# OECD Environmental Outlook to 2050

## Climate Change Chapter

PRE-RELEASE VERSION

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# OECD ENVIRONMENTAL OUTLOOK TO 2050

# CHAPTER 3: CLIMATE CHANGE

## PRE-RELEASE VERSION, NOVEMBER 2011

The OECD *Environmental Outlook to 2050* was prepared by a joint team from the OECD Environment Directorate (ENV) and the PBL Netherlands Environmental Assessment Agency (PBL).

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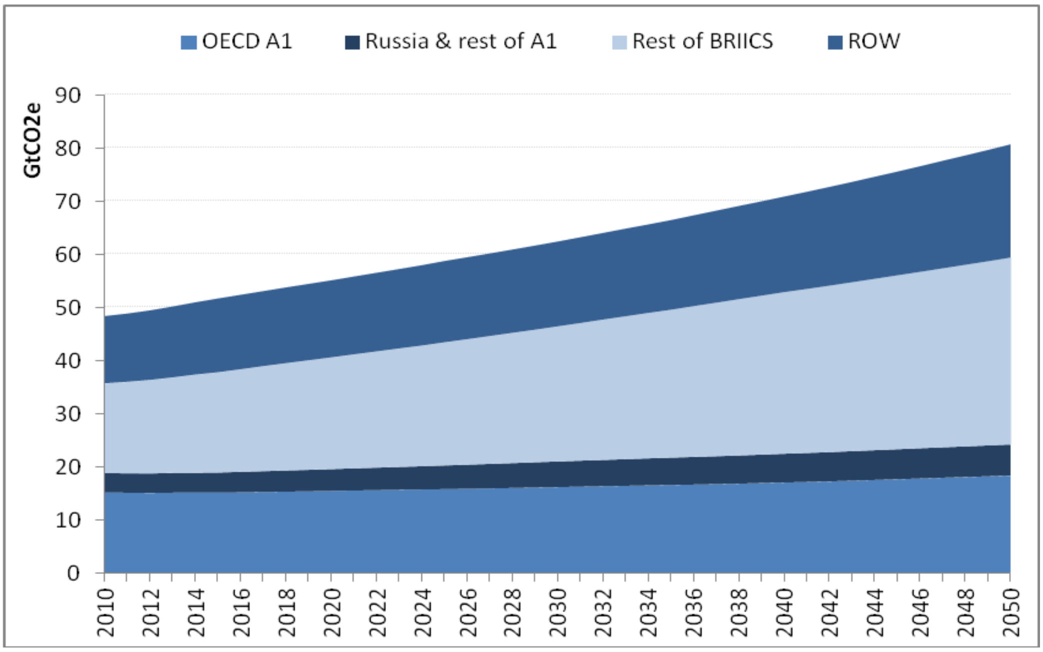
**Climate change presents a global systemic risk to society.** It threatens the basic elements of life for all people: access to water, food production, health, use of land, and physical and natural capital. Inadequate attention to climate change could have significant social consequences for human well-being, hamper economic growth and heighten the risk of abrupt and large-scale changes to our climatic and ecological systems. The significant economic damage could equate to a permanent loss in average per-capita world consumption of more than 14% (Stern, 2006). Some poor countries would be likely to suffer particularly severely. This chapter demonstrates how avoiding these economic, social and environmental costs will require effective policies to shift economies onto low-carbon and climate-resilient growth paths.

***Trends and projections***

*Environmental state and pressures*

- **RED Global greenhouse gas (GHG) emissions** continue to increase, and in 2010 global **energy-related carbon-dioxide ($CO_2$) emissions** reached an all-time high of 30.6 gigatonnes (Gt) despite the recent economic crisis. *The Environmental Outlook Baseline* scenario envisages that without more ambitious policies than those in force today, GHG emissions will increase by another 50% by 2050, primarily driven by a projected 70% growth in $CO_2$ emissions from energy use. This is primarily due to a projected 80% increase in global energy demand. Transport emissions are projected to double, due to a strong increase in demand for cars in developing countries. Historically, OECD economies have been responsible for most of the emissions. In the coming decades, increasing emissions will also be caused by high economic growth in some of the major emerging economies.

**GHG emissions by region: *Baseline,* scenario 2010-2050**




Note*:* "OECD AI" stands for the group of OECD countries that are also part of Annex I of the Kyoto Protocol. $GtCO_2e$ = Gigatonnes of $CO_2$ equivalent.

*Source*: *OECD Environmental Outlook Baseline*; output from ENV-Linkages.

- **RED** Without more ambitious policies, the *Baseline* projects that **atmospheric concentration of GHG** would reach almost 685 parts per million (ppm) $CO_2$-equivalents by 2050. This is well above the concentration level of 450 ppm required to have at least a 50% chance of stabilising the climate at a 2-degree (2 °C) global average **temperature increase**, the goal set at the 2010 United Nations Framework Convention on Climate Change (UNFCCC) Conference in Cancún. Under the *Baseline* projection, global average temperature is likely to exceed this goal by 2050, and by 3 °C to 6 °C higher than pre-industrial levels by the end of the century. Such a high temperature increase would continue to alter precipitation patterns, melt glaciers, cause sea-level rise and intensify extreme weather events to unprecedented levels. It might also exceed some critical "tipping-points", causing dramatic natural changes that could have catastrophic or irreversible outcomes for natural systems and society.

- **YELLOW** Technological progress and structural shifts in the composition of growth are projected to improve the **energy intensity of economies** in the coming decades (*i.e.* achieving a relative decoupling of GHG emissions growth and GDP growth), especially in OECD and the emerging economies of Brazil, Russia, India, Indonesia, China and South Africa (BRIICS). However, under current trends, these regional improvements would be outstripped by the increased energy demand worldwide.

- **YELLOW Emissions** from **land use, land-use change and forestry** (LULUCF) are projected to decrease in the course of the next 30 years, while carbon sequestration by forests increases. By 2045, net-$CO_2$ emissions from land use are projected to become negative in OECD countries. Most emerging economies also show a decreasing trend in emissions from an expected slowing of deforestation. In the rest of the world (RoW), land-use emissions are projected to increase to 2050, driven by expanding agricultural areas, particularly in Africa.

*Policy responses*

- **RED** Pledging action to achieve national GHG emission reduction targets and actions under the UNFCCC at Copenhagen and Cancún was an important first step by countries in finding a global solution. However, **the mitigation actions** pledged by countries are not enough to be on a least-cost pathway to meet the 2 °C goal. Limiting temperature increase to 2 °C from these pledges would require substantial additional costs after 2020 to ensure that atmospheric concentrations of GHGs do not exceed 450 ppm over the long term. More ambitious action is therefore needed now and post-2020. For example, 80% of the projected emissions from the power sector in 2020 are inevitable, as they come from power plants that are already in place or are being built today. The world is locking itself into high carbon systems more strongly every year. Prematurely closing plants or retrofitting with carbon capture and storage (CCS) – at significant economic cost, – would be the only way to reverse this "lock-in".

- **YELLOW** Progress has been made in developing national strategies for **adapting to climate change**. These also encourage the assessment and management of climate risk in relevant sectors. However, there is still a long way to go before the right instruments and institutions are in place to explicitly incorporate climate change risk into policies and projects, increase private-sector engagement in adaptation actions and integrate climate change adaptation into development co-operation.

***Policy steps to build a low-carbon, climate-resilient economy***

**We must act now** to reverse emission trends in order to stabilise GHG concentrations at 450 ppm $CO_2$e and increase the chance of limiting the global average temperature increase to 2 °C. Ambitious mitigation action substantially lowers the risk of catastrophic climate change. The cost of reaching the 2 °C goal would slow global GDP growth from 3.5 to 3.3% per year (or by 0.2 percentage-points) on average, costing roughly 5.5% of global GDP in 2050. This cost should be compared with the potential cost of inaction that could be as high as 14% of average world consumption per capita according to some estimates (Stern, 2006).

**Delaying action is costly**. Delayed or only moderate action up to 2020 (such as implementing the Copenhagen/Cancún pledges only, or waiting for better technologies to come on stream) would increase the pace and scale of efforts needed after 2020. It would lead to 50% higher costs in 2050 compared to timely action, and potentially entail higher environmental risk.

A prudent response to climate change calls for both an ambitious mitigation policy to reduce further climate change, and timely adaptation policies to limit damage from the impacts that are already inevitable. In the context of tight government budgets, finding least-cost solutions and engaging the private sector will be critical to finance the transition. Costly overlaps between policies must also be avoided. The following actions are a priority:

- **Adapt to inevitable climate change.** The level of GHG already in the atmosphere means that some changes in the climate are now inevitable. The impact on people and ecosystems will depend on how the world adapts to those changes. Adaptation policies will need to be implemented to safeguard the well-being of current and future generations worldwide.

- **Integrate adaptation into development co-operation.** The management of climate change risks is closely intertwined with economic development – impacts will be felt more by the poorest and most vulnerable populations. National governments and donor agencies have a key role to play and integrating climate change adaptation strategies into all development planning is now critical. This will involve assessing climate risks and opportunities within national government processes, at sectoral and project levels, and in both urban and rural contexts. The uncertainty surrounding climate impacts means that flexibility is important.

- **Set clear, credible, more stringent and economy-wide GHG-mitigation targets** to guide policy and investment decisions. Participation of all major emission sources, sectors and countries would reduce the costs of mitigation, help to address potential leakage and competitiveness concerns and could even out ambition levels for mitigation across countries.

- **Put a price on carbon**. This *Outlook* models a *450 ppm Core* scenario which suggests that achieving the 2 °C goal would require establishing clear carbon prices that are increased over time. This could be done using market-based instruments like carbon taxes or emission trading schemes. These can provide a dynamic incentive for innovation, technological change and driving private finance towards low-carbon, climate-resilient investments. These can also generate revenues to ease tight government budgets and potentially provide new sources of public funds. For example, if the Copenhagen Accord pledges and actions for Annex I countries were to be implemented as a carbon tax or a cap-and-trade scheme with fully auctioned permits, in 2020 the fiscal revenues would amount to more than USD 250 billion, *i.e* 0.6% of their GDP.

- **Reform fossil fuel support policies.** Support to fossil fuel production and use in OECD countries is estimated to have been about USD 45-75 billion a year in recent years; developing and emerging economies provided USD 409 billion in 2010 (IEA data). OECD *Outlook* simulation shows that phasing out fossil fuels subsidies in developing countries could reduce by 6% global energy-related GHG emissions, provide incentives for increased energy efficiency and renewable energy and also increase public finance for climate action. However, fossil fuel subsidy reforms should be implemented carefully while addressing potential negative impacts on households through appropriate measures.

- **Foster innovation and support new clean technologies.** The cost of mitigation could be significantly reduced if R&D could come up with new breakthrough technologies. For example, emerging technologies – such as bioenergy from waste biomass and CCS – have the potential to absorb carbon from the atmosphere. Perfecting these technologies, and finding new ones, will require a clear price on carbon, targeted government-funded R&D, and policies to reduce the financial risks of investing in new low-carbon technologies and to boost their deployment.

- **Complement carbon pricing with well-designed regulations.** Carbon pricing and support for innovation may not be enough to ensure all energy-efficiency options are adopted or accessible. Additional targeted regulatory instruments (such as fuel, vehicle and building-efficiency standards) may also be required. If designed to overcome market barriers and avoid costly overlap with market-based instruments, they can accelerate the uptake of clean technologies, encourage innovation and reduce emissions cost-effectively. The net contribution of the instrument "mix" to social welfare, environmental effectiveness and economic efficiency should be regularly reviewed.

## 3.1. Introduction

Climate change is a serious global systemic risk that threatens life and the economy. Observations of increases in global average temperatures, widespread melting of snow and ice, and a rising global average sea level indicate that the climate is already warming (IPCC, 2007a). If greenhouse gas (GHG) emissions continue to grow, this could result in a wide range of adverse impacts and potentially trigger large-scale, irreversible and catastrophic changes (IPCC, 2007b) that will exceed the adaptive capacity of natural and social systems. The environmental, social and economic costs of inaction are likely to be significant. Agreements reached in Cancún, Mexico, at the 2010 United Nations Climate Change Conference recognised the need for deep cuts in global GHG emissions in order to limit the global average temperature increase to 2 degrees Celsius (2 °C) above pre-industrial levels (UNFCCC, 2011a). A temperature increase of more than 2 °C is likely to push components of the Earth's climate system past critical thresholds, or "tipping points" (EEA, 2010).

This chapter seeks to analyse the policy implications of the climate change challenge. Are current emission reduction pledges enough to stabilise climate change and limit global average temperature increase to 2 °C? If not, what will the consequences be? What alternative growth pathways could achieve this goal? What policies are needed, and what will be the costs and benefits to the economy? And last, but not least, how can the world adapt to the changes that are already occurring?

To shed light on these questions, this chapter first looks at the "business-as-usual" situation, using projections from the *Environmental Outlook Baseline* scenario, to see what the climate would be like in 2050 if no new action is taken.[1] It then compares different policy scenarios against this "no-new-policy" *Baseline* scenario to understand how the situation could be improved. Section 3.3 ("Climate Change: The state of policy today") describes how a prudent response to climate change involves a two-pronged approach: ambitious mitigation policies[2] to reduce further climate change, as well as timely adaptation[3] policies to limit damage by climate change impacts that are inevitable. Mitigation and adaptation policies are essential, and they are complementary. Most countries have begun to respond through actions at the international, national and local levels, drawing on a mix of policy instruments that include carbon pricing, other energy-efficiency policies, information-based approaches and innovation. Some progress can be noted, but much more needs to be done to achieve the 2 °C goal.

The chapter concludes by outlining how limiting global warming will require transformative policies to reconcile short-term action with long-term climate objectives, balancing their costs and benefits. The transition to a low-carbon, climate-resilient development path requires financing, innovation and strategies that also address potential negative competitiveness and employment impacts. Such a path can also create new opportunities as part of a green growth strategy. Thus, the work presented here shows that through appropriate policies and international co-operation, climate change can be tackled in a way that will not cap countries' aspirations for growth and prosperity.

## 3.2. Trends and projections

### *Greenhouse gas emissions and concentrations*

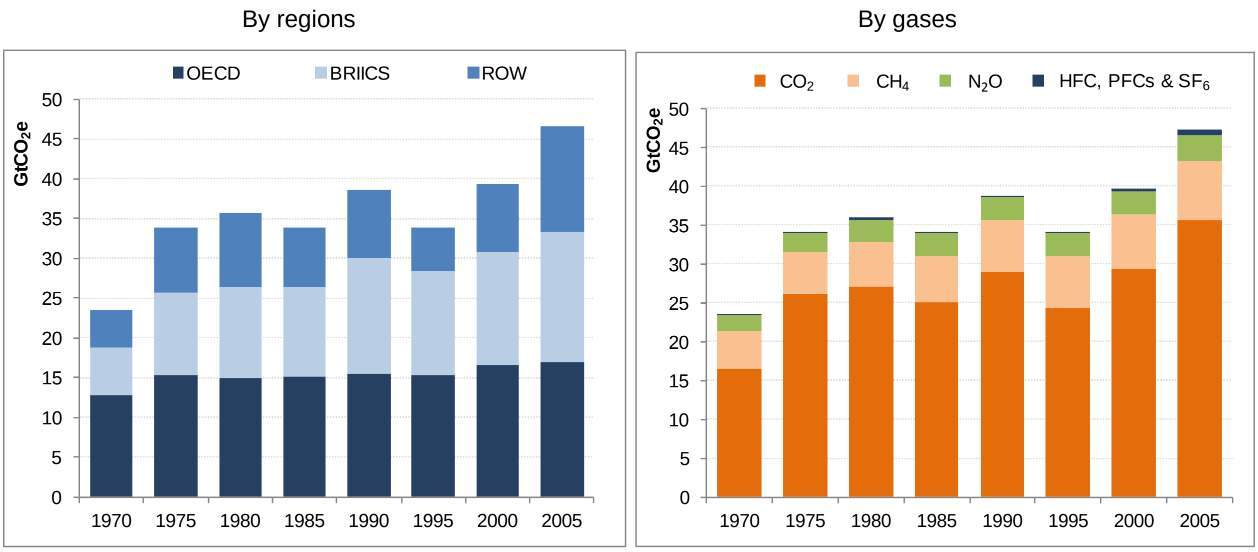
#### *Historical and recent trends*

Several gases contribute to climate change. The Kyoto Protocol[4] intends to limit emissions of the six gases which are responsible for the bulk of global warming. Of these, the three most potent are carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$), currently accounting for 98% of the GHG emissions covered by the Kyoto Protocol (Figure 3.1). The other gases, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride ($SF_6$) account for less than 2%, but their total emissions are growing. These gases differ in terms of their warming effect and their longevity in the atmosphere. Apart from these six GHGs, there are several other atmospheric substances that lead to warming (*e.g.* chlorofluorocarbons or CFCs, and black carbon – see Box 3.14) or to cooling (*e.g.* sulphate aerosols). Unless otherwise mentioned, in this chapter the term "emissions" refers to the Kyoto gases only, while the climate impacts described are based on a consideration of all the climate forcing gases (the term "climate forcer" is used for any gas or particle that alters the Earth's energy balance by absorbing or reflecting radiation).

Global GHG emissions have doubled since the early 1970s (Figure 3.1), driven mainly by economic growth and increasing fossil-energy use in developing countries. Historically, OECD countries emitted the bulk of GHG emissions, but the share of Brazil, Russia, India, Indonesia, China and South Africa (the BRIICS countries) in global GHG emissions has increased to 40%, from 30% in the 1970s.

Overall, the global average concentrations of various GHGs in the atmosphere have been continuously increasing since records began. In 2008, the concentration of all GHGs regulated in the Kyoto Protocol was 438 parts per million (ppm) $CO_2$-equivalent ($CO_2$e). This was 58% higher than the pre-industrial level (EEA, 2010a). It is coming very close to the 450 ppm threshold, the level associated with a 50% chance of exceeding of the 2 °C global average temperature change goal (see Section 3.4).

**Figure 3.1. GHG emissions: *Baseline*, 1970-2005**




Note*:* BRIICS excludes the Republic of South Africa which is aggregated in the rest of the world (RoW) category. The emissions of fluor gases are not included in the totals by region.

*Source*: *OECD Environmental Outlook Baseline*; output from IMAGE.

## Carbon-dioxide emissions

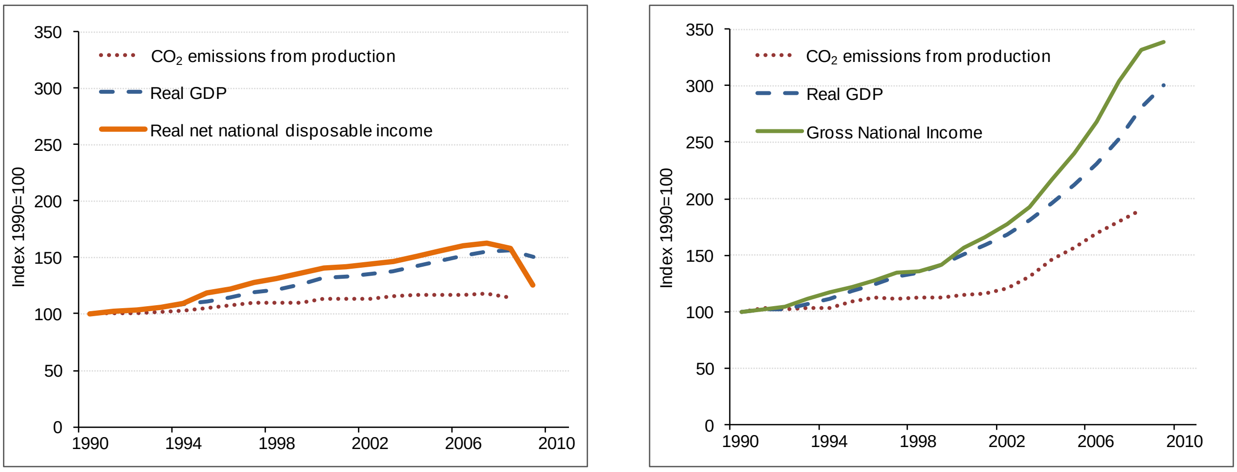
Today $CO_2$ emissions account for around 75% of global GHG emissions. While global $CO_2$ emissions decreased in 2009 – by 1.5% – due to the economic slowdown, trends varied depending on the country context: developing countries (non-Annex I, see Section 3.3) emissions continued to grow by 3%, led by China and India, while emissions from developed countries fell sharply – by 6.5% (IEA, 2011a). Most $CO_2$ emissions come from energy production, with fossil fuel combustion representing two-thirds of global $CO_2$ emissions. Indications of trends for 2010 suggest that energy-related $CO_2$ emissions will rebound to reach their highest ever level at 30.6 gigatonnes ($GtCO_2$), a 5% increase from the previous record year of 2008.[5]

A slow-down in OECD emissions has been more than compensated for by increased emissions in non-OECD countries, mainly China – the country with the largest energy-related GHG emissions since 2007 (IEA, 2011a).

In 2009, $CO_2$ emissions originated from fossil fuel combustions were based on coal (43%), followed by oil (37%) and gas (20%). Today's rapid economic growth, especially in the BRIICS, is largely dependent on increased use of carbon-intensive coal-fired power, driven by the existence of large coal reserves with limited reserves of other energy sources. While emission intensities in economic terms (defined as the ratio of energy use to GDP) vary greatly around the world, $CO_2$ emissions are growing at a slower rate than GDP in most OECD and emerging economies (Figure 3.2). In other words, $CO_2$ emissions are becoming relatively "decoupled" from economic growth.

**Figure 3.2. Decoupling trends: $CO_2$ emissions *versus* GDP in the OECD and BRIICS, 1990-2010**

a. OECD b. BRIICS

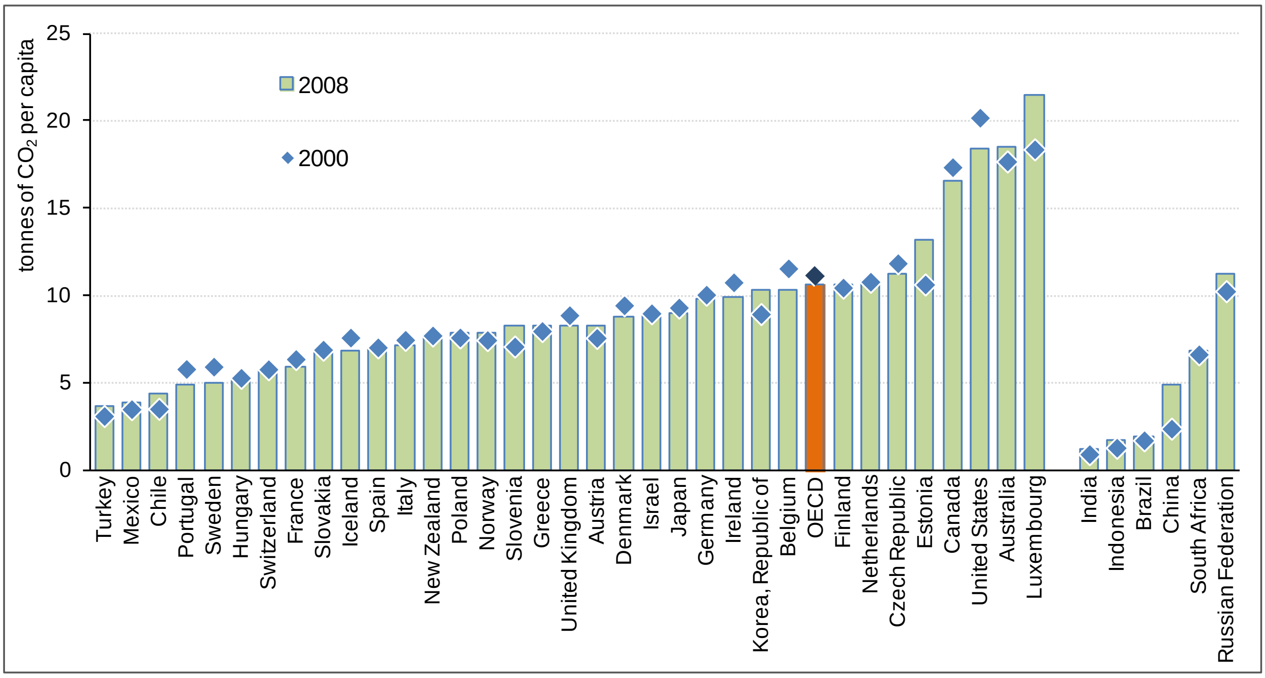



*Note*: $CO_2$ data refer to emissions from energy use (fossil fuel combustion).

*Source:* Adapted from OECD (2011e), *Towards Green Growth: Monitoring Progress*, OECD Green Growth Studies, OECD, Paris, based on OECD, IEA and UNFCCC data.

On a per-capita basis, OECD countries still emit far more $CO_2$ than most other world regions, with 10.6 tonnes of $CO_2$ emitted per capita on average in OECD countries in 2008, compared with 4.9 tonnes in China, and 1.2 tonnes in India (Figure 3.3). However, rapidly expanding economies are significantly increasing their emissions per capita. China for instance doubled its emissions per capita between 2000 and 2008. These calculations are based on the usual definition that emissions are attributed to the place where they occur, sometimes labelled the "production-based emissions accounting approach". If one allocates emissions according to their end-use, *i.e.* using a consumption-based approach, part of the emission increases in the BRIICS regions would be attributed to the OECD countries, as these emissions are "embedded" in exports from the BRIICS to the OECD (see Box 3.1).

**Figure 3.3. Energy-related $CO_2$ emissions per capita, OECD/ BRIICS: 2000 and 2008**




Note: Production-based emissions, in tonnes of $CO_2$ per capita.
*Source*: Based on OECD (2011e), *Towards Green Growth: Monitoring Progress*, OECD Green Growth Studies, from IEA data.

Other gases

Methane is the second largest contributor to human-induced global warming, and is 25 times more potent than $CO_2$ over a 100-year period. Methane emissions contribute to over one-third of today's human-induced warming. As a short-lived climate forcer, limiting methane emissions will be a critical strategy for reducing the near-term rate of global warming and avoiding exceeding climatic tipping points (see below). Methane is emitted from both anthropogenic and natural sources; over 50% of global methane emissions are from human activities[6], such as fossil fuel production, animal husbandry (enteric fermentation in livestock and manure management), rice cultivation, biomass burning and waste management. Natural sources of methane include wetlands, gas hydrates, permafrost, termites, oceans, freshwater bodies, non-wetland soils, and other sources such as wildfires.

Nitrous oxide ($N_2O$) lasts a long time in the atmosphere (approximately 120 years) and has powerful heat trapping effects – about 310 times more powerful than $CO_2$. It therefore has a large global warming potential. Around 40% of $N_2O$ emissions are anthropogenic, and come mainly from soil management, mobile and stationary combustion of fossil fuel, adipic acid production (used in the production of nylon), and nitric acid production (for fertilisers and the mining industry).

CFCs and HCFCs are powerful GHGs that are purely man-made and used in a variety of applications. As they also deplete the ozone layer, they have been progressively phased out under the Montreal Protocol on Substances That Deplete the Ozone Layer. HFCs and PFCs are being used as replacements for CFCs. While their contribution to global warming is still relatively small, it is growing rapidly. They are produced from chemical processes involved in the production of metals, refrigeration, foam blowing and semiconductor manufacturing.

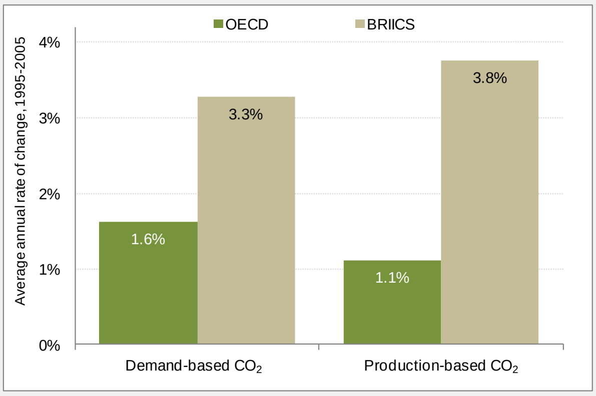
**Box 3.1. Production *versus* demand-based emissions**

Production-based accounting of $CO_2$ emissions allocates emissions to the country where production occurs – it does not account for emissions caused by final domestic demand. Alternatively, consumption-based accounting differs from traditional, production-based inventories because of imports and exports of goods and services that, either directly or indirectly, involve $CO_2$ emissions. Emissions embedded in imported goods are added to direct emissions from domestic production, while emissions related to exported goods are deducted. A comparison between the two approaches shows that total emissions generated to meet demand in OECD countries have increased faster than emissions from production in these countries (Figure 3.4).

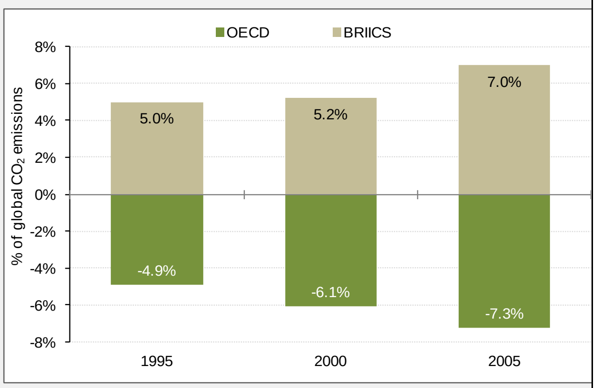
However, international comparisons should be interpreted with caution as country differences are due to a host of factors – including climate change mitigation efforts, trends in international specialisation, and countries' relative competitive advantages. While the fast growth of production-based emissions in the BRIICS may partly reflect the worldwide shift of heavy industry and manufacturing to emerging economies, these figures should not be confused with carbon leakage* effects as they are based on observed trends in production, consumption and trade patterns.

**Figure 3.4. Change in production-based and demand-based $CO_2$ emissions: 1995-2005**

Panel A. Average annual rate of change, 1995-2005




Panel B. Trade balance (production-consumption) in $CO_2$ emissions as % of global $CO_2$ emissions




*Source:* OECD (2011e), *Towards Green Growth: Monitoring Progress*, OECD Green Growth Studies, based on IEA data.

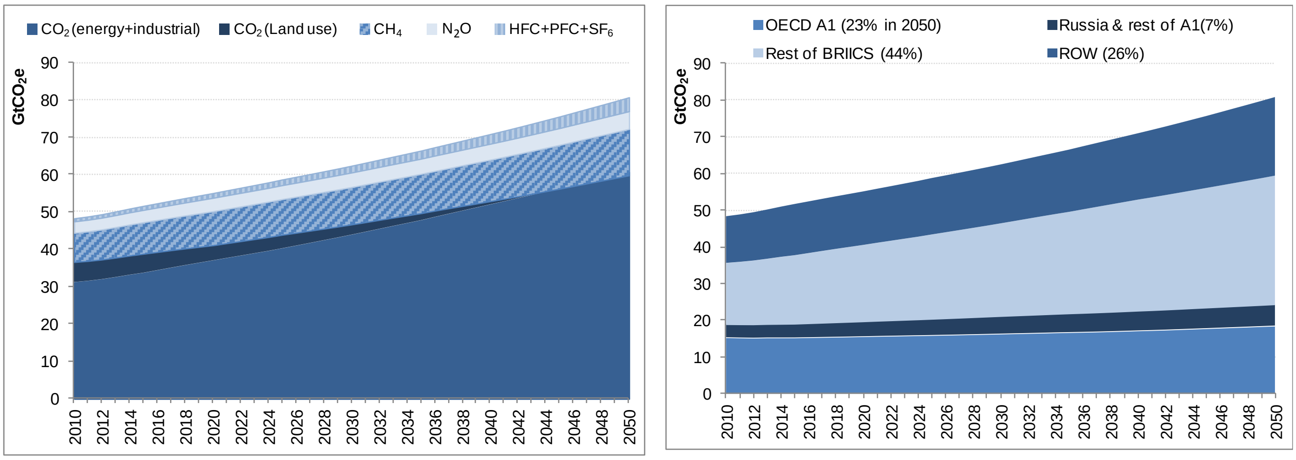
Note: *Carbon leakage occurs when a mitigation policy in one country leads to increased emissions in other countries, thereby eroding the overall environmental effectiveness of the policy. Leakage can occur through a shift in economic activity towards unregulated countries, or through increased fossil-energy use induced by lower pre-tax fuel prices resulting from the mitigation action.

*Future emission projections*

This section presents the key findings of the *Environmental Outlook Baseline* scenario, which looks forward to 2050 and is based on business as usual in terms of policies and on the socio-economic projections described in Chapter 2 (see Annex 3.A1 for more detail on the assumptions underlying the *Baseline*). Any projection of future emissions is subject to fundamentally uncertain factors, such as demographic growth, productivity gains, fossil fuels prices and energy efficiency gains. The scenario suggests that GHG emissions will continue to grow to 2050. Despite sizeable energy-efficiency gains, energy and industry-related emissions are projected to more than double to 2050 compared to 1990 levels. Meanwhile, net emissions from land-use change are projected to decrease rapidly (Box 3.2). Emissions from BRIICS countries are projected to account for most of the increase (Figure 3.5). This is driven by growth in population and GDP per capita, leading to growing per-capita GHG emissions. In the OECD, emissions are projected to grow at a slower pace, partly reflecting demographic decline and slower economic growth, as well as existing climate policies. Overall, the contribution of OECD countries to global GHG emissions is projected to drop to 23%, but OECD countries will continue to have the highest emissions per capita (Figure 3.6).

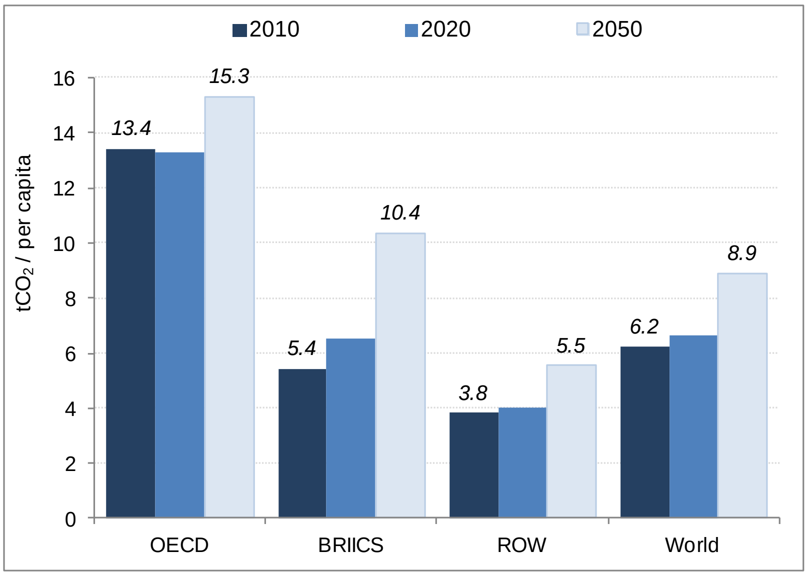
**Figure 3.5. GHG emissions: *Baseline*, 2010-2050**

a. By gases b. By regions




*Source*: *OECD Environmental Outlook Baseline;* output from IMAGE/ENV Linkages.

**Figure 3.6. GHG emissions per capita: *Baseline*, 2010-2050**



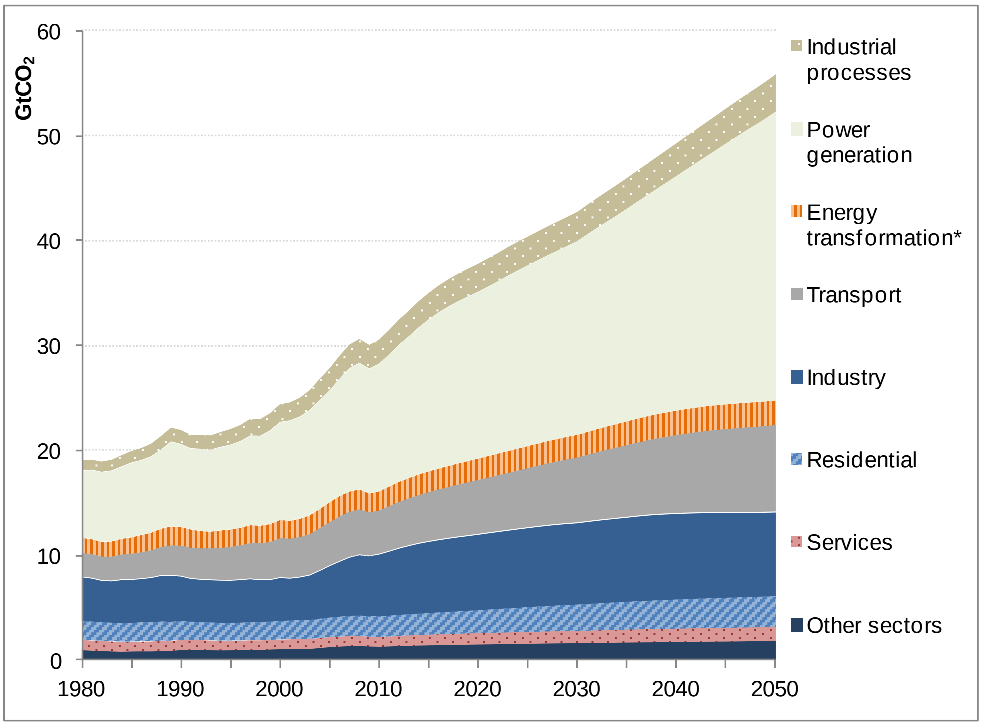

*Source: OECD Environmental Outlook Baseline*; output from IMAGE/ENV-Linkages.

Carbon-dioxide emissions

$CO_2$ emissions are projected to remain the largest contributor to global GHG emissions, driven by economic growth based on fossil fuel use in the energy and industrial sectors. The International Energy

Agency (IEA) estimates that unless policies prematurely close existing facilities, 80% of projected 2020 emissions from the power sector are already locked in, as they will come from power plants that are currently in place or under construction (IEA, 2011b). Under the *Environmental Outlook Baseline*, demand for energy is projected to increase by 80% between 2010 and 2050. Transport emissions are projected to double between 2010 and 2050, due in part to a strong increase in demand for cars in developing countries, and growth in aviation (Figure 3.7). However, $CO_2$ emissions from land use, land-use change and forestry (LULUCF), driven in the last 20 years by the rapid conversion of forests to grassland and cropland in tropical regions, are expected to decline over time and even become a net sink of emissions in the 2040-2050 timeframe in OECD countries (Figure 3.5 and 3.8 and Box 3.2).

**Figure 3.7. Global $CO_2$ emissions by source: *Baseline*, 1980-2050**




Note: The category "energy transformation" includes emissions from oil refineries, coal and gas liquefaction.

*Source: OECD Environmental Outlook Baseline;* output from IMAGE.

Other gases

Methane and nitrous oxide emissions are projected to increase to 2050. Although agricultural land is expected to expand only slowly, the intensification of agricultural practices (especially the use of fertilisers) in developing countries and the change of dietary patterns (increasing consumption of meat) are projected to drive up these emissions. At the same time, emissions of HFCs and PFCs, driven by increasing demand for coolants and use in semiconductor manufacturing, will continue growing rapidly.

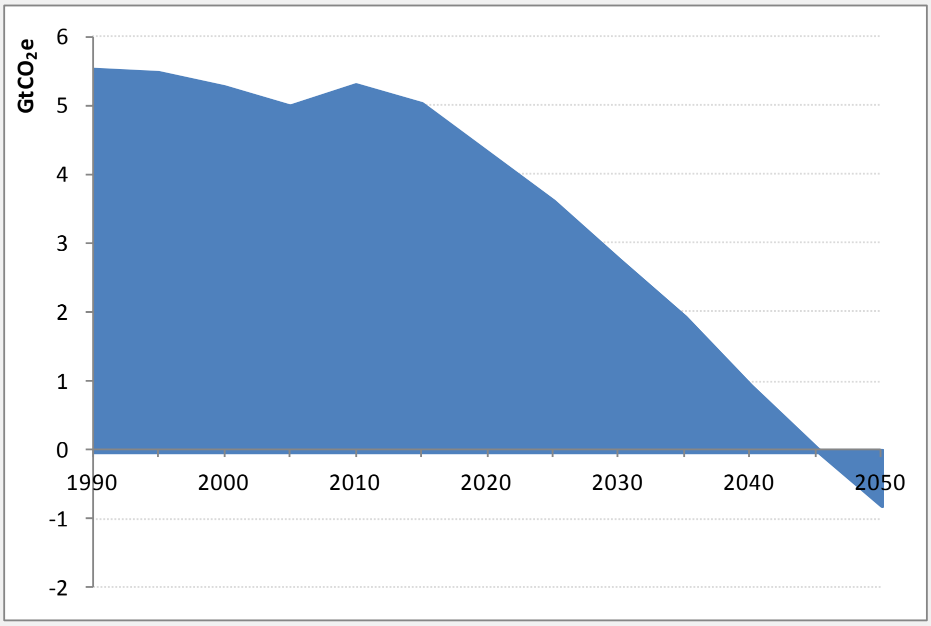
**Box 3.2. Land-use emissions of $CO_2$ – past trends and future projections**

Historically, global net-$CO_2$ emissions from land-use change (mainly deforestation driven by the expansion of agricultural land) have been in the order of 4-8 $GtCO_2$ a year. Other factors also contribute to land-use related emissions, *e.g.* forest degradation and urbanisation.

In the *Baseline* scenario, the global agricultural land area is projected to expand until 2030, and to decline thereafter, due to a number of underlying factors such as demographics and agricultural yield improvements (see Chapter 2 for detailed discussions). However, the projected trends in agricultural land area differ tremendously across regions. In OECD countries, a slight decrease (2%) to 2050 is projected. For the BRIICS as a whole, the projected decrease is more than 17%, reflecting in particular the declining population in Russia and China (from 2035). At least for the coming decades, a further expansion in agricultural area is still projected in the rest of the world, where population is still growing and the transition towards a higher calorie and more meat-based diet is likely to continue. These agricultural developments are among the main drivers of land-use change, and consequently of developments in GHG emissions from land use (Figure 3.8). From about 2045 onwards, a net reforestation trend is projected – with $CO_2$ emissions from land use becoming negative.

However, there is large uncertainty over these projections, because of annual variations and data limitations on land-use trends and the exact size of various carbon stocks.* To date, the key driver of agricultural production has been yield increases (80%), while only 20% of the increase has come from an expansion in agricultural area (Smith *et al.,* 2011). If agricultural yield improvements turn out to be less than anticipated, global agricultural land area might not decline, but could stabilise or grow slowly instead.

**Figure 3.8. $CO_2$ emissions from land use: *Baseline*, 1990-2050**




Source: *OECD Environmental Outlook Baseline*; output from IMAGE.

Note:* Land-use related emissions can be more volatile than energy emissions. For instance, emissions are not only influenced by land-use changes but also by land management. Furthermore, there is considerably more uncertainty in methodologies for evaluating land-use related emissions, as these are less well-established.

***Impacts of climate change***

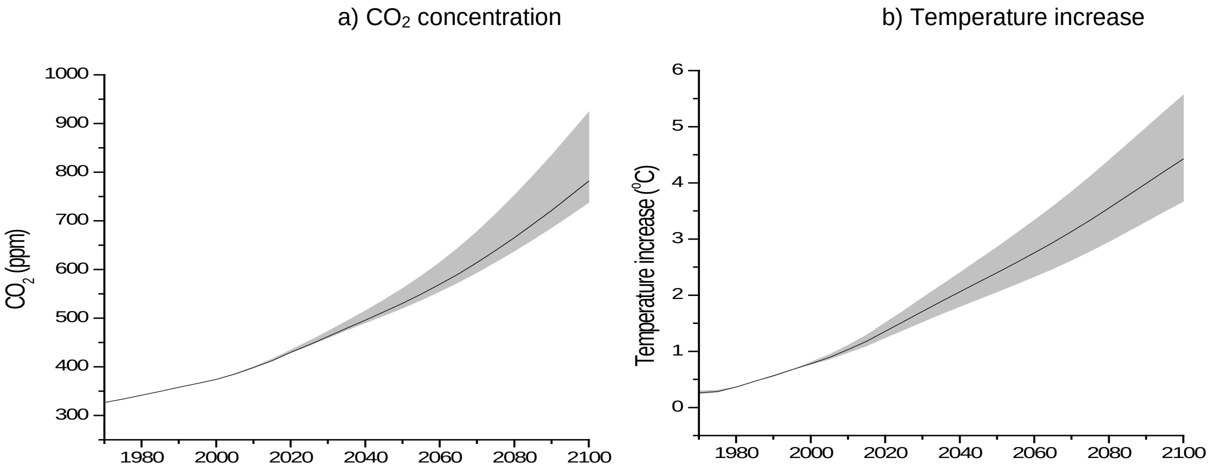
*Temperature and precipitation*

Global warming is underway. The global mean temperature has risen about 0.7 °C to 0.8 °C on average above pre-industrial levels. These observed changes in climate have already had an influence on human and natural systems (IPCC, 2007b). The greatest warming over the past century occurred at high latitudes, with a large portion of the Arctic having experienced warming of more than 2 °C.

The projected large increase in global GHG emissions in the *Baseline* is expected to have a significant impact on the global mean temperature and the global climate. The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC, 2007a) concluded that a doubling of $CO_2$ concentrations from pre-industrial levels (when they were approximately 280 ppm) would likely lead to an increase of temperature somewhere between 2.0 °C and 4.5 °C[7] (the so-called climate sensitivity[8]). However, a growing number of authors suggest that climate sensitivity values above 5 °C, such as 8 °C or higher cannot be ruled out, which would shift even higher the estimated temperatures increase for existing emissions level (Meinshausen *et al.* 2006; Weitzman, 2009).

Under the *Outlook Baseline* scenario, the global concentration of GHGs is expected to reach approximately 685 ppm $CO_2$-equivalent ($CO_2$e) by mid-century and more than 1 000 ppm $CO_2$e by 2100. The concentration of $CO_2$ alone is projected to be around 530 ppm in 2050 and 780 ppm in 2100 (Figure 3.9). As a result, global mean temperature is expected to increase, though there is still uncertainty surrounding the climate sensitivity. The *Outlook Baseline* scenario suggests that these GHG-concentration levels would lead to an increase in global mean temperature at the middle of the century of 2.0 ºC-2.8 ºC, and 3.7 ºC-5.6 ºC at the end of the century (compared to pre-industrial times). These estimates are roughly in the middle ranges of temperature changes found in the peer-reviewed literature (IPCC, 2007b).

**Figure 3.9. Long-run $CO_2$-concentrations and temperature increase: *Baseline*, 1970-2100***

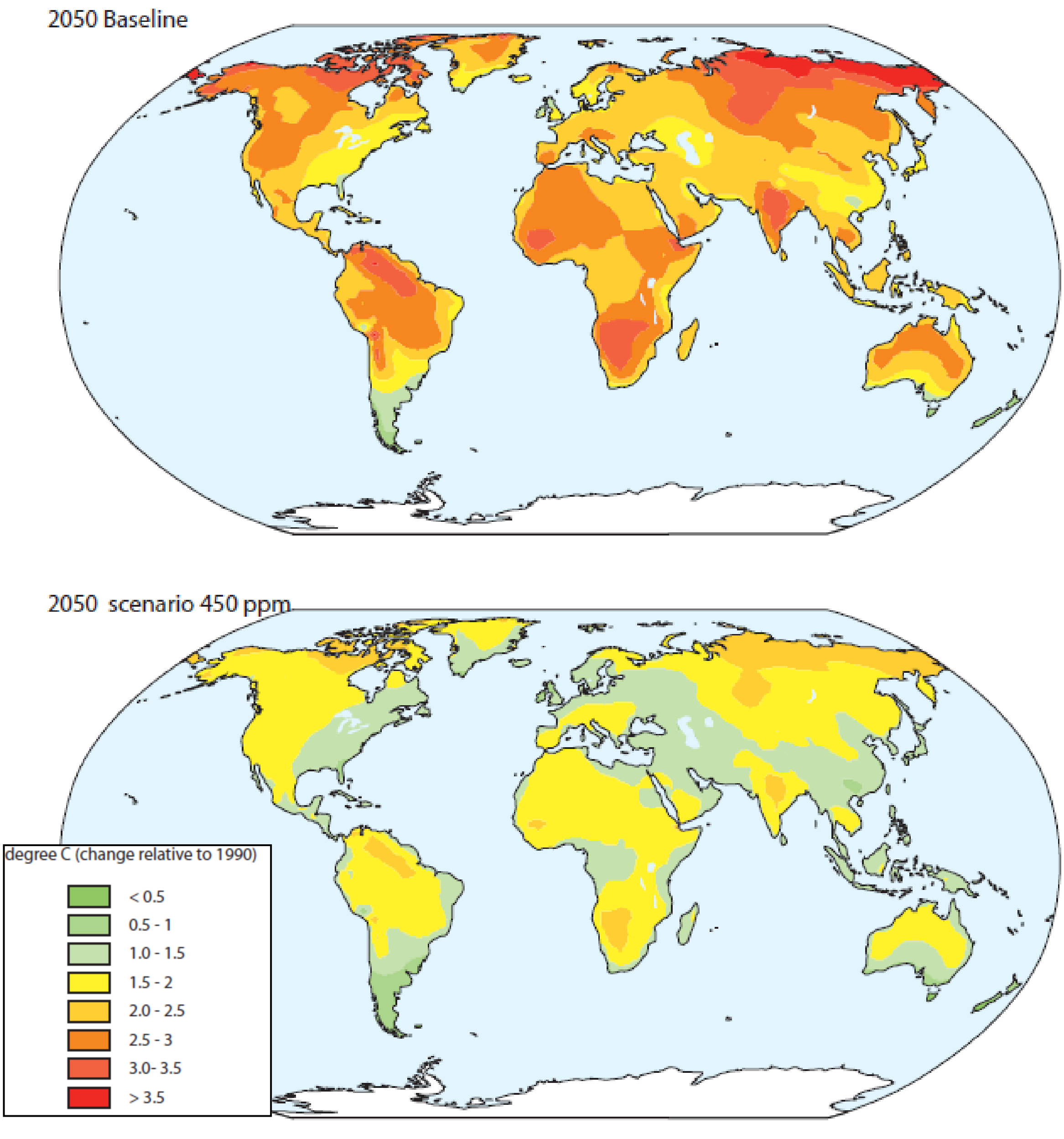



Note: *Uncertainty range is based on calculations of the MAGICC-6 model as reported by van Vuuren *et al.,* 2008.

*Source: OECD Environmental Outlook Baseline*, output from IMAGE.

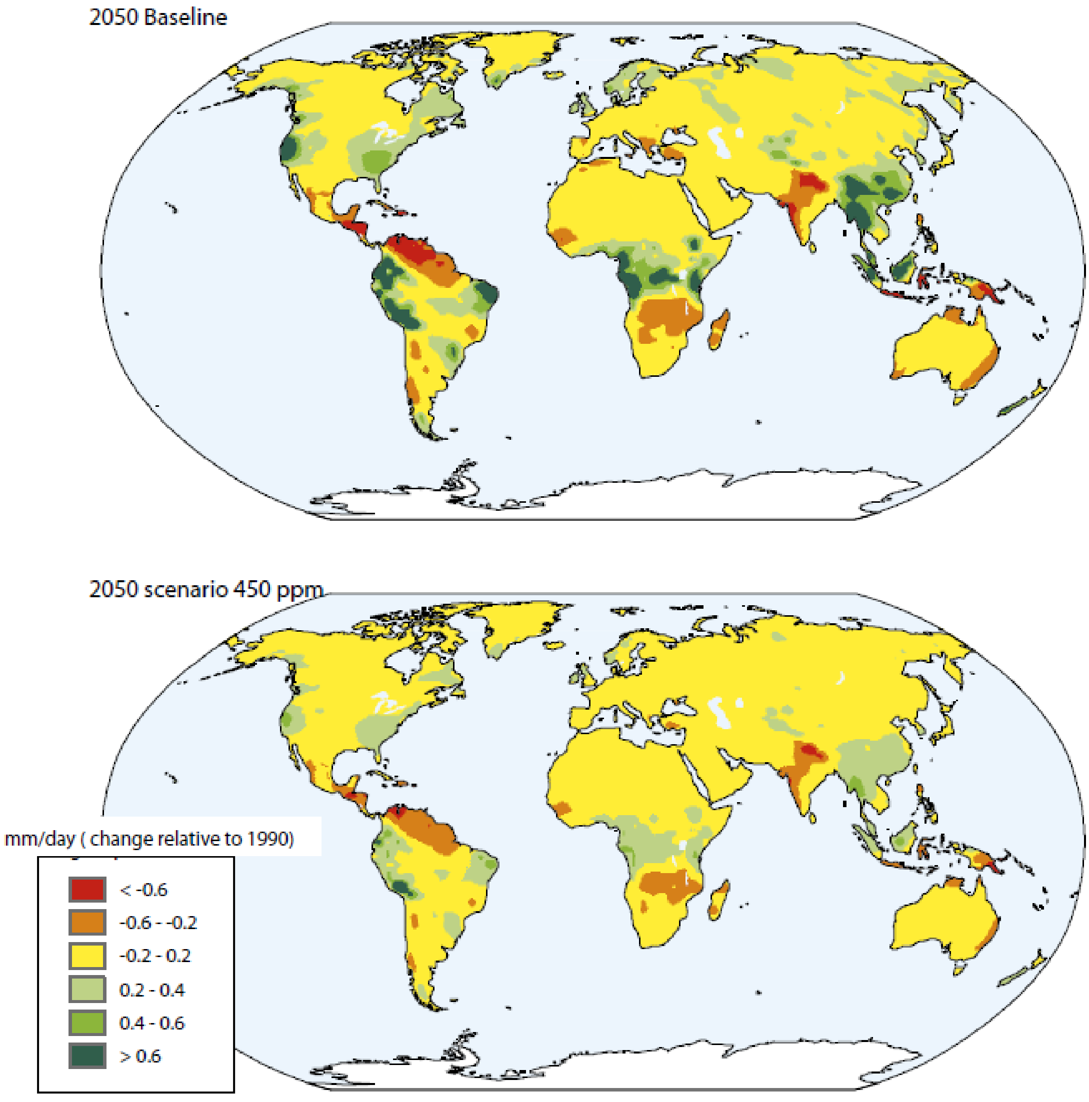
Regions will be affected differently by these changes, and climate change patterns across regions are even more uncertain than the changes in the mean values. Figures 3.10 and 3.11 map the projected temperature and precipitation changes by region, both for the *Baseline* scenario and for the 450 ppm scenarios modeled as part of this *Outlook*, which would limit global average temperature increase to 2 °C above pre-industrial levels (see Section 3.4). For temperature, most climate models agree that changes at high-latitude areas will be larger than at low latitudes. For precipitation, while changes differ strongly across models, they all show that some areas will experience an increase in precipitation, while others will experience a decrease.

**Figure 3.10. Change in annual temperature: *Baseline* and *450 ppm scenarios*, 1990-2050**




*Source: OECD Environmental Outlook projections*, output from IMAGE.

**Figure 3.11 Change in annual precipitation: *Baseline*, 1990-2050**

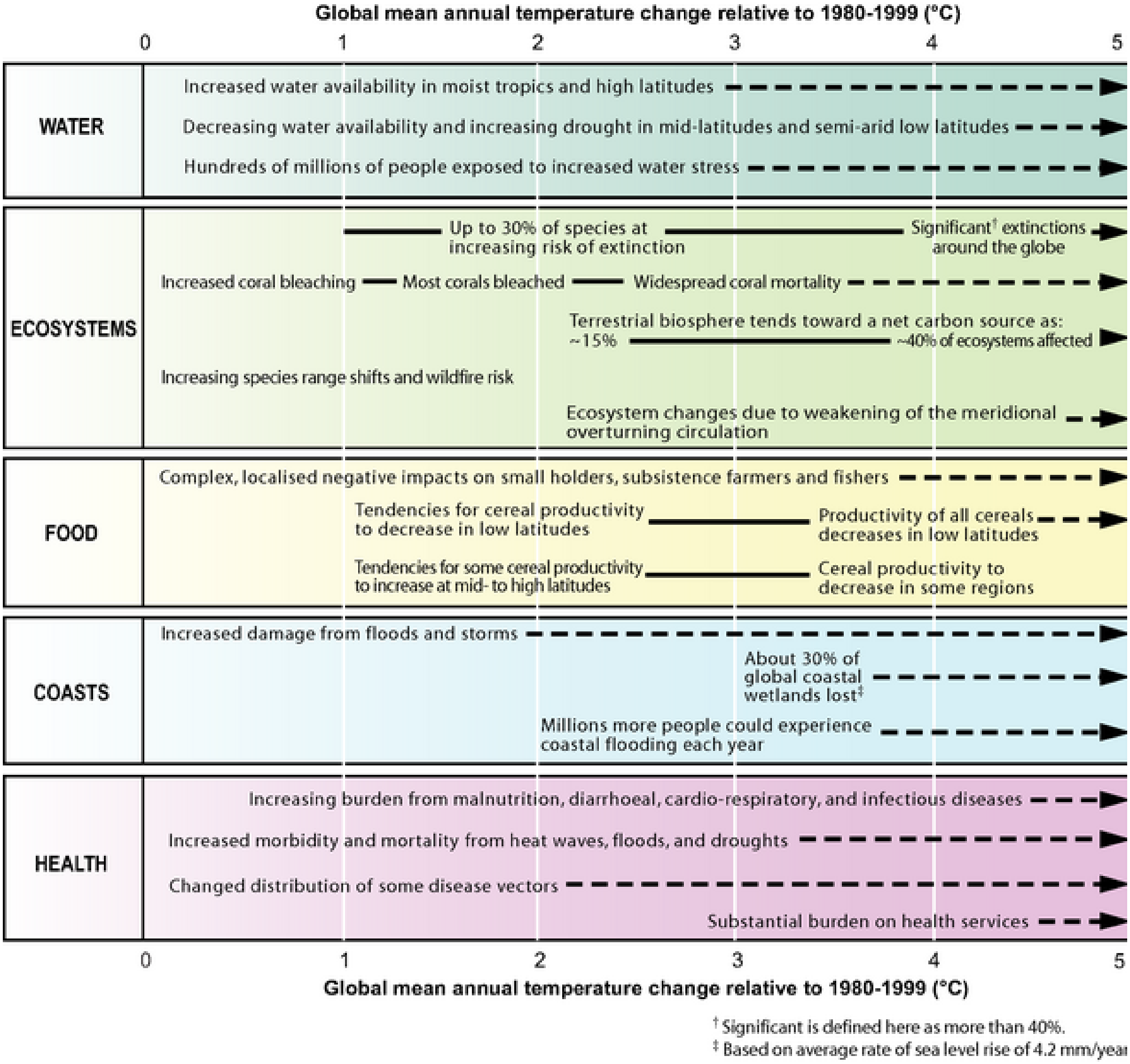



*Source: OECD Environmental Outlook projections*, output from IMAGE.

*Natural and economic impacts of climate change*

In its Fourth Assessment Report, the IPCC concludes that global climate change has already had observable and wide-ranging effects on the environment in the last 30 years (Figure 3.12). Given the expected increase in temperature, the IPCC expects more impacts in the future.

**Figure 3.12. Key impacts of increasing global temperature**




*Source: IPCC* (2007b), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

The impacts will not be spread equally between regions. Some of the regional impacts forecast by the IPCC include:

- **North America:** Decreasing snowpack in the western mountains; 5%-20% increase in yields of rain-fed agriculture in some regions; increased frequency, intensity and duration of heat waves in cities that already experience them.

- **Latin America**: Gradual replacement of tropical forest by savannah in eastern Amazonia; risk of significant biodiversity loss through species extinction in many tropical areas; significant changes in water availability for human consumption, agriculture and energy generation.

- **Europe:** Increased risk of inland flash floods; more frequent coastal flooding and increased erosion from storms and sea-level rise; glacial retreat in mountainous areas; reduced snow cover and winter tourism; extensive species losses; reductions of crop productivity in southern Europe.

- **Africa:** By 2020, between 75 and 250 million people are projected to be exposed to increased water stress; yields from rain-fed agriculture could be reduced by up to 50% in some regions by 2020; agricultural production, including access to food, may be severely compromised.

- **Asia:** Freshwater availability projected to decrease in Central, South, East and Southeast Asia by the 2050s; coastal areas will be at risk due to increased flooding; the death rate from diseases associated with floods and droughts is expected to rise in some regions.

However, overall, all regions are expected to suffer significant net damage from unabated climate change according to most estimates, but the most significant impacts are likely to be felt in developing countries because of already challenging climatic conditions, the sectoral composition of their economy and their more limited adaptive capacities. The costs of damages are expected to be much more important in Africa and Southeast Asia than in OECD or Eastern European countries (see Nordhaus and Boyer, 2000; Mendelsohn *et al.,* 2006 and OECD, 2009a for a compilation of results). Coastal areas would be particularly exposed as well (Box 3.3).

Recent research suggests that the impacts of unabated climate change may be even more dramatic than estimated by the IPCC. The extent of sea-level rise could be even greater (Oppenheimer *et al*., 2007; Rahmstorf, 2007). Accelerated loss of mass in the Greenland ice sheet, mountain glaciers and ice caps could, according to the Arctic Monitoring Assessment Programme (AMAP, 2009), lead to an increase of global sea levels in 2100 of 0.9m-1.6 m. In addition, researchers investigating climate feedbacks in more detail have found that rising Arctic temperatures could lead to extra methane emissions from melting permafrost (Shaefer *et al.*, 2011). They also conclude that the climate sensitivity could be higher than anticipated, meaning that a given temperature change could result from lower global emissions than those suggested in the Fourth IPCC Assessment Report.

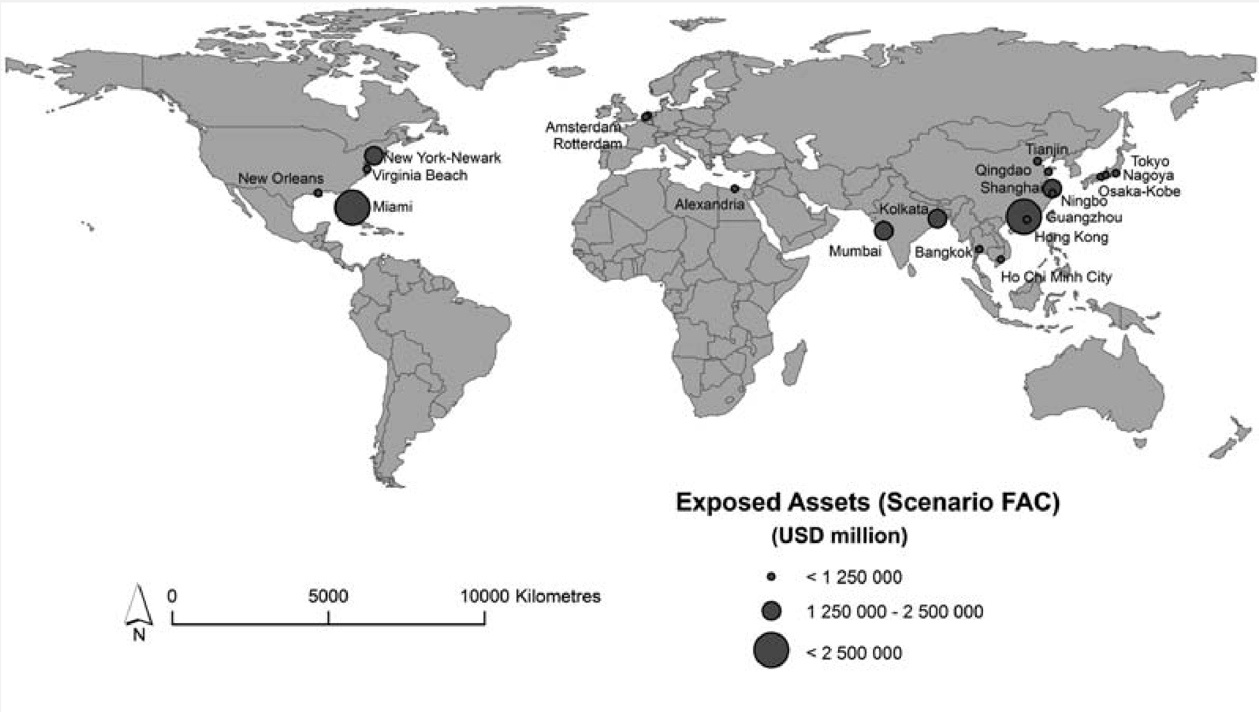
Climate change might also lead to so-called “tipping-points”, *i.e* dramatic changes in the system that could have catastrophic and irreversible outcomes for natural systems and society. A variety of tipping points have been identified (EEA, 2010), such as a 1 °C-2 °C and 3 °C-5 °C temperature increase which would respectively result in the melting of the West Antarctic Ice Sheet (WAIS) and the Greenland Ice Sheet (GIS). The potential decrease of Atlantic overturning circulation[9] could have unknown but potentially dangerous effects on the climate. Other examples of potential non-linear irreversible changes include increases in ocean acidity which would affect marine biodiversity and fish stocks; accelerated methane emissions from permafrost melting, and rapid climate-driven transitions from one ecosystem to another. The level of scientific understanding – as well as the understanding of possible impacts of most of these events – is low, and their economic implications are therefore difficult to estimate. Some transitions are expected to occur over shorter timeframes than others – the shorter the timeframe, the less opportunity to adapt (EEA, 2010).

Climate change impacts are closely linked to other environmental issues. For example, the *Environmental Outlook Baseline* scenario projects negative impacts of climate change on biodiversity and water resources. Without new policies, climate change would become the greatest driver of future biodiversity loss (see Chapter 4 on biodiversity). The cost of biodiversity loss is particularly high in developing countries, where ecosystems and natural resources account for a significant share of income. Climate change can also affect human health; either directly through heat stress or indirectly through its effects on water and food quality and on the geographical and seasonal ranges of vector-borne diseases (see Chapter 6). Climate change will also have an impact on the availability of freshwater (see Chapter 5).

**Box 3.3. Example of assets exposed to climate change: Coastal cities**

Coastal zones are particularly exposed to climate change impacts, especially low-lying urban coastal areas and atolls. Coastal cities are especially vulnerable to rising sea levels and storm surges. For example, by 2070, in the absence of adaptation policies such as land-use planning or coastal defence systems, the total population exposed to a 50cm sea-level rise could grow more than threefold to around 150 million people. This would be due to the combined effects of climate change (sea-level rise and increased storminess), land subsidence, population growth and urbanisation. The total asset exposure could grow even more dramatically, reaching USD 35 000 billion by the 2070s, more than 10 times current levels (Figure 3.13).

**Figure 3.13. Assets exposed to sea-level rise in coastal cities by 2070**




Note: Scenario FAC refers to the “Future City All Changes” scenario in Nicholls *et al*., 2010, which assumes 2070s economy and population and 2070s climate change, natural subsidence/uplift and human-induced subsidence.

*Source:* OECD (2010a), *Cities and Climate Change*, OECD, Paris; Nicholls, R J., *et al.* (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", *OECD Environment Working Papers*, No. 1.

The costs of taking no further action on climate change are likely to be significant, though estimating them is challenging. The types of costs range from those that can easily be valued in economic terms – such as losses in the agricultural and forestry sectors – to those that are more intangible – such as the cost of biodiversity loss and catastrophic events like the potential shutdown of the Atlantic overturning circulation. Cost estimates vary due to the inclusion of different categories of cost and incomplete information. Most studies do not include non-market impacts, such as the impacts on biodiversity. A few include impacts associated with extreme weather events (*e.g.* Alberth and Hope, 2006) and low-probability catastrophic events (*e.g* Nordhaus, 2007). Depending on the scale of impacts covered in the models and the discount rate used, the discounted value of the costs of taking no further action to tackle climate change could equate to a permanent loss of world per-capita consumption of between 2% to more than 14% (Stern, 2006; OECD, 2008a).

These considerations must also be weighed against the potential of extreme and sudden changes to natural and human systems. The impacts of these low-probability but high-impact changes could have very significant or even catastrophic economic consequences (Weitzman, 2009). Some argue that in such contexts standard cost-benefit analyses may not be appropriate. It may be better to approach the issue in terms of risk management, using for example "safe minimum standards" (Dietz *et al.,* 2006) and "more explicit contingency planning for bad outcomes" (Weitzman, 2009; 2011).[10] In this context, assessments need to take into account the uncertainties involved; and decision making should be informed as much through sensitivity analysis which includes the extreme numbers as through central estimates. From a political perspective, the Cancún agreement to focus (at least partly) on the so-called 2 °C goal (see Section 3.1) has already established a political goal based on scientific evidence. This suggests that the world's governments find that the costs of allowing the temperature increase to go beyond 2 °C outweigh the costs of transitioning to a low-carbon economy.

## 3.3. Climate Change: The state of policy today

This section first outlines the international framework for climate change mitigation and adaptation, before dealing with the current policies and challenges facing these two areas of action at the national level.

### *The international challenge: Overcoming inertia*

Tackling climate change presents nations with an international policy dilemma of an unprecedented scale. Climate change mitigation is an example of a global public good (Harding, 1968): each country is being asked to incur costs – sometimes significant – to reduce GHG emissions, but the benefits of such efforts are shared globally. Other factors which complicate the policy challenge include the delay between the GHG being emitted and the impacts on the climate, with some of the most severe impacts not projected to materialise until the last half of this century. Climate impacts and the largest benefits of mitigation action are also likely to be distributed unevenly across a range of countries, with developing countries likely to suffer most from unabated climate change, in addition to having the least capacity to adapt. These all mean that even though the direct benefits and co-benefits of climate action are significant, country incentives to mitigate climate change do not seem to be sufficiently large or clear to trigger the deep and urgent levels of mitigation required to stay within the 2 °C goal (OECD, 2009a).

Concerted international co-operation will be needed to overcome these strong free-rider effects that are causing individual regions and countries to delay action (Barrett, 1994; Stern, 2006). This will need to be underpinned by international agreements and include the use of financial transfers to encourage broad engagement by all economies. Creating an international architecture to advance climate mitigation also requires even stronger co-operation for low-carbon technology transfer and institutional capacity building to support action in developing countries. To be successful and widely accepted, international co-operation on climate change will also need to address equity and fairness concerns, issues which are often referred to as the "burden sharing" elements of the international regime.

Signature of the UNFCCC in 1992 was a first step towards achieving a global policy response to the climate change problem. Countries who signed the convention (the "Parties") have agreed to work collectively to achieve its ultimate objective: "stabilization of GHG-concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference of the climate system" (Article 2, UNFCCC[11]). By signing this convention, OECD and other industrialised economies (known as the Annex I Parties)[12] agreed to take the lead to achieve this objective, and to provide financial and technical assistance to other countries (non-Annex I[13] Parties) to help them address climate change. In 2005, the Kyoto Protocol entered into force and this created a legal obligation for Annex I Parties[14] to limit or reduce their GHG emissions between 2008 and 2012 to within agreed emission levels. By 2009, $CO_2$-emission levels for the group of countries participating in the Kyoto protocol were 14.7% below their 1990 level (IEA, 2011a), although with significant differences among countries.

Recent scientific evidence of climate change, including that provided in IPCC work, has led to agreement about the specific details of Article 2 of the Convention. This resulted in a statement in the 2010 Cancún Agreements that:

> "…recognizes that deep cuts in global GHG emissions are required (…), with a view to reducing global GHG emissions so as to hold the increase in global average temperature below 2 °C above preindustrial levels, (…) also recognizes the need to consider, in the context of the first review, strengthening the long-term global goal on the basis of the best available scientific knowledge, including in relation to a global average temperature rise of 1.5 °C" (UNFCCC, 2011a).

Another step forward has been the mitigation pledges made by many countries – both developed and developing – first in the 2009 Copenhagen Accord and later in the Cancún Agreements, to reduce emissions by 2020 (see Table 3.8 in Section 5; UNFCCC, 2009; and UNFCCC, 2011a).[15] Our analysis of all these pledges and commitments, however, shows that without significant further action post-2020, they are unlikely to be sufficient to stay within the 2 °C goal (see Section 3.4 and UNEP, 2010).

In order to share equitably the burden of action needed to meet the 2 °C goal, the Cancún Agreements reiterated the commitment by developed countries to provide new and additional financial resources to developing countries for climate action. This will include "Fast Start Finance" of USD 30 billion between 2010 and 2012, with a longer-term goal of raising USD 100 billion per year by 2020 from public and private sources.[16] Countries also agreed in Cancún to establish a Green Climate Fund that will support projects, programmes, policies and other activities in developing countries.[17] Nevertheless, significant challenges remain in the international climate negotiations regarding the future of the Kyoto Protocol and its instruments after it expires in 2012, and on the ability for governments to unlock additional finance and to monitor, report and verify those flows.

Until the 7th Conference of the Parties (COP7) in Marrakech in 2001, adaptation had received less attention in the international negotiation process, though it was mentioned in both the UNFCCC and the Kyoto Protocol. Parties at COP7 established three funds dealing with adaptation, the Least Developed Countries Fund, the Special Climate Change Fund and the Adaptation Fund. Adaptation has received more attention since then. The Cancún Agreements stressed the importance of adaptation and established a Cancún Adaptation Framework with an associated Adaptation Committee. The Green Climate Fund also recognises the need for balanced treatment of adaptation and mitigation.

***National action to mitigate climate change***

Despite some progress and the media attention focused on the global summits, only decisive policy action at the national level will limit local and global climate risks. To achieve the 2 °C goal, economies worldwide will have to go through unprecedented transformations in terms of energy production, consumption, transport and agriculture patterns. The transition to a low-carbon, climate resilient economy will require significant investments in mitigation and adaptation, and a shift of investment from fossil fuels and conventional technologies to newer, cleaner technologies and less carbon-intensive infrastructure. In the context of tight government budgets, finding least-cost solutions and engaging the private sector will be critical to finance the transition (OECD 2012), and costly overlaps between policies must be avoided (OECD, 2011b). Government intervention will be needed to overcome existing barriers and create the appropriate market conditions for green investments.

The multiple market failures presented by climate change call for a mix of policy instruments to cut GHG emissions effectively. While there is no single recipe for a successful climate policy mix, there are certainly some important common ingredients, as noted by the OECD Green Growth Strategy (OECD, 2011e) and earlier OECD work (OECD, 2011a; OECD, 2009a; Duval, 2008). Key elements of a least-cost policy mix include (Table 3.1):

- national climate change strategies;
- price-based instruments, *e.g.* cap and trade, carbon taxes and removing fossil fuels subsidies;
- command and control instruments and regulations;
- technology support policies, including R&D;
- voluntary approaches, public awareness campaigns and information tools.

Each of these is discussed in turn below.

**Table 3.1. Examples of policy tools for climate change mitigation**

| | |
|---|---|
| Price-based instruments | Taxes on $CO_2$ emissions.<br>Taxes on inputs or outputs of process (energy or vehicles).<br>Removal of environmentally harmful subsidies (*e.g* for fossil fuels).<br>Subsidies for emissions-reducing activities.<br>Emissions trading systems (cap-and-trade or *Baseline*-and-credit). |
| Command and control regulations | Technology standards.<br>Performance standards.<br>Prohibition or mandating of certain products or practices.<br>Reporting requirements.<br>Requirements for operating certification.<br>Land-use planning, zoning. |
| Technology support policies | A robust intellectual property rights system.<br>Public and private R&D funding.<br>Public procurement of low-carbon products and services.<br>Green certificates (*e.g.* renewable portfolio standard).<br>Feed-in tariffs for electricity from renewable.<br>Public investment in infrastructure for new low-carbon technologies.<br>Policies to remove financial barriers to green technology (loans, revolving funds, direct financial transfers, preferential tax treatment).<br>Capacity building for the workforce, infrastructure development . |
| Information and voluntary approaches | Rating and labelling programmes.<br>Public information campaigns.<br>Education and training.<br>Product certification and labelling.<br>Award schemes. |

*Source:* Adapted from de Serres A., F. Murtin and G. Nicoletti (2010) “A Framework for Assessing Green Growth Policies”, *OECD Economics Department Working Papers*, No. 774, OECD, Paris.

*National climate change strategies and legislation*

The Cancún Agreements state that industrialised countries should develop low-carbon development plans and strategies and also assess how best to meet them, including through market mechanisms. Developing countries are encouraged to do the same. Many industrialised countries have already developed national laws or strategies to address climate change. The objective of these tends to be centred on achieving Kyoto commitments and/or medium- to long-term emissions reduction targets. These targets, plans or strategies are essential within a policy framework to encourage and steer investment to low-carbon, climate resilient outcomes; they also provide a long-term, stable investment signal to the private sector (Clapp *et al*., 2010; Buchner, 2007; Bowen and Rydge, 2011).

National climate policy frameworks are emerging in Annex I countries, some of which establish legally binding, economy-wide emission constraints and/or long-term emission goals (Table 3.2). These aim to implement, reinforce or – in some cases – go beyond the country's international obligations. For example, the United Kingdom has a legally binding absolute emissions reduction target of at least 34% below 1990 levels by 2020 and at least 80% below 1990 levels by 2050 in its Low Carbon Transition Plan (LCTP). It introduces the concept of five-year carbon budget periods with binding milestones, beginning in 2008. The European Union's "20-20-20 Energy and Climate Package", adopted in January 2008, is an example of a comprehensive and legally binding climate strategy with three different objectives:

i. A reduction of GHG emissions by at least 20% compared to 1990 by 2020, with a commitment to increase it to 30% if a satisfactory international agreement is reached.

ii. A target of 20% of energy coming from renewable sources by 2020, supplemented by 10% of renewable transport fuel.

iii. A commitment to reduce the European Union's energy consumption by 20% compared to the *Baseline* in 2020.

In the Unites States, there is no federal law or economy-wide commitment to reduce GHG emissions, but the United States is bound by law to achieve reductions as a result of a Supreme Court case (Massachusetts v. EPA[18]). Fuel-efficiency standards for transport and stationary power plants have been finalised for 2012-2016 and regulations for 2017-2025 are in the process of being proposed. Also, following another two court cases and settlement agreements, the Environmental Protection Agency (EPA) will regulate GHGs from oil refineries and electric utilities by mid-2012.

Table 3.2 shows the emerging range of national climate policy and legislative frameworks, based on the *Climate Legislation Study* conducted by the Global Legislators Organisation (GLOBE). The study considers various areas of mitigation: specific energy-efficiency policies, carbon pricing, renewable energy and transport, as well as activities that can help both in adaptation and mitigation, such as forestry and land use. The authors analyse "flagship" legislation – a key piece of legislation on climate change policy – and consider the different sectoral priorities of the countries. Table 3.4 only considers activities implemented at national level, and not at local or regional level.

**Table 3.2 National climate change legislation: Coverage and scope, selected countries**

| Country | Coverage of legislation | | | | | | | Examples of flagship national legislation |
|---|---|---|---|---|---|---|---|---|
| | Pricing Carbon | Energy Efficiency | Renewable Energy | Forestry | Other land use | Transport | Adaptation | |
| **Australia** | M | X | X | X | X | | X | Clean Energy Act (2011) |
| **Brazil** | X | X | X | M | X | X | O | National Policy on Climate Change (NPCC) (2009) |
| **Canada** | | M | O | X | X | X | | Canadian Environmental Protection Act, 1999 (CEPA 1999) and the Energy Efficiency Act (EEA) |
| **Chile** | | X | X | | | | M | National Climate Change Action Plan (2008) |
| **China** | | M | X | X | X | X | X | 12th Five Year Plan (2011) |
| **EU** | M | X | X | O | O | X | O | Climate and Energy Package *(2008)* |
| **France** | X | M | X | | O | X | X | Grenelle I et II (2009 et 2010) |
| **Germany** | X | X | M | | | X | | Integrated Climate and Energy Programme (2007, updated 2008) and 2010 Energy Concept |
| **India** | | M | X | X | X | X | X | National Action Plan on Climate Change (NAPCC) (2008) |
| **Indonesia** | X | X | X | M | X | X | X | Presidential Regulation on the National Council for Climate Change (NCCC) (2008) |
| **Italy** | X | M | X | O | | X | | Climate Change Action Plan (CCAP) (2007) |
| **Japan** | X | M | X | X | X | X | X | Law Concerning the Promotion of Measures to Cope with Global Warming (1998, amended in 2005) |
| **Mexico** | X | X | M | X | X | O | O | Inter Secretariat Commission on Climate Change; LUREFET (1) *(2005 and 2008)* |
| **Russia** | | M | O | O | | | X | Climate Doctrine *(2009)* |
| **Portugal** | O | M | M | X | X | X | | National Climate Change Programme (PNAC), last revised in 2008 |
| **South Africa** | X | X | M | | | X | X | Vision, Strategic Direction and Framework for Climate Policy *(2008)* |
| **Korea** | M | X | X | X | X | X | X | Framework Act on Low Carbon Green Growth *(2009)* |
| **UK** | M | X | X | | | X | X | Climate Change Act *(2008)* |
| **US** | | X | M | O | O | X | | No integrated federal climate change legislation (2) |

Notes*:* M main focus; X detailed coverage; O some coverage. (1) Law for the Use of Renewable Energies and for the Finance of the Energy Transition; (2) Key environmental legislations include the Executive Order 13514; federal leadership in environmental energy and economic performance; and American Recovery and Re-investment Act. This table only considers activities implemented at national level, and not at local or regional level.

*Source:* Adapted from Townshend, T., Fankhauser, S., Matthews, A., Feger, C., Liu, J., and Narciso, T. 2011, The 2nd *GLOBE Climate Legislation Study,* GLOBE International, London.

Countries have also devised a variety of planning and strategy tools to meet specific targets, building on collection and analysis of historical trend data and often using model-based projections. France is undertaking a projection exercise to forecast energy consumption and GHG emissions to 2030 and to inform policy makers and stakeholders about progress to date and the need for further action. Japan has used model-based projections to prepare a roadmap for policy and measures to achieve a reduction of GHG emissions by 25% below 1990 levels by 2020 and 80% by 2050. Japan has developed the Asia-Pacific Integrated Model (AIM) and jointly used it in collaboration with institutes in other Asian countries to assess climate policy options through the low carbon scenario exercises. It is also using the modelling tool to work with sub-national stakeholders in regions and cities, as well as at the national level, to inform dialogue and decision making about climate policy. Experiences from all these collaborative activities are shared among researchers and policy makers through the International Research Network for Low Carbon Societies (LCS-RNet), a platform to link policies and researchers in the field of low-carbon strategies.

*Price-based instruments*

Putting a clear, credible and long-term price on carbon emissions across the economy through market-based instruments such as emission trading schemes or carbon taxes is necessary to drive investments in low-carbon technologies. It penalises carbon-intensive technologies and processes, creates markets for low-carbon technologies (*e.g.* for energy efficiency, solar, wind energy and carbon capture and storage (CCS)[19]) and stimulates action in the energy, industry, transport and agriculture sectors. Putting a price on carbon can also help trigger green innovations and enhance energy efficiency (OECD, 2010b).

Emission trading schemes

Under emission trading systems (ETS) – often referred to as "cap and trade" – a central authority (usually a government body) sets a limit or cap on the amount of a pollutant that can be emitted. The limit or cap is allocated or sold to firms in the form of emissions permits which represent the right to emit or discharge a specific volume of the specified pollutant. Firms are required to hold a number of permits (or carbon credits) equivalent to their emissions. The total number of permits cannot exceed the cap, limiting total emissions to that level. Firms that need to increase their emission permits must buy permits from those who require fewer permits. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions. Thus, in theory, those who can reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest cost to society.

Emission trading schemes are becoming increasingly important in the climate policy portfolio. In the last 10 years, almost all Annex I Parties have either established or strengthened existing trading schemes and are in some way participating in either national or international carbon markets (UNFCCC, 2011b; Hood 2010). As of March 2011, there were seven active GHG-emissions trading schemes in OECD countries (some of which are sub-national), and several more under discussion, including in developing countries (Table 3.3). Nevertheless, there are several issues that need to be considered in order to increase the environmental effectiveness and economic efficiency of permit trading (*e.g.* the choice between a cap-and-trade system versus a *Baseline*-and-credit system[20]; the initial allocation of the emission allowances; and ways of limiting the transaction costs associated with the permit trading system), (OECD, 2008b).

**Table 3.3. Status of emission trading schemes**

| Existing | Planned |
|---|---|
| The New South Wales Greenhouse Abatement Scheme (2003) | The Western Climate Initiative (WCI) (US) |
| European Union Emission Trading Scheme (2005) | California cap-and-trade programme |
| The New Zealand Emissions Trading Scheme (2008) | The Australian Clean Energy Future plan[2] |
| The Swiss Emission Trading Scheme and $CO_2$ Tax (2008) | The Midwestern Greenhouse Gas Reduction Accord (US) |
| The Regional Greenhouse Gas Initiative (RGGI) in the northeast of the US (2009) | The Japanese National Trading System |
| The United Kingdom Carbon Reduction Commitment (CRC) Energy Efficiency Scheme (2010) | Schemes are being discussed and implemented in Brazil, the State of California, Chile, China, Korea, Mexico, Turkey |
| The Tokyo Cap and Trade Programme | India is scheduled to launch an industrial sector energy-efficiency, or "white" certificate, trading programme in 2011 |
| Alberta, Canada, Climate Change and Emissions Management Act (2007)[1] | |

Notes:
[1] This is an emissions intensity reduction programme, not a cap-and-trade system. Facilities can purchase offset credits to meet their intensity reduction goals or purchase emissions performance credits, but there is no cap.
[2] See *www.cleanenergyfuture.gov.au.*

*Source:* Based on data in UNFCCC (2011b), Compilation and Synthesis of Fifth National Communications, UNFCCC, Montreal.

The EU-Emission Trading Scheme (EU-ETS) is the world's largest emissions trading system and has led the way in building an international carbon market (Box 3.4). Outside the European Union, the New Zealand emissions trading scheme is the most developed. It is more comprehensive than any other trading schemes, covering all six Kyoto Protocol Gases ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs and $SF_6$) from energy, transport, industry, waste, synthetic gases, and forestry sectors. It began operating in 2008 in the forestry sector, adding energy, industry and transportation in 2010. A recent independent review of the scheme has recommended that it should continue beyond 2012, although with changes to aspects of its design (Emissions Trading Scheme Review Panel, 2011).

**Box 3.4. The EU-Emissions Trading Scheme: Recent developments**

Launched in January 2005, the EU-Emissions Trading Scheme is the world's largest trading scheme, operating in 30 countries* and covering more than 10 900 large installations in Europe, such as power stations, combustion plants, oil refineries, iron and steel works, and factories making cement, glass, lime, bricks, ceramics, pulp and paper. The installations currently covered account for half of the European Union's $CO_2$ emissions (40% of GHG emissions). The EU-ETS faced significant challenges in its first two phases (2005-2007 and 2008-2012), such as over-allocation of permits, windfall profits for electricity generators due to free allocation systems, and price volatility, all of which reduced the efficiency of the scheme. However, it has shown that the price signal has been effective in promoting low carbon pathways.

For Phase III (2013-20), European Union heads of state and government and the European Parliament have revised legislation to include the following changes:

- a single EU-wide cap instead of 27 national caps;
- more allowances auctioned (50% or more by 2013, rising to 100% over time) to avoid windfall profits;
- harmonisation of rules governing free allocation of emissions and extending coverage to petrochemicals, aluminium, ammonia, and new gases, including $N_20$ and PFCs;
- higher rate of free allocation (based on benchmarks) for sectors and sub-sectors considered at risk of carbon leakage, in the absence of a comprehensive international agreement;
- coverage of domestic and international aviation emissions from 2012.

Note *: This includes EU27 and Norway, Iceland and Lichtenstein.

*Source:* Ellerman, A. and B. Buchner (2008), "Over-Allocation or Abatement? A Preliminary Analysis of the EU-ETS Based on the 2005-06 Emissions Data", *Environmental and Resource Economics*, Vol. 41, No. 2, pp267-287; Ellerman, A., *et al*. (2010), *Pricing Carbon: The European Union Emissions Trading Scheme*, Cambridge University Press.

To promote green electricity, several countries use quotas and certificates which allow sectors a certain level of emissions. They are tradable and are thus in effect market-based instruments. The certificates are usually not accounted for in tonnes of $CO_2$, but in amounts of energy produced from different sources (*e.g*. green certificates for energy from renewable sources, white certificates for energy savings, blue certificates for electricity production from combined heat and power). Such national trading schemes are in use in Poland, Sweden, the United Kingdom, Italy, Belgium, and some US states. Energy savings programmes (white certificates) are used in France, Demark, Italy, the United Kingdom, Australia, Belgium and around 30 US States. The Australian Renewable Energy Target (RET) of 20% by 2020 is implemented through a system of tradable green certificates known as renewable energy certificates. Quotas and feed-in tariffs have been used extensively in the energy sector in the European Union under the "20-20-20 Energy and Climate Package" (see above). Most EU Member States use feed-in tariffs to meet their renewable energy target, while others – such as Poland, Romania and Sweden – use green certificates. Belgium, Italy and the United Kingdom use both feed-in tariffs and certificates.

In the absence of national regulation in a number of countries, sub-national governments, states and cities have initiated mandatory emission trading schemes. For example, the Regional Greenhouse Gas Initiative (RGGI) began operating in 2009 as a $CO_2$ cap-and-trade programme for electricity generators in 10 of the northeastern US States; and Tokyo in Japan has implemented the first local government-level

$CO_2$ ETS. Offset market mechanisms[21] (such as the Clean Development Mechanism – see below – and Joint Implementation[22]) could be designed to provide better carbon market access to urban mitigation projects so as to tap the potential for cost-effective mitigation in this area, (Clapp *et al.*, 2010).

Carbon taxes

Carbon taxes are a cost effective way to reduce emissions. These taxes provide incentives for polluters and resource users to change their behaviour today. They also provide long-term incentives to innovate. Although carbon taxes are not strongly supported by the public in all contexts, there are various ways in which this support can be increased over time (*e.g.* through measures to limit negative impacts on the competitiveness of certain sectors and/or on income distribution), (OECD, 2008a).

Countries are increasingly considering ETSs and carbon taxes as complementary measures, with the former targeting energy-intensive sectors and the latter targeting the residential and commercial sector (UNFCCC, 2011b). Where carbon taxes are in place, they are usually applied to fuels and electricity so that prices reflect their $CO_2$-emission factors. It is, however, important to note that if electricity generation is covered by a trading scheme (as for example in the EU ETS), taxes on electricity use will not affect total $CO_2$ emissions (OECD, 2011f).

Carbon taxes are currently used in 10 OECD countries, with Denmark, Finland, the Netherlands, Norway, Sweden and the United Kingdom leading these efforts since the early 1990s (OECD, 2009a). Sweden was one of the first countries to introduce a carbon tax in 1991, with the general level of the tax increasing over the years to reach EUR 111 per tonne in 2010. A positive side effect of the UK's Climate Change Levy, which taxes industrial and commercial GHG-emitting power production, has been to stimulate innovation (OECD, 2010b). Those companies that pay a lower-than-normal tax rate under negotiated Climate Change Agreements (which entitle them to an 80% discount off the tax liability, provided they adopt a binding target on their energy use)[23] have registered fewer patents for inventions to tackle climate change than those that pay the full levy. In Canada, British Colombia (BC) has had a carbon tax in place since 2008.[24] The carbon tax is a critical component of BC's Climate Action Plan to reduce GHG emissions by 33% by 2020.

The state of play in developing countries

Emerging economies and developing countries are already participating in carbon markets through the Clean Development Mechanism (CDM) implemented under the Kyoto Protocol.[25] A further deepening and extension of carbon markets could enable substantial transfers of private funds from developed to developing countries. In the near term, the main channel for such transfers may be based on scaled-up versions of existing crediting mechanisms such as the CDM. Improving the CDM framework, supporting institutions, and addressing barriers to investments through this mechanism could increase the potential for attracting financial flows for mitigation in developing countries (Ellis and Kamel, 2007). Well-functioning crediting mechanisms also reduce the global cost of mitigation (OECD, 2009a).

Some developing countries are also investigating domestic market-based instruments to mitigate GHG emissions. For example, in July 2010 India introduced a national clean energy tax on both imported and domestically produced coal to fund R&D in renewable energy technologies. In April 2011 it implemented a scheme called "Perform Achieve Trade", to improve the energy efficiency of large energy-intensive industries (GoI, 2010). In September 2010 South Africa introduced a carbon related rate differentiation on taxes for new vehicles. It also plans carbon taxes to meet its national long-term mitigation scenarios (South Africa Revenue Service, 2010). In China, 10 areas have been selected to draft plans to reduce their carbon emissions under a low-carbon pilot programme researching the use of market mechanisms to promote emissions reductions. Announcements have been made on the launch of a domestic ETS in 2015

(Reuters, 2011). In 2009, Brazil launched a National Climate Change policy outlining its commitments to reduce GHG emissions by 36%-40% of projected emissions by 2020. It plans to draft specific legislation for tax measures to stimulate emission reductions (Government of Brazil, 2008). Indonesia released its climate change green paper in December 2009, which suggested carbon pricing initially through a carbon tax, indicating that later transition to emissions trading is a possibility. While the emergence of all these trading schemes is encouraging, fragmented markets are less efficient and effective than one global market (see Section 3.4 for a discussion).

Removing environmentally harmful subsidies

Removing or reforming inefficient and environmentally harmful support to fossil fuel production and consumption is an important step in "getting the prices right" on GHG emissions. Reforming fossil fuel support can help to shift the economy away from activities that emit $CO_2$, can encourage energy efficiency, and can promote the development and diffusion of low-carbon technologies and renewable energy sources (Section 3.4 presents a model simulation of reforming fossil fuel subsidies). Furthermore, removing fossil fuel subsidies and other support will save money for governments and taxpayers. An inventory of 24 OECD countries indicates that fossil fuel production and use in these countries was supported by about USD 45-75 billion per year between 2005 and 2010 (OECD, 2011b). The inventory is a first step towards increased transparency on fossil fuel support, but further analysis of the merits of the individual measures is needed to understand which might be harmful or inefficient. Fossil fuel consumption subsidies in developing and emerging economies amounted to more than USD 300 billion in 2009, increasing to just over USD 400 billion in 2010 (IEA, 2011b).

Removing those subsidies that are inefficient can however be politically challenging, and may also lead to more use of traditional bioenergy in developing countries with potentially negative health effects (see Chapter 6 on health and environment). The combustion of traditional bioenergy is associated with high black carbon emissions, and these can also contribute to climate change. As a result, reform of fossil fuel support should be implemented carefully, in particular to ensure that potential negative impacts on household affordability and well-being are mitigated through appropriate measures (*e.g.* means-tested social safety net programmes).

*Regulations and command and control instruments*

Regulations are needed in a policy mix along with market-based instruments, and can be most appropriate where markets cannot provide price signals to individuals or organisations that reflect the costs of polluting behaviour. This can be the case where, for example, pollution cannot be adequately monitored at source or there is no good proxy that could be subject to taxation. Regulatory approaches may also be more politically feasible where certain sectors are strongly against tax increases. The design of regulations is important. They should be:

- closely targeted to the policy goal;
- stringent enough so that the benefits outweigh the cost;
- stable enough to give investors confidence;
- flexible enough to foster genuinely novel solution;
- updated regularly to provide incentives for continuous innovation.

In the transport sector, fuel-economy and $CO_2$-emission standards are increasingly mandatory, and have been widely implemented in many countries. Fleet renewal schemes have also been introduced, but they have shown mixed results. They are often put in place as a way of stimulating consumer spending and/or assisting car manufacturers in times of economic recession. During the economic crisis of 2008-2009, several countries implemented fleet renewal schemes as part of economic stimulus plans, claiming that they would also deliver significant $CO_2$ and pollution reduction benefits as new cars are more fuel efficient than the old fleet. However, an analysis of such programmes in France, Germany and the United States suggests that they are not cost effective (OECD/ITF, 2011). There is also a risk of significant rebound effects (see below) if fuel prices are not increased at the same time (as the cost per kilometre of driving decreases with higher fuel efficiency).

Regulations are also used to reduce emissions of gases that are subject to the Montreal Protocol on Substances that Deplete the Ozone Layer. For example, Australia has the Ozone Protection and Synthetic Greenhouse Gas Management regulation; the European Union has directives on fluorinated gases, mobile air conditioning and integrated pollution prevention and control; and the United States has a Significant New Alternatives Programme.[26] Regulations have also long contributed to landfill methane emissions reductions as well as industrial $N_2O$ and HFC reduction in industrialised countries. For example, France's industrial $N_2O$ emissions were cut by 90% in the 1990s through those schemes.

Energy-efficiency measures can be encouraged by carbon pricing (see above), but might require additional targeted regulatory instruments (such as fuel, vehicle and building-efficiency standards). If well designed to target market barriers[27] and avoid costly overlap with market-based instruments, these measures can accelerate the uptake of clean technologies, promote innovation and support cost-effective mitigation. Policy makers should pay attention also to the "rebound effects": higher efficiency without proper pricing will lower the costs of using the equipment in question, hence providing a potential incentive to use it more intensively. Mixing energy-efficiency measures and carbon pricing is therefore critical (OECD, 2009a).

*Fostering innovation and supporting green technologies*

Technological innovation is key for the transition to a low-carbon economy. For example, OECD work shows that the cost of mitigation in 2050 could be halved, from about 4% to 2% of GDP, if R&D could come up with two carbon-free backstop technologies in the electricity and non-electricity sector (OECD, 2011c). However, fostering innovation faces a number of challenges. First, it is difficult for firms to appropriate the returns to their investments in innovation (see Box 3.5). Second, specific barriers to entry exist for new technologies and competitors due to the prevalence of dominant designs in energy and transport markets.

The following three factors are necessary to foster innovation in low-carbon technologies. Each is discussed further in the sections which follow:

i. Public investment in basic research: this area is often too risky or uncertain for private-sector investments. International co-operation could help to share the cost of public investment, improve access to knowledge and foster international transfer of technologies.

ii. Carbon pricing: without this, potential users will have few incentives to take up any low-carbon technologies that are invented – this significantly reduces the incentives to develop such innovations. However, carbon pricing alone is unlikely to be sufficient to drive short-term investments in costly technologies that have long-term CO2 reduction impact.

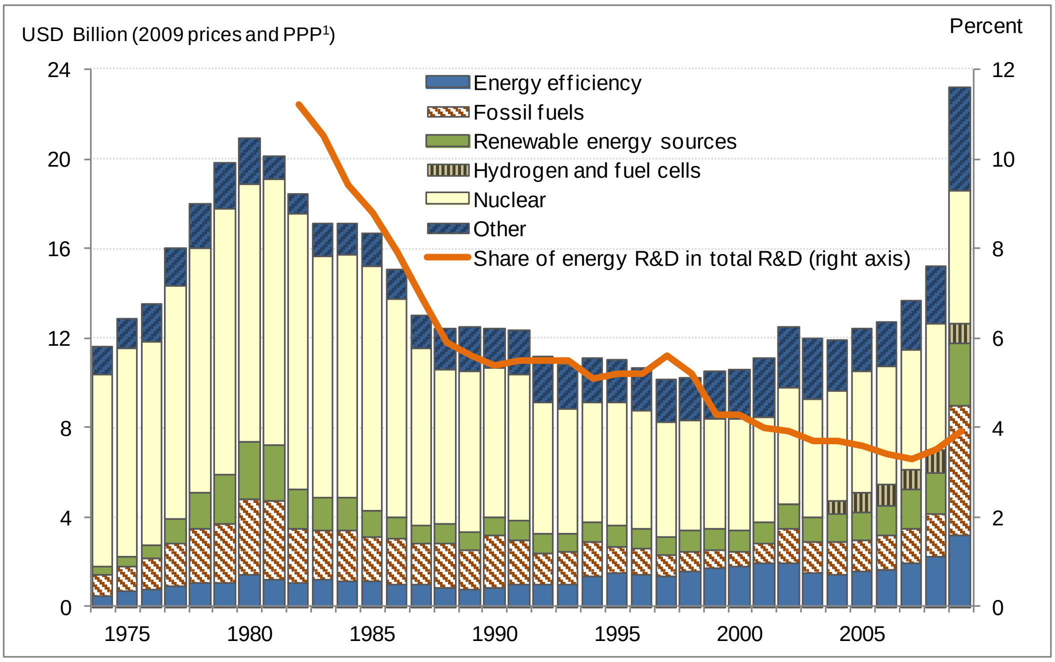
iii. Public policy framework, tools and instruments: these can help to overcome the dominance of existing technologies, systems and firms, again through the establishment of competitive market conditions, as well as public support for R&D and in the commercialisation of green innovations.

Public investment in basic research

More investment in low-carbon energy technology research, development and demonstration (RD&D) is needed, including direct government funding, grants and private-sector investment. After years of stagnation, government spending on low-carbon energy technologies has risen. But current levels still fall well short of what is needed to deliver green growth (Figure 3.14). The current tight fiscal situations faced by many governments may further limit public spending on energy-related R&D.

In 2009, governments of both the Major Economies Forum[28] and the IEA intervened directly in energy markets in order to promote investment in low-carbon technologies, such as renewable energy power plants, with a view to doubling investments in low-carbon RD&D by 2015. Such measures appear to have had some success (Box 3.5).

**Figure 3.14. Government RD&D expenditures in energy in IEA member countries: 1974-2009**




Notes: [1]PPP= Purchasing Power Parities. RD&D budgets for the Czech Republic, Poland and Slovak Republic have not been included for lack of availability.

*Source*: IEA (2010), Global Gaps in Clean Energy RD&D Update and Recommendations for International Collaboration, IEA Report for the Clean Energy Ministerial OECD/IEA, Paris.

However, simply increasing funding will not be enough to deliver the necessary low-carbon technologies. Current government RD&D programmes and policies need to be improved by adopting best practices in design and implementation. This includes the design of strategic programmes to fit national policy priorities and resource availability; the rigorous evaluation of results and adjusting support if needed; and the increase of linkages between government and industry, and between the basic science and applied energy research communities to accelerate innovation. Examples of public support for RD&D in low-carbon technology include the European Technology Platform Programme[29] (2007-2013) and the Innovation and New Technology[30] programme support in Germany.

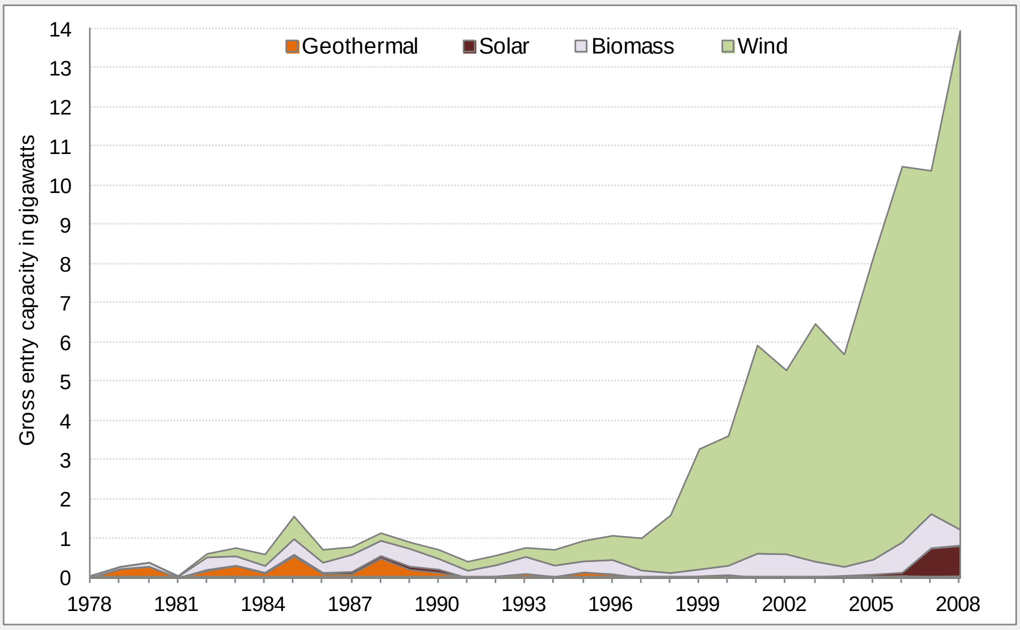
Using carbon pricing to spur innovation

Spurring innovation in low-carbon technologies would require a higher price of carbon than the price set by current initiatives. Governments can intervene with additional targeted policies to raise the carbon price and create a market for low-carbon alternatives (Box 3.5). OECD work demonstrates that carbon pricing provides much broader innovation incentives than technology adoption subsidies (OECD, 2010b). Subsidies can encourage the adoption of low-carbon technologies and market transformations, but are an expensive option, especially when public budgets are strained.

**Box 3.5. The growth in renewable energy power plants**

Figure 3.15 gives an overview of the total plant entry capacities (measured in megawatts electric) for major renewable energy sources – wind, solar, biomass and geothermal – built between 1978 and 2008. The increasing trend for investment in renewable energy power facilities in all regions since 1997 coincides with the agreement and implementation of the Kyoto Protocol. In this period, developed-country governments have provided targeted support for renewable energy investment, which can be justified by the relative immaturity of these technologies. This immaturity makes it more difficult for lenders to accurately price relative risk of investments in "clean" energy, and thus for investors in the sector to obtain financing at reasonable cost. Moreover, in some cases there can be important learning and demonstration effects, which will not be realised without initial support (Kalamova *et al.,* 2011). At the same time, the rate of entry of coal and oil-based plants plummeted in these countries.

**Figure 3.15. New plant entry by type of renewable energy in North America, Pacific and EU-15 regions, 1978-2008**




*Source:* Kalamova, M., C. Kaminker and N. Johnstone (2011), "Sources of Finance, Investment Policies and Plant Entry in the Renewable Energy Sector", *OECD Environment Working Papers*, No. 37.

Technology deployment subsidies

Most new technologies will require, at some stage, both the "push" of RD&D and the "pull" of market deployment (IEA, 2009b). The over-riding objectives of public policy should be to reduce some of the financial and policy risk of investing in new, low-carbon technologies, stimulate uptake and bring down costs. Evidence suggests that a large proportion of breakthrough innovations tend to come from new firms that challenge existing business models. Thus, government measures to remove barriers to entry and to support growth of new firms have an important part to play in low carbon energy technology development.

Government-support policies need to be appropriately tailored to different stages of technology development and should be based on assessments of *expected* costs and *expected* benefits – taking any interactions with other instruments into account. Examples of technology support policies include minimum feed-in tariffs for electricity production from renewable sources, differentiated purchase taxes on automobiles based on fuel economy, and grants, loans and guarantees for emission mitigation projects. However, technology-specific policies risk "locking in" outdated technology and can dampen incentives to innovate and search for cheaper and better abatement options. It is also important to consider carefully how these policies interact with any caps on total emissions that might be in place (OECD, 2011b). The policies should be carefully designed to avoid capture by vested interests and regularly evaluated to make sure they are efficient and directed towards policy objectives. While predictability and long-term policy signals are necessary if investors are to invest in low-carbon energy technologies, predictability should not be equated with permanence. It is important to phase out technology support policies.

OECD work on innovation suggests that general factors beyond technology support policies may also play a key role in inducing clean technology innovation and diffusion (OECD, 2011g). General market conditions such as competition policy, intellectual property regimes, and education policy are important complements to direct technology support policies. Also, the stringency of the environmental policy framework matters (*e.g.* level of emission caps or carbon price) as well as the predictability and the flexibility of policy regimes. Governments could be tempted to "pick winners", but it is more efficient to be technology neutral. The use of "flexible" environmental policy instruments is one means of ensuring neutrality. If targeted support is required, it may be more efficient to support general infrastructure or technologies which benefit a wide range of applications, such as improved energy storage and grid management in the electricity sector. The design of the schemes plays a critical role, to ensure competitive selection processes, focus on performance, avoid vested interests and ensure evaluation of policies (Johnstone and Haščič, 2009; Haščič *et al.*, 2010)

*Voluntary approaches, public awareness campaigns and information tools*

Information instruments, education and public awareness programmes encourage consumer and investor behavioural changes by improving the availability and accuracy of information. They include labels indicating the energy and emissions profile for appliances and automobiles, audits for buildings and plants, and dissemination of best practices. Many energy-efficiency improvements, such as phasing-out incandescent lamps, can cost little or nothing to implement, but can bring potentially large and rapid emission reductions. However, people need to be persuaded to take them up. Well-designed information-based instruments, such as energy-efficiency labels on household appliances, combined with market-based and regulatory tools, can be an effective approach (OECD 2007a, b; OECD, 2011d; Box 3.7).

Labelling the environmental characteristics of products – such as their carbon footprint – is becoming increasingly popular. In the United States, the retailer Wal-Mart obliges some of its suppliers to use carbon indicators. In the United Kingdom, highlighting the carbon footprint of different goods and services is also becoming common. The EU Energy Label or Energy Star labels (used in Canada, the European Union, Japan, New Zealand, Taiwan and the United States) have been in place for several years. Currently none of these schemes is mandatory, although under France's Grenelle Law for the environment, the government plans to make labelling of a number of environmental indicators on certain products a legal requirement from 2012.

**Box 3.6. Greening household behaviour: The role of public policies**

As consumers account for 60% of final consumption in the OECD area, their purchasing decisions have a major impact on the extent to which markets can work to promote green products. However, their decisions to buy "green" depends on the financial cost of green options and the infrastructure to support such choices; the quality and reliability of information on the products; and the knowledge consumers have of environmental issues. Industry, government and civil society can play an important role in creating the enabling environment for consumers to make greener purchasing choices.

Recent OECD work on environmental policy and household behaviour is exploring the factors driving households' environment-related decisions in order to inform policy design and implementation. A survey of over 10 000 households across 10 OECD countries (Australia, Canada, Czech Republic, France, Italy, Korea, Mexico, the Netherlands, Norway and Sweden) confirms the impact of economic incentives on household behaviour and the important complementary role played by information-based measures such as energy-efficiency labelling of appliances and housing.

The findings confirm the importance of providing the right economic incentive to spur behavioural changes, in particular in energy and water savings. The evidence also indicates that pricing consumption by volume is partially useful – the mere act of metering and introducing a price on the use of natural resources has an effect on people's decision making. The survey indicates that "softer" instruments, such as information to consumers and public education, can play a substantial complementary role. Eco labels are particularly useful, as long as they are clear and comprehensible, and that they identify both "public" and "private" benefits. These "soft" instruments need to be given close attention in developing more comprehensive strategies for influencing consumer and household environmental behaviour.

*Sources:* OECD (2011d), *Greening Household Behaviour*, OECD Publishing.

The use of voluntary approaches has declined in recent years in Annex I countries to the benefit of binding instruments and regulations (UNFCCC, 2011b). Although voluntary arrangements should not be viewed as a replacement for mandatory mitigation policies, carbon prices and other climate policies, they can strengthen domestic climate policies. Their adoption is often much easier than mandatory instruments, and helps raise awareness of climate change issues. In Japan, voluntary measures such as the Keidanren's Voluntary Action Plan played a role in reducing industrial GHG emissions. Voluntary enterprise partnerships are particularly important in the United States to improve the energy performance of buildings (Save Energy Now and Energy Star for Industry Programmes) and in the transport sector (SmartWayTransport Partnership). There are also active programmes in the waste sector, such as the Landfill Methane Outreach Programme in the United States aimed at reducing GHGs from landfills by supporting the recovery and use of landfill gas for energy.

*Getting the policy mix right*

The previous sections have shown that there is no single instrument available to policy makers for achieving a cost-effective reduction of GHG emissions. Instead, a mix of policies is needed. However, poorly designed policy mixes can result in undesirable overlaps, can undermine cost-effectiveness and, in some cases, can themselves be environmentally damaging (Duval, 2009; OECD, 2011b; Hood, 2011). The wide range of GHG emissions-reducing policies available and the many possible interactions among them, raise the issue of whether and how they can be integrated into a coherent framework.

For instance, a great advantage of cap-and-trade systems compared to most other policy instruments is that they give all sources covered an equal incentive to abate emissions, enhancing the cost-effectiveness of emission abatement. It is, however, important to keep in mind that with the use of a cap-and-trade system, other policy instruments addressing the same emission sources will only affect total emissions if they allow for setting a stricter emissions cap in the future. As long as the cap remains unchanged, overlapping instruments will not influence total emissions, and will only increase the overall cost of mitigation (OECD, 2011b).

Thus policies have to be designed as a package, taking these interactions into account. In addition, interactions can happen beyond specific climate change policies. The cost-effectiveness of global emission cuts can be further enhanced by reforming a number of policies that either increase GHG emissions or distort the incentives – and, therefore, raise the cost – of mitigation instruments. These include fuel tax rebates, energy price regulations and lack of property rights to forests in a number of developing countries, as well as import barriers to emissions-reducing technologies and agricultural support in a number of developed countries.

***National action to adapt to climate change***

The existing stock of GHG in the atmosphere means that the world is now committed to several decades of climate change. Although changes in the climate are now inevitable, the effects they will have on people and ecosystems will depend on the actions taken in response to those changes (adaptation). Adaptation can also involve harnessing any beneficial opportunities that may arise.

Adaptation encompasses a multitude of behavioural, structural and technology adjustments. As a result, there are many possible typologies of adaptation strategies and instruments. These include structural and technological measures; legislative and regulatory instruments; institutional and administrative measures; market-based instruments; and on-site operations (Table 3.4). This section summarises the state of play of many of these, focusing especially on:

- national adaptation strategies and risk assessments;
- innovative insurance systems to reduce climate risks;
- price signals and environmental markets to improve natural resource management;
- the role of the private sector;
- integrating adaptation into development co-operation.

For regions affected by particularly extreme events or climate conditions, many adaptation measures may not be sufficient to offset the impacts. In these cases, the role of early warnings and disaster risk management are particularly important.

**Table 3.4. Adaptation options and potential policy instruments**

| Sector | Adaptation options | Potential policy instruments |
|---|---|---|
| Agriculture | Crop insurance; investment in new technologies; removal of market distortions; change crops and planting dates; yield-development of yield-improving crops (*e.g.* heat and drought resistant crops). | Price signals/markets; insurance instruments; microfinance; R&D incentives and other forms of public support. |
| Fisheries | Installations to prevent storm damage; techniques to deal with temperature stress; breeding technology innovations; improved food sourcing away from reliance on fish; reduced antibiotic use; ecosystem approach to fisheries; aquaculture. | R&D incentives and other forms of public support; regulatory incentives, marine spatial planning. |
| Coastal zones | Coastal defences/sea walls; surge barriers; sediment management; beach nourishment; habitat protection; land-use planning; relocation. | Coastal zone planning; differentiated insurance; PPPs for coastal defence schemes. |
| Health | Air conditioning, building standards; improvements in public health; vector control programmes; disease eradication programmes; R&D on vector control, vaccines, disease eradication. | R&D incentives and other forms of public support; regulatory incentives (*e.g.* building codes); insurance; heat alert and response systems; air quality health indices. |
| Water resources | Leakage control; reservoirs; desalination; risk management to deal with rainfall variability; water permits, water pricing; rational water use, rainwater collection. | Price signals/markets; regulatory incentives; financing schemes; R&D incentives and other forms of public support. |
| Ecosystems | Reduce *Baseline* stress; habitat protection; change in natural resource management; market for ecological services; facilitate species migration; breeding and genetic modification for managed systems. | Ecosystem markets; land-use planning; environmental standards; microfinance schemes; R&D incentives and other forms of public support. |
| Settlements and economic activity | Insurance, weather derivatives; climate-proofing of housing stock and infrastructure; zone planning, location decisions. | Building standards; insurance schemes; adjustments to infrastructure PPPs, direct public support. |
| Extreme weather events | Insurance; flood barriers; storm/flood-proof infrastructure, housing stock; early warning systems; enhanced disaster management; land-use planning, location decisions; green infrastructure or ecosystems based adaptation. | Building codes, land-use planning; private finance or PPPs for defence structures. |

*Source*: Adapted from OECD, (2008c), *Economic Aspects of Adaptation to Climate Change. Costs, benefits and policy instruments* OECD, Paris.

### *National adaptation strategies and risk assessments*

Establishing national adaptation strategies is particularly important to identify the main climate vulnerabilities and to prioritise among them. Progress has been made in implementing national strategies for adaptation, which also encourage the management of climate risks in all relevant sectors. However, in a preliminary review of adaptation actions undertaken by OECD countries, Gagnon-Lebrun and Agrawala (OECD, 2006) found that climate change impacts and adaptation received much less attention within the National Communications (NCs)[31] than discussions on GHG emissions and mitigation policies. Any discussion on impacts and adaptation in the NCs was dominated by the assessment of future climatic changes and impacts. The discussion on adaptation is often limited to identifying generic options rather than specific action plans or policies. However, more recently, Bauer *et al*., (2011) show that adaptation and information on climate risks is becoming more integrated into the national policies of the countries they reviewed.[32] Other studies similarly find that most countries do mention adaptation in their national policies, but in most cases not as prominently as mitigation (Townshend *et al*., *2011*; and see Table 3.2). However if one includes forestry and land-use measures as a part of adaptation (both have adaptation benefits), the coverage increases significantly.

Assessing climate risks and vulnerabilities is fundamental for evaluating different adaptation options at the national, local and project levels. Governments have invested considerable effort in recent years in developing methodologies and tools to screen the risks posed by climate change and to conduct vulnerability assessments. The OECD proposes the use of environmental impact assessment (EIA) or Strategic Environmental Assessment (SEA) to incorporate climate change impacts and adaptation within existing approaches for project design, approval and implementation in both developed and developing countries (Agrawala *et al*., 2010a). Using an integrated framework to address climate change in the context of other environmental impacts would also diminish the risks of maladaptation, as an integrated assessment would ensure that a project does not affect the vulnerability of natural and human systems. Although countries have shown progress in examining the possibility of incorporating climate change impacts and adaptation measures within EIA, much less has been done in adjusting current policy frameworks, creating guidance and actually incorporating climate change into EIA. A recent assessment could only find examples from three countries – Australia, Canada, and the Netherlands (Agrawala *et al*., 2010b). Some progress has been made in the use of SEA (Agrawala *et al*., 2010a). For instance, Spain's National Climate Change Adaptation Plan includes the objective of mainstreaming climate change adaptation in sectoral legislation.

There are significant gaps in the available evidence on the costs and benefits of adaptation. A review of this literature shows that there is a relatively large amount of information available about adaptation options and their costs at the sectoral level, although it is unevenly distributed across sectors and by applicable geographic coverage (OECD , 2008c; Agrawala *et al.*, 2011). In particular, there is a significant body of literature on assessing adaptation in coastal zones and agriculture. By contrast, the information on costs of adaptation is much less diffused for the water resources, energy, infrastructure, tourism and public health sectors and limited largely to developed country contexts. A notable exception is Chile – between 2008 and 2010 it carried out the first ever quantification of the impacts of climate change in eight river basins throughout its central valley. Such information is also very context-specific, making broader generalisations difficult.

*Innovative insurance systems to reduce climate risks*

There is a long track record of insurance provision to deal with weather risks. Insurance schemes will need to consider the effects of increasing climate damage. Insurance companies see climate adaptation insurance mechanism as a business opportunity (NBS, 2009), and are developing new ways of spreading risk away from affected communities while encouraging adaptation actions by exposed populations. They have already developed specific insurance products to mitigate climate risks, such as risk transfer mechanisms; weather related insurance and catastrophe bonds; and weather index-based insurance, which are especially relevant for developing countries. Swiss Re, through its Climate Adaptation Development Programme, has developed financial risk transfer markets to tackle the effects of adverse weather in non-OECD countries through partnerships with local insurers, banks, micro-finance institutions, government and NGOs (PwC, 2011). It has already designed and implemented index-based weather risk transfer instruments in India, Kenya, Mali and Ethiopia.

Despite the encouraging developments in this area, the application of insurance to climate change adaptation faces some challenges. These mainly concern the lack of available data and information on climate change. Government intervention is critical to support the private sector through gathering information, or through public private partnerships to share risk. Nevertheless, care should be taken, as in some cases insurance may not be viable[33] and subsidising it may be more costly and more likely to delay adaptation (OECD, 2008c). Another critical role for governments is therefore to evaluate whether the level of insurance cover is adequate and whether risk-sharing systems are fair. They also might have to develop publicly funded adaptation measures that bring down risks, or share the most extreme layer of risks with commercial insurers.

*Price signals and environmental markets to improve natural resource management*

Policies to price natural resources create incentives for owners to preserve natural assets and for consumers to use them carefully. From an adaptation point of view, environmental markets and pricing such as for ecosystem services help to reduce stress and make systems more resilient to climate change. They also help to monetise the adaptation services provided by ecosystems or other natural resources (see Chapter 4). Examples of such policies include water prices and water markets, and payments for ecosystems services (*e.g.* watershed protection, carbon sequestration, biodiversity protection and landscape and cultural preservation; see Chapter 4). Governments need to ensure that the trade-offs among the financial sustainability of schemes, efficiency of allocation and social impacts are appropriately dealt with.

*The role of the private sector*

In a context of tight government budgets in both developed and developing countries, the private sector will have to play an important role in financing adaptation and can help to overcome operational constraints and accelerate investment in infrastructure (Agrawala *et al.,* 2011). This is particularly relevant for expensive infrastructure investments, such as the construction and operation of dedicated defence structures (flood barriers), or the climate proofing of existing infrastructure (road, water systems and electric power networks), which constitute the majority of the required adaptation funding.

Some adaptation by private actors will take place out of self interest, as it will reduce vulnerability and improve resilience to climate change. Business opportunities may also arise from designing new products or entering new markets when implementing adaptation actions (OECD, 2008c). Reducing or managing climate change risks can translate into competitive advantage, cost savings (though perhaps not in the short-term), reduced liabilities, and investor confidence. In addition to internalising climate change adaptation into their own decision-making processes, businesses can support local-level adaptation by providing economic opportunities and growth, delivering services, providing financial, technical and human resources, and influencing policy making.

However, in some of the potentially worst affected areas, such as low-lying island states, the challenge is great and the necessary capacity for the private sector to reduce vulnerability may be lacking. Private action may be insufficient because of external effects or other market or information failures. Governments have to implement the right mix of policy instruments to ensure the engagement of private actors in making timely, well-informed, and efficient adaptation decisions. Setting up the right incentive and partnership structures to promote adaptation will be a daunting task.

Public private partnerships (PPPs) are one means for governments to enhance the adaptive capacity of industries. They can also play a significant role in many sectors, especially by stimulating investments in R&D. Indeed, technological innovation is key to reducing the cost of adapting to climate change. However, the public good nature of this type of innovation may cause the private sector to underinvest in R&D. In such cases, policy instruments need to be put in place to give the private-sector incentives to engage. PPPs can help to realign research incentives, along with fiscal incentives and intellectual protection provided by appropriate policy frameworks (OECD, 2008c).

*Integrating adaptation into development co-operation*

The management of climate risks is closely intertwined with development activities as climate change has a particularly strong impact on the poor and most vulnerable populations. International donor agencies are playing an important role in scaling up the financing for adaptation and integrating climate change into development co-operation. Donor agencies can support a variety of activities ranging from R&D and technological development, to information gathering and diffusion, co-ordination or development of adaptive capacity. In order to support donors and partner countries, the OECD has developed guidance on *Integrating Climate Change Adaptation into Development Co-operation,* which advocates a "whole-of-government" approach (OECD, 2009b). It proposes assessing and addressing climate risks and opportunities within centralised national government processes, at sectoral and project levels, as well as in urban and rural contexts.

The integration of adaptation at each of these levels requires an analysis of the governance architecture and the different stages of the policy cycle to identify entry points where climate change adaptation could be incorporated. At the national level, typical entry points include various stages in the formulation of national policies, long-term and multi-year development plans, sectoral budgetary allocation processes, as well as regulatory processes. On the other hand, the entry points would be very different for on-the-ground projects, where climate change adaptation considerations might need to be factored within specific elements of the project cycle.

*Information, monitoring and evaluation*

It is necessary to collect and provide information on climate hazards, vulnerability, resilience and adaptive capacity. The establishment of international organisations that encourage information sharing and exchange is also very important. One example is the Asia Pacific Adaptation Network (APAN) launched in October 2009 in response to an urgent need for immediate and adequate actions to adapt to climate change. It is a regional hub of the Global Climate Change Adaptation Network (GAN). The GAN aims to support countries to build the climate resilience of vulnerable human systems, ecosystems and economies through the mobilisation and sharing of knowledge and technologies to support adaptation capacity building, policy setting, planning and practices.

With increasing investment in adaptation, one important challenge for the future will be to establish the right sets of indicators for identifying priorities, as well as monitoring and evaluation frameworks for adaptation. While progress on mitigation can be interpreted from trends in national GHG emissions, comparable measurable outcomes do not yet exist for adaptation. The difficulties in monitoring and evaluating adaptation range from the ambiguous definition of adaptation to the identification of targets and the choice of indicators used to monitor performance. Consequently, while international discussions on adaptation have focused on implementation of adaptation and the associated costs, systematic evaluation of how much progress is being made in this direction is generally lacking and needs further development (Lamhauge *et al*., 2011).

***Getting the policy mix right: Interactions between adaptation and mitigation***

In recent years progress has been made in recognising the importance of adapting to climate change, in understanding climate projections and in assessing climate impacts and adaptation options. However, there is still a long way to go before the right instruments and institutions are in place for adaptation. In particular, improvements are needed in establishing institutional mechanisms and explicitly incorporating climate change risks in projects and policies. At the national level it is also necessary to increase the understanding of climate change in order to be able to set priorities. Progress is also needed in increasing private-sector engagement and integrating climate change in development co-operation.

Both mitigation and adaptation policies are essential and complementary: the near-term impacts of climate change are already locked-in, thus making adaptation inevitable; and over the longer term, without mitigation, the magnitude and rate of climate change will exceed the capacity of natural and social systems to adapt. OECD and other analysis show that the total costs of climate change will be lowest when both mitigation and adaptation occur together (Agrawala *et al.,* 2010b; de Bruin *et al.,* 2009; IPCC, 2007b).

However, there is a need to find an appropriate balance between short- and long-term action, both for mitigation and adaptation. Taking early action implies a degree of irreversibility and opportunity cost, as, at least hypothetically, there is some value in waiting for better information about the severity of climate impacts or availability of new abatement technologies and many of the investments undertaken are "sunk", embodied in long-lived capital stocks and infrastructure. The optimal means and timing of interventions remains unknown and there is a difficult trade-off between avoiding irreversible policy cost and avoiding irreversible, and possibly extreme, damages. However, policies can influence this trade-off (Jamet and Corfee-Morlot, 2009; Weitzman, 2009).

The sector emphasis of national climate strategies, the balance between mitigation and adaptation and the mix of policy instruments used to address climate change will vary among countries according to national circumstances, economic and demographic profiles, cultural (and regulatory) preferences, energy mix, the nature and size of the market failures and differences in institutional capacities. Adaptation and mitigation policy strategies may compete for resources in some contexts. However, investing heavily in one option will undoubtedly reduce the need for investments in the other. Yet unlimited investments in adaptation do not replace the need for mitigation.

Multilevel governance is increasingly a feature of national climate mitigation and adaptation strategies and plans, where regional and local/city level actions contribute to overall national climate policy strategies (OECD, 2010a). Given their concentration of population, economic activities and GHG emissions, cities and local governments have an important role to play in mitigating and adapting to climate change (OECD, 2010a). However, aligning incentives and effective co-ordination among different levels of government will help to avoid duplicative or costly policy measures. For example, there is a danger that measures taken by one city automatically will be counteracted by another city failing to reduce emissions, especially if total emissions across a certain area are "capped" (OECD, 2011b).

## 3.4. Policy steps for tomorrow: Building a low-carbon, climate-resilient economy

Having looked at the international and national policy instruments that are currently in place, this final section outlines what further policies are required for achieving the 2 $^{o}$C goal. To do so, the section draws on a number of different OECD *Outlook* modelling scenarios to highlight the feasibility, cost and emission implications of different emission pathways. It also looks at the implications of less stringent targets and of phasing out fossil fuel subsidies. The section ends with a discussion of synergies between climate change policies and other goals.

The Cancún Agreements also indicate the necessity of considering strengthening the long-term global goal, for example to limit the global average temperature rise to 1.5 °C. Achieving this more stringent target would require even more significant and urgent mitigation action. The UNEP overview (Box 3.7 and UNEP, 2010) could find virtually no integrated assessment model able to identify cost-effective pathways that would have a medium chance, let alone a likely chance, of reaching this more ambitious goal by the end of the century. The models used in this *Outlook* are also not able to simulate the pathways that would have at least a medium chance of achieving this more ambitious goal.

### *What if …? Three scenarios for stabilising emissions at 450 ppm*

Research shows that if the world could stabilise GHG concentrations[34] at 450 ppm $CO_2$e, the chance of keeping the global temperature increase under 2 °C would be between 40% and 60% (Meinshausen *et al*., 2006; 2009).[35,] To explore the feasibility and implications of achieving this target, three different scenarios for stabilising concentrations at 450 ppm by the end of the 21$^{st}$ century have been modelled. Table 3.5 summarises the main characteristics of the three scenarios, as well as a less ambitious 550 ppm scenario for comparative purposes. Annex 3.A1 contains further details of the assumptions underlying these scenarios, while Chapter 1 provides background information on the models used for the analysis.

**Table 3.5. Overview of the *Environmental Outlook* mitigation scenarios**

| Scenario | Assumptions | Average GHG emissions per decade ($GtCO_2e$) | | | |
|---|---|---|---|---|---|
| | | 2010 - 2020 | 2020 - 2030 | 2030 - 2050 | 2050 - 2100 |
| *450 Core* | Concentrations of GHGs limited to 450 ppm by the end of the 21st century; policy starts in 2013; full flexibility across time, sources and gases; global carbon market | 485 | 450 | 315 | 80 |
| *450 Accelerated Action* | As *450 Core*, plus additional mitigation efforts between 2013 and 2030 | 480 | 435 | 280 | 85 |
| *450 Delayed Action* | As *450 Core*, but until 2020 no mitigation action beyond Cancún and Copenhagen pledges & fragmented regional carbon markets | 505 | 495 | 325 | 65 |
| *550 Core* | As *450 Core*, but aiming at 550 ppm by the end of the century | 505 | 525 | 490 | 280 |

*Source: OECD Environmental Outlook projections*; output from IMAGE.

The ***450 Core*** pathway assumes full flexibility in the timing of emission reductions and the use of mitigation options, including biomass energy with CCS known as “BECCS”[36] (see also Box 3.13). It further assumes that global co-operation is achieved for tackling climate change, and thus the pathway is implemented through a fully harmonised carbon market that encompasses all regions, sectors and gases. Achieving this pathway thus depends on: (i) acting now to put a price on carbon, and immediately tapping into the cheap mitigation options in all sectors, regions and gases; (ii) gradually transforming the energy system to become a low-carbon sector; and (iii) using the large opportunities for low-cost advanced technologies – including BECCS – that are stimulated by the carbon price. As all least-cost mitigation options are included in the analysis, this scenario acts as the cost-effective reference point against which to compare the other scenarios.

The *450 Core* scenario assumes that there can be negative emissions in some regions in the latter half of the century by using BECCS. This allows this pathway to be achieved despite relatively high emission levels in the first half of the century. However, experience with bioenergy and CCS technologies is currently limited. Both face challenges related to climate policy uncertainty, public acceptance, first-of-a-kind technology risks, and high costs relative to other technologies (especially CCS). Bioenergy can also have harmful side-effects through indirect land-use change, potentially leading to higher emissions and biodiversity losses. Thus, uncertainty about the costs and effectiveness of the BECCS technology remains considerable (Box 3.13). If BECCS turns out not to fulfill its promise of negative emissions, the world runs the risk of being locked into higher temperature increases. Thus, an optimal pathway for the coming decade should balance the long-term climate risks, short-term costs and mitigation potentials and expectations about technology development.

By contrast, the ***450 Accelerated Action*** scenario assumes greater mitigation effort in the first half of the century, and less reliance on unproven emissions technologies (like BECCS) in later decades. Additionally, this scenario would offer greater potential for achieving more ambitious long-term temperature stabilisation targets, such as 1.5 °C, although opportunities are limited to speed up emission reductions beyond the pathway shown here.

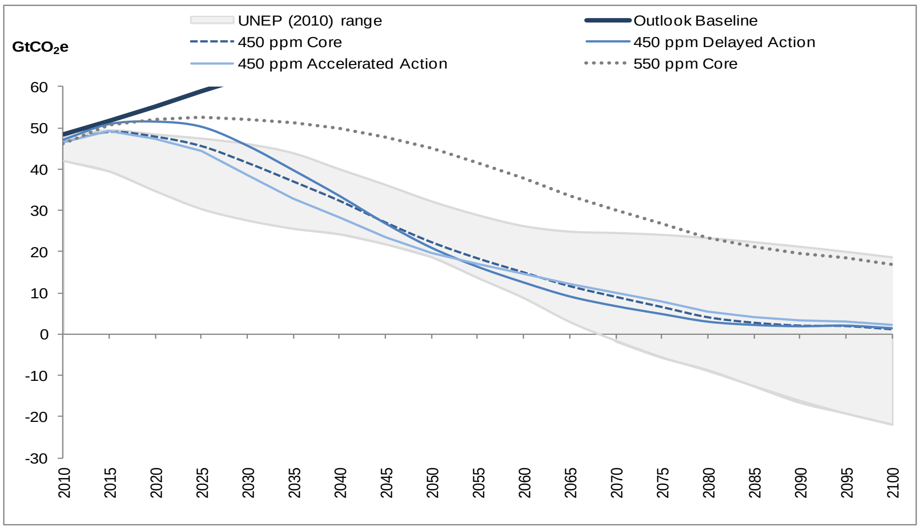
On the other hand, the ***450 Delayed Action*** scenario starts from the premise that it may not be realistic to expect large emission reductions in the coming decade.[37] It reflects the current situation in that it models the high end of the pledges made in the Copenhagen Accord and Cancún Agreements (with strict land-use accounting rules and no use of surplus emission credits from the current Kyoto Protocol commitment period). It also assumes that the various domestic carbon markets are not linked to each other until 2020. If this scenario comes to pass, by 2020, emissions would be outside the 41-48 $GtCO_2e$ range that UNEP (2010) suggests is necessary for least-cost pathways to have at least a medium chance of limiting average global temperature to 2 °C. The *450 Delayed Action* scenario assumes that significant additional efforts will have to be made after 2020 to "catch up" and very rapid rates of emission reduction will be required to give a 50% chance of meeting the 2 °C goal. Postponing compensation for the higher short-term emissions until after 2050 would increase the chance of exceeding the temperature limit and increase the risks of negative environmental consequences caused by a 10% higher annual temperature increase in the coming decades than under the *450 Core* scenario. Moreover, it relies heavily on (i) unlocking the global energy system from its current high-carbon reliance; and (ii) the ability to rapidly transform the energy system later in the century. This goes against the current trend, in which the world is in fact locking itself into high-carbon systems more strongly every year (IEA, 2011b).

Finally, the *550 Core* scenario explores what is needed to limit GHG concentrations at the higher level of 550 ppm by the end of the century. Under this scenario the chance of the average global temperature increasing beyond 2 °C is much higher, and there is only a medium chance of limiting temperature increase to 2.5 °C-3 °C. Other climate change impacts are also more severe than in the 450 ppm scenarios.

Figure 3.16 shows how these different pathways affect the growth of global emission levels over time and compares it to the range of pathways presented in UNEP (2010), (see Box 3.7). All three 450 ppm scenarios show emissions peaking before 2020. The *450 Delayed Action* scenario shows a short delay before global emission levels start reducing, implying that after 2025 there would need to be a rapid reversal of current trends to still achieve the 2 °C target. Note that until 2020, the *450 Delayed Action* pathway is almost identical to the 550 ppm scenario.

**Figure 3.16. Alternative emission pathways, 2010-2100**

Annual net emissions of all Kyoto gases in $GtCO_2e$




*Source*: *OECD Environmental Outlook projections*; output from ENV-Linkages.

**Box 3.7. The UNEP Emissions Gap report**

The Copenhagen Accord declared that deep cuts in global emissions are required "so as to hold the increase in global temperature below 2 °C". The Accord called for an assessment that would consider strengthening the long-term goal including "temperature rises of 1.5 °C". Since December 2009, many countries have pledged to reduce their emissions or constrain their growth up to 2020. Some of the pledges have conditions attached, such as the provision of finance and technology or ambitious action from other countries. For these reasons, it is not easy to tell what the outcomes will be from these various pledges. UNEP (2010) reviewed the literature on the assessment of the pledges.

The review shows that emission levels of approximately 44 gigatonnes of $CO_2$ equivalent ($GtCO_2e$) (with a range of 39-44 $GtCO_2e$) in 2020 would be consistent with a "likely" chance of limiting global warming to 2 °C (*i.e*. greater than 66% probability), and for a medium (at least 50%) chance of staying below 2 °C temperature increase, the range is 41-48. The corridor for emissions for the medium chance is represented in Figure 3.16. Under business-as-usual projections, *i.e*. if no pledges were to be implemented, the studies reviewed indicated global emissions could reach 56 $GtCO_2e$ (within a range of 54-60 $GtCO_2e$) in 2020, leaving a gap of 12 $GtCO_2e$ for the likely chance (with a range of 10-21).

The report suggests this gap could be reduced substantially by:

- Countries implementing more ambitious, conditional pledges, such as the provision of adequate climate finance and ambitious action from other countries.
- The negotiations adopting rules that avoid a net increase in emissions from (i) "lenient" accounting rules which allow credit to be given for land use, land-use change and forestry (LULUCF) activities that would have happened in any case without further policy intervention; and (ii) the use of surplus emission units, particularly those that could be carried over from the current commitment period of the Kyoto Protocol, to meet industrialised country targets.
- Avoiding "double counting" of offsets.

If the above policy options were to be implemented, the size of the gap could be reduced to 5 $GtCO_2e$. This is approximately equal to the annual global emissions from all the world's cars, buses and transport in 2005 and is also more than half the way towards reaching the 2 °C goal. More ambitious domestic actions, some of which could be supported by international climate finance, could close the gap further.

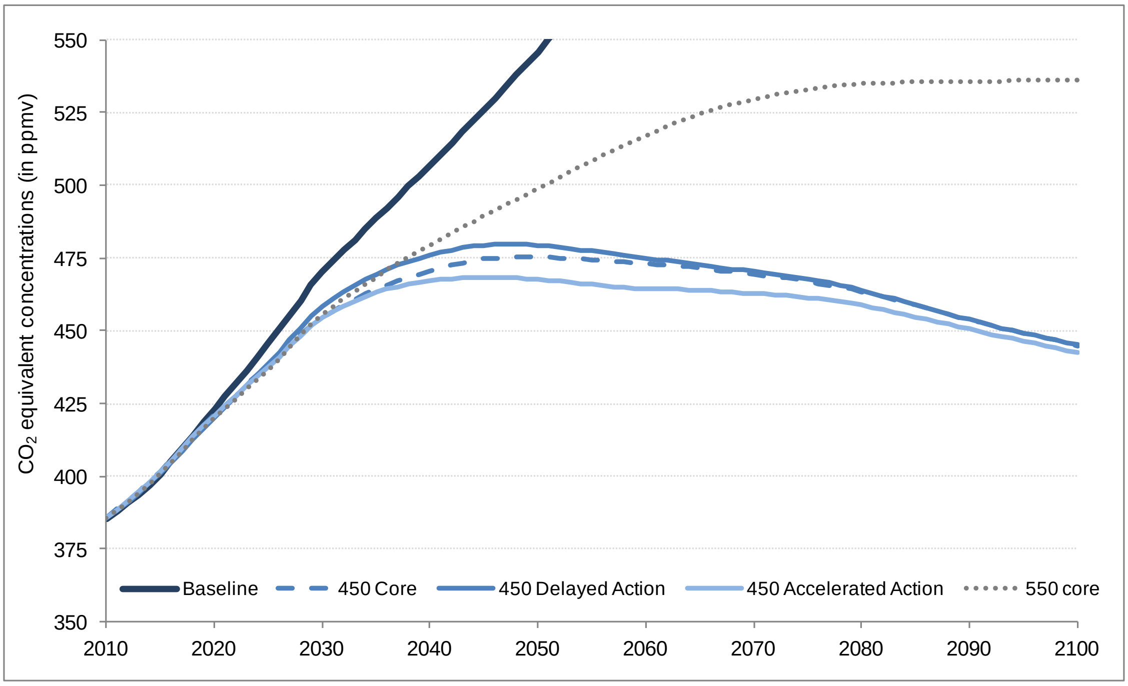
The review has been updated in UNEP (2011c), which revealed that the emissions gap has somewhat increased, not because the pledges themselves have changed, but because business-as-usual emissions projections for 2020 have been revised upwards.

*Source*: UNEP (2010), *The Emissions Gap Report*, UNEP, Nairobi.

The 2 °C pathways presented in this *OECD Environmental Outlook* assume an optimal allocation of mitigation efforts across different sources and gases. These stylised optimisation scenarios temporarily allow the targeted concentration level (450 ppm) to be exceeded or overshot in the middle of the century, before falling to reach the target concentration by the end of the century (Figure 3.17). However, overshooting may have serious environmental impacts by causing higher rates of temperature change in the coming decades than if action was taken earlier. A more rapidly changing climate and a greater overshoot of concentration targets could have serious consequences for some systems that are already under threat at lower levels of change (*e.g*. coral reefs and possibly ocean marine systems more broadly; IPCC, 2007a and b; Hoegh-Guldberg *et al*., 2007). In principle, the delay in temperature response from changes in concentrations implies that for small changes in emissions – if compensated for within two to three decades – changes in global climate parameters will be very small (den Elzen and van Vuuren, 2007) and the scenarios presented here do not result in overshooting the 2 °C goal.

Figure 3.17 illustrates the projected concentration pathways of the various scenarios, including all climate forcers.[38] It shows that the pathway of the *450 Delayed Action* scenario reflects a larger degree of overshoot than the other two 450 ppm scenarios. The catch-up in mitigation efforts in the middle of the century implies that concentration levels gradually fall back to the pathway of the *450 Core* scenario and are nearly identical from 2080 onwards. In contrast, the *450 Accelerated Action* scenario prevents some of the overshoot and has concentration levels peaking at less than 470 ppm. In all three 450 scenarios concentration levels decline after 2050 to ensure that temperature increases do not overshoot. Finally, note that the lower mitigation efforts in the coming decade under the *450 Delayed Action* and 550 ppm scenarios lead to higher emission levels of aerosols, especially sulphur. This is because energy use is generally reduced less. The cooling effect of these gases would reduce temperatures in the short run compared to the *450 Core* scenario, which explains the very similar concentration levels until 2030.

**Figure 3.17. Concentration pathways for the four *Outlook* scenarios including all climate forcers, 2010-2100**




*Source: OECD Environmental Outlook projections;* output from IMAGE.

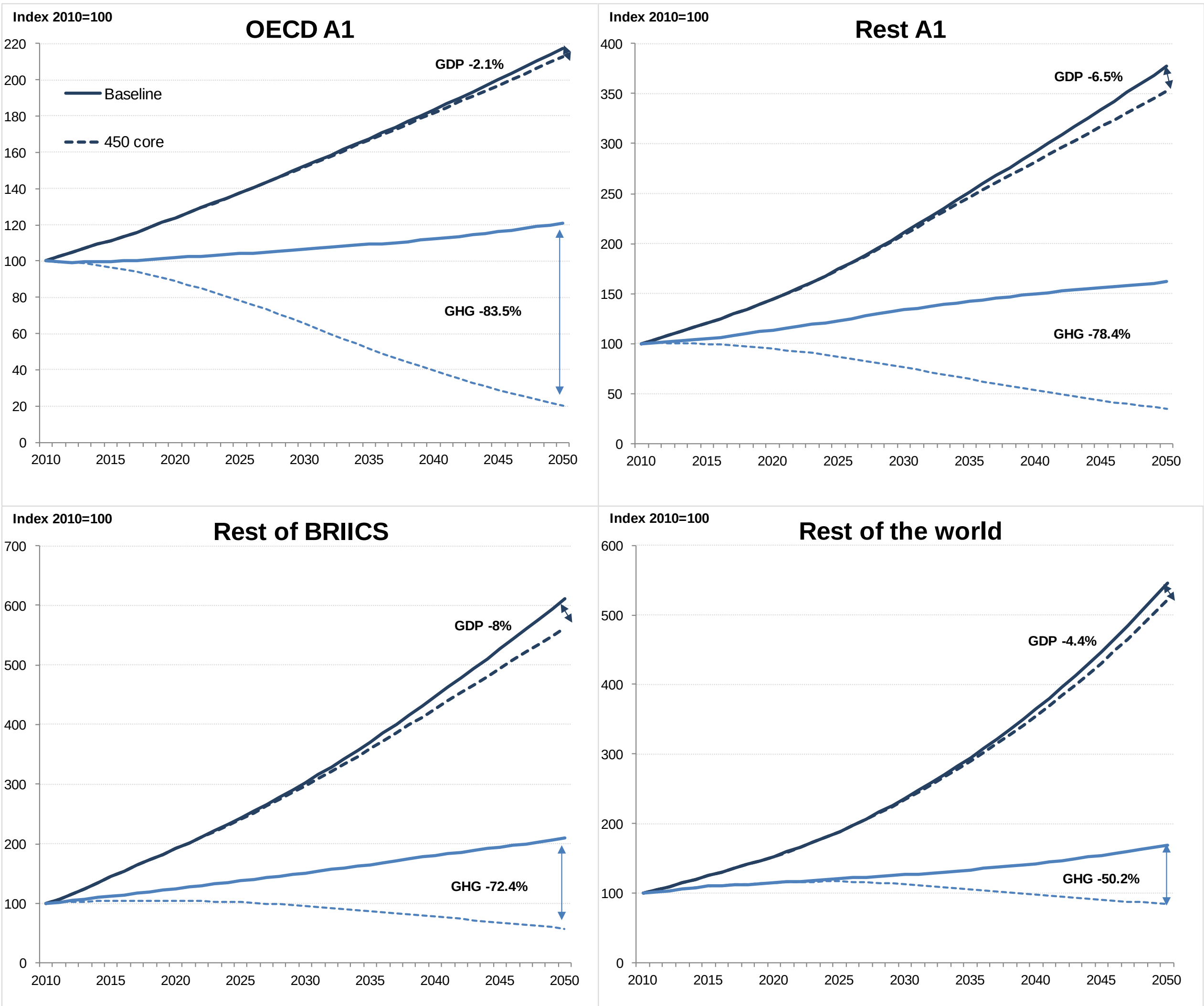
Compared with the "no new policies" *Baseline* projection, all three 450 ppm scenarios would have significantly lower climate impacts, and offer at least a medium chance of limiting global average temperature increase in 2100 to 2 °C.[39] Precipitation patterns would also change less in the 450 scenarios than in the *Baseline* (see Figure 3.10 and 3.11). However, the mitigation efforts undertaken in the 450 ppm scenarios will not avoid all climate impacts. Thus, adaptation to remaining impacts will still be required.

*The implications of achieving the* 450 Core *scenario*

Figure 3.18 indicates that to achieve the 450 ppm stabilisation target, global emission reductions of 12% will be needed by 2020 and 70% by 2050 compared to the *Baseline* (for 2050 this means 52% below 2005 levels, and 42% below 1990 levels). Emissions would therefore have to decrease at an average rate of

1.7% per year between 2010 and 2050, compared to the increase of +1.3% projected under the *Baseline*. Reduced $CO_2$ emissions from fossil fuel combustion would account for 75% of the global reduction by 2050. For emissions from land-use change the situation is reversed: the *450 Core* scenario would require additional land for growing bioenergy crops. Thus there would be a less rapid reduction of emissions from land-use change compared to the *Baseline*, and lower levels of net $CO_2$ uptake in the later decades (the difference is 1.2 $GtCO_2e$ in 2050). In order to achieve the 450 ppm target these additional emissions (and reduced uptake) would have to be compensated for by greater emission reductions by energy and industry.

**Figure 3.18. *450 Core* scenario: emissions and cost of mitigation, 2010-2050**




Notes: Emission projections are before permit trading, *i.e.* they reflect emission allowances.

"OECD AI" stands for the group of OECD countries that are also part of Annex I of the Kyoto Protocol; "Rest AI" stands for the other Annex I parties, including Russia; "Rest of BRIICS" are the BRIICS countries excluding Russia, and "Rest of the World" represent all other regions distinguished in the ENV-Linkages model.

GDP figures do not include the costs of inaction.

*Source: OECD Environmental Outlook projections;* output from ENV-Linkages.

The scenario assumes that carbon pricing is used to give incentives for mitigation efforts in all parts of the economy. A relatively large portion of emission reductions could be achieved relatively cheaply and quickly by limiting emissions of non-$CO_2$ gases from industries (*e.g.* coal mining, oil and gas processing and shipping, acid production) and the agricultural sector (*e.g.* changing rice cultivation patterns and nutrient management); and improving waste handling (waste recycling and methane capture from landfills). Curbing global emissions beyond 2020 would require a rapidly increasing carbon price (to USD 325/t$CO_2$e in 2050) to discourage intensive reliance on carbon-based energy sources. Only a strong and lasting carbon price signal will achieve the major transition required in carbon-intensive sectors, and those with large-scale infrastructural investments.

This scenario implies that world GDP growth would slow down between 2010 and 2050 as a result of lower energy consumption and the shift in supply options driven by higher energy prices. The average growth rate decreases from 3.5% per year in the *Baseline* to 3.3% per year in the *450 ppm Core* scenario, giving a world GDP that is 5.5% lower in 2050 than under the *Baseline* scenario. However, it should be stressed that a major limitation of all the results presented here (Box 3.8) is that they do not factor in any benefits of the mitigation action (see Chapter 2 on the cost of inaction and Section 3.4 for synergies with other environmental issues). The economic impacts therefore reflect purely the cost of action, not the net costs or benefits.

Energy use grows between 2010 and 2020 in both the *Baseline* projection and the *450 Core* scenario (although at a slower pace in the latter). After 2020, emissions would be reduced primarily by energy-efficiency improvements and strong supply changes. The ENV-Linkages simulations find that energy-efficiency improvements are the main driver (especially producers substituting more expensive energy with labour and capital, such as more expensive but energy-efficient machines), leading to a sharp drop in emissions by 2050.[40] A vast decarbonisation is required in the power generation and transport sector, as well as replacing existing dirty energy use by consumers (*e.g.* use of cooking fuels) with more efficient electricity-based technologies. This all involves a drastic restructuring of the energy sector.

**Box 3.8. Cost uncertainties and modelling frameworks**

Apart from uncertainties about climate and emission reduction timing, there are also significant uncertainties surrounding the costs of implementing climate change policies. The variations in the cost estimates across different modelling frameworks reflect fundamental uncertainties about the availability of technological options and their costs and development over time, as well as assumptions about economic growth, treatment of options that could have negative net costs (such as energy savings) and other model characteristics. For example, the ENV-Linkages model assumes a higher mitigation potential for non-$CO_2$ GHGs at moderate cost than the IMAGE model suite. Consequently, the *450 Core* scenario in ENV-Linkages leads to substantially lower carbon prices by 2020 than IMAGE (USD 10/t$CO_2$e *versus* USD 50/t$CO_2$e).

While results presented here only come from the ENV-Linkages and IMAGE models, these belong to a large family of models designed to study climate change policy. Modelling comparison exercises have been conducted to better understand the influence of modelling frameworks on the results, as well as to identify the range of cost estimates (see Edenhofer *et al.*, 2009 and 2010; Clarke *et al.,* 2009; and van Vuuren *et al.,* 2009. A 450 ppm pathway would lead to a reduction of GDP in 2050 of either 5%-6% (ENV-Linkages) or 4% (IMAGE). These results fall within the range of estimates found in Luderer *et al.* (2009), which vary from about -0.5% to 6.5% (in 2060), and are similar to cost estimates for 2050 cited in IPCC (2007c). As emphasised by Tavoni and Tol (2010) such ranges should be assessed with care, because they usually exclude models which are unable to meet the target. Within the range, larger mitigation costs can for instance be caused by more conservative assumptions on substitution across production factors and energy technologies or by the limited availability of advanced technologies in the models (Edenhofer *et al.*, 2010). The low end of the range usually corresponds to models with a wide technology portfolio and optimistic assumptions about technological advances.

The costs shown in Figure 3.18 result from a regional permit allocation rule where regional emission allowances evolve over time towards equal per-capita allowances (Box 3.9). This so-called "contraction and convergence" allocation rule is not meant as a policy recommendation, but is used here purely for illustrative purposes. Alternative permit allocation rules lead to similar global costs, at least when full permit trading is allowed, but the allocation of these costs across the regions can vary significantly.

**Box 3.9. What if…the mitigation burden was shared differently? How permit allocation rules matter**

In a global cap-and-trade system (as assumed in the *450 Core* scenario), emission allowances are allocated to individual countries. As illustrated in Figure 3.19, determining regional emission allowances could be an effective step in shifting part of the burden of mitigation costs from developing economies to OECD countries. All the cases presented here assume that countries can auction their domestically allocated permits, with the revenues redistributed to households as a lump sum. The international burden sharing regime is thus primarily aimed at distributing costs among countries, not between individual polluters. Also, it is assumed that full international trading of permits is allowed. Essentially, this separates the place where mitigation action takes place from where the economic burden falls. Unless transaction costs are prohibitive, these permit allocation rules are a very powerful mechanism for ensuring that least-cost options are taken.

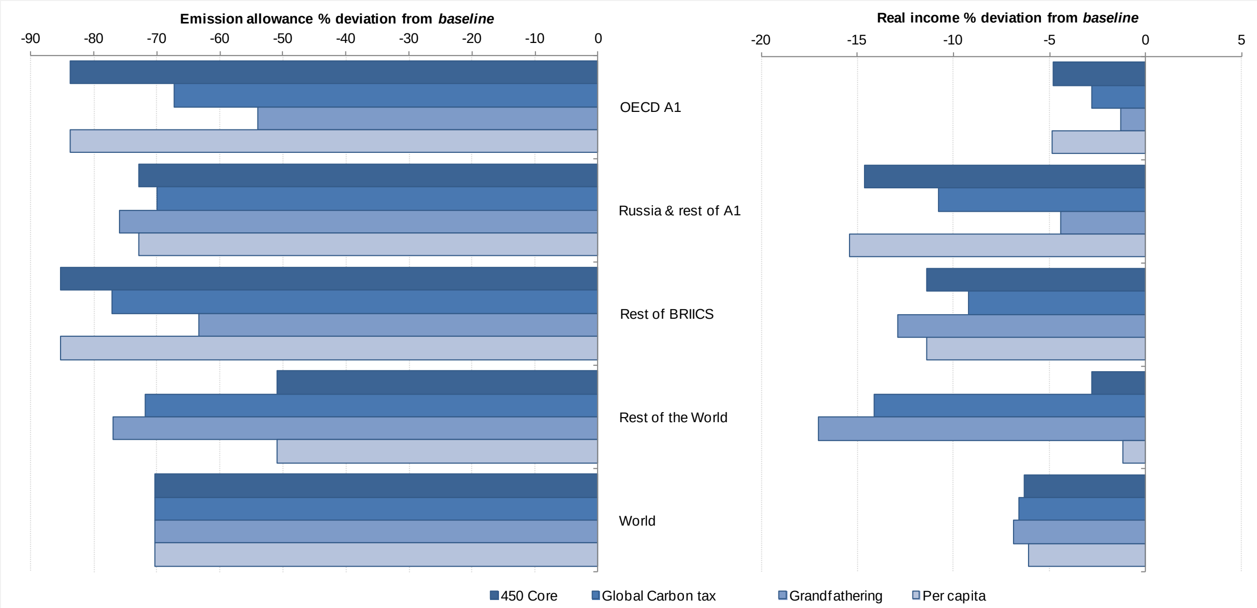
The following different permit allocation rules, which all have the same global emission pathway as the *450 Core* scenario, are considered here:[1]

- The *450 Core* scenario: assumes a "contraction and convergence" rule, where the allocation of emission permits across regions is based on a gradual convergence from actual (2010) levels of emissions to equal emission allowances per capita by 2050 in all countries; this is effectively a transition from a grandfathering rule to a per-capita rule. Alternative convergence criteria or convergence dates are also conceivable.
- The *Grandfathering*[2] scenario: assumes that every year countries will receive the same share in global allowances, based on actual (2010) emissions.
- The *Per-capita* scenario: assumes that countries will receive a share in global allowances based on the projected levels of population, *i.e.* per-capita emission allowances are equal across countries.
- The *Global carbon tax* scenario: assumes a carbon tax is implemented globally; this is equivalent to a permit allocation where emission allowances are allocated such that marginal costs are equal across regions, and so there is no permit trading.

As GDP is a poor indicator of the welfare impacts of policies when large volumes of emission permit trading occur, these allocation schemes should be compared using equivalent variation in real income.[3]

Globally, the allocation schemes do not matter much for income levels, as they all constrain global emissions at identical levels (Figure 3.19). Regional differences are quite pronounced, however, largely mimicking the differences in emission allowances. Under the *Per-capita* scenario, poor and populated regions like India and developing countries (rest of the world group or RoW) would become large permit exporters, and the trade in allocations would reduce costs in these regions. Most OECD countries have the lowest income losses under the *Grandfathering* scenario. Russia and China would also be better off in a grandfathering allocation scheme (given their high current emission intensities), although income losses in these regions would be above global levels in all schemes.

**Figure 3.19. Impact of permit allocation schemes on emission allowances and real income in 2050**




*Source: OECD Environmental Outlook projections*, output from ENV-Linkages.

Notes :
[1] More details on the shares of regions in the permit allocation scheme are given in Annex 3.A1.
[2] "Grandfathering" uses a company, sector or country's historical emissions levels to set their future permit allowances.
[3] The equivalent real income variation is defined as the change in real income (in %) necessary to ensure the same level of utility to consumers as in the *Baseline* projection. One problem with using real GDP changes is that permit trades are not valued (see OECD, 2009b for more details). It is also important to note that permit transfers across countries would change international trade patterns and put pressure on exchange rates*, i.e.* the terms of trade across countries would be affected. For this reason real household income could be more affected by the allocation than GDP levels (OECD 2009b).

When allowing full emission permit trading, GHG emission reduction pathways are similar across all regions (ranging from 67% to 71% reduction by 2050 compared to the *Baseline*), as the stringency of the *450 Core* target calls for action in all regions. Nonetheless, mitigation strategies will differ depending on the level of economic development and growth perspectives. Switching rapidly to low-carbon technologies allows OECD economies to be partially decarbonised, while energy-efficiency measures are the main mitigation option in BRIICS countries.[41] Energy intensity, defined as the ratio of energy use to GDP, is projected to decrease by 3.2% annually in OECD countries (close to the world average), while this ratio will reach 3.9% and 4.5% per year in BRIICS and RoW countries respectively. There is more potential for improvement in energy efficiency in these regions as their carbon intensity is on average higher than in OECD countries (IEA, 2009b).[42]

Given the "contraction and convergence" distribution of emission permits under the *450 Core* scenario, the OECD region is the main buyer of permits, implying that they achieve part of their required emission reductions abroad. The developing countries in the RoW group are the main suppliers of permits. The related costs to the economies vary more widely among regions. The relatively high GDP losses in the BRIICS are largely concentrated in (i) Russia – which is negatively affected by the reduced demand for fossil fuels; and (ii) China, where emission growth is much more rapid than population growth, implying that in the later decades China would have to buy substantial amounts of emission permits on the international market.

Using an appropriate system for allocating revenues from market-based mitigation policies domestically could reduce the economic costs of mitigation. For example, using carbon tax or permit revenues to lower labour taxes could stimulate employment and would reduce the cost of mitigation in the short term (*e.g.* see Chateau *et al*., 2011). In the long run, however, when labour markets are more flexible, the scope for such a "double dividend" would be less.

*The implications of achieving the* 450 Accelerated Action *scenario*

Both the *450 Accelerated Action* and the *450 Core* scenarios reduce the projected *Baseline* emissions by more than 75% by 2050. The main difference between the two scenarios is the timing of global mitigation efforts in the next two decades. These result in differences in which gases are reduced most (or which fuel in the case of energy-related $CO_2$ emissions), as well as different regional and sectoral mitigation choices. These elements are illustrated in the four panels of Figure 3.20. Of course, the larger mitigation efforts in the *450 Accelerated Action* scenario imply lower environmental risks but higher costs than the *450 Core* scenario. By 2030 carbon prices would be about 50% higher in the *450 Accelerated Action* scenario than in the *450 Core*.

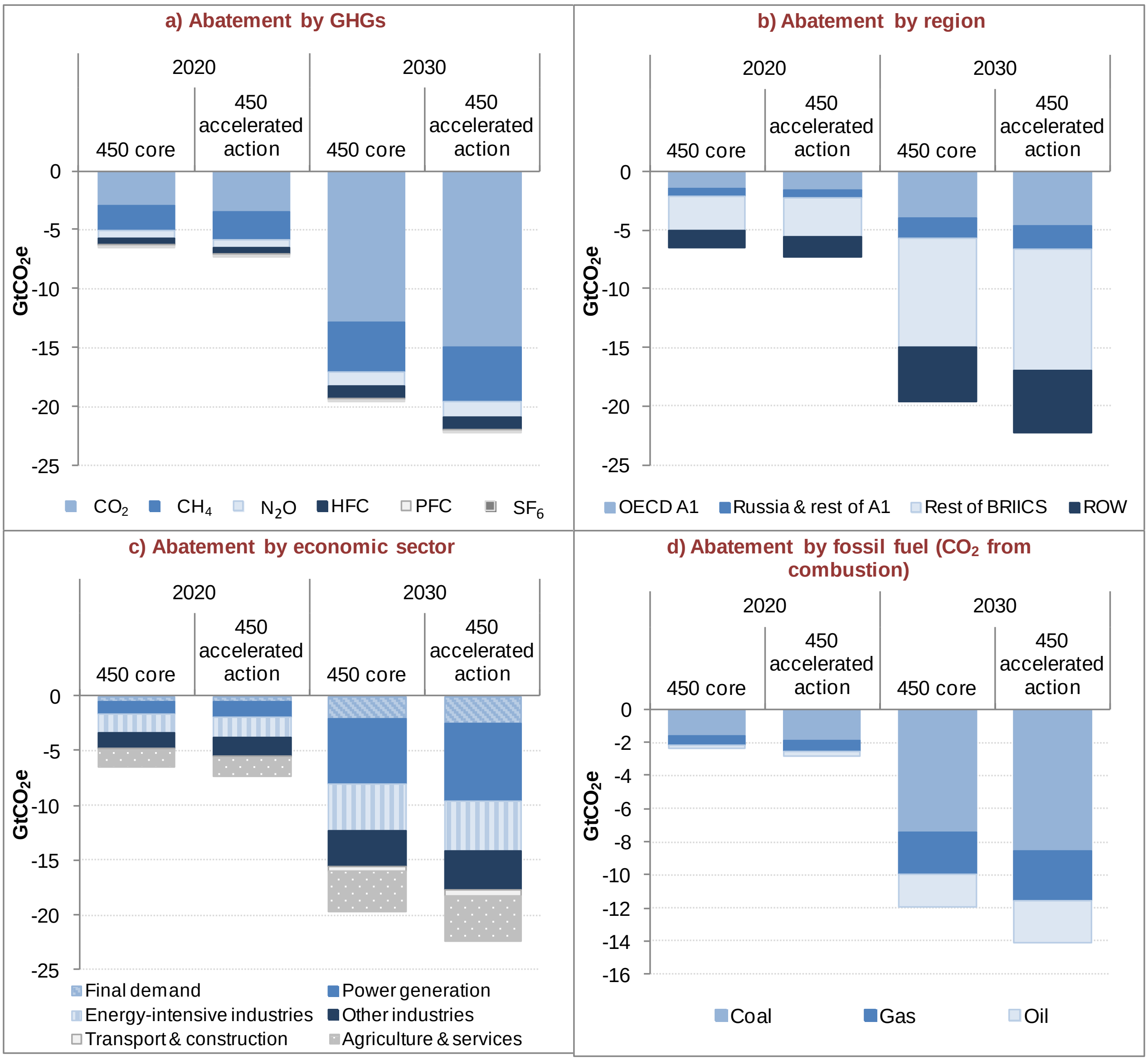
In aggregate terms, both scenarios lead to very similar emission reduction patterns across regions, given the shared permit allocation rule. BRIICS countries account for about half of the total mitigation effort, the other half being split evenly between OECD and RoW countries. However, the analysis of country details reveals larger differences across scenarios: China and the Middle East account respectively for about one-third and 7% of total mitigation in the *450 Accelerated Action* scenario, and are more sensitive to the targeted emission level in 2020. In other countries, such as India, mitigation efforts depend less on the scenario architecture because the mitigation potentials in these countries are less sensitive to the carbon price level around the years 2020 and 2030.

In both simulations, the lowest cost mitigation options are mobilised in the early stages of action, irrespective of the carbon price level. The level of ambition then determines the optimal mix of reduction measures. Non-$CO_2$ GHGs (methane, nitrous oxide and fluorinated or "F gases", such as HFCs, PFCs and sulphur hexafluoride – $SF_6$) have sizeable mitigation potential and reductions can be achieved at moderate cost. These potentials could be tapped into even under modest carbon prices. For example, easily adjusted industrial activities and changes in agricultural practices are projected to help reduce large volumes of methane efficiently (*e.g.* in coal mining, oil and gas processing and shipping; waste recycling and methane capture from landfills). Methane mitigation alone accounts for more than 60% of the total reduction of non-$CO_2$ gases by 2020. The reduction of nitrous oxide arising from changes in rice cultivation patterns, acid production or nutrient management, covers another 20%.

Accelerated action would require a quicker decarbonisation of electricity production, while a more gradual response to climate change would require relatively more effort from energy intensive industries, services and agriculture. In both scenarios, oil is the fossil fuel affected the most over the coming decade. Coal use is particularly discouraged for power generation and even moderate carbon prices are enough to trigger efficiency improvements in coal-based electricity generation and to favour a switch towards gas-based production capacity that is less carbon-intensive, notably in China and India. Natural gas is affected evenly in both scenarios and represents about 20% of total reduction in 2020 and 2030. In both scenarios, gas acts as a bridging fuel until lower carbon technologies become available on a large scale. Nuclear energy is projected to supply almost two-thirds of low-carbon electricity in 2020 and only half of it by 2030 in both cases. The share of hydro electricity tends to diminish over time as wind, solar and other non-hydro renewables take over. However, the carbon price differential between the two scenarios is not significant enough to drive notable changes in the mix of renewable technologies by 2030. Finally, fossil fuel based electricity generation with CCS plays a significant role later in the projection period (see Box 3.10 on the implications of technology options).

**Figure 3.20. GHG abatements in the *450 Core Accelerated Action* and *450 Core* scenarios compared to the *Baseline*, 2020 and 2030**

(a) by GHG, (b) by aggregate region, (c) by economic activity and (d) by fossil fuel




*Source*: *OECD Environmental Outlook projections;* output from ENV-Linkages.

**Box 3.10. Implications of technology options**

Many different pathways are possible for achieving a given mitigation target. The policy scenarios investigated in this *Outlook* model different technology pathways to reduce emissions. In the *Baseline* scenario the power sector globally accounts for more than 40% of $CO_2$ emissions in 2050, and therefore plays a key role in the decarbonisation of the economy. To explore the role of energy technologies under the *450 Accelerated Action* scenario, three alternative simulations were conducted using the ENV-Linkages model (for more details see Annex 3.A1). These scenarios all aim at achieving the same 450 ppm emission pathway, with the same timing of emission reductions but assume different patterns of technological developments to achieve it:

(i) *Low efficiency and renewables*: compared to the default assumptions in the *450 Accelerated* Action scenario assumes less energy-efficiency improvement in energy use through less improvement of energy inputs in production, and slower increases in production of renewables.

(ii) *Progressive nuclear phase-out*: assumes that nuclear capacity currently under construction and planned until 2020 will be built and connected to the grid. However, after 2020, no new nuclear unit will be built so that the world total capacity by 2050 will be reduced because of the natural retirement of existing plants.

(iii) *No CCS*: assumes no greater use of CCS technologies beyond the levels projected in the *Baseline*.

In the short run – to 2020 – altering the set of mitigation technologies results in only limited changes in the electricity generation mix and level because the carbon penalty is too low to overcome the inertia in the energy system. In all simulations the bulk of emission reduction over this timeframe is therefore achieved by decreasing emissions of methane, nitrous oxide and F gases, although there is also some reduction in energy consumption induced by the carbon price.

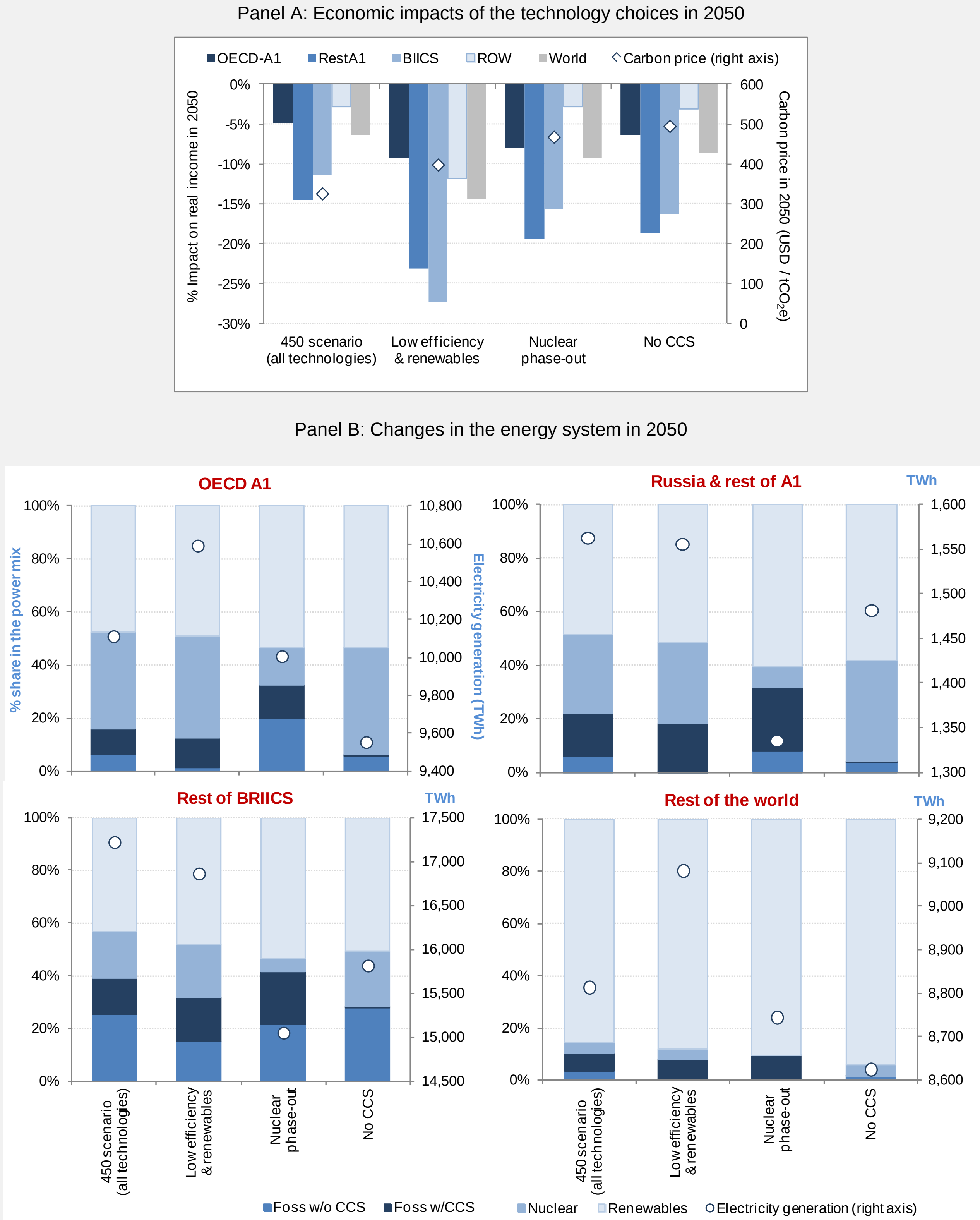
However, the role of these energy technologies in the longer run – to 2050 – is more pronounced as low-carbon technologies are projected to have taken over in all regions of the world (Figure 3.21). Panel A illustrates GDP impacts and carbon prices for each scenario, while Panel B shows the electricity generation mix and the overall production level for each of the three macro-regions. What becomes clear from Panel A is that having sufficient flexibility in the energy system will protect regions against large, sudden, unexpected increases in cost, or reduced availability of a specific technology at the scale originally anticipated.*

By 2050, when all technologies are assumed to be available, renewable electricity is assumed to supply about half of the needs in OECD and BRIICS, which will also rely on capital-intensive nuclear and fossil fuel plants with CCS. The results reveal strong complementarities between nuclear and fossil fuels (with or without CCS) in most regions. Phasing out nuclear facilities in the BRIICS countries, where most new capacity is expected to be built in the coming decades, causes a substantial reduction in electricity generation. Power plants with CCS become competitive around 2030 and increasingly so by the end of the time horizon in both OECD and BRIICS. In the absence of CCS power plants by 2050, switching to more expensive technologies increases electricity prices and alters consumption patterns. Fossil fuel power plants without CCS are projected to decline to about 10% of total power supply worldwide, due to the high carbon price, unless nuclear is phased out, in which case such a steep decline is not feasible.

The RoW region is projected to follow a different mitigation strategy, predominantly relying on increasing renewable energy sources. This region is therefore very sensitive to the assumptions about energy efficiency and productivity of renewable energy technologies, but less affected by the exclusion of nuclear and CCS. Given this projected strategy, substituting away from renewable energy sources is more difficult and costly. In turn, corresponding income losses in the RoW region are more than doubled in the *low efficiency and renewables* scenario compared to the *450 Accelerated Action* scenario.

Note: *The 2011 incident at the Fukushima nuclear plant in Japan and the following reconsideration of nuclear energy use in other countries was a harsh reminder that possible large-scale disruptions to the energy system cannot be ignored.

**Figure 3.21. Technology choices for the *450 Accelerated Action* scenario**




*Source: OECD Environmental Outlook projections;* output from ENV-Linkages.

*The implications of achieving the* 450 Delayed Action *scenario*

As discussed above, the *450 Delayed Action* scenario assumes that until 2020 mitigation efforts will aim to achieve the high end of the pledges made in the Copenhagen Accord and Cancún Agreements (Table 3.6). A large number of countries have submitted reduction targets or national mitigation plans as part of the 2009 Copenhagen Accord – these were subsequently incorporated into the 2010 UNFCCC Cancún Agreements. Almost all developed countries have pledged to meet quantified economy-wide emission targets by 2020, and 44 developing countries have pledged mitigation actions.[43] Table 3.6 summarises the quantitative targets and actions, and also translates these pledges into quantified GHG emission reductions compared with 1990 (for Annex I Parties) and 2020 *Baseline* (for non-Annex I) emission levels in the modelling simulations.[44] Many Annex I Parties have not detailed their policies on the use of offsets; therefore, this information is only added for a few regions, and a default assumption that a maximum of 20% of the reduction targets is used in all other cases. Annex I Parties could potentially use land use, land-use change and forestry (LULUCF) credits to meet their pledged target; the extent to which this is assumed in the simulation is provided in the last column (see Annex 3.A1 for further details).

Although up until 2020 the emission reductions in the *450 Delayed Action* scenario are smaller than in the *450 Core* scenario, real income losses are larger for most regions, because of the fragmentation of the carbon market (Figure 3.22). Carbon prices vary between regions in *Delayed Action*, ranging from zero for regions that do not have a binding pledge (including the Middle East and North Africa and rest of the world countries) to more than USD 50/t$CO_2$e for the combined Japan and Korea region. These results depend on a number of crucial but uncertain assumptions about the interpretation of the pledges (Box 3.11).

As by assumption until 2020 international permit trading is not allowed in the *450 Delayed Actio*n scenario, many low-cost mitigation options remain unexploited until 2020, driving up global costs. Figure 3.22 clearly illustrates that domestic policies are not the only, and sometimes not even the main, determinant of the macroeconomic costs of the policies. Fossil fuel exporters, such as Russia and the Middle East region, are projected to have higher income losses, despite having hardly or no costs from domestic mitigation efforts. Panel A of Figure 3.22 also shows how international financing of mitigation action (assumed to take place in South Africa, Brazil and Mexico, see Annex 3.A1) can help to limit the costs of domestic action. Combined with the opportunity to sell credits on the offset market, the "Rest of BRIICS" group have only very small income losses in the *450 Delayed Action* scenario.

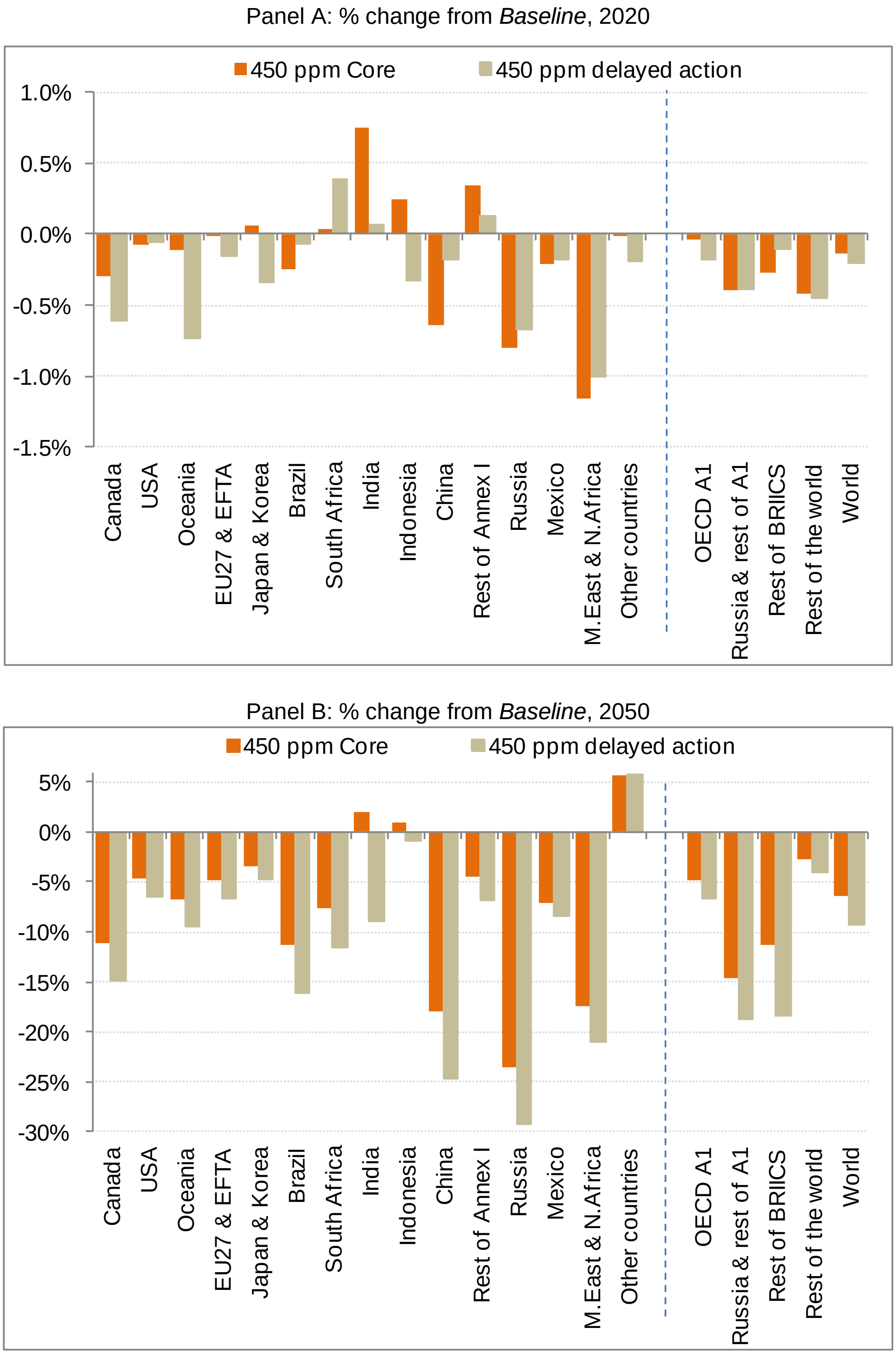
In the longer run (2050), the *450 Delayed Action* scenario requires more ambitious mitigation efforts to bring concentration levels back down to the 450 ppm target before the end of the century. As these efforts occur later than in the *450 Core* scenario, it is not surprising that income losses are again higher in the *450 Delayed Action* scenario (Figure 3.22, Panel B). By 2050 in both the *450 Core* and *Delayed Action* scenarios a global carbon market has formed with permit allocations based on population; thus the larger income losses reflect the additional costs resulting from inadequate mitigation efforts in the earlier decades. There is both a direct effect – stemming from the increased mitigation efforts required in 2050 to limit concentrations – and an indirect effect from the lack of structural reform in the energy sector in the earlier decades.

**Table 3.6. How targets and actions pledged under the Copenhagen Accord and Cancún Agreements are interpreted as emission changes under the *450 Delayed Action* scenario: 2020 compared to 1990**

| Region | Declared country emissions targets and actions | Emissions under *450 Delayed Action* scenario |
|---|---|---|
| Canada | -17% from 2005; no credits from international offsets currently assumed | +2.5% from 1990 (5 $MtCO_2e$ LULUCF credits) |
| Japan & Korea | Japan -25% from 1990; Korea -30% from business as usual (BAU) | -16% from 1990 (35 $MtCO_2e$ LULUCF credits) |
| Oceania | Australia -5% to -25% from 2000; New Zealand -10% to -20% from 1990 | -12% from 1990 (0 $MtCO_2e$ LULUCF credits) |
| Russia | -15% to -25% from 1990 | -25% from 1990 (0 $MtCO_2e$ LULUCF credits) |
| United States | -17% from 2005 | -3.5% from 1990 (150 $MtCO_2e$ LULUCF credits) |
| EU27 & EFTA | EU27, Liechtenstein and Switzerland -20% to -30% from 1990; Norway -30% to -40% from 1990; Iceland and Monaco -30% from 1990; max. 4 percentage-points credits from international offsets; no LULUCF credits for low pledge | -30% from 1990 (195 $MtCO_2e$ LULUCF credits) |
| Rest of Europe | Ukraine -20% from 1990; Belarus -5% to -10% from 1990; Croatia -5% from 1990; emissions for other countries in this group without a pledge (incl. Turkey) are assumed to remain at BAU level. | -19.5% from 1990 (25 $MtCO_2e$ LULUCF credits) |
| Brazil | -36% to -39% from BAU | -39% from BAU (incl. 775 $MtCO_2e$ REDD) |
| China | Carbon intensity -40% to -45% from 2005; share of non-fossil fuels in primary energy consumption 15%; forest coverage +40 mln ha & volume +1.3 bln m3 | -4% from BAU |
| Indonesia | Indonesia -26% from BAU | -26% from BAU (incl. 200 $MtCO_2e$ REDD) |
| India | Carbon intensity -20% to -25% from 2005 | -2% from BAU |
| Middle East & Northern Africa | Israel -20% from BAU; no pledge for other countries in this group | No restriction on emissions |
| Mexico | Mexico -30% from BAU | -30% from BAU (incl. 115 $MtCO_2e$ REDD) |
| South Africa | South Africa -34% from BAU | -25% from BAU* |
| Rest of the world | Pledges have been made by some countries in this group (incl. Costa Rica, Maldives, Marshall Islands) but not by the major emitters in this group. | No restriction on emissions |

Notes:
* The domestic BAU projection used by South Africa has substantially higher emissions than the OECD *Baseline* projection; therefore the target for South Africa has been adjusted for this difference.
The pledges presented here are an interpretation of their main quantitative aspects for the purpose of establishing a stylised modelling scenario. Many countries have provided additional details and nuances in their submissions to the UNFCCC, and often conditions are stated. For full details on the pledges see FCCC/SB/2011/INF.1/Rev.1 and FCCC/AWGLA/2011/INF.1 at *www.unfccc.int*.

**Figure 3.22. Regional real income impacts, *450 Core versus 450 Delayed Action scenarios***




*Source: OECD Environmental Outlook projections*; output from ENV-Linkages.

**Box 3.11. Mind the gap: Will the Copenhagen pledges deliver enough?**

The Copenhagen pledges reflected in the *450 Delayed Action* scenario would not be enough to achieve the 450 ppm pathway in a cost-effective way. This is confirmed by other analysis, which shows that these pledges fall short of UNEP's (2010) cost-effective range of 41-48 $GtCO_2e$ for global GHG emissions in 2020 (see Box 3.8 above). These are the maximum emissions allowed to give the world a medium to likely chance of meeting the 2 °C target at least cost (Dellink *et al*., 2010; UNEP, 2010). Table 3.7 confirms this: global emissions in 2020 would amount to 51.6 $GtCO_2e$ for the high pledges and above 52 $GtCO_2e$ for the low pledges (but including the conditional pledges).[1] The gap between the emission reductions in the *450 Delayed Action* scenario and the pathway consistent with 2 °C is thus between 3 and 11 $GtCO_2e$ (whereas total mitigation efforts in *450 Delayed Actio*n in 2020 amount to less than 4 $GtCO_2e$).[2] As argued in UNEP (2010) and confirmed by our analysis (see next section), it is virtually impossible to identify what temperature increases these pledges to 2020 would lead to, as the assumptions about the pathway after 2020 will largely affect the resulting temperature changes.

Combining the lower end of the pledges with LULUCF accounting rules[3] that result in credits that are not induced by a change in management activities and use of surplus Assigned Amounts Units (AAUs)[4] from the current Kyoto commitment period (2008-2012) could widen this gap even further. There are other uncertainties that have less effect on environmental effectiveness, but do affect costs. They include limitations on the use of offsets, international financing of mitigation action in developing countries and linking of carbon markets in Annex I countries. Table 3.7 shows how these uncertainties affect global emissions (in $GtCO_2e$) and regional costs (in real income deviation from *Baseline*).

**Table 3.7. How different factors will affect emissions and real income from the Cancún Agreements/Copenhagen Accord pledges: *450 Delayed Action* scenario (deviation from *Baseline*)**

based on individual variations in key assumptions (deviation from baseline in %)

| Scenario | Global emissions of GHG incl. LULUCF (GtCO2e) | Income equivalent variation impact | | | |
|---|---|---|---|---|---|
| | | OECD members of Annex I | Russia & Rest of Annex I | Rest of BRIICS | Rest of the World |
| **…the pledge level** (*high vs. low pledges*) | 51.6 vs 52.2 | -0.2 vs -0.1 | -0.4 vs -0.3 | -0.1 vs -0.1 | -0.5 vs -0.4 |
| **… the use of surplus AAUs** *(0% - 100%)* | 51.6 vs 51.6 | -0.2 vs -0.2 | -0.4 vs -0.4 | -0.1 vs -0.1 | -0.5 vs -0.5 |
| **… land use accounting** *(net-net vs. no LU credits)* | 51.6 vs 50.8 | -0.2 vs -0.3 | -0.4 vs -0.6 | -0.1 vs -0.2 | -0.5 vs -0.6 |
| **… international financing** *(100% vs. 0%)* | 51.6 vs 51.6 | -0.2 vs -0.2 | -0.4 vs -0.4 | -0.1 vs -0.1 | -0.4 vs -0.5 |
| **… use of offsets** *(50% vs. 0%)* | 51.6 vs 51.6 | -0.1 vs -0.3 | -0.3 vs -0.5 | -0.1 vs 0 | -0.3 vs -0.5 |
| **… linking carbon markets** *(none vs. Annex I)* | 51.6 vs 51.8 | -0.2 vs -0.1 | -0.4 vs 0 | -0.1 vs 0 | -0.4 vs -0.2 |
| **… linking combined with surplusAAUs** | 53.6 | 0 | -0.2 | 0 | -0.1 |

*Source: OECD Environmental Outlook projections*; output from ENV-Linkages.

Both the high and low pledge levels show limited overall costs, although for some regions and sectors the costs are somewhat higher (see Figure 3.22). Costs increase in the OECD Annex I countries especially when they abstain from using land-use credits and/or offsets. Costs can be reduced in these countries by adopting lower pledges, linking carbon markets or allowing surplus AAUs; however, in all cases these reductions come at the cost of higher global emissions. International financing above and beyond participation in the offset mechanism can reduce the costs for developing countries. However, the effect is limited as the simulations assume that only Brazil, Mexico and South Africa qualify for these international funds (see Annex 3.A1; and note that the other non-Annex I countries are eligible as offset hosts). Russia and the Rest of Europe region (incl. Ukraine) benefit most from linking carbon markets, as they have large amounts of permits to sell. Finally, note that for the rest of the world countries costs can be limited by either allowing more offsets or linking carbon markets in the Annex I countries. Both options lead to price harmonisation across the Annex I countries and limit negative spill-over effects through a global contraction of international trade.

The use of market-based instruments, such as carbon taxes or cap-and-trade with auctioned emission permits, can provide a source of fiscal revenue. If the Cancún Agreements/Copenhagen Accord pledges and actions for Annex I countries as described above were to be implemented as a carbon tax or a cap-and-trade with fully auctioned permits, in 2020 the fiscal revenues would amount to more than USD 250 billion, *i.e.* 0.6% of their GDP.[5] Although there would be many competing uses of such revenue, just a fraction of this amount would make a significant contribution to climate change financing specified in the Cancún Agreements.[6]

Notes.
[1] Some countries made both unconditional (less ambitious) and conditional (more ambitious) pledges. These latter would be honoured if the conditions they attached to the pledges were fulfilled, for example providing adequate climate finance and ambitious action from other countries.
[2] These numbers differ from Dellink *et al*. (2010) because the analysis here is based on the methodology of Den Elzen *et al*. (2011) and includes emissions from land use, land-use change and forestry, not because the pledges themselves have substantially changed.
[3] Accounting rules for land use, land-use change and forestry (LULUCF) can potentially weaken the mitigation targets of industrialised countries. This could occur if credit is given for LULUCF activities that would have happened in any case without further policy intervention.
[4] An Assigned Amount Unit (AAU) is a tradable 'Kyoto unit' or carbon credit representing an allowance to emit one tonne of GHGs. Assigned Amount Units are issued up to the level of the initial "assigned amount" of an Annex I Party to the Kyoto Protocol. See Annex A.31 for more.
[5] These numbers are lower than in Dellink *et al*. (2010) primarily because the use of LULUCF credits lowers the carbon price and because costs are expressed here in constant 2010 USD, not because the pledges themselves have changed.
[6] In the simulations presented here the revenues are redistributed to households in a lump sum manner and alternative destinations would affect this lump sum transfer and, indirectly, the economy.

Table 3.8 shows how competitiveness is likely to be affected by the *450 Delayed Action* mitigation policy. Not surprisingly, energy producers including power plants are projected to reduce their output and export levels following reduced demand due to carbon pricing. Given the low trade exposure of power plants, however, the energy sector is less vulnerable from a competitiveness perspective than energy-intensive industries. The relatively low emission-intensity of energy intensive industry in OECD countries implies that while they would be faced with substantial cost increases due to the mitigation policy, in the long run, they can gain market share at the expense of less efficient competitors in the BRIICS and RoW, and thereby even increase their output levels compared to the *Baseline* scenario. More detailed analysis at the sub-sectoral level could identify more precisely where the largest effects are.

**Table 3.8. Competitiveness impacts of the *450 Delayed Action* scenario, 2020 and 2050: % change from *Baseline***

| | 2020 | | | | | 2050 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OECD AI | Rest of BRIICS | Russia & rest of AI | Rest of the world | GLOBAL | OECD AI | Rest of BRIICS | Russia & rest of AI | Rest of the world | GLOBAL |
| **Panel I: macroeconomic indicators** | | | | | | | | | | |
| Terms of trade (% change from *Baseline*) | 0.3% | 0.6% | -0.6% | -0.7% | 0.0% | 2.9% | 23.4% | -4.4% | -14.4% | 3.5% |
| Share of EII in GDP | 7.2% | 15.0% | 6.8% | 6.8% | 8.5% | 7.2% | 4.3% | 6.7% | 8.1% | 3.9% |
| **Panel II: volume of output in selected sectors (% change from *Baseline*)** | | | | | | | | | | |
| Agriculture | -1.1% | -0.2% | 0.3% | 0.2% | -0.4% | -14.8% | -11.6% | -16.2% | -19.7% | -15.4% |
| Energy-intensive industries | -0.9% | 0.3% | 1.4% | 1.0% | -0.2% | 5.2% | -30.1% | 4.1% | -12.0% | -14.1% |
| Energy producers | -3.9% | -1.0% | 0.1% | -0.4% | -2.0% | -36.0% | -44.5% | -43.3% | -45.2% | -42.1% |
| Services | 0.0% | -0.1% | -0.2% | -0.2% | 0.0% | -2.3% | -6.3% | -6.7% | -1.1% | -3.2% |
| Rest of the economy | -0.1% | -0.3% | 0.0% | 0.0% | -0.1% | -1.0% | -17.9% | -4.4% | -8.4% | -8.2% |
| **Panel III: volume of exports by selected sectors (% change from Baseline)** | | | | | | | | | | |
| Agriculture | -2.4% | -2.3% | 1.3% | 1.0% | -1.4% | -27.2% | -34.1% | -19.0% | -41.4% | -29.7% |
| Energy-intensive industries | -1.4% | 0.8% | 2.1% | 1.9% | -0.4% | 9.7% | -28.1% | 14.1% | -11.3% | -3.8% |
| Energy producers | -4.0% | -4.1% | -1.0% | -1.3% | -2.0% | -43.6% | -30.6% | -55.0% | -52.0% | -49.1% |
| Services | -0.1% | -0.5% | -0.6% | 0.0% | -0.2% | -5.2% | 12.2% | 2.8% | -4.0% | -0.3% |
| Rest of the economy | -0.2% | -0.6% | -0.3% | 0.1% | -0.3% | 0.2% | -17.0% | 0.8% | -15.0% | -7.8% |

*Source: OECD Environmental Outlook projections*; output from ENV-Linkages.

The fragmented carbon markets in the *450 Delayed Action* scenario also lead to some carbon leakage. Table 3.6 shows that as all the largest emitting countries have pledged reductions that effectively cap their emission levels, leakage rates will be rather low. In 2020, global leakage is projected to be around 50 $MtCO_2e$, or 1% of total mitigation action by the countries with pledges. The leakage rates found in the literature for the high end of the Copenhagen pledges vary widely, from no or very low leakage (*e.g.* McKibbin *et al.*, 2011) to 13% (547 $MtCO_2e$) in Peterson *et al.* (2011) and 16% in Bollen *et al.* (2011). Two key differences appear to influence the leakage assessment: (i) to what extent binding targets are included for non-Annex I countries (as these limit the scope for leakage to occur); and (ii) price responsiveness of fossil fuel supply. A price-elastic fuel supply implies that the reduced fuel price leads to smaller global supply and hence less leakage through the fossil fuel channel (see Burniaux and Oliveira-Martins, 2000).

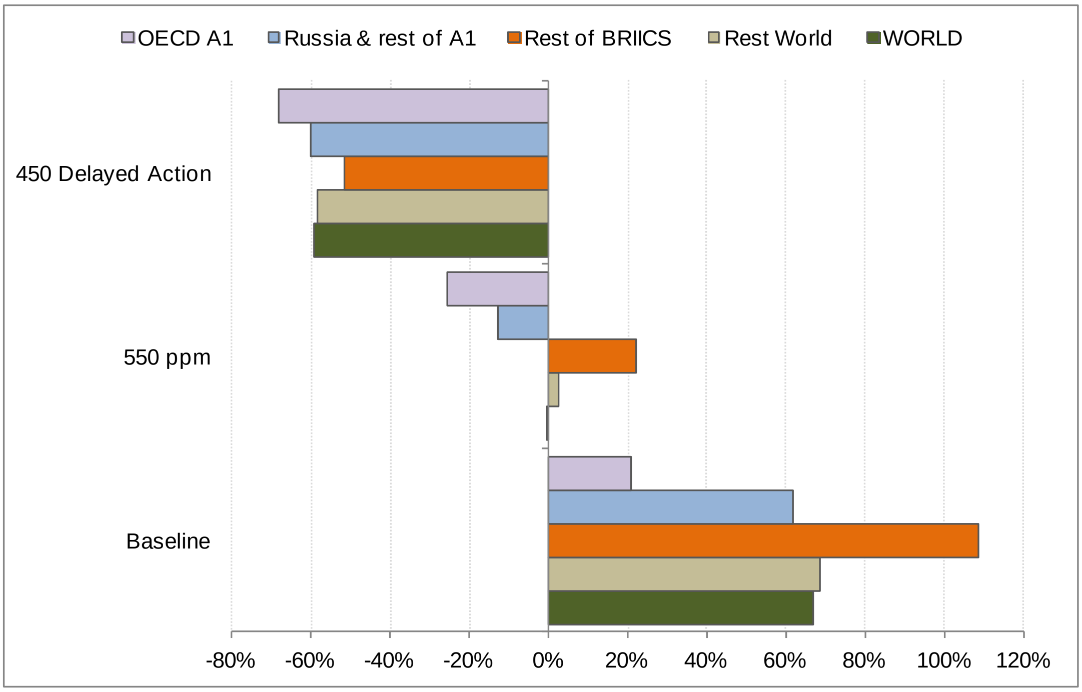
To counter negative leakage and competitiveness impacts, governments have considered exempting firms or industries at risk, or providing financial compensation, *e.g.* through free distribution of permits or output-based rebates, or border tax adjustments. However, while temporary use of some target measures may be a way to ease the transition to a low-carbon economy, these measures should be carefully reviewed in terms of their economic efficiency, the (dis)incentives they create for GHG reductions and their impacts on developing countries (OECD, 2010d; Agrawala *et al.*, 2010a). In addition, they have also been shown to reduce the rate of innovation among firms (OECD, 2010e), and the benefits of these schemes will decline with the increase in the number of countries implementing mitigation policies (OECD, 2009b; Burniaux *et al.*, 2010). Instead, multilateral policy co-ordination would be an efficient alternative to unilateral measures. This was demonstrated by the UNECE Convention on long-range transboundary air pollution, where the transfer of knowledge and technologies was greater among signatories (OECD, 2011e).

***Less stringent climate mitigation (550 ppm) scenarios***

Achieving the 450 ppm scenarios require global emission levels to peak before or around 2020. This is only possible if emissions can be reduced in nearly all global regions and if action starts now. If not, as suggested by the *450 Delayed Action* scenario, emissions in 2020 may be too high to achieve the 2 °C/450 ppm goal cost-effectively. If the 450 ppm target is to be reached, unprecedented rates of emission reductions will be required after 2020. The only way to do this will be to drastically transform the high-carbon energy system into which the world is becoming more tightly locked every year (IEA, 2011b). Given the uncertainties surrounding our ability to achieve this, less stringent long-run targets should also be investigated. Up until 2020, the *450 Delayed Action* scenario is very close to a *550 Core* scenario, which would require less mitigation in the rest of the century (see Figure 3.17 above). However, the 550 ppm *Core* scenario represents a much greater likelihood of a global average temperature rise above 2 °C. This implies that unless the required rapid transformation occurs after 2020, the Copenhagen pledges are more likely to lead to a 2.5 °CC to 3 °C increase in global average temperature than 2 °C.

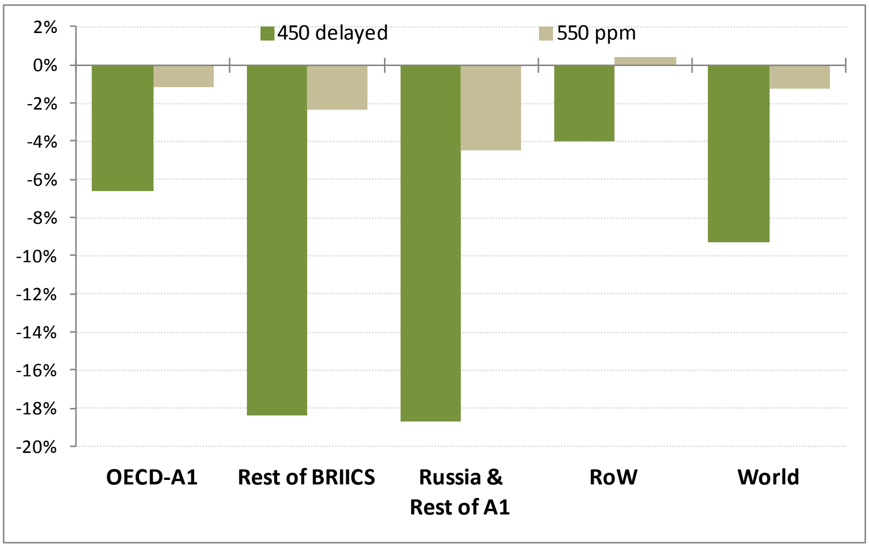
If the *550 Core* pathway is followed this would imply a trade-off between lower short-term mitigation costs and higher long-term costs from more serious climate impacts and the need for higher levels of adaptation than the *450 Delayed Action* scenario.[45] Once the "low-hanging fruit" (cheap mitigation options) have been exhausted, the marginal abatement cost of mitigation actions rises significantly.[46] The *550 Core* scenario requires that emissions in 2050 are down to 2010 levels (Figure 3.23). It leads to a decline in global real income of 1.3% as shown in Figure 3.24. Achieving the additional 28 $GtCO_2e$ reduction necessary to reach the *450 Delayed Action* pathway would lead to an additional real income decline of about 8 percentage-points, and global emissions would be 60% below 2010 levels.[47]

**Figure 3.23. Change in global GHG emissions in 2050 compared to 2010: *450 Delayed Action* and 550 ppm scenarios**




*Source: OECD Environmental Outlook projections*, output from ENV-Linkages.

**Figure 3.24. Change in real income from the *Baseline* for the *450 Delayed Action* and *550 Core* scenarios, 2050**




*Source: OECD Environmental Outlook projections*, output from ENV-Linkages.

### *Actions needed for an ambitious, global climate policy framework*

The first and best solution to address the competitiveness concerns described above would be a global, comprehensive and ambitious climate policy framework that creates a level playing field, covering all sectors and all GHGs (Agrawala *et al*., 2010a). Broadening the scope of mitigation action also reduces the related problem of carbon leakage – when mitigation policy in one country leads to increased emissions in other countries, thereby eroding the environmental effectiveness of the policy. Leakage can occur through a shift in economic activity towards unregulated countries, or through increased fossil energy use in unregulated countries as a result of lower international fuel prices in response to the reduced energy demand in mitigating countries.

As long as countries take such varied approaches to carbon markets, concerns about leakage and international competitiveness will remain a significant stumbling block to ambitious climate change action in many OECD countries (Box 3.12). In evaluating the potential competitiveness impacts, governments may be most concerned about emission leakage and conserving output and employment, whereas energy-intensive industries are more likely to be concerned about profits and market share. In fact, competitiveness impacts of climate policies are likely to be limited to a small number of sectors representing a small share of total economic activity, *i.e.* trade-exposed, energy-intensive industries (including include chemicals, non-ferrous metals, fabricated metal products, iron and steel, pulp and paper, and non-metallic mineral products).

The patchwork of climate policies across the globe today entails higher compliance costs in some countries than others, and raises concerns in some countries about the competitiveness of their energy- and/or carbon-intensive industries at the international level. These in turn often delay action or discourage more ambitious action. The cheapest policy response to climate change would be to set a global carbon price – this would require linking the various ETSs that are emerging locally. Linking generally allows polluters to purchase credits from a larger set of suppliers. Access to cheaper mitigation options lowers costs by reducing domestic efforts for permit buyers; polluters with relatively cheap mitigation options can gain from increasing domestic reduction efforts and selling these on the international market.

**Box 3.12. What if... a global carbon market does not emerge?**

Since reaching the 450 ppm target would require the combined effort of all countries, this box analyses the impact of market fragmentation under the *550 Core* scenario. Linking carbon markets in only some regions will have a number of inefficiencies. These are illustrated in Figure 3.25 using alternative scenarios. The different variations modelled are as follows:

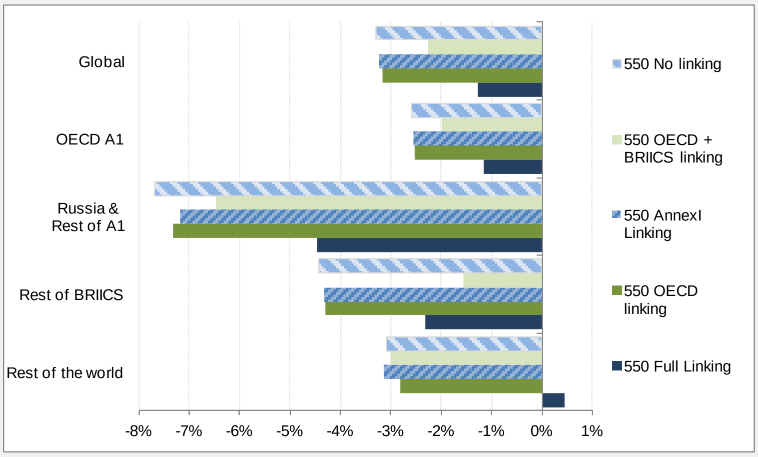
- *550 No linking*: unilateral actions only and no linking at all;
- *550 OECD linking*: regional linking within subsets of OECD countries;
- *550 Annex I linking*: linking within Annex I countries only;
- 550 *OECD-BRIICS linking*: linking within OECD and BRIICS countries only;
- *550 Full linking*: this is the *550 Core* scenario.

The overarching conclusion from these simulations is that linking markets can help limit the costs of mitigation policies for participating countries, but it matters drastically which countries link their ETS systems. Countries that rely mostly on renewable energy sources for electricity generation, and that are therefore more difficult to decarbonise, tend to benefit most from market linking. Linking has only minor effects on countries that are not directly involved in the linked schemes, although they do benefit from the more efficient carbon market through increases in international trade.

OECD countries are projected to be the main permit buyers. Mitigation in OECD countries represents about a third of global efforts when permit exchange is restricted to Annex I countries and has very limited effects on macroeconomic costs. Opening trade further to include the rest of the BRIICS implies that China and India become the major suppliers of permits (similar to the current CDM), decreasing the OECD contribution by 8 percentage-points of global mitigation levels. Full trading further reduces the contribution of the OECD countries to 22% of the global effort.

By 2050, mitigation in the RoW countries would represent 25% of total emission reductions in the *550 Core* (*Full linking*) scenario. This falls to about 10% if their carbon market is not internationally linked. Allowing the RoW countries to sell large volumes of emission permits would be a significant and low-cost mitigation option, and would also earn them sizeable revenues from internationally sold permits. For a detailed discussion of the potential and risks of linking ETSs, see OECD (2009b).

**Figure 3.25. Income impact of fragmented emission trading schemes for reaching concentrations of 550 ppm compared to the *Baseline*, 2050: % change in real income**



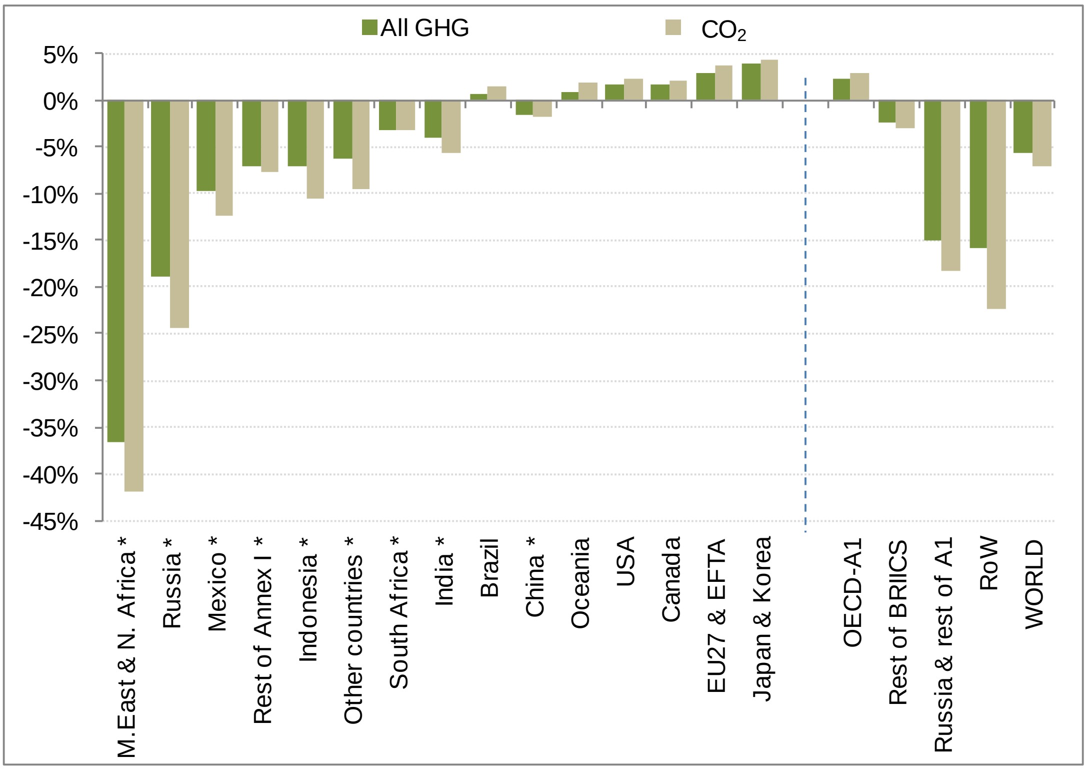

*Source: OECD Environmental Outlook projections*; output from ENV-Linkages.

*Reforming fossil fuels support*

Reforming environmentally harmful subsidies, and specifically fossil fuel subsidies, is an important step in "getting the prices right" to reduce GHG emissions. An inventory of 24 OECD countries finds that fossil fuel production and use was supported by USD 45-75 billion per year between 2005 and 2010 (OECD, 2011f). Fossil fuel consumption subsidies in 37 developing and emerging economies amounted to an estimated USD 554 billion in 2008, USD 300 billion in 2009 and USD 409 billion in 2010 (IEA/OECD/OPEC/WB, 2010; IEA, 2011b and see Annex 3.A1 at the end of this chapter).[48]

Removing these subsidies would lower the global cost of stabilising GHG concentrations, saving money for governments and taxpayers. It helps to shift the economy away from activities that emit $CO_2$, encourages energy efficiency, and promotes the development and diffusion of low-carbon technologies and renewable energy sources. OECD *Outlook* simulations using IEA data (2008 estimates) indicate that phasing-out fossil fuel consumption subsidies in emerging and developing countries could reduce global GHG emissions (excluding land-use change emissions) by 6% globally by 2050, compared with business as usual, and by over 20% in Russia and MENA countries (Figure 3.26). As subsidies artificially reduce the price paid by final consumers, removing this price-wedge would influence behaviour and reduce final energy demand. This could increase global real income by 0.3% in 2050, and would be especially beneficial for the BRIICS countries (+1.1% for the Rest of BRIICS category).

**Figure 3.26. Impact on GHG emissions$^{+}$ of phasing out fossil fuels subsidies, 2050**




Notes: * Regions for which fossil fuel subsidies reform is simulated.

$^{+}$ Excludes emissions from land-use change.

*Source: OECD ENV-Linkages* model using IEA fossil fuel subsidies data (IEA, 2009b).

However, some trade effects offset the pure economic efficiency gains of these subsidy reforms for main fossil fuel exporting countries (*e.g.* Russia and Middle-East). And this because a lower demand for fossil fuels in the reforming countries will cause a decrease in global energy prices. Moreover, unless OECD countries cap their total emission levels, this decrease in international prices could create an increase in emissions in some OECD countries (relative to baseline), leading to a partial offset of the original reduction of demand and GHG emissions. Despite this leakage effect, the net effect on global emissions is, however, projected to be positive.

If fossil fuel subsidy phase-out is included in the *450 Core* scenario, the cost of mitigation would be lower than in the *450 Core* scenario without the subsidy reform. These lower costs would occur first and foremost in the countries undertaking the subsidy reform, but also at the global level (Table 3.9). Note that the high costs for the rest of world in 2020 – both for fossil fuel subsidy reform on its own and a *450 Core* scenario that includes fossil fuel subsidy reform – is due to the impacts on oil-exporting countries in the Middle East. The income gains of the reform are smaller in the *450 Core* scenario than under a fossil fuels subsidy reform only framework. This is because fossil-energy use is lower in the *450 Core* scenario and thus the savings from removing fuel subsidies are also lower.

**Table 3.9. Income impacts of a fossil fuel subsidy reform with and without the *450 Core* scenario, 2020 and 2050: % real income deviation from the Baseline**

| Region | 2020 | | | 2050 | | |
|---|---|---|---|---|---|---|
| | Only FFS reform | 450 Core no reform | 450 Core with FFS reform | Only FFS reform | 450 Core no reform | 450 Core with FFS reform |
| **WORLD** | **0.1** | **-0.1** | **-0.1** | **0.3** | **-6.3** | **-6.0** |
| **OECD AI** | 0.2 | 0.0 | 0.2 | 0.2 | -4.8 | -4.5 |
| **Rest of BRIICS** | 0.6 | -0.3 | 0.3 | 1.1 | -11.4 | -10.7 |
| **Russia & rest of AI** | -0.6 | -0.4 | -1.0 | 0.2 | -14.6 | -13.8 |
| **Rest of the World** | -1.2 | -0.4 | -1.4 | -0.3 | -2.8 | -2.6 |

*Source*: *OECD ENV-Linkages model using IEA fossil fuel subsidies data* (IEA, 2009b).

However, removing these subsidies can be politically challenging, and may also lead to more use of traditional bioenergy (*e.g*. cooking using wood or animal manure) in developing countries, with potentially negative health effects (see Chapter 6). The combustion of traditional bioenergy is also associated with high black carbon emissions that also contribute to climate change (see Box 3.14 below). As a result, fossil fuel subsidy reforms should be implemented carefully to ensure that potential negative impacts on household affordability and well-being are reduced through appropriate measures (*e.g*. means-tested social safety net programmes).

***Finding synergies among climate change strategies and other goals***

Designing policies which address two or more goals at once (environmental, social and economic) can help to multiply the benefits of policy action. This final section explores some opportunities for maximising the benefits of combining climate change action with biodiversity protection, health and green growth.

*Climate change, biodiversity and bioenergy*

Climate change is projected to play the driving role in further biodiversity loss in the future (Chapter 4). The right strategies for mitigating climate change will therefore also have benefits for biodiversity, slowing down the pace of species loss. However, some climate mitigation policies can have negative impacts on biodiversity. For example, the use of bioenergy can be an attractive option – its use can reduce GHG emissions and it can be easily applied as an alternative to liquid fuels in transport (especially for specific purposes such as aviation and freight transport), in power generation or even to create negative emissions (if combined with CCS). But it also may have negative impacts on direct and indirect GHG emissions, and on biodiversity via the need for additional land for biofuel crops (Box 3.13). On the other hand, other mitigation strategies, such as REDD-plus measures, avoided emissions from land-use changes in forested areas, or the use of second generation bioenergy would result in additional biodiversity co-benefits (Chapter 4 on biodiversity presents some more policy simulations on this issue).

**Box 3.13. Bioenergy: Panacea or Pandora's Box?**

Bioenergy is energy generated from food crops such as grains, sugar cane and vegetable oils (first generation bioenergy) or from cellulose, hemicellulose or lignin sourced from non-food crops or inedible waste products (second generation bioenergy). Bioenergy may play an important role in mitigating climate change. It can be used as liquid fuel in the transport sector to replace fossil-energy based fuels,leading to lower $CO_2$ emissions. It can also be used in the power sector as a replacement for coal or natural gas. In power and in hydrogen production, bioenergy can also be combined with CCS to create a technology which could actually remove emissions from the atmosphere (known as BECCS). Through this approach, $CO_2$ is absorbed during the growth phase of the biomass, and then captured and stored when the biomass is converted to power or hydrogen (Azar *et al*., 2010; Read and Lermit, 2005).

*The downsides of bioenergy*

However, the use of bioenergy may also have serious disadvantages. First, the production of bioenergy crops requires land, putting it into competition with other activities (such as food production) (Azar, 2005; Bringezu *et al*., 2009; Searchinger *et al*., 2008). Some studies have reported that considerable food price increases may occur as a result of the direct and indirect land-use impacts of bioenergy (indeed, price rises in 2008 and 2011 have also partly been attributed to the rapid rise in bioenergy use). Secondly, bioenergy may have considerable GHG emissions associated with its production. These include the emissions from nitrogen fertilisers and fuel used during the growth and conversion phase, as well as the $CO_2$ emissions from land-use change either directly (conversion of natural ecosystems) or indirectly (competition with other forms of land use may cause more natural ecosystems to be converted to farmland (Searchinger *et al*., 2008; Smeets *et al.*, 2009). In some cases, the emissions associated with bioenergy may be as much as fossil fuels or even higher. These impacts may be partly mitigated by: (i) using second generation bioenergy (*e.g*. producing fuels from grasses, woody biomass or even biologically derived waste which does not require additional cropland to produce); (ii) the application of sustainability criteria; (iii) careful choices for high-yield crops which limit land-use requirements or using extensive bioenergy production systems; or (iv) the use of biomass both in material and energy applications (so-called cascading). Finally, experience with bioenergy and CCS technologies is still limited. Both face challenges related to climate policy uncertainty, public acceptance and first-of-a-kind technology risks. CCS is currently much more expensive than other technologies.

The impacts of bioenergy on biodiversity, land use, and food prices and availability thus depend on rather complex interactions in the agricultural and energy system. The calculations for the *OECD Environmental Outlook* assume that bioenergy use occurs mostly in the power sector and that fuel production is mostly based on second-generation bioenergy (mainly from residues). The *450 Core* scenario in the IMAGE model simulations assumes that by around 2050 about 20% of primary energy use is supplied from bioenergy. While this substantially reduces emissions from the combustion of fossil fuels, it also implies some increased emissions from land use. The implications for biodiversity are discussed in Chapter 4. As the exact trade-offs are rather uncertain at this stage, more careful monitoring of the use and impacts of bioenergy is needed.

*Can we get by without bioenergy?*

The *550 Core* scenario using the IMAGE model assumes a lower reliance on bioenergy. In the *550 Core* scenario, about 13% of total primary energy use is supplied by bioenergy, while in the *550 Low bioenergy* scenario this is reduced to 6.5%. An important question is whether easily substitutable alternatives exist in the transport sector. In these calculations, hydrogen produced from fossil fuels with CCS would be an alternative with only limited additional costs; however, if this alternative cannot come about, relying less on bioenergy may substantially increase climate policy costs. Achieving lower concentration targets (450 ppm) depends significantly on the use of BECCS. Achieving ambitious climate policy scenarios with less reliance on bioenergy is likely to concentrate its use in the power sector (in combination with BECCS). However, the complete exclusion of bioenergy use might make very low concentration targets unachievable. Given these uncertainties, further work will be important to explore options for sustainable bioenergy use, and several models will be needed to better understand the impacts of different shares of bioenergy in mitigation option portfolios.

*Climate change mitigation and health co-benefits*

Some climate warming gases – such as black carbon (Box 3.14), methane, sulphur dioxide ($SO_2$) and nitrogen oxides ($NO_x$) – are also air pollutants which have negative health impacts. Well-designed climate mitigation policies can therefore also help to meet air pollution reduction objectives. Mitigation policies affect climate in the long run, while the health benefits of reducing local air pollution will be felt in the short to medium run (Bollen *et al.*, 2009; UNEP, 2011b). In these cases, cost-benefits analyses should take account of those additional co-benefits (see Chapter 6 for further discussion). While it is important to stress that targeting short-lived climate forcers or GHGs should not detract from broader GHG-mitigation policies and the need to achieve lasting decarbonisation of the economy, these policies can be a complement to a full range of climate change action.

The existence of any health-related co-benefits can also to some extent depend on the policy instruments being applied. If a cap-and-trade system is used to limit $CO_2$ emissions, any additional policy instruments applied to the same emission sources would (as mentioned above) not lead to further $CO_2$-emission reductions – or any reductions in $SO_2$ or $NO_x$ emissions, due to interactions with the $CO_2$ cap (OECD, 2011b).

**Box 3.14. The case of black carbon**

Black carbon is produced from the incomplete combustion of solid or liquid fuels such as fossil fuels, biofuels, and biomass. It is not a single substance, but is the fraction of particulate matter that most efficiently absorbs visible light (Bond *et al*., 2004; UNEP, 2011b). The sources of black carbon emissions are numerous and include mobile diesel engines without particulate traps, cooking stoves, savanna and forest burning, agricultural waste combustion, and small-scale industry such as brick kilns and coke production (Bond and Sun, 2005). Although black carbon is not a GHG, it is an important short-lived climate forcer and directly affects the Earth's climate by absorbing solar radiation in the upper atmosphere, where it remains for days or weeks (Molina *et al*., 2009). Additionally, deposits of black carbon on snow or ice change a region's "albedo" – the proportion of incident light reflected – leading to more absorbed solar radiation.

It is difficult to measure the total net effect of black carbon, but limiting black carbon emissions is one important element in a climate protection strategy (UNEP, 2011a). For example, some $CO_2$ mitigation measures result in short-term warming by also limiting co-emitted sulphur (UNEP, 2011a). In addition to climate benefits, reducing black carbon can have significant health and agricultural productivity benefits. The full implementation of measures to jointly curtail black carbon and tropospheric (*i.e.* ground-level) ozone precursors would jointly prevent 2.4 million premature deaths, and the loss of between 1% and 4% of the total annual production of wheat, rice, maize and soybeans (UNEP, 2011a). Mitigation approaches vary widely by country due to differing emitting activities. Emissions from OECD countries come largely from diesel vehicles (EPA, 2011). In other countries such as China and India, sources include cookstoves, brick kilns and coke ovens – these also cause indoor air pollution.

Marginal abatement costs for black carbon vary across regions and are higher in North America and Europe where relatively low cost abatement measures for particulate matter have already been implemented (Rypdal *et al*., 2009). Given black carbon's regional variance, more work is needed to develop the best policy approach for reducing it. Further analysis and comparison of cost-effective black carbon mitigation strategies could integrate multiple criteria including (i) local atmospheric conditions; (ii) the proportion of black carbon to other co-emitted particulate matter; (iii) impact on sensitive regions where snow/albedo effect is important; and (iv) impact of black carbon emitting activities on non-climate outcomes such as health and agricultural effects.

*Climate change, green growth and green jobs*

Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. To do that, it must catalyse innovation and investment that will underpin sustained growth and give rise to new economic activities. The financing and investment requirements of shifting the traditional carbon intensive energy sector to a low-carbon sector would require an additional USD 1.6 trillion per year of investment between 2030 and 2050 (USD 750 billion from 2010 to 2030) over and above existing investment (IEA, 2009b). However, the IEA also estimates that the 17% (USD 46 trillion) increase in global energy investment required to deliver low-carbon energy systems could yield cumulative fuel savings equal to USD 112 trillion between 2010 and 2050 (IEA, 2009b). Domestic policies are necessary to provide the adequate risk-return profile to make green investment more profitable than business-as-usual options, with some authors calling for "investment-grade" climate policies (Hamilton, 2009; OECD, 2012). The transition to a low-carbon economy will require the development of new sectors and activities, requiring a new set of skills in both new jobs and existing jobs (OECD, 2011a). Key sectors would include transport, directed towards more efficient and alternative vehicles; building refurbishment and solar installation; and the decarbonisation of the power sector, mainly involving investments in renewable energy technologies. If public policy frameworks manage to shift private-sector investments to low-carbon, climate-resilient alternatives, those investments will create new businesses and jobs and offset losses from the "brown" economy model (IEA, forthcoming).

Labour market and skills development policies can make an important contribution to greener growth. By minimising skill bottlenecks and preventing a rise in structural unemployment, these policies can make the transition to green growth quicker and more beneficial. The OECD report *Towards Green Growth* (OECD, 2011e) underlines how an increasing number of studies are showing the potential for net job creation associated with the restructuring of the energy sector towards a cleaner energy mix.[49] This means that through shifting sources of energy towards renewable sources and emphasising non-energy intensive sectors, climate policies could create more jobs than would be lost in the long run. By causing important changes in relative prices, GHG-mitigation policy will affect the composition of both final and intermediate demand and hence composition of labour demand. In particular, the relative price of energy and energy-intensive goods and services will increase.[50] The macroeconomic impacts of climate policies on employment are various and the global effect is not easy to establish; however, certain policy mixes can improve both environmental and labour market performance (see Box 3.15 for an illustration).

There are several limitations to the potential positive impact on jobs of greening growth. Firstly, the direct effect of energy sector composition of employment is limited, since intensely polluting industries account for only a small share of the total workforce. Secondly, these "first-round" net employment impacts do not fully account for the "second-round" effects of a change in energy mix: they do not fully capture the full macroeconomic impact of climate policies. Barriers to industrial restructuring could hinder the reallocation process consecutive to mitigation policies and, ultimately, reduce the pace of employment growth. Thirdly, as these policies would generally reduce GDP (see Section 3.3), this could have negative impacts on aggregate employment.

Public revenues raised by carbon pricing mechanisms could be used to reduce other taxes and fiscal distortion in the economies. These revenue-neutral mitigation policies are sometimes advocated on the basis that they can generate a "double-dividend": reducing GHGs emissions and improving efficiency by reducing distortive taxes, such as labour taxes.

**Box 3.15. What if…reducing GHGs could increase employment?**

The OECD has investigated the labour market impacts of GHG-mitigation policies (Chateau *et al*., 2011; OECD, 2011e). This analysis uses a specifically revised version of the ENV-linkages model with labour market rigidities, i.e. frictions in the adjustment of wages to differences between supply and demand of labour, to simulate an illustrative climate policy scenario where the OECD area as a whole reduces emissions by 50% in 2050 compared to their 1990 levels (through implementing a joint ETS). Non-OECD countries are assumed to each reduce their emissions by 25% in 2050 relative to business as-usual levels.

Table 3.10 indicates that this mitigation policy has a limited impact on economic growth (real GDP levels are reduced by 0.8% for low labour market rigidity to 2.1% for high rigidity) and job creation (employment levels are reduced by 0.3 to 2.2%). When permit revenues are redistributed in the form of uniform lump-sum transfers, mitigation costs increase with the degree of labour market rigidity. Yet, even in the worst-case scenario, under very strong labour market rigidities, economic growth is only slightly affected by the introduction of carbon permits: on average in the OECD area, real GDP increases by almost 41% over the period 2013-2030, as compared to 44% in the absence of mitigation actions. The resulting slowdown in job creation is more pronounced, but still limited.

**Table 3.10. Economic impact of an OECD-wide emissions trading scheme where labour markets are rigid, assuming lump-sum redistribution, 2015-2030: % deviation from the business-as-usual scenario**

| | **Real GDP** | | **Employment** | | **Real wage** | | **Real income** | |
|---|---|---|---|---|---|---|---|---|
| | Low rigidity | Strong rigidity | Low rigidity | Strong rigidity | Low rigidity | Strong rigidity | Low rigidity | Strong rigidity |
| 2015 | -0.04 | -0.10 | -0.03 | -0.12 | -0.11 | -0.03 | -0.04 | -0.13 |
| 2020 | -0.23 | -0.62 | -0.13 | -0.70 | -0.53 | -0.18 | -0.25 | -0.80 |
| 2030 | -0.78 | -2.09 | -0.32 | -2.19 | -1.30 | -0.56 | -0.83 | -2.68 |

*Source: OECD ENV-linkages* model (based on Chateau *et al.*, 2011).

However, for a medium level of labour market rigidity (between the two extremes presented in Table 3.10), and if the lump-sum redistribution is replaced by a policy where permit revenues are used to reduce taxation on labour, employment growth is boosted (Table 3.11). OECD employment would increase by 0.8% in 2030 compared to the *Baseline* projection, resulting in an increase of 7.5% between 2013 and 2030, compared with 6.5% in the absence of mitigation actions. Moreover, there is no loss of purchasing power for workers.

**Table 3.11. Economic impact of an OECD-wide ETS for different revenue recycling options, assuming medium labour market rigidity, 2015-2030**

% deviation from the business-as-usual scenario

| | **Real GDP** | | **Employment** | | **Real wage** | | **Real income** | |
|---|---|---|---|---|---|---|---|---|
| | Lump sum transfers | Lower labour taxes | Lump sum transfers | Lower labour taxes | Lump sum transfers | Lower labour taxes | Lump sum transfers | Lower labour taxes |
| 2015 | -0.06 | 0.06 | -0.05 | 0.12 | -0.08 | 0.11 | -0.07 | 0.09 |
| 2020 | -0.34 | 0.26 | -0.29 | 0.59 | -0.44 | 0.54 | -0.40 | 0.44 |
| 2030 | -1.08 | -0.03 | -0.75 | 0.80 | -1.14 | 0.76 | -1.26 | 0.24 |

*Source: OECD ENV-linkages* model (based on Chateau *et al.*, 2011).

These estimates illustrate how certain policy mixes can improve both environmental and labour market performance. They also show that both the quality of labour market institutions and the redistribution of permit revenues need to be jointly addressed in order to reap the full potential benefit of climate change policies in terms of job creation. However, empirical estimates on the degree of labour market imperfections are scarce, and therefore the numbers presented here are purely illustrative.

These conclusions are in line with many other studies analysing the employment impact of mitigation actions within the framework of a general equilibrium model. Such models, including ENV-Linkages, allow an evaluation of the transition costs, but over a longer time horizon. Certain employment gains induced by mitigation policies (or job losses avoided) are not captured. Indeed, as innovation is intrinsically difficult to predict, the potential effects of environmental policies in stimulating the innovation of new green technologies are not fully captured.

*Source*: Chateau, J., Manfredi T., Saint-Martin and P. Swaim (2011), “Employment Impacts of Climate Change Mitigation Policies in OECD: A General-Equilibrium perspective”, *OECD Environment Working Paper* No. 32, OECD, Paris (forthcoming).

## NOTES

1 See Chapter 1 for the methodology used for the Environmental Outlook, and Chapter 2 for the key socioeconomic assumptions behind the Baseline scenario. See the Section 3.2.on trends and projections in this chapter for further discussion of the existing policies that are included in the *Baseline*.

2 Mitigation consists of activities that aim to reduce GHG, directly or indirectly, by avoiding or capturing GHGs before they are emitted to the atmosphere or sequestering those already in the atmosphere by enhancing "sinks" such as forests. Such activities may entail, for example, changes to behavioural patterns or technology development and diffusion (IPCC, 2007).

3 Adaptation is defined as adjustments in human and natural systems, in response to actual or expected climate stimuli or their effects, moderate harm or exploits beneficial opportunities (IPCC, 2001).

4 The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC). It was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialised countries and the European Community for reducing greenhouse gas (GHG) emissions. These amount to an average of 5% reduction from 1990 levels between 2008 and 2012.

5 See *www.iea.org/index_info.asp?id=1959*.

6 See *www.epa.gov/methane/scientific.html*.

7 In the IPCC report, the median value is 3 °C and 2 °C-4.5 °C represents the 66% confidence interval. This is the assumption used in the projections outlined in this Outlook.

8 Climate sensitivity is a measure of how responsive the climate system is to a change in the radiative forcing. It is usually expressed as the temperature change associated with a doubling of the concentration of carbon dioxide in Earth's atmosphere.

9 The term overturning or thermoaline circulation refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes. Computer models predict that more freshwater flowing into a few crucial places in the North Atlantic could slow, or even stop, dense water forming and sinking. This could shut down the return flow in this current.

10 Other economists (*e.g*. Nordhaus, 2011 and Pindyck, 2011) suggest that Weitzman's Dismal Theory, which says that cost-benefit analysis breaks down due to potential catastrophes, only holds under very specific circumstances.

11 See *http://unfccc.int/resource/docs/convkp/conveng.pdf*.

12 The Annex I Parties to the 1992 UNFCCC are: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, European Economic Community, Finland, France,

Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lichtenstein, Lithuania, Luxembourg, Malta, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States. See www.unfccc.int. Annex II countries, a sub-group of the Annex I countries, are those that committed to give financial support to action in developing countries. Annex II countries include the OECD members in 1992, excluding those that were economies in transition (EIT countries).

13 For the list of Non-Annex I parties, see *http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php*

14 Note that the United States has not ratified the Kyoto Protocol, and that Turkey had not ratified the UNFCCC at the time that the Kyoto Protocol was negotiated. Both these Annex I countries do not therefore have emission commitments under the Protocol.

15 For a full list of pledges made, see *http://unfccc.int/resource/docs/2011/sb/eng/inf01r01.pdf* (developed countries) and *http://unfccc.int/resource/docs/2011/awglca14/eng/inf01.pdf* (developing countries).

16 The High Level Advisory Group on climate financing suggests that 85% of the funds may need to come from the private sector by 2020 (AGF, 2010).

17 The new Green Climate Fund will be governed by a board of 24 members, with an equal number from developing and developed countries, and will be administered by the World Bank for the first three years (Cancun Agreements 2010, *http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2 § 102-112*)

18 Massachusetts v. Environmental Protection Agency, 549 U.S. 497 (2007), is a U.S. Supreme Court case decided 5-4 in which twelve states and several cities of the United States brought suit against the United States Environmental Protection Agency (EPA) to force that federal agency to regulate carbon dioxide and other GHGs as pollutants. See *http://www.supremecourt.gov/opinions/06pdf/05-1120.pdf*

19 Carbon capture and storage (CCS) is a means of reducing the contribution of fossil fuel emissions to global warming. The process is based on capturing carbon dioxide ($CO_2$) from large point sources, such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere.

20 In these *baseline*-and-credit plans there is no explicit cap on aggregate emissions. Instead, each firm has the right to emit a certain baseline level of emissions. This baseline may be derived from historical emissions or from a performance standard that specifies the permitted ratio of emissions to output. Firms create emission reduction credits by emitting fewer than their *baseline* emissions.

21 “Offsets” are a general term referring to credits that offset the need to reduce emissions elsewhere.

22 Joint implementation is one of three flexibility mechanisms set forth in the Kyoto Protocol to help countries with binding GHG emissions targets (Annex I Parties) meet their obligations. Under Article 6, any Annex I country can invest in emission reduction projects (referred to as "Joint Implementation Projects") in any other Annex I country as an alternative to reducing emissions domestically.

23 The discount was reduced to 65% in April 2011.

24 See *www.fin.gov.bc.ca/tbs/tp/climate/carbon_tax.htm*, accessed September 2011.

25 The purpose of the CDM is to promote clean development in developing countries. The CDM allows industrialised countries to invest in emission-reduction projects wherever it is cheapest globally. The emission-reduction projects in developing countries can earn certified emission reduction (CER) credits, each equivalent to one tonne of $CO_2$. These CERs can be traded and sold, and used by industrialised countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

26 This limits the manufacture of, or improves the manufacturing, handling, use and end-of-life recovery of fluorine-containing gases used as substitutes for ozone-depleting substances.

27 Energy efficiency measures face complex barriers: market and financial barriers with split incentives problems when investors cannot capture the benefits; transaction costs; price distortions; informational barriers on the part of the consumers to make rational consumption and investment decisions; incentive structures that encourage energy providers to sell energy rather than invest in energy efficiency; and technical barriers (see IEA, 2009a).

28 The Major Economies Forum on Energy and Climate (MEF) was launched on 28 March, 2009 to facilitate a candid dialogue among major developed and developing economies, help generate the political leadership necessary to achieve a successful outcome at the December UN climate change conference in Copenhagen, and advance the exploration of concrete initiatives and joint ventures that increase the supply of clean energy while cutting GHG emissions. The 17 major economies participating in the MEF are: Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States. Denmark, in its capacity as the President of the December 2009 Conference of the Parties to the UN Framework Convention on Climate Change, and the United Nations have also been invited to participate in this dialogue. See *www.majoreconomiesforum.org*.

29 See *www.cordis.europa.eu/technology-platforms*.

30 See *www.fp7.org.tr/tubitak_content_files/270/ETP/PV/energyresearchprogramme.pdf*.

31 Parties to the UNFCCC must submit national reports on their implementation of the Convention to the Conference of the Parties (COP). The core elements of the national communications for both Annex I and non-Annex I Parties are information on emissions and removals of GHGs and details of the activities a Party has undertaken to implement the Convention.

32 The countries included in the study are: Australia, Austria, Canada, Denmark, Finland, Germany, Norway, Spain, the Netherlands, and the United Kingdom.

33 Many climate change risks are not monotonic, which makes identification of trends difficult. In these cases weather-based insurance is not viable.

34 The different GHGs have been aggregated using $CO_2$-equivalents ($CO_2$e).

35 Rogelj *et al*. (forthcoming) estimate that a 450oppm pathway will have a around a 60% chance of exceeding 2°C in the long-term (in equilibrium), with a 15% chance of exceeding 3°C and a 5% chance of exceeding 4°C.

36 BECCS combine bioenergy in power and in hydrogen production with carbon capture and storage (CCS) to create a technology which could actually remove emissions from the atmosphere: $CO_2$ is absorbed during the growth phase of the biomass, and then captured and stored when the biomass is converted to power or hydrogen (Azar *et al*., 2010; Read and Lermit, 2005). Several studies have identified BECCS as an attractive mitigation option later in the century (Van Vuuren and Riahi, 2011).

37 The label “delayed action” does not imply that all action is delayed, but rather that in the coming decades less mitigation takes place than in the other scenarios.

38 Due to the cooling effect of the aerosols, these concentration levels are lower than the corresponding concentration levels of the Kyoto gases only.

39 The long-term equilibrium temperature increase will be lower than 2° C, as by the end of the century the declining concentrations of GHGs are already projected to lead to less radiative forcing.

40 The IMAGE suite of models assume that a larger share would come from fuel switching, and have more conservative estimates on energy efficiency improvements.

41 However, energy efficiency also plays a role in the OECD region – energy efficiency improvements are an essential part of a cost-effective mix of mitigation options.

42 Average energy intensity also differs across regions due to national circumstances, including climate,

43 Information from UNFCCC website (*www.unfccc.int*), accessed August 2011.

44 The calculations are based on the methodology described in Den Elzen *et al*. (2011), but revised to reflect the *Environmental Outlook Baseline* projections. More information on the assumptions behind the assessment of the pledges is given in Annex 3.A1.

45 Remember that the benefits of mitigation action are not represented in the cost figures calculated using the ENV-Linkages model.

46 Clearly, these cost estimates depend crucially on the assumptions that are made about the availability and cost-effectiveness of the major mitigation options shown in Box 3.11 on key energy technologies.

47 Regional income losses depend on the permit allocation scheme, which is based on equal per-capita emission allowances in both mitigation scenarios.

48 This annual level fluctuates widely with changes in international energy prices but it also indicates that some recent reform has been undertaken in some major countries (China and India).

49 For example see the recent report by UNEP, ILO, IOE and ITUC, "*Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*" (UNEP/ILO/IOE/ITUC, 2008).

50 Eco-innovation is also likely to have important relative price effects, while also directly affecting labour input and job skill requirements in sectors making use of the new technologies. As a result, new jobs will be created while many existing jobs will need to be "greened" even as others will have to be reallocated from downsizing to expanding sectors or firms.

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## ANNEX 3.A1: MODELLING BACKGROUND INFORMATION ON CLIMATE CHANGE

This annex provides further descriptions of some of the assumptions behind the model-based policy simulations used in this chapter.

### The *Baseline* scenario

The *OECD Environmental Outlook Baseline* scenario makes projections of a number of socioeconomic developments (summarised in Chapters 1 and 2):

- Based on assumptions governing a conditional convergence of the drivers of economic growth across countries, world GDP is projected to nearly quadruple over the coming four decades, in line with the past 40 years and based on detailed projections on the main drivers of economic growth. By 2050, the OECD's share of the global economy is assumed to decline from 54% in 2010 to less than 32%, while the share of Brazil, Russia, India, Indonesia, China and South Africa (BRIICS) is assumed to grow to more than 40%.

- By 2050, the world is assumed to add over 2.2 billion people to the current 7 billion. All world regions are assumed to be facing population ageing but will be at different stages of this demographic transition.

- By 2050, nearly 70% of the world's population is assumed to be living in urban areas.

- World energy demand is assumed to be 80% higher in 2050 under current policies. The 2050 global energy mix is assumed to be fairly similar to today's, with the share of fossil energy still at about 85% (of commercial energy), renewables including biofuels (but excluding traditional biomass) just above 10%, with the balance being nuclear. Among fossil fuels, it is uncertain whether coal or gas will be the main source of increased energy supply.

- Globally, the area of agricultural land is assumed to expand in the next decade, but at a slower rate. It is assumed to peak before 2030 to match the increase in food demand from a growing population, and decline thereafter, as population growth slows down and yield improvements continue (Box 3.2). Deforestation rates are already declining, and this trend is assumed to continue, especially after 2030 with demand for more agricultural land easing.

- No new climate policies are assumed to be introduced, but policies in existence in 2010 are assumed to still be in operation. For instance, the EU Emission Trading Scheme (ETS, see Section 4.2.1) is included in the *Baseline* until 2012 (as these policies are already in place). Additional (new) legislated policies in the European Union are not reflected in the *Baseline*, but the European Union's energy and climate package is assumed to be implemented in all policy simulations carried out in the analysis. Energy-efficiency measures already in place (in the European Union and other countries) are also included in the *Baseline*.

While there are substantial uncertainties around the assumptions, the *Baseline* projected global trend in GHG emissions is within the range of plausible trends identified in a number of model comparison exercises (*e.g* those done by the United Nations Environment Programme – UNEP, 2010; the Intergovernmental Panel on Climate Change – IPCC, 2007a, b&c; and the Energy Modelling Forum – Clark *et al.*, 2009).

**The 450 ppm climate stabilisation scenarios**

The *450 Core* scenario pathway is modelled by the IMAGE model, and allows for temporary overshooting of the concentration levels in the middle of the century. The associated emissions pathway is chosen such that total costs of achieving the target are minimised according to the mitigation technologies available in IMAGE. The ENV-Linkages model harmonises with the corresponding emissions pathway. In the *450 Accelerated Action* pathway, higher mitigation efforts are imposed for the first few decades, implying less negative emissions in the second half of the century stemming from the BECCS (bioenergy with CCS) technology. Finally, the *450 Delayed Action* pathway is based on fragmented carbon markets until 2020 with targets based on the high end of the pledges in the Copenhagen Accord/Cancún Agreements (see below for more details), and a global carbon market from 2021 onwards.

These scenarios all assume a burden sharing regime based on contraction and convergence: global emissions contract over time according to the global pathway, and regional emission allowances (*i.e.* regional permit allocation) as a share of the global budget converge from shares in current emission levels to equal per-capita emissions by 2050 (see also simulation 2 below). Note that in the *450 Delayed Action* scenario the burden sharing regime only applies after 2020.

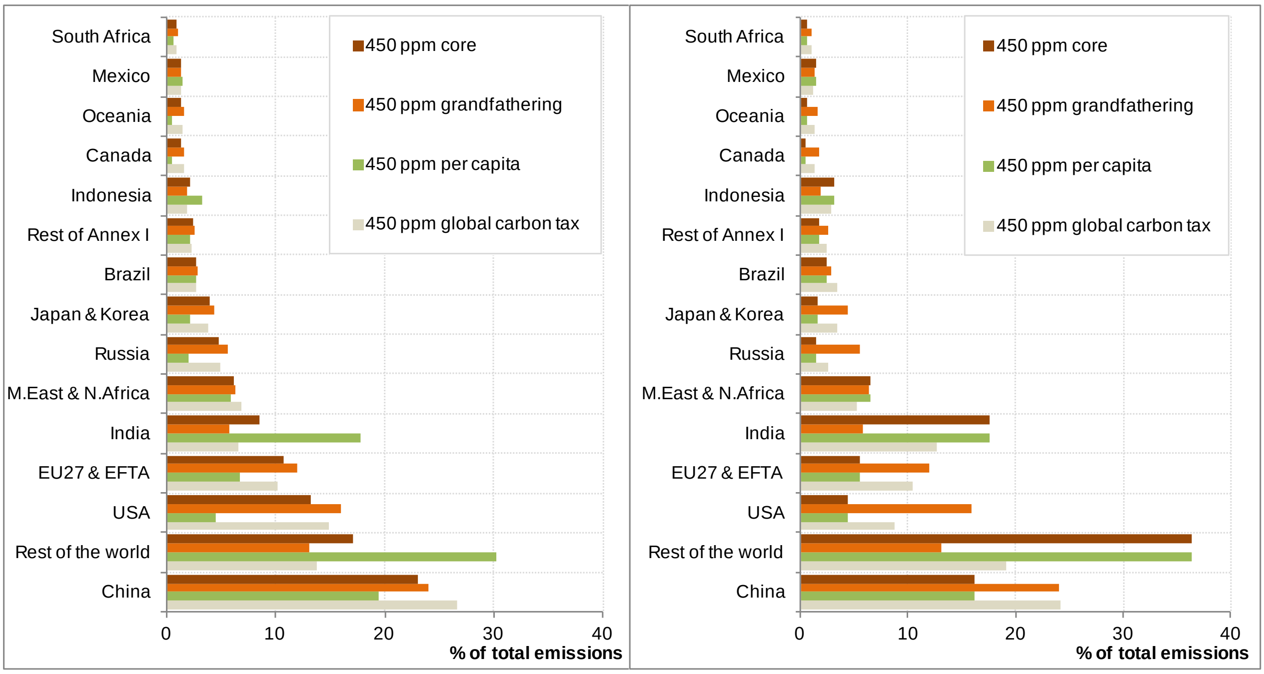
Fossil fuel subsidy reform is not included in these scenarios, but investigated separately (see below).

***Alternative permit allocation schemes***

The regional shares of permits used for the permit allocation schemes presented in Box 3.10 are reported in Figure 3.A1 below. In the *Global carbon tax* scenario (called "450 carbon tax" in the figure) allocation of permits is an endogenous result of the model. It corresponds to the rule where there is no gain from permit trading among countries. For the other rules, when the share of permits received is greater than the share in the global carbon tax case, the country will export permits (and *vice versa*).

**Figure 3.A1. Permit allocation schemes, 2020 and 2050**

(% of total emissions)



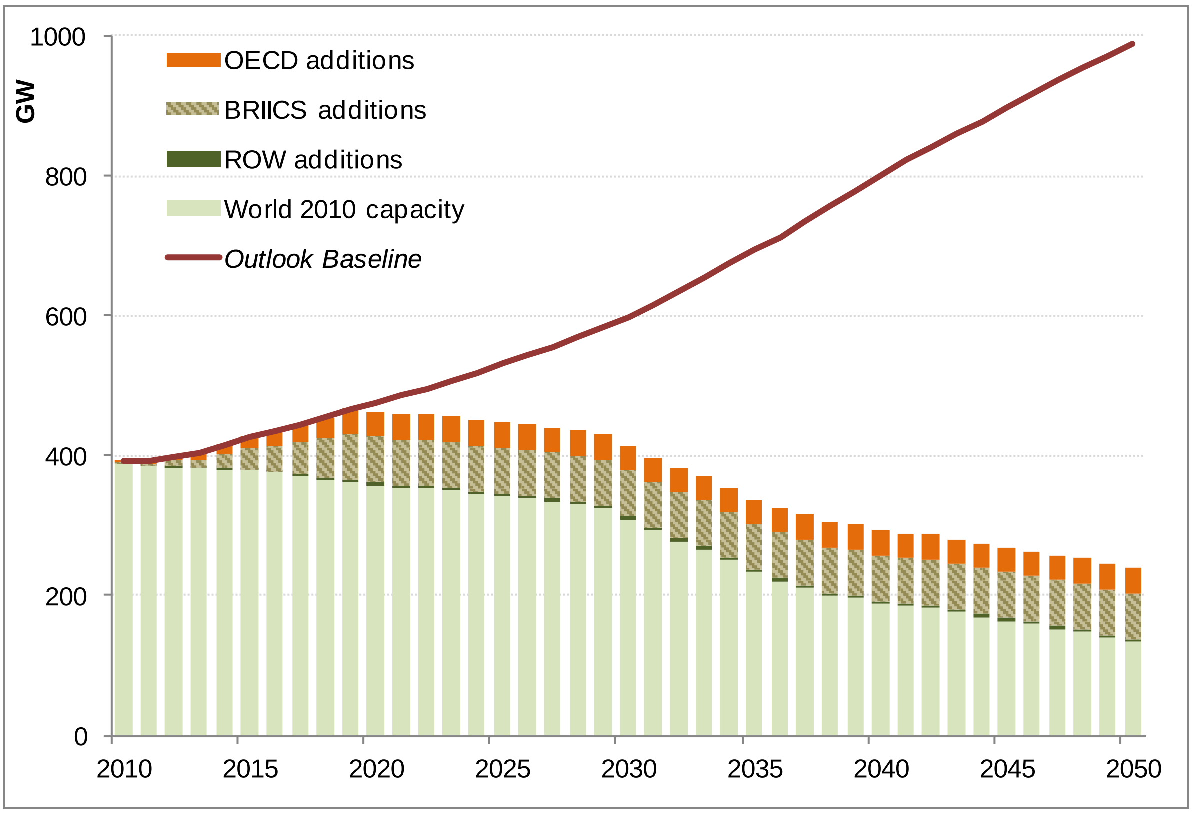

*Source*: *OECD Environmental Outlook projections*, output from ENV-Linkages.

### *Technology options in the 450 ppm scenario*

These policy scenarios incorporate alternative assumptions about advanced technologies to explore how dependant the energy systems in the different regions are on these energy technologies (Box 3.10 in main text). The technology specifications are based on the concurrent Energy Modelling Forum exercise (EMF24) in which both ENV-Linkages and IMAGE are participating. These scenarios are variants of the *450 Accelerated Action* scenario, with all major mitigation technologies available, using the following technology assumptions:

- ***No CCS:*** in the alternative setting CCS is restricted to levels as they are projected in the *Baseline*, and cannot expand further. CCS in the *Baseline* is not directed at avoiding emissions to the atmosphere, but for use of $CO_2$ in the enhanced oil recovery (EOR) technology.
- The ***progressive nuclear phase-out*** scenario is constructed assuming that nuclear capacity currently under construction and planned until 2020 will be built and connected to the grid (data sourced from IAEA Power Reactor Information System database). These mid-term nuclear capacities are consistent with the projections from the IEA Current Policies Scenario (IEA, 2009b). After 2020, no new nuclear unit is allowed, so that the world total capacity by 2050 will be reduced because of the natural retirement of existing plants that come at the end of their technical lifetime. By 2020, cumulative nuclear capacity additions in OECD represent one-third of the total 105 GW. Remaining additions are built in the BRIICS countries, with China alone representing almost half of total new capacity. The expansion of the nuclear fleet in the RoW countries is negligible. The estimated world nuclear capacity in this scenario reaches about 460 GW in 2020, starting from current 390 GW, and falls down to about 240 GW by 2050, a four-fold reduction compared to the 450 scenario (Figure 3.A2).

**Figure 3.A2. Nuclear installed capacity in the *Progressive nuclear phase-out* scenario, 2010-2050**




*Source*: *OECD Environmental Outlook projections*, output from ENV-Linkages.

- ***Low efficiency & renewables*** scenario: Efficiency improvement embedded in energy production together with productivity gains in renewable technologies are assumed to develop more slowly over time than in the *450 Accelerated Action* scenario. Both are 20% lower than the base by 2050, leading to more slowly adoption of efficiency measures and more slowly deployment of renewable technologies.

***Cancún Agreements/Copenhagen Accord pledges***

Some interpretation of the Cancún Agreements/Copenhagen Accord pledges and targets is necessary for the specification of the *450 Delayed Action* scenario, because some pledges are provided in the form of a range, which is dependent on the action or financing of other countries. Due to limited specific information on how countries plan to meet their targets or actions, uncertainty remains about how the emissions reductions will affect different sectors, how much financing will be received from international sources, and how emission reductions are counted towards pledges or offsets. The most important assumptions for interpretation are:

- The methodology for assessing the pledges is based on Den Elzen *et al.* (2011), but the evaluation has been revised to reflect the *OECD Environmental Outlook Baseline* projections.

- In order to estimate costs and effectiveness in a consistent manner, all Annex I emission reduction targets are translated into reductions from the same base year (1990) and all non-Annex I mitigation actions, including the emission intensity targets of China and India, are expressed as emission reductions from business as usual (BAU) in 2020.[1] The ENV-Linkages *Baseline* projections are used for this evaluation, rather than the national baselines used by countries in their submission; this may cause substantial differences (this especially holds for South Africa, and therefore the target for South Africa has been revised to reflect the differences in baselines). In line with the general modelling framework, countries are assumed to implement their policies through the introduction of an economy-wide Emission Trading Scheme (ETS), with full auction of permits.

- Due to the limited information available on what offset policies might be in the future, and to what extent countries intend to meet their pledge through the use of offsets, this analysis requires *ad hoc* assumptions about the level of offsets. For Annex I countries, an assumption of 20% of the total required emission reductions[2] is assumed to be achieved through international offsets, with two exceptions: (i) Canada has currently no government policy on international offset purchases (which is interpreted in the simulations as no use of offsets for Canada); and (ii) the European Union is assumed to limit offsets to 4 percentage-points (for the 20% reduction targets this is equivalent to the default assumption of 20%, but for the higher pledge of 30% reduction this constitutes an offset percentage of 13% of the mitigation requirements). The offsets are assumed to be entirely international and flexible across non-Annex I countries. Further, emission reductions in non-Annex I countries cannot be double-counted towards both domestic pledges and for sale in the international offset market. The default of 20% is varied in sensitivity analysis.

- With respect to credits from land use, land-use change and forestry (LULUCF), the assumption is made that Annex I countries will use a net-net accounting rule for credits from this sector using 2020 as base year.[3] The *OECD Environmental Outlook Baseline* projection for LULUCF emissions is used to calculate the volume of credits. This leads to additional credits for most Annex I countries. Note that the current Kyoto Protocol rules for LULUCF accounting are more lenient and would therefore imply more credits from this sector, less emission reductions in the other sectors and lower short term costs. Non-Annex I countries use REDD activities to reach their pledge, but REDD activities are excluded from the international offset system.

- International financing of mitigation actions in non-Annex I countries is assumed to be limited to Brazil, Mexico and South Africa. China, India and Indonesia have explicitly stated that their actions are unilateral, whereas no commitments are assumed for the Middle East and rest of the world regions. By default, 50% of domestic costs are assumed to be compensated by Annex I countries, but this is varied in a sensitivity analysis.

- Some countries are likely to have emission levels that are below their targets for the current commitment period of the Kyoto Protocol (2008-2012); this creates so-called surplus Assigned Amount Units (AAUs). Based on the *Baseline* projection, the amount of surplus AAUs is estimated to be 6.5 $GtCO_2e$ for Russia, 1.9 $GtCO_2e$ for the Rest of Europe group of countries (primarily Ukraine), and 0.7 $GtCO_2e$ for the European Union and European Free Trade Area (EFTA). The existence of surplus AAUs in the post-2012 period would effectively allow for higher emissions in that period than would occur otherwise (see den Elzen *et al*., 2011, for further discussion) and thus would reduce the costs of action. The impact of potential surplus AAUs depends in part on the assumptions about use of the units across accounting periods. As a default, no use of these surplus AAUs in the period 2013-2020 is assumed. For Russia and Rest of Europe this is varied in a sensitivity analysis, but the surplus for the European Union and EFTA is not used in any simulation as the European Union has stated it will not use its surplus.[4]

- Note that the non-binding targets for Russia and Rest of Europe in the period 2013-2020 also imply that they have some scope to sell permits without undertaking additional mitigation actions when international permit trading is allowed in the simulations.

***Phasing out fossil fuel subsidies***

This policy scenario (discussed in Section 3.4 of the main text) is based on the analysis for the G20 on reform of fossil fuel subsidies. The ENV-Linkages model *Baseline* scenario has been updated using the latest IEA fossil fuel based consumer subsidies for the year 2009 (for developing economies). The IEA energy price gaps calculated by the IEA (2010) have been introduced in the ENV-Linkages model as percentage price-wedges between consume prices and reference or world prices. A negative wedge is then considered as a subsidy rate. Since 2010 this IEA database covers 37 countries, of which 35 are non-OECD and 2 OECD, for the years 2007-2009 (IEA, 2009b). [5] These prices gaps only fall on fossil fuel based energy consumption but distinguish both VAT tax rates from subsidy rates. In the ENV-Linkages *Baseline* projection it is assumed that after 2009 the subsidy and VAT tax rates remain constant in percentage terms up to 2050. Since 2009 subsidy rates are lower than 2008 rates used in Burniaux and Chateau (2011) one could consider that the new *Baseline* takes into account the latest fossil fuel subsidy reforms undertaken during 2009.

In the policy simulations of generic subsidy reforms the subsidy rates are gradually phased-out over the period 2013 to 2020. Two experiments are undertaken. In the first simulation there is a stand-alone multilateral fossil fuel reform in all the 37 countries of the IEA database with no mitigation policies elsewhere (and no EU-ETS after 2012); this is an update of the G20 report simulation. The second simulation assesses the case where these fossil fuel reforms are associated to the *450 Core* mitigation scenario. This second simulation allows an assessment of the importance of fossil fuel subsidy reform in a context where carbon leakages are partly frozen by overall mitigation action.

## ANNEX NOTES

1 Given the expected relatively small impact of the policies on GDP in China and India, the intensity target can be approximated by an absolute cap on emissions.

2 The 20% limit on offsets in most Annex I regions is in line with the assumption in OECD (2009a).

3 An exception is the assumption that when the low ends of the pledges are implemented, no LULUCF credits are assumed for the European Union and European Free Trade Area.

4 In the alternative specification, the surplus is progressively used over the years, as reduction targets become more strict; thus 22% of the surplus enters the market in 2020. This is in contrast with other models that assume the same amount of surplus AAUs will be used yearly between 2013 and 2020 (see UNEP, 2010).

5 Iran, Russia, Saudi Arabia, India, China, Egypt, Venezuela, Indonesia, Uzbekistan, UAE, Iraq, Kuwait, Argentina, Pakistan, Ukraine, Algeria, Thailand, Malaysia, Turkmenistan, Bangladesh, Mexico, South Africa, Qatar, Libya, Ecuador, Kazakhstan, Vietnam, Chinese Taipei, Azerbaijan, Nigeria, Angola, Colombia, Brunei, Rep. of Korea, Philippines, Sri Lanka, Peru.

www.oecd.org/environment/outlookto2050