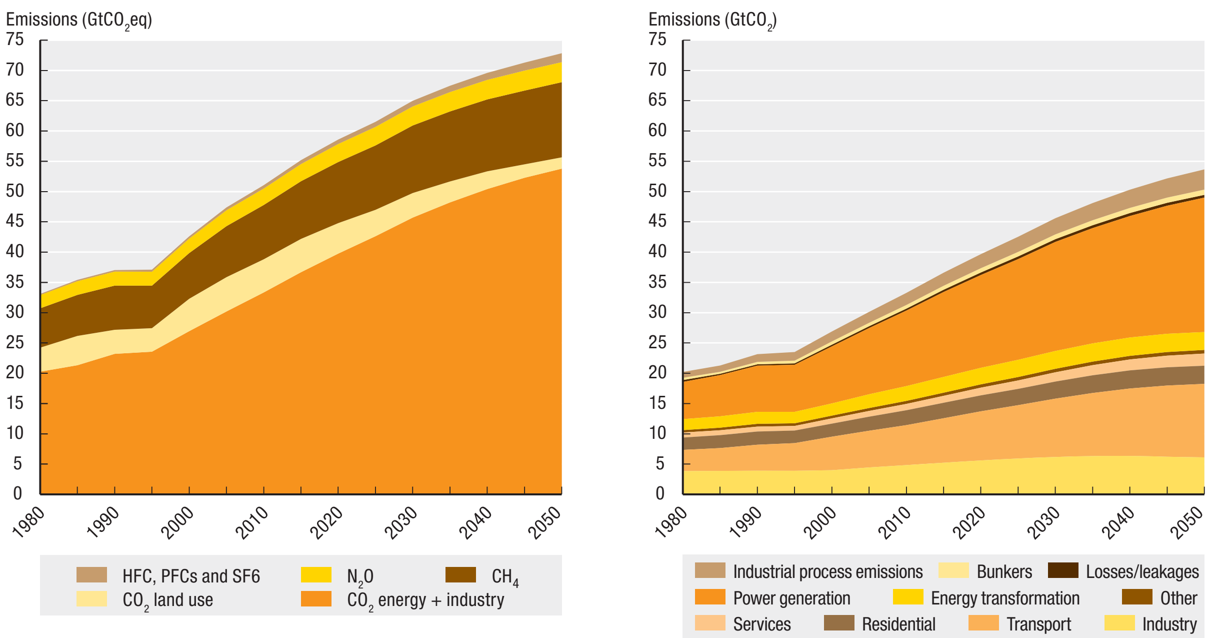
Note: 2005 also included as it is the base year.
Source: OECD *Environmental Outlook* Baseline.

This *OECD Environmental Outlook* also includes projections of greenhouse gas emissions from non-energy sectors (Figure 7.3). Among the most important of these are CO_2 emissions from global land use change, largely derived from rapid conversion of forest to cropland and grassland in tropical regions. These emissions are estimated to be 5.7 CO_2 Gt per year by 2005, and are projected to decline over the coming decades to 4.1 Gt CO_2 in 2030, and 1.9 Gt CO_2 in 2050. This is due in part to slowing population growth which is likely to reduce pressure on forest areas. Although the quality of inventory data is steadily improving, due to monitoring complexities these projections have large uncertainties, as do the base year estimates.

Figure 7.3. **Total greenhouse gas emissions by gas and CO_2 emissions by source category, 1980-2050**

Greenhouse gas emissions by gas | CO_2 emissions from energy and industry, by sector



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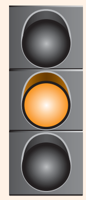
Source: *OECD Environmental Outlook* Baseline.

Emissions of methane from sources such as solid waste disposal on land, enteric fermentation, natural gas pipelines, rice production, etc. are also projected to increase in line with expanding production of animal products and rice, but at slightly lower rates than total food crop production. Between 2005 and 2030 global emissions of methane are projected to increase roughly by 32%, and to continue to increase to 47% above 2005 levels by 2050. Global N_2O emissions from agricultural practices, industrial and other sources are expected to increase by about 20% by 2030 and 26% by 2050 as agricultural land expands and production intensifies in the next decades, with slower growth nearing 2050. HFCs and PFCs from industrial processes have a high global warming potential and will grow most rapidly, projected to more than double from 2005 to 2030, and nearly quadruple by 2050. These gases are being introduced to replace chlorofluorocarbons (CFCs), which are powerful greenhouse gases and also deplete the ozone layer.[12] By 2050 HFCs and PFCs are projected to contribute roughly 4% of the total change in GHG emissions from 2005.

Policy implications

Successful mitigation of climate change will require an international effort to limit global greenhouse gas emissions significantly below current levels over the long-term (*e.g.* see Figure 7.5). The main international means to address climate change is the United Nations Framework Convention on Climate Change (UNFCCC), which has been ratified by 189 countries. Leadership on the climate change issue has emerged at the highest levels of government in many industrialised countries, and the worldwide prominence of the issue has risen in recent years.

Signatories of the Convention have agreed to work collectively to achieve its ultimate objective (Article 2, UNFCCC), which is: "… stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." By signing the Convention, OECD members and other industrialised nations (or Annex I Parties) agreed to take the lead to achieve this objective, as well as to provide financial and technical assistance to other countries[13] to help them address climate change.



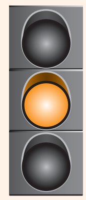
Successful policies to limit GHG emissions will require the participation of all major emitting countries.

In 2005, the Kyoto Protocol entered into force, an event that helped to raise the level of priority attributed to climate change by many governments. The Kyoto Protocol shares the Convention's objectives, but strengthens them through commitments of Annex I Parties (see above) to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. To date 175 countries have ratified the Protocol; 36 of these countries and the EC are required to reduce greenhouse gas emissions below specific levels, a total cut of approximately 5% from 1990 levels by the 2008-2012 period.[14]

When adopting the Kyoto Protocol, governments recognised that it was only a first step in tackling climate change and achieving the Convention's ultimate objective. This has become even clearer today, as the economies and energy demand of some of the developing countries, such as China and India, have grown rapidly in the intervening years, with large increases in emissions (see Figure 7.2). Currently internationally-agreed mitigation targets apply only to industrialised countries and do not extend beyond 2012. At a Conference of the Parties held in Montreal in December 2005, Convention Parties agreed to an on-going dialogue to exchange experiences and analyse strategic approaches for long-term co-operative action to address climate change. This dialogue process will conclude at the Conference of the Parties in December 2007, which is widely expected to agree to launch negotiations for a comprehensive agreement to reduce emissions post-2012.[15] Successfully stabilising atmospheric concentrations to limit emissions and achieve the objectives of the Convention will require the participation of all major emitting countries.

The Convention and the Protocol are not prescriptive, allowing each party the flexibility to decide how to reduce emissions and implement commitments. There is a wide variety of national policies and measures available to governments to mitigate emissions. These include regulations and standards, market-based instruments (emission taxes and charges, tradable permits, and subsidies/financial incentives), voluntary agreements, research and development and information instruments. The environmental effectiveness of policies depends on their stringency and on implementation measures, including monitoring and compliance procedures, whereas the cost-effectiveness will depend to a great extent on how policies are implemented (IPCC, 2007c). Reducing emissions across many sectors and gases requires a portfolio of policies tailored to specific national circumstances. In general, climate change policies will need to be adjusted over time as new knowledge emerges about climate risk as well as about the means to manage climate change and its costs (IPCC, 2007c).

National policy frameworks to address climate change



In industrialised countries some progress in curbing GHG emissions has been made, but efforts are insufficient given national and international goals to limit climate change.

Governments, corporations, states and cities have recently introduced measures to reduce emissions in the near-term and to promote the development of new GHG-friendly technologies that will be needed in the future. GHG emission trends in industrialised countries suggest that some progress, though still limited, has been made to curb GHG emissions since 1990. Most industrialised nations now have 10-15 years of experience with climate change as a national policy issue, suggesting that it is an opportune time to review and draw lessons from what has been achieved for the future.

There is also growing evidence of more significant policy-making capacity to deal with climate change in many countries compared to earlier years. A look at progress to date in efforts to mitigate emissions highlights several important issues. First is the emergence of climate change specific policies, or those that are truly new and designed to target GHG emission reductions. Such policies are often cross-sectoral, are comprehensive in their coverage of GHGs and are more stringent than early mitigation policies. Examples include emission trading schemes, CO_2 and green energy taxes, voluntary measures with industry to address GHG emissions, targeted regulation (*e.g.* for CH_4 emissions), collaborative research and development programmes.

Second, there is progress in many countries to develop "whole-of-government" efforts to integrate climate change into pre-existing sector policy frameworks. Examples include measures to accelerate investment in energy efficiency through energy policy and to promote mass transport options through transportation policy frameworks. In non-energy sectors, waste minimisation, landfill gas recovery and agriculture fertiliser management are examples of pre-existing measures that have been reinforced due to concern about greenhouse gas emissions. All of these low-cost measures have multiple environmental and economic benefits (*e.g.* see Table 7.2). Importantly, there are numerous local and national co-benefits of taking steps to reduce CO_2 and other GHG emissions other than avoiding climate change, such as reduced air pollution and improved energy security. And at the global level, action to limit HFCs and CFCs will benefit both climate and ozone protection efforts (Velders *et al.*, 2007). In addition, land use planning, agriculture and infrastructure design are increasingly taking into account climate change risk at the local scale, flagging the early development of adaptation (see below).

The third area of progress is the emergence of multilevel governance on climate change issues, both vertically (from local to national) and horizontally (across both governmental and non-governmental actors). Leadership and experimentation by cities and other

Table 7.2. **Related aims and co-benefits of sector policies to reduce GHGs**

Sector	Climate policy aims and benefits	Other (non-climate change) benefits
Electricity production and industrial energy use	Encourage fuel switching from coal and oil to low or no-emission energy sources, such as renewable energy and energy efficiency, to reduce CO_2 emissions.	Raise regional and urban air quality and limit SO_x and NO_x air pollution, preserve water quality, protect forests and ecosystems; increase energy security.
Residential – buildings and appliances	Lower energy use requirements of housing and household services, reduce CO_2 emissions.	Lower investment costs for energy suppliers and possibly smooth load; lower operating costs for consumers and avoid pollution from (unnecessary) electricity and/or heat generation; improve comfort and affordability; raise energy security.
Industry – manufacturing	Stimulate investments in energy and materials efficiency, reduce CO_2 and other GHG emissions.	Improve resource efficiency of industrial operations; short- and long-term financial savings; lower energy consumption (and costs); raise profits and energy security.
Transport	Raise the efficiency and emission performance of vehicles and manage demand, reduce CO_2 and possibly other GHG emissions.	Lower congestion in cities and limit harm to human health from urban air pollution; lower dependency on oil imports to raise energy security; gain in technology leadership. However dis-benefits may also exist *e.g.* increased diesel fuel use lowers CO_2 but increases particulates, which have human health risks; also catalytic converters lower NO_x emissions but raise N_2O and CO_2 emissions.
Agriculture	Minimise nitrogen fertiliser use, reduce N_2O emissions.	Lower nitrogen run-off from agriculture and improve water quality; improve sustainability performance.
Waste	Minimise waste, encourage recycling and material efficiency in production and packaging, reduce CH_4 emissions.	Limit needs for costly and unsightly landfilling; improve economic performance.

sub-national governmental authorities are increasingly shaping mitigation strategies. Sweden, the UK and the US, among others, have city governments which have taken the lead on mitigation. Australia, Canada and the US provide examples of proactive state or provincial governments. In the private sector, some companies have also begun to target and regulate GHG emissions. Sub-national regions and cities may also play an essential role in adaptation planning, as seen in emerging efforts in Denmark, Canada, the UK and the US.

Integrating adaptation responses into sector and natural resource management policies is expected to be a key way forward to limit the socio-economic risks of climate change (Agrawala, 2005; Levina and Adams, 2006; McKenzie-Hedger and Corfee-Morlot, 2006). However, much less progress has been made on adaptation compared to mitigation. Adaptation includes coastal zone and water resource management policies as well as disaster prevention and planning policies (*e.g.* to anticipate more frequent flooding, drought, heat waves or fire, depending on the region). Other benefits of such measures include reinforcing sustainability and creating a greater capacity for sectors to respond to climate variability as well as climate change over the longer-term. Table 7.3 highlights the coverage of impacts and adaptation in national reports on progress under the UNFCCC.

In addition to national action on adaptation, the EU is taking steps to advance the adaptation agenda as a priority across its member states. In 2007, the European Commission adopted its first policy document on adaptation highlighting the need for early action where there is sufficient knowledge, using EU research to fill knowledge gaps and integrating global adaptation into external relations policy (CEC, 2007). The OECD Development Assistance and Environment Policy Committees also recently issued a declaration on adaptation, calling for greater co-operation and attention in development assistance and national planning for development (OECD, 2006).

Table 7.3. **Coverage of impacts and adaptation in National Communications under the UNFCCC (including NC2, NC3, and NC4)**

		Climate change impact assessments			Adaptation options and policy responses				
		Historical climatic trends	Climate change scenarios	Impact assessments	Identification of adaptation options	Mention of policies synergistic with adaptation	Establishment of institutional mechanisms for adaptation responses	Formulation of adaptation policies/ modification of existing policies	Explicit incorporation of adaptation in projects
Early to advanced stages of impact assessment	Iceland	■	✖	■					
	Hungary		■	✖					
	Portugal	✖	■	■					
	Estonia	■	■	■					
	Latvia	■		✖	✖				
	Russia	■	✖	■	✖				
Advanced impacts assessment, but slow development of policy responses	Japan		■	■	✖				
	Romania	■	■	■	✖				
	Denmark	■	■	■	✖				■
	Korea	■	■	■	✖				
	Slovenia		■	■	■				
	Ukraine*		✖	■	■				
	Belarus		■	■	■				
	Bulgaria	■	■	■	■				
	Croatia	■	■	■	■				
	Mexico	■	■	■	■				
	Slovak Republic	■	■	■	■				
	Norway		●	■	✖	✖			
	Czech Republic		■	■	■	✖			
	Liechtenstein		✖		✖	■			
	Germany		✖	■	✖	■			✖
	Austria		■	■		■			
	Lithuania	■	■	■	■	■			
	Greece	■	■	■	✖	■			
	Italy*	■		■	■	■			
Moving towards implementing adaptation	Spain		■	■	■	■	●		
	Ireland	■	■	■		■	■		
	Finland	■	■	■	■		■		
	Poland		■	■	✖	■		■	
	Switzerland	■	■	■	✖	■		■	
	Sweden	■	■	■		■		■	
	United States	■	■	■	■	■		■	
	Canada		✖	●	■			■	■
	New Zealand		■	■	■	●	✖	●	
	Belgium		■	■	✖	■	■	■	
	Australia		■	■	✖	■	■	■	
	France		■	■	■	■	■	■	
	Netherlands			■		■	■	■	■
	United Kingdom		■	●	●	■	■	●	■

* NC2/NC3 only.

Coverage:

- Extensive discussion
- Some mention/limited discussion
- No mention or discussion

Quality of discussion:

- ■ Discussed in detail, *i.e.* for more than one sector or ecosystem, and/or providing examples of policies implemented, and/or is based on sectoral/national scenarios.
- ✖ Discussed in generic terms, *i.e.* based on IPCC or regional assessments, and/or providing limited details/no examples/only examples of planned measures as opposed to measures implemented.
- ● Limited information in NCs, but references to comprehensive national studies.

Source: Gagnon-Lebrun and Agrawala, 2008.

Market-based instruments

A large number of market-based instruments are used in a variety of ways by countries to mitigate GHG emissions. These include emission charges and taxes, product charges, tax differentiation and subsidies.[16] Several OECD countries have implemented modest CO_2 emission taxes or "green" energy taxes intending to limit emissions. For example, in Denmark, Finland, the Netherlands, Norway and Sweden, CO_2 or "green" energy taxes have been in place since the early 1990s. In the Netherlands and Sweden significant energy taxes or rebate/refund systems encourage investments in energy efficiency and the use of renewables. The Swiss government also implemented a CO_2 tax in 2006 (UNFCCC, 2006b).

GHG emission trading is another prominent form of market-based instrument for climate change mitigation. The Kyoto Protocol allows industrialised countries to achieve their emission targets through the use of a number of international market-based instruments that are flexible about where emission reductions take place.[17] These include international emissions trading (Box 7.1), the Clean Development Mechanism (CDM) and Joint Implementation (JI). These flexible approaches help to lower the costs of compliance below what they would be if each country worked alone.

Emission trading is being implemented or considered by a number of national governments, for example the EU, Norway, Japan,[18] Australia and New Zealand, and by sub-national entities such as the states in the US and provinces in Canada. The EU Emission Trading Scheme (ETS) is by far the largest of these and is enabling more than 25 countries to test and gain practical experience with this instrument, including design and competitiveness issues. Implementation of the ETS has included extensive discussions about efficient and politically feasible design options and, more generally, the applicability of a cap and trade approach to GHG emission sources (and sinks). This has also prompted a large number of studies on efficiency and equity issues associated with the distribution of permits, the implications of economy-wide *versus* sectoral programmes, mechanisms for handling price uncertainties, different forms of targets, and compliance and enforcement issues.

Two other "flexibility mechanisms" under the Kyoto Protocol will also generate tradable credits. The Clean Development Mechanism (CDM) allows Annex I Parties to implement project activities that reduce emissions by non-Annex I Parties, in return for certified emission reductions (CERs). The CERs generated by such project activities can be used by Annex I Parties to help meet their emissions targets under the Kyoto Protocol, provided that the projects help developing countries achieve sustainable development.[19] The CDM is growing fast and is currently expected to generate 2.1 billion credits by 2012 (UNEP/RISO *www.cdmpipeline.org*) which is already a significant proportion of the expected gap between mitigation targets and national emissions under current policies.

The second of these "flexible mechanisms" is Joint Implementation, where Annex I Parties may implement an emission-reducing project in the territory of another Annex I Party and generate emission reduction units (ERUs) towards meeting its own Kyoto target. It is likely that many countries will have to implement additional policies and/or take more advantage of these flexibility mechanisms to achieve their Kyoto Protocol emission targets.

Box 7.1. **The European Union Emission Trading System (EU ETS)**

The launch of the EU ETS is one of the most significant recent policy developments aimed at reducing GHG emissions in industrialised countries under the Kyoto Protocol. It is a so-called "cap and trade" system where participants agree to work together through a market to achieve fixed emission reduction targets. Its first, pilot, phase ran from 2005-2007. Its second phase runs from 2008-2012, and its third phase will start in 2013. The EU ETS extends to all EU member states (25 in the pilot phase, and 27 in the second phase). In March 2007, the European Council endorsed an energy and climate package, making an independent commitment to reduce greenhouse emissions by at least 20% by 2020 and concluding that the reduction target would be increased to 30% in the context of an international agreement that includes other industrialised countries. A key challenge for the EU will be delivering on these political commitments. Before the end of 2007, the Commission will present a proposal to amend the Emission Trading Directive as well as a Burden Sharing Decision to achieve the agreed greenhouse gas reduction target.

The EU ETS is significant in all EU countries in terms of the scope of emissions covered under the system, which includes approximately half of gross EU CO_2 emissions from almost 11 500 installations during 2005-2007. The share of CO_2 emissions covered in individual countries varies widely, from approximately 22% in Luxembourg to 78% in Finland. Coverage of the EU ETS will expand during the second phase in terms of numbers of installations, the type of GHG emission covered (with some countries choosing to include industrial N_2O emissions), and potentially also the emission sources covered (*e.g.* aviation).

In the pilot phase of the EU ETS, national allocation plans (including reserves for new entrants) allowed for a slight increase in emissions from the covered facilities above baseline emission levels. Actual emissions were below allocation levels by approximately 8% in 2005 and 2% in 2006, indicating that the allocations in the pilot phase did not effectively constrain emissions below what they would have been otherwise. Allocation for the second phase of the EU ETS is much tighter, with the proposed cap for EU25 member countries lower than their EU ETS emissions in 2005, even though the coverage of phase two is larger than phase one.

A number of factors have affected allowance prices in the EU ETS, including the overall size of the allocation, relative fuel prices, weather and the availability of Certified Emission Reductions (CERs) from the CDM. The market has grown enormously, with over one billion tonnes CO_2eq of allowances, corresponding to over USD 24 billion, traded in the EU ETS during 2006 (Capoor and Ambrosi, 2007). The EU ETS has experienced significant price volatility during its pilot phase, with prices rising to over EUR 30 per tonne CO_2, but then dropping dramatically in April 2006 when emissions data from member states were released showing that they had emitted less than anticipated. By late 2007, prices for phase one allowances were lower than EUR 0.1 per tonne. However, prices for phase two allowances are much higher (EUR 21-23/tonne in October 2007) due in part to the much more stringent allocations in this phase.

From 2013, there may be significant changes in the coverage of the EU ETS and in its links to other schemes – as well as increased harmonisation of the cap-setting, allocation, monitoring, reporting and compliance provisions. The Commission's recommendations for such changes will be made in its review at the end of 2007, and should be finalised during 2008-2009.

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Regulations and standards

Regulations and standards specify abatement technologies (technology standard) or minimum requirements for pollution output (performance standard) to reduce emissions. Because performance standards require specific emission levels but often allow firms some discretion in how to meet those requirements, they are regarded as more cost effective than technology standards. Regulations and standards are often most applicable to sectors where consumers do not respond to price signals or where the price elasticity of demand is low (*e.g.* electricity, gas). Relatively few regulatory standards have been adopted solely to reduce greenhouse gases, although standards have been adopted that reduce these gases as a co-benefit. For example, there has been extensive use of standards to increase energy efficiency, including fuel economy standards for automobiles, appliance standards and building codes. Standards to reduce methane and other emissions from solid waste landfills have also been adopted in Europe, the United States, China and other countries. Such standards are often driven by multiple policy objectives, including reducing other pollutants (*e.g.* volatile organic compound emissions), improving safety by reducing the potential for explosions and reducing odours for local communities.

Voluntary agreements

Voluntary agreements and measures (VAs) are agreements between governments and one or more private parties to achieve environmental objectives or to improve environmental performance.[20] They are a common GHG policy in OECD countries (see Box 7.2). It is difficult to compare the "stringency" of agreements in different countries since they use different units, timeframes and/or boundaries. More fundamentally it is difficult to determine the effectiveness of voluntary agreements in reducing GHG emissions below business-as-usual levels (OECD, 2003). However, the benefits of voluntary agreements for individual companies may be significant. Firms may enjoy lower legal costs, enhance their reputation and improve their relationships with shareholders. Negotiations to develop VAs on climate change can help to raise awareness of climate change issues and the potential for mitigation within industry, and help to move industries towards best practices.

Technology research and development

Research and development (R&D) policies may include direct government spending and investment on mitigation technologies and tax credits to improve their performance and lower their costs. Examples of international initiatives that aim to develop and advance cost-effective technologies include the International Partnership for a Hydrogen Economy, the Carbon Sequestration Leadership Forum, and the Asia-Pacific Partnership on Clean Development and Climate. Countries pursue technological R&D in national policy for a number of reasons, such as to foster innovation, induce investments by industry and to help domestic industries to be competitive. Investments in R&D can however be misdirected to the wrong technologies or can result in the "locking in" of inefficient technology paths, and the results may not be seen for decades. While R&D programmes play an essential role, they will need to be supplemented with other policies, for example economic instruments and other incentives such as feed-in tariffs,[21] to promote deployment and diffusion of low carbon technologies and to ensure reductions in GHG emissions.

Box 7.2. **Examples of voluntary agreements in OECD countries**

- Australia's "Greenhouse Challenge Plus" programme: An agreement between the government and an enterprise/industry association to reduce GHG emissions (see *www.greenhouse.gov.au/challenge*).
- Japanese Keidaren Voluntary Action Plan: Voluntary measures taken by 35 industrial and energy converting sectors to reduce GHG emissions, which are followed up by government review. The relationship between the government and industry in Japan, as well as the unique societal norm, make this voluntary programme unique; in other words there is *de facto* enforcement (see *www.keidanren.or.jp*).
- Netherlands Voluntary Agreement on Energy Efficiency: A series of legally binding long-term agreements based on annual improvement targets and benchmarking covenants between 30 industrial sectors and the government to improve energy efficiency.
- United States Climate Leaders: This partnership encourages individual companies to develop corporation-wide GHG inventories, set aggressive reduction goals, report inventory data annually, and document progress towards their goals, reporting annually to the US Environmental Protection Agency. Since 2002 the programme has grown to include 118 corporations (see *www.epa.gov/climateleaders*).

Policy simulations

Model simulations undertaken for the *Outlook* provide insights into several key policy questions (Box 7.3). This section investigates:

- How climate change impacts compare across alternative mitigation strategies, *e.g.* early action compared to phased or delayed action.
- How modest or phased mitigation achieved through a harmonised, global carbon tax compares to atmospheric stabilisation pathways for mitigation (*e.g.* stabilising atmospheric concentrations at about 450 ppm CO_2eq and above).
- The costs and effectiveness of full *versus* more partial participation in global mitigation strategies.

The rest of this chapter focuses on two main sets of policy simulations: *i)* the implementation of a harmonised global "carbon" tax; and *ii)* implementation of a stabilisation objective, in this case, 450 ppm CO_2eq. Both are projected to lead to significant emission reductions and to alter climate change in the next 50 years. The analysis compares the environmental and economic effects of these different policy choices with the *Outlook* Baseline to 2050. It considers changes in GHG emissions (compared to 2000 emission levels) across regions, sectors and sources, as well as the effects on atmospheric concentrations of GHG and global and regional temperature changes. Ancillary or co-benefits of mitigation are also briefly analysed here focusing on three areas: air pollution, biodiversity and security. Economic effects are described as changes in global and regional economic growth – using GDP – comparing the policy cases to Baseline outcomes in a given year. Finally, sectoral economic effects of the different mitigation cases are considered by comparing changes in value added by sector and region against Baseline developments. The key assumptions and uncertainties associated with such projections and simulations are listed in Box 7.4.

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Box 7.3. **Description of Baseline and policy simulations**

Baseline assumptions: The *Outlook* Baseline uses the UN forecast of population growth to 2050 and estimates that global economic growth will be 2.4% per year (expressed in terms of purchasing power parity or PPP) on average to 2050. Productivity growth rates and economic growth, labour force growth rates and population growth are outlined in Chapters 2 and 3.

Policy case 1. Global GHG taxes:

Four cases are considered based on the implementation of a USD 25 tax per tonne of CO_2eq.* As the social costs of carbon** grow over time, the tax is increased in real terms by 2.4% per year. The level of CO_2eq tax used in three of these policy simulations escalates over time (Figure 7.4). The tax applies to the main greenhouse gas (*i.e.* CO_2, CH_4 and N_2O) emission sources across all economic activities, although the timing and countries participating in its application vary by scenario as follows (from least to most environmentally aggressive):

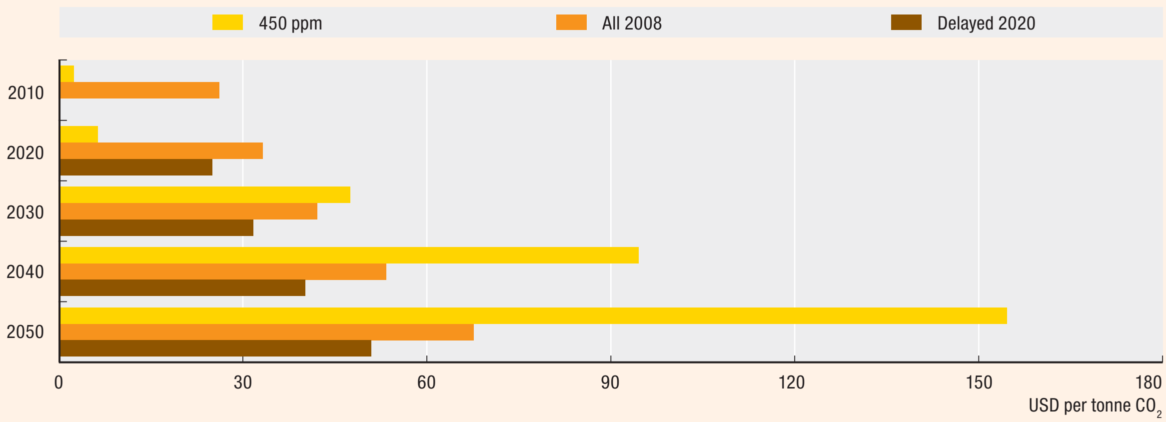
i) **OECD 2008:** OECD countries immediately implement the USD 25 tax on all greenhouse gases and sources.

ii) **Delayed 2020:** all countries impose the tax on greenhouse gas emissions, but the timing is delayed until 2020.

iii) **Phased 2030:** the global tax on greenhouse gas emissions is phased in, beginning with the OECD from 2008; Brazil, Russia, India and China from 2020 and then the rest of the world (ROW) from 2030 onwards.

iv) **All 2008:** in a more aggressive effort to mitigate global GHG emissions, all countries implement the USD 25 tax on CO_2 and other GHG emissions from 2008.

Figure 7.4. **CO_2eq tax by policy case, 2010 to 2050: USD per tonne CO_2 (2001 USD, constant)**



StatLink http://dx.doi.org/10.1787/260656823061

Source: *OECD Environmental Outlook* Baseline and policy simulations.

Policy case 2. 450 CO_2eq ppm stabilisation:

This policy simulation is chosen to demonstrate the level of effort required to stabilise atmospheric concentrations of GHG at 450 ppm CO_2eq (referred to below as 450PPM) and limit global mean temperature change to near 2°C over the long-term. It provides insights into possible mitigation costs for this aggressive mitigation pathway. It simulates an emission reduction pathway across all world regions in a "least-cost" manner across all sources (and sinks) of greenhouse gas emissions. In addition to cost and effectiveness, the simulation also reviews the technologies needed to achieve this aggressive stabilisation target (see Chapter 17). This allows us to understand what technologies and sources of greenhouse gases are expected to offer the most cost-effective means of reducing emissions significantly over the coming decades. The tax that was applied for this simulation increases from USD 2.4 per tonne of CO_2eq in 2010 to USD 155 in 2050 (in 2001 USD, constant).

A variation on this case is also presented to explore burden-sharing, using a cap and trade approach to implementation.

* Note a comparable tax is assessed as part of the policy packages exercise. See Chapter 20.

** The "social cost of carbon" (SCC) refers to the marginal damage costs of carbon emissions, or the incremental damage cost of emitting one additional tonne of carbon (in the form of CO_2) into the atmosphere. This is the key measure of benefits of mitigation within a cost-benefit analysis approach of policy assessment. See Pitinni and Rahman (2004) for a brief explanation of how integrated assessment models typically estimate SCC.

Box 7.4. **Key uncertainties and assumptions**

Projections of climate change depend on a number of parameters, all of which are associated with uncertainty in the future, including:

- Estimates of future population, economic growth and technology change: predictions of GHG emissions are influenced by population and economic growth and assumptions about technological changes. While most emission scenarios vary little to 2030, beyond that period GHG emissions could vary significantly if population, labour force participation, productivity, technological progress and economic growth differ from the assumptions in the Baseline.
- Climate sensitivity: this parameter characterises how global temperatures respond to a doubling of CO_2 concentrations. The IPCC in its 2007 report noted that climate sensitivity is likely to be in the range of 2° to 4.5°C with a "best estimate" of 3.0°C. It is very unlikely to be below 1.5°C and values substantially higher than 4.5°C cannot be excluded.
- Abrupt changes and surprises: the *Outlook* Baseline assumes a linear response to increasing concentrations of GHGs. There is however evidence from the paleo-climatic record that the Earth's systems have undergone rapid changes in the past and that these could occur in the future.
- Probability of outcomes, risks assessment: given these, and other, uncertainties, probabilistic assessment is increasingly used to give policy-makers an idea of the likelihood of achieving identified targets (Jones, 2004; Yohe *et al.*, 2004; Mastrandrea and Schneider 2004). For example, Meinshausen (2006) considers the case of a 2°C target, estimating that a 650 ppm CO_2eq concentration level would offer only a 0% to 18% probability of success. This presents climate change in a risk assessment and management framework.
- Adaptation: human systems are likely to respond to climate change through adaptation, while ecological systems are likely to find it more difficult to adapt. The faster global warming occurs, the more difficult and limited adaptation will be. Most current studies of climate change impacts recognise the need to consider adaptation, but few modelling studies integrate adaptation comprehensively into quantitative analyses.

Climate change and global impacts: mitigation policy compared to the Baseline

Climate change outcomes for the different policy cases already diverge from the Baseline by 2050 and this difference will grow over time. In the nearer-term the *Outlook* Baseline projections suggest that without new climate change and environmental policies, GHG emissions will grow at a pace that raises CO_2eq concentrations significantly to approximately 465 ppm by 2030 and further to 540 ppm by 2050, which is predicted to increase global mean temperature by 1.9°C in 2050 (above the pre-industrial level, within a range of 1.7 to 2.4°C; see Table 7.4c).[22] By 2030 the *Outlook* projects that temperature under the Baseline will be increasing rapidly, by about 0.28°C per decade, up from about 0.18°C per decade today, and will continue at this pace until 2050. Factors like reduced sea-ice cover, which would change the regional albedo (reflectivity of the Earth's surface), and enhanced methane emissions from melting permafrost soils may accelerate unmitigated climate change beyond these levels.

Table 7.4 shows growth in GHG and CO_2 emissions for the Baseline and policy cases compared to 2000 emission levels. All of the policy cases, except the OECD 2008 tax, lead to significant emission reductions compared to 2000, with the 450 PPM case showing the greatest reductions in global GHG emissions (–39%), whereas the All 2008 tax case delivers about two-thirds of this emission reduction by 2050. Interestingly the Phased 2030 and Delayed 2020 tax cases significantly reduce emissions from the Baseline but do not deliver

Table 7.4. **Policy scenarios compared to Baseline: GHG emissions, CO_2 emissions and global temperature change, 2000-2050**

a. % Change in GHG emissions relative to 2000

Region	Baseline		OECD 2008		Delayed		Phased		All 2008		450 ppm	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
World	52	69	34	38	23	3	20	0	7	–21	–7	–39
OECD	28	31	–14	–43	2	–22	–14	–42	–14	–42	–23	–55
BRIC	72	92	72	92	36	14	36	16	16	–13	4	–34
ROW	65	104	66	103	44	31	55	51	30	5	6	–19

b. % Change in CO_2 emissions relative to 2000

Region	Baseline		OECD 2008		Delayed		Phased		All 2008		450 ppm	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
World	54	72	36	38	31	7	26	3	11	–21	–3	–41
OECD	31	34	–9	–42	8	–18	–9	–41	–9	–41	–18	–55
BRIC	81	106	81	107	50	24	36	16	24	–11	13	–34
ROW	65	104	66	103	50	32	55	51	33	3	7	–25

c. Atmospheric GHG concentrations, global mean temperature, rate of temperature change

Region	Baseline		OECD 2008		Delayed		Phased		All 2008		450 ppm	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
CO_2 Concentration (ppmv)	465	543	458	518	458	507	455	501	448	481	443	463
GMT range (°C)[a]	1.2-1.6	1.7-2.4	1.2-1.5	1.6-2.2	1.2-1.5	1.5-2.1	1.1-1.4	1.5-2.0	1.1-1.4	1.4-1.9	1.1-1.4	1.3-1.8
Rate of GMT chg (°C/decade)	0.28	0.28	0.25	0.23	0.22	0.19	0.22	0.18	0.21	0.15	0.16	0.10

StatLink http://dx.doi.org/10.1787/257115140846

a) The range in global mean temperature change is based on MAGICC model calculations as performed by van Vuuren *et al.* (forthcoming). The MAGICC range originates from emulation of different climate models, here showing the impact of climate sensitivity with a range corresponding to a climate sensitivity of 2.0-4.9 °C. The overall range in transient 21st century climate change was used relative to the IMAGE model outcomes to account for differences in the scenarios.

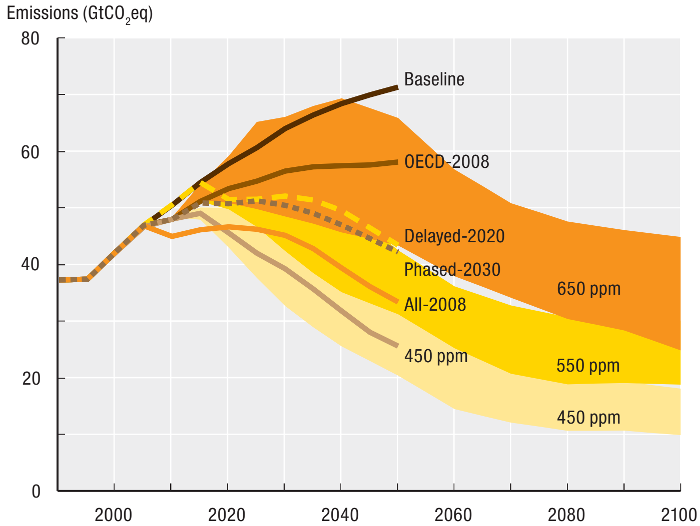
Source: OECD Environmental Outlook Baseline and policy simulations.

absolute emission reductions in 2050. The OECD 2008 tax shows significant reductions in OECD regions (–43%) yet the global emissions still grow by 38% compared to 2000 emission levels (Table 7.4). The spread of outcomes among these cases demonstrates the importance of full participation by all major emitters and early mitigation efforts if substantial emission reductions are to be achieved by 2050.

Figure 7.5 compares the Baseline and policy cases' GHG emission pathways with longer term stabilisation pathways (*i.e.* for 650, 550 and 450 ppm CO_2eq as well as alternative baseline scenarios). A comparison with the IPCC summary of long-term emission scenarios, in Table 7.5, shows that the *Outlook* Baseline clearly is outside of the range of a stabilisation pathway for 750 ppm CO_2eq, with emissions likely to grow throughout the 2100 period. A baseline of this type would be expected to lead to a global mean temperature increase range of 4-6°C (above pre-industrial, equilibrium).[23]

Compared with the Baseline trajectory, the early and more aggressive policy cases deliver significantly lower concentrations and thus lower temperatures and slower rates of change (*i.e.* as illustrated in the 450 PPM and All 2008 cases). The global tax (All 2008) falls within the 550 ppm CO_2eq target by 2050. Delaying mitigation efforts to 2020 (Delayed 2020), or phasing in participation by large emitters outside of the OECD much more slowly (Phased 2030) raises emissions sufficiently to shift global emissions from a

Figure 7.5. **Global GHG emission pathways: Baseline and mitigation cases to 2050 compared to 2100 stabilisation pathways**



Source: OECD Environmental Outlook Baseline and policy simulations; and van Vuuren *et al.*, 2007.

550 CO_2eq to a 650 ppm pathway. By contrast, the OECD-only tax from 2008 (OECD, 2008) starts to bring global emissions into the pathway early for 650 ppm CO_2eq stabilisation, but by the end of 2050 overshoots this because of the limited participation in mitigation efforts.

Table 7.5 shows quite different climate change outcomes at equilibrium for stabilisation pathways; the *Outlook* Baseline and policy simulations can be considered in this longer-term context. The more comprehensive (in terms of participation) and more stringent policy cases – *i.e.* All 2008 and 450 PPM – are likely to avoid roughly 1-3°C of global mean temperature increase (or more) already in the 2080 timeframe compared with scenarios falling at the high end of stabilisation such as the Category V and VI scenarios in Table 7.5.[24] Similarly decadal rates of temperature change differ significantly among the cases. By 2050, the All 2008 and 450 PPM cases slash the rate of change by half and two-thirds respectively compared to the Baseline, demonstrating a strong climate change response to early and more comprehensive action (Figure 7.6c).

The costs of inaction or delayed action are therefore potentially significant (see also Chapter 13, Cost of policy inaction). The latest IPCC report (2007) suggests greater risks than previously for even relatively low levels of temperature increases (*e.g.* 1-3°C above pre-industrial levels) (Schneider *et al.* 2007; IPCC 2007d). Delay in reducing emissions could have serious consequences for the environment and could be costly, especially if society eventually decides that it is prudent to opt for stringent mitigation targets in the long-term. This is demonstrated by the clear differences in climate change outcomes by 2050 associated with the case of a 10-year delay in policy action (Delayed 2020) compared to cases with earlier mitigation action (450 PPM; All 2008) (Figure 7.6). Other literature also explores these risks (Kallbekken and Rive, 2006; Shalizi, 2006). For example, Kallbekken and Rive (2006) show that immediate emission reductions lower the rate at which global emissions need to be reduced for a given climate target; they show that to achieve a given temperature after a delay of 20 years would require emissions to be reduced at a rate that is 3-9 times greater than if emissions were reduced immediately.

Table 7.5. **Characteristics of post TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only**[a]

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a, c]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[a, c]	Global average temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	Year	Percent	°C	metres	
I	350-400	445-490	2000-2015	–85 to –50	2.0-2.4	0.4-1.4	6
II	400-440	490-535	2000-2020	–60 to –30	2.4-2.8	0.5-1.7	18
III	440-485	535-590	2010-2030	–30 to +5	2.8-3.2	0.6-1.9	21
IV	485-570	590-710	2020-2060	+10 to +60	3.2-4.0	0.6-2.4	118
V	570-660	710-855	2050-2080	+25 to +85	4.0-4.9	0.8-2.9	9
VI	660-790	855-1130	2060-2090	+90 to +140	4.9-6.1	1.0-3.7	5

StatLink http://dx.doi.org/10.1787/257132076082

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).*

b) Atmospheric CO_2 concentrations were 379 ppm in 2005. The best estimate of total CO_2eq concentration in 2005 for all long-lived GHGs is about 455 ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375 ppm CO_2eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).*

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also footnote 21).*

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6 m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere Ocean General Circulation Models and EMICs to Earth System Models of Intermediate Complexity.)

* These are cross-references in the original report. The report is also available on the Internet, see: *www.ipcc.ch.*

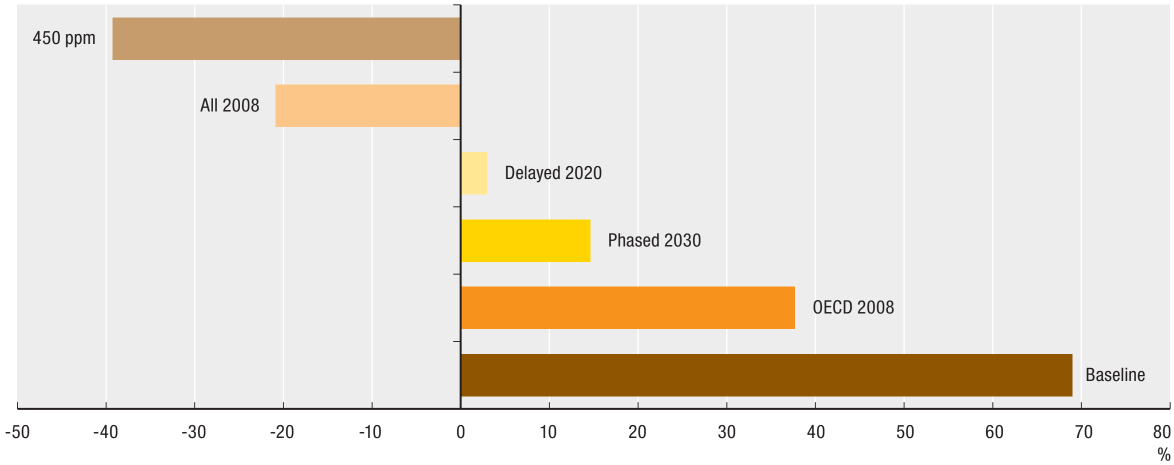
Source: Table SPM.6, IPCC (2007d), *Climate Change: Synthesis Report. The Fourth Assessment Report*, Cambridge University Press, Cambridge, UK (reproduced here with the full set of original notes).

Regional effects of mitigation policy compared to the Baseline

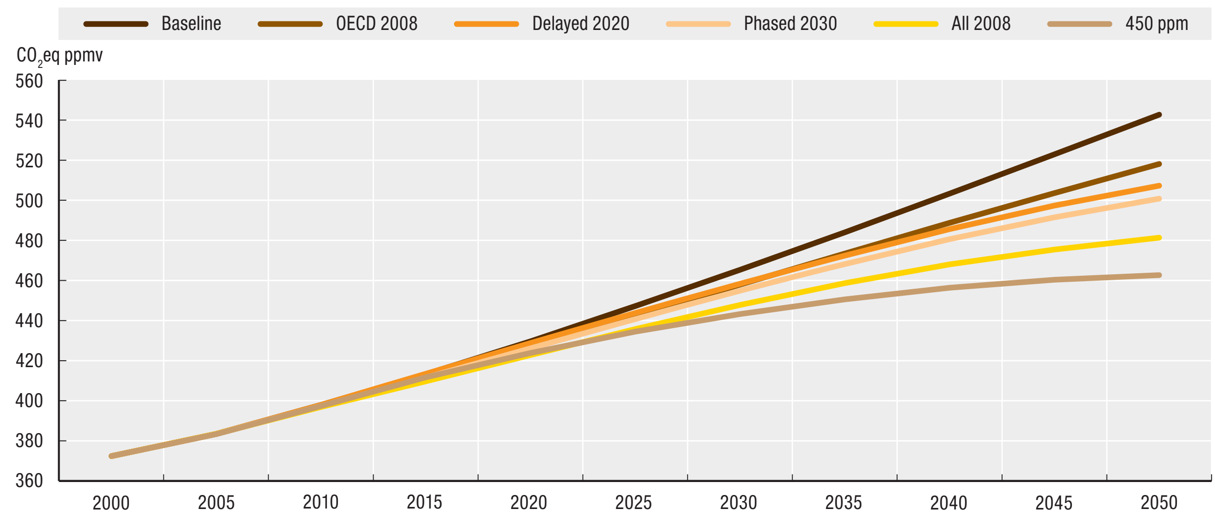
The regional distribution of climate change is projected to vary significantly, with many heavily populated regions of the world experiencing temperature changes that are higher than the projected average (see Figure 7.7a for Baseline temperature patterns). With higher temperatures, the hydrological cycle is also projected to intensify under the Baseline case as more water evaporates and on the whole more precipitation results. As with the temperature pattern though, the effect is very unevenly distributed and many areas may even become drier, while adjacent areas receive more precipitation. In already water-stressed areas such as southern Europe and India, the negative impact on agriculture and human settlements would be substantial. The risk of drought-related problems will be highest in areas where the future drop in surplus is large relative to the current level. These areas are likely to include parts of Africa as well as southern Europe, large parts of Australia and New Zealand. Areas with substantial increases over already high levels in 2000 are more susceptible to encounter water drainage or flooding problems. In general, all areas facing considerable changes in surplus will have to adapt to cope with these changes, including through adjustments in water management practices and/or infrastructure.

Figure 7.6. **Change in global emissions, GHG atmospheric concentrations, global mean temperature: Baseline and mitigation cases**

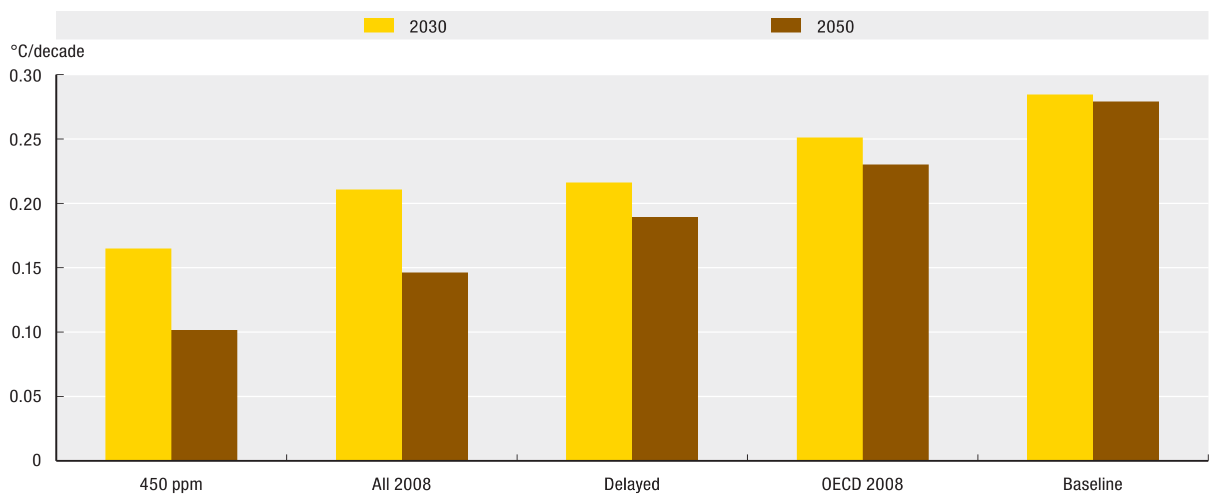
A. Changes in global GHG emissions in 2050 relative to 2000 by policy case



B. Changes in CO_2 concentrations over time by case, 2000 to 2050



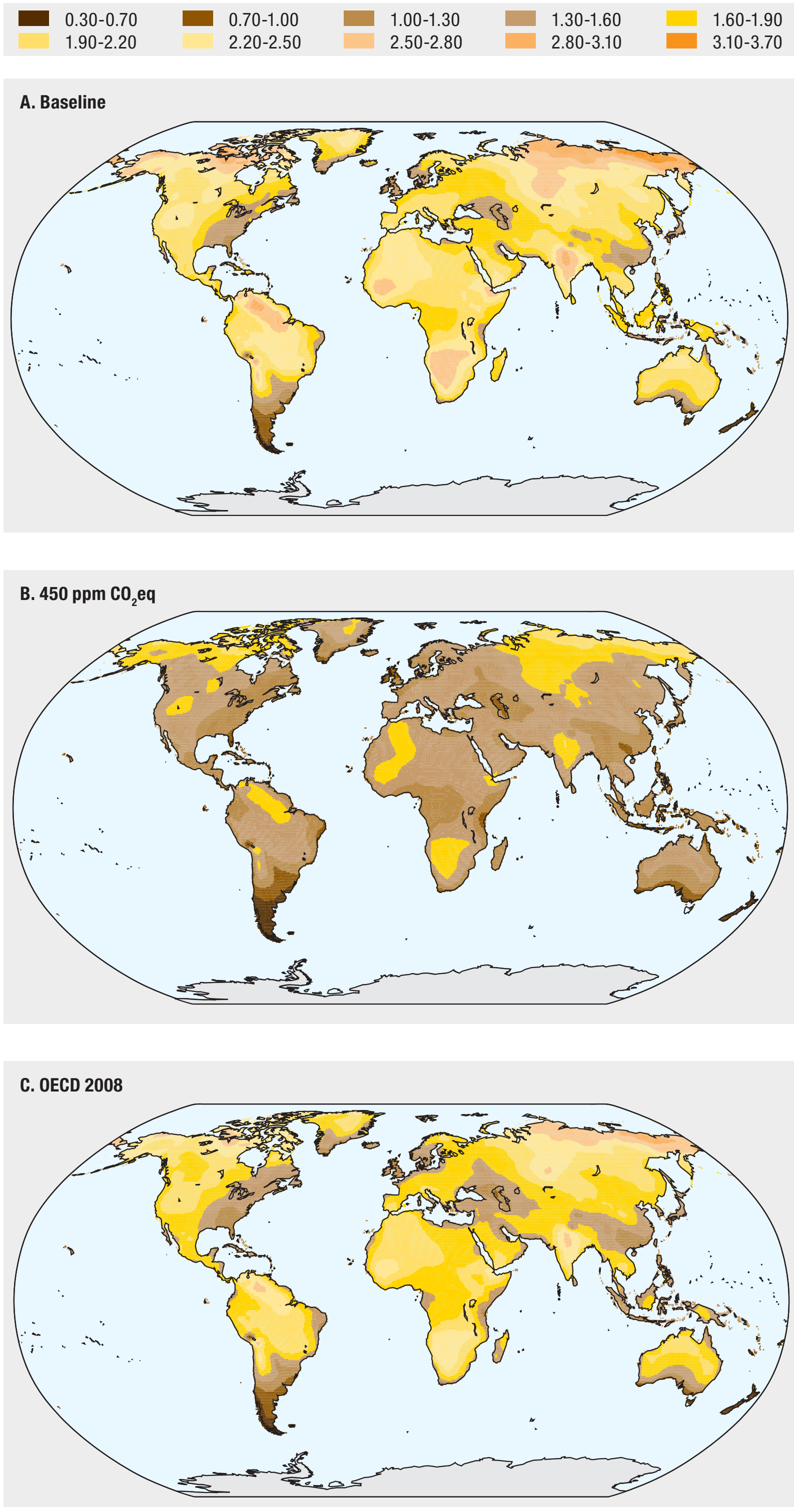
C. Decadal rate of temperature change



StatLink http://dx.doi.org/10.1787/260741607702

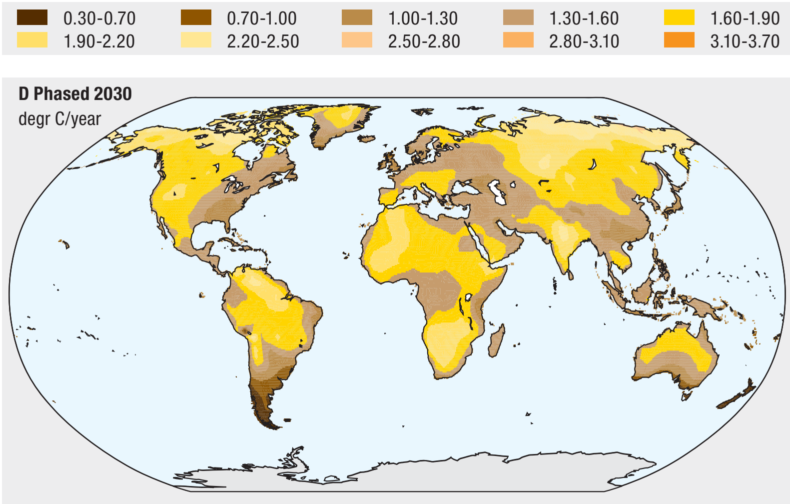
Source: *OECD Environmental Outlook* Baseline and policy simulations.

Figure 7.7. **Change in mean annual temperature levels in 2050 relative to 1990 (degrees C)**



Source: OECD Environmental Outlook Baseline and policy simulations.

Figure 7.7. **Change in mean annual temperature levels in 2050 relative to 1990 (degrees C)***(cont.)*



Source: OECD Environmental Outlook Baseline and policy simulations.

Climate change is expected to affect productivity, commodity prices and the spatial allocation of the various crop types. Under the *Outlook* Baseline, temperate crops are likely to tend to "move north" as growing conditions nearer to the equator become less suitable to 2030 and beyond, while growing conditions may improve at higher latitudes. There is a great deal of uncertainty associated with the potential for irrigation, the availability of fertilisers and changes in pests. For tropical crops like rice, changes in precipitation may affect large areas. Though still uncertain and relatively small in the 2030 timeframe, these changes are accounted for in the estimates of future agricultural productivity for all crop types in this *Outlook* (see Chapters 10 on freshwater and 14 on agriculture).

Mitigation policy will affect the pattern of regional climate change and the distribution and magnitude of regional impacts. Already by 2050, regional temperature patterns show much less dramatic changes under the more aggressive and early action mitigation scenarios compared to the case of inaction (Baseline) (see Figures 7.7a-d). These differences between the policy and Baseline in terms of the predicted climate changes will become even more pronounced into the last half of the 21st century.

Contrasting the OECD 2008 tax case with the Phased 2030 and 450 PPM cases shows that the more stringent and more comprehensive the mitigation effort (in terms of participation) in the next decades the more likely it will be possible to limit temperature changes over large regions of the world. The 450 ppm CO_2eq stabilisation case significantly limits global and regional warming by 2050 compared to the Baseline pattern of warming. As noted above, this difference is projected to widen by the end of the century.

Co-benefits of mitigation[25]

As noted above, the co-benefits of greenhouse gas mitigation can be significant, and could include cost-reductions in the achievement of air pollution policy objectives (see Box 7.5) as well as the direct improvement of human health, urban environments or

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Box 7.5. **Co-benefits and the cost-effectiveness of climate and air pollution policy**

Accounting for the co-benefits of reduced air pollution and reduced greenhouse gas emissions can have significant impacts on the cost effectiveness of climate and air pollution policy. The co-benefit relationship suggests that co-ordination of policy efforts in these areas could deliver important cost savings. For example, van Harmelen *et al.* (2002) found that to comply with agreed or future policies to reduce regional air pollution in Europe, mitigation costs are implied, but these are reduced by 50-70% for SO_2 and around 50% for NO_x when combined with GHG policies. Similarly, in the shorter-term, van Vuuren *et al.* (2006) found that for the Kyoto Protocol, about half the costs of climate policy might be recovered from reduced air pollution control costs. The exact benefits, however, critically depend on how climate change policies are implemented and on the baseline policies that are used for comparison (Morgenstern, 2000). Most available studies do not treat co-benefits comprehensively in terms of reduction costs and the related health and climate impacts in the long-term, thus indicating the need for more research in this area (OECD, 2000; IPCC, 2007a).

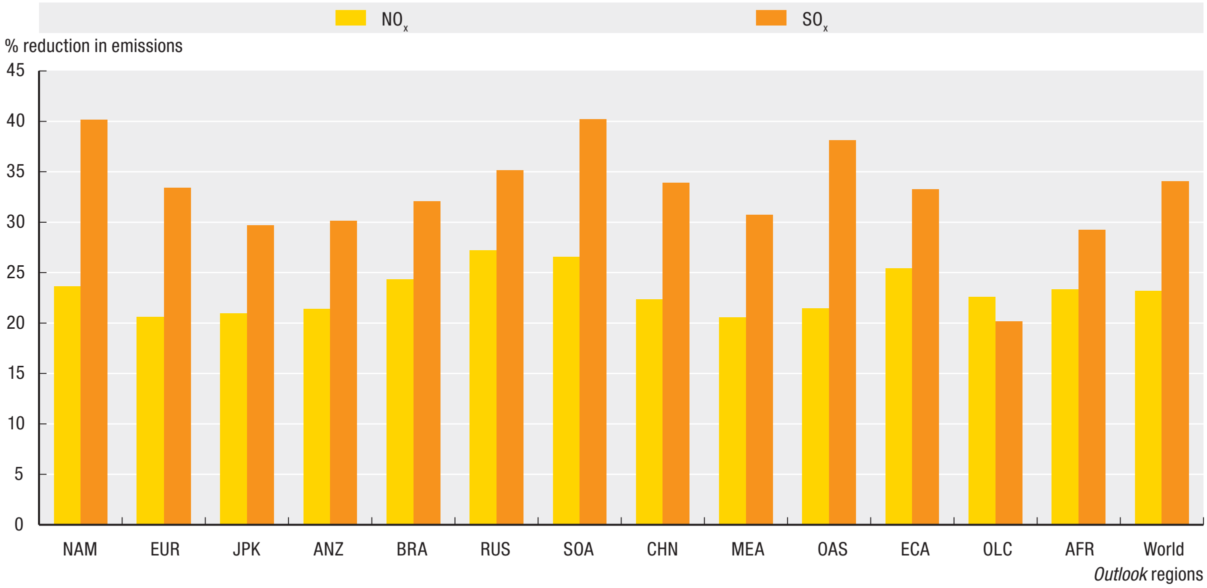
national security. We focus here on the ancillary benefits that accompany GHG mitigation policy in three different areas – air pollution, biodiversity and security – drawing on *Outlook* simulations in the first two areas to illustrate the magnitude of benefits.

Air pollution and biodiversity co-benefits: Outlook *results*

Stabilising concentrations of GHG in the atmosphere at relatively low levels requires reversing trends so that emissions decline in the coming decades. For example, in the 450 ppm case, global CO_2 emissions peak in 2015 and decline thereafter by about 40% relative to 2000 emission levels. Reducing CO_2 emissions by this degree would require a major transformation in the energy sector with energy efficiency, renewable or nuclear energy playing a larger role than in the past (see Chapter 17, Energy). In addition to limiting the scale and the pace of climate change, a transition to clean energy systems and away from fossil fuel combustion will yield a range of environmental benefits including in the area of air pollution and human health. Figure 7.8 shows that the 450 ppm case leads to reductions by 2030 in the range of 20-30% for sulphur oxides (SO_x) and 30-40% for nitrogen oxides (NO_x). SO_x and NO_x cause acid rain, damaging freshwater ecosystems, forest ecosystems and agricultural productivity on a regional scale. NO_x is also a local pollutant and in urban areas is a precursor to ozone formation which is harmful to human health. Urban ozone episodes affect respiratory and lung systems and aggravate asthma and allergies to pollen. In this example, the largest air pollution co-benefits would be found in some of the most rapidly developing and urbanising areas of South Asia (SOA including India), Indonesia and the rest of South Asia (OAS), China (CHN), and eastern Europe and central Asia (ECA). There is also a large relative benefit in North America (NAM – *i.e.* Canada, Mexico and the US) in moving from the Baseline to the 450 PPM case.

As biodiversity will vary with levels of climate change and with approaches to greenhouse gas mitigation policy, ancillary benefits of mitigation policies are also possible in the 2050 timeframe. Using the mean species abundance (MSA) indicator (see Chapter 9, Biodiversity), Figure 7.9 compares the 450 ppm case to the Baseline. These results depend upon the avoided climate change impacts, as discussed above, and the mitigation approaches embedded in the 450 ppm case, where large scale production of second generation biofuels are an important

Figure 7.8. **Air pollution co-benefits of GHG mitigation: reduction in NO_x and SO_x emissions – 450 ppm case and Baseline, 2030**



StatLink http://dx.doi.org/10.1787/260800071717

Note: Regional country groupings are as follows: NAM: North America (United States, Canada and Mexico); EUR (western and central Europe and Turkey); JPK: Japan and Korea region; ANZ: Oceania (New Zealand and Australia); BRA: Brazil; RUS: Russian and Caucasus; SOA: South Asia; CHN: China region; MEA: Middle East; OAS: Indonesia and the rest of South Asia; ECA: eastern Europe and central Asia; OLC: other Latin America; AFR: Africa.

Source: *OECD Environmental Outlook* Baseline and policy simulations.

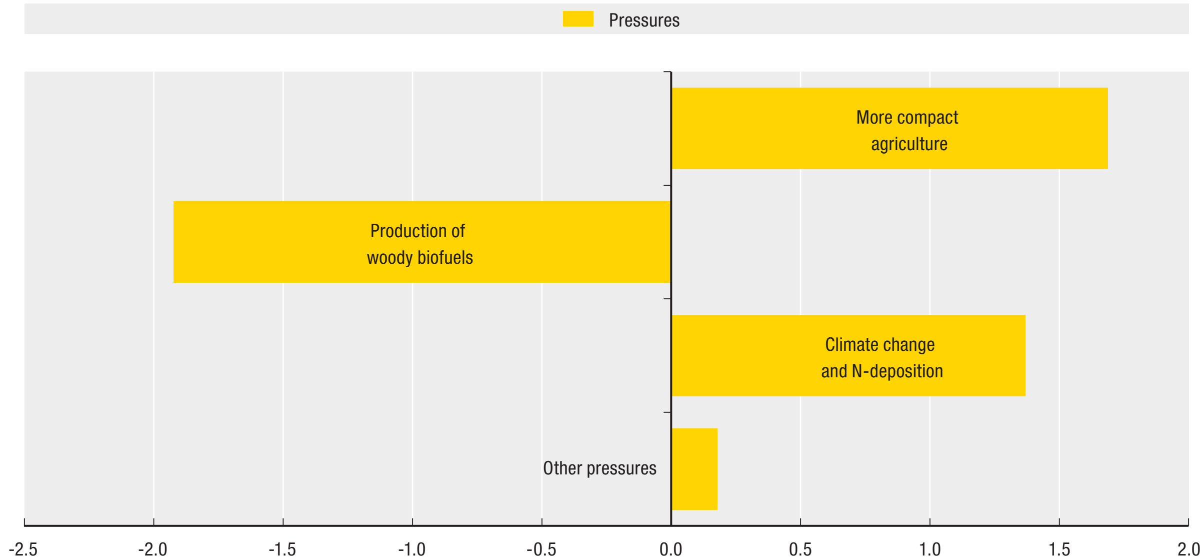
part of the policy portfolio. This biofuel production will affect land use and biodiversity in various ways. Although the 450 ppm case leads to less climate change than in the Baseline, increased land use for biofuel production causes substantial additional biodiversity loss. However, the net balance for the 450 ppm case between avoided and additional losses is slightly positive: 1% less decrease in mean species abundance than in the Baseline by the middle of the century. This reflects the assumption that greenhouse gas mitigation policies also provide incentives to reduce deforestation and thus develop more compact agricultural activity than would otherwise be the case, which in turn is essential to reach the climate target. However, concrete policy instruments to promote this would need to be developed. The benefits from the reduction in the total amount of land conversion from forest to agriculture under the 450 ppm case compared to the Baseline partly compensate for losses from biofuel production (Figure 7.9). It should also be noted that the recent IPCC assessment presents new evidence that suggests that biodiversity might be more sensitive to climate change than previously believed (IPCC, 2007b and d).

National security

In addition to sector policy co-benefits that are mainly local in scale, there are also national and international co-benefits of climate change mitigation and adaptation in the form of reduced security risks. Climate change will affect world regions unevenly, with the greatest costs likely to fall on the poorest regions (IPCC, 2007b; IPCC, 2007d). The uneven distribution of climate change impacts is due in part to high vulnerability of poor nations, where the ability to cope with climate change is low. It follows that climate change has implications for foreign policy and national security, for example by increasing the flood

Figure 7.9. **Biodiversity effects of the 450 ppm case by 2050**

Mean species abundance: percentage points relative to Baseline



StatLink http://dx.doi.org/10.1787/260824878514

Note: MSA effects are presented as change from the Baseline scenario. Avoided loss in mean species abundance (MSA) is presented as a positive value, and additional loss as negative. The figure shows the effect of each individual pressure factor as well as the total effect of all factors. The MSA biodiversity indicator is further explained in Chapter 9, Biodiversity; see also Alkemade *et al.*, 2006; CBD and MNP, 2007.

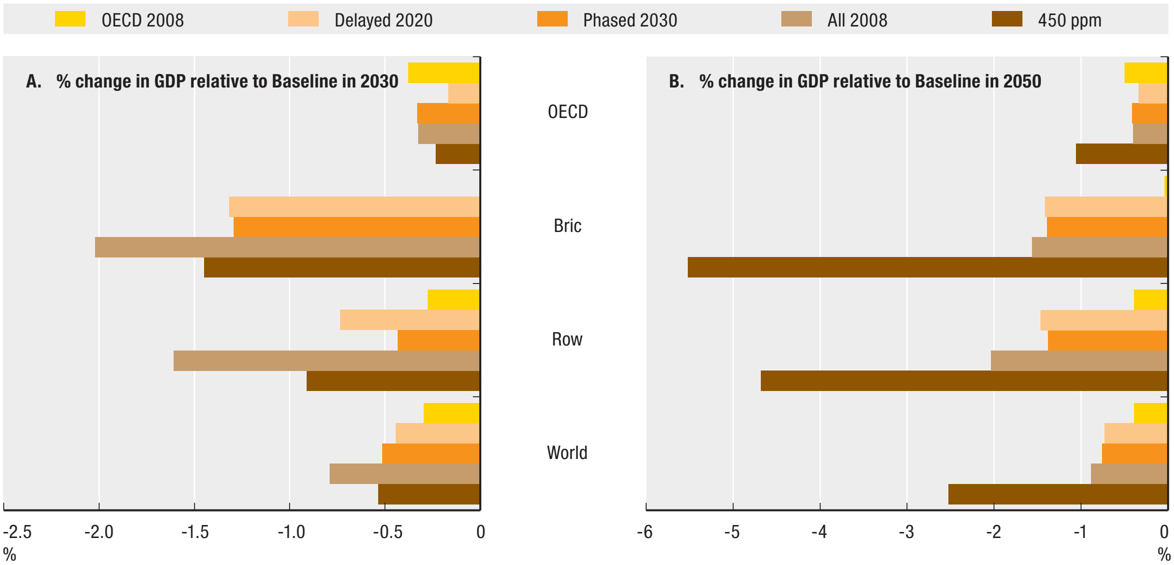
Source: OECD Environmental Outlook Baseline.

risk and exposure to other extremes in poor and heavily populated regions, in addition to increased competition for resources in already water scarce regions of the world (Brauch, 2002; Barnett, 2003; Campbell *et al.*, 2007). Thus a co-benefit of global mitigation policies is to limit "cascading consequences" and national security risks from otherwise unchecked climate change (Campbell *et al.*, 2007; Oberthuer *et al.*, 2002).

Costs of mitigation and implications for innovation

Figure 7.10a, and b and Table 7.6 compare the economic costs of the different policy cases with the Baseline economic projections for 2030 and 2050. These model simulations assume perfect cost-effective implementation pathways of each mitigation policy case, and therefore could be said to underestimate the true implementation costs. However, the model also assumes there are no opportunities for negative or no-cost mitigation and does not explicitly account for co-benefits as an offset to costs even though these may be significant (*e.g.* see discussion in IPCC, 2007c and above). These limitations might therefore be said to overestimate the costs of mitigation.

Figure 7.10. **Economic cost of mitigation policy cases by major country group**



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Note: Scales differ.

Source: *OECD Environmental Outlook* Baseline and policy simulations.

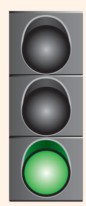
Table 7.6. **Change (%) in GDP relative to Baseline of different scenarios, 2030 and 2050**

Case Region	450 ppm		All 2008		Phased 2030		Delayed 2020		OECD 2008	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
OECD	–0.2	–1.1	–0.3	–0.4	–0.3	–0.4	–0.2	–0.3	–0.4	–0.5
BRIC	–1.4	–5.5	–2.0	–1.6	–1.3	–1.4	–1.3	–1.4	0.0	0.0
ROW	–0.9	–4.7	–1.6	–2.0	–0.4	–1.4	–0.7	–1.5	–0.3	–0.4
WORLD	–0.5	–2.5	–0.8	–0.9	–0.5	–0.8	–0.4	–0.7	–0.3	–0.4
BIC	–1.1	–4.7	–1.6	–1.0	–1.0	–0.9	–1.0	–0.9	0.0	0.0
MEA/Russia	–2.9	–10.6	–4.5	–6.0	–2.3	–4.3	–2.4	–4.2	–0.7	–0.8

StatLink http://dx.doi.org/10.1787/257133737368

Source: *OECD Environmental Outlook* Baseline and policy simulations.

The results show that even for the most aggressive mitigation case – stabilising concentrations at 450 ppm CO_2eq – global costs of mitigation are positive, but manageable. Total loss of GDP (relative to the Baseline) is projected to be roughly 0.5% by 2030, rising to about 2.5% by 2050. This is equivalent to slowing annual growth rates in GDP over the 2005 to 2050 timeframe by about 0.1 percentage point. The regional distribution of costs, however, for this stabilisation case differs broadly in the 2030 and 2050 timeframe. OECD costs are projected to be the lowest, at 0.2% and 1% below the Baseline GDP in 2030 and 2050 respectively. The costs in Brazil, Russia, India and China (BRIC) are roughly five times this level and those in the rest of the world (ROW) about four times as high. For the other tax policy cases, the costs are significantly lower in the



Global costs of mitigation, even for the most stringent mitigation case – stabilising concentrations at 450 ppm CO_2eq – are significant but manageable.

2050 timeframe; however, given the timing of the stabilisation case, the costs in 2030 are sometimes lower under stabilisation than for the USD 25 tax case (see Table 7.6). As noted below, this large regional difference in cost could be addressed through a variety of different burden-sharing mechanisms including, for example, differential target setting in a cap and trade policy scenario.

An important analytical question is the impact of GHG mitigation policy on industrial competitiveness and, possibly, business decisions about where to locate industrial production. Another interesting result from this analysis is that these simulations, with a particularly rich representation of trade, do not show much leakage (or migration) of industrial activity, energy use and CO_2 emissions from the OECD to other parts of the world. This is evident from Table 7.4a, which shows no increase in emissions in other parts of the world under the OECD 2008 tax case, where a tax is imposed in the OECD region alone. Also OECD emission reductions compared to the Baseline (or base year) are comparable across the OECD 2008 tax case and All 2008, or the case where a global tax is imposed.

Oil and natural gas producing countries (including Russia) are projected to experience the greatest change in GDP from mitigation efforts (across all policy cases) because of their economic vulnerability to taxation on the carbon content of fossil fuels (*i.e.* oil and oil products). These countries' export markets for fossil fuels are likely to be affected. Their domestic economies will also be affected significantly since fuel prices are kept low, either through subsidies or exceptionally low energy taxation, which in turn boosts domestic consumption, dependence on fossil fuels and GHG intensity of economic production. This vulnerability might be ameliorated by diversifying the economies of oil-producing countries *and* raising the price of domestic energy to its opportunity cost (*i.e.* the world price, plus whatever taxes are applied to other commodities). While cheap fossil fuels should be a natural comparative advantage for energy-producing economies, they can become liabilities in a carbon-constrained world.[26]

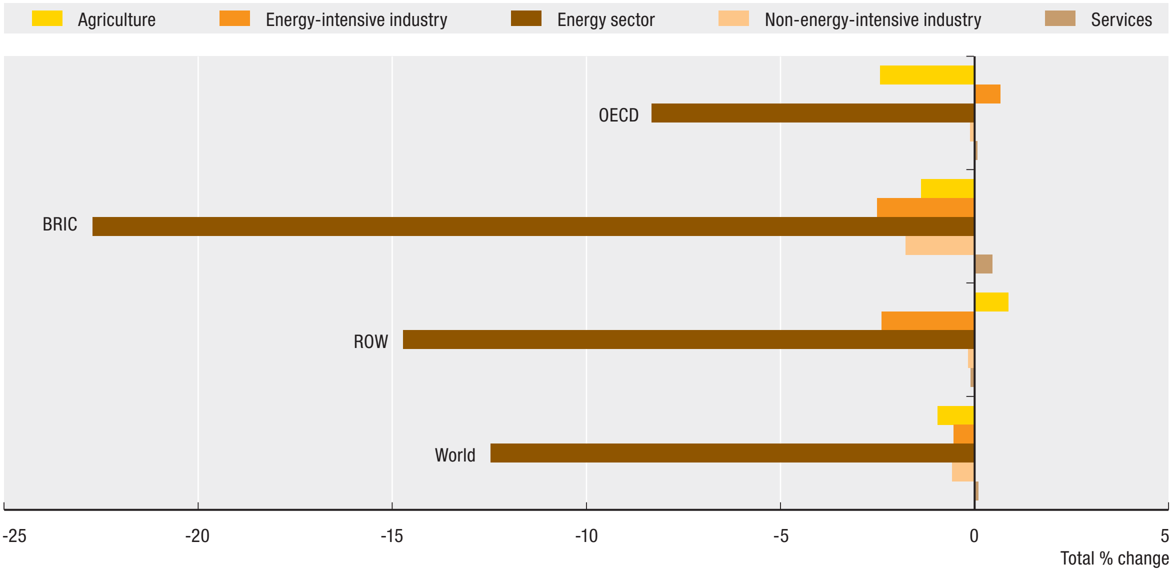
Under the policy simulation of an immediate adoption of a USD 25 tax on CO_2 by all countries (All 2008), annual GDP in the oil-producing countries is estimated to be about 4% and 5% lower than the Baseline in 2030 and 2050 respectively (Table 7.6). Phasing in the tax is projected to roughly halve the economic losses for this oil-producing group of countries, whereas if OECD countries act alone the economic losses associated with the tax fall to about one-tenth of the All 2008 scenario. Of course, as noted above, the environmental effectiveness of the tax in reducing global GHG emissions would also drop significantly if participation is more limited or implementation delayed.

More generally, the high costs of aggressive mitigation (*e.g.* 450 ppm) in non-OECD regions are driven by several factors:

- The large potential for relatively low-cost mitigation in non-OECD regions compared to the OECD becomes especially important under the most stringent mitigation cases.
- The growth in emissions from non-OECD countries is higher than for OECD countries, which means that these countries will need to reduce a relatively larger share of emissions under the stringent mitigation scenario.
- As noted above, the relatively high levels and broad scope of energy subsidisation in some key regions (*e.g.* Russia, newly independent states and many oil-producing regions) raise the cost of mitigation, especially in the energy and the energy-intensive sectors.

Figure 7.11 shows changes in value added[27] by type of industry across major country groupings relative to the Baseline for the 450 ppm stabilisation case in 2030. This

Figure 7.11. **Change in value added: 450 ppm CO_2eq stabilisation case relative to Baseline, 2030**



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Source: *OECD Environmental Outlook* Baseline and policy simulations.

demonstrates that the energy sector is a principal source of mitigation; changes in this sector dominate in all the country groups in 2030 and this result continues to 2050 (not shown here). Other sectors show mixed results. Two main factors contribute to the varied outcomes. First, when the cost of energy goes up, firms switch to other inputs. If those other inputs consist of labour and capital, value-added will increase. In general, this should not be enough to completely offset the impact of energy price increase, so the net impact should be negative. However, when there are differences between regions in fossil-fuel intensity of sectoral production, then some sectors in some regions may, in fact, show a net gain. In other words, the heterogeneity of sectoral results illustrated in the figure reflects regional differences in sectoral fossil-fuel intensity.

Burden sharing

These policy simulations suggest a need for a burden-sharing mechanism in any future international collaboration to reduce global emissions. The burden could be shared through a variety of ways, but one that is often discussed is the use of permit allocation under an emission trading system (see Box 7.1 for an example of how this is done in the EU ETS). Another approach would involve allowing each country/region to set its own local price for abating CO_2 emissions. While this may be workable, it may also be vulnerable to the free-rider problem in allocating emission reductions.[28] In a global trading system, it would be possible to allocate permits in a way that allows OECD countries to carry a relatively greater financial responsibility for emission reduction than non-OECD regions. In addition, a global mitigation effort combined with a burden-sharing scheme could be easier (although still difficult) to agree than internationally harmonised carbon taxes. It is generally recognised that creating harmonised taxes will be very difficult, whereas negotiating a system of tradable permits frames the problem of climate change as one of both challenges and opportunities, and brings mutual benefits from co-operation.

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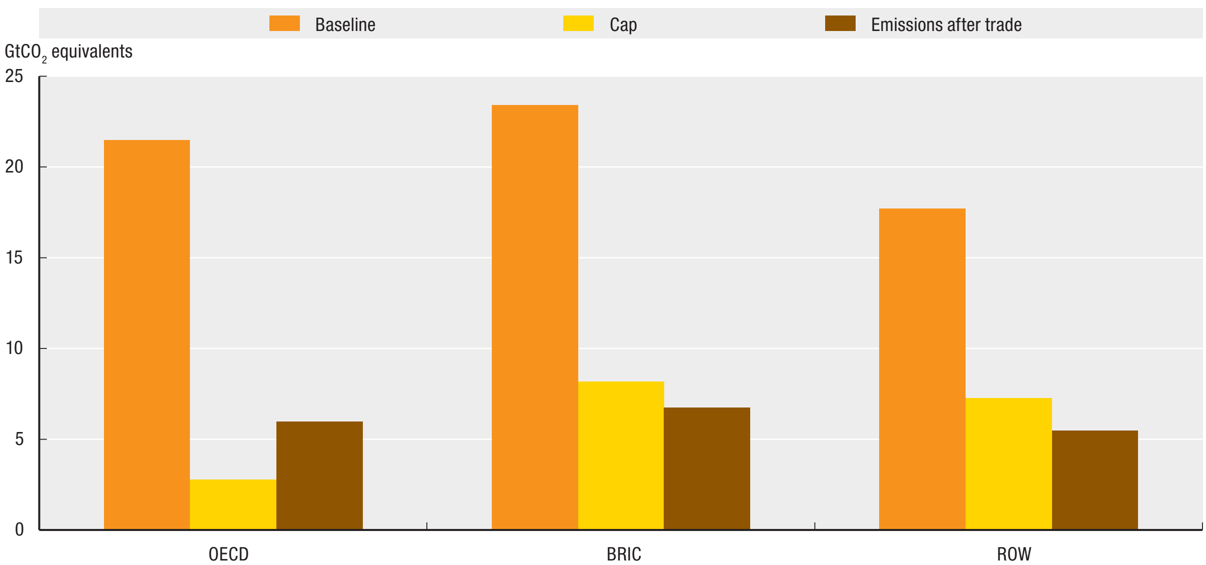
All of the tax cases show lower economic costs (see Table 7.6 and Figures 7.10a and b) but are also less effective in avoiding climate change than the 450 PPM case. The 450 ppm case, however, requires policy to be aggressive in mitigating emissions across all regions. Achievement of this stabilisation target through a harmonised tax results in a global GDP loss of about 2.5% by 2050. An emissions trading policy – aiming to achieve the same target – would keep the GDP loss at similar levels. Alternative policies could increase global costs substantially if they do not encourage least cost abatement in a similar manner.

The regional costs of climate policy strongly depend on how international climate policy is implemented. As an alternative to an international carbon tax (explored above), mitigation may be achieved through a so-called cap and trade system, which has a centrepiece agreement on emission reduction targets or caps, and on how these are to be allocated across regions in combination with international emissions trading. In such a system, international trade still allows all countries to benefit from low-cost reductions worldwide (depending on the extent of participation). Figures 7.12a and b show an illustrative example of what could happen to regional emissions and the regional distribution of direct mitigation costs in striving to stabilise greenhouse gas concentrations at 450 ppm CO_2eq through a global trading system.[29]

Under this simulation, part of the emission rights would be traded internationally. Rather than using a uniform global carbon tax to stabilise greenhouse gas concentrations at 450 ppm CO_2eq (see Box 7.3), this example assumes an annual cap on emissions to achieve the same target. The allocation of emission rights in this example is based on gradual per capita convergence worldwide by 2050. Alternative convergence criteria are conceivable (*e.g.* emissions per GDP, or emission thresholds) as well as alternative convergence years. The model simulation assumes that countries trade emission rights in order to minimise their overall cost of abatement. Thus, assuming full trade, full market access and full information, the simulation determines what proportion of emission rights would be traded and how that would affect regional costs of abatement.

Figure 7.12a. **Greenhouse gas emissions by regions in 2050: Baseline and 450 ppm cap and trade regime**[a]



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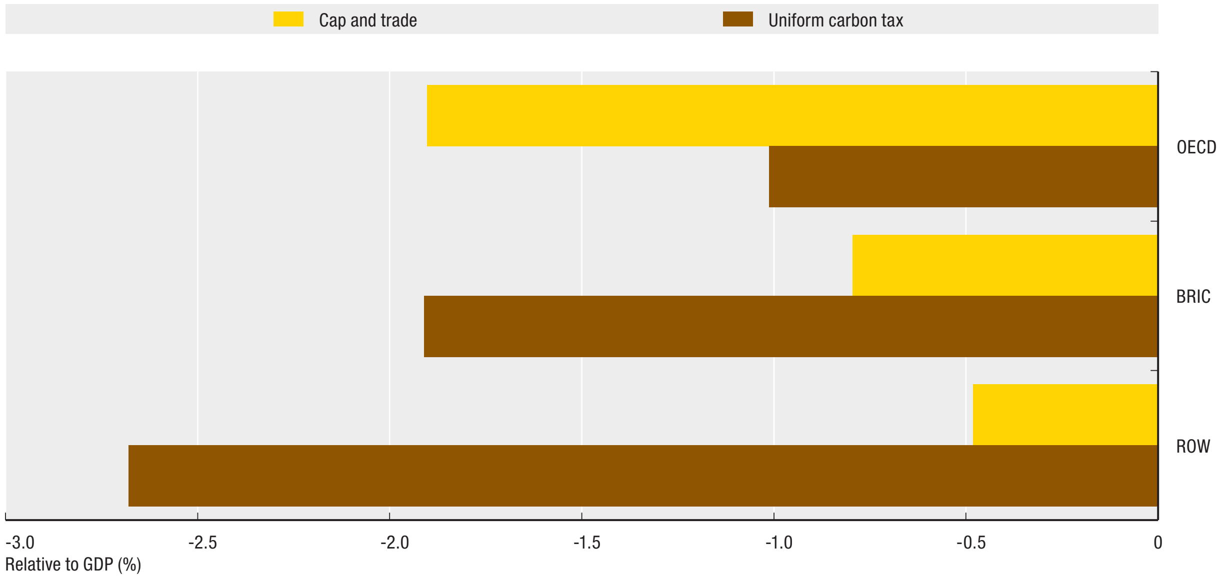
a) Excluding greenhouse gas emissions from land use and forestry.

Source: FAIR model (*www.mnp.nl/fair/introduction*): see note 29 at the end of this chapter.

Figure 7.12b. **Regional direct cost of greenhouse gas abatement under different mitigation regimes, 2050**



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Source: FAIR model (*www.mnp.nl/fair/introduction*): see note 29 at the end of this chapter.

In Figure 7.12a, the difference between the bars representing the Baseline (left) and emissions cap (middle) is the amount of emissions to be cut in each regional grouping to stabilise greenhouse gas concentrations at 450 ppm CO_2eq without trading. In this example, OECD countries would be required to cut emissions by 18.7 Gt CO_2eq by 2050 compared to the Baseline. The difference between these emission caps without trade (middle bars) and emissions after trade (right-hand bars) reflects the emission rights that would be bought or sold between regional groups. In this example of trading, OECD countries buy 3.3 Gt CO_2eq of emission rights by 2050.

The cap and trade system changes the global distribution of direct abatement costs compared with the uniform global tax case (see Figure 7.12b). The costs to OECD countries of achieving 450 ppm CO_2eq stabilisation are more than in the global tax case because they are assigned more ambitious emission reduction targets. These OECD targets are partly met by trading, which brings costs down below what they would be if met unilaterally. Importantly, this simulation limits the imposition of high costs in non-OECD regions relative to their GDP, which would otherwise emerge in the global tax case (Figure 7.10). In moving towards 2050, the ROW group of countries would even see net annual gains in some periods under the trading case (*i.e.* in 2025). In the BRIC group, Russia would initially see considerable gains before coming down, by 2050, to a cost level similar to that in North America. Costs are expected during the whole of the simulated period in Brazil and China; however these costs are offset in the BRIC grouping by gains in India. Overall the emission trading simulation shows the direct costs of mitigation in the BRIC region falling significantly under the cap and trade system.

Summary

The unique challenges of climate change mitigation include balancing concerns about its inter-generational consequences, as there is a lag between when action is taken and when results are reaped (*i.e.* in the form of avoided climate change impacts). The consequences of climate change, and vulnerability to these, are also distributed across regions and countries unevenly, with the greatest risk of relative impacts expected to be in regions and countries where emissions are lowest. Mitigation potential and climate change risk also differ widely within a single country, across locations and actors. Distributional considerations are inevitably an important consideration for policy decision-making across all scales of governance. In addition, there are important questions about how much mitigation is desirable and how fast, and how to act in a cost-effective, economically sustainable and equitable manner.

The *Outlook* on climate change leads to a number of important conclusions for policy:

i) The risks of inaction are high, with unabated emissions in the Baseline leading to about a 37% and 52% increase in global emissions in the 2030 and 2050 timeframe respectively, with a wide range of impacts on natural and human systems. This unabated emission pathway could lead to high levels of global warming, with long-term temperature rises likely in the range of 4 to 6 °C (equilibrium).

ii) Starting early with mitigation policies that stabilise atmospheric concentrations will limit temperature increases and rates of change significantly by mid-century and could limit long-term temperature increases to 2-3 °C.

iii) Broad participation by all the big emitting countries in the coming decades will be required to achieve these outcomes.

iv) The costs of even the most stringent mitigation cases are in the range of only a few percent of global GDP in 2050. Thus they are manageable, especially if policies are designed to start early, to be cost-effective and to share the burden of costs across all regions.

Notes

1. Though from 1990 to 2004, total CH_4 emissions decreased across all OECD countries by roughly 8%, with the largest absolute decreases occurring in Germany, Poland, the United Kingdom and the United States (UNFCCC GHG emission database: *http://GHG.unfccc.int/tables/queries.html*). N_2O emissions have followed a similar trend.
2. CO_2 concentrations are currently increasing at a rate of approximately 1.9 ppm per year (IPCC, 2007a).
3. This warming estimate is relative to 1980-1999; comparing it to pre-industrial temperature adds 0.5 °C for warming of 1.1 °C (best estimate) for a range of 0.8-1.4 °C of warming.
4. Note this period is relevant to accounting for emissions from countries listed in Annex I – or industrialised countries – under the UNFCCC and the Kyoto Protocol. For comparison, emission data are also reported here for non-OECD countries, *i.e.* Brazil, India and China or the BIC group of countries, leaving Russia aside as it has very different patterns of emission growth to the other large non-OECD economies noted here.
5. Data for 2005 are used for all OECD countries except where they were not available: *i.e.*, Greece (2004), Turkey (2004), Mexico (2002) and Korea (2001).
6. Accounting for national emissions according to the Kyoto Protocol separates emissions from land use, land use change and forestry as well as international bunker fuels for aviation and marine activities. The former are accounted for and managed separately by individual nations under the rules for "Kyoto forests", while international bunkers (international aviation and marine fuel use) are to be managed through the agreements under the UN International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO). To date no agreement has been achieved. International bunker fuels were estimated to be about 3% of world CO_2 emissions in 2005 and are growing rapidly (IEA, 2006).
7. In descending order: Korea (1990-2001), Spain, Canada, Portugal, Turkey, Greece, Ireland, Mexico and New Zealand.

8. In descending order: the United States, Austria, Italy, Japan, Switzerland, Australia (where the increase since 1990 has been below the increase allowed under the Kyoto Protocol), Luxembourg and Iceland (both of which have had increases of less than 1% since 1990).
9. Note CO_2eq is used in two ways in this chapter. First it is a "unit" of measurement of aggregate emissions across greenhouse gases. This is based on a reporting convention adopted by the IPCC – global warming potentials – which refer to the integrated radiative forcing of each gas in comparison to that of CO_2 in a given timeframe. Similarly CO_2eq concentrations combine the concentrations of different greenhouse gases into a single metric, accounting for the different radiative forcings of each. See IPCC 2007a, p. 133 for a full description.
10. The *OECD Environmental Outlook* Baseline for CO_2 emissions from energy has been calibrated to that developed by the International Energy Agency (2006) in their *World Energy Outlook* (WEO), which looks in-depth at world energy developments to 2030.
11. The upper and lower bounds of the baseline scenarios represent one standard deviation around the median of the entire distribution of emission pathways within the baseline.
12. CFCs contribute much more to radiative forcing than HFC/PFCs do today or in future predictions, so their reduction is significant to climate change.
13. These countries are also referred to as Annex II countries or Parties (where they are ratified Parties to the Convention or the Protocol).
14. The US signed the Kyoto Protocol but have not ratified it.
15. A number of parallel processes are also proceeding towards a similar end, *e.g.* the Gleneagles dialogue initiated in 2005, among others.
16. See for example: OECD/EEA database on instruments used for environmental policy and natural resources management: *www2.oecd.org/ecoinst/queries/index.htm* [last accessed 17 July 2007].
17. This is because as GHGs are a global pollutant, the impacts are not related to the source or location of the emission.
18. This is a voluntary system.
19. As of 7 Feb. 2007, approximately 112 million CERs are expected to be generated through registered projects.
20. Voluntary agreements and measures are a subset of a larger set of "voluntary approaches" that may include unilateral actions by industry and other stakeholders.
21. The regulated price per unit of electricity that a utility or supplier has to pay for renewables-based electricity from private generators.
22. Unless otherwise noted, this *Outlook* assumes a climate sensitivity of 2.5°C per doubling of carbon dioxide concentrations in the atmosphere, which is lower and more conservative than the IPCC AR4 (IPCC, 2007a). Using the IPCC "best estimate" of climate sensitivity (*i.e.* 3°C) would raise the central estimate of temperature change associated with the Baseline emission pathway.
23. The trajectory of Baseline emissions beyond 2050 is not clearly defined. Based on the emission trajectory to 2050, it is unlikely that the Baseline would lead to stabilisation of greenhouse gas concentrations at a level below the IPCC "category V" and "VI" scenarios (see Table 7.5). This suggests that an indicative value of minimum equilibrium temperature change under the *Outlook* Baseline would be 4-6°C.
24. The case cited here is for 450 ppm CO_2, which is roughly equivalent to 550 ppm CO_2eq taking into account the concentrations of all GHGs in the atmosphere. The data for temperature change in the 2080s associated with stabilisation pathways are cited in Carter *et al.*, 2007. Baseline temperature estimates for the 2080s are taken from van Vuuren *et al.*'s 2007 "modified B2" scenario, which is similar to our Baseline to 2050. Tim Carter and Detlef van Vuuren provided the data for this calculation.
25. See Chapter 8, Air pollution, for a discussion of air pollution policies in their own right. See Chapter 12 for the related benefits in terms of human health. Typically these are more ambitious policies than the co-benefits of climate change policies.
26. Though not shown, Norway fares better than Russia in response to mitigation policy because its domestic energy prices are closer to those of its competitors.
27. Value added is the contribution to GDP of any particular industrial activity, sub-sector or sector.
28. The free-rider problem refers to a situation where parties in a negotiation have an incentive to let others do most of the work.

29. This simulation was conducted using the FAIR model (*www.mnp.nl/fair/introduction*). Unlike Figure 7.10, costs estimated by this simulation and presented in Figure 7.12b are the direct costs of mitigation; that is, they do not represent change in GDP growth as a result of shifts induced in the wider economy. Although the metric for measuring economic effects is slightly different than the one described for the ENV-Linkages simulations above, the relative change from the Baseline to policy simulations – or between policy cases – is indicative of the results that would be obtained using ENV-Linkages. The simulation has been done at the level of 26 global regions, although Figures 7.12a and b aggregate the results to three regional groups. This aggregation masks some of the more detailed results which show that intra-regional trading also occurs to lower the overall costs of mitigation.

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OECD Environmental Outlook to 2030

Introduction: Context and Methodology

Purpose of the report

The purpose of the *OECD Environmental Outlook* is to help government policy-makers to identify the key environmental challenges they face, and to understand the economic and environmental implications of the policies that could be used to address those challenges.

The *Outlook* provides a baseline projection of environmental change to 2030 (referred to as "the Baseline"), based on projected developments in the underlying economic and social factors that drive these changes. The projections are based on a robust general equilibrium economic modelling framework, linked to a comprehensive environmental modelling framework (see below, and Annex B, for more details). Simulations were also run of specific policies and policy packages that could be used to address the main environmental challenges identified, and their economic costs and environmental benefits compared with the Baseline.

This is the second *Environmental Outlook* produced by the OECD. The first *OECD Environmental Outlook* was released in 2001, and provided the analytical basis on which ministers adopted an *OECD Environmental Strategy for the First Decade of the 21st Century*. This second *Outlook:*

- extends the projected baseline used in the first *Outlook* from 2020 to 2030, and even 2050 for some important areas;
- is based on a stronger and more robust modelling framework;
- focuses on the policies that can be used to tackle the main challenges;
- expands the country focus to reflect developments in both OECD and non-OECD regions and their interactions.

Many of the priority issues and sectors identified in this *Outlook* are the same as those highlighted as needing most urgent policy action in the first *OECD Environmental Outlook* (2001) and in the *OECD Environmental Strategy for the First Decade of the 21st Century*. These include the priority issues of climate change, biodiversity loss and water scarcity, and the key sectors exerting pressure on the environment (agriculture, energy and transport). Added to these is a new priority issue: the need to address the health impacts of the build-up of chemicals in the environment. The 2001 *Outlook* indicated the environmental challenges expected in the next couple of decades; this *Outlook* not only deepens and extends this analysis, it also focuses on the policy responses for addressing these challenges. It finds that the solutions are affordable and available if ambitious policy action is implemented today, and if countries work together in partnership to ensure comprehensive action, avoid competitiveness concerns and share the responsibility and costs of action fairly and equitably. This latest *Outlook* analyses the policies that can be used to achieve the *OECD Environmental Strategy*. It will provide the main analytical material to support discussions on further implementation of the *OECD Environmental Strategy* at the OECD Meeting of Environment Ministers planned for early 2008.

Policy context

Why develop an environmental outlook? Many of the economic or social choices that are being made today – for example, investments in transport infrastructure and building construction, fishing fleets, purchase of solar heating panels – will have a direct and lasting affect on the environment in the future. For many of these, the full environmental impacts will not be felt until long after the decisions have been taken. These factors make policy decisions difficult: the costs of policy action to prevent these impacts will hit societies today, but the benefits in terms of improved environmental quality or damage avoided may only be realised in the future. For example, the greenhouse gases released today continue to build up in the atmosphere and will change the future climate, with serious impacts for the environment, the economy and social welfare.

But politicians tend to reflect the short-term interests of the voting public, not the long-term needs of future generations. They also tend to focus on the immediate costs and benefits to their own populations of a given policy approach, rather than on the global impacts. But many of the main environmental challenges countries face in the early 21st century are global or transboundary in nature, including global climate change, biodiversity loss, management of shared water resources and seas, transboundary air pollution, trade in endangered species, desertification, deforestation, etc. Building public understanding and acceptance of the policies that are needed to address these challenges is essential for policy reform.

These political challenges are exacerbated by uncertainty about the future. Often the exact environmental impacts of social and economic developments are poorly understood or disputed. In some cases, scientific uncertainty about environmental or health impacts is a main cause of policy inaction, while in others it is used as a justification for precautionary action. Scientific understanding and consensus about environmental change has been developing rapidly in a number of areas in recent years, for example through the 2005 Millennium Ecosystem Assessment and the 2007 IPCC Fourth Assessment Report on the Science of Climate Change. Despite the improvements in the scientific understanding of such issues, a gap remains in the development and implementation of effective environmental policies based on this scientific understanding.

This *Environmental Outlook* examines the medium to long-term environmental impacts of current economic and social trends, and compares these against the costs of specific policies that could be implemented today to tackle some of the main environmental challenges. The purpose is to provide more rigorous analysis of the costs and benefits of environmental policies to help policy-makers take better, more informed policy decisions now.

Many environmental problems are complex and inter-connected. For example, species loss is often the result of multiple pressures – including hunting, fishing or plant harvesting, loss of habitat through land use change or habitat fragmentation, impacts of pollutants – and thus a mix of policy instruments is needed to tackle the various causes of this loss. These policy packages need to be carefully designed in order to achieve the desired environmental benefits at the lowest economic cost. This *Outlook* examines the policy packages that could be used to tackle some of the key environmental challenges, and the framework conditions needed to ensure their success.

The transboundary or global nature of many of the most pressing environmental challenges identified in this *Outlook* require countries to increasingly work together in partnership to address them. The ways in which OECD environment ministries can work together in partnership with other ministries, stakeholder partners and other countries are explored in this *Outlook*.

A special focus on the emerging economies in the *Outlook*

This *Outlook* identifies the main emerging economies as the most significant partners for OECD countries to work with in the coming decades to tackle global or shared environmental problems. This is because these countries are responsible for an increasingly large share of the global economy and trade, and thus have an increasing capacity to address these challenges, in part because their economies are so dynamic. Moreover, the pressures that they exert on the environment are also growing rapidly.

In some chapters, where data are available and relevant, the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) are highlighted for attention as a country grouping. In other chapters, the smaller country grouping of BRIC (Brazil, Russia, India and China) is examined, or even further disaggregated to each of these four countries individually. The BRIC grouping is used for most of the modelling projections and simulations in the *Outlook*.

Modelling methodology and sources of information

The analysis presented in this *Environmental Outlook* was supported by model-based quantification. On the economic side, the modelling tool used is a new version of the OECD/World Bank JOBS/Linkages model, operated by a team in the OECD Environment Directorate and called ENV-Linkages. It is a global general equilibrium model containing 26 sectors and 34 world regions and provides economic projections for multiple time periods. It was used to project changes in sector outputs and inputs of each country or region examined to develop the economic baseline to 2030. This was extended to 2050 to examine the impacts of policy simulations in specific areas, such as biodiversity loss and climate change impacts. The economic baseline was developed with expert inputs from, and in co-operation with, other relevant parts of the OECD, such as the Economics Department, the International Energy Agency and the Directorate for Food, Agriculture and Fisheries.

The Integrated Model to Assess the Global Environment (IMAGE) of the Netherlands Environmental Assessment Agency (MNP) was further developed and adjusted to link it to the ENV-Linkages baseline in order to provide the detailed environmental baseline. IMAGE is a dynamic integrated assessment framework to model global change, with the objective of supporting decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system. The IMAGE suite of models used for the *Outlook* comprises models that also appear in the literature as models in their own right, such as FAIR (specialised to examine burden sharing issues), TIMER (to examine energy), and GLOBIO3 (to examine biodiversity). Moreover, for the *Outlook* the IMAGE suite included the LEITAP model of LEI at Wageningen and the WaterGap model of the Center for Environmental Systems Research at Kassel University. IMAGE and associated models provided the projections of impacts on important environmental endpoints to 2030, such as climate, biodiversity, water stress, nutrient loading of surface water, and air quality. Annex B provides a more detailed description of the modelling framework and main assumptions used for the *Outlook* report.

The Baseline Reference Scenario presents a projection of historical and current trends into the future. This Baseline indicates what the world would be like to 2030 if currently existing policies were maintained, but *no new policies* were introduced to protect the environment. It is an extension of current trends and developments into the future, and as such it does not reflect major new or different developments in either the drivers of environmental change or environmental pressures. A number of major changes are possible in the future, however, that would significantly alter these projections. A few of these were examined as "variations" to the Baseline, and their impacts are described in Chapter 6 to show how these changes might affect the projections presented here.

Because the Baseline reflects no new policies, or in other words it is "policy neutral", it is a reference scenario against which simulations of new policies can be introduced and compared. Simulations of specific policy actions to address key environmental challenges were run in the modelling framework. The differences between the Baseline projections and these policy simulations were analysed to shed light on their economic and environmental impacts.

The simulations undertaken for the *Environmental Outlook* exercise are illustrative rather than prescriptive. They indicate the type and magnitude of the responses that might be expected from the policies examined, rather than representing recommendations to undertake the simulated policy actions. As relevant, some of the policy simulation results are reflected in more than one chapter. The table below summarises the policy simulation analyses and lists the different chapters containing the results.

Sensitivity analysis was undertaken to test the robustness of key assumptions in ENV-Linkages, and some of the results of this analysis are presented in Annex B. This, in conjunction with the Baseline variations described in Chapter 6, provides a clearer picture for the reader of the robustness of the assumptions in the Baseline.

Throughout the *Outlook*, the analysis from the modelling exercise is complemented by extensive data and environmental policy analysis developed at the OECD. Where evidence is available, specific country examples are used to illustrate the potential effects of the policies discussed. Many of the chapters in this *Outlook* have been reviewed by the relevant Committees and Expert Groups of the OECD, and their input has strengthened the analysis.

The *Outlook* is released at about the same time as a number of other forward-looking environmental analyses, such as UNEP's Fourth Global Environment Outlook (GEO-4); the IPCC Fourth Assessment Report (AR-4); the International Assessment of Agricultural Science and Technology for Development supported by the World Bank, FAO and UNEP; and the CGIAR Comprehensive Assessment of Water Use in Agriculture. Through regular meetings and contacts, efforts have been made by the organisations working on these reports to ensure co-ordination and complementarity in the studies, and to avoid overlap. The *OECD Environmental Outlook* differs from most of the others in its emphasis on a single baseline reference scenario against which specific policy simulations are compared for the purpose of policy analysis. Most of the others explore a range of possible "scenarios", which provide a useful communication tool to illustrate the range of possible futures available, but are less amenable to the analysis of specific policy options. The *OECD Environmental Outlook* also looks at developments across the full range of environmental challenges, based strongly on projected developments in the economic and social drivers of environmental change, while many of the other forward-looking analyses focus on a single environmental challenge.

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Table I.1. **Mapping of the *OECD Environmental Outlook* policy simulations by chapter**

Simulation title	Simulation description	Chapters in which the results are reflected	Models used
Baseline	The "no new policies" Baseline used throughout the *OECD Environmental Outlook*.	All chapters	ENV-Linkages; IMAGE suite
Globalisation variation	Assumes that past trends towards increasing globalisation continue, including increasing trade margins (increasing demand by lowering prices in importing countries) and reductions in invisible costs (*i.e.* the difference between the price at which an exporter sells a good and the price that an importer pays).	4. Globalisation 6. Key variations to the standard expectation	ENV-Linkages; IMAGE suite
High and low growth scenarios	Variation 1: High economic growth – examines impacts if recent high growth in some countries (*e.g.* China) continues, by extrapolating from trends from the last 5 years of growth rather than the last 20 years. Variation 2: Low productivity growth – assumes productivity growth rates in countries converge towards an annual rate of 1.25% over the long-term, rather than 1.75% as in the Baseline. Variation 3: High productivity growth – assumes productivity growth rates in countries converge towards an annual rate of 2.25% over the long-term.	6. Key variations to the standard expectation	ENV-Linkages
Greenhouse gas taxes	Implementation in participating countries of a tax of USD 25 on CO_2eq, increasing by 2.4% per annum. OECD 2008: only OECD countries impose the tax, starting in 2008. Delayed 2020: all countries apply the tax, but starting only in 2020. Phased 2030: OECD countries implement the tax from 2008; BRIC countries from 2020, and then the rest of the world (ROW) from 2030 onwards. All 2008: in a more aggressive effort to mitigate global GHG emissions, all countries implement the USD 25 tax from 2008.	7. Climate change 13. Cost of policy inaction (Delayed 2020) 17. Energy 20. Environmental policy packages	ENV-Linkages; IMAGE suite
Climate change stabilisation simulation (450 ppm)	Optimised scenario to reach a pathway to stabilise atmospheric concentrations of GHG at 450 ppm CO_2eq over the longer term and limit global mean temperature change to roughly 2 °C. A variation on this case was developed to explore burden-sharing, using a cap and trade approach to implementation.	7. Climate change 13. Cost of policy inaction 17. Energy 20. Environmental policy packages	ENV-Linkages; IMAGE suite
Agriculture support and tariff reform	Gradual reduction in agricultural tariffs in all countries to 50% of current levels by 2030. Gradual reduction in production-linked support to agricultural production in OECD countries to 50% of current levels by 2030.	9. Biodiversity 14. Agriculture	ENV-Linkages
Policies to support biofuels production and use	Demand for biofuels growing in line with the IEA *World Energy Outlook* (2006) scenario. DS: a scenario whereby growth in biofuel demand for transport is driven by exogenous changes, keeping total fuel for transport close to the Baseline. OilS: a high crude oil price scenario to determine the profitability of biofuel in the face of increasing costs of producing traditional fossil-based fuels. SubS: a subsidy scenario in which producer prices of biofuels are subsidised by 50%.	14. Agriculture	ENV-Linkages
Fisheries	Global fisheries cap and trade system, representing a 25% reduction in open fisheries catch, with trading allowed within six geographical regions.	15. Fisheries and aquaculture	ENV-Linkages
Steel industry CO_2 tax	Implementation of a carbon tax of 25 USD per tonne CO_2, applied respectively to OECD steel industry only, all OECD sectors, and all sectors worldwide.	19. Selected industries – steel and cement	ENV-Linkages
Policy mix	Three variations of policy packages were modelled, depending on the participating regions: OECD countries only OECD + BRIC Global The policy packages included: • reduction of production-linked support and tariffs in agriculture to 50% of current levels by 2030. • tax on GHG emissions of USD 25 tax CO_2eq, increasing by 2.4% per annum (phased with OECD starting in 2012, BRIC in 2020, ROW in 2030). • moving towards, although not reaching, Maximum Feasible Reduction in air pollution emissions, phased over a long time period depending on GDP/capita. • assuming that the gap to connecting all urban dwellers with sewerage will be closed by 50% by 2030, and installing, or upgrading to the next level, sewage treatment in all participating regions by 2030.	8. Air pollution 10. Freshwater 12. Health and environment 20. Environmental policy packages	ENV-Linkages; IMAGE suite

Structure of the report

The *OECD Environmental Outlook* is divided into two main parts:

i) *The World to 2030 – the Consequences of Policy Inaction:* describes the Baseline, *i.e.* the projected state of the world to 2030 in terms of the key drivers of environmental change and the developing environmental challenges, as well as analysing some possible variations to the Baseline.

ii) *Policy Responses:* focuses on the policy responses at both the sectoral level and in terms of implementing a more comprehensive and coherent policy package.

The first part describes the key elements of the Baseline to 2030, including the main drivers of environmental change (consumption and production patterns, technological innovation, population dynamics and demographic change, economic development, globalisation, and urbanisation) and the key environmental challenges (climate change, air pollution, biodiversity, freshwater, waste and material flows, health and environment). For each of these, the key recent trends and projections to 2030 are presented, as well as some of the policy approaches that are being used to address the environmental challenges. Chapter 6 describes some key variations to the Baseline – for example, how the Baseline would differ if key economic drivers (such as economic growth or global trade) were changing faster than projected in the Baseline. The chapter also explores other sources of uncertainty in the *Outlook* projections. Finally, this first part of the report examines the consequences and costs of policy inaction – essentially the environmental, health and economic impacts embodied in the "no new policies" Baseline scenario.

The second part of the *Outlook* report examines the possible policy responses to address the key environmental challenges, and assesses the economic and environmental impact of these responses. The key sectors whose activities affect the environment are examined, with a brief summary of the trends and outlook for their impacts, followed by an assessment of the policy options that could be applied in that sector to reduce negative environmental impacts. This section assesses the environmental benefits of specific policy options and their potential costs to the sector involved and/or economy-wide (and disaggregated by region where appropriate). This analysis can be used by environment ministries in discussing specific policy options for tackling environmental challenges with their colleagues in other ministries, such as finance, agriculture, energy or transport. The sectors examined include those that were prioritised in the *OECD Environmental Strategy* – agriculture, energy and transport – and also other sectors which strongly affect natural resource use or pollution, such as fisheries, chemicals and selected industries (steel, cement, pulp and paper, tourism and mining).

In addition to analysing sector-specific policies, this part of the *Outlook* also examines the effects of a package of policies (the EO policy package) to tackle the main environmental challenges. The analysis of this EO policy package highlights the potential synergies between policies (*i.e.* where the benefits of combining two or more policies may be greater than the simple sum of their benefits as separate policies), or potential conflicts where policies may undermine each other. Chapter 21 outlines the key framework conditions needed to ensure the successful identification and implementation of appropriate environmental policies at the national level, in particular institutional capacity and policy implementation concerns. Chapter 22, on global environmental co-operation, highlights the issues for which OECD countries will need to work together in partnership with other countries in order to reduce overall costs of policy implementation and maximise benefits. It also assesses the costs of inaction.

Traffic lights in the *OECD Environmental Outlook*

As with the 2001 *Outlook*, this report uses traffic light symbols to indicate the magnitude and direction of pressures on the environment and environmental conditions. Traffic lights are used to highlight the key trends and projections in the summary table in the Executive Summary, in the Key Messages boxes at the start of each chapter and throughout the chapters. The traffic lights were determined by the experts drafting the chapters, and then refined or confirmed by the expert groups reviewing the report. They represent the following ratings:

Red lights are used to indicate environmental issues or pressures on the environment that require urgent attention, either because recent trends have been negative and are expected to continue to be so in the future without new policies, or because the trends have been stable recently but are expected to worsen.

Yellow lights are given to those pressures or environmental conditions whose impact is uncertain, changing (*e.g.* from a positive or stable trend toward a potentially negative projection), or for which there is a particular opportunity for a more positive outlook with the right policies.

Green lights signal pressures that are stable at an acceptable level or decreasing, or environmental conditions for which the outlook to 2030 is positive.

While the traffic light scheme is simple, thus supporting clear communication, it comes at the cost of sensitivity to the often complex pressures affecting the environmental issues examined in this *Outlook*.

While each of the individual chapters discusses the regional developments for the drivers or environmental impacts analysed, Annex A also provides an easily accessible "summary" of the economic, social and environmental developments in the Baseline for each region. Annex B provides a more detailed analysis of the modelling framework used in the development of the *OECD Environmental Outlook*. A number of background working papers, which provide further information on specific issues addressed in the *Outlook*, were developed to complement the report (see: *www.oecd.org/environment/outlookto2030*).

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Acronyms and Abbreviations

BRIC	Brazil, Russia, India and China
BRIICS	Brazil, Russia, India, Indonesia, China and South Africa
CBD	Convention on Biological Diversity
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalents
CSD	Commission on Sustainable Development
DAC	OECD Development Assistance Committee
EJ	Exajoules
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EU25	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom
EUR	Euro (currency of European Union)
FAO	Food and Agriculture Organization of the United Nations
GBP	Pound sterling
GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoules
GNI	Gross national income
Gt	Giga tonnes
GW	Gigawatt
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land use change and forestry
MAD	Mutual Acceptance of Data
MDGs	Millennium Development Goals
MEA	Multilateral environmental agreement
MNP	Netherlands Environmental Assessment Agency
MSA	Mean species abundance

Mt	Million tonnes
MWh	Megawatt-hour
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
ODA	Official development assistance
ppb	Parts per billion
ppm	Parts per million
PFC	Perfluorocarbon
PM	Particulate matter
$PM_{2.5}$	Particulate matter, particles of 2.5 micrometres (µm) or less
PM_{10}	Particulate matter, particles of 10 micrometres (µm) or less
ppmv	Parts per million by volume
ROW	Rest of world
RTA	Regional trade agreement
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SF_6	Sulphur hexafluoride
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
VOC	Volatile organic compound
WHO	World Health Organization
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization

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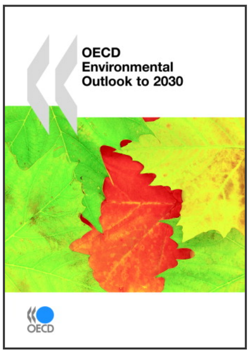

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