

October 3, 2007

## Economics

### The Economics of Climate Change – a Primer

#### Repercussions are broad ranging and complex.

Climate change will likely affect economies and financial markets by causing shocks to long-term growth prospects and shifts in the relative price of carbon-intensive goods. The effects will vary considerably among countries, based on their exposure to climate-related damage, their emission intensity and their ability to adapt to such damage and cut carbon emissions. In this report, we map out individual countries' exposure to climate change.

**Discounting the risks.** Even though climate change is a long-term trend, financial markets need to price in the risks today. Investors therefore need to review their long-term growth, inflation and risk projections in light of climate change. The need to cut emissions is considerably greater in industrial countries although the adverse effects of climate change are likely to be larger in emerging markets where there is also substantial potential to avoid emissions. Globally, climate change will likely cause stagflationary pressure.

**Gaining political momentum.** Climate change is clearly moving up the political agenda. As politics is still mostly national, we discuss climate change from a country perspective. Decisive efforts to contain climate change could trigger a phase of faster technological and structural change. Countries aren't equally well equipped for such creative destruction.

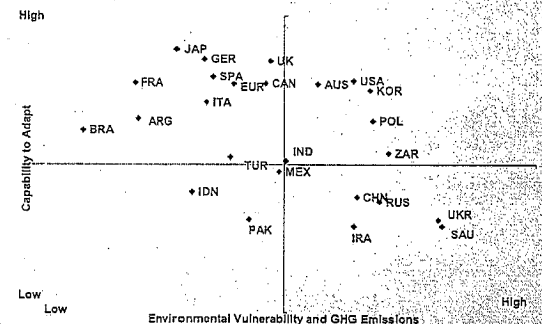
**Uncertainty is pervasive.** This study identifies a large number of risks and uncertainties starting with the process of climate change itself. In addition, the price dynamics of fossil fuels and carbon are important. Specific technological innovations could potentially make a difference, notably carbon capture and sequestration. Finally, the politics of climate change is a key factor because it sets caps for carbon emissions and chooses the policy instruments to achieve them, both of which are key to containing climate change.

#### Economic Effects of Climate Change

- Lower real GDP, particularly in EM
- Higher volatility, higher risk premiums
- Higher inflationary pressures
- More protectionist tendencies
- Greater role of governments
- Faster technical progress
- Substantial structural change
- Shifts in trade and capital flows
- Big differences between countries

Source: Morgan Stanley Research

#### Top 25 Greenhouse Gas Emitters' Exposure to Climate Change and Ability to Adapt



The relative country impact will likely be a function of a country's exposure to the physical damage created by climate change and its need to reduce greenhouse gas emissions. Some countries will have a greater capacity to adapt to the changes potentially brought about by climate changes than others.

Source: ESI, Morgan Stanley Research

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## Executive Summary

Climate change is likely to affect the global economy and financial markets by creating negative shocks to long-term growth prospects and by causing a noticeable shift in the relative prices of carbon-intensive goods. The total impact is determined by three factors. First, how much a country or sector is exposed to the physical damage of climate change. Second, the role of greenhouse gas (GHG) emissions in economic activity in that country or sector. Third, the ability to respond and adapt to both climate change and emission reductions will determine the long-term impact. All three factors will vary substantially between countries, sectors and individual companies.

As environmental policy remains largely national, contrary to other studies, this report focuses on the country impact of climate change. We plan to look at the sector aspects in more detail in the future. In general, developing countries are likely to be hit harder by the damage created by climate change. After a period of catch-up in terms of GDP per capita, climate change might therefore pose a challenge to some emerging market economies, especially at the lower end of the income scale. At the same time, developing countries offer many inexpensive options to reduce greenhouse gas emissions. In addition, many developing economies are still in the process of building an energy infrastructure and therefore, contrary to industrial countries, do not suffer from the sunk costs of the existing high-carbon infrastructure. International emission trading, notably the Clean Development Mechanism (CDM), allows developing countries to capitalize on these abatement opportunities and sell them to industrial countries. Because of international emission trading and even more so because of the highly differentiated country impact, international trade and capital flows will likely be systematically affected by climate change.

In order to aggregate the different dimensions, we present several country screens, which map the largest 25 GHG emitters in terms of their vulnerability to the physical damage created by climate change and the need to reduce GHG emissions against a country's capacity to adapt to these changes. We find that energy-rich developing and transformation countries, such as Saudi Arabia, Ukraine, Russia, China and Iran, are probably the most exposed, while resource-poor European countries and Japan seem the least exposed. Several OECD countries, such as Poland, South Korea, the US and Australia, show a high exposure and a high capacity to adapt. These countries could see the most

pronounced changes in the coming years. In addition to the aggregated country analysis, we outline the expected incidence of damage and GHG emissions in more detail and touch upon some sector implications.

Globally, the impact of climate change will be more muted than at regional or national level. Nonetheless, a number of effects are likely to be felt at this level as well. The damage created by climate change will likely dent long-term growth. The randomness of many climate events will likely raise the volatility of the business cycle and make policy errors more difficult to avoid. Together with the uncertainty stemming from the political process, this will likely increase risk premiums and weigh on investment spending. With potential output likely to be lowered by climate change, inflationary pressures are likely to rise. Inflationary pressures would be reinforced by rising food prices, water charges and carbon taxes. Globally, climate change could thus create a bout of stagflation, especially if no decisive action to contain global warming is taken in the near future.

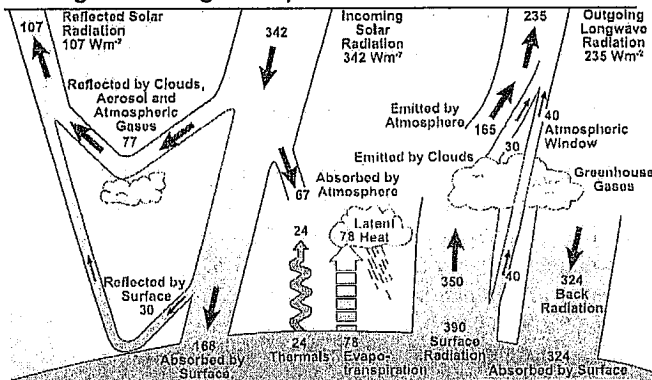
The ability to reduce GHG emissions varies considerably among countries. In particular, countries differ in their ability to handle the massive structural change needed to contain climate change because of differences in their ability to create innovations, diffuse them across the economy, and reallocate resources due to differences in product market regulations and employment protection legislation. In our view, another dose of creative destruction would be necessary. Contrary to the ICT boom of the 1990s, however, containing climate change will be heavily influenced by top-down technological change, partially prescribed by government policies. The political dimension is at the heart of climate change. Political decisions will determine the emission reduction targets and the instruments needed to achieve it. Collectively, both determine the cost of reducing emissions significantly.

If governments manage to raise the rate of technological progress on the back of bold action to contain global warming, this would help to offset some of the negative growth impact of climate change; in an extreme case, it could even overcompensate for it. The need to contain climate change will likely reinforce the current shortfall of the global capital-to-labour ratio compared with its long-term equilibrium. Hence, combating climate change would likely exert additional downward pressure on wages relative to interest rates/profits. Unfortunately, the latter hints at the risk of climate change becoming a scapegoat for protectionism.

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Exhibit 1

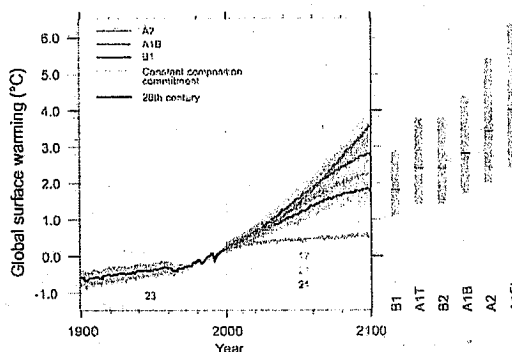
## Link between Greenhouse Gases and Climate Change No Longer Disputed



Source: IPCC

Exhibit 2

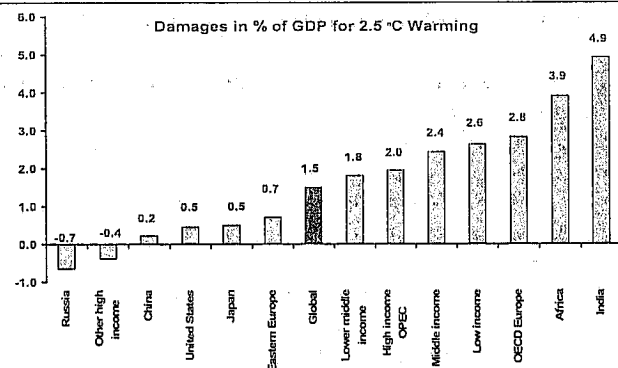
## Global Projections for Future Temperature Increases Are Subject to Uncertainty



A2, A1B, B1 refer to different scenarios the IPCC uses to describe different growth trajectories and different degrees of international political cooperation.  
Source: IPCC

Exhibit 3

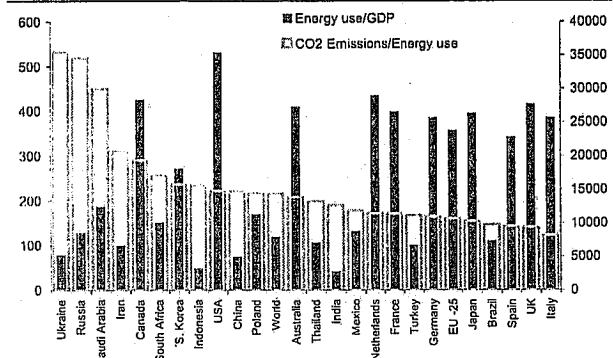
## Damage Created by Climate Change Varies Considerably Between Countries and Regions



Source: Nordhaus and Boyer, RICE model, Morgan Stanley Research

Exhibit 4

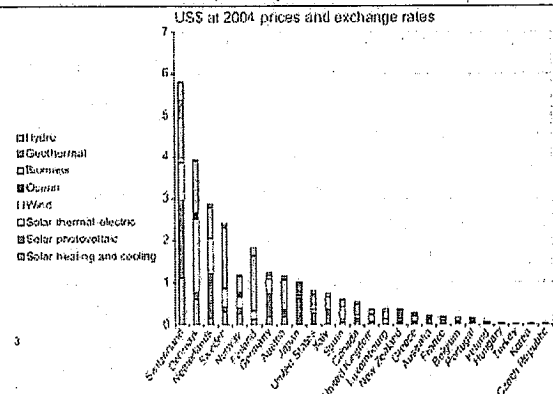
## Energy Efficiency and Carbon Intensity of Energy Use Reveal Big Country Differences



Source: WRI, CAIT, Morgan Stanley Research

Exhibit 5

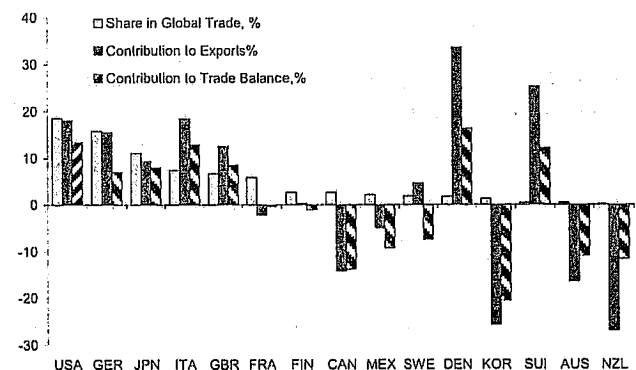
## Renewable Energy R&D Spending Points to Different Tech Potential (Per Capita, 1990-2003 Avg)



Source: IPCC

Exhibit 6

## Some Countries Have Gained a Comparative Advantage in Environmental Protection Goods



Source: NIW, Morgan Stanley Research

Exhibit 7

## Our Main Theses on the Economics of Climate Change

- The impact of climate change on the economic backdrop for financial markets is broad ranging and complex. Financial markets will be key in funding the massive investment needed to mitigate and adapt to climate change and in sharing the remaining risks due to climate change efficiently. Every country, sector and company is affected by climate change.
- Climate change is likely to be the most far-reaching negative side-effect of human activity ever experienced by the global economy. As such, it will require enormous government policy action. Understanding and anticipating government decisions correctly will be key to investment success.
- In addition to defining the emission reduction target, policy-makers will decide on the instruments to implement them. Cap-and-trade combines the advantages of regulatory standards and emission taxes, while limiting the negative impact on corporate profits. Technology policy is another important plank in tackling climate change.
- Due to its negative repercussions on long-term GDP and inflation, climate change will likely reinforce stagflationary pressures. Such an environment would make a more difficult backdrop for risky assets and would argue in favor of a steeper yield curve and, possibly a weaker currency.
- After the fall of the Iron curtain and the ICT revolution, climate change could become the next global mega-trend. While the damage wrought by climate change will adversely affect the global workforce, the need to invest in low-carbon technologies will cause the long-term equilibrium capital-to-labour ratio to rise further above its current level.
- Bold government action to contain climate change could trigger a bout of accelerated creative destruction, causing existing inefficiencies in energy use to be reduced and fostering both technological and structural change. Countries with flexible product and labour markets and a strong R&D framework will be in a better position to gain from these changes.
- Inventing new low-carbon technologies and diffusing existing ones quickly and effectively are at the heart of the efforts to contain climate change. Here, government R&D subsidies and regulatory standards can change market structures by lowering market entry barriers for alternative energy suppliers, causing markets to become more competitive.
- Even where estimates of the global cost of climate change point to relatively limited overall costs, the global aggregates mask big country differences. Country differences are driven by the damage caused by climate change, the role of greenhouse gas emissions and by the ability to change both. Emerging market economies seem more vulnerable.
- These country differences as regards the impact of climate change and the reaction to it will likely affect international trade and capital flows systematically by causing shifts in comparative advantages and locational attributes. International trade in emission permits creates a new product to be traded internationally.
- Concerns that globalization prevents governments from taking action against climate change and other environmental issues, or that international trade has caused additional environmental damage, are not supported by empirical evidence. However, environmental concerns have been used in the past as a scapegoat for protectionism.
- A key variable driving the impact of climate change on individual countries is the expected change in the availability and the quality of water. Hence, in addition to alternative and conventional energy, water could be an interesting angle to play climate change as an investment theme.

## The Economics of Climate Change

Climate change is likely to have serious long-term repercussions on the environment, the economy and financial markets. As such, it constitutes a mega-trend, which, like globalization or demographic change, will shape the long-term economic outlook. In this report, we provide a blueprint of the likely economic impact of climate change. Climate change primarily affects investment opportunities and risks in two ways.

First, it is likely to create shocks to long-term economic growth prospects due to its negative impact on the workforce, the capital stock and productivity dynamics. The ability to adapt to a rapidly changing environment and to mitigate the impact of climate change will help to offset part of the damage that is already in the pipeline due to the current concentrations of GHG in the atmosphere.

Second, both climate change itself, and the actions taken to limit it will likely cause a major shift in relative prices and hence will affect cost comparisons. Currently, the atmosphere is mostly used as a carbon sink 'for free'. In the future, there will likely be limitations on such free use of the atmosphere either via regulation, carbon taxes or tradable emission permits.

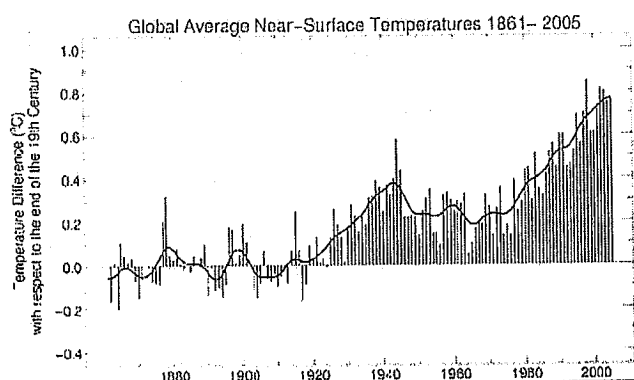
From an economic point, climate change constitutes a **negative externality that is global in its causes and its consequences**. Emitters of GHG impose a cost on the global economy, which they don't have to face directly. The environmental damage created by emitting an additional unit of GHG is called the external cost of carbon. At the moment, emitters have little incentive to reduce GHG emissions. In the presence of such externalities, markets fail to ensure an efficient resource allocation. Hence, policy-makers need to intervene and provide the appropriate incentives to ensure an efficient market outcome. As a result, emitters of GHG will likely face a fee for using the atmosphere as a carbon sink. This fee could be the price of an emission permit, a carbon tax or the cost of reducing emissions to the allowed level under a regulatory policy approach. The efficient level of GHG emissions is likely to be positive, but much lower than the current level. It is reached when the cost of reducing GHG further becomes equal to the additional climate-related damage avoided by that cut in GHG emissions.

Essentially, the atmosphere will become another scarce factor of production, in addition to capital and labour. Official GDP statistics currently measure gross value-added without taking into account the degradation in the environment

and thus likely overstate value-added, productivity and profits. This bias in the official statistics will be larger the higher the emission intensity of a country or sector. If the use of the atmosphere as a carbon sink was indeed considered an input into the production process, this would likely create a negative supply shock. In contrast to an oil-price shock, however, there probably won't be a negative terms of trade effect for fuel-importing countries. In fact, if energy imports drop in response to a broad-based pricing of carbon emissions, there could even be a positive terms of trade effect.

Exhibit 8

### Global Warming Now Becoming Very Noticeable



Source: Stern Report based Hadley Centre for Climate Prediction and Research

Climate change is likely to constitute a considerable risk to the long-term growth prospects of some countries and sectors while offering new growth opportunities for others. The incidence of damage created by climate change and the policies adopted to reduce GHG emissions will affect long-term revenue and costs projections, in many cases materially. Carbon-intensive countries, sectors and companies are more likely to be negatively affected. Countries, sectors and companies offering abatement and adaptation solutions will likely see considerable growth opportunities. In addition to the effects on an absolute basis, there are important relative effects on countries, sectors and companies. It makes sense to start out by discussing the country perspective of climate change because the country dimension is key in committing to emission reductions and implementing policy programs to ensure these reductions.

Only a small part of the damage created by climate change between now and the middle of this century can be avoided. Due to the inertia and the long lead-times of the climate system, only adaptation measures can help to contain

## Integration of Climate Models and Financial Valuation

In principle, existing economic models of climate change can be integrated into financial valuation models in a straightforward way. So-called integrated assessment models of climate change, which estimate trajectories for growth, inflation, carbon emissions, carbon prices, global temperatures etc. in an integrated way can be used to generate the risk-reward profiles for the potential impact of climate change (damage, adaptation, abatement) in different scenarios. Some model variants can also be used to generate probability distributions across the different scenarios. Choosing such an integrated approach allows a systematic analysis of the sensitivity of financial valuation models to their underlying assumptions on economic growth, climate reaction or the rate of technical progress, just to name a few.

When using an existing economic model of climate change it is important, however, to bear in mind some of the differences between economic cost-benefit analysis underlying these types of models and financial valuation models: Net present value (NPV) estimates are based directly on a stream of income. Economic models, by contrast, are usually based on the utility derived from this income stream. Usually, this utility is assumed to rise more slowly than income because of the declining marginal utility of income, which stipulates that an individual finds that eating the first doughnut provides more additional joy than, say, the fifth one. The distinction between income and utility becomes important in two instances.

- First, **NPV estimates usually assume a constant risk-free rate (plus a risk-premium)** rather than a falling discount factor over time like many economic models. In economic models, the discount factor falls over time because income is projected to rise, even if the rate of time preference, the discount rate, is assumed to be constant. The choice of the discount rate is at the heart of the recent controversy about the Stern Report's estimates of the damages caused by climate change, which were considerably higher than those obtained by others. Stern refutes many of the objections on both ethical and technical grounds and argues in favour of a very low discount rate because, in his view, there is no ethical justification to value the welfare of the current generation above that of future generations.

- Second, in terms of the risk-attitude, **NPV estimates typically assume a risk-neutral decision maker** by simply using the expected value of future discounted income streams. Given the large, non-linear risk associated with climate change and the presence of long-tail risks, most economists would advocate a decision-rule based on risk aversion. For a risk-averse decision-maker, the utility derived from an uncertain prospect, offering an equal likelihood of, say, no temperature change and one of 5 C° would be lower than the expected value of that prospect of 2.5 C°.

By appropriately amending existing economic models of climate change, it is possible to align the two approaches and to develop a common framework. This would allow investors to generate quantitative estimates for the two qualitative scenarios outlined in the previous section.

Furthermore, NPV estimates are typically based on market exchange rates rather than purchasing-power-parity estimates. However, when comparing countries of very different price levels and income levels this implies that poor countries are given a relatively small weight. Hence damages caused by the loss of home and shelter to a family in a developing country would be considered to be much smaller than the same event happening in a developed country. Hence, from an economic point of view purchasing-power-parity based estimates are preferable.

Typically, **NPV estimates also ignore non-market effects** such as, say, the reduced enjoyment of leisure due to adverse weather conditions. Economic models of climate change that aim at a more comprehensive cost-benefit analysis often include at least some non-market effects and try to quantify them.

Another important distinction to bear in mind is the **difference between GDP levels and growth rates**. While we cannot rule out that GDP growth could be higher after major destruction caused by climate change, this growth would come from a lower level compared with the baseline, and will most likely not get back to the original baseline GDP level. It is therefore vital to also differentiate carefully between financial variables that are based on rates of change (e.g. interest rates or profit growth) and financial variables based on levels (e.g. stock prices or multiples).

the damage over this timeframe. These adaptation measures would include infrastructure reinforcements such as flood defences or additional health-care spending. By the same token, the action to reduce GHG emissions meaningfully will affect primarily the outlook for climate-related damage in the second half of this century. But, it is in the first half of this century that GHG emissions need to be lowered decisively.

**In order to analyse the implications of climate change, it makes sense to distinguish the following categories.**

1 – Exposure to the damage wrought by climate change and the ability to adapt to it.

2 – The role of GHG emissions in the production process and the overall product mix, which determine the exposure to the necessary abatement of GHG emissions.

3 – The ability and willingness to respond to the changes caused by climate change at the political, industry and company level.

**These factors will vary substantially between countries, sectors and individual companies. There will be winners and losers, both on an absolute and relative basis.** In this report, we give an overview of the economics of climate change and discuss the potential impact on different countries and regions. We plan to assess the sector and company impact in a systematic way in a future study. To start with, we outline the expected incidence of damages, the exposure to GHG emissions and the potential political and economic reactions. All three will have considerable repercussions on long-term growth prospects. Because climate change needs to be addressed first and foremost by public policy, the policy response is a key variable shaping the risk-reward profile of investments affected by climate change considerations.

**Given the uncertainty about the process of climate change itself, its impact on the global economy and the ability (and willingness) of society to combat it, scenario**

**analysis seems to be the most suitable approach** to map out the consequences. In particular, this seems a particular apt way of discussing the impact of climate change at company level and distinguishing between a 'green scenario', where bold global action to combat climate change and reduce GHG emissions is taken in the coming years, and where damage created by climate change is relatively limited; and a 'brown scenario', where decisive global action is not taken quickly enough and major repercussions from climate change have to be reckoned with in the future. We map out both scenarios below and how they compare to a long-term base case of a scenario without climate change.

Exhibit 9  
**Two Different Climate Change Scenarios**

	Base Case	Brown Scenario	Green Scenario
Damage	Medium	High	Low
GHG Emissions	Moderate cuts	Further rises	Marked cuts
GDP Growth			
- global	Trend	Below trend	Close to trend
- developing countries	Catching up	Falling back again	Leapfrogging to low-carbon world
- industrial countries	Slowing on the back of ageing	Faster first, much slower later	Slower first, much faster later
- consumer spending	Like disposable income	Below disposable income	Above disposable income
- energy infrastructure invmt.	Regular, slow replacement	Even slower replacement	Faster replacement
Technical Progress	Medium	Slower	Faster
Inflation	Broadly in line with official targets	Much higher on food, oil and soft central banks	Lower on faster productivity growth, despite carbon costs
Carbon Prices	Medium	Low	High
Oil Price	Medium	High	Low

Note that the base-case refers to a situation without climate change.

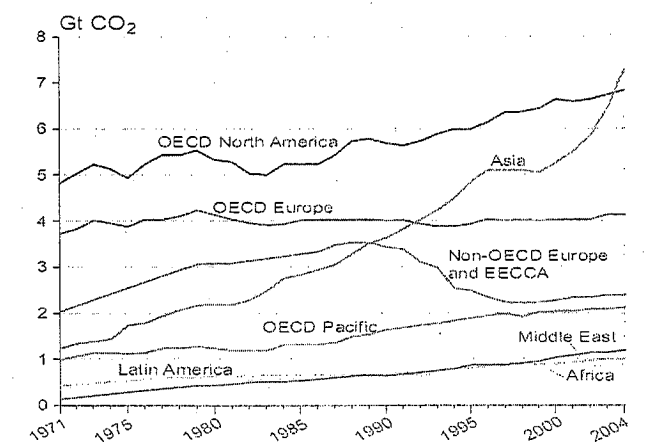
Source: Morgan Stanley Research



## Assessing the Aggregate Country Impact

Climate change is likely to have serious ramifications on the global economy and even more so on individual countries. These ramifications will be determined by a country's exposure to the physical damage created by climate change and by its GHG emission intensity. In addition to the exposure, the ability to adapt will be driving the overall effect. The ability to adapt to the changes triggered by climate change and the effort to contain them depend on a broad range of institutional, economic and technological factors, as we discuss in more detail below (see pages 27 ff).

Exhibit 10  
**Global Trends in Carbon Emissions, 1971-2004**

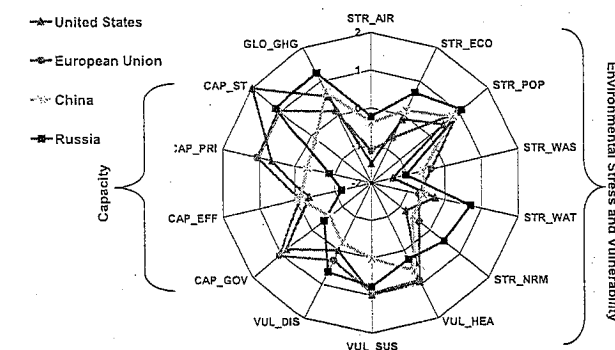


Source: IPCC

To summarise the different dimensions in a single heat-map, we have created two country screens, one for exposure to climate-related environmental damage and one for exposure to GHG emissions. We used the dataset underlying the Environmental Sustainability Index (ESI) compiled by Yale University and Columbia University and developed metrics that allow us to quantify both factors relative to the average. The ESI consists of 76 different datasets for a wide group of countries, which track their natural resource endowment, their past and present pollution levels, their environmental policy efforts and their capacity to improve their environmental performance. The ESI database facilitates a comparative analysis across countries and, in particular, aims to benchmark countries' environmental performance in very broad sense. The resulting country rankings should be interpreted as a snapshot based on the chosen set indicators.

For our purpose, we have used the sub-components on GHG emissions (per unit of GDP and per capita), the reduction of environmental stress and human vulnerability and the social and institutional capacity to improve the environmental performance. To allow meaningful cross-country comparisons, the data need to be normalised by choosing the appropriate denominator, trimming extreme readings and calculating z-scores for each variable. Exhibits 12 and 13 below show these screens for the 25 largest GHG emitters globally. In these charts the x and y axes denote the average of variables in question across the country-sample studied here. The further countries are away from the respective axis or the origin, the higher or lower their ESI ranking. Note, however, that the distance from the origin is not necessarily comparable across different screens because the charts had to be blown up to different degrees so that the countries could be distinguished from each other in the graphs. As with any aggregate assessment, the one presented here might not do full justice to the individual country concerned and a more in-depth country assessment might be useful.

Exhibit 11  
**A Comparison of Detailed Indicator ESI Scores**

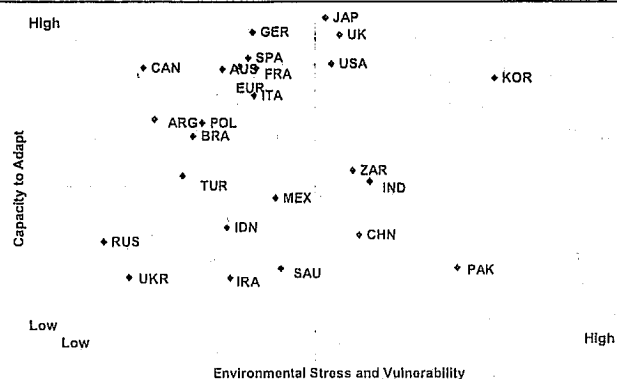


Source: ESI, Morgan Stanley Research

In terms of exposure to climate-related damage, Korea, Pakistan, China, India and South Africa seem most at risk. With the exception of South Korea, these countries also have limited ability to cope with the high degrees of human vulnerability and elevated environmental stress levels. By contrast, resource-rich transformation countries, most European countries, Canada, Australia and the big emerging market economies in Latin America seem to have relatively limited exposure to environmental damage.

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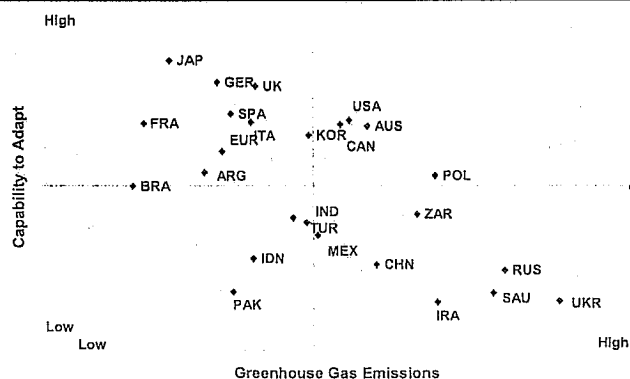
Exhibit 12  
Country Exposure to Climate Related Damage



Source: ESI, Morgan Stanley Research

As for exposure to GHG emissions, as expected, resource-rich countries such as Ukraine, Russia, Saudi-Arabia and Iran are likely to be challenged while Brazil, France, Japan and most other European countries should be least exposed to a drastic reduction in GHG in the coming years.

Exhibit 13  
Country Exposure to Greenhouse Gas Emissions



Source: ESI, Morgan Stanley Research

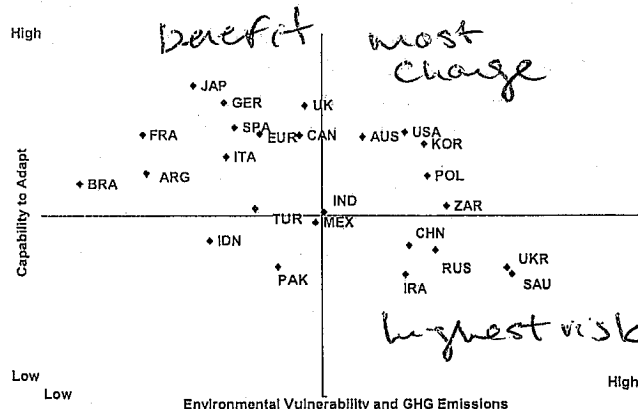
Aggregating both aspects of exposure to climate change yields several interesting country clusters in terms of the impact of climate change.

- The most exposed group are resource-rich developing and transition countries such as Ukraine, Saudi Arabia, Russia, China and Iran, which are highly exposed to climate change and GHG emissions and have a relatively limited ability to adapt.

- Another group of countries, consisting of OECD countries with some natural resources, such as Poland, South Korea, the US and Australia, has an increased exposure to climate change and GHG emissions. Contrary to the first group, these countries also have a high capability to adapt. In this group of countries you would expect to see the most drastic changes in response to climate change in the coming years.
- A number of natural resource-poor European countries and Japan form another country cluster. This cluster, which includes France, Japan, Germany, Spain and Italy, is characterised by low exposure to climate change and high ability to adapt. These countries are the most likely to be net beneficiaries of climate change and, more importantly, the efforts made to contain it. Several of the countries in this group seem to have established a first-mover advantage in reducing carbon emissions.
- Next to these country clusters, some individual emerging markets stand out, notably Brazil, which exhibits the lowest overall exposure to climate change, based on this metric, and has an above-average ability to adapt.

On the whole our findings underscore the more pronounced vulnerability of developing and emerging market economies compared to most industrial countries. But there are a number of interesting differences within each group of countries.

Exhibit 14  
Top 25 Greenhouse Gas Emitters: Exposure to Climate Change and Ability to Adapt



Source: ESI, Morgan Stanley Research

## The Economic Impact of Climate Change

Climate change will likely erode global output via its negative repercussions on the global workforce, the existing capital stock and the productivity of both. While the workforce will grapple mainly with the adverse impact of climate change on health (incl. higher mortality, greater incidence of sickness), the existing capital stock is at risk from physical damage (e.g. (hurricanes, floods). Unless these negative effects are offset by rising employment ratios, faster capital accumulation or additional technical progress, global output will likely be lower because of climate change.

**Depending on the role of climate-sensitive sectors, countries face very different risks from climate change.**

Sectors most likely affected by climate change include agriculture, tourism, leisure, property, and all labour-intensive sectors. Other sectors will be mostly affected by the efforts to contain climate change by reducing emissions. This includes heavy emitters like energy, transport, industry, construction and real estate (especially in industrial countries) and also sectors connected to adaptation measures, which are taken to limit the unavoidable consequences of climate change (infrastructure reinforcements, financial services, capital goods, healthcare).

**In general, developing countries are hit harder by the damage created by climate change,** for several reasons: They often already have a geographical disadvantage to start with. They are also more dependent on agriculture and tourism. In addition, emerging market and developing economies tend to lack adequate public services and the resources to finance necessary adaptation measures. After a period of successfully catching up with industrial countries in terms of GDP per capita, some emerging market economies, especially at the lower end of the income scale, could therefore see their GDP per capita levels start to fall behind again.

**Country size matters.** Larger countries should be in a better position to cope with climate change to the extent that they are geologically and ecologically more diverse than smaller countries. Well integrated, regional economic free-trade areas should help to absorb the consequences of climate change. However, such regional free-trade agreements might also be put to a serious stress-test when climate change creates major asymmetric shocks. This holds true in particular for monetary unions and fixed or quasi-fixed exchange rate regimes, which in an extreme case could fall apart in the event of a major climate shock.

**The global nature of climate change suggests that international trade and capital flows will likely be affected.**

For example, the currently observed pattern of growth could shift due to damage created by climate change. Likewise, the different actions being taken to combat climate change could have ramifications for the pattern of economic activity. International agreements on climate change are likely to create new trade and capital flows relating directly to the international trade in emission permits/credits. Finally, in some parts of the world climate stress will likely lead to more widespread migration. At the global level, concerns about climate change could further fuel protectionism. Unfortunately, environmental concerns make a great scapegoat for protectionist interests.

**With the potential output lower because of climate change, inflationary pressures would rise.** Natural resource constraints will likely become more binding as environmental stress increases (water, land). Increasing food prices, rising commodity prices and a move towards green taxes (carbon taxes, road pricing) will add to consumer price inflation and the currently observed trends are a timely reminder of the building inflation pressure. In addition, consumer preferences should shift towards goods and services with a lower carbon footprint, which can often be more expensive. As ever, the central bank reaction is crucial for the long-term inflation prospects. History shows that central banks tend to tolerate inflation overshoots stemming from one-off external factors, such as freak weather or veterinary diseases. This has especially been the case in emergency situations, when inflation concerns become of secondary importance. Historically, major spikes in consumer price inflation have often coincided with military conflicts, which caused the regular economic order to break down and forced central banks to abandon their price stability targets in favour of other objectives. In extreme cases, inflation spikes could coincide with major climate-related disruptions in the future.

**On the whole, climate change will cause an increase in stagflationary pressures, especially in emerging market economies** which will probably experience the biggest dent to potential output and where climate-sensitive products like food account for a bigger share of the CPI basket; where central banks might not enjoy full institutional independence; and where underlying inflation is generally higher due to the Balassa-Samuelson effect. Another crucial factor in determining the extent of stagflationary pressure is the mechanism setting wages and prices. The wage and price-setting mechanism determines whether an external price

shock, due to a severe drought, say, leads to a second round effect that sets in motion the dreaded price-wage-spiral. After the global economy has been characterised by disinflation over the last 20 years, inflation is likely to return, we think, helped by climate change. Note that climate change is only one reason for our call for a return of inflation. As a long-term phenomenon, climate change should only have a limited effect on inflation. But the abrupt weather events it is expected to cause could trigger temporary run-ups in cost-push inflation.

In addition, random climate events will likely add to the volatility of the business cycle. Such random events make activity data more difficult to interpret and the outlook less certain. As a result, they also make policy mistakes, both in monetary and fiscal policy, more frequent. More generally, the uncertainty created by both the impact of climate change and the political response to it should cause risk premiums to rise. The higher uncertainty and greater volatility will likely have additional negative repercussions on long-term growth dynamics as it would weigh on investment spending.

Climate change itself and even more so the attempts to reduce GHG will likely produce massive structural change. Countries with more flexible product and labour markets will likely be able to cope with structural change better than others. Much will depend on how innovative a country's system is regarding R&D spending, patent generation, and its ability to fund new technological ventures. Next to the generation of new technologies, the speed with which these new technologies are diffused within the overall economy differs considerably between nations. The experience of the Information Communications Technology (ICT) boom of the late 1990s shows that countries differ not only in the speed at which they are able to adopt the new technological platforms, but also in their ability to reap the benefits of higher productivity. Here the size of the economy (or the regional trade block) might be a key determinant of the economies of scale that could be realised.

To sum up, we see the following broad implications of climate change for the different asset classes. It is often felt that climate change is a specialist topic for investors with a specific Socially Responsible Investment (SRI) mandate or for investors with a very specific sector interest, such as alternative energy, utilities or transport. However, we believe that understanding the risks and opportunities created by climate change is key to a much wider range of investors as all asset classes are likely to be affected.

- **Risky assets**, such as equities, would likely be negatively affected by a less favourable long-term growth outlook and a higher volatility of the business cycle, which should cause risk-premiums to rise.
- **In equity markets**, there will be highly differentiated country, sector and company implications. In this study, we focus mainly on the country impact because the relevant policy dimension is still mostly national.
- **Government bonds** will also be affected by lower trend growth, higher cyclical volatility and rising inflationary pressures. In addition, large uninsurable risks as well as some insurable but actually uninsured risks are likely to fall back onto public finances. At the margin, climate change should cause inflation risk premiums to rise and yield curves to steepen.
- **Foreign exchange markets** will have to get to grips with the relative impact of climate change on different countries and the implications of climate change for international trade and capital flows, including international trade in emission permits/credits. Countries suffering from climate-related damages might see their currency weakening.

## Another Dose of Creative Destruction

**Another shock to the global economy.** After the collapse of communism, which led to a massive rise in the global workforce, and the arrival of the internet, which caused distance to change dramatically for many businesses, climate change could be the next major shock to the global economy. Like the fall of the Iron Curtain, climate change could cause part of the existing capital stock to become obsolete as the production structure suddenly faces a big shift in relative prices (driven by carbon pricing). In addition, climate change could trigger major changes in global workforce dynamics. In my view, efforts to reduce GHG emissions and raise energy efficiency have the potential to instigate a technological revolution. The internet has changed the global economic landscape profoundly over the last 10 to 15 years by dramatically changing the concept of distance for many production processes and supply chains. Note that there are some important differences though between the ICT revolution and efforts to contain climate change. The internet started out as a bottom-up technological revolution. As such, it challenged many established companies in what has become known as the 'old economy', unleashing a massive dose of creative destruction. Containing climate change will likely be top-down technological change heavily influenced by government policies.

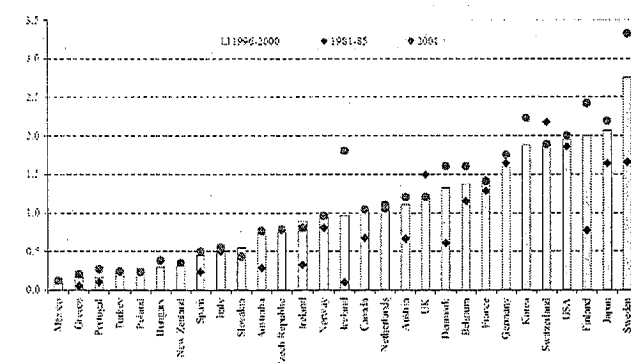
**The political dimension will be vitally important for climate change issues.** Climate change is not only the largest externality ever experienced globally, rectifying it will also require the most far-reaching government intervention. To better understand government decision-making, it makes sense to draw on the extensive academic work in the area of public choice, a branch of economics that tries to explain government decisions in the context of rational behaviour. In the academic literature on public choice, 'rent-seeking' refers to attempts of economic agents to influence the distribution of income (especially rents) arising from environmental policy by lobbying for a regulatory standard or a tradable emission permit rather than an emission tax. The large list of exemptions to many emission taxes, the widespread use of regulatory standards and, more recently, tradable emission permits, is testament to the success of these lobbying efforts. In addition, rational voter-behaviour can result in too low a level of environmental protection because individuals lack the incentives to obtain all the necessary information on climate change and therefore don't express their environmental preferences properly. In this context the rise of 'green' parties in many countries is an interesting breaking of the mould. Models of bureaucratic behaviour explain the inefficiencies

arising from the implementation of an environmental policy target by an environmental protection agency. Given the ambitious emission reductions targeted by many countries, these inefficiencies could potentially make a considerable difference. In our view, a full understanding of government decision-making and the factors that drive it will be essential in getting the climate story right.

**The upshot of the public-choice approach of environmental policy** is that governments are prone to use inefficient means of environmental protection such as regulation because it better suits their own interests and those of the key interest groups than using efficient measures. In addition, government policy often tends to protect incumbents because they are able to lobby for their interests more effectively than yet-to-be-established start-up companies offering alternative technologies or millions of consumers (present and future) who are hit by environmental pollution. While we have seen considerable progress in environmental policy-making over the last decades, it is worth bearing in mind that policies to combat climate change are susceptible to all of these instances of government failure.

Exhibit 15

### Business Sector R&D Spending (% of GDP)



Source: OECD

**Policy-makers are not well suited to picking winners in technology races.** This should rather be left to the trial and error process of market competition. Instead of pushing a certain technology by means of government intervention, it would be more effective for government policy to improve the general framework for R&D, venture capital and for SME financing. In addition, it should foster faster technological diffusion by providing information and, more generally, enable economies to respond rapidly to structural change. The Nordic

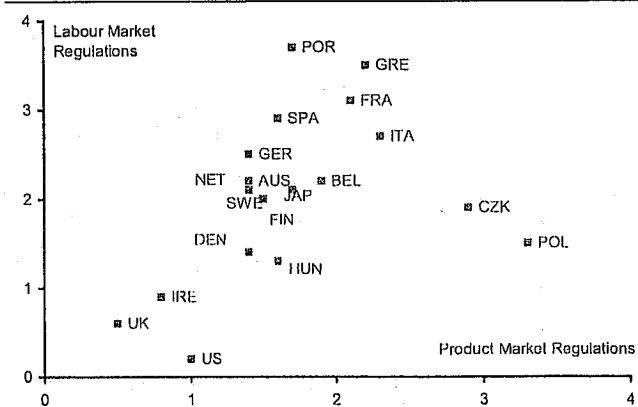
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economies, Japan and the US generally do better on this score than, say, southern Europe (see Exhibit 15). Rigid product market regulations and extensive employment protection make it harder to change the resource allocation towards a low-carbon structure (see Exhibit 16). All of these factors will be crucial in determining how well different countries will be able to deal with the technological challenges posed by climate change.

To this end, undistorted competition between different approaches to contain climate change is essential. The EU Single Market ensures institutional competition between different environmental policy approaches within the EU. The EU manifests diverse energy mixes as individual countries have adopted different strategies to raise their energy efficiency. In addition, by being more energy efficient already, Europe also seems to enjoy a first-mover advantage. It is already a big manufacturer of environmental technology and a leading exporter. Like Japan, it is already more energy efficient than the US and many emerging markets. However, as the ICT boom showed, Europe seems to find it more difficult to adapt to technological and structural change. Despite considerable ICT investment, Europe has not yet been able to reap the same benefits as the US (higher productivity and higher job growth). Hence, the US might not just be a big swing factor in global climate politics, it could also be where a lot of the technological change and innovation takes place.

Like the internet, globalisation or the collapse of communism, efforts to decarbonise the global economy will likely cause another bout of creative destruction. Accelerated change and the rapid resource reallocation it triggers typically help to raise overall productivity and income. At the same time, the change in relative prices created by climate change itself and the efforts to contain them will likely affect the remuneration of production factors, labour and capital, and the distribution of income, that is, the profit share and the wage share, depending on how the capital-to-labour ratio changes as a result. Over the last decade, globalization has caused the global capital/labour ratio to fall sharply as the global workforce has expanded massively. As a result, the wage share has been compressed while the profit share has expanded, allowing profits to expand more quickly than overall GDP. Equipping the enlarged global workforce with machinery, equipment and infrastructure should support a long-term upswing in investment spending, we think, and a prolonged rise in real interest rates. These investment needs are likely to be reinforced by the need to contain climate change. Reducing GHG emissions mostly needs capital rather than labour. Hence, interest rates and profits are set to rise further relative to wages, which will likely see further downward pressure.

Exhibit 16  
**Flexibility of Product and Labour Market Regulations**



Higher values mean more rigid regulations based on summary indicators of product market regulations and employment protection  
Source: OECD, Morgan Stanley Research

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## The Role of Technology

Both the innovation of new technologies and the diffusion of existing low-carbon technologies lie at the heart of any efforts to contain climate change by reducing GHG emissions drastically. Fostering technical progress is therefore becoming increasingly a focus of government policy after carbon-pricing schemes have been introduced in many industrialised countries. As a result, R&D programs, generous feed-in tariffs for renewable energy, energy-efficient product standards and subsidies for low-carbon technologies and products are likely to rise further. While government action might be justified if incentives to reduce emissions via taxes, permits or regulation are not sufficient to generate significant technological advances, government intervention will also have important consequences for market structure and competition.

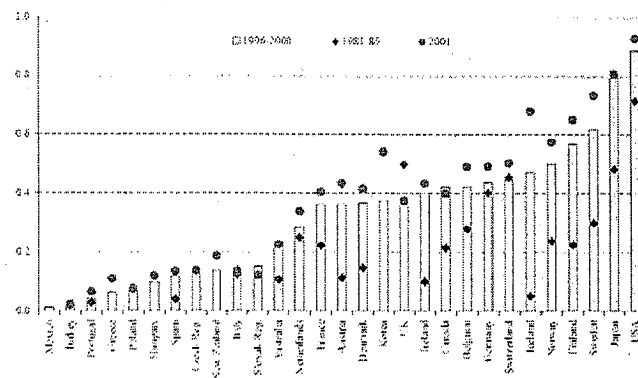
Many of the considerations about the need to stimulate low-carbon innovations are not exclusive to environmental technology. Many would apply to technological innovation in general. The economic basis for government action to promote innovation is the 'new growth theory'. According to this theory, technological innovations produce positive spillover effects. Due to these positive externalities, the private sector does not undertake enough innovation. Hence, the government should step in and fund R&D, especially in the area of basic science.<sup>1</sup>

Strengthening patent legislation and intellectual property rights is another important aspect of safeguarding innovations. The new growth theory created a wave of industrial policy programmes in the 1980s and 1990s aimed at establishing technological leaders through R&D subsidies. One of the most high-profile cases of these programmes is the creation of Airbus. While the Airbus example shows that government policy can establish a new player in a high-tech market, economists counter that the amount of tax revenue spent on subsidies, considerably outweighs the benefits. In the case of environmental technology, the potential reduction in environmental damage is an additional argument in favour of government intervention.

<sup>1</sup> Empirically, long-term economic growth is closely linked to technical progress via its repercussions on productivity growth. In this context, R&D is key. While public R&D plays a key role in stimulating private sector R&D, according to the OECD, it is the latter that seems to have a more meaningful impact on economic growth.

Exhibit 17

### Researchers in the Business Sector, % of Dependent Employees



Source: OECD

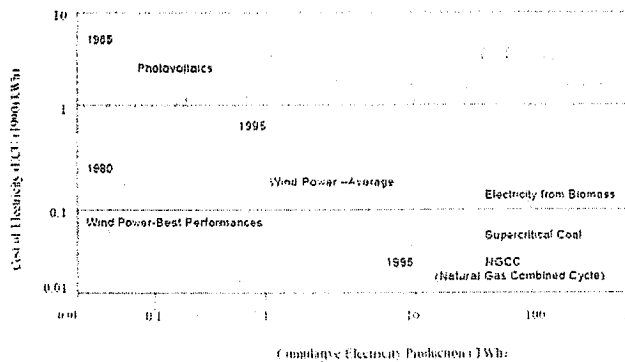
In the real world, barriers to market entry due to the fixed costs of a major R&D program are a key factor in explaining oligopolistic market structures and two-way international trade, where countries are at the same time exporters and importers of the same goods — cars, for example. The presence of fixed R&D costs explains why companies might enjoy a first-mover advantage in production processes that are subject to economies of scale. In the global race for global technological leadership, these first-mover advantages can lead to an acquired comparative advantage. Once the economies of scale have been fully leveraged, the company or country becomes a major exporter.

With regard to environmental policy, the presence of economies of scale has led Professor Michael Porter of Harvard University to argue that a tight, proactive environmental policy can help create a lead in environmental technology that will lead to a strong export position. Thus far, empirical support for the Porter hypothesis has been very limited. This might change, however, once environmental policy becomes a more important driving force of the overall economy. Coming back to climate change, a whole range of low-carbon technologies is already available. While many technologies are not yet cost-competitive relative to fossil fuels, they are expected to become more competitive in the future for two reasons — carbon-pricing and economies of scale.<sup>2</sup>

<sup>2</sup> Consumption of energy is subsidised by almost US\$250bn per year in non OECD countries, according to the IEA. Rethinking the implications of these subsidies and their role in creating a carbon lock-in would seem a sensible starting point.

Exhibit 18

### Learning Curve Estimates for Energy Technologies



Source: Stern Report based on McDonald and Schrattenholzer (1999)

Experience shows that low carbon technologies are subject to significant learning curves and economies of scale. From this point of view, a large home market, generous subsidies and ambitious emission targets can be an advantage. Historically, a doubling of the installed capacity has led costs to fall between 3% and 35% (see Exhibit 18). However, sunk costs associated with the current high-carbon energy infrastructure create a carbon lock-in. This lock-in is difficult to overcome given the slow turnover of the energy capital stock. Therefore, government action might be needed to break carbon lock-ins, raise the speed of capital-stock turnover and overcome market entry barriers.

Despite the debate on climate change and energy-security, R&D expenditure in the energy sector has been trending down since the 1980s. The downward trend in public energy R&D, which has halved since the early 1980s, is at odds with rising overall public R&D expenditure. Several factors help to explain current low R&D levels and the slow deployment of low-carbon technologies in the energy sector (also see Stern Report):

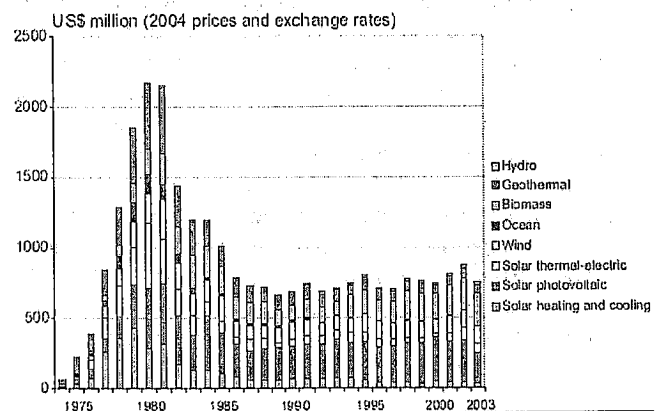
- The market structure (a natural monopoly in distribution) is not very conducive to innovation and change.
- There are substantial market distortions due to direct and indirect subsidies for fossil fuels in many industrial countries and even more so in developing countries.

- The decline in oil prices in the 1980s and beyond was only reversed relatively recently. The downtrend caused energy R&D to stagnate for many years.
- As a result of lower oil prices and several incidents, many governments have cut back on R&D budgets geared towards nuclear.
- The slow learning process means it takes typically several decades before a technology become economically viable.
- The slow turnover of the capital stock slows the deployment of new technologies. Energy market liberalisation seems to have contributed by inducing better leverage of the existing capital stock.
- The existing infrastructure is geared towards centralised power generation, wasting a considerable amount of energy in the transmission.
- The existing infrastructure is largely unable to store energy. However, renewable energy, which might vary over time, needs conventional back-up (hydro power could be used as a store).

With governments now focusing on climate change and with technology key to progress, some of these challenges will be overcome in the future. As a result, existing market barriers could be lifted and energy markets become more competitive.

Exhibit 19

### Renewable Energy R&D Spending on the Decline



Source: IPCC



## International Trade Aspects

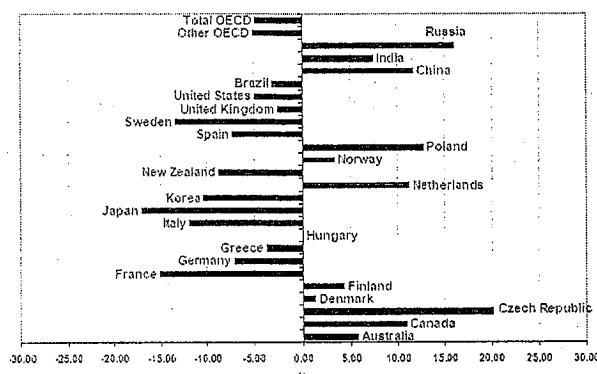
Climate change clearly has a global dimension, both in terms of its causes and its consequences. As such, it is closely intertwined with international trade, capital flows and cross-border migration. Global economic growth is likely to be affected by climate change. Equally, shifts in the global economic landscape will likely affect climate change. In addition, the environmental issues are likely to become a more important factor in determining the comparative advantages of individual countries, either because of the damage caused by climate change or because the efforts to reduce carbon emissions start to become a material factor in location decisions. In addition, coordinated efforts to contain climate change through, amongst other things, international trade in emission permits can lead to a completely new set of trade and capital flows.

Many countries are concerned about the loss of competitiveness and jobs caused by aggressively reducing GHG emissions. Many top emitters are very open economies that are highly integrated into the global economy. Hence, serious actions to cut GHG emissions could affect international trade patterns and movements of factors of production (workers, capital). The ability to reduce CO<sub>2</sub> cost-effectively is essential to maintaining competitiveness, while at the same time reducing emissions. As we argued earlier, selling excess abatement potential (CDM) could become the new driver of emerging market economies' exports. At the same time, exposure to damage caused by climate change could result in shifts in comparative advantages and potentially cause multinational companies to reconsider their operations in very exposed developing countries.

International trade flows include many goods that have a high carbon or GHG content. Estimating the carbon content of international trade flows shows large outflows in the Czech Republic, Russia, Poland and China and to a lesser extent India and Australia. By contrast, Japan, France, Sweden and South Korea would show considerably higher emissions of CO<sub>2</sub> if imported emissions were included. To a lesser extent, this also holds true for Germany, the US, Brazil and the UK. For industrial countries, the average emission level would rise by about 5%, according to OECD estimates, while emissions in developing countries would decline.

Exhibit 20

### Trade Balance in CO<sub>2</sub> Emissions % of Domestic Value Added



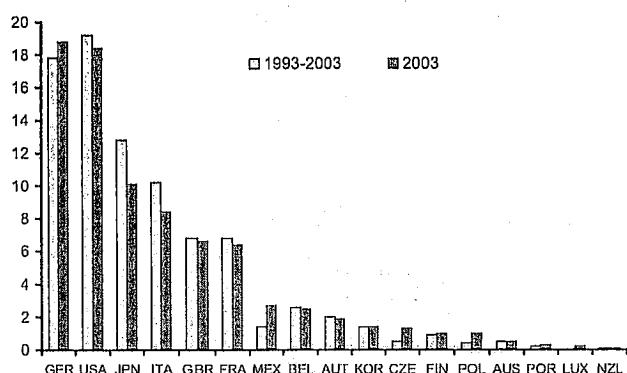
Source: Ahmad and Wyckoff

**Abatement costs will not be felt uniformly across countries and sectors.** The timing of action in other countries will likely affect the cost of reducing emissions. Given that international trade now accounts for roughly half of global GDP, can countries reduce emissions at all without losing competitiveness? However, concerns that carbon-intensive industries could relocate due to loss of competitiveness seem overblown. Only a relatively small number of carbon-intensive industries would feel a significant impact even if GHG emissions were fully priced. Even for those industries, climate policy would be only one of many factors in their decision about location of production. In addition, cross-border trade and investment is mostly regional. If regions move together, like the EU, the impact should be contained further. So far, there is little evidence that globalization prevents action against climate change or that free trade causes additional environmental damage.

**Since GHG emissions are a global externality and as economic activities might be moving to other areas with no or a less strict climate policy,** and as commitments to reduce GHG emissions under the Kyoto Protocol vary considerably, there are concerns that cross-border leakage of carbon emissions will prove counterproductive. The IPCC concluded that in the context of the Kyoto Protocol the relocation of carbon intensive industries to non-Annex I countries and the wider impact of trade flows in response to changes in relative prices might lead to very limited carbon leakage in the order of 5% to 20%.

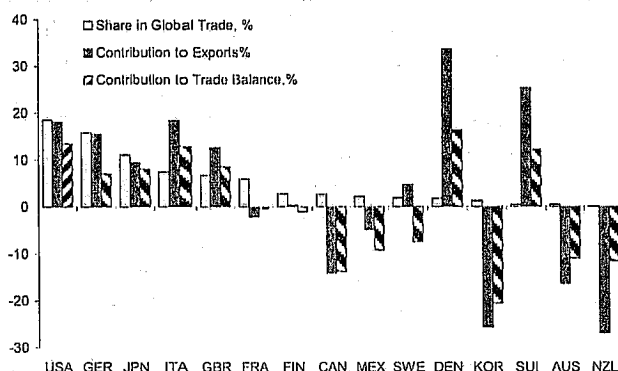
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Exhibit 21  
**Shares in International Trade in Environmental Protection Equipment**



Source: NIW, Morgan Stanley Research

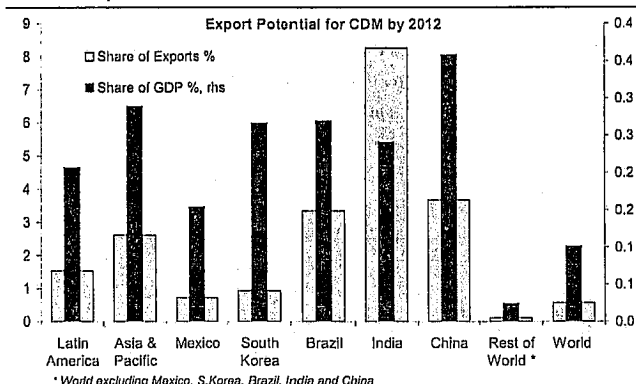
Exhibit 22  
**Many Industrial Countries Have a Strong Position in Trading Environmental Protection Equipment**



Source: NIW, Morgan Stanley Research

Carbon leakage could be reduced further by international emission trading such as CDM. Key savings can be made from international trade in emission permits/credits as (1) some countries which are rich in natural resources will be able to reduce emissions more cheaply than others; (2) countries that have already largely decarbonised their energy sector face higher costs for further savings; (3) some countries are currently in the process of making large capital investments in their energy sector (India, China) and hence would not have to write off the existing capital stock. The IPCC estimates that allowing for flexible mechanisms under Kyoto (incl. international emissions trading, CDM and JI) could lower abatement costs by 1% of global GDP.

Exhibit 23  
**CDM Export Potential, 2012**



Based on a price of US\$30/t. Source: UNEP Risoe CDM/JI Pipeline Analysis and Database, Morgan Stanley Research estimates

Many factors shape competitiveness and foreign direct investment decisions, including labour costs and skills, market size, political stability, income levels, physical infrastructure and a wide range of government policies (taxes, financial and investment regulations). Environmental policy regulations are only one factor and, according to most empirical studies, not yet a significant one. As we argued above, a strict environmental policy might even create a first-mover advantage by shaping new technological leaders in abatement technology by setting tough emission standards. There is some evidence that industrial countries, which on the whole have considerably tighter environmental policy regulations than developing countries, have acquired a strong position in the international trade of environmental protection equipment (Exhibit 22). Government policy likely played a role in the current strong market position of German renewables, French nuclear and Japanese hybrid technology.

In conclusion, concerns about carbon leakage and the potential loss of competitiveness seem overblown, in our view. At least at the anecdotal level often the opposite can be observed. Where clean technologies are disseminated internationally there might even be positive spillover effects. However, environmental concerns have been used successfully in the past as a scapegoat for protectionism and for securing industry-exemptions from environmental regulations or taxes. There is therefore a serious risk that concern about climate change will become another red herring in international trade negotiations.

## Financial Services Sector and Financial Markets

The financial services industry is key for sharing climate-related risks efficiently, overcoming financing constraints and facilitating emission trading. While climate change brings about a gradual change in the global ecosystem, the associated rise in extreme weather events, the highly differentiated country impact and the risk of abrupt large-scale effects need to be taken into account by both global financial markets and the global financial services industry. The expected rise in environmental damage as a result of climate change, the increase in the volatility of output, sales and profits, and the immense financing needs arising from obligations to reduce carbon emissions put financial markets firmly at the heart of both mitigation and adaption strategies.

**Efficient sharing of climate-related risk:** it is clear that a certain degree of damage from climate change over the coming decades is unavoidable. To minimise the repercussions on economic activity and individual behaviour, the risk of suffering these damages need to be shared efficiently. From an economic point of view, the risk should be shifted from a risk-averse economic agent to one that is less risk averse (or even risk neutral) in exchange for paying a premium.<sup>3</sup> In reality, this would typically be a private insurance company or, in some cases, the government. Only recently as the insurance industry started to securitize some large-scale risks and sell them as catastrophe bonds into the market, investors have also emerged as buyers of risks. Due to their ability to pool risks across a sufficiently large number of individuals that could face losses, insurance companies, governments and investors should exhibit a higher risk tolerance than, say, an individual household.

**A number of conditions need to hold for private sector insurance to be able to offer effective cover against losses.** First, the probability of the insured event for a given individual or cohort is independent of anyone else's probability. In this case, thanks to the law of large numbers, the insurance company (or the state) can calculate the expected damages and hence the premium with near certainty. Second, the probability distribution underlying the insured event has to be known or be estimated with a reasonable degree of certainty. Finally, there should be no significant moral hazard or adverse selection. The former arises if an individual can directly

influence the probability of the insured event without the insurer being able to tell. The latter arises in a situation where individuals differ with respect to their idiosyncratic probability to incur the insured risk. The first two conditions are the most relevant for climate change related damages and risk sharing.

**In the case of climate change, obstacles to the provision of private insurance cover arise from the fact that damages will often be highly correlated** at least at the national or regional level and that the probability distributions underlying insured events such as flooding could be subject to systematic shifts. If the high correlation of risks is known *ex ante*, insurance cover typically becomes prohibitively expensive and some damages tend to fall back onto the government, for example, water damage in flood-prone areas. If it only turns out *ex post* that damages were highly correlated or if the probability distribution underlying the damages has shifted substantially, in extreme cases, this can undermine the financial position of an insurer or a reinsurance company. In this context, the presence of long tails in the probability distribution of possible temperature changes and non-linearities in the climate reaction are a source of concern.

In a number of recent events, however, the industry has shown remarkable resilience. Because climate change is global in nature, any systematic insurance solution would need to aim at pooling risks globally, thereby balancing out the highly differentiated regional effects. Given that risk tolerance is often a function of the size of the expected loss relative to income (or wealth), industrial countries are in a good position to insure emerging market economies against damage caused by climate change. As some of them, especially the poorer ones, will lack a developed insurance industry and in some cases also the financial means to take out such cover, it might make sense to set up a global fund for such instances.

**Apart from insurance, a number of climate-related risks can be and are already traded in financial markets.**

Tradable risks include the risks of adverse weather conditions and major environmental catastrophes. The former can already be hedged by using weather derivatives (usually defined by the number of heating/cooling days, precipitation levels or storm strength). As the latter are often large scale and hence by definition highly correlated across a significant population, they might overreach the scope of an individual insurer or an individual government. The insurance industry has therefore started to securitize these risks by issuing catastrophe bonds (cat bonds). These bonds were first issued

<sup>3</sup> As long as the insurance premium is actuarially fair, that is, equal to the expected value of the potential damages, a risk-averse individual prefers to pay this expected value rather than face the uncertain prospect of not incurring any damage or incurring a rather substantial damage.

in the early 1990s when Hurricane Andrew tested the limits of the reinsurance industry's ability to absorb risks. Essentially, cat bonds pay the principal when a pre-defined catastrophe does not occur. If the catastrophe does strike, the principal isn't repaid to investors. It is used to cover the losses incurred instead. Last year, issuance of cat bonds more than doubled, reaching nearly US\$5 billion, underlining the dynamism in the sector. In future, when emission permits under the European Emission Trading Scheme become on- rather than off-balance sheet items, there will likely also be demand from companies subject to the ETS to hedge against abrupt movements in the price of carbon, which would trigger a need to mark-to-market the emission permits. The windfall profits seen in the first phase of the ETS for some companies give an idea of the potential size of the profit impact. In conclusion, financial markets will likely play an important role in ensuring an efficient sharing of the risks surrounding climate change.

**Financial markets will also be instrumental in overcoming budget constraints in financing new infrastructure investment and raising the capital needed for these investments.** In some cases, these can be pure private sector investments. In other cases, they will have to be public-private partnerships. In many cases, the investment horizons for these projects will be very long due to the longevity of the capital stock involved (power plants, public transport, buildings). Given that many pension funds and life insurance companies still face a significant shortfall in the duration of their assets relative to their liabilities, investing in long-duration assets such as infrastructure is an alternative worth considering in a world of limited supply of long-duration government bonds. In addition, infrastructure investments also offer some protection against the risk of inflation over the medium- to long-term and hence offer an interesting option other than inflation-linked bonds.

**Facilitating and financing low-carbon technologies and innovations:** long-term investors such as pension funds were instrumental in the 1990s in funding many research and development projects in the IT space by setting aside part of their investments for venture capital. Such a mobilisation of financial resources would also be essential for bringing about technological advances towards a low-carbon economy. However, compared to the ICT industry, many of the major research and development projects are on a much bigger

scale, such as Carbon Capture and Sequestration (CCS, see page 35). My colleague Robert Feldman therefore proposes that Sovereign Wealth Funds (SWFs) would have the right profile in terms of risk appetite, size and investment horizon to step in and fund major R&D projects in environmental protection (see *SWF – Save the World Funds*, June 11, 2007). I would add that many of the countries in which fast growing SWFs reside, have a profound interest in fast-tracking low-carbon technologies, as this would allow them to leapfrog to a low-carbon infrastructure and avoid at least part of the environmental damage that threatens to undermine their long-term growth potential.

**While there are clearly substantial opportunities for the financial industry, there are also a number of serious risks involved.** As mentioned earlier, ignoring or misjudging the impact of climate change and/or the extent of emission reductions can cause the actual risk-reward profile to turn out rather different from the projected one. Hence, a detailed sensitivity analysis of each investment case, for example, using the green and the brown scenario discussed above, will be key. From a broader portfolio perspective, it is also important to be cognizant of the systemic risks that can be caused by climate change. Such systemic risks would include the risk of physical damage to the market infrastructure as many financial centres are based in low-lying coastal areas. In addition, the risks created by climate change will often be highly correlated. For some it might not even be possible to pool them effectively at the global level. Rises in sea levels, for example, will likely only vary in degrees. In the case of some extremely large risks, it will be essential to repackage these risks and sell them into the financial markets. The recent concerns about special purpose off-balance sheet vehicles and untransparent pricing of credit derivatives could potentially make it more difficult for insurers to overcome their capital constraints, in particular in the face of the Solvency II regulation. Furthermore, banks, rating agencies, and investors might be miscalculating long-term country risk if they disregard the systematic impact of climate change on individual countries.

## The Scientific Basis

While we do not discuss the scientific evidence on climate change in detail here, it is important nonetheless to identify the main characteristics of the science underlying climate change. These characteristics shape the risk-reward profile of the potential impact of climate change and thereby define different investment scenarios. The main scientific characteristics (see, for example, the Stern Report produced by the UK Treasury in October 2006) suggest that climate change and its impact will likely:

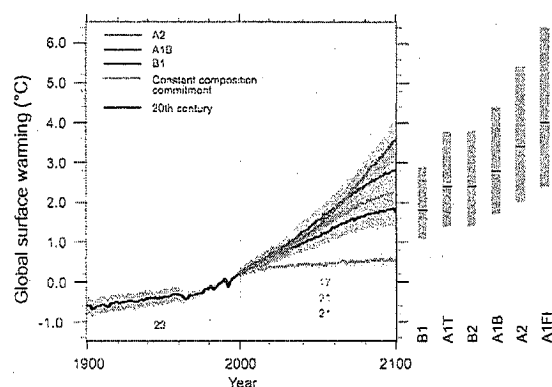
- be very long-term in nature, spanning many decades, if not centuries;
- show very long time-lags between cause and effect;
- still be somewhat uncertain globally regarding the extent of climate change;
- be much more uncertain regionally because of very differentiated regional effects;
- have a probability distribution with very long-tails at higher temperatures;
- be non-linear in many aspects, including self-reinforcing dynamics;
- be subject to unknown threshold levels beyond which the dynamics could change dramatically;
- see some interaction between different aspects of climate change; and
- be much harder to grasp for precipitation than for temperature changes.

The last characteristic underscores that water will likely be a key variable through which climate change will affect the global economy (see Exhibit 27). While some regions will struggle with a higher frequency of droughts, others will have to contend with more floods. Together with falling water quality, this could threaten the livelihoods of 12.5% of the population, especially on the Indian subcontinent and in Latin America, according to the Stern Report. In addition, rising sea levels will likely put pressure on coastal regions, especially in Southeast Asia and islands in the Caribbean and the Pacific. Countries most likely to be

affected by rising sea levels are Vietnam and Bangladesh, according to the same report. A number of large cities such as Tokyo, New York, London, Mumbai and Hong Kong are all situated close to the coast. On the other hand, if the North Atlantic thermohaline circulation were to be weakened, this would counteract warming in Europe and Northeast America. Hence, water could be an important investment theme in the context of climate change. Water will also be a key risk factor in any scenario analysis.

Exhibit 24

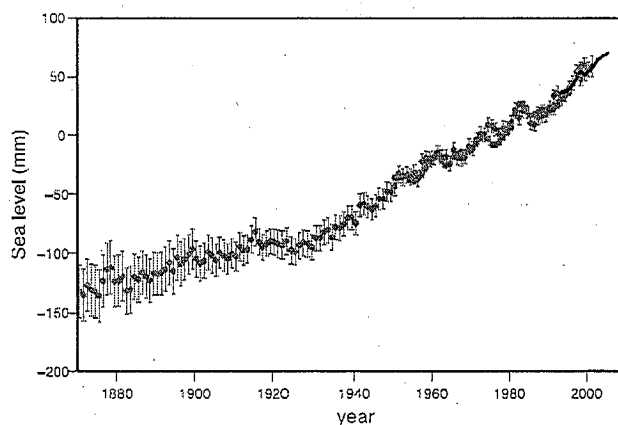
### Projected Increase in Global Temperature



A2, A1B, B1 refer to different scenarios the IPCC is using to describe different growth trajectories and different degree of international political cooperation. Source: IPCC

Exhibit 25

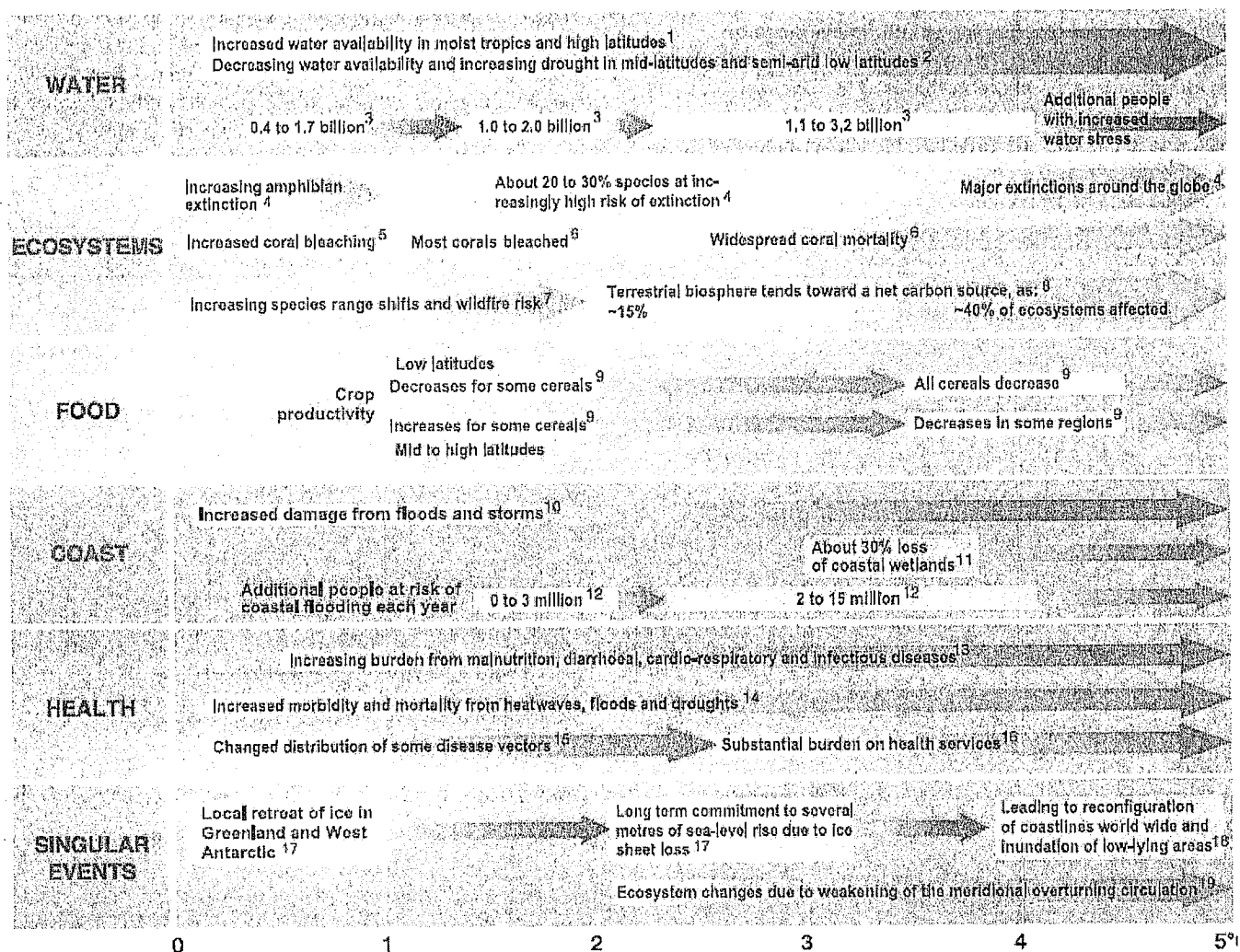
### Measured Sea Level Is Clearly on the Rise Globally



Annual averages of the global mean sea level (mm). The left part of the curve shows reconstructed sea level fields since 1870 (updated from Church and White, 2006); the right part of the curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth, 2004) and the black upper right part is based on satellite altimetry (Leuliette et al., 2004). Error bars show 90% confidence intervals. Source: IPCC

Exhibit 26

## Global Temperature Increases and Their Potential Impacts on Different Eco-Systems

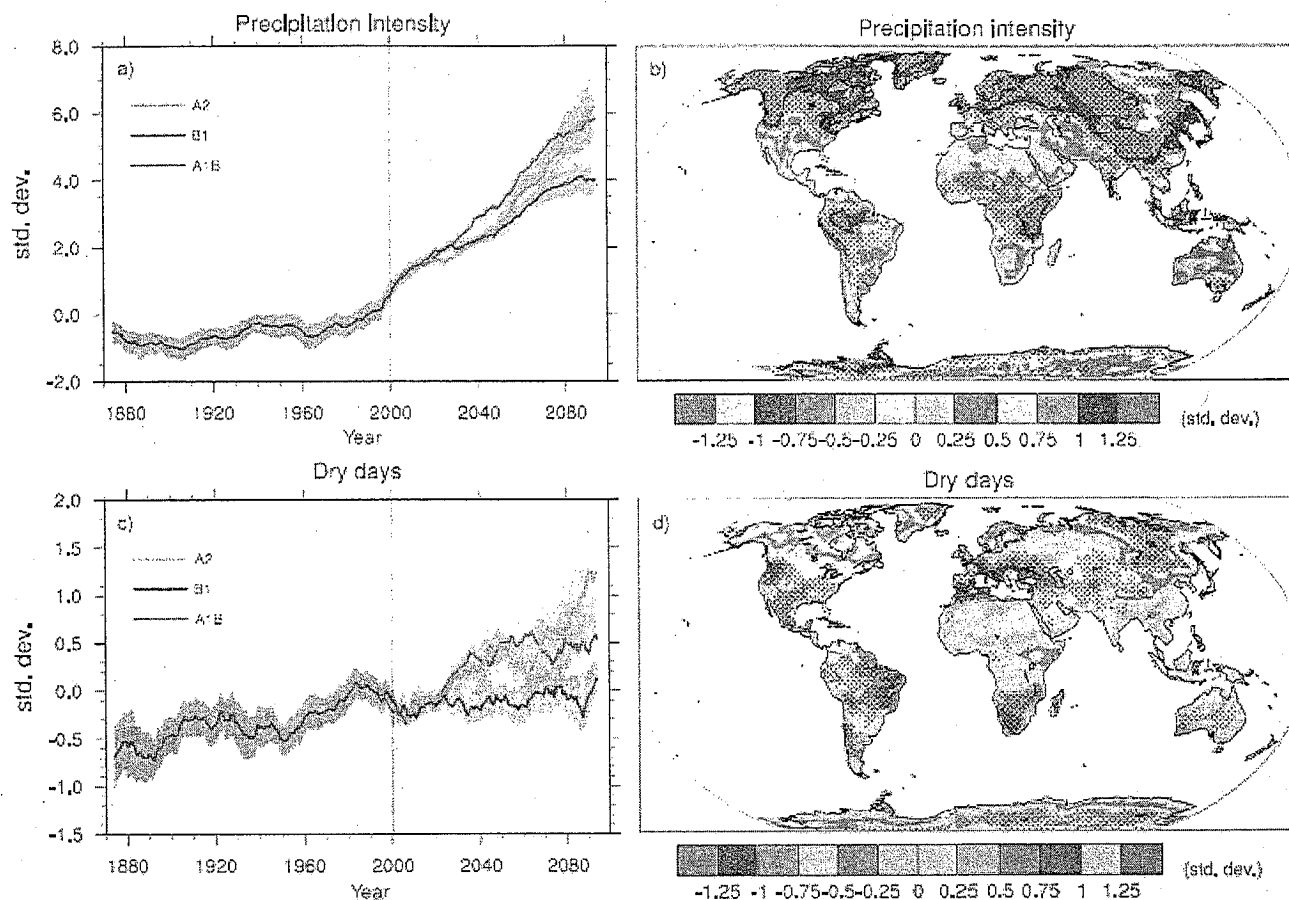


Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. All entries for water stress and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1F1, A2, B1 and B2. Adaptation to climate change is not included in these estimations.

Source: IPCC

Exhibit 27

# Water Will Be a Key Driver of the Climate Impact



Changes in extremes based on multi-model simulations from nine global coupled climate models, adapted from Tebaldi et al. (2006).

(a) Globally averaged changes in precipitation intensity (defined as the annual total precipitation divided by the number of wet days) for a low (SRES B1), middle (SRES A1B) and high (SRES A2) scenario.

(b) Changes in spatial patterns of simulated precipitation intensity between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario.

(c) Globally averaged changes in dry days (defined as the annual maximum number of consecutive dry days).

(d) Changes in spatial patterns of simulated dry days between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario.

Solid lines in (a) and (c) are the 10-year smoothed multi-model ensemble means; the envelope indicates the ensemble mean standard deviation.

Stippling in (b) and (d) denotes areas where at least five of the nine models concur in determining that the change is statistically significant.

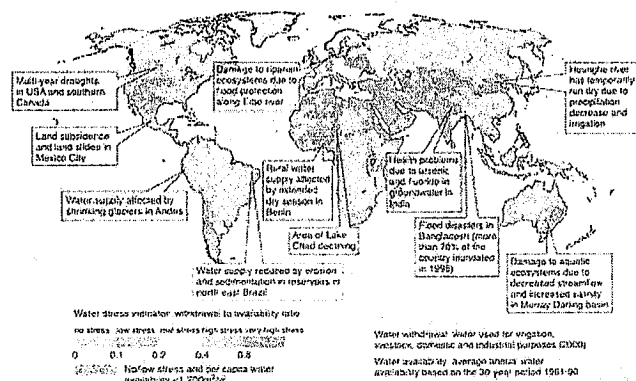
Extreme indices are calculated only over land following Frich et al. (2002). Each model's time series was centred on its 1980 to 1999 average and normalised (rescaled) by its standard deviation computed (after de-trending) over the period 1960 to 2099. The models were then aggregated into an ensemble average, both at the global and at the grid-box level.

Thus, changes are given in units of standard deviations.

Source: IPCC

Exhibit 28

## Examples of Current Vulnerabilities of Freshwater Resources and Their Management



Source: IPCC

It is no longer disputed among scientists that our climate is changing significantly and that human activity is the main cause of the observed changes. There is also evidence that the risks from climate change are on the increase. The latest findings are summarised in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published this year. Since the last report in 2001, it became evident that the climate system shows more dynamic reactions to rising concentrations of GHG and surface temperatures. Crucially, the scientific assumptions about the repercussions on ice, sea levels and the water cycle were updated and new processes, e.g. for aerosols, were included in the projections. The consensus of more than one thousand scientists, who contributed to the IPCC's report, can be summarised as follows:

- the weather is warming up significantly due to human activity;
- polar caps, glaciers and permafrost are melting faster than expected;
- sea levels are rising noticeably and will keep rising for several centuries to come;
- water currents are likely affected (e.g. North Atlantic thermohaline circulation);
- regional weather patterns are changing significantly (monsoon, El Nino);

- extreme weather events have become more frequent (heat, floods, hurricanes);
- ecosystems are clearly affected, biodiversity is starting to fall;
- agriculture crops are already affected by climate change; and
- distribution of vector-borne diseases (malaria, dengue fever, meningitis and encephalitis) starts to shift.

The key variables driving the climate system and its changes are the concentrations of GHG in the atmosphere today and in the future, the resulting temperature change and the feedback effects within the carbon cycle itself. The presence of GHG in the atmosphere traps solar energy, causing the temperature to rise (see accompanying box on page 53). Different scientific scenarios are usually summarised by the level at which the concentration of GHG measured in parts per million (ppm) will likely stabilize, and the expected change in the global mean surface temperature compared with the average temperature measured in pre-industrial times. Currently, scientists estimate a GHG concentration of 430 parts per million ppm (or 380 ppm if only CO<sub>2</sub> is considered), up from 280 ppm before industrialization (ca. 1850). Exhibit 12 provides an overview of the range of different impacts to expect at various GHG concentrations depending on the temperature change they cause on food, water, ecosystems, extreme weather events and the risk of rapid temperature changes and irreversibilities.

The climate sensitivity indicates how much the temperature changes in response to a change in the radiation balance and/or the GHG concentration. The impact on global mean temperature from already emitted greenhouse gases is estimated to likely range between 2.0 and 4.5°C. The median reaction of 3°C is currently regarded the most likely outcome. However, much higher outcomes cannot be ruled out with a sufficient degree of certainty. Recent research suggests the possibility of a larger release of CO<sub>2</sub> by the biosphere as result of global warming. The positive reinforcement effect would raise CO<sub>2</sub> concentrations even further, making temperature increases of 7°C or 8°C plausible.

To put the potential temperature change into perspective: when the last ice age ended about 15,000 years ago, the global temperature rose by around 5°C. In the current century, the Earth will likely witness roughly three times the



global temperature increase seen in the last century. As a result, temperatures will likely be reached that have not been experienced for at least 100,000 years.

**The scientific evidence on climate change shows that the estimated probability distributions are asymmetric and have long tails at high temperatures.** It is therefore essential to avoid severe consequences. The uncertainty should be seen as an argument for doing more not less, according to the Stern Report. Factors creating the uncertainty include the radiative properties of aerosols, the declining reflectivity of the Earth's surface (albedo), the dynamics of the carbon cycle and its feedback effects. Many of these risks involve water (ice, rain, clouds), whose dynamics are still not fully understood. Potentially amplifying factors are the weakening of natural carbon sinks such as plants or oceans, the release of methane from peat deposits, wetlands, thawing permafrost, and/or hydrate stores under the oceans at higher temperature changes.

**To conclude, the impact of climate change on the economic backdrop for financial markets is broad ranging and complex.** Financial markets will be key in funding the massive investment needed to mitigate and adapt to climate change and in sharing the remaining risks due to climate change efficiently. In addition, climate change has an important political aspect, which is another important factor to consider. It is a political decision whether decisive action to combat climate change is taken in the foreseeable future. **The distribution of both the causes and the consequences of climate change will likely be highly differentiated across regions and sectors.** While the impact of climate change is likely to be very long term, financial markets typically discount future risks and reflect them in today's asset prices. As the impact of climate change is likely to be highly persistent, a clear trend in market reaction should emerge once the impact becomes visible. The uncertainty surrounding climate change is pervasive. But, again, financial markets have to price in these risks and the perceived changes to them. Against a backdrop of irreversible and non-linear effects, abrupt movements in asset prices cannot be ruled out. Potentially, climate change could even create systemic risks for the financial system because of physical damage to the market infrastructure, as many financial centres are located in coastal areas, and the highly correlated risks due to the global nature of climate change (e.g. the higher probability of extreme weather events).

**There can be no mistaking that the agenda for climate change is gaining momentum:**

1. Many policy-makers have (re) discovered climate change as a key political global issue.
2. Evidence of unusual weather events has kept the topic in the public discussion.
3. Recent developments in the geopolitical situation and oil prices underline the importance of energy security and the need for alternative fuels.
4. The extension of the European Union's Emission Trading System (EU ETS) beyond 2012 will be discussed later this year.
5. The IPCC is in the process of completing its Fourth Assessment Report on climate change and will present a synthesis to policymakers in November.
6. Talks about an international agreement on climate change after the end of the current Kyoto Protocol (Kyoto II) will start at the UNFCCC Conference of Parties (COP) in early December.

## Exhibit 29

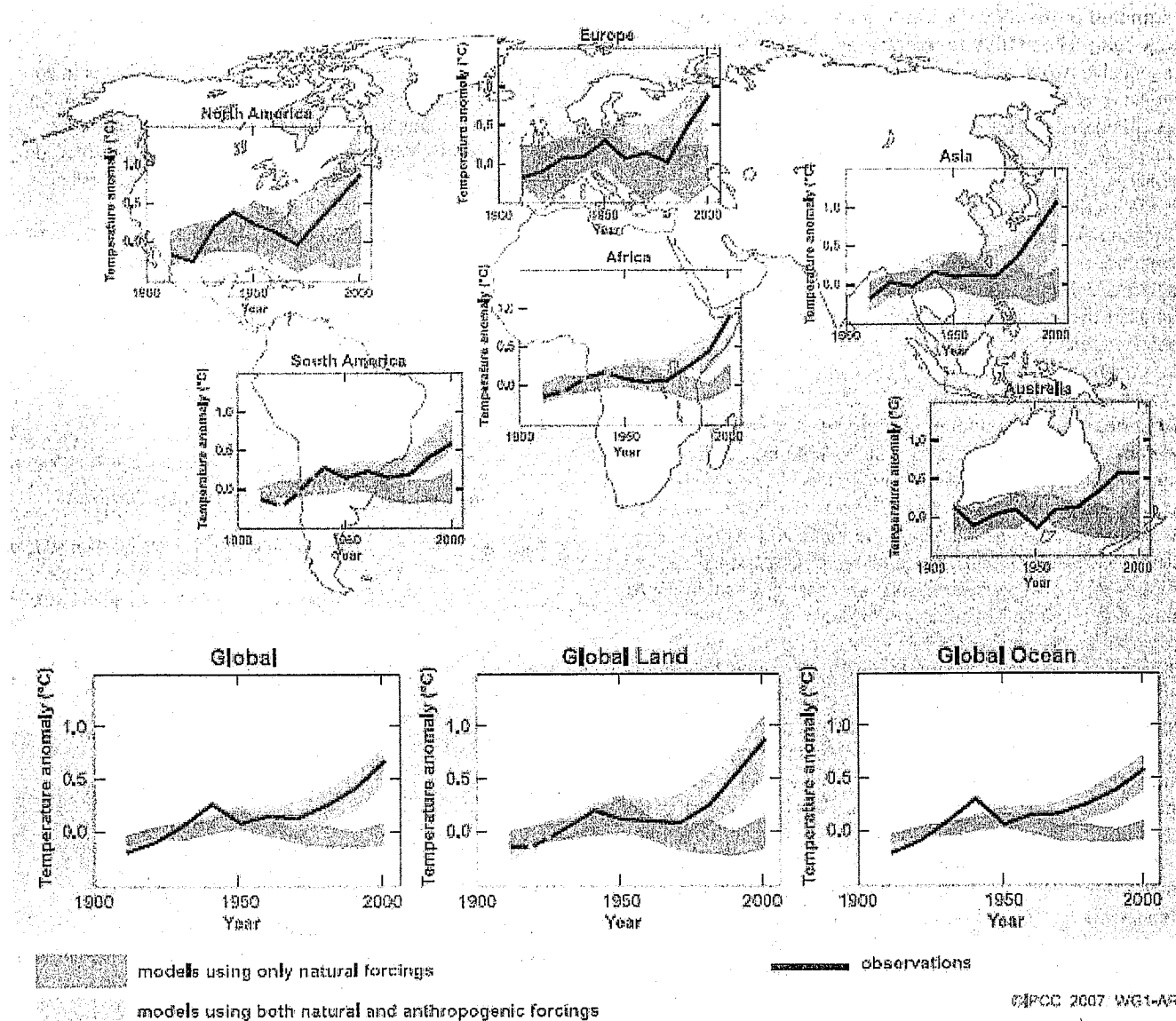
### Key Events in the Politics of Climate Change

Dec 1997	Kyoto Protocol to the UN Climate Convention adopted, which commits developed countries to cut GHG emissions in 2008-12 and introduces a framework of international trade in emission permits.
Jan 2001	Third Assessment Report of IPCC.
Nov 2001	Marrakesh Accord signed, which sets out detailed rules for implementation of the Kyoto Protocol.
May 2004	Russia ratifies Kyoto Protocol causing it to pass critical threshold.
Jan 2005	European Union Emission Trading Scheme starts.
Feb 2005	Kyoto Protocol comes into effect.
Jul 2005	G8 agreement on climate change at Gleneagles.
Nov 2005	Parties to Kyoto Protocol meet in Montreal to discuss future of the treaty.
Oct 2006	UK Treasury publishes Stern Report.
Apr 2007	European Union commits to reducing GHG emissions by 20% by 2020.
Jul 2007	G8 Summit in Heiligendamm, Germany.
Sep 2007	UN and US Conferences on climate change.
Nov 2007	IPCC presents Fourth Assessment Report.
Dec 2007	Conference of Parties to the UNFCCC.
Jan 2008	Second phase of EU ETS starts.
Nov 2008	US Presidential elections.
Dec 2012	Kyoto Protocol expires.

Source: UN, Morgan Stanley Research

Exhibit 30

Climate Change Has Highly Differentiated Impact Across Regions



Source: IPCC

## Impact of Climate-Related Damages

### Implications for the Global Economy

Estimates of the cost of climate change have risen over time as models allow for more dynamic feedback effects and start to consider long-tail events. Lately, it also seems increasingly likely that the increase in temperature could easily exceed 2 to 3°C in the 'business-as-usual' scenario, an assumption made in many of the early estimates. Hence, initial estimates that showed a total output loss of between 0% and 3% of GDP now and in perpetuity have now been revised up to 5% to 10% of GDP now and forever for temperature increases of between 5% and 6°C.

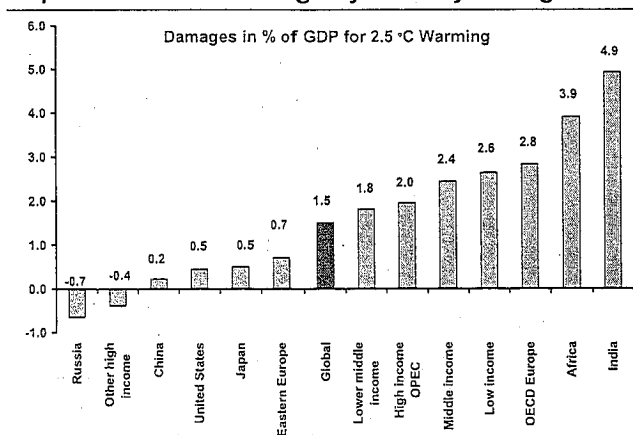
The Stern Report commissioned by the UK government reckons that the cost in the business-as-usual scenario could be as high as 20% of GDP. The report came up with considerably larger estimates for damage caused by climate change than previous models such as those considered in the IPCC's Assessment Report. Using a stochastic model (Policy Analysis of Greenhouse Effect 2002 – PAGE), Stern and his team estimate that the average costs range between 2% and 14% depending on the sensitivity of the climate system, the impact categories considered (market, non-market, risk of catastrophe). The Stern Report triggered a controversial debate among academic researchers, centering on the discount rate used, the aggregation of damage across countries and the treatment of uncertainty and long-tail events. Many of the objections were refuted convincingly though. Notwithstanding the debate about the Stern Report, the evolution of cost estimates over the last 20 years shows that cost estimates are more likely to go up than down.

Taking into consideration the long timeframe over which these estimated losses will likely occur, even the relatively high estimates produced by the Stern Report would have relatively small repercussions on global growth rates. At less than 0.25% in terms of annual growth rates, these clearly lie within the margin error of even the best forecasters, including the estimates produced as official statistics. The global estimates mask very wide country and sector differentials though. The understanding of the differentiated impact on individual countries and regions has improved as climate models have become more refined over time. As Exhibit 31 shows, even a relatively modest impact on the overall economy can imply very substantial country effects. While all model estimates need to be taken with a pinch of salt, the impact on the Indian economy, for example, is estimated at more than three times the size of the global average and the impact on Africa nearly three times the size of the global impact. At the same time, the impact on

the US or Japan is estimated at only one third of the global average. Hence, India would experience ten times the damage experienced in the US, according to this particular model. Relative to China, which is projected to see only one-tenth of the global hit to GDP, or Russia, which comes out as a net beneficiary of climate change, the impact on the Indian economy would seem to be very substantial.

Exhibit 31

### Impact of Climate Change by Country or Region



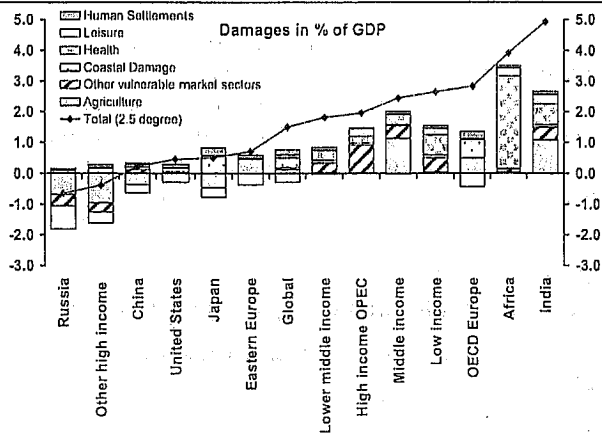
Source: Nordhaus and Boyer, RICE model, Morgan Stanley Research

### Implications for Emerging Markets

**Emerging markets seem more vulnerable to climate change than industrial countries.** They are particularly vulnerable because of their geographic exposure, low income levels, poor governance, limited availability of public services (health-care), less developed financial markets (lending, insurance) and a larger role of climate-sensitive sectors (agriculture, forestry, fishing and tourism). One of the reasons why emerging market economies are poorer today is probably their geographic location, which determines access to natural transport ways, food availability and security, and their exposure to infectious diseases, notably malaria. Climate change could thus meaningfully affect the optimistic growth outlook for emerging market economies. In extreme cases, a downward spiral back into poverty cannot be excluded. The resulting frictions could even undermine political stability. The displacement of millions of people by floods, rising sea levels, desertification and/or the lack of clean drinking water could quickly cause the problems to escalate to the regional and global level by creating a new kind of migration.

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Exhibit 32  
Sector Impact of Climate Change by Country/Region



Source: RICE, Nordhaus and Boyer, Morgan Stanley Research

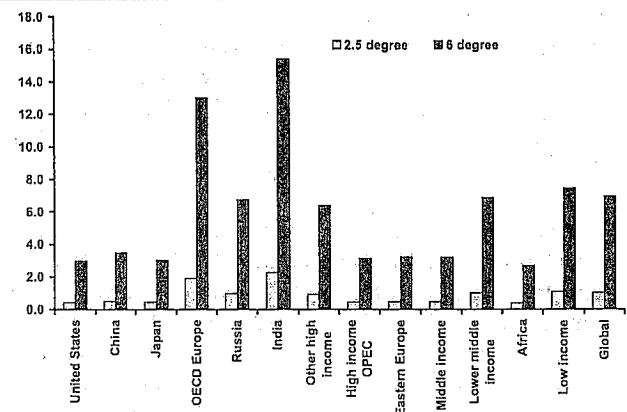
At the same time, there are significant opportunities in emerging markets to contain climate change by reducing GHG emissions markedly. First of all, many emerging markets offer a number of very attractive, low-cost abatement options. Even if they haven't committed to reducing GHG emissions under the Kyoto Protocol, developing countries can still sell their abatement potential to industrial countries under international emissions trading arrangements (notably the so-called Clean Development Mechanism, CDM). In addition, emerging markets could leap-frog to a low-carbon infrastructure as the industrial/energy/transport infrastructure is only in the process of being built up in the coming decades. Contrary to industrial countries, emerging markets might not yet suffer from a 'carbon lock-in'. The ability of the emerging economies to absorb new low-carbon technologies is vital in this context, as is the willingness of industrial countries to make low carbon technologies available to developing countries as part its technology transfer. It is obvious that given the global nature of climate change, transferring low-carbon technology would be highly desirable and should be promoted by governments.

## Implications for Developed Countries

In some developed countries, climate change would have small positive effects for a moderate degree of warming. But even in these countries, it would become mildly damaging if temperatures were to rise further, which now seems increasingly likely. Net beneficiaries for moderate temperature increases are countries at higher latitudes such as Russia, Canada or Scandinavia. However, these countries are also expected to experience the largest temperature change and hence the biggest climate shock. Such big swings in temperature can cause infrastructure, which is drilled into the permafrost, such as pipelines, to become instable.

At lower latitudes, industrial countries will likely see limited net damage. The extent of damage is expected to rise the closer a country is to the equator. The cost of extreme weather events in terms of output lost, infrastructure and capital stock destroyed and lives cut short or harmed by weather-related illnesses is still likely to be meaningful for developed countries. While less vulnerable directly, developed countries are also likely to experience the indirect effect of the impact on emerging markets via multinational companies and global financial markets.

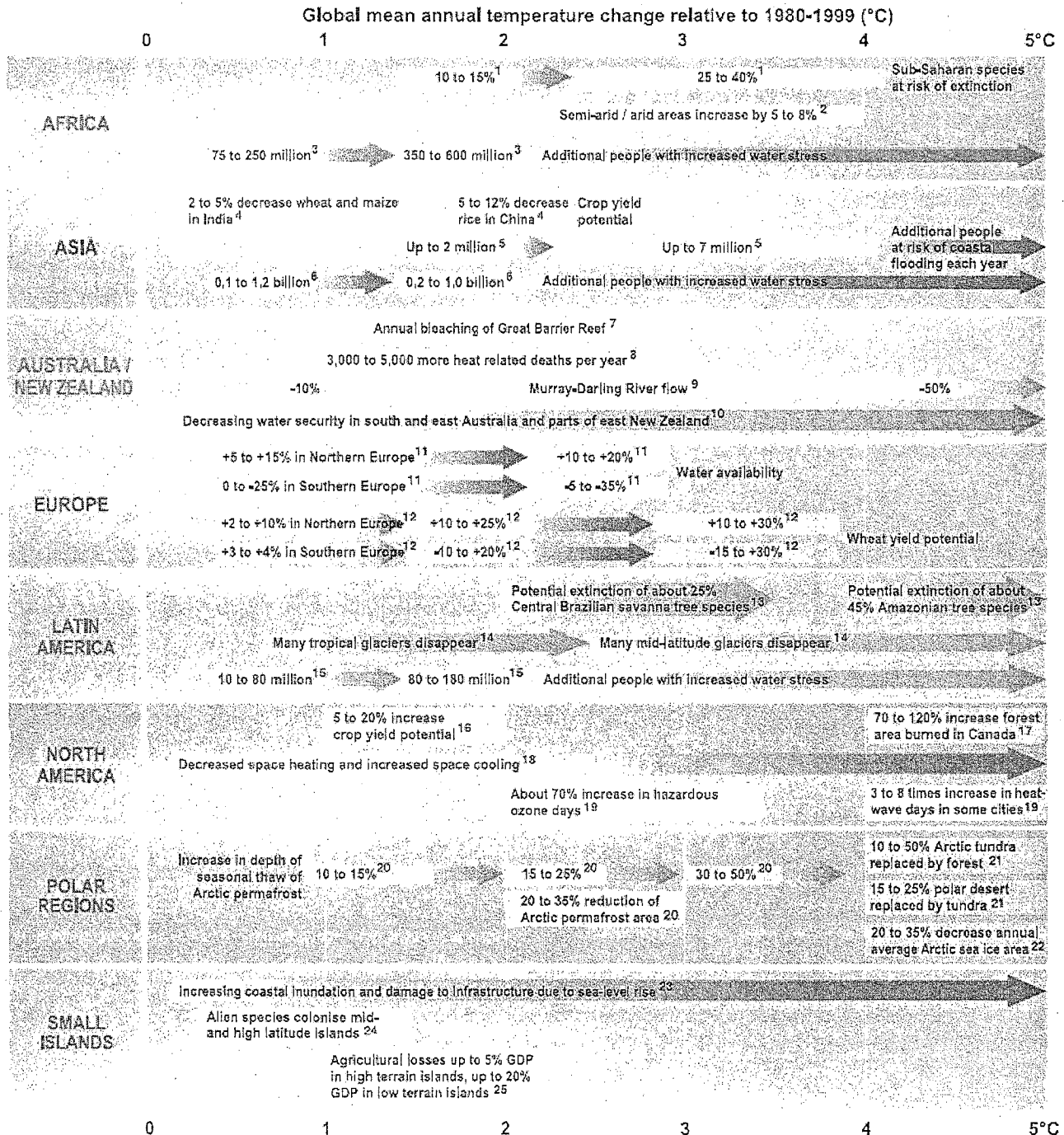
Exhibit 33  
Impact of Climate Change in Two Scenarios  
% of GDP



Source: RICE, Nordhaus and Boyer, Morgan Stanley Research

Exhibit 34

## Examples of the Potential Regional Impact of Climate Change



Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. All entries for water stress and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Source: IPCC

## The Role of Greenhouse Gas Emissions

Next to the incidence of the damage caused by climate change, the reliance on GHG emissions is a key parameter in determining the exposure to climate change and the action taken to contain it for any given country, sector or company. The exposure breaks down into two parts: the role of GHG and the potential to abate them. Hence, it is important to understand where GHG come from, where the overall potential to reduce GHG lies and where the most scope for change can be expected. There is no doubt among climate experts that decisive emission cuts will be needed to limit the extent of climate change. Estimates of the required emission cuts range widely, but central estimates tend to range between 25% and 50% by the middle of this century compared with today's levels, and some go as high as 85%. There is uncertainty about the political will to take the necessary action. If anything, the political pendulum seems to be swinging towards more decisive reductions.

In a top-down macroeconomic perspective, GHG emissions are broken down into their main determinants, including GDP per capita, population size, energy efficiency and carbon intensity. The exposure of an individual country also depends on the role of the main GHG emitting sectors in the structure of the respective country. We therefore briefly discuss sectors and the role they play in different countries before looking at the countries in more detail. But even within a sector there are wide differences in energy efficiency between countries. Structural shifts in sector structure and technological change are key in the long run. In addition, global emissions will depend on changes in the international pattern of economic activity. We therefore also look at the interaction between globalization and climate change.

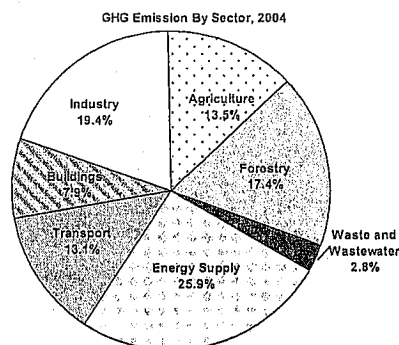
### Global overview of GHG emissions

In this section we discuss the sources of GHG and discuss the outlook for abatement. GHG emissions come from almost every economic activity. The GHG flow diagram summarises these activities and the relative contributions of the different sectors, both directly and indirectly. There are large differences in abatement potential depending on the cost of reducing emissions and the technology options available. They determine the contributions different sectors or countries

can be expected to make in reducing GHG emissions in the future. The abatement potential also determines to what extent sectors would be hit if more broad-based carbon pricing were introduced. We provide a brief overview of the different sectors to highlight which sectors contribute most to the build-up of GHG emissions. Nearly 60% of all global GHG emissions stems from burning fossil fuels in power generation, transport, buildings and industry. The remaining 40% stems from agriculture and changes in land use (e.g. deforestation).

Exhibit 35

### Global Greenhouse Gas Emissions by Sector, 2004

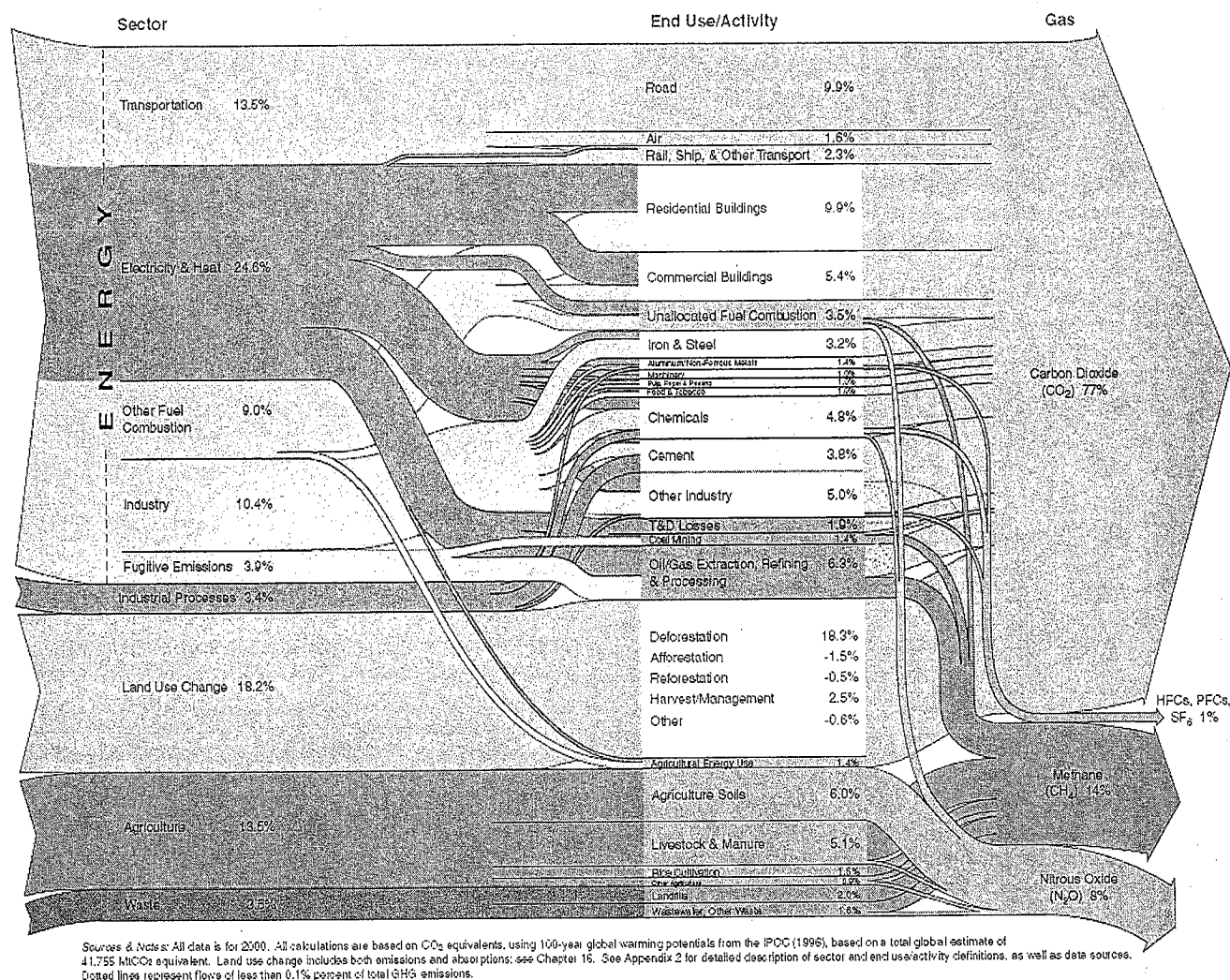


Source: IPCC

For a comprehensive analysis of the exposure to GHG emissions, it is not just the direct GHG emissions that matter, but the final use of goods and services generated along the whole production process. In the national accounts, this 'food chain' can be tracked by means of input-output matrixes and material flow accounts. For individual companies, such a holistic approach runs into serious data problems. These problems could be overcome by superimposing macroeconomic input-output tables onto company data. While giving a somewhat more complete picture of the carbon footprint, precious company-specific information is lost in the process. It is therefore important to remember that direct emissions only provide an incomplete snapshot of the overall exposure to GHG emissions, especially in the energy sector, which is mostly an input into other products and services (for a detailed discussion of GHG by sector and country, see page 47 ff).

Exhibit 36

## World GHG Emissions Flow Chart



Source: Stern Report, WRI

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## Outlook for Greenhouse Gas Emissions

To estimate the long-term development of GHG emissions, a detailed projection of global energy consumption over the next decades is needed, breaking overall energy demand down into the different sources (oil, coal, nuclear, biofuels etc.). Such long-term projections are provided by the International Energy Agency (IEA), which also provides key input into the IPCC Assessment Reports. The IEA outlines three different scenarios: a baseline reference scenario, in which government policies are assumed to be unchanged; an alternative policy scenario, in which all policy initiatives to limit GHG emissions and secure energy supply that are currently considered by governments are implemented; and an enhanced alternative policy scenario, in which there is also accelerated technical progress.

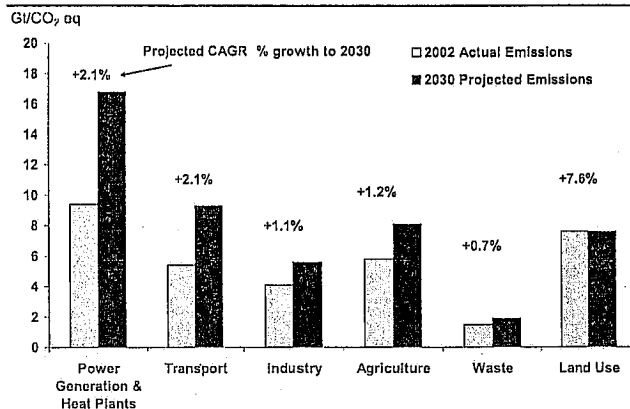
The main finding of the IEA study is that considerable energy and emission savings are possible, which would also reduce private sector spending. Furthermore, it tends to be more cost-effective to improve the efficiency of the end-use of energy rather than to upgrade the energy supply infrastructure. As a result, consumer spending would probably be boosted by the purchase of energy-saving appliances while companies (and governments) would be able to cut back on their infrastructure spending.

**Meeting the world's growing energy needs requires major infrastructure investment.** According to the IEA, cumulative energy infrastructure investment of over US\$20 trillion is needed by 2030 (about US\$910bn p.a.), with the power sector accounting for around two thirds. More than half of this investment would need to take place in emerging markets, where energy demand and production will likely increase most quickly. These huge investment needs and the resulting turnover in the capital stock create massive opportunities to reduce GHG emissions because they allow low-carbon technologies to be diffused more quickly in a capital stock with otherwise very slow turnover.

In the IEA reference scenario (RS), global energy related CO<sub>2</sub> emissions would increase by 1.7% p.a., in line with global energy demand expected to rise by 1.6% in average. Developing countries will likely account for over three-quarters of the increase. The sharp rise in emerging market emissions is driven by a faster rise in energy demand and a more carbon-intensive energy mix due to the extensive use of coal. Power-generation will account for nearly half the increase. Fossil fuels remain the dominant source of energy, accounting for 83% of the rise.

The IEA also maps out an alternative policy scenario (APS) in which all policies currently considered to limit carbon

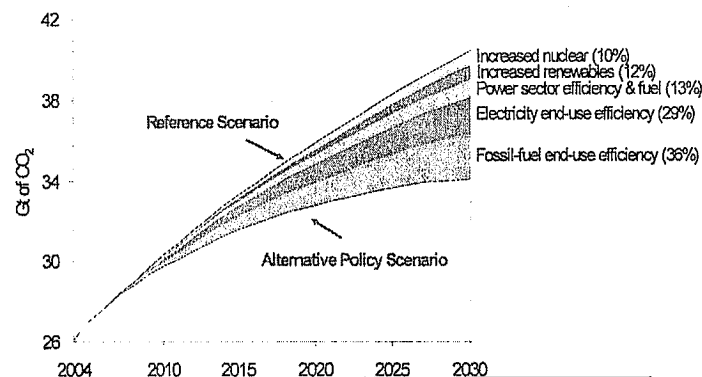
Exhibit 37  
Global Emissions Set to Grow from all Sources



Light bars are actual values, dark bars are estimates for 2030  
Source: International Energy Agency, US Environmental Protection Agency, CO<sub>2</sub> equivalent

emissions and energy imports are fully implemented. In this case, global primary energy demand would be 10% below the reference scenario in 2030. Global energy demand would grow 1.2% compared to 1.6% in the base case and CO<sub>2</sub> emissions would be reduced by 16% in 2030 compared to the RS as emissions in OECD and transition countries fall (in the EU and Japan even below today's levels). Policies encouraging more efficient production and energy use account for nearly 80% of the emission cuts. The remaining 20% would come from fuel switching. More efficient cars and trucks account for more than one-third of the savings while more efficient electricity use (lightening, air-conditioning, electrical appliances and industrial motors) account for slightly less than one-third. Meanwhile, more efficient energy production, higher use of renewables and biofuels and increased deployment of nuclear energy each yield about 10% of the emission savings.

Exhibit 38  
Comparing Two Scenarios for CO<sub>2</sub> Emissions



Source: World Energy Outlook © OECD/IEA, 2006, Figure 7.14, P192



While energy-supply investment would be lower in the APS, consumer spending on more efficient appliances, cars etc. would be higher. The measures considered by IEA APS would yield net savings of US\$560 billion globally. Higher consumer spending on appliances and buildings (US\$2.4 trillion), mainly industrial countries, and lower investment in the energy sector (US\$3 trillion), across both industrial and developing countries. For electricity, in particular, there are significant savings that can be generated by moving towards higher end-use efficiency. The IEA estimates that one additional dollar spent on more efficient electrical equipment, appliances and buildings would do away with the need to spend more than two dollars on electricity infrastructure. Payback periods for these savings are often very short, ranging from one year for light bulbs to eight years for cars. The APS relies on urgent adoption of policies. Only a dozen policies would result in a reduction of 40% in CO<sub>2</sub> emission by 2030 (Exhibit 39).

Keeping global CO<sub>2</sub> emissions at current levels would require an even bigger push than the policies currently considered. In the 'Beyond APS', additional savings would come from further efforts to improve energy efficiency, boost nuclear power, promote renewable energy and strong support for Carbon Capture and Sequestration (CCS). This would require major changes in energy supply and demand. The BASP is characterized by efficiency improvements, fuel switch and faster technical progress (CCS and second-generation biofuels). CCS is a key swing factor on the abatement side. Here 80% of the savings come from reduced energy demand, fuel switching (nuclear and renewables) and CCS.

Exhibit 39

## A Dozen Policies Would Make a Global Difference

	Energy Efficiency	Power Generation
US	Tighter CAFE Standards Improved Efficiency in Residential & Commercial Services	Increased Use of Renewables
EU	Increased Vehicle Fuel Economy Improved Efficiency in Electricity Use in the Commercial Sector	Increased Use of Renewables Nuclear Plant Lifetime Extensions
China	Improved Efficiency in Electricity Use in Industry Improved Efficiency in Electricity Use in the Residential Sector	Increased Efficiency in Coal-Fired Plants Increased Use of Renewables Increased Reliance on Nuclear

Of the total CO<sub>2</sub> reduction, 17% would come from China, 10% from the US and 9% from Europe. Power generation accounts for 16%, energy efficiency for 22%. One of the single biggest items is the US CAFE standards (5%), followed by more efficient energy use in China's industry and increased use of renewables in China (both 4%). Source: IEA

Exhibit 40

**Key Mitigation Technologies and Practices by Sector**

Sector	Key mitigation technologies and practices currently commercially available	Key mitigation technologies and practices projected to be commercialized before 2030
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS, (storage of removed CO <sub>2</sub> from natural gas).	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar PV.
Transport	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning.	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries.
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases.	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings.
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non- CO <sub>2</sub> gas emissions; and a wide array of process-specific technologies.	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture.
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH <sub>4</sub> emissions; improved nitrogen fertilizer application techniques to reduce N <sub>2</sub> O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency.	Improvements of crop yields.
Forestry/forests	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use.	Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change
Waste management	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize CH <sub>4</sub> oxidation.

Note: Sectors and technologies are listed in no particular order. Non-technological practices, such as lifestyle changes, which are cross-cutting, are not included in this table.  
Source: IPCC

## Carbon Capture and Storage

A swing factor in future emission abatement is carbon capture and storage (CCS). CCS has attracted considerable attention because it would allow the continued heavy use of fossil fuels (notably coal) while achieving a major reduction in emissions (for a detailed discussion, see the IPCC's *Special Report on Carbon Dioxide Capture and Storage*, 2005). The available evidence points to huge potential for CCS, which is estimated by the IPCC to be at least 2,000 Gt CO<sub>2</sub> (or 545 Gt C) in terms of storage capacity in geological formations alone. This compares with annual global CO<sub>2</sub> emissions of around 30 Gt at the moment.

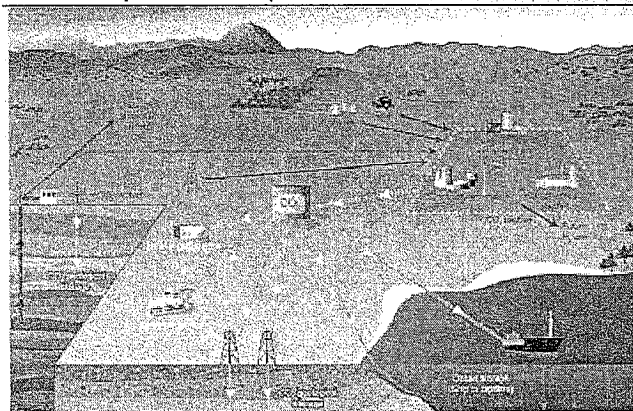
CCS involves separating the emissions when fossil fuels are burned, moving them to a storage facility, and storing them either in the ground, the ocean or geological formations. It can only be applied to large point sources of GHG emissions. Only a large proportion of these are located in a 300 km radius of suitable geological formations, but not of potential ocean storage facilities. The net reduction in emissions that can be achieved by CCS depends on the fraction of CO<sub>2</sub> captured, the loss in thermal efficiency of the power plant or industrial process, and the additional energy requirements of the CCS itself.

While individual components (capture, transport and storage) are used already, there is still little experience with a fully integrated CCS, especially for large-scale power plants. CCS would likely add to the costs of power generation, with estimates varying between zero and US\$270/CO<sub>2</sub>t, and a central range between US\$20 and US\$50/CO<sub>2</sub>t for coal, according to the IPCC. The IEA estimates emission reductions of 25% or more if around 15% of the electricity generated by coal-fired power stations were to use CCS by 2050. CCS could therefore potentially reduce the estimated marginal abatement costs from slightly above US\$40 to US\$25 in the EU and China, according to the UK Treasury.

In a recent research report, our capital goods analyst, Ben Uglow, examined three different clean coal technologies, which make fossil-based power generation more thermally efficient and thereby help to reduce carbon emissions (see *From Clean Coal to Green Coal – Picking the Winners*, September 20, 2007). Clean coal technologies can reduce CO<sub>2</sub> emissions by up to 30% and sulphur dioxide and nitrous oxides by up to 99%. I would highlight that these latter substances cause near-term air pollution such as acid rain. Reducing them therefore offers important co-benefits, especially in a country like China, which suffers increasingly from poor local air quality. Ben argues that CSS is the ultimate clean coal technology, but it still relies heavily on fiscal incentives because at this stage the cost of capturing the CO<sub>2</sub> alone would effectively double the cost of construction due to the costly scrubbing equipment required. In addition to higher construction costs, there is also a loss in thermal efficiency of turbines of around 12%.

Exhibit 41

### Carbon Capture and Sequestration



Source: IPCC

## A Macro View on Greenhouse Gas Emissions

A relatively small number of countries produce the majority of GHG emissions. Many of them are also among the most populous countries. Together, the 25 top emission countries account for more than 80% of global emissions and nearly 90% of global GDP. The largest emitter is the US, followed by China, the EU, Russia and India, which collectively make up 60% of global emissions. Interestingly, the top emitting countries are a very diverse group, consisting nearly equally of developed and developing countries (Annex I and non-Annex I, according to the classification of the UNFCCC). Only a handful of the latter also rank among those with the highest per capita emissions, though. Emission growth is highest among developing countries such as Indonesia, South Korea, Iran and Saudi Arabia. For developed countries collective carbon emissions stagnated between 1990 (the base year for the Kyoto Protocol) and 2002. But there are important country differences led by sharp drops in Germany (-19%), the UK (-15%) and in transition countries (Russia, Ukraine). In contrast, growth was significant in the US (13%), Canada (20%) and Australia (22%). Countries therefore do not have an equal interest in containing climate change, nor are they equally able to make a difference. A country level perspective is most useful because governments, the main drivers behind action to reduce GHG emissions, mainly act on a national (at most on a regional) basis.

### Drivers of greenhouse gas emissions

In general, there is a strong correlation between GHG emissions, population and GDP. A decomposition analysis determines the contribution of different factors to a country's emission level and its changes over time. Total CO<sub>2</sub> emissions from energy use (E) are equal to Population (L) times GDP per capita (GDP/P) times energy use over GDP (E/GDP — the energy intensity) times CO<sub>2</sub> over energy use (CO<sub>2</sub>/E — the carbon intensity). This equation allows each component in turn to be considered. In the majority of countries, economic growth measured as GDP per capita has the strongest influence on emissions. Projections of long-term emissions growth depend heavily on assumptions of such factors as population growth, economic growth and change in technology.

Economic  
Activity

Energy  
Intensity

Fuel  
Mix

$$CO_2 = \frac{GDP}{Person} \cdot Population \cdot \frac{Energy}{GDP} \cdot \frac{CO_2}{Energy}$$

Exhibit 42

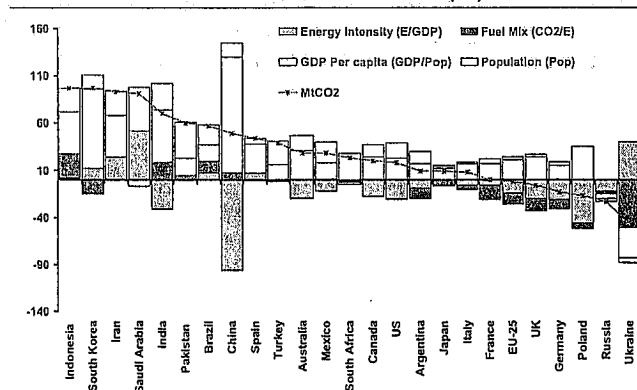
### Key Ratios for Energy related CO<sub>2</sub> Emissions

Country	CO <sub>2</sub> per head (tCO <sub>2</sub> )	GDP per head (\$ppp 2000)	CO <sub>2</sub> emissions/energy uses (tCO <sub>2</sub> /toe)	Energy use/GDP (toe/\$ppp2 000 x 106)
USA	19.9	35,373	2.5	222
China	3.5	4,966	3.2	220
EU -25	8.8	23,770	2.3	160
Russia	10.9	8,524	2.5	519
Japan	9.9	26,270	2.4	154
India	1.1	2,731	2.1	190
Germany	10.5	25,653	2.5	164
UK	9.3	27,605	2.4	141
Canada	17.2	28,311	2.1	291
S. Korea	10.2	18,097	2.4	237
Italy	8.1	25,610	2.6	123
Mexico	3.9	8,784	2.5	178
France	6.6	26,493	1.5	171
South Africa	8.3	10,055	3.2	257
Iran	5.6	6,608	2.7	311
Indonesia	1.6	3,213	2.1	234
Australia	17.2	27,271	3.0	208
Spain	8	22,782	2.5	142
Brazil	1.8	7,306	1.7	146
Saudi Arabia	14	12,460	2.5	450
Ukraine	6.7	5,211	2.4	532
Poland	8.1	11,287	3.3	217
Turkey	3.1	6,668	2.8	167
Thailand	3.4	7,059	2.4	199
Netherlands	11.5	28,932	2.3	172
World	4.1	7,894	2.5	217

Latest available data including energy-related fossil fuel emissions and industry-related emissions Source: WRI

Exhibit 43

### Cumulated Growth in CO<sub>2</sub> Emissions and their Macroeconomic Drivers, 1992-2002 (%)

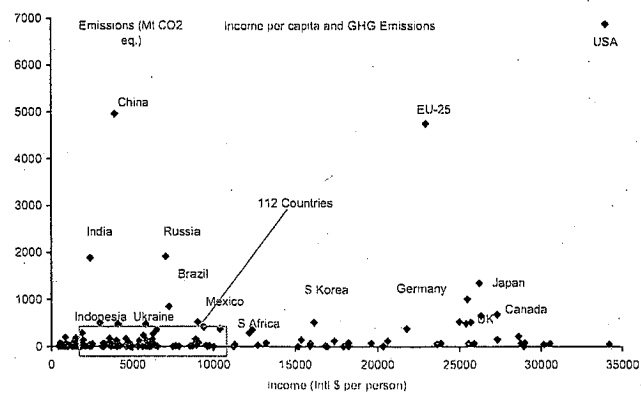


Source: WRI

## Per capita GHG emissions

Only a small number of countries with the largest per capita emissions actually rank among the top 25 emitters in absolute terms. Australia, the US and Canada have the highest per capita emissions, which are more than twice the level in the EU and six times the level in China or 13 times the level in India. Four of the five highest per-capita-emitters globally are Middle Eastern Gulf States. A number of densely populated small islands also have relatively high emissions, such as Trinidad and Tobago, Antigua and Barbuda and Singapore. Several transition economies also rank relatively high, especially those with fossil fuel resources (Estonia, Czech Republic, Turkmenistan and Russia). A number of advanced developing countries such as Singapore, South Korea, Taiwan and South Africa have per capita emission levels above the EU's. The per capita emission levels have important implications for international agreements on climate change, where suggestions have been made recently by Chancellor Merkel of Germany, to base future agreements on an equal entitlement of per capita emissions.

Exhibit 44  
Income per Capita and GHG Emissions



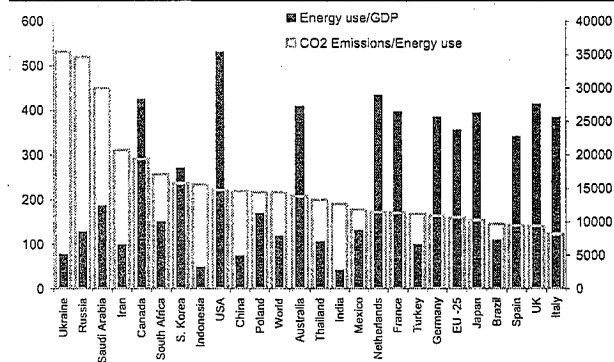
Source: WRI, CAIT. Data is for 2000. There are several countries not shown, such as Luxembourg, with per capita incomes that exceed US\$35,000 per year.

## Emission intensity

Emission intensity – the level of CO<sub>2</sub> emission per unit of output – varies widely between countries depending on their sector structure, energy efficiency and fuel mix. Typically, GDP grows faster than emissions, causing the emissions intensity to decline. While outright decoupling of growth emissions and growth seems unlikely, soft decoupling looks possible. Among the major emitters, emission intensity stretches sevenfold from France to Ukraine, according to WRI. Emissions intensity, the inverse of emissions productivity, is driven by two other factors determining a country's emission report card, namely the

energy intensity (energy used per unit of GDP) and the fuel mix (CO<sub>2</sub> emitted per unit of energy). The energy intensity reflects both the energy efficiency, the sector structure and the carbon content of the trade balance. The energy intensity is not closely correlated with income level, but developing countries tend to show slightly higher levels than industrial countries. The second component is the fuel mix or the carbon content of the energy consumed. Countries vary widely on their fuel mix, which often is highly correlated with their natural endowment such as coal, oil, gas or hydro-power. However, the fuel mix is also influenced by government policies (e.g. nuclear, renewables).

Exhibit 45  
Energy Efficiency and Carbon Intensity of Energy Use Reveal Big Country Differences



Source: WRI, CAIT, Morgan Stanley Research

## Energy intensity and fuel mix

Energy fuel mix and energy intensity play an important role in driving CO<sub>2</sub> emissions. Emission levels are highly correlated with energy use, which account for more than 60% of GHG emissions. Across fuels, oil is the most commonly used (35%), followed by coal (24%), natural gas (21%) and other non-fossil fuels. Coal has the highest carbon content, which stands 34% above oil and 75% above gas.

- **Coal:** Both coal consumption and production are highly concentrated. Five countries or regions account for three-quarters of global coal consumption (China, US, EU, India and Japan) while six countries account for 81% of known reserves (US, Russia, China, India, Australia and South Africa). The IEA projects coal consumption to more than double by 2030, with China and India accounting for more than two thirds of the increase. Electricity and heat account for 70% of coal consumption, followed by industrial consumption (16%). Coal is used primarily in power generation and the major emitting countries

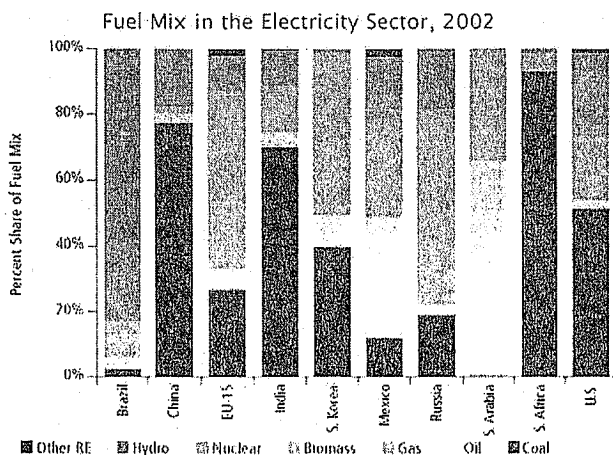
(US, China, India and Russia) have immense reserves. If fuel switch is not an option, capture and sequester CO<sub>2</sub>. Emerging coal-to-liquid technologies, enabling coal to be used as a transport fuel, would raise the carbon intensity of transport.

**Oil:** The top 25 GHG emitters account for 84% of oil consumption, 58% of production and 48% of proven reserves. Reserves are highly concentrated in OPEC countries and will, at the current rate of consumption, probably last another generation. Geographically, oil consumption is extremely widespread due to its dominance in the transport sector and its tradability (about 60% of global production is traded). Oil consumption is largely driven by transport, weakly correlated with local reserves.

**Natural gas:** The top 25 producers account for 84% of global consumption. As with oil, gas reserves are highly concentrated, with 69% of natural gas reserves located in just seven countries. Unlike oil, most gas is consumed domestically although international trade is significant and growing. 75% of it takes place via pipelines, the remainder via tanker transport of liquefied natural gas (LNG), mainly in Asia-Pacific and the Middle East. The latter is expected to grow fast. Natural gas is the least carbon intensive fossil fuel, conducive to a wide range of uses, ranging from power generation to industry to residential use. Where it is used as a substitute for coal, it reduces CO<sub>2</sub> emissions by 40%.

Exhibit 46

### Fuel Mix Varies Widely



Source: WRI based on IEA, 2004b. Shares are based on gigawatt hours of generation.

**The Outlook:** CO<sub>2</sub> emissions will likely rise as the global economy grows unless energy intensity and carbon intensity are reduced markedly in the coming decades. The IPCC estimates that while reductions in energy intensity look achievable, the carbon intensity will at best stay stable. This is because the rising use of coal will likely offset rising shares of nuclear power and alternative energy. Due to ongoing population growth, overall emissions will likely increase more rapidly than per capita emissions. The IEA projections point to very noticeable regional differences in emission growth, with China accounting for half of the increase between now and 2030. Technology and efficiency are key in loosening the link between growth and emissions. Don't count on fossil-fuel scarcity to limit emissions growth. However, as countries become richer, they also become more environmentally conscious as they become more densely populated and as they suffer more from environmental damage.

Exhibit 47

### Projected Change in Energy-Related CO<sub>2</sub> Emissions

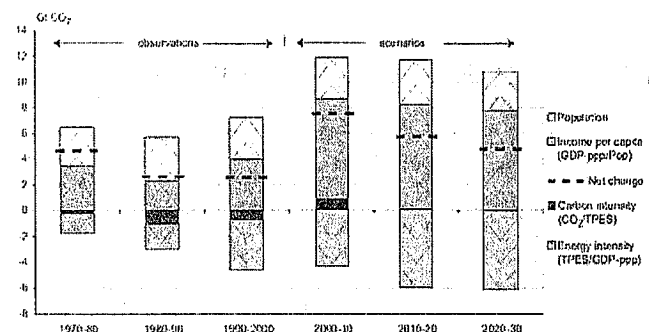
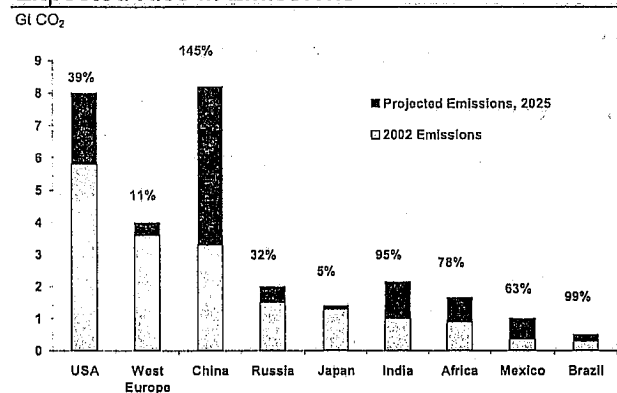


Figure 7B.35 Decomposition of global energy-related CO<sub>2</sub> emissions changes at the global level at three point and three time decades (Figure 1.7)

Source: IPCC

Exhibit 48

### Large Emerging Markets Account for Most of the Expected Rise in Emissions



Source: Stern Report, World Resources Institute, CAIT Energy Information Administration Reference Scenario, Energy emissions only

## Scope for Reducing Greenhouse Gas Emissions

Major reductions in GHG emissions are needed over the next few decades. Depending on the stabilization level for GHG or for the global temperature change, reductions of up to 50% would need to be targeted by 2030. The precise extent of these reductions depends on the underlying base case. Given the underlying expansion of GHG emissions in the business as the usual baseline, very substantial improvements in energy efficiency are needed. And while the overall emission reduction is already rather daunting, the need for individual countries might be even larger if the global targets are to be met. This holds true in particular for developed countries, which will have to do much more than emerging market economies, if the Kyoto Protocol is anything to go by, for future international agreements on climate change.

The abatement costs not only depend on the target set by governments for emission reduction, but on how this target is implemented. The implementation of a given target can create extra costs if the economic efficiency in reducing emissions is not achieved. Whether economic efficiency is achieved depends on the environmental policy instrument chosen. We therefore briefly discuss the properties of the main environmental policy instruments below. A key driver of abatement costs in the long-run is the pace of technological innovation. Hence, the ability to develop new technologies and deploy them swiftly across the economy will be a key factor. We therefore round out our discussion of the scope for abating GHG emissions by discussing the role of technology policy and how countries differ in their ability to innovate and adopt new technologies.

Exhibit 49

### Methods to abate GHG emissions

- (1) Improving energy efficiency using existing technologies in energy production, industry, transport, and buildings.
- (2) Switching to low-carbon technologies (solar, wind, biofuels, nuclear, or hydro power).
- (3) Cutting emissions not related to fossil fuels (forestry, agriculture).
- (4) Shifting demand for goods and services towards low-emission products.

Source: Stern Review, Morgan Stanley Research

From a bird's eye view, macroeconomic models of climate change find total abatement costs ranging from net savings of -2% and net costs +5% of GDP in 2050, according to the Stern Report. The median cost of emission abatement

leading to stabilization of GHG at around 550 ppm is estimated at 1% of GDP. At +/-3% the range of uncertainty regarding the cost of emission abatement is substantial. This is due to the uncertainties about the scale of emission reductions needed and the pace of technological progress. In addition, the degree of flexibility in emission reduction regarding the sector, the technology, the location, the timing and the type of gas emission affected is uncertain. In addition, the impact on individual countries/sectors/companies could be considerably larger than the relatively benign global estimate depending on their emissions intensity. In general, the lower the substitutability, the slower the technical progress and the less flexible the policy and the economy are, the higher the abatement costs. The key findings from a series of academic studies on the potential to reduce emissions, summarised by both the IPCC and the Stern Report, show that reducing GHG emissions is partially (energy) efficiency enhancing. These efficiency gains allow energy costs and emissions to be reduced at the same time. Further action will likely be needed, though. Here governments will need to intervene to provide incentives to reduce carbon emissions further.<sup>4</sup>

Exhibit 50

### Estimated Emission Reductions Needed

Stabilisation level (ppm CO <sub>2</sub> -eq)	Global Mean temperature increase at equilibrium (°C)	Year global CO <sub>2</sub> needs to peak	Year global CO <sub>2</sub> emission back at 2000 level	Reduction in 2050 global CO <sub>2</sub> emissions compared to 2009
445-490	2.0-2.4	2000-2015	2000-2030	-35 to -50
490-535	2.4-2.8	2000-2020	2000-2040	-60 to -30
535-590	2.8-3.2	2010-2030	2020-2060	-30 to +5
590-710	3.2-4.0	2020-2060	2050-2100	-10 to +60
710-855	4.0-4.9	2050-2080		-25 to +85
855-1130	4.9-6.1	2060-2090		+90 to +140

Source: IPCC

The extent to which carbon emissions will be reduced will also depend on the price for carbon. Price will likely be determined politically, directly by setting a carbon tax or indirectly by setting a cap for allowable emissions in a regulatory framework or for tradable emission permits. A large number of studies conducted on the abatement potential suggest there is scope for a substantial reduction in emissions over the coming decades. Drastic action is needed to offset the

<sup>4</sup> As outlined before, the IEA believes that efficiency gains in the use of fossil fuels would be the single largest source of emission savings. The electricity sector would need to be largely decarbonised by 2050 (mix of renewables, CCS and nuclear). The transport sector would still be largely oil-based in 2050, but efficiency gains (biofuels, hydrogen or electric cars) would contain the rise in emissions.

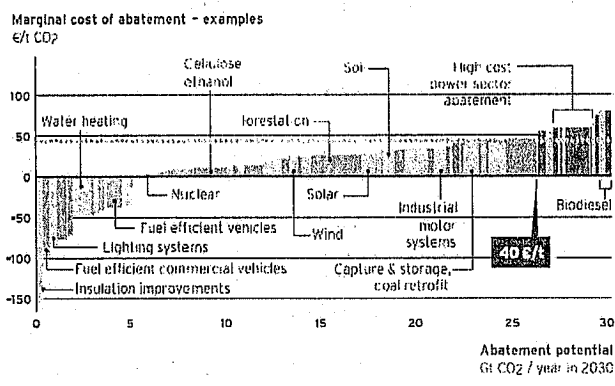
October 3, 2007  
Economics

projected emission growth in the business-as-usual baseline amid continued rapid expansion of GDP.

In a bottom-up micro economic perspective, the incidence of GHG emissions and the potential to reduce them involves many complex issues, such as technology analysis, political factors and the economic backdrop. We outline some of the issues below. The potential to reduce GHG emissions from a bottom-up perspective boils down to an abatement costs curve, which provides an indication of the costs associated with different abatement technologies and their abatement potential (see Exhibit 51 and 52). Two observations stand out. First, a number of technologies are characterised by negative abatement costs (i.e. net savings). These seem to occur mainly in buildings management and transport, in total, an abatement potential of around 6Gt CO<sub>2</sub> globally. In these cases, investment costs would be more than compensated by lower energy costs. Second, another range of abatement technologies is competitive at today's observed ETS carbon prices of around €20/t.

Exhibit 51

## Illustration of the Costs of Abating CO<sub>2</sub> Emissions

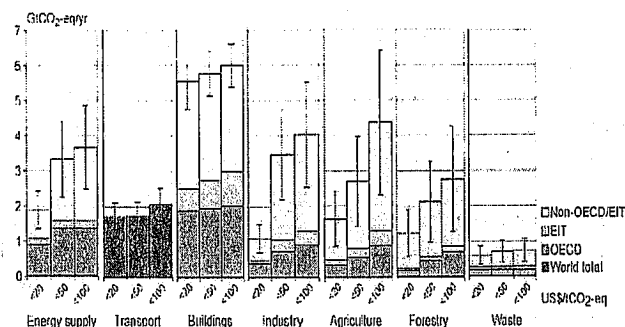


Source: Vattenfall

Aggregating the different abatement options into broader sectors and regions shows that agriculture and forestry have the biggest potential to reduce GHG emissions, followed by the real estate, industrial, energy and transport sectors. Some sectors are more sensitive to changes in the price of carbon (industry, agriculture and forestry) than others (transport, real estate). In several sectors, more than half of the emission reduction will come from developing countries (industry, agriculture, forestry and waste). In all other sectors, roughly half the emission reduction will come from OECD and transition countries (energy supply, buildings). Note that under the Kyoto Protocol abatement is limited for industrial countries (except flexible mechanism). Abatement costs will obviously increase with the stringency of the stabilisation target. However, the efficiency of the environmental policy measures taken and the rate of technical progress assumed are also key variables determining the costs of containing GHG emissions.

Exhibit 52

## Abatement Potential by Sector and Region Depending on the Carbon Price in 2030



Note: estimates do not include non-technical options, such as lifestyle changes.

From bottom-up studies compared to their respective baseline. Vertical lines signify range of estimates based on end-use allocation of emissions. Electricity has been attributed to sectors. Source: IPCC



## Policies to Contain Greenhouse Gas Emissions

**Governments will likely take a wide range of different policy actions to combat climate change.** A comprehensive policy response to the challenges of climate change will likely include three main elements. First, introducing a price for carbon emissions (implicitly or explicitly via environmental regulation, emission taxes or tradable permits) so that emitters bear the external cost of the climate change they cause. Second, additional measures in technology policy might be needed to promote low-carbon technologies. Third, promote behavioural change of consumers and companies alike by providing information, making complex choices easier and overcome financial constraints in meeting upfront costs.

**The economic impact of government actions to contain climate change** will not only be a function of how ambitious the goal of reducing emissions is, but how cost effectively it is being implemented. An economically efficient and environmentally effective climate policy ensures that, globally, all economic agents face the same price for the damage their GHG emissions are likely to cause. Decisions on how best to combat climate change are very difficult from an ethical and a political standpoint. From an economic point of view, it is somewhat simpler because the decision is about how to achieve a certain level of emission reduction or environmental quality at minimal cost.

Four conditions would need to be met to ensure an efficient abatement of GHG emissions. First, the efficient level of abatement is reached where the marginal cost of abatement is equal to the marginal damage prevented. Second, the marginal cost of reducing emissions by another ton of carbon should be equal across all emitters. Third, marginal costs of abating different GHG should be equalized, once their different warming potential has been taken into account. Finally, once the marginal costs of abatement are appropriately discounted, they should also be equal across time. If one of these conditions is not met, there will still be profitable arbitrage opportunities.

**Designing an optimal policy will often be impossible due to the lack of information** (say on damage caused or abatement costs).<sup>5</sup> In this case, the policy will have to be a

<sup>5</sup> The external cost of carbon is difficult to estimate because of uncertainty about the impact of climate change, the valuation of the damages (e.g. non-market damages) and their aggregation across countries and time. Estimates are therefore subject to debate on the aggregation over time (choice of the discount rate) and across countries (income levels even if adjusted for purchasing power parity give higher weight to damages in industrial countries). In addition, environment might or might not have a value per se. Thus, all

second best one. It might use a mixture of different instruments and targets to achieve the policy goal. It is important to provide incentives to abate emissions at the lowest cost and to search for further cost-cutting potential. We briefly review the standard instruments of environmental policy and discuss their impact on corporate profits and technological innovation. All price-based instruments (taxes, subsidies), quantity-based schemes (tradable emission permits), regulation (including technology) and voluntary agreements are currently used to contain climate change. In addition, we look at technology policy and information policy.

### Exhibit 53

#### Criteria for Evaluating Environmental Policy Instruments

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Ecological Incidence  
Economic Efficiency  
Information Requirements  
Implementation and Control Costs  
Practicability in the Political Context  
Time lag of Environmental Impact  
Transition Problems

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Source: Siebert, Morgan Stanley Research

#### 1 – Taxes and subsidies

An emission tax typically requires an individual emitter of GHG to pay a fee, a tax or a charge for every ton of GHG released into the atmosphere. Usually, the amount is fixed independently of the size of the emissions. Each emitter weighs the cost of paying the emission tax against the costs of reducing emissions by an additional ton. While an emission tax raises the cost of a polluting activity, a subsidy will typically lower the cost of abatement or of an alternative low-emission technology. Both encourage the emitter to undertake the least expensive reductions in emissions, thereby ensuring cost-effectiveness. Like an emission tax, a subsidy should reflect the external costs of carbon. The external cost of carbon, like the cost of abatement, can often only be approximated. The lack of precise information reduces the ecological effectiveness of price-based instruments as the level of emissions will crucially depend on price elasticity of demand for polluting products. However, price-based instruments usually lead to cost-efficient abatement. While a

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estimates should be treated with caution. For many practical purposes, it is not necessary to know the exact estimate though. For a reasonable range of assumptions the external cost of carbon is clearly positive and probably also above the current market price for carbon. A wide range of estimates is found in the academic literature, ranging from less than zero and US\$1,000/tC or 367/tCO<sub>2</sub>, with a mean of US\$29/tCO<sub>2</sub>. (see UK Treasury or IPCC AR4 for details)

uniform global carbon tax would adequately reflect the nature of climate change across countries, politically it is very difficult to implement.

Another potential advantage of emission taxes is seen in a 'double-dividend' of green taxes. Raising government revenue by introducing emission taxes allows other distortionary taxes, such as income or corporate taxes, to be cut while at the same time reducing an activity that is having negative effects on the public. An emission tax provides incentives to reduce emissions in a cost-effective way across different emission sources. In addition, it creates an incentive for productivity gains and R&D without interfering with technology decisions. The main drawback is the need to monitor emissions. Sometimes it might not be possible to do this at a reasonable cost. In such cases, proxies are used based on inputs.

Examples include many climate change related taxes, which are levied on energy products or motor vehicles rather than CO<sub>2</sub> emissions directly. For example, carbon taxes were introduced in Scandinavian countries in the 1990s (Sweden, Denmark, Finland and Norway), a climate change levy was implemented in the UK, while congestion charges, though not only climate-related, were introduced in London, Zurich and Stockholm.

## 2 - Regulation and standards

Regulatory standards are the most common form of environmental regulation. Regulation typically sets a target for individual emissions sources (either a technical standard for a plant and a product). The regulatory approach is widely used in environmental policy, notably in water and air quality management. The main advantage is ecological incidence, provided that the target is set correctly and enforced continuously. There are several disadvantages though. Regulation is inefficient because it does not allow any arbitrage between low-cost and high-cost abatement strategies. It also provides few incentives for R&D in low-cost technologies and therefore hampers technical progress and learning effects. Regulation can become a barrier to market entry if a licence to operate is withheld on environmental grounds. Economic inefficiency means the same environmental goal could be achieved at lower abatement costs. Higher abatement costs mean that the action taken is too little too late. Regulation involves a high degree of bureaucracy as government agencies specify allowable emission quantities or even the equipment used by the firm. This can slow decisions down. Finally, regulation does not create an effective price signal for carbon as emission permits will often be allocated on a first come, first serve basis.

Examples include many air pollution regulations and standards, catalytic converters in the US, Europe and Japan, the share of renewables in energy or fuel mixes (e.g. German biofuel), energy efficiency standards for buildings (EU Directive and various national policies), or product standards (ban of conventional bulbs in Australia).

## 3 - Cap-and-trade

Under a cap-and-trade scheme, the total quantity of allowable emissions is set by the regulator, but contrary to direct regulation the emission permits can be traded. A market price for emissions emerges based on government-defined supply and the demand for emission permits by the private sector. If permits are freely tradeable among all emission sources, economic efficiency is ensured. As total emissions are set by the regulator, ecological efficiency can easily be achieved. A cap-and-trade scheme will not necessarily raise government revenues. If permits are handed out 'for free' — grandfathered based on current emissions — emitters are handed a valuable asset and benefits accrue to shareholders of the emitting firm. The impact on costs and output prices is fully compensated.

A cap-and-trade-scheme combines the advantages of regulation and emission taxes, while limiting the negative impact on corporate profits. The impact on corporate profits depends on how the permits are allocated initially, whether they are grandfathered or whether they are auctioned off. In both cases, the emission permit holder will own a tradable asset. In the case of grandfathering, the value of these assets fully compensates the corporate sector for its abatement costs and low-cost emitters might enjoy windfall profits. In the case of auctioning, cap-and-trade becomes very close to a carbon tax.

An early example is the US cap-and-trade system for SO<sub>2</sub> and NO<sub>x</sub> launched in the mid-90s to limit acid rain. More recent examples are the European Union Emissions Trading Scheme (ETS) and the Chicago Climate Exchange (CCX). In the US, there are also a number of important regional initiatives at the state level. The Regional Greenhouse Gas Initiative (RGGI) is mandatory system for curbing CO<sub>2</sub> from power plants in several northeastern states in the US. The California Global Warming Solutions Act is aimed at reducing GHG emissions to 1990 levels by 2020 and linking its trading program to RGGI and, importantly, EU ETS. The cost savings compared with command and control for US Acid Rain Program are estimated at around 50%. For implementing the Kyoto Protocol, the EU Commission estimates cost savings of about one third.

## A Simple Model of Environmental Policy Instruments

To illustrate the impact different environmental policy instruments have on corporate profits, consider two different emission sources, one with high abatement costs and one with low. Abatement costs rise with the size of the emission cut and fall with the emission level. The optimal emission level is reached when the aggregate cost of cutting emissions equals the environmental damage caused by the remaining emissions.

### Emission tax

In the case of an emission tax, both companies will have to pay a uniform emission tax for each ton of carbon emitted. The total tax bill is given by the black dotted rectangles. It is higher for the high-cost company, which emits more than for the low-cost company. On top of the tax bill, each company also bears the cost of emission reductions, so that the total 'hit' to corporate profits is equal to the grey rectangle times two.

### Regulation

In the case of uniform regulation that yields the same overall emission level, each company would face an abatement cost that is equal to the grey rectangle. Note that the costs are different between both emission sources. Hence, there is an arbitrage opportunity: If the emission permits became tradable, the high-cost emitter would be willing to pay up to  $P'$  while the low-cost emitter would accept offers down to  $P''$ . There would be no further arbitrage gains when the permit price equals both companies' costs (which would be the case for  $P = T$ ).

### Emission permits

While, in principle, tradable emission permits bring about the same abatement level as an emission tax, there is an important difference. Instead of facing a tax bill, companies now own an additional asset, the emission permit. Its value is given by the green rectangles in the initial allocation and by the red rectangles after all arbitrage gains have been realized. In the stylized setting of this model, the value of the tradable emission permit fully covers the costs of abatement and there should be no negative impact on company profits.

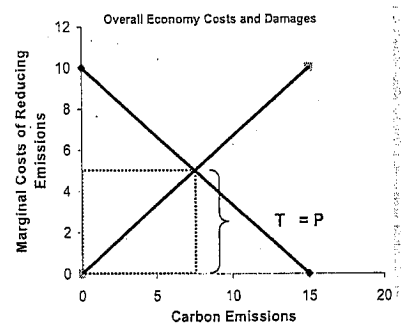
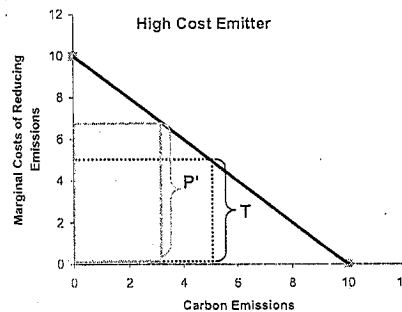
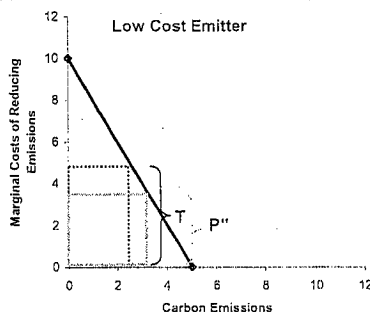
### Impact on corporate profits

In conclusion, an emission tax creates the biggest hit to corporate profits. While a uniform emission target induces a smaller dent on profits, it burdens the corporate sector with abatement costs and additional inefficiencies. Only a tradable emission permit does not affect corporate profits. This stylized setting illustrates the basic mechanics of different environmental policy instruments and their impact on the corporate sector.

Exhibit 54

### A Stylised Model of Environmental

### Policy Instruments



Source: Morgan Stanley Research

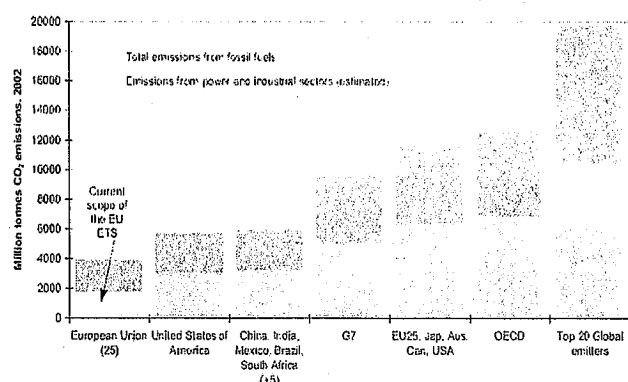
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## ETS: European Union Emission Trading Scheme

The ETS came into effect in January 2005 and is by a wide margin the largest trading scheme globally. It is expected to expand considerably in the future. The first phase (2005-08) covers some 12,000 installations in 25 EU countries (accounting for 45% of CO<sub>2</sub> emissions with a permit market of US\$115bn over three years). The sectors covered are primarily power generation and industrial (ferrous metal production and processing, chemical industry, minerals, pulp and paper). So far, only a small share of the overall CO<sub>2</sub> emissions globally is traded. Hence, the scope for future growth in carbon trading is likely to be substantial (Exhibit 55). My colleague Luciano Diana expects trading volumes to rise to 14 Gt by 2010 from around 2 Gt today (see *Climate Exchange: US Success Priced in, Lots of Options Value*, August 8, 2007).

Exhibit 55

### Substantial Scope to Extend Carbon Trading



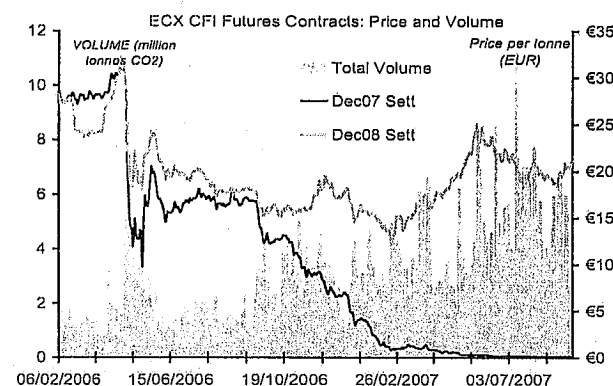
Source: Stern Report

Under the scheme, companies trade so-called European Union Allowances (EUA) to meet their allocated emission allowance as defined in the National Allocation Plan (NAP). The NAPs, which are subject to approval by the EU Commission, must show that national allocations do not exceed expected emissions and that they are in line with Kyoto targets. Companies subject to the scheme have to provide an annual emissions report audited by a third party. Exceeding the allowance leads to a fine of €40 per metric ton of CO<sub>2</sub> in the period 2005-08. This fine rises to €100 per t in the second phase (2009-12).

The effectiveness of the ETS in implementing the EU's commitment to cut emissions by 20% by 2020 depends on whether the resulting carbon price is sufficient to induce

Exhibit 56

### Prices and Trading Volumes for EUA



Source: ECX, Morgan Stanley Research

companies to cut back emissions and invest in R&D to lower abatement costs in the future. Initial allocations, based on estimated current emissions, proved to be too generous and the EUA price collapsed in spring 2006. As a result, political pressure to reduce allocations for the second phase is mounting. Prices in the second phase are somewhat higher, but probably still below the external costs of carbon. In addition, many European countries are currently not on track to meet Kyoto commitments.

Permits are still mainly grandfathered but an increasing share is auctioned off (up to 10% after 5% in Phase I, actually only 0.2% were auctioned in Phase I). Most countries prevent banking between Phase I and II. In addition, the European Commission intends to include aviation in the second phase (2008-12). The EU directive proposes to include intra-EU flights from 2011 and extra-EU flights (from and to the EU airports) from 2012. The price of carbon will depend on national allocations, the availability of Certified Emission Credits (CER) from abroad and the overall GHG reduction targeted by the EU. Given the global nature of climate change, the ETS recognises international emission trading mechanisms of the Kyoto Protocol of the United Nations Framework Convention for Climate Change (UNFCCC). The Clean Development Mechanism (CDM)<sup>6</sup> allows developed countries to obtain emission credit for emission reducing

<sup>6</sup> A large supply of cheap CDM options together with limited emission reductions required of EU countries by 2012 implies a relative low cost of complying with Kyoto. Regulatory restrictions (additional, complementarity) create some small cost increases. But in a recent study, the ZEW estimates more than 1300 Mt CO<sub>2</sub> could be obtained for US\$4/t. Simulations would suggest downside risks to the current CO<sub>2</sub> price if CDM were fully leveraged. But because of practical hurdles in delivering, ratifying and issuing actual credits thus far actual CDMs used have fallen short of expectations.

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projects in developing countries. These credits are called Certified Emission Reduction Units (CER). Joint implementation (JI) allows developed countries to obtain emission credits for emission reducing projects in other developed countries. There is a growing interest in CDM, partly because CDM credits can be banked between Phase I and II.

There is a potential for efficiency improvements in the ETS, according to the Stern Report, broadening the scope of the scheme to include more sectors, countries and GHGs, ensuring appropriate scarcity of EUAs, lengthening the trading periods to a decade, designing more effective allocation mechanisms (auctions), improving the system's transparency and allowing for the permits to be banked.

Exhibit 57

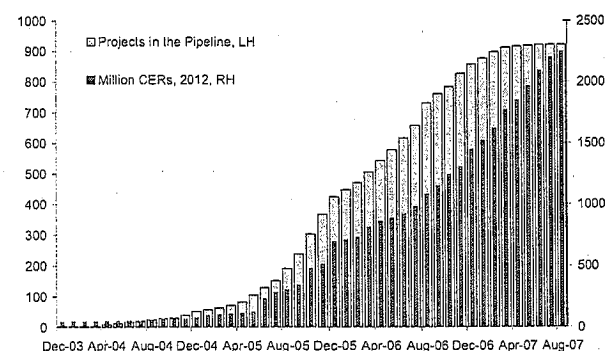
## Emissions Trading in the EU

Trading period 2005-07			
EU member state (mn tonnes)	Allocated CO2 allowances (%)	Share in EU (%)	Kyoto target (%)
Belgium	188.8	2.9	-7.5 (*)
Czech Republic	292.8	4.4	-8
Denmark	100.5	1.5	-2.1 (*)
Germany	1,497.00	22.8	-2.1 (*)
Estonia	56.85	0.9	-8
Greece	223.2	3.4	+25
Spain	523.3	8	+15
France	469.5	7.1	0 (*)
Ireland	76	1	+13 (*)
Italy	697.5	10.6	-6.5
Cyprus	16.98	0.3	-
Latvia	13.7	0.2	-8
Lithuania	36.8	0.6	-8
Luxembourg	10.07	0.2	-28 (*)
Hungary	93.8	1.4	-6
Malta	8.83	0.1	-
Netherlands	285.9	4.3	-6 (*)
Austria	99	1.5	-13 (*)
Poland	717.3	10.9	-6
Portugal	114.5	1.7	+27 (*)
Slovenia	26.3	0.4	-8
Slovakia	91.5	1.4	-8
Finland	136.5	2.1	0 (*)
Sweden	68.7	1.1	+4 (*)
United Kingdom	736	11.2	-12.5 (*)
Total	6,572.40	100	

Source: EU Commission

Exhibit 58

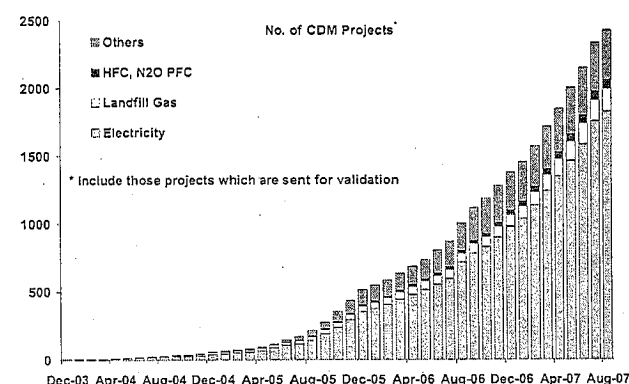
## Evolution of Number of CDM Projects over Time



Source: UNEP Risoe CDM/JI Pipeline Analysis and Database

Exhibit 59

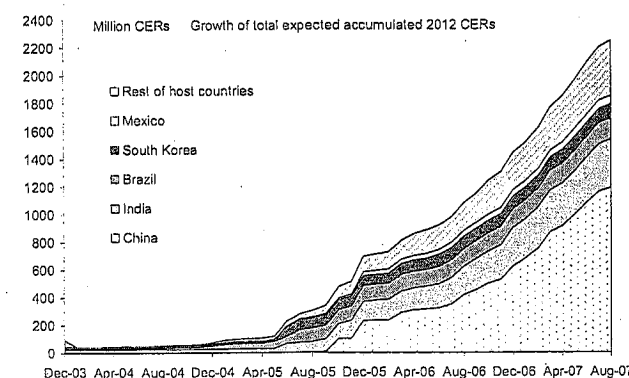
## Evolution of CDM Project Portfolio by Sector



Source: UNEP Risoe CDM/JI Pipeline Analysis and Database

Exhibit 60

## Evolution of CDM Project Portfolio by Host Country



Source: UNEP Risoe CDM/JI Pipeline Analysis and Database

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## The Role of Greenhouse Gases by Sector<sup>7</sup>

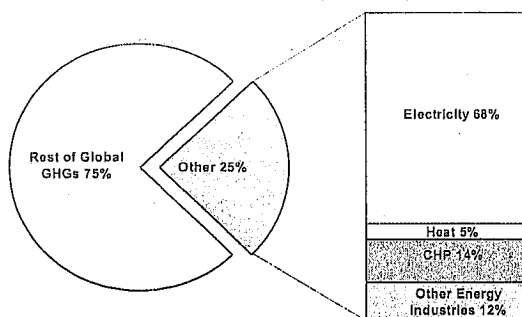
### Electricity and heat

Generation of electricity and heat accounts for a quarter of global GHG emissions and this is the largest sector.

Within the sector, electricity generation accounts for the largest share, followed by combined heat and power generation, other industrial processes and heat generation. More than 40% of electricity is consumed by buildings use; 35% by industry, a further 9% by energy production itself while a further 9% is lost in transmission and distribution. Relatively small amounts are used in agriculture (2.3%) and transport (1.4%). At the global level, emissions from the power sector are also the fastest growing (China, India). The IEA expects a fourfold rise in emissions by the middle of this century due to the rise in the use of coal as a primary energy source and an increase in synfuel production. The energy sector is therefore very much at the heart of efforts to mitigate climate change (see also *Utilities – CO<sub>2</sub>: Back to the Future*, March 29, 2007, for an analysis of the impact of the European Emission Trading System on the European utility sector). There are notable country differences due to different income levels, different levels of efficiency in power generation, and differences in the fuel mix used. These are partly related to natural resources (e.g. coal in Australia, the US, China, India and South Africa) and partly to government decisions (e.g. nuclear in France, wind in Spain and Denmark). Government interventions remain high in the power industry, despite liberalisation and deregulation in many industrial countries.

Exhibit 61

### GHG from Power and Heat, 2003

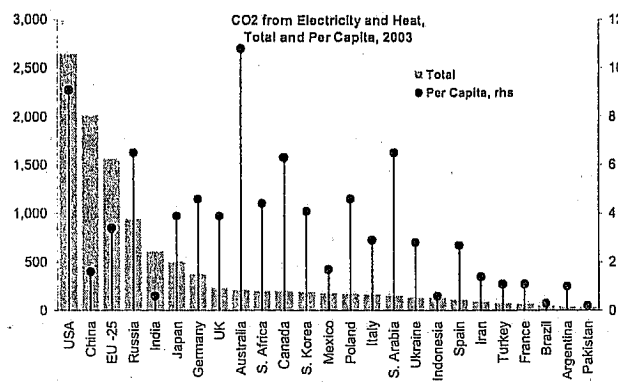


Source: WRI

<sup>7</sup> This section draws on work done by the World Resources Institute.

Exhibit 62

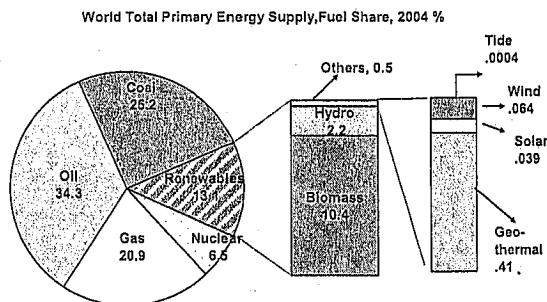
### CO<sub>2</sub> from Electricity & Heat, Total and Per Capita, 2003



Source: WRI

Exhibit 63

### World Energy Supply Shows High Carbon Content



Source: IEA, Morgan Stanley Research

### Lost in Transmission

From an economic point of view, an interesting feature is the natural monopoly in the power grid due to the economies of scale in power generation and transmission. The notable loss of power in transmission (c.10%) in the long-distance transmission of energy between centralized power generation and the decentralized use of power could trigger a challenge to the power grid because these transmission losses would not arise in micro-power-generation. In addition, there are efficiency gains in combined heat and power generation (CHP), especially in colder climates. Currently, national grids are not suited to receive electricity from many small sources (CHP, small solar) or remote locations (wind, hydro) with changing base loads.

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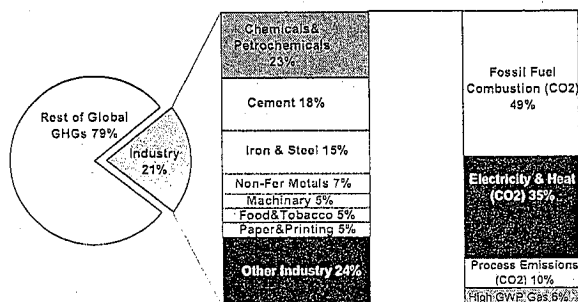
Conceptually, micro-generation could become to power distribution what mobile phones were to the fixed-line telecom network in the 1990. By contesting the natural monopoly position of existing power distributors, micro-generation could largely reduce the barriers to entry in the industry. By the same token, though, the existing power distribution network likely constitutes a major obstacle to more widespread use of micro-generation and reselling of excess micro-power to the grid. An exception to these obstacles are emerging market economies where often no such grids yet exist or where they don't yet offer full cover.

## Industry

The manufacturing and construction industries together account for 21% of global GHG emissions. This figure includes direct fuel combustion (49%) in manufacturing and construction, indirect emissions from electricity and heat consumption (35%), and emissions from industrial processes (16%). Within industry, chemical and petrochemical companies account for the largest share of emissions (23%) followed by cement (18%) and iron and steel production (18%). Unusually, the majority of emissions comes from developing countries. China alone accounts for 22%. The industrial sector is very diverse in terms of economic activities, production processes and technologies that generate GHG emissions. This is in sharp contrast to the power sector, where the product is very homogenous, and the transport sector, where the technology is highly uniform. Industry is characterised by a high degree of international competition and trade. Manufacturing products account for 75% of global trade. The top five countries include China, EU, US, India and Japan (on a per capita basis, Canada, South Korea, US, Japan, Saudi Arabia).

Exhibit 64

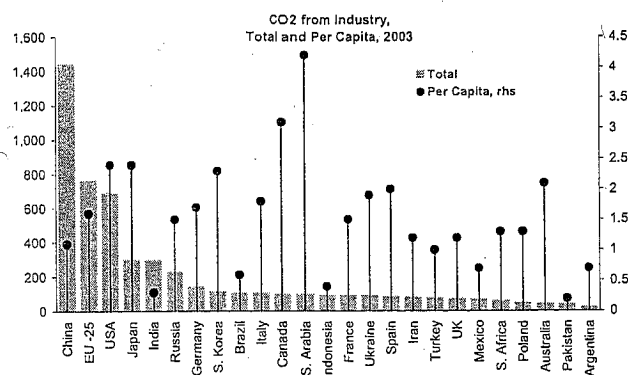
### GHG Emissions in the Industrial Sector, 2004



Source: CAIT, IEA

Exhibit 65

### CO<sub>2</sub> from Industry, Total and Per Capita, 2003



Source: WRI

Within industry, **chemicals** is the second largest energy consuming sector, accounting for nearly 5% of global GHG emissions. The chemical industry is diverse in terms of products and production processes, but highly concentrated geographically, with the EU, US, Japan and China accounting for 75% of global production. About 30% of chemical production is traded internationally. Because of the diversity of the chemical sector many countries are both importers and exporters.

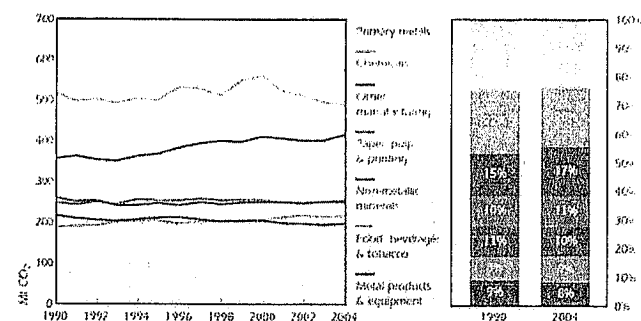
The **cement** sector accounts for 18% of all manufacturing emissions, with CO<sub>2</sub> emitted directly when clinker is made, fossil fuels are burned and indirectly through electricity consumption. About half of the emissions come from the chemical process, 40% from fuel combustion and the remainder from electricity purchases. China is by far the biggest cement producer. While cement is not conducive to international trade, there is considerable cross-border investment in the industry.

The **iron and steel** industry is the largest energy using industry in the world, with steel accounting for 15% of all manufacturing emissions (70% of emissions from direct fuel use and the remaining 30% from indirect electricity and heat use). Steel production techniques are relatively similar globally. They are dominated by two processes: integrated steel mills that use either blast furnace-open hearth or blast furnace-basic oxygen furnace; and mini-mills that use scrap in electric arc furnaces. China, the EU and Japan are the largest steel producers. In addition to chemicals, cement, steel and aluminum, significant contributions come from the manufacture of food and tobacco, pulp and paper and machinery goods.

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Exhibit 66

### CO<sub>2</sub> Emissions by Manufacturing Sub-sector



Source: *Energy Use in the New Millennium* © OECD/IEA, 2007, Figure 3.5, IEA19, P48

### Transport

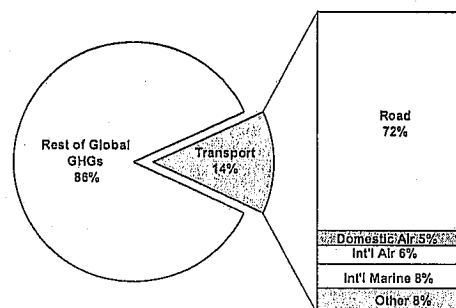
Together with industry and agriculture, transport is the third largest source of GHG, accounting for nearly 15% of global GHG emissions. Within the transport sector, almost three quarters of emissions are due to road transport, 13% are due to aviation (both domestic and international) and a further 12% to rail transport and shipping. With regard to energy sources, the transport sector is very much dominated by oil, which accounts for 96% of its fuel consumption. The top emitter is the US with a 35% share, followed by Europe, which accounts for 17%, and Japan, which accounts for 5%. On a per capita basis, the US, Australia and Canada have very high emissions.

Road transport emissions depend on how many kilometers are being driven per capita, which typically rise with GDP, and the fuel efficiency of the vehicle fleet. The efficiency in road transport varies widely between countries. In the US, fuel efficiency is roughly two thirds of that in Europe and only half of that in Japan. Governments play a key role in determining transport emissions by setting fuel efficiency regulations and building the transportation infrastructure.

Road transport is currently the fastest growing source of GHG emissions, with growth of 20 to 25% over the last decade in many industrial countries and a much faster rate of expansion in emerging markets. CO<sub>2</sub> emissions from the sector are expected to double by 2050, making it the second fastest growing sector after power generation. Further increases of about a third are expected in industrial countries, while much higher growth is projected in developing countries (China 143%, India 67%).

Exhibit 67

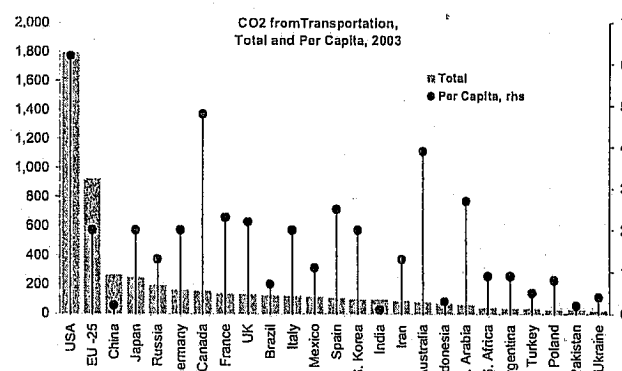
### GHG Emissions in the Transport Sector



Source: IEA, 2004a. See Appendix 2.A for sources and Appendix 2.B for sector definition. Absolute emissions in this sector, estimated here for 2000, are 5,743 MTCO<sub>2</sub>.

Exhibit 68

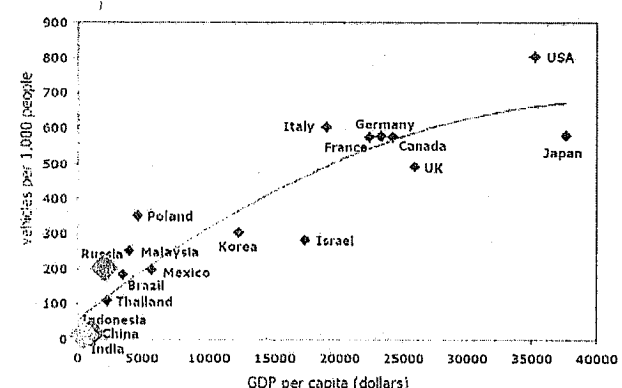
### CO<sub>2</sub> from Transportation, Total and Per Capita, 2003



Source: WRI

Exhibit 69

### Vehicle Ownership Rises with Income Level



Data for 2004

Source: *Energy Use in the New Millennium* © OECD/IEA, 2007, Figure 6.9, P104



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Aviation accounts for about 12% of emissions when international flights are included. The sector has seen tremendous growth in air travel over the past few decades. The global warming effect of aviation is larger than suggested by emissions data themselves. This is because the climate impact of air travel is amplified by ozone-producing NO<sub>x</sub> emissions, contrail formation, water vapour release and other high-altitude effects. The IPCC estimates that, while only accounting for 2% of GHG emissions, air travel accounts for 3.5% of total radiative forcing from human activity. Aviation emissions are also difficult to attribute correctly. They are usually registered at the point of refuelling, independent of the subsequent destination or passenger nationalities of the airplanes. Hence, hubs like Hong-Kong, the Netherlands, Thailand and Singapore move up onto the list of top emitters.

The transport sector is characterised by the high concentration of manufacturers (esp. in motor vehicles) and close international integration. A small number of multinational carmakers produce half of all motor vehicles and virtually all manufacturers have assembly and production facilities in multiple countries. Autos, auto-parts are heavily traded internationally, accounting for 10% of global trade. Most of the international trade in motor vehicles is regional though, taking place within Europe and North America. Aviation products are also highly uniform, as nearly all aircraft rely on jet engines. Production is also highly concentrated as nearly all aircraft are manufactured by five companies, mostly in North America or Europe. The top five countries include the US, EU, Japan, China, Russia (on a per capita basis, the US, Canada, Australia, Spain and France).

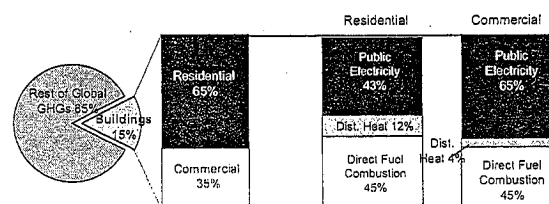
## Buildings use

The buildings sector, including residential and commercial buildings uses, accounts for 15% of global GHG emissions. About 10% of global GHG emissions are due to commercial buildings and more than 5% due to residential housing. Emissions from building use are mainly a function of energy consumption for public electricity consumption, direct fuel combustion or district heating. Electricity use comes from lighting, appliances, refrigeration, air conditioning and to some extent space heating and cooking. These activities account for 65% of commercial buildings' emissions and 43% of residential buildings' emissions. Globally, buildings are responsible for more electricity consumption than any other sector (42%).

Direct fuel consumption results primarily from space heating and albeit more modestly from cooking, air conditioning and refrigeration. Building design and materials have a significant influence on energy consumption for a number of uses (heating, airconditioning). Other uses, however, are independent of building design (cooking, appliances). Emissions from buildings use vary greatly between countries, both in absolute and per capita terms depending on the degree of electrification, urbanisation, building space per capita, prevailing climate and policy measures regarding efficiency or building standards. The top five countries are the US, the EU, China, Russia and Japan (US, Australia, Canada, Germany and Russia on a per capita basis).

Exhibit 70

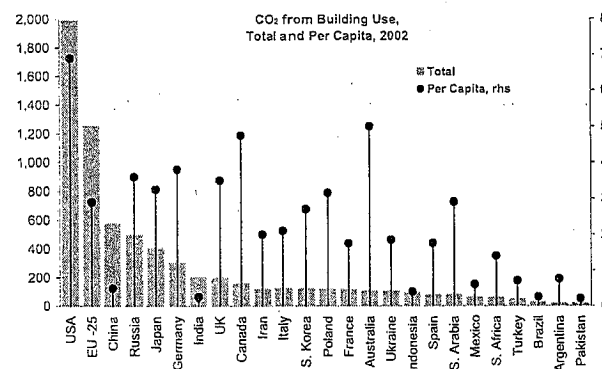
## GHG Emissions from the Real Estate Sector, 2004



Source: IEA, 2004. See Appendix 2.A for sources and Appendix 2.B for sector definition. Absolute emissions in this sector, estimated here for 2000, are 6,418 MtCO<sub>2</sub>

Exhibit 71

## CO<sub>2</sub> from Building Use, Total and Per Capita, 2002

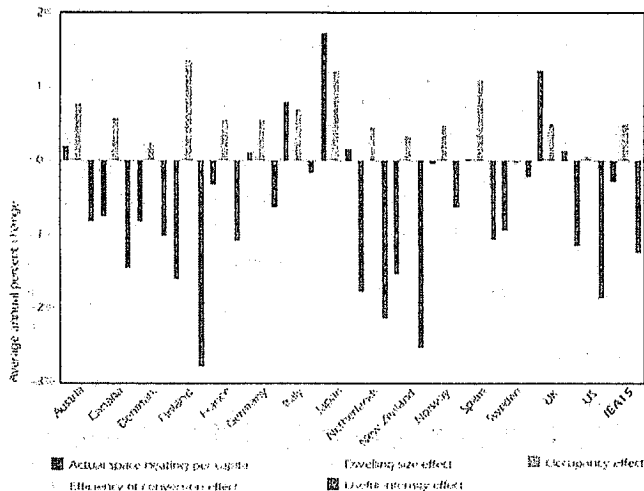


Source: WRI

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Exhibit 72

### Changes in Space Heating per Capita, 1990-2004



Source: Energy Use in the New Millennium © OECD/IEA, 2007, Figure 4.16, P80

### Changes in Land Use

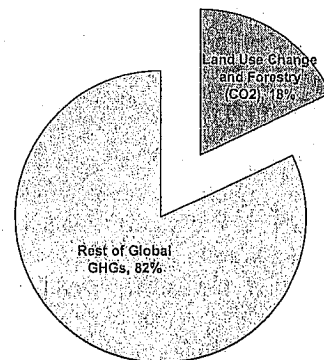
Changes in land use and forestry are estimated to account for nearly 20% of global GHG emissions, making it the largest sector contributor apart from power generation. Changes in land use and forestry are a unique sector in several ways.

- First, the emission pattern across countries is very different from other sectors. Emissions are almost entirely due to deforestation, which is highly concentrated in a few tropical countries (especially Indonesia and Brazil). Meanwhile some industrial countries are net absorbers of CO<sub>2</sub> due to land use changes (afforestation, reforestation).
- Second, emissions and absorptions depend on complex interactions between the carbon cycle, the nutrient cycle and the hydrological cycle. Hence, the attribution of emissions to human activity remains controversial.
- Third, GHG emissions themselves are also subject to extraordinary uncertainty even though satellites allow changes in land use to be monitored effectively.
- Finally, absorption through land use changes is reversible which can create problems in CDM projects.

The top five emission countries are Indonesia, Brazil, Mexico, Canada, Argentina (or on a capital basis Indonesia, Brazil, Canada, Argentina and Mexico). Avoiding adverse changes in land use is one of the cheapest ways to avoid emissions currently available. The cost of reducing non-fuel emission is relatively low. Estimates vary between US\$5/tCO<sub>2</sub> and US\$1/tCO<sub>2</sub> for avoiding deforestation and between US\$5 and US\$15/tCO<sub>2</sub> for afforestation, according to the Stern Report.

Exhibit 73

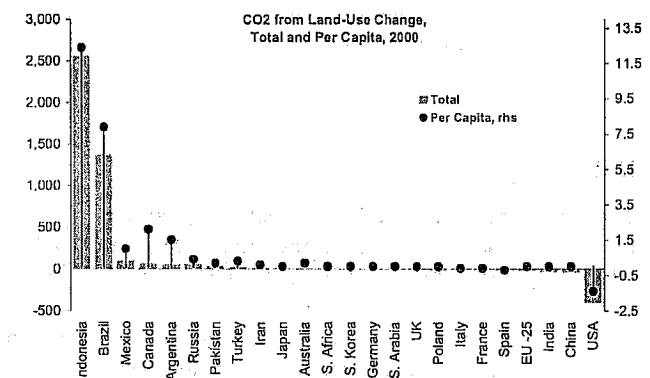
### CO<sub>2</sub> Emissions from Land Use Changes & Forestry



Source: WRI

Exhibit 74

### CO<sub>2</sub> from Land-Use Change, Total and Per Capita, 2000



Source: WRI

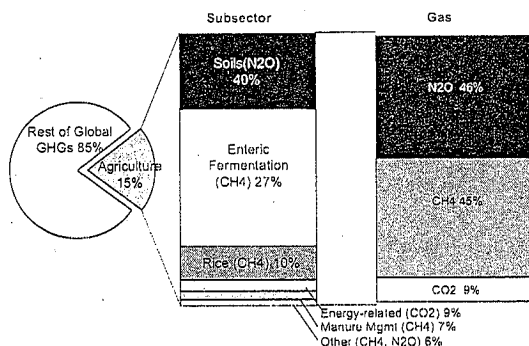
### Agriculture

Emissions from agriculture account for about 15% of global GHG, with 45% stemming from CH<sub>4</sub> and N<sub>2</sub>O respectively and the remainder coming from CO<sub>2</sub> emitted in fuel combustion and electricity use. The agricultural activity creating most of the

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emissions is soils management, which creates emissions from tillage and cropping practices such as fertilizer use (40%). The second largest source (27%) is methane emissions from livestock. Other important emission sources include wetland rice cultivation and manure management. Finally, agriculture contributes to CO<sub>2</sub> emissions via land clearing and biomass burning.

Exhibit 75  
**GHG Emissions from the Agricultural Sector**



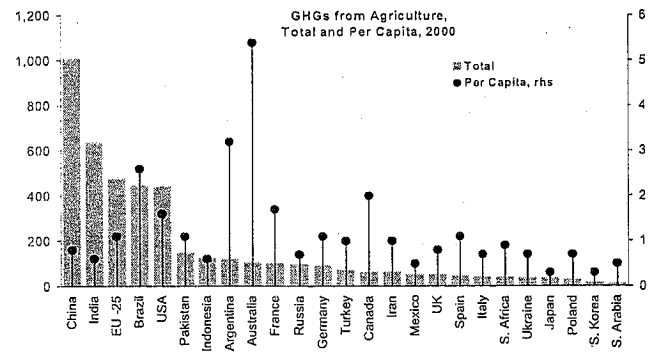
Source: EPA, 2004. See Appendix 2.A for sources and Appendix 2.B for sector definition. Absolute emissions in this sector, estimated here for 2000, are 6,205 MtCO<sub>2</sub> equivalent.

The relevance of agriculture for the overall economy varies widely between countries, ranging from India and China where the sector accounts for between 15% and 20% of the economy to industrial countries where it is noticeably below 5%. Thus over half of the agricultural emissions stem from developing countries. Currently, the top five emitters are China, India, the EU, the US and Brazil (Australia, Argentina, Brazil, Canada and US on a per capita basis).

## Waste

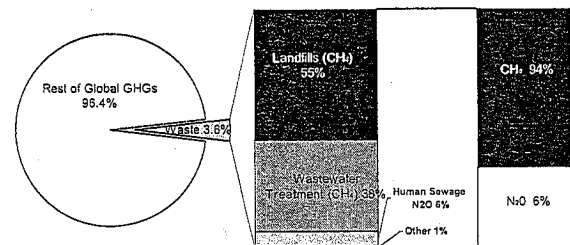
Emissions from waste account for just under 4% of global GHG emissions. They consist mainly of methane, CH<sub>4</sub>, with the largest source being the landfilling of solid waste (55%) and handling and treatment of wastewater the second largest (38%). Waste disposal is usually a public sector service provided by local municipal authorities. The biggest waste producers are the US, the EU, China, India, Russia (Australia, Canada, US, Ukraine, and Poland on a per capita basis).

Exhibit 76  
**CO<sub>2</sub> from Agriculture, Total and Per Capita, 2000**



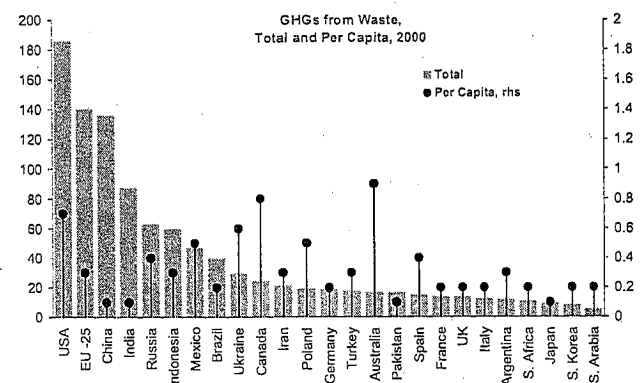
Source: WRI

Exhibit 77  
**GHG Emissions in the Waste Sector**



Source: WRI

Exhibit 78  
**GHG Emissions from Waste, Total and Per Capita, 2000**



Source: WRI

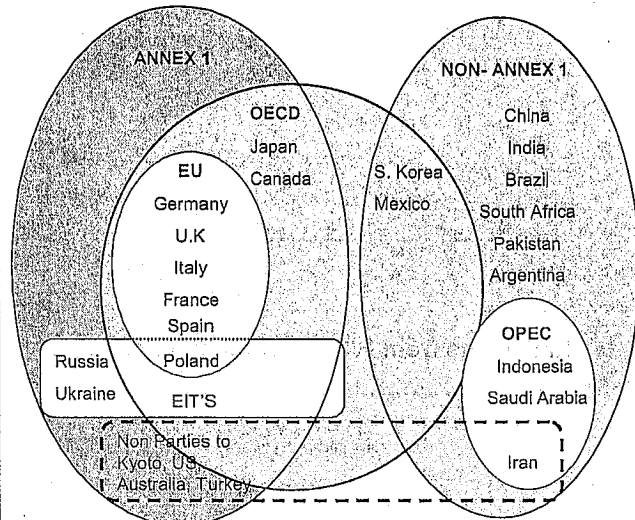
October 3, 2007  
Economics

## The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international agreement between a broad group of over 160 industrial and developing countries that sets targets for reducing GHG emissions for 35 industrial countries listed in Annex I for the period 2008-12. Signed in late 1997, the Kyoto Protocol came into force in spring 2005. Thirty five industrial countries are committed themselves to reducing their GHG while developing countries are not required to lower GHG emissions due to their low emission level per capita, lower level of per capita GDP, and their smaller contribution to current GHG concentrations in the atmosphere. Globally, the Kyoto Protocol aims to cut GHG emissions by 5% compared with 1990. At first glance, a reduction of 5% seems relatively small. Note though that it probably corresponds to a reduction of about 30% compared to the baseline (due to the growth between 1990 and now).

Exhibit 79

### Top 25 Greenhouse Gas Emitters by Region and Organisation



Source: WRI

Unfortunately, the Kyoto Protocol's original goal — to reduce overall GHG emissions from industrial countries by 5% — is unlikely to be achieved. In principle, countries that fail to meet the obligation to reduce emissions will be penalised by having to make up the difference, plus an additional 30% in the second commitment period. In addition, that country will be suspended from making transfers under the emissions trading program. Without the participation of the US and Australia and with

considerable emission overshoots in Europe, even such a small reduction in emissions now looks unlikely and an emission trajectory close to the business as usual scenario seems more likely. However, Kyoto has introduced important instruments (flexible mechanisms, cap-and-trade) and together with the IPCC provides a platform for taking bolder action in the future.

Non-annex I countries have no obligation to reduce their GHG emissions. However, they can sell any GHG emission reduction to an Annex I country as a credit under the CDM. This reduces significantly the cost of compliance for Annex I countries. The Protocol allows international emissions trading between the countries listed in Annex I (mostly industrial countries and transition economies). In 1990, many transition countries were big polluters. A sharp fall in GDP in the first half of 1990s and subsequent modernisation has left them with excess permits, dubbed 'hot air'. In addition, the Protocol foresees Joint Implementation (JI) between Annex I countries and the Clean Development Mechanism (CDM).

In addition, it provides an operational framework for attaining these reductions by introducing three flexible mechanisms to attain these targets. These flexible mechanisms include international emission trading, joint implementation (JI) and Clean Development Mechanism (CDM). (see also *Multi-sector Report: Cross-Industry Insights: Kyoto Mechanism and CO2 Emission Trading*, October 20, 2006)

Exhibit 80

### Countries Included in the Annex I of the Kyoto Protocol and their Emission Reductions

	Emission Reduction 1990 – 2008-12	Base-year emissions MtCO <sub>2</sub> -eq.
EU 15, Bulgaria, Czech Republic, Baltic States, Romania, Slovakia, Slovenia, Switzerland	-8%	5110
US	-7%	6103
Canada, Hungary, Japan, Poland	-6%	2559
Croatia	-5%	31
New Zealand, Russia, Ukraine	0%	4027
Norway	+1%	50
Australia	+8%	423
Iceland	10%	3

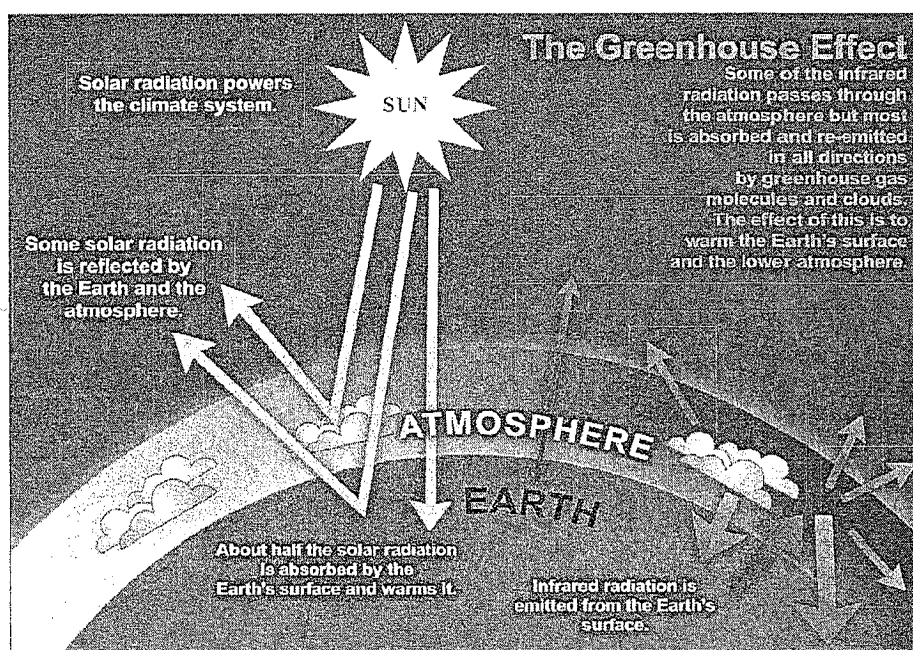
Note that the EU has an internal burden sharing scheme so that emission reductions for individual member states can and do differ from overall commitment. The Kyoto Protocol allows countries to join forces and create a so-called bubble, a group of countries with an overall emission cap. The EU has chosen this approach. The US and Australia have not ratified the Kyoto Protocol. Turkey and Belarus were not parties to the Convention when the Protocol was adopted and hence are not listed in Annex B.

Source: UNFCCC

## Appendix: The Greenhouse Effect

Exhibit 81

### The Greenhouse Effect



Source: IPCC

The greenhouse effect stems from the trapping of long-wave heat radiation from the earth in the atmosphere. Without the greenhouse effect, life as we know it would not be possible. It warms the surface temperature of the earth up by about 3°C, making it habitable in the first place. The greenhouse effect is generated by the sun's short-wave radiation entering the atmosphere and eventually reaching the earth's surface unless it is reflected back into the atmosphere on the way (albedo), which happens to be part of the radiation. The earth's surface then re-emits the heat and some of it is absorbed in the atmosphere while the rest escapes into space.

The amount of heat absorbed by the atmosphere is largely determined by the concentration of GHG. Apart from the most important GHG gas water vapour (H<sub>2</sub>O), several man-made GHG are key determinants of the surface temperature. These gases include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur Hexafluoride (SF<sub>6</sub>), all of which are regulated under the Kyoto Protocol. Note that the different GHG gases tend to have very different global warming potential. Methane, for example, has a warming potential that is 23 times as powerful as that of carbon dioxide over a 100-year period. In the wake of industrialisation, human activity has raised the concentration of GHG significantly since 1850.

Exhibit 82

### Overview of Greenhouse Gases (GHG)

GHG	Global Warming		Current Concentration	Radioactive Forcing
	Potential	Pre-industrial Concentration		
Carbon Dioxide CO <sub>2</sub>	1	280 ppm	380 ppm	1.66
Methane CH <sub>4</sub>	23	730 ppb	1847 ppb	0.5
Sulphur Hexafluoride SF <sub>6</sub>	23900	0	5.22 ppt	0.002
Hydro-fluorocarbons HFC	2547	0		0.34 for all halocarbons
Perfluorocarbons PFC	6648	0		

Source: IPCC



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